Designation: F2247 – 11 (Reapproved 2017)

Standard Test Method for Metal Doors Used in Blast Resistant Applications (Equivalent Static Load Method)[1]

This standard is issued under the fixed designation F2247; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the structural performance of metal doors and frames and their restraining hardware (such as latches and hinges) used as a blast resistant barrier. This method involves applying an equivalent static pressure based on the characteristics of the specified blast pressure and structural properties of the door panel design.

1.2 The static tests are valid for the unit size tested or for smaller units of analogous construction. Extrapolation of test results for units larger than the test specimen are not permitted.

1.3 This standard test method is not applicable to tests where the forces are created by explosive charges, forced air from a shock tube apparatus, or any other method used to generate a dynamic load.

1.4 The proper use of this method requires knowledge of the principles of pressure, deflection, and when applicable, strain gauge measurement.

1.5 Using this method, specimens may be tested to determine ultimate static capacity or tested to specific static test loads.

1.5.1 *Procedure A* shall be used when a load-deflection curve is not required and a single load is applied.

1.5.2 *Procedure B* shall be used when a load-deflection curve is required and a single or multiple loads are applied.

1.6 The values stated in SI units are to be regarded as the standard. The values provided in parenthesis are for information only.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E330/E330M Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

2.2 *Other Standard:*

UFC 3-340-02 Unified Facilities Criteria (UFC), Structures to Resist the Effects of Accidental Explosions[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *metal door*—a term used in reference to doors which are built from steel sheets, internally stiffened with cold-formed shapes or structural steel shapes. Materials can be carbon or stainless steel. The materials may be joined together by any fabrication technique (that is, welding, bolting, structural adhesive, etc.). The material voids may be filled with insulation.

3.1.2 *permanent deformation*—the permanent displacement from an original position that remains after an applied load has been removed. Measured in millimetres (mm) (inches (in.)).

3.1.3 *rebound*—stress reversal in the material of the door.

3.1.4 *seating pressure*—an applied pressure that causes the door panel to seat against the frame that is expressed in pascals (Pa) (pounds-force per square foot (psf) or pounds-force per square inch (psi)).

3.1.5 *specifier*—individual or party requesting that a metal door assembly meet specific blast resistance criteria.

3.1.6 *specimen*—the entire assembly unit submitted for test as described in Section 6.

3.1.7 *steady state pressure*—a test pressure held for a minimum of 3 min.

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Institute of Building Sciences, 1090 Vermont Avenue, NW, Suite 700, Washington, DC 20005, http://www.wbdg.org/index.php.

3.1.8 *test director*—the individual identified as being responsible to complete the specified tests as required and to document the results.

3.1.9 *test load*—the specified static pressure differential (positive or negative) for which the specimen is to be tested, expressed in pascals (Pa) (pounds-force per square foot (psf) or pounds-force per square inch (psi)).

3.1.10 *ultimate load*—the pressure (positive or negative) at which failure of the specimen occurs expressed in Pa (psf or psi).

3.1.11 *unseating pressure*—an applied pressure that tends the door panel to unseat from the frame so that the door reactions must be resisted by the restraining hardware, that is expressed in pascals (Pa) (pounds-force per square foot (psf) or pounds-force per square inch (psi)).

4. Summary of Test Method

4.1 This test method consists of sealing the test specimen into or against one face of a test chamber, supplying air to the chamber at a ratio required to maintain the test pressure difference across the specimen, and observing, measuring, and recording the deflection, deformations, stresses (if recorded), and nature of any failures of principal or critical members or the entire specimen.

5. Significance and Use

5.1 Blast resistant doors are designed to protect against the problems and dangers created by a planned or accidental explosion or pressure leak. This test method will provide reasonable assurance to the specifier of the reliability of a door's structure, the restraining hardware, the frame, and the frame anchors when used in a blast resistant application.

6. Specimen Preparation

6.1 *Construction*—The door panel shall meet the general definition of a metal door as outlined in 3.1.1. The test method is general and does not limit the door manufacturer to a specific door panel construction or fabrication process. Ultimately, the design of the door panel is based upon the target pressure rating established by the specifier or door manufacturer.

6.1.1 The size of the specimen (door panel and frame) shall be representative or larger than the application under investigation.

6.1.2 Configuration and spacing of the door panel's internal stiffeners will be as designed by the specifier or the door manufacturer. Space between stiffeners may be filled with insulation.

6.1.3 The typical door panel shall be considered as a three side supported, one edge free loading condition for a seating load case. Generally, the bottom edge of the door panel is free (no structural threshold). If the door assembly does have a structural threshold, the door panel may be considered as a four side supported condition for a seating load case. The door panel is supported by the restraining hardware during the unseating load case. The door panel will be attached to the frame with the same quantity and size of hinge fasteners that the specifier or the door manufacturer intends to use in the actual door installation. The door frame will be attached to the test fixture using the same quantity, size, and spacing of fasteners or anchors that the specifier or door manufacturer intends to use in the actual door installation.

7. Apparatus

7.1 Equipment capable of performing the test procedure described in this standard within the allowable tolerances is acceptable. Figs. 1-4 are examples of apparatus layout.

7.2 *Major Components:*

7.2.1 *Test Chamber*—A chamber or box with an opening and a removable mounting panel, into which the specimen is installed. At least one pressure tap shall be provided to measure the chamber pressure and shall be so located that the reading is unaffected by the velocity of the fluid supply to or from the chamber or any other fluid movement. A means of access is permitted to be provided to facilitate adjustments and observations after the specimen is installed. The test chamber must not deflect under the test load in such a manner that the performance of the specimen will be affected.

7.2.2 *Air System*—A controllable blower or a compressed air supply, designed to provide the required air-pressure difference across the specimen. The system shall provide a constant air pressure difference for the duration of the test.

7.2.3 *Combined Air/Water System*—A combined air and water (fluid) system (See Fig. 1).

7.2.4 *Pressure-Measuring Apparatus*—A device to measure the test pressure difference with accuracy of ±2 % of the reading over the full range of test pressures.

7.2.5 *Deflection-Measuring System*—A means of measuring deflections with an accuracy of ±0.25 mm (±0.01 in.).

7.2.5.1 *For Procedure A* (see 10.2), any locations at which deflections are to be measured shall be stated by the Specifier or the Test Director. See Figs. 2 and 3 for suggested locations.

7.2.5.2 *For Procedure B* (see 10.3), any locations at which deflections are to be measured shall be stated by the Specifier or the Test Director. See Figs. 2 and 3 for suggested locations.

7.2.5.3 Deflection measurements shall be independent of movements of, or movements within, the specimen or member supports.

7.2.6 If desired, strain gauges to measure strain shall be mounted on the side of the door panel in tension. Strain gauges are attached to the tension side of the door panel. They are to be mounted in accordance with the strain gauge manufacturer's instructions.

7.2.6.1 The location of the gauges are to be determined by the specifier or the door manufacturer and they shall be placed where the greatest changes in strain are anticipated, typically at the points of greatest flexure. See Figs. 2 and 3 for suggested locations.

8. Hazards

8.1 Proper care must be taken for the possibility of a failure. The system used in this test method contains considerable stored energy and constitutes a hazard. The testing apparatus shall be equipped with a method to restrain the specimen in the event of failure. The restraint method shall not interfere with the test nor the results of the test.

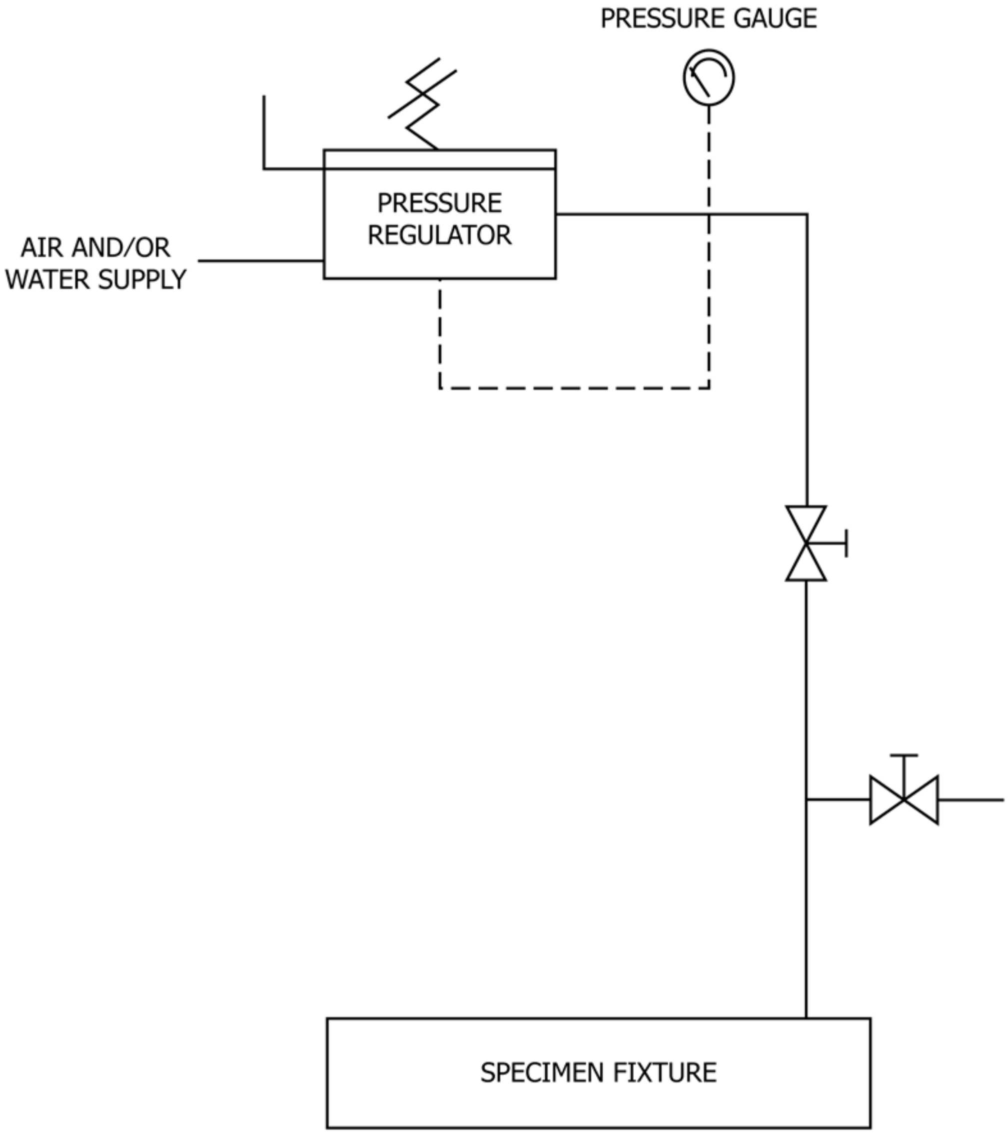


FIG. 1 Schematic of Test Arrangement

9. Calibration

9.1 *Pressure Gage,* deflection-measuring devices, and strain gauges shall be calibrated prior to testing to make certain the devices are within specifications and requirements (see 7.2.4 and 7.2.5). Calibration of test equipment shall be in accordance with the manufacturer's recommendations and to a national recognized standard.

10. Required Information

10.1 The following information shall be supplied by the specifier:

10.2 *Procedure A—Single Loading with no Deflection Curve:*

10.2.1 Performance criteria and the number and gage location.

10.2.2 The blast duration defined as the time interval between time of arrival of the blast wave at a given location and the time for the magnitude of the pressure to return to ambient pressure. See Annex A1 for example of converting a dynamic pressure into an equivalent static load.

10.2.3 The permitted damage level category in accordance with Section 11.

10.2.4 The number and location of deflection and, if applicable, strain gages.

10.3 *Procedure B—Single or Multiple Loading with Deflection Curve:*

10.3.1 Same as 10.2.1 – 10.2.4, additionally:

10.3.2 The number of load cycles at which deflection and stress-strain measurements are required.

10.3.3 The number and location of required deflection and strain gages (if desired).

11. Acceptance Criteria

11.1 Acceptance of the door is based on the end use of the door. The door is classified into one of four damage level categories. The criterion and acceptance for each category is:

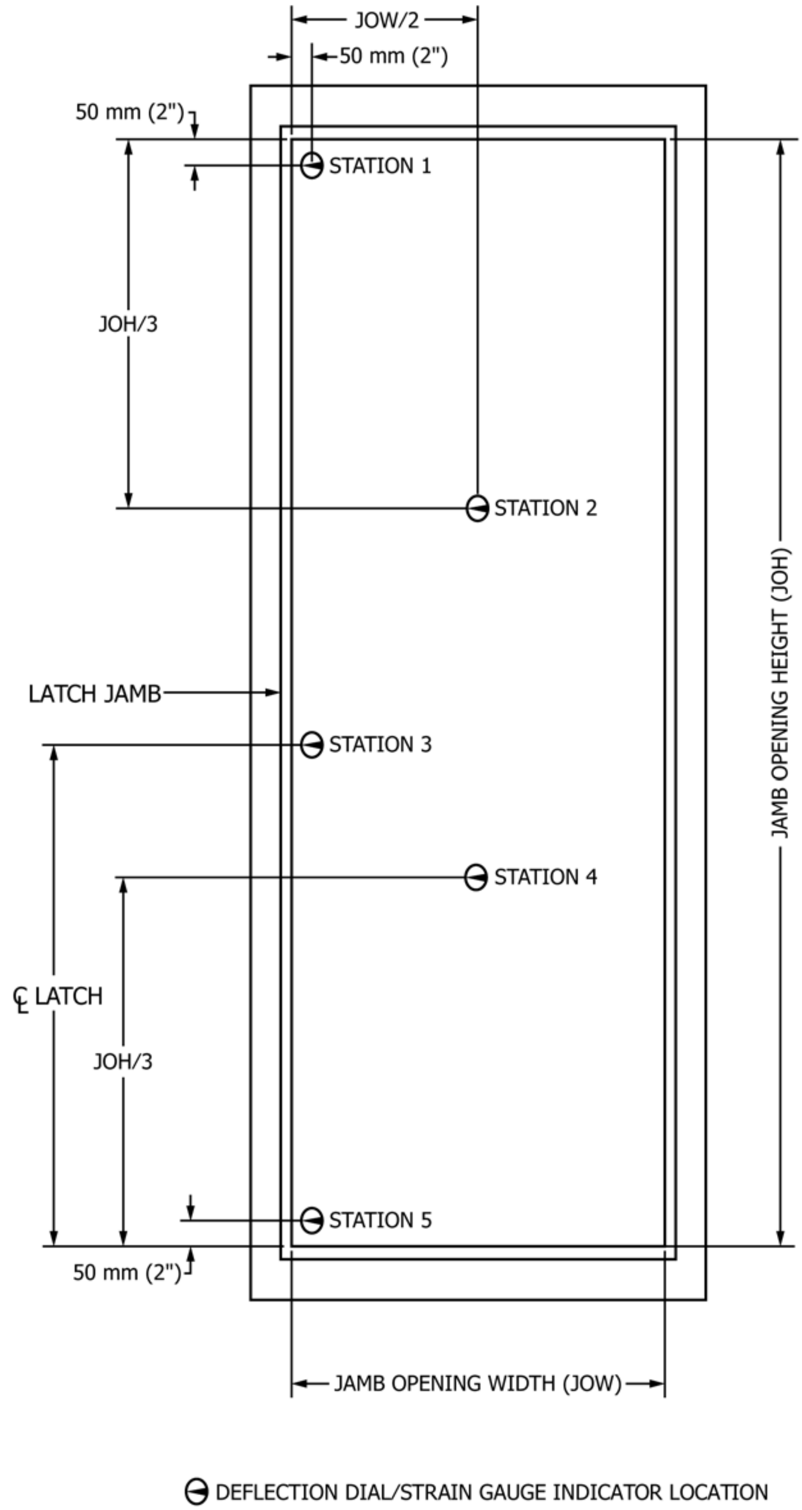


FIG. 2 Test Fixture Elevation—Unseating Load Case

11.1.1 *Category I*—The specimen is unchanged (no permanent deformation) after the loading incident and the door is fully operable. The specimen remains intact and responds elastically.

11.1.1.1 *Acceptance:*

(1) After the specimen has been unloaded, verify that the deflection gages have returned to zero reading with a tolerance of +2 mm (5⁄64 in.).

(2) Verify that the door is operable by unlatching the door and swinging the panel.

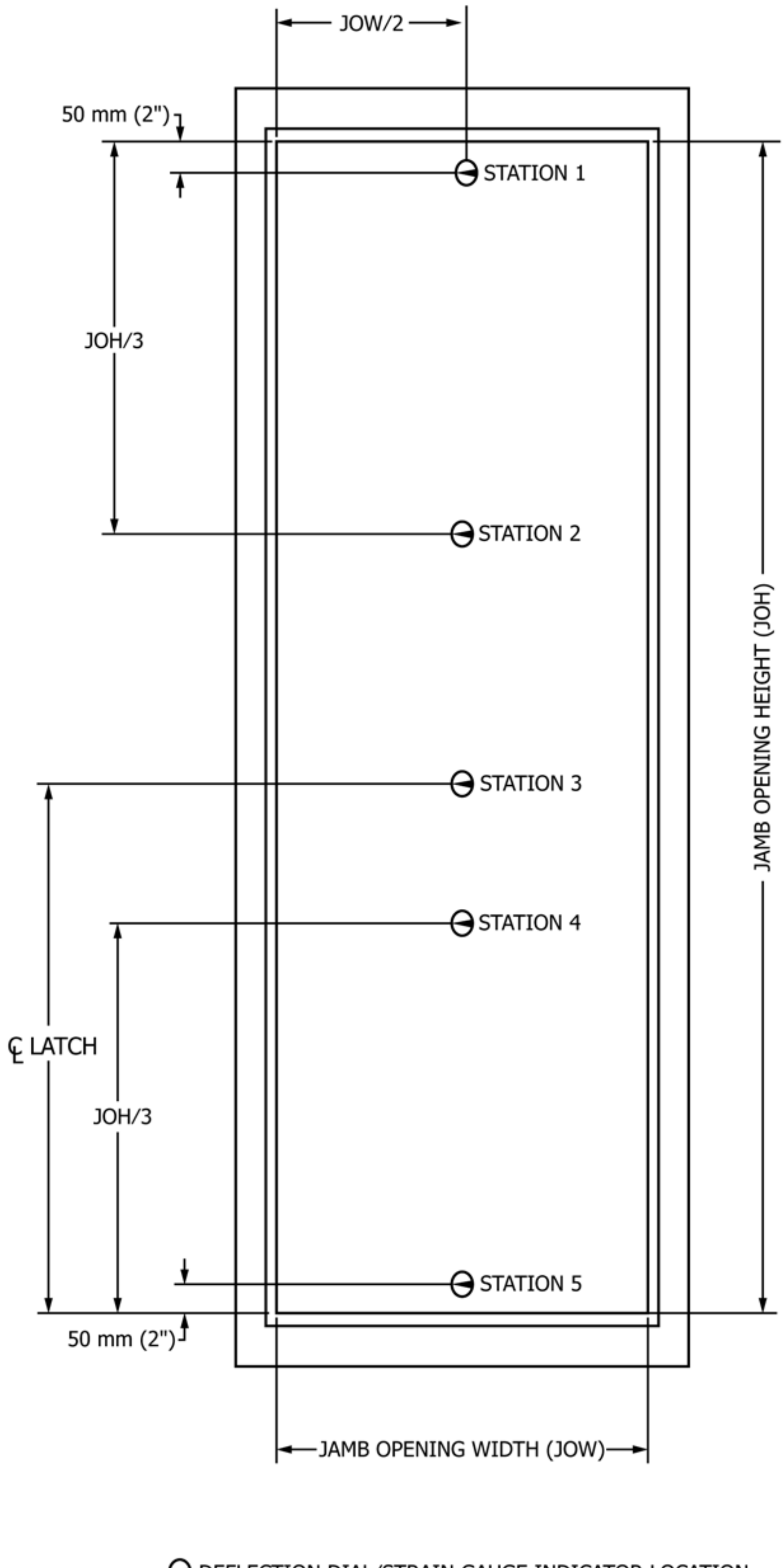


FIG. 3 Test Fixture Elevation—Seating Load Case

(3) If strain gages are used, check that the recorded stresses are within acceptable limits of door material.

(4) Verify that the door can be latched.

(5) Verify that the external portions of the latch and hinges have not suffered any permanent set.

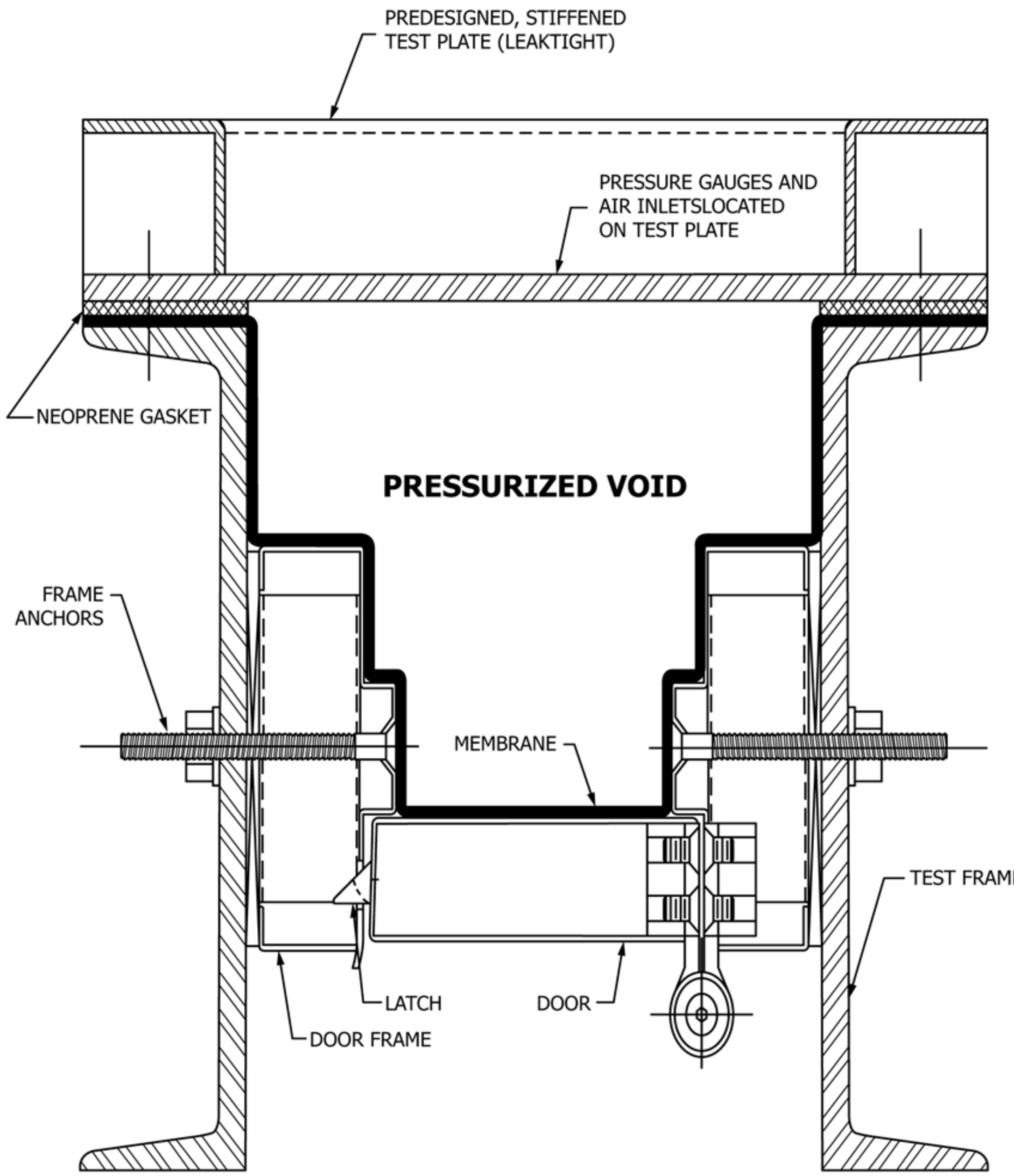


FIG. 4 Horizontal Section—Unseating Load Case

11.1.2 *Category II*—The door is operable but measurable; permanent deformation to the door panel exceeding the tolerance listed in 11.1.1.1 has been experienced. The specimen remains as an integral system.

11.1.2.1 *Acceptance:*

(1) After the specimen has been unloaded, verify that the measurable deformation is acceptable to the end use of the door.

(2) Verify that the specimen remains an integral system.

(3) If strain gages are used, check that the recorded stresses are within acceptable limits of door material.

(4) Verify that the door is operable by unlatching the door and swinging the panel.

11.1.3 *Category III*—Non-catastrophic failure. No structural failure occurs to the specimen that prevents the specimen from providing a barrier to blast wave propagation. However, the specimen is permanently deformed and the door panel is inoperable.

11.1.3.1 *Acceptance:*

(1) After the specimen has been unloaded, verify that the measurable deformation is acceptable to the end use of the door.

(2) Verify that the specimen remains an integral system.

11.1.4 *Category IV*—The door panel is severely deformed. For a seating load test, the deformation of the door panel must be limited to a level that does not cause the door panel to be forced through the door frame opening. For an unseating load test, the latching mechanism is permitted to fail, allowing the door to swing open; however, the door panel shall remain supported by the hinges and it is evident that the door panel will not become a flying debris hazard.

11.1.4.1 *Acceptance:*

(1) After the specimen has been unloaded, verify that the measurable deformation is acceptable to the end use of the door.

(2) Verify that the specimen remains an integral system and there has been no flying debris hazards.

11.2 The frame anchorage connections shall not fail in shear or tension. Limited permanent deformation in the anchors is permitted for Categories II, III, and IV.

11.2.1 In applying the results of tests by this method, consideration must be given that performance of the door assembly, of the wall or its components, or both, may be a function of fabrication, installation, and adjustment, and that the test specimen is or is not truly representative the actual structure. In service, the performance depends on the rigidity of supporting construction and on the resistance of components to deterioration by various causes.

12. Procedure

12.1 The door shall be installed in the test fixture as shown in Figs. 4 and 5 for an unseating load case and as shown in Figs. 6 and 7 for a seating load case. The test fixture shall be positioned vertically with the specimen hung in the operational mode.

12.2 The entire specimen is to be covered with a flexible, tear-resistant membrane. For example, a 3 mm (⅛ in.) thick sheet of solid neoprene or polyethylene. Refer to Figs. 4-7. The membrane shall allow uninhibited load transfer to the specimen. The membrane shall not prevent movement or failure of the specimen. The membrane is to be applied loosely with extra folds of material at each corner and at all offsets and recesses. When the load is applied, there shall be no fillet caused by tightness of membrane. Sponge rubber pads are permitted to be placed over any protrusions that may puncture the membrane. Tape shall not be used when it can restrict differential movement between adjoining members.

12.3 *Procedure A*—Use Procedure A when a load-deflection curve is not required:

12.3.1 Check the specimen for proper adjustments and clearances in the closed position and close all latches,

12.3.2 Install any required deflection and if applicable, strain measuring devices at their suggested locations (see Figs. 2 and 3),

12.3.3 Apply half the full test load and maintain this load at a steady state until the pertinent test data are recorded (not less than 3 min),

12.3.4 Apply the full test load and maintain this load at a steady state until the pertinent test data are recorded (not less than 3 min),

12.3.5 Reduce the pressure difference to zero, and after a recovery period of not less than 3 min, take readings to determine any permanent deformation,

12.3.6 Determine the damage category of the door according to Section 11 criteria,

12.3.7 Repeat the procedure in the other loading direction.

12.4 *Procedure B*—Use Procedure B when a load-deflection curve is required:

12.4.1 Follow 12.3.1 and 12.3.2.

12.4.2 Apply the load in the number of increments specified up to the maximum specified test load. The Specifier or Test Director shall determine the number of increments to be used in the test, or no less than four approximately equal increments to maximum test load. At each increment, maintain the load at a steady state (not less than 3 min) until test data are recorded. Unload.

12.4.3 After a recovery period of not less than 3 min, measure any permanent deformation.

12.4.4 At each increment, determine the damage category of door according to Section 11 criteria.

12.4.5 When the behavior of the specimen under load indicates that sudden failure may occur and damage to the measuring devices is imminent, the deflection measuring devices may be removed and the load continuously increased until the maximum test load or the maximum load that can be sustained is reached.

13. Report

13.1 The report shall include the following information:

13.1.1 Date of the test and date of the report,

13.1.2 Identification of the specimen (manufacturer, source of supply, dimensions, model number, materials, and other pertinent information),

13.1.3 Detailed drawings of the specimen, showing dimensioned section profiles, door dimensions and arrangement, framing layout, test panel arrangement, locking arrangement, hinge arrangement, hardware, sealants, and any other pertinent construction details. A complete description of the type, quantity, and location(s) of the restraining latching device, hinges, and frame anchors. Any modifications made to the specimen, such as strain gauge attachments and location, shall be noted on the drawings,

13.1.4 *For Procedure A,* tabulation of pressure differences exerted across the specimen during the test and the deflections, permanent deformations, stresses (if recorded) and door operability determined for each specimen tested.

13.1.5 *For Procedure B,* tabulation of the number of test load increments, the pressures exerted on the specimen at these test load increments, temporary and permanent deformations, and stresses (if recorded), and door operability,

13.1.6 The duration that each load is held, including incremental loads for Procedure B,

13.1.7 A log of visual observations of performance,

13.1.8 For tests that are made to check conformity of the specimen to a particular specification, an identification or description of the specification,

13.1.9 A statement that the tests were conducted in accordance with this method, and a full description of any deviations from this method, and

13.1.10 A statement as to whether or not tape or film, or both, were used to seal against leakage, and whether, in the judgment of the Test Director, the tape or film influenced the results of the test.

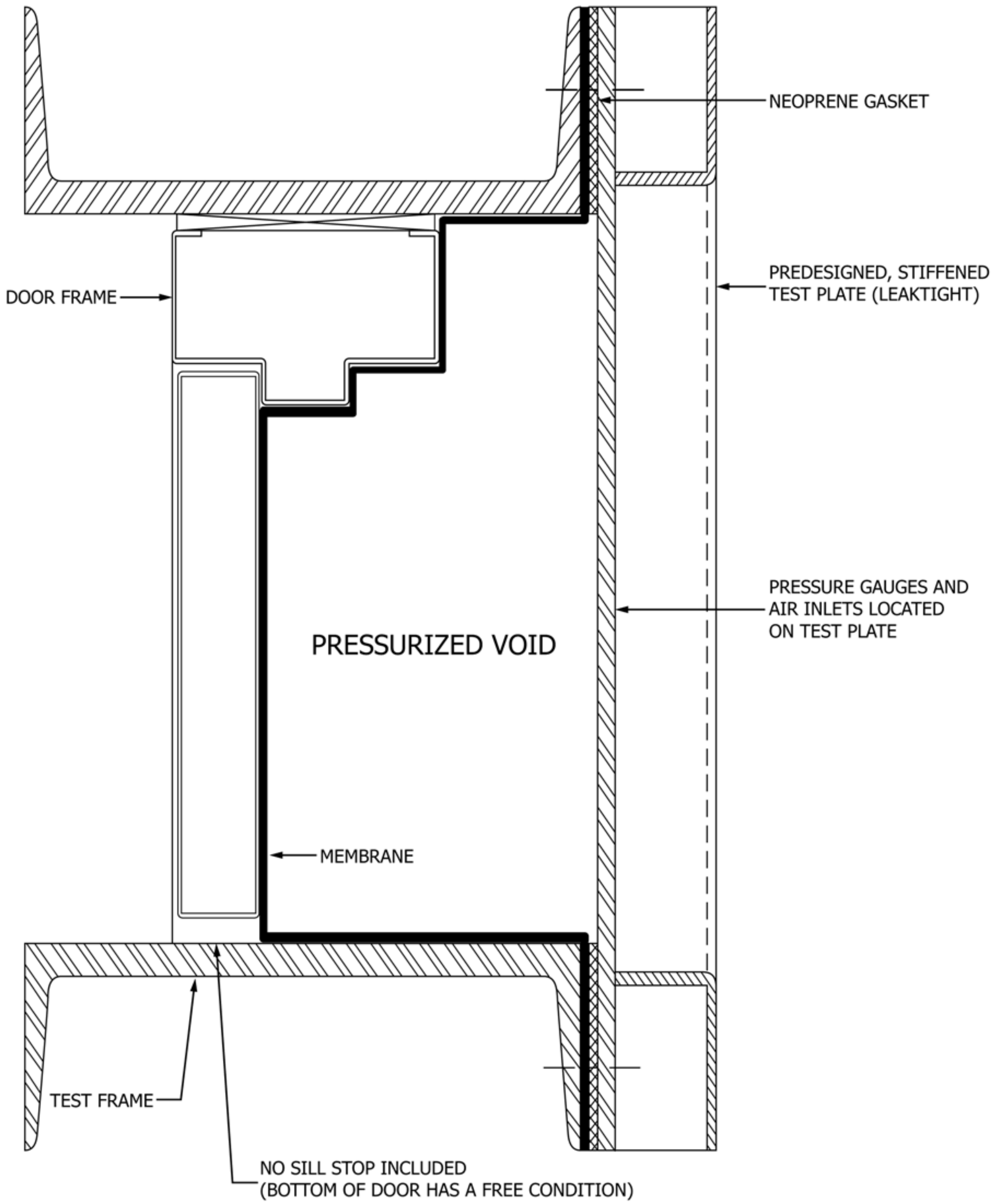


FIG. 5 Vertical Section—Unseating Load Case

13.1.11 Identification of the Test Director and an indication of his concurrence with the report.

13.2 If several specimens are tested, results for each specimens shall be reported, each specimen being properly identified, particularly with respect to distinguishing features or differing adjustments. Differences between specimens may be noted on a single drawing common to all.

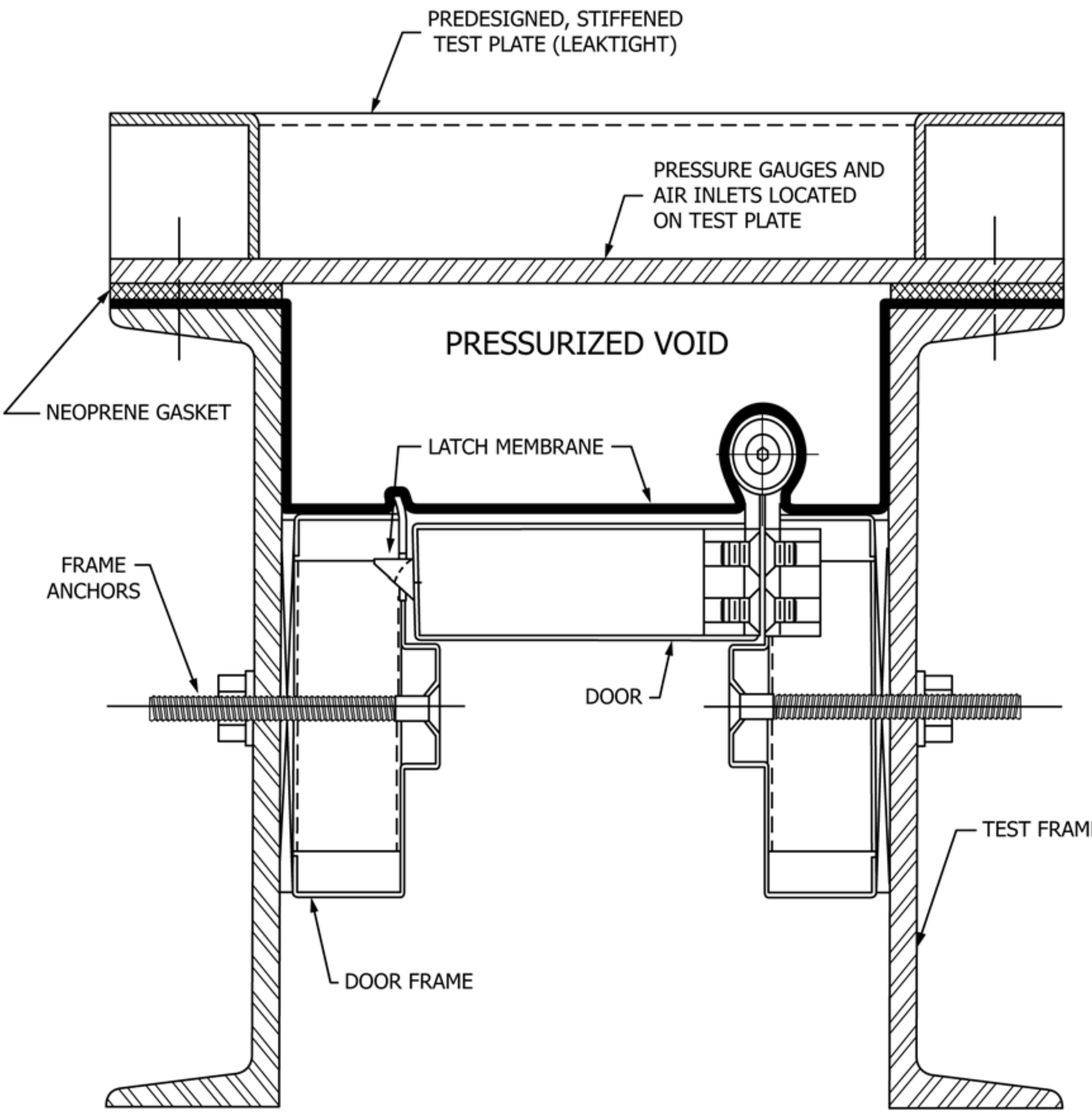


FIG. 6 Horizontal Section—Seating Load Case

14. Precision and Bias

14.1 *Precision and Bias*—No statement is made concerning the precision of this test method since the result merely states whether the door assembly can resist a pressure loading.

15. Keywords

15.1 blast pressure; blast resistance; door; door frame; equivalent static load; hinge; latch; seating load; unseating load

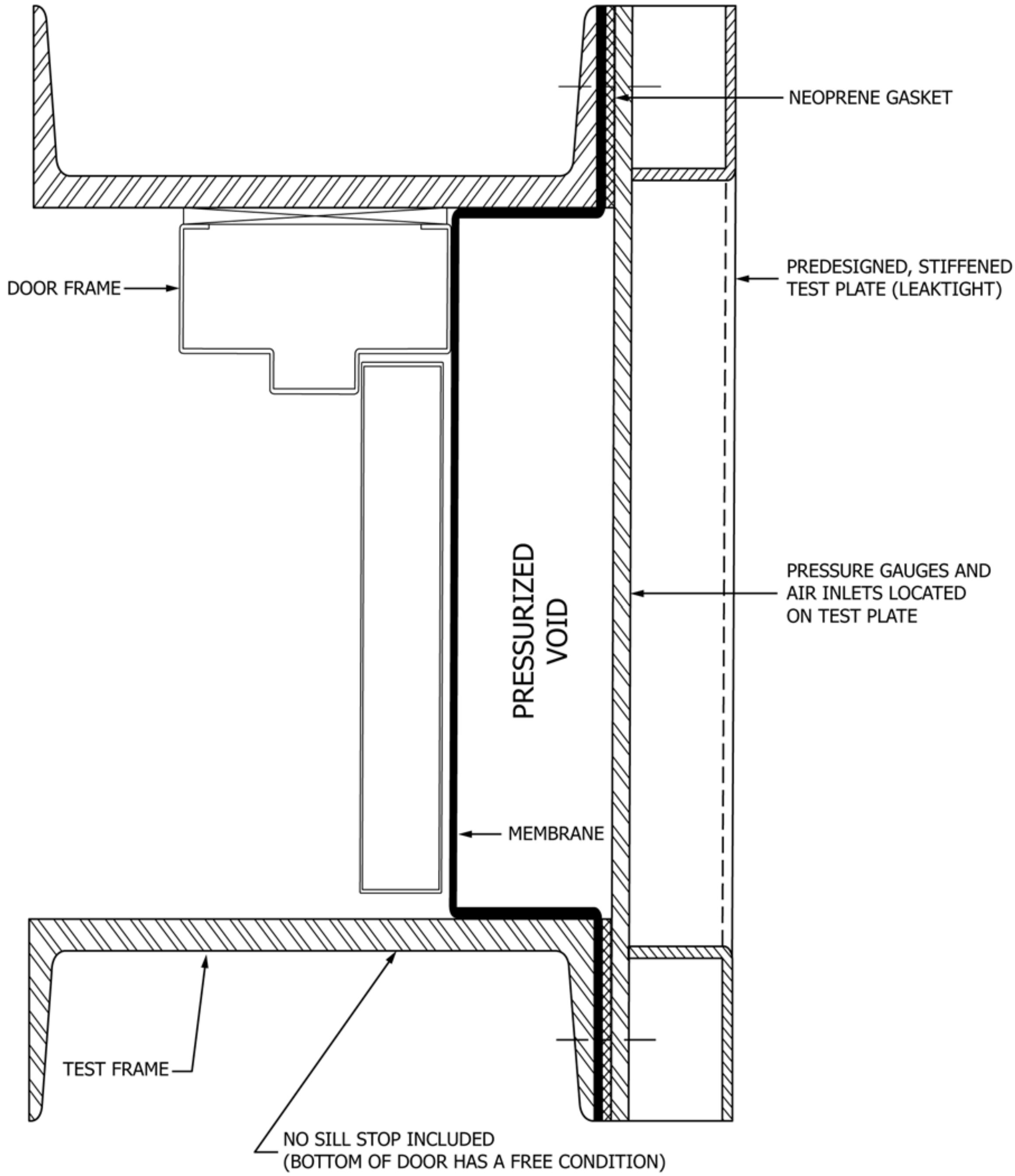


FIG. 7 Vertical Section—Seating Load Case

ANNEX

(Mandatory Information)

A1. DETERMINATION OF EQUIVALENT STATIC LOAD

A1.1 The loading of a metal door varies with the blast magnitude, location, and duration. Other contributing factors include the height of the explosion above grade, building characteristics, terrain, and surrounding structures. To economize and simplify the test, the specifier must anticipate the various blast pressure and duration scenarios and convert them into an equivalent static pressure. The basis of the Equivalent Static Load Method is a load triangle. This triangle is defined by the peak pressure (*Pm*) and the duration (*t*) that it is applied on the door. The area under the triangle is known as the impulse. Due to the structural dynamics of most metal door designs, the static pressure, when compared to common dynamic blast pressure durations, should approach two times the dynamic blast pressure specified. The following example will calculate the impulse and equivalent static pressure on a metal door when subjected to an arbitrary dynamic blast pressure and loading duration.

A1.1.1 *Example—Graphical Representation of a Load Triangle*—See Fig. A1.1.

A1.1.1.1 As stated in Fig. A1.1, the impulse is equal to the area under the load triangle. The formula used to calculate the impulse is the following:

$i = ½ \cdot Pm \cdot t$
$i = ½ \cdot 21\ kPa \cdot 20\ ms\ (½ \cdot 3\ psi \cdot 20\ ms)$
$i = 210\ kPa \cdot ms\ (30\ psi \cdot ms)$

A1.2 Metal doors are designed with internal stiffeners and face sheets and are considered a damped flexure member that deflects as it absorbs energy.

A1.2.1 Consider an example of a typical horizontal section of a 914 mm (36 in.) wide by 2134 mm (84 in.) high metal door. The door consists of 3 mm (0.12 in.) thick carbon steel face sheets and 63.5 by 63.5 by 4.76 mm (2.5 by 2.5 by 0.188 in.) structural tube stiffeners. The stiffeners are spaced 203 mm (8 in.) on center and span the door panel horizontally.

A1.3 *Assumptions:*

A1.3.1 The door panel is a simply supported beam element.

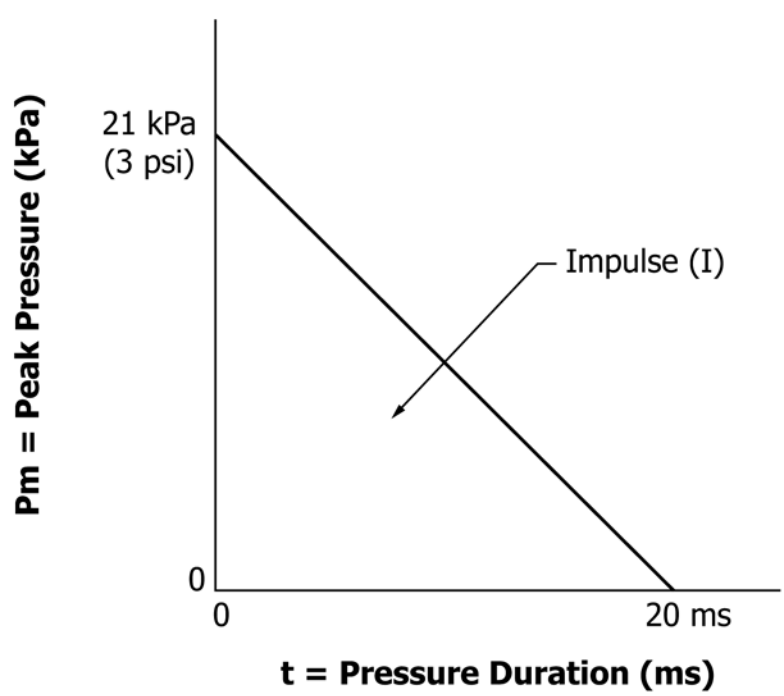
A1.3.2 The peak pressure is uniformly distributed and normal to the face of the door panel.

A1.3.3 The door panel is considered an equivalent single degree of freedom system.

A1.3.4 The door panel vibrates in its fundamental mode only.

A1.3.5 The door panel acts independent of the response of the wall/frame which supports it.

A1.4 *Properties of the Example Door Panel:*



Peak Pressure (*Pm*): *Pm* = 21 kPa (3 psi)
Time Duration of Peak Pressure Acting on Door (*t*): *t* = 20 ms

FIG. A1.1 Graphical Representation of a Load Triangle

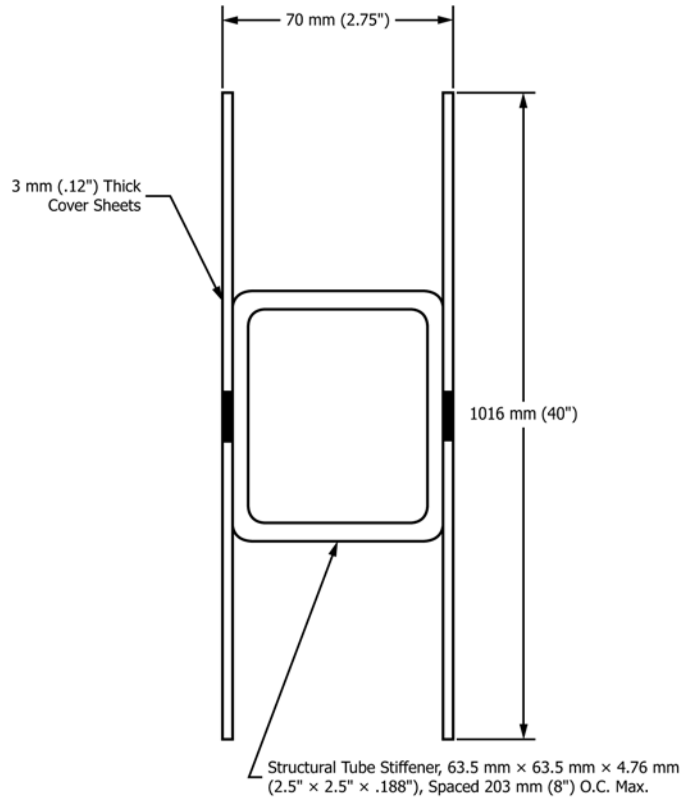


FIG. A1.2 Diagram of a Horizontal Section in a Door Panel

A1.4.1 Consider a face panel 203 mm (8 in.) wide containing one horizontal stiffener. The stiffener can be modeled as a simply supported beam with a uniform load.

Moment of Inertia (I):

$I = 1.309 \cdot 10^{-6}$ m^4 (3.146 in.^{4})

Cross Sectional Area (A):

$A = 1.706 \cdot 10^{-3}$ m^2 (2.644 in.^{2})

Density of ASTM A500 Grade B Structural Tube (ρ):

ρ = 7860 kg/m^3 (0.284 lb/in.^{3})

Modulus of Elasticity of Structural Tube (E):

$E = 2 \cdot 10^{11}$N/m^2 ($29 \cdot 10^6$ psi)

Door Width (l):

l = 914 mm (36 in.)

Width of Door Face Panel Between Stiffeners (w):

w = 203 mm (8 in.)

Peak Dynamic Pressure (Pm):

Pm = 21 kPa (3 psi)

A1.4.2 By using the above properties, the following values can be calculated:

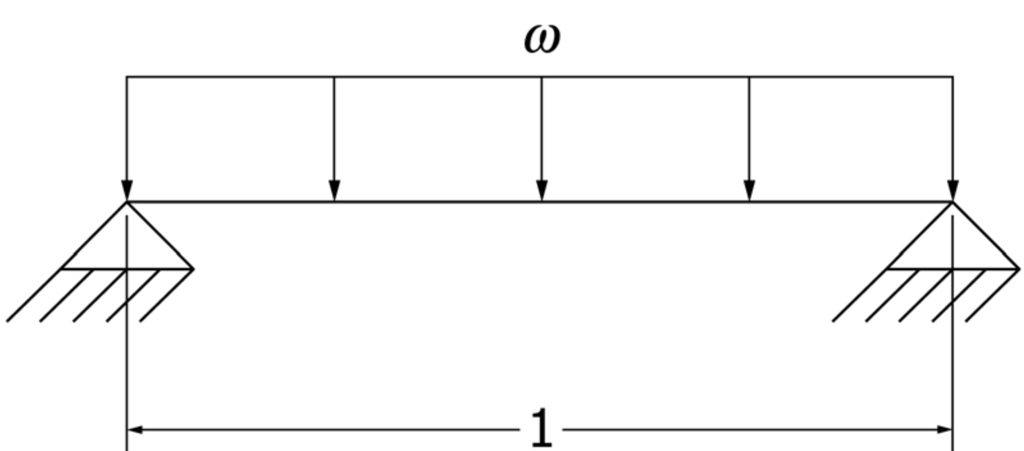


FIG. A1.3 Door Width

Uniform Load Being Exerted on Horizontal Stiffener (ω):

$\omega = Pm \cdot w$
ω = 21 kPa · 203 mm (3 psi · 8 in)
ω = 4.263 N/mm (24 lb/in.)

Effective Mass (*Me*):

$Me = 0.79 \cdot \rho \cdot A \cdot l$
$Me = 0.79 \cdot 7860\ kg/m^3 \cdot 1.706 \cdot 10^{-3}\ m^2 \cdot 0.914\ m$
$(0.79 \cdot 0.284\ lb/in.^3 \cdot 2.644\ in.^2 \cdot 36\ in.)$
Me = 9.682 kg (21.36 lb)

Stiffness (*k*)

From Hooke's Law:

$$k = \frac{F}{\Delta}$$

where:

F = applied load, and
Δ = deflection resulting from applied load.

Therefore:

$$k = \frac{\omega \cdot l}{\frac{5 \cdot \omega \cdot l^4}{384 \cdot E \cdot l}}$$

$$k = \frac{4.263 \cdot (N/mm) \cdot 914 \cdot (mm)}{\frac{5 \cdot 4.263 \cdot (N/mm) \cdot 914 \cdot (mm)^4}{384 \cdot 2 \cdot 10^{11} \cdot (N/m^2) \cdot 1.309 \cdot 10^{-6} \cdot (m)^4}}$$

$$\frac{24 \cdot (lb/in.) \cdot 36 \cdot (in.)}{\frac{5 \cdot 24 \cdot (lb/in.) \cdot 36 \cdot (in.)^4}{384 \cdot 29 \cdot 10^6 \cdot (psi) \cdot 3.146 \cdot (in.)^4}}$$

$$k = 26333\ N/mm\ (150363\ lb/in.)$$

Natural Period of Vibration (*Tn*):

$$Tn = 2\pi\sqrt{\frac{Me}{k}}$$

$$Tn = 2\pi\sqrt{\frac{9.682 \cdot (kg)}{26333 \cdot (N/mm)}} \quad 2\pi\sqrt{\frac{21.36\ lb}{150363\ lb/in.}}$$

$$Tn = 4\ ms\ (4\ ms)$$

Ratio of the Natural Period of Vibration and Peak Pressure Duration (*Tr*):

$$Tr = \frac{T}{Tn}$$

$$Tr = 5.249$$

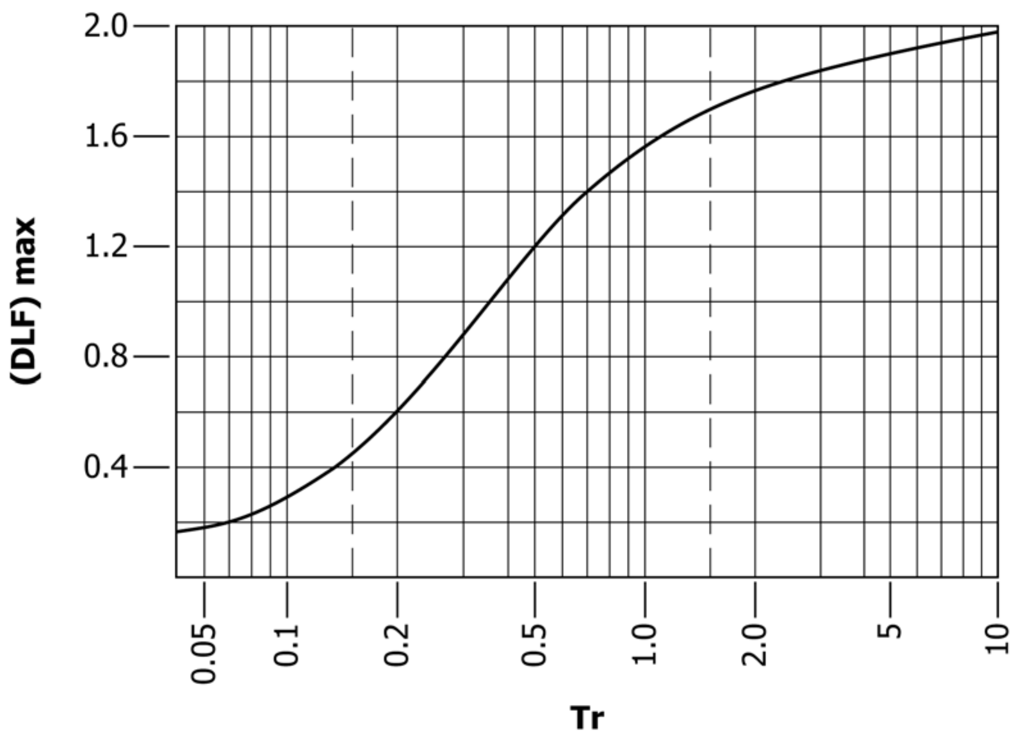
A1.5 *Determination of the Equivalent Static Pressure:*

A1.5.1 By using the graph in Fig. A1.4, the Dynamic Load Factor (*DLF*) max can be obtained. This graph can be found in UFC 3-340-02. The only value that needs to be known is the ratio of the natural period of vibration and peak pressure duration.

A1.5.2 From Fig. A1.4, the Dynamic Load Factor (*DLF*) max is approximately 1.9. The equivalent static pressure (*Ps*) is equal to the peak dynamic pressure times the Dynamic Load Factor.

$Ps = Pm \times (DLF)max$
Ps = 21 kPa · 1.9 (3 psi · 1.9)
Ps = 40 kPa (5.7 psi)

A1.6 *Rebound*—Specify 100 % rebound resistance in the case when the blast pressure duration is much shorter than the expected period of the door and when rebound resistance must



NOTE 1—(DLF) max and Tr are unitless.

FIG. A1.4 Elastic Analysis of a One-Degree of Freedom System

be guaranteed. Specify 50 % rebound resistance in the case when the blast pressure duration is much longer than the expected period of the door. Specify zero rebound in the extreme case in which the door need not remain in place after the blast. Without performing additional structural analysis to estimate the actual rebound resistance, one can be safe by applying the peak equivalent static load in both the seating and unseating directions.