DESIGN DATA SHEET
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

DDS 100-7

15 MAY 1984

STRUCTURE TO RESIST WEAPONS FIRING EFFECTS

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APPENDICES

PART I. INTRODUCTION

100-7-a. References

(a) G.R. Moore, G.S. Miller, and D.A. Pollet, "Gun and Missile Blast on Ship's Structure," Naval Surface Weapons Center, Report No. NSWC/DL TR-3588, November 1977.

(b) Deleted

(c) Raymond J. Roark and W.C. Young, Formulas for Stress and Strain, Fifth Edition, McGraw Hill Book Company, New York, 1975.

(d) "General Requirements for Hull Structure," General Specifications for Ships of the United States Navy, NAVSEA S9AA0-AA-SPN-010/GEN-SPEC, Department of the Navy, Current Edition.

(e) Manual of Steel Construction, American Society of Steel Construction, Inc., New York, 8th Edition.

100-7-b. Purpose and Scope

This Design Data Sheet (DDS) provides general guidelines for the design of structures to resist weapon firing effects. Standard methods for prediction of gun and missile blast pressure fields are shown in order to help the designer establish design loadings.

Structural design criteria, procedures and materials used in the analysis of ship structures subject to gun (muzzle) blast, missile launching blast, and accidental missile ignition are presented.

100-7-c. Approach

The approach used in this DDS involves a two-step design procedure. The first step determines the missile or gun blast pressure on the structure. This is accomplished by graphically locating the point in question relative to the missile or gun and then solving an empirical equation based on graphically determined dimensions. The second step involves a check for structural adequacy.

Two appendices have been included in this DDS for expanding this procedure to the development of deck blast pressure envelopes. In general, this approach will identify the most critical loading areas on the deck. A computer program developed by the Naval Surface Weapons Center is also available for development of these pressure contours (reference a).

In design and analysis, measurements and properties may be expressed in either inch-pound or SI (metric) units, unless a specific unit system is specified in the ordering document. The example problems in this DDS have been completed using inch-pound units. Appendix 3 has been provided for convenient conversion.

100-7-d. Materials and Material Properties

Stresses in plating subjected to weapon firing effect loads shall not exceed the yield strength of the applicable material. Stiffeners shall be designed such that the stress will not exceed the allowable stress of the material. The yield strength and allowable stress of the material will be as listed in the Ship Specifications for the ship being considered. In the event that Ship Specifications are not available, the designer should refer to the current revision of the General Specifications for Ships of the U.S. Navy, reference d.

100-7-e. Symbols and Abbreviations

The symbols and abbreviations for information required for analysis used in this DDS generally conform to standard Navy usage and are listed in Table I.

TABLE I: LIST OF SYMBOLS

A = Blast impingement area (in^2)

a = Distance from centerline of launcher arm to missile centerline (in)
  = Long dimension of plating panel (in)

b = Short dimension of plating (in)

C = Constant for plate bending stresses under gun blast

c = Distance from missile tangency point to nozzle exit plane (in)

d = Diameter of gun muzzle (in)

F_Y = Material yield strength (lb/in^2)

H = Blast load due to gun firing, in feet of water

H_T = Trunnion height (in)

h_d = Height from deck to launcher datum line (in)

L_B = Length of gun barrel (in)

M = Maximum bending moment (in-lb)

m = Major axis of missile blast impingement area (in)

n = Minor axis of missile blast impingement area (in)

P = Blast loading due to missile firing (lb/in^2)

R = Burning rate of missile booster (lb/sec)

r = Missile nozzle radius (in)
  = For guns, distance of radius vector equal to distance from gun muzzle to point under consideration (in)

r_L = Distance of launcher arm centerline from launcher centerline (in)

s = Stiffener spacing (in)

T = Total thrust of missile (lbs)

t = Thickness of plating (in)

V = Equivalent concentrated load for missile blast (lbs)

W = Uniformly distributed load on stiffener (lb/in)

α = Angle of incidence for missile blast (deg)

β = Space angle between gun barrell and the radius vector (deg)

θ = Gun depression angle (deg)

σ = Plate or stiffener design stress (lb/in^2)

PART II - DESIGN PROCEDRES

100-7-f. Missile Blast

General.- Ship's structure and equipment exposed to missile blast are subjected to high temperatures, high pressures, and debris. There are two missile firing conditions that affect the design of the structures: (1) the normal launch or "fly-away" condition from the launcher and (2) the restrained burn. This restrained burn condition is generally the most severe in terms of potential for shipboard damage (reference a) and is used as the design condition. Data concerning missile blast is usually presented in terms of stagnation pressure isobars. Based on this data, an analytical expression for the blast plume properties, pressures, and temperatures, can be developed. Unfortunately, in this form, analysis is difficult to perform. Therefore, an empirical formula for Static Equivalent (SE) overpressure based on total missile thrust, elevation angle, and plume deck impingement area has been developed. The empirical formula (Equation 1) and its application is presented in the following sections.

Review of the relationships presented in this section will give the designer an idea of which variables cause the worst loading conditions for missile blast. For missile blast, a coupled relationship actually exists; that is, the distance from the launcher, D_1, determines the angle of incidence, α, which "in turn" governs the blast loading calculation. Specifically, and D_1 decreases, the blast pressure increases; conversely, as α decreases, D_1 increases and the blast pressure decreases. The reasons for this are twofold. First the static equivalent blast pressure is directly related to "$\sin \alpha$" which reaches a maximum value of 1.0 at 90 degrees. Second, the blast pressure is inversely related to the impingement area, A, which is a function of α; that is, as α approaches 90 degrees the impingement area decreases, thus increasing the blast pressure.

Missile Static Equivalent (SE) Blast Overpressure.- The design of ship structure for missile blast loading is based on an empirical formula that relates a static equivalent pressure to the booster motor thrust, angle of incidence, and area of impingement on the structure.

The structure is designed for the following loading:

$$P = T(\sin\alpha + (0.0225/\sin\alpha))/A \qquad (1)$$

where P = static equivalent pressure, in lb/in^2.
T = total thrust of the missile, in pounds.
α = angle of incidence, in degrees.
A = impingement area of the surface in square inches, bounded by the blast cone. (The blast cone is generated by rotating about the missile axis, a line with a 3 degree-divergence from the axis and passing through the circumference of the exit nozzle.)

This formula provides a static equivalent load for the design of decks and bulkheads for the pressure loading of missile blast. It does not require the designer to determine any blast pressure loading variation with time. The equation does not take into account thermal effects of the blast, since it has been found that thermal protection (such as, ablative coatings) is generally unnecessary for steel decks and bulkheads. For aluminum construction, ship structures built to current standards are almost always adequate. However, in those cases where relatively thin aluminum is subject to direct impingement by TARTAR or TERRIER-type missiles, ablative coating has been utilized (reference b).

In order to develop the total SE pressure loading of the missile, the angle of incidence, and the impingement area bounded by the blast cone, the following specific dimensions are required. These dimensions are generally provided in the applicable contract design phase as Government-Furnished Information (GFI).

- Missile Launcher Required Dimensions

  H_T - Trunnion height from gage point or deck.
  c - Distance of missile nozzle from the missile pivot point or tangency.
  a - Distance from centerline of launcher arm to centerline or missile.

- Missile Required Dimensions

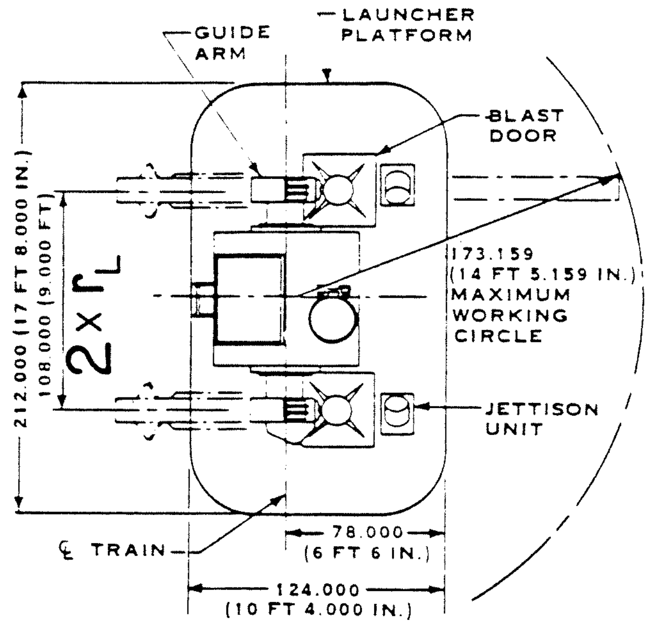
  r - Nozzle radius
  T - Maximum thrust

Figure 1 illustrates, as an example, a MK 26 missile launcher from which most of the above dimensions would be obtained.

<u>SE Pressure Impingement on Decks</u>.- This section presents a step-by-step methodology for determining the angle of incidence (α) and the blast impingement area (A) for a given point of interest on the deck. This process requires the development of various sketches depicting the physical arrangement of the missile launcher in relation to the deck structure under consideration. The sketches should be drawn to an appropriate scale to insure accuracy. Once "α" and "A" have been determined, the SE pressure can be calculated and the deck scantlings can be verified.

The deck blast impingement procedure begins by constructing a plan view sketch showing the missile launcher and surrounding deck areas (similar to Figure 2). The procedure continues by utilizing the 10 steps listed below:

<u>Step 1</u>: On the deck sketch (similar to Figure 2), locate the point under consideration, Point A' (by dimensions, X and Y). Draw the circle made by the launcher arms with radius r_L (distance of launcher arm centerline from launcher centerline). NOTE THAT ALL DIMENSIONS SHOULD BE IN INCHES.



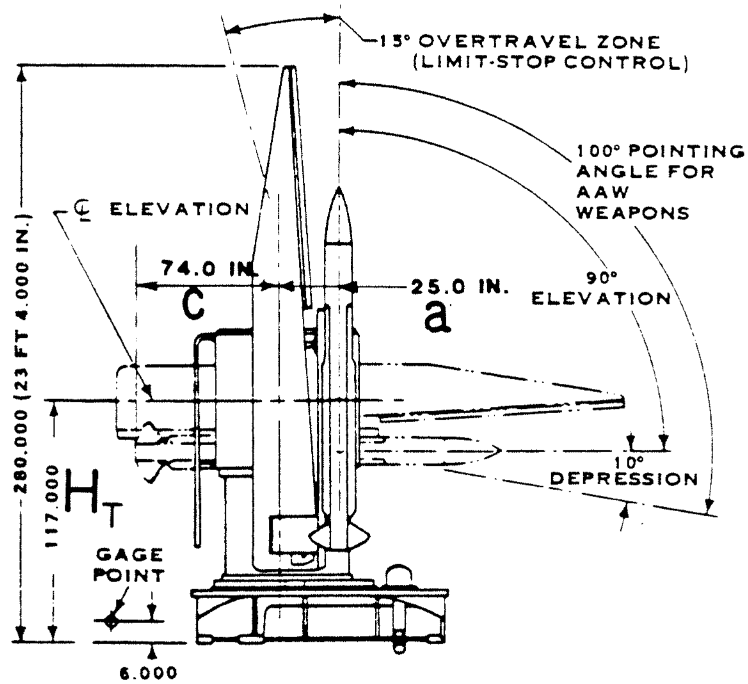


FIGURE 1
GENERAL DIMENSIONS OF A MARK 26 LAUNCHER

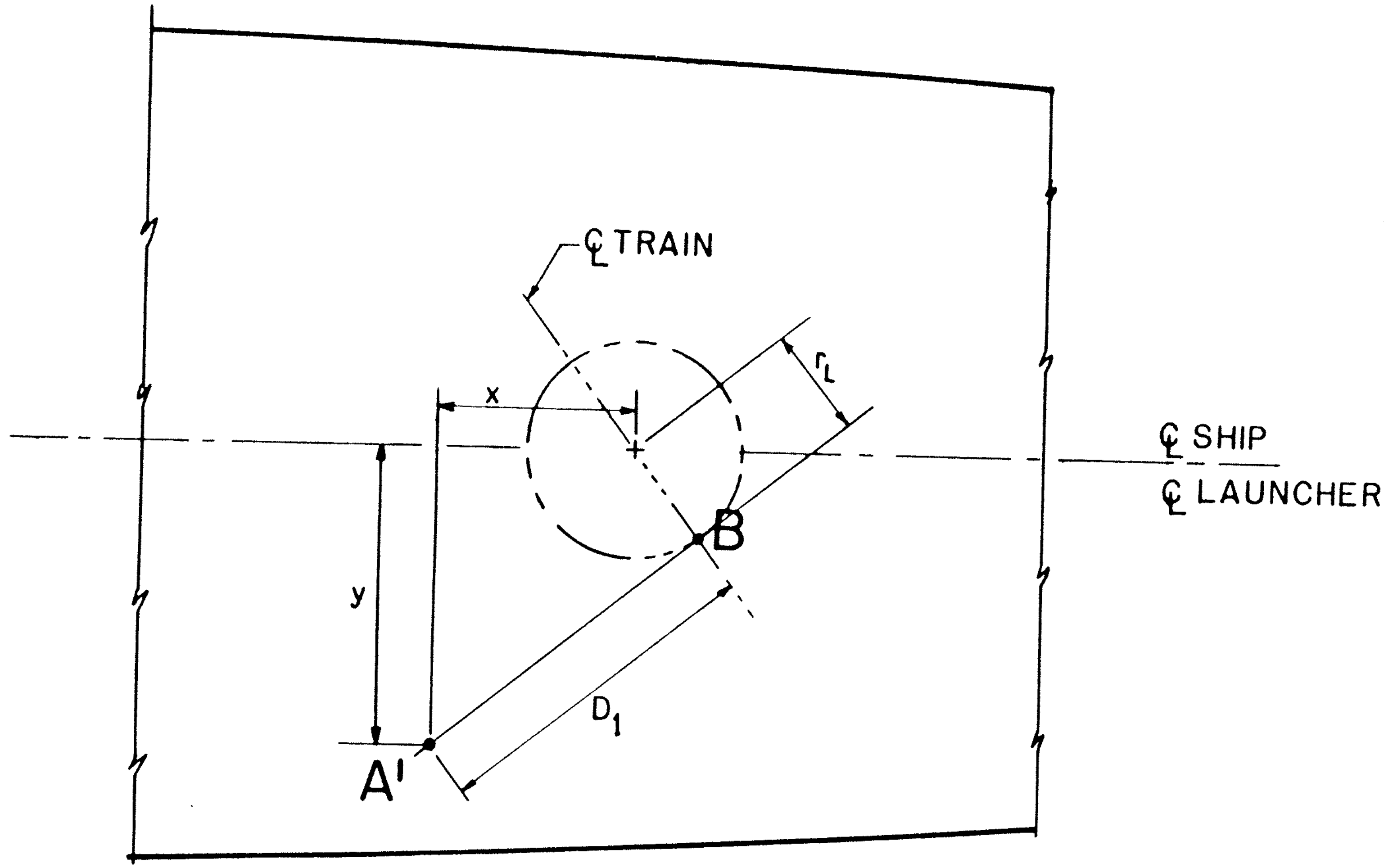


FIGURE 2

PLAN VIEW: POINT A' RELATIVE TO LAUNCHER

(STEPS 1–3)

Step 2: Draw the line A'B which is made by the Points A' and B; where B is the point of tangency with the launcher train centerline.

Step 3: Determine D_1 by measuring the length of A'B.

Step 4: Construct the elevation drawing (to scale) similar to Figure 3 given the following dimensions:

D_1 = distance from point under consideration (A') to train centerline

H_T = trunnion height (elevation of launcher arm pivot point) from gage point

a = radial distance from launcher arm pivot to missile centerline tangency point (B')

c = distance from missile tangency point (B') to nozzle exit plane

4a) Establish launcher centerline (train centerline) and, based on trunnion height (H_T), locate pivot of launcher arm. Draw the Datum Line to elevation h_D, equal to (H_T-a).

4b) Draw the swing envelope of the launcher arm about the launcher arm pivot point having the radius "a".

4c) Locate Point A' on the deck using the distance D_1 from the train centerline.

Step 5: Draw the line A'B', which is made by the points A' and B'; where B' is the point of tangency of the missile centerline with the launcher arm swing envelope. Locate the nozzle exit plane on the line A'B' using the dimension "c."

Step 6: Determine the dimensions b_1, Y and α:

6a) Determine b_1 (the distance from the point of tangency B' to the deck of point A') by measuring the length of line A'B'.

6b) Determine Y (the elevation of point B above the deck) by measurement.

6c) Determine the angle of incidence, α, by using a protractor or by the following relationship:

$$\alpha = \sin^{-1} (Y/b_1) \tag{2}$$

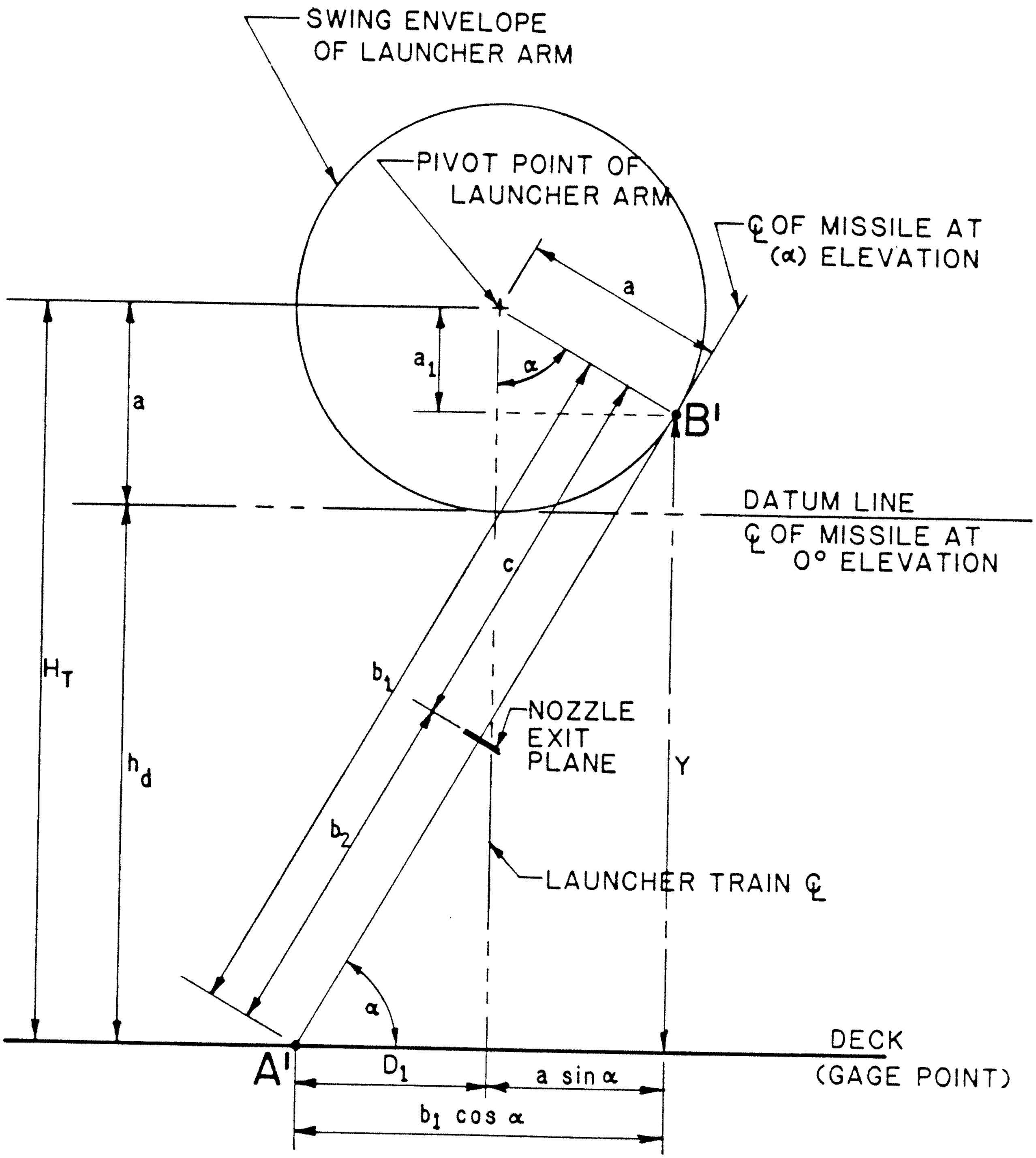


FIGURE 3
ELEVATION DIAGRAMMATIC OF LAUNCHER
(STEPS 4–7)

Step 7: Using (7a) or (7b), determine the dimension b_2:

7a) Determine b_2 by measuring the distance on the scale elevation drawing.

7b) Calculate b_2 using the following relationships:

$$b_2 = b_1 - c = \frac{h_d + (a - a_1)}{\sin\alpha} - c \quad (3)$$

where: $a_1 = a\cos\alpha$ (4)

Step 8: The impingement area takes an unsymmetrical shape. To simplify the calculations it is assumed to be elliptical. Referring to Figure 4, calculate the following variables associated with the blast impingement area on the deck:

$$\beta = 90° - \alpha \quad (5)$$
$$b_3 = b_2 - r \tan \beta \quad (6)$$
$$b_4 = b_2 + r \tan \beta \quad (7)$$

where: r = radius of missile nozzle

$$x_1 = \frac{b_3 \sin 3°}{\sin (\alpha + 3°)} \quad (8)$$

$$x_2 = \frac{r}{\sin\alpha} \quad (9)$$

$$x_3 = \frac{b_4 \sin 3°}{\sin (\alpha - 3°)} \quad (10)$$

Step 9: Calculate the major axis (m), minor axis (n), and the impingement area (A) of the blast pressure on the deck.

$$m = x_1 + 2 (x_2) + x_3 \text{ (major axis)} \quad (11)$$

$$n = 2r + 2b_2\tan3° \quad \text{(minor axis)} \quad (12)$$

$$A = \frac{\pi}{4} m n \quad (13)$$

$$= 0.7854 \; m \; n \quad (13a)$$

Step 10: Calculate the SE missile blast pressure for the point under consideration using Equation (1), based on the information developed in Steps 1 through 9.

$$P = [T (\sin\alpha + (0.0225/\sin\alpha))]/A \text{ (lb/in}^2\text{)} \quad (1)$$

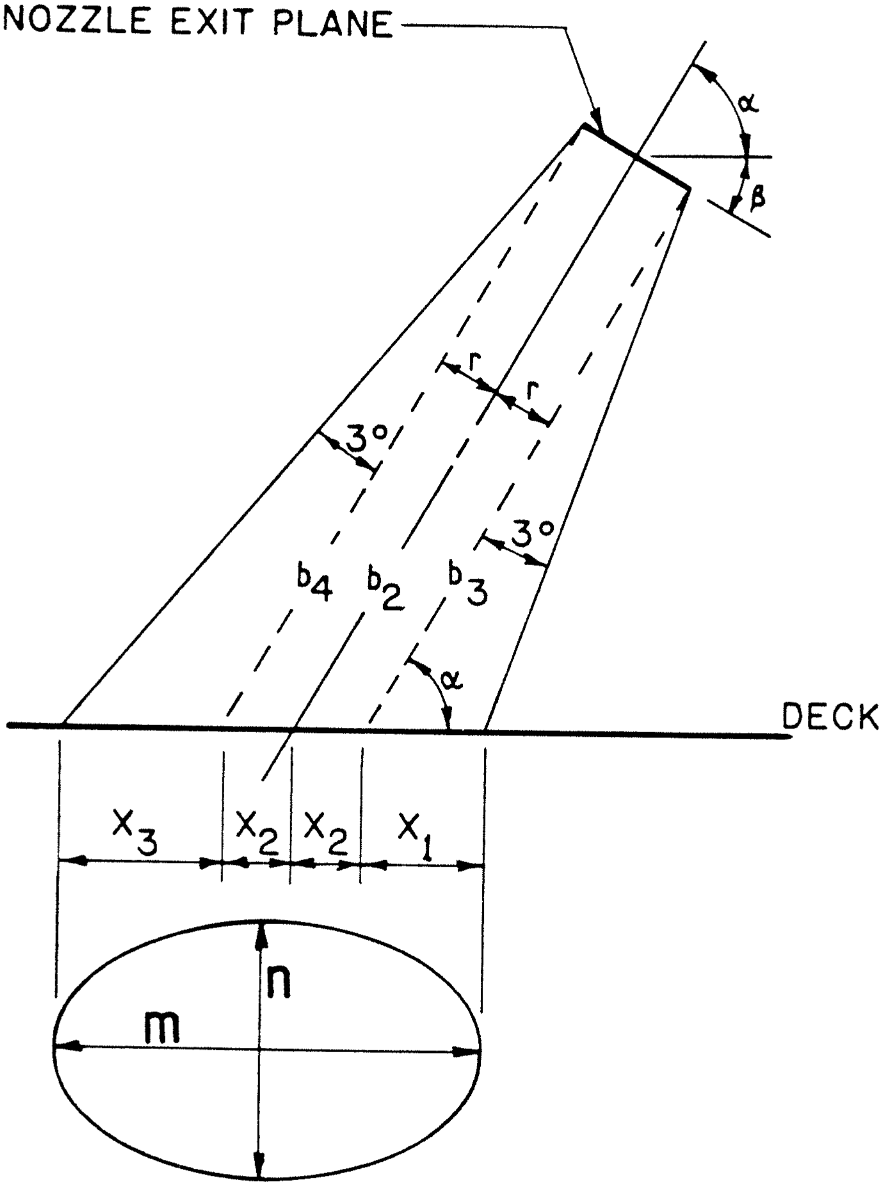


FIGURE 4
BLAST CONE IMPINGEMENT ON DECK
(STEPS 8-9)

SE Pressure Impingement on Bulkheads.- In general, design of bulkheads follows the same procedures as those used for decks. The basic difference between the two is that the reference plane (that is, the deck line or gage point) must be rotated 90 degrees. Another difference that must be recognized is that the angle of incidence, α, becomes a compound angle derived from the train angle and the angle of elevation. In this situation, analysis becomes somewhat complicated and, therefore, assumptions simplifying the analysis are made. First of all the train angle is assumed to be 0 degrees; that is, the missile launcher is trained fore-and-aft. Second, in order to predict a worst-case situation, the angle of elevation is assumed to be 0 degrees; that is, the launcher is horizontal.

In some cases, these assumptions may not be physically possible; for instance, where a gun mount is located directly forward of the launcher. However, the attempt here is to predict a worst case design condition and, thus, physical constraints will be ignored. Should a more accurate representation of blast impingement on the bulkheads be required, a design procedure utilizing train angles would be possible. This method would follow the procedures presented previously for the determination of blast overpressure on decks beginning at Step 4. It should be noted that consistent variable changes should be made, such as:

- "D_1" would then become the distance from the launcher centerline to the bulkhead.
- "a" would become r_L - the distance of the launcher arm centerline from the launcher centerline.
- The angle of incidence, α, would be equal to the train angle.

The following three steps present a simplified method for the determination of pressure loading on the bulkhead. Figure 5 illustrates the launcher position discussed in the preceding paragraphs; that is, train and elevation angles are zero. This implies that the angle of incidence (α) with respect to the bulkhead is 90 degrees; thus, the procedures and equations are modified as shown below:

Step 1: Given an angle of incidence (α) of 90 degrees, the geometric parameters are reduced to:

$$b_1 = x = \text{distance from bulkhead to launcher} \qquad (14)$$

$$b_2 = b_1 - c \qquad (15)$$

$$b_3 = b_4 = b_2 \qquad (16)$$

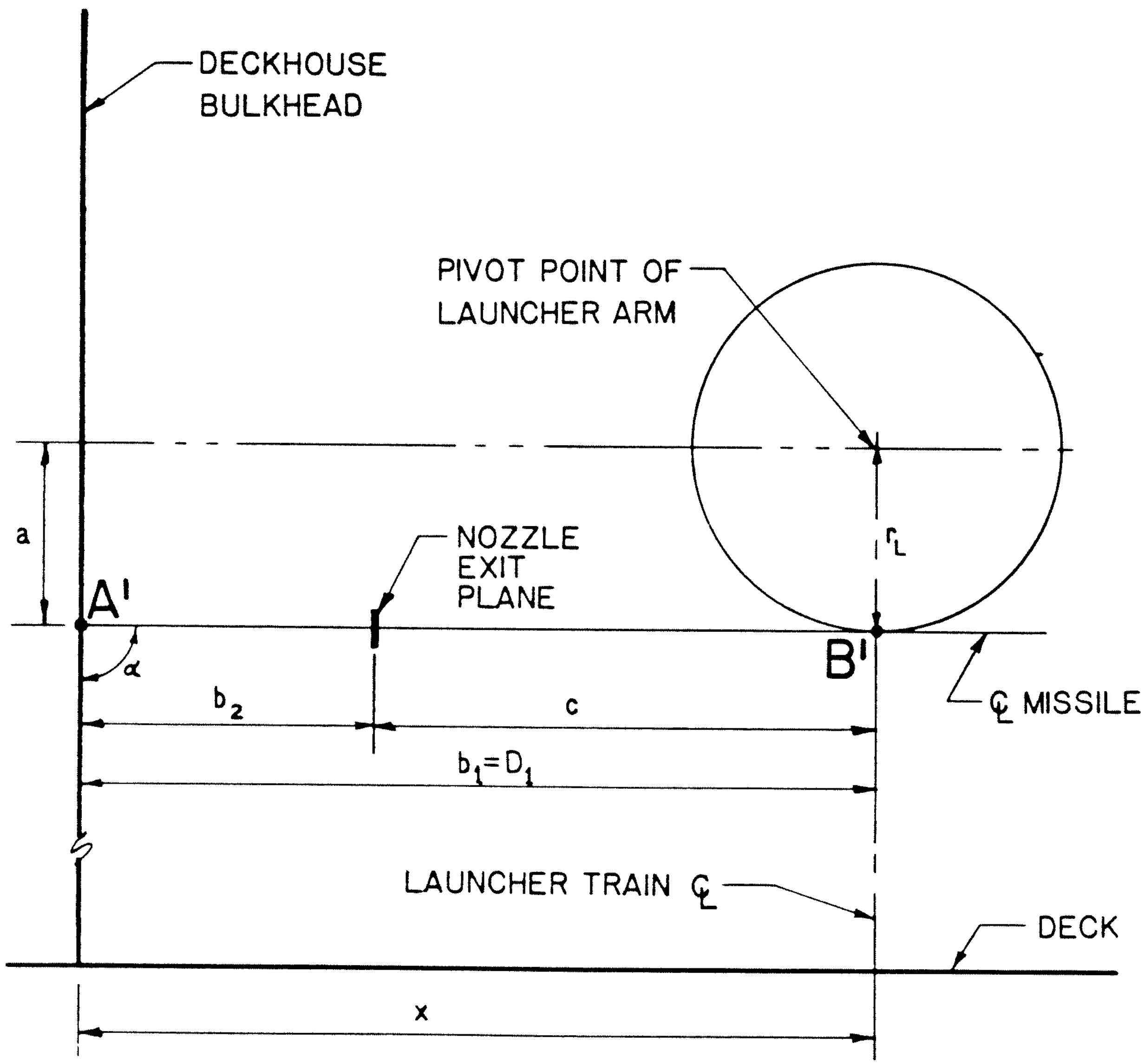


FIGURE 5

MISSILE BLAST IMPINGEMENT ON BULKHEAD

Step 2: Noting that the blast impingement area on the bulkhead will be a circle, the following relationships apply:

$$x_1 = x_3 = b_3 \sin 3° = b_4 \sin 3° \quad (17)$$

$$x_2 = r \quad (18)$$

$$m = n = 2x_1 + 2x_2 \quad (19)$$

$$A = \frac{\pi}{4} m^2 \quad (20)$$

$$= 0.7854m^2 \quad (20a)$$

Step 3: The SE blast pressure is now calculated based on Equation (1). Noting that sin 90 degrees = 1, Equation (1) takes the form:

$$P = 1.0225\ T/A\ (lb/in^2) \quad (1a)$$

100-7-g. Accidental Missile Ignition

The design of ship structure for accidental missile ignition is based on an empirical formula that relates a static equivalent pressure to the booster burning rate and the total area of blowout openings.

The structure is designed for the following loading:

$$H = 4.5\ R/A \quad (21)$$

where: H = pressure head in feet of seawater
R = burning rate of the missile booster, in lb/sec
A = total area, in square feet, of blowout opening

100-7-h. Gun Blast

General.- The shock wave from a gun blast has two major components that affect ship structures, namely incident free-air overpressure and reflected overpressure. Incident free-air overpressure is the overpressure behind the shock wave immediately before the wave interacts with the structure. Reflected overpressure is the overpressure that results from the incident wave interacting with the structure. Since the structure causes the incident wave to change direction, the reflected wave pressure is greater than the free-air overpressure. The actual form of these overpressures is dependent upon many factors, primarily, time and angle of incidence.

To simplify determination of the overpressure, a Static Equivalent (SE) blast pressure provides an approximate method to account for dynamic loading factors associated with the transient blast load. This static equivalent approximation has been used successfully to design conventional decks and bulkheads for both aluminum and steel ship structures (reference a). The SE methodology is discussed further in the following sections.

In terms of worst case loadings for gun blast, there are two variables that govern the pressure relationship. The first is the depression angle, θ. The depression angle will determine the effect of the second variable, the radius vector, r. The radius vector defines the distance from the gun muzzle to the point in question. Thus for decreasing depression angles, the radius vector will also decrease. As a result, for any given space angle, β, a decrease in the radius vector will result in a higher blast pressure (this effect is shown more clearly by the blast pressure envelopes in Appendix 2). Figure 6 shows typical gun blast pressure contours which demonstrate the effect of these two variables.

Gun Static Equivalent Blast Pressure.- In most cases, design of the ship structure for gun blast loading utilizes the relationship for static equivalent (SE) overpressure. Worst case locations on the ship structure are identified and SE pressures are calculated, respectively. For some designs, it is useful to develop SE blast pressure contours similar to Figure 6. Using these contours as an overlay with the ship's structural arrangement drawings, critical loading areas on the ship can be easily identified. Development of these blast pressure contours is discussed in detail in Appendix 2.

The SE blast overpressure load is based on an empirical formula that relates a static equivalent pressure head to the size (caliber) of the gun and the proximity of the gun nozzle to the structure in question. The formula for the prediction of SE blast load is given by:

$$H = \frac{450(1 + \cos\beta)^2}{(r/d)^{1.5}} \tag{22}$$

where: H = static equivalent head, in feet of salt water
β = angle between the gun barrel axis and the radius vector, r, in degrees
r = the length of the radius vector defined by the distance from the gun muzzle to the point in question, in inches
d = diameter (caliber) of the gun, in inches

The above formula gives a blast pressure load for one muzzle only. The blast pressure for two or more guns firing simultaneously is not additive and therefore the determination of the scantlings shall be based on the blast pressure of the nearest gun.

SE Pressure Impingement on Decks.- In order to calculate the SE pressure on the deck, it is necessary to first determine the length of the radius vector, r, and the space angle, β. Three dimensions of the gun installation are required to determine r and β and are usually provided as GFI. These dimensions are: (see Figure 7)

- H_T - Trunnion height, in inches
- L_b - Barrel length, in inches
- d - Gun diameter (caliber), in inches

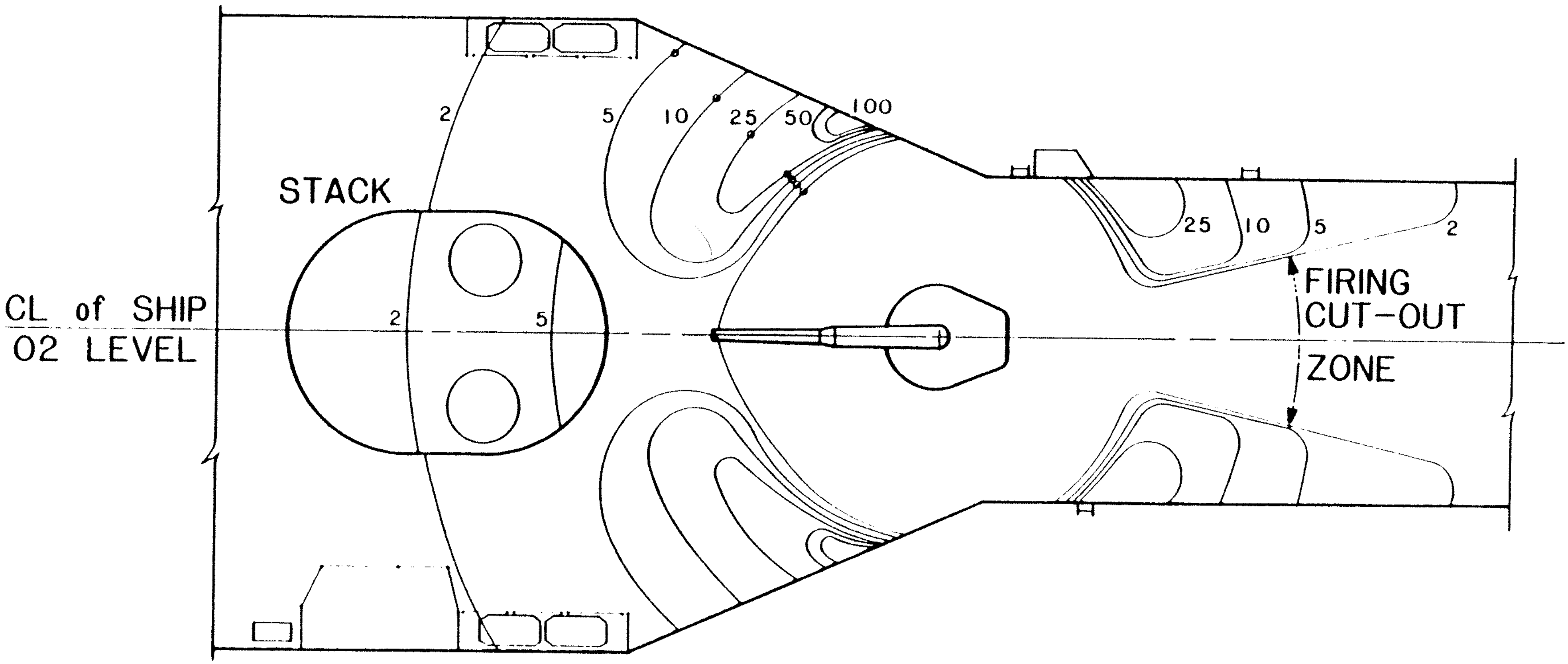


FIGURE 6

76 MM GUN STATIC EQUIVALENT BLAST PRESSURE IMPINGEMENT ON DECK

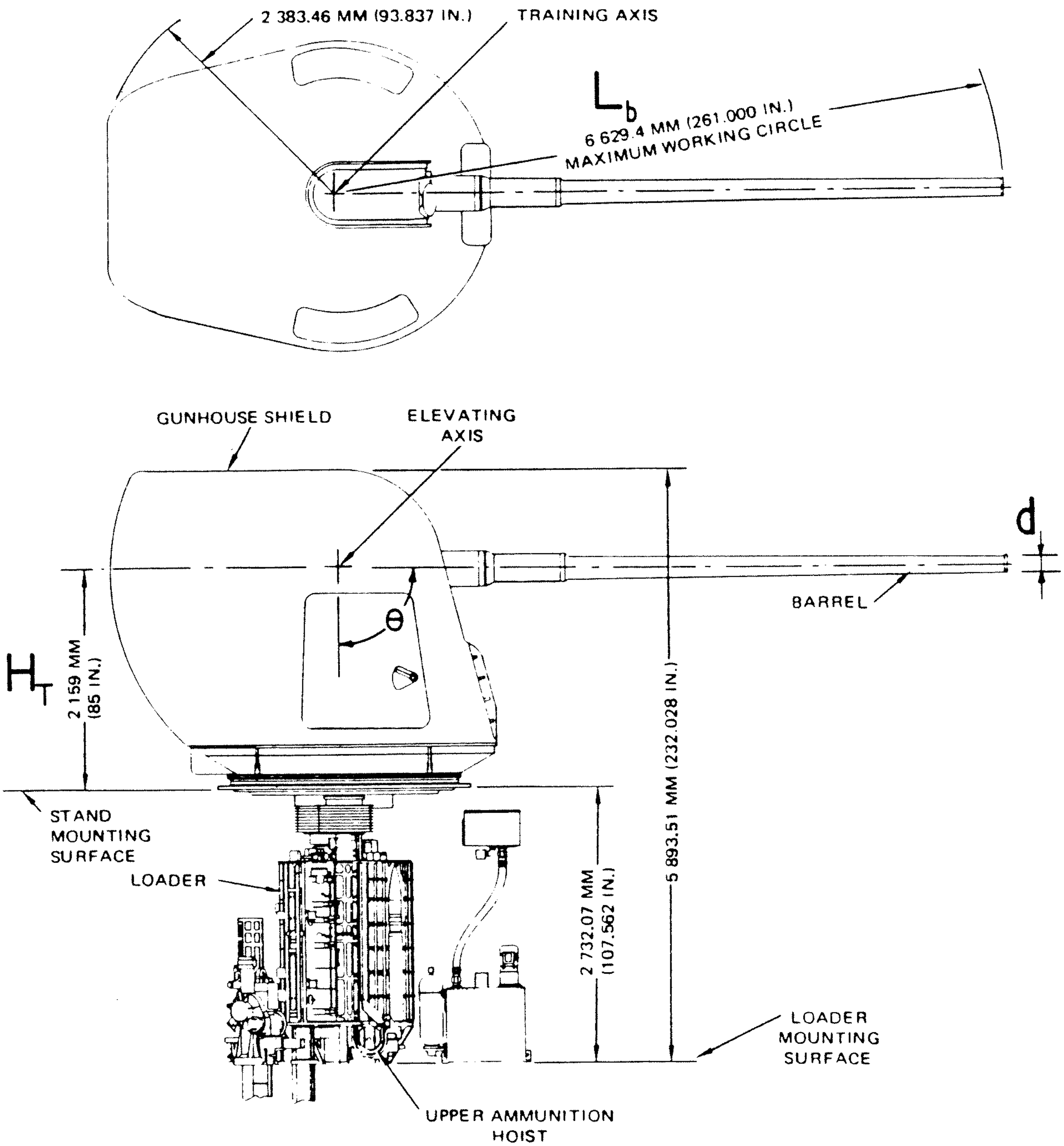


FIGURE 7
GENERAL DIMENSIONS OF THE 5"/54 GUN MOUNT

A graphical method for determining r, and β is presented in the following paragraphs. For accuracy, drawings or sketches should be drawn to scale carefully.

Step 1: Locate Point A', the point under consideration, on the deck drawing (Figure 8). Draw a line representing the firing line from the gun centerline through Point A', thus locating Point B at the deck edge. The distance to the deck edge along the firing line (L) should then be scaled off the deck drawing. In addition, the distance to Point A' (L') should be scaled from the drawing (L' can also be calculated based on the dimensions X and Y).

Step 2: Using the length (L) as the baseline, a depression angle sketch, similar to Figure 9, should be drawn (to scale). The trunnion height, barrel length, and gun caliber are also necessary to construct this depression angle sketch.

NOTE: The maximum loadings for that particular train angle result when (1.5 x Caliber) is used as a depression limit; however, other depression angles (θ) can be specified. Also, it should be noted that θ should not exceed the maximum depression angle.

Step 3: After locating Point A' on the depression angle drawing, the radius vector length (r) can be scaled from the drawing. In addition, the space angle (β) between the radius vector and the firing line (or axis of the gun barrel) should be scaled off using a protractor.

Step 4: Given r and β calculate the blast load at Point A' based on an equivalent head of water.

$$H = 450 \frac{(1 + \cos\beta)^2}{(r/d)^{1.5}} \qquad (22)$$

SE Pressure Impingement on Bulkheads.- Gun static equivalent blast pressure on vertical structure (that is, deckhouse bulkheads) is determined in relatively the same manner as the deck structure. For design of bulkhead structure, only development of a deck plan layout is required; a gun elevation is not necessary. Procedures for the determination of bulkhead blast pressure are outlined below.

Step 1: Using a deck plan, develop a scale drawing similar to Figure 10. Note that the clearance criterion of 1.5 times the gun caliber is employed unless otherwise specified. Locate Point A', the point under consideration, on this drawing.

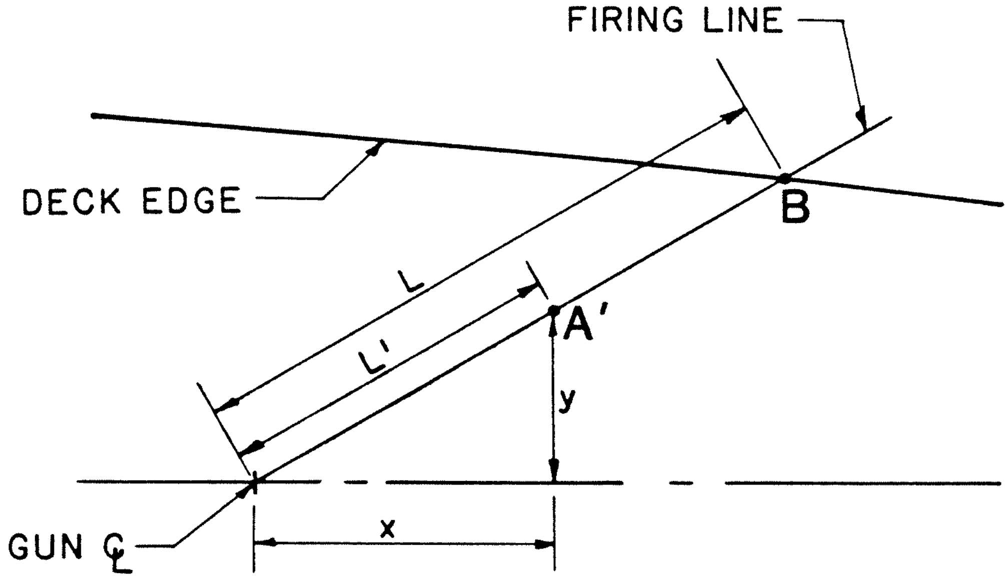
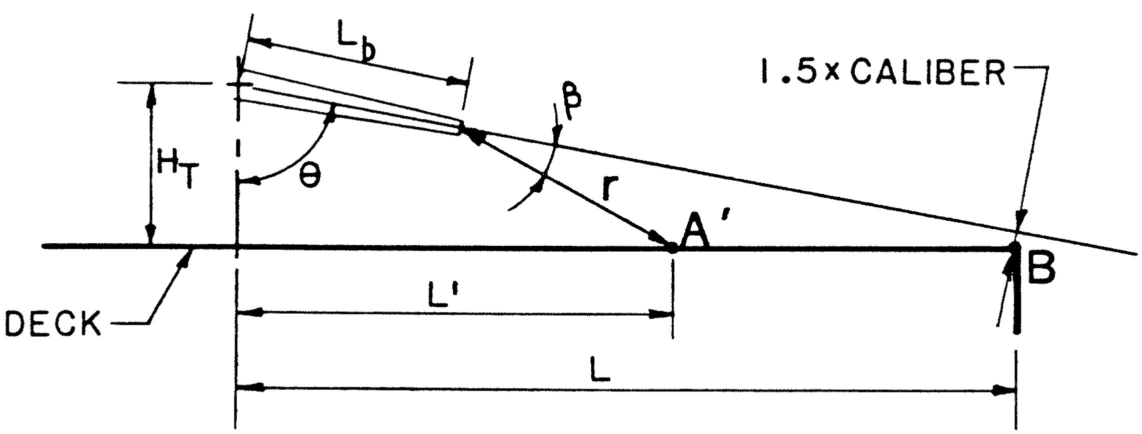


FIGURE 8
PLAN VIEW: FIRING LINE TO DECK EDGE
(STEP 1)



WHERE: L_b = BARREL LENGTH

FIGURE 9
ELEVATION: POINT A' RELATIVE TO GUN
(STEPS 2-3)

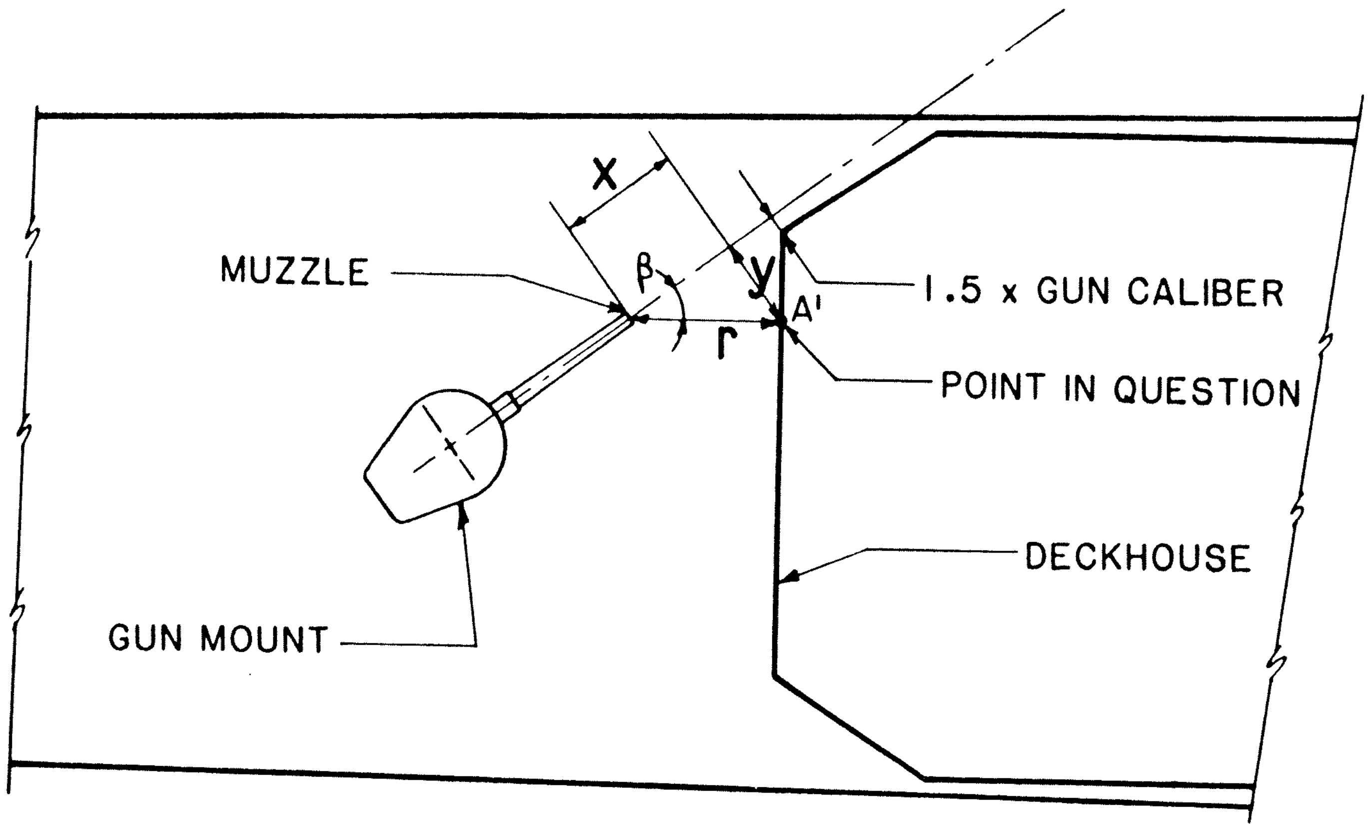


FIGURE 10

GUN BLAST PRESSURES ON BULKHEAD STRUCTURES

Step 2: Determine the dimensions "r", "X", and "Y" by measurement. With these dimensions the variable can be calculated using the following relationship:

$$\beta = \tan^{-1}(Y/X) \qquad (23)$$

NOTE: In situations where β is greater than 90 degrees, that is, the point under consideration is behind the gun nozzle, the following relationships should be applied:

$$\beta_1 = \tan^{-1}(Y/X) \qquad (24)$$

$$\beta = 180° - \beta_1 \qquad (25)$$

Step 3: Calculate the SE pressure head using equation (21):

$$H = 450 \frac{(1 + \cos\beta)^2}{(r/d)^{1.5}} \qquad (21)$$

100-7-i. Gun Recoil

The design of a gun mount supporting structure is generally not governed by recoil forces. In addition, tests have shown that only a negligible amount of shock is transmitted into ship structure from trunnion forces. If it is necessary to check gun mount structure for recoil loads, the static equivalent of dynamic recoil forces shall be assumed to be 1.3 times the rated brake load of the recoil mechanism. Design stress shall not exceed one-half the yield strength of the material.

100-7-j. Structural Analysis

General.- The design of plating, plate stiffeners, and other structure is drawn from basic engineering theory. The procedures presented in this section are aimed at making the design analysis as simple as possible.

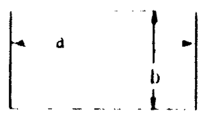
The designer should note that the gun and missile blast pressures are treated as independent secondary loads. For this reason stresses derived from plating and stiffener analyses should not be combined with Design Primary Stresses.

Plating Panel Design for Missile Blast.- Given the blast pressure load zones developed for the deck structure, the deck plating panels may be analyzed to withstand the localized load induced by the missile blast. It should be noted that for a given missile system various pressure loadings on various panel configurations can be realized; therefore, several plating analyses must be conducted to insure proper plate performance in way of the missile blast region. Missile blast loadings on the plating panels can vary from nearly concentrated to fully uniform; consequently, plating analyses using formulas presented by Roark (reference C) have been selected for this DDS and are presented in table II. For this design procedure the boundary conditions for the plating panels are treated as simply supported.

TABLE II: PLATE PANEL DESIGN FOR MISSILE BLAST

LOADING TYPE	FORMULAS AND TABULATED SPECIFIC VALUES

A. UNIFORM OVER ENTIRE PLATE

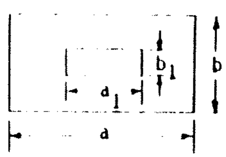


(At center) Max $\sigma = \frac{\beta \cdot P \cdot b^2}{t^2}$; max. $y = \frac{-\alpha \cdot P \cdot b^4}{E \cdot t^3}$; and Max. Reaction @ long side = $\gamma \cdot P \cdot b$

a/b	1.0	1.2	1.4	1.6	1.8	2.0	3.0	4.0	5.0	∞
β	0.2874	0.3762	0.4530	0.5172	0.5688	0.6102	0.7134	0.7410	0.7476	0.7500
α	0.0444	0.0616	0.0770	0.0906	0.1017	0.1110	0.1335	0.1400	0.1417	0.1421
γ	0.420	0.455	0.478	0.491	0.499	0.503	0.505	0.502	0.501	0.500

(for ν = 0.3)

B. UNIFORM OVER CENTRAL RECTANGULAR AREA



(At center) Max $\sigma = \frac{\beta \cdot W}{t^2}$; where: $W = P \cdot a_1 \cdot b_1$

a_1/b	a = b						a = 1.4b						a = 2b					
b_1/b	0	0.2	0.4	0.6	0.8	1.0	0	0.2	0.4	0.8	1.2	1.4	0	0.4	0.8	1.2	1.6	2.0
0.0		1.82	1.38	1.12	0.93	0.76		2.00	1.55	1.12	0.84	0.75		1.64	1.20	0.97	0.78	0.64
0.2	1.82	1.28	1.08	0.90	0.76	0.63	1.78	1.43	1.23	0.95	0.74	0.64	1.73	1.31	1.03	0.84	0.68	0.57
0.4	1.39	1.07	0.84	0.72	0.62	0.52	1.39	1.13	1.00	0.80	0.62	0.55	1.32	1.08	0.88	0.74	0.60	0.50
0.6	1.12	0.90	0.72	0.60	0.52	0.43	1.10	0.91	0.82	0.68	0.53	0.47	1.04	0.90	0.76	0.64	0.54	0.44
0.8	0.92	0.76	0.62	0.51	0.42	0.36	0.90	0.76	0.68	0.57	0.45	0.40	0.87	0.76	0.63	0.54	0.44	0.38
1.0	0.76	0.63	0.52	0.42	0.35	0.30	0.75	0.62	0.57	0.47	0.38	0.33	0.71	0.61	0.53	0.45	0.38	0.30

(for ν = 0.3)

WHERE:

σ = Plate Bending Stress (lb/in²)

P = Blast Pressure (lb/in²)

t = Plate Thickness (in)

a & b = Plate Dimensions (in)

NOTE: All plate edges are simply supported.

(DATA OBTAINED FROM ROARK, REFERENCE C)

Using the applicable formula, a plating stress (given loading and plating thickness) can be determined. As stated in the General Specifications, plating subjected to missile blast shall be designed to the yield strength of the material. For aluminum structures, the applicable yield strength is that for welded material. Thus, if the plating stress is below the applicable material yield strength, the plating will perform satisfactorily under missile blast. If the plating stress exceeds the yield strength, there are three options open to the designer: (1) plating thickness can be increased; (2) plating material can be changed to increase the yield strength; (3) panel dimensions can be reduced by adding local stiffening. These three options must be carefully considered based on cost and weight to achieve a satisfactory result.

Plating Panel Design for Gun Blast.- Once gun blast pressure loadings have been developed for the deck structure, the deck plating panels can be analyzed. In contrast to missile blast, gun blast pressures are given in equivalent feet of seawater. In general, gun blast results in uniform pressure loading on the plating panels. For gun blast analysis, the simplified required plate thickness criterion presented in the applicable Ship Specifications or in the General Specifications (reference d) are utilized and are shown in Table III. Only the "C" values associated with gun blast are presented here (this is in agreement with the General Specifications for Ships).

On the basis of this criterion the designer must satisfy a required panel breadth to thickness ratio (b/t). Similarly, by a simple reordering of the equation the designer can satisfy a required thickness.

$$\text{Required } t = \frac{b\ k\ \sqrt{H}}{C} \tag{26}$$

Should the required "b/t" ratio (or the required thickness) not be satisfied, then the designer has three options to rectify the problem: (1) plating thickness can be increased; (2) plating material can be changed to increase the yield strength; (3) panel dimensions can be reduced by adding local stiffening. These three options must be carefully considered based on cost and weight to achieve a satisfactory result.

Deck or Bulkhead Stiffeners.- The design of deck and bulkhead stiffeners for gun or missile blast basically follows the same procedure. Stiffeners shall be designed such that the allowable stress of the material is not exceeded. A simplified approach for stiffener analysis is employed in this DDS with the stiffeners being treated as pinned-pinned beams (this treats panel stiffeners as noncontinuous members, for continuous members some partial fixity could be assumed). The stiffener analysis follows a simple three-step procedure: (1) calculation of stiffener bending moment; (2) calculation of the required section modulus; (3) comparison of the required section modulus with the furnished section modulus. Standard formulas for Steps (1) and (2) are provided in Table IV.

TABLE III: REQUIRED PLATE THICKNESS FOR GUN BLAST

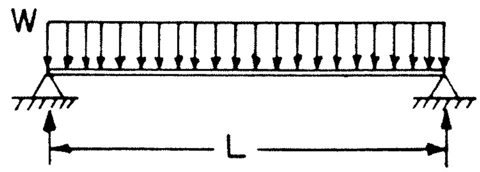
$$\frac{b}{t} \leq \frac{C}{K\sqrt{H}}$$

H = HEAD OF SEA WATER (FEET)
a = LONG DIMENSION OF PLATE PANEL (INCHES)
b = SHORT DIMENSION OF PLATE PANEL (INCHES)
t = PLATE THICKNESS (INCHES)

RATIO b/a	K - VALUE
.5 or less	1.0
.6	.98
.7	.94
.8	.89
.9	.84
1.0	.78

MATERIAL	C - VALUE
AL5086 H116	250
AL5456 H116	300
ORD. STR. STEEL	350
HIGHER STR. STEEL	400
HY80	500
HY100	550

TABLE IV: STIFFENER DESIGN FORMULAS



CASE 1) STIFFENER WITH UNIFORM LOADING

OF "W" lb/in:

a) FOR GUN BLAST:

$$W = H \cdot s \cdot 64 \cdot \frac{1}{144} \quad \text{(lb/in)}$$

WHERE: H = Equivalent Hydrostatic Head (ft)

s = Stiffener Spacing (in)

b) FOR MISSILE BLAST:

$W = P \cdot n$; WHERE: P = Static Equivalent Pressure (lb/in^2)

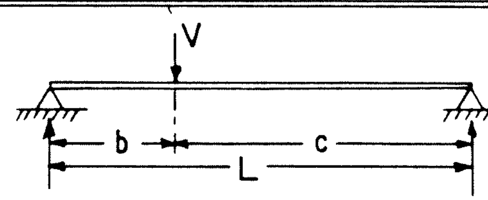
n = Minor Axis of Impingement Area (in)

c) MAXIMUM MOMENT:

$M = \frac{wL^2}{8}$; WHERE: L = Stiffener Length (in)

d) REQUIRED SECTION MODULUS:

Req'd. SM = $\frac{M}{\sigma}$; WHERE: σ = Material Allowable Stress (lb/in^2)



CASE 2) STIFFENER WITH CONCENTRATED LOAD

(FOR MISSILE BLAST ONLY)

a) CONCENTRATED LOAD:

$V = P \cdot A$; WHERE: P = Static Equivalent Pressure (lb/in^2)

A = Blast Impingement Area (in^2)

b) MAXIMUM MOMENT:

$M = \frac{V \cdot b \cdot c}{L}$; WHERE: L = Stiffener Length (in)

b & c = Load Dimensions (in)

c) REQUIRED SECTION MODULUS:

Req'd. SM = $\frac{M}{\sigma}$; WHERE: σ = Material Allowable Stress (lb/in^2)

In general, stiffeners will be designed for a uniform load over the length of the stiffener. For situations where a missile blast impingement length is significantly less than the stiffener length, the missile blast load can be treated as a concentrated load. While conservative, this approach should yield satisfactory results. However, if this approach results in unsuitable stiffener sizes (for example, 8-inch or 10-inch T's where 5-inch or 6-inch T's are preferred), then the designer should consider treating the missile blast in a more exacting manner, such as a partial distributed uniform load (applicable formula available in such texts as the AISC Steel Construction Manual, reference e).

In the case where the blast load acts over a small area relative to the stiffener spacing, specifications generally allow a load reduction. Where the impingement width is not greater than the distance between stiffeners, only two-thirds of the load is assumed to fall on one stiffener in a normal longitudinally framed structure. Where the impingement width is greater than the distance between stiffeners, the load is to be distributed proportionally among the stiffeners.

Other Structure.- The design of major supporting structure, such as longitudinal or transverse girders, follows a similar procedure as that for stiffeners. The structural member is assumed to have pinned connections at support points and subjected to the appropriate uniform or concentrated load. Girders shall be designed such that the calculated stresses do not exceed the allowable design stress of the material.

Stanchions or other vertical structure are designed to support the live load which can be attributed to that structural member. The attribution area is generally considered to be a rectangle with dimensions of one half the distance between support points in each direction (longitudinal and transverse). As in standard Navy design procedures, stanchions or other supporting structures are considered to be pin ended. The calculated column stress shall not exceed 60 percent of the column buckling stress for free standing stanchions. For vertical support members made of plates and stiffeners, the ratio of calculated column stress to column buckling stress shall not exceed 67 percent for L/r rations greater than 60 and 80 percent for L/r ratios less than, or equal to 60.

Missile Blast Design Example.- A Mk 26 missile launcher (Mk 56 motor) mounted on the steel deck is shown in Figure 11. The following information concerning the launcher (see Figure 1) and the missile has been provided:

- Missile nozzle radius = r = 3.6 in.
- Maximum thrust = T = 25,000 lbs.
- Distance of launcher arm centerline from launcher centerline - r_L = 54 in.
- Launcher arm pivot point to missile centerline = a = 25 in.
- Distance from deck to datum line - h_d = 117-6-25 = 86 in.
- Launcher arm pivot point to nozzle exit plane = c = 74 in.

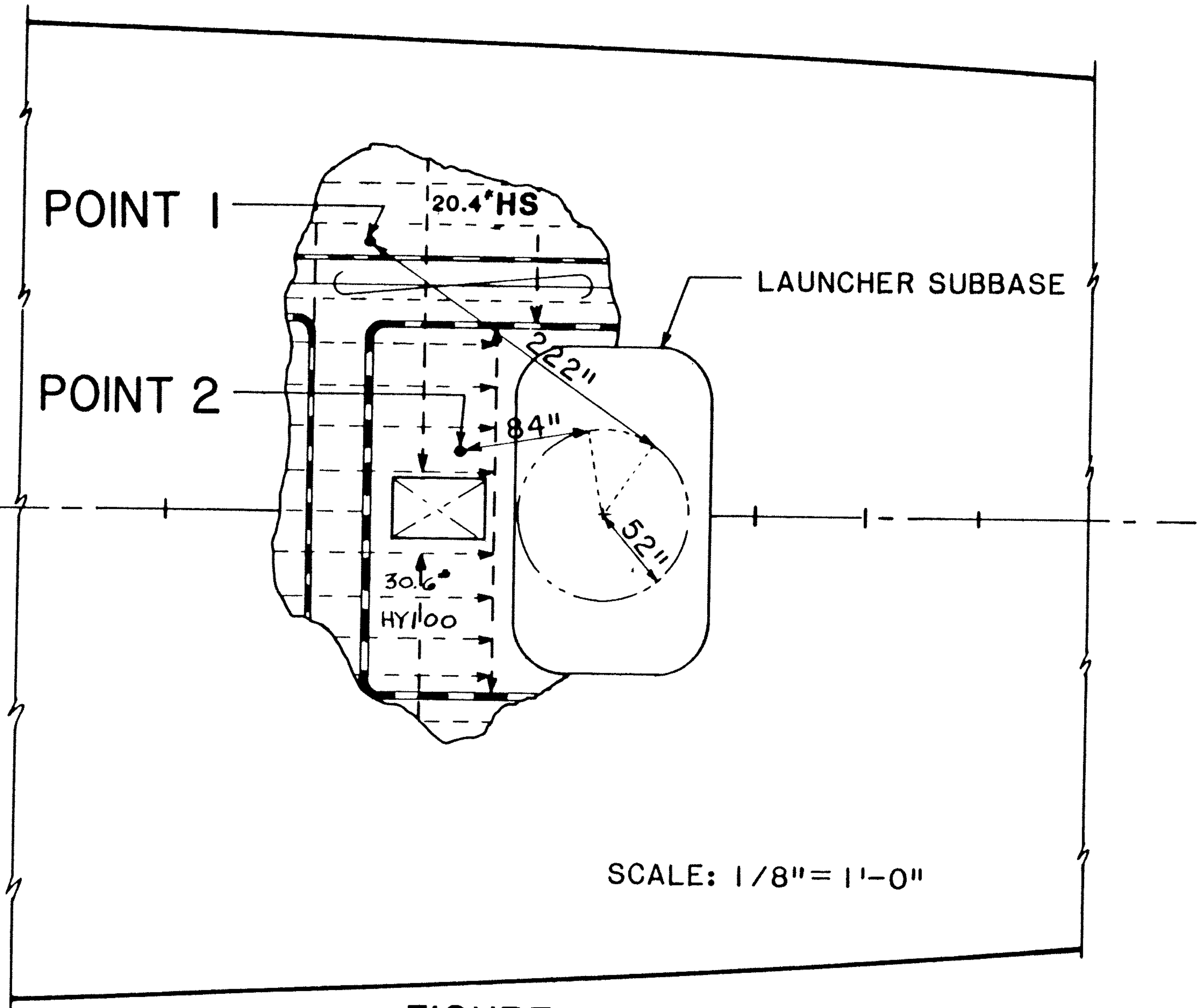


FIGURE 11
MISSILE BLAST DESIGN EXAMPLE - PLAN VIEW -

For this example two points are chosen to demonstrate the calculation procedures:

PROBLEM: Develop blast loading and check structural adequacy of scantlings for the two locations listed below (distances in relation to launcher centerline):

Point 1: X_1 = Distance aft of launcher CL = 94 in.

Y_1 = Distance off ship CL = 42 in.

Point 2: X_2 = Distance aft of launcher CL = 156 in.

Y_2 = Distance off ship CL = 174 in.

The solution of this design problem is divided into two parts: 1) identification of blast pressures, and 2) determination of structural adequacy.

Calculation of Missile Blast Pressure

Step 1: Points under consideration are located on the deck plan view drawing, Figure 11. The circle made by r_L is also drawn.

Step 2: Tangent lines from Points 1 and 2 are then drawn to the launcher as shown in Figure 11.

Step 3: The length D_1 are then measured for the two points and are found to be:

Point 1 = D_1 = 84 in.

Point 2 = D_1 = 222 in.

Step 4: The launcher elevation diagrammatic, Figure 12, is now developed based on the dimensions "a", "h_d", and "c", and the "D_1" distances determined in Step 3. Note: For clarity, only Point 1 is shown in Figure 12.

Step 5: Using Figure 12, the tangent line is drawn from Point 1 to the launcher arm swing envelope. The missile nozzle exit plane is located on this line using the dimension "c."

Step 6&7: Determine the dimensions b_1 and b_2 and the angle of incidence, α by measurement from Figure 12. These dimensions are presented in tabular form below.

Point	b_1	b_2	α
1	137"	63"	42.5°
2	247"	173"	21.0°

Step 8: The dimensions required to define the blast impingement area on the deck (see Figure 4) are calculated using equations (5) through (10). The results are tabulated below.

Point	β	b_3	b_4	X_1	X_2	X_3
1	47.5	59.1	66.9	4.33	5.33	5.51
2	69.0	163.6	182.4	21.1	10.0	30.9

Step 9: Given the information developed in Step 8, the major (m) and (n) axes as well as the blast impingement areas are calculated for the two points.

Point	a	b	m	n	A	Stress Formula (Table II)
1	48"	30"	20.5"	13.8"	222.2	Case B
2	72"	24"	72"	25.3"	1430.7	Case A

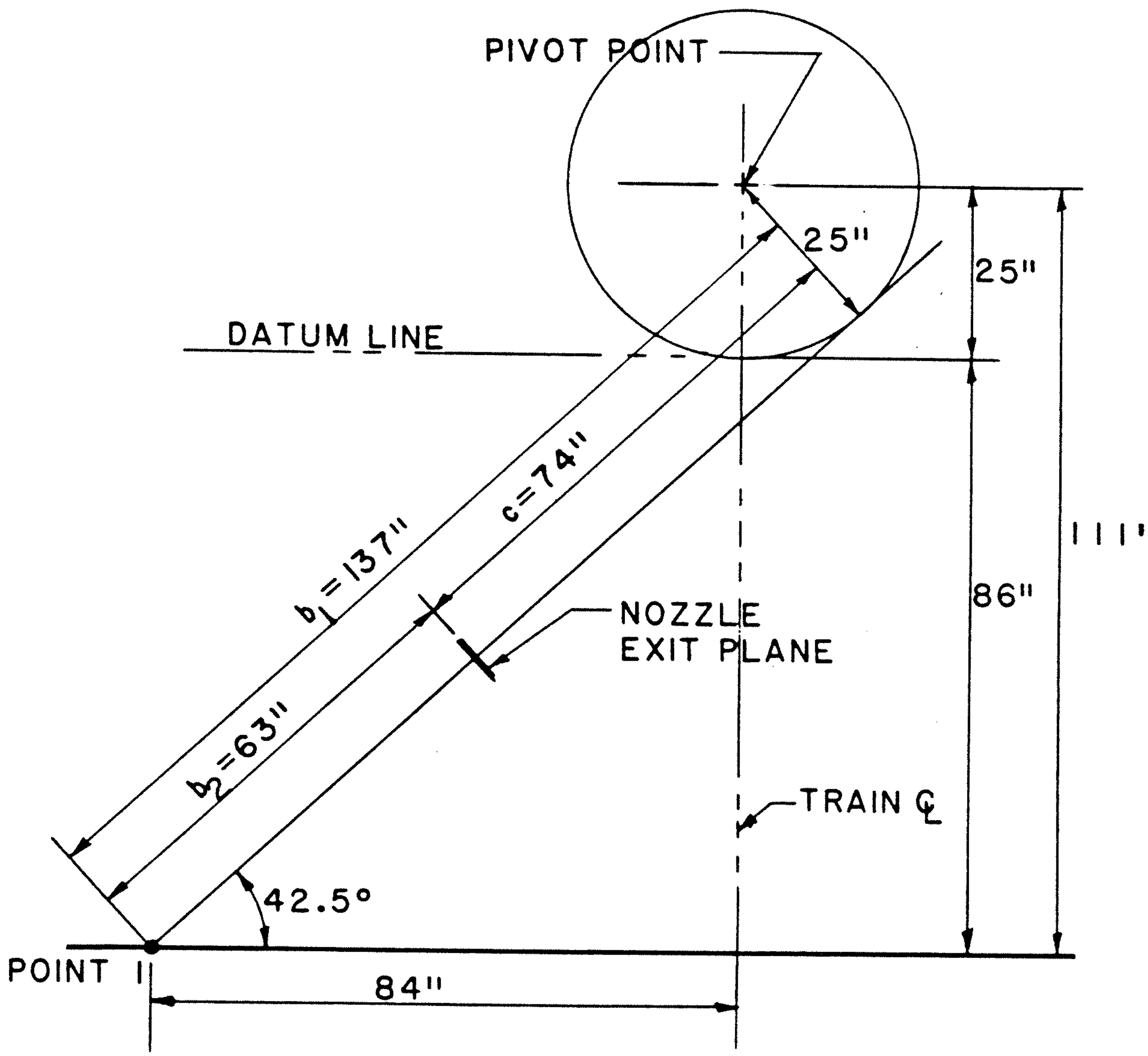


FIGURE 12
DESIGN EXAMPLE - LAUNCHER ELEVATION

Step 10: Using equation (1), the blast pressure can now be calculated for the two points under consideration.

Point 1:

$$P = \frac{25000\ (\sin 42.5\ \ + (0.0225/\sin 42.5\ ))}{222.2}$$

$$P = 79.8\ lb/in^2$$

Point 2:

$$P = \frac{25000\ (\sin 21\ \ + (0.0225/\sin 21\ ))}{1430.7}$$

$$P = 7.4\ lb/in^2$$

Determination of Structural Adequacy

Step 11: Plating analysis

(a) Panel Dimensions (from scantling drawing, Figure 11):

Point	a	b	t
1	48"	30"	0.75"
2	72"	24"	0.50"

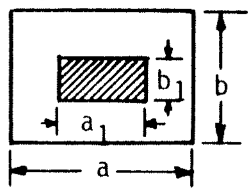
(b) Material:

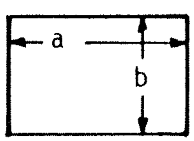
At Point 1: HY-100; yield strength = 100 KSI
At Point 2: HS; yield strength = 51 KSI

(c) Stress calculation - stress calculations for the two points under consideration are presented in Table V. The panel geometries shown in Table V have been tabulated to indicate how the major and minor axes are used to describe the loading footprint on the panel. For Point 1, the axes describe a non-uniform load at the center of the panel. The axes of Point 2 are approximately equal to the panel dimensions; thus, the loading of the second panel is assumed to be uniform.

(d) Stress analysis - For missile blast, maximum stresses in the plating panels shall not exceed the yield strenth of the plating material (see reference d, Part I). It should be noted that stresses from missile blast are to be considered independent of primary stresses. The table below indicates that the plating of the two locations here is structurally adequate.

TABLE V: MISSILE BLAST DESIGN EXAMPLE

α	PANEL GEOMETRY	LOADING	b_1/b	a_1/b	β	t	MAX. STRESS (σ)
42.5	POINT 1:  a = 48" a_1 = 20.5" b = 30" b_1 = 13.8"	BLAST AREA: ⬭ = 222 in^2 P = 79.8 lb/in^2 W = 17732#	0.46	0.43	0.932	0.75	$\sigma = \frac{\beta W}{t^2}$ $\sigma = \frac{0.932(17732)}{(.75)^2}$ $\sigma = 29380\ lb/in^2$

α	PANEL GEOMETRY	LOADING	a/b	b^2	β	t	MAX. STRESS (σ)
21.0	POINT 2:  a = 72" a_1 = 72" b = 24" b_1 = 25.3"	P = 7.4 lb/in^2 (UNIFORM)	3.0	576	0.7134	0.50	$\sigma = \frac{\beta P b^2}{t^2}$ $\sigma = \frac{0.7134(7.4)(24)^2}{(.5)^2}$ $\sigma = 12163\ lb/in^2$

Point	Maximum Stress	Allowable Stress	Structural Adequacy
1	29.4 KSI	100. KSI	O.K.
2	12.2 KSI	51. KSI	O.K.

Step 12: Stiffener analysis. This step requires the calculation of the maximum bending moment for a pinned-pinned beam. Because of the relative size of the blast footprint to the stiffener length, the blast load of Point 1 will be treated as a point load located at the center of the beam and the blast load of Point 2 will be treated as a uniformly distributed load. A required section modulus is calculated for each longitudinal based on the maximum moment. The required section modulus is then compared to the actual section modulus to check structural adequacy.

NOTE: Stiffener material is VHS; allowable stress = 40 KSI.

(a) Point 1: Stiffener length = 48 in.
Stiffener = 8 x 4 x 13# I/T on 30.6# HY-100
Actual SM = 13.2 in.^{3}

From Table 4:

$$\text{Load} = V = P \times A = 79.8 \times (222.2) = 17732 \text{ lbs.}$$

$$\text{Moment} = M = \frac{Vbc}{L} = \frac{VL}{4} = \frac{17732\ (48)}{4\ (1000)} = 212.78 \text{ in-kips}$$

$$\text{Red'd S.M} = \frac{M}{\sigma} = \frac{212.78}{40} = \underline{5.32} \text{ in}^3 < 13.2 \ \underline{\text{O.K.}}$$

(b) Point 2: Stiffener length = 72 in.
Stiffener = 6 x 4 x 7# T on 20.4# HS
Actual SM = 7.7 in.^{3}

$$\text{Load} = W = (P)(n) = 7.4\ (25.3) = 187.2 \text{ lb/in.}$$

$$\text{Moment} = \frac{WL^2}{8} = \frac{187.2(72)^2}{8\ (1000)} = 121.3 \text{ in-kips}$$

$$\text{Req'd S.M} = \frac{M}{\sigma} = \frac{121.3}{40} = \underline{3.03 \text{ in.}^3} < 7.7 \ \underline{\text{O.K.}}$$

Conclusions: For the point under consideration, the structure -- plating and stiffeners -- is found to be structurally adequate. This example shows clearly the effect of distance from the launcher. Point 1 and Point 2 are 84 in. and 222 in., respectively, from the launcher; thus, Point 2 is about 2.5 times further away from the launcher. This change in distance results in a blast pressure at Point 2 that is only 9 percent of the blast pressure at Point 1.

Gun Blast Design Example.- This example is a calculation to determine if a 76-mm gun could be mounted on a 02 LEVEL deck with the following scantlings:

Deck Plating - 0.375 in.; Al 5456-H116
Deck Longitudinals - 8 x 5.0 T; Al 5456-H111
Spacing - 18"
Length - 96"

For this example a representative point is chosen on the 02 LEVEL with the following location (distances in relation of gun mount centerline):

X = Distance aft of gun CL = 168 in.
Y = Distance to port of gun CL = 168 in.

The solution of this design problem is divided into two phases: 1) identification of blast pressure, and 2) determination of structural adequacy.

Blast Pressure Determination - Refer to para. 100-7-h which outlines the blast determination procedure.

Step 1: The point under consideration (A') is located on the deck plan view drawing, (see Figure 13). The required distances L and L' are measured and are found to be:

L = 396 in.
L' = 237 in.

Step 2: With L = 396 in. as a baseline, Figure 14 is developed. The trunnion height and barrel length of the 76-mm guns are added to Figure 14. Point A' is located on Figure 14 by using the measurement L'.

Step 3: With the location of A' it is then possible to measure the radius vector, r, and the space angle β. Measurements for the gun are contained in a table on Figure 14.

Step 4: The blast and pressure head, in feet of water, is now determined based on "r" and "β", using equation (22). The calculation for the 76-mm is shown in tabular form.

Gun Type	$(1+\cos\beta)$	$(r/d)^{1.5}$	H
76 mm	3.381	43.313	35.12

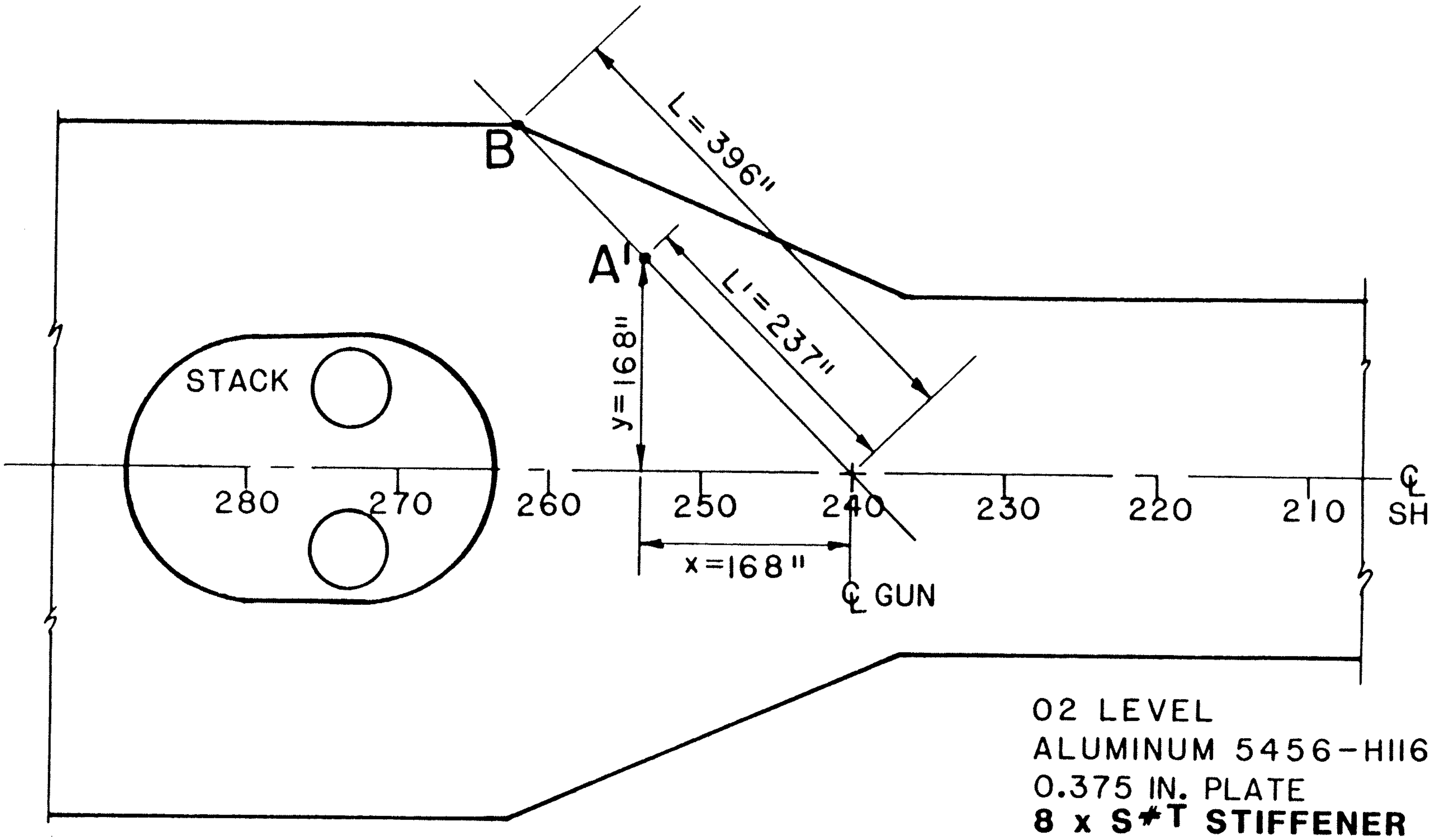
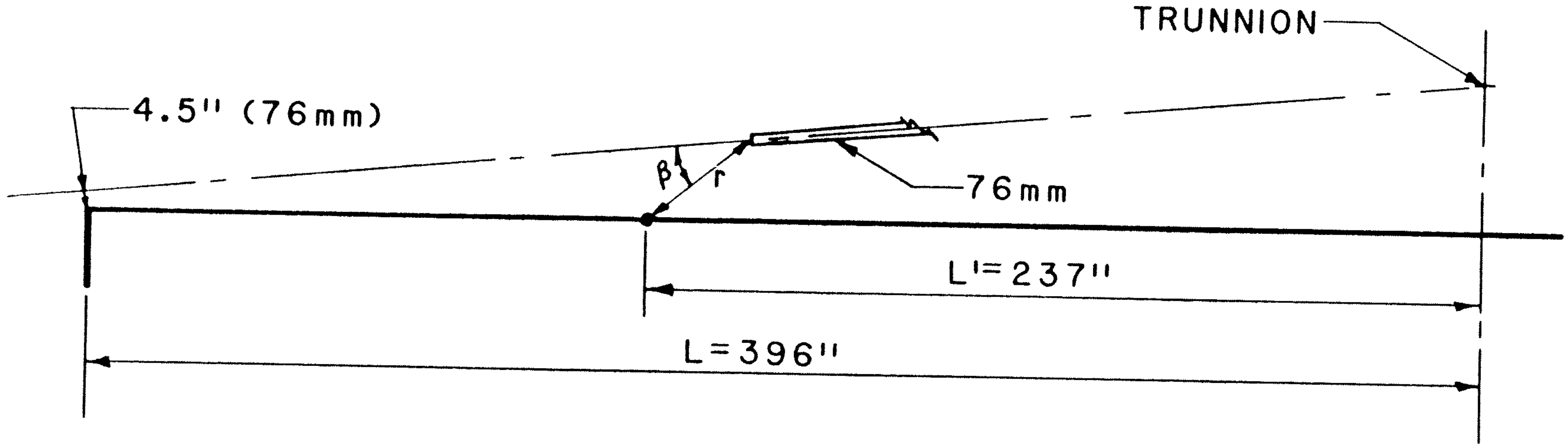


FIGURE 13
GUN BLAST DESIGN EXAMPLE - PLAN VIEW



GUN TYPE	TRUNNION HEIGHT	BARREL LENGTH	r	β
76mm	41.69"	208.11"	37"	33^0

FIGURE 14
GUN BLAST DESIGN EXAMPLE - ELEVATION

Determination of Structural Adequacy

Plating analysis.

(a) Panel Dimensions:

a = 96 in.
b = 18 in.
t = 0.375 in.
b/a = 0.188; K = 1.0

(b) Material: AL5456; C = 300

(c) Plating Analysis:

$$\text{Allowable } b/t = \frac{C}{k\sqrt{H}}$$

Gun Type	Allowable b/t	Actual b/t	Structural Adequacy
76 mm	50.6	48.0	O.K.

Note: For this analysis, required thicknesses could be checked versus the actual thickness of 0.375 in. For the point considered here required plating thicknesses would be:

$$t = \frac{k\sqrt{H}}{C}\, b$$

t = 0.356 in.

Stiffener analysis.- This step requires first the calculation of the maximum bending moment for a pinned-pinned beam and then the calculation of a required section modulus. The required section modulus is finally compared to the actual section modulus of the stiffener to check structural adequacy. The following dimensions are used in the analysis:

Stiffener = 8 x $S^{\#T}$
Stiffener spacing = S = 18 in.
Stiffener length = L = 96 in.
Allowable stress of 5456-H111 = 17.0 KSI

Gun Type	Head	W (LB/IN.)	M (IN.-KIPS)	Required S.M.	Actual S.M.	Structural Adequacy
76mm	35.12	281.0	323.7	19.0 $in.^3$	20.7 $in.^3$	O.K.

Conclusions: For the point under consideration, the structure -- plating and stiffeners -- is found to be structurally adequate. It should be noted, however, that the point selected may not be the most critical along that particular firing line.

APPENDIX 1

MISSILE STATIC EQUIVALENT BLAST PRESSURE

1.1 General

The procedures for missile blast analysis outlined in para 100-7-f of this DDS have been developed to aid in analyzing blast impingement at specific points on a given deck or bulkhead. The purpose of this appendix is to present a brief summary of the method required to develop missile SE blast pressure contours. It should be noted that a computer program developed by the Naval Surface Weapons Center (reference a) is capable of developing these pressure contours.

1.2 Missile Static Equivalent Blast Pressure

The following paragraphs contain the analytical expressions necessary to define the blast impingement areas and pressures for various angles of incidence. The ultimate goal of this procedure is the development of a graphical relationship between blast pressure and distance from missile launcher. As noted previously in para. 100-7-f, the following equation is used to determine the missile blast pressure:

$$P = T\,(\sin\alpha + (0.0225/\sin\alpha))/A \qquad (1\text{-}1)$$

Figures 1-1 to 1-3 illustrate graphically the location of the missile nozzle relative to the deck. In addition, analytical relationships have been developed in conjunction with these figures for the purpose of determining missile blast pressure regions on the deck. Equations (1-2) through (1-4) were derived from Figure 1-1 and are used to determine the angle of incidence, α, as well as the distances between the missile and the deck. However, for this procedure, various angles of incidence will be assumed in order to determine blast pressures parametrically.

$$\sin\alpha = \frac{Y}{b_1} = \frac{h_d + (a - a_1)}{b_1} \qquad (1\text{-}2)$$

$$b_1 = \frac{h_d + (a - a_1)}{\sin\alpha} \qquad (1\text{-}3)$$

$$b_2 = \frac{h_d + (a - a_1)}{\sin\alpha} - c \qquad (1\text{-}4)$$

Where: c = distance from launcher arm pivot point to the nozzle exit plane

$$a_1 = a\cos\alpha \qquad (1\text{-}4a)$$

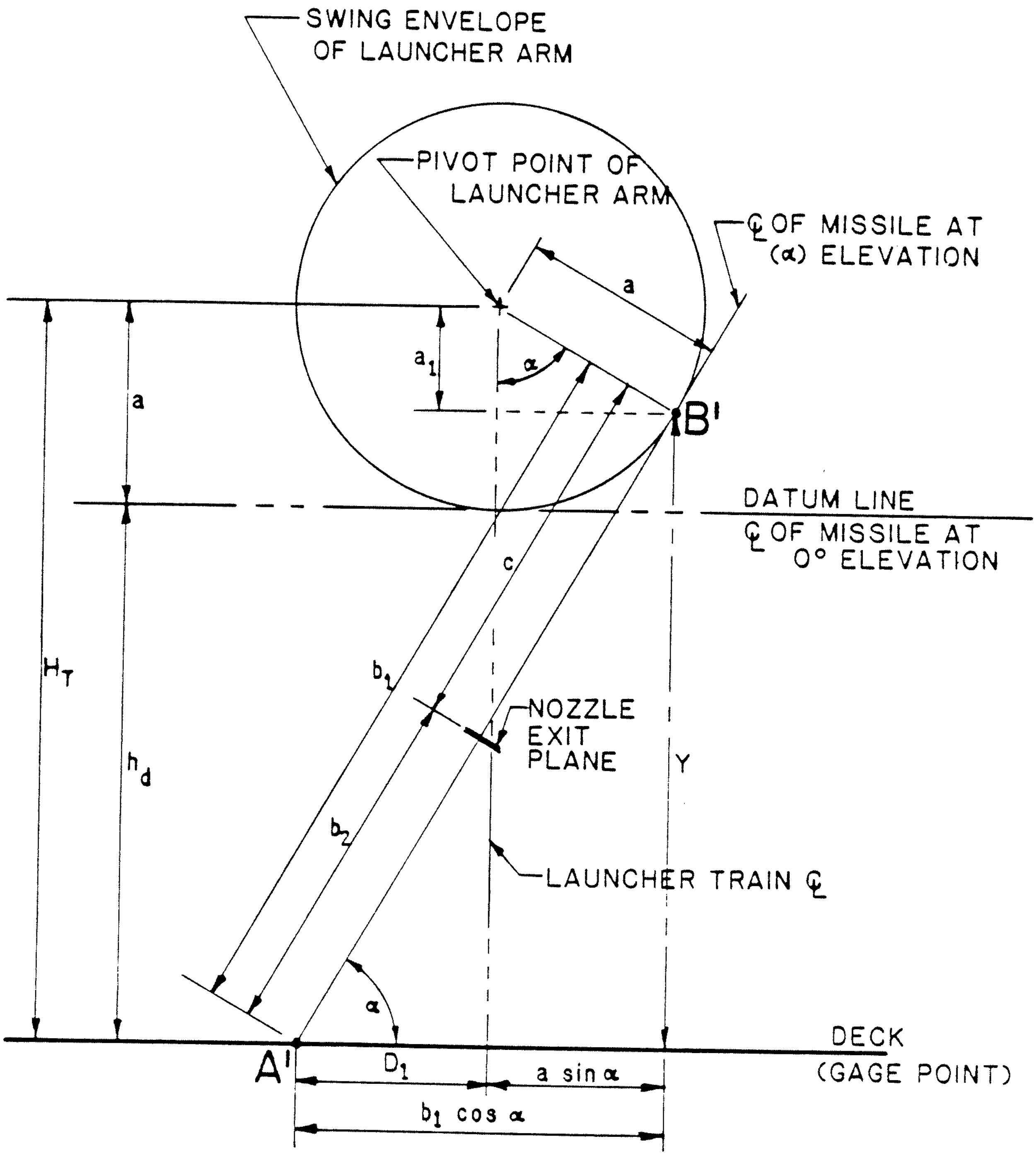


FIGURE 1-1
ELEVATION DIAGRAMMATIC OF LAUNCHER

Based on Figure 1-2, the following relationships were derived for use in determining the blast impingement area. The "b" and "x" terms are used to define the intersection of the blast cone with the deck. The blast cone is generated by rotating about the missile axis a line having a three degree divergence from the axis and passing through the circumference of the exit nozzle. When the centerline of the missile is perpendicular to the deck the area in question is circular. When the centerline of the missile is less than 90 degrees to the deck the area in question is elliptical.

$$\beta = 90° - \alpha \qquad (1-5)$$

$$b_3 = b_2 - r \tan \beta \qquad (1-6)$$

$$b_4 = b_2 + r \tan \beta \qquad (1-7)$$

Where: r = radius of missile nozzle

$$x_1 = \frac{b_3 \sin 3°}{\sin (\alpha + 3°)} \qquad (1-8)$$

$$x_2 = \frac{r}{\sin\alpha} \qquad (1-9)$$

$$x_3 = \frac{b_4 \sin 3°}{\sin (\alpha - 3°)} \qquad (1-10)$$

$$m = x_1 + 2 (x_2) + x_3 \text{ (major axis)} \qquad (1-11)$$

$$n = 2r + 2b_2 \tan 3° \text{ (minor axis)} \qquad (1-12)$$

$$A = 0.7854 \; m \; n \qquad (1-13)$$

Figure 1-3 illustrates the distance from the launcher centerline to the outside extreme of the blast impingement cone on the deck. This distance, D, is obtained from the following relationships:

$$D_1 = b_1 \cos\alpha - a \sin\alpha \qquad (1-14)$$

$$D = x_2 + x_3 + D_1 \qquad (1-15)$$

$$= \frac{r}{\sin\alpha} + \frac{b_4 \sin\alpha}{\sin (\alpha - 3°)} + b_1 \cos\alpha - a \sin\alpha \qquad (1-15a)$$

The calculated area of missile blast impingement, A, and the corresponding angle of incidence are then used with Equation (1-1) to determine the missile static equivalent blast pressure. As noted previously, this procedure is performed for a range of angles of incidence. Table 1-I illustrates a typical calculation if impingement areas for a Mark 26 missile launcher (See Figure 1)

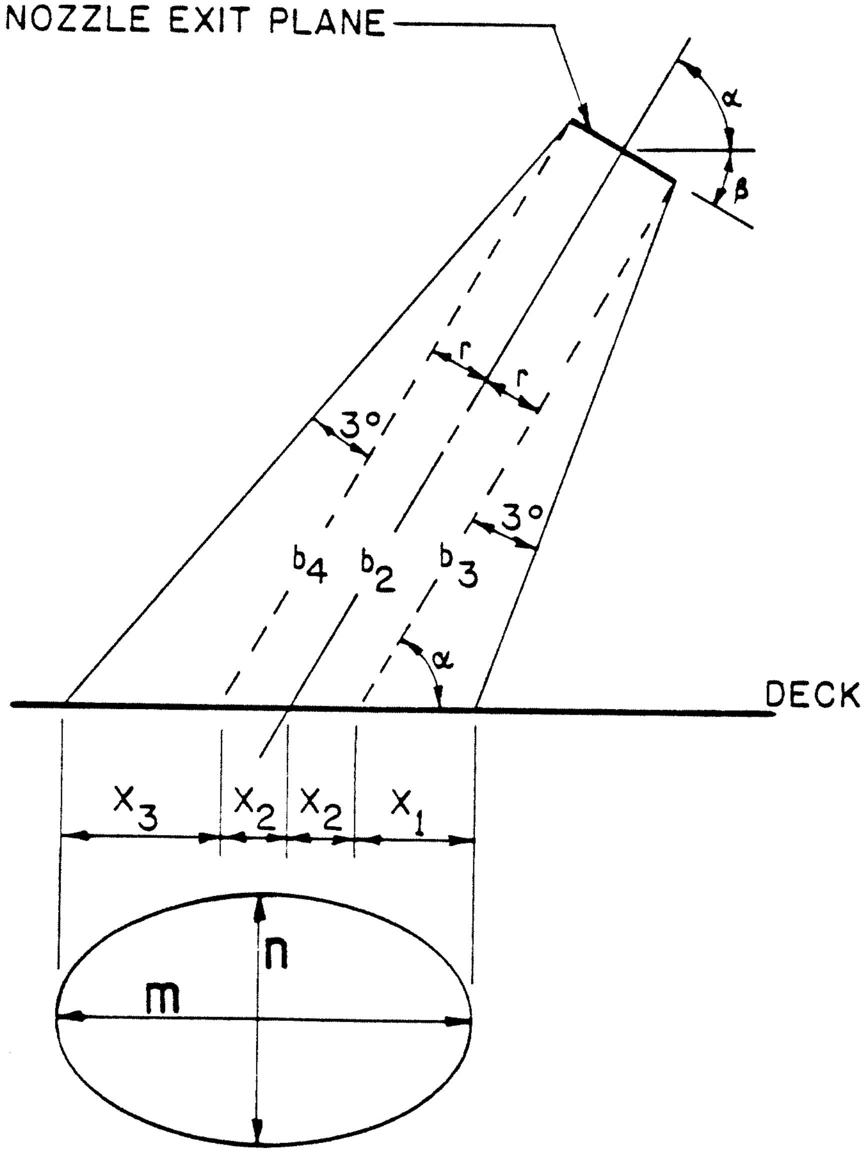


FIGURE 1-2

BLAST CONE IMPINGEMENT ON DECK

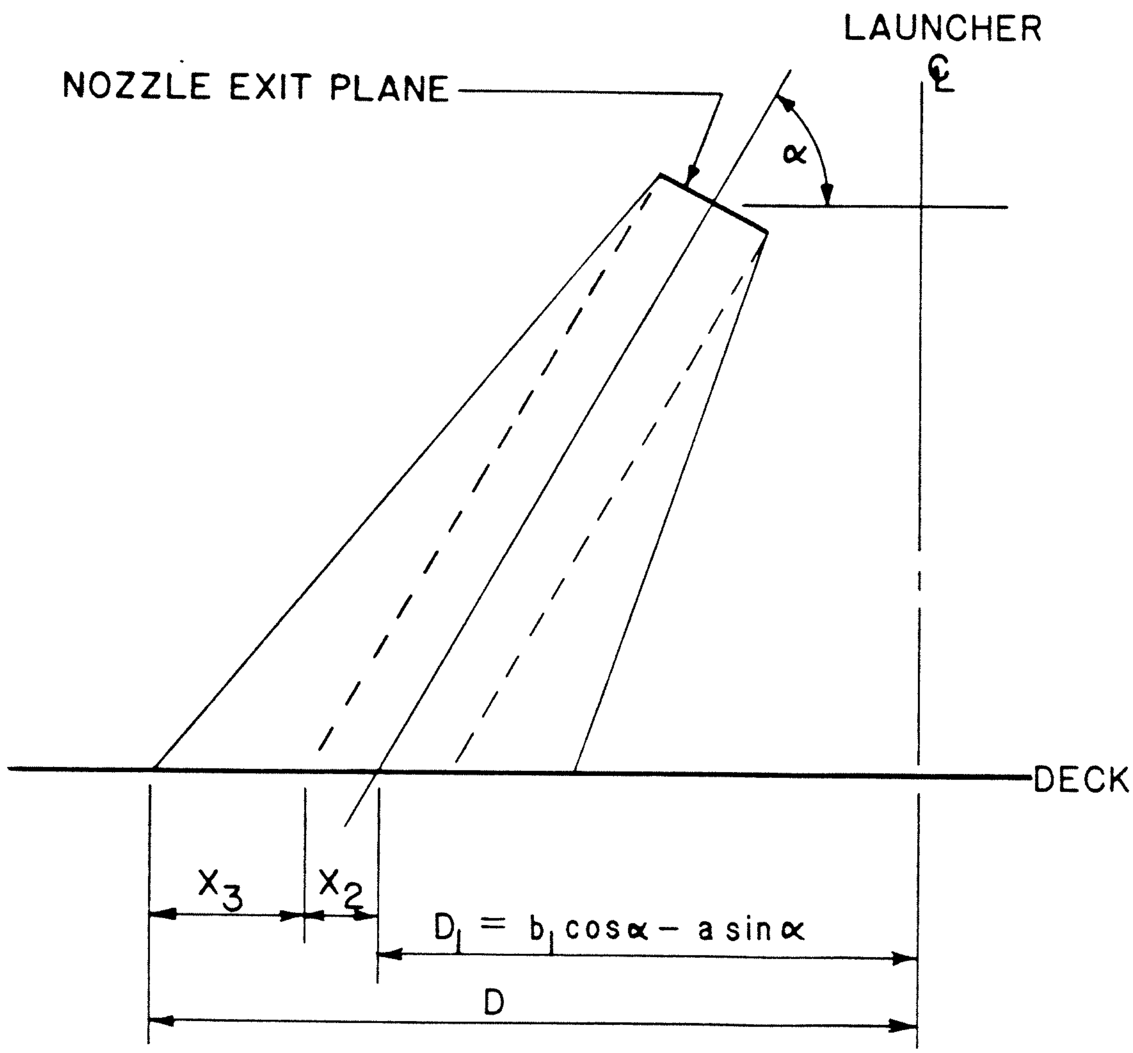


FIGURE 1-3
LOCATION OF BLAST IMPINGEMENT AREA
RELATIVE TO THE LAUNCHER

TABLE 1-I

DETERMINATION OF BLAST IMPINGEMENT AREA

α	β	a_1	b_1	b_2	b_3	b_4	X_1	X_2	X_3	Major Axis	Minor Axis	Impingement Area
0°	90°	25.0"	-	-	-	-	-	-	-	-	-	- -
10°	80°	24.6"	498"	424"	404"	444"	94.0"	20.7"	190.7"	326.1"	51.6"	13,216 in^2
20°	70°	23.5"	256"	182"	172"	192"	23.0"	10.5"	34.4"	78.4"	26.3"	1,619 in^2
30°	60°	21.7"	179"	105"	99"	111"	9.5"	7.2"	12.8"	36.7"	18.2"	525 in^2
40°	50°	19.2"	143"	69"	65"	73"	5.0"	5.6"	6.3"	22.5"	14.4"	255 in^2
50°	40°	16.1"	124"	50"	47"	53"	3.1"	4.7"	3.8"	16.3"	12.4"	159 in^2
60°	30°	12.5"	114"	40"	38"	42"	2.2"	4.2"	2.6"	13.2"	11.4"	118 in^2
70°	20°	8.6"	109"	35"	34"	36"	1.9"	3.8"	2.0"	11.5"	10.9"	98 in^2
80°	10°	4.3"	108"	34"	33"	35"	1.7"	3.7"	1.9"	11.0"	10.8"	93 in^2
90°	0°	0"	111"	36"	36"	36"	1.9"	3.6"	1.9"	11.0"	11.0"	95 in^2

for angles of incidence varying from 10 degrees to 90 degrees (values for 0 degrees approach infinity). Note that the area decreases with increasing angles of incidence. Given these impingement areas and a maximum thrust of 25,000 pounds, values for blast pressure and distance from launcher can be determined as shown below:

α	A(in)	P (lb/in^2)	D
0°	-	-	-
10°	13,216	.57	698" (58')
20°	1,619	6.30	277" (23')
30°	525	25.95	163" (14')
40°	255	66.45	105" (9')
50°	159	125.06	69" (6')
60°	118	188.99	42" (4')
70°	98	245.83	20" (2')
80°	93	270.88	- .27" (0')
90°	95	269.08	-19.5" (-2')

With the above values of P and D the pressure versus distance curve of Figure 1-4 can be developed. This graph illustrates the significant decrease in SE blast pressure as distance from the launcher increases (decreasing angles of incidence). Finally, Figure 1-4 can be used to develop blast pressure contours on the ship's deck plan. Typical blast pressure contours are shown in Figure 1-5. In this figure, various angles of incidence are shown by concentric circles, and the associated SE blast pressure loadings are indicated by shadowed ellipses.

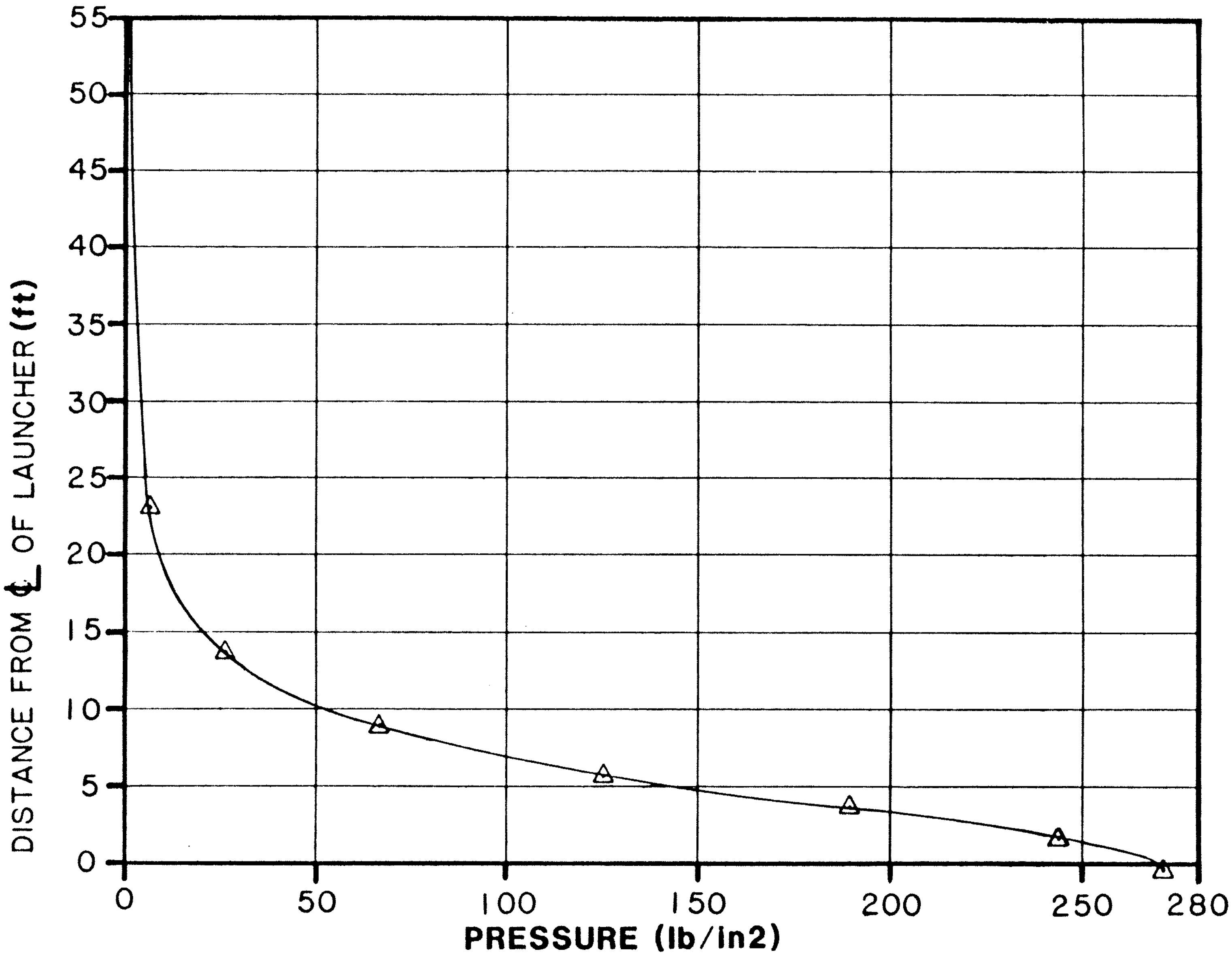


FIGURE 1-4 - GMLS MARK 26 STATIC EQUIVALENT BLAST PRESSURE VS. DISTANCE FROM LAUNCHER

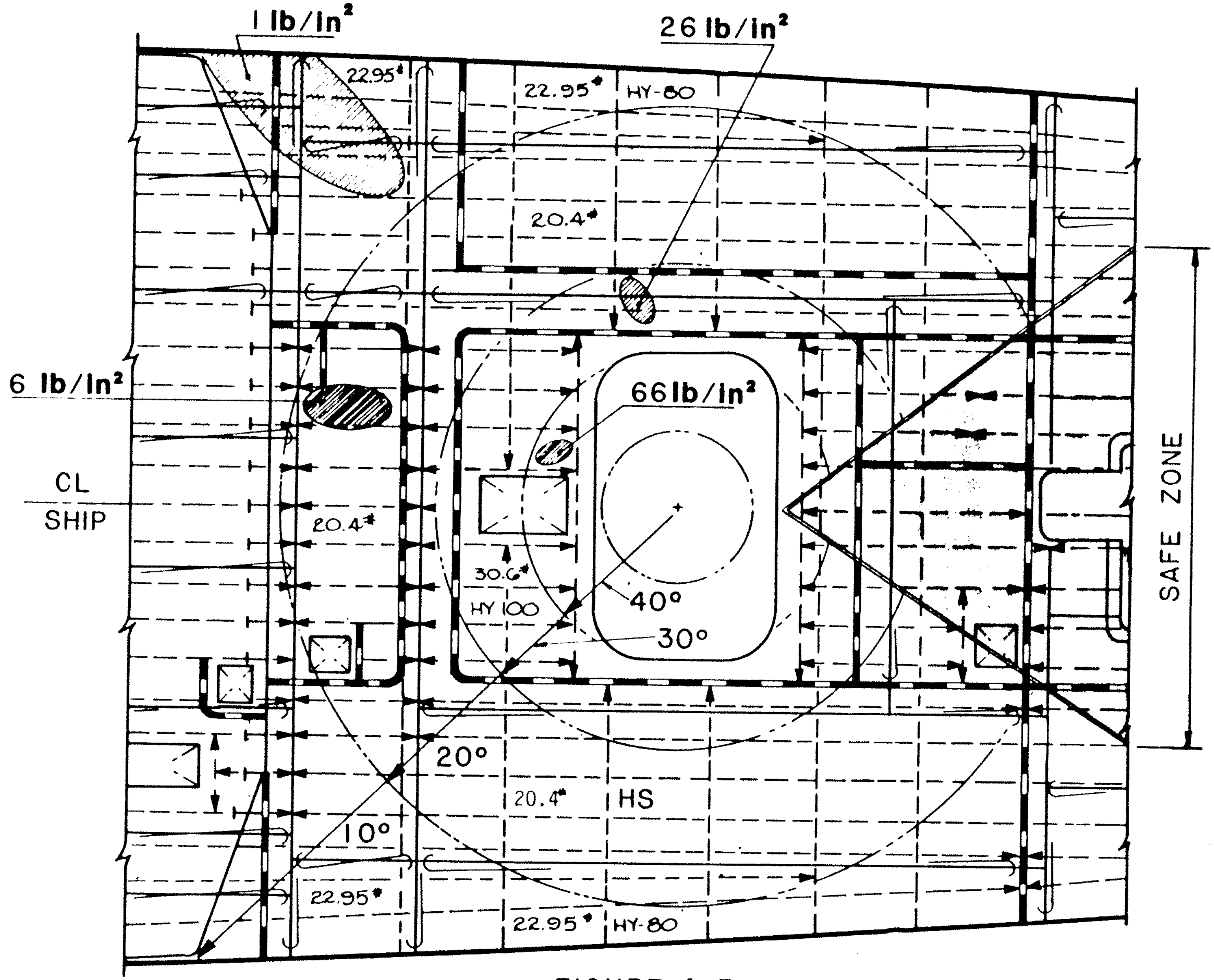


FIGURE **1-5**
TYPICAL MISSILE BLAST PRESSURE LOADINGS

APPENDIX 2

GUN STATIC EQUIVALENT BLAST PRESSURE

2.1 General

The procedures for gun blast analysis outlined in Section 2.3 of this DDS are intended to be used in checking gun blast impact on a localized deck or bulkhead region. The purpose of this appendix is to present a brief summary of the method required to develop gun SE blast pressure contours. It should be noted that a computer program developed by the Naval Surface Weapons Center (reference a) is capable of developing these pressure contours.

2.1 Gun Static Equivalent Blast Pressure

There are primarily three factors that govern the determination of gun SE blast pressure: gun diameter, the radius vector defining the distance from the gun muzzle to the point in question, and the space angle between the axis of the gun barrel and the radius vector. Measured in terms of static equivalent head, in feet, the gun blast pressure is given empirically by the following equation:

$$H = \frac{450\ (1 + \cos\beta)^2}{(r/d)^{1.5}} \qquad (2\text{-}1)$$

In order to develop pressure contours on the ship's deck, it is necessary to first develop, to scale, the blast pressure envelopes for the gun in question. The blast pressure envelopes for a 76-mm gun are shown in Figure 2-1. These envelopes are developed by assuming various values for H and β and solving for the radius vector, r. This calculation requires the reordering of equation 2-1 as shown below:

$$r = d \left(\frac{450\ (1 + \cos\beta)^2}{H} \right)^{0.67} \qquad (2\text{-}1a)$$

Typical values of r for a 76-mm gun at various values of β and H are tabulated below. These values are then plotted, to scale, in order to obtain the blast pressure envelopes of Figure 2-1. Note that the envelopes of Figure 2-1 are actually three dimensional.

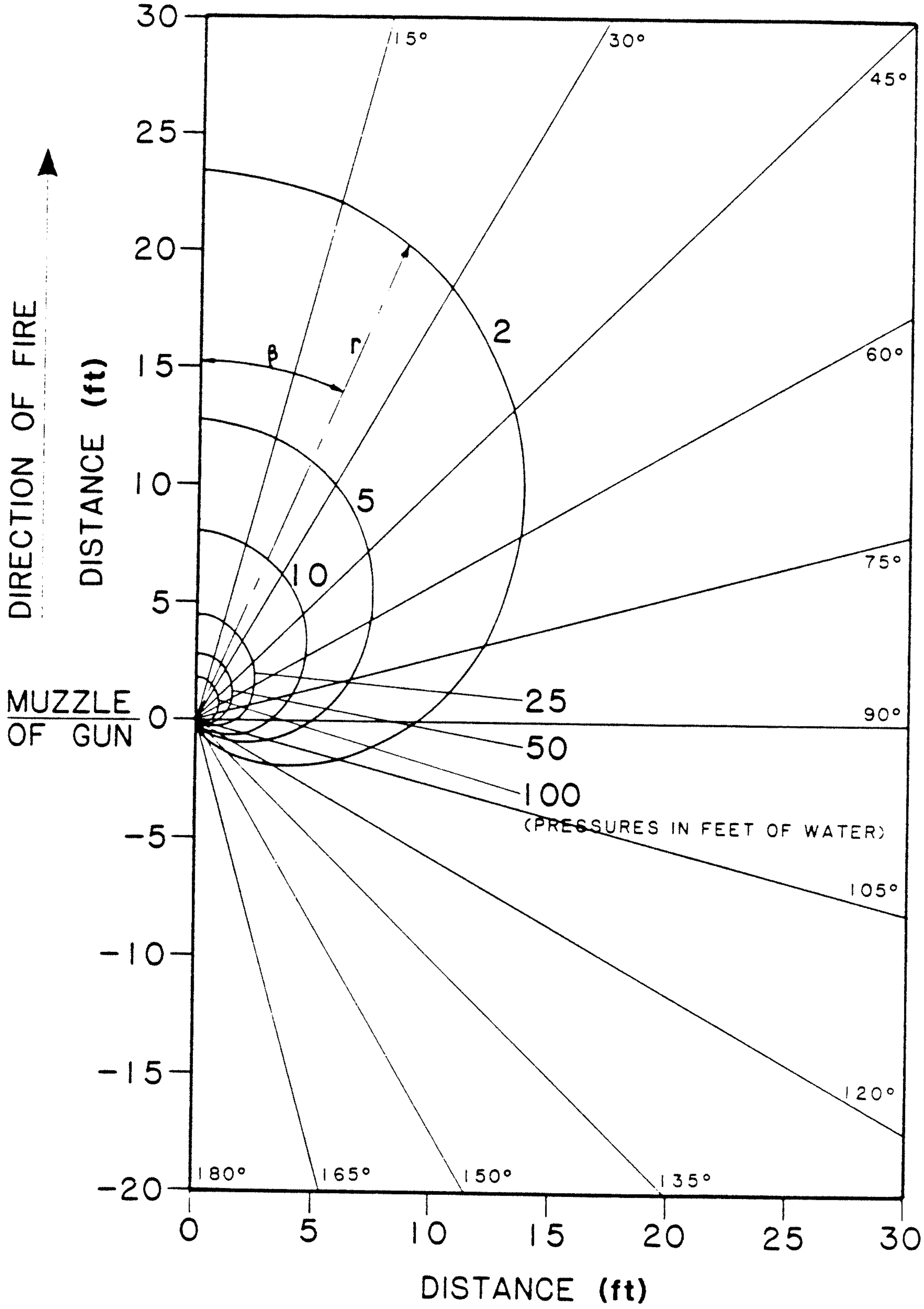


FIGURE **2-1**
GUN STATIC EQUIVALENT
BLAST PRESSURE ENVELOPES

β	2	5	H(ft) 10	25	50	100
0°	280	152	96	52	33	21
15°	274	149	94	51	32	20
30°	256	139	87	47	30	19
45°	227	123	78	42	27	17
60°	191	104	65	35	22	14
75°	151	82	52	28	18	11
90°	111	60	38	21	12	8
105°	75	41	26	14	9	6
120°	44	24	15	8	5	3
135°	22	12	7	4	5	3
150°	8	4	3	1	1	1
165°	1	1	0	0	0	0
180°	0	0	0	0	0	0

A scale drawing must now be made which identifies clearance requirements associated with fixed structures. This clearance is usually taken as a distance equal to 1.5 times the gun diameter. In addition, this drawing should include a number of different train lines from which the gun blast deck contours will be constructed. Note that, in general, the blast contours will be symmetric with respect to the ship centerline; therefore, only one side of the ship need be considered. Figure 2-2 illustrates a typical drawing for gun clearance and train angles.

For each train line shown on Figure 2-2, a section drawing indicating the maximum gun depression must be developed. On this drawing, maximum gun depression is to be equal to 1.5 times the gun diameter clear of the deck edge or in some situations the maximum depression may have a specific angular limitation such as 15 degrees for a 5-inch gun. This drawing is shown schematically in Figure 2-3. As shown in Figure 2-3, the blast envelopes of Figure 2-1 are superimposed over the gun barrel axis. In this manner, intersections of the blast envelopes with the deck are clearly identified. Figure 2-4 shows the blast envelope impingement on deck structure for a 76-mm gun. This step should be repeated for several train angles in order to obtain a suitable set of intersection points. In regions where contour lines are expected to merge, several train angle sections should be made. Intersection points are then transferred to the deck drawing and smooth contour lines are drawn through the points. The result is a SE blast pressure contour drawing similar to Figure 2-5. A similar procedure can be conducted to obtain blast pressure contour lines on bulkheads.

In conclusion, from Figure 2-5, the effect of the depression angle can clearly be seen. In the athwartship direction, the gun is capable of much smaller train angles (that is, the gun is capable of aiming downward much closer to the deck). The result is smaller radius vectors, r, for a given space angle, thus higher blast pressures.

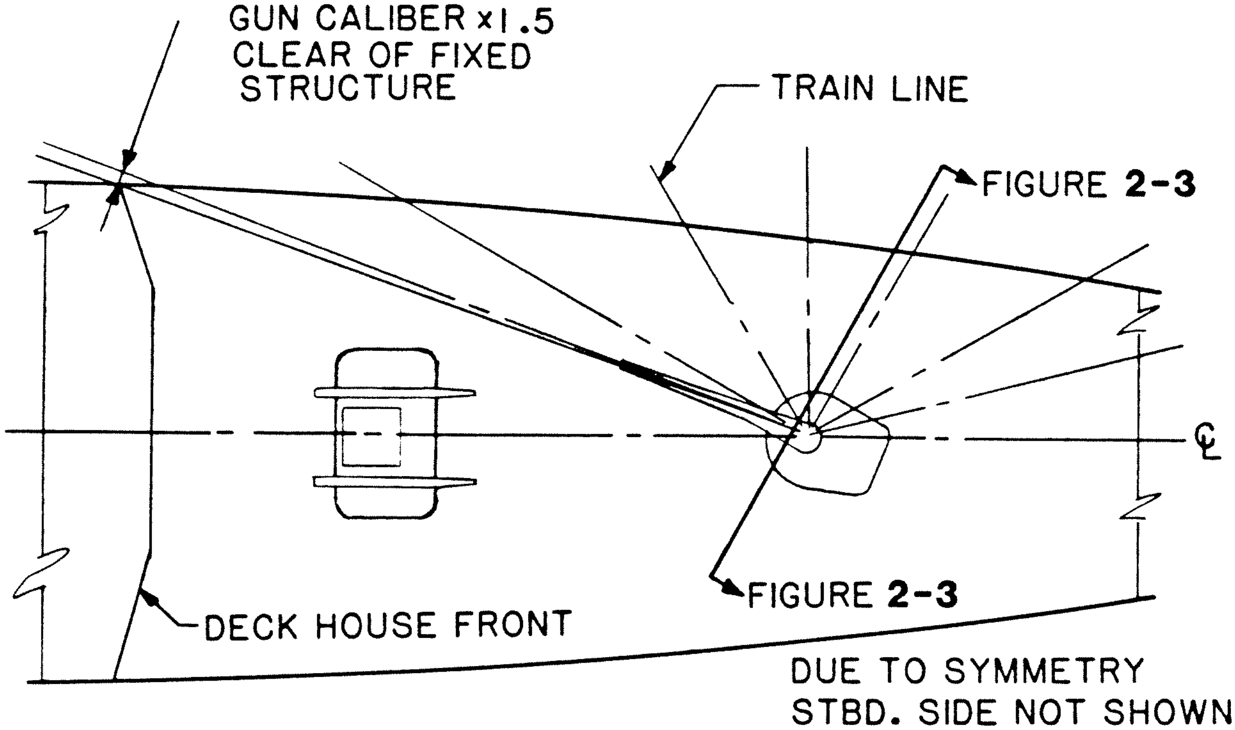


FIGURE 2-2
GUN CLEARANCES AND TRAIN LINES

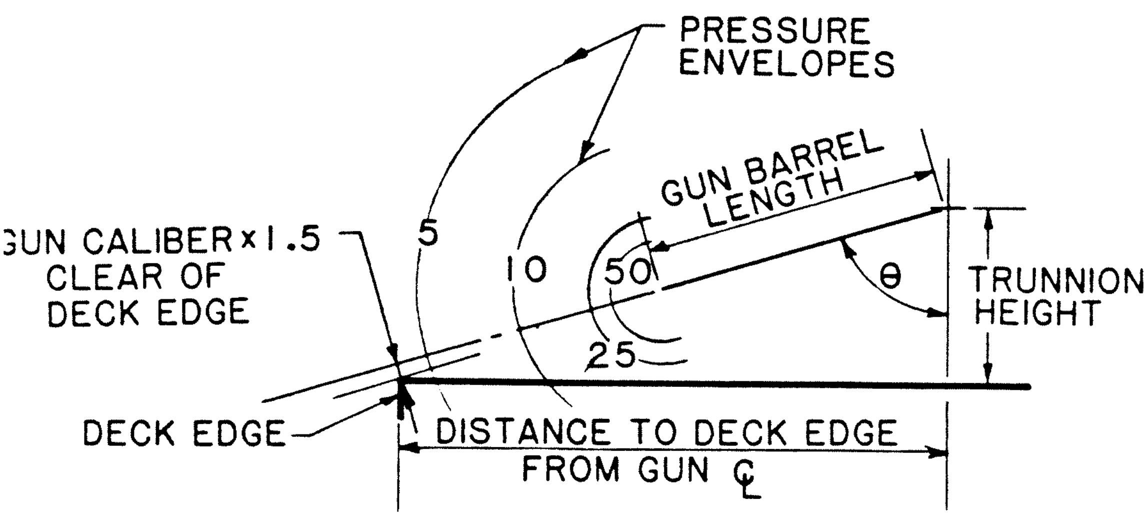


FIGURE 2-3
GUN DEPRESSION

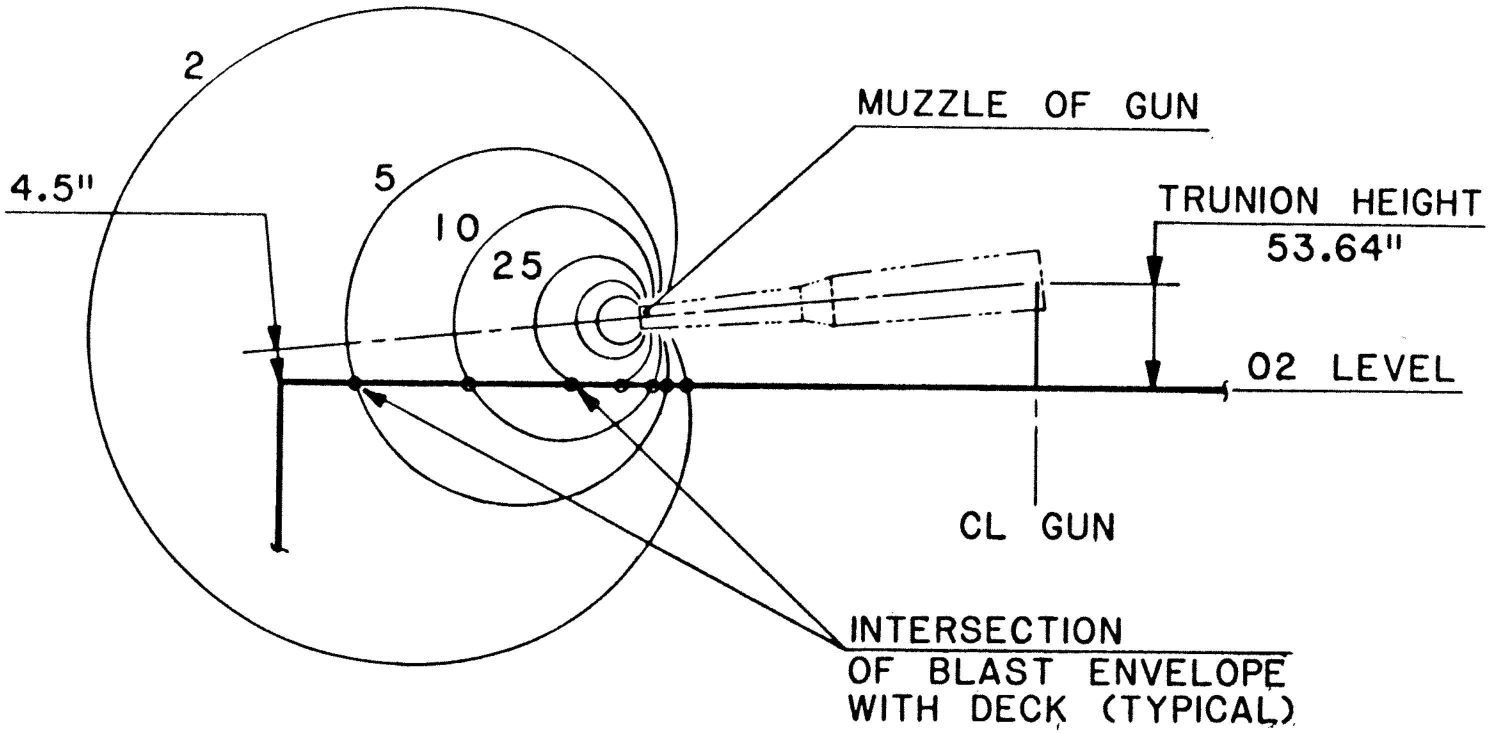


FIGURE 2-4

76 MM GUN STATIC EQUIVALENT BLAST PRESSURE IMPINGEMENT ON DECK

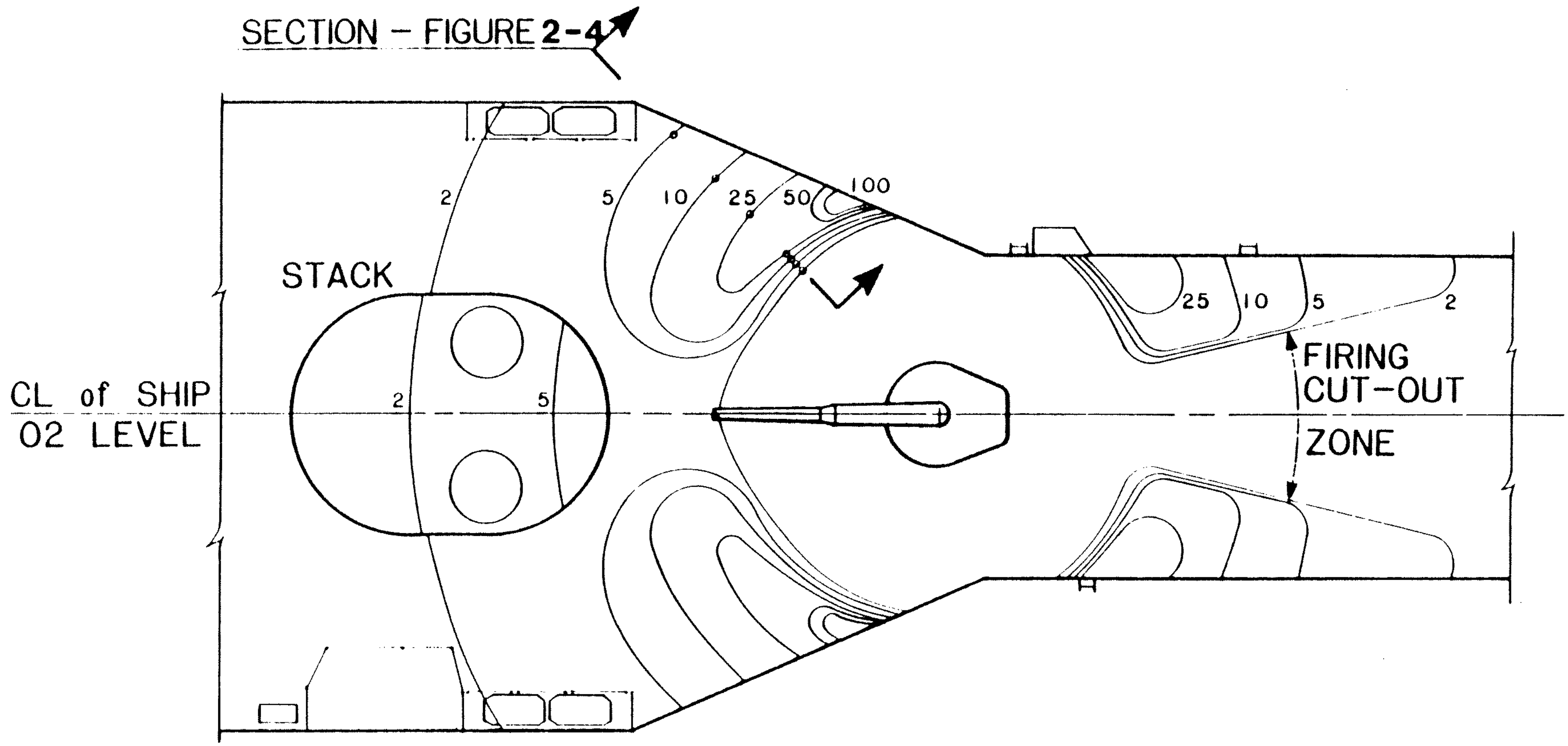


FIGURE 2-5
76 MM GUN STATIC EQUIVALENT BLAST PRESSURE IMPINGEMENT ON DECK

APPENDIX 3

SELECTED MEASUREMENT UNITS AND CONVERSION FACTORS

This design data sheet establishes strength requirements in Inch-Pound. Measurement units recommended for use as well as the pertinent conversion factors are compiled in Table 3-I.

TABLE 3-I: SELECTED SI CONVERSION FACTORS

Category	To Convert From Inch-Pound Units	To SI Units	Multiply By
LENGTH:	foot (ft)	meter (m)	0.3048
	inch (in)	meter (m)	$2.540\ 10^{-2}$
	inch (in)	mm	25.4
AREA:	foot^2 (ft^2)	meter^2 (m^2)	$9.290\ 10^{-2}$
	inch^2 (in^2)	mm^2	$6.452\ 10^{2}$
FORCE:	kip	newton (N)	$4.448\ 10^{3}$
	pound-force (lbf)	newton (N)	4.448
MASS:	pound (lb)	kilogram (kg)	.454
	ton (long, 2240 lb)	metric ton	1.016
	kip/inch^2 (ksi)	pascal (Pa)	$6.895\ 10^{6}$
STRESS(FORCE/AREA)	pound-force/inch^2 (psi)	pascal (Pa)	$6.895\ 10^{3}$

SI makes extensive use of prefixes to form decimal multiples; it officially establishes 16 prefixes. Those 5 prefixes most frequently used are as follows:

mega	M	$1,000,000 = 10^6$
kilo	k	$1,000 = 10^3$
centi	c	$0.01 = 10^{-3}$
milli	m	$0.001 = 10^{-3}$
micro	µ	$0.000.001 = 10^{-6}$