EVALUATION OF OPERATOR PROTECTION FROM REMOTE OPERATIONS IN EXISTING BUILDINGS WITH 12-INCH SUBSTANTIAL DIVIDING WALLS (SDWs)

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ABSTRACT

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 has been developed. Protection is IAW DoD and Army policy: 2.3 psi maximum overpressure exposure and no hazardous fragments. The procedures are reported in a two-volume guide: Volume I is a "how to" guide for installation use, and Volume II is the rationale behind Volume I. Protection from thermal effects (flash fire, deflagration, etc.) is not addressed. The guide is a "simple-to-use stand-alone" document that can be used by operating contractors and installation personnel.

This paper summarizes key features of the guide and provides an example problem using the guide methodology.

1.0 BACKGROUND

In recent years, the Department of Defense Explosive Safety Board (DDESB), introduced increased protection requirements for personnel exposed to remotely controlled operations. One of the requirements is limiting exposure of personnel to blast pressures not in excess of 2.3 psi. This requirement has; 1) forced some Army installations to relocate operators to bays sufficiently removed from the donor bay to comply with the new regulation, and 2) for the most part, imposed operational constraints since intervening bays can be occupied only when the remote operation is not in progress.

As a result of the above, The US Army Technical Center for Explosive Safety (USATCES) saw a need for relating Net Explosive Weight (NEW) to combinations of intervening 12-inch SDWs. Figure 1 shows a representative ammunition production facility layout. The primary goal was development of a "simple-to-use" guide that would allow installation personnel to assess existing munition facilities for conformance with present safety requirements.

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The guide supplements the DDESB approved method in determining the 2.3 psi boundary arc from the front, sides and back of three walled cubicles without a roof. This method, developed by USATCES has been made an integral part of the guide.

2.0 FORMAT AND AVAILABILITY OF THE GUIDE

The guide is organized into two volumes: Volume I, User's Guide and Volume II, Rationale. Volume I is developed as a "stand-alone" document. Volume II forms the basis for the User's Guide and is not required for field use. The guide is available through the Defense Technical Information Center (DTIC) and the National Technical Information Service (NTIS).

1. DoD Activities can order the guide from DTIC.

   a. DTIC address is:

      Defense Technical Information Center
      Cameron Station
      Alexandria, VA 22304-6145

   b. DTIC report numbers:

      Volume I: ADA 250251
      Volume II: ADA 250252

2. Non DOD activities can order the guide from NTIS.

   a. Their address:

      National Technical Information Service (NTIS)
      5285 Port Royal Road
      Springfield, VA 22161

   b. Copies can be ordered by mail of phone; (703) 487-4650

   c. The cost of the guide is $26.00 (paper) or $12.50 (microfiche). When ordering, ask for NTIS accession number PB92-180140.

3.0 GENERAL

The approach taken in development of the guide was the recognition that the guide must be a "stand-alone" and "simple-to-use" document. The intent is not to burden installation personnel with tedious complicated procedures in performing the required analysis, and in particular predicting the blast loading. Installations do not have the necessary computer software to accomplish such a task, neither it is expected that they perform such a complicated engineering function. As a result, all data needed to evaluate facilities constructed with 12-inch SDWs are contained within the guide. The guide assumes 12-inch SDWs are reinforced with #4 reinforcements each way each face and spaced at 12 inches on centers, and considers wall elements that are cantilevered, fixed on two-sides and fixed on three-sides. These are prevalent fixity conditions at existing ammunition production facilities. The guide includes:

a. Dynamic properties and blast capacities of Substantial Dividing Walls. Using TM5-1300 methodology, walls ultimate resistance, stiffness, and natural frequency were developed for various wall sizes and fixity conditions.

b. Overpressure prediction at personnel occupied bays due to an incident in a donor bay where the remote explosive operation is underway. The method developed by USATCES is used, and supplemented by Table 1 which provides a quick evaluation of the number of unoccupied bays required to separate the operator from the donor bay.

c. Assessment of Substantial Dividing Wall' capability to provide the necessary protection to operators (Category I protection) from a remote controlled operation. The procedure entails prediction of the blast loading at the acceptor bay, and comparing the walls resistance to the predicted loads. Pressure-Load Duration (P-T) plots have been generated for various size walls and fixity condition. Figure 2 is a representative plot contained in the guide.

d. Concepts for upgrading SDWs for increased capacity. The guide addresses two methods, namely; structural strengthening of wall elements by providing additional fixity condition to increase the wall's ultimate resistance, and/or increasing the mass of the element to alter the dynamic response of the wall. The latter option is achieved through the addition of sand layer behind the deficient wall. P-T plots showing sand layer effects are also included in the guide. Figure 3 is a representative plot contained in the guide.

e. Application Example.

4.0 ANALYSIS PROCEDURE

4.1 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.

4.2 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 overpressure, 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.

4.3 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

4.4 EQUIVALENT CHARGE WEIGHT (W)

The equivalent charge weight is determined using the following equation:

$$W = NEW \times TNT\ Equivalency \qquad \text{EQ. 4-1}$$

TNT Equivalences are presented in Table 2.

4.5 DESIGN CHARGE WEIGHT

The design charge weight is determined using the following equation:

$$W' = NEW \times TNT\ Equivalency \times 1.20\ Safety\ Factor \qquad \text{EQ. 4-2}$$
$$= W \times 1.20\ Safety\ Factor$$

Note: W' is used in the evaluation of wall elements. The 1.20 safety factor is required by TM5-1300.

4.6 SCALED DISTANCE

The customary scaled distance Z is used in this guide.

$Z = R/W^{1/3}$ used for overpressure determination EQ. 4-3a

or $Z = R/W'^{1/3}$ used for determining wall capacity EQ. 4-3b

where:

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

4.7 PREDICTION OF BLAST OVERPRESSURE AT OPERATOR'S LOCATION

The prediction of overpressures from an incident in a donor bay follow the method developed by USATCES. This method is based on on the default distance of $D=24w^{1/3}$. For a quick determination of the number of unoccupied bays required between the explosive source and the operator, Table 1 may be used.

4.8 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:

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

where n = number of reflective surfaces

4.9 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 4. The design charge weight W' is used in this scaled distance.

b. Estimating the effects of walls reflection on the element in question using EQ 4-4.

c. Applying correction coefficients to both the free-field shock wave pressure and impulse using Figures 5 and 6. These coefficient are applied to accurately duplicate the blast loading if the the computer program "SHOCK" was used.

d. Comparing the predicted pressure and load-duration on the element in question to the wall capacity. This comparison reveals wall adequacy or inadequacy and requirements for upgrade.

5.0 EXAMPLE PROBLEM

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 $W' = NEW \times TNT$ equivalency x 1.20 safety factor	Table 2 for TNT equivalency factor and EQ. 4-2.
2.	Calculate the scaled distance $Z = R/W'^{1/3}$	EQ. 4-3b
3.	Determine the reflected pressure (P_r) and reflected scaled impulse ($i_r/W'^{1/3}$) corresponding to Z	Figure 4
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. 4-4
6.	Determine the coefficients C_{pr} and C_{ir} corresponding to the standoff distance R.	Figure 5 & Figure 6
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 2 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 4 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 5 and 6 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 2 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. The example problem 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. Table 1 or USATCES method may be used in assuring that personnel are not exposed to overpressures greater than 2.3 psi. Overpressure will usually control.

3. Also wall breach must be checked. Refer to the guide for this procedure. Breach does not normally control, but may control at close range.

Table 1 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.

TABLE 2 TNT EQUIVALENCY

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

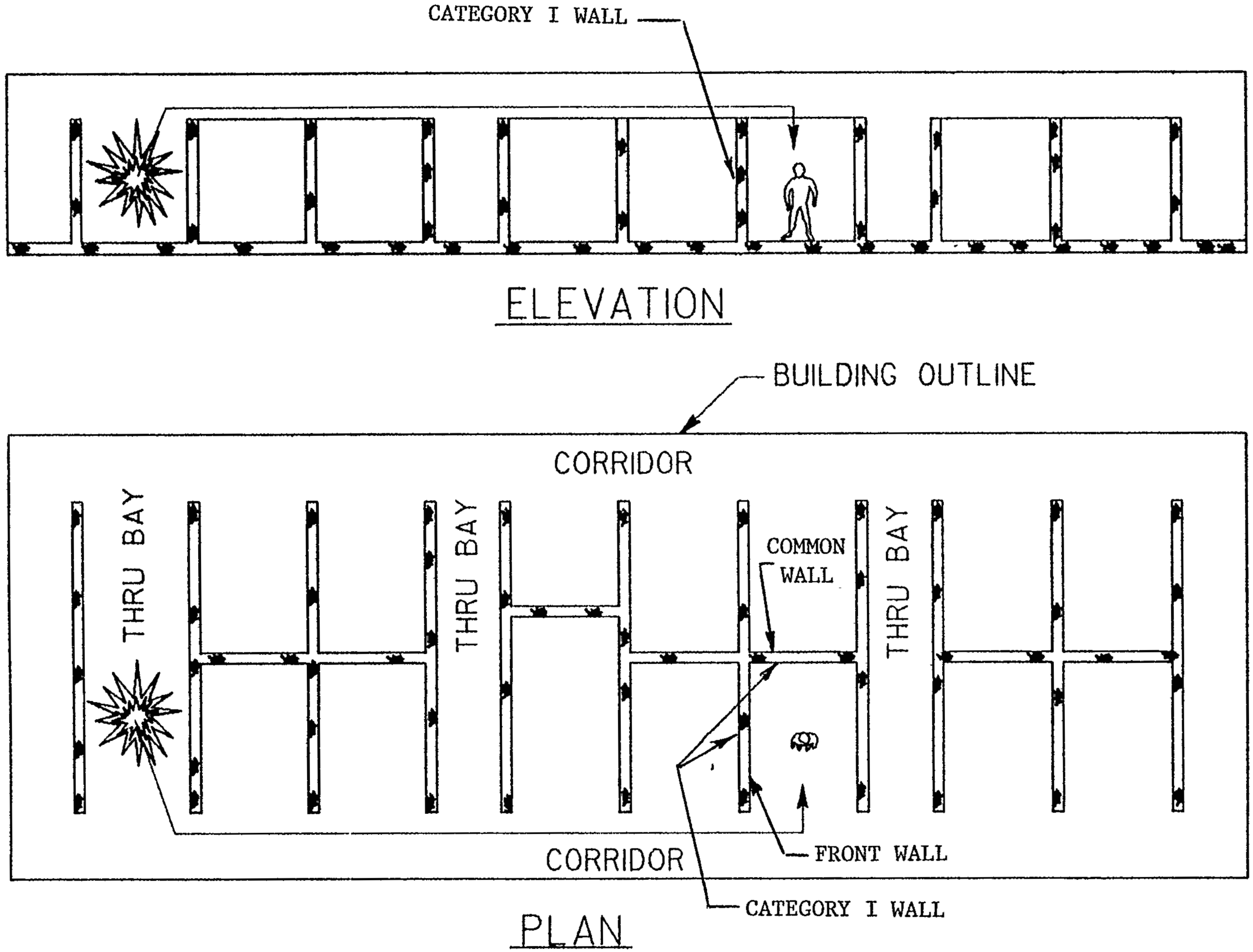

FIGURE 1 OPERATOR LOCATED AT DISTANCE OF INCIDENT OVERPRESSURE ≤ 2.3 PSI

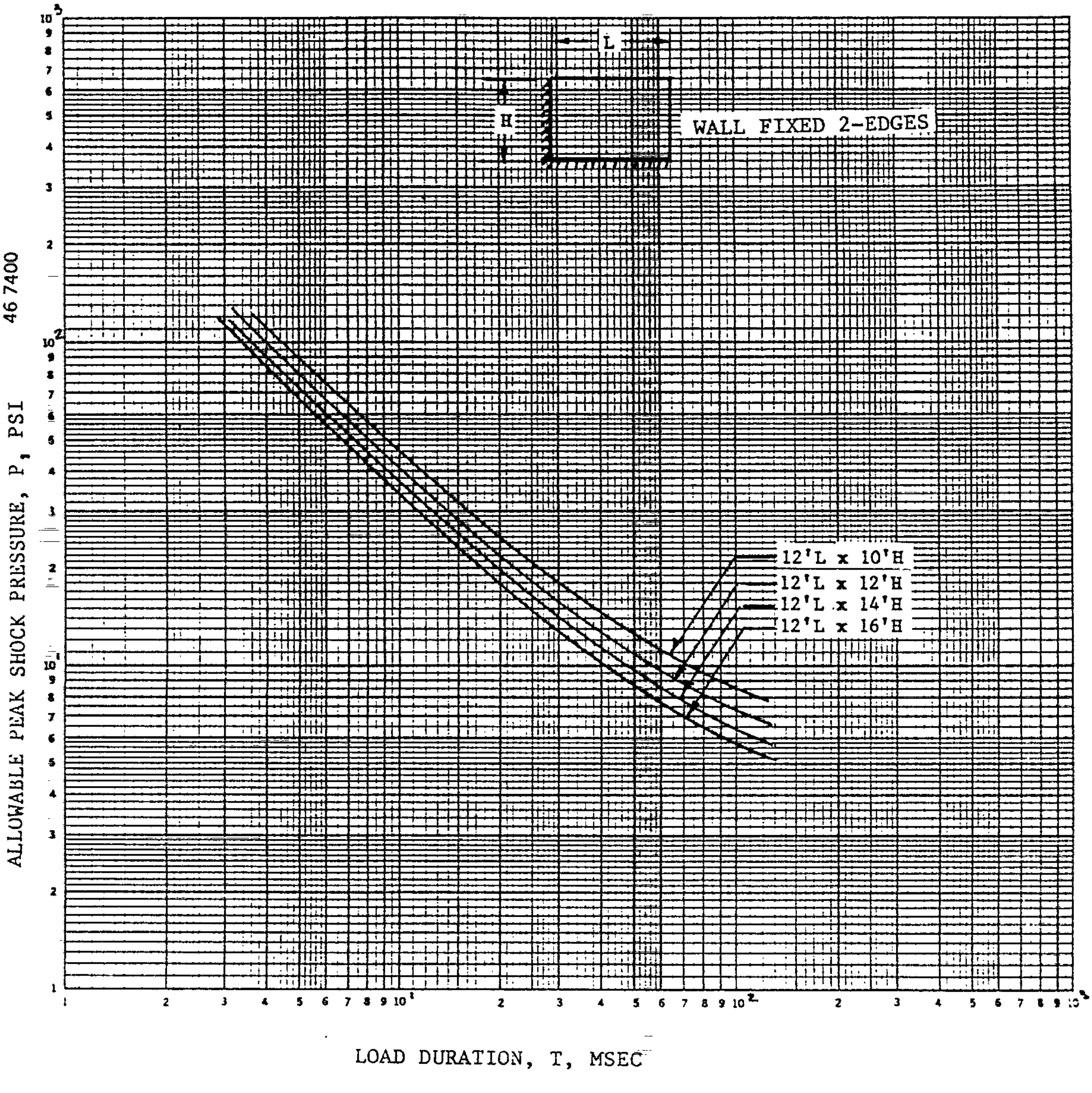

FIGURE 2 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

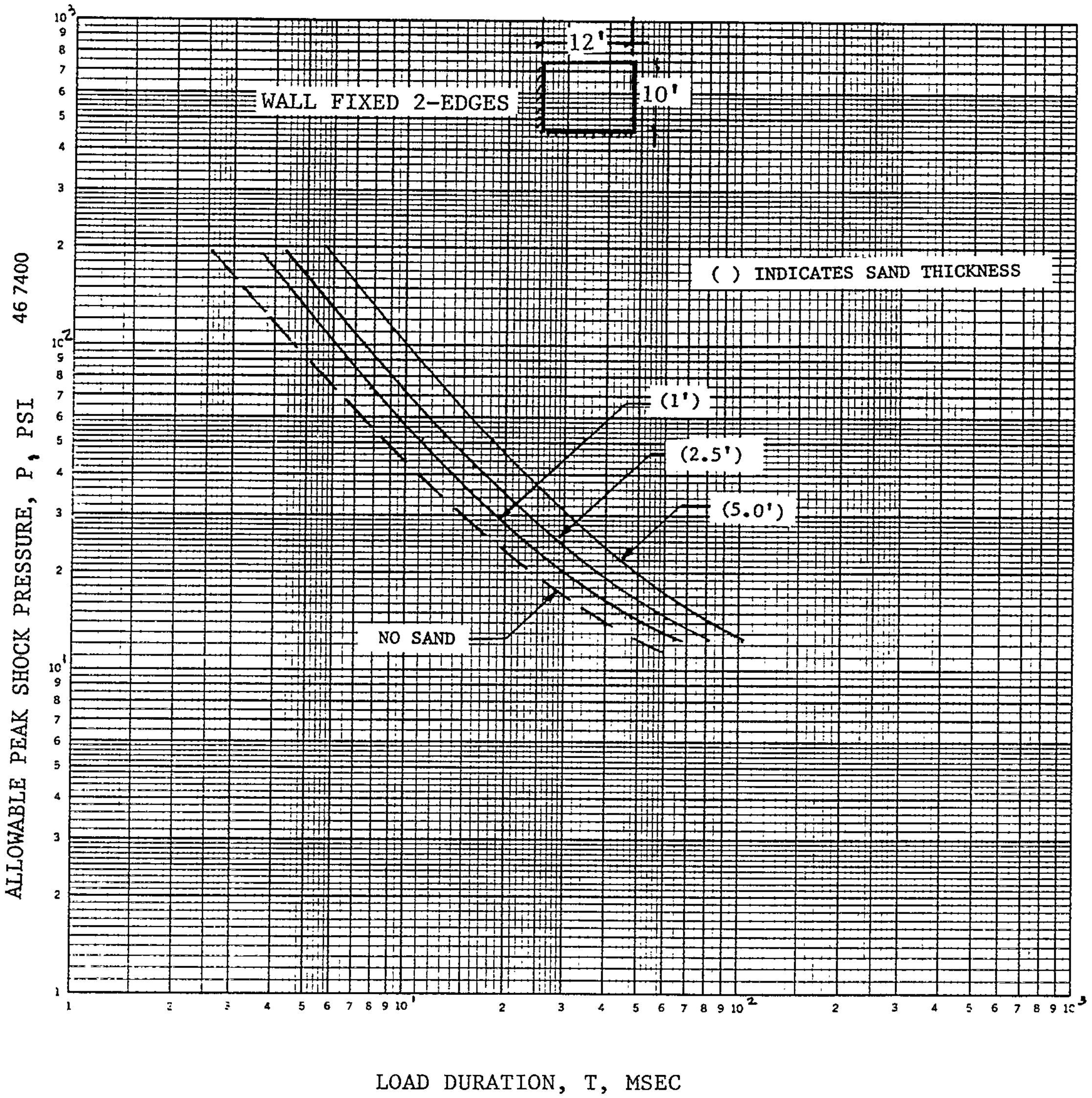

FIGURE 3 ALLOWABLE PEAK SHOCK PRESSURE VS LOAD DURATION

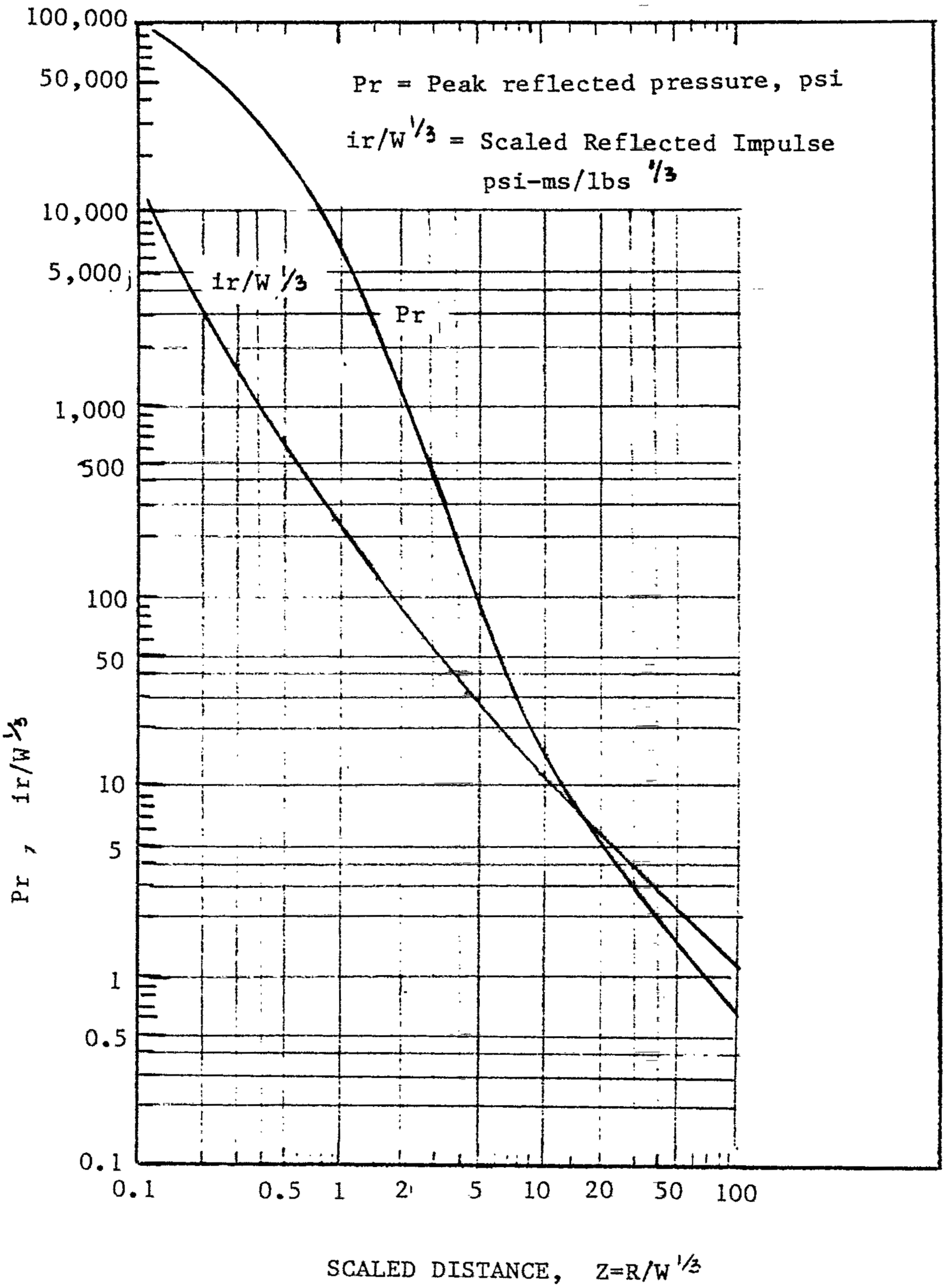

FIGURE 4 SHOCK WAVE PARAMETERS

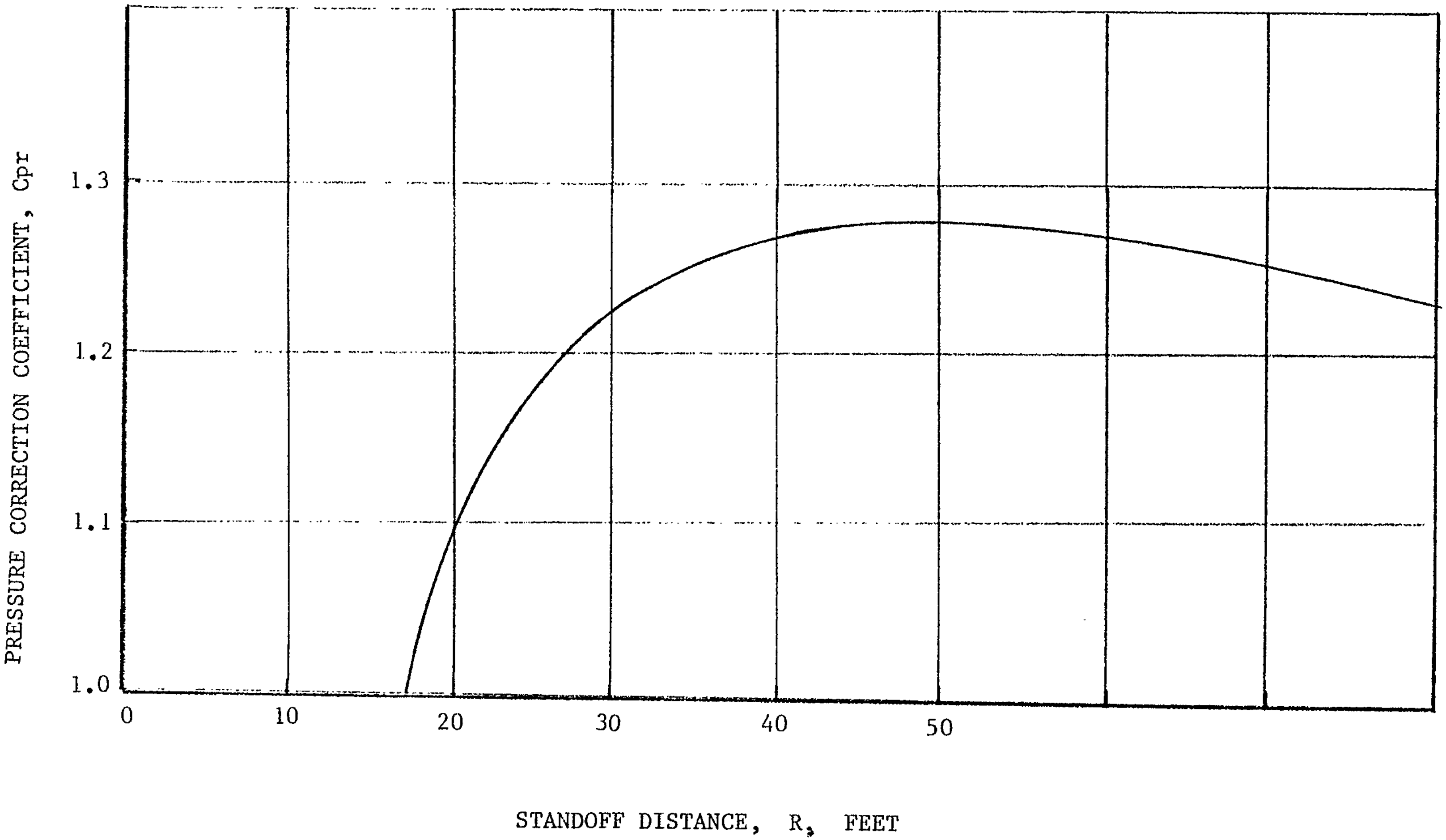

FIGURE 5 PRESSURE CORRECTION COEFFICIENT VERSUS STANDOFF DISTANCE

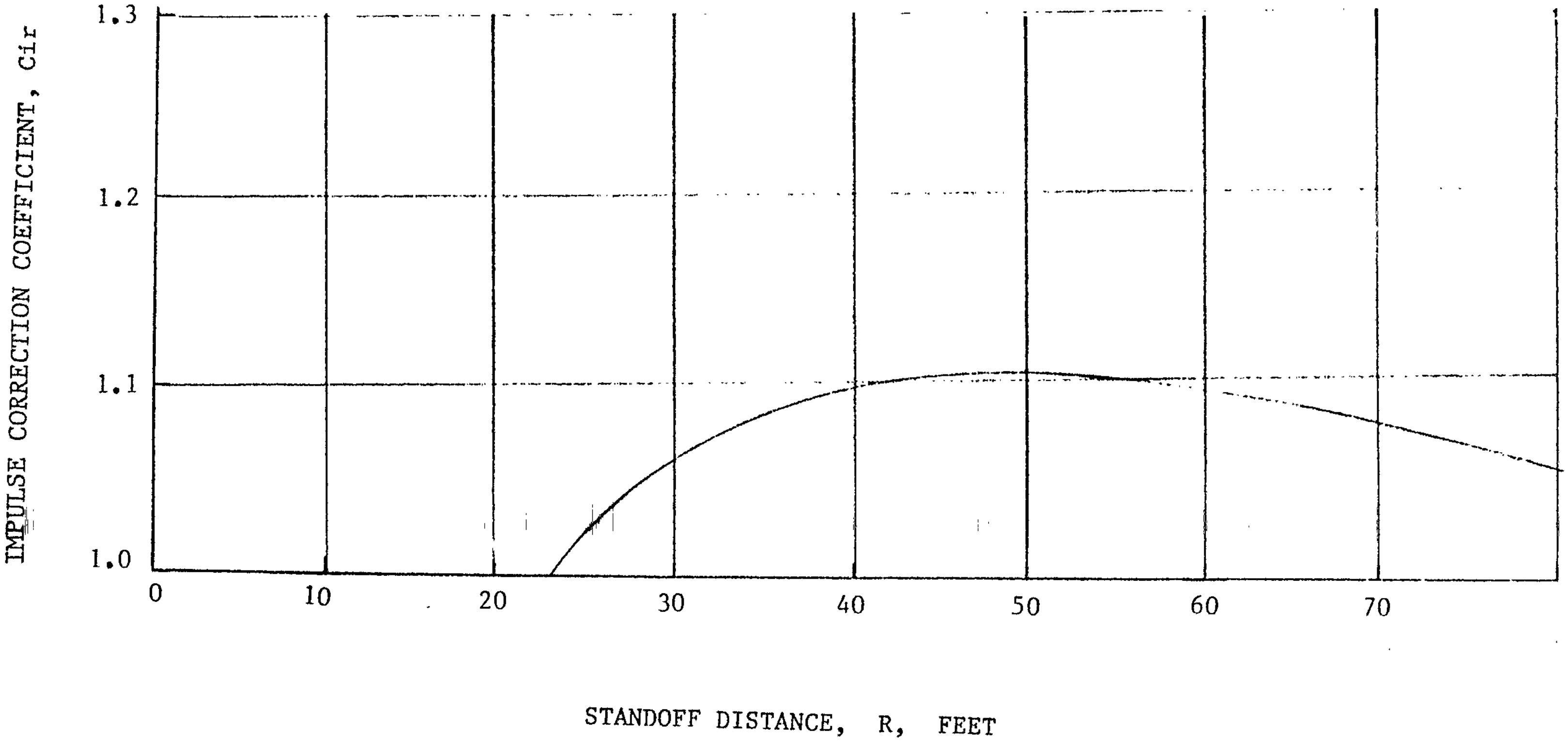

FIGURE 6 IMPULSE CORRECTION COEFFICIENT VERSUS STANDOFF DISTANCE