### AGENDA

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

**August 10-12, 2022**

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

### 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. |
CAM 70-56: Reject an Identifiable Part of Second Correlating Revision No. 136. CAM 70-56 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-f

CAM 70-57: Reject Second Correlating Revision No. 135. CAM 70-57 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-g

CAM 70-58: Reject Second Correlating Revision No. 111. CAM 70-58 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-h

CAM 70-60: 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-bb

See Attachment 22-8-5-i

CAM 70-61: Consider the Appeal of Peter Graser, Copperweld Bimetals, requesting the Standards Council overturn the results of Code-Making Panel 6 on CAM 70-61. This CAM failed to achieve simple majority support of the voting Association Members during the NFPA Technical Meeting.

See Attachment 22-8-5-j

Comment received from Scott Harding, Chair, CMP 5, regarding the appeal of CAM 70-61.

See Attachment 22-8-5-j-1

Comment received from Trevor Bowmer, Bunya Telecom Consulting, LLC, regarding the appeal of CAM 70-61.

See Attachment 22-8-5-j-2

CAM 70-63: Accept Public Comment No. 2028. CAM 70-63 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 14 voting members/7 agree/6 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-k

CAM 70-63: 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
| 22-8-5-k-2 | Comment received from Christel Hunter, Cerrowire, regarding the appeal of CAM 70-63.  
See Attachment 22-8-5-k-3 |
| 22-8-5-k-3 | Comment received from Tim Earl, GBH International, regarding the appeal of CAM 70-63.  
See Attachment 22-8-5-k-4 |
| 22-8-5-l | **CAM 70-82**: Reject Second Correlating Revision No. 46. CAM 70-82 passed vote of the participating Membership during the NFPA Technical Meeting.  
**PASSED** Panel 3 Ballot – 20 voting members/16 agree/3 disagree/1 abstained/0 ballots not returned.  
**PASSED** Panel 14 Ballot – 19 voting members/16 agree/0 disagree/0 abstained/3 ballots not returned.  
**PASSED** 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 |
| 22-8-5-m | **CAM 70-83**: Reject Second Revision No. 8298 and any related portions of First Revisions and First Correlating Revisions.  
**No Ballot Necessary per NFPA Regulations**  
See Attachment 22-8-5-m |
| 22-8-5-n | **CAM 70-85**: Reject Second Revision No. 8133 and any related portions of First Revisions and First Correlating Revisions.  
**No Ballot Necessary per NFPA Regulations**  
See Attachment 22-8-5-n |
| 22-8-5-o | **APPEAL**  
**CAM 70-88**: 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 |
| 22-8-5-o-1 | Comment received from Nathan Philips, Chair, CMP 10, regarding the appeal of CAM 70-88.  
See Attachment 22-8-5-o-1 |
| 22-8-5-o-2 | Comment received from Keith Waters, Schneider Electric, regarding the appeal of CAMs 70-88.  
See Attachment 22-8-5-o-2 |
| 22-8-5-p | **APPEAL**  
**CAM 70-89/CAM 70-109**: 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 |
| 22-8-5-p-1 | Comment received from Nathan Philips, Chair, CMP 10, regarding the appeal of CAMs 70-89/70-109.  
See Attachment 22-8-5-p-1 |
| 22-8-5-p-2 | Comment received from Keith Waters, Schneider Electric, regarding the appeal of CAMs 70-89/70-109.  
See Attachment 22-8-5-p-2 |
| 22-8-5-q | 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 | 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 | 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 |
| 22-8-5-w | **CAM 70-117:** Accept Public Comment No. 2058. CAM 70-117 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 15 voting members/5 agree/9 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-w |
|---|---|
| 22-8-5-w-1 | **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:** Accept Public Comment No. 2198. CAM 70-120 passed vote of the participating Membership during the NFPA Technical Meeting. **FAILED** panel Ballot – 15 voting members/4 agree/9 disagree/1 abstained/1 ballots not returned. **PASSED** CC Ballot – 12 voting members/10 agree/2 disagree/0 abstained/0 ballots not returned.  
See Attachment 22-8-5-x |
| 22-8-5-y | **APPEAL**  
**CAM 70-126:** Consider the appeal of Peter Graser, Copperweld Bimetallics, 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-z through 22-8-5-aa-1.  
See Attachment 22-8-5-y |
| 22-8-5-y-1 | Comment received from David Watson, Southwire, regarding the appeal of CAM 70-126.  
See Attachment 22-8-5-y-1 |
| 22-8-5-y-2 | Comment received from Brian Deacy, Atkore, regarding the appeal of CAM 70-126.  
See Attachment 22-8-5-y-2 |
| 22-8-5-y-3 | Comment received from Christel Hunter, Cerrowire, regarding the appeal of CAM 70-126.  
See Attachment 22-8-5-y-3 |
| 22-8-5-z | **APPEAL**  
**CAM 70-127:** Consider the Appeal of Peter Graser, Copperweld Bimetallics, 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  
See Attachment 22-8-5-z |
| 22-8-5-aa | **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 |
<table>
<thead>
<tr>
<th>22-8-5-aa-1</th>
<th><strong>APPEAL</strong></th>
<th><strong>CAM 70-128</strong> 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</th>
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<tbody>
<tr>
<td>22-8-5-aa-2</td>
<td></td>
<td>Comment received from Brian Deacy, Atkore, regarding the appeal of CAM 70-128. See Attachment 22-8-5-aa-2</td>
</tr>
<tr>
<td>22-8-5-bb</td>
<td><strong>APPEAL</strong></td>
<td><strong>CAM 70-129</strong> 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</td>
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<tr>
<td>22-8-6</td>
<td><strong>NFPA 86</strong></td>
<td>Act on the issuance of NFPA 86, <em>Standard for Ovens and Furnaces</em>, 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.</td>
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<tr>
<td>22-8-6-1</td>
<td><strong>APPEAL</strong></td>
<td><strong>CAM 86-6</strong>: 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</td>
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<tr>
<td>22-8-6-1-a</td>
<td></td>
<td>Comment received from William Norge, 3M, regarding the appeal of CAM 86-6. See Attachment 22-8-6-1-a</td>
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<tr>
<td>22-8-6-1-b</td>
<td></td>
<td>Comment received from Ted Jablkowski, Fives North American Combustion, Inc., regarding the appeal of CAM 86-6. See Attachment 22-8-6-1-b</td>
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<tr>
<td>22-8-6-1-c</td>
<td></td>
<td>Comment received from Franklin Switzer, TC Chair., regarding the appeal of CAM 86-6. See Attachment 22-86-1-c</td>
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<tr>
<td>22-8-7</td>
<td><strong>NFPA 130</strong></td>
<td>Act on the issuance of NFPA 130, <em>Standard for Fixed Guideway Transit and Passenger Rail Systems</em>, 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.</td>
</tr>
<tr>
<td>22-8-8</td>
<td><strong>NFPA 285</strong></td>
<td>Act on the issuance of NFPA 285, <em>Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Wall Assemblies Containing Combustible Components</em>, 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.</td>
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<tr>
<td>22-8-9</td>
<td><strong>NFPA 502</strong></td>
<td>Act on the issuance of NFPA 502, <em>Standard for Road Tunnels, Bridges, and Other Limited Access Highways</em>, 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.</td>
</tr>
</tbody>
</table>
| 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. |

### TENTATIVE INTERIM AMENDMENTS

| 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*.  
See Attachment 22-8-11-a |
| 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 | **NFPA 13**  
See Attachment 22-8-12 |
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<th>Date</th>
<th>Description</th>
<th>Text Reference</th>
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<tbody>
<tr>
<td>22-8-12-a</td>
<td>Text of proposed TIA No. 1641.</td>
<td>See Attachment 22-8-12-a</td>
</tr>
<tr>
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<td>Ballot results of TIA No. 1641. <strong>PASSED</strong> 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. <strong>PASSED</strong> CC ballot on correlation – 22 voting members/20 agree on correlation/0 disagrees/0 abstained/2 ballots not returned.</td>
<td>See Attachment 22-8-12-b</td>
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<td>Two comments were received.</td>
<td>See Attachment 22-8-12-c</td>
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<tr>
<td>22-8-13-a</td>
<td>Text of proposed TIA No. 1652.</td>
<td>See Attachment 22-8-13-a</td>
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<tr>
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<td>Ballot results of TIA No. 1652. <strong>PASSED</strong> 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.</td>
<td>See Attachment 22-8-13-b</td>
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<td>No comments were received.</td>
<td>No Attachment.</td>
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<tr>
<td>22-8-14-a</td>
<td>Text of proposed TIA No. 1632.</td>
<td>See Attachment 22-8-14-a</td>
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<td>Ballot results of TIA No. 1632. <strong>PASSED</strong> 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. <strong>PASSED</strong> CC ballot on correlation -12 voting members/9 agree on correlation/0 disagree/1 abstained/2 ballots not returned.</td>
<td>See Attachment 22-8-14-b</td>
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<td>Three comments were received.</td>
<td>See Attachment 22-8-14-c</td>
</tr>
<tr>
<td>22-8-15-a</td>
<td>Text of proposed TIA No. 1649.</td>
<td>See Attachment 22-8-15-a</td>
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<td>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, <em>Code for the Manufacture and Storage of Aerosol Products</em>.</td>
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<td>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®, <em>National Electrical Code®</em>.</td>
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<td>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®, <em>National Electrical Code®</em>.</td>
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<td>Item</td>
<td>Description</td>
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| 22-8-15-b | 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 |
| 22-8-15-c | Seventy-nine comments were received. 
See Attachment 22-8-15-c |
| 22-8-16 | 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®. |
| 22-8-16-a | Text of proposed TIA No. 1653. 
See Attachment 22-8-16-a |
| 22-8-16-b | 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 |
| 22-8-16-c | 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 | 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®. |
| 22-8-17-a | 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/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 22-8-17-b |
| 22-8-17-c | Seven comments were received.  
See Attachment 22-8-17-c |
| 22-8-17-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-d, 22-8-19-d, 22-8-20-d  
See Attachment 22-8-17-d |
| 22-8-17-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, 22-8-17-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 | **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-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 | **NFPA 70** Act on the issuance of proposed Tentative Interim Amendment No. 1655 to revise paragraph 215.15 of the proposed 2023 edition of NFPA 70, *National Electrical Code®*. |
| 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 | **NFPA 70** 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
<table>
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<tr>
<th>Date</th>
<th>Action</th>
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<tr>
<td>22-8-19-c</td>
<td>Four comments were received.</td>
<td>See Attachment 22-8-19-c</td>
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<tr>
<td>22-8-19-d</td>
<td><strong>APPEAL</strong> 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</td>
<td>See Attachment 22-8-19-d</td>
</tr>
<tr>
<td>22-8-19-e</td>
<td><strong>APPEAL</strong> 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</td>
<td>See Attachment 22-8-19-e</td>
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<td><strong>22-8-20</strong></td>
<td><strong>NFPA 70</strong> 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>
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<tr>
<td>22-8-20-a</td>
<td>Text of proposed TIA No. 1657.</td>
<td>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.</td>
<td>See Attachment 22-8-20-b</td>
</tr>
<tr>
<td>22-8-20-c</td>
<td>Five comments were received.</td>
<td>See Attachment 22-8-20-c</td>
</tr>
<tr>
<td>22-8-20-d</td>
<td><strong>APPEAL</strong> 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</td>
<td>See Attachment 22-8-20-d</td>
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<tr>
<td>22-8-20-e</td>
<td><strong>APPEAL</strong> 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</td>
<td>See Attachment 22-8-20-e</td>
</tr>
<tr>
<td><strong>22-8-21</strong></td>
<td><strong>NFPA 70</strong> 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>
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<tr>
<td>22-8-21-a</td>
<td>Text of proposed TIA No. 1658.</td>
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| Date       | Description                                                                maxcdn
|------------|-----------------------------------------------------------------------------|---
| 22-8-21-b | Ballot results of TIA No. 1658. **FAILED** Panel ballot on technical merit but **PASSED** 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. **PASSED** 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 | ---
| 22-8-21-c | Fourteen comments were received. See Attachment 22-8-21-c | ---
| **22-8-22** \*NFPA 70** | 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*®. |  
| 22-8-22-a | Text of proposed TIA No. 1659. See Attachment 22-8-22-a | ---
| 22-8-22-b | Ballot results of TIA No. 1659. **PASSED** 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. **PASSED** 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 | ---
| 22-8-22-c | Nine comments were received. See Attachment 22-8-22-c | ---
| **22-8-23** \*NFPA 70** | 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*®. |  
| 22-8-23-a | Text of proposed TIA No. 1660. See Attachment 22-8-23-a | ---
| 22-8-23-b | Ballot results of TIA No. 1660. **PASSED** 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. **PASSED** 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 | ---
| 22-8-23-c | Eight comments were received. See Attachment 22-8-23-c | ---
| **22-8-24** \*NFPA 70** | 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*®. |  
| 22-8-24-a | Text of proposed TIA No. 1661. See Attachment 22-8-24-a | ---
| 22-8-24-b | Ballot results of TIA No. 1661. **FAILED** 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 | ---

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<td>22-8-24-c</td>
<td>Three comments were received. See Attachment 22-8-24-c</td>
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<td>22-8-24-d</td>
<td><strong>APPEAL</strong> Consider the appeal of Thomas Kilpatrick, Kilpatrick Law Group, PLLC, requesting that the NFPA Standards Council overturn the ballot results of TIA No. 1661 and issue the TIA. See Attachment 22-8-24-d</td>
</tr>
<tr>
<td>22-8-24-d-1</td>
<td>Comment received from Michael Weaver, Chair, CMP 17, regarding the appeal on TIA No. 1661. See Attachment 22-8-24-d</td>
</tr>
<tr>
<td>22-8-24-d-2</td>
<td>Comment received from Ryan Jackson, CMP 17, regarding the appeal on TIA No. 1661. See Attachment 22-8-24-e</td>
</tr>
<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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<td>22-8-25-a</td>
<td>Text of proposed TIA No. 1668. See Attachment 22-8-25-a</td>
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<td>22-8-25-b</td>
<td>Ballot results of TIA No. 1668. <strong>FAILED</strong> Panel ballot on technical merit and <strong>PASSED</strong> on emergency nature – 16 voting members/11 agree on technical merit/4 disagree/1 abstained/0 ballots not returned/12 agree on emergency nature/3 disagree/1 abstained/0 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -12 voting members/11 agree on correlation/0 disagree/1 abstained/0 ballot not returned. See Attachment 22-8-25-b</td>
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<tr>
<td>22-8-25-c</td>
<td>Four comments were received. See Attachment 22-8-25-c</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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<td>22-8-26-a</td>
<td>Text of proposed TIA No. 1643. See Attachment 22-8-26-a</td>
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<td>22-8-26-b</td>
<td>Ballot results of TIA No. 1643. <strong>PASSED</strong> TC ballot on both technical merit and emergency nature – 21 voting members/16 agree on technical merit/2 disagree/0 abstained/3 ballots not returned/16 agree on emergency nature/2 disagree/0 abstained/3 ballots not returned. <strong>PASSED</strong> CC ballot on correlation -19 voting members/16 agree on correlation/2 disagree/0 abstained/1 ballot not returned. See Attachment 22-8-26-b</td>
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<td>22-8-26-c</td>
<td>One comment was received. See Attachment 22-8-26-c</td>
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<td>22-8-27</td>
<td>NFPA 855</td>
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<td>22-8-29</td>
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<td><strong>22-8-30</strong></td>
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<td><strong>22-8-31</strong></td>
<td>NFPA 1851</td>
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<td><strong>22-8-31-a</strong></td>
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<td>22-8-33</td>
<td>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, <em>Standards for Protective Ensembles for Hazardous Materials and Emergency Medial Operations</em>.</td>
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<td><strong>22-8-33-a</strong> Text of proposed TIA No. 1628.</td>
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<td>See Attachment 22-8-33-a</td>
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<td><strong>22-8-33-b</strong> 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.</td>
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<td>See Attachment 22-8-33-b</td>
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<td><strong>22-8-33-c</strong> No comments were received.</td>
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<td>22-8-34</td>
<td>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, <em>Standards for Protective Ensembles for Hazardous Materials and Emergency Medial Operations</em>.</td>
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<td><strong>22-8-34-a</strong> Text of proposed TIA No. 1650.</td>
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<td>See Attachment 22-8-34-a</td>
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<td><strong>22-8-34-b</strong> 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.</td>
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<td>See Attachment 22-8-34-b</td>
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<td><strong>22-8-34-c</strong> No comments were received.</td>
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<td><strong>22-8-35-a</strong> Text of proposed TIA No. 1651.</td>
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<td>See Attachment 22-8-35-a</td>
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<td><strong>22-8-35-b</strong> 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.</td>
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<td>See Attachment 22-8-35-b</td>
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<td><strong>22-8-35-c</strong> No comments were received.</td>
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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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<td>NFPA 415</td>
<td>2022</td>
<td>PI Closing: January 4, 2024</td>
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<td>NFPA 423</td>
<td>2022</td>
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<td>NFPA 1082</td>
<td>2023</td>
<td>PI Closing: January 4, 2024</td>
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<tr>
<td>NFPA 1850</td>
<td>New</td>
<td>PI Closing: June 1, 2023</td>
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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 |

Dates of upcoming Council meetings:

- **December 7-8, 2022**
  - Location to be determined

- **March 29-30, 2023**
  - Location to be determined

- **August 2023**
  - Dates and location to be determined

| 22-8-42 | Updates from the Council Secretary
No Attachment. |
The FSA conducted flame propagation tests in a system comprising two interconnected, vented 35 ft³ (1 m³) vessels. Experiments were carried out with pipe diameters of 1.1 in. (27 mm), 1.6 in. (42 mm), and 3.2 in. (82 mm) [all less than 4 in. (102 mm)]. Corn starch \( (K_{\text{St}} = 200 \text{ bar.m/s}) \) and wheat flour \( (K_{\text{St}} \approx 100 \text{ bar.m/s}) \) were used as fuels. Even with a small pipe diameter of 1.1 in. (27 mm) and with wheat flour \( (K_{\text{St}} \approx 100 \text{ bar.m/s}) \) used as test dust, there was a flame propagation through a pipe length of at least 39 ft (12 m) in length.

For interconnected vessels that are relatively close together, measures to reduce \( P_{\text{red}} \) for each interconnected vessel, taking into account that propagation could occur, would eliminate the need for isolation techniques.

Dense phase pneumatic transfer [i.e., air velocities down near 600 fpm (183 m/min), and solids loading ratios greater than 30] is also much less likely to provide a conduit for flame spread propagation than for dilute phase pneumatic transfer [i.e., air velocities in the region of 2200 fpm to 3600 fpm (672 m/min to 1098 m/min), and solids loading ratios not greater than 15]. It has been reported by Pineau that it is not uncommon for propagation to occur as few as one time in ten in controlled experiments for 5.9 in. (150 mm) piping even for dilute phase systems. However, recent testing has shown that propagation is more likely with dust concentrations in the lean region. Metal dusts are more likely to propagate deflagrations. For organic dusts, where small diameter pipes with dense phase transfer are utilized, the need for isolation techniques could be obviated if the hazard analysis is acceptable to the AHJ.

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated \( P_{\text{red}} \) for the related process equipment, the diameter and length of the connecting air duct, and the quantity of dust in the work area that can be entrained by a pressure pulse from a deflagration in the related process equipment.

See Z.1.2.21 for additional information.

### 13.9.9 Fire Protection.

#### 13.9.9.1 General.

Fire protection systems, where installed, shall be specifically designed to address building protection, process equipment, and the chemical and physical properties of the materials being processed.

#### 13.9.9.2 System Requirements.

Where fire-fighting water or wet product can accumulate in the system, vessel and pipe supports shall be designed to support the additional water weight.

#### 13.9.9.3 Reserved.

#### 13.9.9.4 Reserved.
13.9.9.5* Automatic Sprinklers.

A.13.9.9.5
Automatic sprinkler protection in AMSs, silos, and bucket elevators should be considered. Considerations should include the combustibility of the equipment, the combustibility of the material, and the amount of material present.

13.9.9.6 Detection and Extinguishing Systems.

13.9.9.6.1
Where fire detection systems are incorporated into the pneumatic conveying, dust collection, or centralized vacuum cleaning system, the fire detection systems shall be interlocked to shut down any active device feeding materials to the pneumatic conveying, dust collection, or centralized vacuum cleaning system, on actuation of the detection system.

13.9.9.6.2
Where spark or infrared detection and extinguishing systems are provided, the process shall be permitted to continue operating on activation of the detection system.

13.9.9.6.3
Where a spark or infrared detection system actuates a diverter valve that sends potentially burning material to a safe location, the process shall be permitted to continue operating on activation of the detection system.

13.9.9.6.4
Where the actuation of fire-extinguishing systems is achieved by means of electronic fire detection, the fire detection system, including control panels, detectors, and notification appliances, shall be designed, installed, and maintained in accordance with NFPA 72.

13.9.9.6.5
All fire detection initiating devices shall be connected to the fire detection control panel via Class A or B circuits as described in NFPA 72.

13.9.9.6.6
All fire detection notification appliances shall be connected to the fire detection control panel via Class A or B circuits as described in NFPA 72.

13.9.9.6.7
All fire-extinguishing system releasing devices, solenoids, or actuators shall be connected to the fire detection control panel via Class A or B circuits as described in NFPA 72.

13.9.9.6.8
The supervision in 13.9.9.6.7 shall include the continuity of the extinguishing system releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

13.9.9.9
All supervisory devices that monitor critical elements or functions in the fire detection and extinguishing system shall be connected to the fire detection control panel via Class A or B circuits as described in NFPA 72.

13.9.9.7 Fire Alarm Service.
Fire alarm service, if provided, shall comply with NFPA 72.

13.9.10 Process and Facility Design.

13.9.10.1
The design of processes and facilities that handle combustible particulate solids shall consider the physical and chemical properties that establish the hazardous characteristics of the materials.

13.9.10.2 *
The design and its basis shall be documented and maintained for the life of the process.

A.13.9.10.2
The design basis generally includes, but is not limited to, the general scope of work, design criteria, process description, material flow diagrams, basis for deflagration protection, basis for fire protection systems, and the physical and chemical properties of the process materials. The design generally includes, but is not limited to, equipment layouts, detailed mechanical drawings, specifications, supporting engineering calculations, and process and instrumentation diagrams.

Chapter 14 Prevention of Sulfur Fires and Explosions

14.1 Administration.

14.1.1 Scope.

14.1.1.1 *
This chapter addresses the size reduction of sulfur and the handling of sulfur in any form.

A.14.1.1.1
Sulfur differs from most other combustible dusts found in industry in that it has relatively low melting and ignition points. Depending on purity, sulfur melts at or slightly below 246°F (119°C). The ignition temperature of a dust cloud is 374°F (190°C); the ignition temperature of a dust layer is 428°F (220°C). Dilution of sulfur with inert solids is not effective in raising the ignition temperature. Sulfur is handled
and processed in the liquid and vapor states in some cases. The liquid is highly combustible, and the
vapor is explosive when mixed with air in the proper proportions.

The finely divided sulfur produced during size reduction and size reduction is the most hazardous from
an explosion standpoint. Also, mixtures containing finely divided elemental sulfur can be just as
hazardous if the sulfur is present in sufficient quantity. Some explosion and fire hazards also accompany
the handling and processing of sulfur in bulk in coarse sizes due to the fine dust present.

14.1.1.2
This chapter shall not apply to the mining of sulfur, recovery of sulfur from process streams, or
transportation of sulfur.

14.1.1.3
This chapter shall not apply to the recovery of sulfur from process streams, such as sour gas processing or
oil refinery operations, and all its encompassed processes and operations, which include block melting,
degassing, and forming.

14.1.1.4
The owner/operator shall be responsible for implementing the requirements in this chapter.

14.1.1.5*
This chapter shall be used in conjunction with the requirements of Chapters 1 through 9 and Chapter 13.
Where conflicts exist, refer to Section 1.6.

A.14.1.1.5
This chapter is to be used to supplement the requirements of Chapters 1 through 9 and 13.

14.1.2 Purpose.
The purpose of this chapter shall be to provide requirements to eliminate or reduce the hazards of
explosion and fire inherent in the processing and handling of sulfur.

14.1.3 Retroactivity.
When major replacement or renovation of existing facilities is planned, provisions of this chapter shall
apply.

14.2 Reserved.

14.3 Reserved.

14.4 General Requirements.
14.4.1 General.
Sections 14.4 through 14.9 shall apply to the handling and processing of solid sulfur at size reduction facilities.

14.4.2 Objectives.

14.4.2.1 Reserved.

14.4.2.2 Reserved.

14.4.2.3 Reserved.

14.4.2.4 Compliance Options.
The performance-based provisions in accordance with Chapter 6 and 14.9.5 and 14.9.9 of this chapter shall be a compliance option in addition to those in 4.2.4.

14.3 Reserved.
14.4 Reserved.
14.5 Reserved.
14.6 Reserved.

14.7 Dust Hazards Analysis (DHA).

14.7.1 General Requirements.
Those portions of size reduction facility where dust accumulations exist shall be evaluated to determine if a dust explosion hazard or flash-fire hazard exists.

14.7.2 Reserved.

14.7.3 Methodology.
14.7.3.1 General.
14.7.3.1.1
Building, rooms, compartments, and other interior spaces shall be assessed in accordance with 14.7.3.1.2 and either 14.7.3.5 or 14.7.3.6, unless the colors of the surfaces underlying the dust accumulations are readily discernible.

14.7.3.1.2
Dust explosion hazard areas and dust flash-fire hazard areas shall be deemed to exist where dust clouds of a hazardous concentration exist.

14.7.3.1.3
All dust accumulated on structures above the lowest footprint shall be evaluated as if accumulated on the lowest footprint.

14.7.3.1.4
Dust accumulation amounts shall reflect the conditions that exist just prior to routinely scheduled cleaning and shall not include short-term accumulations cleaned in accordance with Chapter 7.

14.7.3.1.5
Personnel exposed to a dust explosion hazard or dust flash-fire hazard shall be protected in accordance with Section 8.6.

14.7.3.1.6
A dust explosion hazard area shall be deemed to exist in process equipment where all the following conditions are possible:

(1) Combustible dust is present in sufficient quantity to cause rupture of the vessel if suspended and ignited.
(2) A means of suspending the dust is present.

14.7.3.2 Reserved.

14.7.3.3 Reserved.

14.7.3.4 Reserved.

14.7.3.5 Layer Depth Criterion Method.

14.7.3.5.1*
For materials with bulk density less than 75 lb/ft³ (1200 kg/m³), the layer depth criterion of $\frac{1}{32}$ in. (0.8 mm) shall be permitted to be increased according to the following equation:

$$\text{Allowable Thickness} = \left(\frac{\frac{1}{32} \text{ in.}}{\text{bulk density}}\right) \left(\frac{75 \text{ lb/ft}^3}{\text{lb/ft}^3}\right)$$

A.14.7.3.5.1
The layer depth criterion would be approximately $\frac{1}{16}$ in. (1.7 mm) based on a typical bulk density of rubbermakers sulfur (45 lb/ft³ [720 kg/m²]). If the sulfur at the facility has a different bulk density, the thickness should be corrected for that specific bulk density.

14.7.3.5.2
The footprint area shall be determined as the lesser of the building/room area or 21,500 ft² (2000 m²).

14.7.3.5.3*
A dust explosion hazard and dust flash-fire hazard shall be deemed to exist in any building or room where either of the following conditions exists:

1. The total area of dust accumulations exceeding the layer depth criterion is greater than 5 percent of the footprint area.
2. The total volume of dust accumulations is greater than the layer depth criterion multiplied by 5 percent of the footprint area.

A.14.7.3.5.3
A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

Using a bulk density of 45 lb/ft³ (720 kg/m³), it has been calculated that a dust layer averaging $\frac{1}{16}$ in. (1.7 mm) thick and covering the floor of a building is sufficient to produce a uniform dust cloud of 0.37 oz/ft³ (370 g/m³) 10 ft (3 m) high throughout the building. This is a conservative value for the optimum concentration with respect to explosion damage potential. This situation is idealized, and several factors should be considered.

First, the layer rarely will be uniform or cover all surfaces. Second, the layer of dust probably will not be dispersed completely by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the $\frac{1}{16}$ in. (1.7 mm) thick layer is suspended, this material is still sufficient to create an atmosphere within the explosible range of sulfur dusts.

Consideration should be given to the proportion of building volume that could be filled with a
combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a 1/16 in. (1.7 mm) layer of dust on the floor is obviously hazardous and should be cleaned. This same 100 ft² (9.3 m²) area in a 2025 ft² (188 m²) building is also a moderate hazard. This area represents about 5 percent of the floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges also should be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

From the preceding information, the following guidelines have been established:

(1) Dust layers 1/16 in. (1.7 mm) thick can be sufficient to warrant immediate cleaning of the area.

(2) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.

(3) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.

(4) Due consideration should be given to dust that adheres to walls, since it is easily dislodged.

(5) Attention and consideration should be given to projections such as light fixtures, which can provide surfaces for dust accumulation.

(6) Dust collection equipment should be monitored to ensure that it is operating effectively. For example, dust collectors using bags operate most effectively between limited pressure drops of 2 in. to 5 in. of water (0.5 kPa to 1.24 kPa).

Guidelines (1) through (5) serve to establish a cleaning frequency.

14.7.3.6 Mass Method

Unless the method in 14.7.3.5 is being used, dust explosion hazard areas and dust flash-fire hazard areas shall be deemed to exist when the total accumulated dust on any surfaces exceeds the thresholds calculated in 14.7.3.6.1 or 14.7.3.6.2, respectively.

14.7.3.6.1*

The threshold dust mass establishing a building or room as a dust explosion hazard area, \( M_{\text{basic - exp}} \), shall be determined according to the following equation:

\[
M_{\text{basic - exp}} = 0.01 \cdot A_{\text{floor}} \cdot H
\]

where:

\( M_{\text{basic - exp}} \) = threshold dust mass (kg) based on building damage criterion

\( A_{\text{floor}} \) = lesser of the enclosure floor area (m²) or 2000 m²

\( H \) = lesser of the enclosure ceiling height (m) or 12 m

A.14.7.3.6.1
14.7.3.6.2*
The threshold dust mass establishing a building or room as a dust flash-fire hazard area, $M_{\text{basic - fire}}$, shall be determined according to the following equation:

\[
14.7.3.6.2\quad M_{\text{basic - fire}} = 0.05 \cdot A_{\text{floor}}
\]

where:

- $M_{\text{basic - fire}}$ = threshold dust mass (kg) based on personnel fire exposure criterion
- $A_{\text{floor}}$ = lesser of the enclosure floor area (m²) or 2000 m²
See A.14.7.3.6.1.

14.8 Management Systems.

14.8.1 Reserved.

14.8.2 Reserved.

14.8.3 Operating Procedures and Practices.
Operation and maintenance of all size reduction machinery shall be under supervision.

14.8.4 Housekeeping.
The requirements of 14.8.4 shall be applied retroactively.

14.8.4.1 Reserved.

14.8.4.2 Methodology.

14.8.4.2.1 Procedure.

14.8.4.2.1.1 Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

14.8.4.2.1.2* Sweeping shall be the preferred method.

A.14.8.4.2.1.2 Push brooms should have natural bristles.

14.8.4.2.3 Vacuuming shall be permitted.

14.8.4.2.2 Reserved.

14.8.4.3 Reserved.
14.8.4.2.4 Reserved.

14.8.4.2.5 Reserved.

14.8.4.2.6* Compressed Air Blowdown Method.

A.14.8.4.2.6
Because the mixture of sulfur dust and water can corrode materials of construction, the use of steam is discouraged. All the listed precautions in 8.4.2.6.1 might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts.

14.8.4.6 Frequency and Goal.

14.8.4.6.1*
Where the facility is intended to be operated with less than the dust accumulation defined by the thresholds in 14.7.3, a planned inspection process shall be implemented to evaluate dust accumulation rates and the housekeeping frequency required to maintain dust accumulations below the threshold dust accumulation.

A.14.8.4.6.1
See A.13.8.4.6.2 for tables showing unscheduled housekeeping timing based on accumulation for floor-accessible surfaces and remote surfaces.

14.8.4.6.2
Where the facility is intended to be operated with more than the dust accumulation defined by the thresholds in 14.7.3, a documented risk assessment acceptable to the authority having jurisdiction shall be conducted to determine the level of housekeeping consistent with any dust flash-fire and dust explosion protection measures provided in accordance with Section 14.9.3 and 14.8.8 through 14.8.10.

14.8.7 Inspection, Testing, and Maintenance

14.8.7.1 General Requirements.
The requirements of 14.8.7.1 through 14.8.7.3 shall be applied retroactively.

14.8.7.1.1
An inspection, testing, and maintenance program shall be developed and implemented to ensure that the fire and explosion protection systems and related process controls and equipment perform as designed.

14.8.7.1.2
In addition to the items in 8.7.2, the inspection, testing, and maintenance program shall include process changes.

14.8.7.1.3
Records shall be kept of maintenance and repairs performed.

14.8.7.2 Specific Equipment Maintenance.

14.8.7.2.1 Maintenance of material-feeding devices shall comply with 13.8.7.2.1.

14.8.7.2.2 Maintenance of fans and blowers (air-moving devices) shall comply with 13.8.7.2.2.

14.8.7.2.3 Maintenance of dust collectors and air-material separators shall comply with 13.8.7.2.3.

14.8.7.2.4 Maintenance of fire and explosion protection systems shall comply with 13.8.7.2.5.

14.8.8 Training and Hazard Awareness.

14.8.8.1
The requirements of Chapter 8 shall be applied retroactively.

14.8.8.2
Operating and maintenance procedures and emergency plans shall be developed.

14.8.8.3
Initial and refresher training shall be provided to employees who are involved in operating, maintaining, and supervising facilities that handle combustible particulate solids.

14.8.8.4
Initial and refresher training shall ensure that all employees are knowledgeable about the following:

(1) Hazards of their workplace
(2) General orientation, including plant safety rules
(3) Process description
(4) Equipment operation, safe start-up and shutdown, and response to upset conditions
(5) The necessity for related fire and explosion protection systems to function as designed and installed
(6) Equipment maintenance requirements and practices
(7) Housekeeping requirements
(8)* Emergency response plans

A.14.8.8.4(8)
Training should be provided to plant fire squads or fire brigades where they exist.
14.8.8.5
The employer shall certify annually that the training and review required by 14.8.8 through 14.8.10 have been completed.

14.8.9 Contractors.
Contractors involved in the commissioning, repair, or modification of explosion protection equipment shall be qualified as specified in Chapter 15 of NFPA 69 when such devices are employed.

A.14.8.9
With regards to 8.9.2, qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps or professional licenses.

14.8.9.1 Reserved.

14.8.9.2 Reserved.

14.8.9.3* Contractor Training.
Documentation shall be maintained detailing the training that was provided and who received it.

A.14.8.9.3
With regards to 8.9.3.4, it is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, and smoking and nonsmoking areas.

14.8.10 Emergency Planning and Response.
The plans and procedures shall be reviewed annually and as required by process changes.

14.9 Hazard Management: Mitigation and Prevention.

14.9.1 Reserved.

14.9.2 Reserved.

14.9.3 Building Design.
14.9.3.1 Construction.

14.9.3.1.1 All buildings shall be of Type I or Type II construction, as defined in NFPA 220.

14.9.3.1.2 Where local, state, and national building codes are more restrictive, modifications shall be permitted for conformance to these codes.

14.9.3.1.3* Floor-ceiling assemblies, roof assemblies, and load-bearing walls that are exposed to dust explosion hazards shall be designed so as to preclude failure during an explosion. *(See NFPA 68.)*

A.14.9.3.1.3 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

14.9.3.1.4 Buildings or enclosures containing a dust explosion hazard area shall be constructed with deflagration venting designed in accordance with NFPA 68.

14.9.3.1.5 Building Construction Requirements for Housing Size Reduction Machinery.

14.9.3.1.5.1 Where Type 1 equipment is located outdoors, it shall be permitted to transfer reduced material in enclosed downstream equipment, provided either of the following conditions exists:

(1) The transferred material is continuously wetted with water sufficient to prevent ignition.
(2) An inert gas isolation system is provided between the Type 1 equipment and the enclosed downstream equipment.

14.9.3.1.5.2* Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be segregated from other areas by noncombustible walls designed to withstand the force of a vented sulfur dust explosion. *(See NFPA 68.)*

A.14.9.3.1.5.2 It is preferable that the size reduction space be detached. Exterior walls could require explosion venting. Steel frame construction, with light, nonbearing exterior walls and a light roof, is preferable.

14.9.3.2 Building or Building Compartment Protection.
14.9.3.2.1 Reserved.

14.9.3.2.2 Fire Resistance Rating.

14.9.3.2.2.1* Interior stairs and elevators shall be enclosed in shafts designed to prevent the migration of dust and that have a minimum fire resistance rating in accordance with Section 8.6 of NFPA 101.

A.14.9.3.2.2.1

14.9.3.2.2.2* Doors that are the automatic-closing or self-closing type and that have a minimum fire protection rating of 1 hour shall be provided at each landing.

A.14.9.3.2.2.2
An appropriate test method is in accordance with NFPA 252.

14.9.3.2.2.3 Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed.

14.9.3.2.3 Protection of Openings and Penetrations.

14.9.3.2.3.1 Where floors, walls, ceilings, and other partitions have been erected to control the spread of deflagrations, penetrations in these structures shall be sealed dusttight in normal operation and protected to maintain their fire resistance rating and physical integrity in a deflagration.

14.9.3.2.3.2 Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire resistance rating equivalent to the wall design.

14.9.3.2.3.3 Fire doors shall be installed according to NFPA 80 and shall normally be in the closed position.

14.9.3.2.3.4 All pathways between the space used for size reduction and the rest of the building shall be from the
outside or via indirect means as described in 14.9.3.2.3.5.

14.9.3.2.3.5 *
Indirect pathways through segregating walls by means of vestibules or stairways shall be permitted, provided the wall opening to the size reduction area is protected by an automatic-closing fire door suitable for 3-hour openings, and the opening into the vestibule or stairway is protected by an automatic-closing fire door suitable for 2-hour openings.

A.14.9.3.2.3.5
It is recommended that an emergency escapeway for personnel be provided independently.

14.9.3.2.3.5.1
The two automatic-closing fire doors in 14.9.3.2.3.5 shall be installed at right angles to each other.

14.9.3.2.3.5.2
Both fire doors in 14.9.3.2.3.5 shall be installed in accordance with NFPA 80.

14.9.3.3 Life Safety.
Means of egress shall comply with NFPA 101.

14.9.4 Equipment Design.

14.9.4.1 Reserved.

14.9.4.2 Reserved.

14.9.4.3 Reserved.

14.9.4.4 Dust Collectors.

14.9.4.4.1 General.

14.9.4.4.1.1 Reserved.
14.9.4.4.1.2 Reserved.

14.9.4.4.1.3 Protection.

(A) Where an explosion hazard exists, dust collectors with a dirty-side volume of 8 ft³ (0.2 m³) or greater shall be located outside of buildings.

(B) For dust collectors that are located outside of buildings, a risk assessment shall be permitted to be conducted to determine the level of explosion protection to be provided.

(C) The requirement of 14.9.4.4.1.3(A) shall not apply to dust collectors protected in accordance with 14.9.8.2.

(D) Where both an explosion hazard and a fire hazard exist in a dust collector, provisions for protection of each type of hazard shall be provided.

(E)* Isolation devices shall be provided for dust collectors in accordance with 14.9.8.3.

A.14.9.4.4.1.3(E)
For design requirements for fast-acting dampers and valves, flame front diverters, and flame front extinguishing systems, see NFPA 69.

(F)* Where lightning protection is provided, it shall be installed in accordance with NFPA 780.

A.14.9.4.4.1.3(F)
Annex L.6 of NFPA 780 and IEC 62305-2, Protection Against Lightning — Part 2: Risk Management, provide methods for assessments to determine the need for lightning protection.

14.9.4.4.1.4 Manifolding of Dust Collection Ducts.

(A) Manifolding of dust collection ducts to dust collectors shall not be permitted.

(B) Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded.
(C) Dust collection ducts from nonassociated pieces of equipment shall be permitted to be manifolded provided that each of the ducts is equipped with an isolation device prior to manifolding in accordance with 14.9.8.3 except as prohibited by 4.6.7.

(D) Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded.

14.9.4.4.2 Reserved.

14.9.4.4.3 Reserved.

14.9.4.4.4 Reserved.

14.9.4.4.5 Reserved.

14.9.4.4.6 Dust Collector Location.
See 14.9.4.4.1.3(A) through 14.9.4.4.1.3(C).

14.9.4.4.7 Clean Air Exhaust.
Conveying gas from dust collectors shall be permitted to be recirculated within enclosed equipment systems.

14.9.4.4.8 Construction.
Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

14.9.4.5 Reserved.

14.9.4.6 Reserved.

14.9.4.7 Reserved.
14.9.4.8 Reserved.

14.9.4.9 Reserved.

14.9.4.10 Size Reduction: Location of Size Reduction Machinery and Containers.

14.9.4.10.1 Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be used only for the size reduction process and the filling of containers with the reduced material when size reduction of sulfur is in progress.

14.9.4.10.2* Containers shall be removed from the area as soon as possible after being filled.

A.14.9.4.10.2 It is not the intent of this requirement to prohibit interim storage of bags, drums, or filled containers.

14.9.4.11 Reserved.

14.9.4.12 Reserved.

14.9.4.13 Mechanical Feeding Devices.

Mechanical feeding devices shall comply with 13.9.4.13.

14.9.4.14* Bucket Elevators.

Bucket elevators shall comply with 13.9.4.14.

A.14.9.4.14 Also see 14.9.4.15.3 through 14.9.4.15.5.

14.9.4.15 Conveyors.

14.9.4.15.1* Only conveyors or spouts with isolation devices, such as rotary valves designed to prevent deflagration propagation in accordance with NFPA 69 shall be permitted to pass through segregating walls between
size reduction rooms and adjacent spaces.

A.14.9.4.15.1
Screw conveyors and conveyors in general can be used for applications other than explosion isolation.

14.9.4.15.2
Conveyors used to feed or discharge sulfur to or from size reduction machinery shall be in dusttight housings.

14.9.4.15.3
Nonferrous buckets or bucket elevators shall be used where they are housed in ferrous casings.

14.9.4.15.4*
Aluminum buckets or bucket elevators shall not be used where they are housed in ferrous casings.

A.14.9.4.15.4
This restriction is not intended to preclude the use of any or all aluminum components, but it should be understood to apply to components in relative motion with each other. The reaction of a metal with the oxide of a different metal is called a thermite reaction. The reactants provide their own oxygen supply and thus present a high fire risk. An example of this is the reaction of aluminum with ferric oxide (rust), where the products would be aluminum oxide and free elemental iron. The rubbing of aluminum metal buckets against a rusted surface will first commingle the aluminum with the ferric oxide and with continued rubbing generate sufficient heat to initiate the reaction and provide an ignition source for the combustible dust in the bucket elevator. For more information, see Hawley, Condensed Chemical Dictionary.

14.9.4.15.5
Ferrous buckets or bucket elevators shall be permitted to be used with ferrous casings, provided that steam shall be blown into the elevator boot while the elevator is in operation or that an inert gas system meeting the requirements of 14.9.8.2(1) shall be used.

14.9.4.15.6
Unless the conveying system is inerted in accordance with 14.9.8.2(1), pneumatic conveying of sulfur shall not be permitted.

14.9.4.15.7
Each pulverizer shall have a separate and self-contained system.

14.9.4.15.8
Enclosed conveyors shall comply with 13.9.4.15.

14.9.4.16 Mixers and Blenders.
Mixers and blenders shall comply with 13.9.4.16.

14.9.4.17 Reserved.

14.9.4.18 Reserved.

14.9.4.19 Inert Gas Systems.

14.9.4.19.1 Use of inert gas shall not be required for Type 1 machinery.

14.9.4.19.2 Type 2 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

1. The feed and discharge shall be provided with isolation devices, such as rotary valves designed in accordance with NFPA 69.
2. The isolation devices and all machinery between them shall be capable of withstanding an overpressure of 100 lb/in.² (690 kPa).
3. An inspection of the machinery shall be performed at least once per shift during operation to detect abnormalities in operating conditions.

14.9.4.19.3 Type 3 Machinery.

14.9.4.19.3.1 Type 3 machinery shall not be operated without the use of an inert gas system meeting the requirements of NFPA 69.

14.9.4.19.3.2 Where the pulverized sulfur is removed from the machinery by blower or exhaust systems, inert gas protection shall extend to all piping and collectors.

14.9.4.19.3.3* The inert gas system shall be equipped with sampling and recording instruments to obtain a reliable and continuous analysis of the inert atmosphere in that part or parts of the machinery where the inert atmosphere is normally weakest.

A.14.9.4.19.3.3 Auxiliary instrumentation should be provided for sampling and recording the quality of the inert atmosphere in other parts of the system.
14.9.4.19.3.4
Provisions shall be made for automatically shutting down the size reduction machinery if the oxygen content of the atmosphere inside the inerted equipment rises above the maximum levels stated in 14.9.8.2(1).

14.9.4.19.4*
Type 4 machinery shall be permitted to be operated without inert gas protection if the following requirements are met:

(1) Manually operated valves shall be installed at each machine for control of feed and air lines.
(2)* The equipment shall be under supervision during operation and shall be shut down for detailed inspection and any necessary cleaning when abnormalities in operation indicate the possibility of fire within the machine.
(3) All valves shall be closed before opening the machine.

A.14.9.4.19.4
The large volumes and high velocities of air and the compactness of the Type 4 unit make inerting usually impractical.

A.14.9.4.19.4(2)
Flooding with inert gas or steam, combined with delayed opening to permit smothering of any residual fire, is recommended.

14.9.5 Ignition Source Control.
The requirements of 14.9.5.7 and 14.9.5.13 shall be applied retroactively.

14.9.5.1 Reserved.

14.9.5.2 Reserved.

14.9.5.3 Hot Surfaces.
Unprotected hot surfaces, such as steam lines, that can attain temperatures high enough to melt and ignite sulfur dust shall not be exposed in enclosures housing sulfur processing equipment.

14.9.5.4 Reserved.

14.9.5 5 Reserved.

14.9.5.6* Electrostatic Discharges.
All machinery, conveyors, housings, and collectors shall be thoroughly bonded and grounded with a resistance of less than $1.0 \times 10^6$ ohms to ground to prevent the accumulation of static electricity.

A.14.9.5.6
See NFPA 77 for information on the subject.

14.9.5.6.1 Reserved.

14.9.5.6.2 Maximum Particulate Transport Rates.

Maximum particulate transport rates shall comply with 13.9.5.6.2.

14.9.5.6.3 Reserved.

14.9.5.6.4* Intermediate Bulk Containers for Solid Sulfur.

A.14.9.5.6.4
For further information regarding the hazards and uses of flexible and rigid intermediate bulk containers, see Section 9.1 of NFPA 77 and Avoiding Static Ignition Hazards in Chemical Operations, pp. 199–204.

14.9.5.6.4.1
The requirements of 14.9.5.6.4.2 through 14.9.5.6.4.4 shall be applied retroactively.

14.9.5.6.4.2*
Dispensing solid sulfur from intermediate bulk containers shall only be performed under the following conditions:

1. A conductive (i.e., metallic) rigid intermediate bulk container (RIBC) shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided the RIBC is electrically grounded with a resistance less than 1 megohm to ground.

2.* A Type C FIBC shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmosphere for which the FIBC has been tested and found suitable, provided the FIBC is electrically grounded with a resistance less than 1 megohm to ground.

3.* A Type D FIBC shall be permitted to be used for dispensing into flammable vapor, gas, dust, or hybrid atmospheres for which the FIBC has been tested and found suitable.

4.* Type A FIBC, Type B FIBC, or insulating RIBCs shall not be permitted to be used for solid sulfur applications, processes, or operations unless a documented risk assessment assessing the electrostatic hazards, including the potential presence of hydrogen sulfide, is acceptable to the authority having jurisdiction.

A.14.9.5.6.4.2
Unless intentionally removed by the process, sulfur typically contains adsorbed hydrogen sulfide. Dispensing generates static charge, which can ignite not only the combustible dust atmosphere but also the hydrogen sulfide. Minimum ignition energy (MIE) of less than 1 mJ has been reported for particulate sulfur, while MIE of 0.068 mJ has been reported for hydrogen sulfide. MIEs are measured in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

**A.14.9.5.6.4.2(2)**
Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers’ Type C FIBCs in the presence of hydrogen sulfide atmospheres should be determined. Failure to provide grounding for a Type C FIBC can create a potential static discharge hazard greater than using Type A or Type B FIBCs.

**A.14.9.5.6.4.2(3)**
Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers’ Type D FIBCs in the presence of hydrogen sulfide atmospheres should be determined.

**A.14.9.5.6.4.2(4)**
The use of Type A or Type B FIBCs and insulating RIBCs should be based on a documented risk assessment acceptable to the authority having jurisdiction. Type A and Type B FIBCs and insulating RIBCs can generate sufficient electrostatic energy discharge to ignite ground or crushed sulfur powder (i.e., powders with MIE values = 3 mJ). Dry sulfur can be delivered as formed sulfur (prills, flakes, granules, and pastilles) as well as powders. Attrition through normal handling could produce fines. Larger forms of sulfur generally would be expected to have higher MIE values, which should be determined by test in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, or similar international protocol, and might allow the use of Type A or Type B FIBCs and insulating RIBCs. The determination of the suitability of Type A or Type B FIBCs and insulating RIBCs should be based not only on MIE but also on electrostatic properties, such as electrostatic chargeability and volume resistivity tested in general accordance with ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*, and MEC tested in accordance with ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, or similar international protocol. The evaluation should also consider sulfur-handling and sulfur-processing operations prior to FIBC filling and unloading. Generally speaking, faster filling and unloading rates (such as with pneumatic conveying) would be expected to generate higher levels of static charge and should be avoided. If fines with MIE = 3 mJ are present in sufficient quantity to form a suspended dust cloud of sufficient concentration to support a deflagration, as determined in accordance with ASTM E1515 [typically 0.035 oz/ft³ (35 g/m³)], then there is sufficient risk to preclude the use of Type A or Type B FIBCs and insulating RIBCs.

**14.9.5.6.4.3 * **
FIBCs that are listed or tested by a recognized testing organization and are shown not to ignite flammable atmospheres, including hydrogen sulfide, during transfer shall be permitted to be used.

**A.14.9.5.6.4.3**
Certain fabrics that pose significantly less risk of ignition in flammable atmospheres have been developed
for use in FIBCs. One such fabric that has been tested for use in flammable atmospheres and has been used in FIBCs is documented in Ebadat and Mulligan, “Testing the Suitability of FIBCs for Use in Flammable Atmospheres.”

14.9.5.6.4.4
Documentation of test results shall be made available to the authority having jurisdiction.

14.9.5.7 Open Flames.
Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

14.9.5.8 Reserved.

14.9.5.9 Reserved.

14.9.5.10 Reserved.

14.9.5.11 Friction and Impact Sparks.

14.9.5.11.1
Floor sweepings shall not be returned to any machine.

14.9.5.11.2*
Foreign materials, such as tramp metal, that are capable of igniting sulfur being processed shall be removed from the process stream by one of the following methods:

(1) Permanent magnetic separators or electromagnetic separators that indicate loss of power to the separators
(2) Inerted gas separators
(3) Grates or other separation devices

A.14.9.5.11.2
It should be recognized that magnetic separators will not remove nonferrous tramp material, including stones, brick, and concrete. Every care, using other means, should be taken to ensure excluding such materials from the size reduction system.

14.9.5.11.3
All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is
minimized.

14.9.5.11.4 Interlocking controls shall be installed to stop the dust feed if the size reduction machines stops or if the fans or blowers stop for any reason.

14.9.5.12* Propellant-Operated Tools.

A.14.9.5.12 Propellant-operated tools include all of the following:

(1) Cartridge operated
(2) Powder operated
(3) Tools using combustible gas as the propellant

14.9.5.12.1 Propellant-operated tools shall not be used where combustible dust or dust clouds are present.

14.9.5.12.2 When the use of such tools becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors, and walls shall be cleaned thoroughly; and all accumulations of dust shall be removed.

14.9.5.12.3 After such work has been completed, a check shall be made to ensure that no cartridges or charges have been left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or dust-handling machinery is resumed.

14.9.5.12.4 Use of propellant-operated tools shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B.

14.9.5.13 Smoking. Smoking shall be permitted only in designated areas.

14.9.5.14* Electrical Systems.

A.14.9.5.14 Although sulfur is not now included in atmospheres classified as Class II, Group G, it has been the experience of the sulfur industry that such equipment can be suitable. However, consideration should be given to the melting point of sulfur, 233°F to 246°F (112°C to 119°C), in the selection of heat-producing electrical equipment.
All electrical equipment and installations shall comply with the requirements of NFPA 70.

**14.9.5.14.2***
Hazardous (classified) areas that are identified shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

*A.14.9.5.14.2*
Refer to NFPA 499. See also table A.13.9.5.14.2 which provides guidance for area electrical classification.

**14.9.5.15 Heating.**
Heating shall be by indirect means.

**14.9.5.16 Shovels.**
Where shovels are used to handle sulfur dust, they shall be nonferrous and spark-resistant.

**14.9.6 Reserved.**

**14.9.7 Dust Control.**

**14.9.7.1***
Continuous suction shall be provided for processes where combustible dust is liberated in normal operation so as to minimize the escape of dust.

*A.14.9.7.1*
It is recommended that the interior of size reduction and packaging rooms or buildings be painted a color that contrasts with the color of the dust.

**14.9.7.2**
The dust shall be conveyed to dust collectors.

**14.9.8 Explosion Prevention/Protection.**

**14.9.8.1 Reserved.**

**14.9.8.2*** Equipment Protection.
The design of explosion protection for equipment shall incorporate one or more of the methods of protection in 14.9.8.2(1) through 14.9.8.2(4).

(1) Oxidant concentration reduction in accordance with NFPA 69 and Section 14.9.4.19 of this chapter
(a) Under normal operating conditions, the limiting oxidant concentration (LOC) shall be permitted to be as follows:
   i. 12.0 percent where carbon dioxide is used as the inert
   ii. 9.3 percent where nitrogen is used as the inert

(b) Where oxygen monitoring is used, it shall be installed in accordance with ANSI ISA 84.00.01, Functional Safety: Safety Instrumented Systems for the Process Industry Sector.

(2) Deflagration venting in accordance with NFPA 68

(3) Deflagration pressure containment in accordance with NFPA 69

(4) Deflagration suppression systems in accordance with NFPA 69

A.14.9.8.2
Pre-deflagration detection and control systems can be applied where installed in accordance with NFPA 69. However, a pre-deflagration detection and control system should not be used as the primary explosion prevention device. In addition, users are cautioned that infrared or near-infrared detectors are not effective on sulfur fires.

14.9.8.2.1
Dilution with a noncombustible dust to render the mixture noncombustible shall not be permitted.

14.9.8.2.2
Deflagration venting through a dust retention and flame-arresting device shall not be permitted unless the device is listed for use with sulfur.

14.9.8.3* Equipment Isolation.

A.14.9.8.3
Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A.14.9.8.3(a) shows an example of how this propagation might occur. Isolation techniques as shown in Figure A.14.9.8.3(b) through Figure A.14.9.8.3(e) can be used to prevent the propagation of the deflagration by arresting the flame front.

Figure A.14.9.8.3(a) An Example of Deflagration Propagation Without Isolation.
Both the direction and extent of potential deflagration propagation must be considered. Usually, a dust deflagration occurs in a fuel-rich regime (i.e., above the stoichiometric fuel-air ratio), making it likely that the initial deflagration will expand into volumes that are many times greater than the initial deflagration volume.

The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. This dust is expelled from the containment vessel via every available exit path, in all possible directions of flow, including flow via all connecting ducts and out through any provided explosion venting. The driving force pushing the dust away from the point of initiation (which, under vented conditions, might be in the range of a few pounds per square inch) can easily overcome the force of normal system flow (which typically might be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

The conveyance of the flame front via both the in-feed and outflow ducts should be evaluated. In most cases, this movement of dust and propagating flame front will commit the deflagration to the connected equipment via ductwork. Where equipment and ducts are adequately protected pursuant to Chapter 14 and NFPA 68 (where explosion venting is used), the consequences of explosion propagation might not increase the life safety hazard or significantly increase the property damage. However, in other cases, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

In the case of several pieces of equipment connected via ductwork, where each piece of equipment and the ductwork are provided with explosion venting, the dust explosion can nevertheless propagate...
throughout the system. Explosion venting on the equipment of deflagration origin will prevent overpressure damage to that vessel. If the concentration within the connecting ductwork is below the minimum explosible concentration (MEC) prior to the deflagration, the deflagration can still spread to the next vessel, but the explosion venting there should protect that second vessel from overpressure damage. In such a case, the provision of explosion isolation would not provide any significant reduction in either the property damage or life safety hazard.

If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct will result in an accelerating flame front. Without explosion venting on the ductwork, this accelerating flame front will result in a significant prepressurization of the equipment at the other end of the duct and in a very powerful jet flame ignition of a dust deflagration within that second vessel. Such a deflagration can overwhelm the explosion venting on that vessel, even if the design is based on information in NFPA 68, resulting in the catastrophic rupture of the vessel. In this case, the explosion propagation results in a significant increase in the property damage and, quite possibly, in an increase in life safety hazard due to the vessel rupture. Consequently, explosion isolation is a critical component to the management of the fire and explosion risk.

In the case of a dust collector serving a large number of storage silos, an explosion originating in the dust collector can produce an acceptable level of damage to the collector if it is provided with adequate explosion venting per NFPA 68. However, the propagation of that explosion upstream to all the connected silos could cause ignition of the material stored in all those silos. The initiation of such storage fires can significantly escalate the magnitude of the incident, in terms of property damage, interruption to operations, and life safety hazard. As with the previous example of a connecting duct having a concentration above the MEC prior to deflagration, explosion isolation would be warranted in this case.

When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A.14.9.8.3(b) for an example of rotary valves.

Figure A.14.9.8.3(c) illustrates one example of deflagration propagation using mechanical isolation.

Figure A.14.9.8.3(d) illustrates one example of deflagration propagation using flame front diversion.

Figure A.14.9.8.3(e) illustrates one example of deflagration propagation using chemical isolation.

Figure A.14.9.8.3(b) Rotary Valves.
Figure A.14.9.8.3(c) Deflagration Propagation Using Mechanical Isolation.
14.9.8.3.1 Isolation of Equipment.
Isolation devices shall not be required where oxidant concentration in the connected equipment has been
reduced in accordance with 14.9.8.2(1) and the general requirements of NFPA 69.

**14.9.8.3.2* Isolation of Upstream Areas.**
Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

**A.14.9.8.3.2**
Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations, in which the discharge of a fireball from the pickup point would endanger personnel.

A common example for the application of such isolation would be in the upstream duct work associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered duct work. Due to a high likelihood of ignition of sulfur dust, dust collectors should be operated under inert atmosphere.

**14.9.9 Fire Protection.**

**14.9.9.1 General.**
Where the owner/operator chooses to assign an industrial fire brigade to respond to plant emergencies, the brigade shall meet the requirements of NFPA 600.

**14.9.9.2***
Steam and inert gases shall be permitted to be used as extinguishing agents for tightly closed containers provided that the sulfur dust is not disturbed.

**A.14.9.9.2**
If a container is tightly closed and the volume of oxygen enclosed is not too large, a fire will be smothered by the sulfur dioxide formed. When steam is used for fire suppression in enclosed equipment, the rate of application should be at least 2.5 lb/min/100 ft³ (1.13 kg/min/2.83 m³).

**14.9.9.3**
In all cases, it shall be made certain that the fire is completely extinguished before disturbing the dust and that the sulfur has cooled sufficiently to prevent reignition.

**14.9.9.4***
When size reduction or other processing equipment is opened for cleaning following an ignition, the feed, discharge, and other openings shall first be closed by suitable metal valves or gates.

**A.14.9.9.4**
A period of at least 15 minutes should elapse between closing the valves or gates and opening the equipment to smother any residual fire in the equipment. As an added precaution, the equipment should be flooded with inert gas or steam, if available, prior to opening.
14.9.9.5 Hose, Standpipes, Hydrants, and Water Supply.

14.9.9.5.1 Reserved.

14.9.9.5.2 Nozzles.

14.9.9.5.2.1 Reserved.

14.9.9.5.2.2 Reserved.

14.9.9.5.2.3*
It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with the nozzles specified in 9.9.4.2.1.

A.14.9.9.5.2.3
Where a straight stream must be used to reach fires in inaccessible locations, the stream should be directed above the burning material so that the water rains down on the material.

14.10 Handling of Liquid Sulfur at Normal Handling Temperatures.

14.10.1* General.
This chapter shall apply to the handling of liquid sulfur in the temperature range of 246°F to 309°F (119°C to 154°C).

A.14.10.1
The normal handling temperature of liquid sulfur is 250°F to 309°F (121°C to 154°C), which is slightly above the melting point of 246°F (119°C). At the melting point sulfur is a transparent, mobile liquid. As the temperature of the liquid is raised, it darkens, becoming deep orange in hue. Up to about 320°F (160°C) the viscosity drops with rising temperature. Above this point the viscosity increases with rising temperature. At 370°F (188°C) the viscosity reaches a tremendously high maximum that practically prevents it from flowing and the liquid is so intensely colored as to be nearly opaque. Above 370°F (188°C) it again acts in a more normal fashion, with its viscosity falling somewhat as the temperature continues to rise.

At the normal handling temperature of liquid sulfur [250°F to 309°F (121°C to 154°C)] the vapor concentration above the pure sulfur, free of hydrocarbons or hydrogen sulfide, is too low to form a flammable mixture in air. While the flash point of liquid sulfur varies with purity, it is always higher than the normal handling temperature. For pure sulfur, the flash point can be as low as 370°F (188°C) and for relatively impure crude sulfur, the flash point can be as low as 334°F (168°C).
The relative low ignition temperature of sulfur and the possible presence of hydrogen sulfide are the primary fire and explosion hazards of liquid sulfur. Impure sulfur (sometimes referred to as “dark sulfur”) contains hydrocarbons, which react slowly with the liquid sulfur to form hydrogen sulfide. Recovered sulfur, such as that produced from petroleum gas streams containing the hydrogen sulfide using the Claus Process, often contain dissolved hydrogen sulfide, which will be liberated slowly from a quiescent body of liquid sulfur. Agitation of such liquid sulfur will cause rapid evolution of hydrogen sulfide, which can create a flammable atmosphere within the storage tank. In the temperature range at which the liquid sulfur is normally handled, the lower flammable limit for hydrogen sulfide is at about 3.4 percent compared to 4.3 percent at room temperature.

Pure sulfur will not generate a flammable atmosphere in the normal temperature range of the liquid. Transfer of liquid sulfur using air pressure should be avoided. If air pressure is applied to the vapor space of an enclosure containing molten sulfur with high concentrations of hydrogen sulfide, there is a danger that the hydrogen sulfide/air mixture will become flammable. Transfer by pressure should be restricted to using an inert gas. Use of pumps would be the preferred transfer method.

Because impurities can cause generation of H$_2$S or pyrophoric iron sulfides, testing a representative sample of incoming batches for carbon content and hydrogen sulfide should be performed. These impurities should be kept to a minimum.

### 14.10.2 Detection of Unsafe Conditions.

#### 14.10.2.1

Devices for measuring the concentration of combustible gas in the atmosphere over liquid sulfur shall be designed for operation in atmospheres containing hydrogen sulfide.

#### A.14.10.2.1

The sensing elements of some explosimeters are not designed for and are adversely affected by hydrogen sulfide–containing atmospheres.

#### 14.10.2.2

Instruments used for detecting explosive atmospheres shall be capable of measuring the lower explosive limit of hydrogen sulfide, since it is the primary gas evolved from sulfur that can contribute to an explosive atmosphere.

#### 14.10.2.3

Operations shall be discontinued whenever instruments show a combustible gas concentration of 35 percent or more of the lower explosive limit in the gas space of liquid sulfur containers.

#### 14.10.2.4

Operations shall not be resumed until the instruments indicate a concentration of 15 percent or less of the lower explosive limit.
14.10.3 Equipment Design.

14.10.3.1 Liquid sulfur storage tanks shall be designed with fill lines that extend to near the tank bottom so that the incoming sulfur enters the tank below the surface of the sulfur in the tank, thereby minimizing agitation and release of hydrogen sulfide.

14.10.3.2 Vent Systems.

14.10.3.2.1 Covered storage tanks shall be provided with heated vent systems to provide natural venting of hydrogen sulfide.

14.10.3.2.2 Vent systems shall be maintained at a temperature above the melting temperature of sulfur.

14.10.3.3* Bonding and Grounding.

A.14.10.3.3 See NFPA 77 for information on the subject.

14.10.3.3.1 Sulfur lines and storage tanks shall be bonded and grounded with a resistance of less than $1.0 \times 10^6$ ohms to ground to prevent accumulation of static electricity.

14.10.3.3.2 Grounding connections shall be provided for the bonding of liquid sulfur tanks and tank cars being loaded or unloaded.

14.10.3.4* In pits or sections of tanks used for melting sulfur, and in liquid storage tanks that are regularly emptied, cooled, and exposed to air (moisture), the sulfur level shall be maintained above the heating coils.

A.14.10.3.4 Pyrophoric iron sulfide compounds can form from impurities in the sulfur. When heating coils are exposed to air, ignition can occur.

14.10.3.5* All electrical wiring and equipment installed in areas handling liquid sulfur shall meet the requirements of Article 501 of NFPA 70.

A.14.10.3.5
Due to the potential for release of dissolved hydrogen sulfide, molten sulfur handling systems require a Class I, Group C, classification for confined areas.

14.10.4 Open Flames and Sparks.
The requirements of 14.10.4.1 through 14.10.4.3 shall be applied retroactively.

14.10.4.1
Smoking shall be permitted only in designated areas.

14.10.4.2
Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

14.10.4.3
Activities described in 14.10.4.2 shall be controlled by a hot work permit system in accordance with the requirements of NFPA 51B.

14.10.5 Firefighting.

14.10.5.1
Protection for covered liquid sulfur storage tanks, pits, and trenches shall be by one of the following means:

(1) Inert gas system in accordance with NFPA 69
(2)* Steam extinguishing system capable of delivering a minimum of 2.5 lb/min (1.13 kg/min) of steam per 100 ft³ (2.83 m³) of volume
(3)* Rapid sealing of the enclosure to exclude air

A.14.10.5.1(2)
The steam should preferably be introduced near the surface of the molten sulfur. See NFPA 86, Section F.3.

A.14.10.5.1(3)
For enclosed sulfur tanks or sulfur pits with air sweep systems designed to meet the requirements of NFPA 69, the sealing steam should be fed into the enclosure very near the air inlets. For such sulfur tanks and sulfur pits the use of a steam rate of 1.0 lb/min (0.45 kg/min) of steam per 100 ft³ (2.83 m³) of total tank or pit volume is expected to develop a positive pressure in the enclosure, thereby sealing the sulfur tank or sulfur pit and preventing air ingress and extinguishing the fire.

As the sealing steam vents backwards through the air inlets the sealing steam will quickly stop air ingress to the fire. Sealing steam should be fed into the sulfur tank or sulfur pit for a minimum of 15 minutes or until the temperature has returned to near normal. For further information and good engineering practice
regarding sealing steam, see Mosher et al., *Molten Sulfur Fire Sealing Steam Requirements*.

14.10.5.2 Snuffing Steam and Sealing Steam Precautions.

14.10.5.2.1
The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

14.10.5.2.2
The vent systems shall also be designed for proper operation during normal operation.

14.10.5.3 Water Extinguishing Precautions.

14.10.5.3.1
Liquid sulfur stored in open containers shall be permitted to be extinguished with a fine water spray.

14.10.5.3.2
Use of high-pressure hose streams shall be avoided.

14.10.5.3.3
The quantity of water used shall be kept to a minimum.

14.10.5.4 Dry Chemical Extinguishers.
Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with NFPA 17 shall be provided.

14.11 Handling of Liquid Sulfur and Sulfur Vapor at Temperatures Above 309°F (154°C).

14.11.1 General.

14.11.1.1
This chapter shall apply to liquid sulfur and its vapors when heated in closed containers to temperatures above 309°F (154°C).

14.11.1.2
The requirements of Section 14.10 shall apply.

14.11.2 Operating Precautions and Equipment Design.

14.11.2.1
Equipment shall be designed to be closed as tightly as possible to prevent escape of vapor and to exclude air from the system during operation.
14.11.2.2 Deflagration Venting.

14.11.2.2.1 Process equipment shall be provided with deflagration venting, in accordance with NFPA 68.

14.11.2.2.2 Where vent ducts are required, the vent pipes or ducts shall be heated to prevent condensation of sulfur vapor.

14.11.2.3 An adequate supply of a suitable inerting agent such as steam shall be available at all times for blanketing and purging equipment.

14.11.2.4 All buildings or enclosures for such processes shall comply with 9.3.5.2.1, 14.9.3.1.1, 14.9.3.1.2, 14.9.3.2.2, 14.9.3.2.3.1, 14.9.3.2.3.2, 14.9.3.2.3.3, and 14.9.3.3.

14.11.2.5 Where sulfur is vaporized and subsequently condensed to sulfur dust, handling of the finely divided sulfur from the process shall comply with the requirements of Sections 14.4 through 14.9.

Chapter 15 The Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities

15.1 Administration.

15.1.1 Scope.
This standard provides the minimum requirements for fire and explosion prevention and protection of industrial, commercial, or institutional facilities that process wood or manufacture wood products using wood or other cellulosic fiber as a substitute for or as an additive to wood fiber, and facilities that process wood, creating wood chips, particles, or dust.

15.1.1.1 Woodworking and wood processing facilities shall include, but are not limited to, wood flour plants, industrial woodworking plants, furniture plants, plywood plants, composite board plants, lumber mills, production-type woodworking shops, and carpentry shops.

15.1.1.2* The requirements contained in the following sections shall not apply to woodworking operations that
occupy areas smaller than 465 m² (5000 ft²), and where dust-producing equipment requires an aggregate dust collection flow rate less than 2549 m³/hr (1500 ft³/min):

(1) Section 15.4
(2) Section 15.5
(3) Section 15.6
(4) Section 15.7
(5) Sections 8.1 through 8.3
(6) Section 15.9, with the exception of 15.9.4.20, 15.9.5.13, and 15.9.7
(7) Sections 15.10 and 15.11

A.15.1.1.2
Specific criteria in this standard are advisable for facilities that fall outside this document's scope. A hazard and risk analysis should be performed to identify areas where specific criteria are appropriate.

15.1.2 Purpose.
The purpose of this standard shall be to provide minimum requirements, with due function, for the design, operation, and maintenance of woodworking and wood processing facilities for the safety to life, property protection, and mission continuity from fire and explosion.

15.1.2.1 Goal.
The goal of this standard shall be to provide for a woodworking and wood processing facility that is reasonably protected from fire or deflagration in a cost-effective manner.

15.1.3 Application.

15.1.3.1
This standard shall be applied to new facilities and to new processes within existing facilities.

15.1.3.2
This standard shall be used to supplement the requirements established by Chapters 1 through 9.

15.1.4 Retroactivity.

15.1.4.1*
When renovating existing facilities, equipment, or processes, provisions of this standard shall apply to that portion of the facility, equipment, or process.

A.15.1.4.1
The retroactivity of the standard is triggered when a change is made that changes the existing design of the process. This is basically anything other than a "replacement in kind."

15.2 Reserved.

15.3 Reserved.

15.4 General Requirements.

15.4.1 Reserved.

15.4.2 Objectives.

15.4.2.1 Reserved.

15.4.2.2 Reserved.

15.4.2.3 Reserved.

15.4.2.4 Reserved.

15.4.2.5 Structural Integrity.
The facility shall be designed, constructed, and equipped to maintain its structural integrity despite the effects of fire or deflagration for the time necessary to evacuate, relocate, or defend in-place occupants who are not intimate with ignition.

15.5 Hazard Identification.

15.5.1 Reserved.

15.5.2 Screening for Combustibility or Explosibility.
Wood particulates in a facility shall be assessed for their hazards in accordance with Chapter 5.

15.5.2.1
A wood particulate having a moisture content of less than 25 percent (wet basis) and a mass median particle size of less than 500 micron shall be deemed to be a deflagrable wood dust unless testing shows it not to be capable of propagating deflagration.

15.5.2.2
A wood particulate having a moisture content of less than 25 percent, wet basis, and having a mass median particle size greater than 5.0 mm (0.2 in.) (3.5 mesh sieve) shall be permitted to be considered nondeflagrable wood dust on the basis of particle size.

15.5.2.3*
The assessment of hazard on the basis of mass median particle size shall be limited to those locations in the process and facility where the wood particulate remains a uniform mixture.

A.15.5.2.3
For example, the material coming from a hog or a planer through a duct can be considered a uniform mixture during the conveying process; however, material entering a silo, storage vessel, or other enclosure will separate, with the fines occupying the ullage space and creating a potential deflagration hazard.

15.5.2.4*
When the testing laboratory reports that a sample cannot be tested in accordance with ASTM E1226, Standard Test Method for Explosibility of Dust Clouds, or ASTM E1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts, or an equivalent protocol, based on particle size only, it shall be permitted to consider the particulate to be nondeflagrable.

A.15.5.2.4
In addition to excessive particle size, there are other reasons why a test sample cannot be tested, such as insufficient material or agglomeration issues, which would not necessarily mean the particulate is nondeflagrable.

15.6 Performance-Based Design Option.

15.6.1 General Requirements.

15.6.1.1 Reserved.

15.6.1.2 Reserved.

15.6.1.3 Reserved.
15.6.1.4 Documentation Requirements.
The content and format of the documentation shall comply with NFPA 101 and be acceptable to the authority having jurisdiction.

15.6.1.5* Reevaluation.
Performance-based designs shall be subject to a complete, documented reevaluation and reapproval if and when any of the assumptions upon which the original design is based are changed or when other aspects of the facility’s operations are changed.

A.15.6.1.5
Relevant aspects that could require a re-evaluation include, but are not limited to, changes to the following:

(1) Storage of hazardous materials
(2) Storage of nonhazardous materials
(3) Machinery
(4) Machinery layout
(5) Motor horsepower
(6) Fan and blower specifications
(7) Pneumatic conveying and dust collection system ducts
(8) Process operating temperatures
(9) Other procedures and processes, and equipment

15.6.1.6 Reserved.

15.6.1.7 Reserved.

15.6.1.8* Independent Review.
The authority having jurisdiction shall be permitted to require an approved, independent third party to review the proposed design and provide an evaluation of the design to the authority having jurisdiction.

A.15.6.1.8
The SFPE Guidelines for Peer Review in the Fire Protection Design Process provides guidance concerning the peer review process for fire protection designs.

15.6.2 Reserved.

15.6.3 Performance Criteria.

15.6.3.1 Life Safety.
15.6.3.1.1
The life safety objectives of 4.2.1 with respect to a fire hazard shall be deemed to have been achieved when the following conditions are met:

1. Ignition has been prevented.
2. Extension of the fire beyond the locus of ignition has been prevented.
3. Under all fire scenarios, no person, other than those intimate with the ignition, is exposed to untenable conditions due to the fire.
4. Under all fire scenarios, no structural element of the building is damaged, during the period of time necessary to effect complete evacuation of the occupants, to the extent that it can no longer support its design load.

15.6.3.1.2
The life safety objectives of 4.2.1 with respect to a deflagration hazard shall be deemed to have been achieved when the following conditions are met:

1. Ignition has been prevented.
2. Under all deflagration scenarios, no person, other than those intimate with the ignition, is exposed to untenable conditions due to the occurrence of a deflagration.
3. Under all deflagration scenarios, no person, other than those intimate with the ignition, is subject to missile impact due to the occurrence of a deflagration or explosion.
4. Under all deflagration scenarios, no structural element of the building is damaged, during the period of time necessary to effect complete evacuation of the occupants, to the extent that it can no longer support its design load.

15.6.3.2* Structural Integrity.

The structural integrity objective of 15.4.2.5 with respect to deflagrations shall be deemed to have been achieved when the pressure resulting from a deflagration within a building, vessel, enclosure, duct, or compartment during deflagration is limited to that pressure the containment can withstand, by design, without release of flame, burning fuel, hot combustion product gases, or missiles.

A.15.6.3.2
As part of a design of structural fire resistance, SFPE S.01, Engineering Standard on Calculating Fire Exposures to Structures, provides guidance in the determination of the thermal exposure to a structure resulting from fire; and SFPE S.02, Engineering Standard on Calculation Methods to Predict the Thermal Performance of Structural and Fire Resistive Assemblies, provides guidance in the determination of the temperature history within a structure.

15.6.3.3 Reserved.

15.6.3.4 Mitigation of Spread of Fires, Flash Fires, and Explosions.
15.6.3.4.1 and 15.6.3.4.2 shall apply in addition to 6.3.4.
15.6.3.4.1
When limitation of fire spread is to be achieved, the following criteria shall be demonstrated:

(1) Radiant flux to adjacent combustibles shall not exceed 20 kW/m².
(2) Combustibles outside the compartment of fire origin shall not attain their ignition temperature.
(3) Particulate processing systems shall be designed, constructed, equipped, and maintained to prevent fire or deflagration from propagating from the process equipment to the building interior.
(4) Particulate processing systems shall be designed, constructed, equipped, and maintained to prevent fire or deflagration from propagating from one process system to an adjacent process system.
(5) The surface area, smoothness, and inclination of all interior surfaces shall be such that the aggregate dust accumulations of these surfaces will not propagate a deflagration if half the dust were suspended in a cloud and ignited.

15.6.3.4.2
Where the prevention of fire extension to adjacent buildings is to be achieved, the following criteria shall be demonstrated:

(1) Radiant flux to adjacent combustibles shall not exceed 20 kW/m².
(2) Combustibles outside the compartment of fire origin shall not attain their ignition temperature.
(3) The pressure within a building, vessel, enclosure, duct, or compartment during deflagration shall be limited to that pressure the containment can withstand, by design, without release of flame, burning fuel, hot gases, or missiles due to the internal deflagration pressure to an adjacent building.

15.6.3.5 Reserved.

15.6.3.6 Effects of Deflagrations.
Where the prevention of damage due to deflagration is to be achieved, the criteria in 15.6.3.6.1 through 15.6.3.6.4 shall be demonstrated.

15.6.3.6.1
Deflagrations shall not produce any of the following conditions:

(1) Internal pressures in the containment vessel, room, or equipment sufficient to threaten the structural integrity of the equipment or the building
(2) Exposure of occupants to untenable conditions
(3) Damage in excess of the permissible loss

15.6.3.6.2
Deflagrations shall not result in the extension of the deflagration flame front outside the compartment or equipment of origin except where intentionally vented to a safe location.

15.6.3.6.3
Deflagrations shall not result in the rupture of the compartment or equipment of origin and the ejection of fragments that can constitute missile hazards.

15.6.3.6.4
The pressure within a vessel, enclosure, duct, or compartment during deflagration shall be limited to a pressure lower than the yield strength of the vessel, enclosure, duct, or compartment, without release of flame, burning fuel, hot gases, or missiles due to the internal deflagration pressure to an unsafe location.

15.6.3.7 Prevention of Ignition.

15.6.3.7.1*
Prevention of ignition shall be deemed to be achieved when the temperature of the combustible materials present in the facility is maintained at a temperature lower than the following:

(1) Lowest reported dust layer ignition temperature for the dusts
(2) Lowest temperature at which pyrolysis has been reported
(3) The ignition temperature of the combustible materials present

A.15.6.3.7.1
Fire losses have occurred where steam piping was identified as the ignition source for wood dust deposits. This apparently occurred because prolonged exposure to elevated temperatures caused the decrepitation of the cellulose into pyrolysis products that can have lower ignition temperatures than those normally associated with wood. The same process is possible with some other combustible particulates. In permitting maximum surface temperatures above 100°C (212°F) (the minimum steam temperature), it is assumed that appropriate personnel safety measures are in place and that a rigid housekeeping program exists to keep dust accumulations under control. Equipment surfaces in hard-to-access locations that will collect dust and are likely to be cleaned less frequently should be insulated to keep the maximum surface temperature below 100°C (212°F).

15.6.3.7.2
For performance evaluation for prevention of ignition, the power (energy per unit time) criterion used shall be based upon the median particle mass, specific heat, coefficient of thermal conductivity, and emissivity. No credit shall be allowed for radiant or convective heat losses from the target particle.

15.6.4 Reserved.

15.6.5 Evaluation of Proposed Design.

15.6.5.1* General.

A.15.6.5.1
The SFPE Engineering Guide to Performance-Based Fire Protection outlines a process for evaluating
whether trial designs meet the performance criteria during the design fire scenarios. 

Procedures described in Section 6.5 identify required design fire scenarios within which a proposed fire safety design needs to perform and the associated untenable conditions that need to be avoided in order to maintain life safety. Additionally, this same process should be used to establish the level of tolerance that specific contents, building features, or both, can sustain without incurring irreparable damage. This section discusses methods that form the link from the scenarios and criteria to the goals and objectives.

Assessment methods are used to demonstrate that the proposed design will achieve the stated goals/objectives, by providing information indicating that the performance criteria of this section can be adequately met. Assessment methods can be either tests or modeling.

### 15.6.5.2 Input Data.

#### 15.6.5.2.1 Data.
Input data for computer fire models shall be obtained in accordance with ASTM E1591, *Standard Guide for Obtaining Data for Deterministic Fire Models*. Data for use in analytical models that are not computer-based fire models shall be obtained using appropriate measurement, recording, and storage techniques to ensure the applicability of the data to the analytical method being used.

#### 15.6.5.2.2 Data Requirements.
A complete listing of input data requirements for all models, engineering methods, and other calculation or verification methods required or proposed as part of the performance-based design shall be provided.

#### 15.6.5.2.3* Uncertainty and Conservatism of Data.
Uncertainty in input data shall be analyzed and, as determined appropriate by the authority having jurisdiction, addressed through the use of conservative values.

##### A.15.6.5.2.3
Procedures used to develop required input data need to preserve the intended conservatism of all scenarios and assumptions. Conservatism is only one means to address the uncertainty inherent in calculations and does not remove the need to consider safety factors, sensitivity analysis, and other methods of dealing with uncertainty. The *SFPE Engineering Guide to Performance-Based Fire Protection* outlines a process for identifying and treating uncertainty.

#### 15.6.5.3* Output Data.
The assessment methods used shall accurately and appropriately produce the required output data from input data based on the design specifications, assumptions, and scenarios.

##### A.15.6.5.3
An assessment method translates input data, which can be test specifications, parameters or variables for modeling, or other data, into output data that is measured against the performance criteria. Computer fire models should be evaluated for their predictive capability in accordance with ASTM E1355, *Standard...*

15.6.5.4 Validity.
Evidence shall be provided confirming that the assessment methods are valid and appropriate for the proposed building, use, and conditions.

15.6.6 Safety Factors.
A safety factor, acceptable to the authority having jurisdiction, shall be applied to the results of the design calculations as appropriate for the design method used to reflect uncertainty in the assumptions, data, and other factors associated with the performance-based design.

15.7* Process and Dust Hazards Analysis.

A.15.7
A process analysis is a methodical review of the facility, each operation housed within, and the identification of where a hazard exists. For example, in a woodworking facility it would include where fire hazards exist, where explosion hazards exist, and what protective measures are in place to protect the personnel and property from those hazards. For additional information, see Chapter 7.

15.7.1 General Requirements.

15.7.1.1
The design of the fire and deflagration safety provisions of the facility shall be based upon an analysis of the facility, the process, and the fire or deflagration hazards encompassed by the facility and process.

15.7.1.2
The design of systems and facilities that handle combustible particulate solids shall address the physical and chemical properties and hazardous characteristics of the materials in the hazard area.

15.7.1.3
The results of the facility and process analysis shall be permanently documented.

15.7.1.4
The facility and process analysis shall be reviewed and the documented results revised when the process is changed in accordance with the management-of-change criteria in Section 8.12 and 15.8.12.

15.7.1.5
The results of the process analysis shall be maintained for the life of the facility and process.

15.7.1.6
The process analysis shall include a dust hazards analysis performed in accordance with Chapter 7.
15.7.2 Reserved.

15.7.3 Methodology.

15.7.3.1 Reserved.

15.7.3.2 Reserved.

15.7.3.3 Reserved.

15.7.3.4 Building or Building Compartments.

15.7.3.4.1*
A deflagration hazard shall be deemed to exist in a building compartment when the layer of accumulated fugitive deflagrable wood dust averaged over all upward-facing surfaces in the building compartment exceeds 3.2 mm (1/8 in.) in thickness.

A.15.7.3.4.1
NFPA 664 used a layer depth of 3.2 mm (1/8 in.) for many years as the criterion for determining where a deflagration hazard exists due to the accumulation of deflagrable wood dust. The loss history in the forest products industries does not include events of building compartment deflagrations (i.e., flash fires) where dust layers are as low as 3.2 mm (1/8 in.) in thickness. The losses have been in facilities where dust accumulations are far greater. Therefore, the 3.2 mm (1/8 in.) criterion appears to have a substantial margin of safety.

In previous editions of NFPA 664 there was advisory text in the annex that recommended 93 m² (1000 ft²) or 5 percent of the floor area limitation be considered when determining where a building compartment deflagration hazard exists. This recommendation is based on calculations, not loss history. In the last edition, those recommendations were moved to the body of the standard. With this edition, the recommendations have returned to this annex.

Where a large building compartment is involved 3.2 mm (1/8 in.) of dust distributed evenly over the entire area can result in a substantial quantity of dust. If that quantity is all ignited a serious deflagration will result. But this conclusion is reliant upon a number of simplifying assumptions in calculations used to support such a prediction. The lack of loss history with dust accumulations at the (3.2 mm) (1/8 in.) thickness level suggests that some of those simplifying assumptions might not be valid. To date no
research has been done that provides advice on how valid those simplifying assumptions actually are. Because designating a building compartment a deflagration hazard places significant limitations on how processes are operated in such an environment, the technical committee has concluded that there must be a solid technical basis for making the area limitation an enforceable part of the standard. At this time that basis does not exist.

A relatively small initial dust explosion will disturb, and suspend in air, dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for a secondary explosion, which usually causes the majority of the damage. Therefore, recognizing and reducing dust accumulations is, a major factor in reducing the hazard in areas where a dust hazard can exist. Prudent operating policies would advise evaluating dust levels wherever a visible dust cloud exists. Where dust accumulations are identified, an engineering analysis should be performed to determine whether a deflagration hazard exists.

Using a bulk density of 320 kg/m³ (20 lb/ft³) and an assumed concentration of 350 g/m³ (0.35 oz/ft³), it has been calculated that a dust layer that averages 3.2 mm (1/8 in.) thick covering the floor of a building is sufficient to produce a uniform dust cloud of optimum concentration, 3 m (10 ft) high, throughout the building. This situation is idealized, and several factors should be considered.

First, the layer will rarely be uniform or cover all surfaces, and second, the layer of dust will probably not be completely dispersed by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the 3.2 mm (1/8 in.) thick layer is suspended, this material is still sufficient to create an atmosphere within the explosive range of most dusts.

Consideration should be given to the proportion of the building volume that could be filled with a combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 3 m × 3 m (10 ft × 10 ft) room with a 3.2 mm (1/8 in.) layer of dust on the floor is a hazard and should be cleaned. Now consider this same 9.3 m² (100 ft²) area in a 188 m² (2015 ft²) building — this is also a moderate hazard. This area represents about 5 percent of a floor area and is about as much coverage as should be allowed in any plant.

To gain proper perspective, the overhead beams and ledges should also be considered. Rough calculations show that the available surface of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

Based on this information, the following guidelines have been established:

1. Dust layers 3.2 mm (1/8 in.) thick can be sufficient to warrant immediate cleaning of the area.
2. This dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building area.
3. Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.
(4) The 5 percent factor should not be used if the floor area exceeds 1858 m² (20,000 ft²). In such cases, a 93 m² (1000 ft²) layer of dust is the upper limit.

(5) Due consideration should be given to dust that adheres to walls, because this is easily dislodged.

(6) Attention and consideration should also be given to other projections, such as light fixtures, which can provide surfaces for dust accumulation.

(7) Dust collection equipment should be monitored to be certain it is operating effectively. For example, dust collectors using bags operate more efficiently between limited pressure drops of 0.75 kPa to 1.24 kPa (3 in. to 5 in.) of water. An excessive decrease or low drop in pressure indicates coating that is insufficient to trap dust.

These guidelines will serve to establish a cleaning frequency.

15.7.3.4.2
A deflagration hazard shall be determined to exist unless otherwise determined by a dust hazard analysis, as described in Chapter 7. For additional information, see Chapter 7 of NFPA 652.

15.7.3.4.3*
The layer thickness criterion in 4.1.3.1 shall be permitted to be corrected for dusts having a settled bulk density other than 320 kg/m³ (20 lb/ft³) using the following formula:

For SI units:

\[
T = \frac{(3.2 \text{ mm})(320 \text{ kg/m}^3)}{\text{Settled Bulk Density, kg/m}^3}
\]

where:

\(T\) = The allowable thickness (mm)

For US customary units:

\[
T = \frac{(0.125 \text{ in.})(20 \text{ lb/ft}^3)}{\text{Settled Bulk Density, lb/ft}^3}
\]

where:

\(T\) = The allowable thickness (in.)

A.15.7.3.4.3
In some cases, such as fine particulates generated from hardwoods, it is advisable to correct for a settled bulk density in excess of the 20 lb/ft³ (320 kg/m³), used in this requirement.
The measurement of bulk density is very dependent upon the particle, size, shape, and chemical content. Settled bulk density is not the same as tapped bulk density. Settled bulk density is the density as the material has settled in the facility under normal operating conditions. Tapped bulk density is the maximum density that can be achieved without intentional compression. Tapped bulk density measurement numbers are almost always higher than settled bulk density measurement numbers.

Moisture content is a factor that has a profound effect on dust deflagration propagation. Moisture in dust particles raises the minimum ignition temperature (MIT), minimum ignition energy (MIE), and minimum explosible concentration (MEC) by increasing agglomeration of particles.

Moisture content can be determined using the following method:

1. Weigh the material of which a moisture content is to be determined in the moist, as-received state.
2. Then dry it for 24 hours in a drying oven set at 75°C (167°F).
3. Then reweigh the sample.

Calculate the moisture content from the following relation:

\[
%MC = \left( \frac{\text{moist weight} - \text{dry weight}}{\text{moist weight}} \right) \times 100
\]

While no ASTM method currently exists for determining settled bulk density, the following method has been utilized to produce usable results. Since the use of bulk density measurements is to determine the permissible dust layer depth for hazard assessment, bulk density should be based upon the dried weight, not moist weight; the water in the moist sample does not add combustible material to the mixture.

**Recommended Tools:** Neoprene or other similar plastic-type gloves, ruler, two natural bristle brushes (100 mm (4 in.) width), scales (that measure grams), pre-weighed container (weighed in grams to nearest tenth of a gram), and a drying oven.

**Recommended Procedure:**

1. Pre-weigh and record container weight.
2. Locate horizontal surface area where dust is present and is evenly distributed across a flat surface. This is an important criterion.
3. Mark off a 1 ft² (0.09 m²) area. (It is easier if one of the four sides is the horizontal surface ledge). If one square foot is not available due to size of surface use: 1/2 ft × 2 ft; 1/4 ft × 4 ft, etc.
4. Using the ruler as a guide, carefully scrape the other dust surrounding the marked 1 ft² (0.09 m²) (or other established one square foot dimension) back away from the dust square (or rectangle) to at least 8–12 in. Use the first brush if needed to clean dust away from the 1 ft² (0.09 m²) selected for density measurement [ensuring that the 1 ft² (0.09 m²) area does not receive any of the dust being brushed away].
(5) Measure and record the height (to the nearest $\frac{1}{32}$ in.) of the dust layer as it sits on the horizontal layer. Take a minimum of three to five measurements along the edge of the dust layer to establish an average height (to the nearest $\frac{1}{32}$ in.) of the dust layer.

(6) Take the second clean, natural bristle brush and carefully brush the dust contained inside the $1 \text{ ft}^2 (0.09 \text{ m}^2)$ area into the pre-weighed container.

(7) At this time, the dust sample must be dried as outlined above.

(8) Weigh the dried dust sample and the container together and record the weight in grams.

(9) Subtract the weight of the container from the weight of the dried dust-filled container to obtain the weight of the dried dust in grams. Record the dust weight.

(10) Calculate volume of the dust layer using average height measured (in inches) × length (12 in.) × height (12 in.) to obtain cubic inches of volume.

(11) Convert cubic inches to cubic feet.

(12) Convert grams of dust measured to pounds. (Note: 453.6 g = 1 lb).

(13) Divide pounds of dust by cubic feet to establish estimated density in pound per cubic feet (lb/ft$^3$).

**Example:**
Container pre-weight is 500 g.

Average dust height measured is $2\frac{1}{32}$ in.

Container plus dust weight is 660 g.

**Dust Volume Determination in cubic feet (ft$^3$):**
$2\frac{1}{32}$ in. = $\frac{65}{32}$ in., or 2.03125 in. (51.6 mm)

$\text{Volume (in.}^3\text{)} = L \times W \times H = 12 \text{ in.} \times 12 \text{ in.} \times 2.03125 \text{ in.} = 292.5 \text{ in.}^3$

Convert cubic inches to cubic feet: There are 1728 in.$^3$ in 1 ft$^3$.

$\text{Volume (ft}^3\text{)} = \frac{\text{Volume (in.}^3\text{)}}{1728} = \frac{292.5}{1728} = 0.169 \text{ ft}^3 (0.0048 \text{ m}^3)$

$(305 \text{ mm} \times 305 \text{ mm} \times 51.6 \text{ mm}) = (0.305 \text{ m} \times 0.305 \text{ m} \times 0.0516 \text{ m} = 0.0048 \text{ m}^3)$

**Dust Weight Determination in pounds (lb):**
To obtain the weight of the dust, subtract container weight in grams from weight of the container containing the dried sample:

$660 \text{ g} - 500 \text{ g} = 160 \text{ g}$

Convert grams to pounds. There are 453.6 g in 1 lb, therefore:

$160 \text{ g} \div 453.6 \text{ g/lb} = 0.353 \text{ lb (of dust)}$
**Dust Density Determination:**
Divide pounds of dust by volume of dust in cubic feet:

\[ \frac{0.353 \text{ lb}}{0.169 \text{ ft}^3} = 2.087 \text{ lb/ft}^3. \]

Round off to nearest tenth of a pound = 2.1 lb/ft³

\[ \frac{0.16 \text{ kg}}{0.0048 \text{ m}^3} = 33.43 \text{ kg/m}^3. \]

15.8 Management Systems.

15.8.1 Reserved.

15.8.2 Reserved.

15.8.3 Reserved.

15.8.4 Housekeeping.

15.8.4.1 General.

15.8.4.1.1*
This section shall apply to the monitoring and removal of combustible waste materials in order to prevent these materials from accumulating outside, on, or around operating equipment or otherwise within the facility in sufficient quantity to create an undue fire hazard.

A.15.8.4.1.1
These materials include, but are not limited to, bark, chips, scrap lumber, wood dust, and other debris within wood processing and woodworking facilities.

15.8.4.1.2*
Any waste material or debris found in large enough quantity that the material is heavily coated or is in any way impeding the operation of energized or moving equipment shall be collected and removed immediately.

A.15.8.4.1.2
Examples of energized or moving equipment include, but are not limited to, transformers, switches, buses, conveyor rollers or drums, motors, mechanical drive equipment, steam lines, heated air transfer ducts, and thermal oil lines.
15.8.4.1.3
Combustible waste that cannot be reintroduced to the production process or utilized as fuel shall be placed in covered metal receptacles until removed to a safe place for daily disposal.

15.8.4.1.4
Any metal collected through the cleanup process shall be separated from wood debris or combustible waste to prevent entry into the wood-handling or processing equipment, the dust-collecting system, or the scrap wood hog.

15.8.4.1.5*
Production equipment shall be maintained and operated in a manner that minimizes the escape of debris or dust in accordance with Chapter 9.

A.15.8.4.1.5
It is always preferable and inherently safer to prevent the escape of dust through the provision of a properly designed, operated, and maintained dust collection system than it is to clean up dust that has escaped due to leaks and other deficiencies of the dust collection system.

15.8.4.1.6*
Combustible or flammable liquid spills or leaks from any source shall be cleaned up without delay.

A.15.8.4.1.6
Temporary control measures for leaks include drip pans or approved absorptive materials. These measures should not be used as an alternative to regular preventive maintenance. Consideration should be given to the use of fire-resistant hydraulic fluids to reduce the fire hazards of hydraulic systems in plant process equipment.

15.8.4.1.7
Residue from condensation of oil and resin volatiles shall be removed from areas within, around, and over curing ovens, dryers, fume extraction systems, or ventilation systems.

15.8.4.1.8
Oil-soaked cloths or waste material shall be stored in approved metal receptacles with self-closing covers.

15.8.4.1.9
Oily clothing, if stored between shifts, shall be kept in metal lockers.

15.8.4.1.10
Flammable liquids shall be handled and stored in accordance with NFPA 30.

15.8.4.2 Methodology.
Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

15.8.4.2.1 Procedure.

15.8.4.2.1.1*
Documented housekeeping and inspection programs shall be developed and maintained.

A.15.8.4.2.1.1
The facility should implement a weekly housekeeping inspection in the facility's fire prevention and maintenance program. Cleaning schedules for production equipment and the facility in general can be based on the findings of the housekeeping inspection. Typical cleanup routines, as a minimum, should include the following:

1. Daily, or per shift, cleanup of personal work areas, walkways, emergency escape routes, and accessways to fire protection equipment.
2. Weekly cleanup of floors throughout the facility, and specific cleanup in and around materials-handling equipment or production equipment (e.g., beneath lumber sorting decks, beneath or at the transfer points of belted chip or scrap conveyors, and beneath board presses). Machinery, motors, and hot surfaces should be kept clean of materials such as sawdust, oil, or grease.
3. Weekly to semi-annual cleanup of dust collection on horizontal surfaces (e.g., ducts, hoods, interior mezzanines, or ceilings) and on structural building members, such as ledges, beams, and joists, to minimize dust accumulations. As a rule of thumb, do not exceed 3.2 mm (1/8 in.) in depth. In all cases, consideration should be given to minimizing horizontal surfaces where dust can accumulate. One method of reducing horizontal surfaces on structural building members is to install angled members (angle of repose) or shields to minimize buildup.

15.8.4.2.2 Vacuum Cleaning Method.

15.8.4.2.2.1* Portable Vacuum Cleaners.
When used in Class II areas, as determined in accordance with 15.9.5.14.2, portable vacuum cleaners shall be listed for use in Class II hazardous locations or shall be a fixed-pipe suction system with remotely located exhauster and dust collector installed in conformance with 15.8.4.

A.15.8.4.2.2.1
Unapproved portable vacuum cleaning equipment can be used if the powered suction source is located in a remote, unclassified area.

15.8.4.2.3 Reserved.

15.8.4.2.4 Reserved.
15.8.4.2.5 Reserved.

15.8.4.2.6 Compressed Air Blowdown Method.

15.8.4.2.6.1*
Blowing down with steam or compressed air or vigorous sweeping shall be permitted only if the following conditions are met:

(1) Prior to using compressed air, vacuum cleaning, sweeping, or water washdown methods are used to clean surfaces that can be safely accessed.
(2) Dust accumulations in the area after vacuum cleaning, sweeping, or water washdown do not exceed the threshold housekeeping dust accumulation.
(3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 207 kPa (30 psi) in accordance with Occupational Safety and Health Administration (OSHA) requirements in 29 CFR 1910.242(b).
(4) All electrical equipment, including lighting, potentially exposed to airborne dust in the area during cleaning is suitable for use in a Class II, Division 2, hazardous (classified) location in accordance with NFPA 70.
(5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.
(6) After blowdown is complete, residual dust on lower surfaces is cleaned prior to re-introduction of potential ignition sources.
(7) All fire protection equipment is in service.

A.15.8.4.2.6.1
Sweeping and/or vacuuming are the preferred methods to be utilized. Blowing down with steam or compressed air, or even vigorous sweeping, produces dust clouds. Facilities should not be operating during blowdown. Blowdown should be done in individual sections of the building, starting near the center and working out, to prevent filling the entire building with dust-laden air. Blowdown should be frequent enough that large amounts of dust are not blown into suspension.

15.8.4.2.6.2*
A documented risk assessment shall be permitted to be used to determine which precautions in 15.8.4.2.6.1 are required for the specific conditions under which compressed air is being used.

A.15.8.4.2.6.2
All of the listed precautions in 15.8.4.2.6.1 might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts.

15.8.5* Hot Work.
The use of propellant-actuated tools outside of areas specifically designated for this activity shall comply
with Section 8.5.

15.8.6 Reserved.

15.8.7 Inspection, Testing, and Maintenance.

15.8.7.1
An inspection, testing, and maintenance program shall be developed to ensure that fire and explosion protection systems are in accordance with Chapter 9 and Section 15.9.

15.8.7.2
The inspection, testing, and maintenance program shall be a documented program detailing the equipment inspected, testing performed, test results formulated, and maintenance or repair requirements.

15.8.7.3*
Process controls, equipment, and machinery shall be inspected, tested, and maintained in accordance with the manufacturer’s recommended guidelines and safe practices.

A.15.8.7.3
In addition to inspecting the fire and explosion protection systems that could be in place, such a program should include, but not be limited to, inspections of dust collection system components, electrical transformers, switchgear and switches, large motors (e.g., greater than 200 hp), hydraulic and lubricating systems, rotating machinery (e.g., debarkers, chippers, mills, refiners, dryers, and roll presses), and deficiencies with electrical devices (e.g., arcing, lighting, and damaged wiring) in and around dust-producing processes. Arcing switches, worn bearings, worn belts, damaged wiring, and misaligned parts, including gears, pulleys, guards, and fairings, have all been identified as being sources of ignition.

15.8.7.4 Dust Collection Systems.

15.8.7.4.1*
The entire system, including each fan, motor, blower unit, operating control panels, fume scrubbers, flexible connections, and dampers, shall be inspected and maintained in accordance with the manufacturer’s recommended guidelines and safe practices.

A.15.8.7.4.1
Recommended inspection items include, but are not limited to, the following:

(1) Fans and blowers should be checked for excessive heat and vibration pursuant to manufacturer’s recommendations.
(2) The surfaces of fan housings and other interior components should be maintained free of rust (iron oxide). Such rust can become dislodged and, while transported, strike against the duct walls. In some cases this can cause an ignition of combustibles within the duct.

(3) The interior sections of the collection system (e.g., ducts, fan housings, collectors) should be inspected and cleaned frequently enough to prevent accumulation within the system. Combustible deposits thicker than 3.2 mm (1/8 in.) should be removed. The method of cleaning will vary with the nature of the deposits. Lint and dust can be removed with brushes. Soft, gummy deposits are commonly scraped with safety tools. Where the deposits are exceptionally hard, it can be necessary to melt them with steam. Open flames should not be used.

(4) Abort gates and abort dampers should be adjusted and lubricated pursuant to manufacturer's recommendations.

15.8.7.4.2*
Aluminum paint shall not be used on interior steel surfaces.

A.15.8.7.4.2
The use of aluminum paint makes the fire hazard worse. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause ignition of the aluminum particle, thereby initiating a fire.

15.8.7.4.3
Filters shall be cleaned or replaced when their resistance to airflow exceeds the manufacturer’s specifications.

15.8.7.4.4
Filter media shall not be replaced with an alternative type unless a thorough evaluation of the fire hazards has been performed, documented, and reviewed by management.

15.8.7.4.5
Where ducts are protected with sprinklers, sprinklers covered with deposits or corrosion shall be replaced or sent to a recognized testing lab for evaluation of suitability for continued service.

15.8.7.4.6
All vents for the relief of pressure caused by deflagrations shall be maintained free and clear of all obstructions and pursuant to the manufacturer's recommendations.

15.8.7.4.7
Maintenance shall not be performed on fans, blowers, or other equipment while the unit(s) is operating.

15.8.7.5 Impairments of Fire Protection and Explosion Prevention Systems.

15.8.7.5.1*
Impairments shall include anything that interrupts the normal intended operation of the fire protection or explosion prevention system.
A.15.8.7.5.1
Impairments can include isolating of fire pump controllers, closing of sprinkler system control valves, and isolating and disabling or disconnecting of detection and suppression systems.

15.8.7.5.2*
A written impairment procedure shall be followed for every impairment to the fire protection or explosion prevention system.

A.15.8.7.5.2
The impairment procedure consists of identifying the impaired system and alerting plant personnel that the protection system is out of service.

15.8.7.5.3*
Impairments shall be limited in size and scope to the system or portion thereof being repaired, maintained, or modified.

A.15.8.7.5.3
The facility manager is responsible for ensuring that the condition causing the impairment is promptly corrected.

15.8.7.5.4*
Impairment notification procedures shall be implemented by management to notify plant personnel and the authority having jurisdiction of existing impairments and their restoration.

A.15.8.7.5.4
When the impairment notification procedure is used, it triggers followup by the relevant authorities having jurisdiction. This followup helps to ensure that impaired fire and explosion protection systems are not forgotten. When the system is closed and reopened, most companies notify their insurance company, broker, or authority having jurisdiction by telephone or other predetermined method.

15.8.8 Training and Hazard Awareness.

15.8.8.1 The training and hazard awareness requirements in Section 8.8 shall also apply to non-combustible-dust hazards covered by this chapter.

A.15.8.8.1
Employees’ health and safety in operations depend on recognizing actual or potential hazards, controlling or eliminating these hazards, and training employees to work safely.

15.8.8.2
General safety training shall ensure that all employees are knowledgeable about the following:
15.8.8.3
Job-specific training shall ensure that all employees are knowledgeable about the following:

1. The hazards of their working environment and their behavior and procedures in case of emergencies, including fires, explosions, and hazardous materials releases
2. Emergency response plans, including safe and proper evacuation of their work area and the permissible methods for fighting incipient fires in their work area
3. The necessity for proper functioning of related fire and explosion protection systems that are under their responsibility
4. Equipment maintenance requirements and practices, including lockout/tagout procedures
5. Safe handling, use, storage, and disposal of hazardous materials used in the employees’ work areas
6. The location and operation of fire protection equipment, manual pull stations and alarms, emergency phones, first-aid supplies, and safety equipment
7. Equipment operation, safe startup and shutdown, and response to upset conditions
8. The decision-making process necessary to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely

A.15.8.8.3(1)
An important part of preventive maintenance is employee training in the proper care and use of equipment. Employees should be given instructions in selecting the proper tool for the job and the limitations of the tool. Training in operating and maintenance procedures and emergency plans should be developed. A training program appropriate to the types and quantities of hazardous materials stored or used should be conducted to prepare employees to handle hazardous materials safely on a daily basis and during emergencies. This training program should include the following:

1. Identification of all hazardous materials present and specific hazards of these materials
2. Instructions in safe storage and handling of hazardous materials, including maintenance of monitoring records
3. Instructions in emergency procedures for leaks, spills, fires, or explosions, including shutdown of operations and evacuation procedures

15.8.8.4*
A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method, and shall be trained to recognize and avoid potential hazards present with respect to that equipment or work method.
A.15.8.8.4
Such persons should also be familiar with the proper use of special precautionary techniques, personal protective equipment, lockout/tagout requirements, insulating and shielding materials, and test equipment. A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.

Employees should be trained to recognize obvious defects or malfunctioning equipment within their work area. Such defects should be reported immediately.

15.8.8.5
Training programs and procedures shall be reviewed and updated at least annually and whenever workplace conditions (i.e., equipment, process, chemical, material storage) change.

15.8.8.6*
Emergency awareness training shall be given to all employees when emergency plans are initially implemented, revised, or updated and at least annually.

A.15.8.8.6
Training should also be given to new employees when they join a company and to company employees transferring to a new department or location.

In addition to the requirements in 15.8.8, employee training should comply with the following standards, as applicable:

(1) NFPA 1
(2) NFPA 10
(3) NFPA 25
(4) NFPA 30
(5) NFPA 49 (Incorporated into the NFPA Fire Protection Guide to Hazardous Materials)
(6) NFPA 55
(7) NFPA 68
(8) NFPA 69
(9) NFPA 70
(10) NFPA 72
(11) NFPA 80
(12) NFPA 85
(13) NFPA 600

Note that although NFPA 49 has been officially withdrawn from the National Fire Codes®, the information is still available in NFPA’s Fire Protection Guide to Hazardous Materials.

15.8.9 Contractors.
15.8.9.1
The requirement in 8.9.3.3 shall also apply to potential hazards from and exposures to toxic releases.

15.8.9.2*
The requirement in 8.9.3.4 shall apply to safe work practices and policies including but not limited to equipment lockout/tagout permitting, hot work permitting, fire system impairment handling, smoking, housekeeping, use of personal protective equipment, and so forth.

A.15.8.9.2
It is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, smoking and nonsmoking areas, and so forth.

15.8.9.3
Contractors shall be informed of whom to report emergencies to and be advised of safe egress points and evacuation areas in the event of an emergency such as fire, explosion, or toxic release.

15.8.10 Emergency Planning and Response.

Emergency planning and response shall be in accordance with Section 8.10, NFPA 600, and NFPA 1600.

15.8.11 Incident Investigation.

15.8.11.1*
Every incident that results in a fire or explosion shall be investigated and recorded.

A.15.8.11.1
The size and extent of the incident that triggers this requirement should be proportional to the hazard. For example, a spark in a protected duct with a spark detection system would likely not require an investigation unless a significant increase in sparks per unit time was noted or the spark fails to be extinguished. This incident is considered "recorded" with the spark detection system. For every hazard area, there is a de minimis level below which recording cannot be justified. It is up to the owner/operator to determine that level.

15.8.11.2*
Once the scene has been released by the authority having jurisdiction, incident investigations shall be promptly initiated by management personnel or their designee who has a good working knowledge of the facility and processes.

A.15.8.11.2
Incident reports should include the following information:
(1) Date of the incident
(2) Location of the incident and equipment/process involved
(3) Description of the incident, contributing factors, and the suspected cause
(4) Operation of automatic/manual fire protection systems and emergency response
(5) Recommendations and corrective actions taken or to be taken to prevent a reoccurrence

The incident report should be reviewed with appropriate management personnel and retained on file for future reference. The recommendations should be addressed and resolved.

15.8.12* Management of Change.
Management shall implement and maintain a system to evaluate proposed changes to the facility and processes, both physical and human, for the impact on safety, loss prevention, and control.

A.15.8.12
Management of change should be applied to more than just new construction projects. Management of change encompasses anything that could adversely impact loss potentials, including physical and human element changes, whether at the site, in the corporation, in the industry, or in the community.

It is critical that changes be evaluated early enough to easily accommodate all loss prevention objectives. Opportunities to enhance fire safety should be investigated during the management-of-change process.

15.8.12.1
Management of change shall include review by all relevant authorities having jurisdiction.

15.8.12.2*
Management of change shall include review of all projects involving the following:

(1)* Occupancy and process changes involving storage configurations and heights, process equipment and materials, or rates of production
(2)* Changes to all fire protection and alarm systems
(3)* Exposure changes
(4) Human element changes involving key members of loss prevention programs
(5) New construction or modification to an existing structure

A.15.8.12.2
Modifications to existing programs, equipment, or personnel should include review of the original design parameters to ensure that they have not been compromised.

A.15.8.12.2(1)
Often, changes to the occupancy and process precipitate the need to change the fire protection strategy employed for that process or occupancy.

A.15.8.12.2(2)
Changes to fire protection and alarm systems can include, but not be limited to, automatic sprinkler
protection, special protection systems, water supplies, and alarm equipment.

**A.15.8.12.2(3)**
Exposure changes include yard storage and changes to neighboring facilities.

### 15.8.13 Documentation Retention.

**15.8.13.1**
Records requiring retention shall include, but are not limited to, drawings and supporting documents relating to initial installation/purchase of equipment, routine equipment inspections, testing and repair history, fire and safety inspection or audit reports, service records, and manufacturer's data sheets.

**A.15.8.13.1**
The following standards have explicit requirements for record retention:

1. **NFPA 10**
2. **NFPA 13**
3. **NFPA 20**
4. **NFPA 24**
5. **NFPA 25**
6. **NFPA 68**
7. **NFPA 69**
8. **NFPA 70**
9. **NFPA 72**
10. **NFPA 80**

**15.8.13.2**
Records of inspections, tests, and maintenance of fire protection equipment and components shall be retained and made available to the authority having jurisdiction upon request.

**A.15.8.13.2**
For record retention to be useful, the minimum acceptable documentation should identify what was tested/inspected, and when and whether it performed successfully. Corrective action taken should be noted on or maintained with the inspection/testing record.

**15.8.13.3**
All records required to be kept shall be retained until their usefulness has been served or until no longer required by the applicable standard or authority having jurisdiction.

**A.15.8.13.3**
At a minimum, records should be retained until subsequent inspection or testing has superseded them. Consideration should be given to identifying and maintaining records that can serve as predictive maintenance tools. Original records, such as manufacturers' data sheets, as-built drawings, or contractor test certificates, should be retained for the life of the equipment.
15.8.13.4*  
Records shall be maintained on-site by the owner.

A.15.8.13.4  
Permissible media for records can include written, printed, or computer-generated documents, drawings, or photographs.

15.8.13.5*  
Retained records shall indicate the procedure performed (e.g., installation, inspection, testing, training, or maintenance), the organization that performed the work, the results, and the date the work was performed.

A.15.8.13.5  
Files, inspection reports, investigations, training programs, and related documents should be maintained in compliance with the recordkeeping policies of the organization so that information can be easily retrieved.

Computer programs that file inspection and test results should provide a means of comparing current and past results and should indicate the need for corrective maintenance or further testing.

15.9 Hazard Management: Mitigation and Prevention.

15.9.1 Reserved.

15.9.2 Reserved.

15.9.3 Building Design.

15.9.3.1* Construction.

A.15.9.3.1  
It is preferable for buildings engaged in wood processing either to be of Type I or II construction or to be sprinklered, or both, if a hazard analysis deems it is warranted.

15.9.3.2 Building or Building Compartment Protection.

15.9.3.2.1* Compartmentation.  
Where required by other sections of this standard, passive fire protection features shall be utilized to prevent the spread of fires or deflagrations to adjacent compartments or occupancies. Passive fire protection features shall include, but not be limited to, space separation, fire walls, fire partitions, or draft
curtains.

A.15.9.3.2.1
Refer to NFPA 80A for buildings using open space separation techniques.

15.9.3.2.2 Fire Resistance Rating.
When applying 9.3.5.2.2, where no building code exists, fire barrier walls shall have a minimum fire resistance rating of 1 hour.

15.9.3.2.3 Protection of Openings and Penetrations.

15.9.3.2.3.1
Penetrations of walls, floors, or ceilings that provide a required fire separation shall be protected by listed systems or approved materials that have a fire resistance rating equal to that of the wall, floor, or ceiling and shall conform to the relevant requirements of NFPA 221.

15.9.3.2.3.2
Penetrations in barriers erected to segregate dust hazards shall be dusttight.

15.9.3.2.3.3*
Conveyor and chute openings in fire walls shall be protected by listed or approved, automatic-closing fire doors or fire dampers that have a fire resistance rating equivalent to the fire wall.

A.15.9.3.2.3.3
Penetrations for piping and ductwork used to convey combustible materials should not penetrate fire walls. Fire dampers in ducts handling wood particulates have not been shown to provide reliable operation over the lifetime of the facility. The wood waste often clogs dampers, rendering them inoperative.

15.9.3.2.3.4
Fire doors shall be designed, installed, tested, and maintained in accordance with NFPA 80.

15.9.3.2.3.5
Openings in walls designed to be explosion resistant shall be protected by doors that provide the same degree of explosion resistance protection as the walls.

(A)
Such doors shall be kept closed at all times when not actually being used.

(B)*
Such doors shall not be considered as part of a required means of egress to satisfy the requirements of NFPA 101.
15.9.3.2.3.5(B) Such doors should be marked “Not An Exit.” The unique requirements of doors in explosion-resistant walls preclude their use as a means of egress, because NFPA 101 requires exit doors from high-hazard areas to swing in the direction of exit travel.

15.9.3.3 Life Safety.

15.9.3.3.1 Occupant life safety systems shall be designed, constructed, installed, and maintained in accordance with NFPA 101.

15.9.3.3.2 The means of egress shall comply with NFPA 101.

15.9.3.3.2.1* Means of egress for building or building compartments that contain a deflagration hazard area shall be designed according to Section 7.11 in NFPA 101.

A.15.9.3.3.2.1 This provision requires shorter travel distances and wider egress pathways resulting in shorter egress times for those occupancies with high hazard contents. In many cases it requires multiple means of egress so that occupants do not have to travel past a hazardous situation while evacuating the facility.

15.9.3.3.3 The design and construction of the building, mechanical and electrical systems, and systems and equipment necessary to the wood utilization occupancy shall be such that the occupants are able to recognize hazards and egress safely from the building in the event of one of the anticipated hazards.

15.9.3.3.4 The building design shall be such that the means of egress is clearly identifiable and usable for occupancy.

15.9.3.4* Construction Features to Limit Accumulation.
Spaces inaccessible to housekeeping shall be sealed to prevent dust accumulation.

A.15.9.3.4 Structural steel that is out of the reach of normal vacuuming or sweeping operations and that has horizontal ledges (such as I-beams or U-shaped channels in the up or sideways position) should be boxed in with a limited-combustible material to eliminate pockets for dust accumulation. New interior walls should be specified as being smooth and with minimal ledges.

Surfaces not readily accessible for cleaning should be inclined at an angle of not less than 45 degrees from
the horizontal to minimize dust accumulation.

As much as a 60 degree angle of inclination could be necessary for maximum effectiveness with many types of wood dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops.

15.9.3.5 Separation of Hazard Areas from Other Hazard Areas and from Other Occupancies.

15.9.3.5.1 Reserved.

15.9.3.5.2 Reserved.

15.9.3.5.3* Use of Separation.

A.15.9.3.5.3
Ideally, upward-facing surfaces within the facility are painted a contrasting color to the dust that is being handled. This facilitates recognizing when and where accumulations occur. This information then serves to prioritize and schedule cleaning. It is clearly not recommended that the interior surfaces be the same color as the dust that is apt to escape the process and accumulate within the facility.

One method that has proved useful is to print self-adhesive paper or plastic labels with the words “Clean Enough” in bold black type along with a serial number. These labels are installed at representative locations throughout the facility with the locations recorded on a floor-plan drawing. This allows the facility manager to have employees survey the labels at scheduled frequencies and record which labels were “clean enough” to be read, and which were not. This facilitates focusing the housekeeping efforts where the dust accumulations are developing most rapidly.

15.9.3.6* Damage-Limiting Construction.

A.15.9.3.6
See FM Data Sheet 1-44, Damage-Limiting Construction, for more information.

15.9.3.6.1
Dust deflagration hazard areas shall be separated or segregated from all other areas.

15.9.3.6.2*
Where a deflagration hazard is known to exist in a room or building, exterior walls shall be designed, constructed, and maintained such that they relieve the pressure from a dust deflagration without damage to the load-bearing capacity of the structure.
A.15.9.3.6.2
See NFPA 68 for guidance on predicting the effects of dust deflagrations based on the strength of resisting and relieving walls.

15.9.3.6.3*
Interior walls erected to isolate dust explosion hazards shall be designed for sufficient explosion resistance to preclude damage to these walls before the explosion pressure can be safely vented to the outside.

A.15.9.3.6.3
See NFPA 68 for guidance on the strength of relieving and resisting walls.

15.9.3.7 Draft Curtains.

15.9.3.7.1
Where required, draft curtains shall be constructed and installed in accordance with Chapter 7 in NFPA 204.

15.9.3.7.1.1
Minimum 26 gauge steel sheeting [0.455 mm (0.018 in.)] shall be used.

15.9.3.7.1.2
Where automatic sprinkler protection is provided, draft curtains shall be permitted to be constructed of wood panels 12.7 mm (1/2 in.) thick or greater.

15.9.3.7.1.3
Aluminum sheeting, fiberglass reinforced plastic (FRP), or other plastic materials shall not be used.

15.9.3.7.2
Solid beams, purlins, and other solid structural members extending down from the roof deck or ceiling shall be deemed equivalent to draft curtains if the depth criteria in Chapter 7 of NFPA 204 is met.

15.9.4 Equipment Design.

15.9.4.1 General.

15.9.4.1.1* Applicability.
Subsection 15.9.4 shall apply to storage, all pneumatic systems, dust control systems, mechanical conveyors, and mechanical equipment of all types used to convey, resize, pulverize, dry, or otherwise process wood and wood-derived particulate and other cellulosic materials used as a substitute or supplement for wood.
A.15.9.4.1.1 These systems include, but are not limited to, dust collection systems and pneumatic bulk conveying systems transporting material from hogs, hammermills, grinders, flakers, planers, refiners, sanders, and chippers.

15.9.4.1.2 Designer and Installer Qualifications.
Systems that handle combustible wood particulates shall be designed by and installed under the supervision of qualified engineers who are knowledgeable of these systems and their associated hazards.

15.9.4.1.3 Fire Protection and Explosion Suppression Systems.
Where required, fire protection and explosion suppression systems shall be provided in accordance with Sections 9.8, 9.9, 15.9.8, and 15.9.9.

15.9.4.2 Reserved.

15.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

15.9.4.3.1* General Requirements.
The hazard associated with the particulate conveying system shall be determined through a hazard analysis.

A.15.9.4.3.1 Assume that all wood waste in an enclosed dust collector is potentially deflagrable, unless a dust deflagration test demonstrates it is not. Wood waste usually has a dust deflagration risk where the mean particle size is less than 500 microns and where as little as 10 percent of the mixture contains dust less than 80 microns in size. Only weak deflagrations are likely where the mean particle size exceeds 500 microns.

Wood waste is commonly produced by the following:

(1) Fine cutting (e.g., sanding), which produces a dust of very fine particle size. This dust is usually assumed to be deflagrable.
(2) Machining and sawing softwoods, which produces chips, shavings, and coarse dust with only a small amount of fine dust. This process does not normally create a deflagration risk, so long as the fine dust is not allowed to separate and accumulate within confined spaces.
(3) Sawing and machining hardwoods, which often produces wood waste containing considerably more dust than that from softwood. This dust is usually assumed to be deflagrable.
(4) The processing of MDF chipboard and similar boards by machining and sawing. This process can be expected to produce waste containing much fine dust. This dust is usually assumed to be deflagrable.

When mixed processing of a variety of woods occurs, the waste produced should be assumed to be
deflagrable.

15.9.4.3.1.1
The analysis of the fire and deflagration hazard shall address the moisture content and particle size distribution of the particulate at each point of material entry into the duct system to determine whether the material is green, dry nondeflagrable, or deflagrable.

15.9.4.3.1.2
The analysis of the fire and deflagration hazard shall identify the minimum explosible concentration (MEC) for all deflagrable material.

15.9.4.3.1.3
Fire and deflagration hazards shall be permitted to be deemed nonexistent where only green material is collected or conveyed and construction of the equipment handling and storing the material is all noncombustible.

15.9.4.3.1.4*
A fire hazard shall be deemed to exist in the system wherever dry wood particulate is collected or conveyed or wherever components of the conveying system are constructed of combustible materials.

A.15.9.4.3.1.4
For example, dust collectors having combustible filter bags and rubber belt conveyors would pose a fire hazard, even if only green wood particulate were handled.

15.9.4.3.1.5*
In addition to the fire hazard, a deflagration hazard shall also be deemed to exist where deflagrable wood dust is, or could be, suspended in air during operation at a maximum concentration above 25 percent of the MEC.

A.15.9.4.3.1.5
The hazard threshold used is less than 100 percent to allow for concentration increases that can occur due to system imbalances and minor changes or adjustments to material or airflow rates, and at fans, elbows, hopper feed points, and so forth. For systems that have intermittent operation and/or multiple particulate entry points, the maximum concentration should be based on the simultaneous maximum material flow rate from all entry points. For example, the dust loading for a pneumatic system that collects dust from two panel sanders should be based on the material being removed from panels passing through both sanders at the same time, even if this happens randomly.

15.9.4.3.2 Specific Requirements for Pneumatic Conveying Systems.

15.9.4.3.2.1 General Requirements.
(A) Pneumatic conveying systems shall be designed in accordance with NFPA 654 except as modified by this standard.

(B)* Woodworking pneumatic conveying systems shall be restricted to handling wood residues; under no circumstances shall another operation that generates sparks, such as from grinding wheels, or flammable vapors, such as from a finishing operation, be connected to a woodworking pneumatic conveying system.

A.15.9.4.3.2.1(B) Dust collectors for wood working should be labeled, “For Wood Dust Only — Do not use with metal dust or operations that generate sparks or flammable vapors, to avoid fire and/or explosion.” It is the responsibility of the owner of the dust collector to provide this warning label or a similar one on the dust collector, if the label is not provided by the dust collector manufacturer.

In addition, similar warning labels could be located at woodworking machines.

(C) Once a system airflow has been properly balanced, additional pickup points, duct modifications, and modification of balancing damper settings shall not be made without ensuring that the remaining portions of the system still have sufficient capture and conveying air velocities for their intended function.

(D)* Every section of the collection system shall be sized for not less than the minimum air velocity and volume required to collect and transport the material through the ducting and into the collection equipment.

A.15.9.4.3.2.1(D) While conditions can vary, 20 m/sec (4000 ft/min) is generally accepted as a minimum conveying velocity for wood particulate. Actual capture velocity can be much higher; the manufacturer should be consulted for specific recommendations.

15.9.4.3.2.2 Duct System.

(A) Ductwork shall be metallic.

(B) Flexible ducting shall be permitted for final machine connection in a length not exceeding the minimum required for machine operation.

(C)* Nonconductive ducts such as PVC pipes shall not be permitted.
A.15.9.4.3.2.2(C)
A ground wire or other grounding system for PVC pipe is not acceptable.

(D)
Where extinguishing is present, horizontal ductwork subject to water accumulation shall be capable of supporting the weight of the duct system plus the weight of the duct half-filled with water.

(E)
Ductwork shall be protected from corrosion.

(F)
Dust collection air velocity and volume shall be calculated according to 15.9.4.3.2.2(G) and 15.9.4.3.2.2(H).

(G)
The capacity of the system shall be calculated on the basis of all hoods and other openings connected to the system being open or equipped with means to ensure minimum conveying velocity of 15.9.4.3.2.1(D) in all sections of the system.

(H)
Floor sweeps, which are normally closed and are only opened on an occasional basis to facilitate housekeeping, shall be permitted to be excluded from the air flow calculations for the system.

(I)*
Where dampers or gates are used for individual equipment, the volume and velocity resulting from the operation of such dampers or gates shall not reduce the system velocity below the design minimum.

A.15.9.4.3.2.2(I)
Where dampers or gates are necessary to achieve balance on systems that have been altered, they should be permanently fastened in place. Dampers should not be opened and closed during operation so that more suction can be diverted to other machines/branches, because the imbalance of airflow can cause insufficient velocity in the main duct, which will result in an accumulation of wood waste and become a potential fuel source for fire.

An automatic damper that is located in a branch duct and dedicated to an individual woodworking machine, and that opens when the machine is activated and closes when the machine is deactivated, should not be used if it will cause insufficient velocity [less than 20 m/sec (4000 ft/min)] in the main duct.

Variable speed controls, whether manual or automatic, should not be used if they can cause insufficient velocity in the main duct.
Sufficient velocity can be achieved by a number of methods, including the following:

1. Automatic damper and variable speed controls (if the branch pipe with the damper does not feed into the main duct but goes directly to the dust collector)
2. Dampers controlled by programmable controllers
3. Other engineered systems that maintain design velocity

(J)
Ducts used to convey particulate shall have a circular cross-section unless a non-circular cross-section of equal area is needed where the duct connects to other equipment or where external obstructions necessitate a non-circulation cross-section be used.

(K)
Ductwork shall be bonded and grounded in accordance with 9.4.8.2(1).

(L)* Hazard Determination.
The dust accumulation hazard associated with the duct system shall be determined by means of a hazard analysis.

A.15.9.4.3.2.2(L)
Resinous woods such as southern yellow pine, spruce, and fir tend to yield wood dust that is tacky and can adhere to duct interiors. This is especially true on ducts serving abrasive planers and sanders, which also introduce heat input to the dust.

Hardwoods such as maple, oak, hickory, and cherry lack the resins of the soft woods and are much less likely to coat duct interiors with accumulated dust.

(M)* Duct Access
For duct systems subject to dust accumulation, access doors, openings, or removable sections of ductwork shall be provided in accordance with 15.9.4.3.2.2(L)

A.15.9.4.3.2.2(M)
Ductwork subject to dust accumulation should have sufficient access for inspection and fire department access, as determined by the configuration, length, and size of the duct.

15.9.4.3.2.3 Hoods and Enclosures.

(A)
Hoods or enclosures shall be designed and located such that the wood dust or particulate generated will fall, be projected, or be drawn into the hoods or enclosures so as to minimize fugitive dust emissions without interfering with the safe and satisfactory operation of the machine.

(B) Reserved.
(C) Reserved.

(D) All hoods and enclosures shall be of noncombustible construction unless protected with automatic sprinklers installed in accordance with NFPA 13.

15.9.4.3.2.4 Fans and Blowers (Air-Moving Devices).

(A)* Fans or blowers shall be of appropriate type and sufficient capacity to maintain the required rate of airflow in all parts of the system.

A.15.9.4.3.2.4(A) Although conditions can vary, 20 m/sec (4000 ft/min) is generally accepted as a minimum conveying velocity for wood particulate.

Many believe that fans should be located only on the clean-air side of dust collection equipment because this removes the fan, a potential ignition source, from the dusty airflow. Where deflagrable dusts are being conveyed, turbulence induced by fans can also accelerate deflagration burning, increasing the pressure rise (and damage potential) to the fan and duct in proximity to the fan inlet and outlet. However, the frequency of fans being an ignition source is very low.

Additionally, there is an advantage to having the fan upstream of the collection equipment. The fan can be left running to rapidly purge the duct of any material and discharge it from the system through a fast-acting abort gate. When actuated by a spark detector located a sufficient distance upstream, such an arrangement can effectively keep burning material from entering the dust collection equipment where the fire and explosion potential is known to be extremely high. Although this can also be done with negative pressure systems where the fan is located on the downstream side of the collector, it is a much more complex and expensive solution.

(B) Fans and blowers shall be permitted to be located in accordance with 15.9.4.3.2.4(B)(1) through 15.9.4.3.2.4(B)(6):

(1)* On the clean air side of dust collectors, regardless of the moisture content or particle size of the material being conveyed

(2)* Upstream of the dust collector when the material being conveyed has a moisture content in excess of 25 percent (wet basis)

(3) Upstream of the dust collector when the material being conveyed has a moisture content of less than 25 percent (wet basis) and the concentration of sub-500 micron particulate is less than
25 percent of the MEC, and the duct downstream of the fan is equipped with a listed spark detection extinguishing system and/or abort system

(4) Upstream of the dust collector when the material being conveyed has a moisture content of less than 25 percent (wet basis) and the concentration of sub-500 micron particulate is in excess of 25 percent of the MEC, and the duct and dust collector are equipped with either deflagration relief venting or deflagration suppression systems

(5) Upstream of enclosureless dust collectors, in accordance with 15.9.4.4

(6) Upstream of outdoor cyclone collectors receiving knife planer shavings when the fan and the cyclone are located outdoors and exhaust to outdoor atmosphere

A.15.9.4.3.2.4(B)(1)
The clean-air side of the dust collector is the preferred location for the fan or blower. When wood particulates are passed through the fan, there is the potential for ignition of the wood particulate due to the impact of the impeller, frictional heat from the fan motor, and bearings or fan impeller failure. Acceptable means for addressing this ignition potential are dependent upon the moisture content, particle size distribution, and minimum explosible concentration of the fines.

A.15.9.4.3.2.4(B)(2)
No experience in the forest products industry is known to the members of the Technical Committee that indicates that an ignition of green wood particulates has occurred in the context of the conveyance systems. However, the user should keep in mind that wood particulates will lose moisture as they are conveyed. Variations in feedstock will also result in variations in the moisture content of the conveyed material. The conveyed material should be sampled at all extremes of operations to verify that the conditions that allow transport without downstream fire protection exist reliably. Furthermore, the wood particulates in such systems should be routinely sampled to ensure that the conveyance system is not operating outside of the design parameters.

(C)*
When fans with a deflagration hazard are arranged as material-handling fans on ducts, the fan housing shall meet the same design strength criteria required of the duct in 9.7.1.1.

A.15.9.4.3.2.4(C)
Designing a fan housing that can withstand maximum unvented explosion pressures is generally impractical except for very small fans. Also, the fan wheel or blower impeller acts as an obstruction to deflagration propagation and increases the air turbulence, both of which can increase deflagration pressures. Because of this, explosion suppression systems generally need to inject suppression agent into both the inlet and exhaust openings of the fan housing. Also, explosion venting might not be practical on the fan housing itself, so vents need to be located on the inlet and outlet ducts as close to the fan housing as practical. The duct vents should have an area equal to the cross-sectional area of the duct.

15.9.4.3.3 Specific Requirements for Dust Collection Systems.
The requirements in 15.9.4.3.2 shall apply to dust collection systems.
15.9.4.4* AMS.
The system shall be provided with collection equipment of sufficient size and capacity to maintain the required airflow and efficiently separate the wood dust from the air before the air is exhausted.

A.15.9.4.4
NFPA 68 provides equations for calculating the distance needed when using distance to achieve the safe location required by 9.4.4.1.

15.9.4.4.5* Enclosureless AMS.
The requirements in 15.9.4.4 allowing the use of enclosureless AMS shall be limited to enclosureless AMS that meet all of the following criteria:

1. The filtration is accomplished by passing dust-laden air through filter media, collecting the dust on the inside of the filter media, and allowing cleaned air to exit to the surrounding area.
2. The filter media are not enclosed or in a container.
3. There is no means to mechanically shake or pressure-pulse the filter media while the fan is on.
4. The filter media are under positive pressure.
5. Removal of the collected dust is not automatic, continuous, or mechanical.

A.15.9.4.4.5
Item (2) is intended to ensure that nothing becomes a projectile and represents a missile hazard in the event of a deflagration within the filter media. Cloth filter bags, unenclosed cartridge-type felt, or paper filter media are acceptable. Additionally, where wire screen is used to provide mechanical support for the filter media, it is not considered a serious missile hazard. However, a cartridge enclosed within a metal container is not acceptable. Two typical enclosureless dust collectors are shown in Figure A.15.9.4.4.5.

Figure A.15.9.4.4.5 Two Typical Enclosureless Dust Collectors.
15.9.4.4.6* AMS Locations.

Dust collectors shall be located in accordance with one of the following:

1. Outside of buildings
2. Indoors when deemed to have no fire or deflagration hazard
3. Indoors for dust collectors with only a fire hazard when protected in accordance with this standard
4. Indoors when equipped with listed deflagration suppression system
5. Indoors when equipped with deflagration relief vents with relief pipes extending to safe areas outside the building and the collector meets the strength requirement of this standard
6. Indoors when equipped with deflagration relief vents exhausting through listed flame-quenching devices and the collector meets the strength requirement of this standard
7. Indoors for enclosureless dust collectors meeting all of the following criteria:
   a. The collector is used only for dust pickup from wood processing machinery (i.e., no metal grinders and so forth).
   b. The collector is not used on sanders, molders, or abrasive planers having mechanical material feeds through the machine.
   c. Each collector has a maximum air-handling capacity of 2.36 m³/sec (5000 cfm).
   d. The fan motor is of a totally enclosed, fan-cooled design.
   e. The collected dust is removed daily or more frequently if necessary to ensure efficient operation.
   f. The collector is located at least 6.1 m (20 ft) from any means of egress or area routinely occupied by personnel.
Multiple collectors in the same room are separated from each other by at least 6.1 m (20 ft).

A.15.9.4.4.6
Although alternatives to out-of-doors locations are permitted, allowing indoor locations under special circumstances, outdoor locations are highly recommended. It is not advisable to locate dust collectors on the roofs of buildings.

A.15.9.4.4.6(7)
It is good practice to protect an enclosureless dust collector with either an automatic sprinkler located above the unit or a spark detection and extinguishing system in the main duct, upstream of the unit.

15.9.4.4.7 AMS Clean Air Exhaust.

15.9.4.4.7.1*
In addition to 9.4.4.5.3, recycling of AMS exhaust to buildings shall be permitted if the provisions of 15.9.4.4.7.2 are met.

A.15.9.4.4.7.1
It is recommended that a secondary filter be used as part of the return air duct to prevent dust propagation into the building interior due to primary filter failure. See ACGIH's Industrial Ventilation — A Manual of Recommended Practice.

15.9.4.4.7.2*
Air from air-material separators or dust collectors deemed to have a fire hazard shall meet the provisions of 15.9.4.4.7.2(A), 15.9.4.4.7.2(B), 15.9.4.4.7.2(C), or 15.9.4.4.7.2(D).

A.15.9.4.4.7.2
The requirement for the return air diversion is in place to protect the occupants from the products of a dust collector fire. This requirement is normally achieved with the use of abort gates that are activated by spark detectors. However, the committee has not achieved consensus regarding the design of this feature.

One approach is to locate the spark detection and abort gate on the inlet duct to the dust collector, which is shown in Figure A.15.9.4.4.7.2(a). With this approach, the burning material is detected by the spark detectors as it travels towards the dust collector. The operation of the spark detectors actuates the abort gate release, diverting the burning material from the dust collector. This prevents the burning material from entering the dust collector and thereby prevents the recirculation of smoke, flame, and other fire products back to the occupied portion of the facility. An additional advantage to this approach is protection of the dust collector.
This approach works best when a fan is located upstream of the dust collector so that the airflow from the fan accelerates the closure of the abort gate. However, fans are often ignition sources and this approach has the disadvantage of initiating comparatively frequent dust collection system shutdowns due to sparks.

The second approach is shown in Figure A.15.9.4.7.2(b). In this design the spark detectors and abort gate are located on the clean air side of the dust collector. With this approach the return air diversion relies upon sparks from burning bags and ignited dust flowing through holes in the bags for the stimulus to actuate the abort gate. This approach has the advantage that it does not divert the airflow except under circumstances of an established fire in the dust collector. However, it does not prevent the introduction of burning material into the dust collector.

The experience of many committee members leads them to believe that most dust collector explosions arise from fires within the dust collector. When the automatic bag-cleaning feature operates, it produces a dust cloud within the collector and this dust cloud is ignited by the pre-existing fire. Consequently, once a fire has become established within the dust collector, the airflow should not be shut down as that causes accumulated dust to slough off the bags, producing a dust cloud that can deflagrate. Instead, the airflow should be maintained. This limits the rate at which dust can slough off of the bags and minimizes the probability that a large dust cloud and resulting deflagration will occur. The flow of air through the dust collector also removes heat from the dust collector. Where the dust collector represents a critical or high value asset, a water deluge system can be added to minimize damage to the dust collector.

Figure A.15.9.4.7.2(a) Spark Detection and Abort Gate on Inlet Duct to the Dust Collector.

Figure A.15.9.4.7.2(b) Spark Detection and Abort Gate on Clean Air Side of the Dust Collector.
For dust collection systems of capacity less than or equal to 2.36 m³/sec (5000 cfm), one of the following shall apply:

1. The system shall be equipped with listed spark detection, designed and installed in conformance with the relevant sections of NFPA 72 located on the duct upstream from the dust collector and downstream from the last material entry point, connected directly to a listed spark extinguishing system, designed and installed in conformance with NFPA 15 or

2. The system shall be protected in accordance with 15.9.4.4.7.2(B).

A.15.9.4.4.7.2(A)
Dust collection systems 2.36 m³/sec (5000 cfm) and smaller represent less hazard due to their relatively small size and can be adequately managed with spark detection and extinguishment rather than requiring the additional expense of an abort gate.

For dust collection systems of capacity greater than 2.36 m³/sec (5000 cfm), the following shall apply:

1. The system shall be equipped with a listed spark detection system, designed and installed in conformance with the relevant sections of NFPA 72 located on the duct upstream from the dust collector and downstream from the last material entry point, or on the exhaust side of the dust collector, to detect fire entering or occurring within the dust collector, respectively, and

2. The exhaust air duct conveying the recycled air back to the building shall be equipped with a high-speed abort gate activated by the spark detector in 15.9.4.4.7.2(B)(1), and the abort gate shall be sufficiently fast to intercept and divert any burning material to atmosphere before it can enter the plant.

3. The abort gate is provided with a manual reset so that, after it has aborted, it can be reset to the normal position only by manual interaction at the damper; automatic or remote reset shall not be allowed. A powered reset is acceptable if it can be activated only by manual interaction at the damper location.
A.15.9.4.4.7.2(B)
Dust collection systems greater than 2.36 m³/sec (5000 cfm) in capacity represent a greater inherent hazard and risk and were deemed to require the inherently greater reliability of an abort gate as opposed to extinguishing systems. Where extinguishing systems can be shown to be equally reliable to the abort gate, it can be used as a performance-equivalent alternative design pursuant to Chapter 6 and 15.6.

A.15.9.4.4.7.2(B)(3)
Manual interaction at the abort gate is required so that the damper can be examined for any damage that could render it unsuitable for continued use.

(C)
Air from enclosureless dust collectors meeting the requirements of 15.9.4.4.6(7) shall be permitted to be exhausted into the building.

(D)
Air from cyclone pre-cleaners, located outside the building and having a capacity of 2.36 m³/sec (5000 cfm) or less shall be permitted to be ducted directly to enclosureless dust collectors located within the building.

15.9.4.4.8 AMS Construction.

15.9.4.4.8.1
The enclosures of collection equipment shall be designed and constructed entirely of noncombustible material suitable for the use intended.

15.9.4.4.8.2*
Dust collectors shall have independent supporting structures capable of supporting the weight of the following:

(1) Collector
(2) Material being collected
(3) Any water from fire-extinguishing systems that will not readily drain from the system

A.15.9.4.4.8.2
Dust collectors that have rotary airlocks on their hopper outfeed sections should not be given credit for drainage through the airlocks. Dedicated drain ports with counter-weighted doors or other latching means designed to open under a slight head of water pressure are commonly provided near the bottom of hopper sections to drain fire protection water. The drain doors are adjusted so that they just barely stay closed during normal operation, and the weight of any water accumulation then causes them to open and drain off the water.
15.9.4.5 Reserved.

15.9.4.6 Reserved.

15.9.4.7 Reserved.

15.9.4.8 Reserved.

15.9.4.9 Reserved.

15.9.4.10* Size Reduction.

A.15.9.4.10
This equipment typically consists of high-speed rotating machinery that cuts, shears, breaks, or pulverizes wood fractions into smaller pieces. Equipment in this category includes, but is not limited to, hogs, chippers, stranders, flakers, disk refiners, hammermills, and pulverizers.

The size and power of the equipment is sufficient to create high heat and showers of sparks if any foreign material enters the equipment. Tramp metal in the material being processed is a common problem, as are rocks or other foreign material.

Fires and explosions can occur in the equipment and propagate rapidly into downstream equipment. The degree of hazard is primarily a function of the moisture content of the material being processed and the size distribution of the particulate produced by the size reduction equipment.

15.9.4.10.1* Unless the particulate size reduction equipment is strictly dedicated to handling green material or is pressurized with steam, it shall be considered a high-frequency ignition source.

A.15.9.4.10.1
Steam-pressurized disk refiners are commonly used in medium-density fiberboard processes.

15.9.4.10.2
The fire and deflagration potential of each piece of particulate size reduction machinery shall be determined by a hazard analysis.
15.9.4.10.3* 
All equipment shall be designed in accordance with 15.9.4.15.

A.15.9.4.10.3
Dust collection pickup ducts are sometimes used to pull a slight negative pressure on equipment such that it operates at a pressure lower than ambient conditions outside the equipment. This can effectively minimize dust emissions by offsetting any slight pressurization of the equipment that occurs during the normal conveying of material.

15.9.4.10.4* 
Exclusion or removal of foreign material shall comply with 9.4.10.

A.15.9.4.10.4
Removal of foreign material from the process stream is the single most important method of eliminating ignition sources created by size reduction equipment. Pneumatic separators (also referred to as air separators) are preferred because they can remove not only ferrous metal, but also nonferrous metal, rocks, and other heavy foreign material that can otherwise cause sparks, frictional heat, and equipment damage. Pneumatic separators are strongly recommended when the material being processed is stored on the ground or hauled in from offsite via trucks, rail cars, and so forth. Material to be processed is commonly passed through air separators when reclaimed from storage, with magnetic separators located on the infeed conveyor to the size reduction equipment as well as other strategic points on the conveying system.

15.9.4.10.5 Size reduction equipment with a deflagration hazard shall comply with 15.9.8.2.5.

15.9.4.10.6 Size reduction equipment with a fire hazard shall comply with 15.9.9.7.5.

15.9.4.11 Reserved.

15.9.4.12 Reserved.

15.9.4.13 Mechanical Feeding Devices.

15.9.4.13.1* 
As determined by a DHA when failure of a mechanical feeding device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.
A.15.9.4.13.1

Possible protection methods could include but not be limited to the following:

(1) Zero speed switches
(2) Flow indicators
(3) Level and/or plug sensors
(4) Heat sensors
(5) Dust level sensors
(6) Belt tracking sensors
(7) Power monitoring
(8) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm.
(9) Alarms that sound at an operator control station or other constantly attended location
(10) Direct connection of drives used in conjunction with feeders, air locks, and other material feeding devices
(11) Belt, chain and sprocket, or other indirect drives that are designed to stall the driving forces without slipping and to provide for the removal of static electric charges

15.9.4.13.2

Controls shall be provided to monitor the operation status of the equipment.

15.9.4.14* Bucket Elevators.

A.15.9.4.14 Examples of bucket elevators can be Z conveyors, open bucket elevators, enclosed bucket elevators, and angled bucket elevators.

15.9.4.14.1 All Legs.

15.9.4.14.1.1

Casing, head and boot sections, access openings, and connecting spouts shall be as dusttight as practicable and shall be constructed of noncombustible materials.
15.9.4.14.1.2*

Inspection openings shall be provided in the boot section to allow clean-out of the boot and inspection of the alignment of the boot pulley and belt.

A.15.9.4.14.1.2

Access doors should be dusttight. Pits should be lighted and accessible and should provide ample room for cleaning, lubrication, repairs, and replacement of parts. Elevator boot sections and the spouts feeding them should be constructed so as to minimize choking of the boot.

15.9.4.14.1.3

Inspection openings shall be provided in the head section to allow complete inspection of the head pulley lagging, the belt and pulley alignment, and the discharge throat of the leg.

15.9.4.14.1.4*

Each leg shall be independently driven by motor(s) and drive train(s) capable of handling the full-rated capacity of the elevator leg without overloading.

A.15.9.4.14.1.4

Any motor or combination of motors utilized should be no larger than the smallest standard motor(s) capable of meeting this requirement.

(A) Reserved.

(B)

Multiple motor drives shall be interlocked to prevent operation of the leg upon failure of any single motor.

(C)
The drive shall be capable of starting the unchoked leg under full (100 percent) load.
15.9.4.14.1.5*

Each leg shall be provided with a speed sensor device that will cut off the power to the drive motor and actuate an alarm in the event the leg belt slows to 80 percent of normal operating speed. Feed to the elevator leg by mechanical means shall be stopped or diverted.

A.15.9.4.14.1.5

Belt alignment monitoring devices are recommended for all elevator legs. Bearing monitoring systems are recommended for head, tail, and bend (knee) pulley bearings on elevator legs.

15.9.4.14.1.6

The use of plastic, rubber, and other combustible linings shall be limited to high-impact areas and wear surfaces.

15.9.4.14.1.7

The leg head section between the up and down casings shall be sloped at an angle of not less than 45 degrees.

15.9.4.14.1.8

All spouts shall be designed and installed to handle the full-rated elevating capacity of the largest leg feeding such spouts.

15.9.4.14.1.9

Legs shall have lagging installed on the head pulley to minimize slippage.

15.9.4.14.1.10*

Leg belts and lagging shall have a surface resistivity not greater than 300 megohms per square.

A.15.9.4.14.1.10

See A.9.3.15.4.
15.9.4.14.1.11

Leg belts and lagging shall be fire resistant and oil resistant.

(A) Reserved.

(B) Reserved.

(C)

Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 18.65 (July 2006), or the flame test for belting in Part 13.2 of ASTM D378, Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type.

15.9.4.14.1.12* Monitors.

A.15.9.4.14.1.12

Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether monitoring is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require monitoring.

(A)*

Inside legs shall have monitors at head, tail, and knee pulley bearings that indicate high bearing temperature or vibration detection.

A.15.9.4.14.1.12(A)

This requirement is also desirable for outside legs.

(B)

Inside legs shall have monitors for head, tail, and knee pulley alignment and belt alignment.
(C)
Abnormal conditions shall actuate a visual or an audible and visual alarm requiring corrective action.

15.9.4.14.2* Bucket Elevator Legs.

15.9.4.14.2.1*

Bucket elevator legs shall be installed either as an outside leg or as an inside leg with compliance with one of the following cases:

1. Legs are located within 3 m (10 ft) of an exterior wall and are vented as outlined in 15.9.4.14.2.2 to the outside of the building and designed so that the explosion pressures will not rupture the ductwork or the leg.

2. Legs are vented in accordance with NFPA 68.

3. Legs are protected in accordance with NFPA 69.

A.15.9.4.14.2.1

Inside legs located in concrete leg wells should be avoided. Where venting is provided for an inside bucket elevator, explosion vents should be directed to outside areas following the guidelines of NFPA 68 and distributing leg vents along the leg as recommended. Vents should never be directed to the inside of a structure. It is preferable to locate inside legs that are to be vented next to outside walls, to minimize the length of explosion relief ducts.

Explosion suppression devices can be used in conjunction with leg feed and discharge points to limit flame propagation into structures.

15.9.4.14.2.2*

All newly installed outside legs shall be provided with explosion relief panels located at intervals no greater than 6 m (20 ft) along the casings as shown in Figure 15.9.4.14.2.2(a) and Figure 15.9.4.14.2.2(b).

Figure 15.9.4.14.2.2(a) Typical Elevator Explosion Venting for a Single Casing Leg.
Figure 15.9.4.14.2.2(b) Typical Elevator Explosion Venting for a Double Casing Leg.
A.15.9.4.14.2.2

Explosion venting is recommended for all outside legs, regardless of size or use. All legs handling combustible materials are subject to an explosion. The leg is the most frequent location for a primary explosion to occur.

(A)

To minimize personnel exposure, explosion venting for outside legs shall start between 2.5 m to 3.5 m (8 ft to 12 ft) above grade, or the bottom of the explosion vent shall be within 0.3 m to 1 m (1 ft to 4 ft) after the leg penetrates the building roof.

(B)

Venting shall not be required on portions of outside legs located below grade or passing through ground-level buildings.
(C)

Each side vent shall have a minimum area equivalent to two-thirds of the cross-sectional area of the leg casing.

(D)

A single face vent shall be permitted to replace a pair of opposing side vents in those portions of a double-casing leg where either of the following situations exists:

1. Side venting could expose personnel on access ladders or platforms.
2. Structural interferences are present that would interfere with vent operation.

(E)

Single face vents shall be equal to the area of two side vents [four-thirds of the cross-sectional area of the leg casing as indicated in Figure 15.9.4.14.2.2(b)].

(F)

The head section of bucket elevators shall be provided with explosion vents in the top surface or on the sides using a method to deflect the explosion upward. The vent area shall be a minimum of 0.46 m² (5 ft²) of vent area per 2.83 m³ (100 ft³) of head section volume. The largest vent area as practicable shall be used in the head section to help minimize the development of explosive pressure. Vents shall deploy when an internal pressure of 3.5 kPa to 6.9 kPa (0.5 psi to 1.0 psi) occurs.

(G)

Explosion relief panels shall be provided on the leg housing so the ducts will not be a collection point for dust during normal operations.

15.9.4.14.3 Reserved.

15.9.4.14.3.1

Explosion venting of legs into buildings shall not be permitted unless a flame-arresting and particulate retention vent system in accordance with NFPA 68 is used.
15.9.4.14.3.2*
Newly installed outside legs shall be equipped with explosion venting in accordance with 15.9.4.14.2.2.

A.15.9.4.14.3.2
For guidance on explosion venting design guidelines, see A.15.9.4.14.2.2.

(A)
The requirement in 15.9.4.14.3.2 shall not apply to those portions of outside legs, as defined in this standard, below grade or passing through ground-level buildings.

15.9.4.14.3.3*
Legs or portions of legs that are located inside shall have the maximum practicable explosion relief area directly to the outside, a flame-arresting and particulate retention vent system in accordance with NFPA 68, or explosion suppression in accordance with NFPA 69.

A.15.9.4.14.3.3
Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether explosion protection is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require explosion protection.

15.9.4.15 Conveyors.

15.9.4.15.1 General Requirements.

15.9.4.15.1.1
All equipment shall be designed, installed, and operated to maintain alignment and lubrication to avoid excessive heat buildup from friction, hot bearings, and so forth.

15.9.4.15.1.2*
All equipment shall be designed to minimize fugitive dust emissions from the equipment.

A.15.9.4.15.1.2
Dust collection pickup ducts are often used to pull a slight negative pressure on equipment such that it operates at a pressure lower than ambient conditions outside the equipment. This can effectively minimize dust emissions by offsetting any slight pressurization of the equipment that occurs during the normal conveying of material.

15.9.4.15.1.3 Dusttight ball or roller bearings shall be used wherever practicable.

15.9.4.15.1.4 All bearings and bushings shall be dusttight.

15.9.4.15.1.5* Bearings and bushings shall be located outside the equipment unless equipment design makes it impractical.

A.15.9.4.15.1.5 An example of a case in which no other practical location exists, and bearings or bushings can therefore be permitted inside equipment, would be hanger bearings on long screw conveyor shafts.

15.9.4.15.1.6 Shaft seals shall be provided where rotating shafts penetrate equipment walls.

15.9.4.15.1.7* Access hatches and removable equipment covers shall be tight fitting and securely fastened for dusttight operation.

A.15.9.4.15.1.7 Gaskets or smooth machined mating surfaces are generally required for dusttight operation.

15.9.4.16 Mixers and Blenders.

15.9.4.16.1 Mixers and blenders shall be designed to control fugitive dust emissions.

15.9.4.16.2* Foreign materials that can become ignition sources shall be prevented from entering the mixer or blender.
A.15.9.4.16.2

Typical methods include magnets, screens, or other methods of detection or classification and that could occur in upstream processes.

15.9.4.16.3

Clearance and alignment of moving parts in equipment processing combustible particulates shall be checked at intervals established by the owner/operator based on wear experience, unless the equipment is equipped with vibration monitors and alarms, or routine manual monitoring is performed.

15.9.4.16.4

Mixers and blenders shall be made of metal, other noncombustible material, or material that does not represent an increased fire load beyond the capabilities of the existing fire protection.

15.9.4.16.5

Where an explosion hazard exists as described in Chapter 7, protection shall be in accordance with Section 9.7.

15.9.4.16.6

Where a fire hazard exists, protection shall be in accordance with ____.

15.9.4.17 Dryers.

15.9.4.17.1 Reserved.

15.9.4.17.2* Veneer and Fiberboard Dryers.

A.15.9.4.17.2

Enclosed dryers are used for drying plywood veneer and fiberboard. The most common configuration uses vertically stacked horizontal trays that convey the material through the dryer. The trays typically vary from 7.6 cm to 30.5 cm (3 in. to 12 in.) apart vertically, and the material on the top tray obstructs the lower tiers from sprinkler protection at the top of the dryer enclosure. This requires additional protection arranged at the sides for the lower tiers. These dryers typically measure 2.4 m to 3 m (8 ft to 10 ft) in cross-section and can be well over 30.5 m (100 ft) long. A series of access doors extend along both sides of the metal enclosure for maintenance and cleaning access.
A less common wicket-type configuration can be used for drying veneer. This style has the veneer held vertically between metal arms that move horizontally through the dryer, and there is little obstruction to sprinkler water discharged from the top of the dryer enclosure.

Direct-fired gas or oil burners are most common, but wood dust burners are sometimes used. Indirect heating using integral thermal oil heat exchangers is also now being used. Fans circulate heated air from side-to-side across the dryers. Several separate drying zones, defined by internal plenum walls across the dryer cross-section, are typically used for better drying control. An unheated cooling section is provided on the dryer outfeed end. These plenum walls are obstructions that need to be taken into consideration when laying out sprinkler placement.

Conventional horizontal tray-type dryers are open on both sides of the trays to allow air to flow parallel across the material surfaces. Fires in these trays can be protected by flat fan spray nozzles located along both sides of the dryer. Vertical jet-type dryers have a special design that utilizes hollow metal arms across the dryer width to supply the drying air. These arms have openings that discharge the air perpendicular to the veneer surfaces. The air supply plenum for the drying arms completely isolates the air supply side of the dryer trays from the opposite side. This means fires in these trays can be reached only by flat fan spray nozzles located along the return air side of the dryer.

Dryer enclosures commonly collect combustible dust and resin deposits on all interior surfaces, and material scraps fall and accumulate on the floor. Fires can spread rapidly throughout the entire dryer for this reason. If thermal oil is used for heating, horizontal floor or plenum sections that can collect spilled oil need to be protected from a flammable liquid spill fire.

15.9.4.17.2.1*
Automatic water spray deluge protection shall be provided for horizontal tray dryers, air plenums, and air exhaust stacks.

A.15.9.4.17.2.1
The fire protection for the interior of the dryer should be engineered to ensure adequate water density throughout the interior of the unit. Specific engineering guidelines can be found in FM 7-10, Wood Processing and Woodworking Facilities.

(A)
Protection shall not be required for the following:

1. Portions of the dryer where the material has a moisture content greater than 40 percent (wet basis), there are no thermal oil heat exchangers in the dryer, and combustible debris or deposits do not accumulate inside the dryer.
2. Portions of the dryer that have two or fewer trays, there are no thermal oil heat exchangers in the dryer, and combustible debris or deposits do not accumulate inside the dryer.
15.9.4.17.2.2
Where two or more deluge systems are provided in the same dryer, the water demand shall be designed for two systems operating at one time. *(See Annex X.)*

15.9.4.17.2.3*
The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to less than 3.2 mm (1/8 in.) thick.

A.15.9.4.17.2.3
The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual. Cleaning by manually activating fixed water spray deluge systems is common and encouraged. This helps clear any foreign material from the deluge piping and nozzles and keeps pipe traps filled with water to help prevent dryer airflow from circulating through the open deluge piping.

15.9.4.17.2.4*
The ceiling areas above these dryers shall receive regular cleaning, especially around roof exhaust fan openings, to keep dust and resin deposits to less than 3.2 mm (1/8 in.) thick.

A.15.9.4.17.2.4
Flash fires can occur across the entire area of dust deposits unless stopped by a physical barrier. Ceiling exhaust fan openings will have the largest accumulations, and the fan motors are frequent ignition sources.

15.9.4.17.2.5
Ceiling areas above veneer and fiberboard dryers shall have draft curtains to contain dust and resin deposits locally to each dryer.

15.9.4.17.2.6
Where automatic sprinkler protection is provided within the draft curtained area, the sprinkler design operating area shall be based on all heads flowing within the curtained area if this area is greater than the normal design area.

15.9.4.17.3* Rotary Dryers.

A.15.9.4.17.3
Rotary dryers are used in composite panel manufacturing. Construction typically consists of steel drums that are oriented horizontally and rotate on trunnion bearings, similar to a kiln. Dryer drums are commonly 2.4 m to 6 m (8 ft to 20 ft) in diameter and 9 m to 15 m (30 ft to 50 ft) long. The drums have internal baffles, or "flights," which lift the material and advance it through the dryer as the drum rotates. Dryers are typically either single-pass or triple-pass design. In single-pass designs, the material enters one end and exits the other end after traversing the length of the dryer once. Triple-pass designs have
three concentric drums and internal baffles, which force the material to traverse the length of the dryer three times before exiting the far end.

Heated airflow is induced through the dryer to both dry the material and assist its movement through the system. Material exiting the drum can be collected in a fall-out chamber called a wind box, or conveyed pneumatically to a cyclone. Dryer exit temperature is used to control the firing rate of the burner. Direct firing of the dryer is typical, with gas, oil, or wood dust used as fuel. Occasionally, waste heat from boilers can be ducted to rotary dryers as a base-load heat source. Indirect thermal oil heating can also be used via oil-to-air heat exchangers.

15.9.4.17.3.1
Rotary dryers having a deflagration hazard shall be located in one of the following places:

1. Outdoors
2. In a separate detached building
3. In a separate cutoff room with damage-limiting construction

15.9.4.17.3.2*
Rotary dryers shall have automatic spark detection and extinguishing systems installed between the dryer drum and downstream material-handling equipment, such as cyclones or wind boxes.

A.15.9.4.17.3.2
A combination of spark detection and extinguishing, water spray deluge, and process isolation devices and interlocks have proven to be highly effective and are recommended. Commonly provided protection features include the following:

1. Provide a spark detection and extinguishing system on the main airflow duct between the dryer drum and cyclone. The spark extinguishing system should activate every time a single spark is detected. It will reset after a few seconds (if no additional sparks have been detected), and the dryer can continue to operate. The spark counting features available in some approved spark extinguishing systems can be used to shut down dryers when an excessive number of sparks are encountered, but they should never be used as a measure of when to actuate the extinguishing spray.

2. Provide a second “fail-safe” detection point on the duct between the spark extinguishing nozzles and the cyclone collector. Detection at this location should be interlocked to safely shut down the dryer as follows:
   (a) Isolate the dryer cyclone outfeed to prevent smoldering material from being conveyed into downstream process areas. This should be accomplished by stopping rotary feeders (metal tipped) or diverting material to a fire dump via reversing conveyors or diverter gates. Refer to NFPA 68 and NFPA 69 for effective isolation techniques.
   (b) Stop material infeed to the dryer and shut off all dryer heat sources. The dryer conveying fan and dryer drum drive should be left running to purge material from the system and help prevent warping of the drum.
(c) Initiate an automatic water spray deluge in the dryer cyclone. Automatic sprinklers are a less desirable alternative. Provide a means for water to drain out of the cyclone. Steam should not be used as an extinguishing medium.

(3) Provide high-temperature limit switches on the inlet and outlet of the dryer drum interlocked to initiate all of the functions in A.15.9.4.17.3.2(2), as well as actuate water spray deluge in the dryer inlet and outlet.

(4) When the dryer duct on which spark detectors are mounted is subject to resinous accumulations, provide test lights that are mounted across the duct from each detector to facilitate remote testing. An alternative is frequent inspection and cleaning to ensure continuous operability.

(5) Provide rotary dryers, which incorporate a “wind box” on the dryer outlet, where the majority of the conveyed material drops out, with an additional spark detection zone, isolation measures, and water spray deluge protection similar to the main cyclone.

(6) For dryers processing particleboard furnish or other material having a similar high concentration of fines, provide deflagration relief venting on the cyclone if it does not exhaust directly to atmosphere and on the wind box (if present). Use NFPA 68 or equivalent, for vent design. Figure W.1(c) and Figure W.1(d) show typical protection schematics and interlock logic for rotary dryers.

15.9.4.17.3.3*
The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep combustible deposits to a minimum.

A.15.9.4.17.3.3
The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual.

15.9.4.17.4* Conveyor Dryers.

A.15.9.4.17.4
In addition to rotary dryers, oriented strand board material can be dried in conveyor dryers (also used to dry tobacco). These dryers are similar in size to horizontal tray veneer dryers but are only about half as tall, since only one horizontal conveyor tray is used to dry and move the material through the dryer. These dryers operate at lower drying temperatures that decrease exhaust air emission problems but increase the material dwell time. As many as nine individual dryers, arranged in series, have been needed to get the required material dwell time.

Mechanical conveyors are used to feed material into and collect material from the dryers. The dryer conveyor “belt” is a continuous loop of perforated metal plates about 203 mm (8 in.) wide and 2.4 m (8 ft) long, hinged together along the long edge to form a continuous track belt. Thermal oil indirect heating is common utilizing integral oil-to-air heat exchangers.

Heated air is circulated from side-to-side through several separate heating zones, with the air distribution plenums arranged such that air flows through the perforations in the conveyor belt, perpendicular to the material surface, much like a vertical jet veneer dryer.
15.9.4.17.4.1*
Conveyor dryers shall be protected with water spray deluge systems, activated by spark, flame, and/or heat detectors.

A.15.9.4.17.4.1
Dryer enclosures commonly collect combustible dust and resin deposits on all interior surfaces, and material scraps fall and accumulate on the floor. Fires can spread rapidly throughout the entire dryer for this reason. Also, thermal oil heating adds the potential for a flammable liquid spill fire inside the dryer.

A combination of spark detection/extinguishing, water spray deluge, and process isolation devices and interlocks have proven to be highly effective and are recommended as follows:

1. Provide protection inside individual dryer enclosures similar to that in A.9.3.9.1.1 for horizontal tray veneer dryers [however, (1) and (2) in 9.3.9.1.1.1 do not apply to conveyor dryers].
2. Provide approved spark detection at dryer outfeed points interlocked to reverse the take-away conveyor and dump the material in a safe location. The conveyor dryer heat source should also be interlocked to shut down, but the dryer belt should continue to run to empty the dryer.

Where fire extinguishing systems are provided for thermal oil utilization equipment, the systems should be designed to protect the equipment from a thermal oil spill fire or from the material being processed, whichever poses the more severe fire hazard.

15.9.4.17.4.2
Dust collection systems used to capture dust emissions in or between individual conveyor dryers shall be designed in accordance with 15.9.4.3.2.

15.9.4.17.4.3*
The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to a minimum.

A.15.9.4.17.4.3
The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual. Cleaning by manually activated fixed water spray deluge systems is common and encouraged. This helps clear any foreign material from the deluge piping and nozzles and keeps pipe traps filled with water to help prevent dryer airflow from circulating through the open deluge piping.

15.9.4.17.5* Flash Tube Dryers.

A.15.9.4.17.5
Flash dryers are used to dry wood fiber in hardboard and medium-density fiberboard manufacturing. They are basically just pneumatic transport blowpipes 1.5 m (5 ft) in diameter, with the conveying air heated to dry the material as it is conveyed. Wet wood fiber is injected via a high-pressure blowpipe into the hot induced air stream at the head end of the dryer tube. Constant diameter dryer tubes can be over
61 m (200 ft) long to get adequate material retention time in the dryer. Some configurations use vertical duct sections with increased diameters to reduce the velocity and increase the material dwell time (similar to wood pulp flash dryers). Dryer exit temperature is used to control the heat-source firing rate.

Some dryers utilize a process known as “blowline blending” where the resin binders, needed to form a rigid panel in the hot press, are added to the fiber before it is injected into the dryer. This is done for better resin mixing with the wood fiber, but it also makes the dried fiber more tacky and subject to buildup in the dryer system.

Both direct firing — using gas, oil, or wood dust burners — and indirect heating — using steam or thermal oil heat exchangers — are common.

15.9.4.17.5.1
The location of the flash dryers shall comply with one of the following:

1. Flash dryers shall be located outdoors.
2. Flash dryers shall be located in a building physically detached from the main production building.
3. Flash dryers shall be permitted to be installed such that the head-end portion of a flash dryer, in which the moisture content of the material being dried is greater than 40 percent (dry basis), is located inside the main production building.
4. Flash dryers shall be permitted to be installed such that any portion of a flash dryer, in which the moisture content of the material being dried is less than 40 percent (dry basis), is located inside the main production building if it has explosion protection designed in accordance with NFPA 69.

15.9.4.17.5.2*
Flash tube dryers shall be protected by a combination of spark detection and extinguishing systems, water spray deluge, deflagration relief venting, and process isolation devices and interlocks.

A.15.9.4.17.5.2
Commonly provided protection features include the following:

1. Protect flash dryers with spark detection and extinguishing systems, isolation methods, and automatic deluge systems in cyclones similar to A.15.9.4.17.3 for rotary dryers. Flash dryer protection differs only in that there is no dryer drum. The “fail-safe” detector should also initiate a water spray deluge at the head end of the dryer tube in addition to the cyclone.
2. Provide high-temperature limit switches on the dryer duct at the material injection point and inlet to the cyclone. These detectors will act as backup detection to the “fail-safe” spark detector and should initiate the same functions.
3. Provide flash dryers with explosion protection on the dryer tube and cyclone designed in accordance with NFPA 69. If explosion venting is the protection method selected, vents should be smooth and flush fitting on the inside to prevent material buildup.
4. Provide a diverter on the fiber injection pipe to direct fiber to a dump area during initial startup until the material flow is uniform.

15.9.4.17.5.3*
The dryer duct shall be regularly inspected and cleaned to minimize fiber accumulations.

A.15.9.4.17.5.3
The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual for dryers that utilize blowline resin blending.

15.9.4.17.6* Kiln Dryers.

A.15.9.4.17.6
Lumber that is to be dried is first prepared by stacking it in uniform loads, with each layer of lumber separated by a “sticker” of wood approximately 25.4 mm (1 in.) square. The loads of “stuck lumber” are stacked as high as 4.9 m (16 ft) on wheeled carts that run on tracks to convey the loads into each dry kiln compartment. The kiln is then closed, and heated air is circulated through the stacks from side to side until the desired moisture content is reached. This batch process can take several hours to complete.

Kilns can be indirectly heated by steam or thermal oil heat exchangers inside the kiln enclosure, or directly heated by gas-, oil-, or wood dust–fired burners.

Once the drying cycle is complete, kiln loads are removed and placed in a “cooling shed” (usually just a canopy) to cool before the stacks are broken down for further processing of the dried lumber.

Humidifying and Tempering Ovens. The finishing of hardboard panels usually includes a tempering or humidifying process to stabilize the moisture content. This is done in large oven enclosures similar in size to lumber dry kilns. Hardboard panels are stacked up to 3.7 m (12 ft) high on wheeled carts, with spacers between individual panels to permit airflow through each stack. Indirect heating using steam heat exchangers is the most common heat source.

15.9.4.17.6.1*
Automatic sprinkler protection shall be provided within dry kilns and ovens with a rating over 150,000 Btu/hr.

A.15.9.4.17.6.1
The following should also be considered when designing protection for dry kilns:

(1) Automatic sprinklers over lumber loads should be located such that the top and sides of the lumber loads are wetted. Consideration should be given to obstructions such as heating coils and movable airflow baffles that could block sprinkler discharge when the kiln is in operation.

(2) Flow of thermal oil through the kiln should be interlocked to stop automatically on sprinkler water flow or detection of oil loss in the kiln-heating loop. Manual shutoff is acceptable where alarms for sprinkler water flow and loss of oil annunciate at an onsite constantly attended location, the oil isolation valve is readily accessible and not exposed by a kiln fire, and the emergency response team includes a trained person assigned to this task.

(3) Hydraulic calculations should include 1900 L/min (500 gpm) for hose streams.
(4) A dry pipe or deluge system should be used if sprinkler piping is subject to freezing when the kiln is idle.

(5) Sprinklers should be used with glass bulb–type thermal elements rated for approximately 28°C (50°F) above the maximum normal operating temperature.

(6) Roofs or canopies over kiln cooling shed areas (dry lumber) and infeed areas (green lumber) should have automatic sprinkler protection designed for the equivalent height of lumber storage.

15.9.4.17.6.2
Sprinklers below the fan decks of dry kilns shall be based on the storage height of product within the kiln, with the operating area being the entire area.

15.9.4.17.6.3
Sprinklers above the fan decks of dry kilns shall be designed to provide 6.1 L/min/m² (0.15 gpm/ft²) density over the entire area.

15.9.4.17.6.4
If the dry kiln is heated by a thermal oil system with hot oil piping inside the kiln that is not all welded (e.g., bolted connections), the minimum sprinkler design density shall be per the requirements in NFPA 13 for Extra Hazard Group 1 occupancies over the entire kiln area.

15.9.4.17.6.5
Hydraulic calculations shall be balanced for the simultaneous operation of all sprinklers above and below the fan deck.

15.9.4.17.6.6*
The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to a minimum.

A.15.9.4.17.6.6
The required inspection frequency is best determined for each dryer, based on actual operating conditions. Weekly inspection is not unusual.

15.9.4.17.6.7
Fuel burner combustion controls and interlocks shall conform to Section 15.10.

15.9.4.17.7 Finishing Room Dryers.
Sprinkler protection provided in finishing room dryers (flammable and combustible solvents) shall be protected as an Extra Hazard Group 2 occupancy as outlined in NFPA 13.

15.9.4.18 Reserved.

15.9.4.19 Hot Presses.
15.9.4.19.1 Continuous Presses.

15.9.4.19.1.1*
Continuous presses shall be protected in a manner acceptable to the authority having jurisdiction.

A.15.9.4.19.1.1
A number of options are available for the protection of continuous presses, including, but not limited to, water spray systems, water mist systems, and gaseous extinguishing systems. The design of the protective features should address the unique characteristics of the press.

The system should provide sufficient volume to extinguish any fire in or on the press without causing any structural damage to the belts, hydraulics, oil hoses, or press frame. In case of an oil leak, the system should be able to control the fire until emergency responders arrive.

Continuous presses were introduced in North America in the late 1980s. Continuous presses can be found as large as 10 m to 55 m (33 ft to 160 ft) long, 1.83 m to 3.05 m (6 ft to 10 ft) wide. The fiber mat enters at the inlet and the finished board exits at the outlet at speeds of up to 1.5 m/sec (295 ft/min). This high-production equipment presents a number of new protection design challenges, as follows:

1. 75,700 L to 113,550 L (20,000 gal to 30,000 gal) of thermal heat transfer oil operating well above its flashpoint
2. Thousands of gallons of hydraulic oil
3. Lubrication grease covering frames and surfaces
4. Dust, fiber, glue, and release agent, all of which are combustibles and make up the mat
5. Friction of moving parts
6. Flexible low-pressure hoses for hot thermal oil
7. Flexible high-pressure hoses for hydraulic oil
8. Raw material of dry wood fiber, resins, glues, and release agents, all of which are combustibles, moving forward under high pressure and temperatures well in excess of 149°C (300°F)
9. Return belts that travel in upper and lower heat tunnels that are subject to buildup of fiber, oil, grease, and fumes
10. The board’s ignition upon exposure to oxygen when exiting from the press
11. Operator errors

Protection by conventional sprinkler systems and deluge systems can be very detrimental to the integrity of the press. Such systems are slow and use large volumes of water, causing too-rapid cooling, which can cause damage to steel frames, hot platens, and steel belts. It is advisable to employ optical flame and spark detection systems for early detection. The detectors activate the fine water mist spray nozzles that protect the area of the fire. A press can typically be split up in five independent zones: inlet, middle, outlet, upper, and lower heat tunnels. The fine droplets will hit the fire and immediately turn into steam, expanding more than one thousand times. The conversion of water to steam cools, and the expansion smothers the fire.

The small droplet size greatly reduces the possibility of damage to steel frames and instrumentation or of
warping of the belt. Fine water spray typically requires one-third of the water volume of conventional systems and less cleanup time, less damage, and shorter downtime. Fine water mist sprays have proven themselves most successful in Europe and elsewhere.

The Technical Committee knows of dozens of incidents where continuous presses have caught fire. Most of the fires have caused less than one million dollars in damage, with a few running into multimillion dollars. Conventional fire fighting using hoses has caused more damage, due to the water, to the press frames, belts, and instrumentation than was caused by the initial fire.

Most fires have occurred at the outlet and the upper heat tunnel. The majority of fires can be referred to human error in operation or programming. Most of the fires have occurred in Europe, where the majority of presses are in operation.

15.9.4.19.1.2
Pits beneath continuous presses shall be protected in accordance with 15.9.4.19.2.

15.9.4.19.2 Multiopening Batch-Type Presses.

15.9.4.19.2.1
For press pit installations that do not utilize thermal oil heating, automatic sprinkler protection shall be provided with a minimum density of 8.15 L/min/m² (0.20 gpm/ft²) over the entire pit area, with a hose stream allowance of 1893 L/min (500 gpm) included in the hydraulic calculations.

15.9.4.19.2.2*
For press pit installations where thermal oil heating is used, automatic sprinkler protection shall be designed to provide a minimum density of 10.2 L/min/m² (0.25 gpm/ft²) over the entire pit area, with a hose stream allowance of 1893 L/min (500 gpm) included in the hydraulic calculations.

A.15.9.4.19.2.2
Where thermal oil heating is employed, there is a greater risk of ignition and greater availability of fuel. This condition can warrant the use of deluge protection rather than closed head sprinkler protection.

15.9.4.19.2.3
Where presses are supported on steel columns and thermal oil heating is used, automatic sprinkler protection for steel support columns shall be provided unless the columns are protected with a 2-hour fire-rated material.

15.9.4.20 Portable Appliances.

15.9.4.20.1*
A written policy shall be established to regulate the use of portable appliances.
A.15.9.4.20.1
The policy should include the type, use, and location of appliances. The intent of this procedure is to recognize the inherent hazards associated with the use of appliances in certain locations. Any exception to this written policy should be reviewed on a case-by-case basis. All exceptions should require written approval from the facility manager.

15.9.4.20.2*
The policy shall identify locations where specific portable appliances are permitted or prohibited.

A.15.9.4.20.2
Electrical appliances should be located only in authorized, designated locations intended to support these types of appliances. Low-hazard locations such as offices, administrative facilities, and distribution centers often allow the following appliances:

1. Refrigerators, microwaves, ice machines, small ovens, and coffee makers, located in vending/break room areas or other areas designated by the facility manager
2. Fans, radios, and so forth, located in employee’s personal work areas as authorized by the facility manager

Where electrical appliances are authorized in areas containing stored combustible materials (e.g., copy paper, office supplies, and so forth), combustibles stored in the open should not be closer than 2 m (6 ft) to the appliance.

Care should be taken to ensure that the appliance is not left plugged in and unattended. A person should be appointed to ensure that the appliance(s) is turned off at the end of each working day except for refrigerators, ice makers, and so forth.

Some examples of locations where portable appliances should not be allowed include the following:

1. Manufacturing, storage, fabricating, finishing, or other hazardous areas
2. Motor control rooms, computer rooms, computer rack rooms, electrical rooms, or other equipment rooms
3. Unoccupied buildings or intermittently occupied areas
4. Employee’s personal work area, except for small authorized appliances such as fans, radios, and so forth

Some examples of appliances that should not be authorized in any location include but are not limited to the following:

1. Hot plates
2. Toasters, toaster ovens, and popcorn poppers, other than used in the food service or vending area
3. Space heaters (The use of space heaters presents an unnecessary hazard from a fire protection standpoint. The company or business management is responsible for maintaining a proper working environment.)
4. Extension cords not provided by the company or business
15.9.4.20.3*
The policy shall provide for inspections conducted periodically to ensure compliance with this standard.

A.15.9.4.20.3
Consideration of the following items can be included as part of the electrical appliance inspection:

(1) Does the appliance meet specifications as outlined in this standard, and is it used for its designated purpose?
(2) Is the appliance in an approved building location?
(3) Is the appliance clean and in good working condition?
(4) Is the appliance cord in good condition? Is the cord worn or frayed?
(5) Do the appliances’ ratings exceed the circuit rating, potentially overloading the electrical protection devices?
(6) Are only authorized extension cords in use? Does each cord support no more than one appliance?
(7) Where appliances are authorized in areas with stored combustible materials, is there a door that could be closed?
(8) Are combustible materials (e.g., paper, binders, and files) stored in the open closer than 2 m (6 ft) to the appliance?

15.9.4.21 Spray Finishing.
Spray finishing operations shall be in accordance with NFPA 33.

15.9.4.22 Dipping and Coating.
Dipping and coating operations shall be in accordance with NFPA 34.

15.9.4.23* Pollution Control Equipment.

A.15.9.4.23
Dryer systems can require pollution control equipment to reduce emissions of both particulate (e.g., dust, ash, and so forth) and vapors (e.g., volatile organic compounds, or VOCs, known in the industry as “blue haze”).

Commonly used particulate collection equipment includes bag filters, wet and dry scrubbers, electrostatic precipitators, and other specially designed hybrid collection devices such as electrified filter beds (EFBs).

Commonly used vapor collection or incineration equipment includes regenerative thermal and catalytic oxidizers (RTOs and RCOs), incineration chambers, and bio-filters. In all cases, the ducts between dryers and vapor collection or control equipment are subject to buildup of combustible deposits. Although insulating ducts can help reduce the rate of condensation deposits, they cannot be relied upon to totally prevent them. In some instances, dryer air exhaust can be ducted into the combustion air supply for fuel burners.
15.9.4.23.1
The pollution control exhaust system shall be designed and maintained in accordance with NFPA 91.

15.9.4.23.2
Pollution control bag filters shall be designed in accordance with 15.9.4.3.2.6.

15.9.4.23.3
Where an extinguishing system is provided in pollution control equipment, the system shall be designed
to operate simultaneously with any extinguishing system in the process equipment.

15.9.4.24 Panel Product Manufacturing Machinery.

15.9.4.24.1
Panel formers utilizing dry wood or other cellulosic materials, consisting of particles or fiber of various
sizes, shall be provided with dust control to minimize dust clouds within the enclosure.

15.9.4.24.2
Bearings, rollers, and bushings shall be in accordance with 15.9.4.15.1.

15.9.4.24.3
Foreign material shall be removed from the process material feed into all particulate size reduction
equipment by permanent magnet or self-cleaning electromagnet-type magnetic separators, or by
pneumatic separators, or by both.

15.9.4.24.4
All dust-producing equipment shall be designed for dusttight operation, or the equipment and dust-
producing operations shall be provided with dusttight hoods or enclosures that comply with the
requirements of 15.9.4.3.

15.9.5 Ignition Source Control.

15.9.5.1 Reserved.

15.9.5.2 Reserved.

15.9.5.3 Hot Surfaces.

15.9.5.3.1*
In areas where a dust explosion hazard or dust flash-fire hazard exists, the temperature of external
surfaces shall be maintained below 80 percent (in degrees Celsius) of the lower of the dust surface
ignition temperature or the dust-cloud ignition temperature.
A.15.9.5.3.1
Fire losses have occurred where steam piping was identified as the ignition source for wood dust deposits. This is possible because prolonged exposure to elevated temperatures will cause the decrepitation of the cellulose into pyrolysis products that can have lower ignition temperatures than those normally associated with wood. In permitting maximum surface temperatures above 100°C (212°F) (the minimum steam temperature), it is assumed that appropriate personnel safety measures are in place and that a rigid housekeeping program exists to keep dust accumulations under control. Equipment surfaces in hard-to-access locations that will collect dust and are likely to be cleaned less frequently should be insulated to keep the maximum surface temperature below 100°C (212°F).

Dust layer and dust cloud ignition temperatures should be determined by ASTM E2021, Test Method for Hot-Surface Ignition Temperature of Dust Layers; ASTM E1491, Test Method for Minimum Autoignition Temperature of Dust Clouds; or other recognized test methods acceptable to the AHJ. Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust; however, this is not universally true (see NFPA 499). The minimum ignition temperature typically decreases with increasing layer thickness, and testing up to maximum layer thickness to be expected on external surfaces is recommended.

The ignition temperature of a layer of dust on hot surfaces could decrease over time if the dust dehydrates or carbonizes. The ignition temperatures for many materials are shown in NFPA 499.

15.9.5.3.2*
Bearings shall be dusttight ball or roller type and shall be monitored for adequate lubrication and excessive wear in accordance with 15.9.4.15.1.

A.15.9.5.3.2
Bearings in dusty or inaccessible areas where overheating can cause ignition of fires or explosions should be equipped with journal temperature alarms.

15.9.5.6* Electrostatic Discharges.

A.15.9.5.6
Grounding and bonding information can be found in NFPA 77. Because cellulosic materials are highly hydroscopic, active humidity controls can be useful in limiting the tendency to accumulate static electrical charge.

15.9.5.6.1 Conductive Equipment

Where equipment is subject to the accumulation of static electric charge, the accumulation of static electric charge shall be controlled by one of the following:
(1) Permanent grounding and bonding of production equipment
(2) Grounded metal combs to provide discharge paths
(3) Other means shown to be effective and acceptable to the authority having jurisdiction

15.9.5.6.2 Maximum Particulate Transport Rates (Reserved)

15.9.5.7 Open Flames and Fuel-Fired Equipment.

15.9.5.7.1 Wood-fired burners and boilers shall be designed, installed, and operated in a manner that prevents the unintentional ignition of wood or other cellulosic material outside the combustion zone.

15.9.5.7.2* Provisions shall be made to prevent the accumulation of wood and cellulosic dust on the heated surfaces of heating units operating at temperatures exceeding 180°C (356°F).

A.15.9.5.7.2 Wherever possible, heating units should be installed in compartments separate from woodworking and wood processing activities and processes. Guidance is available in FM 6-7, Fluidized Bed Combustors and Boilers, and FM 6-13, Waste Fuel-Fired Boilers.

15.9.5.7.3 An emergency shutoff valve, readily accessible during a fire, shall be provided for flammable fuel lines.

15.9.5.8* Industrial Trucks.

A.15.9.5.8 The following provisions can be used to reduce the fire hazard from diesel-powered front-end loaders used in Class II hazardous areas as defined in Article 500 of NFPA 70:

(1) Only essential electrical equipment should be used, and wiring should be in metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
(2) Where practical, a water-cooled manifold and muffler should be used.
(3) Loaders that are certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, “Approval Requirements for Permissible Mobile Diesel-Powered Transportation Equipment,” are also acceptable.
(4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry chemical extinguishing systems.
(5) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning should also be done.
(6) Loaders should never be parked or left unattended in the storage building.
15.9.5.9 Reserved.

15.9.5.10 Reserved.

15.9.5.11* Friction and Impact Sparks.

A.15.9.5.11
Collection points used for manual cleanup, such as vacuum hoses or floor sweeps, should incorporate features for prevention of foreign material entry. Magnetic separators, grates, or screening are typical protective features.

15.9.5.11.1
Wood stock shall be inspected for foreign materials, such as nails, sugar taps, fencing wire, and so forth, prior to being processed.

15.9.5.11.2
Prevention of foreign materials in dust collection systems shall be in accordance with 15.9.4.3.2.

15.9.5.11.3
Prevention of foreign materials in particulate size reduction equipment shall be in accordance with 15.9.4.10.

15.9.5.11.4
All equipment shall be designed, installed, and operated to maintain alignment and lubrication to avoid ignition from frictional heating.

15.9.5.11.5*
Roller or ball bearings shall be used on all processing and transfer equipment in accordance with 15.9.4.15.1.

A.15.9.5.11.5
Consideration should be given to the potential for overheating due to dust entry into bearings. Bearings should be located outside the wood waste stream, where they are less exposed to dust and more easily inspected and serviced. Sealed bearings are preferable.

15.9.5.11.6
Bushings shall be permitted to be used where an engineering analysis has shown that the mechanical loads and speeds preclude attainment of temperatures sufficient to ignite wood particulates in the environment of the machines in question.

15.9.5.12 Propellant-Actuated Tools.
15.9.5.12.1 Propellant-actuated tools shall not be used in areas where combustible dust or dust clouds are present.

15.9.5.12.2 When the use of propellant-actuated tools becomes necessary, the following procedures shall be performed prior to their use:

(1) All dust-producing machinery in the area shall be shut down.
(2) All equipment, floors, and walls shall be carefully cleaned.
(3) All dust accumulations shall be removed.

15.9.5.12.3 A check shall be made after the work is completed to ensure that no cartridges of charges are left in the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or -handling machinery is resumed.

15.9.5.13 Smoking.
Smoking shall be permitted only in designated areas equipped with ample devices for smoking material disposal and free of combustible/flammable hazards or storage.

15.9.5.14 Electrical Systems.

15.9.5.14.1 All electrical systems and system components shall be installed in accordance with NFPA 70.

15.9.5.14.2* Portions of the facility where dust accumulations occur or where suspensions of wood dust in air could occur shall be equipped with electrical systems and equipment per Article 502 or 503 of NFPA 70.

A.15.9.5.14.2 Refer to NFPA 499.

15.9.5.15 Fans and Blowers.

15.9.5.15.1 Requirements for fans and blowers used in pneumatic conveying systems shall be in accordance with 15.9.4.3.2.5.

15.9.5.15.2* Fans that are subject to combustible residue buildup on the fan, fan shroud, and drive mechanism shall be kept clean to prevent overheating and ignition of the deposits.
A.15.9.5.15.2
Building exhaust fans over hot presses, veneer dryers, and finishing area or booth exhaust fans are particularly susceptible to this problem.

15.9.5.16* Lighting.
Lighting system fixtures shall be designed, installed, and maintained such that they do not pose a potential ignition hazard due to the heat evolved from normal operation or as a result of catastrophic failure or damage.

A.15.9.5.16
Serious consideration should be given to installing lighting that is suitable for Class II, Division 2, Group G hazardous locations in all woodworking and wood processing areas where wood dust is likely to occur. Such lighting will permit the use of blowdown methods for cleaning while the lighting is operating. Failure to use lighting suitable for Class II, Division 2, Group G hazardous locations will necessitate locking out and tagging out the lighting power supply before commencing blowdown, and explosion-proof lighting will have to be provided on a temporary basis while blowdown is being conducted.

15.9.5.17* Portable Electric Equipment and Appliances.
Portable electric equipment and appliances used in hazardous areas shall be listed for the area in which they are to be used.

A.15.9.5.17
Electric appliances, including but not limited to coffee pots and portable space heaters, have been found to cause fires in industrial occupancies. The use of these appliances should be controlled by management to limit the probability of ignition.

15.9.5.18* Machines and Processing Equipment.

A.15.9.5.18
Most fires involving woodworking and wood processing facilities are ignited by the process equipment. Whenever wood or wood-derived products and materials are cut, shaped, planed, or smoothed, heat is generated in the process. This heat can be sufficient to raise the wood or wood-derived materials to their ignition point, igniting a fire. It is important to note that most cellulosic materials will begin to pyrolyze (decompose due to heat) as their temperatures are raised above 200°C (392°F). At these temperatures, this process is endothermic, requiring the investment of heat to continue. However, once the temperature of the wood or wood-derived material attains temperatures in excess of approximately 280°C (536°F), the chemical reactions involved in pyrolysis change and become exothermic, producing more heat than is needed to continue the process. This results in the ignition of the wood waste generated by the equipment. Whenever the wood is visibly discolored (i.e., singeing or charring), an ignition has occurred and burning material has been introduced into the dust collection (wood waste conveyance) system.

15.9.5.18.1* Feed-Rate Controls.
Feed rates and machine adjustments for the stock being processed on wood cutting, shaping, planing, and
sanding operations shall be controlled to prevent ignition (hot cuts).

A.15.9.5.18.1
High feed rates generate more heat per unit of time and unit of wood processed. This increased rate of heat generation increases the likelihood that embers and sparks will be produced that can lead to the ignition of wood particulates conveyed in the pneumatic wood waste removal system. This is particularly important when working with wood species that exhibit wide variations in density and hardness with the same board, such as maple, oak, cedar, and hickory.

15.9.5.18.2 Cutter and Abrasive Maintenance.

15.9.5.18.2.1*
Wood cutting, shaping, and planing equipment shall be maintained at a level of sharpness to minimize the heat generated from woodworking operations.

A.15.9.5.18.2.1
The quantity of heat generated during a woodworking operation is affected by the sharpness of the tool(s). Whether the tool is a saw, shaper, router, planer, or one using abrasives, properly sharpened cutters operate more coolly and are far less likely to ignite stock or wood waste.

15.9.5.18.2.2*
Abrasive cutting belts, disc surfaces, and devices shall not be used beyond their design lifetime and shall be replaced or cleaned in the manner specified by the manufacturer when showing signs of loading of the grit.

A.15.9.5.18.2.2
Abrasive belts have been identified as the source of ignition in a number of serious fires. This necessitates careful management of the abrasive condition. Once grit begins loading up, all of the power dissipated by the machine motor is essentially converted to frictional heat. Extreme care should be employed with abrasive shaping and surfacing machines for this reason.

15.9.5.19 Machinery Setup and Maintenance.

15.9.5.19.1
Provisions shall be made to ensure that machine setup, including but not limited to depth of cut and feed rate, is properly fixed and secure from unintentional change during the production run, consistent with the manufacturer’s operation manual.

15.9.5.19.2*
Woodworking machines shall be maintained as required in the manufacturer’s operation and maintenance manual.
A.15.9.5.19.2
In some cases, the use of spark-resistant tools might be advisable.

15.9.5.20* Lightning Protection.
Lightning protection, where provided, shall be designed, installed, and maintained in accordance with NFPA 780.

A.15.9.5.20
Particular attention should be paid to the potential for a lightning strike on roof-mounted dust collectors, cyclones, and ductwork. The electromagnetic pulse from a lightning strike to these pieces of equipment can cause severe damage to any electronic equipment, including spark detection and extinguishing systems, installed on such equipment. The impulse current from a direct lightning strike on roof-mounted dust collectors, cyclones, and ductwork can ignite wood waste within this equipment that can subsequently be conveyed to other locations in the facility.

15.9.5.21 Spontaneous Ignition and Chemical Action.

15.9.5.21.1*
When storage of wood or wood substitute particulates is employed, the wood or wood substitute particulates shall be evaluated for the potential for spontaneous ignition from chemical reactions during storage.

A.15.9.5.21.1
There have been some reports of autoignition of wood particulates where large quantities of particulates have been stored undisturbed for extended periods of time. The common denominator in these events has been particulates with relatively high polymerizable oil contents stored in large piles for extended periods of time where the heat generated by the polymerization reaction cannot easily and rapidly dissipate.

15.9.5.21.2
Wood or wood substitute particulates that are determined to have a spontaneous ignition potential shall be stored in one of the following locations:

(1) Outside
(2) Inside in accordance with Chapter 11
(3) In separate buildings
(4) In bins designed such that the particulate flow occurs in a first-in/first-out basis

15.9.5.21.3*
Rags, cloths, filter media, or other similar material containing finishing oils that have been determined to have a spontaneous ignition potential shall be disposed of pursuant to 8.4.1.10.

A.15.9.5.21.3
Linseed, tung, and similar oils have been identified as having a spontaneous ignition history.
15.9.6 Reserved.

15.9.7 Reserved.

15.9.8 Explosion Prevention/Protection.

15.9.8.1 Reserved.

15.9.8.2 Equipment Protection.

15.9.8.2.1 General. (Reserved)

15.9.8.2.2* Dust Collectors with Deflagration Hazards.

Dust collectors with a deflagration hazard having a dirty side volume greater than 0.23 m³ (8 ft³) shall be designed and constructed in accordance with one of the following options:

1. Dust collectors constructed of welded steel or other noncombustible material of sufficient strength to withstand the maximum unvented deflagration pressure of the material being collected
2. Dust collectors protected by a listed deflagration suppression system in accordance with NFPA 69 with a design strength exceeding the maximum reduced deflagration pressure of the material being collected
3. Dust collectors equipped with deflagration relief vents in accordance with NFPA 68 with a design strength exceeding the maximum reduced deflagration pressure of the material being collected
4. Dust collectors located outdoors and representing minimal exposure to personnel and the public at large with weaker construction, subject to a risk analysis acceptable to the authority having jurisdiction
5. Enclosureless dust collectors of any strength suitable for the use intended shall be permitted without any additional explosion protection requirements

A.15.9.8.2

Some dust collectors, especially bag filters designed to collect dust on the inside of the filter media, can operate without any enclosure, but they sometimes have very lightweight, self-venting enclosures just for weather protection.

A.15.9.8.2.2(1)

When dust collectors are designed and installed in accordance with 15.9.8.2.2(1), administrative controls such as lockout/tagout or inspection programs to assure that access hatches are in place before equipment is operated are recommended.
A.15.9.8.2.2(2)
The manufacturer of the listed deflagration suppression system should be consulted to determine the maximum reduced deflagration pressure to be expected with their protection hardware.

A.15.9.8.2.2(3)
If relief pipes are used in conjunction with deflagration relief vents to direct the vented gases to a safe location, the reduced deflagration pressure will be higher than if no relief pipes were present. Deflagration relief vent design and reduced deflagration pressure requirements are found in NFPA 68. If listed flame-quenching devices are used in conjunction with deflagration relief vents to extinguish flames in the vented gases, the reduced deflagration pressure will be higher than if no flame-quenching devices were present. The manufacturer of the listed flame-quenching device should be consulted to determine the maximum reduced deflagration pressure to be expected with the protection hardware.

15.9.8.2.3* Ducts with a Deflagration Hazard.
Ducts having a deflagration hazard shall be designed, constructed, and installed pursuant to one of the following:

1. Ducts, including all access hatches, shall be constructed of metal of sufficient strength to withstand the maximum unvented deflagration pressure of the material being conveyed.
2. Metal ducts shall be protected by a listed deflagration suppression system that has a design strength exceeding the maximum reduced deflagration pressure.
3. Metal ducts located indoors shall be equipped with deflagration relief vents and vent ducts designed, installed, and maintained in accordance with NFPA 68 and shall have a design strength exceeding the maximum reduced deflagration pressure.
4. Metal ducts located indoors shall be equipped with deflagration relief vents and vent ducts designed, installed, and maintained in accordance with NFPA 68 that exhaust through listed flame-quenching devices and shall have a design strength exceeding the maximum reduced deflagration pressure.
5. Metal ducts located outdoors shall be equipped with deflagration relief vents designed, installed, and maintained in accordance with NFPA 68 and shall have a design strength exceeding the maximum reduced deflagration pressure.
6. Metal ducts that are located outdoors and have weaker construction shall be permitted to be used subject to a risk analysis acceptable to the authority having jurisdiction.

A.15.9.8.2.3
Although criteria are given for designing and operating pneumatic conveying ducts close to or above the MEC, it is safer and preferable to operate below this threshold by keeping airflow sufficiently high to prevent the maximum concentration of dust in the duct from exceeding 25 percent of the MEC. The one exception to this is bulk transport using high-pressure ductwork that utilizes smaller-diameter and stronger duct than low-pressure systems. These systems transport particulate in very high concentrations and have an excellent loss history relative to deflagration propagation or damage.
A.15.9.8.2.3(1)
High-pressure conveyance lines (blowpipes) made of steel or iron pipe with Schedule 40 or greater wall thickness normally meet the strength requirement of 15.9.8.2.3(1). Administrative controls such as lockout/tagout or inspection programs to ensure that access hatches are in place before equipment is operated are recommended.

A.15.9.8.2.3(2)
The manufacturer of the listed explosion suppression system should be consulted to determine the maximum reduced deflagration pressure to be expected with their protection hardware. Welded steel of 12-gauge minimum thickness is normally strong enough to prevent failure during an explosion, especially for small ducts.

A.15.9.8.2.3(6)
Ducts located outdoors do not pose an undue potential for property damage or expose plant personnel or the public at large to the risk of injury from rupture of the duct. Therefore, they might not need strong construction.

15.9.8.2.4* Silos and Storage Bins with a Deflagration Hazard.

Silos and storage bins with a deflagration hazard shall be equipped with either of the following:

(1) Deflagration relief venting designed to relieve the deflagration to a safe area and maintain the pressure below the yield strength of the vessel
(2) Explosion suppression systems designed, installed, and maintained in accordance with NFPA 69

A.15.9.8.2.4
Refer to NFPA 68.

15.9.8.2.5* Size Reduction Equipment with a Deflagration Hazard.

A.15.9.8.2.5
This subsection includes additional requirements for size reduction equipment deemed to have a deflagration hazard.

15.9.8.2.5.1
Size reduction equipment shall be located in accordance with one of the following:

(1) Outdoors
(2) Inside a detached building
(3) Indoors, separated from other areas by damage-limited construction

15.9.8.2.5.2*
Size reduction equipment shall be constructed in accordance with one of the following:
An enclosure shall be constructed of welded steel or other noncombustible material of sufficient strength to withstand the maximum unvented explosion pressure of the processed material.

An enclosure shall be constructed of noncombustible material, protected by a listed explosion suppression system with a design strength exceeding the maximum reduced explosion pressure of the processed material.

An enclosure constructed of noncombustible material, equipped with adequate deflagration relief vents having relief pipes extending outdoors or discharging through listed flame-quenching devices, shall have a design strength exceeding the maximum reduced explosion pressure of the processed material.

A.15.9.8.2.5.2
The manufacturer of the listed explosion suppression system should be consulted to determine the maximum reduced explosion pressure to be expected with their protection hardware.

If relief pipes are used in conjunction with deflagration relief vents to direct the vented gases to a safe location, the reduced explosion pressure will be higher than if no relief pipes were present. Deflagration relief vent design and reduced explosion pressure guidelines are found in NFPA 68. If listed flame-quenching devices are used in conjunction with deflagration relief vents to extinguish flames in the vented gases, the reduced explosion pressure will be higher than if no flame-quenching devices were present. The manufacturer of the listed flame-quenching device should be consulted to determine the maximum reduced explosion pressure to be expected with their protection hardware.

Size reduction equipment located outdoors that does not pose an undue property damage loss potential to the property owner or expose plant personnel or the public at large to the risk of injury from an explosion might not need strong construction or any special protection.

15.9.8.2.5.3
Rooms containing the size reduction equipment shall be classified in accordance with Article 500 of NFPA 70.

15.9.8.2.6 Conveyors with a Deflagration Hazard.

15.9.8.2.6.1
Enclosed conveyors with a deflagration hazard shall comply with the criteria in 15.9.8.2.2.

15.9.8.2.6.2*
Access hatches and removable equipment covers shall be secured with fasteners capable of withstanding design deflagration pressure in accordance with 15.9.8.2.2, unless that hatch or cover is designed to function also as a deflagration relief vent.

A.15.9.8.2.6.2
Administrative controls such as lockout/tagout or inspection programs are recommended to ensure that access hatches are in place before equipment is operated.
15.9.8.2.7 Mixers and Blenders with a Deflagration Hazard.

Where an explosion hazard exists as described in Chapter 7, mixers and blenders shall be equipped with either of the following:

1. Deflagration relief venting in accordance with NFPA 68
2. Explosion protection systems designed, installed, and maintained in accordance with NFPA 69

15.9.8.3 Equipment Isolation.

15.9.8.3.1* Conveying System Isolation.

A.15.9.8.3.1
The intent of this section is to prevent spread of fires and explosions via conveying systems from high-risk processes into work spaces, storage facilities, or other critical processing systems beyond those immediately involved. It is not the intent to isolate each and every piece of conveying equipment from each other. Consideration of when and where to isolate should be based on the frequency of ignition sources and the potential severity of a loss (e.g., property damage, downtime, and personal injury).

15.9.8.3.1.1
Conveying systems with deflagration hazards shall be isolated to prevent propagation of fire and deflagration both upstream and downstream into occupied areas or other critical process equipment. (See Annex W.)

15.9.8.3.1.2
Conveying systems with fire hazards shall be protected in accordance with Chapter 9 to prevent fire extension through the facility.

15.9.8.3.1.3*
Isolation devices shall be listed or approved for the use intended.

A.15.9.8.3.1.3
Except for passive devices, such as flame front diverters, backblast dampers, and material chokes, detection and speed of actuation of the device is critical. For fire isolation, the normal material conveying speed is used to determine the necessary speed of isolation devices. For deflagrations, however, flame propagation through conveying systems will be much faster than normal conveying speeds, and it can also accelerate. Isolation design, device construction, and installation should be done only by engineering consultants, manufacturers, and vendors familiar with the hazards and capabilities and limitations of the hardware. Table A.15.9.8.3.1.3 lists some commonly used isolation devices.

Table A.15.9.8.3.1.3 Commonly Used Isolation Devices
### Isolation Device

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<td>Abort gate</td>
<td>Fire and deflagration</td>
<td>Used on pneumatic conveying ducts. Most practical on positive pressure pneumatic systems (two abort gates needed for negative pressure systems).</td>
</tr>
<tr>
<td>Pant leg gate</td>
<td>Fire and deflagration</td>
<td>Used on gravity flow chutes at material transfer points.</td>
</tr>
<tr>
<td>Slide gate</td>
<td>Fire only</td>
<td>Used on the bottom of mechanical conveyors that slide material through the conveyor enclosure (e.g., screw and flight conveyors).</td>
</tr>
<tr>
<td>Reversing conveyor</td>
<td>Fire only</td>
<td>Used with mechanical conveyors (usually screw conveyors). Not effective with dusty material unless other blocking devices (e.g., rotary feeders) are also used.</td>
</tr>
<tr>
<td>Flame front diverter</td>
<td>Deflagration only</td>
<td>Used on pneumatic conveying ducts.</td>
</tr>
<tr>
<td><strong>Blocking Devices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotary feeders</td>
<td>Fire and deflagration</td>
<td>Must have metal-tipped vanes with narrow wall gap 0.18 mm (0.007 in.). Rubber-tipped vanes cannot be relied on. Must be stopped to remain effective.</td>
</tr>
<tr>
<td>Slide gate</td>
<td>Fire and deflagration</td>
<td>Used to block pneumatic ducts, chutes, and so forth. Usually actuated with high-pressure gas cylinder.</td>
</tr>
<tr>
<td>Flame front extinguishers</td>
<td>Deflagration only</td>
<td>Single-shot pressurized chemical extinguishers, typically used on ducts or enclosed conveyors.</td>
</tr>
<tr>
<td>Backblast dampers</td>
<td>Deflagration only</td>
<td>Used on pneumatic systems to prevent flow counter to normal flow.</td>
</tr>
<tr>
<td>Material chokes</td>
<td>Deflagration only</td>
<td>Normally used on mechanical screw conveyors or at material transfer points.</td>
</tr>
</tbody>
</table>

NFPA 654 also discusses various types of explosion isolation devices.

**15.9.8.3.1.4**
Ducts shall be isolated to prevent propagation of deflagration to other vessels.

**15.9.8.3.1.5**
Where provided, explosion isolation devices shall be installed, inspected, and maintained in accordance with Chapter 15 of NFPA 69.

**15.9.8.3.2**
Dust collectors that discharge into storage bins or silos shall do so in a manner that minimizes the generation of dust clouds.

**15.9.8.3.3**
The discharge arrangement in 15.9.8.3.2 shall be constructed to minimize dust leaks and shall contain a choke to prevent explosion propagation between the collecting equipment and storage facilities.

15.9.9 Fire Protection.

15.9.9.1 Reserved.

15.9.9.2 Reserved.

15.9.9.3* Fire Extinguishers.

A.15.9.9.3
In areas containing thermal oil equipment or piping, a 9 kg to 14 kg (20 lb to 30 lb) dry chemical–type extinguisher is preferable. Portable or fixed foam or aqueous film forming foam (AFFF) extinguishing equipment is an acceptable alternative.

15.9.9.4* Hoses, Standpipes, Hydrants, and Water Supply.
Galvanized piping shall not be used in high-temperature and high-humidity environments.

A.15.9.9.4
Galvanized pipe deteriorates more rapidly than plain black steel pipe due to a galvanic reaction that occurs in high-temperature [greater than 54°C (130°F)] and high-humidity environments.

15.9.9.4.1* Standpipes and Hose.

A.15.9.9.4.1
Inside, 38 mm (1 1/2 in.) hose stations are recommended throughout all major woodworking facilities. Directional water spray nozzles or combination straight stream water spray nozzles are recommended, since careless use of straight hose streams can cause dust explosions by throwing hazardous quantities of dust into suspension. NFPA 600 should be utilized as a guide for employee training.

15.9.9.5* Automatic Sprinklers.

A.15.9.9.5
Automatic sprinkler protection is recommended throughout all major woodworking facilities. Press pits, press hoods, and hood ventilating fans should be protected by automatic sprinkler systems, deluge systems, or both. It is important that sprinkler and deluge heads be located so that hard-to-reach places, such as spaces between press cylinders, are properly protected. The design criteria established in this standard reflect research, testing, and loss history accumulated by the industry and internationally recognized research laboratories.
15.9.9.6* Detection and Extinguishing Systems.
Automatic detection and extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, tested, and maintained in accordance with the following standards, as applicable:

1. NFPA 11
2. NFPA 12
3. NFPA 15
4. NFPA 17
5. NFPA 25
6. NFPA 69
7. NFPA 72
8. NFPA 750
9. NFPA 2001

A.15.9.9.6
The minimum testing and maintenance frequency for spark detection and extinguishing systems should be as given in Table A.15.9.9.6.

<table>
<thead>
<tr>
<th>Item</th>
<th>Operation</th>
<th>Weekly</th>
<th>Monthly</th>
<th>Semi-Annual</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control panel</td>
<td>Clean</td>
<td></td>
<td>X</td>
<td></td>
<td>Visual inspection of all warning/operational lights.</td>
</tr>
<tr>
<td>Emergency power</td>
<td>Test</td>
<td></td>
<td></td>
<td>X</td>
<td>See manufacturer's battery test procedure.</td>
</tr>
<tr>
<td>Detector and spray nozzle</td>
<td>Test</td>
<td></td>
<td></td>
<td>X*</td>
<td>See manufacturer's detector and spray nozzle test procedure. Remove and inspect strainers.</td>
</tr>
<tr>
<td>Detectors/test lights</td>
<td>Maintenance</td>
<td></td>
<td></td>
<td>X†</td>
<td>Inspect and clean.</td>
</tr>
<tr>
<td>Water lines</td>
<td>Flush</td>
<td></td>
<td></td>
<td>X</td>
<td>Flush for 2 minutes. Remove and inspect strainer.</td>
</tr>
<tr>
<td>Booster pump (if provided)</td>
<td>Test</td>
<td></td>
<td></td>
<td>X</td>
<td>See manufacturer's booster pump test procedure.</td>
</tr>
<tr>
<td>Freeze protection</td>
<td>Inspect</td>
<td></td>
<td></td>
<td>X</td>
<td>Check at plant winterization and monthly during freezing.</td>
</tr>
<tr>
<td>Rapid speed abort gates</td>
<td>Test</td>
<td></td>
<td></td>
<td>X</td>
<td>See manufacturer's test procedure.</td>
</tr>
</tbody>
</table>

*See manufacturer's test procedure. Where daily automatic detector response testing is provided by external means (test lights), monthly inspection is acceptable.
†The frequency of cleaning should be adjusted, based on the experience at each detector point. Detectors found to be dirty during scheduled cleaning should have their cleaning frequency increased, and those found to be clean can have their cleaning frequency decreased.

An approved spark detection and extinguishing system should be considered to quench burning material before it can be conveyed into the collecting equipment.

Also, when bag filters are used, with the conveying airflow fan located ahead of the bag filters, a high-speed abort gate activated by infrared spark detectors should be used to divert burning material before it can enter the bag filter. (Refer to T. Frank, “Fire and Explosion Control in Bag Filter Dust Collection Systems.”)

15.9.9.7 Equipment Protection.

15.9.9.7.1 General. (Reserved)

15.9.9.7.2* Dust Collectors with Fire Hazards.
Where automatic sprinkler protection is provided in dust collectors, it shall be hydraulically designed to provide a minimum density of 8.15 L/min/m² (0.20 gpm/ft²) over the horizontal projected area of the piece of equipment.

A.15.9.9.7.2 Adequate drainage (automatic dumping) should be provided to prevent structural collapse.

15.9.9.7.3* Ducts with a Fire Hazard.
Ducts conveying dry material released by equipment having a high frequency of generated sparks shall be designed and constructed in accordance with one of the following:

(1) Equipped with a listed spark detection and extinguishing system installed downstream from the last material entry point and upstream of any collection equipment
(2)* Equipped with a listed spark detection system actuating a high-speed abort gate, provided the abort gate can operate fast enough to intercept and divert burning embers to atmosphere before they can enter any collection or storage equipment
(3) If conveying material to locations representing minimal exposure to personnel and the public at large, equipped without spark detection and extinguishing systems but subject to a risk analysis acceptable to the authority having jurisdiction

A.15.9.9.7.3 Equipment having a history of producing frequent sparks includes, but is not limited to, large belt sanders and planers having automatic feed systems, hammermills, pulverizers, and flakers. This protection is generally employed to protect the downstream equipment rather than the duct itself.

This protection also deserves consideration on dust collection systems for less hazardous equipment (e.g., saws) if the loss potential for property damage or interruption to production is high.
A.15.9.9.7.3(2)
Abort gates can be used on systems that have the air-moving device located upstream of any dust collection equipment (i.e., positive pressure systems). This arrangement facilitates clearing the ductwork of all burning material by stopping material infeed and leaving the fan running when the abort gate activates. This is the recommended arrangement and operating sequence when this alternative is used. Figure A.15.9.9.7.3(2)(a) shows the normal and aborted airflow conditions.

Figure A.15.9.9.7.3(2)(a) Aborting of Positive Pressure Systems.

In situations where the fan is on the clean side and external to the AMS, there is a simple way to arrange an abort gate to divert burning material from the dust collector, which achieves the need to purge the
upstream ducts of material. It is imperative that the fan (AMD) remain running and that the fuel source be eliminated to clear the duct. This is shown in Figure A.15.9.9.7.3(2)(b).

**Figure A.15.9.9.7.3(2)(b) Diversion of Sparks with a Single Abort Gate Up-Stream of Dust Collector.**

**15.9.9.7.4* Silos and Storage Bins.**
Where automatic sprinkler protection is provided in bins, hoppers, and silos, the system shall be hydraulically designed to provide a minimum density of 8.15 L/min/m² (0.20 gpm/ft²) over the horizontal projected area of the piece of equipment.

**A.15.9.9.7.4**
Adequate drainage should be provided to prevent structural collapse. In addition, a means should be available to remove the contents other than through the facility process to permit the removal of burning material without threatening the rest of the facility. Storage bins and silos should be located outside the building on independent supporting structures and should be accessible for fire fighting. It is not advisable to locate bins or silos on the roofs of buildings.

**15.9.9.7.5* Size Reduction Equipment with a Fire Hazard.**
Downstream equipment shall be protected against ignitions caused by size reduction equipment in accordance with 15.9.4.3.

**A.15.9.9.7.5**
This subsection includes additional requirements for size reduction equipment deemed to have a fire
hazard.

15.9.9.7.6* Conveyors with a Fire Hazard.
Where provided, sprinkler protection for rubber belt and other conveyors shall be designed, installed, and maintained in accordance with NFPA 13.

A.15.9.9.7.6
Typical examples of these conveyors are most rubber belt conveyors and bucket elevators. Misalignment is commonly detected by switches mounted near the belt edges. A mistracking belt will contact the switch and shut down the drive. Rotary motion detectors on belt drive and tail spools are commonly used to detect a slipping belt. Motion detection on the drive spool with no corresponding motion detected on the tail spool would indicate a slipping belt and shut down the drive.

Rubber belt conveyors represent a special design challenge that is not specifically addressed in NFPA 13. Valuable additional guidance is available in FM 7-11, Belt Conveyors.

15.9.9.7.7 Mixers and Blenders with Fire Hazards
Where automatic sprinkler protection is provided in mixers and blenders, it shall be hydraulically designed to provide a minimum density of 8.15 L/min/m² (0.20 gpm/ft²) over the horizontal projected area of the piece of equipment.

15.10 Thermal Oil Heating Systems.

15.10.1* Hazard Determination and Design Criteria.
Thermal oil heating systems shall be designed, operated, and maintained such that risk of thermal oil spills is minimized, and any fires or explosions resulting from thermal oil spills are extinguished or controlled in a manner that will not cause unacceptable property damage or interruption of production, or unacceptable risk to operating personnel or the public at large.

A.15.10.1
Refer to FM 7-99, Heat Transfer by Organic and Synthetic Fluids, or NFPA 87.

As shown in Figure A.15.10.1, a typical thermal oil heating system includes the following:

1. Thermal oil heater
2. Primary circulation loop and pumps to keep oil flowing through the heater
3. Secondary thermal oil loop(s) to circulate oil through the utilization equipment
4. Expansion tank to hold the increased volume of the oil as it is heated
5. Drain tank to receive oil intentionally drained from the system or expelled through system relief valves, overflow pipes, or vents
Firing can be by conventional gas or oil burners or by wood dust suspension burners. Large heaters can burn wood waste on a grate, in a fluidized sand bed, or by more complex gasification methods that partially burn and gasify wood waste on a grate using sub-stoichiometric under-fire airflow, and complete the combustion in an upper plenum using secondary air injection. Combustion gases, typically in the 927°C to 1093°C (1700°F to 2000°F) range, then heat the thermal oil via radiant and/or convection air-to-oil heat exchangers. The heat exchanger can be a separate, stand-alone unit or an integral part of the heater. Refractory lining is needed for the burner, heat exchanger, and any interconnecting duct until gas temperatures are reduced to about 427°C (800°F) or less. Conventional water-tube boilers have been adapted to heat thermal oil, with thermal oil replacing the water.

Nonvaporizing thermal oil systems are the norm in wood processing or woodworking occupancies and are preferred because they do not pose a significant room explosion hazard. Vaporizing systems are rare and are discouraged because an oil leak can expel boiling oil/vapor into the surrounding space and form an explosive atmosphere.

Most nonvaporizing systems in these occupancies have expansion tanks operating at atmospheric pressure, with open vents to equalize pressure in the expansion tank as the oil level changes during operation.

Some nonvaporizing systems have oversized expansion tanks that are completely sealed and operate under slight pressure [less than 103.426 kPa (15 psi)] as the heated oil rises in the tank. This arrangement eliminates the possibility of overflowing the expansion tank.
The thermal fluids used are special organic or synthetic oils developed for this type of application, with flash points of several hundred degrees Fahrenheit. For maximum thermal efficiency, the oil is usually heated above its flash point, making an oil spill especially hazardous. Also, because of the high oil temperature, it is sometimes necessary to keep the oil circulating through the heat exchanger at all times to prevent oil breakdown and tube fouling, especially with wood waste–fired heaters. Diesel-driven pumps or emergency generators are usually provided for this purpose in case of a power outage, with an emergency bypass cooling loop to extract heat from the oil when normal utilization equipment would also be inoperable. This continuous oil pumping can increase damage if an oil leak and fire involving the primary heating loop occurs, and special controls and interlocks are needed.

Thermal oil heating systems are used to heat equipment such as lumber dry kilns, plywood veneer dryers, plywood and composite board presses, and wood particulate and fiber dryers, and even for building heat.

15.10.1.1
The hazard posed by the thermal oil system, when the oil is used as heat transfer fluid (HTF), shall be determined on the basis of the largest most credible spill quantity of thermal oil, taking into account the following:

(1)* Total quantity of thermal oil in the system
(2)* Flow rate of thermal oil through system loops
(3)* System instrumentation and alarm features that would detect loss of fluid from the system
(4)* System automatic controls and interlocks, and/or presence of trained operators, that can reliably shut down pumping and/or isolate portions of the system to limit the amount of thermal oil spilled
(5)* Spatial orientation of thermal oil piping and system components that would allow isolated portions of the system to drain their trapped quantities of thermal oil by gravity

A.15.10.1.1(1)
The larger systems in use in wood processing plants have total oil capacities up to 170,345 L (45,000 gal). The smaller ones hold as little as 379 L to 757 L (100 gal to 200 gal).

A.15.10.1.1(2)
Thermal oil flow rates can be as high as 49,210 L/min (13,000 gpm) in large multiopening press secondary loops. Primary loops on these systems typically flow oil up to 9464 L/min (2500 gpm). The very small systems containing just a few hundred gallons could have flow rates under 379 L/min (100 gpm).

A.15.10.1.1(3)
The ability to detect loss of fluid in the system is critical in reducing the amount of oil that can spill. Small leaks can also spill large quantities of oil over time if not detected. Various leak detection methods along with their benefits and limitations are listed in Table A.15.10.1.1(3).
## Table A.15.10.1.1(3) Leak Detection Methods: Benefits and Limitations

<table>
<thead>
<tr>
<th>Leak Detection Method</th>
<th>Benefits and Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion tank low oil limit switch</td>
<td>Installed near bottom of tank. Simple, but tank is emptied before alarm initiated. Can't differentiate between large and small leaks. Might be enough for very small systems.</td>
</tr>
<tr>
<td>Expansion tank low oil deviation switch</td>
<td>Installed higher in tank, below the normal maximum oil level when system is at operating temperature. Simple, and alarms quicker than low limit switch, but changes in oil type, quantity, or operating temperature will change alarm point. Must be bypassed during startup heating process.</td>
</tr>
<tr>
<td>Expansion tank flowmeter</td>
<td>Installed on downcomer pipe connecting tank with primary oil loop combined with control programming to continuously monitor flow rate. More complex control logic, but can detect early loss of oil if flow rate is greater than instrument sensitivity. Might not detect small leaks over time.</td>
</tr>
<tr>
<td>Expansion tank dynamic oil level detection</td>
<td>Using hydrostatic pressure transducer combined with control programming to continuously monitor oil level. Most complex control logic, but most flexible and most accurate. Can detect absolute oil level changes as small as ±6.35 mm (0.25 in.), up or down, as well as rate of change. Self-adjusts to oil level in tank during startup.</td>
</tr>
<tr>
<td>Dual flowmeters</td>
<td>On specific pipe sections (e.g., inlet/outlet of loops, heaters, etc.) combined with control programming to continuously monitor differential oil flow. More complex control logic, but can identify larger leaks in specific pipe sections. Mass flowmeters required for accuracy if change in oil temperature (i.e., volume) between meter locations. Will not detect small leaks below combined accuracy of two flowmeters.</td>
</tr>
<tr>
<td>Single flowmeters</td>
<td>On pipe sections combined with control programming to continuously monitor oil flow. Control logic is simpler, but cannot detect smaller leaks below the accuracy of the flowmeter.</td>
</tr>
<tr>
<td>Low oil pressure switches or pressure transducers</td>
<td>Combined with control programming to continuously monitor oil pressure. Control logic is simpler, but cannot detect smaller leaks below the accuracy of the instrumentation. Cannot differentiate between other conditions causing low pressure (e.g., pump failure, partially closed valve, etc.). Not appropriate where low oil pressure starts emergency oil pumps.</td>
</tr>
<tr>
<td>Liquid spill detection</td>
<td>Near floor level in pits, drains, or sumps around specific equipment. Simple and able to locate leaks at specific equipment. Might be able to detect leaks early if containment area is small. Subject to false alarm from other liquids such as wash-down hoses, etc.</td>
</tr>
<tr>
<td>Acoustic transducers</td>
<td>On specific pipe sections combined with sophisticated monitoring control system to continuously listen for abnormal sound signatures. Potentially able to detect small leaks, but requires calibration setup to filter out normal system sounds. No experience available on feasibility of this method on thermal oil systems.</td>
</tr>
</tbody>
</table>
A.15.10.1.1(4)
If the method of leak detection used does not specifically identify the section of the system where the leak is occurring, controls and interlocks will need to isolate as many sections of the system as required to keep the largest credible spill at an acceptable level, regardless of the location of the leak.

The most common isolation technique is to close off all secondary thermal oil loops to reduce the exposure to important equipment. Where feasible, the primary loop should not leave the cutoff heater area. This will keep the secondary loop connections and control valves in the dedicated cutoff area. If the secondary loop piping is long and/or of large diameter, it can be necessary to have additional valves on pipe runs to reduce the amount of oil that can spill.

Another isolation technique is to close off the downcomer pipe from the expansion tank, removing that volume from the spill potential in the primary and secondary loops. Concurrently, a drain line on the expansion tank is sometimes opened to empty the expansion tank into a storage tank or other safe location.

Isolation of the heater oil piping is a special problem for heaters that need to keep oil flowing due to very high oil temperatures, fuel supplies that cannot be instantly shut off (e.g., wood pile burners), and/or high latent heat storage in heater refractory. Stopping oil flow in these instances before temperatures are reduced can foul the heat exchanger tubes, necessitating their cleaning or replacement. Emergency diesel-driven pumps and emergency bypass cooling heat exchangers are usually provided in these cases so that secondary loops can be isolated without shutting down the primary loop. One major exception to stopping the flow through these heaters is when an oil leak and fire are occurring in the heat exchanger itself. In this case, the desirable action is to actuate an extinguishing system in the heat exchanger, shut down the primary circulation pump(s), and drain or isolate the oil in the expansion tank. In addition to oil leak detection, a second detection means, such as high stack temperature or high stack combustibles, is usually provided to confirm a fire in the heat exchanger.

Valves that need to operate during a spill emergency should be fail-safe, and if manually actuated, should have remote actuation capability. One common method of implementing this is to use spring-loaded ball valves with pneumatic actuators. The spring would cause the valve to go to the full open or full closed position, whichever is the appropriate safe position, when control air pressure is removed. The valve can be made fail-safe by installing a section of plastic tubing in the control air supply line at the valve. A leak and/or fire at the valve will burn through the plastic tubing and cause the valve to go to the safe position.

For all sections of piping that are deadheaded by closed isolation valves, it is necessary to provide a means of negative pressure relief as hot oil cools to prevent possible collapse of piping, vessels, and so forth. This is most easily done by drilling a small hole through isolation valve gates/balls and through check valve clappers, or by small open tubing around the isolation valves to permit a very small amount of oil to flow as it cools and contracts. If the expansion tank has not been isolated, it will supply oil slowly to provide the necessary negative pressure relief to the system. If it has been isolated, its isolation valve should also have the small drilled hole or bypass tubing to allow the expansion tank to equalize the
negative pressure.

**A.15.10.1.1(5)**

When pumps are shut down, gravity will provide the motive force for oil to flow to system low points. Backflow can occur counter to the normal flow direction under these circumstances, so all flow paths, valve types and locations, and relative elevations should be considered when designing isolation systems. A secondary loop arrangement is shown in Figure A.15.10.1.1(5)(a) with a three-way control valve on the secondary loop oil supply leg.

*Figure A.15.10.1.1(5)(a) Three-Way Valve on Supply Leg.*
During normal operation, the three-way valve diverts a portion of the primary loop flow into the secondary loop to maintain temperature in the utilization equipment. Oil can freely flow into or out of the expansion tank as the oil volume changes with temperature. If an emergency shutdown occurs due to an oil leak in the secondary loop, the pump is stopped and the three-way valve moves to full bypass position.
isolating the normal oil infeed line to the secondary loop. However, because the normal secondary loop return line does not have a check valve, the expansion tank and any oil pipe higher than the point of breakage in the secondary loop can drain back through the return pipe. A check valve is needed as shown to reduce the largest credible spill from a break in the secondary loop. Other means would be needed (e.g., rapid drain of the expansion tank and isolation valve on expansion tank downcomer pipe) to isolate the expansion tank if the leak were in the primary loop.

In Figure A.15.10.1.1(5)(b) a three-way oil control valve is located on the secondary loop return leg.

Figure A.15.10.1.1(5)(b) Three-Way Valve on Return Leg.
In this case, gravity flow will feed oil into the secondary loop in the normal flow direction, so a check valve cannot be used to stop the unwanted flow. An automatic isolation valve interlocked with the emergency shutdown sequence is needed to block the flow. This valve should fail in the closed (safe) position.

Because this arrangement is more complex and requires active interlocks and valves, it is less reliable.
than the operation in Figure A.15.10.1.1(5)(a). Placing the three-way control valve on the oil supply leg with a simple passive check valve on the return leg is, therefore, the preferable arrangement.

Figure A.15.10.1.1(5)(a) and Figure A.15.10.1.1(5)(b) are just two examples of flow control valving arrangements used on the larger thermal oil systems. Smaller systems might not have a secondary loop or might have just a single modulating ball valve for flow control. However, the need to evaluate all paths that oil can take to reach a point of leakage is no different for smaller systems. The same isolation concepts apply when trying to control or minimize the amount of oil that can leak, regardless of the system size.

15.10.1.2*
The hazard analysis shall define the location, size, and extent of the maximum most credible thermal oil spill, taking into account the following:

(1) Diversion of a spill due to floor or ground slope
(2) Containment of a spill by pits, curbs, and dikes
(3) Relocation of a spill from the immediate area by drains

A.15.10.1.2
It can be anticipated that 3.79 L (1 gal) of spilled oil will spread out and cover approximately 1.9 m² (20 ft²) on a flat floor.

15.10.1.3
The hazard analysis shall define the fire intensity and duration of the maximum most credible thermal oil spill defined from the analyses in 15.10.1.1 and 15.10.1.2, taking into account the following:

(1) Rate at which oil will be spilled
(2) Rate at which oil will drain away
(3)* Rate at which oil will be consumed during burning
(4) Heat release rate of the oil spill fire

A.15.10.1.3(3)
It can be assumed that a pool of thermal oil will burn down at a rate of about 25 mm (1 in.) every 7 minutes.

15.10.1.4
The hazard analysis shall determine the extent of property damage, loss of production, and risk of injury to operating personnel or the public at large from a fire involving the maximum most credible thermal oil spill, taking into account the following:

(1) Fire resistance of the exposed equipment or structures
(2) Presence and adequacy of automatic sprinklers or other special extinguishing systems for the duration of the fire
(3) Presence of fire alarms and means of egress from the vicinity of the fire
15.10.1.5
For vaporizing thermal oil systems, the risk analysis shall additionally determine the extent of property damage, loss of production, and risk of injury to operating personnel or the public at large from a room explosion involving the sudden release of thermal oil vapor or thermal oil heated above its atmospheric boiling point.

15.10.2* General Criteria.
Thermal oil shall not be permitted to be pumped throughout a facility to provide building heat except under one of the following conditions:

1. All thermal oil piping and points of connection to valves, heat exchangers, or other equipment have welded connections.
2. Areas where mechanical joints for thermal oil piping exist are protected with a sprinkler system designed to control a fire in the largest credible thermal oil spill.

A.15.10.2
When thermal oil is used for building heat, a central heat exchanger should be provided to heat a nonflammable liquid, such as a water/glycol solution, that can then be piped throughout the facility without increasing the fire hazard. This method is strongly preferred even though exceptions are given to allow direct pumping of thermal oil.

While welded connections minimize the risk of an oil leak, there have been significant losses involving thermal oil leaks from cracked welds. If the areas having thermal oil heating have automatic sprinkler protection, it is good practice to design the sprinklers for the thermal oil hazard if that poses a higher fire demand.

The largest credible thermal oil spill should take into consideration the ability of the thermal oil system to automatically detect oil leaks, shut down pumps, and isolate piping loops. The sprinkler demand for a thermal oil spill fire is normally greater than the demand for the woodworking occupancy. Thus, greater cost is incurred for the sprinkler protection of the facility when this exception is followed. This additional cost will normally pay for the nonhazardous fluid heat exchanger system.

When alternatives to 15.10.2(1) and 15.10.2(2) are elected, they demand far greater sprinkler delivery density and the design area can be larger, impacting sprinkler system design.

15.10.3 Location and Construction.

15.10.3.1
Thermal oil heaters shall be physically separated from adjacent manufacturing areas by locating them in one of the following areas (in order of preference):

1. Outdoors where drainage is certain to be away from a building
2. In a detached building
(3) In a building attached to an outside wall of the manufacturing building with the common wall having a 1-hour fire rating

(4) In a cutoff room at an outside wall of the main production building with the three interior walls having a 1-hour fire rating

15.10.3.2
Nonvaporizing thermal oil heaters with an oil capacity less than 1893 L (500 gal) shall be permitted in manufacturing areas if an oil spill at the heater is controlled according to 15.10.3.3.

15.10.3.3*
A vaporizing thermal oil heater shall be located pursuant to the following:

(1) In compliance with 15.10.3.1
(2) In a room or building housing having damage-limiting construction to vent an explosion toward a safe area

A.15.10.3.3
Mist explosions have been known to occur when thermal oil above its boiling point has been released into an enclosed area. The preferred location for a vaporizing system is, therefore, outside or in a detached building.

15.10.3.4
Curbs, dikes, or floor slope combined with drainage to a safe location shall be provided around indoor thermal oil system components (e.g., storage tanks and pump heat exchangers).

15.10.3.5
Drainage shall not be required when an automatic sprinkler system designed and installed in accordance with NFPA 13 is provided over the containment area and the containment area is designed to hold the largest credible oil spill plus 20 minutes of sprinkler discharge.

15.10.3.6*
Where the utilization of ground slope will not increase hazard, ground slope shall be provided under outdoor thermal oil system components that utilize nonwelded mechanical connections to thermal oil circulation piping to divert oil spills to a safe location away from the thermal oil equipment or adjacent buildings.

A.15.10.3.6
For example, when the supports for the thermal oil equipment have fireproofing or automatic sprinkler protection of adequate design to keep structures from collapsing for the expected duration of the largest credible thermal oil spill fire, the hazard is not increased if ground sloping is not employed. In this case, the ground slope requirement can be waived on the basis of the performance-equivalent alternative design.

15.10.3.7*
Process control rooms, which are expected to be manned in an emergency, shall be separated from the thermal oil utilization equipment by 1-hour fire-rated construction.

A.15.10.3.7
An example of such a control room is the main forming line and press control room typically found in composite panel plants. Windows in the control room walls will also need to be listed with the same fire rating as the wall or be otherwise protected by automatic fire shutters or dedicated window sprinklers.

15.10.3.8
At least one path of egress from the control room shall be through an area not susceptible to a fire involving thermal oil.

15.10.4 Heaters.

15.10.4.1
Heaters operating at gauge pressures exceeding 103 kPa (15 psi) shall be designed and operated in conformance with the ASME *Boiler and Pressure Vessel Code*.

15.10.4.2*
Pressure relief devices, when provided, shall be piped to discharge oil or vapor to a safe location.

A.15.10.4.2
This requirement is commonly accomplished by piping the discharge outside or into a thermal oil storage tank.

15.10.4.3
Fire detection systems, fire extinguishing systems, or both for an internal heater fire shall be in accordance with Chapter 9.

15.10.5 Piping.

15.10.5.1 *
Piping shall be securely supported to maintain adequate clearance from combustible construction or other combustible materials.

A.15.10.5.1
Overhead routing of thermal oil piping in buildings should be minimized where practical. Options to overhead pipe runs in buildings include running piping underground, outside, or in floor trenches. Proper clearance from combustibles should be determined based on the maximum operating surface temperature of the pipe, taking into account any pipe insulation.

15.10.5.2*
Welded pipe connections shall be used throughout a thermal oil piping system.
A.15.10.5.2
See 15.10.1.1 for guidelines on determining the size of the largest credible thermal oil spill, as referred to in item (1) of the Exception, and commonly used methods for reducing it.

15.10.5.3
Bolted mechanical joints shall be permitted to be used at pumps, valves, and equipment connections where the following conditions are met:

(1) Mechanical joints are protected with a sprinkler system designed to control a fire involving the largest credible thermal oil spill.
(2) Mechanical joints are insulated and shielded to prevent a leak from becoming a spray fire, and the shielding has a drip hole at the low point to facilitate detection of leaking joints.

15.10.5.4*
Where necessary to reduce the largest credible thermal oil spill to an acceptable level, provisions shall be made to isolate the supply and return piping to and from utilization equipment.

A.15.10.5.4
For larger systems with higher pumping rates, isolation normally requires a thermal oil leak detection system, automatic-closing isolation or three-way valves on loop supply legs, check valves to prevent backflow through return legs, and so forth. Refer to 15.10.1.1 for guidelines on determining the size of the largest credible thermal oil spill and commonly used methods for reducing it.

15.10.5.5
Copper, cast iron, or plastic piping shall not be used.

15.10.5.6
For systems operating above gauge pressures of 103 kPa (15 psi), pipe materials and types shall be in accordance with ANSI/ASME B31.1, Power Piping, or ANSI/ASME B31.3, Chemical Plant and Petroleum Refinery Piping, as applicable.

15.10.5.7*
Piping that is routed through production areas where airborne wood particulate can collect on thermal oil piping shall be insulated to keep surface temperatures below the maximum permitted by 9.4.3.1.

A.15.10.5.7
Closed-cell, nonabsorbent insulation is preferred unless all piping and joints are welded. Fibrous or open-cell insulation can act as a wick and soak up leaking oil. The oil can then break down in the insulation and eventually autoignite. Dust accumulations should be routinely removed from all piping on a regular basis.

15.10.6 Expansion Tank.

15.10.6.1*
Where used as other than an atmospheric tank, expansion tanks shall be designed in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*.

**A.15.10.6.1**
These criteria should apply, even if the tank is operated as an atmospheric tank, as a safeguard against rupture from overpressurization due to overfilling the thermal oil system, inadvertent accumulation of water from condensation or processes, and so forth.

**15.10.6.2**
Expansion tanks that have a breather vent, overflow drain, or pressure relief valve shall have the discharge from these openings piped to a safe location.

**A.15.10.6.2**
This requirement is commonly accomplished by piping the vents and drains into a thermal oil storage tank or to a safe area outside.

**15.10.6.3**
When necessary to reduce the largest credible thermal oil spill to an acceptable level, the expansion tank shall be provided with a remotely operable drain line that allows the expansion tank to be drained to a safe location.

**A.15.10.6.3**
This requirement is best accomplished by draining the oil into a low-level storage tank. The drain line should be sized such that the majority of the oil will go to the drain tank rather than out a leak elsewhere in the system to accomplish the intent of limiting the size of a spill. Adequate breather vents should be provided, based on the maximum emptying or filling rates.

In some cases, it can be necessary to also have a remotely operable blocking valve or a three-way valve on the pipe connecting the expansion tank to the primary loop piping to quickly and completely isolate the expansion tank during an emergency drain. If this is done, vacuum relief should be provided to prevent collapse of any equipment as the oil reduces in volume as it cools. A simple way of doing this would be to drill a small hole in the blocking valve gate or ball as shown in Figure A.15.10.6.3(a) or provide a small-diameter bypass pipe as shown in Figure A.15.10.6.3(b).

**Figure A.15.10.6.3(a) Expansion Tank Isolation Using Drain and Blocking Valves.**
Figure A.15.10.6.3(b) Expansion Tank Isolation Using a Three-Way Valve.
15.10.6.4*
An automatic expansion tank refill system to maintain the thermal oil level in the expansion tank shall not be permitted.

A.15.10.6.4
A properly maintained thermal oil system should not have oil leaks significant enough to require an automatic oil makeup system. Also, an automatic oil refill system can defeat the purpose of some leak detection systems that monitor the oil level in the expansion tank as a means of detecting an oil leak.

15.10.6.5*
Expansion tanks on vaporizing systems or on nonvaporizing systems that heat the oil to within 50 degrees of its atmospheric boiling point shall be provided with an inert gas blanket in the expansion tank vapor space.

A.15.10.6.5
Nitrogen is the most commonly used inert gas. Nitrogen use will eliminate oxidation and oil degradation that occurs when the hot oil is in contact with air. It also prevents the possibility of an expansion tank
explosion should an ignition source find its way into the expansion tank. For these same reasons, inert gas blanketing is recommended for systems operating at lower pressures.

15.10.6.5.1
The inert gas blanket shall operate at a pressure between 103 kPa and 172 kPa (15 psi and 25 psi) above the vapor pressure of the heated oil.

15.10.6.5.2
A low-pressure interlock shall be provided that will shut off the heater fuel source if the inert gas pressure drops to less than 103 kPa (15 psi) above the hot oil vapor pressure.

15.10.7* Storage Tanks.
Both indoor and outdoor aboveground thermal oil storage tanks shall be constructed, located, and arranged in accordance with NFPA 30.

A.15.10.7
The appropriate methods for handling thermal oil depend on the temperature of the oil. When thermal oil is heated to temperatures above its flashpoint, it should be handled as a Class I flammable liquid. At intermediate temperatures, it could be appropriate to handle thermal oil as a Class II liquid. At normal ambient temperatures, many thermal oils are classified as Class IIIB combustible liquids. The oil manufacturer’s Material Safety Data Sheet should be referred to for flashpoint data.

15.10.8 Safety Controls and Interlocks.

15.10.8.1*
All thermal oil systems shall have emergency shutdown and isolation devices in accordance with 15.10.8.1.1 through 15.10.8.1.4.

A.15.10.8.1
Exception No. 1. Buildings that have dry pipe sprinkler systems can be prone to accidental tripping due to leaking air pressure. This can cause unnecessary shutdown of the thermal oil system. If a fire detection system were also provided, it could be used to actuate the thermal oil isolation interlocks instead of the sprinkler water flow. Trained operator response in accordance with Exception No. 3 is also an alternative to a sprinkler water flow interlock.

Exception No. 2. If, for example, a plant had a thermal oil heated dryer and a thermal oil heated press, high temperature or activation of a water spray system in the dryer would require stopping flow of thermal oil to the dryer, but the press could continue to operate if desired.

Exception No. 3. To meet this exception, operators should have direct visual observation of the affected area or remote visual observation via closed circuit television. Regular training sessions should be held to assure proper operator response, and an emergency shutdown switch should be located in proximity to all operators expected to fulfill the emergency shutdown function.
15.10.8.1.1
Systems that limit the largest credible thermal oil spill shall be interlocked to actuate when any one of the following conditions exist:

(1) Automatic sprinkler system water flow in any area containing thermal oil heaters, pumps, utilization equipment, or thermal oil piping that is not fully welded at all connecting joints
(2) Activation of a fire detection system in any area containing thermal oil heaters, pumps, utilization equipment, or thermal oil piping that is not fully welded at all connecting joints
(3) Activation of the thermal oil leak detection system

15.10.8.1.2
Where an area is equipped with both a fire detection system and an automatic sprinkler system, only one of these shall be required to activate the automatic shutdown and isolation.

15.10.8.1.3
Where an area equipped with fire detection, sprinkler water flow, or thermal oil loss can be positively identified by the arrangement and/or control system of the detection devices, only those automatic shutdown and isolation devices required to stop thermal oil flow into and out of the affected area shall be required to be interlocked for automatic actuation.

15.10.8.1.4
Where an area subject to a thermal oil spill is under constant observation by operators or personnel who are trained to respond and have access authority to manually activate the required thermal oil system shutdown and isolation, then automatic shutdown by sprinkler water flow shall not be required for that area.

15.10.8.2*
An accessible, manual, remote emergency shutoff switch shall be provided that is capable of safely shutting down and isolating the heat transfer system in the configuration required to limit the largest credible thermal oil spill.

A.15.10.8.2
Larger plants that have full process control monitoring and alarm annunciation in a constantly attended control room can provide this function in the control room. Other facilities could need one or more emergency shutdown switches more local to the equipment, but the location should not be so close that the switch could not be accessed in a fire emergency.

15.10.9 Fuel Burner Controls and Interlocks.

15.10.9.1
Oil or gas-fired heaters shall be designed and installed in accordance with the applicable requirements of NFPA 85.
15.10.9.2
Wood dust suspension burners shall be designed and installed in accordance with the applicable requirements of NFPA 85.

15.10.9.3*
Heaters that burn wood waste in a fluidized bed or on a grate shall provide a means to prevent the accumulation of explosive concentrations of combustibles in the heater or in any stack gas utilization equipment, following a shutdown with unburned fuel in the heater.

A.15.10.9.3
Fluidized bed burners and burners that combust wood waste on a grate contain a quantity of unburned fuel during normal operation. They cannot be instantly shut off like a conventional gas, oil, or pulverized fuel suspension burner. During any emergency stop or other shutdown that does not fully combust the bed of fuel, or when thermal oil is leaking into the combustion chamber, combustibles (mostly carbon monoxide with small amounts of hydrogen) will be generated due to the latent heat in the fire box and lack of enough air for complete combustion.

Heaters that exhaust directly into a stack can usually prevent the accumulation of explosive concentrations of combustibles by natural draft means. Some facilities recover additional heat from the thermal oil heater stack gas by ducting the burner exhaust into other utilization equipment. Natural draft is unreliable in these instances, and other means, such as continued operation of the Induced Draft (ID) fan at minimum speed, automatic-opening emergency vents on the burner exhaust duct, isolation dampers, or inert gas blanketing systems should be used to prevent buildup of explosive concentrations of combustibles.

Solid fueled burners should be designed per the requirements listed below.

Electrical Classification
The area electrical classification can be general purpose for the handling of Class II or Class III liquids. Consideration should be used in locating electrical devices for ease of access and routine maintenance.

Safety System Features
The thermal oil system should be interlocked to isolate major piping segments in the event of a fire or emergency shutdown to limit the largest credible thermal oil spill. The thermal oil system should be interlocked to actuate in a fail-safe manner. The following should be arranged to actuate:

(1) The supply of heat to the thermal oil system should be shut down (ID fan or fuel supply for gas or suspension burner).
(2) Safety shutoff valves, bypass valves, and or three-way divert valves of fail-safe design should be actuated to isolate all secondary circulating loops from the primary loop.

An accessible, manual, remote emergency shutoff (zone stop) should be provided that is capable of safely
shutting down and isolating the heat transfer system in the configuration required to limit the largest credible thermal oil spill. Larger plants that have full process control monitoring and alarm annunciation in a constantly attended control room can provide this function in the control room.

Measuring instrumentation and interlocks should be provided to sound an alarm and automatically shut down the fuel source to the thermal oil heater when any of the safety conditions are detected.

Alarm set point levels should be below or above the auto emergency shutdown levels to monitor the variables and provide an opportunity for operators to correct the problem before conditions reach an emergency shutdown level.

Validation of data should be implemented in the control system to ensure data integrity of all communications and Input/Output (I/O). This validation of input data or communications should use recognized programming method and should include, but not be limited to:

1. Rack failure
2. Communication loss to remote I/O racks
3. Rack power supply failure
4. I/O card failure
5. Network communication loss
6. Network switch failure
7. Loss of communications
8. Device cable short wire/open wire
9. Underrange/Overrange values
10. External power supply failure

On failure of any of the above validations the logic should force a trip value into the input data tables for the affected device(s).

The system would then shut down as if a trip condition occurred.

Access to programmed safety logic (if used) should be restricted to prevent accidental changes. No forces or jumpers should be applied to any Programmable Logic Controller (PLC) or hardwired safety thermal oil controlled systems.

**Safety System Design**

Safety system design should take into consideration, but not be limited to, the following criteria:

1. Manufacture of hardware and PLC (Platform)
2. Reliability of instrumentation and devices
3. Safety device identification
4. Validation of information
5. Access requirements
6. Maintenance and testing
(7) Segregation of equipment

**Safety Interlocks**

The thermal oil system should have the following interlocks, which should be programmed or wired for fail-safe application:

1. Low thermal oil flow (analog)
2. High thermal oil temperature at heater outlet (analog or thermocouple)
3. Expansion tank level for low detection (analog)
4. Fire zone water flow (discrete)
5. High oil differential pressure (analog) *(under evaluation)*
6. High temperature at heater inlet (analog or thermocouple)
7. Form of system leak detection (optional if rate of change is programmed using expansion tank level)
8. Fill and drain tank level (analog)
9. Expansion tank temperature (analog)
10. Flue gas temperature (analog)
11. Thermal oil pumps seal leak detection (discrete)
12. Emergency cooling water make-up detection (discrete)

**Definitions of Emergency Shutdown/Trip, Alarm, and Warning**

*Emergency Shutdown/Trip.* System is shut down; solid red visual indication; condition must be cleared, and system restarted.

*Alarm.* Requires operator intervention, PLC can impose some control functionality to mitigate reaching emergency shutdown condition; flashing red visual indication.

Condition can be acknowledged; if condition is not cleared, the indication will be reactivated.

*Warning.* Indication to operator; can be acknowledged.

**Mandatory Safety Interlocks**

All trips should be instantaneous and fail-safe conditioned. The following percentages are estimated nominal targets based on normal operating conditions. All conditions, including start-up, cooldown, and mill specifics, need to be taken into consideration for final set points.

*Thermal Oil Flow*

Trip: Set at 80 percent of design flow

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling
Alarm: Set at 95 percent of design flow
Actions: Disable heat modulation and limit all devices producing heat to minimum.

*High Heater Outlet Oil Temperature*

Trip: Set at 110 percent of design temperature not to exceed 274°C (525°F)
Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling
Alarm: Set at 105 percent of temperature
Actions: Disable heat modulation and limit all devices producing heat to minimum.

*Thermal Oil Expansion Low Tank Level*

Trip: Set at 25 percent of tank capacity
Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling
Alarm: Set at 35 percent of tank capacity
Actions: Disable heat modulation and limit all devices producing heat to minimum.

*Fire Zone Water Flow*

Trip: Discrete input from measurement devices
Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling
Alarm: Same as above

*High Oil Differential Pressure*

Trip: Set at *(under evaluation)* of design or normal pressure
Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling
Alarm: Set at *(under evaluation)* of design flow
Actions: Disable heat modulation and limit all devices producing heat to minimum.
High Heater Inlet Oil Temperature

Trip: Set at 110 percent of design temperature not to exceed 274°C (525°F)

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 105 percent of temperature

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Leak Detection Rate of Change

Trip: Set at 110 percent of normal expansion rate

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 105 percent of normal expansion rate

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Emergency Shutdown (Zone Stop)

Trip: Set on activation of stop

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Fill and Drain Tank Level

Trip: Set at 90 percent of tank design level

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 85 percent of tank design level

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Expansion Tank Temperature

Trip: Set at 110 percent of normal tank operating temperature

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 100 percent of normal tank operating temperature
Actions: Disable heat modulation and limit all devices producing heat to minimum.

Flue Gas Temperature

Trip: Set at 115 percent of normal operating temperature

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 110 percent of normal operating temperature

Actions: Visual alarm indication cannot be reset until condition is cleared.

Circulation Pump Seal Leak

Alarm: Set on detection leak

Actions: Visual alarm indication cannot be reset until condition is cleared.

Emergency Cooling Makeup Water

Warning: Set on detection of water flow

Actions: Warning indication.

Annunciation, Display, and Reset of Emergency Shutdown/Trips, Alarms, and Warnings

Emergency shutdown/trips, alarms and warnings should be clearly displayed to the operator as described below. Each event should be accompanied by an audible/visual event suitable for the environment and be capable of 10 dB above normal ambient noise. The reset pushbutton(s) should be wired to the PLC for resetting of the mandatory alarms as specified above, “Definitions of Emergency Shutdown/Trip, Alarm, and Warning.”

1. Emergency Shutdown/Trips
   a. The operator should be alerted to the trip in the current HMI display.
   b. A separate light indication (solid red) should be located in “proximity” to the primary pump room area and inside the main operator console room.
   c. The operator should be able to acknowledge the audible/visual event; however the condition must be cleared before the system can be reset and the system restarted.

2. Alarms
   a. The operator should be alerted to the alarm in the current HMI display.
   b. A separate light indication (flashing red) should be located in “proximity” to the primary pump room area and inside the main operator console room.
(c) The operator should be able to acknowledge this audible alert; however, all alarms (as described above, “Definitions of Emergency Shutdown/Trip, Alarm, and Warning”) should only be reset by pressing local reset pushbuttons, located close to the equipment (primary room; secondary room; heater area). The alert should reappear after a reasonable time, if the condition still exists.

(3) Warnings
(a) The operator should be alerted to the warning in the current HMI display.
(b) The operator should be able to acknowledge the alert via normal actions.

Recording and Logging of Data

Data pertaining to the operation of the thermal oil system should be logged in order to evaluate normal and abnormal operation and performance of the system. The following items constitute the minimum data points required for capture:

(1) Thermal oil flow
(2) Primary pump start and stop time
(3) Heater outlet oil temperature
(4) Primary pump faults
(5) Thermal oil expansion tank level
(6) Secondary pump start and stop time
(7) Heater outlet oil pressure
(8) Secondary pump faults
(9) Heater inlet oil temperature
(10) Isolation valve positions
(11) Thermal oil expansion tank level rate of change
(12) Fixed burner system fuel output (gas or suspension burners)
(13) Heater outlet air temperature
(14) All emergency shutdown/trip and alarm conditions
(15) Primary pump amps bypass valve positions
(16) Secondary system temperatures (all available)
(17) Thermal oil fan start and stop time (for bark burner installations)
(18) Fire protection zone flow switch actuation
(19) Thermal oil fan faults (for bark burner installations)
(20) Flue gas temperature
(21) Alarm reset pushbuttons

All data associated with the above system variables should be captured by Industrial SQL and stored in the facility’s manufacturing server.

15.10.9.4*
If stack gas from the thermal oil heater is recovered to provide auxiliary base load heat for other equipment (e.g., rotary dryers), a means shall be provided to ensure that all equipment is properly purged prior to an attempt being made to ignite a burner on any of the interconnected equipment.
A.15.10.9.4
This is commonly done using suitable dampers, isolation gates, waste stacks, and/or burner control logic. The control logic should anticipate all possible operating modes of burners on individual pieces of equipment, whether operating singly or together, to ensure safe startup and shutdown under normal or upset conditions.

15.10.9.4.1
Temperature and pressure monitoring shall be required for dryer exhaust recirculation into the thermal oil heater.

15.10.9.4.2
Temperature and pressure monitoring shall be required for flue gas recycling into the thermal oil heater.

15.10.9.5
Where solid fuel central energy systems provide hot air stream to more than one user, one of which is a thermal oil heating system, they shall be permitted to be designed to reduce the hot air stream feeding the thermal oil heating system, without the need to shut down the fuel source.

15.10.9.6*
Instrumentation and interlocks shall be provided to sound an alarm and automatically shut off the fuel source or the heat source to the thermal oil heater when any of the following conditions are detected:

1. Low thermal oil flow or pressure at the heater outlet
2. High thermal oil temperature or pressure at the heater outlet
3. Low oil level in expansion tank and, if provided, any other signal indicating loss of thermal oil from the system
4. Low liquid thermal oil level in heater (vaporizing systems only)
5. Activation of a fire detection system, extinguishing system, or both, for the heater heat exchanger, if provided

A.15.10.9.6
An alarm set point should be provided at detection levels earlier than the auto-shutoff levels so as to monitor the variables in 15.10.9.6 and provide an opportunity for operators to correct the problem before conditions reach an unsafe level.

15.10.10 Operational Considerations.

15.10.10.1
Any and all system leaks that are discovered shall be promptly corrected with permanent repairs, regardless of the size of the leak.

15.10.10.2
Any spilled oil shall be cleaned up promptly.
15.10.10.3
Any pipe or equipment insulation that is discovered to be oil-soaked shall be promptly removed and replaced with clean, oil-free insulation.

15.10.10.4*
If it is suspected that the material being heated is infiltrating into the thermal oil loop, the system shall be immediately shut down to find and repair the leakage.

A.15.10.10.4
One major concern in this regard is where thermal oil is used to heat water, such as in log thaw vats common to oriented strand board plants or in steam generators. Water in the thermal oil piping will flash to steam when heated and can cause overflow of the expansion tank or overpressurization in closed systems.

15.10.10.5*
Operators shall be trained at least annually in proper operation of the thermal oil system, including recognition and proper response to upset conditions that could lead to dangerous situations.

A.15.10.10.5
Typical dangerous scenarios should include all the alarm conditions that result in heater shutdown and isolation of piping and equipment, especially those involving a fire in the area and actions necessary to confirm or stop flow of leaking oil.

15.10.10.6
Safety interlocks shall be inspected, tested, and calibrated at least annually to keep them in proper operating condition.

15.10.10.7*
The physical properties of the thermal oil shall be tested and documented annually, with replacement of all oil in the system when recommended by the oil manufacturer.

A.15.10.10.7
With extended exposure to elevated temperatures and/or air in expansion tanks, thermal oils undergo degradation, which can include oxidation and cracking. This degradation can change oil viscosity, heat transfer properties, flash point, and so forth, making the oil unsuitable for continued service.

15.10.11* Fire Protection.

A.15.10.11
Due to a loss history showing that thermal oil fires can be very severe and long lasting, it is highly recommended that automatic sprinkler protection be provided throughout all building areas potentially exposed to a thermal oil spill fire.
15.10.11.1
Automatic sprinkler protection meeting the requirements of NFPA 13 for Extra Hazard Group 1 occupancies shall be provided for building areas containing heat transfer system heaters, vaporizers, equipment using thermal oil, plenums, or any other areas where a hot oil spill could accumulate.

15.10.11.2*
Heaters shall be provided with a means to detect and automatically extinguish a thermal oil spill fire in the fire box or heat exchanger section where spilled oil would collect unless the system complies with one of the following:

1. Systems contain less than 7571 L (2000 gal) of thermal oil, subject to a risk analysis that is acceptable to the authority having jurisdiction.
2. Heaters have a fire detection system interlocked to physically isolate the heater from the external thermal oil piping.
3. Instrumentation is present to alert operators of an oil fire in the heater and operators constantly monitor conditions in the heater and are trained to actuate a manual extinguishing system.

A.15.10.11.2
A common design for an extinguishing system utilizes a water spray injection system designed on the assumption that all water injected will flash to steam and that the resultant flow of steam will equate to 128 kg (8 lb) per minute per 2.8 m³ (100 ft³) of heater or heat exchanger volume. Some thermal oil heater vendors will supply this kind of extinguishing system as a factory option.

When this option is used, prior to water being injected, the heater forced draft fan damper should be closed and the induced draft fan damper moved to the full-open position. This damper arrangement minimizes natural draft airflow through the heater and could deplete the steam concentration and supply air to the fire while simultaneously providing a path for pressure relief from the rapid volume expansion that occurs when the water mist flashes to steam.

Once temperatures are sufficiently reduced in the heater and the fire is extinguished, the water will no longer flash to steam and can collect in the heater enclosure low points. An allowance for draining water and/or unburned thermal oil to a suitable drainage location should be considered.

Inert gas extinguishing systems (e.g., CO₂ or nitrogen) are sometimes used. Although these systems can rapidly extinguish a fire if the concentration can be established and held, they have very little cooling ability. Hot refractory and internal heater surfaces can remain above the autoignition temperature of the thermal oil for many hours. It is critical that the inert gas supply be able to maintain the required extinguishing concentration long enough for the heater’s internal surfaces to cool below the thermal oil autoignition temperature, or reignition will occur.

Automatic operation is preferred. One common way of implementing this is with a high/high temperature alarm (i.e., the first high temperature alarm alerts operators of a malfunction, and a second higher temperature alarm actuates the extinguishing system if operator intervention does not correct the high
temperature condition). Another method uses two independent signals to trip the extinguishing system (e.g., a signal indicating loss of thermal oil combined with another signal indicating high temperature or high combustibles in the heater exhaust).

15.10.11.3*
Activation of a heater fire extinguishing system shall automatically stop the primary thermal oil circulation pumps unless the system complies with both of the following:

(1) The heater contains a bed of wood waste fuel or the refractory inside the heater can retain enough heat to cause thermal oil breakdown and tube fouling if fluid circulation through the unit is stopped.
(2) The primary loop system has an emergency bypass with an oil cooling heat exchanger to rapidly reduce oil temperature.

A.15.10.11.3
Some heaters have auxiliary, diesel-driven standby thermal oil circulation pumps that automatically start if the oil pressure is abnormally low, such as from pump failure or power outage. These standby pumps will also need to be disabled to keep them from automatically starting when the primary pumps shut down, unless they are part of the oil circulation system permitted in the exception.

15.11 Storage.

15.11.1 General.
Except as modified in this chapter, storage shall be in accordance with NFPA 13.

15.11.1.1 Dry Lumber.
Where protected, indoor storage of lumber, panelboard, stuck lumber, dense pack lumber, and veneer shall be protected in the same manner as a Class II commodity in accordance with NFPA 13.

15.11.1.2 Green Lumber.
Where the moisture content is greater than or equal to 25 percent (wet basis), the stored materials shall be protected in the same manner as a Class I commodity in accordance with NFPA 13.

15.11.1.3 Flammable Liquid Storage.
Design protection for bulk and container storage shall be in accordance with NFPA 30.

15.11.2 Indoor Dry, Fine Particulate Storage.

15.11.2.1*
Damage-limiting construction to relieve to a safe area shall be used for buildings storing dry, fine particulates where a deflagration hazard exists.

A.15.11.2.1
A detached building for storage is preferred. Venting should be designed in accordance with NFPA 68 and
additional guidance can be found in FM 7-76, Prevention & Mitigation of Combustible Dust Explosions and Fires. Conventional lightweight, pre-engineered metal panels on steel frame buildings will meet the intent of this recommendation.

15.11.2.2
Construction shall minimize horizontal ledges where dust can accumulate.

15.11.2.3*
Where provided, sprinkler piping shall be protected against explosion damage.

A.15.11.2.3
Refer to paragraph 2.4.3 of FM 7-14, Fire Protection for Chemical Plants.

15.11.2.4
Any areas storing dry wood particulate shall have Class II, Division 1 electrical equipment.

15.11.2.5
Detached buildings that store only green wood particulate shall be permitted to have electrical equipment suitable for Class II, Division I; or Class II, Division 2 hazardous areas in accordance with Article 500 of NFPA 70.

15.11.2.6
Powered front-end loaders used for material reclaim shall comply with 9.4.4.

15.11.3 Wood Scrap or Wood Waste Processing and Disposal.

15.11.3.1
Section 15.11.3 shall apply to the processing and disposal of wood scrap or wood waste for fuel and other purposes.

15.11.3.2
If scrap or waste wood is to be processed by hogs delivering small chips and shredded product, the discharge from such processing shall comply with the requirements in Chapter 9 for dust-collecting systems.

15.11.3.3
Metal detectors interlocked to shut down the flow of material or magnetic separators shall be installed upstream of wood hogs and chippers.

15.11.3.4
Wood scrap or wood waste processed by mills delivering a pulverized product shall comply with the requirements of 15.9.4.10.
15.11.3.5
Boilers, furnaces, and thermal oil heating systems using wood scrap or wood waste as fuel shall comply with the applicable sections of NFPA 85.

15.11.3.6
Where wood scrap or wood waste is disposed of in an incinerator, the incinerator shall be in accordance with the requirements of NFPA 82.

15.12 Special Considerations. (Reserved)
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.

[Material is following the section to which it applies.]
Annex B  Dust Hazards Analysis — Example (CMD-FUN)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Introduction.

This annex is intended to illustrate one example of how to develop a DHA for a facility. Other methods include, but are not limited to, “what-if” analysis, failure mode and effects analysis, fault tree analysis, and HAZOP. Additional guidance on performing a DHA is available in the NFPA Guide to Combustible Dusts and in the AIChE Guidelines for Hazard Evaluation Procedures. It is not the intent of this standard to require users to apply the PHA provisions of OSHA regulations in 29 CFR 1910.119, “Process Safety Management of Highly Hazardous Chemicals,” in developing a DHA. The example is intentionally vague to allow users to match the complexity and extent of the analysis to the complexity and extent of the facility and its process.

B.2 Purpose.

The purpose of a DHA is to identify hazards in the process and document how those hazards are being managed. The hazards addressed by this standard are the fire, deflagration, and explosion hazards of combustible dusts. There might be other hazards associated with a process such as industrial hygiene that are not covered in this annex. However, the process of analysis outlined in this annex could be applied to other hazards.

B.3 Overview.

B.3.1

A DHA is a detailed analysis and documentation of the process and the facility housing the process.

B.3.2

Each part of the process system is considered for potential deflagration hazard.

B.3.2.1

Where the hazard is managed, the means by which it is being managed is documented.

B.3.2.2

Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.3

Each building or building compartment is considered for potential deflagration hazard.

B.3.3.1
Where the hazard is managed, the means by which it is being managed is documented.

B.3.3.2

Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.4

The potential for a dust deflagration should be based upon the potential for all four necessary and sufficient conditions for a deflagration to exist at the point of consideration concurrently.

B.3.4.1

The conditions for a deflagration are as follows:

1. Particulate of a dimension small enough to propagate a deflagration flame front
2. Means of suspending or dispersing the particulate in air or other oxidizing atmosphere
3. Sufficient quantity of particulate to achieve the minimum explosible concentration
4. Competent source of ignition

B.3.4.2

As a general rule in NFPA standards, there is an assumption that ignition will occur. However, some situations of ignition source control could be determined acceptable by taking into account the consequences (i.e., risk analysis). If a deflagration is possible, the results should be managed in such a way that the objectives of the standard are met.

B.3.4.3

The DHA should classify locations into three general categories:

1. Not a hazard
2. Might be a hazard
3. Deflagration hazard

This will help the owner/operator prioritize management of the hazards. Additionally, it will identify the locations where more information is necessary before a definitive determination can be made.

B.3.4.4

The individual assessments in the DHA are brought into a cohesive understanding of the hazards associated with the overall operations as well as the individual components.

B.3.4.5
A well-documented risk assessment that is acceptable to the authorities having jurisdiction can be used to supplement the DHA to determine what protection measures are to be used.

**B.4 Sample DHA.**

**B.4.1**

This example is intended to provide the user with some of the deliberation that can be used in performing a DHA. It is not intended to cover all the methods, situations, and processes that might be encountered in facilities that handle combustible particulate solids. In particular, it does not account for fire hazards that are independent of deflagration hazards. Refer to Figure B.4.1 for the process used in this example.

**Figure B.4.1 An Example Process. (Source: J. M. Cholin Consultants, Inc.)**

**B.4.2**

This process receives wood chips via rail car and over the road trailer truck. The wood chips come from hogging (grinding) operations at other facilities. The chips are unloaded and conveyed pneumatically to a storage silo. From the storage silo the chips are conveyed via screw conveyor to a size reduction mill. The mill discharges particulate to a transport fan, which sends the particulate to a set of screens. The material that is sufficiently fine passes through the screens and proceeds via the product screw to some other location. The particles that exceed the size specification are sent back through the mill.

**B.4.3**

Dust collection is provided for this process. The dust collection system receives the exhaust from the cyclone, ullage space of the silo, out-feed screw conveyor, screens, and the product screw conveyor. The cleaned air is returned to the building interior.

**B.4.4**

Each and every process component should be evaluated, including ducts, conveyors, silos, bunkers, vessels, fans, and other pieces of process equipment. Each point along the process should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed
is then determined. Usually the relevant occupancy standard will provide options. The process and process equipment will often determine which option is most appropriate.

**B.4.5**

Each of the following points in the process in which a deflagration could occur is identified:

1. Each duct
2. Each conveyor
3. Each silo, bunker, or other vessel
4. Each fan
5. Each piece of process equipment

Usually a volume exemption of 8 ft³ (0.2 m³) or less is applied to enclosed pieces of process equipment in deflagration hazard management. This exemption comes from the difficulty in designing deflagration suppression for vessels that small, as well as the modest hazard such small vessels represent. Assuming an 8-to-1 volumetric expansion from a dust deflagration, an 8 ft³ (0.2 m³) enclosure will yield a fireball volume of approximately 64 ft³ (1.8 m³), the volume of a sphere with a 10 ft (3 m) diameter. This is the estimated maximum extent of the fireball volume. This fact can be used to select the parts of the process system to be considered in the analysis. If a piece of process equipment includes a volume less than 8 ft³ (0.2 m³), it should be documented as such in the DHA.

The DHA also considers the building compartment(s) where combustible particulates are being handled or processed. These compartments should be evaluated for both deflagration hazard and building rupture and collapse (explosion) hazard. *(See Figure B.4.5.)*

**Figure B.4.5 An Example Process. (Source: J. M. Cholin Consultants, Inc.)*
B.4.5.1 Location 1: Offload Duct to Offload Fan.

B.4.5.1.1

Is the particulate deflagrable (explosible)? The ability to propagate a deflagration flame front is the artifact of material chemistry – how much heat is released per unit of mass when it burns – and particle size. What are the deflagration metrics for this material? Has the material been tested for MEC, MIE, $K_s$, and $P_{max}$? Depending upon the material, other data might be necessary.

Currently, ASTM E1226, Standard Test Method for Explosibility of Dust Clouds, includes a screening test to determine if the particulate is capable of propagating a deflagration. However, the average particle size is often used as a first order estimate. Some standards use a nominal average particle size of 500 μm as the dividing line. Wood hogs generally have screens that produce particulates between 0.25 in. (6.4 mm) and 1.00 in. (25.4 mm) in largest particle dimension. This is substantially greater than 500 μm. While the particulate is all mixed together, it is probably not deflagrable (explosible). So, for this example the answer is no. But if the particulate is allowed to separate on the basis of size, the “fines” content will probably change the conclusion.

While sieve analysis cannot be relied upon as the sole hazard identification means, it is useful for informing the analysis. There isn’t yet reported research that serves as a basis for establishing a percentage of fine particulate versus coarse particulate sufficient to propagate a flame front.

B.4.5.1.2

Is the particulate suspended in air? Since a fan is used to suck this material through a duct the answer is yes.

B.4.5.1.3
Is there sufficient concentration to propagate a flame front? At this point in the process, a sieve analysis of the process stream could provide some additional information. If the dust concentration exceeds the MEC of the dust, then there is the potential for flame propagation. However, large particles are quenching surfaces and inhibit flame propagation. In the mixture used in this example it is not likely.

**B.4.5.1.4**

Are there competent igniters available? Yes. The material could have been ignited as it was loaded into the railcar or truck trailer. (This has happened.) Tramp metal could be present in the particulate that can strike sparks as it hits the wall of the duct.

**B.4.5.1.5**

What hazard management is in place? Is there metal detection, spark detection, bonding and grounding, or other hazard management means in place?

**B.4.5.2 Location 2: Offload Fan.**

**B.4.5.2.1**

Is the particulate deflagrable (explosible)? See B.4.5.1.1.

**B.4.5.2.2**

Is the particulate suspended in air? Yes. See B.4.5.1.2.

**B.4.5.2.3**

Is there sufficient concentration to propagate a flame front? Maybe. See B.4.5.1.3.

**B.4.5.2.4**

Are there competent igniters available? Yes. In addition to the igniters identified in B.4.5.1.4, a number of ignition mechanisms are introduced by the fan, including the following examples:

1. Overheated drive bearings (especially the inboard bearing) due to bearing failure from lack of proper lubrication, fatigue, wear, etc.
2. Fan impeller/wheel imbalance caused by material accumulation on the blades, bearing failure, wear, etc. (which can result in sparking by housing contact)

**B.4.5.2.5**

What hazard management is in place? (See B.4.5.1.5.) Other hazard management methods would include vibration monitoring (either by personnel on a regular basis or by a monitoring device), temperature monitoring of the drive bearings (by personnel or monitoring device) and amperage monitoring of the drive motor (generally, for a properly operating fan, amperage is directly related to the air mass flow — the higher the amperage, the more air mass flow).

**B.4.5.3 Location 3: Duct from Fan to Cyclone.**
B.4.5.3.1

Is the particulate deflagrable (explosible)? (See B.4.5.1.1.) However, the fan will cause particle attrition, increasing the relative concentration of fine particulate in the mixture. How much it is increased is not known unless a sieve analysis is conducted comparing material before and after the fan.

B.4.5.3.2

Is the particulate suspended in air? Yes. (See B.4.5.1.2.)

B.4.5.3.3

Is there sufficient concentration to propagate a flame front? Maybe. (See B.4.5.1.3, but with the caveat that fan-produced particle attrition will increase the fines content.)

B.4.5.3.4

Are there competent igniters available? Yes. In addition to those from the infeed duct, there are those from the fan. Often a spark detection and extinguishment system is used to detect and quench sparks and burning material before they get to locations where they could serve as ignition sources for a dust deflagration.

B.4.5.3.5

What hazard management is in place? Is there spark detection and extinguishment? Is there metal detection?

B.4.5.4 Location 4: Cyclone.

Cyclones are designed to use particulate inertia to separate the particulate from the conveyance air. Deflagrations can occur in cyclones. Cyclones intentionally concentrate particulate near the perimeter of the cyclone. Cyclones also cause the large particles to separate from the fine material. Both of these factors increase the likelihood that a portion of the volume within the cyclone will have conditions sufficient for a deflagration. (See Figure B.4.5.4.)

Figure B.4.5.4 The Operating Cyclone in Cross-Section. (Source: J. M. Cholin Consultants, Inc.)
B.4.5.4.1

Is the particulate deflagrable (explosible)? If there are any fines in the process particulate they will be separated, at least partially, from the larger particulates and concentrated by the cyclone. Because the fan creates fines and there is particle attrition as particulate goes rattling up the duct, the likely conclusion is yes.

B.4.5.4.2

Is the particulate suspended in air? Yes.

B.4.5.4.3

Is there sufficient concentration to propagate a flame front? Probably, and that translates to a yes. This depends on the quantity of fine, deflagrable (explosible) particulate per unit of mass of total particulate moved and the volume of air to move it. Calculations should be performed to determine if there is sufficient fine material per unit of air volume under the range of operating conditions to achieve a concentration of deflagrable particulate in excess of the MEC and render the cyclone an explosion hazard.

B.4.5.4.4

Are there competent igniters available? Yes. All of the ignition sources identified in the earlier portions of the system will be sending the ignited particulate to the cyclone. Therefore, there is no alternative but to consider the cyclone an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.4.5

What hazard management is in place? The cyclone should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device.
If the system is shut down and there is burning material in the hopper section (base) of the cyclone, how is that managed? Most explosions result from deflagrations that are initiated by ongoing fires. Is there any fire detection in place? What is the plan if a fire is detected? (Dumping burning material into a silo is not an option.)

**B.4.5.5 Location 5: Storage Silo.**

Every storage vessel is a particle size separator. When a mixture of material is dumped into a silo, bin, bunker, and so forth, the large particulate falls rapidly to the bottom of the vessel while the fines are lifted up by the air being displaced by the large particulate. This creates a cloud of fine dust in the ullage space, above the settled material. If any burning material or matter at a temperature above the auto-ignition temperature of the fine dust passes through this cloud, a deflagration is likely to result. *(See Figure B.4.5.5.)*

**Figure B.4.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard. *(Courtesy: J.M. Cholin Consultants, Inc.)*

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**B.4.5.5.1**

Is the particulate deflagrable (explosible)? Yes. The fines have separated from the coarse material and are suspended in a cloud in the ullage space.

**B.4.5.5.2**

Is the particulate suspended in air? Yes. The large particulate falls faster than the fines due to its lower Reynolds Number. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

**B.4.5.5.3**
Is there sufficient concentration to propagate a flame front? Eventually, yes. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

B.4.5.5.4

Are there competent igniters available? Yes. All the ignition sources identified in the earlier portions of the system send the ignited particulate through the cyclone and on to the silo. The rotary air lock at the base of the cyclone hopper section can also be an ignition source in some cases where tramp metal has been introduced in the process stream. Therefore, there is no alternative but to consider the silo an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.5.5

What hazard management is in place? The silo should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device. It is also likely that the mass of material in the bottom of the silo will serve as isolation.

B.4.5.6 Location 7: The Outfeed Screw Conveyor.

B.4.5.6.1

Is the particulate deflagrable (explosible)? The material moving through this conveyor is a mixture of the large chips and the fine dust that eventually settled from the ullage space. So, there is a deflagrable (explosible) fraction included in the coarse material. The question is whether that fine fraction can become suspended.

B.4.5.6.2

Is the particulate suspended in air? It depends on the screw conveyor. Usually materials only fill the bottom half of a screw conveyor. There are exceptions. If the screw conveyor is rotating slowly, the rotation of the flight does not lift the fine material and put it into air suspension in the upper half of the conveyor interior. If the screw conveyor is operating at a high speed, then the rotation of the flight will suspend material above the central axis of the screw and produce a dust suspension within the screw conveyor. We have to assume this is the case unless we can prove otherwise. Generally, edge of the conveyor flight will attain speeds of 16.5 ft/sec (5 m/sec) to achieve a sustained dust cloud. (This number is half the minimum air entrainment value reported for glass microspheres in Ural, “Towards Estimating Entrainment Fraction for Dust Layers.” See also NFPA 68.)

B.4.5.6.3

Is there sufficient concentration to support a deflagration? The fine dust is remixed with the coarse material so the concentration is a function of the percentage of the material that is the fine
fraction and the air volume in the screw conveyor. If this concentration can exceed 25 percent of the MEC, then one can assume that there is sufficient concentration to propagate a deflagration.

**B.4.5.6.4**

Are there competent igniters available? Yes. It is quite possible that burning material was loaded into the silo; wood particulates are notorious for sustaining a smoldering combustion process for extended periods of time. Furthermore, the screw conveyor has bearings. Many screw conveyors have hanger bearings that are in the material stream and are potential ignition sources. Consequently, it is very likely that if the speed of the screw is sufficient, the screw conveyor will be designated as a deflagration hazard and explosion management provisions will be necessary.

**B.4.5.6.5**

What hazard management is in place? Deflagration suppression and isolation is generally needed on high-speed screws. However, it might be possible to manage the hazard by replacing the screw with one that has a larger diameter but operates too slowly to produce a dust suspension. Sometimes changing the process or process equipment can reduce or eliminate the hazard, and that might be the best strategy.

**B.4.5.7 Location 8: The Mill and Discharge Fan.**

Most mills in this kind of process require air flow through the mill as part of the milling process. This is typically provided by a fan package (positive or negative pressure, depending upon type of system), which can be integral to the mill or a separate device.

**B.4.5.7.1**

Is the particulate deflagrable (explosible)? It depends. What is the target product particle size? If the mill has \( \frac{1}{4} \) in. (6.35 mm) screens, then the unit is receiving large particles and making them less large, but they’re still too large to be considered a deflagrable (explosible) particulate. If the mill is reducing the particulate down to a fine powder, then the particulate would probably be considered deflagrable (explosible). Determination of whether the particulate in the mill is typically deflagrable is based on the range of particle size exiting the mill. It is usually necessary to submit this material for a go/no-go screening test to determine if the mixture exiting the mill is capable of propagating a deflagration flame front. However, there is a potential that the concentration of fines inside the mill might be higher than the concentration in the product stream due to recirculation within the mill.

**B.4.5.7.2**

Is the particulate suspended in air? Yes. Inside the mill and its associated fan, the particulate is in continuous air suspension.

**B.4.5.7.3**

Is there sufficient concentration to support deflagration? Because most mills produce fines during the milling process (due to remilling, turbulence, accumulations on internal surfaces,
wear, etc.) and it is difficult to be assured that the fines concentrations do not exceed the MEC, it is best to assume sufficient combustible dusts are present. However, some low-speed mills (e.g., shredders) designed to produce only large particles might allow a determination from a sieve analysis and/or testing. Remember that while a sieve analysis is not a definitive criterion for identifying whether a particulate is deflagrable (explosible), it is a very valuable tool for identifying changes that have occurred in the process that signify a change in the hazard associated with the particulate. It is a management of change and safety assessment audit tool.

B.4.5.7.4

Are there competent igniters available? Most mills are capable of igniting the material being milled. If tramp metal gets into the process stream, there is a potential for ignition. Integral or external fan packages also represent additional hazards similar to the fan described in B.4.5.2.4.

B.4.5.7.5

What hazard management is in place? Are there magnetic separators or traps on the infeed to the mill? Is there deflagration suppression and isolation on the mill? Even if the mill is designed to be strong enough to withstand a deflagration within (many are), the deflagration flame front will exit the mill via the infeed and outfeed. What provisions are in place to isolate the mill from the rest of the process? In addition, any integral or external (in-line) fan package would require management such as that discussed in B.4.5.2.5.

B.4.5.8 Location 9: The Mill Discharge Duct to Screens.

B.4.5.8.1

Is the particulate deflagrable (explosible)? (See B.4.5.7.1.) If the material is deflagrable this duct can pose a significant hazard.

B.4.5.8.2

Is the particulate suspended in air? Yes. It is a pneumatic conveying duct — but what kind? If it is a dilute-phase conveying duct, then the material is suspended in air and the level of concentration becomes an important issue. However, if the plant is designed with a dense-phase or semi-dense-phase conveying system at this location, then the material does not move as an air suspension but as a region of concentrated material that usually does not represent a deflagration hazard in the duct under normal operating conditions.

B.4.5.8.3

Is there sufficient concentration to support a deflagration? If the duct is part of a dilute phase conveying setup, then the duct must be considered a deflagration hazard if the concentration exceeds 25 percent of the MEC for the material in the duct. If the material is tested and it does not propagate a deflagration flame front, then concentration ceases to be an issue. But if the material in the duct can propagate a deflagration flame front, then the concentration must be limited by the system design, or deflagration hazard management must be applied to the duct.
B.4.5.8.4

Are there competent igniters available? Yes. This duct is immediately downstream from the mill or fan package, either of which can be a source of ignition.

B.4.5.8.5

What hazard management is in place? If the particulate is sufficiently small enough to produce an affirmative test for deflagration flame front propagation, then the entire duct represents an explosion hazard, and that hazard must be managed. If it does not, either because the particulate is not deflagrable or dense-phase conveying is being used, then it does not. The analysis should document whether the duct is a deflagration hazard and if it is, how that hazard is being managed.

B.4.5.9 Location 10: The Screens.

B.4.5.9.1

Is the particulate deflagrable (explosible)? This is the same particulate that is exiting the mill, so that analysis is applicable to the screens.

B.4.5.9.2

Is the particulate suspended in air? This depends on the type, make, and model of the screens used. Some agitate the material more aggressively than others. An analysis of the operating screens for the presence of a dust suspension should be undertaken to determine if this criterion is satisfied.

Without proper dust collection, these devices can emit combustible dusts into the surrounding area.

B.4.5.9.3

Is there sufficient concentration to support deflagration? This criterion is again determined by the fraction of the process particulate that is sufficiently small to propagate a dust deflagration flame front. Note that the screens are equipped with dust collection. What is the air flow rate for the dust collection? What is the fraction of the particulate that is sufficiently small to propagate a deflagration flame front? How much of that dust is captured by the dust collection system? There are cases where a deflagration hazard has been successfully managed by just keeping the concentration below the 25 percent MEC threshold with active dust collection.

B.4.5.9.4

Are there competent igniters available? This depends on the type of screens used. Usually the bearings and moving members are located outside of the material flow path. However, there are ignition sources upstream in the process that could be a source of burning material introduced onto the screens. Usually this poses a fire hazard rather a deflagration hazard. But that fire hazard must be managed.
B.4.5.9.5

What hazard management is in place? Depending on whether the screens are found to be a deflagration hazard or a fire hazard, different hazard management strategies will apply. The strategy employed and the reason for selecting that strategy should be documented.

B.4.5.10

This example includes other ducts, conveyors, and other process equipment that would be addressed in a manner similar to those already covered. However, there are two hazards that have not yet been addressed: the building compartment and the dust collector.

B.4.5.11 Location 2: The Building Compartment Housing the Process.

B.4.5.11.1

Is the particulate deflagrable (explosible)? There are a number of pieces of equipment that can leak dust. The leaks always constitute the fines fraction of the particulate being handled. In addition, air movement generally lifts the finest, most hazardous dust highest in the space. So the hazard assessment for the building compartment is based on the test data for the fine dust that is obtained from the highest locations in the building compartment.

Is there sufficient fugitive dust accumulation within the building to trigger the designation of deflagration hazard or flash-fire hazard in the building interior?

If the building compartment contains sufficient fugitive dust accumulations to warrant designating it a deflagration of flash-fire hazard, then the occupant must be protected from the building interior. This requires the use of flame-resistant garments and a housekeeping program. Venting is one common approach to protect against building collapse.

Furthermore, dust accumulations trigger requirements for using electrical equipment that is listed as suitable for Class II hazardous locations in accordance with Articles 500 through 506 of NFPA 70.

B.4.5.11.2

Is the particulate suspended in air? Most large-loss explosions involving combustible dust have occurred because a small event produced an ignition mechanism and a dust dispersion of the accumulated fugitive dust in the building interior.

B.4.5.11.3

Is there sufficient concentration to support a deflagration? Generally, the dust layer criteria in the occupancy standards are derived from calculations that take into consideration the requisite concentrations to propagate a flame front.

B.4.5.11.4
Are there competent igniters available? Under abnormal (accident) conditions the answer is usually yes.

**B.4.5.11.5**

What hazard management is in place? Deflagration venting for compartments is a common management strategy to preserve the building integrity. What provisions are in place to protect the employees from a propagating deflagration (flash fire)? Is the housekeeping program sufficient to prevent fugitive dust layer from developing over time?

**B.4.5.12 The Dust Collector.**

The dust collector in this example is located outside of the building, but it is equipped with a clean air return to the facility interior. This triggers the need to protect the employees within the facility compartment from a fire in the dust collector as well as a deflagration in the dust collector.

**B.4.5.12.1**

Is the particulate deflagrable (explosible)? Probably. This dust collector is collecting the fines that are generated by various process steps including the dust suspended in the silo ullage space, the silo discharge screw conveyor, the screens, and the product out-feed screw.

**B.4.5.12.2**

Is the particulate suspended in air? Yes. Dust collection systems are invariably designed as dilute phase conveying systems.

**B.4.5.12.3**

Is there sufficient concentration to support deflagration? Usually such dust collection systems operate at dust loadings in the ducts in the range of 1 to 3 g/m³; well below the 25 percent MEC range for most dusts. But this parameter must be verified and documented. So the ducts are probably not a deflagration hazard, but the dust collector’s job is to concentrate that dust. So an ignitable concentration of dust within the dust collector is probably certain.

**B.4.5.12.4**

Are there competent igniters available? Generally, yes. All of the ignition sources in the entire process have access to the dust collector via the dust collection ducts. While the concentration in those ducts is typically well below the MEC, there is always the potential for a burning particle to survive the trip from the point of ignition to the dust collector interior, where it can become attached to the filter media and ignite a fire. For many particulates there is an electrostatic ignition mechanism present. For others, the inherent reactivity of the particulate with atmospheric oxygen makes them inherently self-igniting. All these sources of ignition have to be considered.

**B.4.5.12.5**
What hazard management is in place? The occupants must be protected from dust collector — fires as well as dust collector explosions. (In many industries dust collector fires outnumber dust collector explosions.) For dust collector fire, return air diversion to prevent combustion products from entering the building is sufficient. (Generally, dust collectors collecting metallic particulates are not permitted to return air to the building.) To protect occupants from the dust collector explosion, a common approach is to install deflagration isolation as well as either deflagration venting or deflagration suppression. The protection feature in place should be documented.

B.4.6

This example is intended to illustrate one process used in assessing the combustible dust hazards of a facility. Other methods are acceptable as long as they result in a thorough assessment of all the hazards in the process and facility and document how those hazards are managed. This example evaluated the following aspects of the process:

1. Process equipment
2. Process ductwork
3. Facilities compartments

Individual hazards for these three areas would be considered in the aggregate to determine the overall hazards of the process.

Annex C Accumulated Fugitive Dust (CMD-FUN)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Accumulated Fugitive Dust.

As noted elsewhere in the standard, there are two considerations for assessing accumulated fugitive dust hazards — one that indicates that a dust flash-fire or dust explosion hazard exists and the other that indicates where protected electrical equipment might be needed. Figure C.1 is a representation of provisions defined in Articles 500–505 of NFPA 70 to assist in determining where hazardous (classified) locations can exist.

Other factors associated with accumulated fugitive dust include the following:

1. Accumulated fugitive dust is the single most important factor in propagating a deflagration within a building.
2. Dust layers trigger critical hazard management decisions.

Figure C.1 Comparison of Accumulated Fugitive Dust Thicknesses. *Source: J. M. Cholin Consultants, Inc.*)
C.2 Electrical Equipment for Hazardous Occupancies.

All electrical equipment must be listed for use in the occupancy based on the class, division, and group classification. When all electrical equipment in the occupancy is listed for use in that occupancy, the electrical system is deemed to not be a likely igniter. The extent of the electrically classified area is controlled by the rate of dust release and the frequency of clean-up.

C.3 Building Compartments.

Where management of the hazard is dependent on routine cleaning, that cleaning program should be outlined in the DHA.

C.4 Explosion Hazards.

Dust explosion hazards exist wherever combustible particulate solids are handled or produced. There is no alternative to proactively managing the hazard, and the following questions should be considered when assessing the risk:

1. Is there accumulated fugitive dust? If so, how much is there and where is it?
2. What is the MEC, MIE, and $K_{st}$ of the particulate in the dust?
3. Does the building compartment pose a deflagration hazard?
4. Does the building compartment pose an explosion hazard?
5. Does the building compartment pose a fire hazard?

Most instances of property damage and personnel injury are due to fugitive dust accumulations within building compartments. Control, limitation, or elimination of accumulated fugitive dust are critical and the most important criteria for a safe workplace.
Annex D Supplementary Information on Fire Protection (CMD-AGR)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Automatic Sprinklers.
All areas containing combustible materials, except bulk storage tanks and bins, should be protected by suitable automatic sprinkler systems installed in accordance with NFPA 13 and NFPA 1.

D.2 Supervisory Services.
For prompt detection of fires, either security service, an automatic fire detection system, or sprinkler waterflow and supervisory service should be provided. If security service is provided, routing and recording apparatus should meet the requirements of NFPA 601. Automatic fire detection systems to actuate local alarms or other suitable arrangements for automatically notifying the fire department should meet the applicable requirements of NFPA 72.

D.3 Hydrants.
Either public or private hydrants should be provided for fire-fighting use. Hydrants should be fed by an adequate water supply.

D.4 Explosion Suppression.
Explosion suppression systems designed for instantaneous detection and suppression of explosions are available for use in confined areas such as bins, tanks, dust collectors, and so forth. The use of such systems should be considered in unusually hazardous areas where other means of hazard control are not suitable. Such systems should meet the requirements of NFPA 69.

D.5 Firefighting Operations.
Hose streams should be used with great care to avoid creating dust clouds or causing structural damage to bins. Fog nozzles should be used.

D.6 Manual Fire Suppression.
Those individuals responsible for manual fire suppression at these types of facilities should have a fire protection plan. This plan should meet the recommendations contained in the National Grain and Feed Association Research Report, Emergency Preplanning and Fire Fighting Manual — A Guide for Grain Elevator Operators and Fire Department Officials.

Annex E Supplementary Information on Fumigation (CMD-AGR)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.
E.1 Definitions.

E.1.1
Fumigants as used in this annex are substances or mixtures that rapidly or progressively produce gases or vapors to control identified insects or other pests. Carbon dioxide and heat treatment and the use of diatomaceous earth are not included in this definition.

E.1.2
Pesticides, herbicides, and rodenticides are not considered to be fumigants. See NFPA 400 for information on storage of pesticides.

E.1.3
Fumigation is a process whereby commodities stored in a space, or the space itself, are subjected to the vapors, fumes, or gases produced by or from fumigants.

E.2 Regulatory Usage.

E.2.1
Fumigants should not be used in any manner inconsistent with the registered label or labeling.

E.2.2
The manner in which fumigants are sold, used, applied, stored, shipped, or otherwise handled, including disposal procedures, and the manner in which fumigations are conducted, are governed directly by the language of the label or labeling under which a fumigant is registered with the U.S. Environmental Protection Agency's Pesticide Registration Division, located in Washington, DC. It is a violation of federal law for any pesticide, including those registered as fumigants, to be used in any manner inconsistent with the registered label or labeling.

E.3 Fire and Explosion Prevention and Protection.

E.3.1
A thorough cleanup should be made, and all refuse, oily waste, and other combustible material, except that needing fumigation, should be removed from the area to be fumigated prior to the sealing of the premises.

E.3.2
All fire protection equipment such as sprinklers, alarms, and fire pumps should remain in operating condition during fumigation.

E.3.3
While the space is being sealed and during the fumigation and ventilation period, the use of matches, smoking materials, fires, and open flames, including flame-powered fumigant gas detection devices and
any similar source of ignition, should be prohibited.

E.3.4
If it is necessary to heat the enclosure being fumigated during the fumigation, only enclosed steam or hot water systems should be used. The boiler thermostats should be effectively sealed off from the area being fumigated.

E.3.5
When buildings or other enclosures in which electric-powered equipment is located are being fumigated, all switches controlling electric power to the portion of the building being fumigated should be locked in the open position or all current-carrying conductors disconnected prior to fumigation. Electrical equipment that is explosionproof or rated for the area need not be locked out prior to and during fumigation.

E.3.6
Temporary remote control power leads with control switches located outside the fumigated space should be in-stalled for powering circulating fans in the fumigated space. Such fans should be approved for the intended use.

E.3.7
Control valves for gas, oil, or other fuel systems, if in the area of fumigation, should be closed prior to the beginning of the fumigation operation.

E.4 Storage and Handling.

E.4.1
Fumigants, whether packaged in cartons, drums, bulk tanks, or other containers, should be stored in locked, dry, well-ventilated, enclosed areas.

E.4.2
Fire hazards as well as life and health hazards are caused by the misuse of fumigants. Direct contact of metal phosphide fumigants with water, acids, or many other liquids can cause rapid generation of hydrogen phosphide and a fire. Piling of tablets, pellets, prepacked ropes, or dust from their fragmentation can cause a temperature increase and confine the release of gas so that ignition could occur.

E.4.3
Fumigant storage areas should be properly posted to indicate the hazardous nature of the material being stored.

E.4.4
When fumigants are being handled, smoking, matches, open flames, or other sources of ignition should be prohibited in the vicinity of such handling. Metal phosphide fumigant containers should be opened.
outside or near well-ventilated areas and should be protected from water exposure. These containers should not be opened in a hazardous atmosphere.

**E.4.5**

Metal phosphide fumigants can react with water. Therefore, fumigation using metal phosphides should be avoided in wet grain. Containers of metal phosphide fumigants should be opened in open air because, under certain conditions, they can flash upon opening.

**E.4.6**

When fumigants are transferred from storage areas to the area of application, to commodities, or for space fumigation, only a quantity sufficient for a reasonable period of need should be moved. Unused fumigants should be returned to storage or disposed of as directed on the label.

**E.5 Hazard Warning.**

**E.5.1**

All areas where fumigants are stored should be posted, utilizing warning placards in accordance with NFPA 704.

**E.5.2**

It is preferable that fumigant storage areas be located in a secured, detached outside building of noncombustible construction.

**E.5.3**

All areas where fumigants are in use should be placarded according to the fumigant label.

**Annex F Employee Health and Safety (CMD-AGR)**

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**F.1 Recognition.**

Employee health and safety in operations depends on the recognition of actual or potential hazards, controlling or eliminating these hazards, and training employees to work safely.

**F.2 Guidelines.**

The following guidelines are recommended for the recognition, evaluation, and control of actual or potential hazards.

**F.2.1**

Training programs should be instituted to properly inform employees about the hazards involved in starch plants, with emphasis on the following areas:
(1) Fire and dust explosion hazards
(2) Sources of ignition and their control
(3) Confined spaces and bin entry and cleaning
(4) Fumigation
(5) Housekeeping
(6) Fire protection equipment

F.2.2
Emergency procedures to be followed in case of fire or explosion should be established. All employees should be thoroughly indoctrinated in these procedures.

F.2.3
Procedures should be established for the recognition and control of employee exposure to air contaminants.

F.2.4
Procedures should be established for locking out equipment under any conditions where startup of such equipment could subject employees to a hazardous situation.

F.2.5
The work area should be maintained in as clean, orderly, and sanitary a manner as working conditions allow.

F.2.6
Personal protective equipment should be required for each employee wherever bodily injury or health hazard is a possibility.

Annex G Schematics of Typical Pneumatic Conveying Installations (CMD-AGR)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

G.1 Installation Schematics.
Figure G.1(a) through Figure G.1(i) show typical transfer systems.

Figure G.1(a) Multiple Strand System, Negative Pressure Type, Typical for Cereal Mills.
Figure G.1(b) Typical Car Unloader System, Negative Pressure Type, Low Capacity.
Figure G.1(c) Typical Car Unloader System, Negative Pressure Type, High Capacity.
Figure G.1(d) Portable Car Unloader and Transfer System, Combination Negative Pressure Type and Positive Pressure Type, High Capacity.
Figure G.1(e) Typical Transfer System, Positive Pressure Type, High Capacity.
Figure G.1(f) Typical Transfer System, Positive Pressure Type, Low Capacity.
Figure G.1(g) Typical Recirculating Transfer System, Positive Pressure Type, High Capacity.
Figure G.1(h) Typical Recirculating Transfer System, Positive Pressure Type, Low Capacity.
Figure G.1(i) Typical Transfer System, Combination Positive Pressure Type and Negative Pressure Type, High Capacity.
Annex H Checklist for Dust Hazard Analysis — Example for an Existing Facility (CMD-AGR)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.
**H.1 Introduction.**
This annex is intended to illustrate one example of how to develop a dust hazard analysis (DHA) for an existing facility. Other methods include, but are not limited to, "what-if" analysis, failure mode and effects analysis, fault tree analysis, and HAZOP. Additional guidance on performing a DHA is available in the *NFPA Guide to Combustible Dust* and in the AIChE *Guidelines for Hazard Evaluation Procedures*. It is not the intent of this standard to require users to apply the Process Hazard Analysis provisions of OSHA regulations in 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," in developing a DHA. The example is intentionally vague to allow users to match the complexity and extent of the analysis to the complexity and extent of the facility and its process.

**H.2 Purpose.**
The purpose of a DHA is to identify hazards in the process and document how those hazards are being managed. The hazards addressed by this standard are the fire, deflagration, and explosion hazards of combustible dusts. There might be other hazards associated with a process, such as industrial hygiene, that are not covered in this annex. However, the process of analysis outlined in this annex could be applied to other hazards.

**H.3 Checklist.**
See Figure H.3 for an example of an agricultural and food dust hazard analysis (DHA) checklist.

**Figure H.3 Agricultural and Food Dust Hazard Analysis (DHA) Checklist.** [Cross References still to be updated]
Agricultural and Food Dust Hazard Analysis (DHA) Checklist

Completed document and associated reference materials meet the requirements for documentation of 'Dust Hazard Analysis (DHA)'. A systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility.

Meeting Date, Year, Location

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<tr>
<th>1.0 MATERIALS EVALUATION</th>
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<td>1.1</td>
<td>Is there a comprehensive list of all materials at the facility that present a credible combustible dust hazard?</td>
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<td>1.2</td>
<td>Hazard identification is based on the most recent NFPA 61. The list of materials should be kept in an electronic or paper form and should reference the methods used to define hazards in process, plant, and storage and notes that certain dust less than 100 microns should also be listed and evaluated.</td>
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<td>Do any of the materials on the list have a Key greater than 100?</td>
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<td>1.5</td>
<td>If yes, where are those materials stored, transported, and used?</td>
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<td>If yes, where are those materials stored, transported, and used?</td>
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<td>1.8</td>
<td>Are there any processes and facility areas where flash fire and explosion hazards exist?</td>
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<td>What is the frequency of occurrence of any potential hazards?</td>
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<td>2.0 BUILDING AND FACILITY DESIGN (NFPA 61, Section 9.2)</td>
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<td>2.1</td>
<td>The objectives stated in NFPA 61, Section 9.2, shall be deemed to be met when, consistent with the goals of 4.2.1 and the provisions of NFPA 61, Sections 1.4 and 1.5: the following have been achieved.</td>
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<td>2.2</td>
<td>The facility, processes, and equipment are designed, constructed, and maintained in accordance with the prescriptive criteria set forth in this standard.</td>
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<td>2.3</td>
<td>The requirements set forth in this standard are implemented.</td>
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NFPA 61 (p. 1 of 12)
## AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

### 2.0 BUILDING AND FACILITY DESIGN
(NFPA 61, Section 9.2, continued)

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# AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

### 2.0 BUILDING AND FACILITY DESIGN (NFPA 61, Section 9.2, continued)

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<td>2.21</td>
<td>Do any MCCs require a pressurization system and alarms installed per code?</td>
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<td>2.22</td>
<td>Are there any deficient or nonconforming items identified?</td>
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### 3.0 IGNITION SOURCE CONTROL (NFPA 61, Section 9.4)

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<td>3.1</td>
<td>Have grounding and bonding of pipes and equipment been universally applied to the system and its components to ensure static will be dissipated? (Resistance to ground ≤ 1 megohm)?</td>
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<td>3.2</td>
<td>Does any motor-driven equipment meet requirements of NFPA 70E and 9.4.3.2.1 through 9.4.9.6 of NFPA 61?</td>
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<td>3.3</td>
<td>Are antistatic bearings used on all machinery, conveyors, belts, and processing equipment?</td>
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<td>3.4</td>
<td>Are bearings kept free from dust, dirt, and excessive lubrication?</td>
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<td>3.5</td>
<td>Are bearings that are directly exposed to a dust deflagration hazard monitored for overheating?</td>
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<td>3.6</td>
<td>What form does the monitoring take? Describe the program or process and where information is kept?</td>
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<td>3.7</td>
<td>Are bearings on legs and conveyors located outside the machinery enclosure and protected from dust exposure?</td>
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<td>3.8</td>
<td>Are bearings accessible for inspection?</td>
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<tr>
<td>3.9</td>
<td>Are support bearings on screw conveyors and other similar equipment covered?</td>
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<td>3.10</td>
<td>Are pneumatic conveying systems installed in accordance with 9.3.3 and 9.3.5 through 9.3.9 of NFPA 654?</td>
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<td>3.11</td>
<td>Are all system components electrically conductive?</td>
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<td>3.12</td>
<td>Is a hot work program in place for dust hazard-exposed areas to prevent hot work from being conducted, including the use of prohibited equipment? (See 22.26 through 22.42.)</td>
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<td>3.13</td>
<td>Are there any deficient or nonconforming items identified?</td>
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### 4.0 BINS, TANKS, AND SILOS (NFPA 61, 9.3.9)

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<th>Action</th>
<th>Date Due</th>
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<tbody>
<tr>
<td>4.1</td>
<td>Does the construction of bins, tanks, and silos conform to applicable local, state, or national codes?</td>
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<tr>
<td>4.2</td>
<td>Where explosion relief vents are provided on bins, tanks, and silos, are they sized to operate below the container walls fail?</td>
<td></td>
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<tr>
<td>4.3</td>
<td>Do access doors or openings meet the following requirements:</td>
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<tr>
<td>4.4</td>
<td>Where a bin, tank, or silo has a protected access opening provided in the roof or floor, as the smallest dimension, the opening at least 510 mm (20 in.)?</td>
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<tr>
<td>4.5</td>
<td>Are there any deficient or nonconforming items identified?</td>
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</tbody>
</table>

### 5.0 MARINE TOWERS (NFPA 61, 9.2.8)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Does the facility or process include marine towers? If yes, complete if no, skip to f.</td>
<td></td>
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<tr>
<td>5.2</td>
<td>Are marine towers constructed of noncombustible materials?</td>
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</tbody>
</table>

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NFPA 61 (p. 3 of 12)
### AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

#### 5.0 MARINE TOWERS (NFPA 61, 9.2.8, continued)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
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<tbody>
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<td></td>
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</tbody>
</table>

- Are movable marine towers provided with automatic or manually operated brakes?
- Are movable marine towers provided with automatic or manual rail clamps?
- Do rail brakes activate when the wind velocity is just high enough to cause movement of the tower, even when brakes or gear drives are preventing the rail wheels from turning?
- Is equipment to monitor wind velocity installed on movable marine towers?
- Are movable marine towers have provisions for emergency tie-downs?
- Are crane, hoist, and other lifts equipped with auto-stop devices to prevent the equipment from falling if the operating controls break?
- Are there any deficient or noncomplying items identified?
- If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?

#### 6.0 CONVEYORS, SPOUTS, AND THROWS OF MATERIAL (NFPA 61, 9.3.15)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

- Are bulk material conveyor belts designed to either relieve or stop if the discharge end becomes plugged?
- Are bulk material conveyor belts (crush handling or similar) equipped with haulage gate and bun bearing sensors at both ends?
- Are screw, drag, or chain conveyors fully enclosed in metal housing, and designed to either relieve or stop if the discharge end becomes plugged?
- Are fixed spout dusttight?
- Are combustible linings used in spouts or other handling equipment in any location other than wear points or impact points?
- Do dust or conveyors that penetrate fire-rated walls or partitions have necessary modification to prevent fire propagation from area to area?
- Are there any deficient or noncomplying items identified?
- If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?

#### 7.0 GENERAL EQUIPMENT DESIGN (NFPA 61, 9.3.3.2)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
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</table>

- Are any ingredient transport systems present in the process per NFPA 61, 9.3.3.2?
- Is this system to be permitted to be installed inside of a building without explosion protection where all of the following requirements are met:
  1. The system is a negative or positive pressure pneumatic conveying system.
  2. The system, through its design, is isolated from the addition of mechanical or electrical energy and process activities such as cooking or drying, by positive means, such as rotary valves, filters, normally closed valves, or safety barriers, from outside events that could trigger an event such as flash fire or deflagration.
  3. The system is not a bulk raw grain transportation pneumatic system or dust collection system.
- Are magnetic and clearance located upstream of equipment and arranged where they can be easily inspected and cleaned?
- Are conveyor and related devices installed and maintained to ensure appropriate function?
- Are all conveyors and related devices installed and maintained to ensure appropriate function?
- On normal shutdowns of any process that contain combustible dust, does the system maintain design air velocity until the material is purged from the system?
- If a conveyor runs adjacent to buildings or structures of combustible construction or adjacent to walls with vents, windows, or doors or conveyer openings, are these made, altered, or added closing valves to minimize propagation potential through these openings?
# AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

## 7.0 GENERAL EQUIPMENT DESIGN (NFPA 61, 9.3.3.2, continued)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.6</td>
<td>Are all connected fans suitable for material handling?</td>
<td></td>
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<tr>
<td>7.7</td>
<td>Are there any deficient or nonconforming items identified?</td>
<td></td>
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</tr>
</tbody>
</table>

## 8.0 PIPING, VALVES, AND BLOWERS (NFPA 61, 9.3.3.3)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>Are all piping and tubing systems straight, duct-tight, and grounded? (Resistance to ground ≤ 1 megohm)</td>
<td></td>
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<tr>
<td>8.2</td>
<td>Are all piping and tubing systems properly supported to include the weight of material in a full or choked position, and are they be disassembled for cleaning and unblocking in a safe and efficient manner?</td>
<td></td>
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<tr>
<td>8.3</td>
<td>Are all pressure- and vacuum-relief valves located, sized, and set to relieve pressures to prevent system components?</td>
<td></td>
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<tr>
<td>8.4</td>
<td>Are multiple-direction valves of airtight and dirt-tight construction and used to effect a positive diversion of the product, and also diversion in one direction and all other directions from air, dust, or product leakage?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>8.5</td>
<td>Are there any deficient or nonconforming items identified?</td>
<td></td>
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</tr>
</tbody>
</table>

## 9.0 RECEIVING AND SHIPPING CONVEYANCES (NFPA 61, 9.3.3.4)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1</td>
<td>Do all transport modes such as railcars (hopper cars, hopper, or tank cars) and trucks (both receiving and shipping in bulk), into which or from which potentially combustible commodities or products are pneumatically conveyed, electrically bonded to the plant ground system, or earth grounded? (Resistance to ground ≤ 1 megohm)</td>
<td></td>
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<tr>
<td>9.2</td>
<td>Are all systems protected with filters on the inlet air used for transporting the combustible material pneumatically?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9.3</td>
<td>Are all trucks, railcars, and other containers being filled provided with filters designed to prevent dust liberation into the fill building or structure?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9.4</td>
<td>Are unloading systems protected with magnets or magnet detection?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>Are receiving systems equipped with one or more devices (e.g., grating, wire mesh screens, permanent magnets, listed electromagnets, pneumatic separators, or specific gravity separators) to minimize or eliminate transverse material from the product stream?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9.6</td>
<td>Are there any deficient or nonconforming items identified?</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

## 10.0 DUST COLLECTION SYSTEMS PRESCRIPTIVE REQUIREMENTS (NFPA 61, 9.3.3.5)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>NA</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1</td>
<td>Do any fans or blowers transport combustible dust through the fan or blower?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10.2</td>
<td>If yes, are fans built of spark resistant construction?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10.3</td>
<td>If any duct control devices are equipped with equipment that grinds, pulverizes, mill, or hammer mill agricultural or food materials that are combustible isolated from other systems?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>10.4</td>
<td>If so, is the enclosed duct equipment attached only to equipment that is used for mixing of spilled seeds or grain hulls?</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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## AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

### 10.0 DUST COLLECTION SYSTEMS
#### PRESCRIPTIVE REQUIREMENTS
(NFPA 61, 9.3.3.5, continued)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.1 Are the dust collection systems interlocked with related machinery so that it shuts down before the machinery and system are started?</td>
<td></td>
<td></td>
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<tr>
<td>10.5 Is there an alarm (visual or audible) that is triggered when a dust collection system collecting combustible dust is shut down?</td>
<td></td>
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<tr>
<td>10.6 Does the alarm trigger a shutdown process?</td>
<td></td>
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</tr>
<tr>
<td>10.7 Are all dust bins or tanks that store grain dust located outside the building structure, constructed of noncombustible material, and isolated with rotary valves or similar from the other portions of the system?</td>
<td></td>
<td></td>
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<tr>
<td>10.8 Are all dust collectors located outside the facility and isolated with rotary valves or similar from the other portions of the system?</td>
<td></td>
<td></td>
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<tr>
<td>10.9 Do all dust collectors located inside the building have deflagration vents based on NFPA 61 and an explosion suppression system based on NFPA 60? If yes:</td>
<td></td>
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<tr>
<td>(a) Do these dust collectors handle only material generated as a by-product to reacting moisture from an air stream? (e.g., moisture, extrusion, raw grain flour)?</td>
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<tr>
<td>(b) Are these dust collectors located on the top of a bin and do they form a bin vent as defined in NFPA 61?</td>
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<tr>
<td>(c) Are the filters used for classification operations or food products with air classifying or classifiers?</td>
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<tr>
<td>10.10 Is exhaust air from dust collection/ventures returned to the building? If yes, see 14.6.</td>
<td></td>
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<tr>
<td>10.11 Are there any deficient or hazardous items identified?</td>
<td></td>
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</tr>
<tr>
<td>11.0 DUCT SYSTEMS PRESCRIPTIVE REQUIREMENTS (NFPA 61, 9.3.3.5)</td>
<td></td>
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<tr>
<td>11.1 Does the duct ever contain enough dust to support a deflagration above 75% MEC?</td>
<td></td>
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<tr>
<td>11.2 Does the system conveying velocity, as designed, exceed the inert surfact of any piping or ducting in free of combustible dust under all normal operating conditions?</td>
<td></td>
<td></td>
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<tr>
<td>11.3 Are flexible connections static dissipative, bonded, and grounded, resistance to ground &lt; 2 megohm?</td>
<td></td>
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<tr>
<td>11.4 Is the duct lining noncombustible?</td>
<td></td>
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<tr>
<td>11.5 Are all ducts that return air to the building inspected and cleaned at least annually?</td>
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<tr>
<td>11.6 Are isolation devices provided to prevent deflagration propagation from equipment throughout upstream ductwork to the work area?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11.7 Have ducts that handle combustible dust or combustible particulate solids been designed and installed to conformance with the requirements of NFPA 61 with the exception found in NFPA 60?</td>
<td></td>
<td></td>
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<tr>
<td>11.8 Have nonconductive materials such as plastic or fiberglass been used in all duct systems that could potentially handle combustible dust?</td>
<td></td>
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<tr>
<td>11.9 Does the ducts in air return systems where there are combustible dusts in hazardous quantities?</td>
<td></td>
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<tr>
<td>11.10 Are horizontal ducts provided with access openings for the removal of combustible dusts?</td>
<td></td>
<td></td>
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<tr>
<td>11.11 If isolation is used on the ductwork inside a building or structure, is the ductwork designed to withstand the forces imposed?</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>11.12 If yes, are there any deficient or hazardous items identified?</td>
<td></td>
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<tr>
<td>11.13 Are there any deficient or hazardous items identified?</td>
<td></td>
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<tr>
<td>11.14 If yes, was a plan reviewed with the appropriate authorities for bringing structure into compliance with this set of requirements?</td>
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</tbody>
</table>
### AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

<table>
<thead>
<tr>
<th>12.0 CENTRALIZED VACUUM CLEANING SYSTEMS (NFPA 61, 9.3.3.7)</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the facility have a centralized vacuum cleaning system?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>If yes, complete 12.0; if no, go to 13.0.</td>
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</tr>
<tr>
<td>12.1 On normal shutdown of the process, does the system maintain design air velocity until the material is purged from the system?</td>
<td></td>
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</tr>
<tr>
<td>12.2 Does the system provide minimum conveying velocities at all times, whether the system is used with single or multiple simultaneous operations?</td>
<td></td>
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</tr>
<tr>
<td>12.3 If a fire detection system is incorporated into the centralized vacuum, are safety interlocks in place for air-moving devices and process equipment?</td>
<td></td>
<td></td>
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<tr>
<td>12.4 Are there unshielded openings on the central vacuum system, and are they equipped with an isolation device?</td>
<td></td>
<td></td>
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<tr>
<td>12.5 Are the central vacuum system hose stations located at strategic points (where dust explosions are known to occur)?</td>
<td></td>
<td></td>
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<tr>
<td>12.6 Are only static-conductive vacuum cleaning tools used, and are they properly grounded to the hose end?</td>
<td></td>
<td></td>
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<tr>
<td>12.7 Is flexible hose properly grounded to prevent static buildup?</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12.8 Are all vacuum truck hoses and couplings static-dispersive or conductive and grounded?</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>12.9 Are there any deficient or nonconforming items identified?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>13.0 AIR-MATERIAL SEPARATORS (NFPA 61, 9.3.4.1.1 - 9.3.4.1.2)</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are all air-material separators connected to processes that are potential sources of ignition (e.g., hammer mills, ovens, direct-fired dryers, and other similar equipment regardless of location) protected by properly designed vents or suppression systems?</td>
<td></td>
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<tr>
<td>13.2 Are interior separators protected so that explosion pressures will not rupture the ductwork or the device?</td>
<td></td>
<td></td>
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<tr>
<td>13.3 Are there any devices on site smaller than 702 mm (28 in.) in diameter that are not protected because they meet the conditions found in NFPA 61, 9.3.4.1.2?</td>
<td></td>
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<tr>
<td>13.4 Are AMS that handle more than 25% of the AIE of any combustible dust protected with appropriate explosion-venting or monitoring systems?</td>
<td></td>
<td></td>
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<tr>
<td>13.5 Are the explosion venting calculations or suppression design information documented?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13.6 Is there a means of preventing deflagrations from propagating down the ducts of AMS that return air to the building?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13.7 Are there any deficient or nonconforming items identified?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>14.0 RECYCLING OF FILTERED AIR (NFPA 61, 9.3.4.1.3)</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the facility recycle air from air-material separators?</td>
<td></td>
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<tr>
<td>If yes, complete 14.0; if no, go to 15.0.</td>
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<tr>
<td>14.1 Is the air that is returned inside the building to air make-up systems filtered to the efficiency of 0.01 g per dry standard cubic meter of airflow (0.008 gram per dry standard cubic foot of airflow)?</td>
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<tr>
<td>14.2 Is the air from hammer mill blowers or other devices that add energy to the system discharged outside the facility?</td>
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<tr>
<td>14.3 Is the collector or exhaust system provided with explosion suppression or isolation to prevent deflagration from the collector from entering the building?</td>
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<tr>
<td>14.4 Are there any deficient or nonconforming items identified?</td>
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</tbody>
</table>
### AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

**15.0 BUCKET ELEVATOR LEGS (NFPA 61, 9.3.14)**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
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<tbody>
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</table>

- Are any bucket elevators located fully or partially inside of a building, structure, or tunnel?
- Are bucket elevators that move combustible materials that could generate dust hazard (tailing, head and boot sections, access openings, and connecting conveyances) daylight and constructed of noncombustible materials?
- Is explosion venting or suppression provided for each elevator leg?
- If not, is isolation provided on the feed and discharge end with deflagration isolation in accordance with NFPA 69?
- Is each leg independently driven by motor and drive train capable of handling the full-rated capacity of the elevator leg without overheating?
- Are live shaft driven capable of handling the full-rated capacity of all connected equipment without overheating?
- Are multiple motor drives interlocked to prevent operation of the leg upon failure of any single motor?
- Can drive start an unbalanced leg under full (100%) load?
- Is each leg provided with a speed sensor device that will cut off the power to the drive motor and activate an alarm in the event the leg belt slows to 80% of normal operating speed, and will feed to leg be stopped or reversed?
- Has proper logging been installed on system pulleys and related devices?
- Has proper monitoring equipment been installed to ensure that hot bearings, misalignment, and other abnormal conditions are detected before they cause a dangerous situation?
- Are all spouts intended to receive grain or combustible dust hazard materials directly designed and installed to handle the full-rated elevating capacity of the largest leg feeding each spout?
- Are there any deficient or nonconforming items identified?
- If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?

**16.0 PROCESSING MACHINERY AND EQUIPMENT (NFPA 61, 9.3.21)**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
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<tbody>
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</tbody>
</table>

- Are receiving conveyors prior to elevator legs equipped with one or more devices such as getting, wire mesh screen, permanent magnets, lined electromagnets, pneumatic separators, or specific gravity separators?
- Are tributary spouts or conveyors that feed grain or grain products for use reduction into grinders, pulverizers, or rolling mills equipped with permanent magnets, lined electromagnets, pneumatic separators, specific gravity separators, culverts, or screens to exclude metal or foreign matter?
- Is equipment bonded and grounded?
- Are processing machinery and components such as augers mounted to facilitate access for cleaning?
- For starch grinding mills, is carbon steel used in the grinding chamber and for moving parts?
- Are the exit or venue of screw, unloader, and similar devices in dusttight enclosures?
- Are connecting ducts for starch processing machinery metal or electrically conductive, nonmetallic or flexible connecting ducts having an electrical resistance not greater than 1 megohm?
- Where multiple starch material sources are connected to a common conveyer, are material separators, or similar device, in such connected source equipped with deflagration isolation in accordance with NFPA 69?
## AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

### 16.0 PROCESSING MACHINERY AND EQUIPMENT, continued

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.9</td>
<td>Dry milling or grinding of starch performed in a separate building with explosion relief or in a separate room isolated from other areas by interior walls designed not to fail before explosion pressure is vented to a safe, outside location? OR, is the grinding equipment designed to be protected in accordance with NFPA 68 or NFPA 69?</td>
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<tr>
<td>16.10</td>
<td>Have all elevator legs handling bulk raw grain been assessed based on 5.3.14?</td>
<td></td>
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<tr>
<td>16.11</td>
<td>Are there any deficient or nonconforming items identified?</td>
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</tbody>
</table>

### 17.0 GRAIN AND SPRAY DRYER (NFPA 61, 9.3.172 - 9.3.175)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1</td>
<td>Does the facility have grain or spray dryer? (If yes, complete 17.1; if no, skip to 19.0)</td>
<td></td>
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<tr>
<td>17.2</td>
<td>Are there any deficient or nonconforming items identified?</td>
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<tr>
<td>17.3</td>
<td>If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?</td>
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</tbody>
</table>

### 18.0 HEAT TRANSFER OPERATIONS (NFPA 61, 9.3.19)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.1</td>
<td>Are heat transfer devices utilizing air, steam, or vapors of heat transfer fluids provided with pressure relief valves where necessary?</td>
<td></td>
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<tr>
<td>18.2</td>
<td>Are relief valves on systems employing combustible heat transfer media vented to a safe, outside location?</td>
<td></td>
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<tr>
<td>18.3</td>
<td>Are heaters and pumps for combustible heat transfer fluids located in a separate, dust-free room or building of noncombustible construction that is protected by automatic sprinklers?</td>
<td></td>
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<tr>
<td>18.4</td>
<td>Is air for combustion taken from a clean, outside source?</td>
<td></td>
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<tr>
<td>18.5</td>
<td>Are enclosures for heat exchangers constructed of noncombustible materials and equipped with secure openings for cleaning and maintenance?</td>
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<tr>
<td>18.6</td>
<td>Are heat exchangers located and arranged in a manner that does not allow combustible dust to accumulate on fins, fins, or other heated surfaces?</td>
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<tr>
<td>18.7</td>
<td>Are heat exchangers interlocked to shut down the heater and fluid transfer pumps upon activation of the fire protection and/or life-safety protection systems for any area served by this system?</td>
<td></td>
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<tr>
<td>18.8</td>
<td>Are heating units provided with a source of combustion air ducted directly from the building exterior or from an unclassified location?</td>
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<tr>
<td>18.9</td>
<td>Are there any deficient or nonconforming items identified?</td>
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<tr>
<td>18.10</td>
<td>If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?</td>
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</table>

### 19.0 VENTILATION AND VENTING (NFPA 61, 9.3.20)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.1</td>
<td>Have each of the key equipment type designs been assessed based on requirements of NFPA 61, 9.3.20?</td>
<td></td>
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<tr>
<td>19.2</td>
<td>Are there any deficient or nonconforming items identified?</td>
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</table>

### 20.0 MITIGATION

#### Dust Control

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<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.1</td>
<td>Have each of the key equipment type designs been assessed based on requirements of NFPA 61, Section 6.6?</td>
<td></td>
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</tbody>
</table>
# AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

## 20.0, MITIGATION, continued

<table>
<thead>
<tr>
<th>Dust Control, continued</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.2 Are there any deficient or nonconforming items identified?</td>
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<tr>
<td>If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?</td>
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</tbody>
</table>

## Explosion Prevention/Protection

<table>
<thead>
<tr>
<th>Protection</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.3 Have each of the key equipment type designs been assessed based on requirements of NFPA 61, Section 9.7?</td>
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</table>

## Fire Protection

<table>
<thead>
<tr>
<th>Fire Protection</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.5 Are there any deficient or nonconforming items identified?</td>
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<tr>
<td>If yes, was a plan written with estimated dates for bringing structure into compliance with this set of requirements?</td>
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</table>

## 21.0 HUMAN FACTOR

<table>
<thead>
<tr>
<th>Human Factor</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.1 Does the facility have a sanitation program that includes cleaning and equipment integrity assessment based on dust release and accumulations?</td>
<td></td>
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<tr>
<td>21.2 Are all areas shown in 2.3 rated as unclassified due to equipment design and maintenance to prevent or limit dust release, and do they include a sanitation program that calls for frequent cleaning to ensure that the requirements to remain unclassified?</td>
<td></td>
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<tr>
<td>21.3 Does the sanitation program include requirements of NFPA 61, Section 8.4, Housekeeping?</td>
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<tr>
<td>21.4 Are motor control centers (MCCs) pressurized to prevent dust infiltration?</td>
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<tr>
<td>If not, are they arranged to limit dust infiltration, and are they covered with an effective program to keep the room and cabinets free of dust accumulations?</td>
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<tr>
<td>21.5 Does the housekeeping program address combustible dust accumulations at the following priority areas:</td>
<td></td>
<td></td>
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<tr>
<td>a) Floors of enclosed areas containing processing equipment?</td>
<td></td>
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<tr>
<td>b) Floor areas within 10 ft (3.0 m) of inside bucket elevators?</td>
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<tr>
<td>c) Floors of enclosed areas containing dryers located inside the facility?</td>
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<tr>
<td>21.6 Are dust accumulations on ledges, walls, benches, cleaning of hoods, walls, benches, ducts, and ceiling surfaces in identified priority areas maintained below acceptable limits (e.g., 0.32 mg/m³ in MJ7)?</td>
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<tr>
<td>21.7 Is there a plant-issued maintenance training program?</td>
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<tr>
<td>21.8 Do the maintenance programs associated with dust, dust accumulation, and delignification?</td>
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<tr>
<td>21.9 Are the plant programs and records of inspection and training kept?</td>
<td></td>
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<tr>
<td>21.10 Are combustible dust hazard area identification procedures in place, and are all hazardous areas identified to employees and contractors (e.g., by sign, map, or other reference)?</td>
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<tr>
<td>21.11 Before any activity that could cause dust to be suspended in air, e.g., the use of compressed air during cleaning of hoods, walls, benches, ducts, and ceiling surfaces, does the facility require that all unvented electrical equipment be de-energized and all other known sources of ignition be removed or controlled?</td>
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<tr>
<td>21.12 Has a formal preventative maintenance program been established for dryers, dust collectors, flexible connectors, differential pressure gauges, bucket elevators, and any other dust handling, producing, processing equipment that specifically includes the control of grounding and bonding?</td>
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## AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

**21.0 HUMAN FACTOR, continued**

<table>
<thead>
<tr>
<th>No.</th>
<th>Constraint</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.13</td>
<td>Are all critical safety systems inspected, tested, and/or calibrated per the OEM guidelines as required by process safety management and NFPA facility standards?</td>
<td></td>
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<tr>
<td>21.14</td>
<td>Are all bearings maintained per the manufacturers' instructions, or internal practice/maintenance programs, and are they kept free of combustible dust, product, and excessive lubrication?</td>
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<tr>
<td>21.15</td>
<td>Is there a contractor safety training program? Does it include awareness of the plant's dust hazards, hot work program, no smoking requirements per NFPA, and other requirements?</td>
<td></td>
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<tr>
<td>21.16</td>
<td>Is there training for operators, maintenance personnel, and contractors on how to use and repair the central vacuum system?</td>
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<tr>
<td>21.17</td>
<td>Is a means of fire fighting (to include the use of water as an extinguishing agent) covered in operator, maintenance personnel, and contractor training?</td>
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<tr>
<td>21.18</td>
<td>Are portable vacuums used for cleaning up combustible dust listed for use in Class II areas?</td>
<td></td>
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<tr>
<td>21.19</td>
<td>If a portable vacuum is used:</td>
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<tr>
<td></td>
<td>(a) Is it a conductive system?</td>
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<tr>
<td></td>
<td>(b) Are the hoses conductive and grounded, or static-dispersive?</td>
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<tr>
<td></td>
<td>(c) Is the fan protected from dust-laden air by a filter?</td>
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<tr>
<td>21.20</td>
<td>If an electric portable vacuum is used, is the motor rated for a Class II, Division I location?</td>
<td></td>
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<tr>
<td>21.21</td>
<td>Is there training for operators, maintenance personnel, and contractors on how to use and repair the portable vacuum system?</td>
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<tr>
<td>21.22</td>
<td>Is the portable vacuum used only for dry particulate solids so that the filter is always in place?</td>
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<tr>
<td>21.23</td>
<td>Is there training for operators, maintenance personnel, and contractors on how to use and repair the portable vacuum system (e.g., conductive tools, ensuring that the exhaust duct does not disperse and unloads layers of dust deposits)?</td>
<td></td>
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<tr>
<td>21.24</td>
<td>Does combustible dust accumulate on the overhead ductwork so that it could support a deflagration if dispersed?</td>
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<tr>
<td>21.25</td>
<td>When a branch line is disconnected, flushed off, or otherwise modified, is the design of the entire system verified to ensure the whole system operates effectively?</td>
<td></td>
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<tr>
<td>21.26</td>
<td>Is verifying that the ductwork in close of combustible dust a prerequisite to issuing hot work permits?</td>
<td></td>
<td></td>
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<tr>
<td>21.27</td>
<td>Is there a hot work procedure in place before welding or cutting on ducts?</td>
<td></td>
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</tr>
<tr>
<td>21.28</td>
<td>Do maintenance and contract maintenance personnel receive training to learn that hot work produces localized heating of equipment and piping as well as radiation, which can cause dust fires and explosions?</td>
<td></td>
<td></td>
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<tr>
<td>21.29</td>
<td>Does the hot work permit reflect the intent of NFPA 81?</td>
<td></td>
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</tr>
<tr>
<td>21.30</td>
<td>Is a new permit issued for each shift of hot work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.31</td>
<td>Is equipment undergoing hot work always taken out of service and kept inoperable until the work is complete and equipment cooled?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.32</td>
<td>Have all hazards been cleared internally and externally from the equipment before starting hot work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.33</td>
<td>Are all ignitable materials within 11 in (35 ft) removed or protected?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.34</td>
<td>Are all combustible dust layers within 11 in (35 ft) removed by cleaning before starting hot work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.35</td>
<td>Has the area been checked for ignitable vapors and gases?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>21.36</td>
<td>Are flaps and access doors in the work area equipped with fireproofed material or adequately vented with water?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.37</td>
<td>Are welding shields present, if required, to protect pneumohealth?</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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## AGRICULTURAL AND FOOD DUST HAZARD ANALYSIS (DHA) CHECKLIST

<table>
<thead>
<tr>
<th>21.0 HUMAN FACTOR, continued</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Comments</th>
<th>Action</th>
<th>Date Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.38 If spark could travel to an adjacent room through cracks or openings, have combustible materials all been moved or protected?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>21.39 Will any fire protection or detection systems be disabled as a result of this hot work?</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>If yes, is an active fire watch available?</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>21.40 Is a trained fire watch present during the hot work and for 60 minutes after the hot work is completed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.41 Are regular inspections of the work area made to ensure that no combustible dust develop, including a final inspection performed prior to closing the area for the day or weekend?</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>21.42 Have people responsible for the hot work operations received documented training to: (a) inspect the proposed work area to determine that the conditions of the permit system have been met; (b) designate additional precautions as deemed necessary, and (c) sign the permit to authorize the work to begin?</td>
<td></td>
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</tr>
<tr>
<td>21.43 Is combustible dust training provided annually to staff involved in facility design and operation, including plant engineering and maintenance?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.44 Are contractors informed of all known/potential hazards related to their work, as well as site safety rules to reduce combustible dust fire and explosion hazards, including, but not limited to, emergency action plans, hot work permits, avoiding potential ignition sources, grounding requirements, cleaning out of combustible material before commencing work, and prohibition of smoking in hazardous areas?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Annex I Electrically Conductive Floors (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

I.1 General.

I.1.1 Electrically conductive flooring is often employed in aluminum powder plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available materials. Careful examination of the details of Chapter 12 will disclose the logic of the use of conductive flooring materials.

I.1.2 The surface of a conductive floor provides a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges.

I.1.3 The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed 0.9 m (3 ft) apart at any two points on the floor. The minimum resistance is usually greater than 25,000 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values are checked at regular intervals, usually once each month.

I.2 Testing for Minimum and Maximum Resistance.

The equipment and procedures specified in I.2.1 through I.2.6 are accepted practice.

I.2.1 Each electrode weighs 2.27 kg (5 lb) and has a dry, flat, circular contact area 63.5 mm (2.5 in.) in diameter. The electrode consists of a surface of aluminum foil 0.013 mm to 0.025 mm (0.0005 in. to 0.001 in.) thick, backed by a layer of rubber 6.35 mm (0.25 in.) thick and measuring 40 to 60 durometer hardness, as determined by a Shore Type A durometer or equivalent, per ASTM D2240, Standard Test Method for Rubber Property — Durometer Hardness.

I.2.2 Resistance can be measured with a suitably calibrated ohmmeter that can operate on a nominal open circuit output voltage of 500 volts dc and a short-circuit current of 2.5 mA to 10.0 mA.

I.2.3 Measurements can be made at five or more locations in each room, and the results can be averaged.
I.2.4
For compliance with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

I.2.5
For compliance with the minimum resistance limit, no individual measurement should be less than 10,000 ohms, and the average of not fewer than five measurements should be greater than 25,000 ohms.

I.2.6
Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 0.9 m (3 ft) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

Annex J Supplementary Information on Magnesium (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

J.1 Properties.
Magnesium, a silvery white metal with an atomic weight of 24.32 and specific gravity of 1.74, is one of the lightest known structural metals. The melting point of magnesium is 650°C (1202°F). The ignition temperature is generally considered to be close to the melting point, but ignition of magnesium in certain forms can occur at temperatures below the melting point. Magnesium ribbon, fine magnesium shavings, and magnesium powders can be ignited under certain conditions at temperatures of about 510°C (950°F), and a very finely divided magnesium powder has been ignited at temperatures below 482°C (900°F).

Commercially pure magnesium contains traces of aluminum, copper, iron, manganese, nickel, and silicon, but these contaminants in typical analyses generally total less than 0.2 percent. Metal marketed under different trade names and commonly referred to as magnesium might be one of a large number of different alloys containing different percentages of magnesium, aluminum, zinc, and manganese. Some of these alloys can have ignition temperatures considerably lower than that determined for pure magnesium. In some cases, the melting point of certain alloys can be as low as 427°C (800°F) and can ignite if held at this lower temperature for some time.

J.2 Radioactive Alloys.
A few magnesium alloys that are produced contain thorium. Thorium, which is a low-level radioactive material, is used in these alloys up to a nominal concentration of 3 percent.
The natural decay or “daughter” products of thorium are locked in the alloy until such time as the metal is melted, burned, or chemically disintegrated. Under fire conditions, these decay products exist within visible fumes and are diluted as the visible fumes dissipate. These fumes can be inhaled and cause possible irradiation of lung tissue and deposition in bone structure. Maximum permissible airborne concentrations of such radioactive materials have been established by the Nuclear Regulatory Commission and are based on continuous exposure for a normal 40-hour work week.

J.3 Spot Tests for Magnesium.

J.3.1 Acetic Acid Test.
In the construction or assembly of certain machinery or equipment, magnesium or one of its alloys having similar properties might be used for a few of the component parts. Where finished or painted products are being stored or handled, it can be difficult to determine the percentage of magnesium. Investigation has shown that silver nitrate or acetic acid (vinegar) can be used to distinguish between parts composed of magnesium and those composed of aluminum. The portion of metal to be tested is first cleaned of material such as grease, dirt, and oxide, using sandpaper or steel wool. After the test area has been prepared, a drop of acetic acid is placed on it. If hydrogen bubbles develop, the piece being tested is magnesium.

J.3.2 Silver Nitrate Test.
The test solution is prepared by dissolving about 5 g (0.01 lb) of silver nitrate (AgNO₃) in 1 L (0.27 gal) of distilled water. The application of this solution immediately produces a black coloration on magnesium or a magnesium alloy. (This coloration is essentially reduced silver.) No coloration is noted on aluminum and its alloys or on most other metals. Zinc and cadmium exhibit a similar black coloration but are much heavier.

J.4 Combustibility and Explosibility.
The ignitibility potential of magnesium depends to a large extent on the size and shape of the material as well as the size and intensity of the source of ignition. Where magnesium exists in the form of ribbon, shavings, or chips with thin, featherlike edges or as grinding dust, a spark can be sufficient to start the material burning. Heavier pieces such as ingots and thick wall castings are difficult to ignite, because heat is conducted away rapidly from the source of ignition. If the entire piece of metal is raised to the ignition temperature [about 649°C (1200°F) for pure magnesium and many of the alloys], self-sustained burning will occur.

The combustibility of magnesium, the ineffectiveness of ordinary types of extinguishing agents on magnesium fires, and the fact that, under certain conditions, the application of some of these agents intensifies burning and can release hydrogen to form an explosive gas-air mixture, all combine to create serious fire and explosion hazards.

Magnesium in its solid form melts as it burns and can form puddles of molten magnesium that, in the presence of sufficient moisture, can pose explosion hazards similar to those associated with other molten metals.
J.5 General.

J.5.1 Electrically conductive flooring is often employed in magnesium powder plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available materials.

J.5.2 The surface of a conductive floor provides a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges.

J.5.3 The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed 0.3 m (1 ft) apart at any two points on the floor. Minimum resistance is usually greater than 25,000 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against static electric shocks. Resistance values should be checked at regular intervals.

J.6 Testing for Minimum and Maximum Resistance.

The equipment and procedures specified in J.6.1 through J.6.6 are accepted practice.

J.6.1 Each electrode weighs 2.27 kg (5 lb) and has a dry, flat, circular contact area 63.5 mm (2.5 in.) in diameter. The electrode consists of a surface of aluminum foil 0.013 mm to 0.025 mm (0.0005 in. to 0.001 in.) thick, backed by a layer of rubber 6.4 mm (0.25 in.) thick, and measuring 40 to 60 durometer hardness, as determined by a Shore-type durometer or equivalent. (See ASTM D2240, Standard Test Method for Rubber Property — Durometer Hardness.)

J.6.2 Resistance should be measured with a suitably calibrated ohmmeter that can operate on a nominal open circuit output voltage of 500 volts dc and a short-circuit current of 2.5 mA to 10 mA.

J.6.3 Measurements should be made at five or more locations in each room and the results averaged.

J.6.4 To comply with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

J.6.5 To comply with the minimum resistance limit, no individual measurement should be less than...
10,000 ohms, and the average of not fewer than five measurements should be greater than 25,000 ohms.

J.6.6
Where resistance to ground is measured, two measurements are customarily made at each location with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 0.9 m (3 ft) from any ground connection or grounded object resting on the floor. If resistance changes appreciably over time during a measurement, the value observed after the voltage has been applied for about 5 minutes should be considered the measured value.

J.7 Building Construction.
While noncombustible construction is preferred for buildings occupied by magnesium melting and processing operations, limited-combustible and combustible construction can be permitted in appropriate circumstances.

J.7.1
Moisture and foreign material are dangerous where molten metal is present. Such moisture can result from outdoor storage or from collection of condensate during indoor storage.

J.7.2
Flash fires in fine dust can result in serious injury. While the chance of a flash fire igniting castings is remote, a fire in accumulated dust can be intense enough to cause ignition of castings.

J.7.3
Fire can occur in furnaces or ovens where magnesium is being heat-treated if there is lack of proper temperature control or if the surface of the metal is not free of dust or fine particles of metal. Failure to provide for proper circulation of the heated air in the furnace can result in overheating or in higher temperatures in certain zones than those indicated by the thermocouples that operate the temperature control devices.

J.7.3.1
Direct contact between aluminum and magnesium at heat-treating temperatures promotes diffusion and alloying of one metal with the other, resulting in the formation of low-melting, ignitable alloys.

J.7.3.2
Certain commonly used mixtures of molten nitrates and nitrites can react explosively with the magnesium alloys in which they are immersed.

J.8
Machining magnesium includes sawing, turning, chipping, drilling, routing, reaming, tapping, milling, and shaping. Magnesium can usually be machined at the maximum speeds obtainable on modern machine tools. The low power required allows heavy depths of cut and high rates of feed, which are consistent
with good workmanship. The resulting chips are thick and massive; they seldom ignite, due to their large heat capacity.

J.9
Magnesium pigs, ingots, and billets are not easily ignited, but they burn if exposed to fire of sufficient intensity.

J.9.1
Heavy castings [11.4 kg (25 lb) or greater] having walls with large cross sections [at least \( \frac{1}{4} \) in. (6.4 mm)] can be ignited after some delay when in contact with burning magnesium chips or when exposed to fires in ordinary combustible materials.

J.10
Prime (commercially pure) magnesium chips and fines are commonly used in Grignard and other chemical reactions. These chips are generally free of contaminants and are not subject to spontaneous ignition. Where such chips are produced, shipped, and stored for chemical and metallurgical process purposes, the conditions of handling and storage are such that a fire is unlikely.

Although water should not be applied to a large chip fire, automatic sprinklers are valuable in confining or extinguishing an incipient fire in packaging and in small amounts of chips, provided detection and discharge are rapid.

J.11
Although the flame temperature of burning magnesium is about 3983°C (7200°F), the heat of combustion is only about half that of common petroleum products. Thus, fire-fighting personnel can move close to a fire during extinguishment if care is exercised.

J.11.1
Fires in magnesium should be extinguished using a Class D extinguishing agent or a dry, inert granular material.

J.11.2
Magnesium fires are more easily extinguished if attacked with the proper extinguishing agents during the early stages of the fire. Certain extinguishing agents accelerate a magnesium fire. These agents include foam, carbon dioxide, halogenated agents, and dry-chemical agents containing monoammonium or diammonium phosphate. Also, the use of water on a magnesium chip or powder fire should be avoided. It is difficult to extinguish a massive fire in magnesium powder. The major problem involves control of fires in the incipient stage.

The fire area should not be reentered until all combustion has stopped and the material has cooled to ambient temperature.
J.11.3
Re-ignition can occur due to high, localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

J.11.4
It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper method of fighting Class D fires.

J.12
Provisions should be made to automatically cut off electrical power and lighting circuits in manufacturing buildings when one or more safety-sensing devices are activated by high pressure, low airflow, abnormal oxygen content, excessive vibration, or other pertinent factors that are being monitored. Alternatively, these sensing devices should be arranged to sound an alarm in those locations where prompt corrective action can be taken.

J.13
Temperature-sensing elements connected to alarms or machine stop switches should be employed for locations where overheating of bearings or other elements might occur.

J.14
Open-bin storage is not desirable. Storage bins for powders should be sealed and purged with inert gas prior to filling.

Annex K Design for Dust Concentration Control in Ductwork (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

K.1 Introduction.
The finer the dust particle size, the more easily it disperses, the longer it takes to settle, and the easier it is to ignite. For a metal–air dust cloud to experience a deflagration (explosion), the following two conditions are necessary:

1. An ignitable concentration of dust in air
2. An ignition source of sufficient strength to ignite the combustible dust-air mixture

Research conducted by the U.S. Bureau of Mines and others over many years has established values for these parameters. In using these data for the design of industrial equipment and systems, it should be kept in mind that other factors such as metal purity, particle size distribution, moisture, ambient pressure and temperature, and turbulence all affect the exact conditions for initiating explosions in such dust clouds.

Some aspects of safe collection and conveying of combustible metal dust from an air stream in an AMS,
such as a cyclone or dust collector, include ensuring that upstream duct velocities are sufficient to prevent the dust settling out and that upstream duct concentrations are below the MEC to prevent explosion within the ductwork. NFPA 91 addresses the duct design and velocities while NFPA 69 provides prescriptive options for explosion prevention by concentration control. Depending on the MEC and ability to determine the in-process dust concentration, either minimum duct velocity or operation below the MEC could be controlling. The dust concentration within the AMS necessarily increases above the MEC, and other explosion prevention/protection techniques must be applied. An AMS could be located outdoors with restricted access or be protected with explosion suppression or explosion venting in accordance with NFPA 69 or NFPA 68, respectively.

For combustible metal dust, the minimum recommended duct velocity to prevent saltation in horizontal lines and drop-out in vertical lines is a superficial air velocity of 1372 m/min (4500 ft/min). If the dust is sticky, the particle size is large, the density is high, or the vertical distance is excessive, higher air velocity could be necessary. This minimum air velocity should be maintained at all locations within the duct system, both before and after each system inlet. Refer to the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*.

If the concentration is only determined or measured occasionally, NFPA 69 concurrently requires that the dust concentration should be no more than 25 percent of the MEC. Where it is feasible to continuously monitor (i.e., determine or measure) the dust concentration and control the process with interlocks, NFPA 69 permits operation at up to 60 percent of the MEC. Dust concentration should be maintained below the maximum at all locations within the duct system, yet an interlock will most often be based on the concentration measured at a single point considered to be the worst-case (highest) concentration upstream of the AMS.

In a powder production system, the dust flow rate could be determined from the feed rate to the atomizing process, while air rate could be determined from differential fan pressure and the fan flow curve or be directly measured. Using a calculation, such a system could be interlocked for operation up to 60 percent of the MEC in accordance with NFPA 69. On the other hand, a fugitive dust collection system will likely have a range of inlet dust rates, depending on current operations, and a design air flow rate. Such a system can be sampled occasionally to determine dust concentration and be designed for operation at 25 percent of the MEC in accordance with NFPA 69.

**K.2 Example 1 — Powder Production with Known Rate.**

For a particular sample of unalloyed magnesium dust, the MEC was determined to be 0.03 kg/m³ (0.03 oz/ft³) in accordance with ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*.

To transport a controlled, maximum rate of 4.54 kg/min (10 lb/min) of fine, less than 100 mesh [less than 150 μm (0.0059 in.)] magnesium powder introduced uniformly into an air-conveying system, NFPA 69 permits operation at up to 60 percent of the MEC with application of continuous concentration determination and an interlock. The maximum design dust concentration is then as follows:
The fan can be selected to provide enough conveying air, evaluated at standard temperature and pressure, to keep the dust concentration below the maximum. MEC is determined at nominal atmospheric pressure and room temperature, so airflow should be evaluated at those conditions.

For SI units, airflow is determined as follows:

\[ \text{Airflow needed} = \frac{4.54 \text{ kg/min}}{0.018 \text{ kg/m}^3} = 252.2 \text{ m}^3/\text{min} \]

For U.S. units, airflow is determined as follows:

\[ \text{Airflow needed} = \frac{10 \text{ lb/min} \times 16 \text{ oz/lb}}{0.018 \text{ oz/ft}^3} = 8888 \text{ ft}^3/\text{min} \]

Care should be taken, however, to maintain sufficient superficial air velocity [over 1372 m/min (4500 ft/min)] in the duct system as mentioned above. If the initial design is a 500 mm (19.7 inch) diameter round duct, the minimum velocity at the inlet would be as written below.

For SI units, the minimum velocity is determined as follows:

\[
V = \frac{Q}{A} = \frac{252.2 \text{ m}^3/\text{min}}{\left(\frac{500}{1000}\right)^2 \cdot \pi \cdot \frac{4}{4}} = 1284 \text{ m/\text{min}}
\]

For U.S. units, the minimum velocity is determined as follows:

\[ [K.2e] \]
This is slightly below the recommended minimum duct velocity, therefore fan capacity should be increased to at least 269.4 m³/min (9525 ft³/min).

K.3 Example 2 — Fugitive Dust Collection with Variable Rate.
Fugitive dust collection design begins with collection hood design and necessary capture velocity. For further information, refer to ACGIH’s publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*. Often the number and type of collection hoods determines the initial design of the system as each hood’s airflow is combined with the header. The minimum duct velocity controls at this stage. Where the fugitive dust generation rate can be estimated, the concentration at the collection hood can be determined as a check on the design. Where instrumentation is provided to monitor the process flows, typically only the airflow, NFPA 69 permits design for operation at up to 25 percent of the MEC. The maximum design dust concentration is then as follows:

\[ V = \frac{\varphi}{4} = \frac{8888 \text{ ft}^3/\text{min}}{\left(\frac{19.7}{12}\right)^2 \cdot \left(\frac{12}{4}\right) \text{ ft}^2} = 4198 \text{ ft} / \text{min} \]

\[ \pi \cdot \left(\frac{19.7}{12}\right)^2 \cdot \left(\frac{12}{4}\right) \text{ ft}^2 \]

If the fugitive dust collection rate was approximately the same 4.54 kg/min (10 lb/min) as in Example 1 in K.2, the minimum airflow would be much larger.

For SI units, airflow is determined as follows:

\[ \text{Airflow needed} = \frac{4.54 \text{ kg/min}}{0.0075 \text{ kg/m}^3} = 605 \text{ m}^3/\text{min} \]

For U.S. units, airflow is determined as follows:

\[ \text{Airflow needed} = \frac{4.54 \text{ lb/min}}{0.0075 \text{ lb/ft}^3} = 605 \text{ ft}^3/\text{min} \]
Annex L Supplementary Information on Tantalum (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

L.1 History.
Tantalus was a Greek mythological character and the father of Niobe. Tantalum was discovered in 1802 by Ekeberg, but many chemists thought niobium and tantalum were identical elements until Rowe, in 1844, and Marignac, in 1866, showed that niobic and tantalic acids were two different acids. The early investigators isolated only the impure metal. Von Bolton produced the first pure ductile tantalum in 1903. Tantalum occurs principally in mineral columbite-tantalite. Tantalum ores are found in Australia, Brazil, Mozambique, China, Thailand, Portugal, Nigeria, Zaire, and Canada.

The production of tantalum involves separation of the pure tantalum from niobium through a process of steps. Several methods are used to produce the element commercially, including electrolysis of molten potassium fluorotantalate, reduction of potassium fluorotantalate with sodium, and reacting tantalum carbide with tantalum oxide. Twenty-five isotopes of tantalum are known to exist. Natural tantalum contains two isotopes.

L.2 Properties.
Tantalum is a gray, heavy, and very hard metal. Pure tantalum is ductile and can be drawn into fine wire, which is used as a filament for evaporating metals such as aluminum. Tantalum is almost completely immune to chemical attack at temperatures below 150°C (302°F) and is attacked only by hydrofluoric acid, acidic solutions containing fluoride ion, and free sulfur trioxide. Alkalies attack it only slowly. At high temperatures, tantalum becomes much more reactive. The element has a melting point exceeded only by that of tungsten and rhenium. Tantalum is used to make a variety of alloys with such desirable properties as high melting point, high strength, and good ductility. Tantalum has a good gettering ability at high temperatures, and tantalum oxide films are stable and have good rectifying and dielectric properties.

Table L.2 provides more information on the properties of tantalum.

<table>
<thead>
<tr>
<th>Atomic symbol: Ta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number: 73</td>
</tr>
<tr>
<td>Atomic weight: 180.9479</td>
</tr>
</tbody>
</table>
Specific gravity: 16.654  
Melting point: 2996°C (5425°F)  
Boiling point: 5425°C, ±100°C (9796°F, ±180°F)  
Electron configuration: -32-11-2  
Electronegativity valence: 2, 3, 4, or 5

L.3 Combustibility and Explosiveness.

L.3.1 General.
Fire and explosion hazards associated with tantalum powders are high. The degree of danger generally correlates to the surface area and structural complexity of the powder. Additionally, the test data indicate that fire and explosion hazards associated with tantalum powders also correlate to the amount of processing the material has undergone. The degree of processing roughly correlates to surface area in a given tantalum powder. Generally, as powders are processed through manufacturing, they lose surface area with each successive process step. This is most specifically true for sodium-reduced tantalum powders. Some properties of tantalum powder combustibility remain independent of either surface area or the amount of processing.

Two distinct types of tantalum powders are manufactured. The largest market segment is tantalum powder manufactured via the direct reduction of intermediate tantalum fluoride salts using liquid sodium metal. This material is called sodium reduced. A smaller market segment comprises tantalum powders manufactured through electron beam (EB) melting of tantalum electrodes or ingots. These materials are referred to as beam melt powders. Sodium-reduced materials normally are much higher in surface area than are beam melt powders.

High-surface-area tantalum powders are overwhelmingly used in the manufacture of tantalum capacitors. The production cycle of tantalum powders for capacitors generally can be broken down into three main processing steps. The first is the manufacture of the partly refined metal powder. Tantalum powders at this stage are called primary powders. Next, the primary powders are heat treated under vacuum or inert gas to build a more complex structure. These materials are called agglomerated or presintered. Finally, the presintered materials are generally chemically deoxidized and rendered into finished commercial powders.

Because of tantalum’s particular chemistry and reactivity, all inerting of tantalum powders is performed using argon or helium. Other typical inerting gases, such as nitrogen or carbon dioxide, cannot be used. Under specific conditions, tantalum reacts with nitrogen in a strongly exothermic reaction. As such, use of nitrogen to inert material can, under certain conditions, present a significant fire risk. Carbon dioxide is inappropriate as an inerting gas owing to reaction with tantalum powders in which carbon remains as a contaminant. Carbon contamination of tantalum powders severely affects the performance characteristics of the tantalum powder.

L.3.1.1 Minimum Ignition Energy — Sodium-Reduced Tantalum Powders.
For tantalum powders with surface areas in excess of 0.25 m²/g (1221 ft²/lb), minimum ignition energy (MIE) of a dust cloud has been measured consistently at less than 3 mJ (3.17 Btu). This value is independent of process condition and surface area for materials above 0.25 m²/g (1221 ft²/lb). It should be noted that, as the surface area of tantalum powders becomes more uniform and the surface structure becomes very low (particles become coarse and “gravelly”), the MIE increases dramatically. These types of powders can exhibit MIEs in excess of 500 mJ (528 Btu). The overwhelming majority of commercially produced tantalum powders falls into the former category, with extreme risk of dust cloud ignition owing to the low MIE.

L.3.1.2 Minimum Ignition Temperature of a Dust Cloud — Sodium-Reduced Tantalum Powders. The temperature of ignition of a suspended dust cloud for tantalum powder closely follows the condition or processing of the powder. Primary powders, independent of surface area, generally display minimum ignition temperatures for dust clouds in excess of 800°C (1472°F). Finished commercial tantalum powders display minimum ignition temperatures for dust clouds that correlate inversely to the surface area of the powder. That is, high-surface-area powders possess low minimum ignition temperatures for dust clouds. Low-surface-area powders possess higher minimum ignition temperatures for dust clouds. For finished-condition powders, minimum ignition temperatures of dust clouds range from 400°C to 600°C (752°F to 1112°F).

L.3.1.3 Minimum Ignition Temperature of a Dust Layer — Sodium-Reduced Tantalum Powders. Data are available only for primary powders. This property also correlates inversely to powder surface area; that is, as powder surface area increases, the minimum ignition temperature of dust layers decreases.

L.3.1.4 Limiting Oxygen Concentration — Sodium-Reduced Tantalum Powders. Limiting oxygen concentration (LOC) is defined as the concentration of oxygen in an inerted atmosphere at which tantalum powder combustion is not possible. For tantalum powders, LOC is directly related to the amount of processing that the material undergoes. Primary powders present the lowest LOC requirement, independent of surface area. The LOC of primary powders has been measured at 2 percent oxygen numerous times. Presintered powders possess LOC values of 4 percent. Finished powders, independent of surface area, possess LOC values of 6 percent to 8 percent oxygen. It is recommended that all inverting of tantalum powders, independent of the amount of processing, be practiced to the lowest level measured, that is, 2 percent residual oxygen.

L.3.1.5 Minimum Ignition Energy — Beam Melt Tantalum Powder. Electron beam (EB) melt powders display, generally, significantly higher MIEs than do sodium-reduced tantalum powders. MIE correlates inversely to the surface area of the powder; that is, lower-surface-area powders possess higher MIEs, and higher-surface-area powders possess lower MIEs.

L.3.1.6 Minimum Ignition Temperature of a Dust Cloud — Beam Melt Tantalum Powder. Minimum ignition temperatures of dust clouds of beam melt tantalum powders correlate inversely to the powder surface area. Low-surface-area powders possess higher minimum ignition temperatures for dust clouds than do higher-surface-area electron beam melt tantalum powders. Overall, the range of
temperatures for ignition of dust clouds is generally consistent with those of sodium-reduced tantalum powders.

L.3.1.7 Minimum Ignition Temperature of a Dust Layer — Electron Beam Melt Tantalum Powder.
Ignition temperatures of dust layers of EB melt tantalum powders also correlate inversely to powder surface area.

L.3.1.8 Limiting Oxygen Concentration — Electron Beam Melt Tantalum Powders.
LOC data for EB melt powders are consistent with sodium-reduced powders. The level of LOC follows the amount of processing the material has received. Finished powders display LOC values of 6 percent to 8 percent oxygen.

L.3.2 Fire History.
Fire history is still to be developed.

L.3.3 Explosive Limits for Tantalum Powders.
Explosivity characteristics of tantalum powders have been measured and found to be directly proportional to the surface area of the tantalum powder. As the powder surface area increases, the maximum explosion pressure, the maximum rate of pressure rise, and the $K_{St}$ value all increase.

L.3.3.1 Maximum Explosion Pressure of Tantalum Powders.
Maximum explosion pressure has been measured for sodium-reduced tantalum powders in the range of 0.4 $M^2/g$ to 1.2 $M^2/g$ (1954 ft$^2$/lb to 5862 ft$^2$/lb). Maximum explosion pressure was 3.7 bar (54 psi) for the 0.4 $m^2/g$ (1954 ft$^2$/lb) surface area and 6 bar (87 psi) for the 1.2 $m^2/g$ (5862 ft$^2$/lb) surface area powder. The change was calculated as 2.9 bar/m$^2$/g (205,475 psi/ft$^2$/lb).

L.3.3.2 Maximum Rate of Pressure Rise of Tantalum Powders.
Maximum rate of pressure rise also correlates positively with the powder surface area. The maximum rate of pressure rise of a 0.4 $m^2/g$ (1954 ft$^2$/lb) tantalum powder was 358 bar/s (5192 psi/sec), while that of a 1.2 $m^2/g$ (5862 ft$^2$/lb) powder was 549 bar/sec (7962 psi/sec). The rate of change was calculated as 239 bar · m$^2$/sec · g (0.71 psi · ft$^2$/sec·lb).

L.3.3.3 $K_{St}$.
$K_{St}$ is the measure of explosion severity and is calculated as the product of the cube root of the test vessel volume and the maximum rate of pressure rise recorded during the test. The $K_{St}$ value has been measured for a 1.2 $m^2/g$ (5862 ft$^2$/lb) surface area tantalum powder at 149 bar · m/sec (7088 psi · ft/sec). The $K_{St}$ value for a 0.4 $m^2/g$ (1954 ft$^2$/lb) tantalum powder was measured at 97 bar · m/sec (4614 psi · ft/sec). The rate of change in $K_{St}$ per change in surface area was calculated as 65 bar · m/sec/m$^2$/g [1.15 (psi · ft/sec)/ft$^2$/16]. For the powders tested, the $K_{St}$ of tantalum powders indicated that they fall into the category of weak explosion hazard.

L.3.3.4 Explosivity Limits for Tantalum Powders.
The lower explosivity limit for tantalum powder of 1.2 $m^2/g$ (5862 ft$^2$/lb) surface area has been measured
as 160 g/m³ (0.01 lb/ft³) to 165 g/m³ (0.0103 lb/ft³). The upper explosivity limit has not been determined.

L.3.4 Explosion History.
Because of their high surface areas and low MIEs, tantalum powders present a very real explosion hazard.

L.4 Hazards.

L.4.1
Tantalum powders at elevated temperatures can react when introduced to moisture or water. The tantalum can react violently, causing spattering or popping of the powder material.

L.5 Special Hazards: Electrostatics.

L.5.1 Surface Potential.
Static electricity is generated when two materials contact and then separate from each other. The charge level and the voltage level on the material depend on the rate of charge generation and the particular charge relaxation time of the material. Measurements have been made of the surface potential or voltage imparted to tantalum powders during normal processing operations, such as pouring or pneumatic conveyance.

It has been found that pouring operations involving stainless steel containers, whether grounded or ungrounded, resulted in no measurable surface potential being generated on the tantalum powders. For insulating materials, such as plastic or glass, surface charge was measured on tantalum powders. The magnitude of the surface charge was a direct function of the ambient humidity. Low-humidity conditions resulted in higher surface potential being generated onto the tantalum powders. (See Table L.5.1.)

<table>
<thead>
<tr>
<th>Container Material</th>
<th>Low Humidity (27%)</th>
<th>High Humidity (67%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel — ungrounded</td>
<td>0 kV</td>
<td>0 kV</td>
</tr>
<tr>
<td>Stainless steel — grounded</td>
<td>0 kV</td>
<td>0 kV</td>
</tr>
<tr>
<td>Glass</td>
<td>0.7 kV</td>
<td>0.4 kV</td>
</tr>
<tr>
<td>Plastic</td>
<td>0.6 kV</td>
<td>0.5 kV</td>
</tr>
</tbody>
</table>

L.5.2 Resistance to Ground.
Resistance to ground was measured for a 1.0 m²/g surface area tantalum powder. The resistance to ground was measured in the range of 2.5 × 10⁵ ohms to 7.8 × 10⁸ ohms. It was found that the resistance to ground decreased as the measurement probe was pushed deeper and deeper into a bulked sample of tantalum powder.
L.5.3 Charge Relaxation Time.
Charge relaxation time is defined as the time for the charge on an object to decrease or relax by conduction to a level of 1/e, or 37 percent of the initial measured value. When tested under both low- and high-humidity conditions, tantalum powder was found to exhibit a charge relaxation time of less than 1 second. This value for charge relaxation time is consistent with materials considered to be of low resistivity.

L.5.4 Powder Chargeability.
Chargeability testing on tantalum powders has been conducted to determine the charge per unit mass of material that can be developed during normal industrial operations, which typically include pouring, pneumatic conveying, sieving, blending, milling, or crushing. For tantalum powders during pneumatic conveying, the charge per unit mass or charge density increases as the conveying velocity increases. For any given conveyance velocity, the charge density on tantalum powders decreases as the flow rate of the powder increases. The decrease is explained by the fact that, as the flow rate decreases, the number of individual contacts with the process equipment per unit time increases, resulting in higher generation of charge density.

Material of construction also affects the charge density of the tantalum powder. Charge density increases when tantalum powders are handled through insulating materials such as plastics and glasses. When processed through plastics, the polarity of the charge measured on tantalum powders alternated between positive and negative. (See Table L.5.4.)

Table L.5.4 Chargeability of Tantalum Powders

<table>
<thead>
<tr>
<th>Materials</th>
<th>Average Charge per Unit Mass (C/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient humidity (67%)</td>
<td></td>
</tr>
<tr>
<td>Stainless steel</td>
<td>−2.9 × 10^{-6}</td>
</tr>
<tr>
<td>Plastic</td>
<td>−1.0 × 10^{-5} to 7.3 × 10^{-6}</td>
</tr>
<tr>
<td>Glass</td>
<td>−5.3 × 10^{-5}</td>
</tr>
<tr>
<td>Low humidity (27%)</td>
<td></td>
</tr>
<tr>
<td>Stainless steel</td>
<td>−6.1 × 10^{-6}</td>
</tr>
<tr>
<td>Plastic</td>
<td>−7.7 × 10^{-5}</td>
</tr>
<tr>
<td>Glass</td>
<td>−4.7 × 10^{-5}</td>
</tr>
</tbody>
</table>

Powdered materials that display a charge per unit mass of 1 × 10^{-3} C/kg or greater are considered high-chargeability materials. Materials that exhibit charge per unit mass equal to or less than 1 × 10^{-7} C/kg are considered low-chargeability materials. Those materials that fall in between are considered moderate-chargeability materials. Tantalum powders are considered moderate-chargeability materials.

L.5.5 Volume Resistivity.
Volume resistivity of tantalum is humidity dependent, displaying higher values at conditions of low humidity. At ambient humidity (67 percent), the volume resistivity of tantalum powder is 3.3 × 10^{-1} ohm-m. At low humidity (27 percent), volume resistivity of tantalum powder is 1.3 ohm-m. These values of
volume resistivity are consistent with low-resistivity materials.

L.6 Applications.
Scientists at Los Alamos have produced a tantalum carbide graphite composite material, which is said to be one of the hardest materials ever made. The compound has a melting point of 3738°C (6850°F). Tantalum is used to make electrolytic capacitors and vacuum furnace parts, which account for about 60 percent of its use. The metal is also widely used to fabricate chemical process equipment, nuclear reactors, aircraft, and missile parts.

Tantalum is completely immune to body liquids and is a nonirritating material. It has, therefore, found wide use in making surgical appliances. Tantalum oxide is used to make special glass with high index of refraction for camera lenses. The metal has many other uses.

L.7 Production.
Electron beam (EB) melting is the most effective method for the refining of high-purity tantalum metal. The process is operated at a high vacuum [generally less than 10⁻⁴ kPa (10⁻³ mbar)] and high temperature [greater than 3000°C (5432°F)].

Vacuum arc remelting (VAR) is the melting process used to alloy tantalum with other metals. This process also operates at high temperature [greater than 3000°C (5432°F)]. However, it differs from EB melting, because it can operate with either a high vacuum or partial absolute pressure in the furnace chamber of 0.1 kPa to 3.5 kPa (0.0145 psi to 0.5 psi).

The plasma arc melting (PAM) process operates at high temperature [greater than 3000°C (5432°F)]. However, the furnace chamber atmosphere is maintained above an absolute pressure of 28 kPa (4 psi) using argon, helium, or a mixture of reactive gases. PAM can be used to alloy tantalum with other metals or to consolidate scrap.

Tantalum and tantalum alloy powders are produced by various means. These processes, as well as certain finishing and transporting operations, tend to expose a continuously increasing area of new metal surface. Most metals immediately undergo a surface reaction with available atmospheric oxygen that forms a protective coating of metal oxide that serves as an impervious layer to inhibit further oxidation. This reaction is exothermic. If a fine or thin lightweight particle having a large surface area of "new" metal is suddenly exposed to the atmosphere, sufficient heat will be generated to raise its temperature to the ignition point. Completely inert gas generally cannot be used as an inerting medium, because the tantalum powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the nonreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion. To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation, while materially reducing the fire and explosion hazard.

A completely inert gas can be used if the powder so produced will not be exposed to air.
Annex M Supplementary Information on Titanium (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

M.1 Commercial Production.
Commercial production of titanium began in 1948 in a plant whose capacity was less than 18,140 kg (20 tons) per year. By 1951, fulfillment of the needs of the U.S. military had brought about tremendous strides in the titanium industry. Large-scale commercial production had become a reality.

Titanium-bearing ores are plentiful and widely scattered throughout the world, including the United States, the principal ores being rutile and ilmenite. At present, rutile is the more desirable of the two for recovery of titanium. However, it is the ore in shortest supply, coming primarily from deposits in Australia, South Africa, and Sierra Leone.

It is generally recognized that, in time, the greatest tonnage of titanium might be processed from ilmenite ore. Ilmenite mines in the United States are located at Tahawas, NY; Highland, Starke, and Green Cove Springs, FL; and Manchester, NJ.

Titanium sponge is currently produced in the United States, Japan, England, and countries in the former Soviet Union. Three basic processes have been developed for commercial refining of titanium from rutile ore. The most widely used processes employ magnesium or sodium to reduce titanium tetrachloride. An electrolytic process has proved practical, and development of a commercial version is underway.

Titanium ingot is produced by arc melting a consumable electrode of compacted sponge or sponge and alloy into a cooled copper mold under a low vacuum or an inert atmosphere.

M.2 Properties.
Titanium is a silver-gray light metal, about 60 percent heavier than aluminum, but only 56 percent as heavy as alloy steel. Its atomic weight is 47.90, its specific gravity is 4.5, and its melting point is 1727°C (3141°F). Titanium-based alloys are stronger than aluminum alloys and most alloy steels, have excellent ductility, and are superior to all the usual engineering metals and alloys in strength/weight ratio. Their fatigue resistance (ability to resist repeated flexures) is above that of heat-treated alloy steels and far greater than those of nonferrous metals. Titanium alloys are harder than aluminum and almost as hard as the high-alloy steels. Surface hardness comparable to nitrided steel is obtainable.

Titanium is highly corrosion resistant, being greatly superior to aluminum; considerably better than many specialty steels; and unique, compared to commonly available metals, in its immunity to saltwater and marine atmospheres. It is the only known structural metal that is highly resistant to simultaneous exposure to seawater and air. However, it is subject to stress corrosion cracking in methanol containing less than 0.8 percent water. Also, crevice corrosion can be expected in chlorine systems.
Titanium-based alloys can be subject to cracking during hot-forming operations if they are in contact with halide salts. Manufacturers’ recommendations should be sought if applications are considered where high-strength alloys are expected to come into contact with halide salts at temperatures above 260°C (500°F).

Impact resistance (capacity to withstand shock) of titanium is superior to that of aluminum; some titanium alloys approach heat-treated steel in impact resistance. Titanium alloys commonly lose strength above 540°C (1004°F) and can become embrittled after extended exposure to air at temperatures above 430°C (806°F).

Normal compositions of some widely used titanium alloys include the following:

1. Titanium, 90 percent; aluminum, 6 percent; vanadium, 4 percent
2. Titanium, 92.5 percent; aluminum, 5 percent; tin, 2.5 percent
3. Titanium, 90 percent; aluminum, 8 percent; molybdenum, 1 percent; vanadium, 1 percent
4. Titanium, 86 percent; aluminum, 6 percent; vanadium, 6 percent; tin, 2 percent
5. Titanium, 92 percent; manganese, 8 percent

Titanium presents some fire hazards during production of the raw sponge, melting of the sponge, casting, machining that produces fine turnings or chips, powder production and handling, and disposal of scrap containing chips or fines. However, because of its high-temperature-resistance properties in solid form, titanium sheet is extensively used for fire walls in jet aircraft and spacecraft.

In molten form, titanium either dissolves or is contaminated by every known refractory.

Slight contaminations apparently have little effect on the flammable characteristics of chips, turnings, or powder produced in machining operations but might have an important bearing on ignition and explosion hazards associated with acid or salt baths.

Titanium combines readily with oxygen, nitrogen, and hydrogen at temperatures considerably below its melting point. Freshly exposed surfaces tend to form an adherent oxide coating quickly. This oxide coating is evidenced by discoloration that dissolves as temperature increases. Excessive oxidation can cause embrittlement.

**M.3 Tests for Titanium.**
Two relatively simple methods are used to distinguish titanium from other metals.

**M.3.1 Spark Test.**
Distinctive sparks are thrown off when a piece of titanium is held against a grinding wheel. The white lines traced by the flying sparks end with a burst that produces several brilliant white rays or branches.

**M.3.2 Glass Test.**
The softer grades of titanium and titanium alloys are able to wet glass and can be identified by rubbing a moistened piece of the metal on a piece of glass. If the metal is relatively soft titanium, it will leave
distinctive gray-white marks on the glass. A portable metal spectroscope will better serve the purpose in an attempt to identify titanium scrap by grade.

**M.4 Applications.**
While titanium has many uses, production is still largely consumed by commercial and military aircraft applications for use in jet engines, aircraft frames, and outer skin covering on subsonic and supersonic aircraft. Titanium is also being used in space vehicles and communications satellites. Other military uses include armor plate, electrical components, pontoons, cables, structural braces, fire walls, personnel helmets, and protective vests.

Titanium's virtually complete immunity to atmospheric and saltwater corrosion and to such agents as wet chlorine, nitric acid, and most oxidizing chemicals makes it attractive for chemical process applications such as heat exchangers, dryers, mixers, and other equipment.

Specially prepared, very finely divided titanium powders find limited application in powder metallurgy and other relatively small-scale uses.

**M.5 Combustibility and Explosibility.**
In tests conducted by the U.S. Bureau of Mines with titanium powders of less than 200 mesh, ignition of dust clouds in air was obtained at temperatures from 332°C to 587°C (630°F to 1090°F). Ignition of dust layers occurred at temperatures from 382°C to 510°C (720°F to 950°F). In some cases, dust clouds ignited at lower temperatures than static layers of the same dust. *(See U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders," and RI 4835, "Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and Their Hydrides."
)* Titanium fines, nominally under 48 mesh, a by-product of sponge production and handling, and coarser particles, such as swarf from sawing and grinding operations, can be ignited by a spark.

Tests conducted by Underwriters Laboratories showed that dry ductile titanium in the form of thin chips and fine turnings could be ignited with a match. Normal-size machine chips and turnings ignited and burned when heated in the flame of a Bunsen or blast burner. When ignited, titanium sponge or coarse turnings burn slowly with the release of a large quantity of heat, although a sponge fire can spread rapidly immediately after ignition.

Heavy castings or ingots of titanium can give some indication of burning when being cut with an oxyacetylene torch, but when enough surface is available to permit radiation cooling below the ignition temperature, burning ceases when the torch is removed.

Titanium can burn in atmospheres other than air. For example, one titanium powder sample, which ignited in air as a cloud at 480°C (896°F) and as a layer at 471°C (880°F), also ignited as a layer in pure carbon dioxide at 680°C (1260°F). At red heat, about 704°C (1300°F), titanium will decompose steam to free hydrogen and oxygen. Above 800°C (1470°F), titanium burns readily and vigorously in atmospheres of pure nitrogen.
Titanium will burn in the presence of dry chlorine or oxygen at room temperature. In oxygen, the combustion is not spontaneous and occurs only with oxygen concentration above 35 percent at gauge pressures over 2410 kPa (350 psi) when a fresh surface is created. The actual hazard in air is much less than that for aluminum.

**M.6 Special Hazards.**
In spite of titanium's superior resistance to corrosion, as discussed in Section M.2, titanium can react vigorously or even explosively with some hazardous materials. For example, extreme care should be taken when using titanium metal or powder in red fuming nitric acid. While no problems have been reported with normal nitric acid, explosions have occurred in laboratory tests involving titanium and red fuming nitric acid.

These incidents have never been completely explained, although it is believed that the strength of the acid is a controlling factor and that some pyrophoric material is produced, which, when disturbed, releases enough heat to permit rapid oxidation of the metal. Potentially hazardous reactions between titanium and various chemicals are listed in NFPA's *Fire Protection Guide to Hazardous Materials*.

Low-melting eutectics can form when titanium or its alloys are in contact with metals such as iron, nickel, or copper at high temperatures. Phase diagrams for titanium, such as those in *ASM Handbook, Volume 1: Properties and Selection: Irons, Steels, and High-Performance Alloys*, and *ASM Handbook, Volume 2: Properties and Selection: Nonferrous Alloys and Special-Purpose Materials*, should be consulted in such potential situations.

Titanium engages in thermite-type reactions with iron oxides.

Caution should be exercised in introducing titanium into process environments not previously investigated, because titanium can react and, in some cases, become pyrophoric.

**M.7 Spontaneous Combustion.**
Spontaneous ignition has occurred in fine, water-soluble, oil-coated titanium chips and swarf. Such fires, while probably due mostly to the presence of oil and certain contaminants, are difficult to control, and special precautions should be taken so that all fine scrap and oil-covered material is removed from the plant and stored where any possible fire can be segregated and prevented from exposing other combustible material. Dry titanium fines collected in cyclones have, on occasion, ignited spontaneously when allowed to drop freely through the air. Also, sump fines will often ignite when they are dried.

During the early stages of the development of the titanium industry, thin titanium sheets were reported to have ignited spontaneously as they were removed from a sodium hydride descaling bath. However, the use of a potassium hydride solution in recent years has eliminated that problem.

Like any other metal in the high-temperature molten state, titanium can cause a violently destructive explosion if water is present in any mold, pit, or depression into which the molten metal is poured or spilled. Under such circumstances, severe damage can be caused by steam pressure, an exothermic
chemical reaction, or a low-order hydrogen–air explosion.

In the 1950s, several violent explosions occurred in consumable electrode furnaces when water entered the furnace because of a crucible failure. The failures resulted from loss of cooling waterflow and severe arc-through. A committee of industry representatives prepared a set of general recommendations on the design of melting furnaces to improve process safety. Their recommendations, given consideration in Chapter 12, can be found in General Recommendations on Design Features for Titanium and Zirconium Production-Melting Furnaces, published by the Defense Metals Information Center of Battelle Memorial Institute.

M.8 Process Description.
Current titanium production processes involve reduction of titanium tetrachloride to titanium metal. The titanium tetrachloride (TiCl₄) is made from rutile ore (approximately 95 percent titanium dioxide) by high-temperature reaction with chlorine in the presence of a reducing agent, usually carbon. There are two basic commercially used processes for reduction of titanium: the Kroll–Bureau of Mines process, which uses magnesium as the reducing agent, and the sodium process, which uses liquid sodium as the reducing agent. Pilot plant work to develop a commercial electrolytic process is underway. The resulting product of all the processes is referred to as titanium sponge.

In the Kroll–Bureau of Mines process, purified titanium tetrachloride is fed into a steel reaction chamber containing molten magnesium. The reduction takes place under an inert gas blanket of argon or helium and at temperatures between 700°C (1290°F) and 900°C (1650°F). The products of the reduction are magnesium chloride and titanium sponge, so called because of the spongy appearance of the titanium. The magnesium chloride is drawn off in the molten state for recycling or for reprocessing to magnesium and chlorine. After cooling, the sponge mass is bored from the reactor vessel and crushed in a “dry room.” Any residual magnesium or magnesium chloride is removed by acid leaching or vacuum distilling. A modified version of the Kroll process involves vacuum distillation in the reaction vessel before removal of the sponge, thus eliminating the dry room. A detailed description of the Kroll process and equipment is contained in the U.S. Bureau of Mines, RI 4879, “Recent Practice at the Bureau of Mines, Boulder City, NV, Titanium Plant.” A description by Powell, “Chemical Engineering Aspects of Titanium Metal Production,” appears in the AIChE publication Chemical Engineering Progress, March 1954.

In the sodium-reduction process, liquefied sodium is used as the reducing agent. In this process, the reaction vessel is heated to approximately 1000°C (1830°F), and no withdrawal of by-product during the reduction cycle is required. After completion of the reduction cycle, the reactor contains a solid mixture of titanium sponge and sodium chloride (called “spalt”). After the cooling cycle, this solid mixture is usually bored from the reaction vessel. A dry room is not required. The spalt is vacuum dried after removal from the reaction vessel. The sodium-reduction process is described by Forbath in “Sodium Reduction Route Yields Titanium,” in the AIChE publication Chemical Engineering Progress, March 1958.

In the electrolytic process being developed, titanium tetrachloride is fed into a cell containing a molten salt bath (usually sodium chloride), where it is reduced to crystalline metal by fused salt electrolysis. The crystalline mass must be crushed, leached, and dried after removal from the cell. Although this process is
commercially feasible, it has not yet been used significantly.

The titanium-sponge fire risk is affected by the process used. The sodium-reduction process and the electrolytic process produce a sponge that is less apt to be pyrophoric than magnesium-reduced sponge. The fines resulting from the crushing operation of those two processes, likewise, tend to be less pyrophoric.

**Annex N Supplementary Information on Zirconium (CMD-CMM)**

*This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.*

**N.1 History.**

Klaproth first reported the discovery of the element zirconium in 1789 during his analysis of the precious stone called jargon. Other chemists confirmed his discovery, and in 1797 Vauquelin reported on some of its properties and detailed its preparation. At that time, it was called zirconia. Berzelius first isolated the impure metal in 1824, but it was not until 1925 that the ductile metal was produced by van Arkel and deBoer, using their hot-wire reduction process.

A commercial-scale production process for making ductile zirconium was developed at the U.S. Bureau of Mines Laboratories, where Dr. Wilhelm Kroll served as consultant and adviser for the process that bears his name.

**N.2 Properties.**

**N.2.1**

Zirconium is a silver-gray metal having a close-packed hexagonal crystal structure at room temperature. At 862°C (1584°F), the crystal structure changes to a body-centered cubic structure. Both structures are very ductile, and the metal is easily machined, rolled, and extruded using conventional equipment and methods.

**N.2.2**

Some of the physical properties of zirconium are shown in Table N.2.2.

<table>
<thead>
<tr>
<th>Atomic symbol: Zr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number: 40</td>
</tr>
<tr>
<td>Atomic weight: 91.22</td>
</tr>
<tr>
<td>Atomic radius: 1.60 angstrom units</td>
</tr>
<tr>
<td>Specific gravity: 6.5</td>
</tr>
<tr>
<td>Melting point: 1850°C (3360°F)</td>
</tr>
</tbody>
</table>
Boiling point: 3580°C (6475°F)
Electronegativity: 1.6
Valence: +4 (in most chemical reactions)

N.2.3
Zirconium has a very low capture cross section for thermal neutrons (0.18 barns). Its principal alloys have outstanding resistance to corrosion in water and steam at high temperatures. These properties make zirconium desirable as a cladding material for fuel elements in water-cooled nuclear power reactors. However, it becomes embrittled and loses strength on long-term exposure to air at temperatures above 540°C (1004°F).

N.3 Combustibility and Explosibility.

N.3.1
In laboratory tests, a dust cloud of fine particles of zirconium with an average particle diameter of 3.3 μm ignited spontaneously at 20°C (68°F). Powder having an average particle diameter of 17.9 μm would not ignite under similar circumstances until heated to 350°C (662°F). Similar clouds in carbon dioxide had to be heated to 550°C (1022°F) for ignition to occur. In atmospheres of air and helium, at least 5 percent oxygen had to be present to obtain spark ignition of zirconium dust clouds.

N.3.2
Layers of zirconium powder on hot surfaces ignited at 190°C (374°F) in air; at 620°C (1148°F) in carbon dioxide; and at 790°C (1454°F) in nitrogen.

N.3.3
The minimum explosive concentration for zirconium dust in air was found to be 40.5 g/m³ (0.04 oz/ft³). At concentrations of 1000 g/m³ (1.0 oz/ft³), the maximum explosion gauge pressure was 524 kPa to 538 kPa (76 psi to 78 psi), and the maximum rate of gauge pressure rise ranged from 65,500 kPa/sec to 69,000 kPa/sec (9500 psi/sec to 10,000 psi/sec). For further information, see U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders," and RI 4835, "Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium and Their Hydrides."

N.4 Hazards.

N.4.1
Zirconium and its alloys do not present a serious risk when handled in most forms in which they are ultimately used (e.g., tubes, bars, and sheets). However, finely divided chips, turnings, or powder can be easily, sometimes spontaneously, ignited and can burn rapidly. Although other potential hazards exist during melting, those that have resulted in the most serious and lethal accidents have been associated with the handling of zirconium powders, finely divided scrap, and so-called black reaction residues. For that reason, special precautions should be observed during handling or disposal of these materials.
Several companies have reported that fires have occurred while zirconium bars, plates, and other shapes were being chopped. A number of fires have occurred when hot or burning chips fell into accumulations of moist fines on or under lathes or milling machines. The most violent reactions have occurred when burning chips fell into drums or deep containers partially filled with moist turnings or scrap.

N.4.2
In the molten state, zirconium either dissolves or is contaminated by every known refractory. Slight contamination apparently has little effect on the flammable characteristics of chips, turnings, or powder produced in machining operations. However, such contamination should be avoided because of its effect during acid treatment, in salt baths, or during exposure in nuclear reactors.

N.4.3
At temperatures considerably below its melting point, zirconium or zirconium sponge readily combines with oxygen, nitrogen, carbon dioxide, hydrogen, and water vapor. Surface discoloration can indicate contamination. Contaminated sponge can present an increased combustion hazard.

N.5 Special Hazards.

N.5.1
A cloud of zirconium dust in air presents a serious flash fire hazard, as well as a potential explosion hazard. Accumulations of static dust on horizontal and vertical surfaces (e.g., beams, walls, ledges, ductwork) present the potential for a more serious dust explosion, since such static dust is likely to be thrown into suspension by the disturbance created by the ignition of a dust cloud in the same area. Therefore, the importance of preventing and controlling any dispersions of zirconium dust or powder warrants special emphasis.

The provision of inert atmospheres in equipment and storage containers and the use of special cleaning equipment are two methods that aid in preventing explosions. Any dust deposits produced accidentally should be cleaned up promptly and the affected area washed down. All collected dust should be kept in small containers [3.8 L (1 gal) maximum] under water until disposal. Good housekeeping and prevention of ignition sources in areas where zirconium powder is handled are essential.

N.5.2
The burning rate of zirconium chips and turnings increases where water or water-soluble oils are present as a surface coating. The burning rate also increases with increasing pile depth, degree of confinement, and increasing void space in the pile. Chips and turnings less than 0.08 mm (0.003 in.) thick are particularly susceptible to rapid burning. Where all other factors are equal, partially wet material ignites more easily and burns more rapidly than dry material.

N.5.3
Small amounts of water tend to increase the risk of explosion. Additional heat is liberated on formation of the hydrated oxide, thereby increasing the chance of an explosion. Scrap that is fully immersed in water generally does not overheat, because the water provides a substantial heat sink. However, with tightly
packed, very finely divided zirconium, some risk might still be present.

N.5.4
Explosions can occur when specimens of uranium alloys of 1 percent to 50 percent zirconium are immersed in nitric acid or during subsequent handling of the clean, dry surface after nitric-acid pickling. The formation of such explosive surface coatings can be mitigated by providing fluoride ions in the pickling bath. The fluoride should be in the form of 30 g (0.07 lb) of ammonium fluoride per liter of 50 percent nitric acid/50 percent water solution.

N.5.5
Incipient hazards are associated with collected zirconium particulate where it is mixed with ordinary combustibles during cleanup or where it is mixed with laundry. Depending on the particular problems generated, management techniques should be developed to mitigate any hazards to the general public. Any and all zirconium wastes generated should be disposed of in accordance with all federal, state, and local regulations.

N.5.6
In the case of certain common metals, such as nickel and iron, zirconium can form eutectic mixtures that exhibit melting points much lower than the individual metals and can result in unexpected meltdown. The condition can be exacerbated by one or more of the materials being in a finely divided form.

N.6 Molten Metal and Water.

N.6.1
As with any other molten metal, a violently destructive explosion can occur if water is present in any mold, pit, or depression into which molten zirconium is poured or spilled. The damage might be the result of a steam explosion, an exothermic chemical reaction, a low-order hydrogen–air explosion, or a combination of these.

N.6.2
Several violent explosions have occurred in titanium-melting furnaces using consumable electrodes. The explosions occurred when cooling water accidentally entered the furnace. These explosions are of interest to the zirconium production industry because of the chemical and physical similarities between titanium and zirconium and the fact that the same types of furnaces are used for both metals. These accidents resulted in the formation of a committee of industry representatives that prepared general guidelines for the design of titanium- and zirconium-melting furnaces. Their recommendations have been published by the Defense Metals Information Center of Battelle Memorial Institute and have been considered in the development of Chapter 12.

N.7 Pickling of Zirconium.
Several mineral acids are used in the production of zirconium sponge and mill shapes, including hydrochloric, nitric, sulfuric, and hydrofluoric acids. The acids are used to pickle the surfaces of zirconium ingots, to clean reaction vessels and copper crucibles, and to pickle and clean mill shapes of zirconium
and its alloys. Care should be exercised to prevent overheating acid baths during pickling operations to prevent explosions. Acid supplies should be stored remote from production facilities.

**N.8 Tests for Zirconium.**
Several tests can be used in the identification of zirconium and its alloys. It is important that other metals are separated from zirconium alloys if the zirconium is to be recycled.

**N.8.1 Spark Test.**
Titanium, zirconium, and hafnium produce a brilliant spark when held against a grinding wheel. The white lines traced by the flying sparks end with bursts that produce several brilliant white rays or branches.

**N.8.2 Glass Test.**
The softer grades of zirconium, titanium, and hafnium can be identified by rubbing a moistened piece of the metal on a piece of glass. The metal leaves distinctive gray-white marks on the glass.

**N.8.3 Density Test.**
Titanium, zirconium, and hafnium can be separated by density measurement. Their densities are 4.54 g/cm³ (283 lb/ft³), 6.50 g/cm³ (405 lb/ft³), and 13.3 g/cm³ (829 lb/ft³), respectively.

**N.8.4 Spectroscope.**
The use of a portable metal spectroscope is best for identifying and separating zirconium alloys.

**N.9 Zirconium Alloys.**

**N.9.1**
The following nuclear-grade zirconium alloys are available:

1. **UNS R60001** — 99.5 percent, Zr; 0.05 percent maximum, Fe and Cr; 0.005 percent maximum, H₂; 0.025 percent maximum, N₂; 0.05 percent maximum, C; 0.02 percent maximum, Hf.
2. **UNS R60802** — 1.2 percent to 1.7 percent, Sn; 0.07 percent to 0.2 percent, Fe; 0.05 percent to 0.15 percent, Cr; 0.03 to 0.08 percent, Ni; balance, Zr.
3. **UNS R60804** — 1.2 percent to 1.7 percent, Sn; 0.18 percent to 0.24 percent, Fe; 0.07 percent to 0.13 percent, Cr; balance, Zr.
4. **UNS R60901** — 96 percent, Zr; 3 percent, Nb; 1 percent, Sn.

**N.9.2**
Non-nuclear grades of the alloys specified in N.9.1 are available and contain up to 4.5 percent hafnium. *(See Table N.9.2.)*

**Table N.9.2 Nuclear and Non-Nuclear Zirconium Alloy Grades**
N.10 Applications.

N.10.1
One of the major uses of zirconium alloys is in the nuclear field, where it is used for the cladding of fuel elements of water-cooled power reactors.

N.10.2
Zirconium alloys are used for chemical process equipment and chemistry laboratory equipment. They also are used as filament material for photo flashbulbs.

N.10.3
In zirconium processing and production plants, zirconium is used for critical parts where corrosion resistance and minimal contamination are of extreme importance. Some typical applications include raffinate storage vessels, venturi scrubbers, pollution-control piping and ducts, fan housings and blades, heat-exchanger shells and tubes, and other equipment exposed to chloride attack.

N.10.4
Zirconium is an efficient gettering agent for removing hydrogen, oxygen, nitrogen, and carbon dioxide from vacuum tubes. Where alloyed with titanium at a ratio of 66 percent Zr to 34 percent Ti, zirconium gettering efficiency is increased.

N.10.5
In powder form, zirconium is used as an ingredient in lighter flints and in the pyrotechnic component of safety flares.

N.10.6
Zirconium sheet is formed into special crucibles used for sodium peroxide fusions conducted in analytical chemistry laboratories.

N.11 Production.

N.11.1
The most abundant mineral containing zirconium is zircon; the second is baddeleyite (ZrO₂). Only zircon is used currently for the production of zirconium. Zircon-bearing sand is found throughout the world, including the United States.
The element hafnium is associated with zirconium in each of the two ores. In zircon, it is present in the ratio of one part hafnium to 49 parts zirconium. Most of this hafnium is removed by liquid-liquid extraction in glass columns before the zirconium can be used for nuclear-grade alloys.

N.11.3
The production of zirconium begins with the manufacture of zirconium tetrachloride (ZrCl₄) by high-temperature reaction with chlorine (Cl₂) in the presence of a reducing agent, usually carbon. The zirconium tetrachloride is made into zirconium sponge by means of the Kroll process.

N.11.4
In the Kroll process, zirconium tetrachloride vapor is fed to a steel reaction chamber containing molten magnesium. The reduction is carried out under an inert atmosphere of dry argon or helium at 700°C to 900°C (1292°F to 1652°F), with magnesium chloride formed as a by-product. Any residual magnesium chloride or magnesium is vacuum distilled from the reaction chamber, leaving behind a porous form of zirconium called “sponge.”

The reactor is cooled to 50°C (122°F), and the sponge is treated with air for a short period to reduce the possibility of igniting the sponge. The reactor then is evacuated, backfilled with inert gas, and cooled to 20°C (68°F). The sponge then is removed, crushed, and sized.

N.11.5
An electrolytic process for producing zirconium is currently under development. In this process, zirconium tetrachloride is fed to a fused salt bath containing sodium chloride and other materials. The zirconium produced is a crystalline form of the metal that then is crushed and leached.

N.11.6
Zirconium ingot is produced by arc-melting a consumable electrode of compacted sponge (or sponge and alloy) in a cooled copper crucible. The molten metal is protected by a vacuum or an inert atmosphere.

Annex O Extinguishing Agents That Should Not Be Used on Lithium Fires (CMD-CMM)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1
Several extinguishing agents should not be used as lithium fire-extinguishing agents.

O.1.1 Water.
The application of water in any form on lithium releases considerable amounts of hydrogen gas, steam, and heat and is not recommended on lithium.

Tests have demonstrated that the effect of water on lithium fires is the formation of hydrogen gas. In
some cases, hydrogen burns and intensifies the fire; in other cases, hydrogen results in rapid heat rise with an explosivelike effect.

The amount of hydrogen gas present in the vicinity of any lithium reaction is directly proportional to the degree of further reaction. If the environment surrounding the fire is such that the hydrogen gas is driven off or its concentration is reduced to a level below its lower explosive limit, the reaction is less intense.

O.1.2 Aqueous Film Forming Foam (AFFF).
Past testing of the application of AFFF on burning lithium resulted in extreme reactions.

O.1.3 Halon.
Halon should not be used as a lithium fire–extinguishing agent.

When applied to a lithium fire, halon exhibits an immediate reaction. One effect is that the reaction will track the agent stream, putting the fire fighter in increased danger.

O.1.4 CO₂.
The application of CO₂ produces minimal reactions, yet the force of this agent can greatly spread burning lithium. Therefore, CO₂ is not recommended as a lithium fire–extinguishing agent.

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

P.1 Further Testing.
Should the explosivity screening test determine that a material is capable of initiating and sustaining an explosion, it is strongly urged that explosion severity testing, limiting oxygen concentration (LOC) (percent by volume), minimal explosible concentration (MEC), minimum ignition energy (MIE), and thermal stability testing be performed on the material. The determination of hazard level of thermal stability risk for combustible metals, metal powders, metal dusts, and alloys of these materials can be determined by using the flow chart in Figure P.1.

Figure P.1 Onset Temperature Safe Storage Temperatures.
Thermal stability classification screening tests can serve as the basis to determine whether a combustible metal, metal powder, metal dust, or alloy of these materials is capable of self-heating or self-ignition when processed, dried, or stored in bulk.

Should the bulk powder test indicate that the material is undergoing a chemical reaction when it is exposed to temperatures typically encountered in processing, it is strongly urged that further testing of thermal stability be performed. Test type is dependent on screening test results and the actual process exposure or storage conditions. Should the bulk powder screening test indicate that the onset temperature of the material is less than 100°C (212°F), it is strongly urged that testing to determine the safe storage temperature of the material be performed. Should the bulk powder screening test indicate that the onset temperature of the material is less than 100°C (212°F), and the material is normally stored, shipped, or handled in bulk, it is strongly urged that testing be conducted to determine the safe storage temperature for the geometries and volumes of material typically used for storage, shipment, or handling.

Many solid particulate materials are capable of undergoing exothermic decomposition reactions. With metals, the most common manifestation of this occurrence is via oxidation. Exothermic oxidation occurs more readily and at lower temperatures for powders and dusts.

There are several tests to determine the tendency of a material to undergo exothermic reaction during process or storage. Each test provides meaningful information, and some are of more value than others, depending on the types of exposure a combustible metal, powder, or dust might experience during processing and handling.
P.2 Aerated Powder Screening Test.
This test provides information on thermal stability of a powder when exposed to air. In this test, preheated air is passed through a sample of bulked powder. This test simulates fluidized-bed drying.

P.3 Bulk Powder Screening Test.
This test permits only a limited amount of air to pass through the bulked powder sample, akin to natural diffusion through the material. It provides insight into bulk drying of powders as well as conditions in storage containers.

P.4 Air Over Layer Test.
This test simulates tray drying of powders. Normally, a thin layer of powder [15 mm (0.6 in.) deep] is exposed to preheated air being blown over the sample. This test, as well as the thin-layer ignition test, provides useful information with respect to electrical classification as well as the specification of electrical equipment for hazardous areas.

P.5 Carius Tube Screening Test.
This test provides information about de-aerated samples and thermal stability. It is an analog test for processes using vacuum dryers. Normally, the exothermic decomposition under study is not due to oxidation.

P.6 Basket Testing.
This is not a spot test but rather a series of tests that provide information on thermal stability that is scalable and can be mathematically treated to provide extrapolations to large-scale storage. It also provides exposure times for any specific geometry of stored material before the material will go into onset. In this test regimen, a minimum of three samples of cubic geometry of varying size are repeatedly tested to determine the onset temperatures corresponding to the volume and surface area of the sample. The incubation periods are also measured, and subsequent treatment of the data allows prediction of the behavior of the specific form under a wide range of storage conditions.

Combustible metals, metal powders, and metal dusts demonstrate a wide range of values for MIE. The range of values encountered depends on the metal and the specific properties of the sample. Typically, metal powders and dusts demonstrate MIE values in the range of 10 mJ (0.00239 calorie) to 80 mJ (0.019 calorie). Some, however, display MIE values much lower. Below 10 mJ (0.00239 calorie), the risk of electrostatic origins to ignition becomes great. It is often of great value to determine the mechanisms for charge generation and accumulation both on the material in question and on the process plant and equipment.

Additional tests are available to obtain data to better monitor electrostatic risk.

The measurement of the volume resistivity of a powder provides a measure of the electrical resistance at unit length and unit cross-sectional area through a bulked powder sample.
P.7 Volume Resistivities.
Powders can be categorized into three groups, according to their volume resistivities, as shown in Table P.7.

<table>
<thead>
<tr>
<th>Resistivity (ohm·m)</th>
<th>Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than $10^6$</td>
<td>Low resistivity</td>
<td>Most metal powders</td>
</tr>
<tr>
<td>$10^6$ to $10^9$</td>
<td>Medium resistivity</td>
<td>Organic powders</td>
</tr>
<tr>
<td>Greater than $10^9$</td>
<td>High resistivity</td>
<td>Synthetic polymers</td>
</tr>
</tbody>
</table>

Low- and medium-resistivity powders usually can have accumulated static charge removed via effective grounding strategies.

P.8 Powder Chargeability.
Powder charge generation is tested to determine the level of charge per unit mass that can be developed on a specific material during processing. It is particularly useful for processes using pneumatic conveyance of powders. Key variables include conveying velocity, mass flow rate, and the effects of humidity on chargeability.

Powder chargeability can provide information on the level of charge generation that occurs during typical industrial operations such as blending, pouring, spraying, and pneumatic conveyance. It can also provide information on the potential to which plant equipment may become charged during operations. Powder materials can be categorized according to their chargeability as shown in Table P.8.

<table>
<thead>
<tr>
<th>Charge per Unit Mass (C/kg)</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 \times 10^{-3}$</td>
<td>High chargeability</td>
</tr>
<tr>
<td>$1 \times 10^{-3}$ to $1 \times 10^{-7}$</td>
<td>Moderate chargeability</td>
</tr>
<tr>
<td>$1 \times 10^{-7}$ and below</td>
<td>Low chargeability</td>
</tr>
</tbody>
</table>

Charge decay or charge relaxation measures the ability of accumulated static charge to decay or relax by conduction. It provides a measure for both the importance of and the effectiveness of grounding and bonding strategies. The charge decay properties of a powdered material also are related to its volume resistivity. Charge decay is strictly defined as the time it takes for the charge on a charged sample to decay to a level of $1/e$ or 0.37 (37 percent) of its original value. Conductive materials should provide a value of charge decay less than 1 second.

P.9 Surface Potential.
In situations where electrostatic discharge is of great concern, an additional valuable test measures the surface potential of the test material after application of electrostatic charge. It is often of great value to know the surface potential resulting from the charging of a metal, metal powder, or metal dust.
Annex Q Explosion Protection [CMD-HAP]

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

Q.1 General.
This annex covers the following common methods of explosion protection:

(1) Containment
(2) Inerting
(3) Deflagration venting
(4) Deflagration suppression
(5) Deflagration isolation

Q.2 Containment.
The basis for the containment method of protection is a process designed to withstand the maximum deflagration pressure of the material being handled. The equipment is designed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The final deformation pressure depends on the maximum initial pressure in the vessel prior to the deflagration. NFPA 69 limits the maximum initial gauge pressure to 30 psi (207 kPa) for containment vessels.

The equipment is designed either to prevent permanent deformation (working below its yield strength) or to prevent rupture with some permanent deformation allowable (working above its yield strength but below its ultimate strength). The shape of the vessel should be considered. To maximize the strength of the vessel, its design should avoid flat surfaces and rectangular shapes. The strength of welds and other fastenings should also be considered.

The major advantage of containment is that it requires little maintenance due to its passive approach to explosion protection.

The disadvantages of containment are as follows:

(1) High initial cost
(2) Weight loading on plant structure

Q.3 Inerting.
Inerting protection is provided by lowering the oxygen concentration, in an enclosed volume, below the level required for combustion. That is achieved by introducing an inert gas such as nitrogen or carbon dioxide. Flue gases can be used, but they could first require cleaning and cooling. (See NFPA 69.)

The purge gas flow and oxygen concentration in the process should be designed reliably with appropriate
safety factors in accordance with NFPA 69. Consideration should be given to the potential for asphyxiation of personnel due to purge gas or leakage.

The major advantage of inerting is prevention of combustion, thereby avoiding product loss.

The disadvantages of inerting are as follows:

1. Ongoing cost of inert gas
2. Possible asphyxiation hazard to personnel
3. High maintenance

Q.4 Deflagration Venting.
Deflagration venting provides a panel or door (vent closure) to relieve the expanding hot gases of a deflagration from a process component or room.

Q.4.1 How Deflagration Venting Works.
Except for an open vent, which allows flammable gases to discharge directly to the atmosphere, deflagration vents open at a predetermined pressure referred to as $P_{\text{stat}}$. The vent is either a vent panel or a vent door. The pressurized gases are discharged to the atmosphere either directly or via a vent duct, resulting in a reduced deflagration pressure, $P_{\text{red}}$. The deflagration vent arrangement is designed to ensure that pressure, $P_{\text{red}}$, is below the rupture pressure of the process vessel or room. This process is illustrated in Figure Q.4.1.

Figure Q.4.1 Pressure–Time Graph of a Vented Deflagration.
Q.4.2 Deflagration Vent Panel.
The deflagration vent panel is a flat or slightly domed panel that is bolted or otherwise attached to an opening on the process component to be protected. The panel can be made of any material and construction that allows the panel to either rupture, detach, or swing open from the protected volume; materials that could fragment and act as shrapnel should not be used. Flat vents could require a vacuum support arrangement or a support against high winds. Domed vents are designed to have a greater resistance against wind pressure, process cycles, and process vacuums. A typical commercially available vent panel is detailed in Figure Q.4.2. Such vents are either rectangular or circular.

Figure Q.4.2 Deflagration Vent Panel and Support Grid.
**Q.4.3 Deflagration Vent Door.**
A deflagration vent door is a hinged door mounted on the process component to be protected. It is designed to open at a predetermined pressure that is governed by a special latch arrangement. Generally, a vent door has a greater inertia than a vent panel, reducing its efficiency.

**Q.4.4 Applications.**
Deflagration vents are used for applications that handle gases, dusts, or hybrid mixtures. Typical applications include air-material separators, silos, spray dryers, bucket elevators, and mixers. Figure Q.4.4 shows a typical vent panel installation on a dust collector.

**Figure Q.4.4 Vented Dust Collector.**
The advantages of deflagration venting are as follows:

1. Low cost, if the process component is located outside
2. Low maintenance due to use of passive device

The disadvantages of deflagration venting are as follows:

1. The potential for a postventing fire within the component, particularly if combustible materials such as filter bags are still present
2. The recommendation that the plant component be near an outside wall or located outside
(3) Fireball exiting a vented component, which is a severe fire hazard to the plant and personnel located in the vicinity of the deflagration vent opening
(4) Contraindication of the process for toxic or corrosive material

Q.4.5 Design Considerations.
The following points should be considered in the design and evaluation of the suitability of deflagration venting:

(1) Reaction forces
(2) Postexplosion fires
(3) Material toxicity or corrosiveness
(4) Good manufacturing practices (GMP) (food and pharmaceutical applications)
(5) Vent efficiency
(6) Connections to other process equipment
(7) Vent duct backpressure
(8) Thermal insulation
(9) Safe venting area
(10) Vacuum protection
(11) Location

Q.5 Deflagration Suppression.
Deflagration suppression involves a high-speed flame-extinguishing system that detects and extinguishes a deflagration before destructive pressures are created.

Q.5.1 How Deflagration Suppression Works.
An explosion is not an instantaneous event. The growing fireball has a measurable time to create its destructive pressures. Typically the fireball expands at speeds of 30 ft/sec (9 m/sec), whereas the pressure wave ahead of it travels at 1100 ft/sec (335 m/sec). The deflagration is detected either by a pressure detector or a flame detector, and a signal passes to a control unit, which actuates one or several high-rate discharge extinguishers. The extinguishers are mounted directly on the process to be protected, rapidly suppressing the fireball. The whole process takes milliseconds. The sequence for deflagration suppression is shown in Figure Q.5.1(a).

Figure Q.5.1(a) Deflagration Suppression Sequence of Starch in a 35 ft³ (1 m³) Vessel.
Because the fireball is suppressed at an early stage, rupture of the vessel is prevented. Figure Q.5.1(b) shows the pressure–time graph of the suppression of a starch deflagration in a 67 ft³ (1.9 m³) vessel. Note that the reduced deflagration gauge pressure is approximately 3.5 psi (24 kPa) in this test.

**Figure Q.5.1(b) Pressure Versus Time in a Suppressed Deflagration.**
Q.5.2 Applications.
Deflagration suppression systems are used for applications that handle gases, dusts, or hybrid mixtures. Typical applications include air-material separators, silos, spray dryers, bucket elevators, and mixers. Figure Q.5.2 shows a typical suppression system installation on a dust collector.

Figure Q.5.2 Dust Collector Suppression System.

Note: Pressures are gauge pressures.

### Figure Q.5.2 Dust Collector Suppression System

- **Vessel:** 67 ft³ (1.9 m³)
- **Dust:** dry starch
- **Dust concentration:** 35 oz/ft³ (1000 g/m³)
- **Ignition energy:** 1.2 kcal (5 kJ)
- **Agent:** sodium bicarbonate
- **Detection pressure:** 0.5 psi (34 kPa)

![Graph of pressure over time](image)
The advantages of a deflagration suppression system are as follows:

1. Elimination of flame and reduced chance of subsequent fire
2. Reduced risk of ejected toxic or corrosive material
3. Flexibility in process component locations

The disadvantages of a deflagration suppression system are as follows:

1. Generally higher cost than for deflagration venting
2. Requirement for regular maintenance
(3) Ineffectiveness for certain metal dusts, acetylene, and hydrogen

Q.5.3 Design Criteria.
Deflagration suppression systems are designed in accordance with NFPA 69 and ISO 6184-4, Explosion protection systems — Part 4: Determination of efficiency of explosion suppression systems. The following information is required for design of a suppression system:

1. Process material
2. $K_s$ or $K_G$ value in psi-ft/sec (bar-m/sec)
3. Vessel strength
4. Vessel dimensions and volume
5. Maximum and minimum operating pressures and temperatures
6. Connections to other process equipment

Q.6 Deflagration Isolation.
A process component such as a dust collector or silo could be protected from an explosion by venting, suppression, or containment. However, its connections to other process components by pipes and ducts pose the threat of deflagration propagation. A deflagration vent on a dust collector could save it from destruction, but the inlet duct could still propagate flame to other parts of the plant. Such propagation can result in devastating secondary explosions. The importance of ducts is stated in NFPA 68, which says:

Interconnections between separate pieces of equipment present a special hazard....Where such interconnections are necessary, deflagration isolation devices should be considered, or the interconnections should be vented. [68:A.8.12]

Although NFPA 68 indicates venting as an option for interconnections, venting is valid only when interconnected equipment is protected from explosions.

The need for isolation is further supported by research that shows that interconnecting vessels can result in precompression of gases in connected vessels caused by a deflagration. The result is that a deflagration in one vessel can produce considerably higher pressures in the connected vessel. Mechanical or chemical isolation methods should therefore be considered where interconnections between vessels are present.

Q.6.1 Mechanical Isolation.
Mechanical deflagration isolation can be provided by rotary airlock valves of suitable construction. An example of their use is at the discharge of dust collector hoppers. To be effective and to prevent the transmission of flame and burning materials, rotary airlock valves should be stopped at the moment a deflagration is detected. To be truly effective, rotary airlock valves should be integrated into an explosion detection/protection system for the piece of equipment being protected.

Rotary airlock valves for deflagration isolation should be of rugged construction and suitable design. Such design is particularly important for pieces of equipment protected by deflagration venting and containment. This application puts more demand on the integrity of rotary airlock valves than on the components protected by suppression. The reason is that suppression extinguishes the flame in addition
to mitigating the pressure.

Another example of mechanical isolation is the high-speed knife gate valve. High-speed gate valves should be capable of withstanding the maximum deflagration pressure. Typically, valves are rated for gauge pressures up to 150 psi (1035 kPa) and should be capable of closing in milliseconds. The pipework also needs to withstand the maximum deflagration pressure, $P_{\text{max}}$. Figure Q.6.1 shows a typical arrangement for a high-speed gate valve. A detector, which could be a pressure switch or an optical detector, detects the deflagration pressure or flame front. The trigger then initiates the rapid valve closure to prevent the propagation of flame and pressure. If the connected piece of equipment is protected by deflagration venting or deflagration suppression, then little pressure can be expected. In such cases, the valve that isolates a connected pipe can be replaced by a chemical isolation barrier.

**Figure Q.6.1 Mechanical Isolation Using a High-Speed Gate Valve.**

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**Q.6.2 Chemical Isolation.**

Chemical isolation is achieved by the rapid discharge of a chemical extinguishing agent into the interconnecting pipe or duct. Figure Q.6.2 shows a typical arrangement for chemical isolation. A deflagration detector, which could be a pressure switch or an optical detector, detects the deflagration pressure or flame front. The trigger then initiates the rapid discharge of extinguishing agent from a high-speed extinguisher bottle, thus preventing the propagation of flame and burning materials.
Chemical deflagration isolation should not be confused with ignition source (spark) suppression systems. Such systems are intended to detect burning particles traveling down a duct and extinguish them with a downstream spray of water. They are not designed to stop deflagrations once they have started and are ineffective for preventing deflagration propagation through interconnected equipment.

Q.7 Limitations of Flame Front Diverters.
Flame front diverters can divert deflagration flames by directing them to the atmosphere. However, these devices do have limitations. If the AMD is located downstream of the flame front diverter, an explosion originating upstream of the diverter can propagate past it because of the deflagration flames being sucked into the downstream side, despite the open diverter cover. Also, tests suggest that some diverters could be ineffective in completely diverting a deflagration involving a hybrid mixture whose vapors exceed the LFL, regardless of the location of the AMD. Nevertheless, in both situations where a flame front diverter allows propagation, the deflagration severity in the system is expected to be reduced.

Annex R Informational Primer on Spark Detection and Extinguishing Systems [CMD-HAP]

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.


R.1.1 Spark/Ember Detectors.
Spark/ember detectors are radiant energy–sensing fire detectors. The design, installation, and maintenance of radiant energy–sensing fire detectors are covered in Chapter 5 of NFPA 72. Where required by NFPA 660, spark detectors are used to actuate an abort gate to divert fuel, flames, and combustion gases to a safe location.
However, spark detectors are more commonly integrated into a spark detection and extinguishing system. In this second case, the extinguishment is usually an intermittent water spray designed and installed pursuant to NFPA 15 and maintained pursuant to NFPA 25. Because the overwhelming majority of the applications that employ spark/ember detectors are pneumatic conveying systems, it is appropriate to provide a primer on these devices as part of this standard.

**R.1.1.1 Actuation of Abort Gate.**
When spark detectors are used to actuate an abort gate, the design concepts are fairly straightforward. The detectors are mounted on the duct upstream from the abort gate and are wired to a control panel listed and approved for that purpose. When a detector senses a spark, the signal causes the control panel to alarm, and the solenoid or other releasing device on the abort gate is energized. This type of system is shown in Figure R.1.1.1.

**Figure R.1.1.1 Spark Detectors and Abort Gate.**
R.1.1.2 Spark Detection and Extinguishing Systems.
Spark detection and extinguishing systems usually consist of a group of detectors that are located on the conveying duct, a control panel in a safe accessible location, and an extinguishment solenoid valve and nozzle set located on the duct downstream from the detectors. Such a system is shown in Figure R.1.1.2.

Figure R.1.1.2 Typical Spark Detection and Extinguishing System.

When a spark or ember enters the detector(s), the detector responds with an alarm signal that actuates the extinguishing system valve, establishing an extinguishing concentration of water before the spark arrives. The water spray is maintained for a time period long enough to ensure extinguishment and is then turned off. This feature minimizes the quantity of water injected into the duct. The pneumatic conveying system is not shut down; it continues to run. Each time a spark comes down the duct, it is quenched.

R.1.2 Critical Design Concepts.
For both system design concepts, several critical factors should be addressed if they are to work. First, the detector should be able to reliably detect a spark, an ember, or a flame. Second, the alarm signal should be processed quickly. The timing should be predictable enough to allow the abort gate to operate or to allow the extinguishing system sufficient time to establish the water spray. Finally, in the case of the extinguishing system, there should be a provision to reapply the water spray extinguishment repetitively. The occurrence of an individual, isolated spark is rare; usually sparks are produced in a burst or stream. The extinguishing system should be able to reactivate as each successive spark is detected. Unless all
these concerns are addressed, spark/ember detection and extinguishment cannot be used as usually supplied.

R.1.2.1 Spark Detector Reliability.
The first concern regarding a spark/ember detector is its ability to detect a spark, ember, or fire. NFPA 72 defines a spark as “a moving ember” and defines an ember as “a particle of solid material that emits radiant energy due either to its temperature or the process of combustion on its surface.” Figure R.1.2.1 shows the radiation intensity as a function of wavelength for an oak ember and a gasoline flame.

Figure R.1.2.1 Emissions of an Oak Ember and Gasoline Flame Compared to the Spectral Sensitivity of a Spark/Ember Detector.

![Emission Spectra](attachment:22-8-38)

The spectral sensitivity of the typical spark/ember detector is superimposed on the graph in Figure R.1.2.1. One can see that the spark/ember detector will sense the radiation from both an ember (spark) and a flame.

R.1.2.2 Detector Sensitivity and Speed.
The second concern regarding the detectability of a spark or flame in a duct is the sensitivity and speed of the detector. Because the detector is designed to be mounted on a duct that is dark, silicon photodiode sensors can be used, and there will be few, if any, sources of spurious alarm within the duct. The sensors allow the detectors to be made both extremely sensitive and extremely fast. Sensitivities of 1.0 µW and speeds of 100 microseconds are common. The result is a detector that can detect a spark the size of a pinhead moving faster than the speed of sound. The outcome is that both sparks and flames are easily
detected in pneumatic conveying systems with modern spark/ember detectors.

**CAUTION:** Spark/ember detectors are motion sensitive. If the fire is moving too slowly, the typical spark/ember detector might not detect it. In general, spark/ember detectors do not detect a stationary ember or flame.

Another consideration is the absolute necessity for a predictable amount of time between the detection of the spark and the actuation of the abort gate or the establishment of the water spray extinguishing concentration. The response times of the detector, control panel, and solenoid valve are known, verified, and extremely reliable. However, unless the arrival time of the spark at the abort gate or extinguishing water spray is equally predictable, these systems are not appropriate.

The arrival time of the spark is a function of the conveying system air speed and the distance between the detector and the extinguishing system. Most spark detection and extinguishing systems provide designers a formula to compute the required distance between the detectors and the abort gate or extinguishment. Generally, it is in the following form:

\[
[R.1.2.2] \quad \text{(Air speed)} \times \text{(System factor)} = \text{Distance between detectors and extinguishment}
\]

The air speed and hence the ember speed should be both constant and controlled. It is this necessity that established the requirement that the combustible concentration be less than one-half the LFL or MEC. If the combustible concentration exceeds the LFL or MEC, a deflagration can result from the introduction of a spark. The speed of the flame front equals the sum of the flame front velocity for that combustible at that concentration plus the nominal air velocity of the conveying system. The deflagration flame front would pass the abort gate before it had opened or would pass the extinguishment before the valve had opened and established a spray pattern. That is why the criteria regarding combustible concentration are so important. A spark detection system on a conveying line where the concentrations are above the LFL or MEC cannot be expected to make a meaningful contribution to the survival of the site or its occupants should a deflagration occur.

**R.1.2.3 Control Panel Design.**

The third concern regarding these systems involves the extinguishing component. Because the cause of the first spark usually causes additional sparks, the control panel should be designed for the successive and repetitive reapplication of the extinguishing agent. This type of function is not found in the average fire alarm control panel. Specially designed control panels for spark detection and extinguishment are the norm.

**R.2 System Basics.**
R.2.1 General.
This standard requires the use of spark detection systems in those installations in which conveying air is being returned to the building. It requires that the spark detection be used to activate an abort gate, diverting the airstream to outside ambient air. This requirement is a critical life safety and property conservation measure. Sparks entering an AMS are apt to initiate a deflagration. If the abort gate is not activated, the flames and combustion gases would be conveyed back into the facility, igniting secondary fires and posing a serious threat to the occupants. Figure R.2.1 is a diagram of this type of system.

Figure R.2.1 Minimum Compliance Spark Detection System.

R.2.2 Dual Detectors.
Because spark detectors have limited fields of view, most systems require two detectors to cover a round duct. Both detectors are usually situated at the same duct diameter located on the discharge side of the collector, as shown in Figure R.2.1. This system is the only type of spark detection system required by this standard. However, because it is a minimum compliance standard, additional measures are allowed.
R.2.3 Limitations of Minimum Compliance Approach.
The problem with the minimum compliance approach is that it can often reduce the productivity of the site. When a spark is detected, the abort gate transfers. The air-handling system then should be shut down to restore the abort gate to the normal position. This shutdown could require an hour of production time. If a spark is a rare occurrence, this is not a serious problem. However, in many systems, sparks are a common occurrence. For example, in a woodworking facility, one could expect several sparks per day. Obviously, a system that shuts down the facility for an hour several times a day is not a viable system.

R.2.4 Approach to Minimize Shutdowns.
The use of a spark detection and extinguishing system on the inlet to the AMS is an extremely effective way of preventing production stoppages. This type of system mounts a second zone of spark detectors on the pneumatic conveying duct far enough upstream to allow the installation of an intermittent water spray extinguishing system on the inlet duct prior to entry into the primary AMS. This spark detection and extinguishing system quenches each spark as it comes down the duct, before it reaches the AMS. A properly designed and installed spark detection and extinguishing system is very effective in preventing ignitions in the AMS. The spark detector that actuates the abort gate is moved to the outlet of the AMS, providing a secondary detection. This type of system is shown in Figure R.2.4.

Figure R.2.4 Basic Spark Detection and Extinguishing System for a Single AMS.
R.2.5 Additional System Features.
The spark detection and extinguishing system involves more than just detectors and a water spray. To provide the degree of performance necessitated by the application, the system should require a number of additional system attributes.

First, the detectors should be listed and approved to operate in conjunction with the control panel and the water spray extinguishing unit. All three components should be listed as a system. The nozzles that are used are specifically designed for this type of service; they are not off-the-shelf sprinkler heads. The solenoid valve is specifically matched to the control panel to ensure a uniform, predictable response time.

The operating requirements of a spark detection and extinguishing system call for additional features. The windows or lenses of detectors can become scratched, broken, or coated with material, reducing their sensitivity. Consequently, a means should be provided to measure the sensitivity of the detectors to ensure that they are capable of detecting sparks after the initial installation tests. The sensitivity measurement capability is required by NFPA 72. If the material is discovered to cling to the interior surfaces of the duct, a means to keep the detector window/lens clean is required by NFPA 72. This usually involves an air-purging option that bathes the detector window/lens with clean air.

To work reliably, the extinguishing system should have a strainer (required by NFPA 15) to prevent pipe scale from clogging the nozzle. The water supply should be reliable and supervised with a pressure switch. Because the extinguishing system components are mounted on a duct that could be outdoors, freeze prevention measures should be implemented. Antifreeze solutions are not a viable option on extinguishing systems that are expected to operate regularly. Consequently, heat tracing should be thought of as a mandatory constituent of the system along with thermostats to turn the heat trace on and to warn of impending freeze-up.

Finally, desirable system components such as system testing, event recording, and flow indicators should be considered as part of any system.

Annex S Dust Layer Characterization and Precautions [CMD-HAP]

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

S.1
The threshold mass equations in Section 7.2 provide a means to determine whether the normal accumulation of combustible dust in the building/room requires the addition of a safeguard for workers in the immediate area or a safeguard for workers remote from the immediate area. This is similar to the concept of maximum allowable quantity in control areas in building codes. Above the maximum quantity, the area is considered hazardous, and additional safeguards are required. NFPA 5000 indicates in Chapter 6 that when combustible dusts are stored, used, or generated in a manner creating a severe fire
or explosion hazard the building/room would be considered to contain High Hazard Level 2 contents.

This document acknowledges that accumulation of combustible dust external to equipment can present a severe hazard when the quantity exceeds certain thresholds. When the threshold is exceeded, this document imposes physical barriers and explosion venting to limit and control the explosion hazard, as well as personal protective equipment (PPE) and fire separations to address the flash-fire hazard.

In addition to the many process design constraints intended to limit ignition potential, use of proper electrical equipment is separately addressed. It is important to recognize that the criteria for requiring electrically classified equipment are different from the thresholds for flash-fire or explosion hazard. For example, in a single room the total dust accumulation could be large enough that the entire room is deemed an explosion hazard area, yet if the dust accumulation is evenly distributed, it is possible that electrically classified equipment is not needed. Conversely, there could be an isolated area with thick layers of dust that would require the installation of electrically classified equipment even though the room, in total, does not contain sufficient dust accumulation to exceed the threshold mass.

S.2 Layer Depth Criterion Method.
The dust accumulation is a product of the actual layer depth and the total area of accumulation. The limitations in 7.2.3.2(1) and 7.2.3.2(3) are expressed as a product of the layer depth criterion and a percentage of the footprint area of the room or building. Within a single room or building, areas of significant dust accumulation can be nonseparated or separated. When they are nonseparated, the accumulations are combined and compared to the permissible dust accumulation. When accumulations are segregated, detached, or separated in accordance with 9.2.1, the accumulations are individually compared to the permissible dust accumulation. The layer depth criterion can be increased for a specific dust when the bulk density is known. For rooms or buildings where dust accumulations are limited to a small area, one way to determine if the actual dust accumulation is sufficient to result in a dust deflagration hazard is to ratio the actual dust accumulation to the permissible dust accumulation. If the ratio exceeds 1, then a dust deflagration hazard exists in the subject building or room.

Surfaces where dust could settle include floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures, and walls. Particular attention should be given to dust adhering to walls and vertical surfaces because it can be easily dislodged.

When determining the total volume of dust accumulations, accumulation areas where the surface color is discernible can be excluded.

*Example 1:* A single floor accumulation area in a small portion of a 25 ft × 40 ft (7.6 m × 12.2 m) room. The dust has a bulk density of 75 lb/ft³ (1200 kg/m³).

Layer depth criterion = \( \frac{1}{32} \text{ in.} \) (0.8 mm)

Room footprint area = 1000 ft² (92.9 m²)
Actual accumulation area = 20 ft² (1.9 m²)

Average layer depth in accumulation area = \(\frac{1}{16}\) in. (1.6 mm)

[S.2a]

\[
\text{Ratio} = \frac{20 \text{ ft}^2 \cdot \frac{1}{16} \text{ in.}}{0.05 \cdot 1000 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.}} = \frac{1.3 \text{ ft}^2\text{-in.}}{1.6 \text{ ft}^2\text{-in.}} \leq 1
\]

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. When the actual accumulation area is less than 5 percent of the room footprint, the layer thickness can be greater without resulting in a dust deflagration hazard.

**Example 2**: A single floor accumulation area in a portion of a 25 ft × 40 ft (7.6 m × 12.2 m) room. The dust has a bulk density of 30 lb/ft³ (481 kg/m³). First adjust the layer depth criterion for the reduced bulk density.

[S.2b]

\[
\text{Layer depth criterion} = \frac{\frac{1}{32} \text{ in.} \cdot 75 \text{ lb/ft}^3}{30 \text{ lb/ft}^3} = 0.078 \text{ in.} \approx \frac{1}{16} \text{ in.}
\]

Room footprint area = 1000 ft² (92.9 m²)

Actual accumulation area = 100 ft² (9.3 m²)

Average layer depth in accumulation area = \(\frac{1}{32}\) in. (0.8 mm)

[S.2c]

\[
\text{Ratio} = \frac{100 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.}}{0.05 \cdot 1000 \text{ ft}^2 \cdot 0.78 \text{ in.}} = \frac{3.1 \text{ ft}^2\text{-in.}}{3.9 \text{ ft}^2\text{-in.}} \leq 1
\]

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. A dust with a bulk density less than the basis 75 lb/ft³ (1200 kg/m³) can accumulate to \(\frac{1}{32}\) in. (0.8 mm) layer depth in more than 5 percent of the room footprint area and still not present a dust deflagration hazard.

**Example 3**: Multiple floor level and elevated accumulation areas with different layer depths for each area. The room is 100 ft × 100 ft (30 m × 30 m). The dust has a bulk density of 30 lb/ft³ (481 kg/m³). First
adjust the layer depth criterion for the reduced bulk density.

\[ [S.2d] \]

\[
\text{Layer depth criterion} = \frac{\frac{1}{32} \text{ in.} \cdot 75 \text{ lb/ft}^3}{30 \text{ lb/ft}^3} = 0.078 \text{ in.} \approx \frac{1}{16} \text{ in.}
\]

Room footprint area = 10,000 ft² (929 m²)

\[ [S.2e] \]

\[
\text{Ratio} = \frac{50 \text{ ft}^2 \cdot \frac{1}{16} \text{ in.} + 500 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.} + 100 \text{ ft}^2 \cdot \frac{1}{8} \text{ in.}}{0.05 \cdot 100,000 \text{ ft}^2 \cdot 0.078 \text{ in.}}
\]

\[
= \frac{31 \text{ ft}^2 \text{-in.}}{39 \text{ ft}^2 \text{-in.}} \leq 1
\]

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. There could be many more separated accumulation areas than listed in Table S.2(a), and all significant areas should be included. Note that areas where the surface color is discernible beneath the dust layer would not be included.

**Table S.2(a) Multiple Accumulation Areas for Example 3**

<table>
<thead>
<tr>
<th>Accumulation Location</th>
<th>Accumulation Area (ft²)</th>
<th>Average Layer Depth (in.)</th>
<th>Accumulation (ft²-in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>50</td>
<td>( \frac{1}{16} )</td>
<td>3.1 ft²-in.</td>
</tr>
<tr>
<td>Beam surfaces</td>
<td>500</td>
<td>( \frac{1}{32} )</td>
<td>15.6 ft²-in.</td>
</tr>
<tr>
<td>Equipment surfaces</td>
<td>100</td>
<td>( \frac{1}{8} )</td>
<td>12.5 ft²-in.</td>
</tr>
</tbody>
</table>

When there is a single accumulation area or the actual layer depth is the same over all accumulation areas, Figure S.2 indicates the actual layer depth that results in a dust deflagration hazard.

**Figure S.2 Layer Depth Producing Dust Deflagration Hazard.**
Example 4: Machining operation resulting in piles of dust accumulations. The machining operation is located in a 10 ft × 10 ft (3 m × 3 m) area in a 100 ft × 100 ft (30 m × 30 m) room. Between periodic housekeeping, the machining operation results in three 12 in. × 12 in. × 16 in. high piles of dust with a bulk density of 40 lb/ft³ and a uniform dust layer thickness throughout the room of less than 1/64 in.

Room footprint area = 10,000 ft² (929 m²)

Actual accumulation area = 100 ft² (9.3 m²)

1. Determine adjusted layer depth criterion:
   
   Layer depth criterion = (1/32 in. ⋅ 75 lb/ft³)/40 lb/ft³ = 0.059 in. (1.5 mm)

2. Determine the allowable volume of dust:
   
   Allowable volume of dust = 0.05 · 10,000 ft² · 0.059 in. · 1 ft/12 in. = 2.46 ft³ (0.07 m³)

3. Determine the actual volume of dust (The layer of dust less than 1/64 in. (0.4 mm) does not need to be factored into the calculation.):

   Volume of dust per pile = (12 in. × 12 in. × 16 in.) · 1 ft³/1728 in.³ = 1.33 ft³ (0.04 m³)

   Total volume of dust = 3 · 1.33 lb = 4 ft³ (0.1 m³)
The total volume of dust exceeds the allowable volume of dust; therefore, a dust deflagration hazard exists.

The limitations in 7.2.3.2(2) and 7.2.3.2(4) are expressed as a product of the layer depth criterion and a maximum 1000 ft² (92.9 m²) area. For a building or room with a footprint larger than 20,000 ft² (1858 m²), the 1000 ft² (92.9 m²) dust accumulation area and equivalent volume become limiting in determining whether a deflagration hazard area exists. Table S.2(b) provides guidance for evaluating isolated accumulations of dust in a building larger than 20,000 ft² (1858 m²). These types of accumulations commonly occur due to leaks in equipment and machining operations. Table S.2(b) lists various areas of nonseparated accumulation and the corresponding layer depth criterion. It assumes a bulk density of 75 lb/ft³ (1200 kg/m³) and a rectangular shaped accumulation. The layer depth can be adjusted for bulk density.

**Table S.2(b) Corresponding Layer Depths for Nonseparated Accumulations**

<table>
<thead>
<tr>
<th>Dust Accumulation Area</th>
<th>Layer Depth Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft²</td>
<td>m²</td>
</tr>
<tr>
<td>1000</td>
<td>93</td>
</tr>
<tr>
<td>100</td>
<td>9.3</td>
</tr>
<tr>
<td>50</td>
<td>4.6</td>
</tr>
<tr>
<td>25</td>
<td>2.3</td>
</tr>
<tr>
<td>16</td>
<td>1.5</td>
</tr>
<tr>
<td>9</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Example 5:* Processing operation with several areas of accumulation. The building area is 350 ft × 150 ft (107 m × 46 m). There are three accumulation areas:

1. 15 ft × 100 ft (4.6 m × 30 m) mezzanine with 1/2 in. (12.7 mm) dust accumulation
2. 50 ft × 150 ft (15 m × 46 m) area with 1/8 in. (3.2 mm) dust accumulation at east end
3. 15 ft × 10 ft (4.6 m × 3 m) area with 11/2 in. (38 mm) average depth at west end

The dust has bulk density of 2 lb/ft³ (32 kg/m³).

Room footprint area = 350 ft × 150 ft = 52,500 ft² (4877 m²) (Note: The mezzanine area does not increase the room footprint area.)

1. Determine adjusted layer depth criterion. Layer depth criterion = (1/32 in.·75 lb/ft³)/2 lb/ft³ = 1.17 in. (30 mm)
2. Determine the allowable volume of dust [limited to 1000 ft² (92.9 m²) because the total room footprint exceeds 20,000 ft² (1858 m²)]. Allowable volume of dust = 1000 ft²·1.17 in.·1 ft/12 in. = 97.5 ft³ (2.8 m³)
3. Determine the actual volume of dust.
   a. Volume of mezzanine dust = 1500 ft²·1/2 in.·1 ft/12 in.² = 62.5 ft³ (1.8 m³)
   b. Volume of east end dust = 7500 ft²·1/8 in.·1 ft/12 in.² = 78.13 ft³ (2.2 m³)
The total volume of dust exceeds the allowable volume of dust; therefore, a dust deflagration hazard exists.

S.3 Mass Methods A and B.

The user can apply both of the mass method A equations in 7.2.4.1 and 7.2.4.2 to separately determine if an explosion hazard or a flash-fire hazard from total accumulated dust mass exists in the building/room. If a hazard does exist, then safeguards are required for workers remote from the area for an explosion hazard or in the immediate area for a flash-fire hazard. Alternatively, the user can apply both of the mass method B equations in 7.2.5.1 and 7.2.5.2 to separately determine if an explosion hazard or a flash-fire hazard from total accumulated dust mass in the building/room exists.

When the dust accumulations are nonseparated, the accumulations are combined and compared with the permissible dust accumulation. When accumulations are segregated, detached, or separated in accordance with 9.2.1, the accumulations are individually compared with the permissible dust accumulation.

The equations for mass method A, in 7.2.4.1 and 7.2.4.2, do not require measurement of any physical or combustibility properties for application. They are independent of those properties and offer a generally conservative approach. The only variables are the total building/room floor area and the general height of the building/room, which provide a volume correction. In practice, the user can weigh the amount of accumulated dust in various areas external to equipment to estimate the total dust mass in the building/room. If the dust mass exceeds the threshold determined according to 7.2.4.1, then the area is a dust explosion hazard area. If the dust mass exceeds the threshold determined according to 7.2.4.2, then the area is a dust flash fire hazard area. Depending on building height, the area of dust accumulation could be a dust explosion hazard area, a dust flash-fire hazard area, or both.

The equations for mass method B, in 7.2.5.1 and 7.2.5.2, require not only combustibility properties of the dust but also, for the equation in 7.2.5.1, information about the building/room strength against explosions. With this information, it is possible to be more accurate when evaluating the potential hazards created by the dust accumulation.

An example application is a 10,764 ft² (1000 m²) building, having a peaked roof with eave height of 29.5 ft (9 m) and peak height of 32.8 ft (10 m). The owner/user expects only minor dust accumulation near certain activities and has provided electrically classified equipment in these limited areas. When operations began, a routine housekeeping schedule was documented and instituted to minimize dust accumulation. After 2 months of operation the owner/user weighed dust samples from six different areas in the plant, as listed in Table S.3.

Table S.3 Example Dust Sample Results
Based on the weighed samples, the user multiplied the mass per unit area by the estimated floor area for the samples and estimated the weight of dust in each section of the plant. As a result, the user determined that practicable housekeeping allowed the dust to accumulate to about 132 lb (60 kg) over the building.

According to the equations in 7.2.4.1 and 7.2.4.2, the threshold masses are 84 lb (38 kg) for an explosion hazard area and 44 lb (20 kg) for a flash-fire hazard area.

$$M_{\text{basic-exp}} = 0.004 \cdot A_{\text{floor}} \cdot H = 0.004 \cdot 1000 \ m^2 \cdot 9.5 \ m = 38 \ kg \ [S.3a]$$

$$M_{\text{basic-fire}} = 0.02 \cdot A_{\text{floor}} = 0.02 \cdot 1000 \ m^2 = 20 \ kg \ [S.3b]$$

Practicable housekeeping has resulted in too much dust without additional safeguards, and the owner/user would have to modify equipment to better contain the dust or provide the additional prescribed safeguards. The owner/user could decide to proceed with the results of the basic equations without further evaluation. However, since the building is new, the design information is readily available, and the owner/user decides to evaluate the current dust accumulation using the equations in 7.2.5.1 and 7.2.5.2.

The building is constructed of pre-engineered columns with metal siding on steel girts. The girts stabilize the columns, and fail at 75 lb/ft$^2$ (0.036 bar) internal pressure. The metal siding is designed for 35 lb/ft$^2$ (0.017 bar) internal pressure; however, the owner/user determines there is nothing of importance mounted to the metal siding. It is the owner/user’s choice to accept potential siding damage during an explosion. A sample of the accumulated dust was tested according to ASTM E1226 and has a $K_{St}$ of 150 bar-m/sec, $P_{\text{max}}$ of 7 bar, and $C_w$ of 0.60 kg/m$^3$. See Figure S.3 showing Mass Methods A and B.

**Figure S.3 Example Mass Accumulation Producing Dust Hazard Condition.**

<table>
<thead>
<tr>
<th>Section</th>
<th>Floor Area</th>
<th>Above Floor Area</th>
<th>Sampled Area</th>
<th>Sampled Weight</th>
<th>Estimated Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ft$^2$</td>
<td>m$^2$</td>
<td>ft$^2$</td>
<td>m$^2$</td>
<td>lb</td>
</tr>
<tr>
<td>Bag unloading</td>
<td>215</td>
<td>20</td>
<td>—</td>
<td>21.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Processing</td>
<td>6458</td>
<td>600</td>
<td>—</td>
<td>43.0</td>
<td>0.11</td>
</tr>
<tr>
<td>Packaging</td>
<td>1938</td>
<td>180</td>
<td>—</td>
<td>32.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Shipping</td>
<td>2153</td>
<td>200</td>
<td>—</td>
<td>43.0</td>
<td>0.11</td>
</tr>
<tr>
<td>Bar joist</td>
<td>—</td>
<td>538</td>
<td>50</td>
<td>21.5</td>
<td>0.22</td>
</tr>
<tr>
<td>Mezzanine</td>
<td>—</td>
<td>1130</td>
<td>105</td>
<td>32.3</td>
<td>0.22</td>
</tr>
<tr>
<td>Total</td>
<td>10,764</td>
<td>1000</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
In order to evaluate the threshold mass for the explosion hazard, the owner/user must establish the enclosure strength, $P_{es}$, based on the weakest structural element not intended to vent or fail. According to the description, this would be the girts at 75 lb/ft$^2$ (0.036 bar). The second building construction parameter is the dynamic load factor (DLF). (See NFPA 68 for more information.) In this case, the owner/user can assume the value of 1.5. The owner/user must also choose the tolerable probability of flash-fire injury, ($p$), limited to a maximum of 0.05 (5 percent). In this case, 5 percent is chosen.

$$M_{exp} = \left[ \frac{P_{es}}{DLF} \right] \left[ \frac{C_w}{P_{max}} \right] \cdot \frac{A_{floor} \cdot H}{\eta_D} = \left[ \frac{0.036 \text{ bar g}}{1.5} \right] \left[ \frac{0.60 \text{ kg/m}^3}{7 \text{ bar g}} \right] \left[ \frac{1000 \text{ m}^2 \cdot 9.5 \text{ m}}{0.25} \right] = 78 \text{ kg (172 lb)}$$

For U.S. units, 1 kg = 2.2 lb; 1 m$^2$ = 10.8 ft$^2$. 
Using mass method B, the user determines that the practicable housekeeping result of 132 lb (60 kg) dust accumulation exceeds the threshold for a flash-fire hazard area, but not for a dust explosion hazard area.

Because the building is without internal fire-rated separation walls, all the workers will have to be protected from a flash-fire hazard, as prescribed in Chapter 8. Current housekeeping is maintaining total dust mass below 168 lb (76 kg), meaning that the structure of the building not intended to vent or fail is safe from the explosion hazard. Since the original design of the building presumed which areas would experience dust accumulation external to equipment, the owner/user should review the electrical area classification against the actual locations of accumulations, based on NFPA 499.

S.4
While the threshold mass equations consider all the dust mass throughout the building, it is not anticipated that the dust will be evenly distributed. Rather there will be localized areas of accumulation where fugitive dust is not completely captured. If the threshold mass of dust actually were evenly distributed, it typically would be an extremely thin layer. The layer would be too thin to create a hazard because the entrainment fraction would be much smaller and only a small portion of the dust mass would actually be involved in the event. The inclusion of all accumulated dust mass is conservative in this respect.

By separating processing areas by walls and making the entries self-closing, the owner/users can limit the area where it is necessary to apply safeguards against a flash-fire hazard. Similarly, separation walls and entries that are pressure-resistant can be used to limit the area where the owner/user has to apply safeguards against an explosion hazard. Where a multifloor building is effectively separated at the floor levels, explosion and flash-fire hazards can be evaluated on a floor-by-floor basis.

Where there are open mezzanines above a floor level, the accumulated dust on those levels is added to that on the main level without increasing the floor area.

When determining the total dust mass in a building or room, due consideration should be given to dust that adheres to walls, since it is easily dislodged. Attention and consideration also should be given to other projections, such as light fixtures, which can provide surfaces for dust accumulation.

Dust collection equipment should be monitored to ensure it is operating effectively. For example, dust collectors using bags operate most effectively between limited pressure drops of 3 in. to 5 in. of water.
(0.74 kPa to 1.24 kPa). An excessive decrease or low drop in pressure indicates insufficient coating to trap dust.

Annex T Deflagration Propagation Isolation Methods [CMD-HAP]

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

T.1
Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure T.1 shows an example of how such propagation could occur. Isolation techniques can be used to prevent the propagation of the deflagration by arresting the flame front.

Figure T.1 Deflagration Propagation Without Isolation.

Both the direction and the extent of potential deflagration propagation should be considered. Usually, a dust deflagration occurs in a fuel-rich regime (i.e., above the stoichiometric fuel-air ratio), making it likely that the initial deflagration will expand into volumes many times greater than the initial deflagration volume.

T.2
The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. The unburned dust is expelled from the containment vessel via every
available exit path, in all possible directions of flow, including flow via all connecting ducts, and out through any provided explosion venting. The driving force pushing the dust away from the point of initiation [which, under vented conditions, could be in the range of only a few pounds per square inch (kilopascals)] can easily overcome the force of normal system flow (which typically could be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

T.3
The conveyance of the flame front via both the infeed and outflow ducts should be evaluated. In most cases, the movement of dust and propagating flame front commutes the deflagration to the connected equipment via ductwork. Where equipment and ducts are adequately protected pursuant to this standard and NFPA 68 (when explosion venting is used), the consequences of explosion propagation might not increase the life safety hazard or significantly increase property damage. In other cases, however, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

T.3.1
In the case of several pieces of equipment connected via ductwork, where each piece of equipment and the ductwork are provided with explosion venting, the dust explosion can nevertheless propagate throughout the system. Explosion venting on the equipment of deflagration origin prevents overpressure damage to that vessel. If the concentration within the connecting ductwork is below the MEC prior to the deflagration, the deflagration can still spread to the next vessel, but the explosion venting there should protect that second vessel from overpressure damage. In such a case, the provision of explosion isolation would not provide any significant reduction in either the property damage or life safety hazard.

T.3.2
If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct results in an accelerating flame front. Without explosion venting on the ductwork, the accelerating flame front results in a significant prepressurization of the equipment at the other end of the duct and in a powerful jet flame ignition of a dust deflagration in that second vessel. Such a deflagration can overwhelm the explosion venting on that vessel, even if the design is based on information in NFPA 68, resulting in the catastrophic rupture of the vessel. In that case, the explosion propagation results in a significant increase in property damage and, quite possibly, in an increase in life safety hazard due to the vessel rupture. Consequently, explosion isolation is a critical component to the management of the fire and explosion risk.

T.3.3
In the case of an AMS serving a large number of storage silos, an explosion originating in the AMS can produce an acceptable level of damage to the collector if it is provided with adequate explosion venting per NFPA 68. However, the propagation of that explosion upstream to all the connected silos could cause ignition of the material stored in all those silos. The initiation of such storage fires can significantly escalate the magnitude of the incident, in terms of property damage, interruption to operations, and life
safety hazard. As with the example in T.3.2, explosion isolation would be warranted in this case.

Annex U Use of Water as Extinguishing Agent for Combustible Particulate Solids [CMD-HAP]

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

U.1
As noted in A.9.9.2.1, the classification of combustible particulate solids according to their behavior with water affects the effectiveness of water as an extinguishing medium.

Water-compatible particulate solids are those combustibles that can be extinguished with water and that neither react with nor form mixtures with it. These solids include the following materials:

1. Wood dusts, fibers, chips, shavings, and flakes
2. Some paper dusts, depending on ultimate use
3. Municipal solid wastes (MSWs), including refuse-derived fuels (RDFs)
4. Coal chunks, pellets, and dusts
5. Shredded plastic and papers at recycling facilities
6. Many plastic powders and pellets
7. Pulverized cork used in a flooring product’s manufacturing process
8. Conveyed agricultural commodities such as oilseeds, walnut shells, and cocoa beans in a deshelling operation
9. Chopped feathers in a dryer

The chemical and physical properties, range of particle sizes, and types of process equipment used with these combustibles usually allow these applications to be considered water compatible. A principal concern is the ignition of a dust cloud in the AMS or the storage vessel. When the source of ignition is generated upstream, this risk can often be reduced if the spark or ember is detected and extinguished prior to its entry into the AMS or the storage vessel. In some applications, spark detection and intermittent water spray extinguishing systems can be effectively used because the ultimate usefulness of the particulate material is not affected if it is wet.

In numerous drying, chopping, crushing, and grinding operations, the introduction of water does not represent a serious threat to the transported material or to the process equipment. For example, in woodworking plants, the wood waste is usually sold as raw material for particleboard or is used as fuel to heat the facility. The moisture from the operation of an extinguishing system is of no consequence. That allows the use of spark detection and intermittent water spray as the fire protection strategy. For other applications, a water deluge system is a more appropriate fire protection strategy even though it could disrupt the normal flow of material or interrupt the process operation.

U.2
In contrast, in water-incompatible systems, the introduction of water causes unacceptable damage to the
equipment or to the material being processed. In these systems, the particulate solids are combustibles that can be extinguished with water but dissolve in water or form a mixture with it that renders them no longer processable, or the process equipment cannot tolerate the introduction of water. Water-incompatible solids include the following materials:

1. Cotton fibers (due to the resultant equipment damage from water discharge)
2. Many foodstuffs such as sugar, flour, spices, cornstarch, and yeasts
3. Grains and cereals
4. Tobacco
5. Many pharmaceuticals
6. Many chemicals

Because the conveyed material or the process equipment is irreparably degraded when water is added to these materials, the first line of defense is an extinguishing system that utilizes some other agent. Examples of agents used in these systems include carbon dioxide, sodium bicarbonate, monoammonium phosphate, nitrogen, and clean agents. However, a water-based extinguishing system can be employed as a backup to the special agent extinguishing systems.

An example of a water-incompatible system is one involving flour. A spray of water into a pneumatic conveying duct that transports flour can extinguish a spark, but the water will combine with the flour to form a paste that can clog the system and promote fermentation. Consequently, there is an operations-based incentive to consider alternatives to water-based extinguishing systems.

**U.3**

Water-reactive materials chemically react with water to produce some other material that could represent a different set of fire protection problems. The most notable water-reactive materials are the powdered metals. Many powdered metals, including aluminum, magnesium, titanium, zirconium, and lithium, react violently with water to form an oxide, liberating hydrogen gas as a by-product. These materials can start a fire when exposed to water if they are of a sufficiently small particle size. Consequently, water is not usually an option as an extinguishing agent for an established fire involving these materials.

Other metals react less violently with water and only under certain circumstances. The use of water on these materials once they have achieved ignition temperature can also produce hydrogen. However, if used in copious quantities, water can be an effective extinguishing strategy. Nevertheless, all metals should be handled with care, given that their reactivity is highly dependent on the particular metal, particle size, and temperature.

The list of water-reactive combustibles is not limited to combustible metals but also includes some pharmaceuticals and chemicals. These chemicals produce either a fire or a toxic or corrosive by-product when mixed with water.

Often an inerted system is used because of the difficulties encountered in extinguishing these materials. However, it should be noted that some commonly considered inerting agents, such as CO₂ or nitrogen,
could be incompatible with certain metals at high temperatures.

**U.4**

In summary, a combustible particulate solid should be classified only after a thorough review of the chemistry and physical form of the particulate, the type of process equipment, the subsequent use or processes, the relevant literature regarding loss history in similar processes and products, other hazards associated with the process material, and the response capabilities of the fire service.

**Annex V Dust Layer Characterization and Precautions (CMD-HAP)**

_This annex is not a part of the requirements of this NFPA document but is included for informational purposes only._

**V.1**

The threshold mass equations in 14.7.3.6 provide a means to determine whether the normal accumulation of combustible dust in the building/room requires the addition of a safeguard for workers in the immediate area or a safeguard for workers remote from the immediate area. This is similar to the concept of maximum allowable quantity in control areas in building codes. Above the maximum quantity, the area is considered hazardous and additional safeguards are required. Chapter 6 of NFPA 5000 indicates that where combustible dusts are stored, used, or generated in a manner creating a severe fire or explosion hazard the building/room is considered to contain high hazard Level 2 contents.

This standard acknowledges that accumulation of combustible dust outside of equipment can present a severe hazard when the quantity exceeds certain thresholds. When the threshold is exceeded, this standard imposes physical barriers and explosion venting to limit and control the explosion hazard as well as personal protective equipment and fire separations to address the flash-fire hazard.

In addition to the many process design constraints intended to limit ignition potential, the use of proper electrical equipment is addressed separately. It is important to recognize that the criteria for requiring electrically classified equipment are different from the thresholds for flash-fire or explosion hazard. As an example, in a single room the total dust accumulation could be large enough that the entire room is deemed an explosion hazard area, yet if the dust accumulation is evenly distributed, it is possible that electrically classified equipment is not needed. Conversely, there could be an isolated area with thick layers of dust that would require the installation of electrically classified equipment, and yet the room, in total, does not contain sufficient dust accumulation to exceed the threshold mass.

The user can apply Equation 14.7.3.6.1 and Equation 14.7.3.6.2 to separately determine if an explosion hazard or a flash-fire hazard exists from total accumulated dust mass in the building/room. If so, then safeguards are required for workers remote from the area or in the immediate area, respectively.

The basic equations in 14.7.3.6.1 and 14.7.3.6.2 do not require measurement of any physical or
combustibility properties for application. They are independent of those properties and offer a generally conservative approach. The only variables are the total building/room floor area and the general height of the building/room, which provides a volume correction. In practice, the user can weigh the amount of accumulated dust in various areas outside of equipment to estimate the total dust mass in the building/room. If the dust mass exceeds the threshold determined according to 14.7.3.6.1, then the area is a dust explosion hazard area. If the dust mass exceeds the threshold determined according to 14.7.3.6.2, then the area is a dust flash-fire hazard area. Depending on building height, the area of dust accumulation could be a dust explosion hazard area, a dust flash-fire hazard area, or both.

An example application is a 10,764 ft² (1000 m²) building having a peaked roof with eave height of 30 ft (9 m) and peak height of 33 ft (10 m). The owner/user expects only minor dust accumulation near certain activities and has provided electrically classified equipment in these limited areas. When operations began, a routine housekeeping schedule was documented and instituted to minimize dust accumulation. After 2 months of operation, the owner/user weighs dust samples from six different areas in the plant, as listed below in Table V.1.

<table>
<thead>
<tr>
<th>Section Name</th>
<th>Floor Area</th>
<th>Above-Floor Area</th>
<th>Sampled Area</th>
<th>Sampled Weight</th>
<th>Estimated Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m²</td>
<td>ft²</td>
<td>m²</td>
<td>ft²</td>
<td>kg</td>
</tr>
<tr>
<td>Bag unloading</td>
<td>20</td>
<td>215</td>
<td>—</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Processing</td>
<td>600</td>
<td>6458</td>
<td>—</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>Packaging</td>
<td>180</td>
<td>1938</td>
<td>—</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>Shipping</td>
<td>200</td>
<td>2153</td>
<td>—</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td>Bar joist</td>
<td>—</td>
<td>—</td>
<td>50</td>
<td>538</td>
<td>2</td>
</tr>
<tr>
<td>Mezzanine</td>
<td>—</td>
<td>—</td>
<td>105</td>
<td>1130</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
<td>10764</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Based on the weighed samples, the owner/user multiplies the mass per unit area by the estimated floor area for the samples and estimates the weight of dust in each section of the plant. As a result, the owner/user determines that practicable housekeeping has allowed the dust to accumulate to about 132 lb (60 kg) over the building. According to Equations 14.7.3.6.1 and 14.7.3.6.2, the threshold masses are 209 lb (95 kg) for an explosion hazard area and 110 lb (50 kg) for a flash-fire hazard area:

\[ M_{basic-exp} = 0.01 \cdot A_{floor} \cdot H \]

\[ M_{basic-exp} = 0.01 \cdot 1000 \text{ m}^2 \cdot 9.5 \text{ m} = 95 \text{ kg} \]
Thus practicable housekeeping has resulted in too much dust without additional safeguards for the flash-fire hazard, and the owner/user would have to consider Chapter 8 to determine appropriate PPE needs or modify equipment to better contain the dust. In this example, current housekeeping is sufficient to discount an explosion hazard. The user could decide to proceed with the results of the basic equations without further evaluation or to use the method in 14.7.3.5.

Since the original design of the building presumed which areas would experience dust accumulation outside equipment, the owner/user should review the electrical area classification against the actual locations of accumulations, based on NFPA 499.

V.2
The dust accumulation is a product of the actual layer depth and the total area of accumulation. The limitation in 14.7.3.5.3 is expressed as a product of the layer depth criterion and a percentage of the footprint area of the room or building. Within a single room or building, areas of significant dust accumulation could be contiguous or separated. Where they are separated, the separate accumulations are combined and compared to the permissible dust accumulation. The layer depth criterion can be increased for a specific dust when the bulk density is known.

For rooms or buildings where dust accumulations are limited to a small area, one way to determine if the actual dust accumulation is sufficient to result in a dust deflagration hazard is to ratio the actual dust accumulation to the permissible dust accumulation. If the ratio exceeds 1, then a dust deflagration hazard exists in the subject building or room.

Surfaces where dust could settle include floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures and walls. Because dust adhering to walls and vertical surfaces can be easily dislodged, particular attention should be given to these surfaces.

When the total volume of dust accumulations is being determined, accumulation areas where the underlying surface colors are readily discernible can be excluded.

Example 1: A single floor accumulation area in a small portion of a 25 ft by 40 ft (7.62 m by 12.2 m) room. The dust has a bulk density of 75 lb/ft³ (1200 kg/m³).

Layer depth criterion = \( \frac{1}{32} \) in. (0.8 mm)
Room footprint area = 1000 ft$^2$ (93 m$^2$)

Actual accumulation area = 20 ft$^2$ (1.86 m$^2$)

Average layer depth in accumulation area = $\frac{1}{16}$ in. (1.6 mm)

\[
\text{Ratio} = \frac{20 \text{ ft}^2 \cdot \frac{1}{16} \text{ in.}}{0.05 \cdot 1000 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.}} = \frac{1.3 \text{ ft}^2 \cdot \text{in.}}{1.6 \text{ ft}^2 \cdot \text{in.}} \leq 1
\]

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. Where the actual accumulation area is less than 5 percent of the room footprint, the layer thickness can be greater without resulting in a dust deflagration hazard.

Example 2: A single floor accumulation area in a portion of a 25 ft by 40 ft (7.62 m by 12.2 m) room. The dust has a bulk density of 30 lb/ft$^3$ (481 kg/m$^3$). First adjust the layer depth criterion for the reduced bulk density:

\[
\text{Layer Depth Criterion} = \frac{\frac{1}{32} \text{ in.} \cdot 75 \text{ lb/ft}^3}{30 \text{ lb/ft}^3} = 0.078 \text{ in.} \approx \frac{1}{16} \text{ in.}
\]

Room footprint area = 1000 ft$^2$ (93 m$^2$)

Actual accumulation area = 100 ft$^2$ (9.3 m$^2$)

Average layer depth in accumulation area = $\frac{1}{32}$ in. (0.8 mm)

\[
\text{Ratio} = \frac{100 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.}}{0.05 \cdot 1000 \text{ ft}^2 \cdot 0.78 \text{ in.}} = \frac{3.1 \text{ ft}^2 \cdot \text{in.}}{3.9 \text{ ft}^2 \cdot \text{in.}} \leq 1
\]
Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. A dust with a bulk density less than the basis of 75 lb/ft³ (1200 kg/m³) can accumulate to \(\frac{1}{32}\) in. (0.8 mm) layer depth in more than 5 percent of the room footprint area and still not present a dust deflagration hazard.

Example 3: Multiple floors and elevated accumulation areas with different layer depths for each area. The room is 100 ft by 100 ft (30.5 m by 30.5 m). For rooms less than 20,000 ft² (1858 m²), the limitation is based on a maximum of 5 percent of the footprint area. The dust has a bulk density of 30 lb/ft³ (481 kg/m³). First, adjust the layer depth criterion for the reduced bulk density:

\[
\text{Layer Depth Criterion} = \frac{\frac{1}{32} \text{ in.} \cdot 75 \text{ lb/ft}^3}{30 \text{ lb/ft}^3} = 0.078 \text{ in.} = \frac{1}{16} \text{ in.}
\]

Room footprint area = 10,000 ft² (929 m²)

\[
\text{Ratio} = \frac{50 \text{ ft}^2 \cdot \frac{1}{16} \text{ in.} + 500 \text{ ft}^2 \cdot \frac{1}{32} \text{ in.} + 100 \text{ ft}^2 \cdot \frac{1}{8} \text{ in.}}{0.05 \cdot 10,000 \text{ ft}^2 \cdot 0.78 \text{ in.}}
\]

\[
= \frac{31 \text{ ft}^2 \cdot \text{ in.}}{39 \text{ ft}^2 \cdot \text{ in.}} \leq 1
\]

Since the ratio is less than or equal to 1, a dust deflagration hazard does not exist in the room. There could be more separated accumulation areas than are listed in Table V.2, and all significant areas should be included. Note that areas where dust layers are such that the underlying surface colors are readily discernible would not be included.

Where there is a single accumulation area or the actual layer depth is the same over all accumulation areas, Figure V.2 indicates the actual layer depth that results in a dust deflagration hazard.

<table>
<thead>
<tr>
<th>Accumulation Location</th>
<th>Accumulation Area (ft²)</th>
<th>Average Layer Depth (in.)</th>
<th>Accumulation (ft² · in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>50</td>
<td>(\frac{1}{16})</td>
<td>3.1</td>
</tr>
<tr>
<td>Beam surfaces</td>
<td>500</td>
<td>(\frac{1}{32})</td>
<td>15.6</td>
</tr>
<tr>
<td>Equipment surfaces</td>
<td>100</td>
<td>(\frac{1}{8})</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Note: For SI units, 1 in. = 25.4 mm, 1 ft² = 0.093 m².
V.3
While the threshold mass equations consider all of the dust mass throughout the building, it is not anticipated that the dust will be evenly distributed. Rather, there will be localized areas of accumulation where fugitive dust is not completely captured. If the threshold mass of dust were actually evenly distributed, it would typically be an extremely thin layer. Such a layer would be too thin to create a hazard because the entrainment fraction would be much smaller, and only a small portion of the dust mass would actually be involved in the event. The inclusion of all accumulated dust mass is conservative in this respect.

Where processing areas are segregated by walls and the entries are self-closing, this can be used to limit the area where the user has to apply safeguards against a flash-fire hazard. Similarly, where segregating walls and entries are also pressure resistant, this can be used to limit the area where the user has to apply safeguards against an explosion hazard. Where a multifloor building is effectively segregated by intervening floors, explosion and flash-fire hazards can be evaluated on a floor-by-floor basis.

Where there are open mezzanines above a floor level, the accumulated dust on these levels is added to that on the main level without increasing the floor area.

When the total dust mass in a building or room is being determined, due consideration should be given to dust that adheres to walls, since it is easily dislodged. Attention and consideration should also be given to other projections, such as light fixtures, that can provide surfaces for dust accumulation.
Dust collection equipment should be monitored to ensure that it is operating effectively. For example, dust collectors that use bags operate most effectively between limited pressure drops of 2 in. to 5 in. of water (0.50 kPa to 1.24 kPa). An excessive decrease or low drop in pressure indicates insufficient coating to trap dust.

**Annex W Conveying System Isolation (CMD-WOO)**

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

**W.1**

Critical equipment includes equipment of high value, high fire/explosion hazard, high production dependence, or high exposure to operating personnel or the public at large.

For example, a sander dust collection system has a relatively high frequency of sparks, fires, and explosions. Isolation goals in this case could be as follows:

1. Prevent explosions from propagating back into the production building through the pneumatic conveying duct using a backblast damper
2. Prevent burning collected material from being conveyed to storage silos using spark detection and a fire dump screw arrangement with steel-tipped rotary airlocks
3. Minimize the chance of conveying burning material into a bag filter dust collector using a high-speed abort gate

One popular arrangement using this isolation philosophy that has proven to be very effective in reducing fires and explosions uses a fan pulling through a cyclone (to remove the majority of material) and blowing into a dust filter. Figure W.1(a) and Figure W.1(b) show a typical interlock logic and arrangement, respectively, with the previously listed isolation features, plus other fire protection features (e.g., spark extinguishing and dust collector water spray) and explosion venting to protect against the fire and deflagration risks.

**Figure W.1(a) Typical Interlock Logic for Conveying System. (© 2000 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-73, “Dust Collectors and Collection Systems.”)**
Figure W.1(b) Typical Arrangement of Conveying System. (© 2012 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-73, “Dust Collectors and Collection Systems.”)
The following three-zone spark detection interlocking and control scheme maximizes process uptime and minimizes equipment damage. All interlock functions for a specified detection zone operate simultaneously. The three zones are as follows:

1. **Zone 1** (primary protection)
   - (a) Activate spark extinguishing nozzles for several seconds.
   - (b) No process shutdown.

2. **Zone 2** (backup to the primary protection in case it fails)
   - (a) Activate high-speed abort gate, but leave conveying fan running. (This action will divert burning material away from bag filter and clear the duct of burning material.)
   - (b) Stop wood material feed into dust-producing equipment, and shut down equipment. (This action will eliminate the likely source of ignition and prevent additional wood dust from being produced.)
   - (c) Activate cyclone fire suppression system. (This action will minimize thermal damage to the cyclone and begin extinguishment of burning material.)
   - (d) Activate cyclone material isolation system. (In this example, this action would stop the normal outfeed rotary feeder, reverse the fire dump screw under cyclone, and start the fire dump rotary feeder. This action will prevent the fire from spreading to downstream areas.)

Note: The main fan must be left running in any fire shutdown situation until the collection equipment has been purged and the fire has been brought under control.
process equipment and empty burning material and fire suppression water from the cyclone.

(3) **Zone 3** (fail-safe protection for bag filter)
   
   (a) Activate all the interlocks associated with Zone 2 for added reliability.
   
   (b) Activate fire suppression system in bag filter. (This action will minimize thermal damage to the bag filter and begin extinguishment of any burning material in the filter.)
   
   (c) Activate bag filter isolation system. (In this example, the material collected in the bag filter is put back into the cyclone, so the cyclone material isolation system also keeps any burning material from the bag filter from reaching downstream equipment.)

To further illustrate isolation of critical equipment, assume that the collected material dropped into a high-pressure blowline instead of a fire dump screw, and the material could be relayed to a silo or diverted to a small clam-shell truck dump bin for disposal. The silo would normally be considered critical equipment needing isolation (typically done with a high-speed abort gate), but the truck dump bin would not normally need isolation because it has lower value, is of low production importance, and can be quickly emptied by dropping the contents on the ground for fire fighting.

As another example, a particleboard direct-fired rotary dryer represents a high frequency of ignition sources and conveys dried material to a screening operation (process equipment with high production impact and high explosion risk). An isolation goal in this case could be to prevent conveying burning material into the downstream process equipment, using spark detection to stop steel-tipped rotaryfeeders and stop or reverse conveyors. Figure W.1(c) and Figure W.1(d) show a typical interlock logic and arrangement along with other fire protection (spark extinguishing and collector water spray) and deflagration protection (explosion vents).

**Figure W.1(c) Typical Interlock Logic for a Particleboard Direct-Fired Rotary Dryer System.** (© 2002 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, “Wood Processing and Woodworking Facilities.”)
Figure W.1(d) Typical Arrangement of a Particleboard Direct-Fired Rotary Dryer System. (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, “Wood Processing and Woodworking Facilities.”)

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

X.1

Automatic water spray deluge protection has proven to be the most effective. Dryers with only one or two heating zones can usually be protected by a single deluge system, but long dryers where the water demand is high [e.g., 7571 L/min (2000 gpm)] can require two or more deluge systems. The dryer geometry will dictate nozzle placement, but the following criteria can be used as a basis for system design:

1. For conventional tray dryers, provide nozzles on both sides so that one nozzle on each vertical pipe drop is at alternating tier levels and below the bottom tier. Nozzles should have wide-angle spray patterns capable of reaching at least halfway across the tray. Vertical pipe drops should be spaced along the sides of the trays so that the spray patterns overlap in the center of the dryer.
(2) For vertical jet-type dryers, where nozzles are arranged to discharge from only one side, provide one nozzle with a flat spray pattern located at each tier on each vertical pipe drop and below the bottom tier, as shown in Figure X.1(a) and Figure X.1(b). Provide the same type of nozzle on each vertical pipe drop, with wide-angle nozzles on one vertical pipe drop and narrow-angle, longer throw nozzles on the alternating pipe drop. Vertical pipe drops should be spaced along the sides of the trays so that the spray patterns overlap in the center of the dryer.

(3) Provide nozzles on each tier level of the cooling section.

(4) Provide standard upright open sprinklers in the top and side plenum chambers of both standard and vertical jet-type dryers. Heads should be spaced no more than 45 m (13 ft) apart.

(5) Provide standard open sprinklers in each exhaust stack.

(6) Provide water traps [as shown in Figure X.1(b) and Figure X.1(c)] to help prevent air movement through the deluge piping (which can cause plugging). Traps should be inspected weekly to ensure they are kept filled with water.

(7) Provide strainers in the deluge valve water supply line to remove any foreign material in the water supply that could plug nozzles.

(8) Provide a dry pilot head system or other reliable detection system to actuate the deluge system. Figure X.1(a), Figure X.1(c), and Figure X.1(d) show suggested locations of the detectors or pilot heads.

(9) Provide manual pull stations, which are recommended, to trip the deluge system from either side of the dryer.

(10) Interlock the dryer fans and heat source to shut down when the deluge system(s) trips. The dryer conveying system should continue to operate to empty as much combustible material from the dryer as possible.

(11) Tripping of the deluge system is recommended as part of the dryer scheduled cleaning program. For wicket-type dryers, provide standard sprinklers inside at the top of the dryer enclosure and in exhaust plenums and stacks as shown in Figure X.1(e).

(12) Flash fires can readily occur in the resinous deposits above veneer dryers, spreading throughout the draft-curtained area ahead of operating sprinklers. Sprinklers can control the residual fire if properly designed, but they cannot be relied upon to limit the number of heads that will open.

Figure X.1(a) Typical Arrangement of Deluge Protection for Vertical Jet-Type Dryer. (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, "Wood Processing and Woodworking Facilities.")
Figure X.1(b) Section View A-A of Deluge Protection for Typical Vertical Jet-Type Dryer in Figure X.1(a). (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, “Wood Processing and Woodworking Facilities.”)

Note: See Figure E.1(b).
Figure X.1(c) Typical Arrangement of Deluge Protection for Standard Veneer Dryer. (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, "Wood Processing and Woodworking Facilities.")
Figure X.1(d) Typical Arrangement of Deluge Protection for Special Vertical Jet-Type Dryer. (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, “Wood Processing and Woodworking Facilities.”)
Figure X.1(e) Typical Arrangement of Automatic Sprinkler Protection for Wicket-Type Veneer Dryer. (© 2010 Factory Mutual Insurance Company. Reprinted with permission. All rights reserved. Source: Property Loss Prevention Data Sheet 7-10, "Wood Processing and Woodworking Facilities").
For a diagram of typical sprinkler system arrangements for veneer dryers, see Figure X.1(a) and Figure X.1(b).

Annex Y Combustible Dust Test Data

Y.1 General.

Refer to Tables Y.2(a) through Y.4(d) for examples of combustible dust test data. These tables are not all-inclusive. Additionally, material properties and testing methods can provide results that vary from those presented in these tables.

Y.2 Agricultural Dusts. [CMD-AGR]

Table Y.2(a) Test Data — Agricultural Dusts

<table>
<thead>
<tr>
<th>Dust Name</th>
<th>Test Report Date</th>
<th>Sample Dried</th>
<th>Percent Moisture as Tested (%)</th>
<th>Median Particle Size as Received (µm)</th>
<th>Median Particle Size as Tested (µm)</th>
<th>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</th>
<th>P_{max} (bar g)</th>
<th>K_{0} (bar m/sec)</th>
<th>Minimum Explosive Concentration (MEC) (g/m³)</th>
<th>Minimum Ignition Energy (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa concentrate</td>
<td>1997</td>
<td>Yes</td>
<td>2.1</td>
<td>Unk</td>
<td>36</td>
<td>99</td>
<td>6.7</td>
<td>94</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Alfalfa powder</td>
<td>2011</td>
<td>Yes</td>
<td>4.5</td>
<td>Unk</td>
<td>103</td>
<td>100</td>
<td>7.9</td>
<td>75</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Angel food cake mix</td>
<td>2012</td>
<td>No</td>
<td>4.1</td>
<td>107</td>
<td>41</td>
<td>100</td>
<td>7.5</td>
<td>132</td>
<td>NT</td>
<td>NT</td>
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<td>Apple</td>
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<td>Unk</td>
<td>Unk</td>
<td>155</td>
<td>Unk</td>
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<td>34</td>
<td>125</td>
<td>NT</td>
<td>NT</td>
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<td>Barley</td>
<td>2016</td>
<td>Yes</td>
<td>2.3</td>
<td>Unk</td>
<td>28</td>
<td>Unk</td>
<td>8.7</td>
<td>192</td>
<td>75–100</td>
<td>10–30</td>
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<td>Unk</td>
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<td>7.5</td>
<td>107</td>
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<td>NT</td>
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<td>Betaine – nutraceutical</td>
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<td>Unk</td>
<td>&lt;45</td>
<td>100</td>
<td>9</td>
<td>286</td>
<td>190</td>
<td>NT</td>
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<td>anhydrous betaine</td>
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<td></td>
</tr>
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<td>Canola dust</td>
<td>2016</td>
<td>Yes</td>
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<td>Unk</td>
<td>12</td>
<td>Unk</td>
<td>6.2</td>
<td>40</td>
<td>60–75</td>
<td>10–30</td>
</tr>
<tr>
<td>Canola meal</td>
<td>2016</td>
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<td>2.4</td>
<td>Unk</td>
<td>59</td>
<td>Unk</td>
<td>7.1</td>
<td>91</td>
<td>110–125</td>
<td>100–300</td>
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<tr>
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<td>No</td>
<td>6.4</td>
<td>Unk</td>
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<td>(59.8)</td>
<td>6.2</td>
<td>15</td>
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<td>NT</td>
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<td>Carrageen</td>
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<td>Unk</td>
<td>Unk</td>
<td>100</td>
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<td>140</td>
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<td>Unk</td>
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<td>100</td>
<td>5.2</td>
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<td>NT</td>
<td>NT</td>
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<tr>
<td>Dust Name</td>
<td>Test Report Date</td>
<td>Sample Dried</td>
<td>Percent Moisture as Tested (%)</td>
<td>Median Particle Size as Received (µm)</td>
<td>Median Particle Size as Tested (µm)</td>
<td>Percent &lt;200 (or &lt;&lt;250) Mesh as Tested (%)</td>
<td>Pmax (bar g)</td>
<td>K0 (bar m/sec)</td>
<td>Minimum Explosive Concentration (MEC) (g/m³)</td>
<td>Minimum Ignition Energy (mJ)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------------------</td>
<td>--------------</td>
<td>-------------------------------</td>
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<td>--------------</td>
<td>----------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Carrot</td>
<td>1997</td>
<td>Yes</td>
<td>4</td>
<td>Unk</td>
<td>29</td>
<td>97</td>
<td>6.9</td>
<td>65</td>
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<td>NT</td>
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<td>Cereal dust</td>
<td>2003</td>
<td>Yes</td>
<td>4.9</td>
<td>Unk</td>
<td>94</td>
<td>80</td>
<td>6.6</td>
<td>96</td>
<td>265</td>
<td>NT</td>
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<td>Cheesy pasta (corn starch and various spices)</td>
<td>2014</td>
<td>Unk</td>
<td>7.9</td>
<td>Unk</td>
<td>45</td>
<td>80</td>
<td>7.2</td>
<td>99</td>
<td>NT</td>
<td>30–100</td>
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<tr>
<td>Chili (corn starch and various spices)</td>
<td>2014</td>
<td>Unk</td>
<td>7</td>
<td>Unk</td>
<td>79</td>
<td>65</td>
<td>6.6</td>
<td>60</td>
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<td>30–100</td>
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<td>Cocoa bean shell dust</td>
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<td>Yes</td>
<td>4.4</td>
<td>Unk</td>
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<td>100</td>
<td>6.7</td>
<td>42</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Cocoa powder</td>
<td>2009</td>
<td>Yes</td>
<td>3.9</td>
<td>Unk</td>
<td>194</td>
<td>50</td>
<td>8</td>
<td>162</td>
<td>65</td>
<td>100–180*</td>
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<td>Coconut shell dust</td>
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<td>Unk</td>
<td>6.5</td>
<td>Unk</td>
<td>Unk</td>
<td>80</td>
<td>6.8</td>
<td>111</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Coffee grounds dust</td>
<td>2009</td>
<td>Yes</td>
<td>4</td>
<td>Unk</td>
<td>40</td>
<td>100</td>
<td>7.7</td>
<td>158</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Coffee dust – coarse particles</td>
<td>Unk</td>
<td>Unk</td>
<td>4.8</td>
<td>Unk</td>
<td>321</td>
<td>0.4</td>
<td>6.9</td>
<td>55</td>
<td>NT</td>
<td>160*</td>
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<tr>
<td>Coffee dust (instant coffee)</td>
<td>2016</td>
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<td>2.4</td>
<td>Unk</td>
<td>45</td>
<td>100</td>
<td>6.8</td>
<td>101</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Coffee (green)</td>
<td>2009</td>
<td>Yes</td>
<td>4.6</td>
<td>Unk</td>
<td>57</td>
<td>100</td>
<td>7.6</td>
<td>116</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Coffee creamer (French vanilla)</td>
<td>2006</td>
<td>Yes</td>
<td>3.1</td>
<td>Unk</td>
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<td>(94.6)</td>
<td>7.6</td>
<td>156</td>
<td>NT</td>
<td>NT</td>
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<td>Corn maize</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
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<td>55</td>
<td>8.7</td>
<td>117</td>
<td>30</td>
<td>&gt;10</td>
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<td>1996</td>
<td>Yes</td>
<td>1.6</td>
<td>Unk</td>
<td>589</td>
<td>8</td>
<td>7</td>
<td>35</td>
<td>NT</td>
<td>NT</td>
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<td>Unk</td>
<td>11.4</td>
<td>Unk</td>
<td>45</td>
<td>98</td>
<td>7.8</td>
<td>139</td>
<td>NT</td>
<td>NT</td>
</tr>
<tr>
<td>Cornstarch – coarse particles</td>
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<td>Yes</td>
<td>2.2</td>
<td>Unk</td>
<td>217</td>
<td>(62.5)</td>
<td>7.9</td>
<td>186</td>
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<td>Cotton (flocks, pulverized)</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>44</td>
<td>100</td>
<td>7.2</td>
<td>24</td>
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<td>Cotton lint dust</td>
<td>2006</td>
<td>Yes</td>
<td>4.8</td>
<td>Unk</td>
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<td>(43.6)</td>
<td>8.6</td>
<td>88</td>
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<tr>
<td>Dust Name</td>
<td>Test Report Date</td>
<td>Sample Dried</td>
<td>Percent Moisture as Tested (%)</td>
<td>Median Particle Size as Received (µm)</td>
<td>Median Particle Size as Tested (µm)</td>
<td>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</td>
<td>P_{max}(bar)</td>
<td>K_{St}(bar m/sec)</td>
<td>Minimum Explosive Concentration (MEC) (g/m³)</td>
<td>Minimum Ignition Energy (mJ)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------</td>
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<td>------------------</td>
<td>-----------------------------------------------</td>
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<tr>
<td>Cottonseed (expeller, silo entrance)</td>
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<td>Unk</td>
<td>Unk</td>
<td>245</td>
<td>245</td>
<td>(50)</td>
<td>7.7</td>
<td>35</td>
<td>125</td>
<td>NT</td>
</tr>
<tr>
<td>Dried distillers dried grains w/solubles (DDGS)</td>
<td>2016</td>
<td>No</td>
<td>3.8</td>
<td>26</td>
<td>Unk</td>
<td>7.6</td>
<td>135</td>
<td>75–100</td>
<td>10–30</td>
<td>NT</td>
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<tr>
<td>Dried distillers dried grains (yellow corn) w/solubles (DDGS)</td>
<td>2009</td>
<td>Yes</td>
<td>4.2</td>
<td>225</td>
<td>(43.8)</td>
<td>6.5</td>
<td>42</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Dried distillers dried grains (wheat) w/solubles (DDGS)</td>
<td>2011</td>
<td>Yes</td>
<td>4.4</td>
<td>189</td>
<td>(67.1)</td>
<td>7.5</td>
<td>105</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Fudge brownie mix</td>
<td>2012</td>
<td>No</td>
<td>4.8</td>
<td>291</td>
<td>221</td>
<td>(65.3)</td>
<td>5.8</td>
<td>43</td>
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<td>Garlic powder</td>
<td>1988</td>
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<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>164</td>
<td>NT</td>
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<tr>
<td>Garlic powder, onion powder extract loc bac and salt (from dust collector)</td>
<td>2010</td>
<td>Yes</td>
<td>2.3</td>
<td>176</td>
<td>(35.3)</td>
<td>4</td>
<td>15</td>
<td>NT</td>
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<td>NT</td>
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<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>150</td>
<td>Unk</td>
<td>7.7</td>
<td>110</td>
<td>125</td>
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<td>Gluten – wheat</td>
<td>1999</td>
<td>Unk</td>
<td>5.2</td>
<td>81</td>
<td>(96)</td>
<td>7.3</td>
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<tr>
<td>Grain dust – mixed (wheat, corn, beans)</td>
<td>2016</td>
<td>Yes</td>
<td>3.3</td>
<td>Unk</td>
<td>48</td>
<td>7.1</td>
<td>108</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Grain dust – mixed (wheat, corn, beans)</td>
<td>2016</td>
<td>No</td>
<td>4.4</td>
<td>Unk</td>
<td>33</td>
<td>8.3</td>
<td>170</td>
<td>60–75</td>
<td>10–30</td>
<td>NT</td>
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<tr>
<td>Grain dust – mixed (reintroduced from dust collector)</td>
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<td>No</td>
<td>8.3</td>
<td>Unk</td>
<td>65</td>
<td>(83.1)</td>
<td>7.7</td>
<td>129</td>
<td>NT</td>
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<td>Grass dust</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>200</td>
<td>Unk</td>
<td>8</td>
<td>47</td>
<td>125</td>
<td>NT</td>
<td>NT</td>
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<td>Hops, malted</td>
<td>Unk</td>
<td>Unk</td>
<td>Unk</td>
<td>490</td>
<td>Unk</td>
<td>8.2</td>
<td>90</td>
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<td>NT</td>
<td>NT</td>
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<td>Hops dust (overhead ceiling structure)</td>
<td>2006</td>
<td>No</td>
<td>8.3</td>
<td>54</td>
<td>(98)</td>
<td>7.4</td>
<td>159</td>
<td>75</td>
<td>NT</td>
<td>NT</td>
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<tr>
<td>Dust Name</td>
<td>Test Report Date</td>
<td>Sample Dried</td>
<td>Percent Moisture as Tested (%)</td>
<td>Median Particle Size as Received (µm)</td>
<td>Median Particle Size as Tested (µm)</td>
<td>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</td>
<td>Pmax (bar g)</td>
<td>K0 (bar m/sec)</td>
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<td>Minimum Ignition Energy (mJ)</td>
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<td>Median Particle Size as Tested (µm)</td>
<td>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</td>
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<td>KSt (bar m/sec)</td>
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<td>Minimum Ignition Energy (mJ)</td>
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<td>Sample Dried</td>
<td>Percent Moisture as Tested (%)</td>
<td>Median Particle Size as Received (µm)</td>
<td>Median Particle Size as Tested (µm)</td>
<td>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</td>
<td>P_{max} (bar g)</td>
<td>K_{St} (bar m/sec)</td>
<td>Minimum Explosive Concentration (MEC) (g/m³)</td>
<td>Minimum Ignition Energy (mJ)</td>
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<td>73</td>
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<td>12.7</td>
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### Dust Name

<table>
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<tr>
<th>Dust Name</th>
<th>Test Report Date</th>
<th>Sample</th>
<th>Percent Moisture as Tested (%)</th>
<th>Median Particle Size as Received (µm)</th>
<th>Median Particle Size as Tested (µm)</th>
<th>Percent &lt;200 (or &lt;250) Mesh as Tested (%)</th>
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<th>Ko (bar m/sec)</th>
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<th>Minimum Ignition Energy (mJ)</th>
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<td>Yucca seed dust (hydrolyzed)</td>
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Unk: Unknown. NT: Not Tested.

*Data is not from this product test. It is from the SFPE *Handbook of Fire Protection Engineering*, 4th Edition, Table 3-18.2 of a similar product.

Notes:

1. **Please note that the information provided in this table is for the specific agricultural/food dust sample tested.** Explosion severity and ignition sensitivity parameters are greatly influenced by many factors such as particle size, shape, and moisture content. Differences in specific mixture composition and possible contamination will also affect explosibility parameters. The information in this table should be used for general hazard assessment and not be used for design purposes.

2. Normalized to 1 m³ test vessel pressures, per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

3. See also Table F.1(a) in NFPA 68 for additional information on agricultural dusts with known explosion hazards.

4. For those agricultural dusts without known explosion data, the dust should be tested in accordance with established standardized test methods.

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### Table Y.2(b) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Agricultural Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (µm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>Pmax (bar)</th>
<th>Ko (bar m/sec)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>33</td>
<td>60</td>
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<td>229</td>
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<td>42</td>
<td>30</td>
<td>9.9</td>
<td>62</td>
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<td>42</td>
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<tr>
<td>Egg white</td>
<td>17</td>
<td>125</td>
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<td>38</td>
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<td>Milk, powdered</td>
<td>83</td>
<td>60</td>
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<td>28</td>
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<tr>
<td>Soy flour</td>
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<td>200</td>
<td>9.2</td>
<td>110</td>
<td>1</td>
</tr>
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</table>
### Starch, corn
- Mass Median Diameter: 7 μm
- Minimum Flammable Concentration: —
- $P_{\text{max}}$: 10.3 bar
- $K_{St}$: 202 bar-m/s
- Dust Hazard: Class 2

### Starch, rice
- Mass Median Diameter: 18 μm
- Minimum Flammable Concentration: 60 g/m³
- $P_{\text{max}}$: 9.2 bar
- $K_{St}$: 101 bar-m/s
- Dust Hazard: Class 1

### Starch, wheat
- Mass Median Diameter: 22 μm
- Minimum Flammable Concentration: 30 g/m³
- $P_{\text{max}}$: 9.9 bar
- $K_{St}$: 115 bar-m/s
- Dust Hazard: Class 1

### Sugar
- Mass Median Diameter: 30 μm
- Minimum Flammable Concentration: 200 g/m³
- $P_{\text{max}}$: 8.5 bar
- $K_{St}$: 138 bar-m/s
- Dust Hazard: Class 1

### Sugar, milk
- Mass Median Diameter: 27 μm
- Minimum Flammable Concentration: 60 g/m³
- $P_{\text{max}}$: 8.3 bar
- $K_{St}$: 82 bar-m/s
- Dust Hazard: Class 1

### Sugar, beet
- Mass Median Diameter: 29 μm
- Minimum Flammable Concentration: 60 g/m³
- $P_{\text{max}}$: 8.2 bar
- $K_{St}$: 59 bar-m/s
- Dust Hazard: Class 1

### Tapioca
- Mass Median Diameter: 22 μm
- Minimum Flammable Concentration: 125 g/m³
- $P_{\text{max}}$: 9.4 bar
- $K_{St}$: 62 bar-m/s
- Dust Hazard: Class 1

### Whey
- Mass Median Diameter: 41 μm
- Minimum Flammable Concentration: 125 g/m³
- $P_{\text{max}}$: 9.8 bar
- $K_{St}$: 140 bar-m/s
- Dust Hazard: Class 1

### Wood flour
- Mass Median Diameter: 29 μm
- Minimum Flammable Concentration: —
- $P_{\text{max}}$: 10.5 bar
- $K_{St}$: 205 bar-m/s
- Dust Hazard: Class 2

[68: Table F.1(a)]

---

### Y.3 Metal Dusts. [CMD-CMM]

**Table Y.3(a) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Metal Dusts**

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>$P_{\text{max}}$ (bar)</th>
<th>$K_{St}$ (bar-m/s)</th>
<th>Dust Hazard</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>29</td>
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<td>12.4</td>
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<td>Bronze</td>
<td>18</td>
<td>750</td>
<td>4.1</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>Iron carbonyl</td>
<td>&lt;10</td>
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<td>111</td>
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<tr>
<td>Magnesium</td>
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<td>30</td>
<td>17.5</td>
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<tr>
<td>Phenolic resin</td>
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[68: Table F.1(d)]
## Table Y.3(b) Explosibility Properties of Metals

<table>
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<tr>
<th>Material</th>
<th>Median Diameter (μm)</th>
<th>K_st (bar·m/s)</th>
<th>P_max (bar)</th>
<th>Cloud Ign Temp (°C)</th>
<th>MIE (ml)</th>
<th>MEC (g/m³)</th>
<th>UN Combustibility Category</th>
<th>LOC (v%)</th>
<th>Data Source</th>
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<tr>
<td>Aluminum</td>
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<td>50</td>
<td>45</td>
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<td>2 (C)</td>
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<td>MIE</td>
<td>MEC</td>
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<td>Industry</td>
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<td>Industry</td>
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<td>125</td>
<td>BZ 3</td>
<td>Eckhoff</td>
<td>Industry</td>
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<tr>
<td>Silicon, from dust collector</td>
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<td>Eckhoff</td>
<td>Industry</td>
</tr>
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<td>BZ 1</td>
<td>Eckhoff</td>
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<td>Industry</td>
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<td>$P_{\text{max}}$ ((\text{bar-g}))</td>
<td>Cloud Ign Temp ((\degree C))</td>
<td>MIE ((\text{ml}))</td>
<td>MEC ((\text{g/m}^3))</td>
<td>UN Combustibility Category</td>
<td>LOC(^1) ((%))</td>
<td>Data Source</td>
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<td>160</td>
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<td>2(Ar)</td>
<td>Industry</td>
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<td>2(Ar)</td>
<td>Industry</td>
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<td>&lt;2(Ar)</td>
<td>Industry</td>
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<td>&lt;2(Ar)</td>
<td>Industry</td>
</tr>
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<td>3.3</td>
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<td></td>
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<td>—</td>
<td>BGIA</td>
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<td>—</td>
<td>Eckhof</td>
</tr>
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<td>4.7</td>
<td>—</td>
<td>70</td>
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<td>LOC1 ((v%))</td>
<td>—</td>
<td>Cashdollar &amp; Zlochower</td>
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<tr>
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<td>—</td>
<td>4.8</td>
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<td>—</td>
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<td>570</td>
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<td>250</td>
<td>LOC1 ((v%))</td>
<td>BZ 3</td>
<td>Eckhoff</td>
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<tr>
<td>Zinc (from collector)</td>
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<td>—</td>
<td>125</td>
<td></td>
<td>LOC1 ((v%))</td>
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<td>Eckhoff</td>
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<tr>
<td>Zinc (from Zn coating)</td>
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<td>85</td>
<td>6</td>
<td>800</td>
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<td>Zinc (from Zn coating)</td>
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<td>93</td>
<td>6.8</td>
<td>790</td>
<td></td>
<td>250</td>
<td>LOC1 ((v%))</td>
<td>—</td>
<td>Eckhoff</td>
</tr>
<tr>
<td>Zirconium</td>
<td>&lt;44</td>
<td>—</td>
<td>5.2</td>
<td>20</td>
<td>5</td>
<td>45</td>
<td>LOC1 ((v%))</td>
<td>Ignites in $N_2$ &amp; $CO_2$</td>
<td>BuMines RI 6516</td>
</tr>
<tr>
<td>Zirconium (Zircalloy-2)</td>
<td>50</td>
<td>—</td>
<td>3.0</td>
<td>420</td>
<td>30</td>
<td></td>
<td>LOC1 ((v%))</td>
<td>—</td>
<td>BuMines RI 6516</td>
</tr>
</tbody>
</table>

(1) Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen.
(2) UN Dust Layer Combustibility Categories are as follows: BZ1 No self-sustained combustion; BZ2 Local combustion of short duration; BZ3 Local sustained combustion, but no propagation; BZ4 Propagating smoldering combustion; BZ5 Propagating open flame; BZ6 Explosive combustion.

(3) BGIA is the GESTIS-DUST-EX database maintained by BGIA-online.hvbg.de


Table Y.3(c) Atomized Aluminum Particle Ignition and Explosion Data

<table>
<thead>
<tr>
<th>Particle Size (d_{50})</th>
<th>BET (m²/g)</th>
<th>MEC (g/m³)</th>
<th>Pmax</th>
<th>dP/dtmax</th>
<th>K_{St}</th>
<th>Sample Concentration That Corresponds to Pmax and dP/dtmax</th>
<th>MIE (mJ)</th>
<th>LOC (%)</th>
<th>Most Easily Ignitible Concentration (g/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonspherical, Nodular, or Irregular Powders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dP/dtmax (g/m³)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>0.18</td>
<td>170</td>
<td>123</td>
<td>3,130</td>
<td>59</td>
<td>1,250 (Pmax), 1,250 (dP/dtmax)</td>
<td>1,250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>0.19</td>
<td>70</td>
<td>133</td>
<td>5,720</td>
<td>107</td>
<td>1,000 (dP/dtmax)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.34</td>
<td>60</td>
<td>142</td>
<td>7,950</td>
<td>149</td>
<td>1,250</td>
<td>10</td>
<td>750 (Pmax), 1,500 (dP/dtmax)</td>
<td>11</td>
</tr>
<tr>
<td>32</td>
<td>0.58</td>
<td>65</td>
<td>133</td>
<td>8,880</td>
<td>167</td>
<td>1,250</td>
<td>10</td>
<td>750 (Pmax), 1,500 (dP/dtmax)</td>
<td>11</td>
</tr>
<tr>
<td>30</td>
<td>0.10</td>
<td>60</td>
<td>10</td>
<td></td>
<td>10</td>
<td>1,250</td>
<td>11</td>
<td>1,000 (Pmax), 1,250 (dP/dtmax)</td>
<td>11</td>
</tr>
<tr>
<td>28</td>
<td>0.11</td>
<td>55</td>
<td>140</td>
<td>6,360</td>
<td>119</td>
<td>1,000 (Pmax), 1,250 (dP/dtmax)</td>
<td>1,250</td>
<td>11</td>
<td>Ignition @ 8.0% Nonignition @ 7.5%</td>
</tr>
<tr>
<td>28</td>
<td>0.21</td>
<td>55</td>
<td>146</td>
<td>8,374</td>
<td>157</td>
<td>1,500</td>
<td>11</td>
<td>750 (Pmax), 1,500 (dP/dtmax)</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>0.90</td>
<td>65</td>
<td>165</td>
<td>15,370</td>
<td>288</td>
<td>1,000 (dP/dtmax)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>0.74</td>
<td>90</td>
<td>153</td>
<td>17,702</td>
<td>332</td>
<td>1,000 (Pmax), 1,000 (dP/dtmax)</td>
<td>1,000</td>
<td>12</td>
<td>500 (dP/dtmax)</td>
</tr>
<tr>
<td>6</td>
<td>0.15</td>
<td>80</td>
<td>176</td>
<td>15,580</td>
<td>292</td>
<td>750</td>
<td>3.5</td>
<td>500 (Pmax), 750 (dP/dtmax)</td>
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<tr>
<td>6</td>
<td>0.70</td>
<td>75</td>
<td>174</td>
<td>15,690</td>
<td>294</td>
<td>500 (Pmax), 750 (dP/dtmax)</td>
<td>500</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Particle Size (d_{50})(μm)</td>
<td>BET (m²/g)</td>
<td>MEC (g/m³)</td>
<td>P_{max} (psi)</td>
<td>dP/dt_{max} (psi/sec)</td>
<td>K_{St} (bar·m/sec)</td>
<td>Sample Concentration That Corresponds to P_{max} and dP/dt_{max} (g/m³)</td>
<td>MIE (mJ)</td>
<td>LOC (%)</td>
<td>Most Easily Ignitible Concentration (g/m³)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
<td>-------------</td>
<td>---------------</td>
<td>------------------------</td>
<td>-------------------</td>
<td>---------------------------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.00</td>
<td>70</td>
<td></td>
<td></td>
<td>1,000 (dP/dt_{max})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.78</td>
<td>75</td>
<td>167</td>
<td>15,480</td>
<td>291</td>
<td></td>
<td></td>
<td>1,000 (P_{max})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>750 (dP/dt_{max})</td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Spherical Powders</strong></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>63</td>
<td>0.15</td>
<td>120</td>
<td>101</td>
<td>1,220</td>
<td>23</td>
<td>1,250</td>
<td>N.I.</td>
<td>Ignition @ 8.0% Nonignition @ 7.5% 1,750</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td>36</td>
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<td>60</td>
<td>124</td>
<td>4,770</td>
<td>90</td>
<td>1,250</td>
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<td>13</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.10</td>
<td>60</td>
<td>140</td>
<td>5,940</td>
<td>111</td>
<td>1,000</td>
<td></td>
<td>13</td>
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<tr>
<td></td>
<td>15</td>
<td>0.50</td>
<td>45</td>
<td>148</td>
<td>10,812</td>
<td>203</td>
<td>1,000</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.30</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.53</td>
<td>75</td>
<td>174</td>
<td>16,324</td>
<td>306</td>
<td>750</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.30</td>
<td>167</td>
<td>14,310</td>
<td>269</td>
<td>750</td>
<td></td>
<td></td>
<td>Ignition @ 6.0% Nonignition @ 5.5% 750</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>1.00</td>
<td>70</td>
<td>155</td>
<td>14,730</td>
<td>276</td>
<td>1,250</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ignition @ 6.0% Nonignition @ 5.5% 1,250</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2.50</td>
<td>95</td>
<td>165</td>
<td>15,900</td>
<td>298</td>
<td>1,250</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.00</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For U.S. conversions: 1 m²/g = 4884 ft²/lb; 1 g/m² = 0.000062 lb/ft²; 1 bar/sec = 14.5 psi/sec; 1 bar·m/sec = 0.226 psi·ft/sec.

BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O₂) concentration.

Notes:
(1) The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.
(2) Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E1515, Standard Test Method for Minimum Explosible Concentration of Combustible Dusts; MIE: ASTM E2019, Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air; maximum pressure rise (P_{max}), maximum pressure rise rate (dP/dt), and deflagration index.

(3) Particle size data represent the \( d_{50} \) measurement determined by the laser light–scattering technique.

(4) Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.

(5) The determination of explosibility parameters (i.e., \( P_{\text{max}} \), LOC, \( K_{\text{St}} \)) for nanometals should be conducted with representative nanometal samples, because the values of some explosibility parameters can be significantly different than the corresponding values measured with micrometer-sized samples. In the case of many nanometals, the ASTM E1226 test methods to determine explosibility parameters require modification to prevent pre-ignition during compressed air injection into the test vessel. (See Bouillard 2010 and Boilard 2013.)

### Table Y.3(d) Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 mesh (75 \( \mu \)m)]

<table>
<thead>
<tr>
<th>Explosion Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum explosion pressure (gauge)</td>
<td>793 kPa (115 psi)</td>
</tr>
<tr>
<td>Maximum rate of pressure rise (gauge)</td>
<td>793 kPa/sec (15,000 psi/sec)</td>
</tr>
<tr>
<td>Ignition temperature cloud</td>
<td>1040°F (560°C)</td>
</tr>
<tr>
<td>Minimum cloud ignition energy</td>
<td>0.04 J (26.4 W/sec)</td>
</tr>
<tr>
<td>Minimum explosion concentration</td>
<td>0.328 kg/m(^3) (0.03 oz/ft(^3))</td>
</tr>
<tr>
<td>Limiting oxygen percent for spark ignition*</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: \( K_{\text{St}} \) values vary for specific particle sizes.

*Burns in carbon dioxide, nitrogen, and halons.

### Y.4 Other. [CMD-FUN]

#### Table Y.4(a) 1 m\(^3\) Vessel Test Data from Forschungsbericht Staubexplosionen — Carbonaceous Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter</th>
<th>Minimum Flammable Concentration</th>
<th>( P_{\text{max}} )</th>
<th>( K_{\text{St}} )</th>
<th>Dust Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal, activated</td>
<td>28</td>
<td>60</td>
<td>7.7</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table Y.4(b) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Chemical Dusts

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;St&lt;/sub&gt; (bar-m/s)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal, wood</td>
<td>14</td>
<td>60</td>
<td>9.0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Coal, bituminous</td>
<td>24</td>
<td>60</td>
<td>9.2</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>Coke, petroleum</td>
<td>15</td>
<td>125</td>
<td>7.6</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>Lampblack</td>
<td>&lt;10</td>
<td>60</td>
<td>8.4</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>Lignite</td>
<td>32</td>
<td>60</td>
<td>10.0</td>
<td>151</td>
<td>1</td>
</tr>
<tr>
<td>Peat, 22% H₂O</td>
<td>-</td>
<td>125</td>
<td>84.0</td>
<td>67</td>
<td>1</td>
</tr>
<tr>
<td>Soot, pine</td>
<td>&lt;10</td>
<td>-</td>
<td>7.9</td>
<td>26</td>
<td>1</td>
</tr>
</tbody>
</table>

[68: Table F.1(b)]
Material | Mass Median Diameter (μm) | Minimum Flammable Concentration (g/m³) | P<sub>max</sub> (bar) | K<sub>St</sub> (bar·m/s) | Dust Hazard Class
--- | --- | --- | --- | --- | ---
Paraformaldehyde | 23 | 60 | 9.9 | 178 | 1
Sodium ascorbate | 23 | 60 | 8.4 | 119 | 1
Sodium stearate | 22 | 30 | 8.8 | 123 | 1
Sulfur | 20 | 30 | 6.8 | 151 | 1

[68: Table F.1(c)]

**Table Y.4(c) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen (except where noted) — Plastic Dusts**

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass Median Diameter (μm)</th>
<th>Minimum Flammable Concentration (g/m³)</th>
<th>P&lt;sub&gt;max&lt;/sub&gt; (bar)</th>
<th>K&lt;sub&gt;St&lt;/sub&gt; (bar·m/s)</th>
<th>Dust Hazard Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>(poly) Acrylamide</td>
<td>10</td>
<td>250</td>
<td>5.9</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Acrylonitrile</td>
<td>25</td>
<td>—</td>
<td>8.5</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Ethylene (low-pressure process)</td>
<td>&lt;10</td>
<td>30</td>
<td>8.0</td>
<td>156</td>
<td>1</td>
</tr>
<tr>
<td>Epoxy resin</td>
<td>26</td>
<td>30</td>
<td>7.9</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td>Melamine resin</td>
<td>18</td>
<td>125</td>
<td>10.2</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Melamine, molded (wood flour and mineral filled phenol-formaldehyde)</td>
<td>15</td>
<td>60</td>
<td>7.5</td>
<td>41</td>
<td>1</td>
</tr>
<tr>
<td>Melamine, molded (phenol-cellulose)</td>
<td>12</td>
<td>60</td>
<td>10.0</td>
<td>127</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Methyl acrylate</td>
<td>21</td>
<td>30</td>
<td>9.4</td>
<td>269</td>
<td>2</td>
</tr>
<tr>
<td>(poly) Methyl acrylate, emulsion polymer</td>
<td>18</td>
<td>30</td>
<td>10.1</td>
<td>202</td>
<td>2</td>
</tr>
<tr>
<td>Phenolic resin</td>
<td>&lt;10</td>
<td>15</td>
<td>9.3</td>
<td>129</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>—</td>
<td>7.9</td>
<td>269</td>
<td>2</td>
</tr>
<tr>
<td>(poly) Propylene</td>
<td>25</td>
<td>30</td>
<td>8.4</td>
<td>101</td>
<td>1</td>
</tr>
<tr>
<td>Terpene-phenol resin</td>
<td>10</td>
<td>15</td>
<td>8.7</td>
<td>143</td>
<td>1</td>
</tr>
<tr>
<td>Material</td>
<td>Mass Median Diameter (μm)</td>
<td>Minimum Flammable Concentration (g/m³)</td>
<td>$P_{max}$ (bar)</td>
<td>$K_{st}$ (bar·m/s)</td>
<td>Dust Hazard Class</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------</td>
<td>----------------------------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Urea-formaldehyde/cellulose, molded</td>
<td>13</td>
<td>60</td>
<td>10.2</td>
<td>136</td>
<td>1</td>
</tr>
<tr>
<td>(poly) Vinyl acetate/ethylene copolymer</td>
<td>32</td>
<td>30</td>
<td>8.6</td>
<td>119</td>
<td>1</td>
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<tr>
<td>(poly) Vinyl alcohol</td>
<td>26</td>
<td>60</td>
<td>8.9</td>
<td>128</td>
<td>1</td>
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<tr>
<td>(poly) Vinyl butyral</td>
<td>65</td>
<td>30</td>
<td>8.9</td>
<td>147</td>
<td>1</td>
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<tr>
<td>(poly) Vinyl chloride</td>
<td>107</td>
<td>200</td>
<td>7.6</td>
<td>46</td>
<td>1</td>
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<tr>
<td>(poly) Vinyl chloride/vinyl acetylene emulsion copolymer</td>
<td>35</td>
<td>60</td>
<td>8.2</td>
<td>95</td>
<td>1</td>
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<tr>
<td>(poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer</td>
<td>60</td>
<td>60</td>
<td>8.3</td>
<td>98</td>
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</table>

[68: Table F.1(e)]

### Table Y.4(d) 20 L and 1 m³ Vessel Test Data, PVC and Copolymer Plastic Resins and Dusts

<table>
<thead>
<tr>
<th>PVC Resin Sample</th>
<th>Type of polymerization process</th>
<th>GP&lt;sup&gt;a&lt;/sup&gt; Dispersion</th>
<th>VA&lt;sup&gt;b&lt;/sup&gt; Copolymer</th>
<th>Baghouse Dust from GP Pipe (as received)</th>
<th>GP Pipe Resin&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Baghouse Dust from GP Pipe (as received)</th>
<th>GP Pipe Resin (as received)</th>
<th>High Molecular Weight Resin (as received)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant designator</td>
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<td></td>
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</tr>
<tr>
<td>Test lab</td>
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<td>Chilworth</td>
<td>Chilworth</td>
<td>Chilworth</td>
<td>Chilworth</td>
<td>Chilworth</td>
<td>Chilworth</td>
<td>Chilworth</td>
</tr>
<tr>
<td>Minimum Ignition Energy (MIE), Joules</td>
<td>&gt;10 J</td>
<td>&gt;10 J</td>
<td>&gt;500 mJ</td>
<td>&gt;4653 mJ</td>
<td>&gt;10 J</td>
<td>&gt;10 J</td>
<td>&gt;4468 mJ</td>
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</tr>
<tr>
<td>Explosion severity, $K_{st}$ (bar·m/s), 20 L test chamber</td>
<td>91</td>
<td>68</td>
<td>84</td>
<td>18</td>
<td>54</td>
<td>9</td>
<td>81</td>
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<tr>
<td>Dust explosion class in 20 L test chamber</td>
<td>ST 1</td>
<td>ST 1</td>
<td>ST 1</td>
<td>ST 1</td>
<td>ST 1</td>
<td>ST 1</td>
<td>ST 1</td>
<td></td>
</tr>
</tbody>
</table>
Dispersion

VAb

Copolymer

Baghouse Dust from GP Pipe (as received)

GP Pipe Resin

Baghouse Dust from GP Pipe (as received)

GP Pipe Resin

High Molecular Weight Resin (as received)

<table>
<thead>
<tr>
<th>PVC Resin Sample</th>
<th>Type of polymerization process</th>
<th>Emulsion</th>
<th>Suspension</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Explosion severity, $K_d$ (bar-m/s), 1 m³ test chamber</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td></td>
<td>Not tested</td>
<td>Not tested</td>
<td>ST 0</td>
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<tr>
<td></td>
<td>Not tested</td>
<td>ST 0</td>
<td>ST 0</td>
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<tr>
<td></td>
<td>Dust explosion class in 1 m³ test chamber</td>
<td>Not tested</td>
<td>Not tested</td>
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<tr>
<td></td>
<td>Not tested</td>
<td>ST 0</td>
<td>ST 0</td>
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<tr>
<td></td>
<td>Particle size, avg. (µm)</td>
<td>1 (est.)</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>N.A.</td>
<td>162</td>
<td>N.A.</td>
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<tr>
<td></td>
<td>N.A.</td>
<td>158</td>
<td>128</td>
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<tr>
<td></td>
<td>Dust fraction (&lt;75 µm, %)</td>
<td>100</td>
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<tr>
<td></td>
<td>100</td>
<td>0.1</td>
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<tr>
<td></td>
<td>97</td>
<td>0</td>
<td>0.6</td>
</tr>
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Note: Sponsored by the Vinyl Institute, 1747 Pennsylvania Avenue, NW, Suite 825, Washington, DC 20006.

*GP: General Purpose

*VA: Vinyl Acetate

*Date for MIE and 20 L test were performed by Fike on sample screened to <150 µm and data for 1 m³ tests were performed by Fike on ‘as received’ sample.


**Table Y.4(e) Selected Combustible Dusts Layer or Cloud Ignition Temperature**

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>CAS No.</th>
<th>NEC Group Code</th>
<th>Layer or Cloud Ignition Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetal, linear</td>
<td></td>
<td>G</td>
<td>NL</td>
</tr>
<tr>
<td>Acetoacet-p-phenetidide</td>
<td>122-02-7</td>
<td>G</td>
<td>NL</td>
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<tr>
<td>Acetoacetanilide</td>
<td>102-01-2</td>
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<td>M</td>
</tr>
<tr>
<td>Acetylamino-t-nitrothiazole</td>
<td></td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Acrylamide polymer</td>
<td></td>
<td>G</td>
<td></td>
</tr>
<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>---------</td>
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<td>----------------------------------------</td>
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<tr>
<td>Acrylonitrile polymer</td>
<td></td>
<td>G</td>
<td>460</td>
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<tr>
<td>Acrylonitrile-vinyl chloride-vinylidenechloride copolymer (70-20-10)</td>
<td></td>
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<tr>
<td>Acrylonitrile-vinyl pyridine copolymer</td>
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<tr>
<td>Adipic acid</td>
<td>124-04-9</td>
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<td>550</td>
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<tr>
<td>Alfalfa meal</td>
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<td>G</td>
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<tr>
<td>Allyl ketone dimer sizing compound</td>
<td></td>
<td>G</td>
<td>160</td>
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<tr>
<td>Allyl alcohol derivative (CR-39)</td>
<td></td>
<td>G NL</td>
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<tr>
<td>Almond shell</td>
<td></td>
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<tr>
<td>Aluminum, A422 flake</td>
<td>7429-90-5</td>
<td>E</td>
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<tr>
<td>Aluminum, atomized collector fines</td>
<td></td>
<td>E CL</td>
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<tr>
<td>Aluminum—cobalt alloy (60-40)</td>
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<tr>
<td>Aluminum—copper alloy (50-50)</td>
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<tr>
<td>Aluminum—lithium alloy (15% Li)</td>
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<tr>
<td>Aluminum—magnesium alloy (downmetal)</td>
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<td>Aluminum—nickel alloy (58-42)</td>
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<td>Aluminum—silicon alloy (12% Si)</td>
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<td>Amino-5-nitrothiazole</td>
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<tr>
<td>Anthranilic acid</td>
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<td>Apricot pit</td>
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<tr>
<td>Aryl-nitrosomethylamidine</td>
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<tr>
<td>Asphalt</td>
<td>8052-42-4</td>
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<td>510</td>
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<tr>
<td>Aspirin [acetol (2)]</td>
<td>50-78-2</td>
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<tr>
<td>Azelaic acid</td>
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<td>Chemical Name</td>
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<td>Ignition Temperature (°C)</td>
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<tr>
<td>Azo-bis-butyronitrile</td>
<td>78-67-1</td>
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<td>350</td>
</tr>
<tr>
<td>Benzethonium chloride</td>
<td></td>
<td>G, CL</td>
<td>380</td>
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<tr>
<td>Benzoic acid</td>
<td>65-85-0</td>
<td>G, M</td>
<td>620</td>
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<tr>
<td>Benzotriazole</td>
<td>95-14-7</td>
<td>G, M</td>
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<td>Beta-naphthalene-axo-dimethylaniline</td>
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<td>Bis[(2-hydroxy-5-chlorophenyl) methaner</td>
<td>97-23-4</td>
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<tr>
<td>Bisphenol-A</td>
<td>80-05-7</td>
<td>G, M</td>
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<tr>
<td>Boron, commercial amorphous (85% B)</td>
<td>7440-42-8</td>
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<tr>
<td>Calcium silicide</td>
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<td>E</td>
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<tr>
<td>Carbon black (more than 8% total entrapped volatiles)</td>
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<td>F</td>
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<tr>
<td>Carboxymethyl cellulose</td>
<td>9000-11-7</td>
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<tr>
<td>Carboxypolymethylene</td>
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<td>G, NL</td>
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<tr>
<td>Cashew oil, phenolic, hard</td>
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<td>Cellulose</td>
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<td>Cellulose acetate</td>
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<td>Cellulose acetate butyrate</td>
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<td>Cellulose triacetate</td>
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<tr>
<td>Charcoal[activated]</td>
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<tr>
<td>Charcoal (more than 8% total entrapped volatiles)</td>
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<td>Cherry pit</td>
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<td>Chlorinated phenol</td>
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<td>Chlorinated polyether alcohol</td>
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<td>Chloroacetoacetanilide</td>
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<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------</td>
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<td>Chromium (97%) electrolytic, milled</td>
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<td>Cinnamon</td>
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<td>Citrus peel</td>
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<tr>
<td>Coal, Kentucky bituminous</td>
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<td>F</td>
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<tr>
<td>Coal, Pittsburgh experimental</td>
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<td>170</td>
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<td>Coal, Wyoming</td>
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<tr>
<td>Cocoa bean shell</td>
<td></td>
<td>G</td>
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<tr>
<td>Cocoa, natural, 19% fat</td>
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<tr>
<td>Coconut shell</td>
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<td>Coke (more than 8% total entrapped volatiles)</td>
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<td>Cork</td>
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<td>Corn</td>
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<td>Corn dextrine</td>
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<td>Corn cob grit</td>
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<td>Cornstarch, commercial</td>
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<td>Cornstarch, modified</td>
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<td>Cottonseed meal</td>
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<td>Coumarone-indene, hard</td>
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<td>Crag No. 974</td>
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<td>Cube root, South America</td>
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<td>Di-alphacumyl peroxide, 40-60 on CA</td>
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<td>Diallyl phthalate</td>
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<td>Chemical Name</td>
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<td>Layer or Cloud Ignition Temperature (°C)</td>
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<td>Dieldrin (20%)</td>
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<td>Dimethyl isophthalate</td>
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<td>Dimethyl terephthalate</td>
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<td>Dinitro-o-toluamide</td>
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<td>Dithane m-45</td>
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<td>Ethyl cellulose</td>
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<tr>
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<td>Ethylene oxide polymer</td>
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<td>Ethylene-maleic anhydride copolymer</td>
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<td>Ferbam™</td>
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<td>Ferromanganese, medium carbon</td>
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<td>Ferrosilicon (88% Si, 9% Fe)</td>
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<td>800</td>
</tr>
<tr>
<td>Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)</td>
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<td>E CL</td>
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<td>Flax shive</td>
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<td>Fumaric acid</td>
<td>110-17-8</td>
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<tr>
<td>Garlic, dehydrated</td>
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<td>Gilsonite</td>
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<td>Chemical Name</td>
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<td>Layer or Cloud Ignition Temperature (°C)</td>
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<tr>
<td>Green base harmon dye</td>
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</tr>
<tr>
<td>Guar seed</td>
<td>G</td>
<td>500</td>
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<tr>
<td>Gulasonic acid, diacetone</td>
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<tr>
<td>Gum, arabic</td>
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<tr>
<td>Gum, karaya</td>
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<tr>
<td>Gum, manila</td>
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<tr>
<td>Gum, tragacanth</td>
<td>9000-65-1</td>
<td>G</td>
<td>260</td>
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<td>Hemp hurd</td>
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<tr>
<td>Hexamethylene tetramine</td>
<td>100-97-0</td>
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<td>S</td>
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<tr>
<td>Hydroxyethyl cellulose</td>
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<td>NL</td>
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<td>Iron, 98% H2 reduced</td>
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<tr>
<td>Iron, 99% carbonyl</td>
<td>13463-40-6</td>
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<tr>
<td>Isotoic anhydride</td>
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<td>NL</td>
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<td>L-sorbose</td>
<td>G</td>
<td>M</td>
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<tr>
<td>Lignin, hydrolized, wood-type, fine</td>
<td>G</td>
<td>NL</td>
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<tr>
<td>Lignite, California</td>
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</tr>
<tr>
<td>Lycopodium</td>
<td>G</td>
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</tr>
<tr>
<td>Malt barley</td>
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<tr>
<td>Manganese</td>
<td>7439-96-5</td>
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<tr>
<td>Magnesium, grade B, milled</td>
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<tr>
<td>Manganese vancide</td>
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<tr>
<td>Mannitol</td>
<td>69-65-8</td>
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<td>M</td>
</tr>
<tr>
<td>Methacrylic acid polymer</td>
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<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
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<td>----------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Methionine (l-methionine)</td>
<td>63-68-3</td>
<td>G</td>
<td>360</td>
</tr>
<tr>
<td>Methyl cellulose</td>
<td></td>
<td>G</td>
<td>340</td>
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<tr>
<td>Methyl methacrylate polymer</td>
<td>9011-14-7</td>
<td>G NL</td>
<td>440</td>
</tr>
<tr>
<td>Methyl methacrylate-ethyl acrylate</td>
<td></td>
<td>G NL</td>
<td>440</td>
</tr>
<tr>
<td>Methyl methacrylate-styrene-butadiene</td>
<td></td>
<td>G NL</td>
<td>480</td>
</tr>
<tr>
<td>Milk, skimmed</td>
<td></td>
<td>G</td>
<td>200</td>
</tr>
<tr>
<td>N,N-dimethylthio-formamide</td>
<td></td>
<td>G</td>
<td>230</td>
</tr>
<tr>
<td>Nitropyridone</td>
<td>100703-82-0</td>
<td>G M</td>
<td>430</td>
</tr>
<tr>
<td>Nitrosamine</td>
<td></td>
<td>G NL</td>
<td>270</td>
</tr>
<tr>
<td>Nylon polymer</td>
<td>63428-84-2</td>
<td>G</td>
<td>430</td>
</tr>
<tr>
<td>Para-oxy-benzaldehyde</td>
<td>123-08-0</td>
<td>G CL</td>
<td>380</td>
</tr>
<tr>
<td>Paraphenylene diamine</td>
<td>106-50-3</td>
<td>G M</td>
<td>620</td>
</tr>
<tr>
<td>Paratertiary butyl benzoic acid</td>
<td>98-73-7</td>
<td>G M</td>
<td>560</td>
</tr>
<tr>
<td>Pea flour</td>
<td></td>
<td>G</td>
<td>260</td>
</tr>
<tr>
<td>Peach pit shell</td>
<td></td>
<td>G</td>
<td>210</td>
</tr>
<tr>
<td>Peanut hull</td>
<td></td>
<td>G</td>
<td>210</td>
</tr>
<tr>
<td>Peat, sphagnum</td>
<td>94114-14-4</td>
<td>G</td>
<td>240</td>
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<td>Pecan nut shell</td>
<td>8002-03-7</td>
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<td>Pectin</td>
<td>5328-37-0</td>
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<td>200</td>
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<tr>
<td>Pentaerythritol</td>
<td>115-77-5</td>
<td>G M</td>
<td>400</td>
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<tr>
<td>Petrinit acrylate monomer</td>
<td>7659-34-9</td>
<td>G NL</td>
<td>220</td>
</tr>
<tr>
<td>Petroleum coke (more than 8% total entrapped volatiles)</td>
<td></td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Petroleum resin</td>
<td>64742-16-1</td>
<td>G</td>
<td>500</td>
</tr>
<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
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<tr>
<td>Phenol formaldehyde</td>
<td>9003-35-4</td>
<td>G NL</td>
<td>580</td>
</tr>
<tr>
<td>Phenol formaldehyde, polyallylene-p</td>
<td>9003-35-4</td>
<td>G</td>
<td>290</td>
</tr>
<tr>
<td>Phenol furfural</td>
<td>26338-61-4</td>
<td>G</td>
<td>310</td>
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<td>Phenylbetanaphthylamine</td>
<td>135-86-6</td>
<td>G NL</td>
<td>680</td>
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<td>Phthalic anhydride</td>
<td>85-44-9</td>
<td>G M</td>
<td>650</td>
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<tr>
<td>Phthalimide</td>
<td>85-41-6</td>
<td>G M</td>
<td>630</td>
</tr>
<tr>
<td>Pitch, coal tar</td>
<td>65996-93-2</td>
<td>F NL</td>
<td>710</td>
</tr>
<tr>
<td>Pitch, petroleum</td>
<td>68187-58-6</td>
<td>F NL</td>
<td>630</td>
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<tr>
<td>Polycarbonate</td>
<td></td>
<td>G NL</td>
<td>710</td>
</tr>
<tr>
<td>Polyethylene, high pressure process</td>
<td>9002-88-4</td>
<td>G</td>
<td>380</td>
</tr>
<tr>
<td>Polyethylene, low pressure process</td>
<td>9002-88-4</td>
<td>G NL</td>
<td>420</td>
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<tr>
<td>Polyethylene terephthalate</td>
<td>25038-59-9</td>
<td>G NL</td>
<td>500</td>
</tr>
<tr>
<td>Polyethylene wax</td>
<td>68441-04-8</td>
<td>G NL</td>
<td>400</td>
</tr>
<tr>
<td>Polypropylene (no antioxidant)</td>
<td>9003-07-0</td>
<td>G NL</td>
<td>420</td>
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<tr>
<td>Polystyrene latex</td>
<td>9003-53-6</td>
<td>G</td>
<td>500</td>
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<tr>
<td>Polystyrene molding compound</td>
<td>9003-53-6</td>
<td>G NL</td>
<td>560</td>
</tr>
<tr>
<td>Polyurethane foam, fire retardant</td>
<td>9009-54-5</td>
<td>G</td>
<td>390</td>
</tr>
<tr>
<td>Polyurethane foam, no fire retardant</td>
<td>9009-54-5</td>
<td>G</td>
<td>440</td>
</tr>
<tr>
<td>Polystyrene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyvinyl acetate</td>
<td>9003-20-7</td>
<td>G NL</td>
<td>550</td>
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<tr>
<td>Polyvinyl acetate/alcohol</td>
<td>9002-89-5</td>
<td>G</td>
<td>440</td>
</tr>
<tr>
<td>Polyvinyl butyral</td>
<td>63148-65-2</td>
<td>G</td>
<td>390</td>
</tr>
<tr>
<td>Polyvinyl chloride-dioctyl phthalate</td>
<td></td>
<td>G NL</td>
<td>320</td>
</tr>
<tr>
<td>Potato starch, dextrinated</td>
<td>9005-25-8</td>
<td>G NL</td>
<td>440</td>
</tr>
<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
<tr>
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<td>-------------</td>
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<td>----------------------------------------</td>
</tr>
<tr>
<td>Pyrethrum</td>
<td>8003-34-7</td>
<td>G</td>
<td>210</td>
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<tr>
<td>Rayon (viscose) flock</td>
<td>61788-77-0</td>
<td>G</td>
<td>250</td>
</tr>
<tr>
<td>Red dye intermediate</td>
<td></td>
<td>G</td>
<td>175</td>
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<tr>
<td>Rice</td>
<td></td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Rice bran</td>
<td></td>
<td>G, NL</td>
<td>490</td>
</tr>
<tr>
<td>Rice hull</td>
<td></td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Rosin, DK</td>
<td>8050-09-7</td>
<td>G, NL</td>
<td>390</td>
</tr>
<tr>
<td>Rubber, crude, hard</td>
<td>9006-04-6</td>
<td>G, NL</td>
<td>350</td>
</tr>
<tr>
<td>Rubber, synthetic, hard (33% S)</td>
<td>64706-29-2</td>
<td>G, NL</td>
<td>320</td>
</tr>
<tr>
<td>Safflower meal</td>
<td></td>
<td>G</td>
<td>210</td>
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<tr>
<td>Salicylanilide</td>
<td>87-17-2</td>
<td>G, M</td>
<td>610</td>
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<tr>
<td>Sevin</td>
<td>63-25-2</td>
<td>G</td>
<td>140</td>
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<tr>
<td>Shale, oil</td>
<td>68308-34-9</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Shellac</td>
<td>9000-59-3</td>
<td>G, NL</td>
<td>400</td>
</tr>
<tr>
<td>Sodium resinate</td>
<td>61790-51-0</td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Sorbic acid (copper sorbate or potash)</td>
<td>110-44-1</td>
<td>G</td>
<td>460</td>
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<tr>
<td>Soy flour</td>
<td>68513-95-1</td>
<td>G</td>
<td>190</td>
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<tr>
<td>Soy protein</td>
<td>9010-10-0</td>
<td>G</td>
<td>260</td>
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<tr>
<td>Stearic acid, aluminum salt</td>
<td>637-12-7</td>
<td>G</td>
<td>300</td>
</tr>
<tr>
<td>Stearic acid, zinc salt</td>
<td>557-05-1</td>
<td>G, M</td>
<td>510</td>
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<tr>
<td>Styrene modified polyester-glass fiber</td>
<td>100-42-5</td>
<td>G</td>
<td>360</td>
</tr>
<tr>
<td>Styrene-acrylonitrile (70-30)</td>
<td>9003-54-7</td>
<td>G, NL</td>
<td>500</td>
</tr>
<tr>
<td>Styrene-butadiene latex (&gt;75% styrene)</td>
<td>903-55-8</td>
<td>G, NL</td>
<td>440</td>
</tr>
<tr>
<td>Chemical Name</td>
<td>CAS No.</td>
<td>NEC Group Code</td>
<td>Layer or Cloud Ignition Temperature (°C)</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>----------</td>
<td>----------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Styrene-maleic anhydride copolymer</td>
<td>9011-13-6</td>
<td>G CL</td>
<td>470</td>
</tr>
<tr>
<td>Sucrose</td>
<td>57-50-1</td>
<td>G CL</td>
<td>350</td>
</tr>
<tr>
<td>Sugar, powdered</td>
<td>57-50-1</td>
<td>G CL</td>
<td>370</td>
</tr>
<tr>
<td>Sulfur</td>
<td>7704-34-9</td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Tantalum</td>
<td>7440-25-7</td>
<td>E</td>
<td>300</td>
</tr>
<tr>
<td>Terephthalic acid</td>
<td>100-21-0</td>
<td>G NL</td>
<td>680</td>
</tr>
<tr>
<td>Thorium (contains 1.2% O)</td>
<td>7440-29-1</td>
<td>E CL</td>
<td>270</td>
</tr>
<tr>
<td>Tin, 96%, atomized (2% Pb)</td>
<td>7440-31-5</td>
<td>E</td>
<td>430</td>
</tr>
<tr>
<td>Titanium, 99% Ti</td>
<td>7440-32-6</td>
<td>E CL</td>
<td>330</td>
</tr>
<tr>
<td>Titanium hydride (95% Ti, 3.8% H)</td>
<td>7704-98-5</td>
<td>E CL</td>
<td>480</td>
</tr>
<tr>
<td>Trithiobisdimethylthio- formamide</td>
<td></td>
<td>G</td>
<td>230</td>
</tr>
<tr>
<td>Tung, kernels, oil-free</td>
<td>8001-20-5</td>
<td>G</td>
<td>240</td>
</tr>
<tr>
<td>Urea formaldehyde molding compound</td>
<td>9011-05-6</td>
<td>G NL</td>
<td>460</td>
</tr>
<tr>
<td>Urea formaldehyde-phenol formaldehyde</td>
<td>25104-55-6</td>
<td>G</td>
<td>240</td>
</tr>
<tr>
<td>Vanadium, 86.4%</td>
<td>7440-62-2</td>
<td>E</td>
<td>490</td>
</tr>
<tr>
<td>Vinyl chloride-acrylonitrile copolymer</td>
<td>9003-00-3</td>
<td>G</td>
<td>470</td>
</tr>
<tr>
<td>Vinyl toluene-acrylonitrile butadiene</td>
<td>76404-69-8</td>
<td>G NL</td>
<td>530</td>
</tr>
<tr>
<td>Violet 200 dye</td>
<td></td>
<td>G</td>
<td>175</td>
</tr>
<tr>
<td>Vitamin B1, mononitrate</td>
<td>59-43-8</td>
<td>G NL</td>
<td>360</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>50-81-7</td>
<td>G</td>
<td>280</td>
</tr>
<tr>
<td>Walnut shell, black</td>
<td></td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>G</td>
<td>220</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>130498-22-5</td>
<td>G</td>
<td>360</td>
</tr>
</tbody>
</table>
### Chemical Name | CAS No. | NEC Group Code | Layer or Cloud Ignition Temperature (°C)
--- | --- | --- | ---
Wheat gluten, gum | 100684-25-1 | G NL | 520
Wheat starch | | G NL | 380
Wheat straw | | G | 220
Wood flour | | G | 260
Woodbark, ground | | G | 250
Yeast, torula | 68602-94-8 | G | 260
Zirconium hydride | 7704-99-6 | E | 270
Zirconium (contains 0.3% O) | 7440-67-7 | E CL | 330

**Notes:**

1. Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears in the “Code” column, then the layer ignition temperature is shown. “CL” means the cloud ignition temperature is shown. “NL” means that no layer ignition temperature is available, and the cloud ignition temperature is shown. “M” signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. “S” signifies that the dust layer sublimes before it ignites; the cloud ignition temperature is shown.

2. Certain metal dusts might have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium and thorium dusts can ignite spontaneously in air, especially at elevated temperatures.

3. Due to the impurities found in coal, its ignition temperatures vary regionally, and ignition temperatures are not available for all regions in which coal is mined.

[499: Table 5.2.2]
Annex Z Informational References

Z.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.

Z.1.1 NFPA Publications.
National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.
NFPA 77, Recommended Practice on Static Electricity, 2019 edition.


**Z.1.2 Other Publications.**

**Z.1.2.1 ACGIH Publications.**

American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.


**Z.1.2.2 AIChE Publications.**

American Institute of Chemical Engineers, 120 Wall Street, 23rd floor, New York, NY 10005.


AIChE Center for Chemical Process Safety (CCPS), *Chemical Reactivity Worksheet (CRW).*


**Z.1.2.3 AIHA Publications.**

American Industrial Hygiene Association, 3141 Fairview Park Drive, Suite 777, Falls Church, VA 22042.


**Z.1.2.4 AMCA Publications.**


**Z.1.2.5 ASM International Publications.**

American Society of Metals, 9639 Kinsman Road, Materials Park, OH 44073-0002.


**Z.1.2.6 ASME International Publications.**

American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.


**Z.1.2.7 ASTM Publications.**

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


Z.1.2.8 Battelle Memorial Institute Publications.
Battelle Memorial Institute, Defense Metals Information Center, 505 King Ave., Columbus, OH 43201.


Z.1.2.9 BSI Publications.
BSI British Standards, 12110 Sunset Hills Road, Suite 200, Reston, VA 20190-5902.


Z.1.2.10 FM Publications.
FM Global, 270 Central Avenue, P.O. Box 7500, Johnston, RI 02919.


Z.1.2.11 IEC Publications.

International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland.


Z.1.2.12 IFA Publications.

Institute for Occupational Safety and Health of the German Social Accident Insurance, Alte Heerstr. 111, 53757 Sankt Augustin, Germany.


Z.1.2.13 ISO Publications.

International Standards Organization, 1 rue de Varembé, Case Postale 56, CH-1211 Genève 20, Switzerland.


Z.1.2.14 National Grain and Feed Association Publications.
National Grain and Feed Association, 1400 Crystal Drive, Suite 260, Arlington, VA 22202.


Z.1.2.15 NIBA Publications.

NIBA — The Belting Association, 22 North Carroll Street, Suite 300, Madison, WI 53703.


Z.1.2.16 SFPE Publications.

Society of Fire Protection Engineers, 9711 Washingtonian Boulevard, Suite 380, Gaithersburg, MD 20878.


SFPE S.01, Engineering Standard on Calculating Fire Exposures to Structures, 2011.

SFPE S.02, Engineering Standard on Calculation Methods to Predict the Thermal Performance of Structural and Fire Resistant Assemblies, 2015.

Z.1.2.17 UL Publications.

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

ISA-12.12.03/UL 121203, Portable Electronic Products Suitable for Use in Class I and II, Division 2, Class I, Zone 2 and Class III, Division 1 and 2 Hazardous (Classified) Locations, 2011.

Z.1.2.18 UN Publications.

United Nations Publications Customer Service, P.O. Box 960, Herndon, VA 20172.


Z.1.2.19 U.S. Bureau of Mines Publications.


RI 8798, “Thermal and Electrical Ignitability of Dusts.”

Z.1.2.20 U.S. Government Publications.


Occupational Safety and Health Administration Act of 1970.

OSHA, Firefighting Precautions at Facilities with Combustible Dust, 2013.


Z.1.2.21 Other Publications.


FM Global Data Sheet 7-76, “Prevention and Mitigation of Combustible Dust Explosions and Fire,” January 2012.


GESTIS-DUST-EX, Combustion and Explosion Characteristics of Dusts (database), Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Germany (IFA).


**Z.2 Informational References.**
The following documents or portions thereof are listed here as informational resources only. They are not a part of the requirements of this document.

**Z.2.1 Aluminum Association Publications.**
The Aluminum Association, 1400 Crystal Drive, Suite 430, Arlington, VA 22202.


**Z.2.2 NMERI Publications.**
New Mexico Engineering Research Institute, University of New Mexico, 901 University SE, Albuquerque, NM 87106-4339.

(NMERI OC 90/10).


**Z.2.3 Other Publications.**


Donat, C., “Pressure Relief as Used in Explosion Protection,” *Chemical Engineering Progress*, 11th Loss Prevention Symposium, Houston, TX, 1977.


### Z.3 References for Extracts in Informational Sections.

