US ARMY CORPS
OF ENGINEERS
Engineering and Support
Center, Huntsville

GUIDE FOR EVALUATING BLAST RESISTANCE OF EXISTING UNDEFINED ARCH-TYPE EARTH-COVERED MAGAZINES

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GUIDE FOR EVALUATING BLAST RESISTANCE OF EXISTING UNDEFINED ARCH-TYPE EARTH-COVERED MAGAZINES

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May 2013

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FOREWORD

The information in this guide is the result of full and reduced scale tests that were made in order to determine the explosive effects resulting from an explosion in an earth-covered magazine. The guide also represents the application of the structural analyses methods given in UFC 3-340-02, "Structures to Resist the Effects of Accidental Explosions," in order to develop procedures that can be used to determine the adequacy of existing undefined earth-covered magazine headwalls and doors to withstand the effects from an explosion in an adjacent earth-covered magazine. This guide should not be used for establishing the requirements for new earth-covered magazine designs. This document can be used to make an initial evaluation of an existing arched-roof earth-covered magazine of unknown structural strength designation to determine if it might qualify as 3-bar or 7-bar, but a structural analysis in accordance with UFC 3-340-02 would be required to obtain approval from DDESB to site the earth-covered magazines as 3-bar or 7-bar.

SUMMARY OF REVISIONS

- General terminology changes were incorporated. “Nonstandard” earth-covered magazines were amended to “undefined” earth-covered magazines. “Standard” earth-covered magazines were amended to “7-bar” or “3-bar” earth-covered magazines.
- The confined explosion curves in Figures 2-1 and 2-2 were amended.
- The example problems were modified to account for new curve values in amended figures.
- The material strengths originally used to evaluate structural components and develop the capacity curves were added to the narrative.

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this guide is to provide installations with procedures to determine the adequacy of undefined earth-covered magazine headwalls to withstand the blast from a known quantity of explosives at a known distance. This is accomplished by comparing the impulse capacities of the various headwall elements (wall, pilaster, and door) to the impulse generated by an imposed blast environment. The impulse capacities for the various headwall elements and the blast environment data are supplied by this guide. An undefined magazine is any earth-covered magazine (ECM) not listed as 3-bar or 7-bar in Table AP1-1 of Appendix A in DDESB Technical Paper No. 15. This guide should not be used for establishing the requirements for new ECM designs. This document can be used to make an initial evaluation of an existing arch type ECM of unknown structural strength designation to determine if it might qualify as 3-bar or 7-bar, but a structural analysis in accordance with UFC 3-340-02 "Structures to Resist the Effects of Accidental Explosions" would be required to obtain approval from DDESB that the ECM meets the requirements of a 3-bar or 7-bar structural strength designation.

In order for the results of the analysis made by using this guide to be considered reliable, it is important that the structural values (i.e., wall or door thicknesses and percent steel in the walls or pilasters) used in the analysis accurately reflect the as-built conditions. For this reason, the guide should only be used with data taken from as-built drawings or from field measurements. If as-built drawings are not available for determining the percentage of steel in the concrete portions (wall and pilaster) of the headwall, then the default values given in paragraph 1.5 can be used.

1.2 Scope of Guide

This guide is applicable to the analysis of headwalls for ECMs having an inside radius of approximately 13 feet. The ECM arch may consist of either corrugated steel or reinforced concrete. This guide is applicable to headwalls with or without thickened wall sections (pilasters) at the door. The wall and pilaster rotations are limited to a maximum of 12 degrees for the indicated wall impulse capacities. At this rotation, the wall or pilaster will approach an imminent collapse but detonation of stored explosives is not expected. The door rotations are also limited to a maximum of 12 degrees for the indicated door impulse capacities. At this rotation, the door will experience a large plastic deflection but will not fail and subject the ECM contents to blast effects that could lead to propagation. It is assumed that the ECMs are arranged in parallel rows with all ECMs facing the same direction.

1.3 Types of Headwall Configurations

As shown in Figure 1-1, the ECM headwall combinations that are covered by this guide are divided into six types which are described as follows:

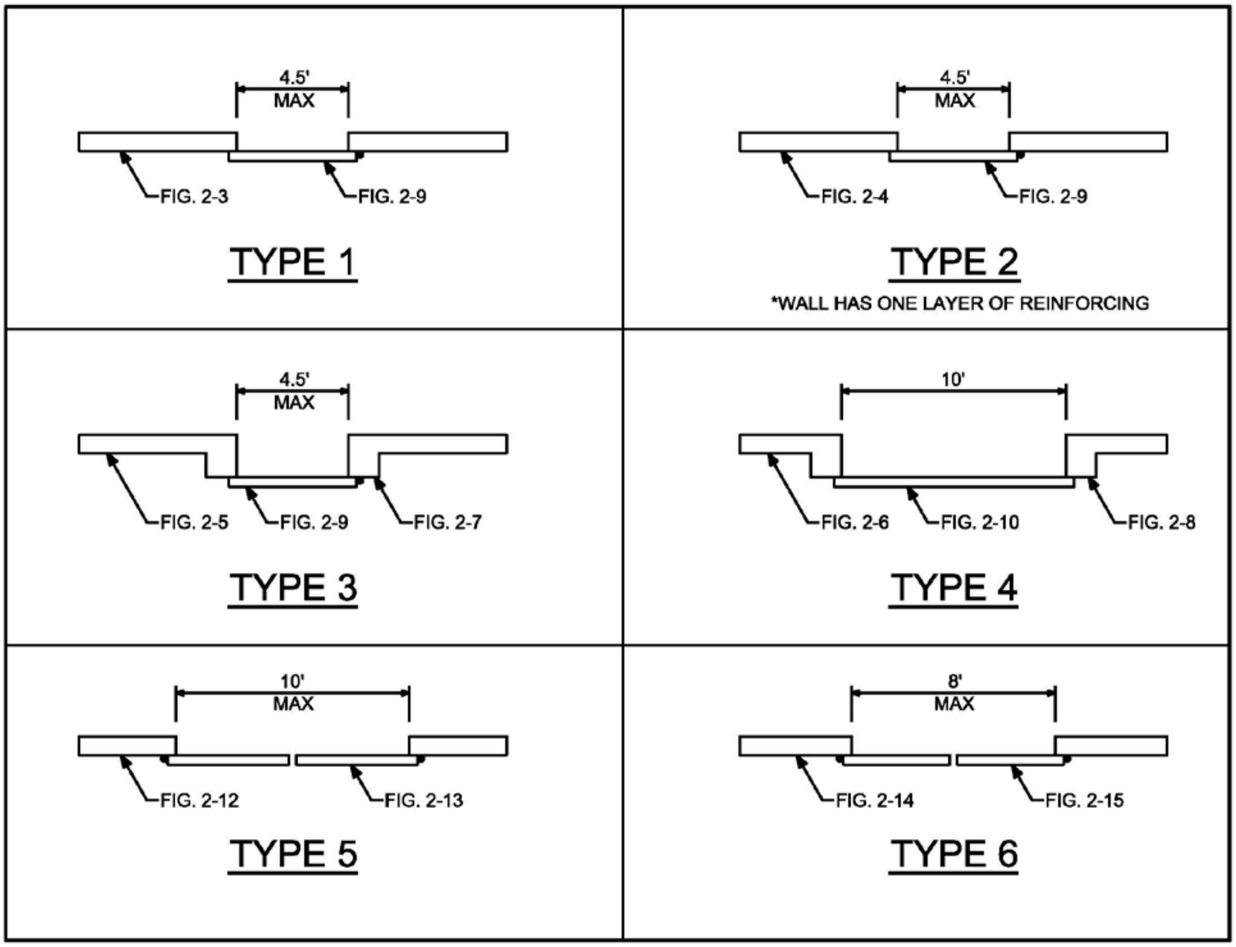


FIGURE 1-1: Headwall Configuration Types (Plan View)

a. Type 1 Headwall Configuration

(1) Wall. The wall for the Type 1 configuration consists of a wall with equal amounts of reinforcing in each direction at each face. The wall opening for the single-leaf door has a maximum clear height of 8 feet and a maximum clear width of 4.5 feet. The wall impulse curves are valid for walls with smaller door openings but not larger openings.

(2) Door. The door for the Type 1 configuration is a single-leaf door consisting of an unstiffened single-thickness plate with variations in door sill support conditions. The clear opening for the door has a maximum height of 8 feet and a maximum width of 4.5 feet. The door impulse curves are valid for doors that cover smaller wall openings but not larger openings.

b. Type 2 Headwall Configuration

(1) Wall. The wall for the Type 2 configuration consists of a wall with equal amounts of reinforcing in each direction at the centerline of the wall. The wall opening for the single-leaf door has a maximum clear height of 8 feet and a maximum clear width of 4.5 feet. The wall impulse curves are valid for walls with smaller door openings but not larger openings.

(2) Door. The door for the Type 2 configuration is a single-leaf door consisting of an unstiffened single-thickness plate with variations in door sill support conditions. The clear opening for the door has a maximum height of 8 feet and a maximum width of 4.5 feet. The door impulse curves are valid for doors that cover smaller wall openings but not larger openings.

c. Type 3 Headwall Configuration

(l) Wall. The wall for the Type 3 configuration consists of a wall with equal amounts of reinforcing in each direction at each face. The opening for the single-leaf door has a maximum clear height of 8 feet and a maximum clear width of 4.5 feet. The wall impulse curves are not valid for any other size door openings.

(2) Pilaster. The pilaster for the Type 3 configuration has equal amounts of vertical steel bars at each face. The pilaster impulse curves are valid for pilasters with smaller door openings but not larger openings.

(3) Door. The door for the Type 3 configuration is a single-leaf door consisting of an unstiffened single-thickness plate with variations in door sill support conditions. The clear opening for the door has a maximum height of 8 feet and a maximum width of 4.5 feet. The door impulse curves are valid for doors that cover smaller openings but not larger openings.

d. Type 4 Headwall Configuration

(1) Wall. The wall for the Type 4 configuration consists of a wall with equal amounts of reinforcing in each direction at each face. The clear opening for the door is 10 feet in both height and width. The wall impulse curves are not valid for larger size door openings, but can be conservatively used for smaller doors.

(2) Pilaster. The pilaster for the Type 4 configuration has equal amounts of vertical steel bars at each face. The pilaster impulse curves are valid for pilasters with smaller door openings but not larger openings.

(3) Door. The door for the Type 4 configuration consists of a single-unit steel door that has support at each door jamb. Any support provided at the top of the door has conservatively not been considered. The door structure consists of interior and exterior steel face plates welded to standard structural shapes spanning in the horizontal direction. These structural shapes must span in the horizontal direction in order for the analysis procedures to be valid. The clear opening for the door is 10 feet in both height and width. The door impulse curves are valid for smaller door sizes but not larger sizes.

e. Type 5 Headwall Configuration

(1) Wall. The wall for the Type 5 configuration consists of a wall with equal amounts of reinforcing in each direction at each face. The wall opening for the double-leaf door has a maximum clear height of 10 feet and a maximum clear width of 10 feet. The wall impulse curves are valid for walls with smaller door openings but not larger openings.

(2) Door. The door for the Type 5 configuration consists of stiffened double-leaf steel doors that are continuously supported at the head and hinge jamb and with either a continuous support at the sill or with a 1.375" diameter sill latch pin on each leaf with no continuous sill support. The door structure consists of interior and exterior steel plates separated by spacer bars. The clear opening for the double door is 10 feet in both height and width. The door impulse curves are valid for smaller door sizes but not larger sizes.

f. Type 6 Headwall Configuration

(1) Wall. The wall for the Type 6 configuration consists of a wall with equal amounts of reinforcing in each direction at each face. The wall opening for the double-leaf door has a maximum clear height of 8 feet and a maximum clear width of 8 feet. The wall impulse curves are valid for walls with smaller door openings but not larger openings.

(2) Door. The door for the Type 6 configuration consists of stiffened double-leaf steel doors that are continuously supported at the head and hinge jamb and with either a continuous support at the sill or with a 1.3125" minimum diameter sill latch pin on each leaf with no continuous sill support. The door structure consists of interior and exterior steel plates separated by stiffeners. The clear opening for the double door is 8 feet in both height and width. The door impulse curves are valid for smaller door sizes but not larger sizes.

1.4 Format for Guide

The guide is presented as a set of 15 figures as follows:

a. Blast Loadings. Figures 2-1 and 2-2 provide the scaled incident and reflected impulses respectively, resulting from an explosive detonation in an adjacent ECM. All scaled impulses represent those at the exterior face of the acceptor ECM. The scaled impulses resulting from an unconfined surface explosion are also provided. The scaled impulses represent the upper range of field measurements taken during full and reduced scale explosive tests.

(1) Figure 2-1 presents the scaled incident impulse resulting from an explosion originating inside an ECM located to the side of and parallel to the acceptor ECM. The incident impulse is plotted as a function of the side to side scaled distance between the ECMs. The scaled distance for Figure 2-1 is the clear distance between the sides of the parallel ECM arches. The maximum scaled incident impulse loading value of 11.3 psi-ms/lb$^{1/3}$ corresponds to the design loading for a 3-bar ECM.

(2) Figure 2-2 presents the scaled reflected impulse resulting from an explosion originating inside an ECM located to the front of and facing in the same direction as the acceptor ECM. The reflected impulse is plotted as a function of the scaled back to front distance between the ECMs. The scaled distance for Figure 2-2 is the distance from the rear wall of the donor ECM to the front wall of the acceptor ECM.

b. Wall Capacities. Figures 2-3 through 2-6 and 2-12 through 2-14 provide the wall impulse capacities for the acceptor ECM. The impulse capacities were determined by analyzing various wall configurations using procedures given in UFC 3-340-02. The wall configurations represent those that might be found in many of the existing undefined ECMs. The figures present the wall impulse capacity as a function of the percent of reinforcing steel for various wall thicknesses. The percent steel should be calculated using the gross section of the wall. The reinforced concrete material strengths used to calculate the wall impulse capacities are f'_c=3000 psi and f_y=40,000 psi.

(1) Figures 2-3, 2-4, 2-12, and 2-14 provide the wall impulse capacities for walls without a thickened wall section (pilaster) at the door jambs.

(2) Figures 2-5 and 2-6 provide the wall impulse capacities for walls with a thickened wall section (pilaster) at the door jambs.

c. Pilaster Capacities. Figures 2-7 and 2-8 provide the pilaster impulse capacities for the acceptor ECM. The impulse capacities were determined by analyzing various door configurations using the procedures given in UFC 3-340-02. The pilaster configurations represent those that might be found in many of the existing undefined ECMs. The figures present the pilaster impulse capacity per foot of pilaster width as a function of percent of pilaster vertical reinforcing steel for various pilaster thicknesses. The percent steel should be calculated using the gross section of the pilaster.

d. Door Capacities. Figures 2-9, 2-10, 2-13, and 2-15 provide the ECM door impulse capacities for the acceptor ECM. The impulse capacities were determined by analyzing various door configurations using procedures given in UFC 3-340-02. The door configurations represent those that might be found in many of the existing undefined ECMs.

(1) Figure 2-9 provides the door impulse capacity for an unstiffened single-leaf door with or without edge support at the door sill. The door impulse capacity is plotted as a function of door plate thickness.

(2) Figure 2-10 provides the door impulse capacity for a stiffened single-unit steel door for various door thicknesses. The door capacity is plotted as a function of the door strength value V. The value of V is determined by the equations presented in Figure 2-11.

(3) Figure 2-13 provides the door impulse capacity for a stiffened double-leaf steel door for various door thicknesses. The door capacity is plotted as a function of the door strength value V. The value of V is determined by the equations presented in Figure 2-11.

(4) Figure 2-15 provides the door impulse capacity for a stiffened double-leaf steel door for various door thicknesses. The door capacity is plotted as a function of the door strength value V. The value of V is determined by the equations presented in Figure 2-11.

1.5 Default Values for Wall and Pilaster Percent Steel

In the absence of as-built drawings that provide information from which the percentages of steel can be determined for the walls and pilasters, the values shown below can be used. These values are based on minimum requirements for wall and beam (pilaster) percent steel as historically required by the American Concrete Institute.

For all walls (with or without pilasters):

- Use percent steel (each way, each face) = 0.12
- Use Figure 2-4 for all walls.[*]

For all pilasters:

- Use percent vertical steel (each face) = 0.50[**]
- Use Figures 2-7 or 2-8.

[*] When using assumed percentage of steel for the wall, Figure 2-4 must be used for determining the wall impulse capacity for all wall configurations (i.e. Figure 2-4 must be used in place of Figures 2-3, 2-5, 2-6, 2-12, and 2-14)

[**] {0.50 percent = [$(200/f_y)(100) = (200/40{,}000)(100)$], from old ACI codes that were in effect when magazines were built.}

2.0 ANALYSIS PROCEDURES

2.1 General.

The procedures listed below were developed for the purpose of evaluating the blast resistance of existing undefined ammunition storage ECMs or for determining the amount of explosives that may be stored in an adjacent ECM without creating a blast propagation hazard to an adjacent undefined ECM.

a. Procedure 1 - Evaluate Blast Resistance of Undefined ECM.
The procedure involves a series of sequential steps which are applicable to the Type 1 through Type 6 Headwall Configurations shown in Figure 1-1. The number of steps will vary depending on the headwall configuration being analyzed. The basic procedure is as follows:

(1) Determine the impulse loading on the acceptor ECM from Figure 2-1 and/or Figure 2-2.

(2) Determine the impulse capacity for each of the applicable ECM elements (wall, pilaster, and door) from Figure 2-3 through Figure 2-15 and compare each capacity to the impulse loading.

The Type 4 Headwall Configuration will be used to illustrate Procedure 1. Since the Type 4 Configuration is composed of three structural elements (wall, pilaster, and door), it will be necessary to analyze each of these three elements to determine if any one fails to provide the required resisting impulse capacity. A similar but shorter procedure can be used for the Types 1 and 2 headwall configurations because a pilaster analysis is not required. Since the door for the Type 4 Configuration consists of a stiffened plate structure, the analysis procedure will be more involved because of the requirement to determine the door strength value (V). The procedure for determining the door impulse capacity for Types 1, 2, and 3 configurations is less involved because only the door thickness is required to determine the door impulse capacity.

b. Procedure 2 - Determine Allowable Quantity of Stored Explosive.
Procedure 2 is similar to Procedure 1, except in reverse order and involves a trial and error process for determining the allowable quantity of stored explosive. The basic procedure is as follows:

(1) Determine the smallest impulse capacity of the applicable ECM elements (wall, pilaster, and door) from Figures 2-3 through 2-10.

(2) Select a value for the allowable quantity of stored explosive.

(3) Determine the impulse loading on the acceptor ECM from Figure 2-1 and/or Figure 2-2 and compare to the impulse capacity previously determined.

(4) Adjust the value for the allowable quantity of stored explosive as necessary and repeat Step 3.

2.2 Procedure 1 - Evaluate Blast Resistance of Undefined ECM.

STEP 1: From Figure 1-1, select the headwall configuration type that most closely matches the existing ECM. The configuration type will determine the figures to be used in the analysis. For this example, Headwall configuration Type 4 will be used.

STEP 2: Determine the net explosive weight (W) in pounds of the explosive material stored in the donor ECM.

STEP 3: For the condition with the donor ECM located to the side of the acceptor ECM, determine the clear distance in feet (R) between the sides of the ECM arches (see Figure 2-1).

STEP 4: Calculate the scaled distance by dividing the distance (R) in Step 3 by the cube root of the net explosive weight (W) determined in Step 2.

STEP 5: Enter Figure 2-1 with the scaled distance $R/W^{1/3}$ from Step 4 and read the value of the scaled incident impulse $I_s/W^{1/3}$ from the solid lined curve for a confined explosion.

STEP 6: Calculate the incident impulse (I_s) by multiplying the scaled incident impulse value from Step 5 by $W^{1/3}$.

STEP 7: If there is no ECM in front of the acceptor ECM, then steps 7 through 10 will not be necessary. For the condition with a donor ECM located in front of the acceptor ECM, determine the clear distance in feet (R) between the rear wall of the donor ECM and the front (head) wall of the acceptor ECM (see Figure 2-2).

STEP 8: Calculate the scaled distance by dividing the distance (R) in Step 7 by the cube root of the net explosive weight (W) determined in Step 2.

STEP 9: Enter Figure 2-2 with the scaled distance $R/W^{1/3}$ from Step 8 and read the value of the scaled reflected impulse $I_r/W^{1/3}$ from the solid line curve for a confined explosion.

STEP 10: Calculate the reflected impulse (I_r) by multiplying the scaled reflected impulse value from Step 9 by $W^{1/3}$.

STEP 11: Select the larger of the values from Step 6 and Step 10 (only one value from step 6 will exist if there is no donor ECM in front of the acceptor ECM.)

STEP 12: From Figure 2-6, determine the wall impulse capacity (I_w).

STEP 13: From Figure 2-8, determine the pilaster impulse capacity (I_p). Note that the values presented in Figure 2-8 must be multiplied by the pilaster width in feet in order to obtain the total pilaster impulse capacity.

STEP 14: From Figure 2-10, determine the door impulse capacity (I_d). The door strength value (V) is determined by the information given in Figure 2-11.

STEP 15: Each impulse capacity I_w, I_p, and I_d determined from Steps 12 through 14 must be equal to or greater than the imposed impulse loading determined in Step 11. If any one of these impulse capacities is less than the value of Step 11, then the ECM structure is not adequate to resist the imposed blast loading. Possible solution would be either to increase the impulse capacity of the ECM by structural modifications or reduce the quantity of stored explosives to an acceptable quantity as shown in Procedure 2.

2.3 Procedure 2 - Determine Allowable Quantity of Stored Explosive.

STEP 1: From Figure 1-1, select the headwall configuration type that most closely matches the existing ECM. The configuration type will determine the figures to be used in the analysis. For this example, Headwall Configuration Type 1 will be used.

STEP 2: From Figure 2-3, determine the wall impulse capacity (I_w).

STEP 3: From Figure 2-9, determine the door impulse capacity (I_d)

.

STEP 4: Select the smaller of the values from Steps 2 and 3.

STEP 5: Select a value of net explosive weight (W).

STEP 6: For the condition with the donor ECM located to the side of the acceptor ECM, determine the clear distance in feet (R) between the sides of the ECM arches (see Figure 2-1).

STEP 7: Calculate the scaled distance by dividing the distance (R) in Step 6 by the cube root of the net explosive weight (W) determined in Step 5.

STEP 8: Enter Figure 2-1 with the scaled distance $R/W^{1/3}$ from Step 7 and read the value of the scaled incident impulse $I_s/W^{1/3}$ from the solid line curve for a confined explosion.

STEP 9: Calculate the incident impulse (I_s) by multiplying the scaled incident impulse value from Step 8 by $W^{1/3}$.

STEP 10: If there is no ECM in front of the acceptor ECM, then Steps 10 through 13 will not be necessary. For the condition with the donor ECM located in front of the acceptor ECM, determine the clear distance in feet (R) between the rear wall of the donor ECM and the front (head) wall of the acceptor ECM (see Figure 2-2).

STEP 11: Calculate the scaled distance by dividing the distance (R) in Step 10 by the cube root of the net explosive weight (W) selected in Step 5.

STEP l2: Enter Figure 2-2 with the scaled distance $R/W^{1/3}$ from Step 11 and read the value of the scaled reflected impulse $I_r/W^{1/3}$ from the solid line curve for a confined explosion.

STEP 13: Calculate the reflected impulse (I_r) by multiplying the scaled reflected impulse value from Step 12 by $W^{1/3}$.

STEP 14: Select the larger of the values from Step 9 and Step 13 (only one value from Step 9 will exist if there is no donor ECM in front of the acceptor ECM).

STEP 15: Compare the impulse value determined by Step 4 with that of Step 14. If the value determined by Step 4 is equal to or larger than the determined in Step 14, then the structure of the acceptor ECM is adequate to resist the blast from the quantity of explosives selected in Step 5. If the value determined by Step 4 is less than that determined by Step 14, then the structure of the acceptor ECM is not adequate for the quantity of explosive selected. Try a lower value of explosive quantity for Step 5 and repeat Steps 6 through 15.

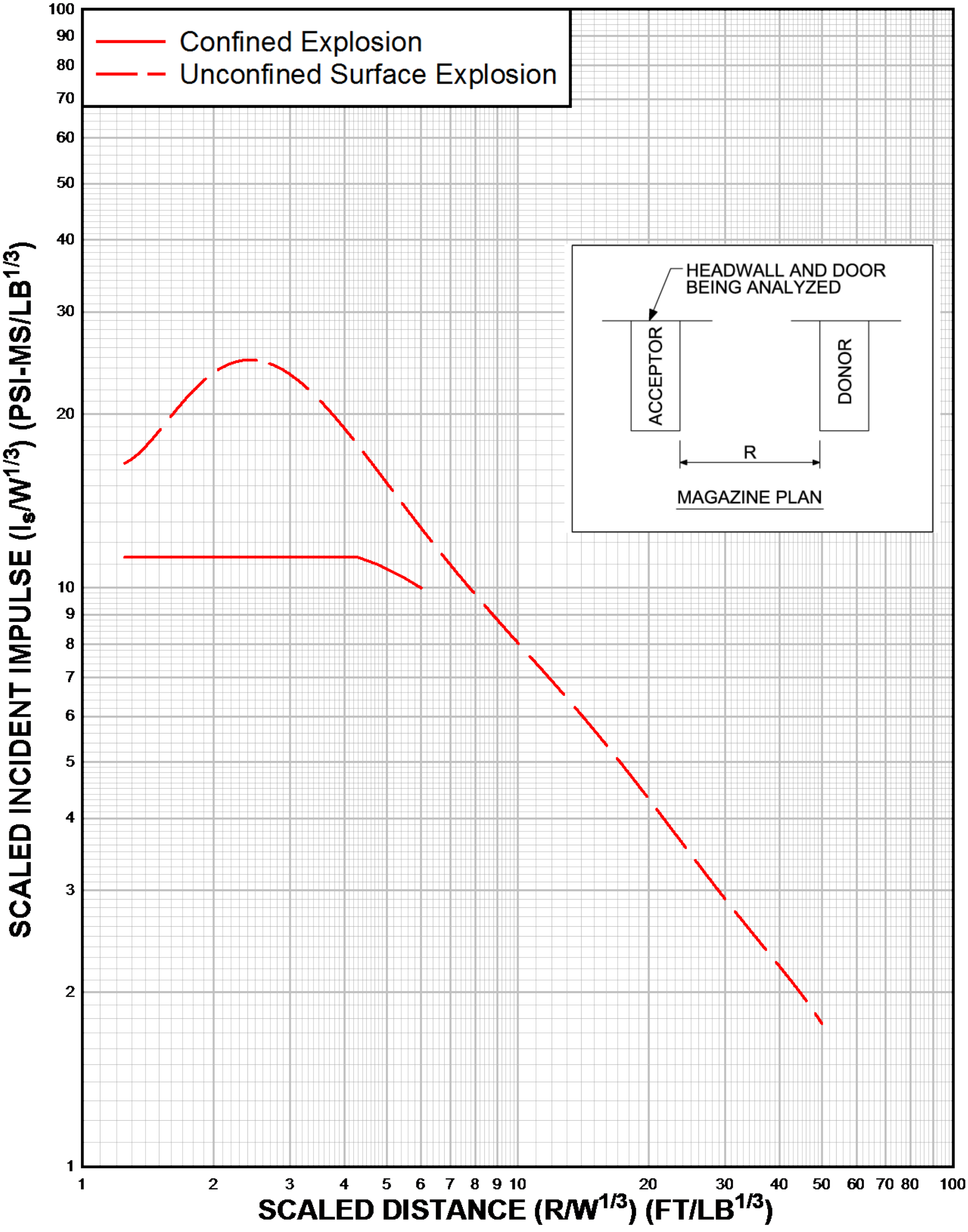


FIGURE 2-1: SCALED INCIDENT IMPULSE VS. SCALED DISTANCE (SIDE TO SIDE)

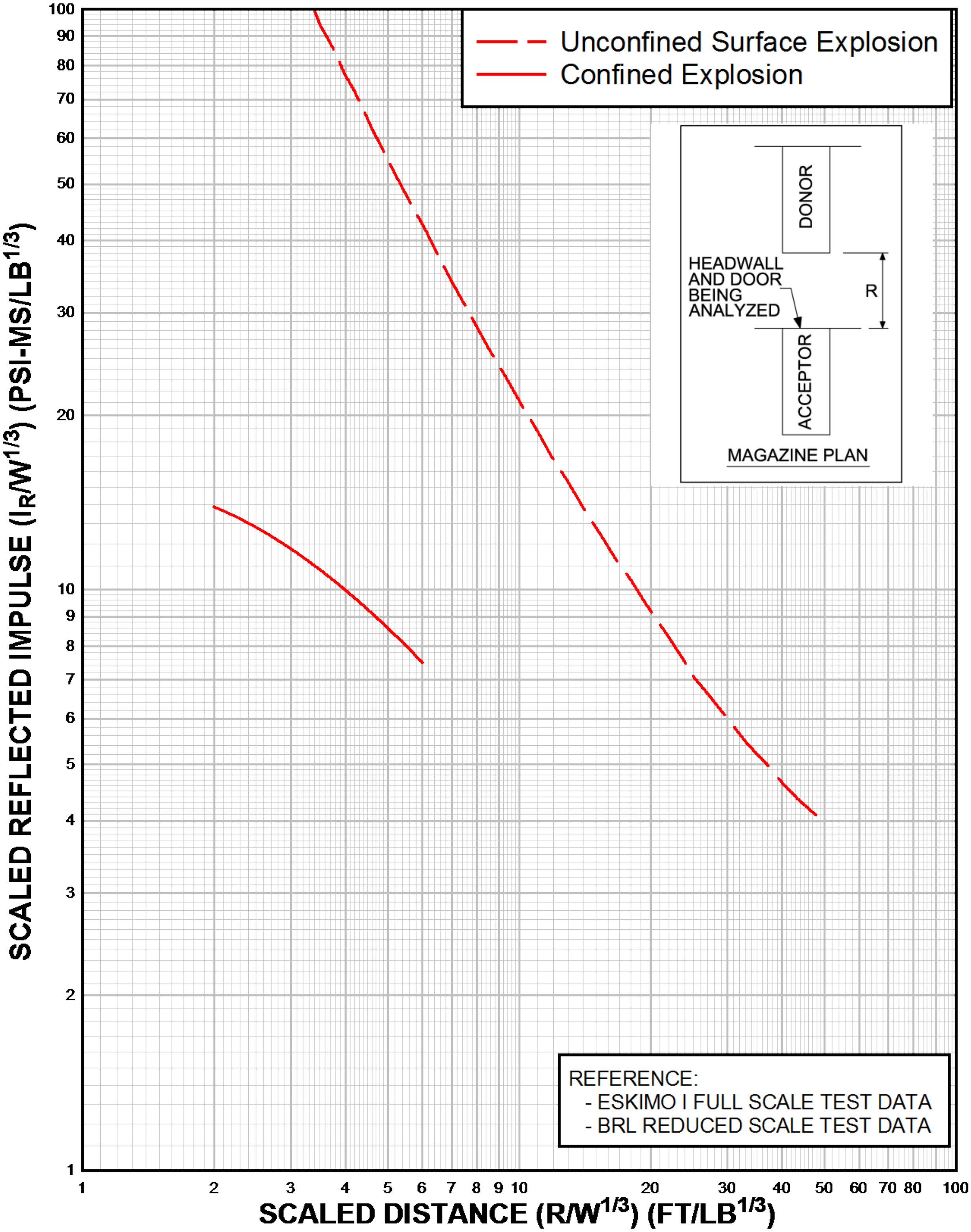


FIGURE 2-2: SCALED REFLECTED IMPULSE VS. SCALED DISTANCE (REAR TO FRONT)

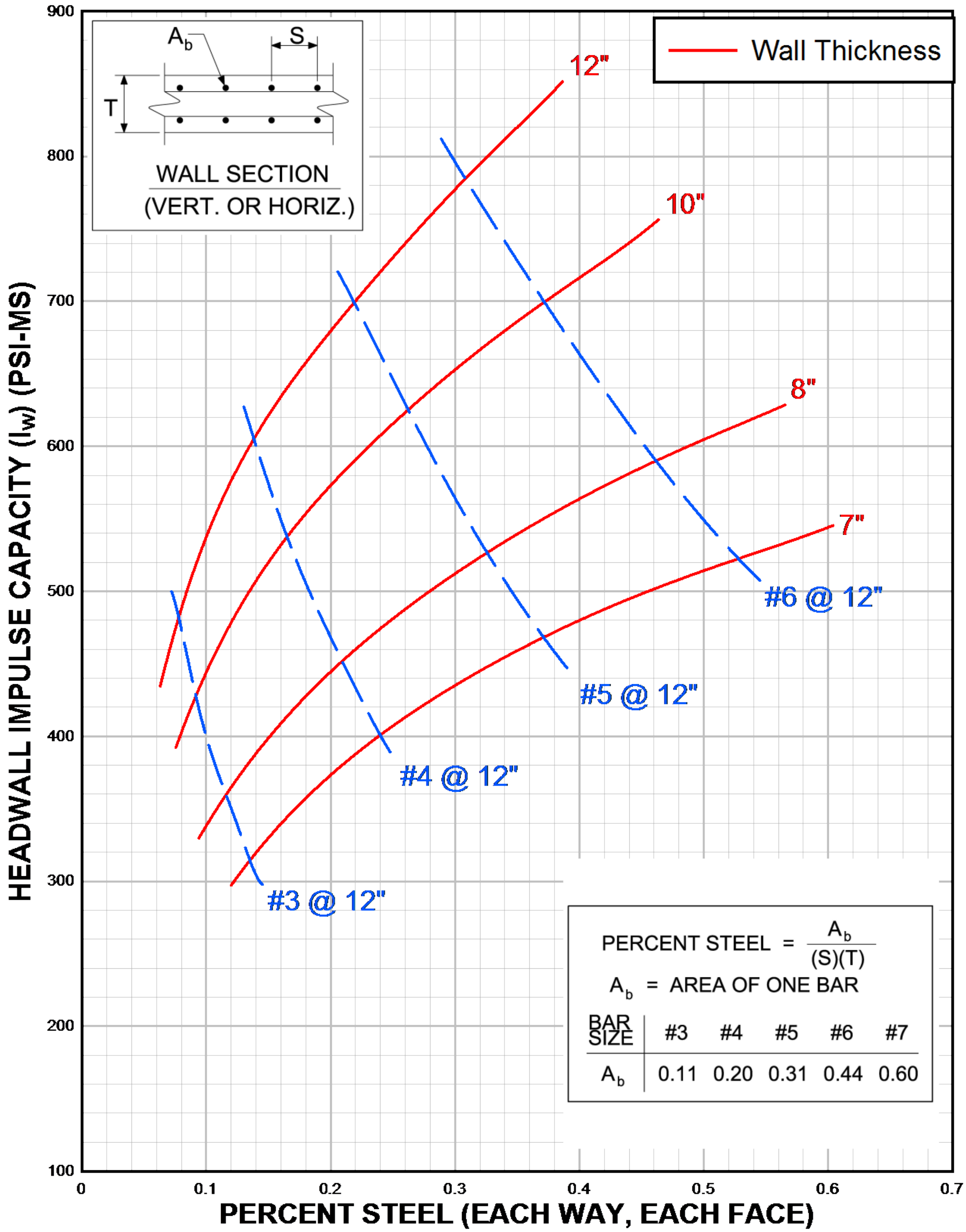
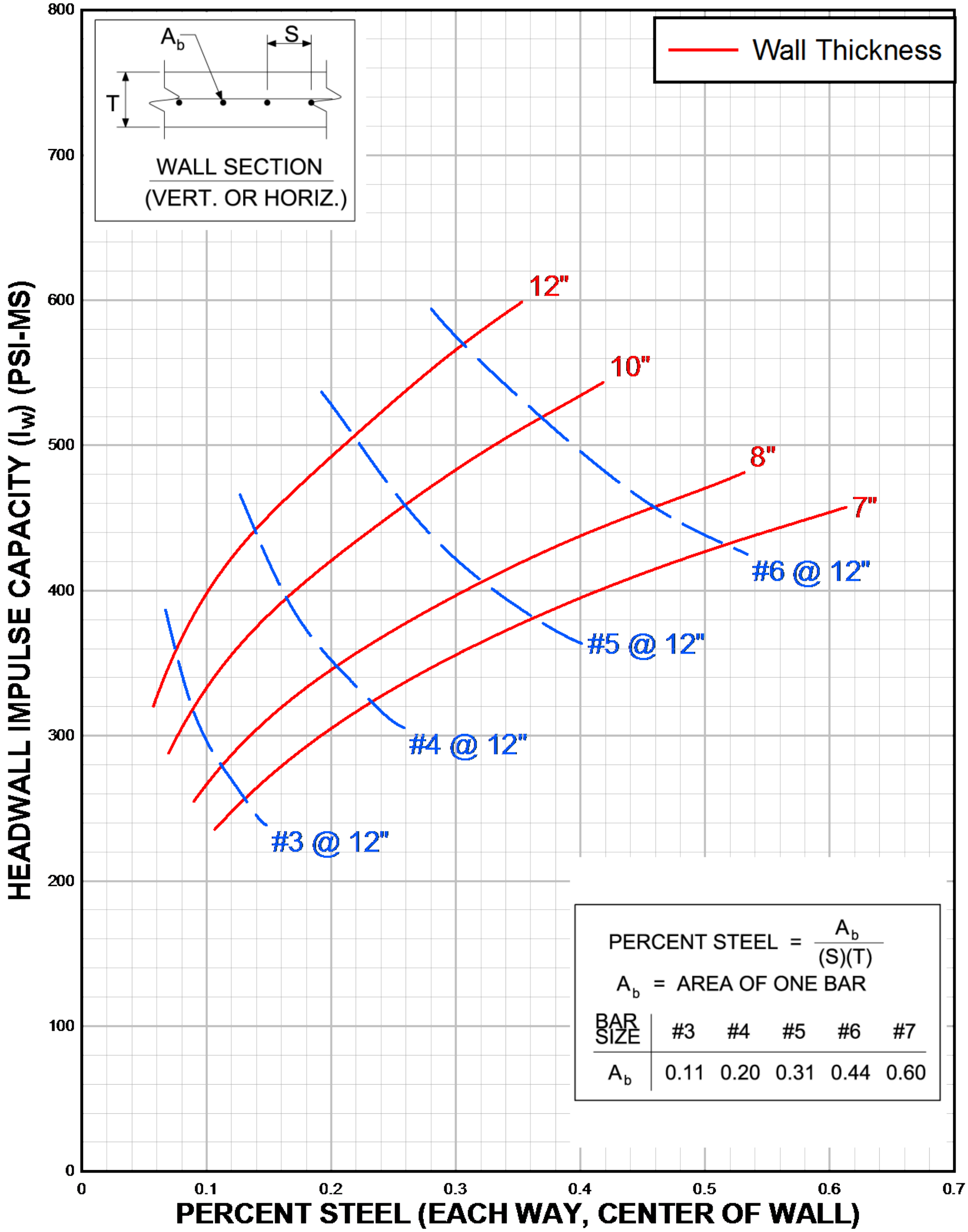


FIGURE 2-3: WALL IMPULSE CAPACITY VS. PERCENT STEEL (WITH 4.5'X8' DOOR) (WITHOUT PILASTERS)



BAR SIZE	#3	#4	#5	#6	#7
A_b	0.11	0.20	0.31	0.44	0.60

FIGURE 2-4: Wall Impulse Capacity vs. Percent Steel

(With 4.5'x8' Door) (Without Pilasters) (Single Steel Layer)

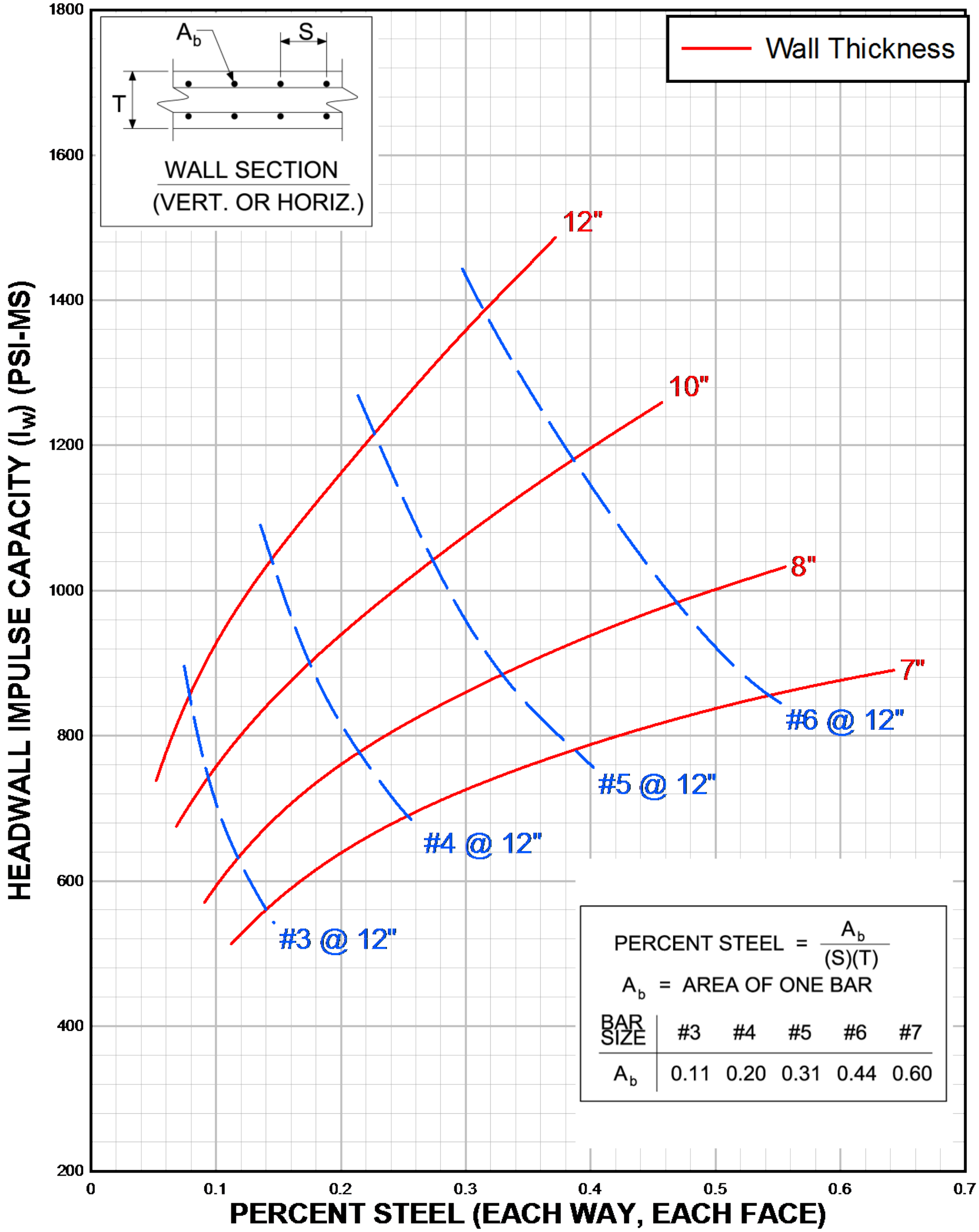


FIGURE 2-5: Wall Impulse Capacity vs. Percent Steel

(With 4.5'x8' Door) (With Pilasters)

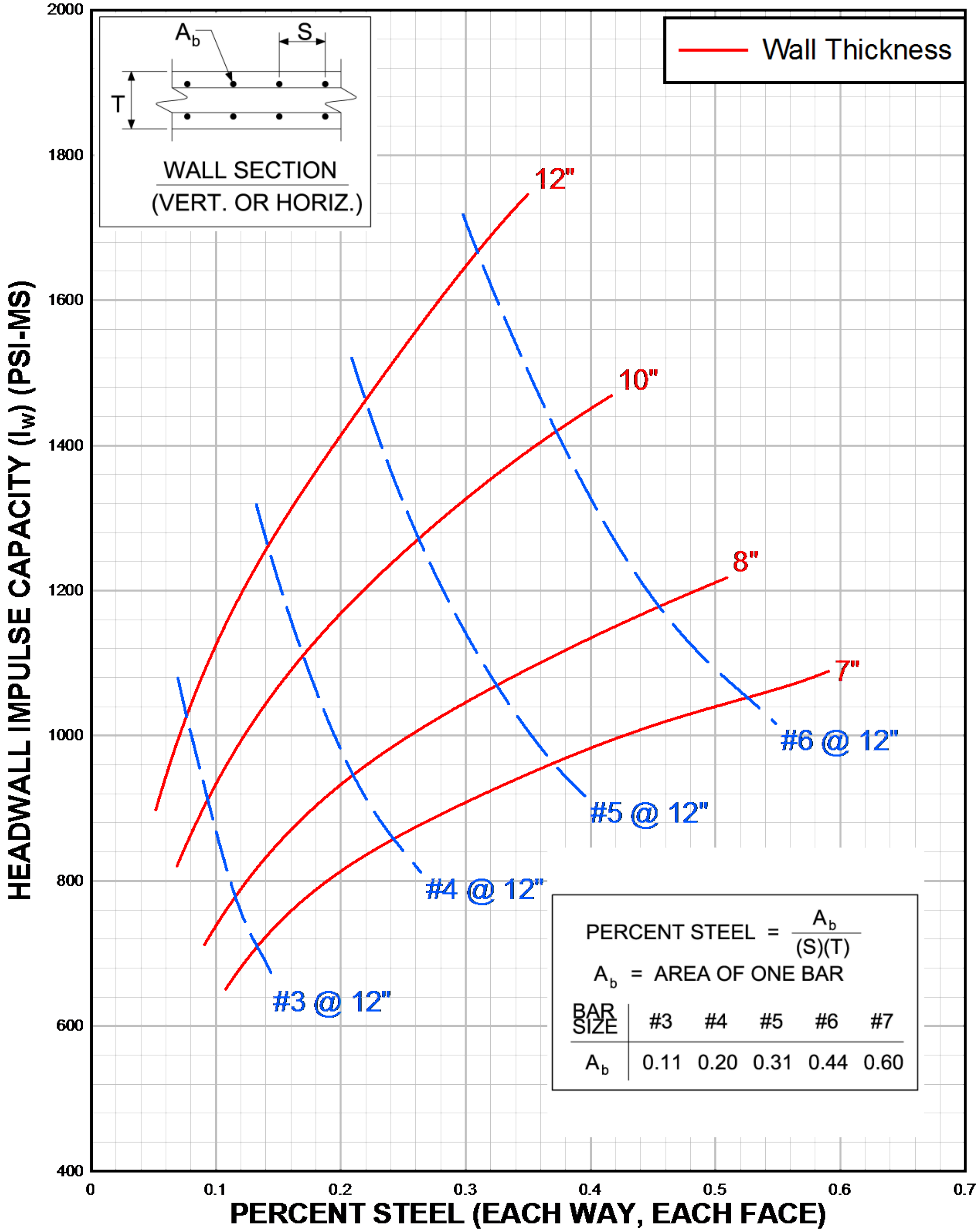


FIGURE 2-6: Wall Impulse Capacity vs. Percent Steel

(With 10'x10' Door) (With Pilasters)

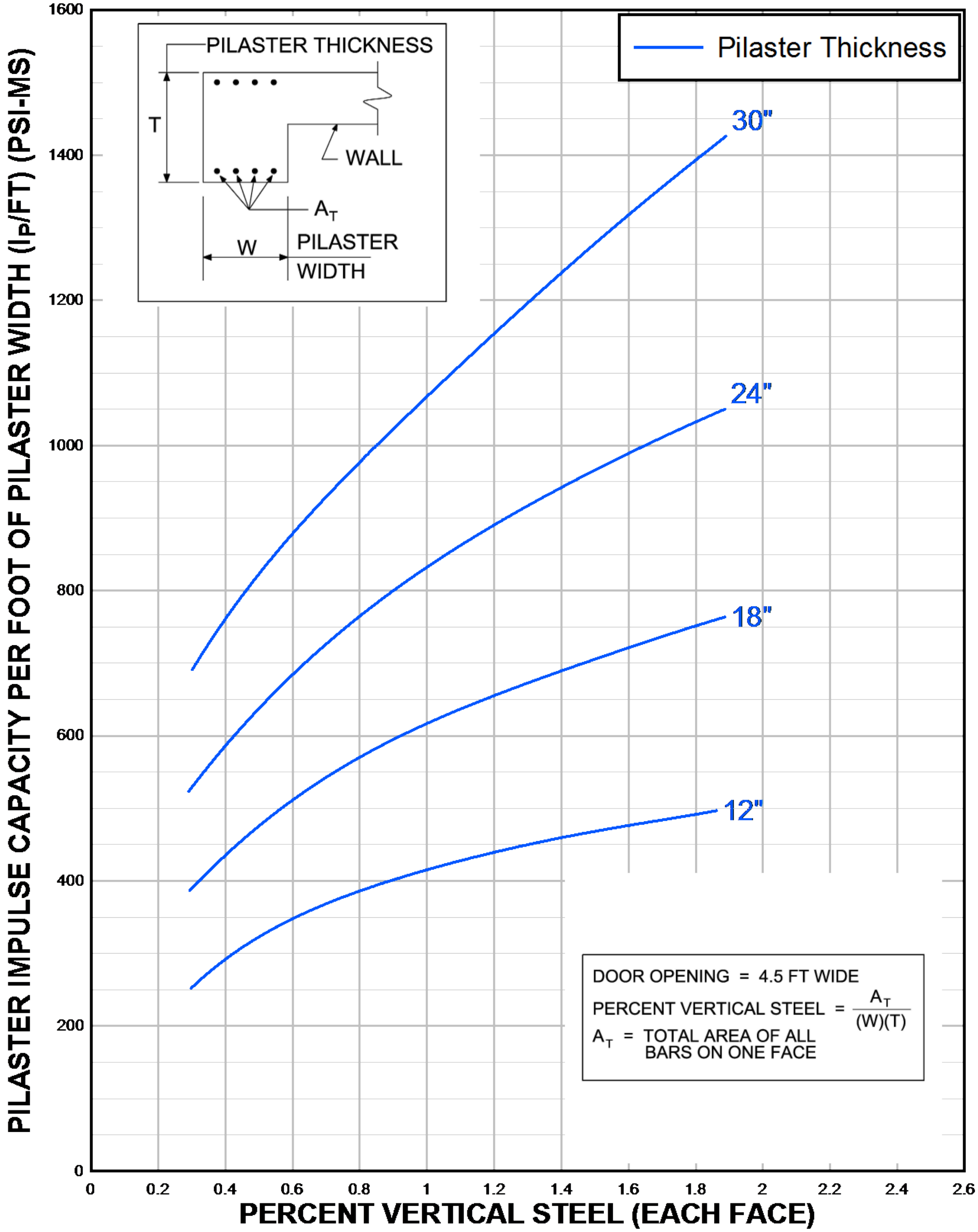


FIGURE 2-7: Pilaster Impulse Capacity vs. Percent Steel

(With 4.5'x8' Door)

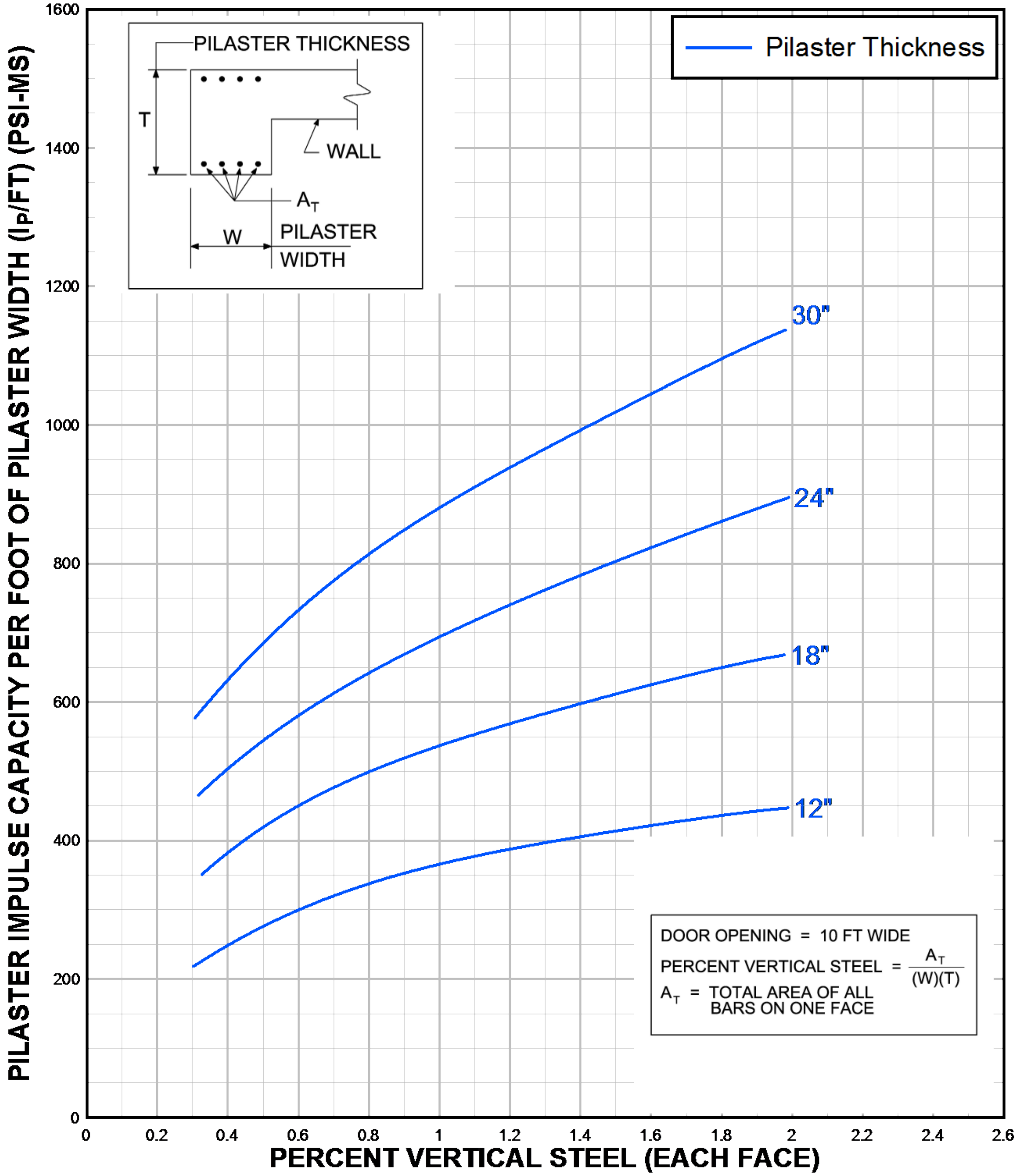


FIGURE 2-8: Pilaster Impulse Capacity vs. Percent Steel

(With 10'x10' Door)

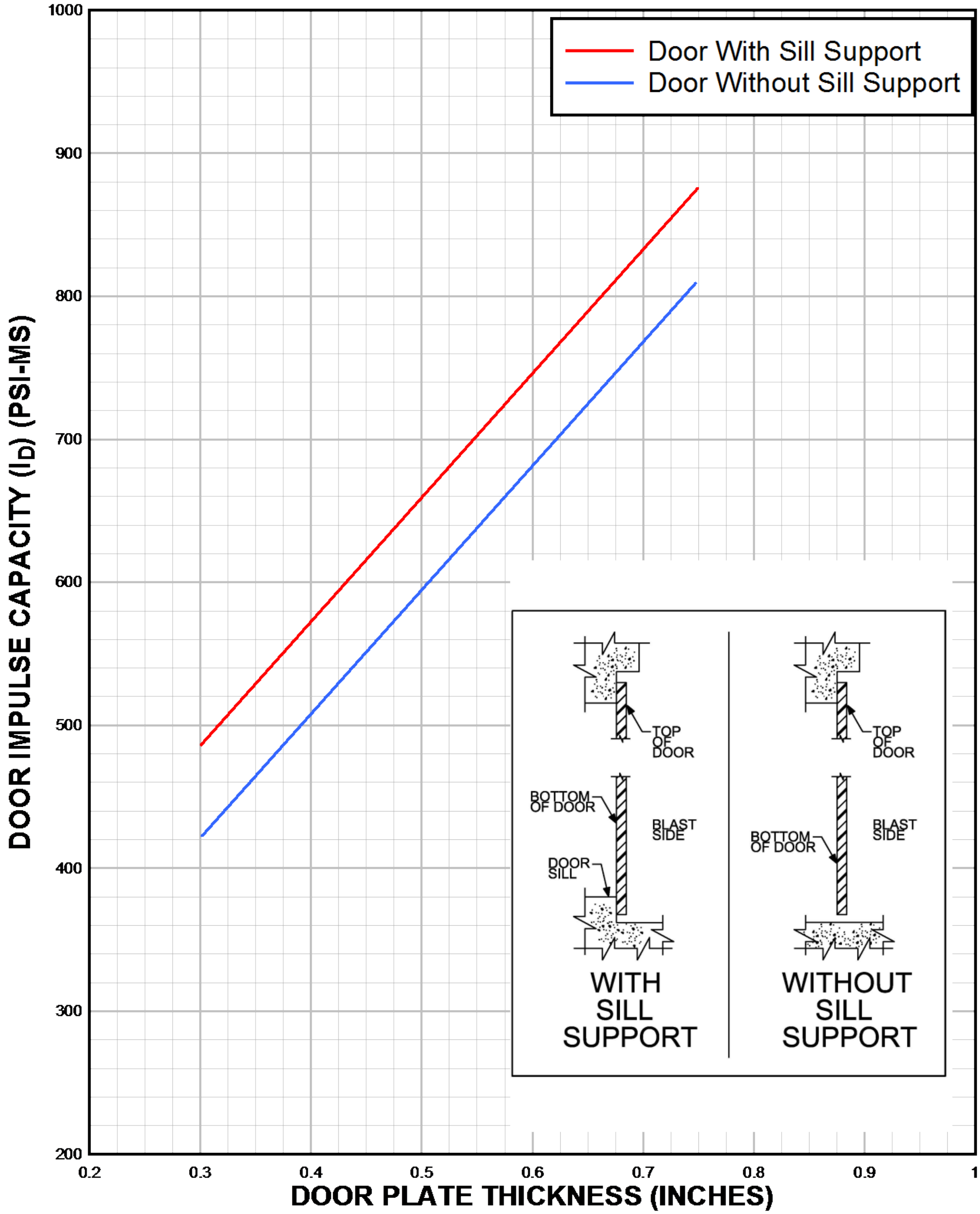


FIGURE 2-9: Door Impulse Capacity vs. Door Plate Thickness

(4.5’x8’ Unstiffened Single Leaf Door)

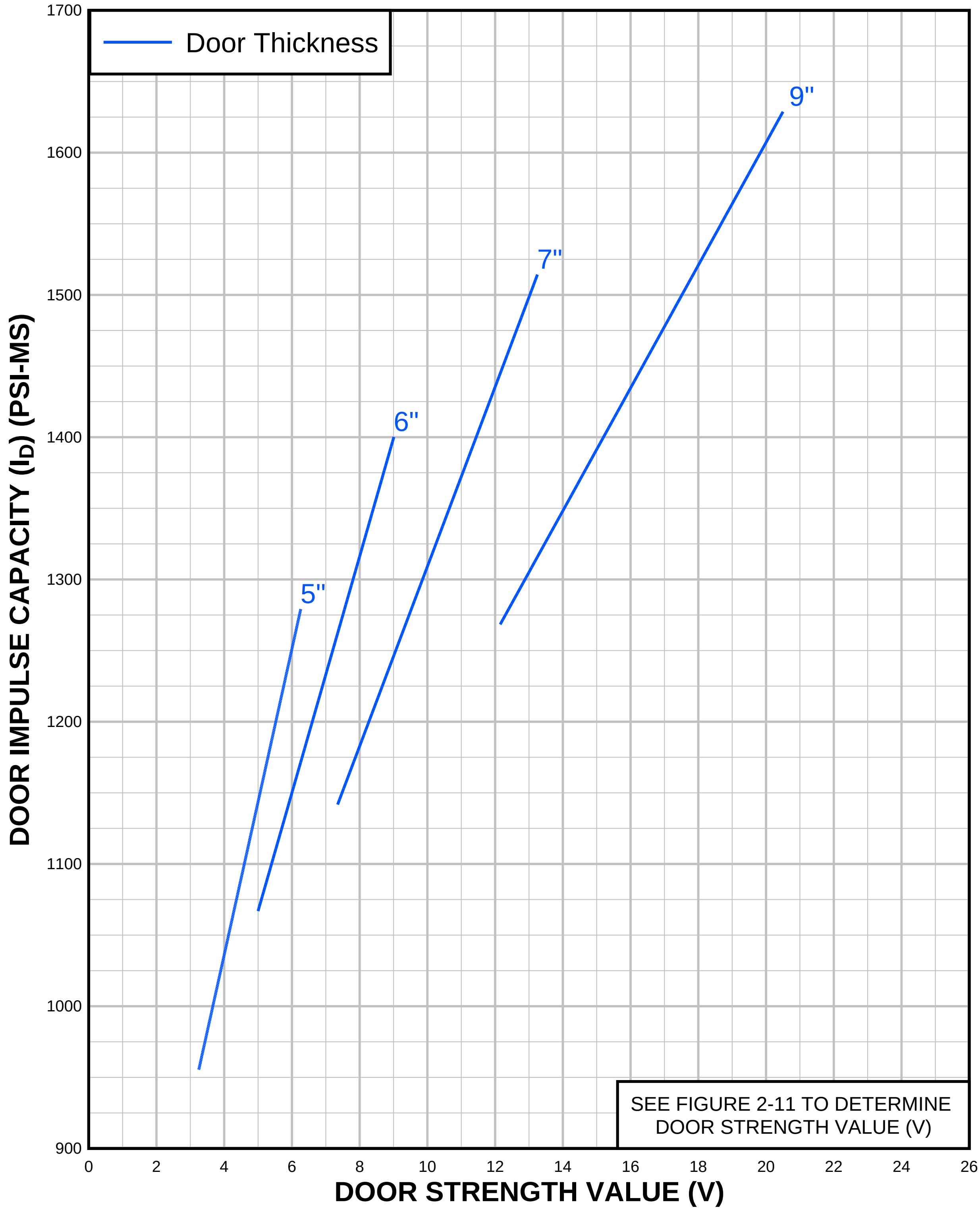


FIGURE 2-10: Door Impulse Capacity vs. Door Strength Value

(10'x10' Stiffened Single Unit Door)

DETERMINE DOOR STRENGTH VALUE (V) FOR FIGURE 2-10 FROM THE FOLLOWING EQUATIONS:

$$V = (T_2)(A)^2 + (T_1)(T_3 - A)^2$$

WHERE:

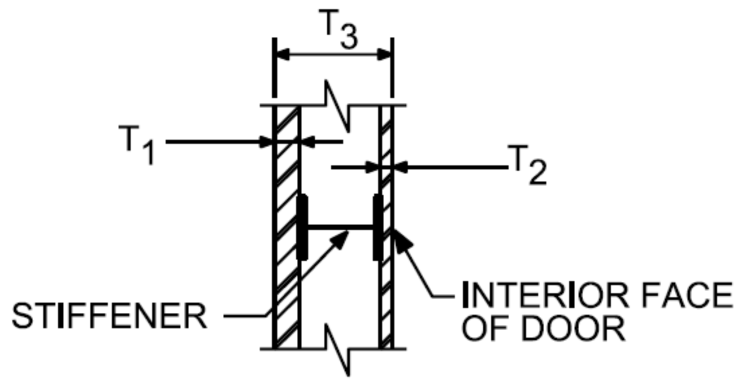
$$A = \frac{(0.5)(T_2)^2 + (T_1)(T_3)}{T_1 + T_2}$$

T_1 = OUTER PLATE THICKNESS (INCHES)

T_2 = INNER PLATE THICKNESS (INCHES)

T_3 = DOOR THICKNESS (INCHES)

*STIFFENERS NEGLECTED TO SIMPLIFY CALCULATIONS



SECTION THRU DOOR

(DOOR FOR TYPE 4 HEADWALL CONFIGURATION)

FIGURE 2-11: Equations for Door Strength Value (Stiffened Doors)

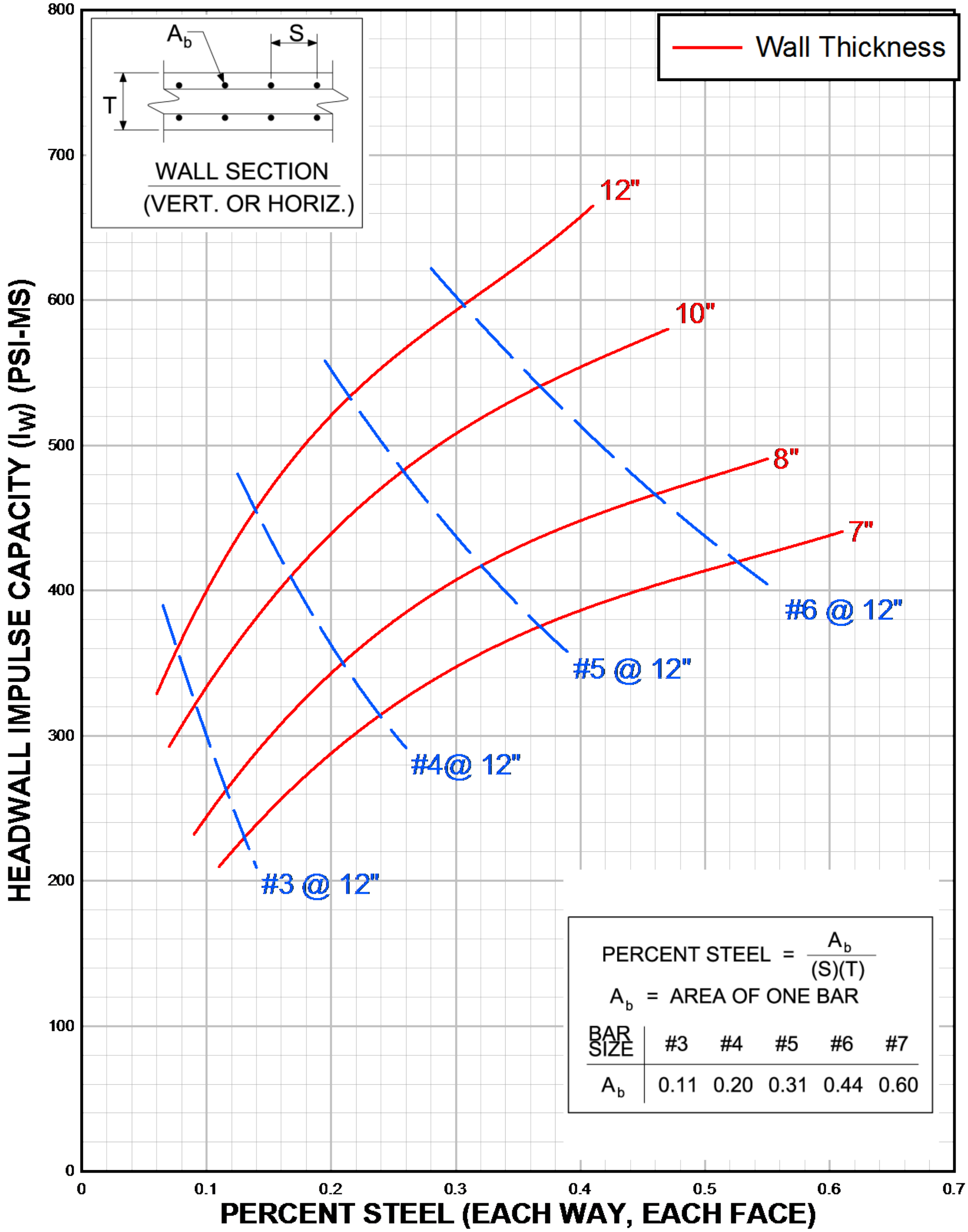


FIGURE 2-12: Wall Impulse Capacity vs. Percent Steel

(With 10'x10' Door) (Without Pilasters)

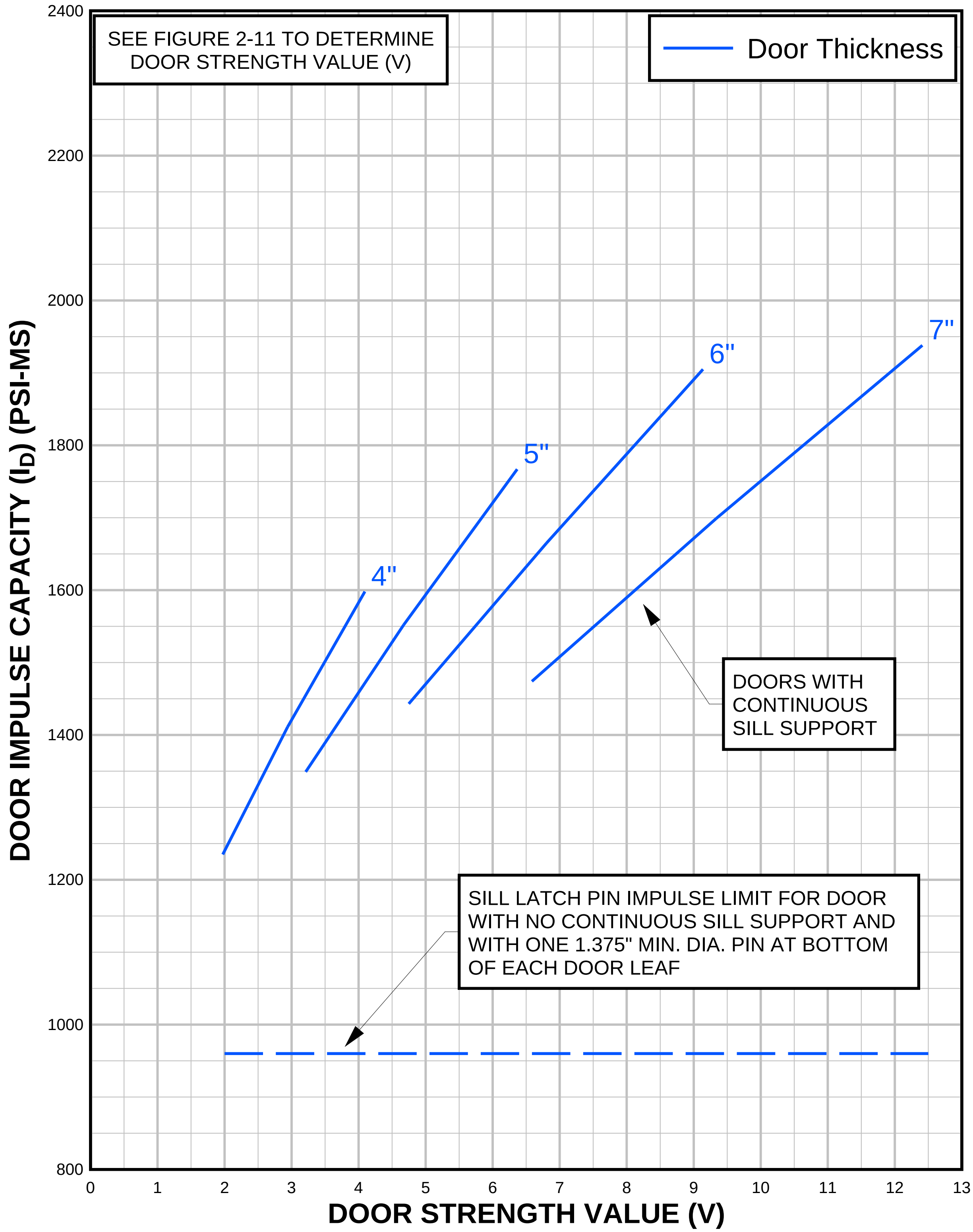


FIGURE 2-13: Door Impulse Capacity vs. Door Strength Value

(10'x10' Stiffened Double Leaf Door)

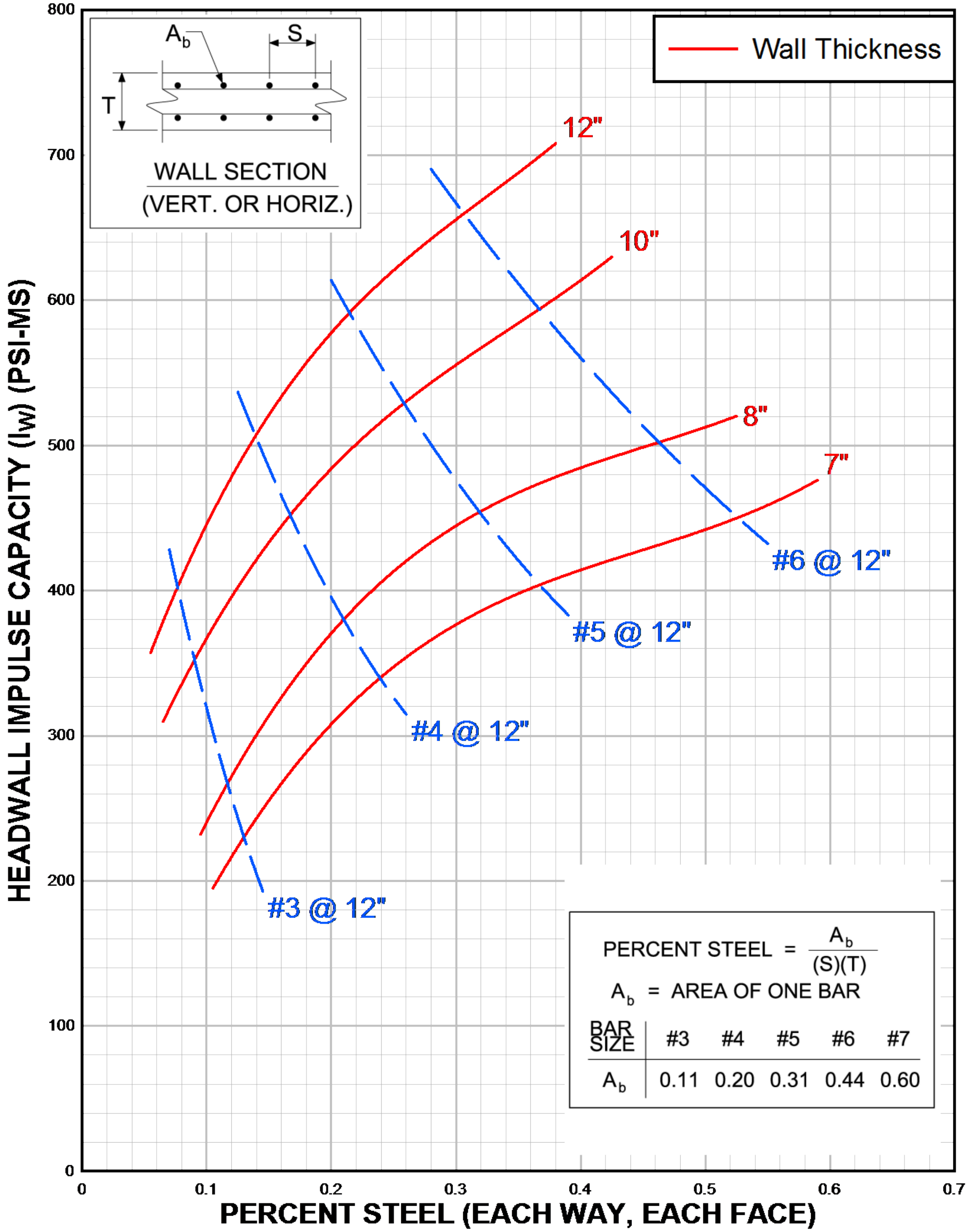


FIGURE 2-14: Wall Impulse Capacity vs. Percent Steel

(With 8'x8' Door) (Without Pilasters)

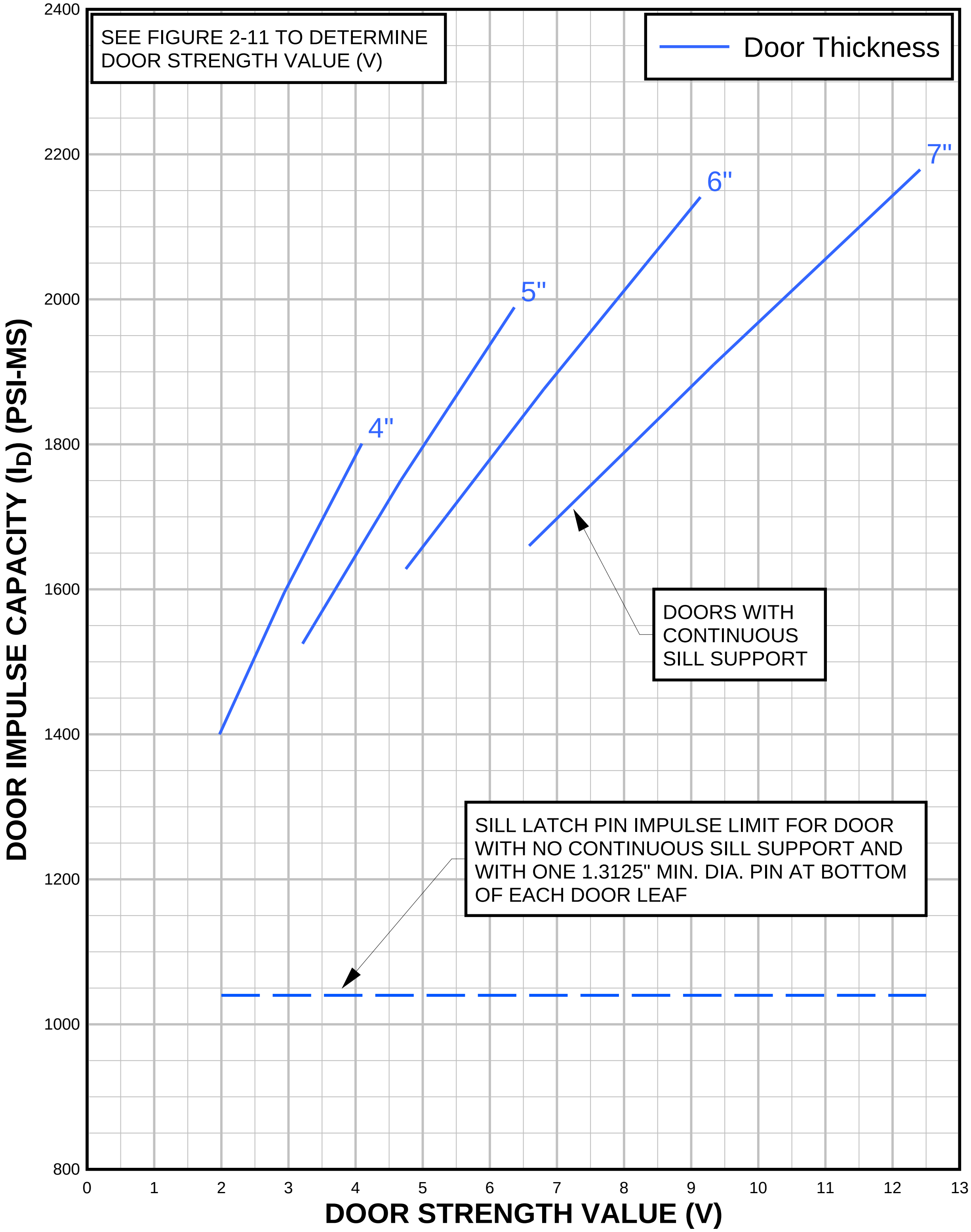


FIGURE 2-15: Door Impulse Capacity vs. Door Strength Value

(8'x8' Stiffened Double Leaf Door)

3.0 EXAMPLE PROBLEMS

3.1 Example Problem 1.

PROBLEM: Determine the adequacy of an existing undefined ECM to withstand the blast impulse from a quantity of explosives stored in adjacent ECMs.

GIVEN:
Net explosive weight = 500,000 LBS
Clear distance between sides of ECMs = 100 FT
Donor rear wall to acceptor front wall distance = 475 FT
Headwall Configuration = Type 4
Headwall thickness = 10 IN
Headwall percent steel = 0.258 (#5@12") (E.W., E.F.)
Pilaster width = 1.5 FT
Pilaster thickness = 24 IN
Pilaster percent vertical steel = 1.5
Door thicknesses:
- T_1 = 0.375 IN (exterior plate)
- T_2 = 0.250 IN (interior plate)
- T_3 = 5.0 IN (door thickness)

SOLUTION: Use Procedure 1

STEP 1: From Figure 1-1, select Type 4 Headwall Configuration.

STEP 2: W = 500,000 LBS

STEP 3: R = 100 FT

STEP 4: $R/W^{1/3} = 100/(500{,}000)^{1/3} = 1.26$

STEP 5: From Figure 2-1 with a scaled distance of 1.26, read a value of 11.30 for the scaled incident impulse.

STEP 6: $I_s = (11.30)\ (500{,}000)^{1/3} = 897$ PSI-MS

STEP 7: R = 475 FT

STEP 8: $R/W^{1/3} = 475/(500{,}000)^{1/3} = 5.98$

STEP 9: From Figure 2-2 with a scaled distance of 5.98, read a value of 7.45 for the scaled reflected impulse.

STEP 10 $I_r = (7.45)\ (500{,}000)^{1/3} = 591$ PSI-MS

STEP 11: Select the larger of the values from Steps 6 and 10.
Use 897 PSI-MS.

STEP 12: From Figure 2-6 with a percent steel of 0.258 (#5@12") and a wall thickness of 10 inches, read 1265 PSI-MS for the wall impulse capacity. Since 1265 PSI-MS is larger than 897 PSI-MS value of Step 11, the wall element is adequate for the blast loading.

STEP 13: From Figure 2-8 with a percent vertical steel of 1.5, and a pilaster thickness of 24 inches, read 803 PSI-MS for the pilaster -impulse capacity per foot of pilaster width. Multiply this value by the pilaster width of 1.5 feet to obtain a total pilaster impulse capacity of 1205 PSI-MS. Since 1205 PSI-MS is larger than the 897 PSI-MS value of Step 11, the pilaster is adequate for the blast loading.

STEP 14: From Figure 2-11 with T_1 = 0.375”, T_2 = 0.250” and T_3 = 5” calculate V = 3.75. Then from Figure 2-10 with V = 3.75 and a 5-inch thick door read 1010 PSI-MS for the door impulse capacity. Since 1010 PSI-MS is larger than the 897 PSI-MS value of Step 11, the door is adequate to resist the imposed blast loading.

***All structural components of this ECM have an impulse capacity higher than the applied impulse. This ECM is considered a good candidate for further analysis using the UFC 3-340-02.*

3.2 Example Problem 2

PROBLEM: Determine the amount of explosives that may be stored in adjacent ECMs without creating a blast propagation hazard to an undefined ECM.

GIVEN: Clear distance between sides of ECMs = 100 FT
Donor rear wall to acceptor front wall distance = 475 FT
Headwall configuration = Type 1
Headwall thickness = 10 IN
Percent steel in headwall face = 0.258 (#5@12") (E.W., E.F.)
Door size = 4.5 FT wide
Door plate thickness = 0.625 IN
Door has sill support

SOLUTION: Use Procedure 2

FIRST ITERATION

STEP 1: From Figure 1-1, select Type 1 Headwall Configuration.

STEP 2: From Figure 2-3 with a percent steel of 0.258 and a 10-inch wall thickness, read 622 PSI-MS for the wall impulse capacity.

STEP 3: From Figure 2-9 for a 4.5 FT wide X 0.625 IN thick door supported on all four sides, read 768 PSI-MS for the door impulse capacity.

STEP 4: Select the smaller of the values from Steps 2 and 3.
Use 622 PSI-MS.

STEP 5: Select a value of 500,000 LBS for the net explosive weight.

STEP 6: R = 100 FT

STEP 7: $R/W^{1/3} = 100/(500{,}000)^{1/3} = 1.26$

STEP 8: From Figure 2-1 with a scaled distance of 1.26, read a value of 11.30 for the scaled incident impulse.

STEP 9: $I_s = (11.30)\ (500{,}000)^{1/3} = 897$ PSI-MS

STEP 10: R = 475 FT

STEP 11: $R/W^{1/3} = 475/(500{,}000)^{1/3} = 5.98$

STEP 12: From Figure 2-2 with a scaled distance of 5.98, read a value of 7.45 for the scaled reflected impulse.

STEP 13: $I_r = (7.45)(500{,}000)^{1/3} = 591$ PSI-MS

STEP 14: Select the larger at the values from Steps 9 and 13.
Use 897 PSI-MS

STEP 15: Since the impulse capacity (622 PSI-MS) determined by Step 4 is less than the impulse loading (897 PSI-MS) determined by Step 14, then the acceptor ECM is not adequate to resist the blast loading from the 500,000 LBS of explosives. Repeat Steps 5 through 15 with a lower quantity of net explosive weight.

SECOND ITERATION

STEP 5b: Try a value of 100,000 LBS for the net explosive weight.

STEP 6b: R = 100 FT

STEP 7b: $R/W^{1/3} = 100/(100{,}000)^{1/3} = 2.15$

STEP 8b: From Figure 2-1 with a scaled distance of 2.15, read a value of 11.30 for the scaled incident impulse.

STEP 9b: $I_s = (11.30)\ (100{,}000)^{1/3} = 524$ PSI-MS

STEP 10b: R = 475 FT

STEP 11b: $R/W^{1/3} = 475/(100{,}000)^{1/3} = 10.23$ (use Fig. 2-2 maximum curve value of 6.0)

STEP 12b: From Figure 2-2 with a scaled distance of 6.0, read a value of 7.5 for the scaled reflected impulse.

STEP 13b: $I_r = (7.5)\ (100{,}000)^{1/3} = 348$ PSI-MS

STEP 14b: Select the larger of the values from Steps 9b and 13b.
Use 524 PSI-MS

STEP 15b: Since the impulse capacity (622 PSI-MS) determined by Step 4 is greater than the impulse loading (524 PSI-MS), 100,000 lbs is an acceptable quantity of stored explosive in the donor ECM. Additional iterations may be performed if additional storage capacity is needed.

***All structural components of this ECM have an impulse capacity higher than the applied impulse. This ECM is considered a good candidate for further analysis using the UFC 3-340-02.*