# Table of Contents

1.0 SCOPE .......................................................................................................................... 5
  1.1 Changes ......................................................................................................................... 5

2.0 LOSS PREVENTION RECOMMENDATIONS ........................................................................... 5
  2.1 Introduction .................................................................................................................... 5
  2.2 MFL Limiting Factor: Fire Walls ......................................................................................... 5
     2.2.1 Introduction ............................................................................................................... 5
     2.2.2 Construction and Location ......................................................................................... 5
     2.2.3 Fire Resistance of Wall Construction ......................................................................... 5
     2.2.4 Stability and Strength ................................................................................................ 6
     2.2.5 Cantilever Walls ....................................................................................................... 12
     2.2.6 Tied Walls ................................................................................................................ 16
     2.2.7 One-Way Walls ......................................................................................................... 20
     2.2.8 Double Walls ............................................................................................................ 20
     2.2.9 Panel Walls in Reinforced Concrete Buildings .......................................................... 21
     2.2.10 Control of Cracking ................................................................................................. 21

  2.3 MFL Limiting Factor: Space Separation ........................................................................... 41
     2.3.1 Introduction ............................................................................................................... 41
     2.3.2 Classification of Exposed Wall Construction .............................................................. 42
     2.3.3 Exposed Wall Length (L) .......................................................................................... 43
     2.3.4 Classification of Exposing Wall Construction ............................................................. 49
     2.3.5 Exposing Fire Hazard Categories ............................................................................. 54
     2.3.6 Yard Storage, Conveyors, Pipes, Passageways, and Roof Protection ......................... 55
     2.3.7 Side Wall Protection .................................................................................................. 55
     2.3.8 Vegetation ................................................................................................................ 56
     2.3.9 Motor Vehicle Parking .............................................................................................. 56
     2.3.10 Ignitable Liquid and Flammable Gas Loading and Unloading Stations ...................... 57
     2.3.11 Rail Lines and Sidings ............................................................................................. 57

  2.4 MFL Limiting Factor: Prevention of Exterior Vertical Fire Spread ......................................... 57
     2.4.1 Mechanical Floors .................................................................................................... 57
     2.4.2 Setbacks ................................................................................................................... 59
     2.4.3 Balconies ................................................................................................................ 59
     2.4.4 Podium Floors ......................................................................................................... 59

  2.5 Protection of Openings in MFL Limiting Factors ................................................................ 60
     2.5.1 Introduction ............................................................................................................... 60
     2.5.2 Construction and Location ......................................................................................... 60
     2.5.2.1 Fire Doors .............................................................................................................. 60
     2.5.2.2 Material Handling Systems ................................................................................... 81
     2.5.2.3 Pneumatic Conveyors .......................................................................................... 84
     2.5.2.4 Roller and Belt Conveyors with Inclined Gravity Sections ..................................... 86
     2.5.2.5 Roller and Belt Conveyors without Inclined Gravity Sections ............................... 88
     2.5.2.6 Automatic Guided Vehicle Systems (AGVS) .......................................................... 89
     2.5.2.7 Air Handling Systems ........................................................................................... 89
     2.5.3 Operation and Maintenance ...................................................................................... 90
3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Application of MFL Limiting Factors ................................................................. 91
3.2 MFL Fire Walls ....................................................................................................... 92
  3.2.1 Fire Resistance of Wall Construction ................................................................. 92
  3.2.2 Stability and Strength .......................................................................................... 92
  3.2.3 Cantilever Fire Walls .......................................................................................... 93
  3.2.4 Tied Fire Walls ................................................................................................... 94
  3.2.5 One-Way Fire Walls ........................................................................................... 94
  3.2.6 Double Fire Walls .............................................................................................. 95
  3.2.7 Panel Walls in Reinforced Concrete Buildings ..................................................... 95
  3.2.8 Control of Cracking ............................................................................................ 95
  3.2.9 Parapets and Roof Protection ............................................................................ 95
  3.2.10 End Walls and Angle Exposure ......................................................................... 96
  3.2.11 Pipes, Conduit, Cables, and Ducts ................................................................... 96
3.3 Openings in MFL Fire Walls .................................................................................. 96
  3.3.1 Material-Handling Systems .............................................................................. 96
  3.3.2 Automatic Guided Vehicle Systems .................................................................... 97
  3.3.3 Chain or Rail Conveyors ................................................................................... 97
  3.3.4 Tow Conveyors .................................................................................................. 98
  3.3.5 Air Handling Systems ....................................................................................... 98
3.4 Space Separation .................................................................................................... 99
  3.4.1 General Space Separation Information ................................................................. 99
  3.4.2 Categorizing Exposed Construction in MFL Space Separations ....................... 99
  3.4.3 Space Separation Analysis Methodology ............................................................ 100
  3.4.4 MFL Space Separation Analysis Example ......................................................... 100

4.0 REFERENCES ........................................................................................................ 101
  4.1 FM Global ............................................................................................................. 101
  4.2 Other .................................................................................................................... 101

APPENDIX A GLOSSARY OF TERMS ........................................................................ 102
APPENDIX B DOCUMENT REVISION HISTORY ...................................................... 106
APPENDIX C FIRE DOORS .......................................................................................... 108
  C.1 Fire Door Construction .......................................................................................... 108
  C.2 Detectors .............................................................................................................. 110
  C.3 Door Closers ........................................................................................................ 110
  C.4 Power Operators .................................................................................................. 110
  C.5 Electromagnetic Door Holder Releases ................................................................. 110
  C.6 Electromechanical Door Holders .......................................................................... 110
  C.7 Fire Door Operation and Inspection ...................................................................... 111
    C.7.1 Horizontal Sliding Doors .................................................................................. 111
    C.7.2 Inclined Track .................................................................................................. 115
    C.7.3 Straight Track with Counterweight Closure .................................................... 115
    C.7.4 Straight Track with Spring Closure ................................................................... 115
    C.7.5 Swinging Doors ............................................................................................... 116
    C.7.6 Telescoping Vertical Sliding Doors ................................................................... 116
    C.7.7 Counterbalanced Elevator Doors .................................................................... 116
    C.7.8 Passenger-Elevator Doors .............................................................................. 116
    C.7.9 Rolling Steel Doors .......................................................................................... 116
    C.7.10 Vertical Sliding Doors .................................................................................... 117
  C.8 Rating Practices for Fire Doors ............................................................................. 117
  C.9 Selection of Fire Doors ........................................................................................ 118

List of Figures
Fig. 1. Cantilever wall: Minimum clearance between MFL fire wall and aligned steel framing ............... 8
Fig. 2. Double wall: Minimum clearance between fire walls ......................................................... 9
Fig. 3. Cantilever wall: Maximum clearance for support under fire conditions ................................... 9
Fig. 4. Tied wall: Conviental through-wall tie, shown with primary steel perpendicular to wall .......... 10
Fig. 4a. Tied wall: Tilt-up wall, diaphragm roof with embed plate through-wall tie, shown with primary steel perpendicular to wall .......................................................... 11
Fig. 5. Tied wall: Conventional through-wall tie, shown with primary steel parallel to fire wall .......................................................... 12
Fig. 5a. Tied wall: Tilt-up wall, diaphragm roof with embed plate through-wall tie, shown with primary steel parallel to fire wall .......................................................... 13
Fig. 6. One-way wall: Corbel arrangement for one-way wall .......................................................... 14
Fig. 7. Cantilever wall: Corbel arrangement (masonry and corbel reinforcing not shown) .................. 14
Fig. 8. Double wall: Corbel arrangement ..................................................................................... 15
Fig. 9. Typical cantilever wall; used at expansion joints, or at joints between buildings .................. 15
Fig. 10. Reinforced masonry cantilever wall .............................................................................. 16
Fig. 11. Flashing detail ............................................................................................................. 16
Fig. 12. Typical tied fire wall; used with continuous building framework ...................................... 17
Fig. 13. A tied wall at the center of a continuous steel frame ....................................................... 17
Fig. 14. Tied wall where framing is not continuous throughout the building ................................. 18
Fig. 15. Tied wall off center of continuous steel frame ................................................................. 18
Fig. 16. Flexible masonry anchors ............................................................................................ 19
Fig. 17. Double MFL fire wall ..................................................................................................... 20
Fig. 18. Typical double fire wall; used at expansion joints, or at joints between buildings .......... 20
Fig. 19. Examples of roof flashing details .................................................................................. 21
Fig. 20. Expansion joint ............................................................................................................ 22
Fig. 21. Typical control joints in concrete masonry (reinforcing not shown) ................................. 22
Fig. 22. Typical joint detail in precast concrete ........................................................................... 22
Fig. 23. Horizontal joint reinforcing and control joint in concrete block wall construction .......... 23
Fig. 24. Bond beam reinforcing at intersecting concrete masonry walls ...................................... 23
Fig. 25. Bond beam reinforcing termination detail for concrete masonry walls in FM Global earthquake zones .............................................................................. 24
Fig. 26. Typical concrete masonry bond beam .......................................................................... 24
Fig. 27. An MFL fire wall divides a one-story facility ................................................................. 25
Fig. 27a. Single-ply membrane roof at an MFL fire wall ............................................................. 25
Fig. 28a. MFL wall arrangement at elevation difference (double wall) ........................................... 27
Fig. 28b. MFL wall arrangement at elevation difference (cantilever wall) ...................................... 28
Fig. 29a. End wall exposure protection; end walls tied to steel framing ........................................ 29
Fig. 29b. End wall exposure protection; end walls not tied to steel framing ................................. 29
Fig. 30. Alternative end wall protection ....................................................................................... 29
Fig. 31. Angular wall exposure protection ................................................................................... 30
Fig. 32. Exterior wall protection ................................................................................................ 31
Fig. 33. Independent feeds for automatic sprinkler systems on each side of an MFL fire wall ...... 31
Fig. 34. Breakaway connections; slip joints ................................................................................ 32
Fig. 35a. Vertical reinforcing detail at concrete masonry wall corner ......................................... 38
Fig. 35b. Vertical reinforcing detail at concrete masonry wall intersection .................................... 38
Fig. 36. Vertical reinforcing detail at concrete masonry wall opening or termination ...................... 39
Fig. 37. Vertical reinforcing detail at concrete masonry wall control joint ...................................... 39
Fig. 38. Boundary element reinforcing detail (plan view) for concrete walls in FM Global earthquake zones .................................................................................. 40
Fig. 39. Length of exposing wall for overlapping buildings ........................................................ 44
Fig. 40a. Exposure envelope ..................................................................................................... 44
Fig. 40b. Offset buildings: longer exposing wall exposing shorter exposed wall ......................... 45
Fig. 40c. Offset buildings: shorter exposing wall exposing shorter exposed wall ......................... 45
Fig. 40d. Offset buildings: longer exposing wall exposing longer exposed wall ......................... 46
Fig. 40e. Offset buildings: shorter exposing wall exposing longer exposed wall ......................... 46
Fig. 41. Exposed buildings at angles ............................................................................................ 47
Fig. 41a. Multiplier for buildings exposed at an angle ................................................................. 48
Fig. 42. Exposing wall adjustment factor for unprotected openings in an SFR wall .................... 49
Fig. 43a. Base space separation for exposed noncombustible walls (English units) ................. 50
Fig. 43b. Base space separation for exposed noncombustible walls (metric units) ...................... 51
Fig. 44a. Base separation for exposed combustible walls (English units) .................................... 52
Fig. 44b. Base separation for exposed combustible walls (metric units) ..................................... 53
Fig. 45. Small storage areas in HC-1/HC-2 hazard buildings ..................................................... 56
Fig. 46. Window and spandrel heights ....................................................................................... 58
Fig. 47. Mechanical floor fire break and theoretical flame height .................................................. 59
Fig. 60. Use of expansion anchors to secure guides/tracks
Reprinted with permission from NFPA 80, Fire Doors and Windows ........................................... 71
Fig. 61. Lintels of fire-resistive construction. ................................................................................... 72
Fig. 62. Asphalt emulsion floor over concrete ramp. ....................................................................... 72
Fig. 63. Rolling steel doors—surface mounted .................................................................................. 73
Fig. 64. Rolling steel doors between jamb mounted .......................................................................... 74
Fig. 65. Interconnection of trip assemblies through fire wall. ........................................................ 76
Fig. 66. Rolling steel fire doors in double MFL wall using reinforced concrete frame (stacked) .... 77
Fig. 67a. Rolling steel fire doors in double MFL wall using reinforced concrete frame (side-by-side) 78
Fig. 67b. Rolling steel fire doors in double MFL wall using reinforced concrete frame (section details) ... 79
Fig. 67c. Rolling steel fire doors in double MFL wall using reinforced concrete frame (plan details) ...... 80
Fig. 68. Binder arrangements to reduce smoke penetration around horizontal sliding doors ...... 80
Fig. 69. Clearance area at fire doors. .................................................................................................. 81
Fig. 70. Fire door arrangement around conveyor rail. ..................................................................... 82
Fig. 71. Notched fire door label. ......................................................................................................... 82
Fig. 72. Door-pack installation .......................................................................................................... 83
Fig. 73. Fire dampers .......................................................................................................................... 85
Fig. 74. Breakaway connections (slip joints) ..................................................................................... 86
Fig. 75. Roller conveyor protection. ................................................................................................ 87
Fig. 76. Belt conveyor protection. ...................................................................................................... 87
Fig. 77. Conveyor penetration without incline .................................................................................. 88
Fig. 78. Steel not lined up vertically ................................................................................................ 94
Fig. 79. One-way fire walls .............................................................................................................. 94
Fig. 80. Two one-way fire walls tied to areas 1 and 3 respectively .................................................. 95
Fig. 81. FM Approvals oversize label ............................................................................................... 109
Fig. 82. Horizontal sliding door; inclined track .............................................................................. 111
Fig. 83. Horizontal sliding door; level track, counterweight closure ............................................. 112
Fig. 84. Horizontal sliding inclined track fire door showing stay rolls and binders .................... 113
Fig. 85. Stay roll for horizontal sliding fire door .............................................................................. 114

List of Tables
Table 1. Minimum Clearance Between Structural Steel and MFL Fire Wall ..................................... 7
Table 2. Length of End Wall Protection ............................................................................................. 28
Table 3. Verification and Inspection of Concrete Masonry MFL Wall Construction .......................... 37
Table 4. Verification and Inspection of Reinforced Concrete MFL Wall Construction. ..................... 40
Table 5. Base Separation Distance for Fire-Rated Construction ...................................................... 41
Table 6. Exposed Wall Categories for MFL Space Separation ......................................................... 42
Table 7. Exposing Fire Hazard Categories ....................................................................................... 54
Table 8. Damper Leakage Classification .......................................................................................... 99
Table 9. Mortar Proportions by Volume ........................................................................................... 104
Table 10. Allowable Glazing Area For Fire Doors .......................................................................... 109
Table 11. Classification of Fire Wall Openings ............................................................................... 117
1.0 SCOPE

This data sheet provides design criteria and guidelines for maximum foreseeable loss (MFL) limiting factors and the protection of openings in MFL limiting factors. Data Sheet 1-23, *Fire Barriers and Protection of Openings*, addresses non-MFL fire walls, floors, ceilings, and protection of openings used to separate occupancies within the same building.

1.1 Changes

**February 2014.** Minor editorial changes were made.

**October 2013.** The following changes were made:

- Revised Section 2.2.2.2.10 on explosion hazard distances.
- Revised penetration and fire stop recommendations based on comments from the Firestop Contractors International Association (FCIA).
- Changed Light/Ordinary occupancy hazard classification to HC-1/HC-2 to be in agreement with Data Sheet 3-26, *Fire Protection Water Demand for Non-Storage Sprinklered Properties*.
- Revised recommendations on roof drains and scuppers near MFL walls.
- Corrected the analysis of the exposure length (L) to make it consistent with Data Sheet 1-20, *Protection Against Exterior Fire Exposure*.
- Corrected the numbering as there were two sections numbered 2.5.2.1.23.
- Relocated the text of Figures 8 and 16 into the recommendations.
- Revised figures have been revised for clarity.
- Made minor editorial changes.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

The maximum foreseeable loss (MFL) is the largest loss to result from an insured event, as calculated from an understanding of the overall hazard and associated business impact. This event assumes that active protection systems or safety devices are impaired, with the exception of specifically approved and tested MFL fire doors.

The event can be related to fire, explosion, equipment failure, or other scenario, with the exception of natural hazards. MFL limiting factors are physical barriers or conditions that limit the spread of fire or contain explosive forces and control the amount of damage from the event.

2.2 MFL Limiting Factor: Fire Walls

2.2.1 Introduction

Ensure all MFL walls and supporting structures are designed by a registered civil or structural engineer.

Except where noted otherwise, recommendations in sections 2.2.2.1, 2.2.2.2, 2.2.2.8 through 2.2.2.13 apply to all types of MFL fire walls.

2.2.2 Construction and Location

2.2.2.1 Fire Resistance of Wall Construction

2.2.2.1.1 Design MFL fire walls for 4-hour fire resistance, unless otherwise specified. Masonry, brick, and concrete are the preferred materials for MFL walls. Refer to Data Sheet 1-21, *Fire Resistance of Building Assemblies*, for methods of analyzing various building elements and materials fire-resistance ratings.

A. Do not use EIFS as part of an MFL wall or as part of end walls or angular exposure walls.

2.2.2.1.2 Use only assemblies or materials listed by a nationally recognized testing laboratory that provide the needed fire resistance. Do not use wall assemblies that contain foam plastic insulation.
2.2.2.1.3 Construct lintels used in openings in MFL fire walls of reinforced concrete, reinforced concrete masonry, or concrete-encased steel. Design the lintel to have a fire-resistance rating equivalent to the rating of the wall. Do not leave the bottom steel flange of steel members exposed.

2.2.2.1.4 When the fire rating of concrete masonry construction relies on grouted cores, ensure cores are grouted for the full height of the wall. Use low-lift grouting techniques (grout in a maximum of 5 ft lifts [1.5 m]) to prevent grout voids in the lower cores. Do not use loose fill material because it may spill out if the wall is later damaged.

2.2.2.1.5 Use only those autoclaved aerated concrete (AAC) wall assemblies that have passed a well-documented fire test (in accordance with ASTM E 119, BS 476, or similar), including a hose stream test. Note that E 119 requires a hose stream test for walls (with 1 hr or greater fire endurance), but BS 476 does not. Provide the same wall joints as those in the fire-tested assembly or use a listed joint system with a proper fire endurance rating.

2.2.2.2 Stability and Strength

Each type of MFL fire wall achieves stability in a different way:

- Cantilever walls are entirely self-supporting without any ties to adjacent framing.
- Tied walls are laterally supported by the steel building frames on each side, which are tied together through the wall. The frames must be of sufficient strength so the force of collapsing steel on the fire-exposed side is resisted by the steel framing on the cold side.
- One-way walls are laterally tied to steel framing members on one side only.
- Double fire walls consist of two one-way walls back to back, with no connections between the two.
- Panel walls in reinforced concrete buildings are tied to the concrete columns and/or floor and roof framing.

2.2.2.2.1 Do not use MFL fire walls as bearing walls; that is, do not use them to support any gravity loads other than their own weight. Special precautions must be taken regarding the detailing of wall penetrations for structural elements to ensure MFL fire walls do not unintentionally provide vertical support to adjacent structure.

2.2.2.2.2 MFL fire walls can be used as shear walls as part of the lateral-force-resisting system of the building provided the walls are properly designed and constructed to adequately resist the design loads. Where MFL fire walls are not intended to act as part of the lateral-force-resisting system of the building, special precautions must be taken regarding connection detailing and deflection compatibility between the walls and the adjacent building framing to ensure MFL fire walls are not stressed or damaged by lateral forces.

2.2.2.2.3 Where any significant modifications are intended to be made to an existing MFL fire wall, or to an existing wall intended to be accepted as an MFL fire wall, retain a registered civil or structural engineer to provide an evaluation and to ensure the wall will function as required. Significant modifications could include changes to the strength, stiffness, stability, mass, durability, and connections associated with the wall.

2.2.2.2.4 Do not use unreinforced masonry or unreinforced concrete walls or portions of walls as MFL walls.

2.2.2.2.5 When using tilt-up or precast concrete construction, provide joint integrity and prevent differential movement between panels by using a shiplap joint, tongue-and-groove joint, or other positive mechanical means. All joints must obtain the same fire resistance rating as the wall. (Refer to Fig. 22.)

2.2.2.2.6 Clearance Between MFL Fire Walls and Steel Framing

Provide adequate clearances between MFL fire walls and steel framing, and between adjacent MFL fire walls to prevent damage from horizontal thermal expansion of the steel during a fire. For buildings located in FM Global earthquake zones 50-year through 500-year, adjust clearances as necessary to prevent pounding during seismic events.

Use one of the following methods:

a) Provide minimum adequate clearance (according to Table 1) between the wall and the steel framing (see Figure 1) on each side of the wall or between the two walls of a double wall system (see Figure 2).
Table 1. Minimum Clearance Between Structural Steel and MFL Fire Wall

<table>
<thead>
<tr>
<th>Length of Bay Perpendicular to the Fire Wall</th>
<th>Minimum Clearance Between Wall and Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>20</td>
<td>6.1</td>
</tr>
<tr>
<td>25</td>
<td>7.6</td>
</tr>
<tr>
<td>30</td>
<td>9.1</td>
</tr>
<tr>
<td>35</td>
<td>10.7</td>
</tr>
<tr>
<td>40</td>
<td>12.2</td>
</tr>
<tr>
<td>45</td>
<td>13.7</td>
</tr>
<tr>
<td>50</td>
<td>15.2</td>
</tr>
<tr>
<td>55</td>
<td>16.8</td>
</tr>
<tr>
<td>60 or longer</td>
<td>18.3</td>
</tr>
</tbody>
</table>

b) Provide a maximum of \( \frac{3}{4} \) in. (19.1 mm) clearance between the wall and the structural framework for walls up to 40 ft (12.2 m) high if the steel is aligned horizontally and vertically on both sides of the wall (see Figs. 3, 4, and 5). For walls higher than 40 ft (12 m), this maximum space may be increased \( \frac{1}{4} \) in. (6.4 mm) for each additional 10 ft (3.0 m) of wall height. Install a bond beam in the first full course below the bottom of the primary steel for the full length of the wall.

Where the adjacent primary steel is parallel to the MFL fire wall, grout all cores above the bond beam to the top of the wall; however, in FM Global earthquake zones 50-year through 500-year, grout the cores above the bond beam along the full length of the wall, but only to the first course above the top of the primary steel.

Where the adjacent primary steel is perpendicular to the MFL fire wall, grout cores above the bond beam to the top of the wall, but only to 16 in. (0.4 m) on each side of the columns.

In all cases, grout reinforced cores the full height of the wall, and continue vertical reinforcement for the full height of the wall (i.e., ensure vertical reinforcing is not interrupted at bond beams).

c) For existing construction where the clearance guidelines in either (a) or (b) of this section are not met, construct solid masonry or concrete pilasters or corbels (see Figs. 6, 7, and 8) between the wall and structural steel. This alternative applies only if the steel framing lines up horizontally and vertically on both sides of the wall.

In Figure 8, if the distance A+B equals that recommended in Table 1, then a corbel or pilaster is not needed between Wall No. 2 and its respective frame. Similarly, if the distance B+C is that recommended in Table 1, then a corbel or pilaster is not needed between Wall No. 1 and its respective frame. If a rigid masonry anchor or corbel is provided, do not consider the space between the respective wall and framing.

Place a layer of building paper over the structural steel to prevent bonding to it. If clearance is needed for normal building expansion, maintain a small space as described above in part (b) between the column and the pilaster or corbel. Make the pilaster or corbel at least 2 ft (0.6 m) wide. Locate corbels at least as high on each face as the adjacent primary structural steel member, and ensure the face abutting the walls is at least 2 ft (0.6 m) high. Ensure the space between corbels or pilasters and adjacent framework does not exceed the guidelines stated in part (b) above.

A steel assembly may be used in lieu of a corbel; design it to withstand the load due to steel frame expansion without crushing the wall construction. Note that a steel assembly is generally preferable to a concrete or masonry corbel for buildings located in FM Global earthquake zones 50-year through 500-year.
2.2.2.2.7 Design and construct MFL fire walls to provide adequate strength, stiffness, stability, and durability.

a) Design wall panels to adequately resist a minimum uniform lateral pressure of 5 psf (0.24 kN/m²) for allowable stress design (ASD) or working stress design (WSD) (using a load factor of 1.0); use a load factor of 1.6 for load and resistance factor design (LRFD) methodology (1.6 x 5 psf = 8 psf [0.38 kN/m²]). This usually is accomplished easily in all walls except the cantilever type.

For buildings located in hurricane-prone regions (see definition in FM Global Data Sheet 1-28), ensure wall panels can adequately resist design wind pressures derived from the basic wind speed per Data Sheet 1-28, Wind Design. Examine both enclosed and partially enclosed conditions if applicable. Do not, under any circumstances, use uniform wind pressures less than 5 psf (0.24 kN/m²) for ASD design or 8 psf (0.38 kN/m²) for LRFD design.

b) Apply the lateral pressure, which is perpendicular to the wall face, on the side of the wall that produces the more severe demand. This minimum lateral load typically will not be adequate for walls exposed directly to wind (i.e., fire walls used as temporary exterior walls or walls subjected to interior wind force due to partially enclosed buildings) or in FM Global earthquake zones 50-year through 500-year.

Where MFL fire walls are subjected directly to wind forces (e.g., a fire wall used as a temporary exterior wall), the wall must be designed to adequately resist these forces (see Data Sheet 1-28, Wind Design).

2.2.2.2.8 Use fire-resistive material that is durable enough to resist the forces described in Section 3.2.2, to construct the MFL fire wall. Some material may have adequate fire resistance but not adequate durability.
Fig. 2. Double wall: Minimum clearance between fire walls

Walls are tied to columns

Double Wall

Fig. 3. Cantilever wall: Maximum clearance for support under fire conditions. Note: This condition applies only when steel is aligned horizontally and vertically.
2.2.2.9 For locations in active seismic areas (FM Global 50-year through 500-year earthquake zones as shown in Data sheet 1-2, Earthquakes), refer to Section 2.2.2.12 for seismic design criteria.

2.2.2.10 Walls designed to be MFL fire walls do not typically have sufficient strength to act as explosion-resistant walls. Locate any occupancy presenting an explosion hazard a minimum of 125 ft (38 m) from MFL fire walls.

Examples of occupancies that present an explosion hazard:
- Any ignitable liquid process that has a weak or severe explosion hazard as defined in FM Global Data Sheet 7-32, Ignitable Liquid Operations.
- Storage of ignitable liquids in non-relieving-style metal containers greater than 6 gal (22.7 L)
- Improperly vented ignitable liquid tanks
- Improperly protected dust-handling equipment
- An occupancy with a dust room explosion hazard
- Ammonia compressor rooms
- Any storage or use of flammable gases
- Equipment with a PV rupture potential

2.2.2.11 Due to the complexity of rack-supported structures, double MFL fire walls are preferred for interior subdivision in this type of construction. Other types may be used but generally will cost much more.

2.2.2.12 Arrange storage racks perpendicular to the fire wall so they pose less of an impact exposure in case of rack collapse during an MFL fire.
Fig. 4a. Tied wall: Tilt-up wall, diaphragm roof with embed plate through-wall tie, shown with primary steel perpendicular to wall.
2.2.2.2.13 Do not allow bridging and bracing for joists or trusses to be continuous through an MFL fire wall.

2.2.2.2.14 Foundations require careful design to provide adequate bearing support and resistance to overturning, particularly for cantilever walls. Ensure a registered civil or structural engineer with experience in geotechnical engineering which is familiar with local geological conditions, is retained to provide the foundation design.

2.2.2.3 Cantilever Walls

2.2.2.3.1 Design cantilever walls for the lateral loads specified in section 2.2.2.2.7 to ensure stability under MFL fire conditions (Figs. 9 and 10). Ensure there are no connections between the wall and the building frame on either side. Design the flashing on each side to release easily when the roof on one side of the wall collapses (see Figure 11).

2.2.2.3.2 High walls (more than 30 ft [9.1 m] high) may require a steel column in each pilaster rather than vertical reinforcing bars, and anchorage of the columns to deep foundations, to provide adequate strength and stability.

2.2.2.3.3 Anchor cantilever walls to their foundations to properly resist overturning moments and base shears. Permanent soil overburden and concrete floor slab may be used to resist overturning moment when needed.

2.2.2.3.4 If tilt-up or precast concrete construction is used in a cantilever wall design, pay particular attention to the connections to the foundation, structural slabs, or pilasters. If connections are added external to the wall panels to allow the wall to adequately resist the overturning moment, fireproof these connections with a durable material to obtain the same fire resistance rating as the wall.

2.2.2.3.5 Cantilever fire walls used as temporary exterior walls (until future construction occurs) will be subjected directly to wind loads, and therefore must be properly designed and temporarily connected to the building frame until the additional building is constructed. Ensure all connections to the wall are completely removed or cut when the new construction has been completed.

An alternative to temporarily affixing the wall to the building frame is to design the wall as a cantilever wall to adequately resist the full lateral loads; note that foundations would also need to be designed to support the forces on a cantilever wall. This method could be costly due to the larger design loads on both the wall and the foundation.
Fig. 5a. Tied wall: Tilt-up wall, diaphragm roof with embed plate through-wall tie, shown with primary steel parallel to fire wall
Fig. 6. One-way wall: Corbel arrangement for one-way wall

Fig. 7. Cantilever wall: Corbel arrangement (masonry and corbel reinforcing not shown)
Fig. 8. Double wall: Corbel arrangement

Fig. 9. Typical cantilever wall; used at expansion joints, or at joints between buildings
2.2.2.3.6 Do not use cantilever walls in active seismic areas (FM Global 50-year through 500-year earthquake zones as shown in Data sheet 1-2, *Earthquakes*). If they must be used, specifically design them to resist anticipated seismic conditions; see Section 2.2.2.12.

2.2.2.4 Tied Walls

2.2.2.4.1 Design tied walls for the lateral loads specified in Section 2.2.2.2.7 to ensure stability under MFL fire conditions.

2.2.2.4.2 A tied wall (Fig. 12) must follow a column line to take advantage of the vertical strength of the column and to minimize lateral and torsional forces on the wall. Fireproof the steel columns and roof framing in line with the wall to have fire resistance equal to the wall. For situations where the wall is constructed between columns on a double-column line, the columns and beams or trusses parallel to the wall immediately on each side must have fire resistance equal to the wall to prevent the steel from buckling and fracturing the wall. Use concrete, masonry, or durable fire-resistant coatings to provide fire resistance for the steel.
2.2.2.4.3 Ensure the building framing on each side of a tied MFL fire wall is at the same elevation and in line horizontally.

2.2.2.4.4 Locate a tied fire wall near the center of the building frame (Figs. 13 and 14) so the building frame on each side of the fire wall will provide roughly the same lateral resistance. Consider breaks in continuity of the building frame (e.g., double-column expansion joints) when locating a tied fire wall.

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Fig. 12. Typical tied fire wall; used with continuous building framework

Fig. 13. A tied wall at the center of a continuous steel frame. The horizontal force from collapsing steel on either side must be resisted by the lateral strength of steel on the other side.
2.2.2.4.5 The lateral resistance of the frames on either side of the wall must be sufficient to resist the horizontal component of the force resulting from the collapsing frame on the opposite side. This is critical if the building frames on both sides of the wall are not of equivalent strength (see Figure 15). Remember to consider collapse on both sides, since the fire could occur on either side. The horizontal force may be computed by using the following catenary cable formula:

\[ H = \frac{W L^2}{8S} \]

Where:
- \( H \) = Horizontal force, lb (kg)
- \( W \) = Tributary dead load of the roof per unit length of truss or beam, lb/ft (N/m)*
- \( L \) = Truss or beam span, ft (m)
- \( S \) = Sag in ft (m) that may be assumed as:
  - 0.09L for solid-web steel beams
  - 0.07L for open-web steel trusses
  - 0.06L for open-web wood trusses

*Note: Under certain conditions, \( W \) must also include environmental loads. Include the weight of rainwater when roofs are capable of ponding water. In locations where snow could accumulate on the roof for a significant period of time during the year (locations with 20 psf [0.96 kN/M^2] or greater ground snow load as determined using Data Sheet 1-54, Roof Loads for New Construction), add 25% of that ground snow load to the dead load to determine \( W \). If both of the above conditions exist, use the higher figure.

Assume the horizontal force, \( H \), is applied at two adjacent column lines simultaneously; use a worst-case scenario in deciding where to apply these design forces.

2.2.2.4.6 At roof level, the expected horizontal force must be transmitted through the wall with continuous framing (for single-column line tied walls) or through-wall ties (for double-column line tied walls). Masonry anchors from the wall to the respective framework on each side will not provide adequate reliability.
2.2.2.4.7 For walls constructed between columns on a double-column line, design the strength of ties based on the horizontal force, \( H \), calculated using the formula in section 2.2.2.4.5. For design purposes, use an allowable tensile stress of not more than \( 0.3F_y \) and an allowable shear stress of \( 0.2F_y \) for steel tie rods and connection assemblies.

Use two (2) tie rods per column to reduce torsion (see Fig. 4) when primary roof framing is perpendicular to the wall. The ties must connect the roof framing members on each side of the wall over the columns. When the primary roof framing is parallel to the wall it may be necessary to install ties at a more frequent interval than every column line (see Fig. 5); in this case, the tie rods and wall penetrations must be designed and detailed to ensure vertical deflections of the roof framing due to gravity loads will not transfer load to the tie rods or fire wall. Nuts for through-wall ties must be backed off slightly (up to ¾ in. [19 mm] for walls up to 40 ft [12 m] high and an additional ¼ in. [6 mm] for every additional 10 ft [3.0 m] of wall height) to allow for normal building movement.

Where tie rod penetrations will be core-drilled, locate the penetrations such that vertical and horizontal reinforcing is avoided. Where tie rod openings are to be blocked out, ensure the horizontal and vertical wall reinforcing runs continuously through the openings. In all cases, properly pack the fire wall penetrations with a flexible fire-proofing material, such as mineral wool, to ensure the fire resistance of the wall is not compromised. Install an integral steel cover plate or escutcheon plate at all penetrations to hold the fire-proofing material in place.

While through-wall connections are needed to make framework continuous across the wall, it is also essential to provide flexible concrete or masonry anchors (see Fig. 16) at approximately 2 to 4 ft (0.6 to 1.2 m) on center to brace the wall laterally. Allow enough slip in the anchors to compensate for the slip (as noted above) in the through-wall ties; this is to prevent the collapsing frame from pulling on the wall before the frame on the non-fire side provides the needed resistance. The maximum space is 3/4 in. (19 mm) for walls up to 40 ft (12.2 m) high and an additional 1/4 in. (6 mm) for every additional 10 ft (3.0 m) of wall height.

2.2.2.4.8 In the case of single-column-line tied MFL walls (Fig. 12), the framing on the unexposed side of the wall will resist steel expansion on the fire side. However, the connection of the wall to the columns must allow some flexibility, as the building frame on the unexposed side will deflect laterally due to the pull from the sagging steel on the fire side.

Use flexible masonry anchors (see Fig. 16) or concrete blocks that loosely key into the reentrant space of the column to provide the needed flexibility. If sprayed-on fireproofing is used, spray the entire column before constructing the wall.
2.2.2.5 One-Way Walls

2.2.2.5.1 Design one-way walls for the lateral loads specified in Section 2.2.2.2.7 to ensure stability under MFL fire conditions.

2.2.2.5.2 Connect one-way walls only to the frame of the area to be protected.

2.2.2.6 Double Walls

2.2.2.6.1 Design double MFL walls for the lateral loads specified in Section 2.2.2.2.7 to ensure stability under MFL fire conditions.

2.2.2.6.2 A double MFL fire wall consists of two one-way walls adjacent to each other. Connect each wall only to its respective building frame (Figs. 17 and 18).

2.2.2.6.3 Ensure each of the two wall elements has a 3-hour fire resistance rating.

2.2.2.6.4 If masonry walls are not sufficiently separated to prevent bonding, install a layer of building paper or other suitable bond breaker between the walls.

2.2.2.6.5 Anchor each wall to its respective steel framework at roof level and at columns if necessary. Allow no connections between the two walls other than the roof flashing. Pay particular attention to details at openings in the walls and at the roof flashing between the walls (see Fig. 19).
2.2.2.7 Panel Walls In Reinforced Concrete Buildings

2.2.2.7.1 Design panel walls for the lateral loads specified in Section 2.2.2.2.7 to ensure stability under MFL fire conditions.

2.2.2.7.2 If the panel wall is tied to a 4-hour fire-rated reinforced concrete building (including floor and roof decks and all structural framing) on one side, but the building on the other side is of different construction (such as steel), do the following:

   a) Make structural connections of the panel wall only to the adequately fire-rated building frame. Do not make connections to the building frame on the opposite side if it could collapse in an uncontrolled fire.

   b) Follow the recommendations listed in the Section 2.2.2.5.

   c) Follow all recommendations in Section 2.2.2.11; however, note the exceptions for panel walls in Sections 2.2.2.11.2 and 2.2.2.11.5.

2.2.2.7.3 If tilt-up or precast concrete construction is used, pay particular attention to the connections at foundations, structural slabs and decks, and pilasters. Fireproof all connections as necessary to obtain the same fire resistance as the rating of the wall.

2.2.2.8 Control of Cracking

2.2.2.8.1 Locate expansion joints for masonry MFL fire walls so they are spaced a maximum of 200 ft (61 m) on center and in line with those of the building frame. Make the joints no more than 2 in. (51 mm) wide, and fill them with compressible, fire-resistive sealer, held in place by steel cover plates. Install the plates over each face of the joint, but fasten them to only one side of the joint (Fig. 20). Keep combustibles at least 1 ft (0.3 m) away from expansion joints.
2.2.2.8.2 To prevent irregular cracking due to initial shrinkage of the concrete masonry in an MFL fire wall, provide control joints at intervals not exceeding 50 ft (15 m). Any of the types shown in Figures 21, 22, and 23 are applicable. Use an elastomeric fire stop sealant for caulking all joints.

Fig. 20. Expansion joint (courtesy of the National Concrete Masonry Association)

Fig. 21. Typical control joints in concrete masonry (reinforcing not shown) (courtesy of the National Concrete Masonry Association)

Fig. 22. Typical joint detail in precast concrete (courtesy of the National Concrete Masonry Association)
2.2.2.8.3 Detail bond beam reinforcement as follows:

a) Expansion joints: If structural continuity is required, provide tapered (18 in. [0.46 m] on each side) or smooth dowel laps. Otherwise, interrupt bond beam reinforcing, but provide 180 degree hooks to vertical rebar. Provide at least two grouted and reinforced cores on each side of the joint. (See Figures 24 and 25.)

b) Control joints: Extend bond beam reinforcing uninterrupted through control joints. Provide at least one grouted and reinforced core on each side of the joint (see Fig. 26).
2.2.2.8.4 Provide minimum shrinkage and temperature reinforcement per the applicable building code (e.g., ACI 318).

2.2.2.8.5 Provide minimum concrete protection for reinforcement per the applicable building code (e.g., ACI 318) or for the required fire resistance, whichever is greater. Refer to Data Sheet 1-21.

2.2.2.9 Parapets, Roof Protection, and Elevation Differences

2.2.2.9.1 Except where noted otherwise, provide MFL fire walls with parapets at least 30 in. (0.76 m) high (see Fig. 27) constructed of material having fire resistance equal to the wall. A parapet is an extension of the wall above the roof being protected. Measure the 30 in. (0.76 m) dimension from the top surface of the protected roof to the top of the parapet. Design the wall assembly to withstand the appropriate wind loads applied to the parapet (see Data Sheet 1-28, Wind Design).

For reinforced concrete frame buildings with concrete roof deck and gravel surfacing as in section 2.2.2.9.4 below, a parapet may be omitted.
2.2.2.9.2 If steel deck roofs are used, provide FM Approved Class I construction assemblies.

2.2.2.9.3 Provide roof cover assemblies that have a Class A rating by ASTM E 108 on the entire roof of buildings separated by MFL fire walls. (See Data Sheet 1-28R/29R, Roof Systems.)

For new construction, provide FM Approved roof decks and above-deck assemblies. For existing construction, wood roofs are acceptable, provided the above-deck assembly meets the requirements for Class A rating. This may require the use of a thermal barrier above the wood deck.

2.2.2.9.4 Protect the top surface of roof assemblies as follows:

a) Surface built-up roofs for at least 50 ft (15 m) on both sides of the MFL fire wall with pea gravel or slag embedded in a flood coat of asphalt (see Fig. 27). Use a gravel application rate of at least 4 psf (0.19 kN/m²).

b) For single-ply membrane assemblies, use an assembly that has a Class A rating (for the specific maximum slope and assembly in question). In addition, protect the top surface with paver blocks or large gravel ballast (ASTM No. 3 stone) for at least 50 ft (15 m) on both sides of the MFL wall (ASTM No. 4 stone is acceptable if the membrane is fully adhered or mechanically attached and doesn’t require ballast for wind uplift).
the gravel at a rate of 10 to 12 psf (0.48 to 0.57 kN/m$^2$). If added to an existing roof during re-roofing, have a registered civil or structural engineer analyze the roof to verify it can support the additional load.

c) Do not use polyurethane foam roof cover systems that are spray-applied to roofs within 50 ft (15 m) of an MFL fire wall.

d) Since it is not practical to provide gravel on a standing seam steel roof, install a layer of ceramic fiber or mineral wool or glass fiber batt insulation between the bottom of the roof panels and the top of the purlin flange for at least 50 ft (15 m) on each side of the MFL wall. Ensure the batt is a minimum of 1 in. (25.4 mm) thick ceramic fiber or mineral wool, or 2 in. (50.8 mm) thick glass fiber.

e) Roof drains within the 50 ft (15 m) are acceptable provided the drain cover is noncombustible and at least the first 3 ft (1 m) of drain pipe is steel or cast iron. Gravel, slag, ballast, and pavers can be held back away from the roof drain as needed for proper drainage as long as it does not exceed 3 ft (1 m).

2.2.2.9.5 Where a higher building or higher portion of a building adjoins a lower building at an MFL fire wall, ensure the exterior wall above the roof of the lower building is blank and has a 3-hour fire resistance, depending on the occupancy and construction of the exposing building (see Figs. 28a and 28b). Ensure the lower building has a 30 in. (0.76 m) high parapet. A parapet may be omitted on the higher building if there is at least a 15 to 50 ft (4.6 to 15.2 m) elevation difference, depending on the severity of the exposure. When the parapet is omitted, ensure the exterior wall construction extends up to the gravel stop. Gravel surfacing (or paver blocks) is still recommended for 50 ft (15 m) on the higher roof and at least 50 ft (15 m) on the lower roof to protect against flying brands.

Construct the upper section of the wall of fire-rated insulated metal panel or precast concrete panel to reduce the probability of damage to the lower roof from falling concrete masonry units. However, to provide penetration resistance from falling upper wall material if masonry units are used, design the roof of the lower building for minimum 100 psf (4.8 kN/m$^2$) construction for a length equal to the height of the elevation difference or one bay, whichever is less.

The assembly can be arranged in either of two ways:

a) Separate the high bay and low bay with a double MFL fire wall, each wall tied to its respective framework (see Fig. 28a), or
b) Construct a cantilevered, 4-hour fire wall from the foundation to the top of the parapet level for the lower roof. Ensure the upper wall section is 2- or 3-hour fire rated and tied to the framework of the higher building. Ensure the upper wall section is not connected to or does not extend over the face of the lower wall section. Fill the space between the upper and lower wall sections with a fire-resistive material (see Fig. 28b).
2.2.2.9.6 Monitors, penthouses, cooling towers, or other structures, either combustible or noncombustible, mounted on roofs can present special problems and require individual attention. Evaluate the space separation requirements for such structures or equipment using the methodology and guidelines in Section 2.3. Locate such structures at least far enough from fire walls, or construct them of sufficiently fire-resistant material, to prevent ignition.

Unusually high roof structures (over 20 ft [6 m] high) may require a greater separation distance. When this is not practical, construct fire partitions on the exposed side of the roof projection.

Locate heat and smoke vents, skylights, roof hatches, and roof penetrations for air-handling equipment at least 50 ft (15 m) from the MFL fire walls.

2.2.2.10 End Walls and Angle Exposure

2.2.2.10.1 Base the length and arrangement of end walls (exterior walls that are perpendicular to the MFL fire wall on each side) on the height of the building exposing the fire wall and in accordance with Figures 29a and 29b and Table 2. Use blank construction, with a minimum 2-hour fire-rating. Roof scuppers in end walls or angular exposure walls are acceptable provided the criteria in Section 2.2.2.9.4 are met.

An alternative end-wall arrangement is to extend the fire wall itself beyond the exterior walls of the building a distance equal to \( \frac{1}{2} \times \). (See Fig. 30 and Table 2.) Be aware that this type of wall extension may be difficult and expensive to accomplish, since it must be designed for wind load as a cantilever.

<table>
<thead>
<tr>
<th>Height of exposing area, ft (m)</th>
<th>Length of end wall protection*, ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 40 (12.2)</td>
<td>6 (1.8)</td>
</tr>
<tr>
<td>41 to 70 (21.3)</td>
<td>10 (3.1)</td>
</tr>
<tr>
<td>71 (21.6) and over</td>
<td>14 (4.3)</td>
</tr>
</tbody>
</table>

*Protection must consist of blank, 2-hour fire-rated construction.
Fig. 29a. End wall exposure protection; end walls tied to steel framing

Noncombustible exterior walls

Const. jts.

2 Hr. fire rated blank const.

(See recommendations for X dimension)

Fig. 29b. End wall exposure protection; end walls not tied to steel framing

Noncombustible exterior walls

Const. jts.

2 Hr. fire rated blank const. free standing

(See recommendations for X dimension)

Fig. 30. Alternative end wall protection

Fire wall

Construction joints

Noncombustible exterior walls

Min. 1/2 X

(See recommendations for X dimension)
2.2.2.10.2 Protect angle exposure at the end of an MFL fire wall (or section of it) by constructing both exterior walls of blank, 3-hour-rated masonry or metal sandwich panels (Fig. 31). The length of protection (Y) is 20 ft (6 m) if the exposing building has light combustible loading; 30 ft (9 m) if the exposing building has ordinary combustible loading, and 35 ft (11 m) if the exposing building has high combustible loading. In addition, construction of each wall and eave must be noncombustible up to a point of 60 ft (18 m), 75 ft (23 m), or 100 ft (30 m) away from the junction (of the MFL wall and the exterior walls) for light, ordinary, or high hazard exposures, respectively. Use wired glass, glass block, or special windows that have passed a ¾ hr fire test for windows within this area, beyond the 3-hour rated portion.

![Fig. 31. Angular wall exposure protection](image)

2.2.2.10.3 Provide a minimum 12 in. (0.3 m) parapet atop end wall and angular exposure wall protection. Ensure the parapet is at least as tall as the gravel stop.

2.2.2.10.4 For at least 20 ft (6 m) on each side of the end walls, ensure there are:

- no unprotected openings (truck docks, windows, personnel doors, ventilation openings, etc.).
- no combustible equipment.
- no combustible yard storage.

Determine the MFL space separation from the exterior walls based on the exposed construction beyond the end walls, and severity of the exposure from the exposure (e.g., yard storage or trailers) using Section 2.3 for MFL space separation.

Provide barriers when necessary to prevent temporary vehicle parking, combustible equipment, or yard storage being placed within 20 ft (6 m) of the end walls.

2.2.2.10.5 Locate railroad sidings at the end of the building that is parallel to the MFL fire wall. Alternatively, if the railroad siding runs perpendicular to the MFL fire wall on the outside of the building, do not install combustible construction or exterior wall openings for at least 50 ft (15 m) on each side of the MFL wall.

2.2.2.10.6 Protect elevation drops perpendicular to fire walls as angle exposure (See Fig. 32 and Section 2.2.2.10.2).
2.2.2.10.7 Locate fire-resistive end/angular exposure wall protection on the exterior surface. Do not place siding materials that are combustible or of limited combustibility over them.

2.2.2.11 Pipes, Conduit, Cables, and Ducts Penetrations

2.2.2.11.1 Where penetrations by pipes, conduit, cables, and or ducts, spaces are created for expansion or other joints in the building at top, bottom or in MFL Walls, provide through or membrane penetration or joint firestop materials that when installed to the tested and listed system, become firestop systems that conform to FM 4990, Approval Standard for Firestopping, or equivalent tested assembly.

Where MFL walls have been penetrated by pipes, conduit, cables, and or ducts, or spaces are created for expansion or other joints in the building at top, bottom or in MFL walls, firestop materials should be installed by an FM 4991 Approved Firestop Contractor.

2.2.2.11.2 Feed automatic sprinkler systems on either side of an MFL fire wall independently (Fig. 33) so it is not necessary to penetrate the wall.

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2.2.2.11.3 Avoid penetration of MFL fire walls by pipes, conduit, cables, and ducts. Keep any unavoidable penetrations to a minimum and arrange them as outlined below.

A. Position pipes, conduit, and cables (regardless of size) penetrating MFL fire walls to pass through the wall as close as practical to, but no more than 3 ft (1.0 m) above, the finished ground floor level. Provide a steel sleeve with a 1 in. (25 mm) annular clearance around the pipe or conduit, to be filled with an FM Approved fire stop assembly with a minimum 3-hour fire rating. Provide mesh reinforcement in the horizontal joints above and below pipes in concrete block walls, and fill all cores of the concrete block immediately adjacent to pipe penetrations with concrete grout. Do not penetrate the wall with clusters of pipes or conduit. If more than one pipe penetrates the wall in the same area, provide center-to-center spacing of at least three times the largest pipe diameter. Exception: The structural aspects of this recommendation do not apply to panel walls in reinforced concrete buildings, providing the frames on both sides of the wall are reinforced concrete. However, FM Approved fire stop materials still need to be used to seal around penetrations.

B. Protect exposed cables with combustible insulation with an FM Approved fire-resistive coating or wrap for at least 3 ft (1.0 m) on each side of the wall, unless a 4-hour fire stop assembly is used.

C. Specify that fire stops be installed by an FM Approved Firestop Contractor whenever possible.

2.2.2.11.4 Arrange heating, ventilating, and air conditioning ducts penetrating MFL fire walls with a slip joint (Fig. 34) located on each side of the wall as near to the face of the wall as practical. Provide 3-hour rated fire doors or dampers in the section of duct that penetrates the wall and securely fasten it to the wall at the opening. Provide two dampers for a double wall (one damper in each wall) with a slip joint between the walls. Install access panels nearby. For more information see Section 2.5.2.7 and 3.3.5.

Building code requirements may not allow the use of dampers in ducts conveying hazardous materials or used for smoke removal. In such cases, reroute the duct to avoid penetration of the fire wall.

Fig. 34. Breakaway connections; slip joints (Courtesy of the Sheet Metal and Air Conditioning Contractor's National Association, Inc. [SMACNA].)
and supported from the building columns and not the MFL wall. **Exception:** This does not apply to double MFL fire walls or MFL panel walls in reinforced concrete buildings.

2.2.2.11.6 Do not penetrate an MFL wall with piping that conveys combustible gas or ignitable liquid (such as fuel oil). Provide separate supplies to areas on each side of the wall.

2.2.2.11.7 Allow only steel or iron pipe, conduit, or ducts to pass through any MFL fire wall.

2.2.2.11.8 Keep combustibles at least 1 ft (0.3 m) away from pipes, ducts, plates, conduit, etc., where they penetrate the wall.

### 2.2.2.12 Design of MFL Fire Walls in FM Global Earthquake Zones

The design intent for MFL walls in FM 50-year through 500-year earthquake zones is for the wall to withstand the shake forces from the design earthquake and the thermal forces of an MFL fire directly after the earthquake.

2.2.2.12.1 This section applies to MFL fire walls in facilities located in FM Global 50-year through 500-year earthquake zones as shown in **Data Sheet 1-2, Earthquakes**.

2.2.2.12.2 Ensure MFL fire walls are designed by an engineer familiar with earthquake design and registered to practice structural design in the jurisdiction in which the project is located.

Meeting earthquake design requirements may eliminate one or more options that would otherwise be allowed in non-earthquake areas. For example, preventing damage to a fire wall from steel expansion during a fire by aligning the steel members on both sides of the wall and providing essentially no clearance is not an option in active seismic areas if it will allow pounding during an earthquake.

2.2.2.12.3 Anchor MFL fire walls to those roofs, floors, columns, foundations, or other structural elements that are intended to provide lateral support for the wall with positive direct connections adequate to resist required forces. Do not attempt to transfer lateral forces perpendicular to the wall using friction, nails in withdrawal, wood ledgers bolted to concrete or masonry walls, or similar connections.

2.2.2.12.4 Design MFL fire walls located in the United States, Puerto Rico, the Virgin Islands, and Guam for earthquake loads in accordance with the requirements of the Structural Engineering Institute/American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures*, Standard SEI/ASCE 7, or a building code based on this standard (e.g., the *International Building Code*). Use a seismic importance factor \( I_E \) of 1.5 for the design of MFL fire walls. Where MFL walls are intended to provide resistance to earthquake forces as part of the lateral-force-resisting system of the building (i.e., seismic shear walls), and if the overall building structure is designed using an \( I_E \) less than 1.5, increase all design forces for the wall to an \( I_E \) of 1.5; also design connections transferring forces to and from the MFL shear wall based on an \( I_E \) of 1.5.

2.2.2.12.5 In locations other than in Section 2.2.2.12.4, MFL fire walls may be designed using the recommendations in Section 2.2.2.12.4 if appropriate earthquake acceleration parameters are available. If these parameters are not available, use a seismic importance factor \( I_E \) of 1.5 and the values of \( S_{DS} \) provided below in the following equations (these forces are applied perpendicular to the face of the wall unless noted otherwise):

- FM 50-year earthquake zone: \( S_{DS} = 1.3 \) (g)
- FM 100-year earthquake zone: \( S_{DS} = 0.9 \) (g)
- FM 250-year earthquake zone: \( S_{DS} = 0.55 \) (g)
- FM 500-year earthquake zone: \( S_{DS} = 0.55 \) (g)

Calculate the forces on the walls as follows:

**Cantilever walls** – The wall is supported at the base only, with no attachment to the superstructure.

Seismic design force = \( 0.4 \ast S_{DS} \ast I_E \ast W_W \)

The force distribution on a cantilever wall is assumed to be an inverted triangular shape (i.e., with the force resultant located above the base of the wall a distance equal to \( \frac{2}{3} \) of the wall height).

**Tied, one-way, double, and panel walls** – The wall is supported at the base and connected to the structure at floors and roofs.
a) Wall and wall connections to supporting base or columns:
Seismic design force = 0.4*S_{DS}I_{E}W_{W}

b) Wall connections to elevated floors and roof:

1. Concrete or masonry wall to flexible diaphragm (a diaphragm other than a rigid diaphragm)
Seismic design force = 0.8*S_{DS}I_{E}W_{W}

2. Concrete or masonry wall to rigid diaphragm (a roof or floor structure that is monolithic structural concrete, structural concrete topping over metal deck, or structural concrete topping over concrete planks) or MFL wall not of concrete or masonry material.
Seismic design force = 0.4*S_{DS}I_{E}W_{W}

For rigid and flexible diaphragm construction, ensure the seismic design force perpendicular to the wall, for connections from concrete or masonry walls to floor or roof diaphragms, is not less than 280 lb/ft (4.1 kN/m) nor 400*S_{DS}I_{E} (lb/ft) (5.84*S_{DS}I_{E} [kN/m]); also, the spacing of the connections does not exceed 4 ft (1.2 m) on center.

The force distribution on tied, one-way, double, and panel walls can be applied as a uniform force.

Parapets

a. Cantilever parapets
Seismic design force = 1.2*S_{DS}I_{E}W_{W}

b. Braced parapets
Seismic design force = 0.5*S_{DS}I_{E}W_{W} (for wall and bracing elements)
Seismic design force = 0.8*S_{DS}I_{E}W_{W} (for bracing connections)

Where:
S_{DS} is the site (soil) adjusted, 5% damped, design spectral response acceleration at a short (0.2- second) period, expressed as a portion of the gravitational acceleration (g).
I_{E} = seismic importance factor = 1.5.
W_{W} = the weight of the wall in lbs (kN).

These design forces are intended for use in load and resistance factor design (LRFD) — also known as strength design or ultimate limit state design — and are provided factored (i.e., no additional load factors are required). If allowable stress design (ASD) or working stress design (WSD) is used, the LRFD design forces shown can be multiplied by 0.7 to determine equivalent approximate ASD design forces.

The Response Modification Factor (R-factor) is already embedded in these formulae. The forces should not be further reduced by an R-factor.

2.2.2.12.6 Where MFL walls are intended to provide resistance to earthquake forces as part of the lateral force resisting system of the building (i.e., seismic shear walls), design MFL walls using the recommendations in Section 2.2.2.12.4.

2.2.2.12.7. Provide adequate clearance between adjacent independent structures (e.g., between double walls, or between a cantilever wall and the structure on either side) to minimize the potential for pounding.

Assume the actual deflection of a cantilever fire wall during an earthquake will be 2\(\frac{1}{2}\) times the deflection determined, assuming the wall behaves elastically and using the LRFD forces in Sections 2.2.2.12.4 or 2.2.2.12.5 with an importance factor (I_{E}) of 1.0. Criteria to determine the actual deflections of the building structures adjacent to cantilever fire walls, or to which double walls are attached, is beyond the scope of this document. The registered engineer responsible for the building structural design must determine these deflections (amplifying deflections from design forces as necessary) and provide clearance adequate to prevent pounding based on appropriate analysis.

2.2.2.13 Structural Design Details, Detailing Guidelines, and Quality Assurance for MFL Fire Wall Construction

2.2.2.13.1 Reinforced Concrete Masonry

Provide concrete masonry walls with sufficient strength, durability, and stability to meet or exceed the performance requirements. The provisions in this section represent the minimum requirements — additional strength, durability, and stability may be needed to meet project-specific performance requirements.
Use 2-core concrete masonry units (blocks) installed in a running bond pattern. Do not use 3-core concrete masonry units or stack bond patterns. The thickness of the mortar bed joint is typically $\frac{3}{8}$ in. [9.5 mm]. Ensure it does not exceed $\frac{5}{8}$ in. [16 mm].

Ensure the 28-day compressive strength of concrete masonry units is not less than 1500 Lb/in$^2$ (10.3 MPa) and the units conform to ASTM C 90.

Assume face shell mortar bedding in design calculations rather than full area mortar bedding.

2.2.2.13.1 Minimum Reinforcing Ratio

The sum of the cross-sectional area of vertical and horizontal steel reinforcement is not less than 0.002 times the gross cross-sectional area of the wall; and the minimum cross-sectional area of steel reinforcement in each direction (vertical and horizontal) is no less than 0.0007 times the gross cross-sectional area of the wall. The horizontal cross-sectional reinforcing area can include horizontal joint reinforcing wire and continuous bond beam reinforcing.

See Section 3.2.2 for an example calculation of reinforcing ratios.

2.2.2.13.1.2 Vertical Reinforcing

Space vertical reinforcement no greater than 4 ft (1.2 m), or 1/3 the wall length or 1/3 the height between support points, whichever is less. In all cases, ensure vertical reinforcing is continuous through bond beams and for the entire height of the wall. Where splices are required for continuity, lap reinforcement no less than 48 bar diameters (for example, $\frac{1}{2}$ in. [13 mm] diameter reinforcing bars would be lapped at least 24 in. [610 mm]). Provide a minimum clearance of $\frac{1}{2}$ in. [13 mm] between the reinforcement and the interior surfaces of the masonry unit. Use rebar positioners spaced no greater than 8 ft [2.4 m] to fix vertical reinforcing in place, ensuring the position assumed for design is held during construction.

Provide no fewer than two (2) full-height, reinforced grouted cores at each wall corner or intersection. See Figures 35a and 35b.

Provide no fewer than two (2) full-height, reinforced grouted cores at each wall termination and at each side of horizontal wall openings 8 ft (2.4 m) and greater. Provide no fewer than one (1) full-height, reinforced grouted core at each side of horizontal wall openings less than 8 ft (2.4 m) and greater than 1.33 ft (0.4 m). See Figure 36.

Provide no fewer than two (2) full-height, reinforced grouted cores at each wall control joint or expansion joint, one on each side of the joint. See Figure 37.

For grouted reinforced cores at wall corners, intersections, terminations, openings, control joints, and expansions joints, use the same reinforcing bar size and number of reinforcing bars per core as used for the typical wall reinforcing.

2.2.2.13.1.3 Horizontal Reinforcing

Provide horizontal joint reinforcing consisting of minimum two (2) No. 9 (0.1483 in. [4 mm] diameter) diameter longitudinal steel side wires, one at each face shell, with No. 9 (0.1483 in. [4 mm] diameter) cross wires spaced at 16 in. [400 mm]. Use ladder-type horizontal joint reinforcing rather than truss-type (truss-type diagonals can interfere with the proper placement of the vertical reinforcing). Ensure horizontal joint reinforcing shall be factory fabricated and shall conform to ASTM A 82 (minimum yield strength 70,000 psi [480 MPa], minimum tensile strength 80,000 psi [550 MPa]); do not use tack welded construction. Provide joint reinforcement in flat sections not less than 10 ft (3 m) in length; lap splice longitudinal side wires not less than 6 in. (15 mm). Provide factory formed tees and ells for continuity of horizontal joint reinforcing at wall intersections and corners. Ensure all joint reinforcing is hot-dip galvanized in conformance with ASTM A 153 Class B2 (zinc coating 1.5 oz/ft$^2$ [450 g/m$^2$]) unless exposed to extremely humid or corrosive atmospheres, in which case use stainless steel in conformance with ASTM A 580 Type 304.

Place steel joint reinforcement in every second horizontal joint of concrete masonry walls (spaced not more than 16 in. [0.4 m on center] for stiffening and additional shrinkage control (see Fig. 23). In addition, place joint reinforcement in every first and second bed joint above and below wall openings and extend it at least 2 ft (0.6 m) horizontally beyond the openings. Provide joint reinforcement in the three joints immediately below the top of the wall. Interrupt joint reinforcement at control joints and expansion joints.

Incorporate at least one (1) continuous bond beam located at the same elevation of each level of adjacent structural floor or roof framing. Bond beams (Fig. 26) spaced at a maximum of 3.3 ft (1.0 m) on center vertically.
may be used in lieu of horizontal joint reinforcement; however, horizontal joint reinforcement still must be
provided midway between bond beams. Provide bond beams with minimum steel reinforcement of two (2)
#4 (\(\frac{1}{2}\) in. [12.7 mm] diameter) bars for 8-inch (20 mm) nominal concrete masonry units, or two (2) #5 (\(\frac{5}{8}\) in.
[15.9 mm] diameter) bars for 10 in. (25 mm) nominal and larger concrete masonry units. Provide continuous
steel reinforcing for bond beam by means of lap splicing, including at wall intersections and corners. Provide
lap lengths of not less than 48 times the diameter of the lapped reinforcing bar (see Figure 24). Provide a
minimum clearance of \(\frac{1}{2}\) in. [13 mm] between the reinforcement and the interior surfaces of the masonry
unit.

Fill all bond beams solid with grout; do not use mortar or other materials.

Ensure bond beam reinforcing extends uninterrupted through control joints.

Position continuous bond beams to incorporate lintels at the same elevation whenever practicable. Where
lintels cannot be incorporated into continuous bond beams, provide no less than 8 in. (200 mm) of lintel
bearing length at each side of the opening. Limit lintel deflection due to combined dead load and live load
to 1/600 of the span, or 0.3 in. (8 mm), whichever is less.

Provide lintels at all openings greater than 16 in. (405 mm).

2.2.2.13.1.4 Grout and Mortar

Provide grout in conformance with ASTM C 476. Ensure the compressive strength of the grout is equal to
or greater than the compressive strength of the masonry unit, but never less than 2000 lb/in
\(^2\) (13.8 MPa). Determine the compressive strength of grout in accordance with ASTM C 1019. Ensure the grout mix has a
consistency such that the measured slump is between 8 in. and 11 in. (200 to 280 mm). Where openings
are restricted or congested with reinforcing, use only fine grout. Ensure the maximum aggregate size is less
than 1/5 the narrowest clear dimension within the grout space; under no circumstances use an aggregate
size greater than \(\frac{3}{8}\) in. (9.5 mm) for coarse grout.

Place grout using low-lift grouting procedures; use 5 ft (1.5 m) maximum lifts. If low-lift grouting procedures
are not used, ensure cleanouts are provided at the base of the wall at each grouted core. For solid grouted
walls, provide cleanouts at a maximum spacing of 32 in. (810 mm) on center. For each grout lift, stop grout
pours at least 1 in. (25 mm) below the top of the masonry in order to form a grout key with the next lift (except
for final grout pour at the top of the wall).

Use only Type M or Type S mortars for masonry walls. (See Appendix A, Glossary of Terms, for a description
of each.)

2.2.2.13.2 Reinforced Concrete

2.2.2.13.2.1 Provide reinforced concrete walls with sufficient strength, durability, and stability to meet or
exceed the performance requirements. The recommendations in this section represent the minimum
requirements; additional strength, durability, and stability may be needed to meet project-specific performance
requirements.

2.2.2.13.2.2 Provide concrete with a 28-day compressive strength of not less than 3,500 psi (24 MPa).

2.2.2.13.2.3 Ensure the cross-sectional area of steel reinforcing in each direction (vertical and horizontal)
is at least 0.0025 times the effective gross cross-sectional area of the wall. Space horizontal and vertical
reinforcing no greater than 18 in. (0.46 m).

2.2.2.13.2.4 Provide continuous steel reinforcing by means of lap splicing, including at all wall intersections
and corners.

2.2.2.13.2.5 Provide lap lengths of not less than 60 times the diameter of the reinforcing bar. Do not use
welding or mechanical couplers to join reinforcing steel.

2.2.2.13.2.6 Provide steel reinforcing oriented diagonally at all wall openings greater than 8 in. (20 mm);
provide not less than two (2) #5 (0.625 in. [16 mm] diameter) reinforcing bars at each corner of each opening.

2.2.2.13.3 Detailing and Inspection of MFL Fire Walls in FM Global Earthquake Zones

2.2.2.13.3.1 Ensure MFL fire walls located in FM Global earthquake zones (50, 100, 250, and 500-year zones)
are in conformance with the recommendations in Sections 2.2.2.1 and 2.2.2.2 unless specifically noted
otherwise.
2.2.2.13.3.2 Provide walls with sufficient strength, durability, and stability to meet or exceed the performance requirements. The recommendations in this section represent the minimum requirements; additional strength, durability, and stability may be needed to meet project-specific performance requirements.

2.2.2.13.3.3 For all vertical reinforcing bars, and all bond beam and lintel reinforcing bars, use reinforcing steel conforming to the following specifications: Actual tested tensile strength not less than 1.25 times the actual tested yield strength; minimum 14% elongation (over 8 in. [203 mm]) at tensile failure for reinforcing bars not greater than 0.75 in. (19 mm) in diameter; minimum 12% elongation (over 8 in. [203 mm]) at tensile failure for reinforcing bars greater than 0.75 in. (19 mm) in diameter. These specifications can be met by using reinforcing bars in conformance with ASTM A 706; alternatively, ASTM A 615 steel reinforcing may be used provided that mill certificates are submitted that indicate the material meets the specifications noted above.

2.2.2.13.3.4 Do not credit heavily reinforced localized portions of the wall — for instance, at pilasters, chords, or wall openings - when determining the amount of reinforcing providing shear resistance for the wall.

2.2.2.13.3.5 Reinforced Concrete Masonry

2.2.2.13.3.5.1 Provide Level 2 Special Inspection in accordance with Chapter 17 of the latest edition of the International Building Code (IBC), with the addition of item 1 in Table 3 below. In locations where the IBC is not available or not in force, provide construction inspection in accordance with Table 3 below.

<table>
<thead>
<tr>
<th>Table 3. Verification and Inspection of Concrete Masonry MFL Wall Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification and Inspection</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
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<tr>
<td>6</td>
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<td>7</td>
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<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

Table 3 Notes:
1. Periodic inspection and verification: Part-time or intermittent observation of the work being performed, and the completion of the work, by an approved inspector.
2. Continuous inspection and verification: Full-time observation of the work being performed by an approved inspector.
3. Approved inspector: Personnel trained in conducting and evaluating tests and inspections; employed by an independent inspection/testing agency hired by the owner, or by the design professional in responsible charge acting as the owner’s agent; approved by the building official.
2.2.2.13.3.5.2 Vertical Reinforcing

Provide no fewer than five (5) full-height reinforced grouted cores at each wall corner or intersection. See Figures 35a and 35b.

Provide no fewer than three (3) full-height reinforced grouted cores at each wall termination, at each side of expansion joints, and at each side of horizontal wall openings 8 ft (2.4 m) and greater. Provide no fewer than two (2) full-height reinforced grouted cores at each side of horizontal wall openings greater than 3 ft (0.9 m) and less than 8 ft (2.4 m). Provide no fewer than one (1) full-height reinforced grouted cores at each side of horizontal wall openings greater than 1.33 ft (0.4 m) but less than 3 ft (0.9 m). See Figure 36.

Fig. 35a. Vertical reinforcing detail at concrete masonry wall corner

Fig. 35b. Vertical reinforcing detail at concrete masonry wall intersection
2.2.2.13.3.5.3 Horizontal Reinforcing

Provide minimum horizontal joint reinforcing consisting of minimum two (2) $\frac{3}{16}$ in. (5 mm) diameter longitudinal steel side wires, one at each face shell, with No. 9 (0.1483 in. diameter [4 mm]) cross wires spaced at 16 in. (400 mm). Lap splice longitudinal side wires not less than 8 in. (20 mm).

Enclose vertical reinforcing bars at pilasters with horizontal joint ties. Space horizontal joint ties no greater than 16 in. (400 mm). Ensure horizontal joint ties are the same size and material as horizontal joint reinforcing, and are provided with 135-degree hooks.

Provide 180-degree standard hooks for all bond beam, lintel, and sill reinforcing terminations; ensure each reinforcing bar hook encompasses at least one vertical reinforcing bar. See Figure 25.

Provide reinforced sills at all wall opening requiring lintels; ensure sills are of similar type, size, reinforcing, and detailing as lintels.

Where masonry lintels 16 in. (406 mm) or more in height are provided, ensure #3 (3/8 inch [10 mm] diameter) shear stirrups spaced at 16 in. (406 mm), and two (2) #4 (1/2 in. [13mm] diameter) top reinforcing bars are provided for the entire length of the lintel; these stirrups and top bars are to be provided in addition to the required bottom reinforcing bars.

2.2.2.13.3.6 Reinforced Concrete

2.2.2.13.3.6.1 Provide Special Inspection in accordance with Chapter 17 of the latest edition of the International Building Code (IBC), with the addition of item 1 in Table 4. In locations where the IBC is not available or not in force, provide construction inspection in accordance with Table 4.
Table 4. Verification and Inspection of Reinforced Concrete MFL Wall Construction.

<table>
<thead>
<tr>
<th>Verification and Inspection</th>
<th>Continuous</th>
<th>Periodic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inspect wall penetrations and associated specified clearances and fire-proofing.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>2. Verify size, grade, and type of reinforcement</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>3. Inspect reinforcing steel and placement, including depth of concrete cover.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>4. Inspect anchors, bolts, and other embedded structural connections.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>5. Verify use of specified concrete design mix.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>6. Inspect sample preparation and verify concrete testing (sampling for strength tests, slump, entrained air, temperature, density).</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>7. Inspect concrete placement.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>8. Inspect for maintenance of specified curing temperatures and techniques.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>9. Inspect protection of concrete during cold weather (below 40°F [4°C]) and hot (above 90°F [32°C]) weather.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>10. Inspect application of stressing force for pre-stressed or post-tensioned concrete.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>11. Inspect grouting of bonded strand for pre-stressed or post-tensioned concrete. or grouting of splice sleeves.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>12. Inspect erection of precast concrete members.</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>13. Verify in-place concrete strength prior to stressing of post-tensioning tendons.</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Notes:
1. Periodic inspection and verification: Part-time or intermittent observation of the work being performed, and the completion of the work, by an approved inspector.
2. Continuous inspection and verification: Full-time observation of the work being performed by an approved inspector.
3. Approved inspector: Personnel trained in conducting and evaluating tests and inspections; employed by an independent inspection/testing agency hired by the owner, or by the design professional in responsible charge acting as the owner’s agent, approved by the building official.

2.2.2.13.3.6.2 Provide at least two curtains of steel reinforcing throughout the entire wall.

2.2.2.13.3.6.3 Provide steel reinforcing oriented diagonally at all wall openings greater than 8 in. (20 mm); provide not less than two (2) #5 (0.625 in. [16 mm] diameter) reinforcing bars at each corner of each opening.

2.2.2.13.3.6.4 Provide boundary elements (see Figure 38) with lengths not less than \( \frac{1}{6} \) the wall segment length. Ensure all vertical reinforcing bars within the boundary element are confined within transverse hoop reinforcement.

2.2.2.13.3.6.5 Ensure the cross-sectional area of vertical reinforcing contained in the boundary element is from 0.01 to 0.06 times the gross cross-sectional area of the boundary element. Ensure the minimum cross-sectional area of transverse hoop and cross-tie reinforcement is at least 0.008 times the gross cross-sectional area of the wall at the boundary element location. Provide vertical spacing of transverse hoop and cross-tie reinforcement based on local code requirements, but never less than 4 in. (100 mm) or more

Fig. 38. Boundary element reinforcing detail (plan view) for concrete walls in FM Global earthquake zones
than 6 in. (150 mm). Provide transverse hoop and cross-tie reinforcement such that the distance between reinforcing bar bends (see dimension “X” on Fig. 38) is no greater than 14 in. (350 mm). Ensure horizontal reinforcing can develop its full yield strength within the boundary element; if the length of the boundary element is insufficient to develop full yield strength, use 135-degree standard hooks to anchor the horizontal reinforcing bars to the vertical reinforcing bars located closest to the wall opening.

For cross-tie reinforcing oriented perpendicular to horizontal reinforcing and engaging the same vertical reinforcing bar, install consecutive cross-tie reinforcing so the 135-degree standard hooks will be located on opposite sides of the wall.

The wall segment length is defined as the distance between wall openings; if there are no wall openings, the wall segment length is equal to the wall length.

2.2.2.13.3.6.6 Where ACI 318, Building Code Requirements for Structural Concrete, is available, providing walls in accordance with ACI 318 requirements for Special Structural Walls with Special Boundary Elements will ensure conformance with the recommendations noted here.

2.2.2.13.3.6.7 Where multiple openings in the walls are proposed, creating horizontal wall segments (coupling beams between multiple openings vertically aligned) or vertical wall segments (wall piers or columns), special reinforcing and detailing is required to ensure adequate performance of the wall. Addressing these conditions is beyond the scope of this document.

2.3 MFL Limiting Factor: Space Separation

2.3.1 Introduction

Space separation is the most common MFL limiting factor. The MFL space separation is the clear distance needed to prevent a fire from propagating across an open space from one building to another (or to/from combustible yard storage). The analysis must include the fire severity, the susceptibility of the exposed construction, heat transfer via convection and radiation, the effect of wind and the potential for burning brands.

Calculate the MFL separation distance ($S_M$) as follows:

$$S_M = S_B \times M \times U$$

where:

- $S_M$ = MFL separation distance
- $S_B$ = Base separation distance from Table 5 or Figures 43 or 44.
- $M$ = Exposure angle adjustment factor (see 2.3.3.4)
- $U$ = Unprotected opening adjustment factor (see 2.3.4.1 and 2.3.4.2)

2.3.1.1 Determine the base separation distance ($S_B$) per Figures 43 and 44 when the exposed walls are combustible or noncombustible.

2.3.1.2 Determine the base separation distance ($S_B$) per Table 5 when the exposed wall is fire rated.

### Table 5. Base Separation Distance for Fire-Rated Construction

<table>
<thead>
<tr>
<th>Exposed Wall Fire Rating (hours)</th>
<th>Exposing Occupancy Fire Hazard</th>
<th>Storage Occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light/Ordinary Occupancy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≤ 30 ft (≤ 9 m)</td>
<td>31-45 ft (9.4-13.5 m)</td>
</tr>
<tr>
<td>&lt; 1</td>
<td>Categorize the exposed wall as either combustible or noncombustible</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15 ft (4.5 m)</td>
<td>40 ft (12.2 m)</td>
</tr>
<tr>
<td>2</td>
<td>10 ft (3.0 m)</td>
<td>30 ft (9.0 m)</td>
</tr>
<tr>
<td>3</td>
<td>5 ft (1.5 m)</td>
<td></td>
</tr>
<tr>
<td>≥ 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Only structural separation and minimum clearance for thermal expansion (see Table 1) are required.

2.3.1.3 The key information needed in order to use the figures is occupancy fire loading, exposed wall category, and length of the exposing wall. The length of the exposing wall is not important when the exposed wall is fire rated.

2.3.1.4 The minimum separation distance is 10 ft (3.0 m) for any situation except for exposed walls greater than or equal to 3-hour fire-rated.
2.3.2 Classification of Exposed Wall Construction

2.3.2.1 Classify non-fire-resistance-rated walls as either noncombustible or combustible using Table 6 and 2.3.2.1.1 and 2.3.2.1.2.

2.3.2.1.1 Classify exterior insulation and finish systems (EIFS) as follows:

- For EIFS that has passed a large-scale test and has plastic insulation, classify the EIFS as equivalent to wood walls.
- For EIFS that has not passed a large-scale test, classify the EIFS as equivalent to asphalt shingle-covered wood walls.
- For EIFS with noncombustible insulation (e.g., glass fiber, mineral wool, perlite, etc.), classify the EIFS as equivalent to a noncombustible wall.

Table 6. Exposed Wall Categories for MFL Space Separation

<table>
<thead>
<tr>
<th>NONCOMBUSTIBLE¹</th>
<th>COMBUSTIBLE²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel-faced panels w/o insulation on steel or reinforced concrete frame</td>
<td>Painted wood</td>
</tr>
<tr>
<td>Steel-faced panels w/ noncombustible insulation on steel or reinforced concrete frame</td>
<td>Unpainted wood</td>
</tr>
<tr>
<td>Cementitious panels w/o insulation on steel or reinforced concrete frame</td>
<td>Asphalt shingled wood sheathing³</td>
</tr>
<tr>
<td>Cementitious panels w/ noncombustible insulation on steel or reinforced concrete frame</td>
<td>Asphalt Coated Metal (ACM)⁴</td>
</tr>
<tr>
<td>FM Approved steel-faced class 1 panels on steel or reinforced concrete frame</td>
<td>Rigid plastic panels (FRP, PVC)</td>
</tr>
<tr>
<td>FM Approved steel-faced noncombustible panels on steel or reinforced concrete frame</td>
<td>Aluminum panels w/o insulation⁴</td>
</tr>
<tr>
<td>FM Approved steel-faced class 1 panels w/ thermoset insulation on steel or reinforced concrete frame</td>
<td>Non-Approved metal-faced panels w/plastic insulation</td>
</tr>
<tr>
<td>FM Approved aluminum-faced class 1 panels w/ thermoset insulation on steel or reinforced concrete frame</td>
<td>All metal-faced panels w/ thermoplastic insulation</td>
</tr>
<tr>
<td>Aluminum-faced panels w/ noncombustible insulation on steel or reinforced concrete frame</td>
<td>Cementitious panels on wood frame</td>
</tr>
<tr>
<td>Cementitious shingles on steel or reinforced concrete frame</td>
<td>Cementitious shingles on wood frame</td>
</tr>
<tr>
<td>Cementitious shingles over noncombustible sheathing on steel or reinforced concrete frame</td>
<td>Any wall with exposed combustible materials</td>
</tr>
<tr>
<td>Any unrated precast, cast-in-place or tilt-up concrete panels (solid, hollow or insulated) on steel or reinforced concrete frame</td>
<td>Other assemblies on unprotected wood frame</td>
</tr>
<tr>
<td>Any unrated glass block</td>
<td>Any wall with windows that can be opened⁶</td>
</tr>
<tr>
<td>Any tempered glass panels in noncombustible frames on a steel or reinforced concrete building frame</td>
<td>FIRE RATED</td>
</tr>
<tr>
<td>Metal lath and plaster</td>
<td>The wall should meet the required fire rating per FM Global Loss Prevention Data Sheet 1-21. Any openings should be protected with a comparable fire-rated door. Any windows should be fire rated to match the rating of the wall.</td>
</tr>
<tr>
<td>Cementitious stucco</td>
<td></td>
</tr>
</tbody>
</table>

¹ Noncombustible exposed walls also can have no overhanging wood eaves.
² Combustible exposed walls include any wall with overhanging wood eaves and any wall with single-pane, annealed (not tempered) glass windows.
³ Increase separation by 25% for asphalt-coated metal walls.
2.3.2.1.2 Windows

A. Where the exposure and actual separation distance (D) are such that a fire-rated exposed wall is needed, protect windows using one of the following methods:

1. If a 1-hour rating is needed, do one of the following:
   a. Replace windows and frames with a listed window assembly of equivalent fire rating.
   b. Protect windows with minimum ¾-hr automatic closing shutters.
   c. Provide noncombustible frames and glazing that is listed, minimum ¾-hour fire-rated glass, glass block or wired glass. Ensure the dimensions of the windows do not exceed the dimensions and area limitations of the listing or applicable building code. Keep combustible material away from the inside of the exposed windows a distance at least equal to the largest dimension of the window.

2. If more than 1-hour rating is needed, do one of the following:
   a. Replace windows and frames with a listed window assembly of equivalent fire rating.
   b. Replace windows and frames with a wall assembly of equivalent fire rating.
   c. Protect windows with fire-rated automatic closing shutters with the appropriate rating for the wall (see DS 1-23).

B. Where the exposure and actual separation distance (D) are such that a noncombustible exposed wall is needed, protect windows as follows:

1. Provide noncombustible window frames and glazing that is one of the following:
   a. tempered glass
   b. laminated glass
   c. double-paned annealed glass
   d. heat-strengthened glass;
   e. min. ¼ inch (6.4 mm) wired glass
   f. glass block
   g. listed fire-rated glass

2.3.3 Exposing Wall Length (L)

2.3.3.1 Unless adjusted by 2.3.3.2-2.3.3.4, the length of the exposure (L) is the length of the exposing building up to a maximum length of 500 ft (150 m).

2.3.3.2 When the buildings overlap each other, use Figure 39 to determine the length of the exposure (L).
2.3.3.3 Evaluate buildings that are offset from one another using a length of the exposure (L) based on a 45 degree angle (see Fig. 39) and a 45 degree exposure envelope (see Figs. 40a through 40e).

![Fig. 39. Length of exposing wall for overlapping buildings](image)

![Fig. 40a. Exposure envelope](image)
2.3.3.4 When the exposed buildings are at an angle to one another, use Figures 41 and 41a to determine the exposure angle adjustment factor (M).
Fig. 40d. Offset buildings: longer exposing wall exposing longer exposed wall

Fig. 40e. Offset buildings: shorter exposing wall exposing longer exposed wall
Fig. 41. Exposed buildings at angles
Fig. 41a. Multiplier for buildings exposed at an angle.
2.3.4 Classification of Exposing Wall Construction

Exposing walls are classified as either Stable Fire-Resistive Walls (SFR) or Non-Stable Fire-Resistive Walls (Non-SFR).

2.3.4.1 SFR Exposing Walls

If the wall and structural frame of the exposing building is fire resistive (i.e., the wall is expected to remain in place throughout the duration of the MFL fire), the base space separation can be reduced. Credit can be given to those portions of exposing SFR walls that will remain in place for the duration of the fire and block the radiant heat from reaching the target. In such cases, the radiant heat experienced by the exposed wall will be limited to the visible flame coming from unprotected openings and flames above the SFR wall.

• Determine the total amount of unprotected openings in the SFR exposing wall as a percentage of the total wall area. Include door openings if the door is not automatic closing or normally closed and the door construction has a lesser fire rating than the wall.

• For exposing walls categorized as SFR, use the unprotected opening adjustment factor (U) from Figure 42 corresponding with the number of stories and percentage of unprotected openings in the exposing wall.

• If the exposing wall is SFR and the roof is considered SFR, then the only radiation will be from the unprotected openings. Do not use Figure 42. Use \( U = \) the actual percentage of the wall area that is unprotected openings.

![Exposing wall adjustment factor for unprotected openings in an SFR wall](image)

2.3.4.2 Non-SFR Exposing Walls

Walls laterally supported by a steel frame without fire-proofing or by a combustible frame can be expected to be damaged or collapse when exposed to an uncontrolled fire. Figures 43 and 44 are based on a flame front unobstructed by the exposing building wall (i.e., collapse of the exposing wall or a wall with 100% openings). For all Non-SFR walls, \( U = 1.0 \)
Fig. 43a. Base space separation for exposed noncombustible walls (English units).
Fig. 43b. Base space separation for exposed noncombustible walls (metric units).
Fig. 44a. Base separation for exposed combustible walls (English units).

- Above 45 ft. storage fire hazard
- 30 to 45 ft. storage fire hazard
- Up to 30 ft. storage fire hazard
- HC-1/HC-2 fire hazard
Fig. 44b. Base separation for exposed combustible walls (metric units).
2.3.5 Exposing Fire Hazard Categories

<table>
<thead>
<tr>
<th>Fire Hazard Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-1/HC-2 (see Data Sheet 3-26, Fire Protection Water Demand)</td>
<td>This category includes manufacturing, office, hotel, and similar occupancies where there are no significant storage areas over 50 ft (15 m) in length as measured parallel to the exposed wall; see Figure 45. In-process storage of Class 1, 2, or 3 commodities, up to 6 ft (1.8 m) is not considered storage. Do not use this category for multistory combustible construction. See the storage categories below. Do not use this category for multistory buildings with unprotected openings between floors and combustible interior finish material (walls and ceiling). If both of those are present, treat the building as a HC-1/HC-2 category. In an office occupancy an example would be wood paneling on the walls and a woodfiber suspended ceiling. In a manufacturing occupancy an example would be non-FM Approved foam plastic insulated metal panel walls and a Class 2 steel deck roof.</td>
</tr>
<tr>
<td>HC-3 (see DS 3-26)</td>
<td>HC-3 occupancies must be evaluated on a case-by-case basis and could fall into either the HC-1/HC-2 category or the storage up to 30 ft (9 m) category.</td>
</tr>
<tr>
<td>Storage occupancies up to 30 ft (9 m) high</td>
<td>This category includes storage of any commodity up to 30 ft (9 m) in height. It also includes multistory combustible construction buildings up to 30 ft (9 m) tall. Storage of noncombustible goods in noncombustible packaging can be considered HC-1 hazard category.</td>
</tr>
<tr>
<td>Storage occupancies greater than 30 ft (9 m) up to 45 ft (14 m) high</td>
<td>This category includes storage of any commodity over 30 ft (9 m) up to 45 ft (14 m) in height. It also includes multistory combustible construction buildings up to 45 ft (14 m) tall. Storage of noncombustible goods in noncombustible packaging can be considered HC-1 hazard category.</td>
</tr>
<tr>
<td>Storage occupancies over 45 ft (14 m) high</td>
<td>This category includes storage of any commodity above 45 ft (14 m) in height. It also includes multistory combustible construction buildings above 45 ft (14 m) tall. Storage of noncombustible goods in noncombustible packaging can be considered HC-1 hazard category.</td>
</tr>
</tbody>
</table>

2.3.5.1 Evaluating Occupancies with Ignitable Liquids

- Classify production areas with isolated systems with less than 500 gal (1,900 L) capacity per reservoir of ignitable liquids as HC-1/HC-2 hazard category.
- Classify production areas with systems with greater than 500 gal (1900 L) reservoirs of ignitable liquids in closed pipe systems (i.e., not ignitable liquids storage) as storage up to 30 ft (9.1 m) high.
- Evaluate the storage of ignitable liquids (i.e., storage in drums, totes, IBCs, etc.) as follows:

Inside Buildings
- Use the greater of the two spacings in Table 3 in DS 7-88; assume all liquids have a flash point below 140°F (60°C).
- Variable D for use in Table 3 is defined by the expected pool fire size. This is determined by the presence of any containment and/or the total amount of ignitable liquid.
- The minimum space separation is 75 ft (22.3 m) for noncombustible exposed walls and 125 ft (38.1 m) for combustible exposed walls.
- The maximum space separation is 200 ft (61 m) for noncombustible exposed walls and 300 ft (91.4 m) for combustible exposed walls.
- If only a small amount of the storage area has ignitable liquid analyze the space for the hazard from the rest of the occupancy.
- Evaluate exposure to fire-rated walls using Table 5 and storage over 45 ft (13.7 m).

**Outside Storage Areas**
- Use the greater of the two spacings in Table 3 in DS 7-88; assume all liquids have a flash point below 140°F (60°C).
- Variable D for use in Table 3 is defined by the length of the contained area.
- The minimum space separation is 75 ft (22.3 m) for noncombustible exposed walls and 125 ft (38.1 m) for combustible exposed walls.
- The maximum space separation is 200 ft (61 m) for noncombustible exposed walls and 300 ft (91.4 m) for combustible exposed walls.
- If there is no containment, assess the slope of the land and the ability of the liquid to flow into and compromise the space.
- Evaluate exposure to fire-rated walls using Table 5 and storage over 45 ft (13.7 m).

For all occupancies with ignitable liquids, evaluate whether or not ignitable liquids can compromise the space by flowing into the area. Provide containment if needed.

2.3.6 Yard Storage, Conveyors, Pipes, Passageways, and Roof Protection

2.3.6.1 Remove combustible yard storage that can negate a space separation. If yard storage cannot be avoided, maintain adequate space between yard storage and the exposed building considering the yard storage as an exposing building.

2.3.6.2 Provide protection for conveyors, pipes, bridges, tunnels, and other connector links that could damage or otherwise compromise the protective wall of an exposed building. Bridges must be independently supported with fireproofed supports to prevent the protecting wall of the exposed building from collapsing.

Ensure construction of all passageways is noncombustible (i.e., no Class 2 steel deck roofs). Provide fire doors at each end of tunnels, passes, connector links, etc., with a minimum fire resistance equal to the needed fire resistance of the walls in accordance with Table 5, but not less than 1 hour.

2.3.6.3 If the buildings are within 50 ft (15 m) of each other, provide the roof of the exposed building with a gravel surface or paver blocks for at least the portion of roof within 50 ft (15 m) of the exposure. For other types of roofs, such as standing seam or lap seam steel roofs, provide the protection on the underside as recommended in Section 2.2.2.9.4(d).

2.3.7 Side Wall Protection

2.3.7.1 When the exposing wall is longer than the exposed wall, side wall protection may be needed. If the space is adequate per this data sheet, then no side wall protection is needed, as long as the construction of the side wall is the same as the exposed wall. If the space is inadequate, analyze the exposure to the side wall as a 90° angle exposure.

The length of the protection needed for the side wall is equal to the space needed for a 90° exposure minus the actual space separation provided. See DS 1-20 for more details.
2.3.8 Vegetation

Trees in temperate climates without significant undergrowth do not contribute to fire spread if the space separation is otherwise acceptable. Each case must be evaluated on its own merits and it is possible that there are exceptions to the above position. In non-temperate or non-tropical climates such as deserts and other hot, arid locales, trees and undergrowth can contribute to fire spread. Data Sheet 9-19, *Wildfire/Bushfire Exposure*, is a good guide to identifying geographic areas where vegetation should be considered a possible contributing factor in MFL scenarios.

Typical urban and suburban areas of eastern North America receive sufficient rainfall or supplemental watering that this type of foliage would not be expected to contribute to the MFL scenario. However, a large tree canopy that spans the entire space and actually comes in contact with wood roofs or wood eaves may result in a space being unacceptable.

2.3.9 Motor Vehicle Parking

2.3.9.1 Grade-Level Open Parking Lots

Private vehicle parking (passenger cars) in an open lot generally will not spread a fire across an open space. Commercial vehicles (trucks, buses, tractor trailers) with or without trailers (loaded or unloaded) can spread a fire across an open space. They have the potential for a significant increase in combustible loading due to the larger plastic body panels and amount of on-board fuel. Each case must be evaluated on its own merits.

2.3.9.2 Open Aboveground Parking Garages and Car Parks

Private vehicle parking (passenger cars) generally will not spread a fire across an open-sided aboveground parking garage.

Commercial vehicles (trucks, buses, tractor trailers) with or without trailers (loaded or unloaded) can spread a fire across an open-sided parking garage.

2.3.9.3 Underground and Enclosed Parking Garages and Car Parks

Private and commercial vehicle parking can spread a fire across an underground and enclosed parking garage.
2.3.10 Ignitable Liquid and Flammable Gas Loading and Unloading Stations

2.3.10.1 Ignitable Liquids
The MFL space separation analysis must consider all the foreseeable hazards associated with these facilities. Consider the following scenarios:

- The fire occurs when a tanker truck is parked at the station in the space.
- The spill of a tanker’s entire contents and a subsequent fire.
- The spill of a tanker’s entire contents into an existing fire.
- Failure of piping and pumping systems and then a subsequent fire.
- Failure of piping and pumping systems at the station that feeds an existing fire.

Also refer to DS 7-43 and 7-88.

2.3.10.2 Flammable Gases
The MFL space separation analysis must consider all the foreseeable hazards associated with these facilities. Consider the following scenarios:

- A vapor cloud fire
- A vapor cloud explosion

Also refer to Data Sheet 7-42, Evaluating Vapor Cloud Explosions Using a Flame Acceleration Method.

2.3.11 Rail Lines and Sidings
The MFL space separation analysis must consider all the foreseeable hazards associated with these facilities. Consider the following scenarios:

- The fire occurs when the siding or rail line is occupied by open cars carrying a combustible material.
- The fire occurs when the siding or rail line is occupied by any one of the typical types of rail car (boxcar, refrigerated boxcar, flatcar, tanker, container carrier, gondola, hopper, center partition car, auto transporter).
- If ignitable liquids are normally delivered to the site via rail, consider that the fire occurs when a tanker car is parked in the space.
- The spill of a tanker’s entire contents and a subsequent fire.
- The spill of a tanker’s entire contents into an existing fire.

2.4 MFL Limiting Factor: Prevention of Exterior Vertical Fire Spread

2.4.1 Mechanical Floors
A mechanical floor can serve as a fire break and stop vertical fire spread. A fire-resistance floor stops interior vertical fire spread. It stops exterior spread when its walls are high enough to prevent exterior flames from reaching beyond the top of the window on the floor above. If both conditions exist, the fire break is adequate.

The formula below provides the minimum floor height needed to stop vertical fire spread. In order to credit a mechanical floor, the following must be true:

- There are no interconnected floors directly below the mechanical floor.
- There are no combustible interior finishes on walls and ceilings.

These factors will help ensure the fire does not spread to a significant number of floors at one time.

\[ B_r = 4.78h - S_1 - 2(S_1 + S_2) \]

Where

- \( B_r \) = required minimum height of the mechanical floor (ft, m)
h = window height (ft, m)
S₁ = height of the lower spandrel (ft, m)
S₂ = height of the upper spandrel (ft, m)

Note: Floor height is equal to S₁ + S₂ + h (see Fig. 46)

Example: A 30-story, reinforced concrete frame high-rise building has no interconnected floors, has 12 ft (3.7 m) high stories, with 5.8 ft (1.8 m) high windows, and spandrels centered on the floor slabs. It has a 20 ft (8 m) high, 17th story mechanical floor with no windows and negligible combustibles. What is the minimum required height for an acceptable mechanical floor break?

Solution:

English Units:

h = 5.8 ft
S₁ = 3.1 ft
S₂ = 3.1 ft
Bᵢ = 4.78(5.8) - 3.1 - 2(3.1 + 3.1)
Bᵢ = 27.7 - 3.1 - 12.4
Bᵢ = 12.2 ft

The mechanical floor is 20 ft tall, so this is an acceptable fire break.

SI Units:

h = 1.8 m
S₁ = 0.95 m
S₂ = 0.95 m
Bᵢ = 4.78(1.8) - 0.95 - 2(0.95 + 0.95)
Bᵢ = 8.6 - 0.95 - 3.8
Bᵢ = 3.85 m

The mechanical floor is 6.1 m tall, so this is an acceptable fire break.
The bottom section of spandrel $S_{17}$ may be deeper than on other floors to accommodate deeper beams supporting the mechanical floor. If $S_{17}$ is deeper, we can consider the mechanical floor fire break to be higher by that distance; e.g., if $S_{17} = 5$ ft, the effective height of the 17th story fire break could be considered $12.2 + (5 - 3.1) = 14.1$ ft.

2.4.2 Setbacks

A high-rise may have one or more abrupt reductions in floor area. Consider the reduction deep enough to stop exterior fire spread if its depth is equal to or greater than the height needed for a mechanical floor break and it extends around the entire building perimeter. In the previous example, we needed a mechanical floor height greater than 12.2 ft. So a setback that goes completely around the building that is greater than 12.2 ft would be sufficient to stop vertical exterior fire spread.

All other criteria in 2.4.1 must also be provided.

2.4.3 Balconies

Noncombustible balconies of adequate size can deflect flames and stop upward exterior fire spread. To qualify as an adequate vertical fire break, the balcony must overlap the openings on the lower floor by at least 4 ft (1.2 m) both outward and to the sides.

2.4.4 Podium Floors

Floor-ceiling assemblies can be used as limiting factors in multistory construction. Typically, a large retail or casino floor is separated from a hotel tower by a reinforced concrete podium floor supported by a reinforced concrete frame. Due to the many variables involved, a complete list of requirements cannot be provided. The following are general guidelines:

- the floor-ceiling assembly must be 4-hr rated.
• the structural frame supporting the podium must be 4-hr rated.
• All penetrations must be adequately fire stopped.
• All openings must be protected with minimum 3-hr rated fire doors. Elevator shafts, vent shafts and utility shafts must be minimum 2-hr rated assemblies.
• Elevator doors must be at least 2-hr rated. Enclosed elevator lobbies must be at least 2-hr rated.
• External fire spread must be prevented by either extending the podium a minimum of 40 ft from the base of the tower on all sides, or by providing mechanical floor breaks, setbacks, or balconies as described above.
• The tower exterior cladding must be noncombustible.

2.5 Protection of Openings in MFL Limiting Factors

2.5.1 Introduction

This section provides guidelines for the protection of openings in MFL limiting factors. Openings are defined as personnel, vehicle, and material-handling-system openings. For guidelines on the protection of penetrations (pipes, cables, etc.), see Section 2.2.2.11.

2.5.2 Construction and Location

Minimize the number of doorways or other openings in MFL fire walls. When they are necessary, keep them as small as practical.

For general information on door types, refer to Appendix C.

2.5.2.1 Fire Doors

2.5.2.1.1 Ensure fire doors in MFL fire walls are FM Approved and labeled (see Fig. 48) and have a minimum 3-hour fire rating. Do not use glazing material in fire doors in MFL fire walls. Except where single fire doors are acceptable, provide one door on each side of the opening. Since MFL conditions assume fire protection is out of service, water spray is not an acceptable substitute for fire doors. Also, do not use sprinkler water flow as the sole means of initiating fire door closure.

2.5.2.1.2 Keep the number of openings in fire walls to a minimum, especially during the design of new MFL fire walls. The fewer the openings, the greater the reliability of the limiting factor.

2.5.2.1.3 Ensure architectural drawings and specifications call for the use of FM Approved fire doors and do not use the phrase “or equal.”

2.5.2.1.4 When purchasing fire doors, specify the hardware, frame (swinging doors), operators, and related devices as part of the assembly.

2.5.2.1.5 When selecting new fire doors in MFL fire walls used to separate warehousing areas, take into consideration the temperature-rise rating of the door. (See Appendix C, Section C.8.)

2.5.2.1.6 When it is necessary to have an opening in an MFL fire wall that is larger than any FM Approved fire door, protect the opening with a door that has a minimum 3-hour FM Approvals oversize label.

2.5.2.1.7 When horizontal sliding doors are mounted in pairs (bi-parting), ensure the center joint is rabbeted or provided with an astragal (Figs. 49, 50, and 51) to provide a minimum lap projection of 3/4 inch (19 mm).

2.5.2.1.8 Where side-by-side exit (egress) doors are required by local authorities to open in opposite directions, use separate doors latching into a mullion (vertical framing member). Where egress doors swing in pairs and have a minimum 3-hour fire rating, ensure they either latch into a mullion or are equipped with an astragal that conforms to National Fire Protection Association (NFPA) Standard No. 80, Fire Doors and Windows (Fig. 52). Provide a device to coordinate door closure.

2.5.2.1.9 Ensure all horizontal sliding doors and metal-clad or sheet metal vertical sliding doors lap the sides and the top of the opening by at least 4 in. (102 mm). Ensure steel sectional vertical sliding doors lap the top and sides of the openings by at least 2 in. (51 mm).

2.5.2.1.10 When an elevator is to be located next to an MFL fire wall, arrange it so the elevator door is not in the plane of the MFL fire wall.
Fig. 48. Labels for FM Approved doors
2.5.2.1.11 Ensure doors that are normally closed are self-closing (install weights, door closers, or spring hinges if necessary) and are equipped with a latch. Make doors that are normally open self-closing by installing a mechanism that will close the door automatically when activated by a detector (Figs. 53 and 54). Locate the activating mechanism where it will be protected against mechanical damage.

2.5.2.1.12 Install doors in accordance with the manufacturer’s instructions and their FM Approval requirements to ensure proper operation and tightness. Doors that are designed for mounting on the face of the wall are sized to lap or rabbet the top and sides of the opening as noted in 2.5.2.1.9.

2.5.2.1.13 Enclose all weights (counterweights, hold-open weights, etc.) used for automatic closing mechanisms in substantial metal enclosures for the entire length of travel. Provide slots in the enclosure to permit raising the weight manually during inspection of the doors (Figs. 55, 56, and 57).

2.5.2.1.14 Use aircraft cable (Fig. 58) for connecting fusible links and weights (counterweights, hold-open weights, etc.) to automatic closing mechanisms. Ordinary cable may take a permanent set, and chain can kink or hang up on other components. Avoid sharp changes in direction (> 90°) unless pulleys are used.

2.5.2.1.15 Provide adequate clearance for vertical guides on rolling steel and vertical sliding fire doors. This clearance allows for the expansion of the steel guides and prevents buckling at elevated fire temperatures. Attach the vertical guides with bolts located in slotted holes to allow for expansion.

Do not attach the guides by welds unless specifically FM Approved and listed that way in the Approval Guide.

2.5.2.1.16 Provide adequate clearance between the curtain end locks and the guides on rolling steel doors to allow for horizontal expansion and to prevent buckling of the curtain slats at elevated fire temperatures (Fig. 59).
Fig. 50. Sliding doors on level tracks. (Reprinted with permission from NFPA 80, Fire Doors and Windows)

Note: Fusible links are needed on both sides of the wall.

Fig. 51. Preferred details at center joint of doors mounted in pairs. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
A hinge for each 30 in. (762 mm) or fraction thereof of the height of the door

Astragal

Top bolt

Single-point latch

Bottom bolt

Active door

Normally stationary door

Note: The astragal can be permitted to be attached to the inside of the inactive leaf or the outside of the active leaf.

Fig. 52. Doors swinging in pairs—flush mounted. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 53. Single swinging fire door. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 54. Swinging fire door with door closer. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 55. Telescoping vertically sliding doors. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 56. Vertically sliding door. (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 57. Horizontal sliding level track counterweight closure. (Reprinted with permission from NFPA 80, Fire Doors and Windows)

Fig. 58. 7x19 aircraft cable.
2.5.2.1.17 Use FM Approved or listed hardware where applicable. Ensure all bolts supporting guides/tracks extend completely through the wall. As an alternative in concrete, brick, or grouted (filled) concrete masonry units, expansion anchors may be used according to Figure 60. Ensure expansion anchors engage the brick or masonry unit and not the mortar joint. Ensure through bolts do not extend through both walls in a double fire wall.
Fig. 60. Use of expansion anchors to secure guides/tracks
Reprinted with permission from NFPA 80, Fire Doors and Windows
2.5.2.1.18 Ensure lintels and opening framing are of fire-resistive construction, such as brick, reinforced concrete, concrete masonry, or protected steel (Fig. 61).

![Fig. 61. Lintels of fire-resistive construction.](image)

2.5.2.1.19 Ensure combustible flooring does not extend through the wall.

2.5.2.1.20 Where it is important to prevent the passage of liquids through openings, install sills, curbs, or ramps made of fire-resistive construction at the opening above floor level (Fig. 62), and provide adequate floor drains nearby.

![Fig. 62. Asphalt emulsion floor over concrete ramp.](image)

2.5.2.1.21 After installation, have rolling steel fire doors satisfactorily tested, reset, and tested again to ensure the installer/operator has reset the door-closing mechanism correctly. When spring tension is used to close the door, make chalk marks noting the gear alignment to the release lever until the proper spring tension has been established. The door can then be reset and placed back in service.

Springs for rolling steel fire doors are under extreme tension. Have only properly trained and qualified personnel test, reset, repair, or adjust these doors.
2.5.2.1.22 Ensure the closing device housing (end cover) on all rolling steel fire doors (Fig. 63) is reinstalled after the door is reset. The housing must also be in place during testing. This will prevent the accumulation of dirt and debris, which could hamper the door closure, and help to detect (during tests) restrictions that will prevent movement of the release lever.

2.5.2.1.23 Use flame baffles (to close the space created when the curtain unrolls, see Fig. 63, 64) on FM Approved rolling steel fire doors.

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*Expansion clearance per door listing. Doors with downward expansion are as shown. Doors with upward expansion require expansion clearance above the top of the door.

Note: Fusible links are needed on both sides of the wall — configuration

---

Wall bolt for masonry construction:
Through-bolt, or expansion anchor, as permitted by door listing.

Wall bolt for nonmasonry wall construction:
Through-bolt, or machine screw into steel jamb, or lag screw into wood jamb, as permitted by door listing.

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Fig. 63. Rolling steel doors—surface mounted (Reprinted with permission from NFPA 80, Fire Doors and Windows).
Fire-resistive or noncombustible construction

*Expansion clearance per door listing. Doors with downward expansion are as shown. Doors with upward expansion require expansion clearance above the top of the door.

Note: Fusible links are needed on both sides of the wall — configuration

Between jamb mount

Wall bolt for masonry construction:
Through-bolt, or expansion anchor, as permitted by door listing.

Wall bolt for nonmasonry wall construction:
Through-bolt, or machine screw into steel jamb, or lag screw into wood jamb, as permitted by door listing.

Fig. 64. Rolling steel doors between jamb mounted (Reprinted with permission from NFPA 80, Fire Doors and Windows)
2.5.2.1.24 To help prevent mechanical damage to fire doors, resulting in their failure to operate, provide the following at any existing installation with a history of vehicular damage:

1. Guard posts (such as concrete-filled steel pipe) rigidly secured to the floor or foundation installed in front of all guides or tracks for rolling steel and vertical sliding fire doors used to protect personnel-operated vehicle openings.

2. Guard rails (such as highway guard rails) installed in front of the entire length of horizontal sliding fire doors (in the open position) to prevent storage from being placed against it, as well as damage from impact.

3. A heavy steel horizontal guard installed in front of the hood of a rolling steel door. Ensure the guard is vertically supported directly off the floor with posts. An alternative is to use surface-mounted doors with at least 2 ft (0.6 m) of clear space between the top of the opening and the bottom of the door hood.

2.5.2.1.25 To ensure the prompt operation of fire doors, locate detectors (such as fusible links; see Appendix C.2) per Data Sheet 5-48, *Automatic Fire Detection*.

2.5.2.1.26 Where fusible links are used, provide at least one link near an upper corner of the opening.

2.5.2.1.27 Where activation is by electric or pneumatic power, arrange the system so the door will close if power is interrupted.

2.5.2.1.28 Arrange all doors on an opening to close automatically upon activation of a detector on either side of the wall.

2.5.2.1.29 When cable is used to interconnect fire door closing mechanisms and detectors on both sides of the MFL fire wall, ensure it passes freely through \( \frac{1}{2} \) inch (13 mm) inner dimension steel pipe embedded in the wall. Ensure the distance between the inlet to the pipe or eyelets and the detector on each side is at least adequate to allow the door mechanism to fully release and allow the door to close. Cut the steel pipe flush with the face of the wall on each side and grind it smooth at each end to prevent abrasion and resistance to cable movement (Fig. 65). It is not necessary to penetrate the wall at the ceiling level. Other arrangements that meet the intent of this recommendation are acceptable.
2.5.2.1.30 Where personnel doors (up to a maximum size of 4 by 8 ft \([1.2 \times 2.4 \text{ m}]\)) swinging in the direction of the exit route are required for egress according to the governing codes, a single minimum 3-hour rated fire door may be provided. Provide the door with a positive latch and door closer. Ensure the door is normally closed.

If a double MFL fire wall is used, provide a narrow, reinforced concrete, self-supporting frame that passes through (but is not structurally connected to) both walls with one normally closed, self-closing fire door supported by the frame.

If double egress doors (a pair of side-by-side doors swinging in opposite directions) are required by the local code, one set of doors may be used on a single fire wall only if the doors are self-closing and latch into a fixed (non-removable) mullion. Otherwise, provide two sets of doors, with one set at each end of a vestibule constructed as described above.

2.5.2.1.31 Ensure vehicle openings in double MFL fire walls use a reinforced concrete, self-supporting frame that passes through (but is not structurally connected to) both walls. Ensure the fire doors on either side of the opening (surface mounted) or in the opening are supported by the frame (Figs. 66 and 67a-c).

![Diagram of interconnection of trip assemblies through fire wall.](image-url)
Fig. 66. Rolling steel fire doors in double MFL wall using reinforced concrete frame (stacked)
2.5.2.1.32 Locate and arrange storage of small, pressurized containers of aerosol products so the rocketing cans cannot pass through protected openings. For other details of protection, see Data Sheet 7-31, *Storage of Aerosol Products*.

2.5.2.1.33 The following recommendations apply to all doors protecting openings where the occupancy is highly susceptible to smoke damage:

1. Arrange fire doors to close automatically by actuation of smoke detectors. Ensure the smoke detector is suitable for the environment.

2. In the case of conveyor openings, make arrangements to shut down the feed conveyor and allow conveyed material to clear the opening before the door is allowed to close. This can be accomplished by using cross-zoned detectors on each side of the wall. Have the first signal initiate feed conveyor shutdown. Receipt of a second signal must initiate door closure. Provide a 15-ft (4.6 m) space between the detectors on respective sides of the fire wall to allow sufficient time delay for the feed conveyor to be shut down and the opening to be cleared.

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Fig. 67a. Rolling steel fire doors in double MFL wall using reinforced concrete frame (side-by-side)
3. An alternative to cross-zoning is to provide a single smoke detector on each side of the wall that upon actuation will shut down the feed conveyor and activate a time delay switch, which will allow delayed door closure. The time delay must be adequate to allow clearing of the opening, but generally must only be a few seconds. In either case, connect the door holder to a back-up power supply using an uninterruptible power supply (UPS) system. This will prevent premature door closure during a power failure.

4. Equip doors with listed 3-hour rated fire door gasket material (that will not restrict door closure). Protect the bottom of swinging personnel doors with either an automatic door bottom or listed 3-hour rated fire door gasket material.

5. Ensure openings protected by horizontal sliding doors are equipped with continuous front, rear, and top binders (Fig. 68), and have listed fire door gasket material at their bottom edges to reduce smoke passage.

6. Ensure fire dampers used to protect openings for air-handling systems have a Class 0, I, or II leakage classification. (See Section 3.3.5.)

2.5.2.1.34 Anchor fire doors and fire door frames to masonry or concrete walls at locations in FM Global earthquake zones 50-year through 500-year.

2.5.2.1.35 Use FM Approved horizontal sliding fire doors in FM Global earthquake zones 50-year through 500-year.

2.5.2.1.36 Where toppling of equipment or stock positioned close to fire doors may interfere with complete closure of the doors, properly anchor or relocate equipment and stock away from doors.
Fig. 67c. Rolling steel fire doors in double MFL wall using reinforced concrete frame (plan details)

Fig. 68. Binder arrangements to reduce smoke penetration around horizontal sliding doors (Reprinted with permission from NFPA 80, Fire Doors and Windows).
### 2.5.2.2 Material Handling Systems

The following recommendations apply to all material handling systems, with the exception of automatic guided vehicle systems (AGVS). For AGVS recommendations, see Section 2.5.2.6.

2.5.2.2.1 Except where otherwise noted in 2.5.2.2.13, provide automatic closing fire doors on both sides of the opening for all MFL fire walls. In the case of a double wall, provide one door on each wall.

2.5.2.2.2 Ensure the design of the material handling system allows for complete closure of the opening upon automatic release of the fire door. (See Section 3.3.1.) Ensure the design is as simple and reliable as possible.

2.5.2.2.3 Design material handling systems to provide a clear distance perpendicular to the opening equal to the maximum dimension (height or width) of the opening. Maintain a clear space of 2 ft (0.6 m) in the direction parallel to the wall. (See Fig. 69 and Sections 2.5.2.4 and 2.5.2.5.)

2.5.2.2.4 Ensure combustible conveyor belts are not continuous through the fire wall. Ensure the system has a discontinuity of combustibles, as well as an opening that will allow for complete closure of the fire door.

2.5.2.2.5 Arrange detectors to do the following:

1. Stop the feed conveyor or otherwise initiate the mechanism that clears the path of the fire door.
2. Provide an adequate time delay to clear the opening.
3. Activate the fire door closing mechanism.

When multiple detectors are used to provide a fire-dependent time delay between the clearing of the opening and closure of the door, ensure the detectors have different temperature ratings and are located no more than a few inches apart.

Ensure the temperature rating of the device used to clear the opening and/or stop the feed conveyor is rated at 135°F or 165°F (57°C or 74°C), but not less than 50°F (28°C) above ambient temperature. Use a combination rate-of-rise, fixed-temperature detector arranged for fail-safe operation for MFL fire walls, except where otherwise noted.

Ensure the detector that initiates fire door closure is 286°F (141°C) rated or the next highest standard rating that is over 100°F (38°C) above the rating of the detector used to clear the opening.

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**Fig. 69. Clearance area at fire doors.**
Locate closely spaced devices of each type near the top of the opening and at ceiling level on each side of the fire wall, and arrange so operation of any one set of devices will allow stoppage of the conveyor and fire door closure, in that order. Where smoke damage is a concern, also see Section 2.5.2.1.32.

2.5.2.2.6 Ensure clearance around rails or chains is a maximum of 3/8 in. (10 mm) and a special factory applied label (Fig. 71) is attached to the door. Small openings for clearance around conveyor rails or chains are acceptable if necessary (Fig. 70), except in occupancies with a significant amount of combustible dust or lint.

2.5.2.2.7 Arrange the conveyor drive mechanism to shut down the conveyor if conveyed material can become lodged in one position and obstruct closure of the fire door. Ensure sections of the conveyor downstream of the obstruction can continue to operate.

2.5.2.2.8 Ensure the fire door(s) at the opening are capable of effective closure regardless of whether or not any section of the conveyor is operating.

2.5.2.2.9 Where it is impractical to provide inclined sections at the junction of the fire wall with roller or belt conveyors, special design is necessary to allow a clear path for the fire door to close (Section 2.5.2.5). Detectors must still be provided as outlined in Section 2.5.2.2.5.
2.5.2.2.10 Design the material-handling system and its support structure in such a way that its collapse will not damage or put any significant loading or stress on the fire wall.

Ensure conveyor sections on either side of the fire wall are supported by the floor or roof, and not by the fire wall. The short section within the plane of the fire wall (between fire doors) may be supported directly by the fire wall (only one of the fire walls in the case of a double fire wall). Where the supports for the sections on either side of the fire wall may be exposed to lift truck traffic, provide guards to prevent movement of these sections into the fire door path.

2.5.2.2.11 Ensure tow conveyors use vestibules with at least one 3-hour rated fire door at each end, and that vestibule walls, roof, and floor are made of 4-hour fire-rated, reinforced concrete (fully grouted and reinforced concrete masonry wall is also acceptable) designed for 100 psf (488 kN/m²). Ensure the vestibule is free-standing and independent of the MFL wall.

2.5.2.2.12 Ensure the clear distance between carts on tow conveyors is greater than the vestibule length, including door widths. Ensure the clear distance between doors is greater than the length of the carts. Only use carts at clip-on points (points where carts are attached to drive chain). Do not place carts between clip-on points and allow them to be pushed by the carts behind them. (See Section 3.3.4.)

2.5.2.2.13 Protect chain or rail conveyors with door packs. (See Fig. 72 and Section 3.3.3.)

Fig. 72. Door-pack installation (Reprinted with permission from NFPA 80, Fire Doors and Windows)
2.5.2.2.14 Ensure the enclosure and baffles in the door pack are constructed of at least 4-hour fire-rated material. If the door pack enclosure is above floor level, ensure its supporting structure has a fire-resistance rating equivalent to that of the wall. Ensure fire doors are rated for at least 3 hours.

2.5.2.2.15 Provide devices to stop the conveyor if a door drifts into a fouling position, and before allowing automatic closure.

2.5.2.2.16 Ensure “Go” and “Return” passes for chain or rail conveyors do not penetrate the same wall opening or use the same door pack enclosure.

2.5.2.2.17 Use the following formula to determine the minimum number of 3-hour fire-rated doors in door packs for chain or rail conveyors (see Section 3.3.3 for an example):

\[ N = \frac{S_h}{S_c - T_d} \]

Where: 
- \( N \) = number of doors
- \( S_h \) = horizontal spacing between hangers, in. (mm)
- \( S_c \) = clear space between stock, in. (mm)
- \( T_d \) = thickness of the door, in. (mm)

2.5.2.2.18 Ensure the door spacings for door packs in chain and rail conveyors are even and meet the following criteria:

\[ S_d = S_c - T_d \]
\[ S_d = \frac{L_s + T_d}{(N-1)} \]

Where: 
- \( S_d \) = center-to-center spacing of doors, in. (mm)
- \( L_s \) = length of stock perpendicular to wall, in. (mm)

2.5.2.2.19 When it is not practical to provide door packs, arrange the chain or rail conveyor system so all fire wall openings can be cleared at the same time. Provide double, minimum 3-hour rated fire doors at each opening along with photo eyes that will allow the openings to be cleared before the material handling system is shut down for any reason. Provide a back-up power supply to prevent conveyed material from stopping in the path of fire doors due to power failure.

2.5.2.2.20 House lowerators for handling of roll paper in a 4-hour fire-rated enclosure. Provide minimum 3-hour rated FM Approved fire doors at each end of the enclosure. Keep at least one door closed at all times.

2.5.2.2.21 Where emergency stops are required on material-handling systems, arrange them in such a manner as to not compromise the reliability of fire door closure. This can be accomplished on conveyor systems by providing an inclined gravity section at the wall, and separately powered feed and take-away sections. Another alternative is to provide three separately powered sections (feed, middle, and takeaway sections) with the middle section at the wall enclosed in a cage that would thus not require an emergency stop mechanism. The feed and take-away sections could then be equipped with the necessary emergency stop mechanisms.

2.5.2.3 Pneumatic Conveyors

2.5.2.3.1 Do not penetrate MFL fire walls with pneumatic conveyors carrying combustible material.

2.5.2.3.2 Protect pneumatic conveyors carrying noncombustible material with two 3-hour fire-rated dampers located in the fire wall. (Provide at least one in each wall in the case of a double wall.) Arrange the dampers for automatic closure by activation of detectors rated at 135°F or 165°F, or 50°F above ambient temperature (57°C or 74°C, or 28°C above ambient temperature) located on each side of the wall (Fig. 73).
2.5.2.3.3 Provide a service opening adjacent to each fire damper and fire detection device (e.g., smoke detector, fusible link). Ensure the opening is large enough to permit testing and resetting of the damper.

2.5.2.3.4 Provide slip joints in the pneumatic conveyor on both sides of the wall (Fig. 74). If a double fire wall is used, provide a slip joint between the two walls.

Fig. 73. Fire dampers (Courtesy of the Sheet Metal and Air Conditioning Contractor’s National Association, Inc. [SMACNA].)
2.5.2.4 Roller and Belt Conveyors with Inclined Gravity Sections

2.5.2.4.1 Interlock the sections of conveyor on each side of the wall so the feed section can only move when the downstream takeaway section is moving. Arrange the feed conveyor to stop prior to operation of the fire door, allowing the gravity roller section to clear the opening. Provide a sufficient gap in the roller conveyor to allow the fire door to close fully (Fig. 75).

2.5.2.4.2 Ensure combustible conveyor belts are not continuous through an opening in an MFL fire wall. Arrange conveyor belts to turn back on each side of the wall, and use an inclined section of roller conveyor of adequate length at the opening. Make arrangements to prevent stock from backing up into the inclined section or wall opening.

A. Provide interlocks so that, if primary power is lost or shut down to the take-away section, the feed conveyor will automatically shut down and cannot be started until the take-away section is operating. Provide photo-eyes at the take-away side of the wall opening so that if a back-up of goods is sensed they will shut down the feed conveyor. Provide a time-delay switch so that, during normal shutdown,

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Fig. 74. Breakaway connections (slip joints). (Courtesy of the Sheet Metal and Air Conditioning Contractor’s National Association, Inc. [SMACNA].)
take-away section will continue to operate briefly after the feed section has been shut down so the opening is clear.

B. Ensure the distance between the upper end of an inclined gravity section and the face of the fire door on its respective side (Y) of the fire wall is at least equal to the maximum dimension of the opening (Figs. 75 and 76). When this is not practical, provide fire doors with a 30-minute temperature rise rating of 250°F (121°C) on the opening.

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**Fig. 75. Roller conveyor protection.**

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**Fig. 76. Belt conveyor protection.**
C. Ensure the distance between the lower end of the inclined gravity section and the face of the fire door on its respective side (X) is at least equal to the maximum dimension of the opening plus twice the length of the longest parcel to be conveyed (2L) (Figs. 75 and 76). A distance of 2L is acceptable if fire doors with a 30-minute temperature rise rating of 250°F (121°C) are provided. If this is still not practical, provide the above rated doors with a downstream incline at least equal to L, and the following:

1. Totally enclose the control panel for the take-away section nearest to the fire wall in metal casing, and interlock it so the control panel will not operate unless its access door is closed.

2. Ensure the motor for the same section has a totally enclosed metal housing, and wiring in conduit.

3. Locate the control panel and motor adjacent to the door opening.

4. Connect the take-away section of the conveyor to a back-up power supply. The back-up power supply may consist of a pneumatic system, a flywheel system, or float-charged batteries with dc-ac inverters capable of powering the take-away section for a long enough period to clear the opening (usually only a few seconds).

If it is not practical to install the control panel and motor near the wall opening, provide a 135° or 165°F (57° or 74°C) detector (or minimum 50°F [28°C] above ambient) over the control panel and motor, or extend a temperature-detection wire over the take-away section nearest the fire wall. Arrange the detector to shut down the feed conveyor. This will help ensure proper fire door closure before the panel or motor on the take-away section is damaged by a fire. Interlock control panels so they will not operate unless the control panel door is closed.

2.5.2.5 Roller and Belt Conveyors without Inclined Gravity Sections

2.5.2.5.1 Where it is impractical to provide inclined sections at the junction of the fire wall, special design is necessary to allow a clear path for the fire door to close. The design generally relies on a normal electrical feed as the primary power supply. In case of a failure of the primary power supply, provide a secondary power supply to temporarily power the intermediate and take-away portions of the conveyor (Fig. 77). This secondary power supply may consist of float-charged batteries with dc-ac inverters, a pneumatic system, or flywheel system.

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![Fig. 77. Conveyor penetration without incline](image-url)
2.5.2.5.2 Do not connect the secondary power feed to a switchboard common to the main power feed. Ensure wiring is in conduit, and control panels and motors are totally enclosed in metal casings and located as close to the fire wall opening as possible.

2.5.2.5.3 Regardless of the power supply arrangement, provide a photo-eye on the take-away side of the opening to prevent back-up of goods near the door. Arrange it to shut down the feed conveyor before goods can back up within a distance equal to the maximum opening dimension.

2.5.2.6 Automatic Guided Vehicle Systems (AGVS)

2.5.2.6.1 Provide a central control station and electromagnetic guidance.

2.5.2.6.2 To maintain the reliability of the opening protection, use one of the following methods:

   A. Keep one of the two fire doors at each vehicle opening in MFL fire walls normally closed and equipped with power operators. Arrange the AGVS for automatic door control. A high-service door may be needed.

   B. Provide a 4-hour fire-rated reinforced concrete vestibule. Ensure the vestibule has at least one 3-hour rated fire door at each end and the clear space between fire doors is longer than the longest vehicle or group of vehicles. Station the zones (see Section 3.3.2) so the horizontal clear space between vehicles or groups of vehicles is greater than the length of the vestibule (including fire door widths). This alternative is more practical when individual vehicles are used.

   C. Provide a vehicle block system. Ensure the first zone station before the MFL fire wall is at least the maximum dimension of the opening away from the fire wall. Ensure the first zone station beyond the MFL fire wall is further away from the fire wall than the length of the vehicles (based on the maximum number of vehicles that can be coupled together, if applicable), plus the maximum dimension of the opening. Ensure the block system allows only one vehicle between the stations at one time. Provide the vehicles with a backup on-board power supply that will power the vehicle to the next station in the event of a loss of power to the central control station. Provide one 3-hour rated fire door on each side of the opening.

2.5.2.6.3 Provide fire door interlocks to immediately stop any oncoming vehicles at the first zone station prior to the fire wall upon fire door closure.

2.5.2.6.4 When multiple detectors are used to create a time delay provide detectors at each door opening and at ceiling level over the door opening on each side of the fire wall (in close proximity to each other). Use a 165°F (74°C) rated, fail-safe combination rate-of-rise, fixed temperature detector to stop all vehicles at the next zone station. Use a 286°F (141°C) rated detector to initiate door closure.

2.5.2.6.5 If two-way travel is needed, arrange controls so oncoming vehicles clear the opening prior to approach by the second vehicle(s).

2.5.2.6.6 Ensure an adequate clearance width is marked and maintained along the entire length of vehicle paths.

2.5.2.7 Air Handling Systems

2.5.2.7.1 Provide slip joints in the ductwork on both sides of the wall (Fig. 74). If a double fire wall is used, provide a slip joint between the two walls.

2.5.2.7.2 Provide openings for ductwork with two 3-hour rated fire dampers located in the plane of the fire wall. (Provide at least one in each wall in the case of a double wall.) Arrange the dampers for automatic closure by activation of 135°F or 165°F, or 50°F above ambient temperature (57°C or 74°C, or 28°C above ambient temperature) rated detectors located on each side of the wall (Fig. 73).

2.5.2.7.3 Ensure duct coverings (insulation) do not extend through the wall. Ensure coverings do not conceal or interfere with the use of any service opening.

2.5.2.7.4 Interrupt duct linings at fire dampers so as not to interfere with automatic closure.

2.5.2.7.5 Provide a service opening adjacent to each fire damper and fire detection device (e.g., smoke detector, fusible link). Ensure the opening is large enough to permit testing and resetting of the damper.
2.5.3 Operation and Maintenance

2.5.3.1 Keep fire doors and accessories in good working condition. Remove dust, lint, and debris. Lubricate parts in contact as recommended by the door manufacturer.

2.5.3.2 Inspect doors, hardware, and closing devices for all fire doors weekly. Replace when necessary, using parts obtained from the original manufacturer. Check the doors to ensure they are free-moving and otherwise in proper operating condition and free from obstructions. Record inspections.

2.5.3.3 Trip-test fire doors at least semi-annually by fusing a link (using an electric heat gun and standing back to avoid solder splatter) or setting off a detector. Trip-testing by shutting off the power supply or other means is acceptable provided the method constitutes an actual test of the door-closing mechanism. Cutting or removing the links could give false results as this could loosen dirt and debris that might otherwise restrain the door.

For convenience in higher buildings, it is acceptable to fuse the link located near the top of the door opening. However, ensure there is enough room for movement in both directions between fusible links or S-hooks to allow sufficient chain movement for the door to close. The direction of movement of a section of chain may be reversed depending on which link actually fuses.

**Example:** An eyelet is located immediately below a ceiling-level fusible link. If the link located near the top of the opening is fused, the chain is free to move upward. However, if the ceiling level link is fused, the chain cannot move sufficiently downward to release the door.

2.5.3.4 Close fire doors during idle periods as this increases the reliability of protection for the openings and helps to detect potential mechanical problems.

2.5.3.5 Ensure adjustments of counterbalancing mechanisms are made by factory-trained personnel or comparably trained, qualified employees.

2.5.3.6 Instruct facility personnel in the importance of keeping openings clear of stock and equipment.

2.5.3.7 Post signs instructing employees to keep fire wall openings clear and to report all damage to fire doors or hardware immediately.

2.5.3.8 Keep combustibles far enough away from fire doors to prevent their ignition. Ensure the clear distance perpendicular to the wall is equal to the maximum dimension (height or width) of the opening. Maintain a clear space of 2 ft (0.6 m) in the direction parallel to the wall (Fig. 69). Unless specifically labeled as a temperature-rise rated door, the door offers virtually no resistance to the passage of heat.

2.5.3.9 Keep doors clean and painted (except as otherwise noted below), particularly when subject to deterioration from corrosion. Examine metal-clad fire doors periodically for evidence of deterioration of wood cores. Keep flame baffles and binders clean and free.

After installation, do not apply paint to the slats of rolling steel fire doors or to the operating components (moving parts) of any type of fire door. This includes detectors, chain, cable, cords, rope, gears, pulleys, springs, the inside of tracks, or any part that must slide, pivot, rotate, or drop.

Do not paint over labels on fire doors, frames, or operators.

2.5.3.10 Keep door tracks clean at all times.

2.5.3.11 Fill in all openings no longer required for passage with concrete or masonry of a fire-resistance rating equivalent to that of the original wall. Remove steel jambs or cover them with fire-resistant material and mortar the masonry fill against the perimeter of the opening.

The following alternative may be applied to openings that are only temporarily out of service: Tightly stack (no mortar needed) concrete masonry units or bricks of a type and thickness equivalent to that of a fire wall in the opening, fill any joints of significant width (such as between the door jambs and masonry units) with mineral wool or ceramic fiber, close the fire doors on both sides, and keep storage at least 1 ft (0.3 m) away from the fire doors on both sides.

2.5.3.12 Replace a fire door if either of the following is true:

   1. The door is obsolete and parts cannot be obtained. (Do not have parts fabricated by installers, contractors, or maintenance personnel.)
2. The door has failed more than once for the same or for related mechanical reasons.

2.5.3.13 Test the AGVS interlocks at least semi-annually.

2.5.3.14 Instruct AGVS operators as follows:
1. Investigate and correct all vehicle alarm conditions immediately after discovery.
2. Take vehicles with low batteries out of service and recharge them.
3. If the emergency bumper is actuated, remove any remaining obstacles, restart the vehicle and continue its route.
4. In the event of a control system malfunction, shut the system down (after all vehicles are stopped at the next zone station); investigate AGV passages through fire walls and remove vehicles from the path of fire doors immediately.

2.5.4 Use of Other Codes and Standards

2.5.4.1 FM Approved Versus Listed Products

Products tested/listed by UL, ULC, Warnock Hersey, and other internationally recognized testing laboratories can be accepted when FM does not Approve that category of product or material or where FM Approved products are not available. This includes fire-rated glass, dampers, and fire door gasketing material.

The following references will assist in this area:
- UL Fire Resistance Directory
- UL Building Materials Directory
- ULC List of Equipment and Materials, Vols. II and III
- Warnock Hersey Certification Listings

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Application of MFL Limiting Factors

Larger properties generally are subdivided into fire areas to limit the spread of fire. Horizontal fire spread is limited by space separations between buildings, or by MFL fire walls. In multi-story buildings, vertical spread from one story to another is limited by floor construction, exterior wall construction, mechanical floors, setbacks, balconies, and by enclosures around stairways, elevator shafts, and other openings.

The need for MFL limiting factors is usually determined by the values exposed in a single fire. Limiting factors may be walls, space separation, lack of continuity of combustibles, fire response or a combination of these. If an MFL fire wall is used, the wall must be designed for stability as well as fire resistance, and must confine an uncontrolled fire to the side of origin. In addition to stability and fire resistance, other factors that must be considered in the design are protection of openings, exterior walls, parapets, penetrations, and roof details. The system design must prevent fire spread through, under, over, or around the MFL fire wall.

The placement of MFL fire walls takes into consideration property damage and loss of production. MFL fire walls are used to subdivide production and to separate manufacturing lines from storage.

Considering MFL fire walls in the design of new construction is imperative. When MFL subdivision is indicated, consideration must be given to providing separate electrical, mechanical, and plumbing systems on each side of the wall to help eliminate the need for penetrations through the wall. Consideration at the planning stage also may help in limiting the number and size of openings in the wall as well as in ensuring that loading docks, roof penetrations, and roof-mounted structures are at an adequate distance from the fire wall.
3.2 MFL Fire Walls

3.2.1 Fire Resistance of Wall Construction

An MFL fire wall must have insulating qualities so temperatures on the unexposed face of the wall will not ignite combustibles. The recommended fire rating of the wall is determined by the expected severity and duration of the fire. MFL fire walls normally need a 4-hour fire-resistance rating. The selection of durable materials and methods to meet this criterion is the designer’s responsibility.

See Data Sheet 1-21, Fire Resistance of Building Assemblies, for methods of providing fire resistance.

3.2.2 Stability and Strength

Stability is an essential property of an MFL fire wall because it must remain standing during a fire, even if the building frame on one side collapses.

Several different types of MFL fire walls exist. Each type achieves stability in a different way. Consequently, combining the stability aspects of two different types of MFL fire walls may result in a lack of stability under fire conditions. Unless otherwise noted, general recommendations for integrity apply to all types of MFL fire walls.

Strength is necessary so the wall will be able to resist glancing blows from falling materials, force and thermal shock of fire hose streams, thermal stresses from the fire, and forces from collapsing portions of floors and/or roofs adjacent to the wall.

Many modern industrial buildings depend on structural steel frames for stability. A wall that obtains its lateral support from a steel frame can be destroyed by collapse of part of the frame in an uncontrolled fire. As unprotected steel trusses, girders, or beams approach and exceed temperatures of 1000°F (538°C), they initially expand and then lose some of their strength, twisting and sagging. Large horizontal forces can develop toward the wall as the steel expands, and then away from the wall as the steel fails. Design considerations must be made to prevent damage as a result of these forces, which may crush the wall or deflect it laterally to the extent that its structural integrity is destroyed.

Reinforced concrete frame buildings have some degree of fire resistance and will remain structurally sound until heat penetrates the concrete cover over the reinforcing steel and weakens the steel. For the amount of cover necessary, or a given fire-resistance rating of a reinforced concrete member, see Data Sheet 1-21, Fire Resistance of Building Assemblies.

The potential for a fire during or after an earthquake increases due to the damage caused by the ground movement. The likelihood that automatic fire protection systems will be damaged or completely out of service also increases as a result of the earthquake. Therefore, passive fire protection, such as fire-resistant construction and fire walls, becomes increasingly important in active seismic zones. The maximum foreseeable loss philosophy dictates that MFL fire walls must remain stable during and after an earthquake in order to perform their purpose of subdividing properties into separate fire areas. To accomplish this, the wall must be designed for seismic loads as well as stability under fire conditions.

The recommendations in Section 2.2.2.12 were developed to ensure reasonable stability during an earthquake. The design criteria are based on Standard SEI/ASCE 7, Minimum Design Loads for Buildings and Other Structures (Structural Engineering Institute/American Society of Civil Engineers). The SEI/ASCE 7 criteria are incorporated in building codes such as the International Building Code (International Code Council, USA).

Meeting earthquake design requirements may eliminate one or more of the options for achieving stability that would otherwise be allowed in non-earthquake areas. For example, preventing damage to a fire wall from steel expansion during a fire by aligning the steel members on both sides of the wall and providing essentially no clearance is not an option in active seismic areas if it will allow pounding during an earthquake.

Since MFL fire walls must be the most reliable method of preventing horizontal fire spread, they are equated with an essential facility. Essential facilities are those structures that must remain functional subsequent to an earthquake. Therefore, an importance factor (I_E) of 1.5 is used for MFL fire walls.

The earthquake accelerations given in Section 2.2.2.12.5 are only intended to be used when other appropriate earthquake acceleration parameters are not available. These accelerations were chosen to provide a degree of reasonableness given the combination of factors relating to both probability and severity.
Specifying a minimum reinforcing ratio is a method of ensuring a minimum level of strength and crack control for the wall.

Example 1: Calculation of reinforcing ratios for a masonry wall.

Given:
- 8-in. nominal (7.625 in. [195 mm] actual) masonry wall;
- 10 ft (3.0 m) in height;
- No. 9 (W1.7) horizontal joint reinforcing (two 0.148 in. [3.7 mm] diameter steel wires) at 16 in. (406 mm) on center;
- One bond beam reinforced with two #4 bars (1\(\frac{1}{2}\) in. [13 mm] diameter);
- Vertical reinforcing #5 (0.625 in. [16 mm] diameter) spaced at 24 in. [610 mm] on center.

Steel Area Calculations
- #4 bars steel area = 0.20 in\(^2\)
- #5 bars steel area = 0.31 in\(^2\)
- No. 9 wires (2) steel area = 2 x 0.0172 in\(^2\) = 0.0344 in\(^2\)

Calculate Ratios:
- Gross horizontal area = 10 ft x 12 in./ft x 7.625 in. = 915 in\(^2\)
- Minimum horizontal steel area = 0.0007 x 915 in\(^2\) = 0.64 in\(^2\)
- Check horizontal steel area = (2)(0.20 in\(^2\)) + (7)(0.0344 in\(^2\)) = 0.641 in\(^2\) > 0.64 in\(^2\)
- Gross vertical area = 12 in./ft x 7.625 in. = 91.5 in\(^2\)/ft
- Minimum vertical steel area = 0.0007 x 91.5 in\(^2\)/ft = 0.064 in\(^2\)/ft
- Check vertical steel area = (0.31 in\(^2\)/24 in.)(12 in./ft) = 0.155 in\(^2\)/ft > 0.064 in\(^2\)/ft
- Check total steel area = (0.641 in\(^2\)/15 in\(^2\)) + (0.155 in\(^2\)/91.5 in\(^2\)) = 0.0007 + 0.0017 = 0.0024 > 0.002

Therefore, the wall reinforcing meets the prescribed minimum values.

3.2.3 Cantilever Fire Walls

Cantilever MFL fire walls (see Figs. 9 and 10) are entirely self-supporting without any ties to adjacent framing. They are usually constructed of reinforced concrete masonry, brick, or reinforced concrete. Such walls are erected at an expansion joint in the framing, but are not fastened to the building frame on either side.

Horizontal forces in cantilever walls are induced by fire. The horizontal forces may be caused by the pull of roof flashing as the burning portion of the building collapses, by irregularities of construction, or by warping of the wall under fire exposure.

For stability against horizontal forces, the wall must rely on its own strength as a cantilever. Such lateral strength may be obtained by providing vertical reinforcing bars in the wall, or reinforced pilasters. Unreinforced pilasters or pilasters constructed on only one side of the wall usually do not adequately strengthen the wall. Cantilever walls over 30 ft (9 m) high become expensive to stabilize.

Use of tilt-up concrete panels for cantilever (and other types) of fire walls has become increasingly popular in recent years. Some key requirements during design and review are the following:

- Stabilize the wall as a cantilever using footing, floor slab, soil, etc., to resist the required overturning moment.
- Pay attention to joint details between panels to ensure they are adequately sealed and no relative panel movement occurs.
- If precast panels are used, ensure they do not contain foam plastic or other combustible material in the cores.

Steel framing on the fire side of the wall will expand and may cause failure of the wall, particularly when steel on each side does not line up horizontally and vertically (see Fig. 78). Clearance between the wall and steel framing (Table 1) on both sides is needed to allow steel framing on the fire side to reach the point of maximum expansion without exerting force on the fire wall (see Fig. 3).
3.2.4 Tied Fire Walls

Tied MFL fire walls (see Figs. 4, 5, and 12) are fastened to (and usually encase) members of the steel building frame. To remain stable, the pull of the collapsing steel on the fire side of the wall must be resisted by the strength of the unheated steel framing on the other side.

Because the fire can occur on either side of the wall, the wall must be located at the center of strength of the building frame. The center of strength is the plane within the building frame in which the steel framing on either side has equal resistance. In small structures, the center of strength generally is in the middle of the building frame (see Fig. 13). The center of strength may lie between two double-column expansion joints (see Fig. 14) in large buildings. Single column line expansion joints do not break the continuity of the building frame.

Fire exposure can cause bowing of the wall. This movement of the wall out of its normal vertical plane could allow normal gravity loads (live and dead roof loads) to overstress the wall. Also, the sagging of the steel on the collapsing side will result in lateral and twisting forces at the top of the wall, which could collapse or otherwise damage the wall.

3.2.5 One-Way Fire Walls

A wall that is tied to a steel building frame on one side and is entirely independent of the frame on the other side is a one-way fire wall. Generally, this type of wall is only effective if an uncontrolled fire starts on the side of the wall that is not providing structural stability for the wall.

One-way walls also may reduce the MFL when used in combination with MFL fire walls. As an example (see Fig. 79), a building could be separated into three areas by an MFL fire wall (A) and a one-way wall (B) tied to the steel frame of areas 1 and 3. Fire originating in area 1 could involve two of the areas (1 and 2) but would be prevented from entering the third area (3) by the one-way wall.
Two distant one-way walls in parallel and supported by separate framework can be built at double-column line expansion joints. As an example (see Fig. 80), one-way fire walls (A) could be tied to the steel framework of Areas 1 and 3 respectively. A single fire would not involve more than two areas. Usually a 4-hour fire rating is needed.

3.2.6 Double Fire Walls
A double MFL fire wall (Figs. 17 and 18) consists of two one-way walls back to back. It is most adaptable where an addition to a facility necessitates an MFL fire wall between an existing structure and a new building.

The existing wall, which is secured to the building frame, is altered to provide the proper fire resistance if necessary. Another fire wall is then constructed adjacent to the existing one and secured to the new building frame. With an uncontrolled fire on either side of this double wall, one building frame will collapse, pulling the wall on that side with it. The other wall, being supported by steel on the protected side, will remain in place to stop the fire spread.

3.2.7 Panel Walls in Reinforced Concrete Buildings
This type of MFL fire wall consists of wall panels (usually 4-hour rated) tied to the columns and/ or floor(s) and roof framing of a reinforced concrete building (columns, floor, and roof supports) of equal fire resistance.

Because the building to which the wall is tied will be stable throughout the duration of the fire, no special considerations need be made regarding stability. The span between, and connection to, columns and/ or floor(s) and roof framing should be adequate to resist the loads specified in Section 2.2.2.2. If construction on both sides of the wall is 4-hour fire-rated reinforced concrete, the roof or floor framing would not sag onto pipe penetrations through the wall and then collapse. Consequently, the structural aspects of recommendations 2a and 4 in Section 2.2.2.11, need not apply to this situation. However, penetrations must still be sealed with FM Approved fire stop materials.

3.2.8 Control of Cracking
MFL fire walls must have expansion joints in line with those of the building frame to prevent cracking. The width of these joints is determined by normal building temperature change.

Control joints also must be provided in masonry walls to accommodate initial shrinkage in the wall. These normally are narrower than expansion joints and usually are spaced one per bay.

3.2.9 Parapets and Roof Protection
MFL fire walls have no value if an uncontrolled fire can sweep over them and spread to the protected area via the roof. Parapets are needed to help prevent this.

Parapets must be high enough to protect adjacent combustible monitors, penthouses, cooling towers, and saw tooth roofs from direct ignition by heat or flames passing over the wall. Resistance of the parapet to wind or earthquake loads also must be considered. Extremely high parapets are impractical to construct; consequently the design of the buildings must allow for roof structures to be as remote as possible from the MFL fire wall.

Burning embers and heat radiating over a parapet of reasonable height necessitate surface protection for the roof covering, and space separation between equipment or structures mounted on or penetrating the roof (see Fig. 27).
3.2.10 End Walls and Angle Exposure

The building walls at each end of an MFL fire wall must be designed to prevent fire from sweeping around the MFL fire wall (see Figs. 29 [a and b], and Fig. 30).

There is also danger of fire spread from the exterior walls of two buildings or sections of a building that form an angle at or near the end of the MFL fire wall (see Fig. 31). Flames or heat can penetrate openings in walls across this intersection and start fires around the MFL fire wall. The degree of protection needed depends upon the expected durability of the exterior walls during an uncontrolled fire, and on the hazards of the occupancies and construction.

3.2.11 Pipes, Conduit, Cables, and Ducts

Pipes, conduit, cables, and ducts must not penetrate MFL fire walls because they could destroy the structural integrity and the resistance of the wall. If pipe, duct, conduit, or cable penetrations of MFL fire walls are necessary, they must be kept to a minimum and the precautions recommended in Section 2.2.11 must be taken to maintain the integrity of the wall. Recommendations 2a and 4 do not apply to panel MFL fire walls in reinforced concrete frame buildings, except that penetrations must still be sealed with FM Approved fire stop materials.

Although automatic sprinklers are not depended upon to limit an MFL loss, feeding the sprinkler systems on each side of the wall separately will reduce the chance of both systems being out of service.

3.3 Openings in MFL Fire Walls

Openings present a severe threat to the integrity of an MFL fire wall and need the best protection available. The fewer openings in an MFL fire wall, the greater its reliability.

Protection of material-handling system openings in MFL fire walls is usually a challenge requiring ingenuity and careful design.

3.3.1 Material-Handling Systems

The intent of the recommendations in Sections 2.5.2.2, 2.5.2.4, and 2.5.2.5 are to ensure that neither the material-handling system nor the material being conveyed will prevent the fire doors from complete automatic closure and that a clear space is provided on either side of the opening. Other arrangements that meet this intent with the same degree of reliability are acceptable.

Protecting openings for material-handling systems in MFL fire walls is a challenge requiring ingenuity and careful design. Conveyors present a problem because of the variety of arrangements and the variation in shapes and sizes of the material being conveyed.

The most desirable solution is to arrange material flow so material-handling systems need not pass through an MFL fire wall. When this is not possible, the openings in the wall must be protected with an arrangement of automatic closing fire doors. Since the design of MFL subdivision assumes sprinkler protection will be out of service, the use of water spray protection in lieu of fire doors and the use of water flow for initiation of fire door closure is not recommended.

For any material handling system passing through an opening in an MFL fire wall, the fire door assembly with its related hardware and controls must be arranged so the doors will close under fire conditions despite the materials on the conveyor.

Controls are needed so that, in the event of fire, the opening is cleared and then the doors automatically operate, completely closing the opening. With chain, rail, or tow conveyors, the conveyor must be de-energized immediately, and then at least one door will find a clear path between the material on the conveyor. With roller or belt conveyors, the feed conveyor is stopped immediately and the downstream conveyor continues to operate (at least briefly) until the opening is cleared, after which the door closes (Figs. 75, 76, and 77).

Unless a gravity section (Figs. 75 and 76) is provided through the MFL fire wall, conveyor protection may not work if the power fails. Systems not using a gravity section (Fig. 77) are consequentially less reliable unless a standby power supply, UPS, or mechanical system is provided. In either case, the door closer must function by gravity or by mechanical means, not by electric motor.
3.3.2 Automatic Guided Vehicle Systems

Automatic guided vehicle systems (AGVS) consist of electric-powered, driverless vehicles that can be programmed to follow various paths and load and unload at various stations. There are two types of guidance systems for the automatic guided vehicles (AGV), both consisting of a sensing unit and steering mechanism. An electromagnetic system follows a signal sent through a guide wire located below the surface of the desired path. An optical system uses a guide path that contrasts in color with the floor.

AGVs can be controlled in any of the following manners:

1. Controls can be located on the vehicle.
2. Programming panels can be located at various fixed stations throughout the systems.
3. A single central control can be provided

The central control station (CSS) is the most elaborate of the three control methods. The CCS can be programmed to interrogate the vehicles on a regular basis and obtain information, such as the identity and location of the vehicle and the status of its route. It can also monitor vehicle alarm conditions such as loss of guide signal, loss of blocking signal, low battery, and emergency bumper actuation.

An AGV may come equipped with the following safety features:

- Warning lights
- Intersection warning horns
- Emergency bumpers
- Brakes
- Wheel bells
- Emergency stop buttons
- Fire door safety interlocks
- Ramp controls
- Door controls
- Low battery indicators

In an emergency stop, the vehicle will stop with maximum deceleration. The emergency bumper projects in front of the vehicle. When it comes in contact with a person or object, the vehicle will stop immediately. Loss of guidance signal or manual actuation of an on-board emergency button can also cause an emergency stop of the vehicle. The vehicle must then be manually restarted. AGVs can be programmed for automatic door control, which allows it to open and close power-operated doors.

3.3.3 Chain or Rail Conveyors

A door pack (see Fig. 72) consists of a set of fire doors spaced in relation to the stock on the conveyor so at least one door will always be able to close fully no matter when the conveyor stops. A door pack requires uniform fixed spacing and length of stock. Its use is impractical where the length of stock (perpendicular to the fire wall/partition) exceeds a maximum of about 2¼ times the clear distance between the stock. Take this into consideration when designing chain conveyors and give ample spacing between main hangers. If the conveyor chain is shortened or lengthened, ensure this is done without reducing the distance between hangers. Conveyors with adjacent “go” and “return” passes can be arranged similarly, but ensure there is a noncombustible dividing partition between conveyors as the stock will usually be in a different position relative to the doors at the two openings.

The following is an example using the formula for determining the minimum number of door packs:

Given: $S_h = 65$ in. (1651 mm)
$L_s = 45$ in. (1143 mm)
$T_d = 3$ in. (76 mm)

1. Is a door pack practical?
2. How many doors are needed?

3. What is the center-to-center spacing of the doors?

Solution:
1. \( S_c = S_m - L_a = 65 - 45 = 20 \text{ in.} \)
   \( (S_c = S_m - L_a = 1651 - 1143 = 508 \text{ mm}) \)
   \( L_a = 45 \text{ in.} \leq (2.25)(S_c) = 45 \text{ in.} \)
   \( (L_a = 1143 \text{ mm} \leq (2.25)(S_c) = 1143 \text{ mm}) \)
   Yes. A door pack is practical.
2. \( N = 65/(20-3) = 3.8 \)
   \( (N = 1651/(508-76) = 3.8) \)
   Use four doors.
3. \( S_d \leq S_c - T_d = 20-3 = 17 \text{ in.} \)
   \( (S_d \leq S_c - T_d = 508-76 = 432 \text{ mm}) \)
   \( S_d \geq (L_a + T_d)/(N-1) = (45 + 3)/(4-1) = 16 \text{ in.} \)
   \( (S_d \geq (L_a + T_d)/(N-1) = (1143 + 76)/(4-1) = 406 \text{ mm}) \)
   Use \( S_d = 16.5 \text{ in.} \) (420 mm)

3.3.4 Tow Conveyors

If the clip-on points of tow conveyors are far enough apart to give a clear space between carts greater than the length of the cart, a fire-resistive vestibule abutting the wall with fire doors at each end is adequate.

Ensure the walls and roof of the vestibule are equal in fire resistance to the fire wall, and that the roof is constructed of reinforced concrete to protect against damage from collapsing roof members.

The same principles apply as for door packs, but conditions are usually much simpler.

\[ D_c > L_v + 2 T_d \]
\[ D_D > L_c \]

Where: \( D_c \) = clear distance between carts, ft (m)
\( L_v \) = length of the vestibule, ft (m)
\( T_d \) = door thickness, ft (m)
\( D_D \) = clear distance between doors, ft (m)
\( L_c \) = length of the carts, ft (m)

This assumes doors are mounted on the face of the vestibule.

**Example:** The distance between clip-on points is 12 ft (3.7 m); carts are 4 ft (1.2 m) long; the space between carts is 8 ft (2.4 m); the vestibule is 6 ft (1.8 m) long and the doors are 0.25 ft (0.1 m) thick and mounted on the faces of the vestibule.

\( L_v = 4 \text{ ft} \) (1.2 m)
\( D_c = 12 \text{ ft} - 4 \text{ ft} = 8 \text{ ft} \) (3.7 m–1.2 m = 2.5 m)
\( L_v = 6 \text{ ft} \) (1.8 m)–\( D_D \)
\( T_d = 0.25 \text{ ft} \) (0.1 m)
\( D_c = 8 \text{ ft} - 6 \text{ ft} + 2 = 0.25 \text{ ft} = 6.5 \text{ ft} \) (meets criteria)
\( (2.5 \text{ m} > 1.8 \text{ m} + 2 \text{ ft} (0.1 \text{ m}) = 2.0 \text{ m} \) (meets criteria)
\( D_D = 6 \text{ ft} > 4 \text{ ft} \) (1.8 m > 1.2 m, meets criteria)

3.3.5 Air Handling Systems

Penetration of MFL walls and fire walls with ductwork must be avoided. When they are necessary, they must be treated like other openings. The recommendations for slip joints on either side of the wall, and for dampers in the plane of the wall, are intended to prevent a collapse on the fire side from reducing the effectiveness of the fire dampers.

Fire dampers are tested in much the same way as fire doors. The assembly is subjected to an exposure conforming with the standard time-temperature curve for the specified time. Immediately after the fire exposure, the assembly is subjected to a hose stream test whose duration and water pressure depend on the size of the assembly and the length of the exposure. Like fire doors, the pass/fail criteria is based on the
passage of flames and restrictions on the size of openings created by the exposure. Fire dampers generally
do not have any significant insulating value or ability to prevent the passage of smoke.

Listed leakage rated dampers used to control the passage of smoke (smoke dampers) are also available.
These dampers do not necessarily have a fire endurance rating. They are classified according to the rate of
smoke leakage through the damper under specified pressure differentials (Table 8).

<table>
<thead>
<tr>
<th>Class</th>
<th>1 in. H₂O (0.249 kPa)</th>
<th>4 in. H₂O (0.995 kPa)</th>
<th>8 in. H₂O (1.99 kPa)</th>
<th>12 in. H₂O (2.99 kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4 (0.0204)</td>
<td>8 (0.0408)</td>
<td>11 (0.0561)</td>
<td>14 (0.0714)</td>
</tr>
<tr>
<td>II</td>
<td>10 (0.0510)</td>
<td>20 (0.1020)</td>
<td>28 (0.1429)</td>
<td>35 (0.1786)</td>
</tr>
<tr>
<td>III</td>
<td>40 (0.2041)</td>
<td>80 (0.4082)</td>
<td>112 (0.5714)</td>
<td>140 (0.7143)</td>
</tr>
<tr>
<td>IV</td>
<td>60 (0.3061)</td>
<td>120 (0.6122)</td>
<td>168 (0.8571)</td>
<td>210 (1.0714)</td>
</tr>
</tbody>
</table>

3.4 Space Separation

3.4.1 General Space Separation Information

MFL subdivision may be provided by adequate space separation between buildings. The area must remain
clear of combustible material.

Space separation is one aspect of MFL subdivision where judgment is extremely important. Many factors
need to be considered in determining how much separation is needed. These factors include the height and
severity of the exposure hazard, the floor area, type of building construction, and length of the exposing wall
of the exposing structure, in addition to the construction of the walls and roof of the exposed building.

In evaluating space separation, items to consider include:
- building height
- slope of land between buildings
- vehicle parking between buildings
- clear space
- yard storage
- vegetation

3.4.2 Categorizing Exposed Construction in MFL Space Separations

In evaluating space separation, the construction features on each side of the separation must be considered
individually because, under MFL conditions, the MFL exposure could occur from either side.

When categorizing the exposed wall construction you must consider not only the combustibility and
susceptibility of the wall itself but also any openings, penetrations and anything attached to the wall. The
assigned wall category must be driven by the least fire resistant element. For example, a concrete masonry
wall consisting of 1-hr fire-rated concrete masonry units, type S mortar has several single-pane, annealed
glass windows. The least fire resistant element of the wall is the windows. The wall must be categorized as
combustible because when exposed to enough radiation, the single-pane, annealed glass windows will break
and expose ordinary combustibles inside the building to radiation and possibly burning brands.

When categorizing exposed walls, consider the fire resistance of the following elements:
- Wall external surface
- Wall insulation
- Penetrations (pipe, cable, utilities, etc.)
- Windows (type of glazing and number of panes)
• Doors (fire-rated, unrated, noncombustible and combustible)
• Roof eaves (wood eaves and soffits)
• Exposed roof surfaces (gravel surfaced, unprotected, ASTM E108 ratings, mineral surfaced cap sheets, etc.)
• HVAC openings

Tempered glass is also called safety glass. It is treated with a special heating and cooling process to increase its resistance to stress. This treatment also changes the way the glass breaks, making it better for use where safety is a concern, such as in doors and car windows. The international codes specify that all safety glass be marked by etching, embossing, or ceramic firing so the label cannot be removed or destroyed.

• Examine the thickness of the glass. Tempered glass is up to five times thicker than standard glass.
• Check for optical distortion. Tempered glass gives a distortion to reflected images as opposed to any other glass. This happens as it is made through extreme heat and cold temperatures.
• Look for roller marks. These will be small whitish-colored streaks on the tempered glass that occurred when it was made.
• Inspect each corner of the glass to see whether it has an etched logo. This may be covered by a frame. The logo may contain wording indicating that it is tempered glass, along with the manufacturer’s identifying information.
• Look along the surface of the glass with light reflecting off it. Tempered glass may have a very slight wavy surface, caused by the rollers used to move it through a horizontal surface. If this is not apparent, the glass may have marks on one edge where tongs held it when moving through the furnace.
• Put on polarized glasses and look at the glass at an angle. A vague checkered pattern is visible at the right angle on tempered glass, which is a result of the tempering process.

Operable windows can obviously be open and thus provide no resistance to convection, radiation or burning brands.

The hazard with windows is that they break and fall out when exposed to significant heat. (While the windows are in place, much of the radiation is reflected or absorbed and does not transmit through the glass.)

3.4.3 Space Separation Analysis Methodology

There are several basic assumptions built into the methodology of analyzing MFL space separation in this document. The first is that the burning building’s exposing wall is either (a) stable, fire resistant, and will remain standing for the duration of the fire, or (b) likely to collapse early in the fire. In the case of the former, the wall will shield some of the radiation allowing only that fraction coming through the openings and from flames above the roof to reach the exposed wall. In the latter case, there is no shielding of the radiation by the exposing building wall and thus the exposed building is subject to 100% of the expected radiation from the fire.

The second assumption is that adequate space separation for exposed wall constructions is based on maintaining a heat flux below the critical heat flux (CHF) for the exposed wall construction.

The third assumption is that the radiant flux on the surface of the exposed wall is generated by the visible portion of the wind-tilted flames above the commodity and from the visible portion of the flames on the commodity itself, to a vertical target.

And the fourth assumption is that the length of the burning array is typically the length of the exposing building but no longer than 500 ft (150 m).

3.4.4 MFL Space Separation Analysis Example

Example: Two 1-story buildings, each 20 ft (6 m) high, are separated by a distance of 35 ft (10.7 m). The exterior walls facing each other across the space separation each have 2-hour fire resistance and parapets. The length of each wall is 80 ft (24 m). Neither wall has any window openings and all door openings are provided with Class D fire doors. The roof of each building is Class 1 steel deck on exposed steel framing. Occupancy in each building is storage. Is the space separation adequate for MFL subdivision?
Solution: From Table 5 for 2-hr fire-rated construction and storage occupancy up to 30 ft (9.1 m). A separation of 30 ft (9.1 m) is needed; 35 ft (10.7 m) is available, so the separation is adequate.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-2, Earthquakes
Data Sheet 1-3, High-Rise Buildings
Data Sheet 1-20, Protection Against Exterior Fire Exposure
Data Sheet 1-21, Fire Resistance of Building Assemblies
Data Sheet 1-28, Wind Design
Data Sheet 1-28R/1-29R, Roof Systems
Data Sheet 1-44, Damage-Limiting Construction
Data Sheet 1-54, Roof Loads for New Construction
Data Sheet 3-26, Fire Protection Water Demand for Non-Storage Sprinklered Properties
Data Sheet 7-4, Paper Machines and Pulp Dryers
Data Sheet 7-32, Ignitable Liquid Operations
Data Sheet 7-42, Evaluating Vapor Cloud Explosions Using a Flame Acceleration Method
Data Sheet 7-43, Loss Prevention in Chemical Plants
Data Sheet 7-54, Natural Gas and Gas Piping
Data Sheet 7-88, Ignitable Liquid Storage Tanks

4.2 Other


American Concrete Institute (ACI). Building Code Requirements for Structural Concrete. ACI 318, latest edition.


Firestop Contractors International Association (FCIA). www.FCIA.org


APPENDIX A GLOSSARY OF TERMS

Actual Separation Distance (D): The existing or proposed separation distance between adjacent buildings or between yard storage and a building.

Allowable stress design (ASD): A method of designing structural members so computed stresses produced by normal gravity design loads (i.e., the weight of the building and usual occupancy live loads) do not exceed allowable stresses that are typically below the elastic limit of the material (e.g., in steel these are typically well below the yield point). Normal allowable stresses are commonly increased by a factor (often a one-third increase) when design includes extreme environmental loads, such as earthquakes. Also called “working stress design” or “elastic design.”

Approval Guide: An on-line resource of FM Approvals listing FM Approved products and services.

Approved inspector: Personnel trained in conducting and evaluating tests and inspections; employed by an independent inspection/testing agency hired by the owner, or by the design professional in responsible charge acting as the owner’s agent; approved by the building official.

Base Separation Distance (SB): The distance determined from figures and tables based on the exposed wall construction and the exposing fire hazard. The base separation distance assumes the exposure and exposed wall are parallel and the exposure has 100% unprotected openings.

Class 1: Class 1 includes FM Approved plastic panels and plastic building panels. FM Approved foam insulated wall/ceiling constructions that use a polyurethane or polyisocyanurate foam core and steel or aluminum-faced panels are considered Class 1. FM Approved insulated steel deck roof assemblies are also considered Class 1.

Combustible (C): Includes painted or unpainted wood, rigid plastic building materials that are not FM Approved, and Class 2 insulated steel decks.

Composite doors: Doors having a noncombustible core with untreated wood veneers or facings of plastic or metal. Single-sliding, bi-parting, and single or double-swinging arrangements are available.

Concrete Block on Exposed (From the Exterior Side) Steel Frame: When any portion of the steel framing is on the exterior side of concrete block, expansion of the steel frame under heat exposure may open up the mortar joints. This tends to weaken the wall and permit the passage of heat and flame to the unexposed side. Some credit, however, can be given to this type of wall to act as a fire barrier under reduced exposure. If an exterior grade fire-resistant coating (such as an intumescent mastic) is applied to the exterior side of the exposed steel to provide a comparable rating to that of the wall, that rating may be used to determine the separation. Otherwise, using the separation distances for noncombustible construction will provide a very conservative estimate of the needed separation.

Continuous inspection and verification: Full-time observation of the work being performed by an approved inspector.

Corbel: In architecture a corbel is a structural member jutting from a wall designed to carry a specified load or bearing.

Detectors: Devices such as fusible links, heat detectors (fixed temperature and/or rate-of-rise), and smoke detectors.

Diaphragm, horizontal: The wood sheathing, concrete slab or fill, or metal deck at a roof or floor capable of transferring earthquake forces to vertical lateral force-resisting elements (e.g., shear walls, braced frames, or moment frames).

Elastic: A mode of structural behavior in which a structure displaced by a force will return to its original state upon release of the force.

Elastic design: See allowable stress design.

Essential facility: A facility where buildings and equipment are intended to remain operational in the event of extreme environmental loading from flood, wind, snow, or earthquake.

Exposure Angle Adjustment Factor (M): An adjustment factor that accounts for the reduced radiation experienced by an exposed wall that is not parallel with the exposing wall.
Exposure Envelope: The area where a potential exposure exists, defined as an area directly parallel to the exposure plus the area created by a 45° angle from a perpendicular line at both ends of the exposure.

Exterior Insulation and Finish System (EIFS): EIFS often uses expanded or extruded polystyrene insulation (EPS). The exterior coating for the EPS is a thin (about 1/8 in.; 3 mm) layer of proprietary plaster-like material that may be only 50% cement and 50% polymers. It offers considerably less thermal resistance than stucco (lath and plaster), which is typically 1/2 in. to 3/4 in. thick (13 mm to 19 mm).

Fire Rated (FR): An assembly that has passed an internationally recognized fire endurance test (e.g., ASTM E119) or is rated based on calculation or convention. For more information, see Data Sheet 1-21, Fire Resistance of Building Assemblies.

Fire-Rated Glass: Glass such as wired glass, glass block, or ceramic glass that has passed a minimum 3/4 hour fire endurance test and hose stream test.

Fire Resistive: For more information, including specific hourly fire ratings, refer to Data Sheet 1-21. This category includes concrete (tilt-up, precast, poured-in-place), concrete block, brick (but not quarter brick which is only about 1/2 in. [13 mm] thick when used as a veneer in EIFS systems), metal sandwich panels with a gypsum board core, and plaster/stucco (not EIFS). Well-maintained concrete or masonry walls without openings usually need little or no separation or protection against fire exposure.

FM Approved: The phrase “FM Approved” is used to describe a product or service that has satisfied the criteria for Approval by FM Approvals. Refer to the Approval Guide for a complete list of products and services that are FM Approved.

HC-1 Hazard Category: See Data Sheet 3-26.

HC-2 Hazard Category: See Data Sheet 3-26.

High-rise building: Any building with an occupied floor located more than 75 ft (23 m) above the lowest level of fire service vehicle access with the exception of:
- Airport traffic control towers
- Open parking garages
- Amusement park structures
- Bleachers
- Grandstands
- Stadiums
- Special industrial buildings (ex. BLRB)
- Buildings with high hazard occupancies

Hollow metal doors: Doors made in seamless, flush panels, rail-and-panel, or stile-and-panel design. They are manufactured from a suitable reinforced, minimum 20-gauge (0.91 mm) outer skin supplemented with an insulating or sound-deadening material, or both. These doors are available in single-and double-swinging units. When used in conjunction with passenger elevator entrance assemblies, they may be arranged for swinging, sliding, vertical bi-parting, or horizontal-slide operation. Hollow metal doors for freight elevators and dumbwaiters are counterbalanced.

Importance factor: A factor used in building codes to increase, for example, the usual wind or earthquake design forces for important or essential structures, tending to make them more resistant to those phenomena.

Jackknife doors: Doors consisting of a curtain of interlocking steel slats that collapse horizontally when operated.

Lap splicing: Preferred method used to get “continuous” reinforcing using several reinforcing bars laid end to end; works by transferring forces from one rebar through the surrounding concrete to the adjacent rebar. The length of the “lap” determines the strength of the connection for a particular rebar size and a particular concrete strength; lap splices are specified as a certain number of bar diameters since the strength of the lapped connection is a function of the contact area between the rebar and the concrete.

Limiting Factor: A physical barrier that stops the spread of fire or provides containment of explosive force. The control of damage from these or other events is entirely dependent on structural integrity, susceptibility of contents, fire-resistant and damage-limiting construction or adequate space separation. Limiting factors can change over time and result in significantly larger losses than anticipated if improperly managed. These factors, therefore, warrant a high level of validation, documentation, and oversight.
**Listed:** Listed by a reputable testing laboratory according to a widely recognized testing standard adopted by model building codes.

**Load and resistance factor design (LRFD):** A method of designing structural members so computed stresses produced by service design loads multiplied by load factors do not exceed the theoretical nominal member strength multiplied by a strength reduction (resistance) factor. Also called strength design or ultimate strength design.

**Make-up:** The action of a client that is beyond their normal operating procedures and is intended to mitigate lost production, services or revenue.

**Masonry:** Brick, stone, tile, or concrete block bonded together with mortar. With reinforcing steel, it is defined as reinforced masonry; without reinforcing steel it is defined as unreinforced masonry (URM).

**Maximum Foreseeable Loss (MFL):** The largest loss to result from an event, as calculated from an understanding of the overall hazard and associated business impact. This event assumes active protection systems or safety devices are impaired, with the exception of specifically FM Approved and tested MFL fire doors. The event can be related to fire, explosion, equipment failure, or other scenario, with the exception of natural hazards. MFL limiting factors are physical barriers or conditions that limit the spread of fire or contain explosive forces and control the amount of damage from the event.

**MFL Separation Distance (Sm):** The distance recommended per this document to prevent ignition of a building or its contents due to an MFL fire in an adjacent building or yard storage.

**Metal-clad doors:** Doors consisting of a two- or three-ply core of well seasoned wood covered with lock-jointed terneplate, Ductillite, or 30 gauge (0.012 in., 0.30 mm) sheet metal. The covering is nailed to the core.

**Mortar:** Type M or S mortars are mixed according to the proportions in the following table:

<table>
<thead>
<tr>
<th>Mortar Type</th>
<th>Parts By Volume of Portland Cement, or Blended Hydraulic Cement</th>
<th>Parts By Volume of Type N Masonry Cement</th>
<th>Parts By Volume of Hydrated Lime or Lime Putty</th>
<th>Parts By Volume of Aggregate, Measured in a Damp, Loose Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>Not less than 2.25 and not more than 3 times the sum of the separate volumes of the cements and lime used</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>—</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.5</td>
<td>1</td>
<td>—</td>
<td>over 0.25 to 0.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>—</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

Note: Type M or S mortar may also be formulated using type M or S masonry cement respectively, without further addition of cements or hydrated lime.

**Multi-story combustible construction:** multi-story buildings (excluding basements) with combustible cladding, frames, floors, ceilings or roofs. Any multi-story building with a wood frame, boards on joists or plank on timber construction. Excluding buildings with Class 2 steel deck roofs in an otherwise noncombustible building. A three-story office building with non-FM Approved polyurethane foam insulated metal panel walls, a steel frame, a Class 2 steel deck roof, concrete floors and mineral tile suspended ceilings would be multi-story combustible construction. The same office building with concrete masonry walls with a brick veneer would not be multi-story combustible construction.

**Noncombustible (NC):** Noncombustible walls are walls that will resist 27 kW/m² of radiant heat exposure indefinitely without ignition, penetration, the opening of joints, or failure. NC walls usually consist of panels over steel framing. Panels may be painted or galvanized steel, corrugated iron, or corrugated cementitious panels supported on a steel frame. The panels are light in weight, and unless protected or adequately separated, they may buckle and open at their joints, or crack under severe radiation or fire exposure. Since heat will easily conduct through thin steel and ignite combustible insulation, insulations acceptable for use in this category include glass fiber, mineral wool, and expanded glass. For other types of insulation, see Class 1 or combustible categories. Noncombustible panels also include protected metal panels and fiber-reinforced cement panels FM Approved and listed in the Approval Guide under Exterior Roofing and Siding.
Non-shear walls: Non-shear walls resist wind forces perpendicular to the face of the building façade and distribute the wind forces into the building frame; they provide the building frame with no resistance to lateral (horizontal) forces, such as those generated by wind or earthquake; examples are curtain walls (most mid-rise and high-rise office building facades with glass and either steel or aluminum frames), infill walls (concrete or masonry panels within the building frame (bounded by beams and columns), insulated metal or corrugated metal wall panels, and EIFS walls.

Periodic inspection and verification: Part-time or intermittent observation of the work being performed, and the completion of the work, by an approved inspector.

Prestressed concrete: A type of precast concrete panel where steel strands (wire) or bars are embedded in the concrete under high tension that is held in equilibrium by compressive stresses in the concrete after hardening.

Pounding: The collision of adjacent buildings during an earthquake due to insufficient lateral clearance.

Ramp-up: Part of the normal post-loss restoration period that covers the time from the start-up of production until the time full production has resumed.

Reinforced concrete: Construction using a composite material made from concrete and steel (or another material, such as glass fiber-reinforced plastic) where the concrete and reinforcement work compositely. Examples of reinforced concrete walls are tilt-up construction and precast concrete construction.

Reinforced masonry: Masonry units, reinforcing steel, grout, and/ or mortar combined to act together to resist design loads. Reinforced masonry generally has both vertical and horizontal steel reinforcement.

Rolling steel doors: Doors that have their housing and mechanism located at the head of the opening and are composed of a curtain of interlocking metal slats that coil upon a barrel. In most models the barrel is provided with a torsion-spring mechanism to counterbalance the weight of the curtain. A detector releases the torsion-spring mechanism that drives the door closed. In some newer models there is no spring. Automatic closure is powered by counterweights or simply the weight of the curtain. Rolling steel doors may be operated by hand, chain, crank, pneumatic, or electric power under normal operating conditions.

Shear walls: Shear walls provide the building frame with substantial resistance to lateral (horizontal) forces, such as those generated by wind or earthquakes; they provide resistance to forces parallel to the horizontal axis of the wall; they serve the same structural purpose as steel cross-bracing; they are typically constructed from concrete or masonry, and wood (plywood, for wood-framed structures).

Sidewall protection: an upgrade in the passive protection of the wall. For example, increasing the rating of the wall for noncombustible to 1-hour fire rating.

Sheet metal doors: Uninsulated or insulated, these doors are two-piece, vertically or horizontally sliding, and may be either counterbalanced or telescoping. The uninsulated doors may consist of a single thickness of galvanized sheet-metal, corrugated or flat, riveted or welded in a structural steel frame. The insulated types are of sandwich-panel construction having mineral-core insulation between steel-faced sheets.

Special purpose doors: Doors of special construction whose intended end use does not lend itself to being included in other classifications. Generally, these doors are not self-latching or provided with automatic closing devices. Examples include acoustical, radiant shielding, or pressure-resistant doors.

Stable Fire Resistant (SFR): SFR walls are constructed of materials having a fire resistance rating at least adequate for the exposing occupancy. The category SFR only applies to exposing walls and not to exposed walls. To qualify as SFR, it must be reasonably foreseeable that the exposing wall will not collapse in an uncontrolled fire. This would include freestanding walls and walls that are laterally supported by structural framework that has adequate fire resistance.

Storage Occupancy: Storage of any commodity, ignitable liquid, plastic, roll paper, rubber tires, and any material judged to have a comparable or higher hazard. When palletized storage of Class 1, 2, or 3 commodities are no more than one tier or 6 ft (1.8 m) high, the hazard may be reduced to HC-2. Storage of noncombustible commodities with no combustible packaging can be considered HC-1.

Strength design: See load and resistance factor design.

Swinging fire doors: Doors that swing on hinges in or out of a room or building.
**Tilt-up concrete:** A construction method where reinforced concrete panels are formed and placed on-site. Once the panel has cured to sufficient strength, the slabs are then lifted by crane and tilted into place. The ability to make the panels on-site eliminates the need to ship them and thus eliminates the restrictions on size that would apply if the panels had to be transported to the site.

**Tin-clad doors:** Doors that have the same specifications as metal-clad doors.

**Two-ply cores:** These doors are available in the standard sliding and swinging type. Metal-clad doors for freight elevators are two-piece vertical sliding, counterbalanced, bi-parting, or telescoping. Rated at 1 1/2 hours; three or more ply cores are rated at three hours, as noted in the Approval Guide.

**Ultimate strength design:** See load and resistance factor design.

**Unprotected Opening:** Openings in walls that have no fire-resistance ratings and are not protected by sprinklers, spray nozzles, open heads, window sprinklers, water curtains, open water-spray nozzles, deluge systems, pre-action systems, special protection systems, fire doors, fire shutters, fire dampers, or fire stop systems. The opening can be a window, door, ventilation opening, opening around a penetration, or any other unobstructed opening in the wall with a width greater than ¾ in. (19 mm).

**Unprotected Opening Adjustment Factor (U):** An adjustment factor to account for radiation from unprotected openings in noncombustible, fire-resistive, and stable fire-resistive exposing walls.

**Unreinforced masonry:** Masonry unit (e.g., bricks, concrete blocks) construction that does not incorporate steel reinforcement, or where reinforcement is minimal and therefore neglected in the structural design.

**Yield point:** The stress at which there is a decided increase in the deformation or strain without a corresponding increase in stress. The strain is inelastic, resulting in permanent deformation.

### A.1 Nomenclature

- **C** = combustible wall (exposing or exposed).
- **D** = actual perpendicular separation distance between exposing and exposed walls.
- **FR** = fire rated exposed wall.
- **H** = exposure height, or yard storage height.
- **L** = exposure length.
- **M** = exposure angle adjustment factor.
- **NC** = noncombustible wall (exposing or exposed).
- **O** = offset distance between parallel exposing and exposed walls.
- **S_B** = the base separation distance needed per figures and tables.
- **S_{100}** = the needed safe separation distance for 100 unprotected openings.
- **S_N** = the needed safe separation distance for N unprotected openings.
- **S_M** = the MFL separation distance.
- **SFR** = stable fire resistive exposing wall.
- **TG** = tempered glass.
- **U** = unprotected opening adjustment factor.
- **WG** = wired glass.
- **WS** = window sprinklers.
- **Θ** = exposure angle.

### APPENDIX B DOCUMENT REVISION HISTORY

February 2014. Minor editorial changes were made.

October 2013. The following changes were made:

- Revised Section 2.2.2.2.10 on explosion hazard distances.
- Revised penetration and fire stop recommendations based on comments from the Firestop Contractors International Association.
- Changed Light/Ordinary occupancy hazard classification to HC-1/HC-2 to be in agreement with Data Sheet 3-36, *Fire Protection Water Demand for Non-Storage Sprinklered Properties*.
- Revised recommendations on roof drains and scuppers near MFL walls.

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• Corrected the analysis of the exposure length (L) to make it consistent with Data Sheet 1-20, Protection Against Exterior Fire Exposure.

• Corrected the numbering as there were two sections numbered 2.5.2.1.23.

• Relocated the text of Figures 8 and 16 into the recommendations.

• Revised figures for clarity.

• Made minor editorial changes.

April 2011. This document now contains all data sheet material on MFL limiting factors and the protection of openings in MFL limiting factors.

• Data Sheet 1-23, Protection of Openings in Fire Subdivisions, former Section 2.1, Openings in MFL Fire Walls, has been relocated to this document.

June 2009. Minor editorial changes were made for this revision.

January 2009. The following changes were made:

• The space separation section was revised.

August 2007. Corrected references in section 2.1.1. Added information to recommendation 2.2.2 on how to treat multi-pane (2 or more) window systems with respect to fire exposure for space separation.

May 2007. Minor editorial changes were made for this revision.

August 2006. The main change to this data sheet is the addition of specific guidance for building MFL walls in FM Global earthquake zones 500-year or less.

Some other additions were made to the MFL wall recommendations to provide better guidance on building MFL walls.

May 2005. Recommendation 2.1.1.11.4 was revised to be consistent with recommendation 2.1.1.3.2 in the Data Sheet 1-23, Protection of Openings in Fire Subdivisions.

September 2004. References to FM Global earthquake zones have been modified for consistency with Data Sheet 1-2, Earthquakes.

May 2000. This revision of the document has been reorganized to provide a consistent format. Added alternative method for evaluating space separation. A multi-phase approach is now possible. For a conservative estimate, evaluate space first using the traditional simpler guidelines contained in Table 3. For situations where a more precise evaluation is required, apply the more complex methodology contained in Data Sheet 1-20, Protection Against Exterior Fire Exposure, without crediting sprinkler protection on either side. Monitors, penthouses, cooling towers or other roof mounted structures should also be evaluated using the Data Sheet 1-20 methodology.

February 1993.

• Additional information has been added for evaluation of space separation between buildings to further clarify acceptable conditions. It is important to remember that construction features on both sides of the separation must be considered individually since the MFL exposure could occur from either direction.

• The alternative for use of a fire retardant coating, such as an intumescent mastic, to protect the top surface of a roof cover next to an MFL wall has been deleted. This is due to adverse experience in at least one application where the material tended to break up due to flexing of the roof deck from foot traffic.

• It is recommended that a portion of the live load, as well as the entire dead load, be considered when using the catenary cable formula for tied walls. The portion of the live load being considered has been reduced from 75% to 25% to be consistent with the logic behind building codes and to reflect the unlikelihood of the two extreme events occurring simultaneously.

• An advisory comment has been added regarding the arrangement of racks adjacent to MFL fire walls to prevent possible damage to the wall from collapsing racks during an uncontrolled fire.

September 1985.

• Table 1 was added to give recommended spacing between the wall and steel framing or between a double wall based on the span of the framing perpendicular to the wall.
• Some changes were made regarding the distance between structural steel and MFL fire walls.
• Recommendations for bond beams and grouted cores of concrete block at the top of MFL fire walls have been made.
• Additional design information was given for tied MFL fire walls.
• End wall exposure protection was added for buildings over 40 ft (12.2 m) in height.
• Angle exposure protection was increased slightly based on theoretical calculations made in conjunction with the Basic Research Department.
• Intumescent dampers are not recommended as they may be damaged by hose streams.
• It is now recommended that cables penetrate walls near floor level to further decrease the probability of cables damaging the fire wall. The alternative of looping cable that penetrated an MFL fire wall at roof level was deleted.
• Alternative protection for roofs, other than built-up roofing, was added.
• Some minor changes were made regarding space separation.
• A loss experience section was added.
• The recommended minimum spacing between the openings in MFL fire walls and combustible storage in the direction parallel to the wall was increased from 1 ft (0.3 m) to 2 ft (0.6 m) due to the low probability of achieving a tight fit between the wall opening and the door or its guide rail.
• It is now recommended that a portion of the live load, as well as the dead load, be considered when using the catenary cable formula for tied walls.
• When roof mounted structures are within 50 ft (15.2 m) of MFL fire walls, fire-rated construction should be provided on the exposed side of the roof projection. The amount of fire resistance the partition should have is dependent upon the severity of the exposure and the distance between the exposure and the roof projection.
• Special protection is needed when heat and smoke vents, skylights and roof penetrations are within 25 ft (1.8 m) of an MFL fire wall. Heat and smoke vents should be of metal construction and skylights should be constructed of wired glass or tempered glass. Intake and exhaust ducts should be equipped with automatic closing fire dampers flush with the roof deck and care should be taken to prevent the closing mechanism from rusting. In each case, combustibles should not be stored within 8 ft (1.8 m) of roof penetrations.

August 1976.

• Loss Prevention Data Sheet 1-22, Criteria for Maximum Foreseeable Loss Subdivision.
• Superseded Handbook Chapter 7.
• Provided the definition of Maximum Foreseeable Loss.
• Provided general design criteria for MFL fire walls and MFL space separation.

April 1952.

• First printing of Loss Prevention Data Sheet 1-22, Fire Walls and Fire Partitions.

APPENDIX C FIRE DOORS

C.1 Fire Door Construction

For door sizes and fire-protection ratings, see the latest edition of the Approval Guide.

There is a maximum size limitation on FM Approved fire doors because larger units cannot be tested. The actual size limit is noted in the Approval Guide and varies, depending on manufacturer and model, up to 152 ft² (14 m²). Where protection of larger openings is necessary, the practice is to use doors that are of the same design and construction as those that have been fire-tested. Factors considered in determining adequacy of oversized doors for a given situation include the building area, type of construction, and the
arrangement and hazard of the occupancy—all with relation to the location of the opening. When an opening that is too large for an FM Approved fire door is contemplated, consult FM Approvals for advice as to the suitability of an oversized door.

For sample labels, refer to Figure 48.

Oversized doors (larger than those tested and listed in the Approval Guide) must be specially labeled (see Fig. 81) to verify construction is similar to that of an FM Approved door. Labeling of oversize doors applies only to rolling steel or sliding doors.

An additional label (see Fig. 71) is available to accommodate sliding doors for use in openings in fire walls penetrated by conveyors. Such doors are notched to provide as much closure as practical around the conveyor track (see Fig. 70). As the track size may vary, so too may the notch; however, the maximum clearances must not exceed those noted in Figure 70.

Vision panels may only be installed on fire doors having a maximum fire rating of 1 ½ hours (interior) or ¾ hours (exterior). Consequently, they may not be used in fire doors protecting openings in MFL fire walls, where a 3-hour fire door rating (Class A opening; see section C.8) is needed, or in exterior fire doors where a severe exposure exists (Class D opening). The maximum area and dimensions of glazing for doors in Class B, C, or E openings are given in Table 10.

### Table 10. Allowable Glazing Area For Fire Doors

<table>
<thead>
<tr>
<th>Fire Door Rating, hr</th>
<th>Maximum Area, in² (cm²)</th>
<th>Maximum Dimension, in. (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ &amp; ½</td>
<td>Maximum area tested</td>
<td>Maximum tested</td>
</tr>
<tr>
<td>¾</td>
<td>1296 (8360)</td>
<td>54 (137)</td>
</tr>
<tr>
<td>1, 1½, 2, 2½</td>
<td>100 (645)</td>
<td>33 (84)</td>
</tr>
<tr>
<td>3, 4</td>
<td>0</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Fire door hardware used with the fire doors is an important part of the overall door installation. Only FM Approved hardware may be used when hardware has been FM Approved for that type door; otherwise, appropriate listed hardware must be used.

Fire door hardware is classified as either builders' hardware or fire door hardware. Builders’ hardware has a subcategory of "fire exit hardware," which consists of devices FM Approved or listed for both fire and panic protection.

Builders' hardware applies only to swinging doors and consists of hinges, locks, latches, top and bottom bolts, and door closers. Builders’ hardware is not required to be shipped from the factory with the fire door. Labels on swinging doors will generally provide the minimum latch throw distance required for that size and type door.

Fire door hardware applies to both swinging and sliding fire doors. This hardware consists of surface-mounted hinges, latches, and door closers. This type of hardware is shipped from the factory with the fire door.
C.2 Detectors

Detectors are devices such as fusible links, heat detectors (fixed temperature and/or rate-of-rise), and smoke detectors. Detectors operate the release mechanism that allows door closers to close the doors.

When heat detectors are used, they must be a restorable type and a combination fixed-temperature and rate-of-rise type. Smoke detectors must be suitable for the environment. Smoke detectors may experience false operation in dusty environments, etc. For more information, refer to Data Sheet 5-48, *Automatic Fire Detection*, and the *Approval Guide*.

FM Approved fusible links are used to operate fire doors, shutters, dampers, and other devices at the predetermined temperature. The fusible-type link consists mainly of two metallic plates joined together by a special solder alloy. The solder melts at a predetermined temperature allowing the plates to separate. Other types of FM Approved links operate by the bursting of a glass bulb due to the expansion of an enclosed liquid or the liquefying of a chemical compound when exposed to heat.

FM Approved fusible links are stamped with the following information:

- Manufacturer’s name
- Listing agency logo
- Load rating
- Temperature rating
- Model designation
- Year of manufacture

The load rating generally varies from 5 to 50 lb (2.3 to 2.7 kg), and can be as high as 500 lb (227.3 kg). The load rating of the links must be at least equal to the load required to hold the door open. This load will vary, depending on the type and size of the door and the counterweights used (if applicable).

C.3 Door Closers

Door closers can be spring-operated arms located at the top of the door or spring hinges and are used to make swinging doors self-closing. Their application must not exceed the sizes and weights listed in the *Approval Guide*, and they must be used in the quantities indicated therein. No hold-open points are permitted in this type of device.

C.4 Power Operators

Occasionally, conditions are such that either pneumatic or electric power operators are desirable for the normal opening and closing of a fire door. Such a practice is acceptable, provided FM Approved or listed power operators or power operator-release devices are used with the appropriate fire doors. Unless the power operator is a “fail-safe” design, it must physically disconnect from the door when automatic closure is initiated. This prevents accidental opening of the door after automatic closure.

FM Approved operators are equipped with an automatic closing feature that must be capable of closing the door completely under fire conditions without power. The electrical components of the operator must be suitable for the occupancy where installed as required by the *National Electrical Code* (NFPA 70).

C.5 Electromagnetic Door Holder Releases

Electromagnetic door holder releases are designed to hold open fire doors until they are de-energized by FM Approved detectors or by power failure. Fire doors held open with these releases must close automatically by either gravity or a door-closing device.

C.6 Electromechanical Door Holders

Electromechanical door holders are designed to hold fire doors open during normal use and release them to close upon receipt of a signal from a detector.
There are two types: one type is normally energized and will release when de-energized, while the other type is normally de-energized and will release when energized. The normally de-energized units are not fail-safe when power is lost; thus, they are not acceptable for use on MFL fire walls.

Doors equipped with these units must be automatic closing upon their release by either gravity or a door-closing device.

C.7 Fire Door Operation and Inspection

C.7.1 Horizontal Sliding Doors

Horizontal sliding doors may be installed on inclined tracks or level tracks (Fig. 49, 50, and Fig. 57). Either a single door to one side of the opening or two doors (biparting) may be used. Horizontal sliding doors are mounted on tracks that are bolted to the face of a fire wall. They are generally used to protect openings for vehicle traffic. They move across the track over the opening to seal off the fire wall penetration. Binders (Fig. 68) are bolted to the face of the wall on the side of the opening opposite the door. They help to hold the leading edge of the door against the wall at the edge of the opening. A stay-roll (Figs. 82, 84, and 85) is provided at floor level near the edge of the opening where the door is held in the open position. The stayroll helps to prevent the door from swaying during operation, and also helps to hold the closed door against the face of the wall at this edge of the opening. A roller strip (Fig. 82) is installed across the face of the door in the plane of the stay-roll to prevent wearing of the door face. The average closing speed for all types of horizontal sliding doors should be between 6 and 24 in./s (0.15 and 0.60 m/s).

There are three methods of operation for a horizontal sliding fire door. They are inclined track, straight track with counterweight closure, and straight track with spring closure.

Note: Fusible links are needed on both sides of the wall.

Fig. 82. Horizontal sliding door; inclined track (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 83. Horizontal sliding door; level track, counterweight closure (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 84. Horizontal sliding inclined track fire door showing stay rolls and binders (Reprinted with permission from NFPA 80, Fire Doors and Windows)
Fig. 85. Stay roll for horizontal sliding fire door (Reprinted with permission from NFPA 80, Fire Doors and Windows)
C.7.2 Inclined Track

The overhead track (Figs. 82 and 84) is inclined at a slight (¼ in./ft, 63 mm/m) downward angle toward the opening to allow for gravity closure. The door is mounted on the track so that, when open, it is on the high side of the track. The door is kept open by hold-open weights that are connected by sash chain, cable, or rope with fusible links in line. The cable must be flexible so as to not develop a permanent set or bind in any way.

One link should be located near the top corner of the opening and another link should be located just below ceiling level and centered over the opening (Fig. 83). When one of the links fuses, the hold-open weight drops and allows gravity closure of the door. Counterweights are used to limit the closing speed to 6 to 24 in./s (0.15 to 0.6 m/s).

It is important that the track be installed at the correct angle and elevation above the floor. If the track is too low or the angle is too steep, the door may hit the floor and stop before closing completely. If the track is too high there may be a gap between the floor and door bottom when the door is in the closed position. In some cases dirt or debris can accumulate at floor level and prevent complete closure of the door.

Also, improper or poorly maintained installation of the track anchor bolts can cause the track to sag resulting in the bottom of the door hitting the floor prematurely, thus preventing complete closure. Careless placement of storage can pin the door against the wall, thus preventing movement when the counterweight is released. This can be avoided by the installation of a guard rail placed in front of the door in the open position.

Brief weekly (MFL fire walls) or monthly (other fire partitions) inspections can be made to detect the above problems. Lifting the hold-open weight can help to detect any obvious problems with the door operation.

Since this is the simplest closure method for horizontal sliding fire doors, the failure rate is lower and its use is preferred to that of the other two types.

C.7.3 Straight Track with Counterweight Closure

In this installation the track is installed in the level position. One or two sets of counterweights are used.

When two sets of weights are used, the hold-open weights are connected in line with a fusible link(s) (Fig. 83). This stabilizes the door in the open position during normal conditions. When a link fuses, the hold-open weights are dropped and the closing weights pull the door closed.

When one set of weights is used, the closing mechanism uses a swivel arm and catch ring arrangement (Fig. 57). The cable connecting the weights to the swivel has no fusible links along its length. At the swivel arm is a catch-ring that hooks the cable onto the swivel arm when it is in the vertical position. Another cable, with fusible links, is attached to the swivel arm opposite the catch ring and runs across the door and opening. When a link in this cable fuses, the swivel arm is released and allowed to rotate. As it rotates, it releases the catch ring. The weights pull the cable and catch ring to the leading edge of the door where the catch ring is caught by the catch bracket. The weight then pulls the door closed by the catch bracket.

Potential problems to be noted during inspections include dirt or debris accumulations at floor level near the door path, improper or poorly maintained installation of track anchor bolts, and storage against or in the path of the door. In addition, storage against the wall can prevent adequate movement of the closing weight. A substantial metal enclosure should be provided for the entire length of travel for the closing weight. Lifting the hold-open weight can help detect obvious problems with the door operation. Guard rails should be provided in front of the door in the open position.

C.7.4 Straight Track with Spring Closure

This installation uses a level track and a spring-actuated closing mechanism to pull the door closed (Fig. 50). The closing mechanism utilizes cable wound around a reel and is powered by springs. Normal door operation should not result in activation of the reel; however, fusing of a link or activation of a detector releases spring tension, allowing the door to be pulled closed. The reel must be pre-wound to ensure there will be enough spring tension to close the door.

Consult the manufacturer’s literature for the proper number of revolutions, which increases according to door size.

Weekly/monthly inspections must include a check for dirt and debris in the path of the door, the presence of storage near the door, and the track condition, as well as manual operation of the door.
C.7.5 Swinging Doors

Swinging fire doors are doors that swing on hinges in or out of a room or building (Fig. 53 and 54). Composite and hollow-metal door assemblies can be normally closed, but are also designed to accommodate a normally open position with detector-activated door closure.

Swinging sheet-metal or metal-clad doors can be normally closed or arranged for automatic-closing under fire conditions. Normally open doors with counterweights have a detector that releases a heavy closing weight that drops into a bob weight used to keep the closing chain or cable taut, and both weights close the door (Fig. 53). Normally closed doors can be equipped with either spring hinges or a spring-actuated door closer (Fig. 54).

Doors arranged to swing in pairs should be equipped with a coordinator that will permit the active leaf to close last. Hardware provisions for these double openings must include appropriate latch devices to maintain the doors in a closed position. Various types of fire exit hardware, either flush or surface-mounted, are available for this application.

C.7.6 Telescoping Vertical Sliding Doors

A telescoping vertical sliding door (Fig. 55) is divided horizontally into two leaves and, when opening, the lower leaf overlaps the upper. A large and small counterweight are attached separately to the lower leaf, which, in rising, lifts the upper leaf by means of an additional set of cables. The counterweights together keep the door in balance in all positions. A detector causes release of small counterweights, permitting both leaves to close. The size of the large counterweight controls the speed of closing. This type of fire door requires minimum space overhead and is particularly adaptable for installations at existing elevator-well openings.

C.7.7 Counterbalanced Elevator Doors

The counterbalanced elevator doors part at mid-height, the upper leaf rising and the lower leaf descending. The two leaves counterbalance each other by means of a chain at each side running over a ball-bearing sheave. The regular-type doors are arranged so the two leaves butt together when in the closed position. In the pass-type, the upper leaf is offset so that in the open position it bypasses the bottom leaf of the door in the story above. In the closed position a formed closure plate fits over the top of the lower leaf. The pass-type is used mainly where the vertical distance between openings and adjacent storage is limited. Installation in existing shafts may require extensive structural modification on the car or shaft. Simple automatic safety interlocks are usually provided to permit opening a door only when the car is at the same floor, and also to prevent the car from moving when the door is open.

C.7.8 Passenger-Elevator Doors

The operation of hollow metal doors used in passenger-elevator entrance assemblies is arranged to accommodate vertical transportation needs. Doors may be obtained for swinging or horizontal slide operation. The sliding doors may be bi-parting.

C.7.9 Rolling Steel Doors

Rolling steel doors (Figs. 63 and 64) are designed to be used as both service and fire doors. They are equipped with a mechanism that closes the door automatically from any position when the mechanism is released by a detector. One or more coil torsion springs provide counterbalancing for normal use and under fire conditions drive the door to the closed position. Adjustment of the counterbalancing mechanisms requires experience.

Rolling steel fire doors may be either face-of-wall (surface) mounted (Fig. 63) or between-the-jamb mounted (Fig. 64). Listed frames are not needed for these doors. Steel plate and/or structural steel must be used for door jambs. Pressed steel frames must not be used with this type of installation. The steel jambs are needed for impact resistance rather than for fire rating. The door bracket assembly should be attached to the wall with through-wall bolts. When walls are unusually thick or zinc- or cadmium-coated, steel expansion anchors may be used in concrete, brick, or grouted concrete masonry units following guidelines in Fig. 60. Bolts securing door guides for double fire walls must not penetrate both walls.

The steel guides for rolling steel fire doors are not usually protected by a fire-resistive coating and therefore heat up and expand when exposed to fire conditions. When vertical steel guides are connected using bolts in the bottom of slotted holes and adequate clearance is provided between the bottom of the guide and the

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floor, the guide is free to expand with minimal stress from frictional resistance. When the guides are welded in place or there is not adequate clearance below the guides, expansion is restricted: the guides tend to bow, high stresses can develop, and the guides may become partially or totally disengaged from the wall, allowing the opening to be breached.

Manual operators or power operators must be arranged so the fusing of a single detector will allow the operator to disconnect from the door mechanism, enabling the door to close automatically in a fire situation. The average closing speed should be from 6 to 24 in. per second (0.15 to 0.60 m/sec).

C.7.10 Vertical Sliding Doors

A vertical sliding door operates in a vertical direction but does not use a spring as does a rolling steel fire door. The door is in one solid piece when it is installed vertically over the opening (see Fig. 56). Alternatively, a sectional type door is used in conjunction with a sloped track (like that of a garage door).

Doors installed vertically over the opening are suspended by a system of weights and ropes, cable (as described previously), or sash chain over pulleys. The hold-open weights keep the door in the open position until a fusible link is actuated. Two sets of counter-balance weights, one on each side of the opening, allow the door to close at a safely regulated speed. A substantial metal closure should be provided for the entire length of travel for all weights. Otherwise, storage adjacent to the fire wall may prevent proper operation. Pulleys should be shielded to prevent the cable/chain from jumping off. The average closing speed should be from 6 to 24 in. per second (0.15 to 0.60 m/s).

Sectional doors are counterbalanced by an overhead horizontal helical spring on a shaft The shaft is attached to a reel with a steel cable, which is attached to both sides of the door near the bottom edge.

Guides for vertical sliding doors must be installed plumb to prevent binding during operation. Guides can be shifted or crimped by lift trucks, resulting in incomplete closure. Guard posts should be installed in front of the vertical guides to prevent such an occurrence. During weekly/monthly inspections, in addition to a visual check of the guide, the door should be manually lowered and raised to detect potential problems with the guides.

C.8 Rating Practices for Fire Doors

Fire doors are rated for the type of openings for which they are suited. The designations are based on a letter class.

For a given class of opening as defined by NFPA Standard No. 80, Fire Doors and Windows, the class of door must match the class of opening. The classes differ according to expected exposure and use (internal or external).

Architectural specifications may call for a door by class only, with no fire protection rating. (Note that Class B has two ratings,) Table 11 relates class to uses and fire protection rating.

<table>
<thead>
<tr>
<th>Class</th>
<th>Type of Opening</th>
<th>Fire Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Openings in fire walls separating buildings or dividing a single building into fire areas. Generally fire doors are required on both sides of the wall at such locations.</td>
<td>3 1</td>
</tr>
<tr>
<td>B</td>
<td>Openings in enclosures for vertical communication within buildings, and 2-hour rated partitions providing horizontal fire separations.</td>
<td>1 1/2 2</td>
</tr>
<tr>
<td>C</td>
<td>Openings in corridor and room partitions having a fire rating of 1 hour or less</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Openings in exterior walls subject to severe external fire exposure.</td>
<td>1 1/2</td>
</tr>
<tr>
<td>E</td>
<td>Openings in exterior walls subject to moderate or light fire exposures.</td>
<td>3/4</td>
</tr>
</tbody>
</table>

1 Only Class A or 3-hour fire rated FM Approved doors are acceptable for use on MFL fire walls.
2 A 1-hour fire rated door is also available for this class of opening, but should only be used when the rating of the subdivision does not exceed 1 hour.

The rating for fire doors in North America is based upon results of tests conducted according to ASTM E152. There is an important difference between this specification and ASTM E119 for fire walls. For ASTM E152, satisfactory performance for a given period is primarily a measure of the deformation of the door. For ASTM E119, a wall assembly must prevent the passage of flame, and the average temperature on the unexposed
face must not exceed 250°F (121°C) above ambient temperature for the rated period. Combustible material placed too near the unexposed face of a fire door could ignite from radiant heat in a time period less than the door’s rated period (hourly rating) (Fig. 69).

Although the insulating value of the door is not part of the mandatory pass/fail criteria for fire doors as it is with fire walls, this desirable property can be the deciding factor when considering the choice of otherwise “equal” doors. Some types of doors are better insulators than others. Composite, kalamein, and metal-clad fire doors have some insulating ability, although not necessarily the same as an equivalently rated fire wall.

In the United States, during the first 30 minutes of a fire door test, the temperature rise on the unexposed side of the door is measured. If the average temperature rise on the unexposed side does not exceed 250°F (121°C), 450°F (232°C), or 650°F (343°C), the door receives that respective maximum temperature-rise rating. The temperature-rise rating is independent of the fire-endurance rating (hourly rating) of the fire door. A fire door may receive an hourly fire-endurance rating even if the temperature rise exceeds 650°F (343°C) in the first 30 minutes. In Europe, a similar rating is provided. The time it takes for the average temperature to reach 121°C (250°F) is monitored, and that number of minutes is assigned as an insulation rating. Consequently, a European door with a minimum 30 minute insulation rating could be considered comparable to a U.S. door with a maximum 250°F (121°C) temperature rise rating.

For new construction or door replacement on MFL fire walls, doors with a minimum 30-minute temperature rise rating of 250°F (121°C) are preferred. This rating ensures the door has some thermal resistance to limit heat conduction through it. Providing such doors is critical where, despite good preventive efforts, temporary storage may be left too close to openings where autoignition may result from an uncontrolled fire on the opposite side of the door. This is a particular concern in warehouses where the probability of having combustible storage adjacent to openings in fire walls is high. The described door does not offer the same protection a fire wall, however, and is not considered as a substitute for adequate space separation between door openings and combustible storage.

The temperature-rise rating is noted on the fire door label. When it is not practical to use a door with a 250°F (121°C) maximum temperature-rise rating, the next preference is to use one with a 450°F (232°C) maximum temperature rise rating. Except where noted, all openings in MFL fire walls should be protected with two automatic closing, minimum 3-hour rated fire doors, one on each side of the opening. Two doors are recommended for all such openings to increase the probability of at least one door closing.

C.9 Selection of Fire Doors

Selection of a suitable fire door is mainly dependent upon its intended use, available clearances, and appearance.

Doors with insulating value are preferred as noted above. When the use of such doors is impractical due to space limitation, rolling steel doors may be used.

In general, single fire doors that close the entire opening without a center joint are preferred. The center joint of doors mounted in pairs is a weakness that can be overcome by rabbeting or dividing with an astragal (Figs. 48, 49, 50, and 51). Such paired doors are useful where wall space is limited; where conveyors or other obstructions are such that doors can be arranged to close around them; for certain elevator enclosures; and for other special applications.

Fire door installations include hardware, frame (where applicable), operators, and related devices. These items are all important and deserve the same careful consideration as the door itself. Assemblies requiring simple closing hardware are preferable to those with complicated arrangements.

Typically, doors and frames are identified by a metal label upon which all information is etched or embossed. A printed, self-adhesive plastic film label may also be used, or the information may be embossed into the door frame using a die. Labels for individual doors will have their own individual serial number. Since it is impractical to make a new die for each frame manufactured, the marking will contain a die code number assigned to that manufacturer.

Personnel door frames are FM Approved separately from the fire door. Guide rails for rolling or sliding doors are considered part of an FM Approved door. The inside of the wall opening is protected against mechanical damage by generic structural steel (channel, angle, or plate).
Labels are located on the hinge edge of the door, near the top hinge for personnel doors. On rolling doors, they are located near the middle of the face of the bottom bar. On sliding doors, they are located in the middle of the face of the door. For sample labels, see Figure 47.