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US Army Corps
of Engineers
Huntsville Division

USER'S MANUAL

GUIDE FOR EVALUATING 12 INCH SUBSTANTIAL DIVIDING WALLS (SDWs) TO PROVIDE PROTECTION FROM REMOTE OPERATION

VOLUME I

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13. ABSTRACT *(Maximum 200 words)*

This report provides installations with procedures to relate Net Explosive Weights (NEWs) to combinations of intervening 12-inch Substantial Dividing Walls (SDWs) to provide protection to personnel from remote operations where an accidental detonation is the hazard. Protection to be provided is IAW DoD and Army policy: 2.3 psi maximum overpressure exposure and no hazardous fragments. The report consists of two Volumes. Volume I is a "how to" guide for installation use: Volume II is the rationale (calculations, etc) behind the Volume I. Protection from thermal effects from flash fires, deflagrations, etc. is not addressed in the Guide.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this guide is to provide installations with procedures to relate Net Explosive Weights (NEW) to combinations of intervening 12-inch Substantial Dividing Walls (SDWs) to provide protection to personnel from remote operations. Protection to be provided is IAW DoD and Army policy: 2.3 psi maximum overpressure exposure and no hazardous fragments. Thermal criteria is not addressed in this guide. Guidance on thermal criteria may be found in References 1 and 2.

1.2 BACKGROUND

In recent years, the Department of Explosive Safety Board (DDESB) introduced increased protection requirements for personnel exposed to remotely controlled operations. Requirements included: (1) limiting personnel exposure to overpressures not in excess of 2.3 psi, and (2) protection of personnel from haxardous fragments and structural failures. These requirements forced some Army installations to relocate operators to bays sufficiently removed from the donor bay, and have imposed operational constraints since intervening bays can then be occupied only when the remote operation is not in progress.

1.3 SCOPE OF GUIDE

This guide is limited to existing Army munition processing facilities constructed of 12-inch Substantial Dividing Walls. The guide is primarily directed toward the following:

a. Overpressures prediction at personnel occupied bays due to an incident in donor bay where the remote explosives operation is underway.

b. Assessment of Substantial Dividing Walls' capability to provide the necessary protection to operators (Category I protection) from a remote controlled operation.

c. Fragmentation resistance of Substantial Dividing Walls.

d. Suggested methods in upgrading SDWs for increased capacity (not design procedures).

The procedures presented in this guide are not applicable to new facility design.

1.4 FORMAT OF GUIDE

This guide is volume I of two volume document. Volume II forms the basis for this guide. Volume II is not required for field use. To cover most wall element configurations, it was necessary to include in this guide a significant number of figures to represent the different Substantial Dividing Walls that may be encountered. Interpolation or extrapolation of data for wall configurations not shown will be required by installation personnel. Commonly accepted symbols have been used as much as possible. A significant number of example problems have also been included to guide field personnel in the implementation of this guide.

1.5 CRITERIA

a. Maximum NEW is 150 lb..

b. Wall height and width of SDWs varies.

c. Design fragment weight[1] .... 3.44 oz.

d. Velocity of fragment[1] .... 4,450 feet per second.

(1) Based on the 8-inch (Composition B) projectile. This represents a "worst case" fragment (Reference 3).

1.6 DEFINITIONS

Definitions used in this guide are presented in Appendix A.

1.7 REFERENCES

References used in this guide are presented in Appendix F.

2.0 BLAST EFFECTS AND SDWs WALL CAPACITY

2.1 BLAST CAPACITIES OF SUBSTANTIAL DIVIDING WALLS

Blast capacity of SDWs has been developed for the types of walls normally found on Army installations, namely: cantilevered walls, walls fixed on 2-sides, and walls fixed on 3-sides (see Appendix B). Blast capacities vary significantly between each type, with the cantilevered wall type exhibiting low ultimate capacity, followed by the 2-sides fixed and 3-sides fixed walls. Wall types and their ultimate resistance are presented in Appendix B.

To quickly assess the adequacy of SDWs for blast effects, ready reference plots of allowable peak shock pressure pressure (P) versus load duration (T) were generated. Appendix C presents P-T curves for the wall types encountered in existing munition facilities. Size of walls were varied as shown. A known P-T point plotted on the figure for a specific wall height would convey whether the wall is adequate in providing personnel protection (Category I). If the plotted point falls below the curve in question, then the wall is adequate. If the plotted point falls above the curve in question, then the wall will not provide personnel protection.

Procedures for using these figures are presented in example problems.

2.2 PERSONNEL EXPOSURE TO OVERPRESSURES

The default distance that meets DDESB requirements for personnel protection is K24. The term "K24" signifies a distance D where $D=24W^{1/3}$. This distance must be used when no personnel protection other than distance is provided. A DDESB approved pressure prediction method that recognizes the pressure mitigating ability of a 3-walled cubicle is described in Appendix D. (See Appendix D for limitations on the application of this method).

2.3 METHOD TO PREDICT BLAST LOADING ON SDWs FOR A SPECIFIED STANDOFF

The basic approach in predicting the blast loadings on SDWs was the development of a simple method that can be used by field personnel. The method presented in this guide requires the prediction of the shock wave loading using Figure 2-1, and applying correction coefficients to closely duplicate results obtained using computer software. Figure 2-2 presents the coefficients that must be applied to the pressure loading. Figure 2-3 presents the coefficients that must be applied to the impulse loading. The method in applying this procedure is presented in Example Problem 3.1.

2.4 SUBSTANTIAL DIVIDING WALLS RESISTANCE TO FRAGMENTS

Based on fragment criteria of Section 1.5, one SDW is capable of arresting the design fragment of 3.44 oz. with a velocity of 4,450 feet per second. The design fragment weight is based on those resulting from accidental detonation of an 8-inch HE Comp B projectile round. This represents a "worst case" fragment as far as Army munitions are concerned. The perforation and spalling thickness for this fragment criteria is 11.7-inches. This is less than the actual thickness of a SDW (12-inch).

2.5 BREACHING OF SUBSTANTIAL DIVIDING WALLS

Breaching of 12-inch SDWs are presented in Figures 2-4, and 2-5 for bare and cased munitions respectively. The three regions shown can be used to predict the extent of damage to a SDW. Breaching is dependent on the quantity of explosive and the standoff distance from the explosive source to the point in question. If the wall is breached or spalls from an incident in a donor bay, either of two conditions must be satisfied: spall plates must be provided if personnel are in the immediate bay, or the personnel must be moved to a standoff distance corresponding to the "no damage" region. Figure 2-6 provides a concept for spall plate installation. Breaching is never a concern as long as the criteria requiring a 3' minimum distance to the wall and a 15 lb limit for the remote operation (given 12" walls) is met.

Note: In most likelihood breach will not control, spillover pressure will.

2.6 INCREASING CAPACITY OF SDWs TO RESIST BLAST PRESSURE

Increasing the capacity of SDW to resist higher blast loadings may be achieved in several ways, namely: structural strengthening and/or increasing the mass of the element in question. Structural strengthening can be achieved by providing fixity condition at the unsupported edge(s) of 12-inch SDW (see Figure 2-7). Changing a wall type from a cantilever to 2-edges fixed or from 2-edges fixed to 3-edges fixed can substantially increase the load capacity of the wall (see Appendix B). Structural strengthening of 12-inch SDWs allows the positioning of operators closer to the donor bay providing all other safety criteria (such as spillover pressure) are met. Increasing the mass of the element achieves similar results. The simplest method would be the inclusion of a specified thickness of sand behind the element in question (toward the acceptor bay). Graphical plots showing the effects of sand layers behind cantilevered walls, and 2-edges and 3-edges fixed walls are presented in Appendix E. The plotted data shows a greater increase at lower load duration than at higher load durations. Figure 2-8 present a concept for increasing the element mass to resist higher blast loading. This concept shows loose sand retained by a structural framing system. The use of sand bags is also an acceptable alternate providing the sand bags are restrained in place, and an adjustment is made to the thickness to account for voids between the sand bag units. A reasonable adjustment in thickness of 15 percent is selected for use in this guide. A concept of restraining the sand bag units, is presented in Figure 2-9. This concept uses a Geogrid polymer material to provide the necessary restraint (see Figure 2-10). The procedure for evaluating wall adequacy and methods of strengthening are presented in Example Problems 3.2 and 3.3.

2.7 METHODS TO PROTECT PERSONNEL IN A REMOTE BAY

Personnel protection can be achieved by:

a. Locating them at the proper default distance (K24). At t' .s default distance, personnel will not be exposed to overpressures greater than 2.3 psi. This approach although places operational constraints, but can be achieved with minimum impact on facility cost.

b. Positioning operators in hardened structures. This approach requires that all structural elements (walls, roof and doors) be capable in resisting the blast loadings. For existing facilities, this may be a major undertaking especially when the occupied bay is in close proximity of the donor bay. The cost effectiveness of this approach must be evaluated on a case-by-case basis. When operators are positioned at the default distance K24, the roof over the operator should provide the necessary protection. Documented data indicate that corrugated asbestos roofing material is capable in resisting a dynamic overpressure of approximately 4 psi. These type of roofs typically found on existing installations constructed with 12-inch Substantial Dividing Walls.

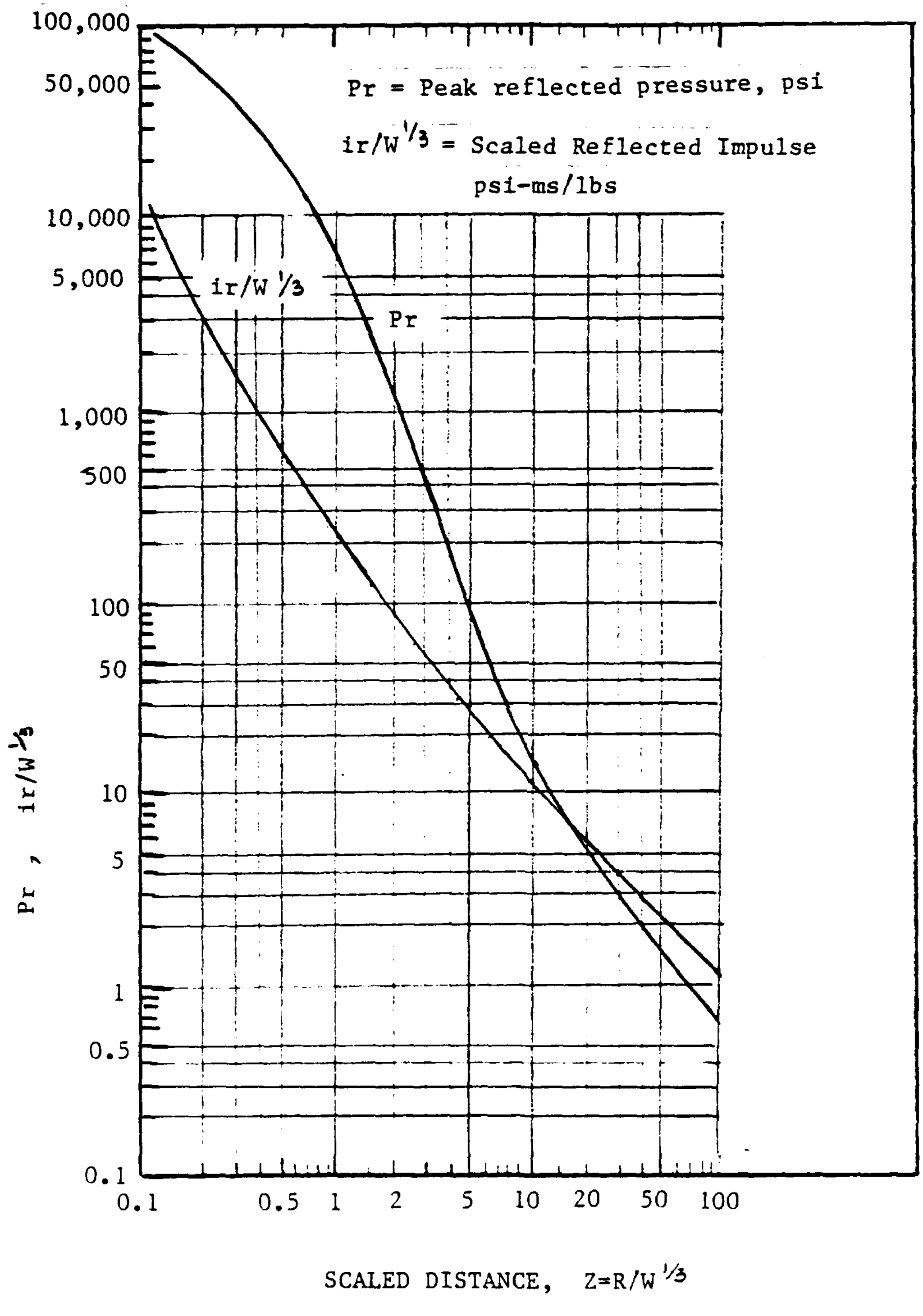


FIGURE 2-1 SHOCK WAVE PARAMETERS

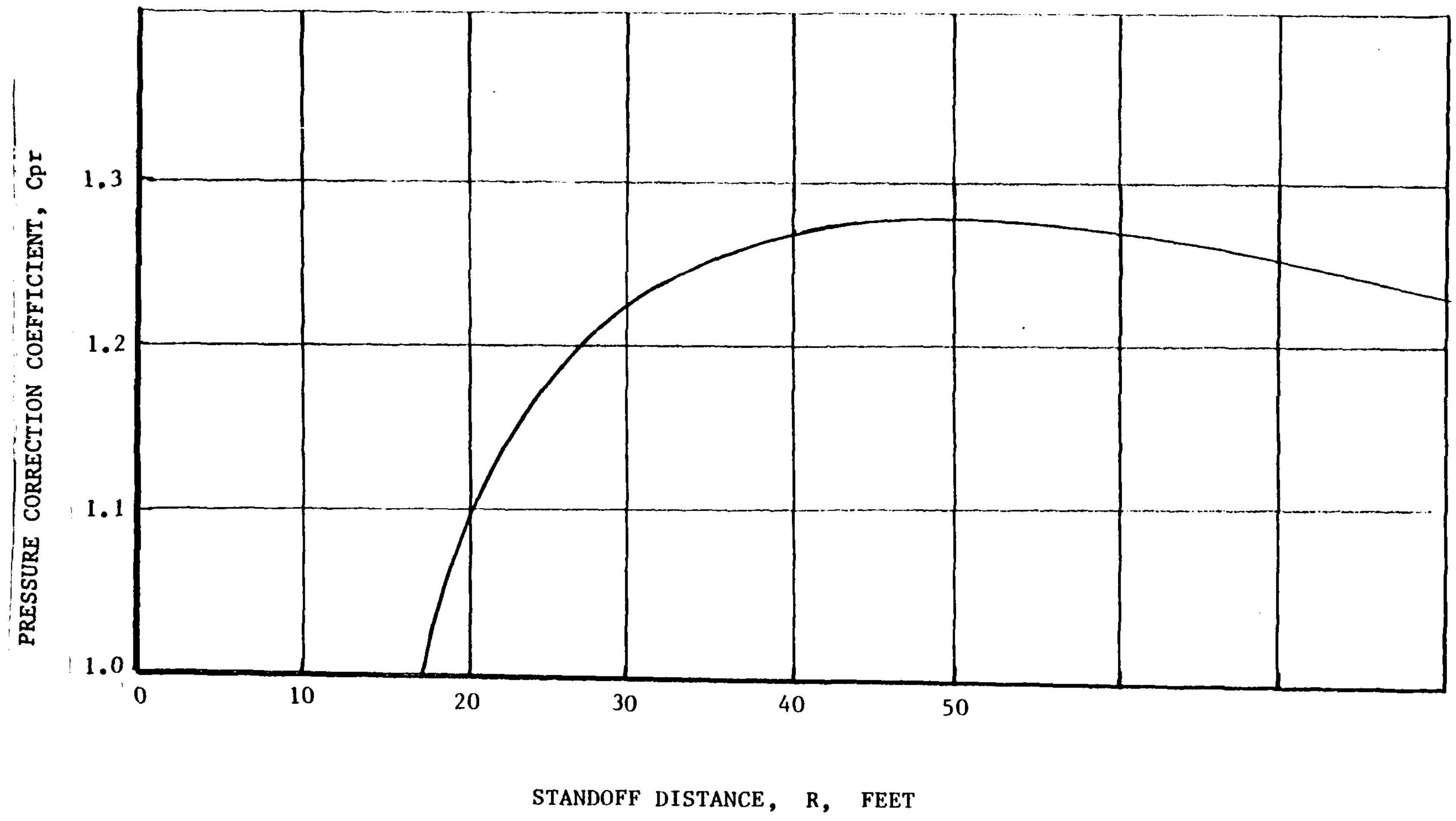


FIGURE 2-2 PRESSURE CORRECTION COEFFICIENT VERSUS STANDOFF DISTANCE

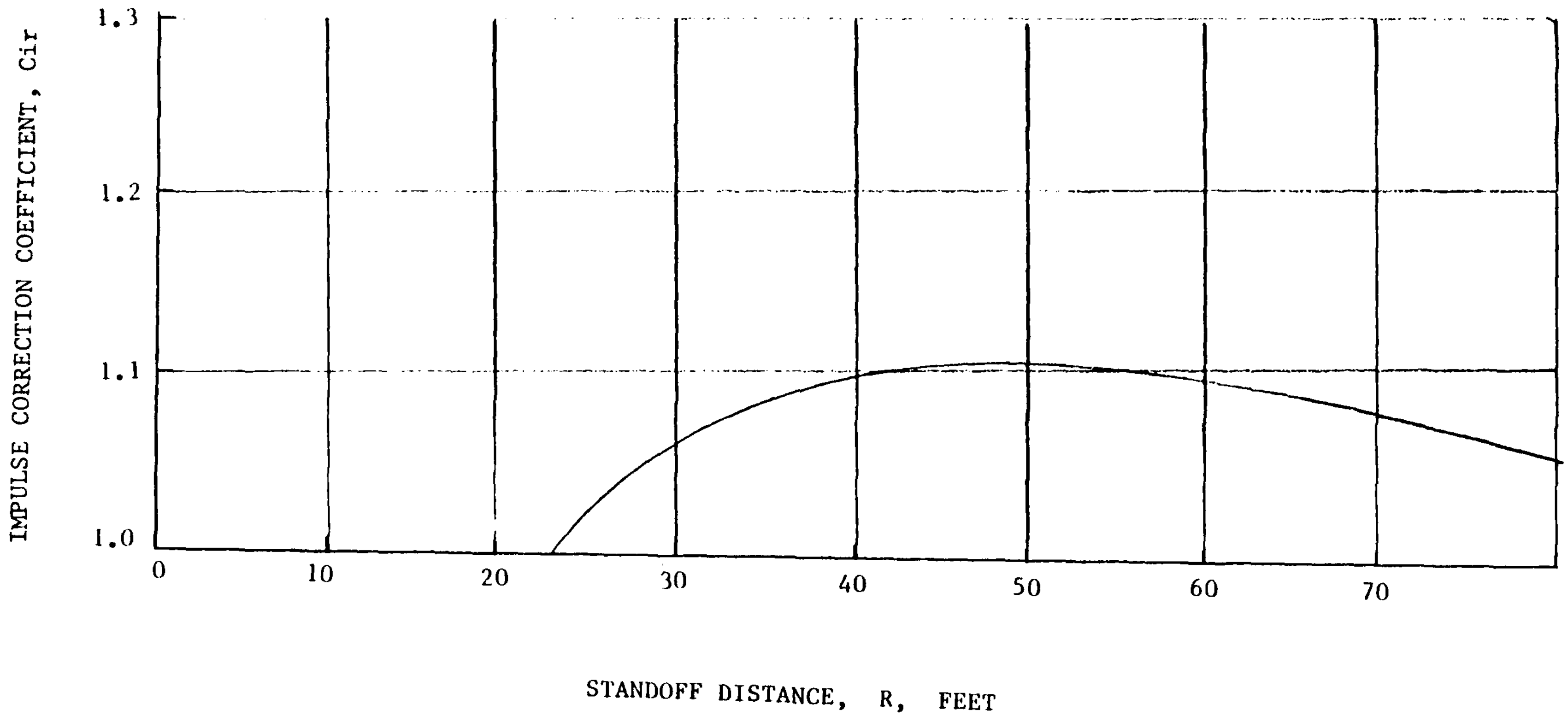


FIGURE 2-3 IMPULSE CORRECTION COEFFICIENT VERSUS STANDOFF DISTANCE

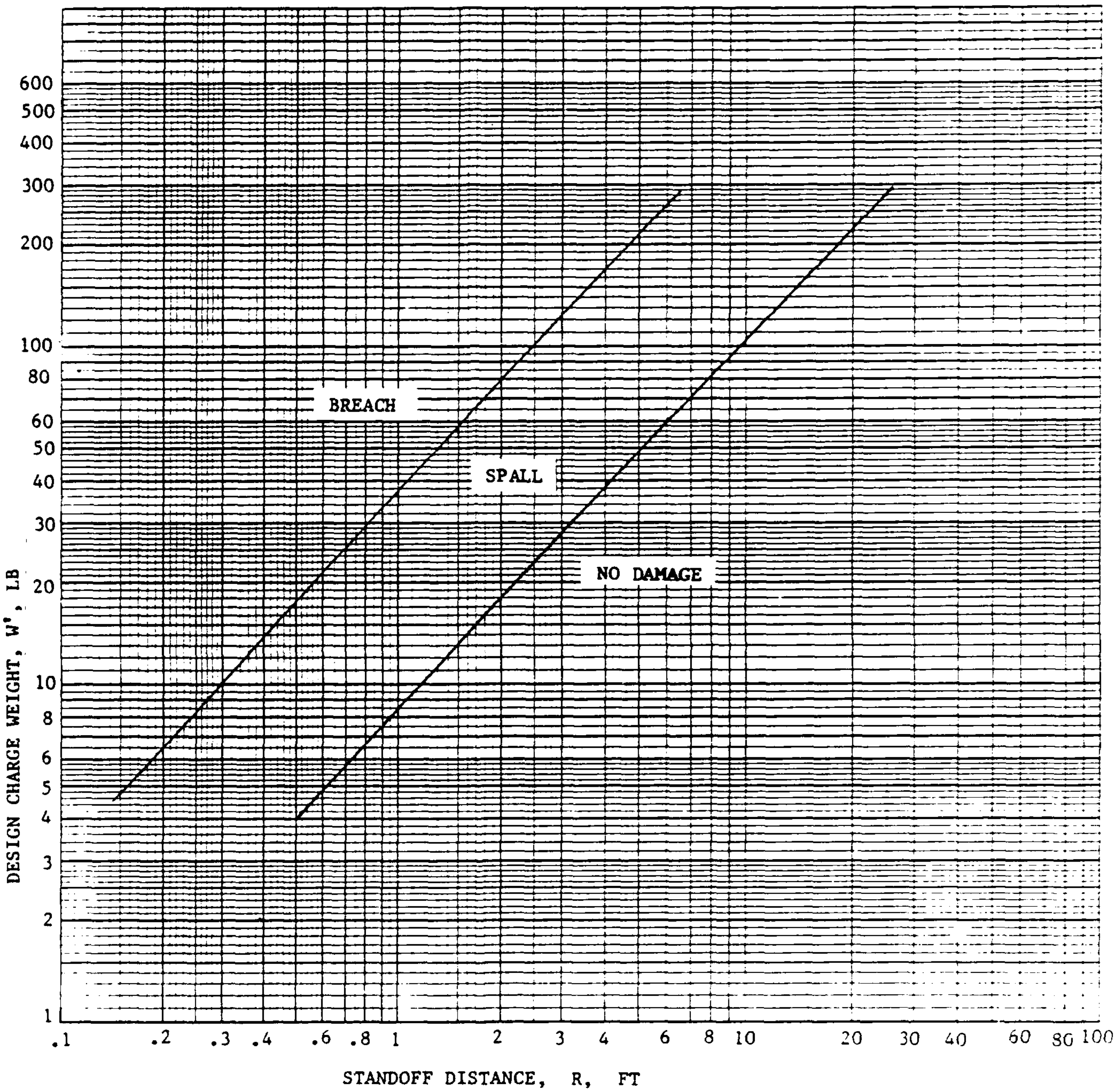
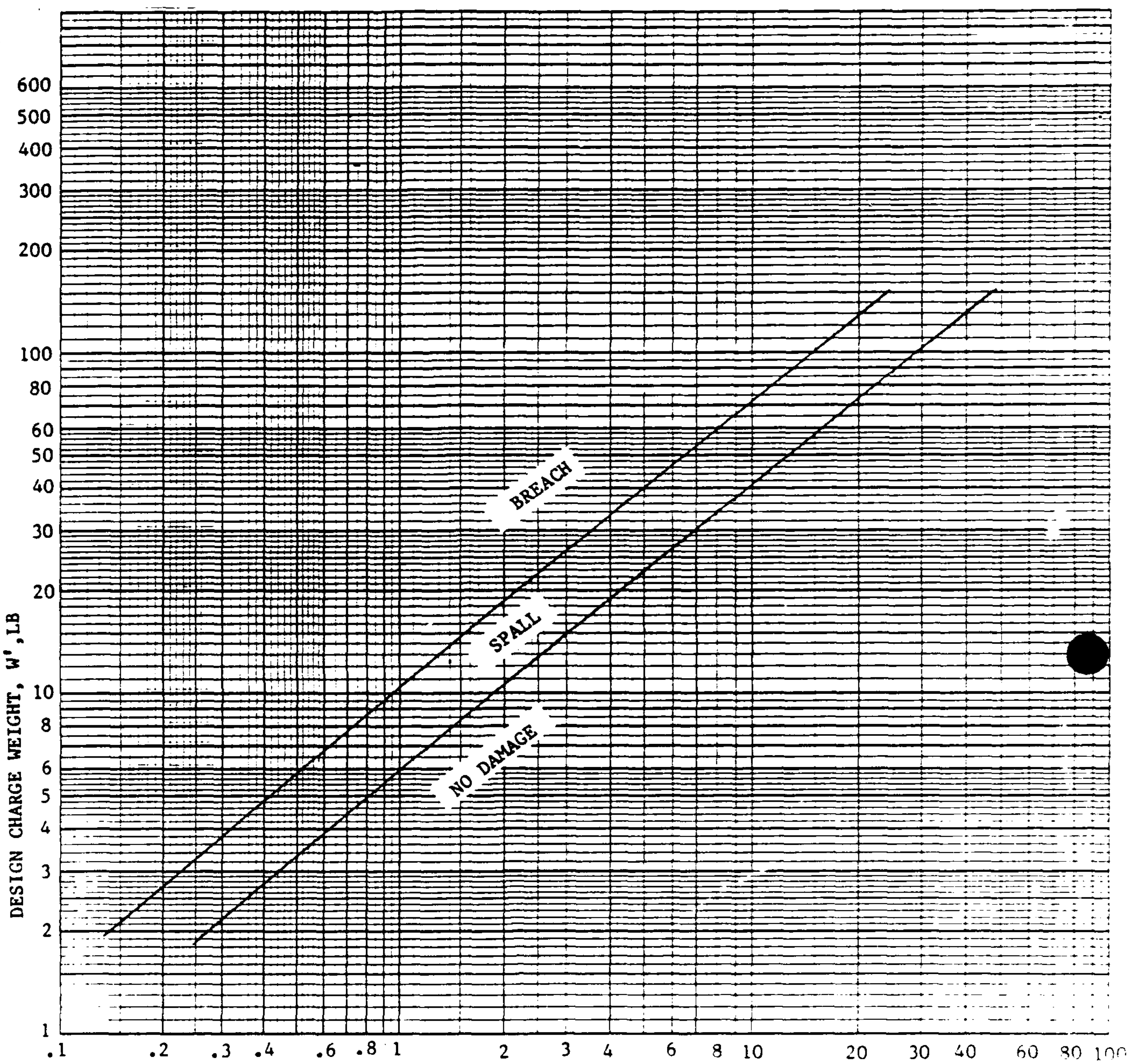


FIGURE 2-4 DESIGN CHARGE WEIGHT VERSUS STANDOFF DISTANCE(BARE CHARGE)



STANDOFF DISTANCE, R, FT

FIGURE 2-5 DESIGN CHARGE WEIGHT VERSUS STANDOFF DISTANCE(CASED CHARGES)

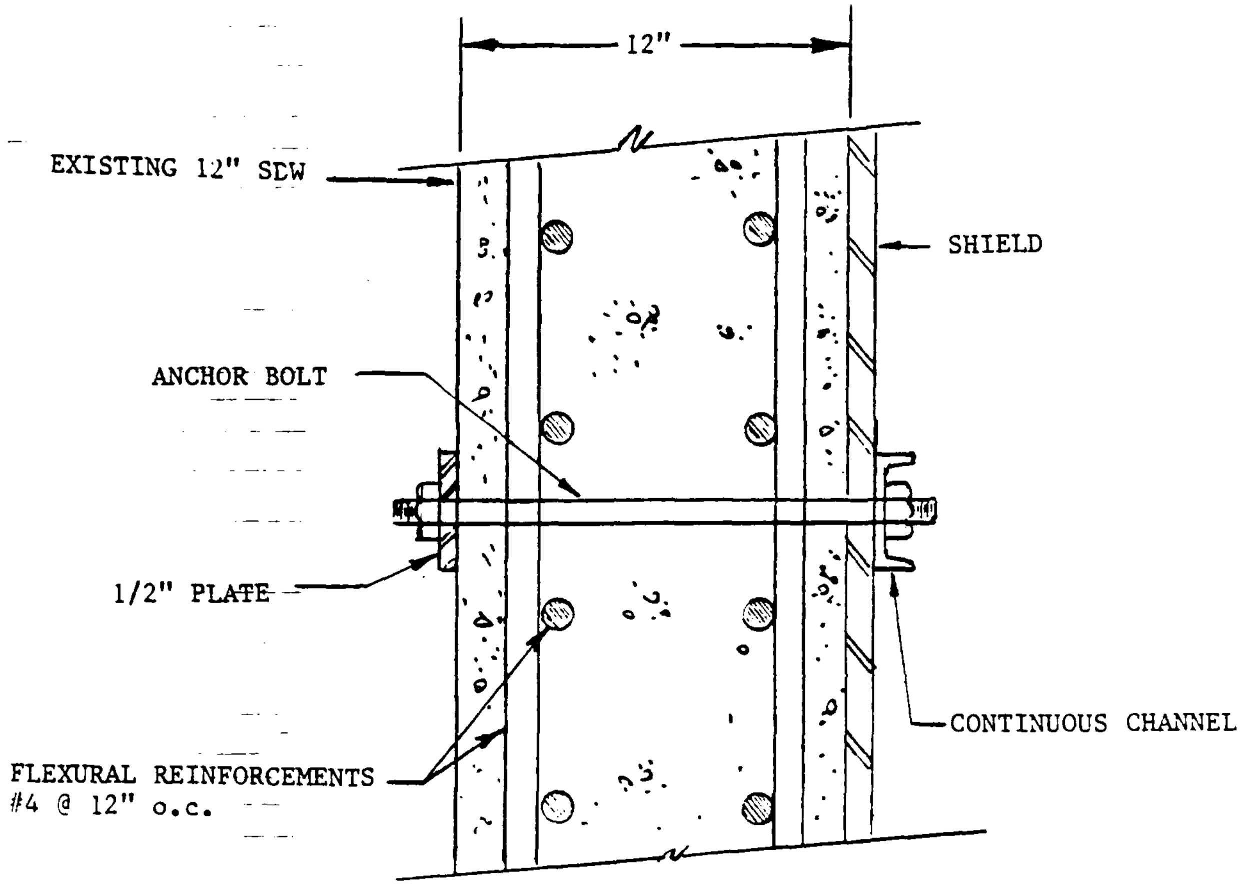
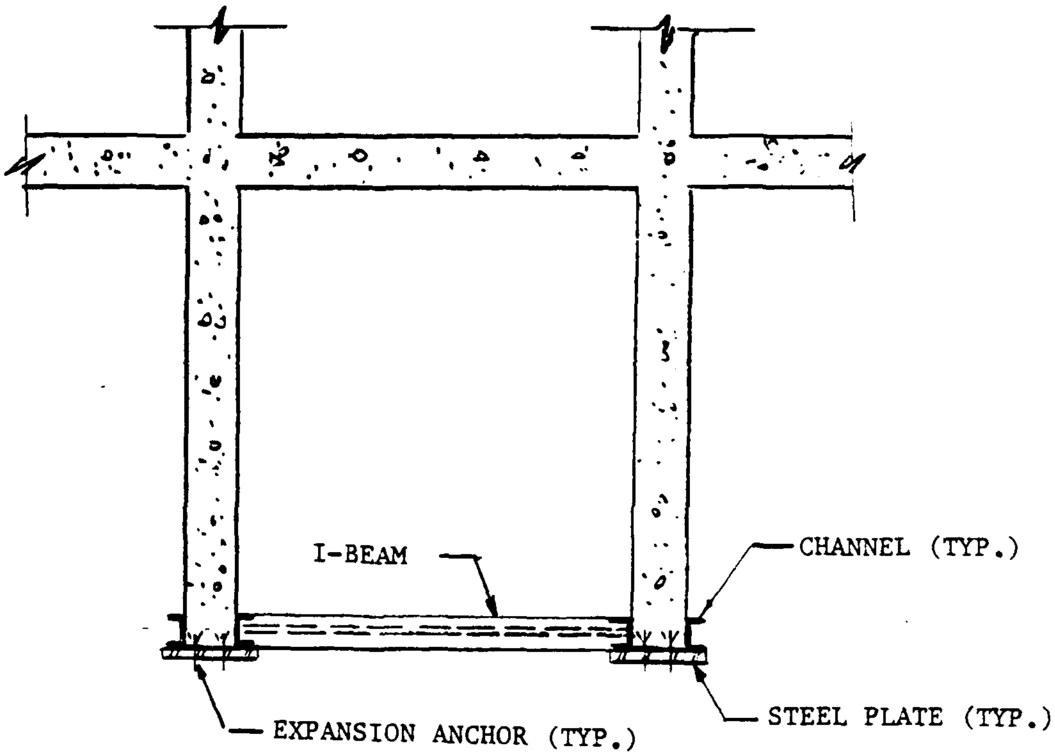
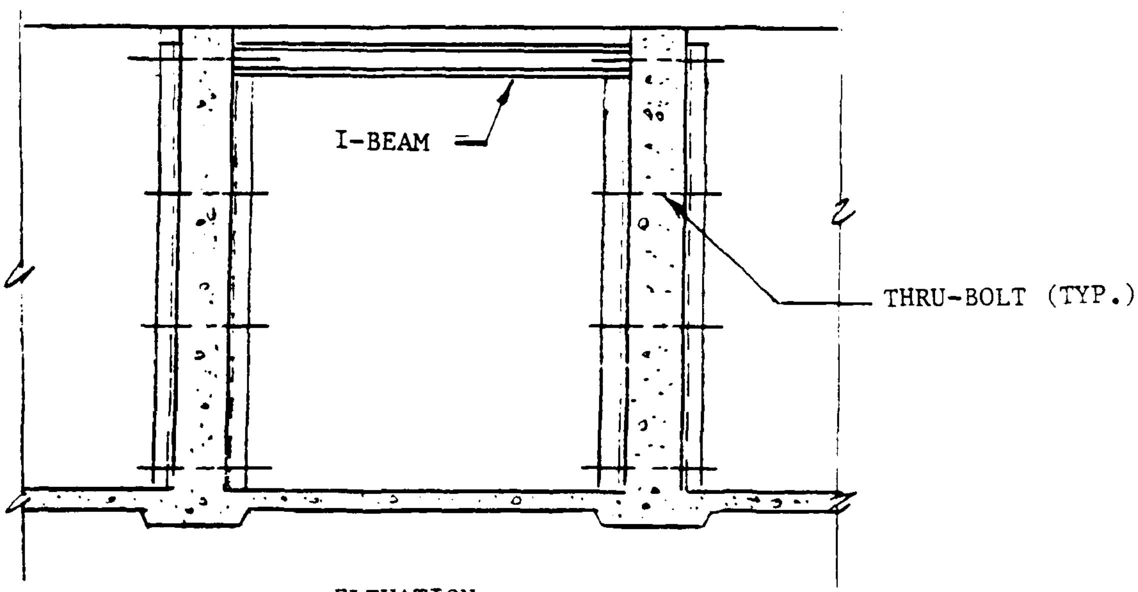


FIGURE 2-6 ATTACHMENT OF FRAGMENT SHIELD TO EXISTING SDW

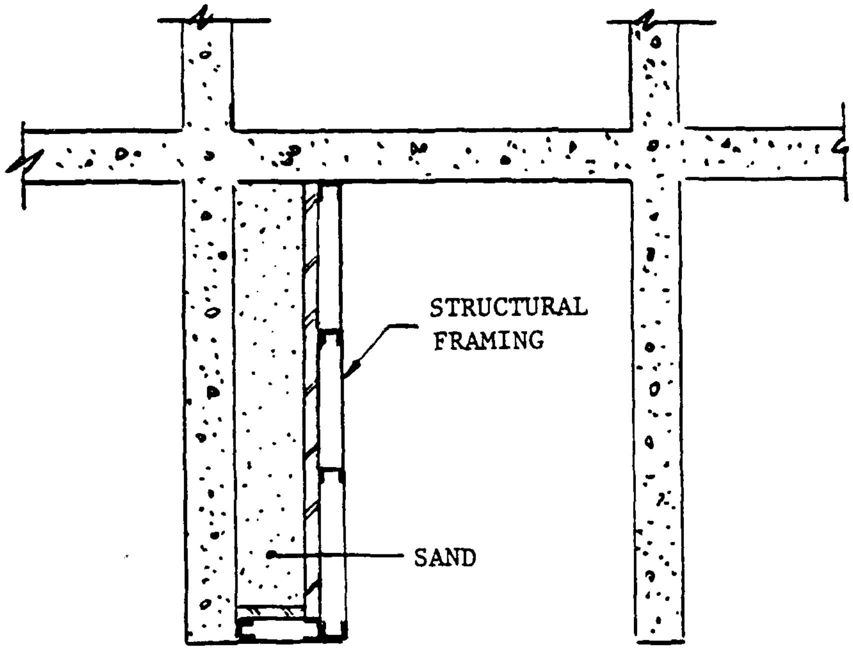


PLAN

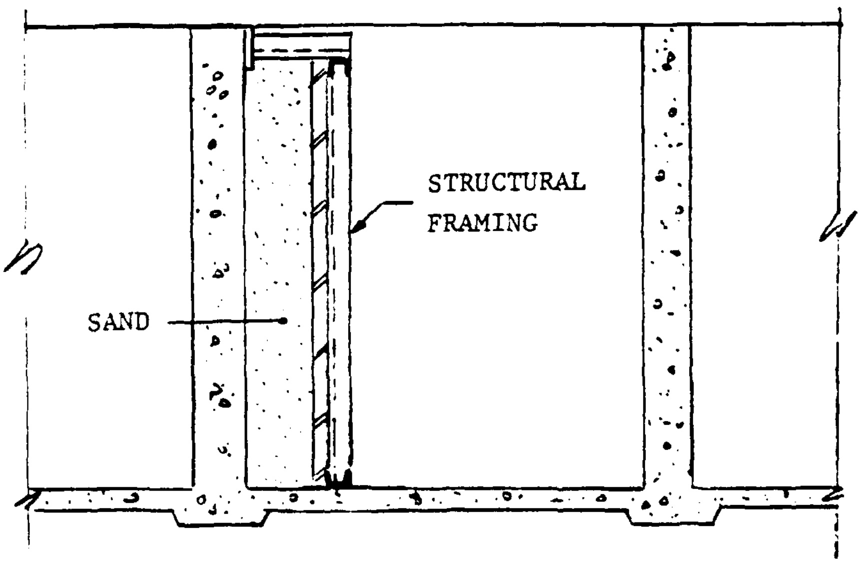


ELEVATION

FIGURE 2-7 STRUCTURAL STRENGTHENING OF SDW

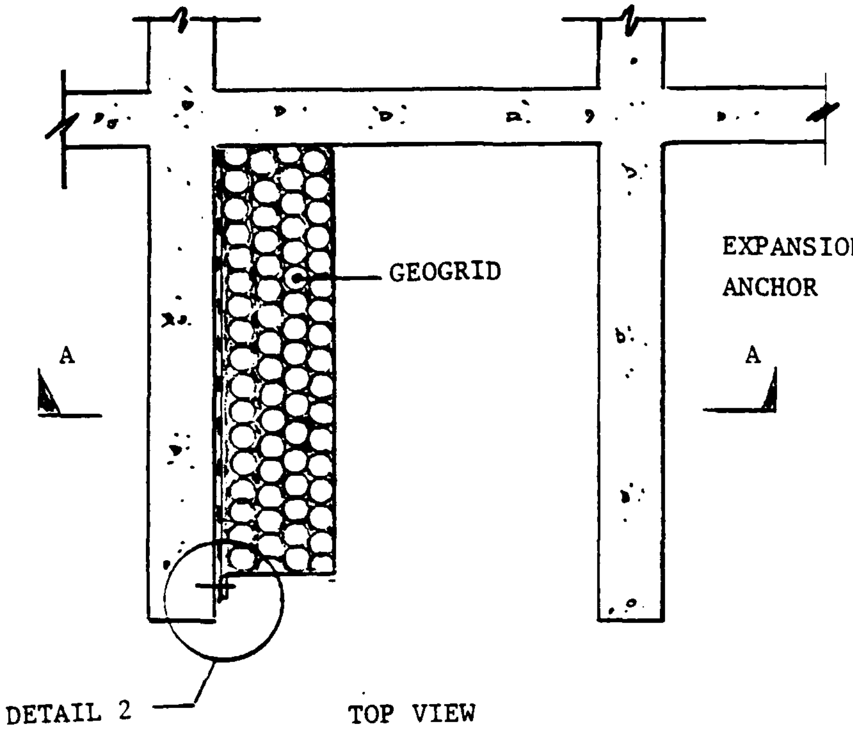


- PLAN

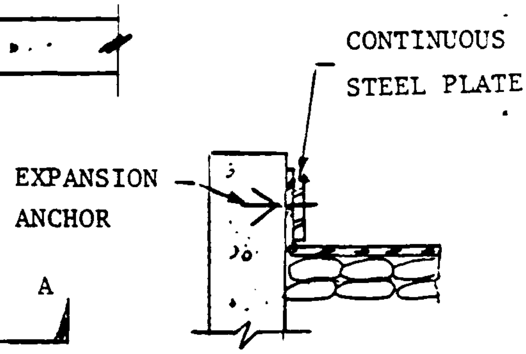


ELEVATION

FIGURE 2-8 SAND MASS BEHIND SDW

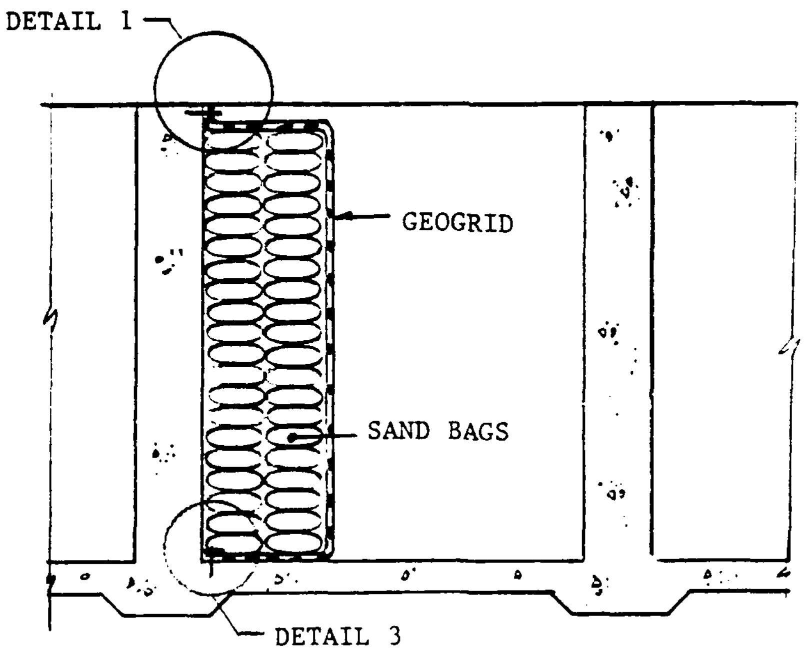


TOP VIEW

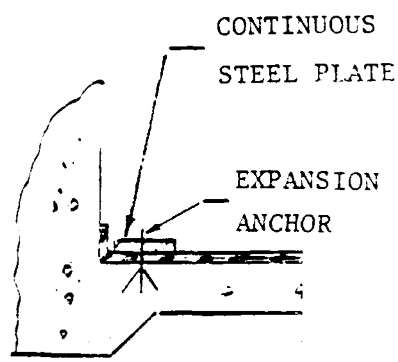


DETAIL 1

DETAIL 2 SIMILAR

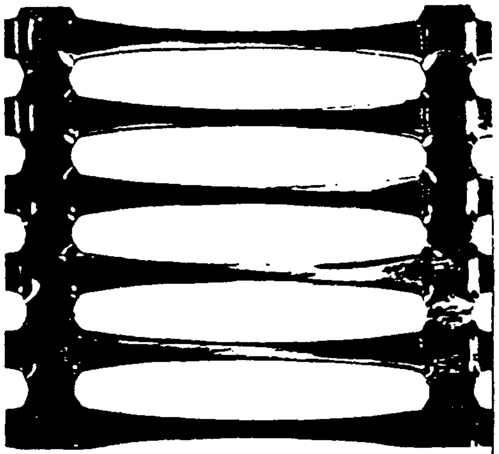


SECTION A-A

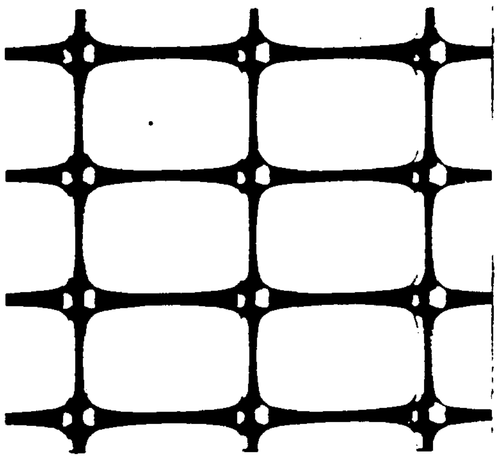


DETAIL 3

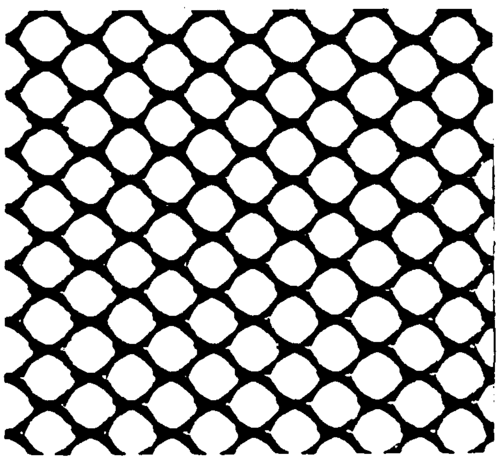
FIGURE 2-9 CONCEPT OF RESTRAINING SAND BAGS



Uniaxial Polymer Grid



Biaxial Polymer Grid



Polymer Net

FIGURE 2-10 GEOGRID MATERIAL

3.0 ANALYSIS PROCEDURE

3.1 GENERAL

The procedures presented below are developed for evaluating existing facilities and possible rehabilitation without compromising safety criteria. These methods should not be used for establishing requirements for a new facility design.

3.2 IDENTIFY HAZARDOUS OPERATIONS

Army installations must determine the nature of the hazardous operations at the particular facility. The primary considerations must be how this operation relates to personnel. Personnel must be afforded Category I protection if the operation is remotely controlled.

3.3 SPECIFIC REQUIREMENTS FOR PERSONNEL

This step requires the determination of location of personnel. Personnel in close proximity of a donor bay may be exposed to hazards from overpressures, fragmentation from cased explosives, spalling of the concrete wall, and collapse of structural elements (wall, roof, etc.). All of these conditions must be considered during the evaluation.

3.4 DETERMINATION OF CHARGE PARAMETERS

Charge parameters must include the following:

a. Net Explosive Weight (NEW)

b. Explosive type (for determining the TNT equivalency)

c. Cased or bare explosives.

d. Fragment parameters. Note: for the design fragment described in paragraph 1.5 above, one 12-inch SDW will resist fragment penetration, and perforation.

3.5 EQUIVALENT CHARGE WEIGHT (W)

The equivalent charge weight shall be determined from the following equation:

$$W = NEW \times \text{TNT Equivalency} \qquad \text{EQ. 3-1}$$

where: TNT Equivalency is determined from Table 3-1.

Note: W is used in determining overpressures at point of interest

3.6 DESIGN CHARGE WEIGHT

The design charge weight shall be determined from the following equation:

$$W' = NEW \times TNT\ Equivalency \times 1.20\ Safety\ Factor \qquad EQ.\ 3\text{-}2$$
$$= W \times 1.20\ Safety\ Factor$$

Note: W' is used in the evaluation of wall elements. The 1.20 safety factor is required by reference b.

3.7 SCALED DISTANCE

The customary scaled distance Z is used in this guide.

$Z = R/W^{1/3}$ used for overpressures determination EQ. 3-3a

or $Z = R/W'^{1/3}$ used for determining wall capacity EQ. 3-3b

where:

R = Standoff distance from center of explosive source to point of interest, ft. (wall element, operator location, etc.).

The use of these equations will be apparent in the example problems.

3.8 PREDICTION OF BLAST OVERPRESSURES AT OPERATOR'S LOCATION

The prediction of overpressures from an incident in a donor bay shall be determined in accordance with Appendix D. The resulting overpressures must be 2.3 psi or less to meet safety criteria. The blast wave overpressures must be evaluated for the two paths shown in Figure 3-1, i.e. over the SDW walls as shown in Elevation and around the front of the cubicle walls as shown in Plan. In the event the overpressures is greater than 2.3 psi, then either the operators must be moved a sufficient distance from the explosive source, the explosive quantity reduced, or the area where operators are located hardened to resist the blast loadings. Table 3-2 provides a quick evaluation to determine the number of unoccupied bays required between the explosive source and the operator(s) for a predetermined explosive quantity. These bays may contain inert materials, or explosives up to bay limit, but must be unoccupied (no personnel) during the actual remote operation. This table can be used with good accuracy even if the donor is not located in the center of the bay. The accuracy is enhanced as the charge weight is increased.

3.9 REFLECTIVE SURFACES

Recent test data indicate that shock wave reflections occur even with frangible elements having a minimum mass. A typical SDW cubicle bay will have 4 reflective surfaces: a floor, a roof, a right wall, a left wall. Each reflection scaled impulse value is set equal to the impulse on the element in question.Therefore the total impulse on the element in question is:

$$\text{Total } i_r/W'^{1/3} = i_r/W'^{1/3} + (4)i_r/W'^{1/3} \qquad \text{EQ. 3-4}$$

3.10 PREDICTION OF THE BLAST LOADS ON THE ELEMENT IN QUESTION

Prediction of the blast loads on the element in question requires the following:

a. Determining the free-field shock wave pressure and impulse, at the prescribed scaled distance Z, using Figure 2-1. The design charge weight W' is used in this scaled distance.

b. Estimating the effects of wall reflections on the element in question.

c. Applying correction coefficients to both the free-field shock wave pressure and impulse.

d. Comparing the predicted pressure and load-duration on the element in question to the wall capacity. This comparisón will reveal wall adequacy and requirements for upgrade.

3.11 WHAT SHOULD BE CONSIDERED FOR ASSURING CATEGORY I PROTECTION ?

Five basic Items:

a. Overpressures spillover into the occupied bay.
b. Wall element adequacy in resisting the blast loadings.
c. Fragmentation when cased munitions are used.
d. Spalling of the wall element.
e. Failure of structural elements (falling of massive overhead items).

Figure 3-1 is a pictorial presentation of a generic building with a series of bays separated by 12-inch SDWs. The operator is shown separated from the donor bay by four inert bays and a thru bay. Safety to the operator is assured if the following conditions are met:

a. The spillover pressure over the bay walls to the point in question does not exceed 2.3 psi (refer to Figure 3-1, Elevation).

b. The spillover pressure around the front of the bay walls to the point in question does not exceed 2.3 psi (refer to Figure 3-1, Plan).

c. Only two of the walls forming the cubicle containing the operator must be considered for structural response. These are the common wall and the 2-sided wall between the explosion and the operator. Deflections of these walls may not exceed those permitted by Category I protection criteria. However, if the 2-sided fixed wall, being the weakest of the two, is adequate then both are adequate.

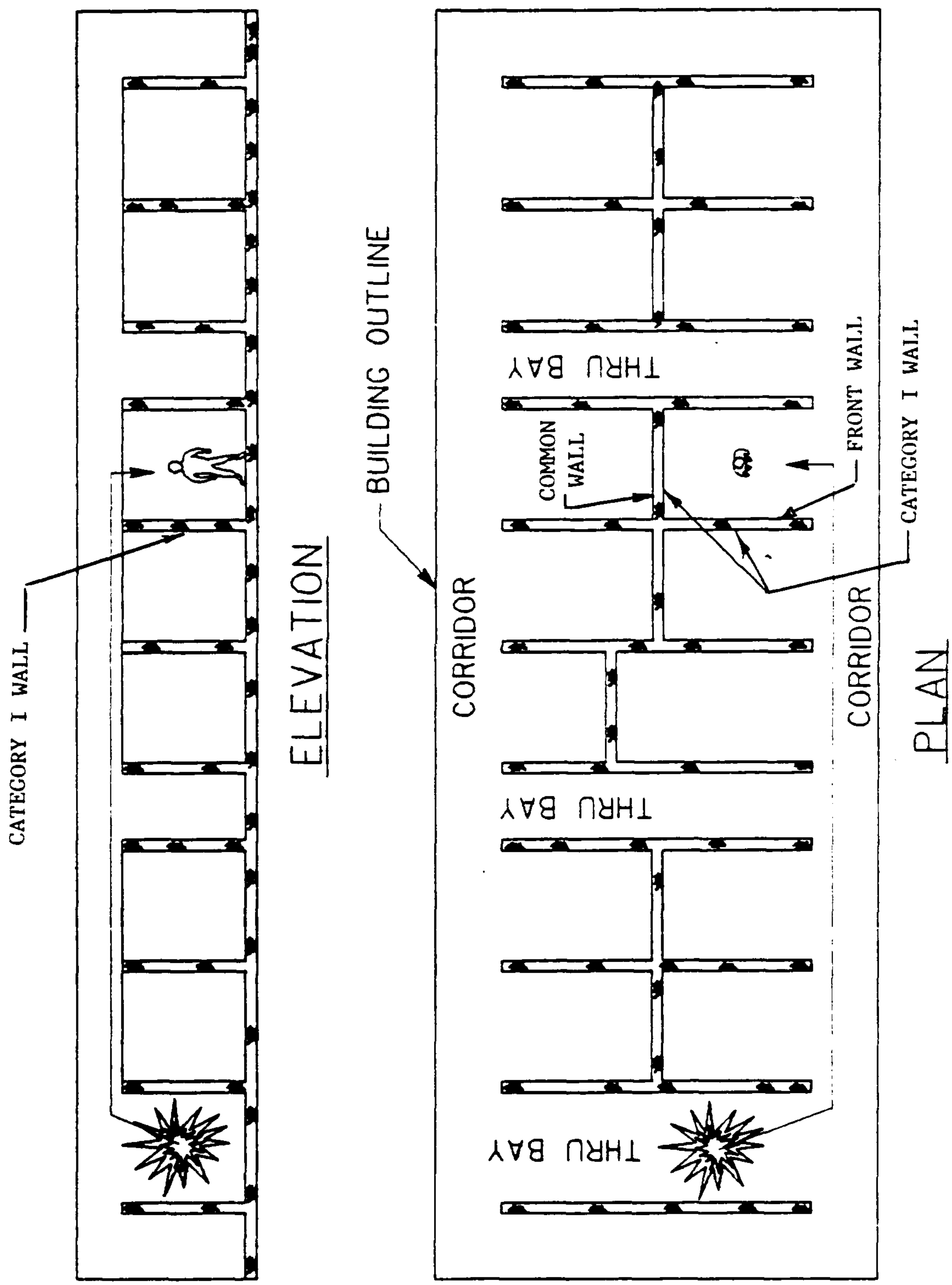


FIGURE 3-1 OPERATOR LOCATED AT DISTANCE OF INCIDENT OVERPRESSURE ≤ 2.3 PSI

TABLE 3-1 TNT EQUIVALENCY

EXPLOSIVE	TNT EQUIVALENCY
Composition A-3	1.09 (2)
Composition B	1.10 (1)
Composition C-4	1.13 (1)
Cyclotol (75/25)	1.12 (1)
HBX-1	1.17 (2)
HBX-3	1.14 (2)
H-6	1.38 (2)
HMX	1.15 (1)
Minol II	1.20 (2)
Octol (70/30)	1.12 (1)
PBX	1.14 (1)
PETN	1.18 (1)
Pentolite (50/50)	1.09 (1)
Picratol	0.90 (2)
RDX	1.16 (1)
Tetryl	1.07 (1)
TNETB	1.36 (2)
TNT	1.00 (1)
Tritonal (80/20)	1.07 (2)

(1) Reference 5 - Calculated using the heat of detonation ratios.

(2) Reference 7.

Table 3-2 ESTIMATE OF NUMBER OF UNOCCUPIED[1] BAYS REQUIRED TO LIMIT PERSONNEL EXPOSURE TO 2.3 PSI OR LESS

EQUIVALENT CHARGE WEIGHT, LB	NUMBER OF UNOCCUPIED BAYS (N)				
	BAY WIDTH				
W = NEW x TNT Equivalency	10'	12'	14'	15'	16'
3	2	2	1	1	1
5	2	2	2	2	1
10	4	3	3	3	2
15	5	4	3	3	2
20	5	5	4	4	3
30	6	6	4	4	4
40	7	6	5	5	5
50	7	7	6	5	5
70	8	8	6	6	6
80	9	8	7	6	6
100	10	9	7	7	6
120	11	10	8	7	7
140	11	10	8	8	7
150	12	10	9	8	7
180	12	11	9	9	8

(1) "Unoccupied" means no personnel allowed during the actual remote operation. Bays may be used for inert materials and explosives up to the bay limit.

<u>Assumptions:</u>

1. Donor bay width same as bay width.
2. Charge in center of donor bay at 3' above finish floor.
3. 2.3 psi limit measured to point 6' above finish floor at center of bay.
4. Reference 6 methodology used.

Table 3-3 ADJUSTMENT VALUES TO ACCOUNT FOR THRU-BAYS

ADJUSTED DISTANCE, C[1]	ADJUSTMENT VALUE, Adj.
Less than bay width	+1
Greater than bay width but less than 2 x bay width	0
2 x bay width but less than 3 x bay width	-1
3 x bay width but less than 4 x bay width	-2
4 x bay width but less than 5 x bay width	-3
5 x bay width but less than 6 x bay width	-4

(1) C = Donor bay width/2 + Total width of thru-bays between the donor and operators' bays

EXAMPLE PROBLEM 3.1

PROBLEM- An ammunition processing building is composed of a series of concrete cubicles. The donor bay is remotely controlled. Personnel must not be exposed to overpressure exceeding 2.3 psi. Estimate the number of unoccupied bays that must separate the operators from the donor bay.

GIVEN:

NEW = Net Explosive Weight, lb.

Type of explosive

Building layout showing cubicle configuration

FIND: Estimate in which bay the operators may be positioned and not be exposed to overpressures exceeding 2.3 psi.

		REFERENCE
SOLUTION:	1. Equivalent charge weight W = NEW x TNT equivalency	Table 3-1 for TNT equivalency factor and EQ. 3-1.
	2. Check for the following: a. If all bays are of equal width, go to step 3 (neglect any thru-bay). If bays are not within the limits shown in Table 3-2 (less than 10' and greater than 16'), then use method of Appendix D. b. If bays are of varying width go to step 10 (neglect any thru-bay).	
	3. Locate point of intersection of equivalent charge weight (W) and bay width, and read the number of unoccupied bays (N). If W falls between two values, use the next higher W to find the number of unoccupied bays. Similarly, use the next higher number of unoccupied bays if point of intersection falls between two bay widths. Note: Using the next higher W and/or next number of unoccupied bays will result in conservative estimate.	Table 3-2
	4. Determine the total width of all thru-bays between the donor and	

"N" bays from step 3.

5. Divide the width of the donor bay by 2.

6. Add steps 4 and 5 to determine the adjusted distance "C"

7. Determine the adjustment value (Adj). — Table 3-3

8. Operators must be positioned in bay N + Adj.

9. Solution complete. You now have the solution. For an exact analysis, one may wish to use method of Appendix D.

10. Sum the width of all bays in the processing building (neglect thru-bays).

11. Divide the sum from step 10 by the total number of bays in the building to get an average width (neglect thru-bays).

12. Set the bay width from step 10 to the nearest lower bay width value shown in the table. If the average bay width is not within the limits shown in Table 3-2 (less than 10' and greater than 16'), then use the method of Appendix D. — Table 3-2

13. Locate point of intersection of the equivalent charge weight (W) and average bay width,and read the number of unoccupied bays (N). If W falls between two values, use the next higher W to find "N". Similarly, use the next higher number of unoccupied bays if point of intersection falls between two bay widths. — Table 3-2

14. Go to step 4.

CALCULATIONS

Given: Building layout shown in Figure 3-2.

NEW = 37.5 lb

Type of explosive: Composition B

Find: For the building layout shown in Figure 3-2, estimate the number of unoccupied bays that must separate the operators from the donor bay.

SOLUTION:

1. W = (37.5)(1.092) = 41 lb

2. From Figure 3-2, all cubicles are 14'-6" wide, except the donor bay which is 14'-0".

3. W = 41 lb and bay width of 14'-6" are not listed in Table 3-2. Therefore, set W = 50 lb and bay width 14'. Enter Table with W = 50 lb and proceed to bay width of 14'. Read number of unoccupied bays:

   N = 6

   Note: N = 6 is conservative since 41 lbs is closer to 40 lbs than 50 lbs. If the 40 lbs was used "N" would be 5 instead of 6. In this situation, one may wish to use Appendix D.

4. There is only one thru-bay between the donor bay and the "N" bay. Width of thru-bay = 6'.

5. The donor bay is 14'-0" wide. 14/2 = 7'

6. Adding value from steps 4 & 5: C = 6' + 7' = 13'

   13' is less than 15' bay width

7. Enter Table 3-3 with "C" less than bay width and read:

   Adj. = +1

8. Position of operators:

   N + Adj. = 6 + (+1) = 7

9. Operators must be positioned in the seventh bay away from the donor bay.
   Note: Since the 7th bay is across a thru-bay, personnel in the thru-bay are also protected.

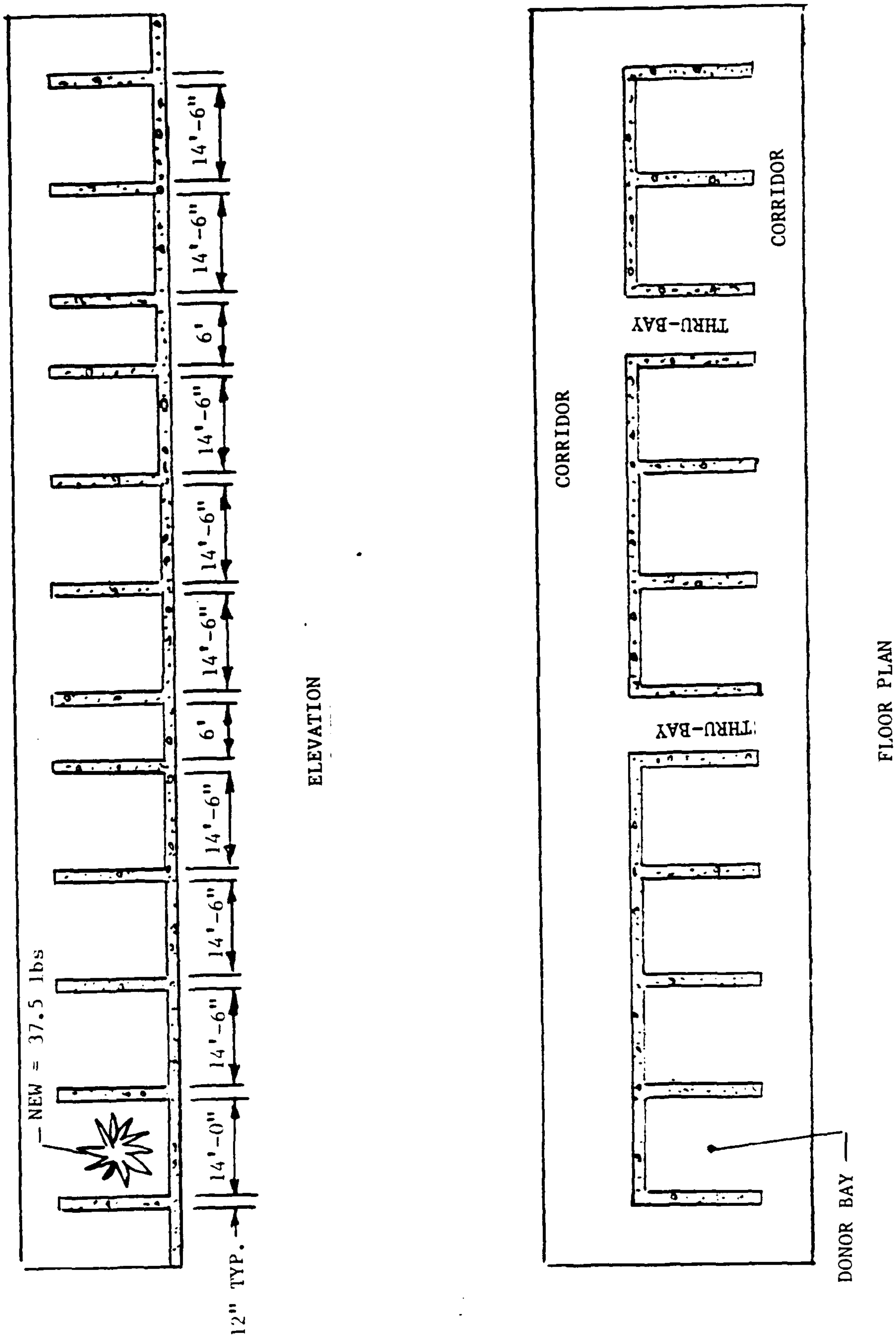


FIGURE 3-2 BUILDING LAYOUT

EXAMPLE PROBLEM 3.2

PROBLEM- An ammunition processing building is composed.of a series of 12-inch Substantial Dividing Walls. A donor bay is remotely controlled by operators located at a specified standoff from the explosive source. The acceptor bay (occupied bay) is a concrete cubicle constructed of 12-inch Substantial Dividing Walls. Safety criteria require that personnel in the acceptor bay be afforded Category I protection.

GIVEN: R = Distance from center of explosive source (standoff [ft]) to point in question, in this case, to nearest wall of cubicle housing operator

NEW = Net Explosive Weight

Type of explosive

Acceptor Bay Size: 12' wide X 14' long X 12' high

Cubicle Configuration (Acceptor Bay): Two side walls, a back wall, a transite roof and a corrugated exterior siding 6 feet from the cubicle.

FIND: a. What is the blast loadings on the wall (pressure and duration)?

b. Will the 12-inch SDW provide Category I protection?

SOLUTION:		REFERENCE
1.	Design charge weight W' = NEW x TNT equivalency x 1.20 safety factor	Table 3-1 for TNT equivalency factor and EQ. 3-2.
2.	Calculate the scaled distance $Z = R/W'^{1/3}$	EQ. 3-3b
3.	Determine the reflected pressure (P_r) and reflected scaled impulse ($i_r/W'^{1/3}$) corresponding to Z	Figure 2-1
4.	Set the number of reflective surfaces = 4	
5.	Total $i_r/W'^{1/3} = i_r/W^{1/3} + (4)i_r/W^{1/3}$	EQ. 3-4
6.	Determine the coefficients C_{pr} and C_{ir} corresponding to the standoff distance R.	Figure 2-2 & Figure 2-3
7.	Calculate $P = P_r\ (C_{pr})$ and calculate $i_r/W'^{1/3}$ = Total $i_r/W'^{1/3}\ (C_{ir})$.	

8. Determine $i_r = (i_r/W'^{1/3})(W'^{1/3})$

9. Determine duration $T = 2\ (i_r)/P$

10. Blast loads summary:

    Pressure on wall from step 7:
    Load duration on wall from step 9:

11. Enter Figure C-4 with T from step 9 and proceed upward to wall size. Read Allowable dynamic pressure P

12. Compare P from step 11 with P from step 7. If P from step 11 is greater than P from step 7 the wall will provide Category I protection. If not the wall is inadequate. If the difference between the calculated value and the required value is within 5%, the wall is acceptable.

CALCULATIONS:

GIVEN: R = 40 ft
NEW = 37.5 lb
Type of explosive - Composition B

FIND: a. The pressure and load duration on the wall between the operator and the donor bay.

b. Whether 12-inch SDW provides Category I protection

SOLUTION:

1. $W' = (37.5)(1.092)(1.20) = 50$ lb.

2. $Z = 40/50^{1/3} = 10.87$ ft/lb$^{1/3}$

3. Enter Figure 2-1 for $Z = 10.87$ ft/lb$^{1/3}$ and read:

   $P_r = 14$ psi and $i_r/W'^{1/3} = 10.0$ psi-msec/lb$^{1/3}$

4. Total reflected surfaces = 4

5. $i_r/W'^{1/3} = (10.0) + (4)(10.0) = 50$ psi-msec/lb$^{1/3}$

6. Enter Figures 2-2 and 2-3 for R = 40 ft and read:

   $C_{pr} = 1.27$ and $C_{ir} = 1.1$

7. $P = (14)(1.27) = 17.8$ psi
   $i_r/W^{1/3} = (50)(1.1) = 55$ psi-msec/lb$^{1/3}$

8. $i_r = (55)(50)^{1/3} = 202.4$ psi-msec

9. T = 2(202.4)/17.8 = 22.74 msec

10. Blast loads summary:
    Pressure on wall .... 17.8 psi
    Load duration .... 22.74 ms

11. Enter Figure C-4 with T = 22.74 msec and wall size 14'L x 12' H and read:

    P = 17.5 psi This is the allowable dynamic pressure.

12. P = 17.5 psi is less than P = 17.8 psi.
    Wall is inadequate. However, since the variance is within 5% consider the wall adequate.

NOTES:

1. Problem 3-3 presents a situation where wall is shown inadequate. Strengthening method is also presented.

2. This example problem does address personnel exposure to overpressure. Its is not sufficient that wall adequacy be checked. Appendix D must be used in assuring that personnel are not exposed to overpressures greater than 2.3 psi. The approximate method using Table 3-2 may be also be used (refer to Example 3.1).

   Overpressure will usually control.

3. Also wall breach must be checked. Example 3.4 shows this procedure. Breach does not normally, control.

EXAMPLE PROBLEM 3.3

PROBLEM- Operational constraints require that operators be located in close proximity of the donor bay. The acceptor bay is a concrete cubicle constructed of 12-inch substantial dividing walls. Are operators afforded Category I protection? and if not what can be done to ensure personnel safety is assured.

GIVEN: R = Distance from center of explosive source to point in question, ft.

NEW = Net Explosive Weight.

Type of explosive

Bay Size: 12' wide x 14' long x 12' high

Cubicle Configuration: Two side walls, a back wall, a transite roof and a corrugated exterior siding 6 feet from the cubicle.

FIND: a. Determine wall adequacy for Category I protection

b. What upgrade is necessary?

SOLUTION:		REFERENCE
1.	Design charge weight $W' = NEW \times TNT$ equivalency x 1.20 safety factor	Table 3-1 for TNT equivalency factor and EQ. 3-2
2.	Calculate the scaled distance $Z = R/W'^{1/3}$	EQ.3-3b
3.	Determine the reflected pressure (P_r) and reflected scaled impulse ($i_r/W'^{1/3}$) corresponding to Z	Figure 2-1
4.	Set the number of reflective surfaces = 4	
5.	Total $i_r/W'^{1/3} = i_r/W'^{1/3} + (4)(i_r/W'^{1/3})$	EQ.3-4
6.	Determine the coefficients C_{pr} and C_{ir} corresponding to the standoff distance R.	Figure 2-2 & Figure 2-3
7.	Calculate $P = P_r (C_{pr})$ and calculate $i_r/W'^{1/3} = i_r/W'^{1/3} (C_{ir})$.	
8.	Determine $i_r = (i_r/W'^{1/3})(W'^{1/3})$	
9.	Determine duration $T = 2 (i_r/P)$	
10.	Enter Figure C-4 with T from step 9 and proceed upward to wall size.	

Read Allowable dynamic pressure P

11. Compare P from step 10 with P from step 7. If P from step 10 is greater than P from step 7 the wall will provide Category I protection. If not the wall is inadequate.

    Note: Before selecting option for upgrade step 12, a check of spillover pressure at opaerator's bay must be made using either Table 3-2 and Example 3.1, or method of Appendix D. If pressure in the operator's bay exceedes 2.3 psi, then spillcver pressure controls. Proceed to next step only if the splillover pressure is equal to or less than 2.3 psi.

12. Select option for upgrade

    Option a. Sand layer behind wall. Go to step 13.

    Option b. Structural modification by adding a fixity condition (from 2-sides fixed to 3-sides fixed). Go to step 15.

13. Enter Figure E-14 with T from step 9 and proceed upward and read P for all sand thicknesses.

14. Compare P from step 13 to P from step 7. If P from step 13 is greater than P from step 7, then the wall will provide Category I protection. If not then the wall is inadequate.

15. Enter Figure C-9 with T from step 9 and proceed upward to specified wall size. Read allowable dynamic pressure P.

16. Compare P from step 15 to P from step 7. If P from 13 is greater than P from step 7, then the wall will provide Category I protection. If not then the wall is inadequate.

<u>CALCULATIONS</u>

GIVEN: R = 25 ft
NEW = 37.5 lb Composition B

FIND: a. Whether 12-inch SDW provides Category I protection
b. What upgrade is necessary? Check both options.

SOLUTION:

1. $W' = (37.5)(1.092)(1.20) = 50$ lb.
2. $Z = 25/50^{1/3} = 6.78$ ft/lb$^{1/3}$

3. Enter Figure 2-1 for $Z = 6.78$ ft/lb$^{1/3}$ and read:

   $P_r = 45$ psi and $i_r/W'^{1/3} = 18.0$ psi-msec/lb$^{1/3}$

4. Total reflected surfaces = 4

5. $i_r/W'^{1/3} = (18.0) + (4)(18.0) = 90$ psi-msec/lb$^{1/3}$

6. Enter Figures 2-2 & 2-3 for R = 25 ft and read:
   $C_{pr} = 1.18$ and $C_{ir} = 1.03$

7. $P = (45)(1.18) = 53.1$ psi
   $i_r/W^{1/3} = (90)(1.03) = 92.7$ psi-msec/lb$^{1/3}$

8. $i_r = (92.7)(50)^{1/3} = 342.1$ psi-msec

9. $T = 2(342.1)/53.1 = 12.89$ msec

10. Enter Figure C-4 with T = 12.89 msec and wall size 14'L x 12' H and read P

    P = 28.5 psi This is the allowable dynamic pressure.

11. P = 28.5 psi is less than P = 51.3 psi.
    Wall is inadequate.

12. In this example problem both options are selected:

    Option a: Go to step 13

    Option b: Go to step 15

13. Enter Figure E-14 with T = 12.89 msec and wall size 14'L x 12'H' and read P at sand thicknesses of 1', 2.5' and 5'

    P = 39 psi with 1' thick sand layer

    P = 52 psi with 2.5' thick sand layer

    P = 67 psi with 5.0' thick sand layer

14. P = 67 psi is greater than P = 53.1 psi (step 7). Therefore, wall with minimum 5' thick sand layer will provide Category I protection.

15. Enter Figure C-9 with T = 12.89 msec and wall size 14'L x 12'H and read P

P = 42 psi. This is the allowable dynamic pressure.

16. P = 42 psi is less than P_r = 53.1 psi
Wall is inadequate if additional fixity
is provided. Therefore, the only option
is strengthening wall by including 5'
sand behind it. Structural strengthening
by inducing another fixed edge is
insufficient.

Note: This guide does not include provisions for design. Modifications to existing walls will require engineerin' support,

and detail analysis by the responsible installation staff. Modifications require DDESB approval.

EXAMPLE PROBLEM 3.4

PROBLEM- Operators are located in the third cubicle from an explosive donor bay. The donor bay as well as all other bays are 12' wide separated by 12-inch Substantial Dividing Walls.

GIVEN: Center of explosives is 4 feet from the dividing wall (toward the operator). This is the standoff distance (R) to the first wall.

NEW = Net Explosive Weight, lb.

Type of explosive

FIND: Will this explosive weight breach the wall?

SOLUTION:			REFERENCE
	1.	Equivalent charge weight W = NEW x TNT equivalency	Table 3-1 for TNT equivalency factor and EQ. 3-1
	2.	Design charge weight W' = W x 1.20 safety factor	EQ.3-2
	3.	Locate point of intersection of standoff (R) and design charge weight (W'). Determine region where the point falls. If point falls in the "no damage" region, then the dividing wall will provide the necessary protection. If point falls in the "spall" or "breach" regions, then go to step 4.	Figure 2-4 or Figure 2-5.
	4.	Calculate a new standoff distance R = Previous R (ft) + wall thickness + bay width (ft)	
	5.	Repeat steps 3 and 4.	
	6.	If point falls in the "no damage" region , then the dividing wall will provide necessary protection. If point falls in the "spall" or "breach" region, then go to step 3 and repeat until point falls in the "no damage" region.	

CALCULATIONS

GIVEN: R = 4 ft
NEW = 50 lb. (TNT explosive type)

FIND: a. Whether a 12-inch SDW will be breached assuming a bare charge.
b. If first wall is breached, what wall will not be breached?

SOLUTION:

1. W = (50)(1.0) = 50 lb.

2. W' = (50)(1.20) = 60 lb

3. Enter Figure 2-4 with R = 4 ft and W = 60 lb.. Point falls in the "spall" region. Wall will not provide the required protection. Continue

3. R = 4 ft. + 1 ft (wall thickness) + 12 = 17 ft

4. Enter Figure 2-4 with R = 17 ft and W = 60 lb.. Point falls in the "no damage" region. The second wall will provide the necessary protection following breaching of the first 12 inch wall.

NOTE: Protection for overpressure, wall adequacy, falling objects are not addressed in this example. These hazards must be evaluated separately.

APPENDIX A

DEFINITIONS

DEFINITIONS

Blast. The brief and rapid movement of air away from a center of outward pressure, as in an explosion; the pressure accompanying this movement.

Blast Impulse. The product of the overpressures from the blast wave of an explosion at the time during which it acts at a given point (that is the area under the positive phase of the overpressure-time curve). Expressed in psi-milliseconds (psi-ms). Example: a blast wave of 10 psi acting on a surface for 5 milliseconds produces blast impulse of 10 x 5 = 50 psi-ms.

Blast Overpressure. The pressure, manifested in the shock wave of an explosion. Expressed in pounds per square inch (psi).

Cantilever Wall. A wall attached only to the floor, i.e, not attached to other walls.

Design Charge Weight. The equivalent charge weight multiplied by a factor of safety of 1.20 expressed in pounds; W' = W x 1.20

Detonation. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure.

Dividing Wall. A wall designed to prevent, control, or delay propagation of an explosion between quantities of explosives on opposite sides of the wall.

Dynamic Pressure. The temporary (short duration) load a blast wave places on a wall.

Equivalent Charge Weight. The Net Explosive Weight multiplied by the TNT equivalency expressed in pounds; W = NEW x TNT equivalency

Explosion. A chemical reaction of any chemical compound or mechanical mixture that, when initiated, undergoes a very rapid combustion or decomposition releasing large volumes of highly heated gases that exert pressure on the surrounding medium.

Explosives Facility. Any structure or location containing ammunition and explosives.

Fragmentation. The breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. Fragments may be complete items, sub-assemblies, pieces thereof, or pieces of equipment or building containing the items.

Frangible Wall. Is an exterior surface that designed to break loose and blow away quickly enough to limit effects from an explosion inside the room.

Incident Pressure. The pressure that a surface parallel to the direction of the blast wave experiences.

Load Duration. The number of milliseconds pressure is exerted on the wall.

Massive Overhead Falling Objects. The structural roof elements failing as a result of blast loadings in excess of the roof resistance capability.

Natural Period. The time interval during which a vibrating body completes one vibration in its fundamental mode.

NEW. Net Explosive Weight expressed in pounds.

Operating Building. Any structure, except magazine, in which operations so arranged as to permit performance of the consecutive steps in the manufacture of an explosive, or in the loading, assembly, modification, and maintenance of ammunition.

Operational Shield. A barrier constructed at a particular location or around a particular machine or operating station to protect personnel, material, or equipment from the effects of a possible localized fire or explosion.

Primary Fragments. Denotes fragments from an explosive-filled container which ruptures into small pieces under detonation of the explosive materials.

Protection Category I. Protection afforded personnel from an accidental explosion. Protection only required from operations whose hazards are deemed unacceptable.

Reflected Pressure. Reinforced pressure when the incident wave comes in contact with a surface.

Remote Operation. An explosive operation for which a hazard analysis is shown unacceptable from overpressure, and fragment risk to operators.

Resistance. The sum of the internal forces in a structural element whose function is to resist movement of the mass produced by the blast.

Secondary Fragments. Consist of objects which are located near an explosive source and are accelerated by the blast wave from the explosion.

Standoff Distance. Distance fron charge to wall in feet.

Stiffness. The slope of resistance deflection curve.

Substantial Dividing Wall. A 12-inch thick concrete wall reinforced with #4 at 12-inches on centers each way each face. The wall has no shear reinforcements. Typical connections to adjacent walls is by bar splicing, or main flexural bars extension into the corners. Walls are doweled to floor slabs.

TNT Equivalency. The effects of energy output on explosive material relative to that of TNT.

Unoccupied Bay. Unoccupied bay means no personnel allowed during the actual operation. Bays may be used for inert materials and explosives up to the bay limit. If explosives materials are present, the possibility of a detonation propagating from a remote operation must be addressed.

APPENDIX B

WALL TYPES

AND

DYNAMIC PROPERTIES

OF

SUBSTANTIAL DIVIDING WALLS

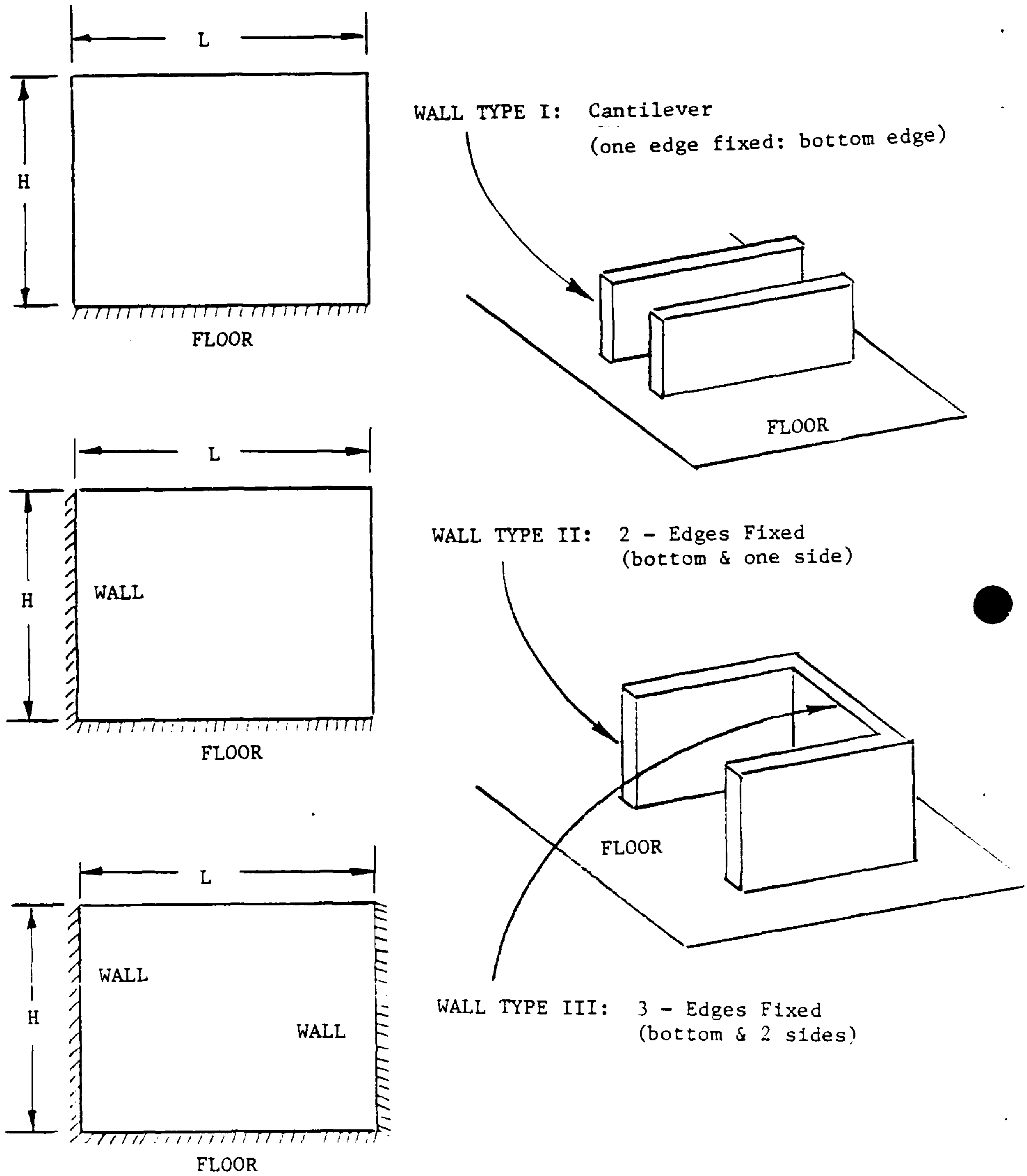


FIGURE B-1 WALL TYPES

TABLE B-1 DYNAMIC PROPERTIES[1] OF 12-INCH CANTILEVER SDW

WALL SIZE FT.	ULTIMATE RESISTANCE PSI	STIFFNESS LBS/IN^3	NATURAL PERIOD MSEC
10L X 10H	1.73	9.59	85.60
10L X 12H	1.21	4.63	123.26
10L X 14H	0.88	2.50	167.77
10L X 16H	0.68	1.46	219.12

L...Wall length
H...Wall height

(1) Reference 8.

TABLE B-2 DYNAMIC PROPERTIES[1] OF SUBSTANTIAL DIVIDING WALL FIXED TWO-SIDES

WALL SIZE FT.	ULTIMATE RESISTANCE PSI	STIFFNESS LBS/IN^3	NATURAL FREQUENCY MSEC
10L X 10H	8.61	27.20	47.61
10L X 12H	7.22	21.39	54.15
10L X 14H	6.23	19.08	57.67
10L X 16H	5.61	17.33	60.84
12L X 10H	7.27	20.91	54.78
12L X 12H	5.98	13.12	68.58
12L X 14H	5.15	11.19	74.76
12L X 16H	4.53	9.52	81.49
14L X 10H	7.27	17.63	60.00
14L X 10H	5.19	10.48	77.28
14L X 14H	4.39	7.08	93.35
14L X 16H	3.86	6.11	101.07
16L X 10H	5.56	15.82	63.66
16L X 12H	4.57	8.92	84.25
16L X 14H	3.89	5.83	103.51
16L X 16H	3.36	4.15	121.92
18L X 10H	5.11	14.69	66.36
18L X 12H	4.08	8.02	89.22
18L X 14H	3.47	5.01	112.27
18L X 16H	3.02	3.50	133.47

L...Wall length
H...Wall height

(1) Reference 8.

TABLE B-3 -- DYNAMIC PROPERTIES[1] OF SUBSTANTIAL DIVIDING WALL FIXED THREE SIDES

WALL SIZE FT.	ULTIMATE RESISTANCE PSI	STIFFNESS LB/IN^3	NATURAL FREQUENCY MSEC
10L X 10H	20.86	211.77	18.11
10L X 12H	19.60	186.25	19.52
10L X 14H	18.59	166.87	20.77
10L X 16H	17.75	189.66	19.59
12L X 10H	16.37	110.74	24.75
12L X 12H	14.49	102.13	26.07
12L X 14H	13.74	91.63	27.78
12L X 16H	13.13	83.33	29.33
14L X 10H	13.40	63.97	32.20
14L X 12H	11.79	59.06	33.96
14L X 14H	10.64	55.13	35.49
14L X 16H	10.17	50.19	37.50
16L X 10H	11.27	39.87	40.28
16L X 12H	9.91	36.69	42.66
16L X 14H	8.90	34.32	44.61
16L X 16H	8.15	32.31	46.35
18L X 10H	9.67	27.35	48.04
18L X 12H	8.51	24.16	52.06
18L X 14H	7.64	22.54	54.58
18L X 16H	6.95	21.28	56.70

L...Wall length
H...Wall height

(1) Reference 8.

APPENDIX C

ALLOWABLE PRESSURE-DURATION

FOR

WALL TYPES

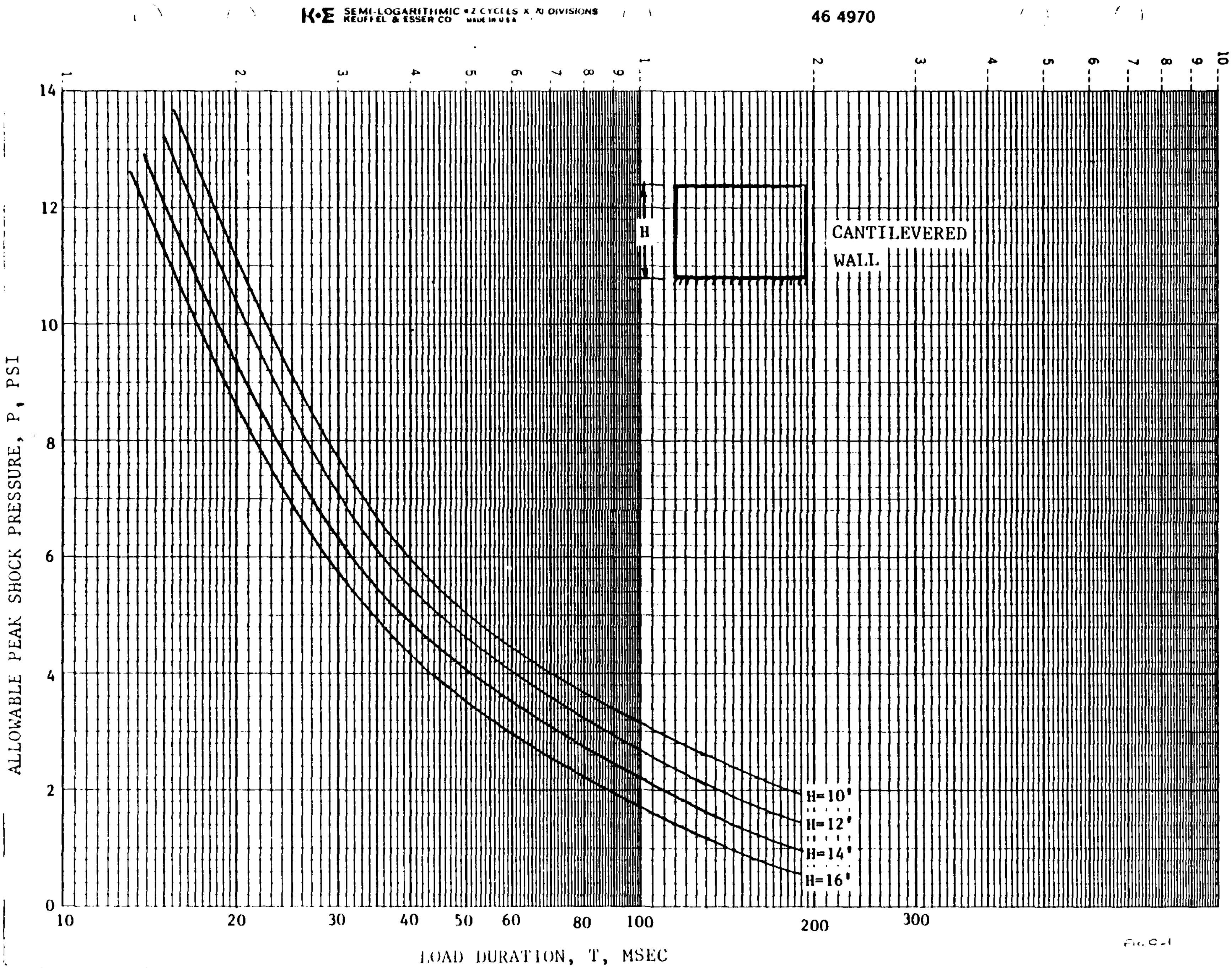


FIGURE C-3 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

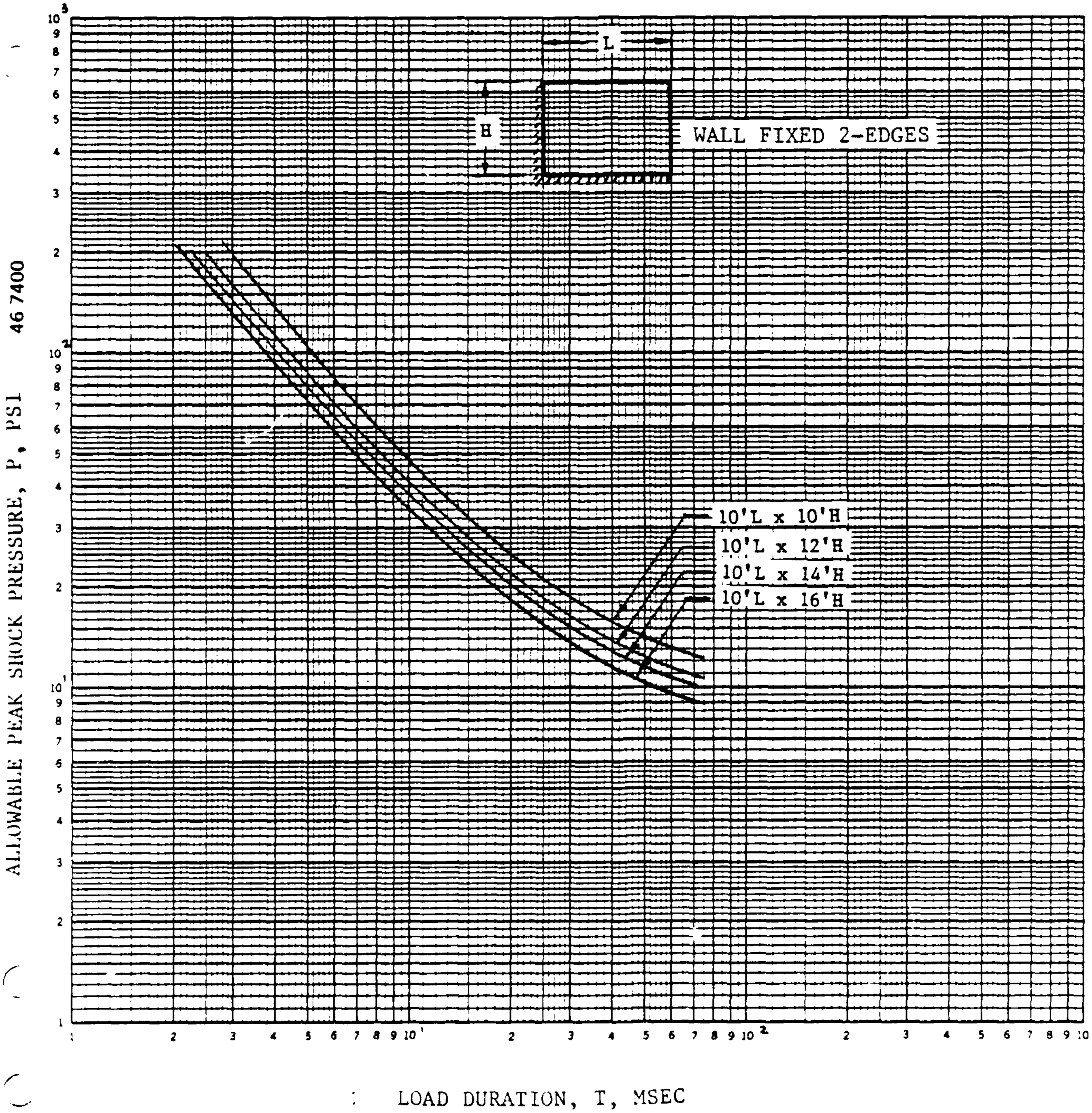


FIGURE C-2 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

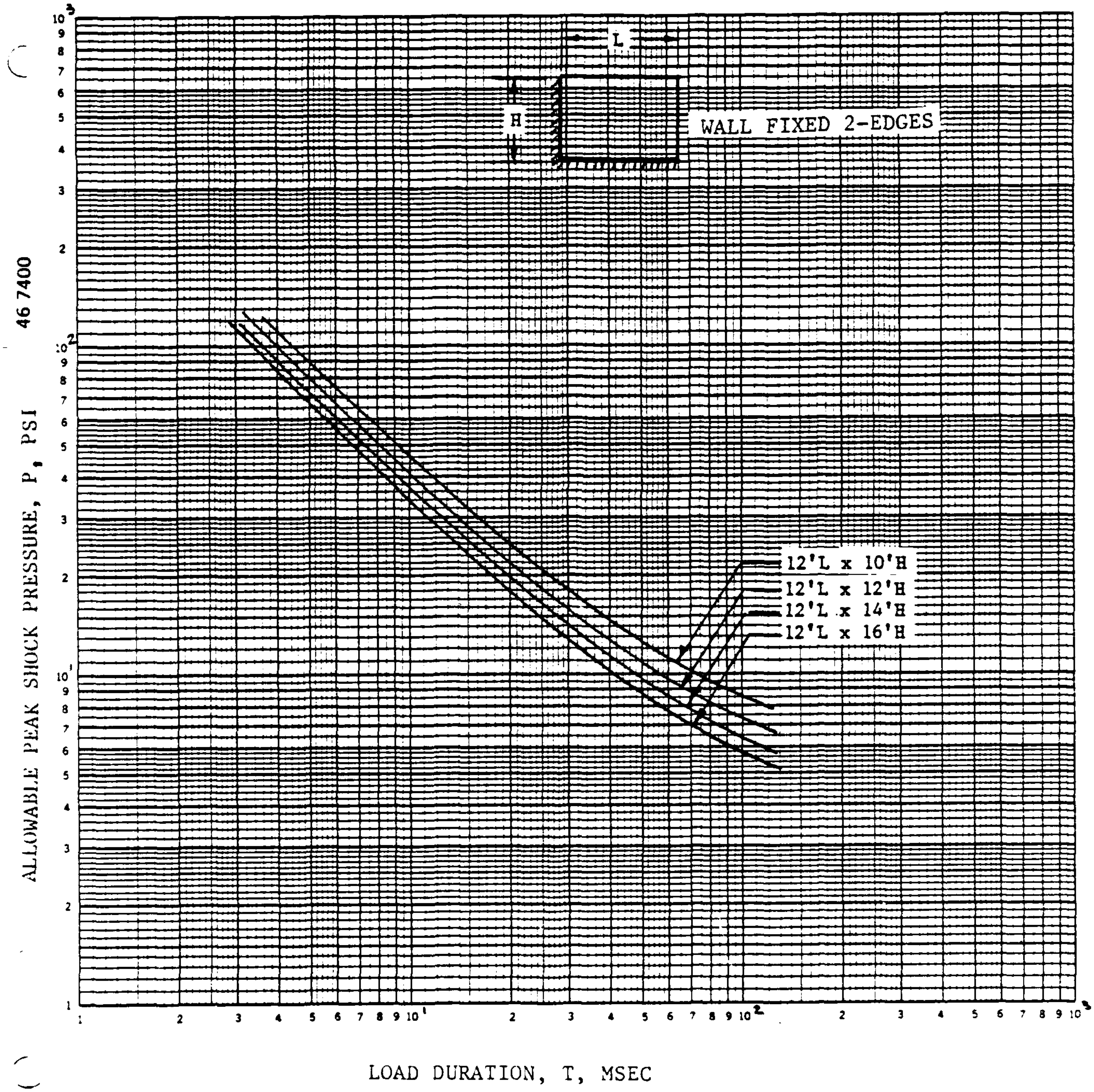


FIGURE C-3 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

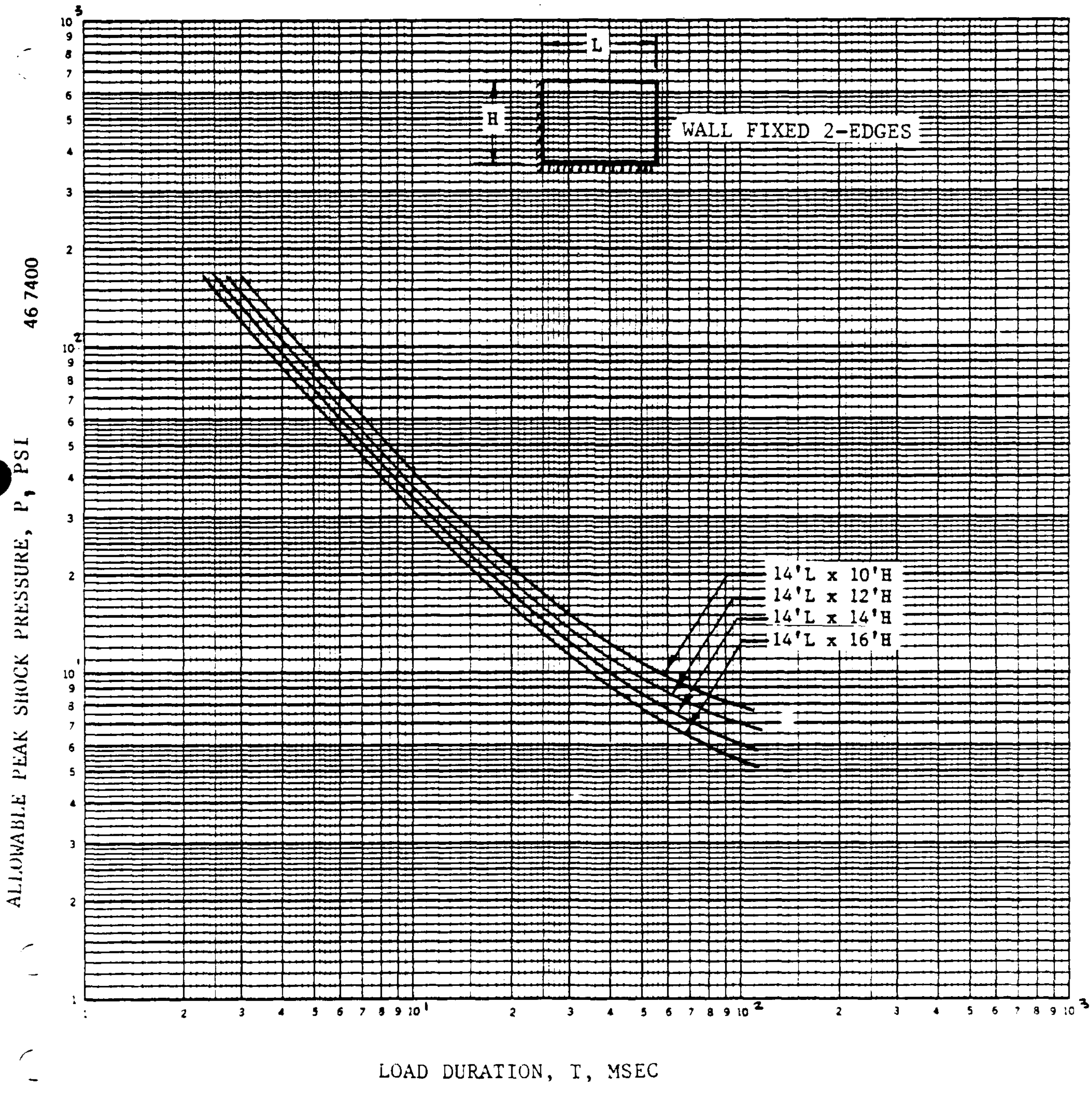


FIGURE C-4 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

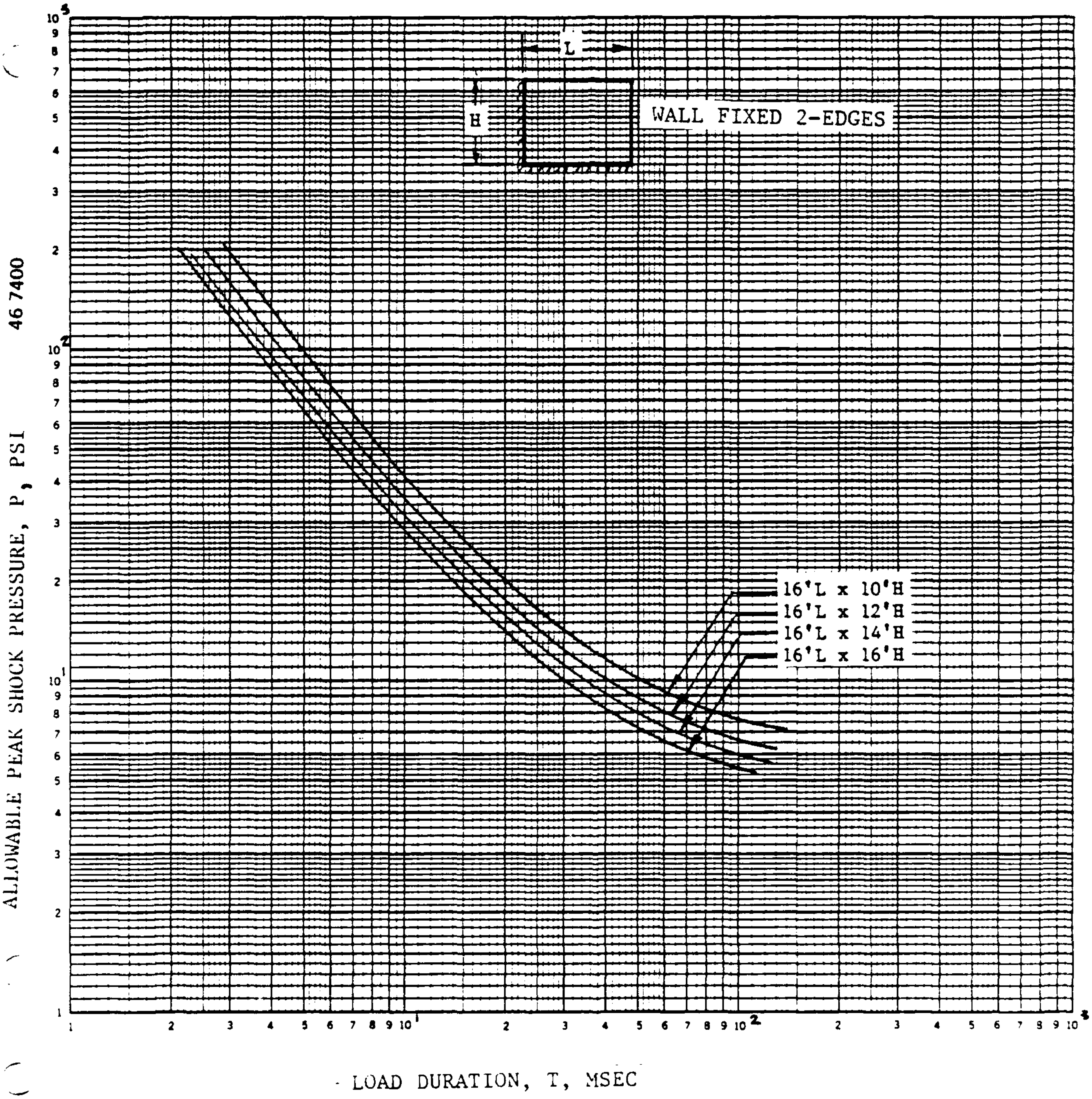


FIGURE C-5 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

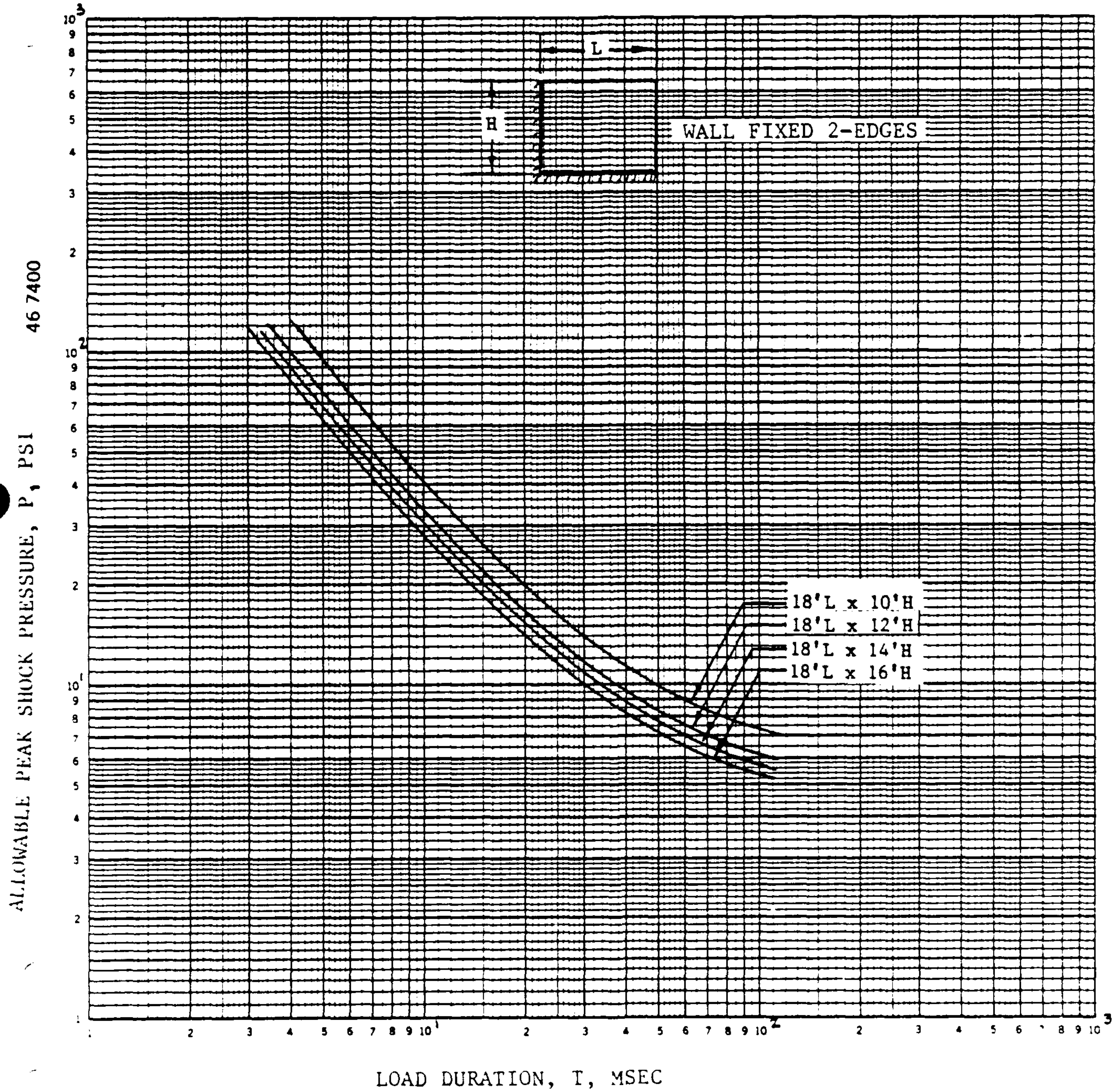


FIGURE C-6 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

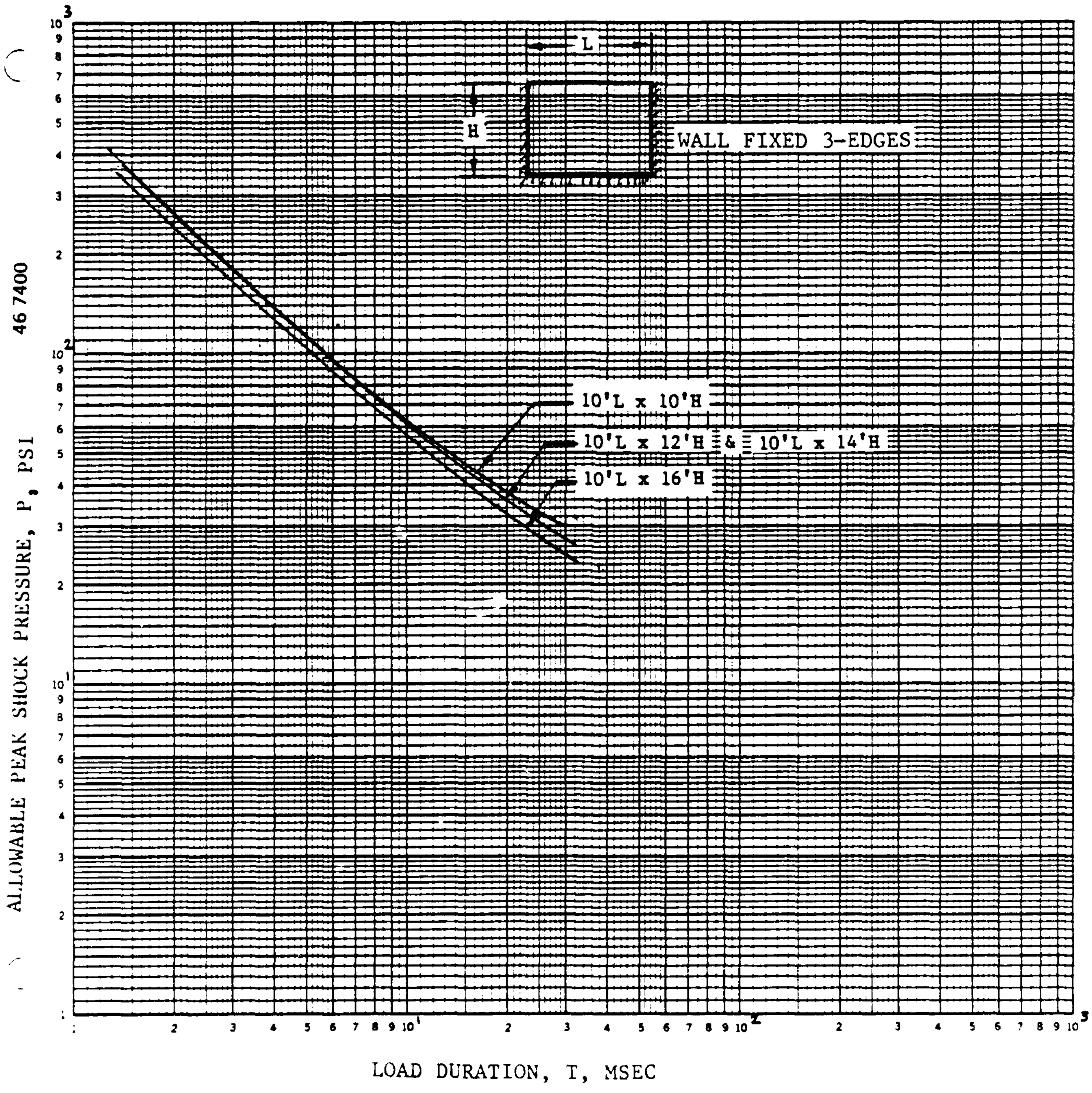


FIGURE C-7 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

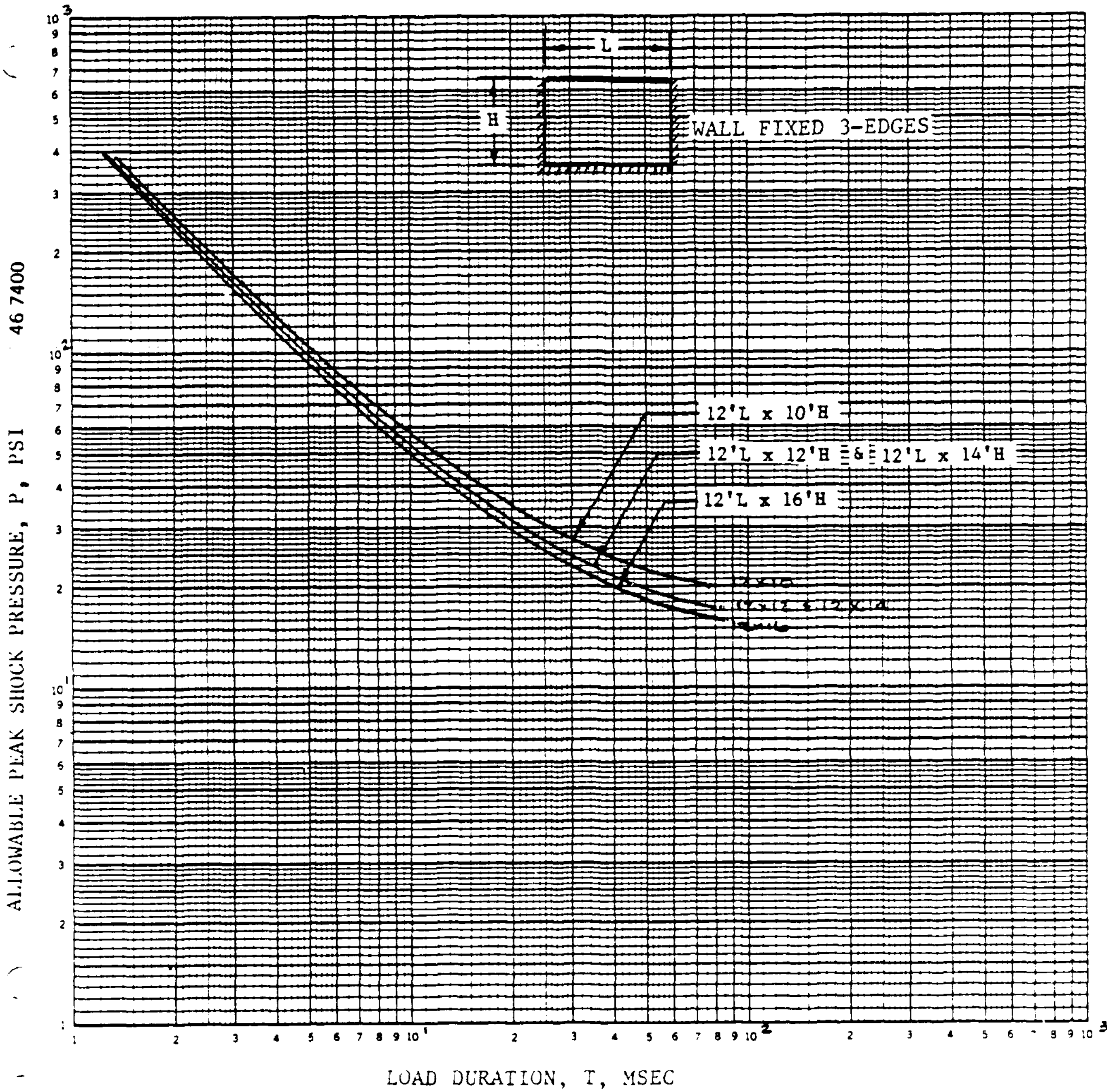


FIGURE C-8 ALLOWABLE PEAK SHOCK PRESSURE
VS LOAD DURATION

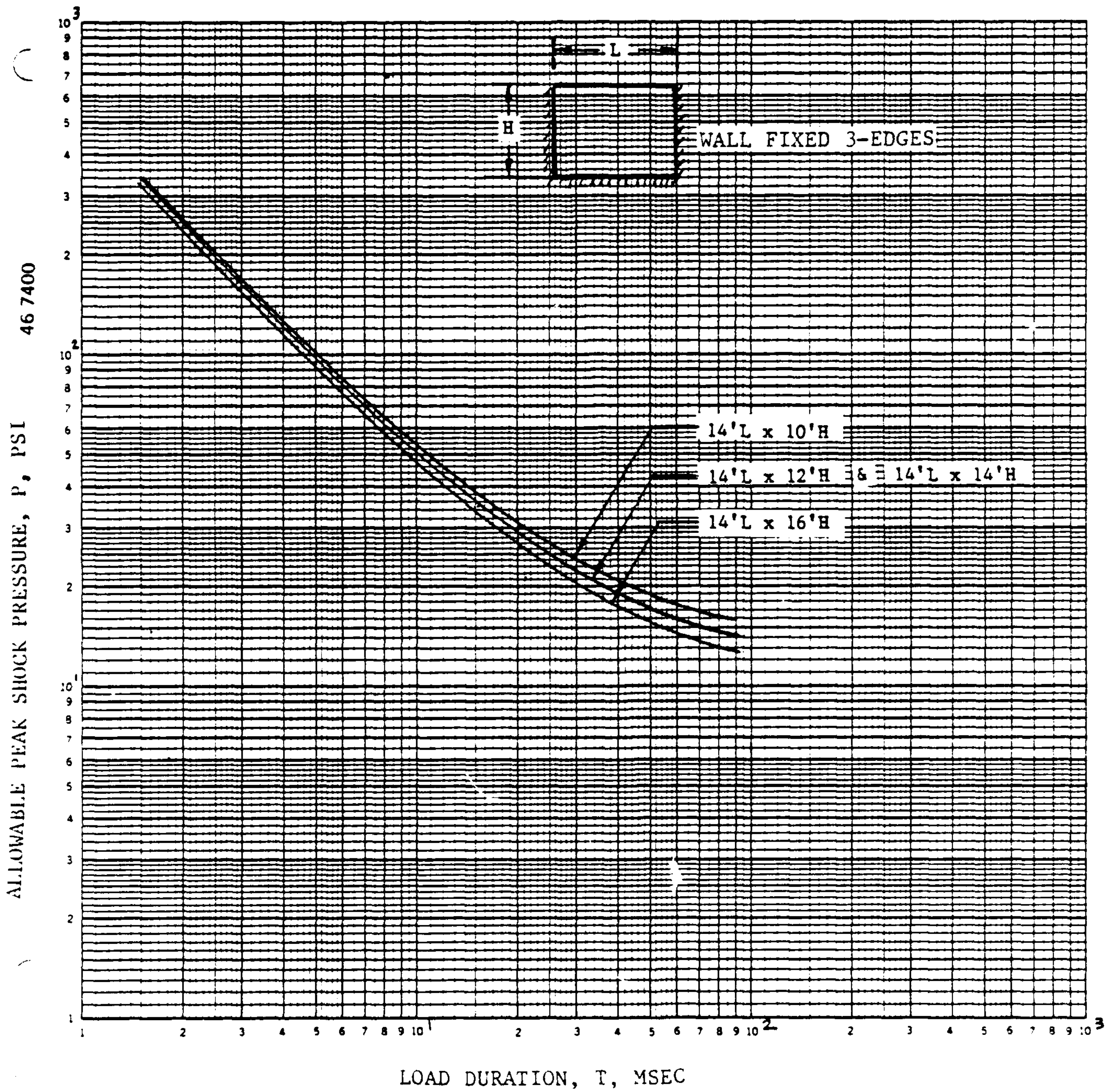


FIGURE C-9 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

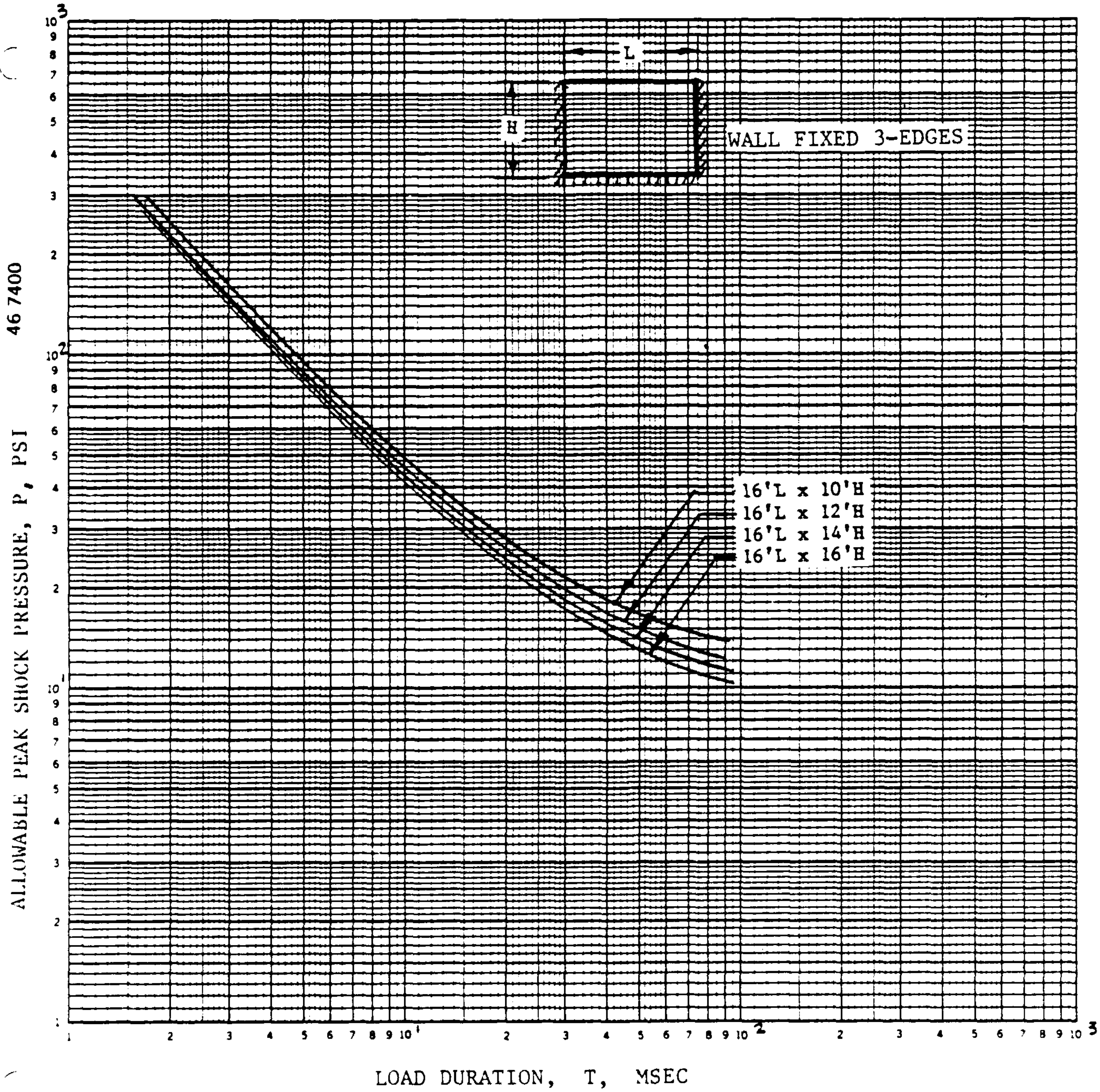


FIGURE C-10 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

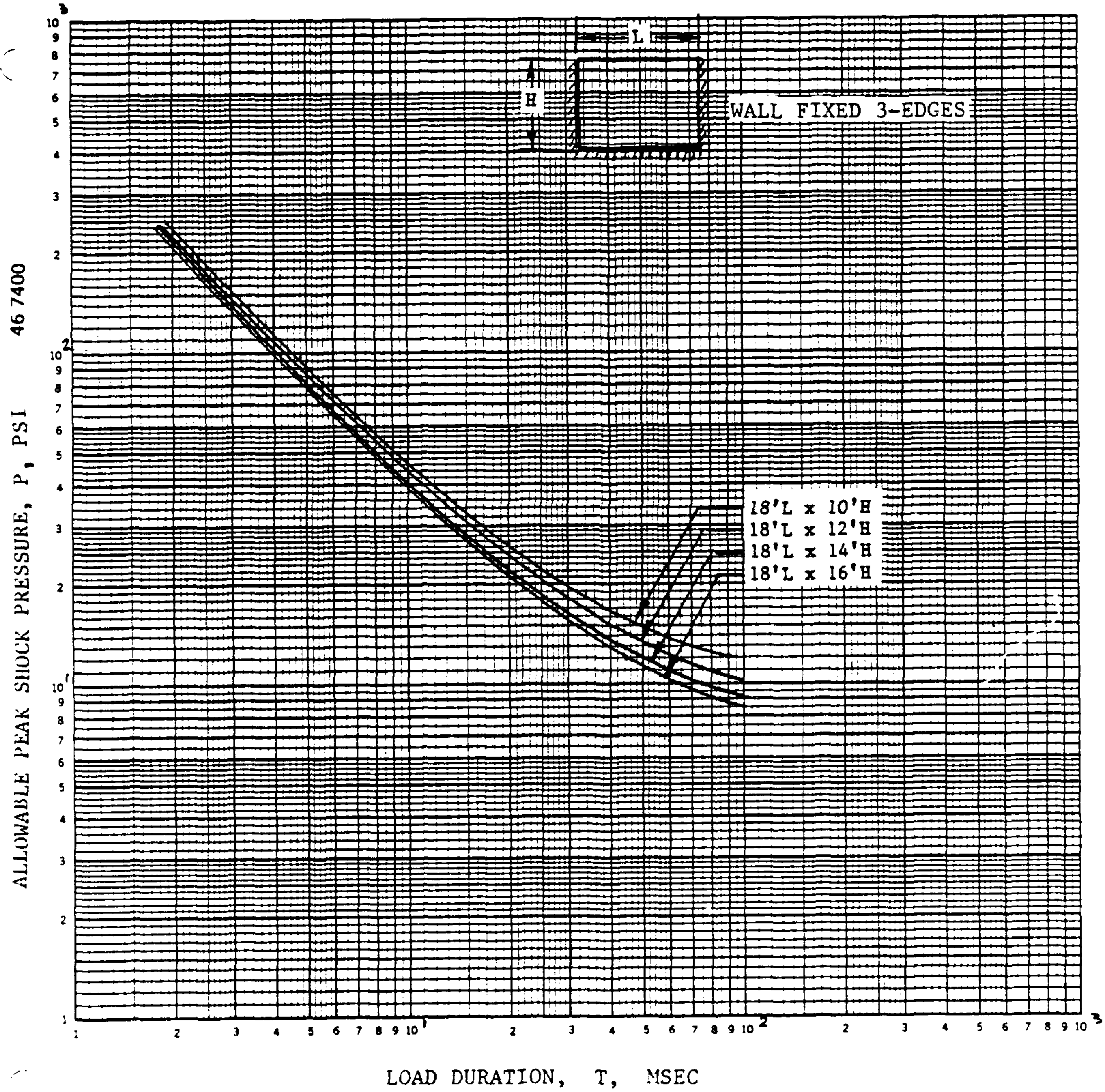


FIGURE C-11 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

APPENDIX D

PERSONNEL EXPOSURE TO OVERPRESSURES

BLAST PROTECTION

FROM

REMOTELY CONTROLLED OPERATIONS

1. The method contained herein will assist you in providing blast protection to personnel at your installation who are exposed to remotely controlled operations.

2. AR 385-64, 22 May 1987, Ammunition and Explosives Safety Standards, chapter 4, requires that personnel in the vicinity of remotely controlled operations must not be exposed to overpressures greater than 2.3 pounds per square inch (psi) in the event of accidental detonation.

3. Unless exposed personnel are in protective shelters, only distance itself plus any blast attenuating features (such as substantial dividing walls) surrounding the remote operation may be used to provide protection. If no substantial dividing walls or other blast attenuating features surround the remote operation, then only distance is used. In this case, personnel located beyond a distance in ft. equal to 24 times the cube root of the explosive weight ($D=24W^{1/3}$) in lbs. are adequately protected. If, on the other hand, susbtantial dividing walls, surround the remote operation and modify the blast output, then the method contained herein may optionally be used in lieu of the default $24W^{1/3}$ distance. Use of this optional method is oftentimes to the installation's advantage, since it can show that a lesser distance than normally required by the $24W^{1/3}$ formula can provide the required protection. However, $24W^{1/3}$ may be used per DoD 6055.9 STD for any remote operation, and is easier to use than this method.

4. The method contained herein applies to remote operations which are surrounded on three sides by sustantial dividing walls. This is the typical 3-walled bay found at most of our ammunition production and maintenance facilities. This method does not apply to 3-walled bays with reinforced concrete roofs, since such a roof produces a completely different blast signature. Use $D=24W^{1/3}$ for bays with other than 3 substantial dividing walls or bays with reinforced concrete roofs. Normal unreinforced roofs, such as the transite variety found at many facilities, do not invalidate this mehtod.

17 JAN 1990

DDESB-KT (SMCAC-ESP/03 Nov 89) 1st End Dr. Canada/sb/325-8624
SUBJECT: Method to Determine the 2.3 Pounds Per Square Inch (psi) Boundary Arc from the Front, Sides, and Back of Three Walled Cubicles Without a Roof

Department of Defense Explosives Safety Board, 2461 Eisenhower Avenue, Alexandria, VA 22331-0600

FOR DIRCTOR, US ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY, ATTN: SMCAC-ES, SAVANNA, IL 6L074-9639

The subject method to compute the 2.3 psi pressure contour from a 3-walled cubicle without a roof has been reviewed with respect to explosives safety. Application of the proposed method for purposes of providing personnel protection from hazardous operations, as addressed in Chapter 4 of DoD 6055.9-STD, is approved.

wd all encls

JACK MATHEWS
Colonel, USAF
Chairman

Method to Determine the 2.3 psi Boundary Arcs

from the Front, Sides, and Back

of Three Walled Cubicles

Without a Roof*

An Example is Integrated into this Method

Symbol	Meaning	Comment
d	Slant distance from the charge to the 2.3 psi boundary arc	
d_p	Plan distance from the charge to the 2.3 psi boundary arc.	In our example, we will solve for d_p three times: Once from the cubicle front, once from the side, and once from the back.
h	Height of cubicle wall in feet.	This is also the horizontal (plan) distance needed for a blast wave to reform after it has passed over the donor cubicle wall.
Z	The scaled distance.	Obtain Z values from Figure 2-168, revised TM 5-1300. This figure is reproduced at page 10. $Z=d/W^{1/3}$ or $d_p/W^{1/3}$, depending upon application.
W	The TNT equivalency in pounds.	In our example, W = 3 pounds.
P_{so}	Peak incident overpressure in psi.	Maximum exposure allowed: 2.3 psi

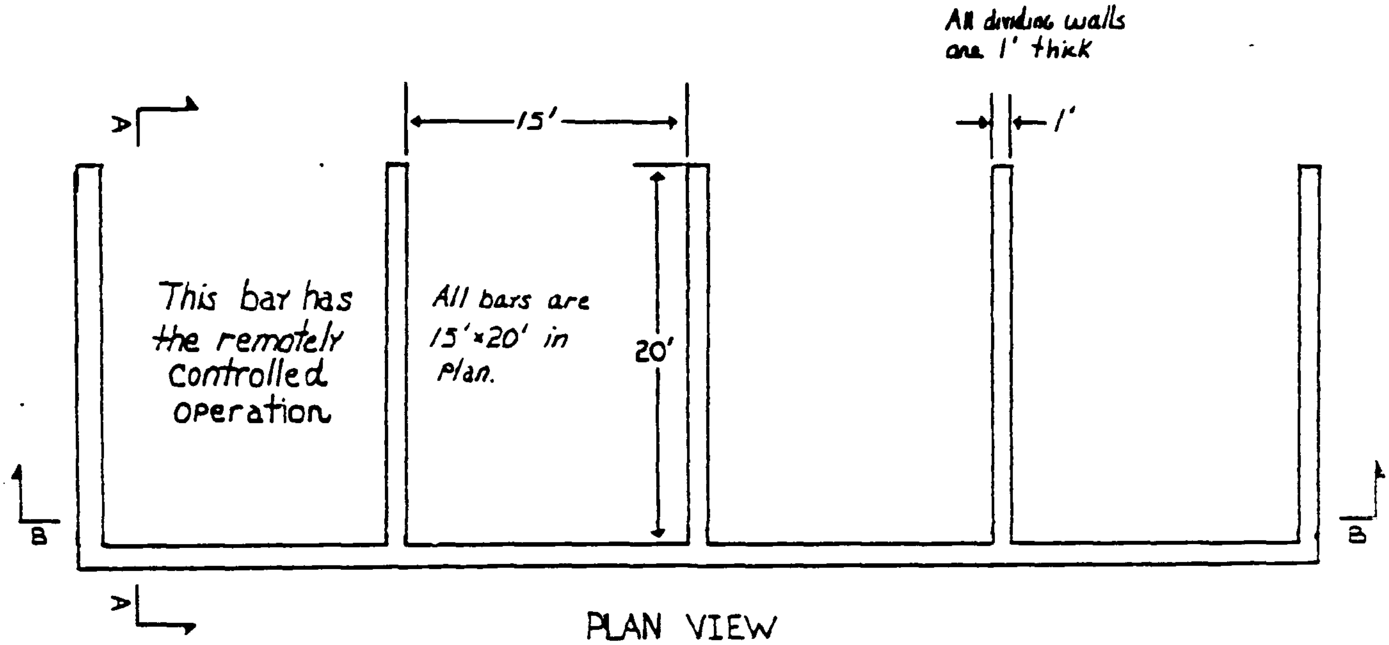
*Without a reinforced concrete roof.

See building used in example on next page.

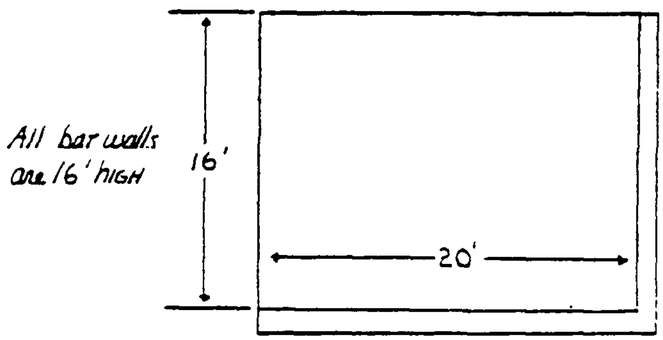
For more information contact the following:

Mr. Clifford H. Doyle, SMCAC-ESL, AV 585-8802 or Commercial 815-273-8802.

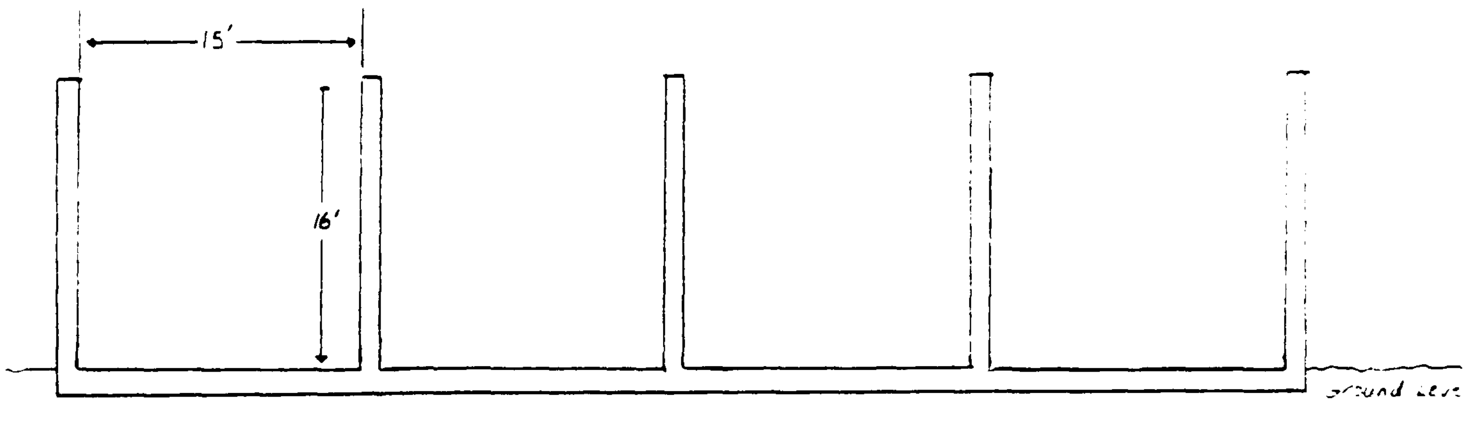
<u>Fig. 1: Building Used in Example</u>



PLAN VIEW



VIEW AA



VIEW BB

Scale 1" = 10'

STEP 1 : Determine nominal 2.3 psi boundary arc (with radius d_p) from the front of the cubicle.

1a. Geometric Definitions

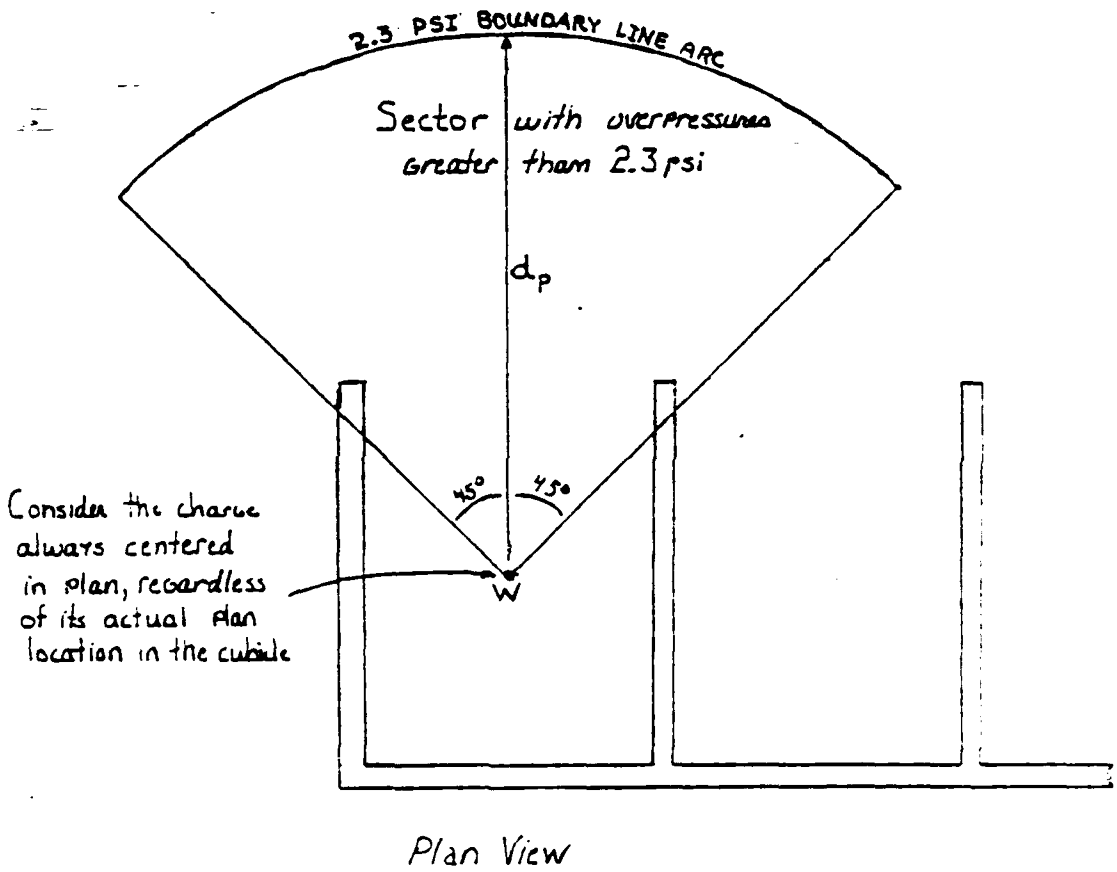


Figure 2 : Geometric Definition of Front

1b. Determine Z. Use Figure 2-168 (from revised TM 5-1300) on page 10. Z is the X coordinate of the intersection of the 2.3 psi line with the "FRONT" curve.

From Figure 2 - 168:
Z = 34.5

STEP 1 (continued)

1c. Determine d_p

$$Z = d_p/W^{1/3}$$

$$d_p = Z \cdot W^{1/3}$$

$$d_p = 34.5 \cdot 8^{1/3}$$

$$d_p = 69 \text{ feet}$$

1d. Using figure 2 as a guide, draw the 2.3 psi boundary arc (and the corresponding sector of overpressures exceeding 2.3 psi) on a site plan of the building and surrounding area. No personnel are allowed in this sector during pressing operations unless they are protected from both pressures exceeding 2.3 psi and from hazardous fragments.

STEP 2 : **Determine the nominal 2.3 psi boundary line (with radius d_p) from the sides of the cubicle.**

2a. Geometric definitions

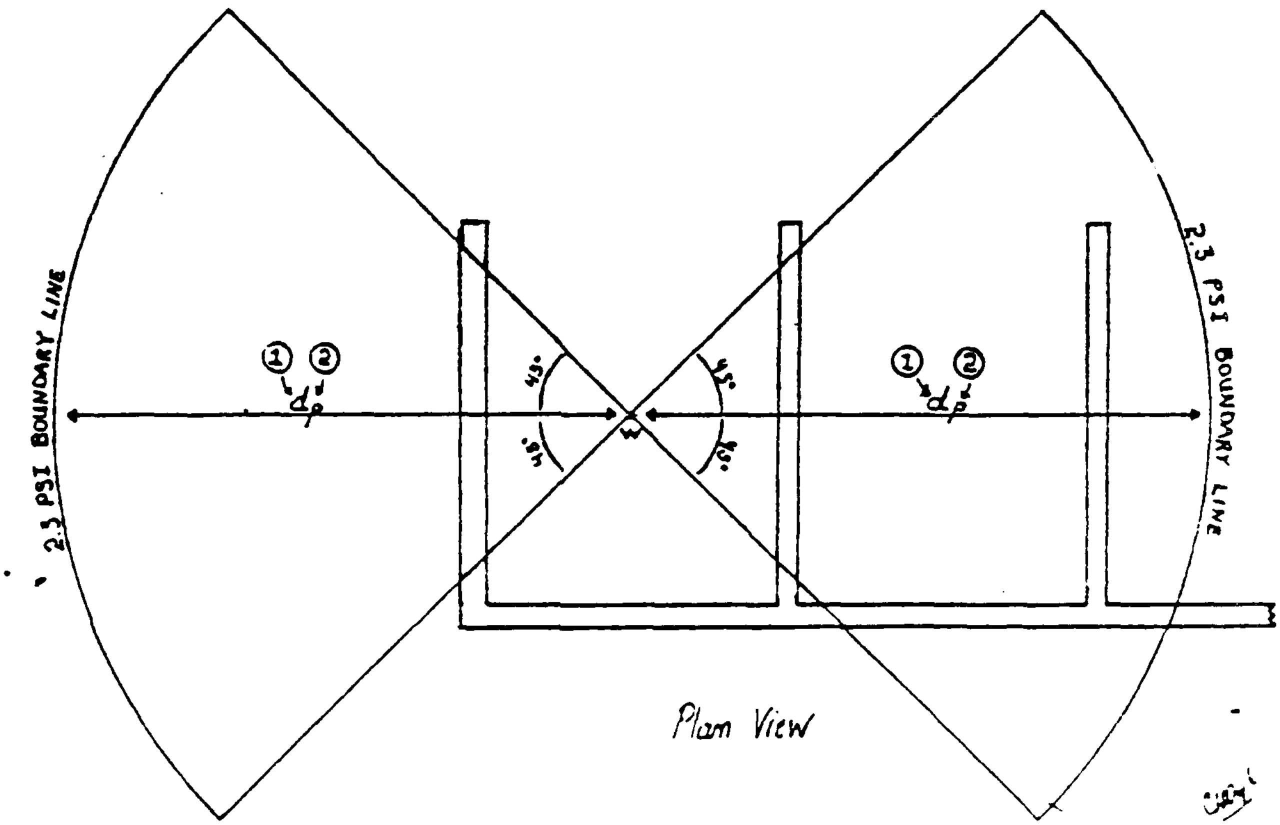


Figure 3 : Geometric Definition of Side

NOTES

1. d_p exists only in plan. However, d_p represents the sum of the horizontal (plan) displacements of a number of lines, some of which exist in both plan and elevation.

2. In the above diagram, the d_p on the left and the d_p on the right have equal displacements; however, in actual practice they may not be equal. See Figure - for diagrammatic explanations.

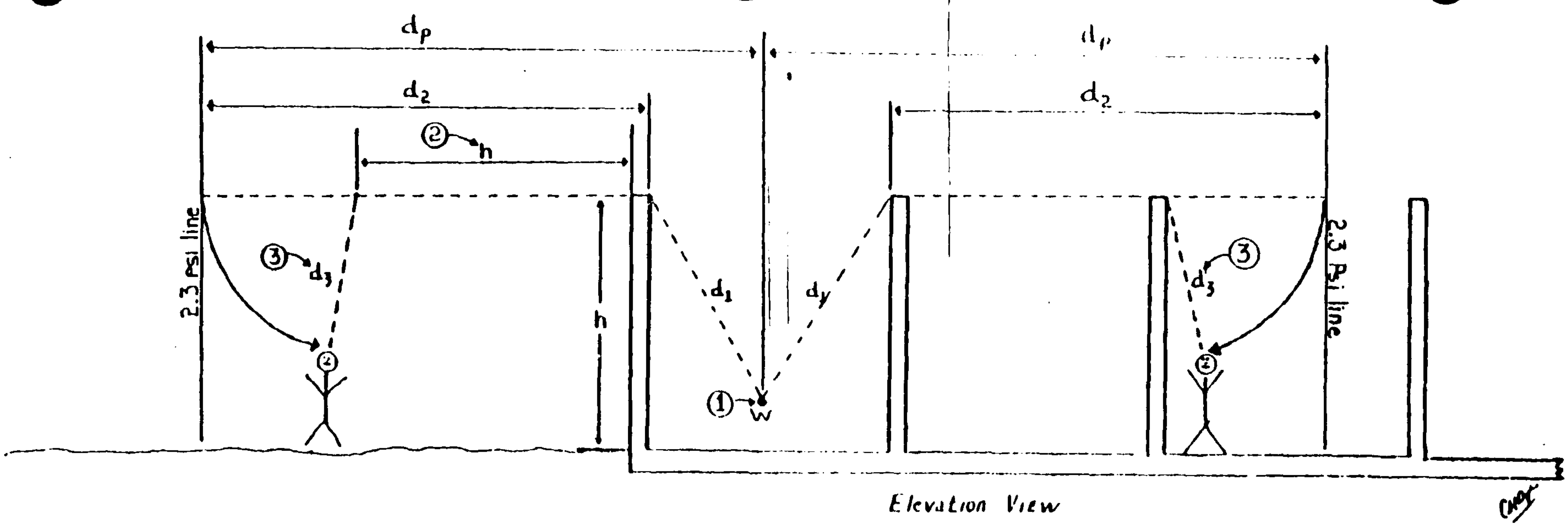


Figure 4 : D_1, D_2, D_3, and D_p

NOTES from Figure

1. Consider the charge as always centered in plan. In elevation, use actual elevation of center of charge above the floor.

2. Blast wave reform (coalescense) distance is equal to the cubicle wall height.

3. When establishing the distance to the 2.3 psi line based on a known explosive weight W, d_2 goes straight out in plan from the top of the cubicle wall. However, when establishing an explosive weight limit W based on definite distance to a personnel location, d_2 takes a different path:

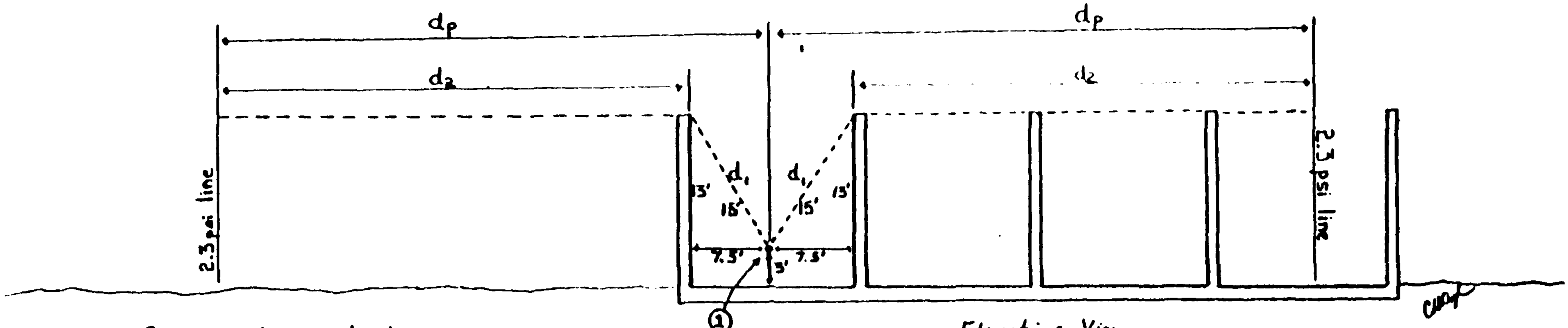
a. Path from cubicle to outside the building (leftward in above figure): Slant that part of line d_2 which lies beyond distance h down to the personnel location. Call this new line d_3.

b. Path from cubicle to other cubicles: Slant the last part of line d_2 down from the top of the wall to the personnel location. Call this new line d_3.

Other Notes

1. $d = d_1 + d_2$ (+ d_3 if one is solving for W given a distance to a known personnel location)

2. d_p = the sum of the horizontal (plan) displacements of d_1 and d_2.



Notes. 1. Charge is always centered in plan. Use actual elevation.

Figure 5 : Example of Computation of D_1, D_2, and D_p
Use this figure with the procedure below.

STEP 2b (continued from page 5)

1. DETERMINE Z
   From Fig. 2-168 on page 10: $Z = 28$

2. COMPUTE d
   $Z = d/W^{1/3}$
   $d = Z \cdot W^{1/3}$
   $d = 28 \cdot 8^{1/3}$
   $d = 56$ feet

3. COMPUTE d_1 and d_2
   $d_1 = \sqrt{7.5^2 + 13^2}$
   $d_1 = 15$ feet

   $d = d_1 + d_2$
   $d_2 = d - d_1$
   $d_2 = 56 - 15$
   $d_2 = 41$ feet

4. DRAW d_1 and d_2 in both left and right directions on an elevation view of the building.

5. COMPUTE d_p. d_p is the sum of the horizontal (plan) displacements of d_1 and d_2.

   $d_p = 7.5 + 41$
   $d_p = 48.5'$

6. Using Figure 3 as a guide, draw the 2.3 psi arcs (with radius = 48.5 feet) and their corresponding sectors with overpressure exceeding 2.3 psi on a site plan of the building and its surroundings. No personnel are allowed in this sector during pressing operations unless they are protected from both overpressures exceeding 2.3 psi and from hazardous fragments.

STEP 3 : Determine the nominal 2.3 psi boundary arc (with radius d_p) from the back of the cubicle.

The geometric definitions and method of computation are similar enough to STEP 2 such that a detailed explanation is not necessary here.

STEP 4 : What to do if personnel are located inside any of the > 2.3 psi sectors:

1. Evacuate them during pressing.

2. Protect them with engineering controls.

3. Reduce the press bay limit W, thus shrinking the > 2.3 psi sector. See example at Figure 6.

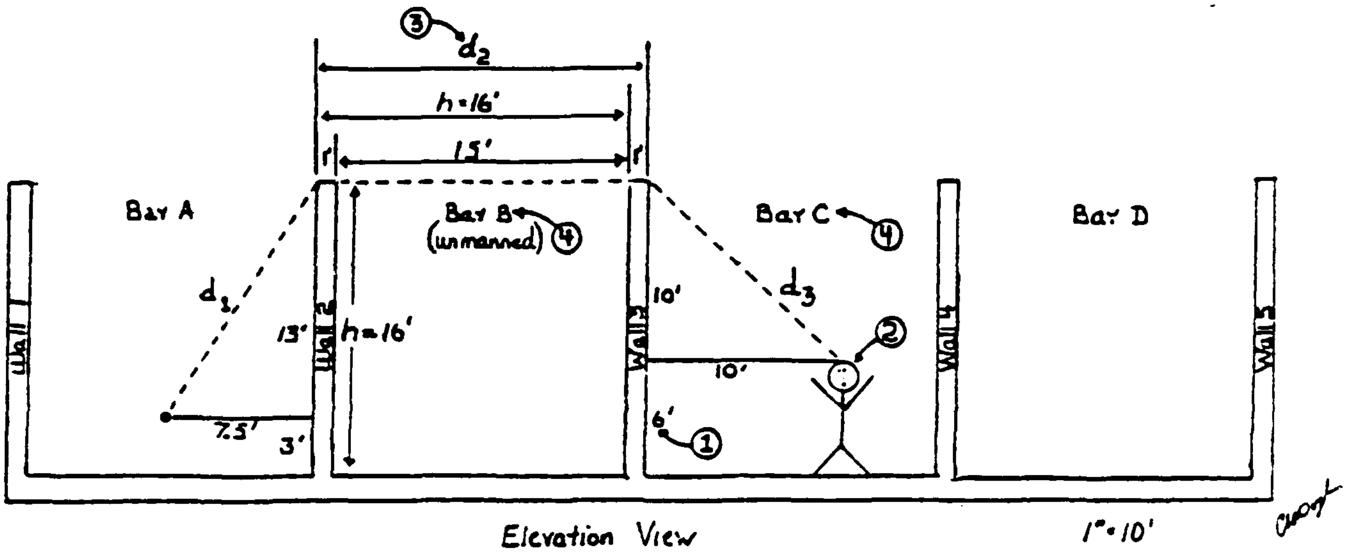


Figure 6 : Example of computation of W when distance to personnel is known. This example is only for a side exposure. Compute W for all exposures (the other side, front, and back). The lowest W is the press bay limit.

-NOTES-

1. This example uses a 6-foot man standing on the floor.

2. The man represents the nearest personnel location in Bay C to Wall 3.

3. d_2 must always extend horizontally a minimum of the blast wave reform distance h before slanting downward to the personnel location. If one were measuring to a personnel location in Bay B (instead of Bay C as shown), and h were unchanged at h = 16 feet, then d_2 would extend horizontally to Wall 3 and then straight down the Bay B side of the wall to head height.

4. If the roof of Bay C is frangible, a wire mesh screen installed beneath it will catch falling roof debris and provide required fragment protection for personnel.

-COMPUTATION of W-

1. COMPUTE d_1, d_2, d_3

$$d_1 = \sqrt{7.5^2 + 13^2} = 15 \text{ feet}$$
$$d_2 = 17 \text{ feet}$$
$$d_3 = \sqrt{10^2 + 10^2} = 14.1 \text{ feet}$$

2. COMPUTE d (d_2 is not needed)

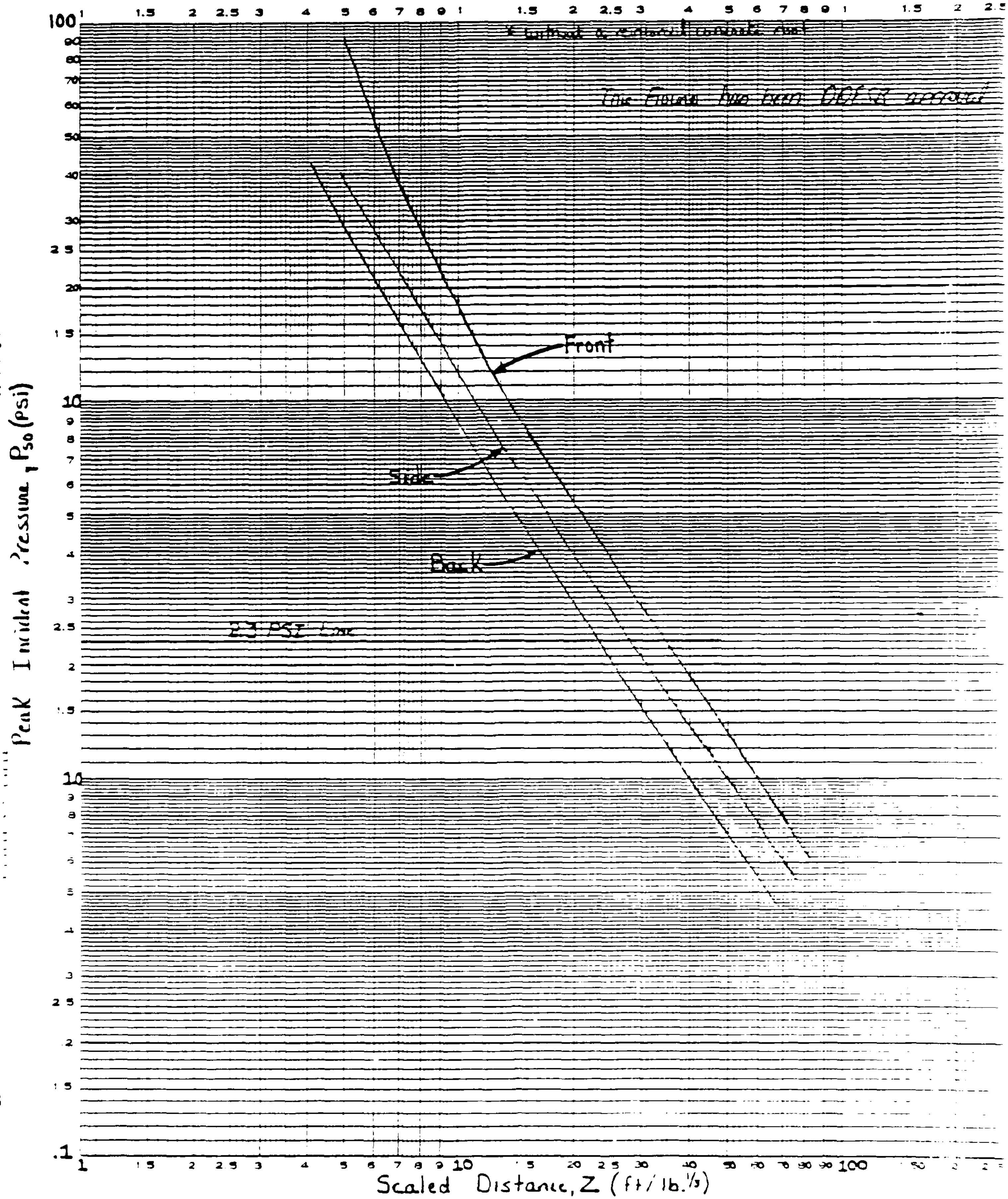
$$d = d_1 + d_2 + d_3 = 15 \text{ feet} + 17 \text{ feet} + 14.1 \text{ feet} = 46.1 \text{ feet}$$

3. COMPUTE W

$$Z = d/W^{1/3}$$
$$Z \cdot W^{1/3} = d$$
$$W^{1/3} = d/Z$$
$$W = (d/Z)^3$$
$$W = (46.1/28)^3$$
$$W = 4.46 \text{ pounds}$$

∴Based on exposure to Bay C, limit is 4.46 pounds.
Compute a limit for each other exposure similarly.
The smallest value is the press bay limit.

From Revised TM 5-1300 · Figure 2-168
Envelope curves for peak positive pressure outside three wall cubicles without a roof*



APPENDIX E

ALLOWABLE PRESSURE-DURATION

OF WALLS

WITH

SAND LAYER BEHIND WALL

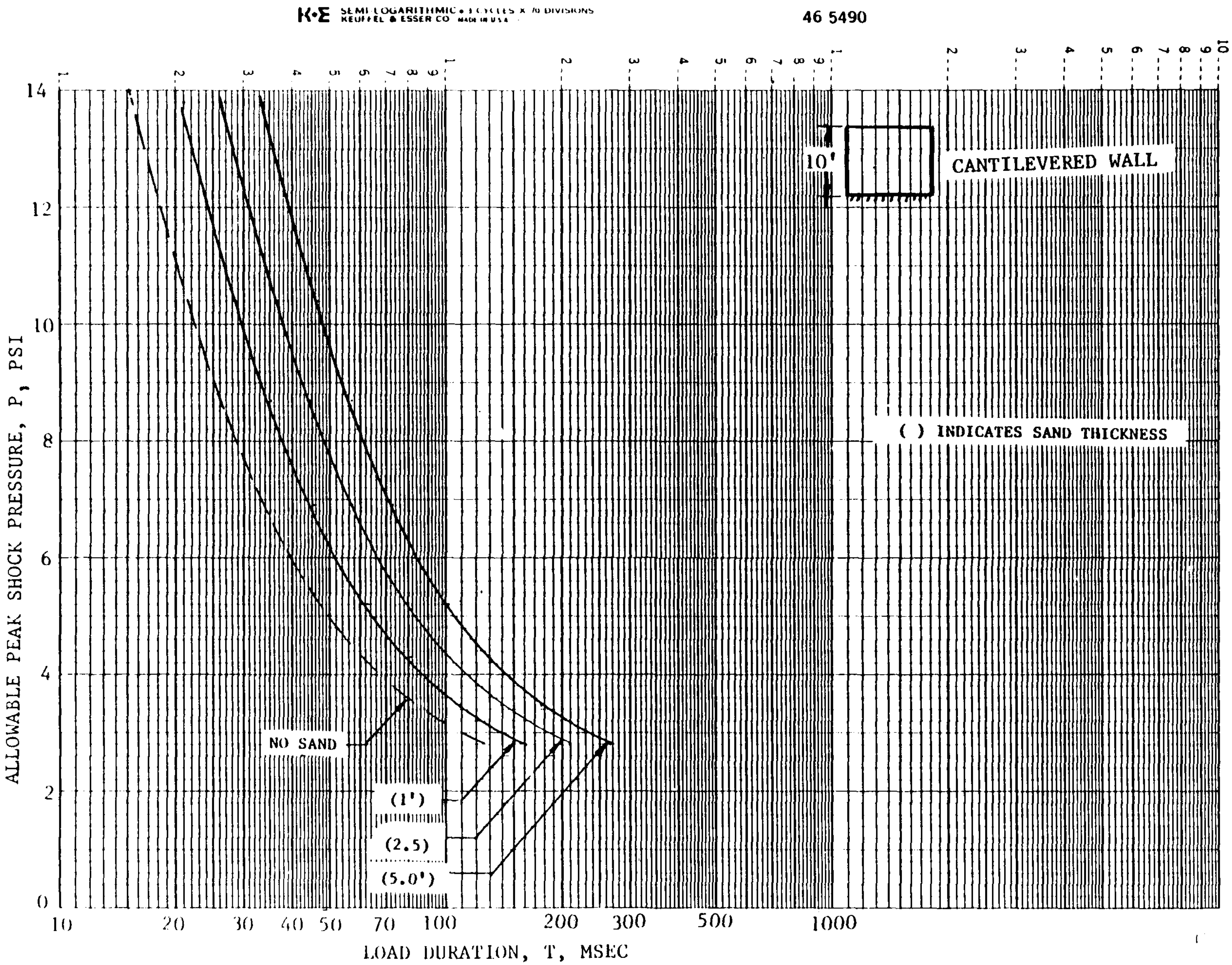


FIGURE E-1 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

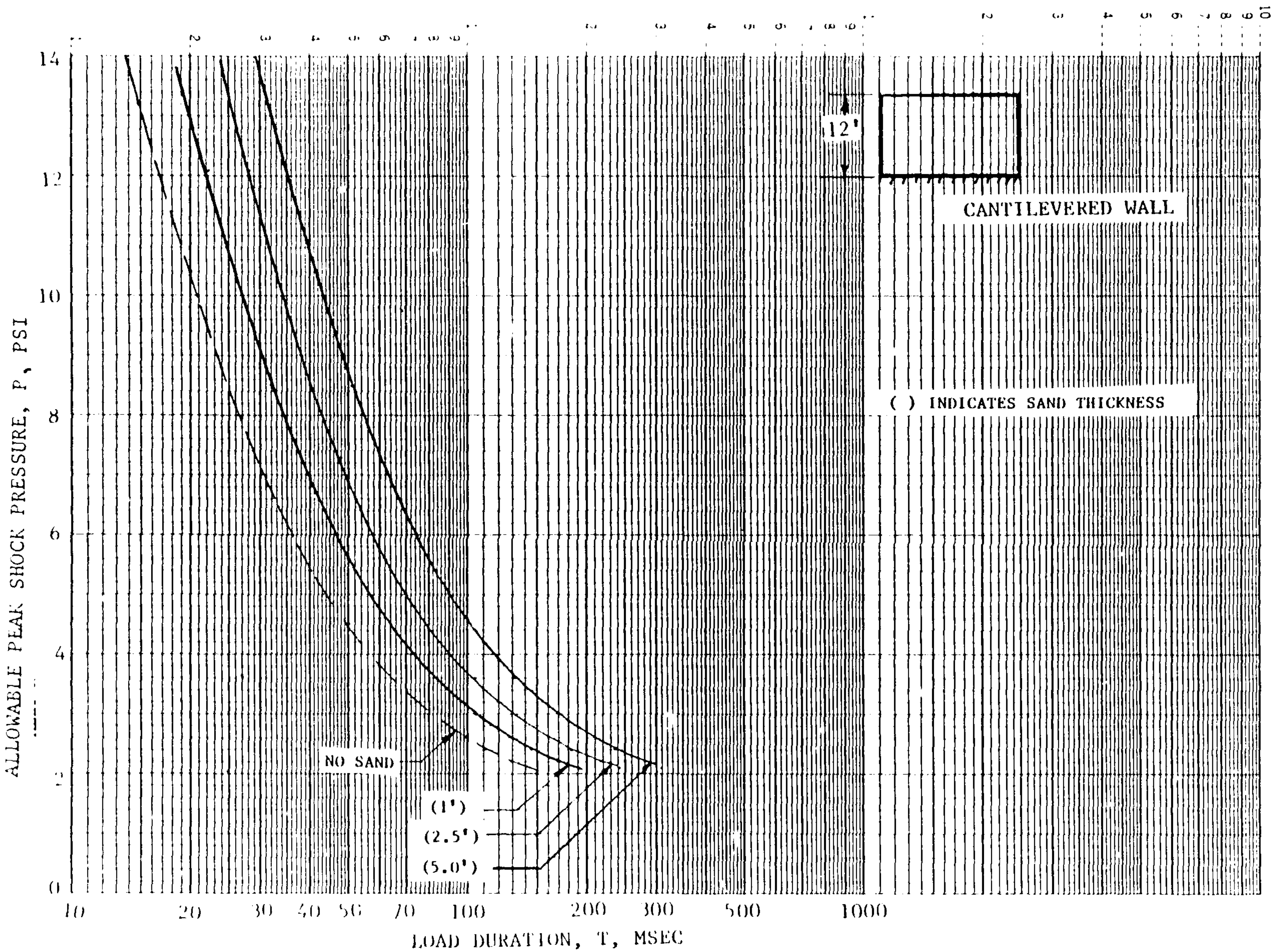


FIGURE E-2 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

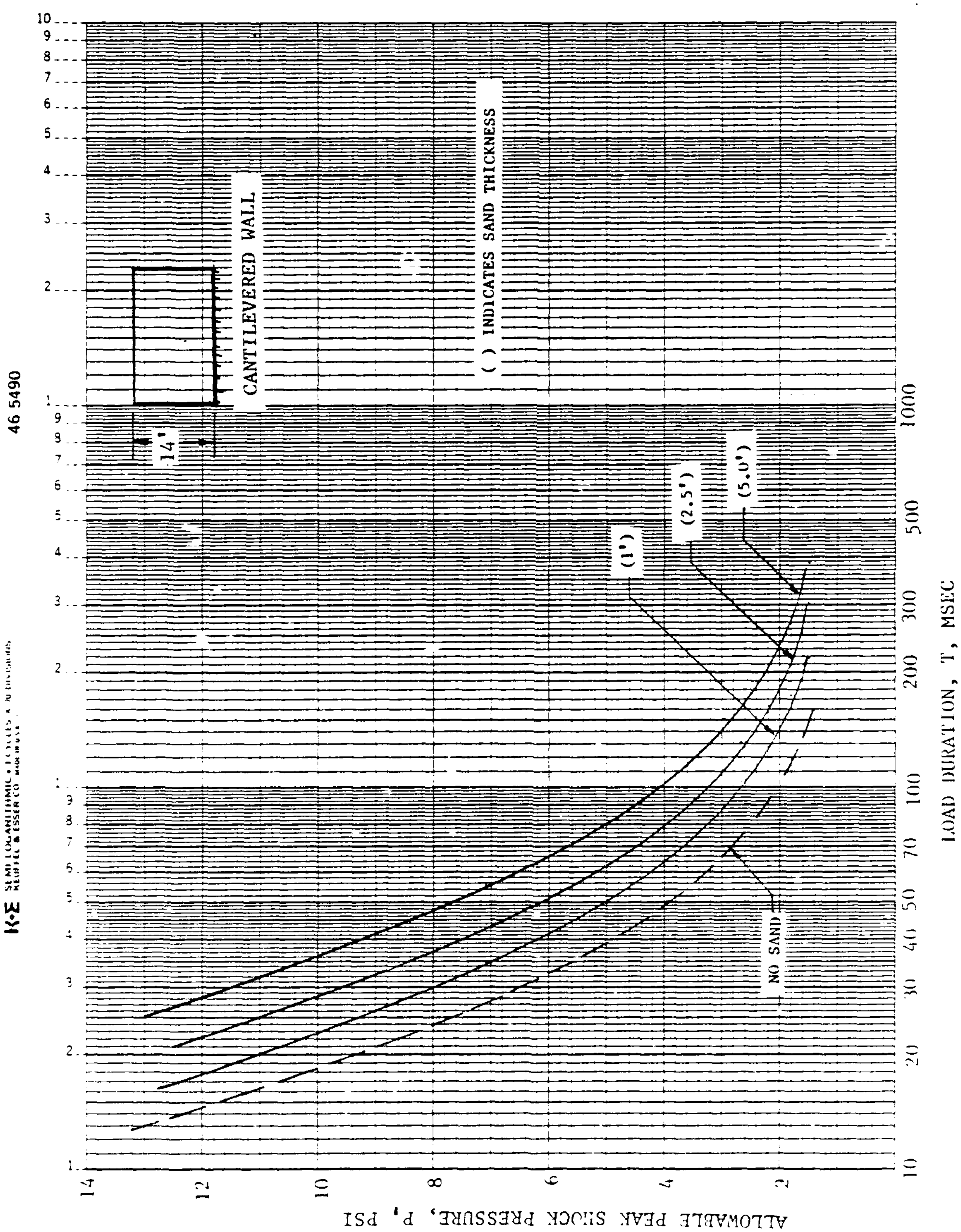


FIGURE E-3 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

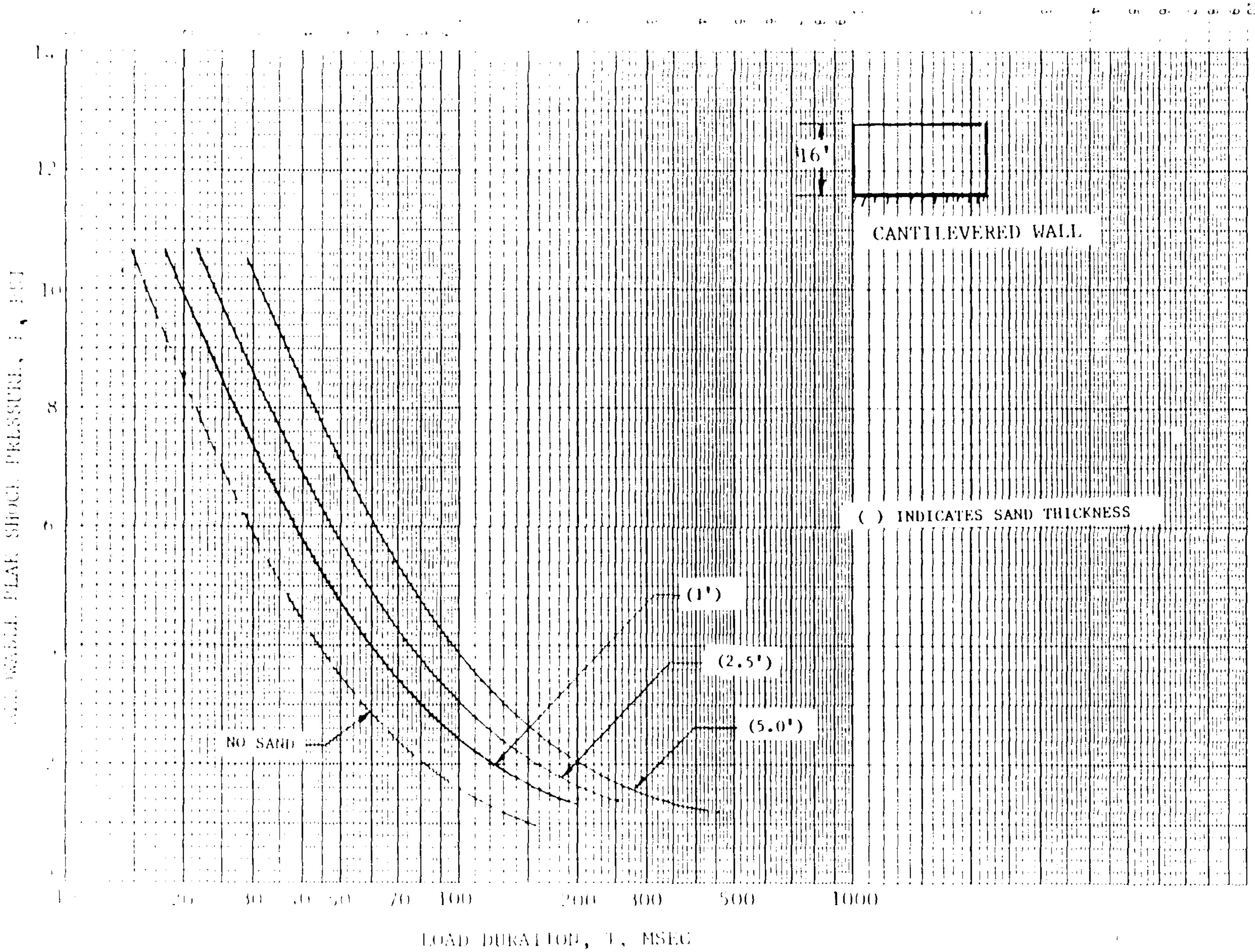
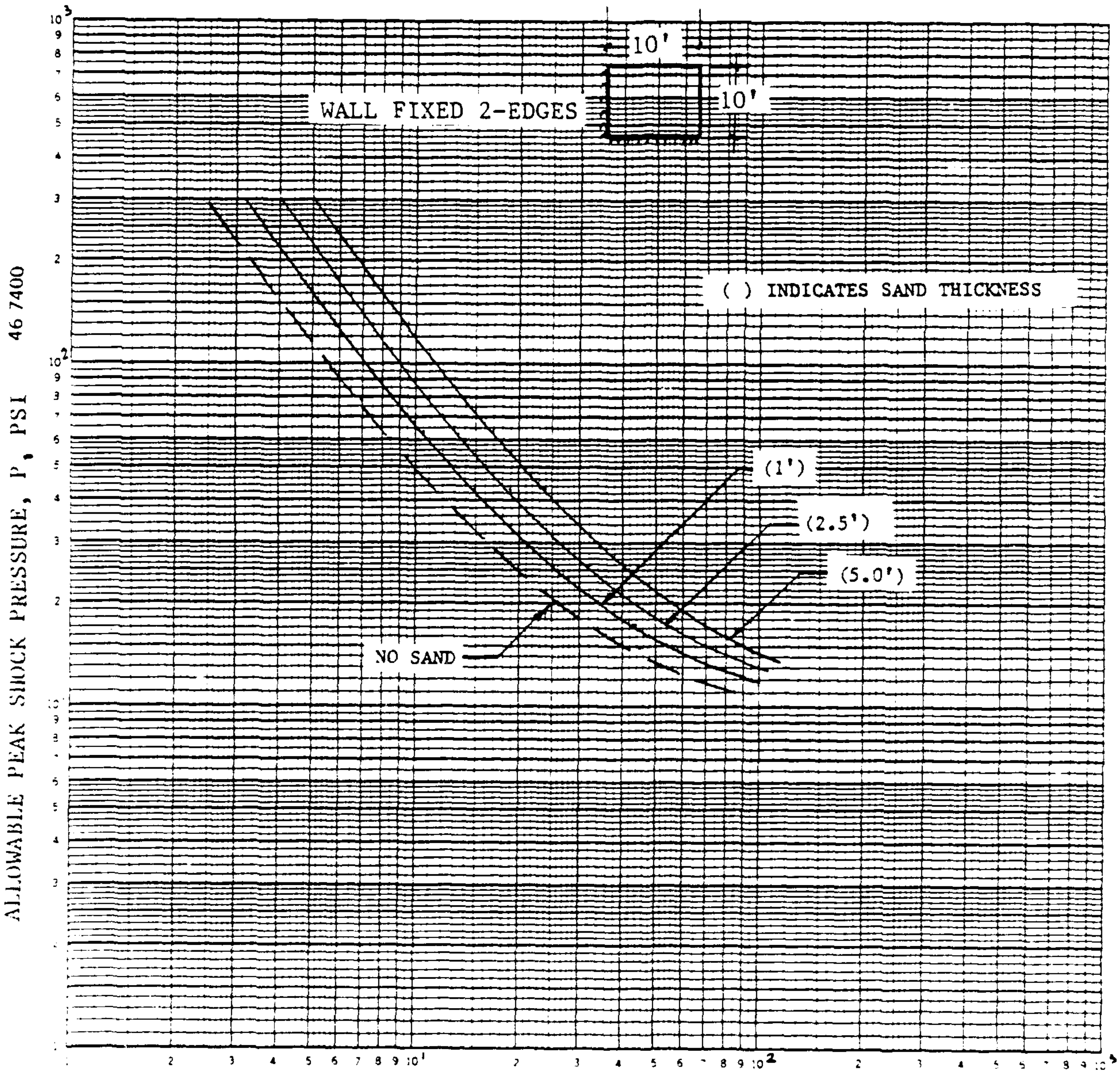


FIGURE E-. ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION



LOAD DURATION, T, MSEC

FIGURE E-5 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

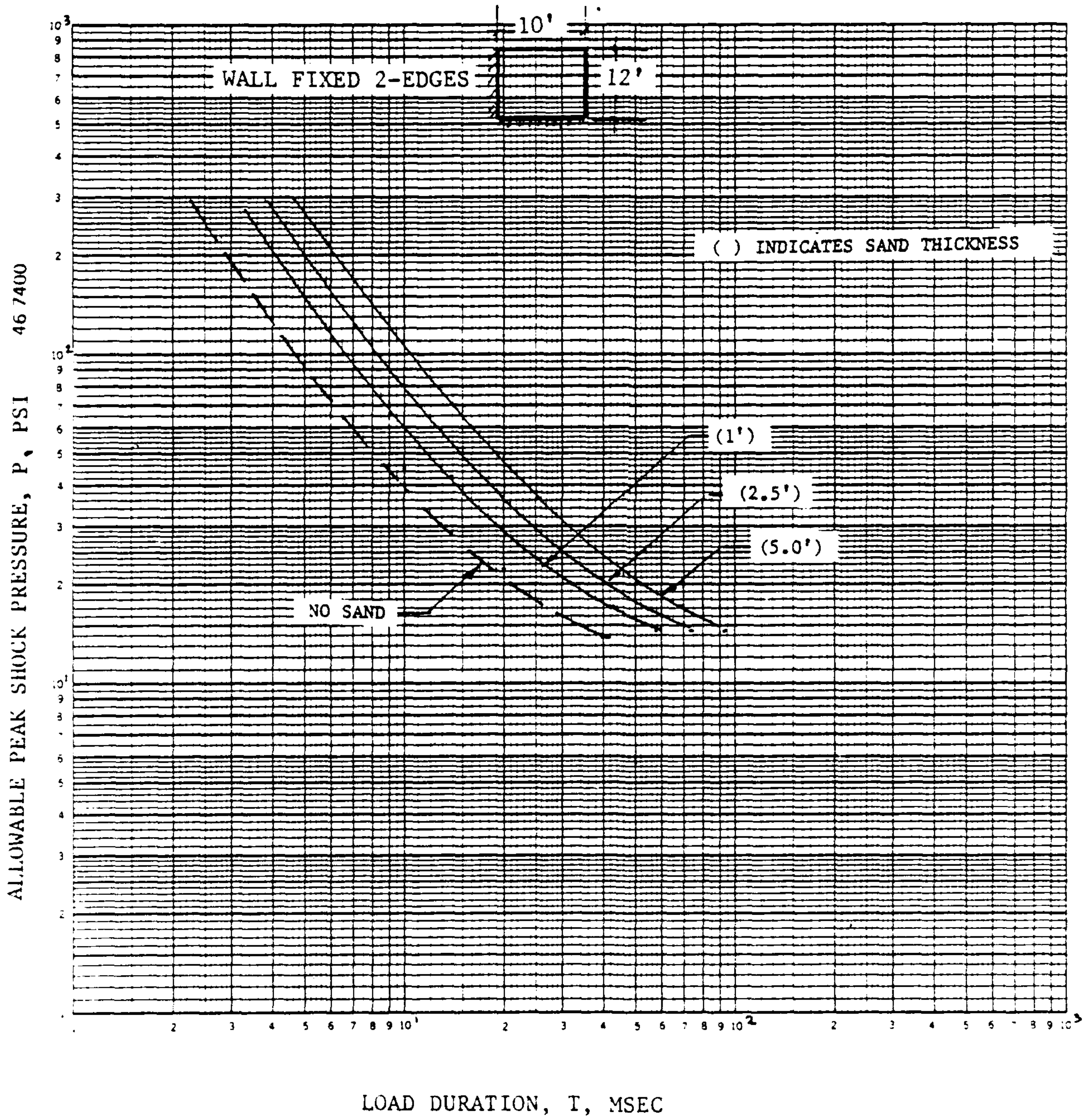


FIGURE E-6 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

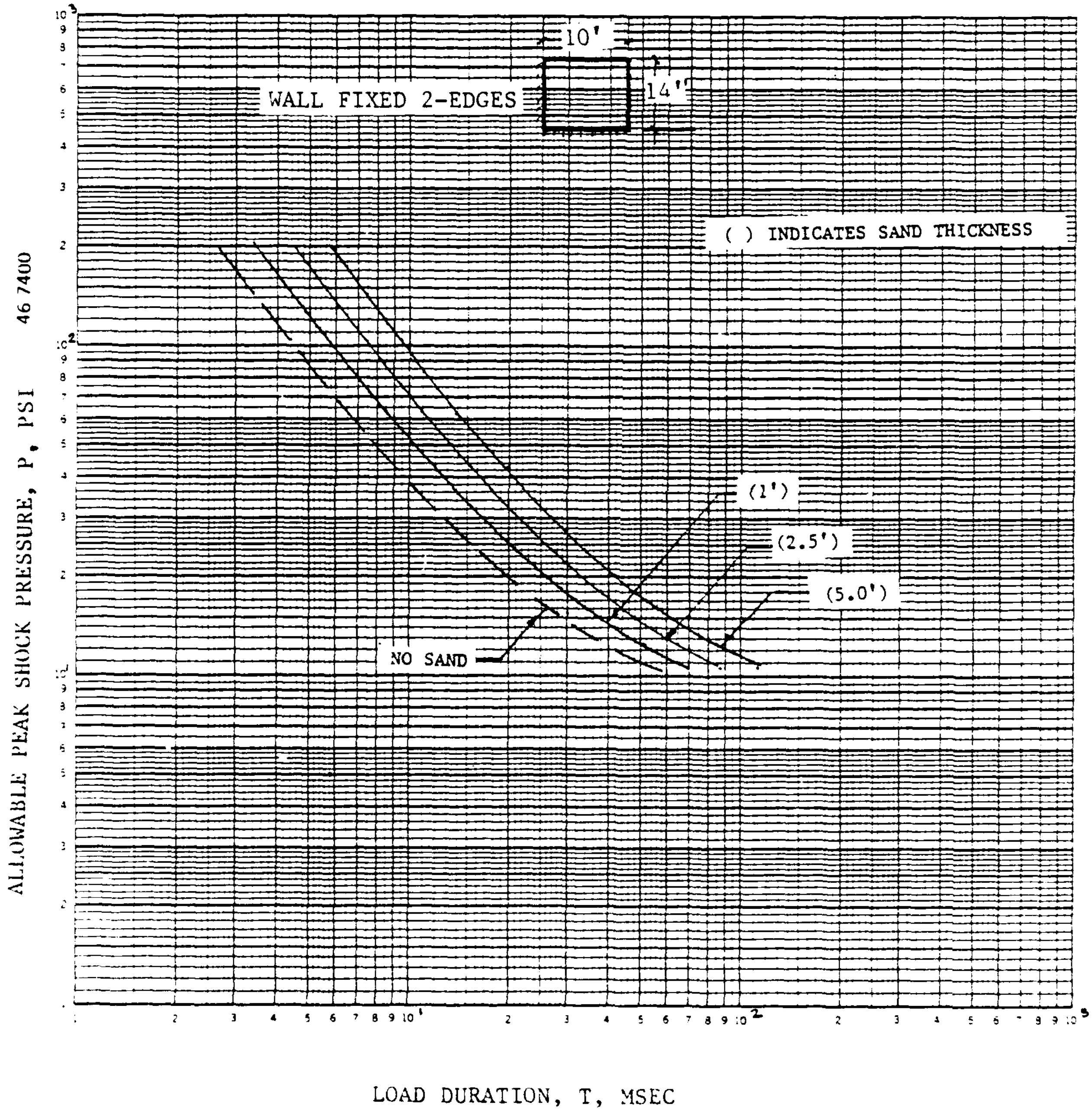


FIGURE E-7 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

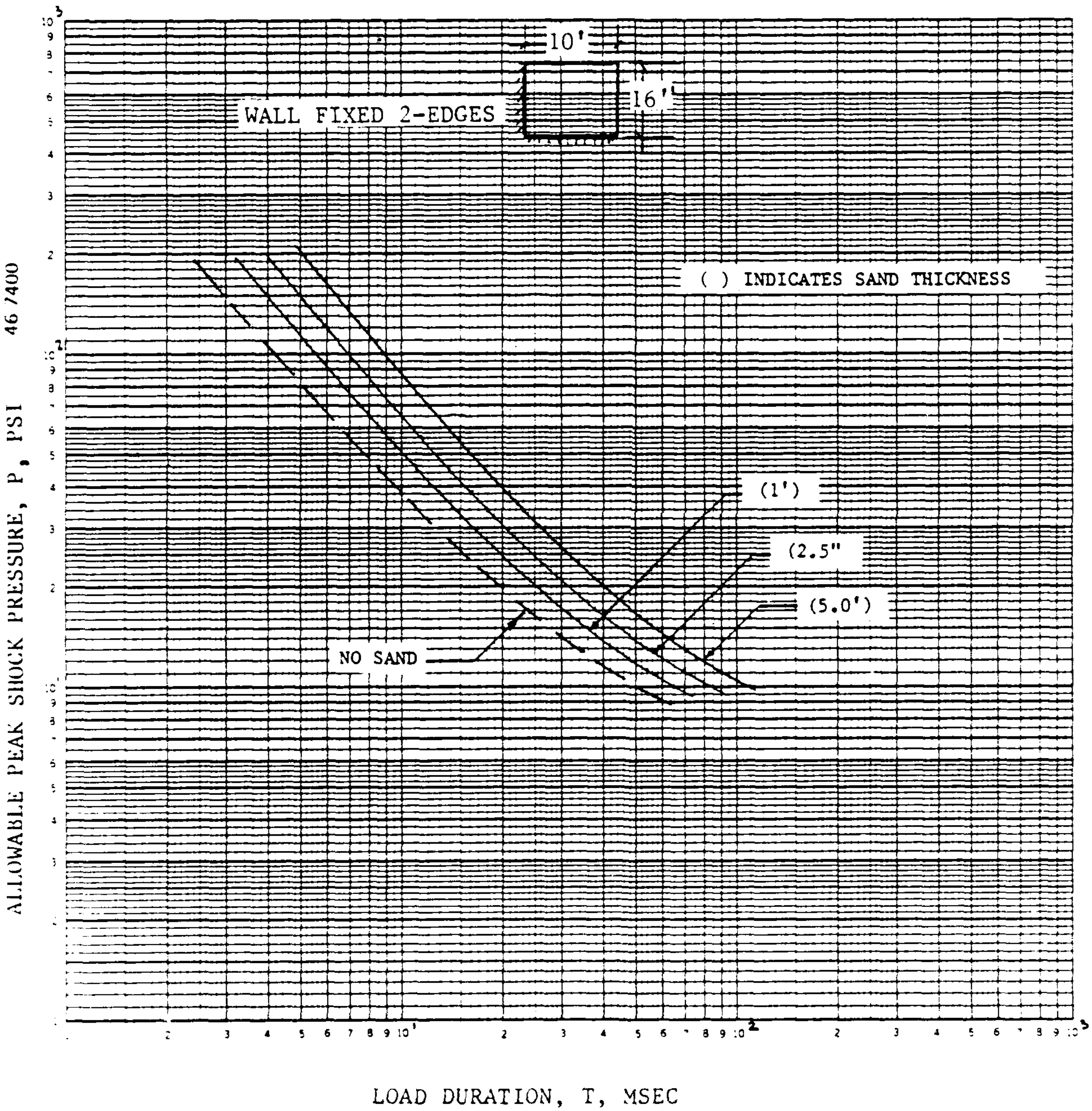


FIGURE E-8 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

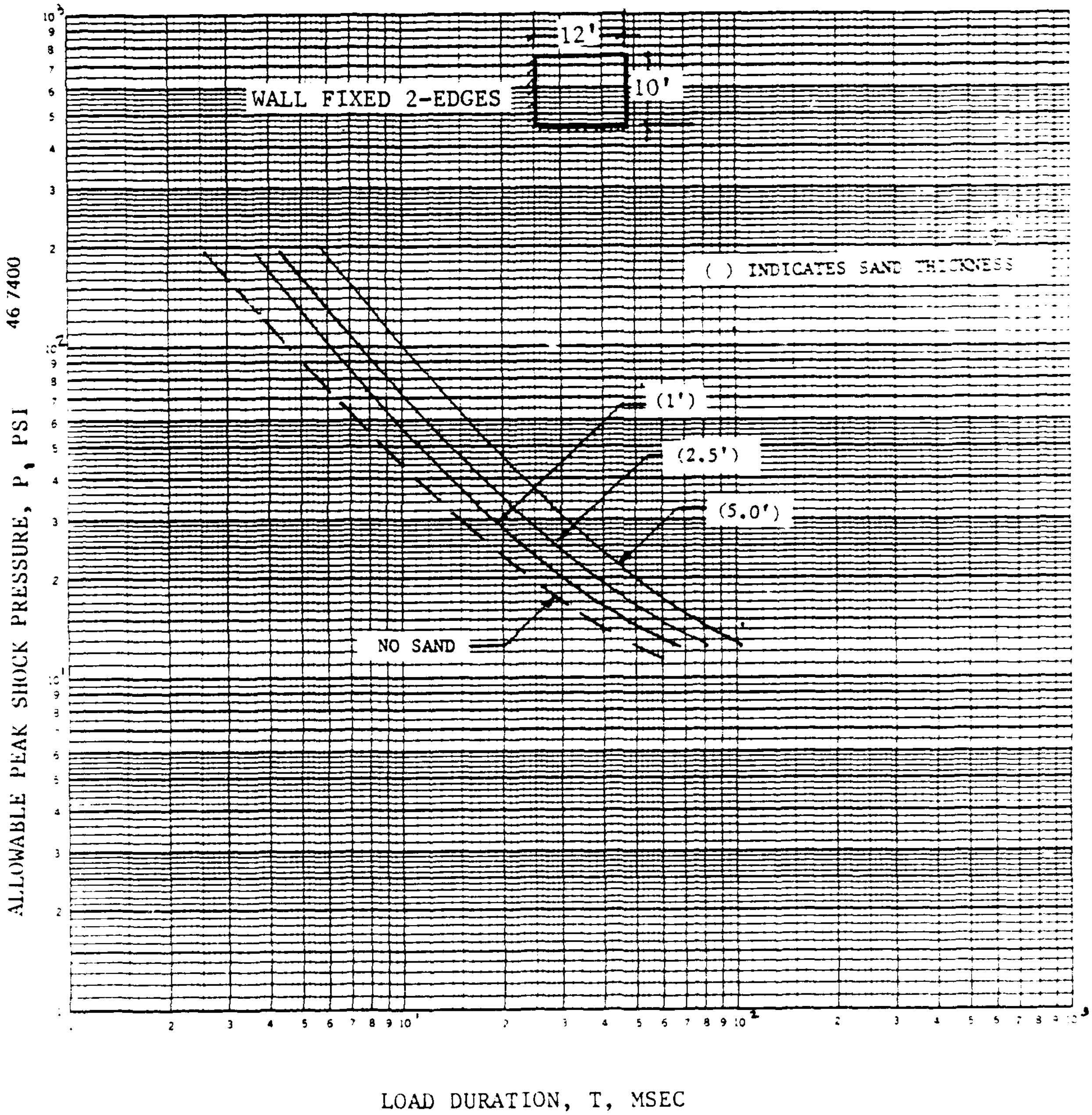


FIGURE E-9 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

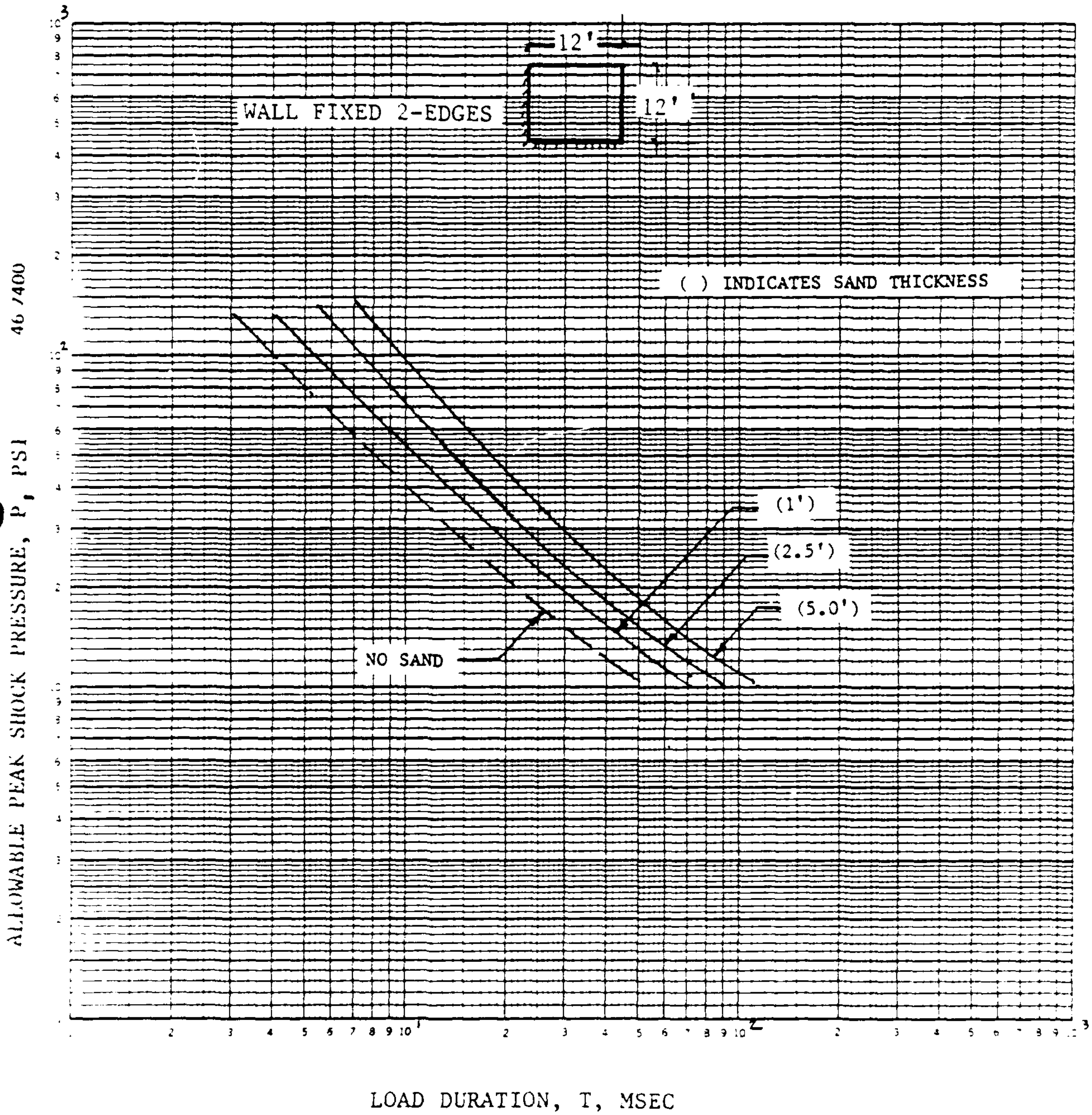


FIGURE E-10 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

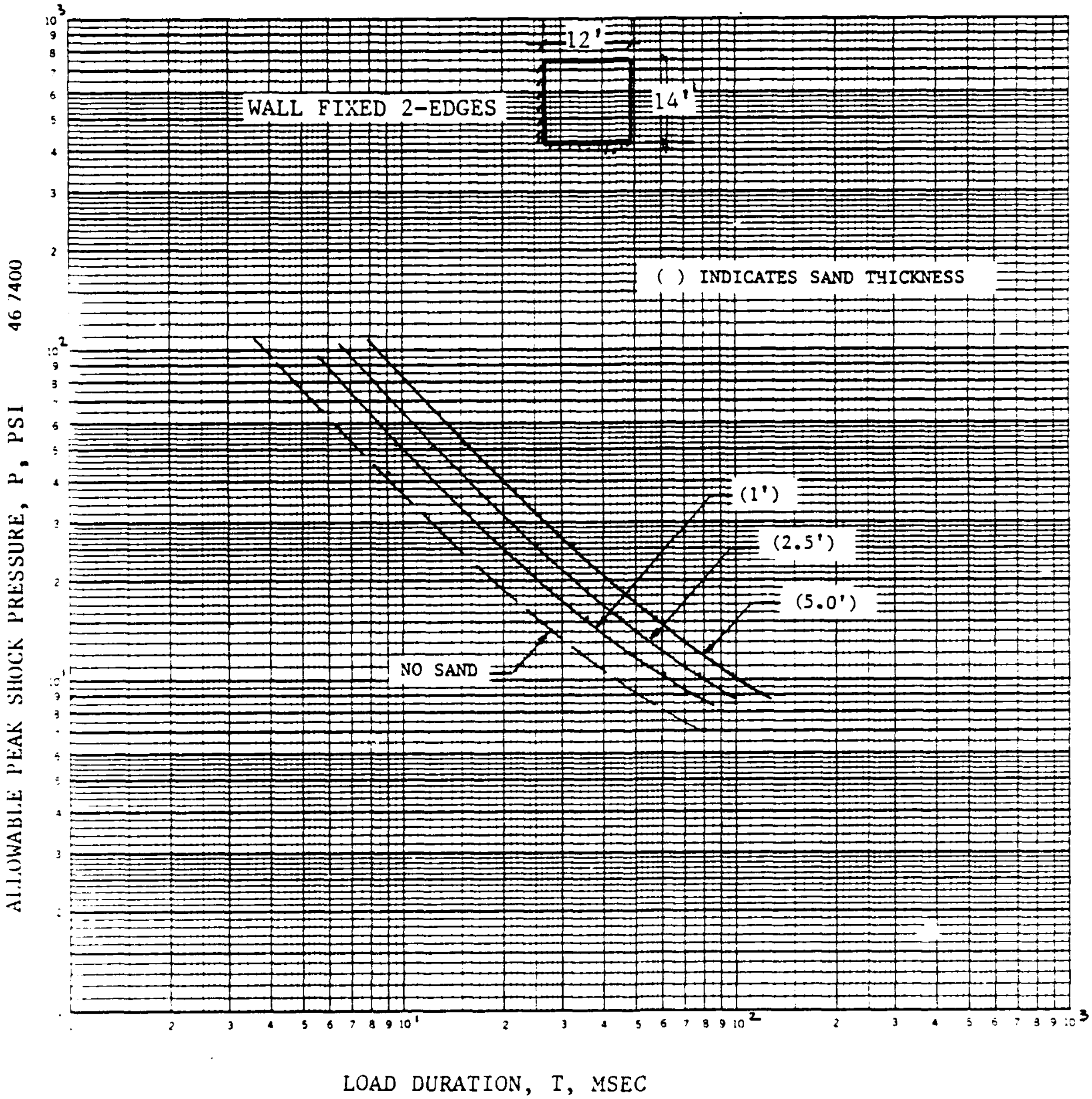


FIGURE E-11 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

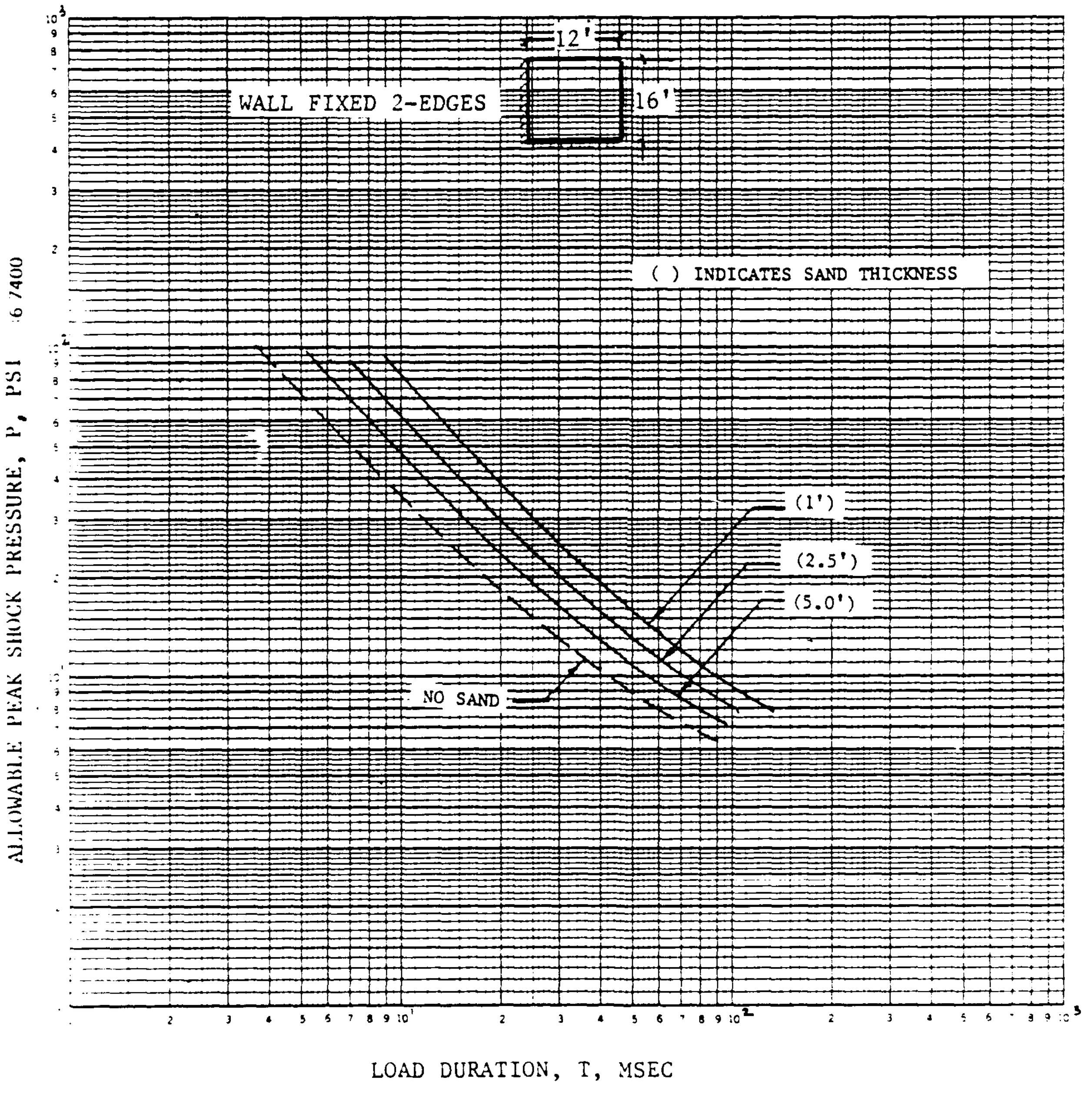


FIGURE E-12 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

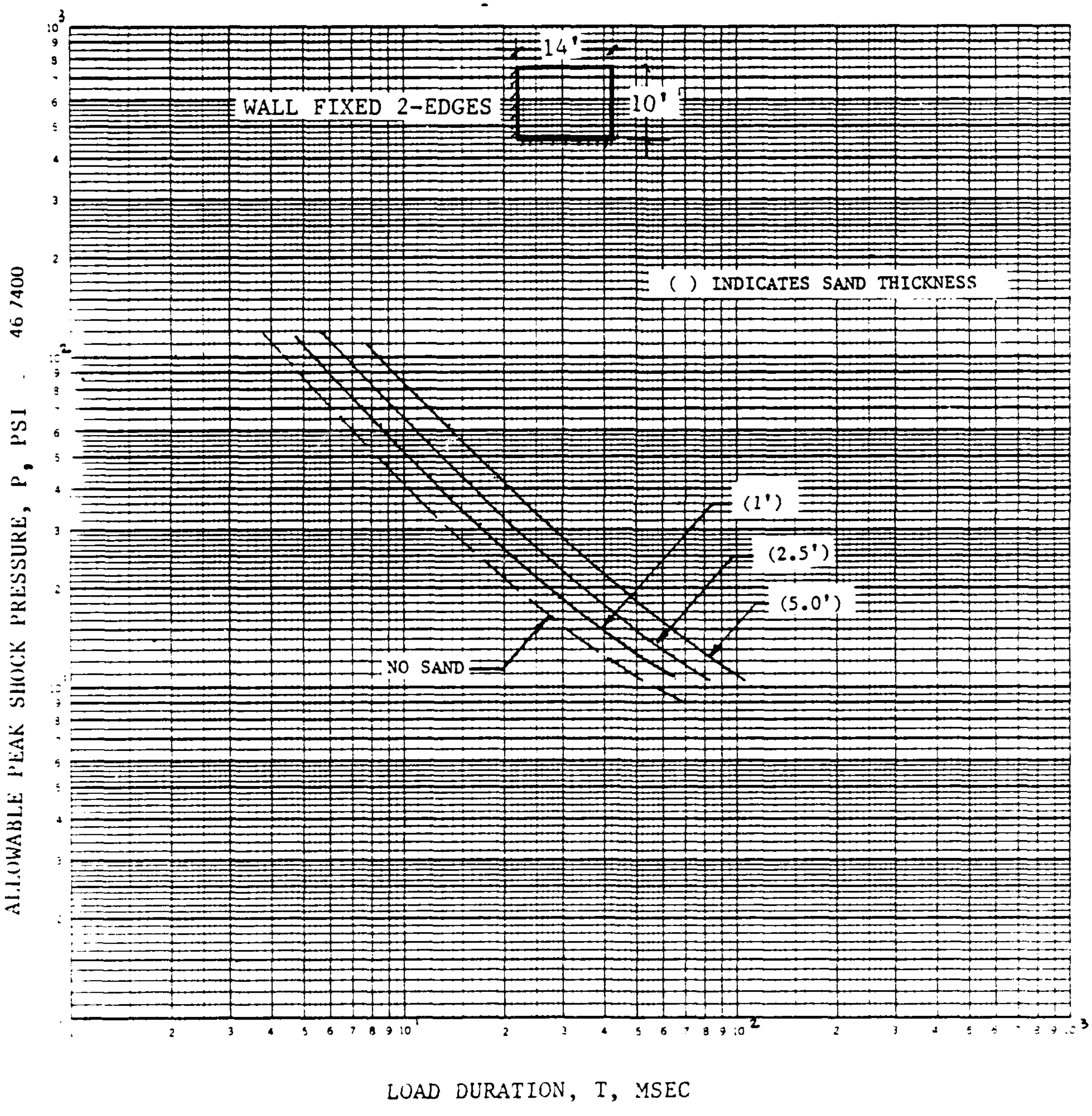


FIGURE E-13 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

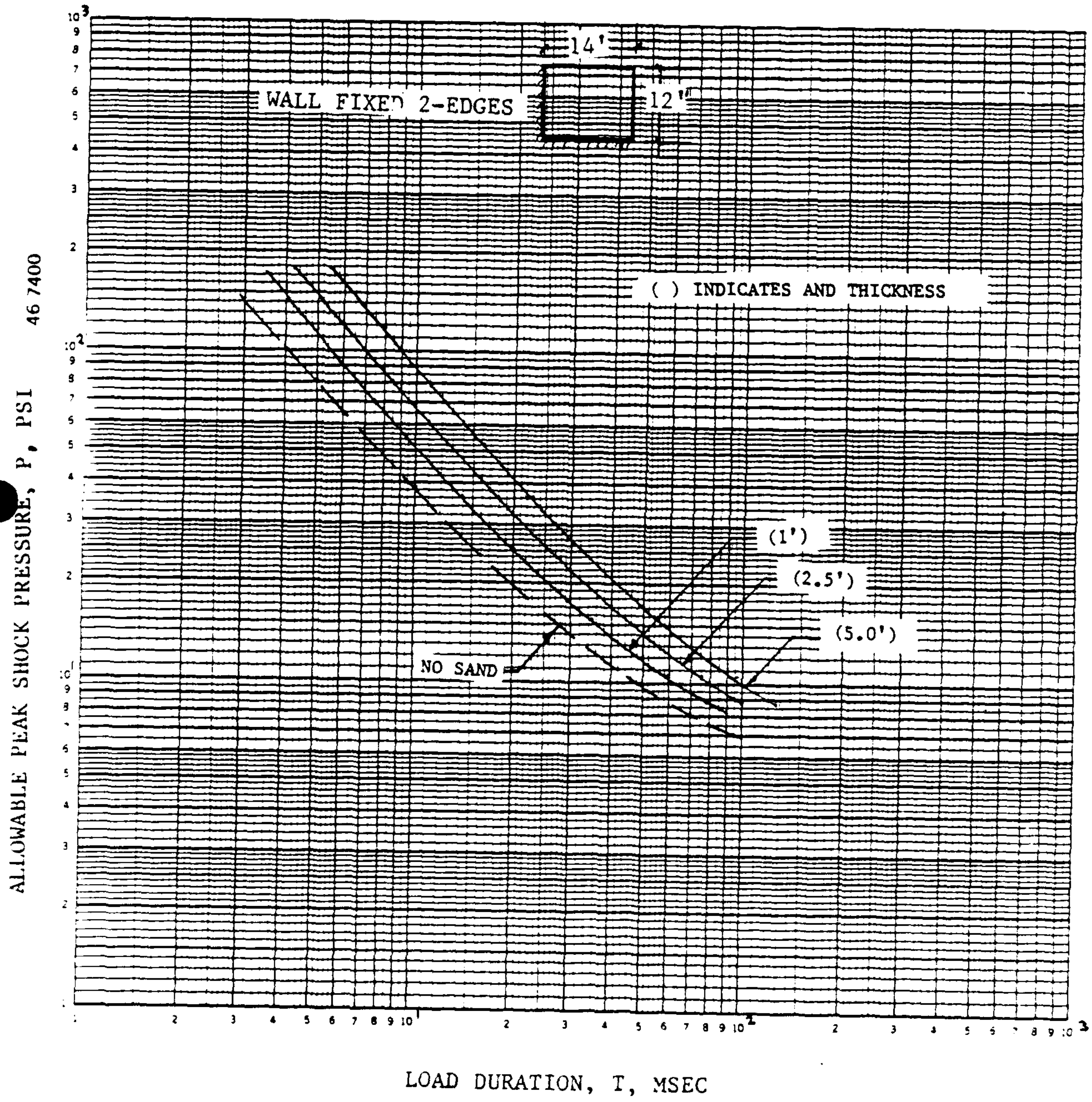


FIGURE E-14 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

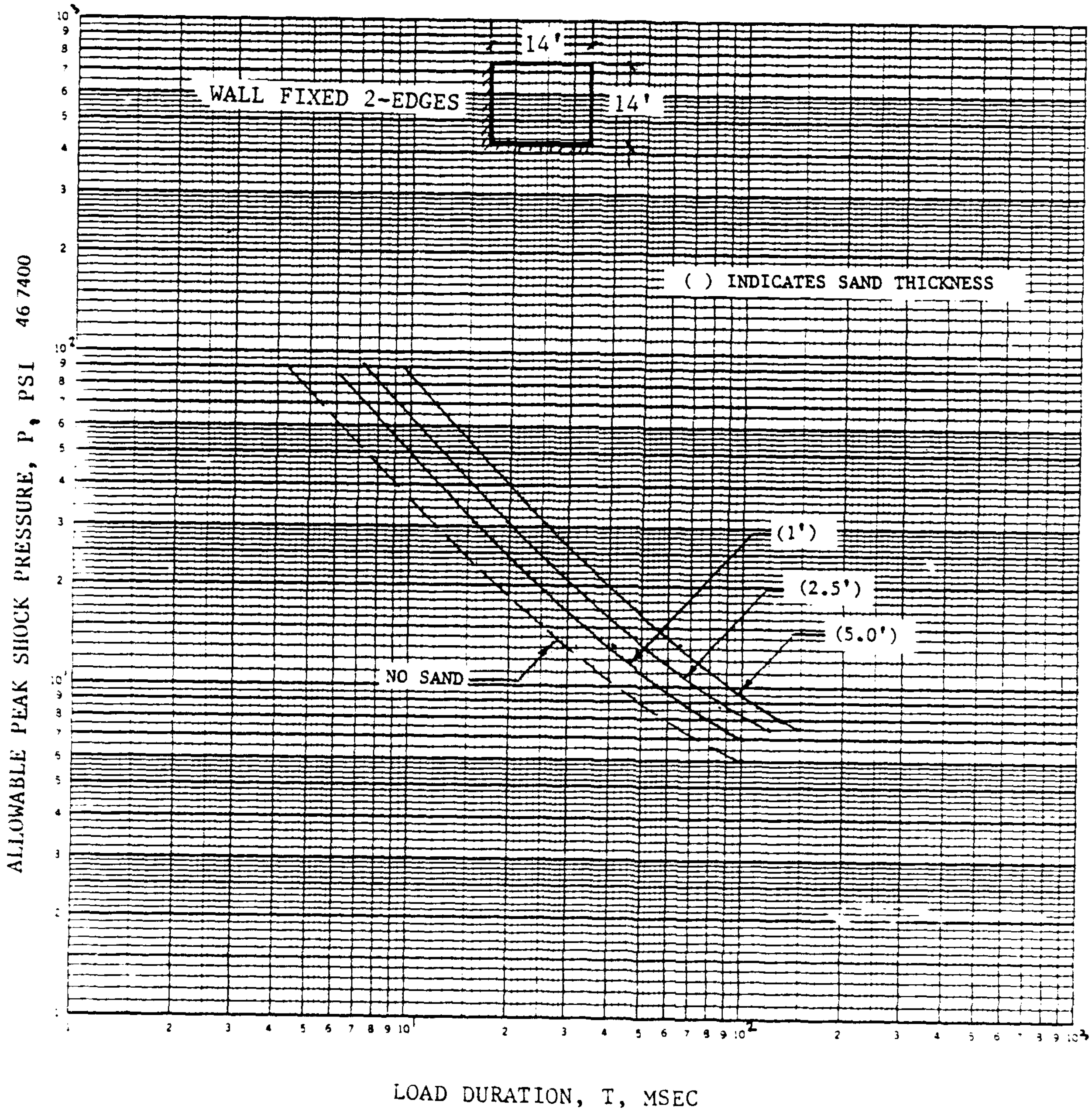


FIGURE E-15 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

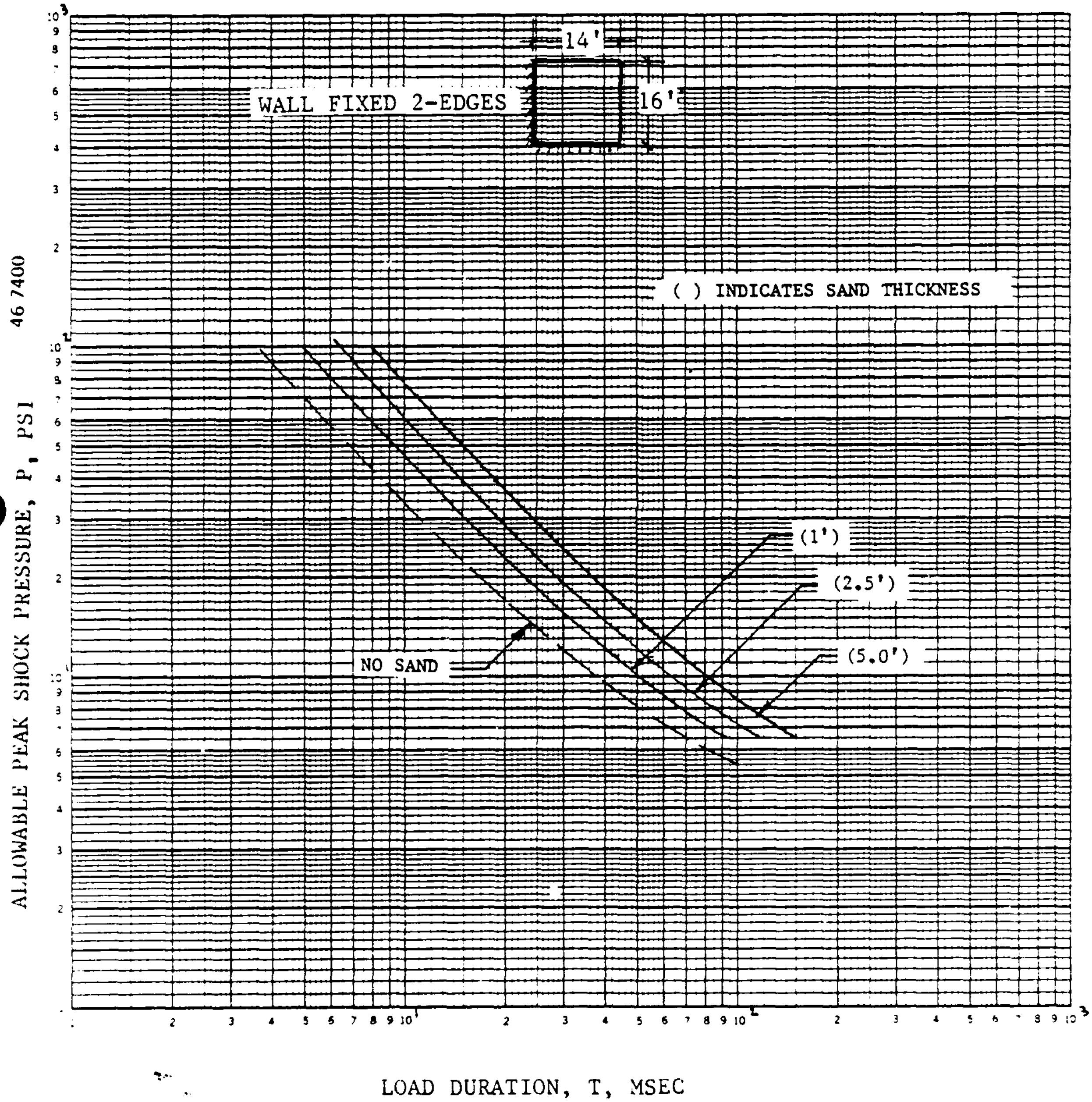


FIGURE E-16 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

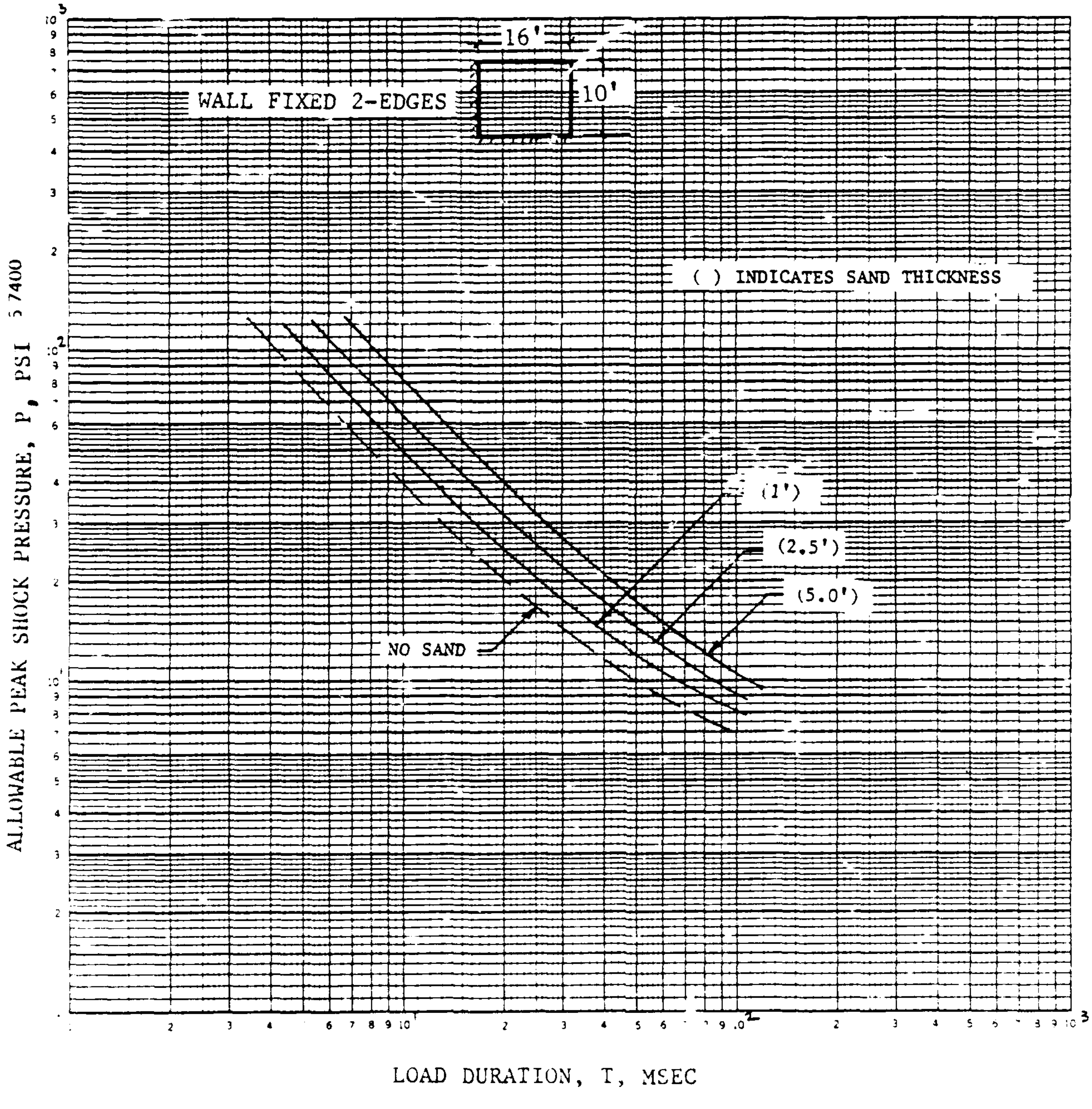


FIGURE E-17 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

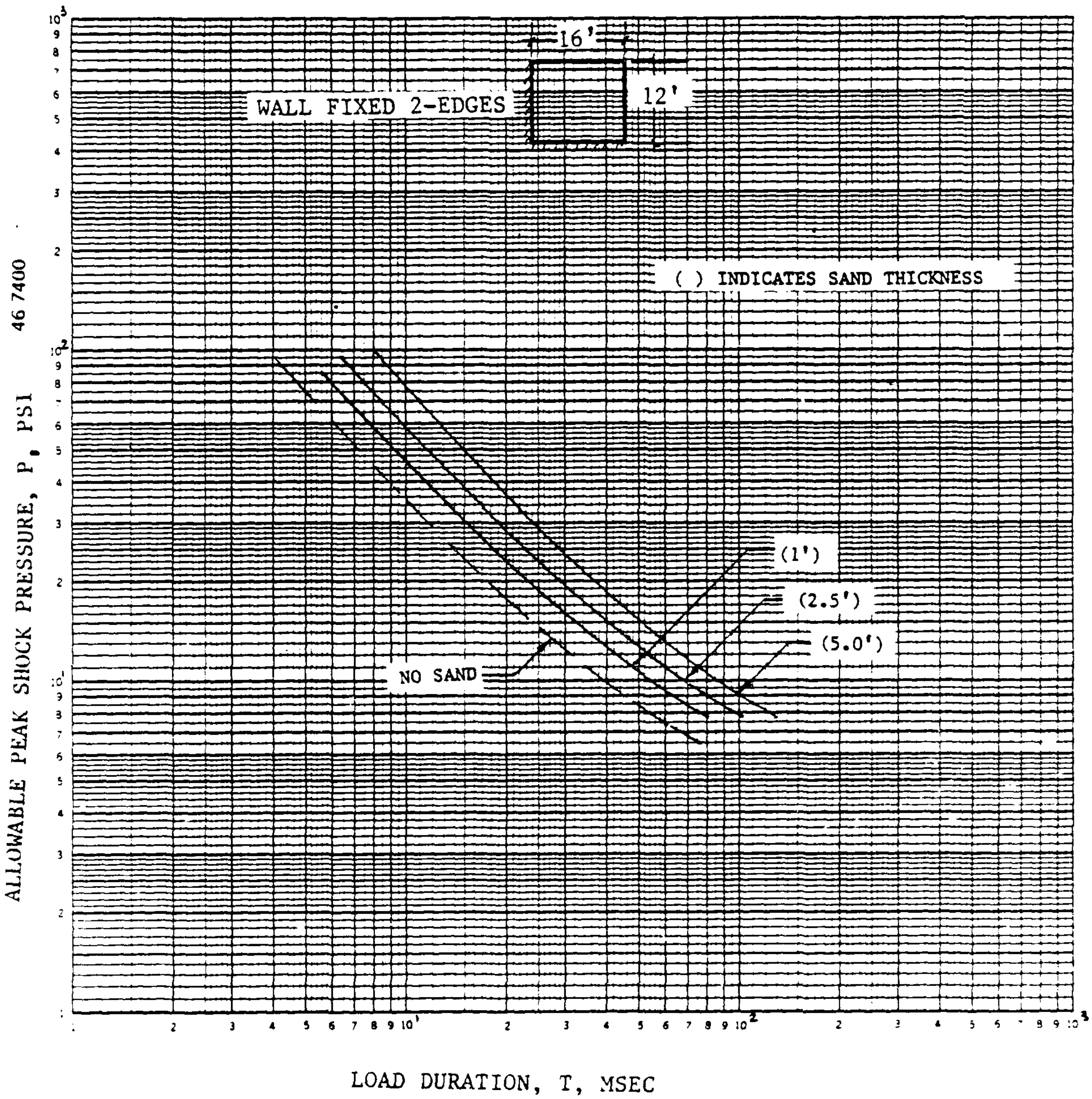


FIGURE E-18 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

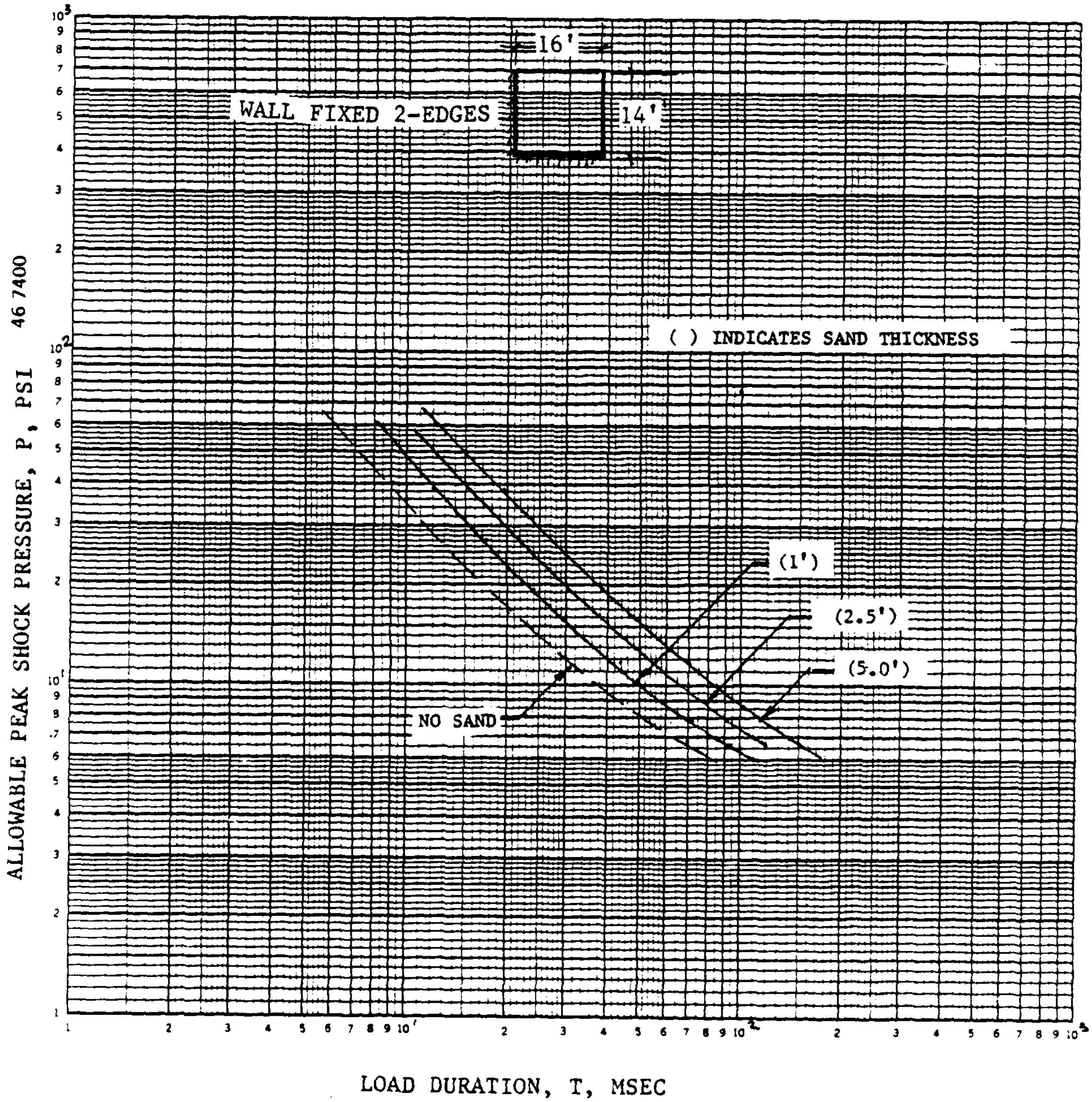


FIGURE E-19 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

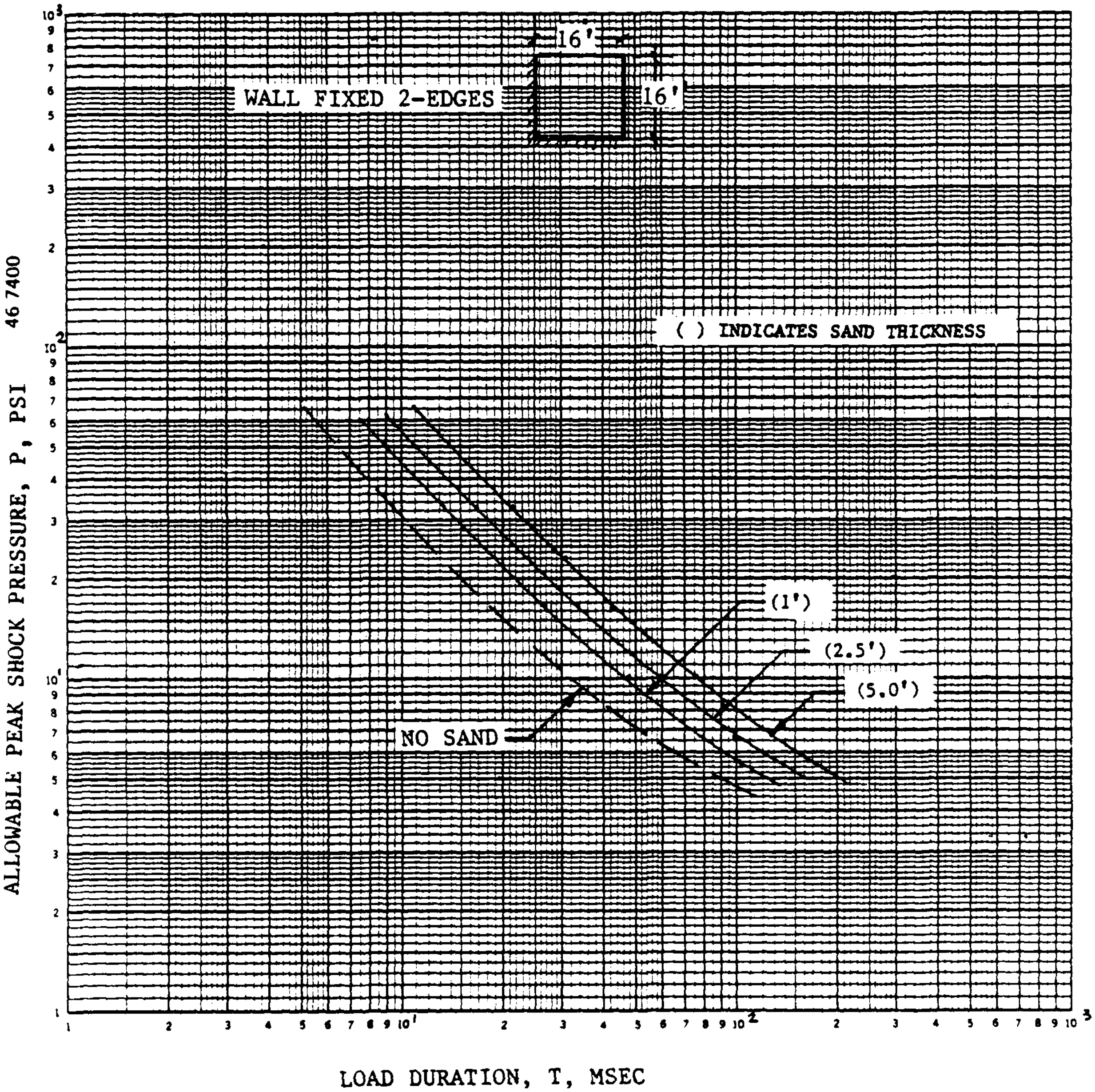


FIGURE E-20 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

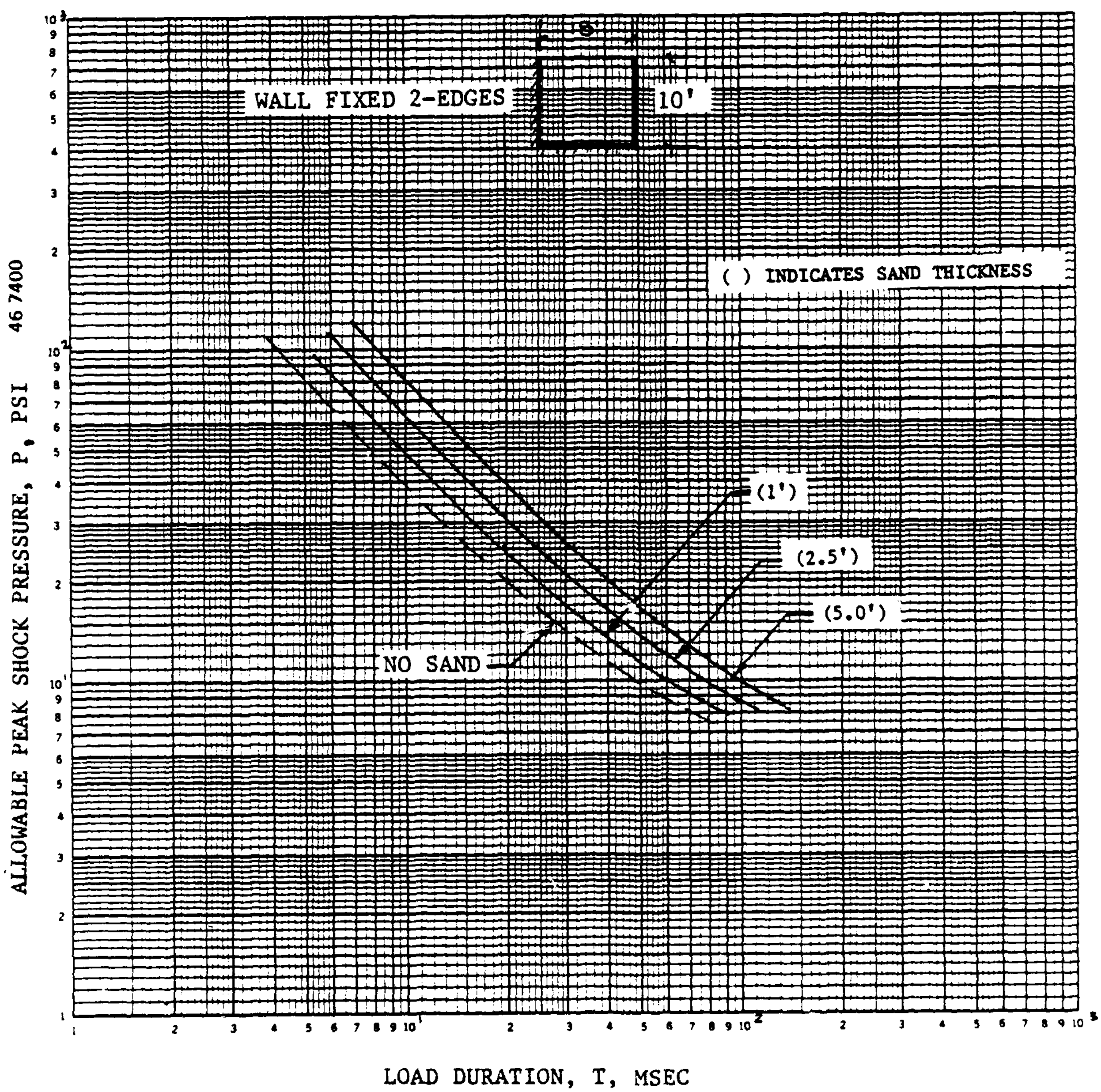


FIGURE E-21 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

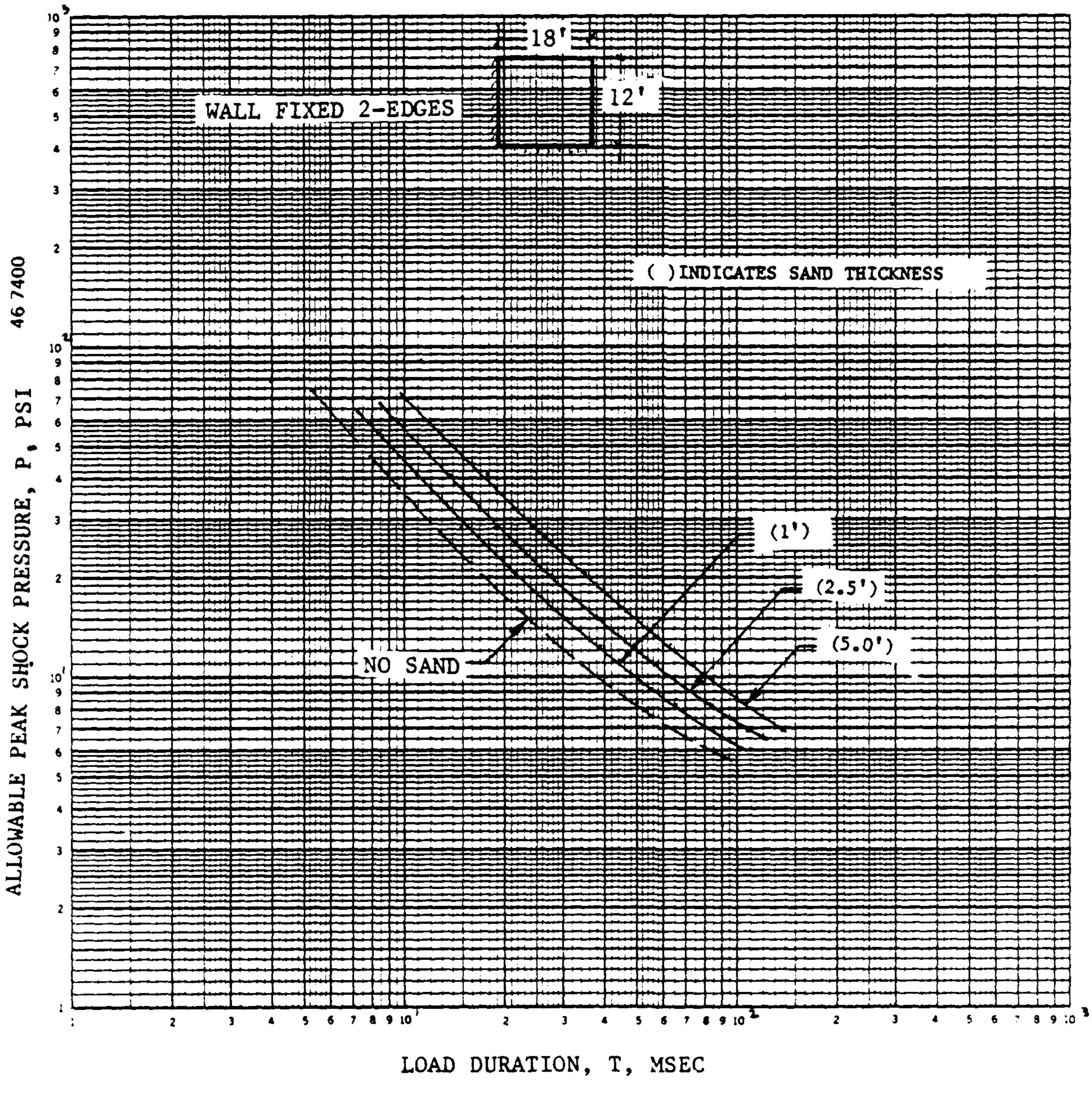


FIGURE E-22 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

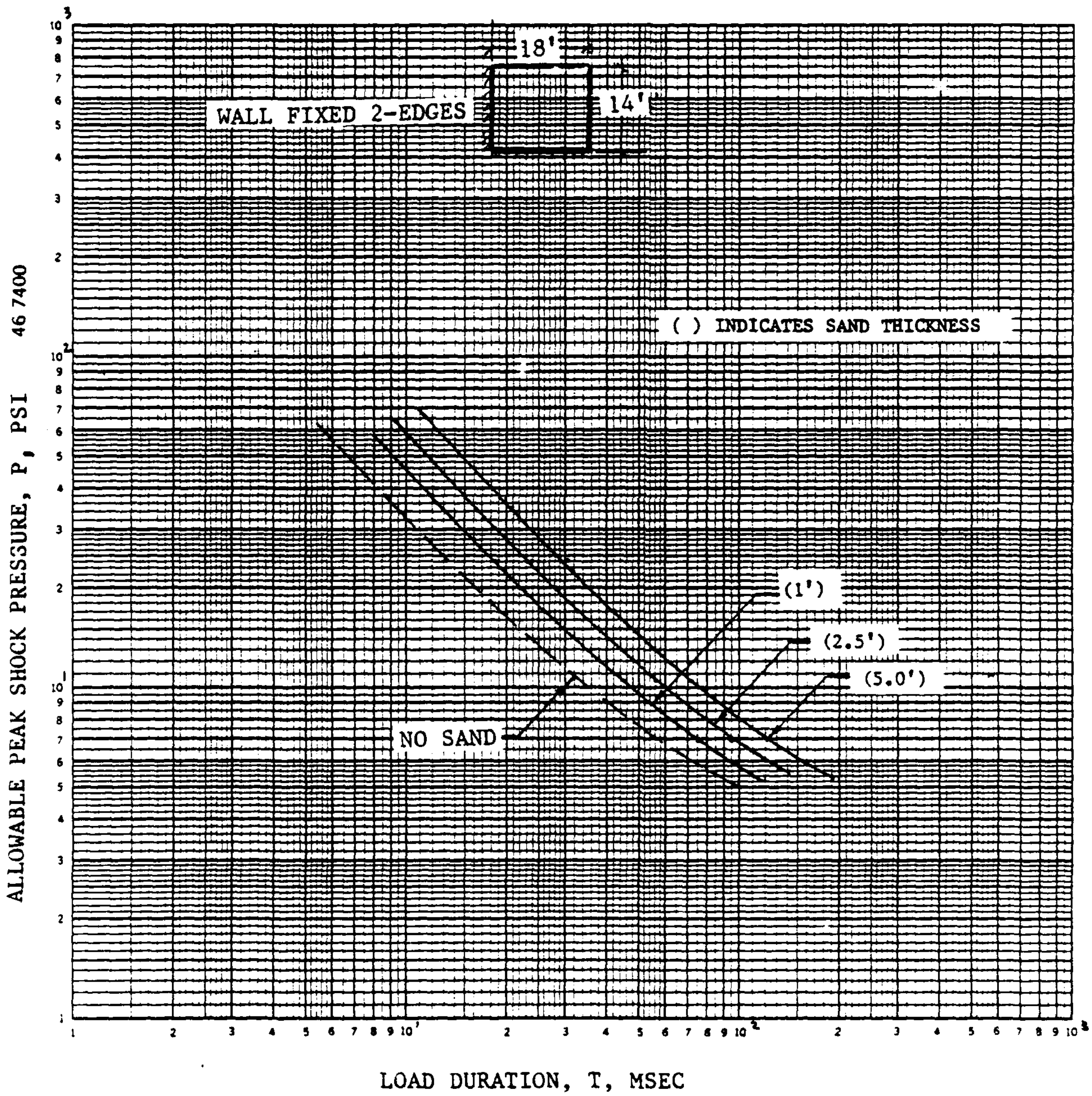


FIGURE E-23 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

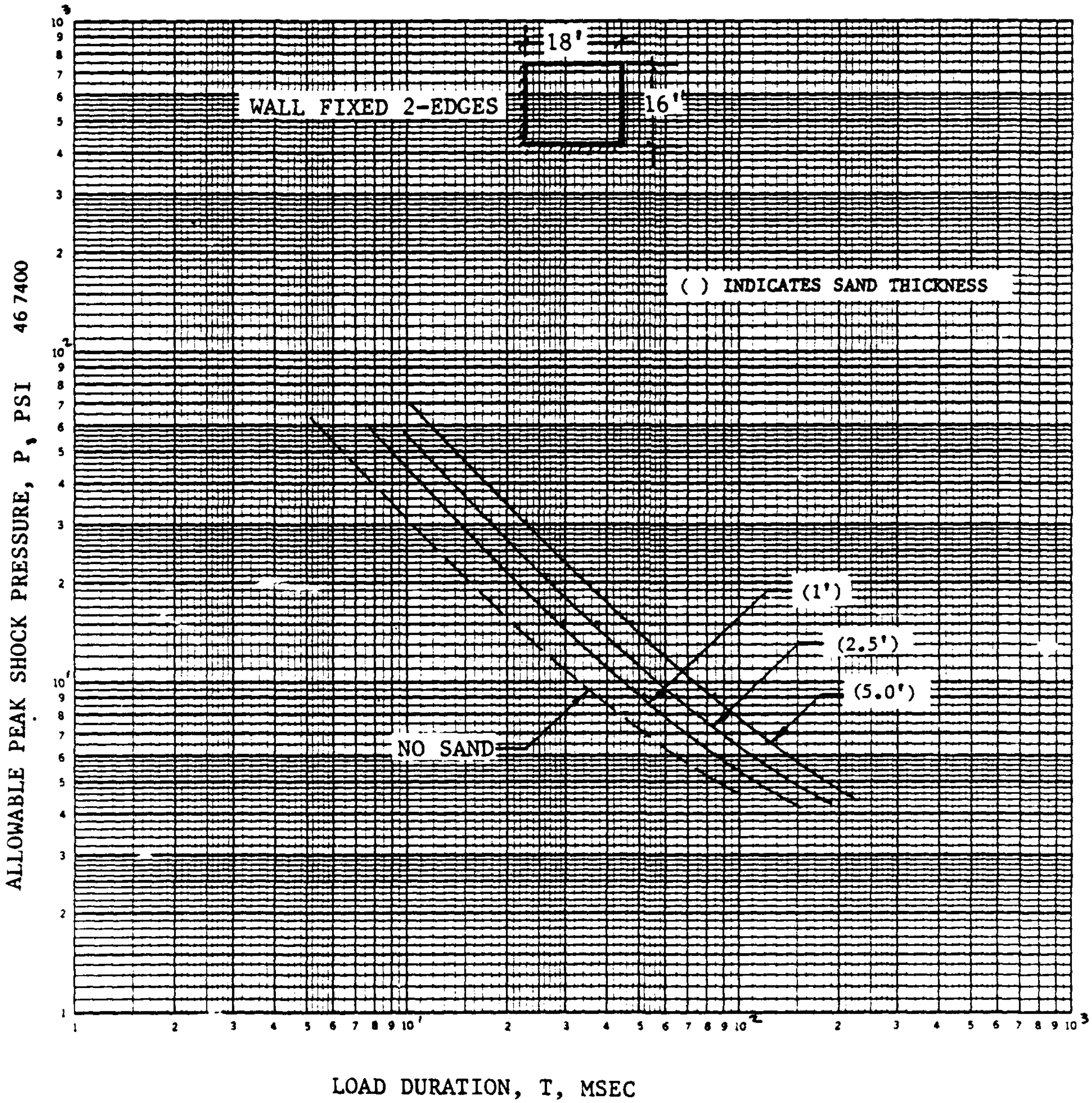


FIGURE E-24 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

APPENDIX F

REFERENCES

REFERENCES

1. AMC-R 385-100, "Safety Manual", August 1986

2. DoD 6055.9-STD, "Ammunition and Explosive Safety Standards", July 1984.

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4. DDESB, "Blast Protection From Remotely Controlled Operations", January 17, 1990.

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6. NCEL Technical Report R-828, "Blast Environment from Fully and Partially Vented Explosions in Cubicles", November 1975.

7. AFESC, ESL-TR-87-57, "Protective Construction Design Manual", November 1989.

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