NRL Memorandum Report 1396

INTERIM DESIGN VALUES FOR SHOCK DESIGN OF SHIPBOARD EQUIPMENT

(Unclassified Title)

George J. O'Hara and Robert O. Belsheim

MECHANICS DIVISION

February 1963

U. S. NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT

The design-analysis method of NAVSHIPS 250-423-30 and NRL Report 5545 requires specification of Shock Design Values. This document contains the formulas applicable to these design problems.

PROBLEM STATUS

This report covers one phase of this problem; work is continuing on other phases.

AUTHORIZATION

NRL Problem F02-05

Manuscript submitted February 1963

LIST OF FIGURES

INTERIM DESIGN VALUES FOR SHOCK DESIGN OF SHIPBOARD EQUIPMENT

INTRODUCTION

NAVSHIPS 250-423-30 presented a design-analysis method for the evaluation of shock resistance of shipboard equipment which is essentially linear and elastic, and which does not rest upon noise or vibration mounts that are non-linear, and/or will bottom. In essence this method presented a simplified modal analysis method in which the values to be used in the design check are prescribed by means of design shock spectra which are functions of the modal weight(s) and frequency(s) of the equipment-and-foundation system.

This document contains the shock design values recommended for analysis of submarine and surface ship equipments. In general these are divided into two categories.

1. Elastic Response

The equipment-and-foundation system, because of its importance and/or other characteristics, shall undergo nothing but insignificant local plastic deformation.

2. Elastic-Plastic Response

The equipment-and-foundation system is allowed to have some residual plastic deformations. These will be several times the maximum elastic deflections, and are allowed only on those systems where such deformations are permissible.

The following terminology is used (See Figs. 1 and 2):

a). Equipment-and-foundation systems mounted directly to basic hull structure (frames, structural bulkheads below water line, and shell plating above the water line) shall be termed "hull mounted."

b). Equipment-and-foundation systems mounted directly to decks, non-structural bulkheads, or, to structural bulkheads which are above the water line, shall be termed "deck mounted."

c). The term "shell plating mounted" shall apply only to equipment mounted directly to shell plating below the water line without intervening foundations.

d). The terms athwartship, fore and aft, and vertical shall have their usual directional meanings.

APPLICATION

1). Analysis of equipment-and-foundation multi-degree of freedom systems shall be in accordance with NAVSHIPS 250-423-30 or another approved method. The analysis shall include the equipment foundation.

2). The determination as to shockproof Grade and whether the equipment or the foundation is in the elastic or elastic-plastic category shall be as indicated in ship specifications, in component specifications, or in the contract.

3). Unless otherwise indicated it shall be assumed that all Grade A shockproof items including their foundations are in the elastic category and Grade B items are in the elastic-plastic category. The exceptions are when such yielding can cause a hazard to exist with ships' personnel and/or vital ships' systems, in which cases Grade B items shall be designed to the elastic criteria.

4). All hold down bolts and/or studs shall be designed in accordance with the elastic category. As a result, for elastic-plastic systems the design loading on the bolts will exceed that of the rest of the system by a factor (or factors) equal to the ratio(s) of the Design Values.

5). Hull mounted criteria shall be used in lieu of deck mounted criteria when the analysis is sufficiently complete to account for the intervening ships structure.

6). Items mounted on non-strength bulkheads shall be designed in accordance with hull mounted criteria for loading directions parallel to the mounting surface, but in accord with deck mounted criteria in the direction perpendicular to the mounting surface.

SHOCK DESIGN CRITERIA

The Shock Design Value (D_a) used for response calculations shall be the lesser of the two values in the same units (acceleration) which are computed from the Design Values V_a and A_a. In no event shall D_a be less than 2316 in/sec^2 (6g). D_a is equal to the lesser of $V_a\omega_a$ or $A_a g$, where A_a and V_a are defined in the next section, ω_a (or $2\pi f_a$) is the modal frequency in radians per second, and g is the acceleration of gravity which is 386 in/sec^2.

The Design Shock Spectrum (Fig. 3) is a function of modal weight, location aboard ship, direction of loading and category of response. However, it never need be drawn as equations are provided.

The Shock Design Values specified herein do not reflect the rigid body or flexural response of the ship (as a beam). These motions, while capable of producing displacements in the order of several feet, are of a very low frequency (1-5 cps) and produce correspondingly low accelerations. These "later" motions of the ship are not normally associated with equipment damage, except when the equipment frequencies are of a corresponding magnitude; i.e., less than about 5 cps. For such low-frequency systems, the inputs of this document are not applicable and the appropriate motion-time histories given in the shock section of NAVSHIPS 250-423-29 should be used instead.

BASIC DESIGN QUANTITIES

The two basic Design Value quantities used in this method are presented in velocity units and acceleration units. These basic quantities are given in terms of the modal weight of the equipment-and-foundation system for each type of shipboard location, and are called the reference equations. These are then multiplied by a factor given in an accompanying table to account for shock direction effects and whether the system response is elastic or elastic-plastic.

The modal weight is defined as:

$$W_a = \frac{g\left(\sum_i M_i \bar{X}_{ia}\right)^2}{\sum_i M_i \bar{X}_{ia}^{\,2}} \quad \text{(lbs)} \qquad (1)$$

for systems which have unidirectional displacements only. Some systems might be considered to have spacial displacements. That is, a load in the X direction causes deflections in the X, Y, Z directions, where X, Y, Z are orthogonal and correspond to fore and aft, vertical, or athwartship. For this three-dimensional case the modal weights are:

$$W_a^x = \frac{g\left(\sum_i M_i \bar{X}_{ia}\right)^2}{\sum_i M_i \left[\bar{X}_{ia}^2 + \bar{Y}_{ia}^2 + \bar{Z}_{ia}^2\right]} \qquad (2)$$

in the X direction,

$$W_a^y = \frac{g\left(\sum_i M_i \bar{Y}_{ia}\right)^2}{\sum_i M_i \left[\bar{X}_{ia}^2 + \bar{Y}_{ia}^2 + \bar{Z}_{ia}^2\right]} \qquad (3)$$

[redacted]

in the Y direction, and

$$W_a^z = \frac{g(\sum_i M_i \bar{Z}_{ia})^2}{\sum_i M_i \bar{X}_{ia}^{-2} + \bar{Y}_{ia}^{-2} + \bar{Z}_{ia}^{-2}} \qquad (4)$$

in the Z direction.

For the purposes of this document and the formulas contained herein the modal weight W_a is used in thousands of pounds (Kips); such that

$$\bar{W}_a = \frac{W_a}{1000} \qquad (5)$$

DESIGN VALUE FORMULAS

A. Ship Type: Submarines.

I. Hull Mounted Systems

a). Reference Equations

$$A_o = 10.4 \left[\frac{480+\bar{W}_a}{20+\bar{W}_a}\right] \quad (g) \qquad (6)$$

$$V_o = 20 \left[\frac{480+\bar{W}_a}{100+\bar{W}_a}\right] \quad (in/sec) \qquad (7)$$

[redacted]

b). Design Values

TABLE I

	Elastic		Elastic-Plastic	
	A_a	V_a	A_a	V_a
Vertical	1.0 A_o	1.0 V_o	1.0 A_o	0.5 V_o
Athwartships	1.0 A_o	1.0 V_o	1.0 A_o	0.5 V_o
Fore and Aft	0.4 A_o	0.4 V_o	0.4 A_o	0.2 V_o

II. Deck Mounted Systems

a). Reference Equations

$$A_o = 5.2 \left[\frac{480+\bar{W}_a}{20+\bar{W}_a} \right] \quad (g) \qquad (8)$$

$$V_o = 10 \left[\frac{480+\bar{W}_a}{100+\bar{W}_a} \right] \quad (in/sec) \qquad (9)$$

b). Design Values

TABLE II

	Elastic		Elastic-Plastic	
	A_a	V_a	A_a	V_a
Vertical	1.0 A_o	1.0 V_o	1.0 A_o	0.5 V_o
Athwartships	2.0 A_o	2.0 V_o	2.0 A_o	1.0 V_o
Fore and Aft	0.8 A_o	0.8 V_o	0.8 A_o	0.4 V_o

[redacted]

III. Shell Plating Mounted Systems

a). Reference Equations

$$A_o = 52 \left[\frac{480+\bar{W}_a}{20+\bar{W}_a} \right] \quad (g) \qquad (10)$$

$$V_o = 100 \left[\frac{480+\bar{W}_a}{100+\bar{W}_a} \right] \quad (in/sec) \qquad (11)$$

b). Design Values

TABLE III

	Elastic		Elastic-Plastic
	A_a	V_a	
Normal to Hull	1.00 A_o	1.00 V_o	This is not permitted
Tangential	0.20 A_o	0.20 V_o	for this classification
Fore and Aft	0.08 A_o	0.08 V_o	of equipment.

B. Ship Type - Surface

I. Hull Mounted Systems

a). Reference Equations

$$A_o = 20 \left[\frac{(37.5+\bar{W})(12+\bar{W}_a)}{(6+\bar{W}_a)^2} \right] \quad (g) \quad (12)$$

$$V_o = 60 \left[\frac{(12+\bar{W}_a)}{(6+\bar{W}_a)} \right] \quad (in/sec) \quad (13)$$

[redacted]

[redacted]

b). Design Values

TABLE IV

	Elastic		Elastic-Plastic	
	A_a	V_a	A_a	V_a
Vertical	1.0 A_o	1.0 V_o	1.0 A_o	0.5 V_o
Athwartships	0.4 A_o	0.4 V_o	0.4 A_o	0.2 V_o
Fore and Aft	0.2 A_o	0.2 V_o	0.2 A_o	0.1 V_o

II. Deck Mounted Systems

a). Reference Equations

$$A_o = 10 \left[\frac{(37.5+\bar{W}_a)(12+\bar{W}_a)}{(6+\bar{W}_a)^2} \right] \text{(g)} \qquad (14)$$

$$V_o = 30 \left[\frac{(12+\bar{W}_a)}{(6+\bar{W}_a)} \right] \text{(in/sec)} \qquad (15)$$

b). Design Values

TABLE V

	Elastic		Elastic-Plastic	
	A_a	V_a	A_a	V_a
Vertical	1.0 A_o	1.0 V_o	1.0 A_o	0.5 V_o
Athwartships	0.4 A_o	0.4 V_o	0.4 A_o	0.2 V_o
Fore and Aft	0.4 A_o	0.4 V_o	0.4 A_o	0.2 V_o

[redacted]

[redacted]

III. Shell Plating Mounted Systems

a). Reference Equations:

$$A_o = 40\left[\frac{(37.5+\bar{W}_a)(12+\bar{W}_a)}{(6+\bar{W}_a)^2}\right] \quad (g) \qquad (16)$$

$$V_o = 120\left[\frac{(12+\bar{W}_a)}{(6+\bar{W}_a)}\right] \quad (in/sec) \qquad (17)$$

b). Design Values

TABLE VI

	Elastic		Elastic-Plastic
	A_a	V_a	This is not permitted for this classification of equipment
Normal to Hull	1.0 A_o	1.0 V_o	
Tangential	0.2 A_o	0.2 V_o	
Fore and Aft	0.1 A_o	0.1 V_o	

SHOCK DESIGN VALUE

The following procedure should be used to find the Shock Design Value after the modal analysis of the structure has progressed far enough:

1. Note type of ship, surface or submarine.

2. Select proper reference equations, dependent upon the system, i.e., is it hull, deck, or shell plating mounted.

3. Using the modal weight (kips) computed for the mode under consideration, calculate the proper A_o and V_o from the reference equations.

4. By means of the table which accompanies the reference equations find the appropriate design values A_a, and V_a, for a mode of frequency ω_a,

[redacted]

by performing the indicated multiplication. This accounts for shock direction, and category of design.

5. Multiply A_a by g (386 in/sec^2) and V_a by ω_a (the frequency in radians per second).

6. The Shock Design Value (D_a) is the lesser of these two values. In the event that a value of D_a less than 2316 in/sec^2 (6 g) is determined by this method, the Shock Design Value of 2316 in/sec^2 shall be used.

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APPENDIX A

EXAMPLE OF USE

Consider a piece of previously shock tested equipment which weighs 20,000 lbs. It is deck mounted on a surface ship and a design check of a proposed foundation is to be made for the elastic-plastic category in the athwartship direction. Assume that, the equipment can be considered to be a rigid body, but because of unsymmetrical foundation stiffness and location of the center of gravity that the system rotates as it translates. Then a two degree of freedom system will be used to check the foundations. Figure A1 is the system under consideration and shows its schematic model for shock design purposes.

First the moment of inertia I_g of the equipment was found about the center of gravity. Since only unidirectional motion is being considered the "rigid" equipment was then divided into two equal masses that were located about the center of gravity such that $\sum_i M_i d_i^2 = I_g$, where d_i is the distance to the mass center from the c.g. Assume this is 30 inches. Then if the spring constants for the left and right hand foundations are, $K_1 = 1.3 \times 10^6$ lbs/in and $K_2 = 3.9 \times 10^6$ lbs/in, the normal mode equations become:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \frac{10^{-2}\omega^2}{386}\begin{bmatrix} .336\,539 & .176\,282 \\ .176\,282 & .194\,088 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

This matrix equation has two solutions:

Mode 1

$\omega_1^2 = 84753$ $\qquad \bar{X}_{11} = 1.000\,000$

$\omega_1 = 291.123$ $\qquad \bar{X}_{21} = .674\,506$

$f_1 = 46.3$ cps

[redacted]

[redacted]

Mode 2

$\omega_2^2 = 513\ 393 \qquad \bar{X}_{12} = 1.000\ 000$

$\omega_2 = 716.514 \qquad \bar{X}_{22} = 1.482\ 584$

$f_2 = 114.0$ cps

The procedure outlined previously, along with that in NAVSHIPS 250-423-30 is now followed.

Mode 1 - Analysis Table

$f_1 = 46.3$ cps $\qquad \omega_1 = 291.123$

Mass	M_i	$\bar{X}_{i1}$	$M_i\bar{X}_{i1}$	$M_i\bar{X}_{i1}^2$	$M_i\bar{X}_{i1}\bar{P}_1 D_1$
1	25.906 736	1.000 000	25.906 736	25.906 736	69.054 lbs
2	25.906 736	.674 506	17.474 249	11.786 486	46.577 lbs
			43.380 985	37.693 222	

$$\bar{P}_1 = \frac{43.380\ 985}{37.693\ 222} = 1.150\ 896$$

$$\bar{W}_1 = \frac{386}{1000}(43.380\ 985)(1.150\ 896) = 19.272 \text{ kips}$$

The reference equations 14 and 15 provide

$A_{o1} = 27.798$ g

$V_{o1} = 37.123$ in/sec.

From Table V $\qquad A_1 = 0.4\ A_o = 11.119$ g

$\qquad V_1 = 0.2\ V_o = 7.425$ in/sec

Now $\qquad A_1 g = 4292$ in/sec^2

$\qquad V_1\omega_1 = 2162$ in/sec^2.

The lesser of these two values is $V_1\omega_1$, but this is less than 2316 in/sec^2,

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so

$D_1 = 2316.$

To complete the table note that $D_1\bar{P}_1 = 2665.475$, and proceed with column $M_iX_{i1}P_iD_1$ to find the forces applied to each mass.

Mode 2 - Analysis Table

$f_2 = 114.0$ cps $\omega_2 = 716.514$

Mass	M_i	$\bar{X}_{i2}$	$M_i\bar{X}_{i2}$	$M_i\bar{X}_{i2}^2$	$M_i\bar{X}_{i2}\bar{P}_2\bar{D}_2$
1	25.906 736	1.000 000	25.906 736	25.906 736	-31 794 lbs
2	25.906 736	-1.482 584	-38.408 912	56.944 438	+47 138 lbs
			-12.502 176	82.851 174	

$$\bar{P}_2 = \frac{-12.502\ 176}{82.851\ 174} = -.150\ 899$$

$$\bar{W}_2 = \frac{386}{1000}(-.150\ 899)(-12.502\ 176) = .728 \text{ kips}$$

The reference Equations 14 and 15 provide

$A_{o2} = 107.490$ g

$V_{o2} = 56.754$ in/sec.

Using the factors of Table V produces

$A_2 = .4\ A_o = 42.996$ g

$V_2 = .2\ V_o = 11.351$ in/sec.

Then D_2 is the lesser of:

$A_2 g = 16\ 596$ in/sec^2

$V_2\omega_2 = 8133$ in/sec^2,

[redacted]

[redacted]

which is 8133 in/sec^2. Since this is greater than 2316 in/sec^2 it becomes the Shock Design Value. $D_2\bar{P}_2$ = -1227.262, and the modal analysis table for mode 2 can be completed.

The forces found by this method for each mode are then used to design check the foundations. After the stresses in each mode for each of the foundations are found they are combined by the method of Appendix C.

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APPENDIX B

NUMBER OF MODES TO USE

Using a method such as outlined in Appendix D the vendor and purchaser should meet and arrange the lumped parameter model to be analyzed. The purchaser when approving such a model shall designate those areas which are to be stress and deflection checked and will also comment upon the number of modes to be used in this process.

The following are some guidelines which might prove useful to both parties, but they are not to be considered as rules.

Guidance on Stress Analysis Procedures

Perhaps the most difficult of all problems which face the stress analyst is that he must base his firm decisions upon approximations. This is very true when considering shock. First the analyst must decide upon those features of the equipment-foundation system that he will stress, or deflection, check. With these in mind, he must then decide upon an adequate model to represent the system. After this model is obtained and analyzed so modes can be computed, there is another decision to be made as to the number of modes to use in the design check. Finally the decision has to be made concerning the shockproofness of the system when it is compared with the various performance criteria.

As can be readily seen there are many decisions to be made. It is the purpose here to establish some guidelines to help in this decision-making process. It is emphasized that these are guidelines and not rules. Hard, firm, and fast rules are never an adequate substitute for experience and intelligent engineering judgment in shock analysis problems.

Number of Degrees of Freedom

Usually the number of design features to be checked, along with a few simple guides based on experience with past shock measurements, will govern in choosing the model. In general, any structure with distributed mass has an infinite number of degrees of freedom, but fortunately it has been well established that in most cases of interest only a few modes will contribute significantly to the stresses and deflections. (In a complex structure different modes may be significant for different points, however). Hence, distributed mass systems can be approximated, for these important modes, by lumped parameter systems. It should be remembered also that, for these distributed-mass systems, the lumped parameter approximation will be reasonably precise for only about one-half as many modes as there are degrees of freedom. When the structure itself does not have "uniformly

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distributed" mass but is more "lumped parameter" to start with, the lumped-parameter approximation should be better and more modes than one-half the number of degrees of freedom should be realistic and useful.

Number of Modes to Use

First consider lumped-parameter systems in which the point masses are assumed to move in translation only, and in which there are no non-point "rigid" masses which have both mass and rotary moments of inertia. Now let "n" be the number of masses in the model. The following <u>guide-lines</u> are given as to the number of modes to calculate and use:

<u>n</u>	Number of Modes to be Computed, N
1	1d
2	2d
3	2d
4	2d
5	3d
6	3d
-	-
-	-
-	-
n (even)	n d/2
n (odd)	(n+1) d/2

where d is the number of degrees of freedom per mass point, i.e., 1,2, or 3. This guideline is restricted as follows: The number of modes computed (a) need never exceed 10 for systems whose mass points have unidirectional translation only, i.e., d = 1, (b) need never exceed 20 for systems whose mass points have translation in two directions only, i.e., d = 2 and (c) need never exceed 30 for systems whose mass points have translation in three directions, i.e., d = 3.

For those lumped parameter systems that have non-point "rigid" masses which have both mass and appropriate rotary moments of inertia there is a slightly different guideline. Since the actual structure has this "lumped-parameter" characteristic (otherwise it would be unrealistic to attempt to model it in this fashion) it is clear that the modes calculated, especially when using only a relatively simple model, should be relatively more precise than those of a distributed mass structure that is replaced by a model with the same number of degrees of freedom.

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Therefore some additional modes may be used in the calculations with the same overall accuracy. A reasonable approach is to (a) simulate the rotary moment of inertia effect by two, or more, point masses moving in translation only, and spaced so as to simulate the rotary inertia (like a "dumb-bell"), (b) then count the number of degrees of freedom in translation only and (c) add to this the number of rotary moments of inertia that are being simulated (this latter number should probably never exceed six); then (d) if this sum (c) is divided by two this yields a probable number of modes to be used. For example: Consider a large "rigid" mass with considerable amounts of rotary inertia about three axis and let an applied force (or torque) cause the mass to deflect with three translations and three rotations. Applying (a) yields a point-mass model with six masses and with six translatory degrees of freedom. Parts (b), (c) and (d) of the above guideline would say, "Calculate (6 + 3)/2 = 4.5 $\approx \underline{5}$ modes."

As a second example, consider an actual structure with two "rigid" masses constrained to move in unidirectional translation but permitting rotation of each mass about one axis. Then the guideline would say "Calculate (4 + 2)/2 = 3 modes."

In using any guideline the stress analyst must realize it does not cover all possible cases, so judgment must be used.

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APPENDIX C

CALCULATION OF STRESSES

The following formula shall be used when calculating the stress or deflection at a point i;

$$\left|R_i\right| = \left|R^1_{ia}\right| + \sqrt{\sum_{j=2}^{N} \left(R^j_{ib}\right)^2} \qquad \text{(B-1)}$$

where:

$\left|R^1_{ia}\right|$ is the absolute value of the largest modal stress or deflection at point i, and R^j_{ib} are the other stress or deflection contributions. This formula is never to be used to combine modal forces on a mass(es) where these resultant forces are then to be used to calculate stresses or deflections.

Example: Suppose the following stresses were calculated for a point on a structure

TABLE CI

Mode No.	Stress at i(ksi)
1	12.2
2	-25.6
3	5.1
4	3.7
5	- 9.3

Then R^1_{ia} = 25.6, and the formula is

$$R_i = 25.6 + \sqrt{12.2^2 + 5.1^2 + 3.7^2 + 9.3^2}$$

$$R_i = 42.2 \text{ ksi.}$$

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APPENDIX D

Usual Working Procedure for Information Exchange
between Purchaser and Contractor

The technical relationships between the specifying Agency and the Contractor(s) are often misunderstood or not adequately defined. When specified, shock resistant design is a performance criteria in the truest sense. Unlike many of the other performance criteria, however, it often cannot be judged by a go or no-go test because of the physical size of the items involved. The true acceptance test would occur if the warship were attacked; then, of course, the equipment had better pass the test. In the absence of this or a reasonable substitute, acceptance or rejection of a unit as meeting shock design requirements must be based on predicted performance under such conditions. It is not enough with the present state of the art to merely specify the environment and allowable deflections or stresses for materials. The intervening stages (contrary to much present day practice) must be jointly reviewed, and decisions rendered, to ensure that the final product is acceptable from all standpoints, without necessitating expensive "re-investigations" or delays in delivery.

Obviously this requires certain information from both parties, and a clear agreement as to what constitutes an acceptable analysis for the particular equipment-and-foundation design under consideration. Of primary concern is the development of an acceptable mathematical model, that is, one which is designed to investigate the more critical areas of the "system" and yet is amendable to analysis using techniques and facilities available to industry in general. The nature of the planned assumptions, the selection of materials for the equipment, and for the foundation, the common knowledge of acceptable shock design practices, the extent of the proposed calculations, the number of "run throughs," etc., should be discussed and mutually agreed upon to the maximum extent practicable before formal design analysis is initiated.

Because a clear understanding of contractor-purchaser relationships and responsibilities are important, the following working procedure has been developed, and unless modified by the contract or purchase order, shall be followed and shall serve as the basis for the development of detailed agreements.

I. Pre-Bid Information - When an item of equipment and its accompanying foundation is to be let out to contract the following information shall be supplied concerning shock proof design:

a. The shock specification or requirement which is to apply.

b. The computer codings and or computational assistance which is available to the contractor.

c. The location aboard ship is to be mentioned.

d. The Grade (A or B) of the system shall be stated.

e. The category of response to be designed for shall be stated, e.g., is it to be elastic or elastic-plastic design?

f. The type of mounting (Hull, Deck, or Shell Plating) shall be specified.

g. If an equipment is to be capable of being placed in several locations aboard ship, the information shall be supplied as to which location (or locations) it shall be designed for. This will in general be the most severe condition.

h. It is to be implicitly and explicitly understood that the foundation is an integral part of the equipment-and-foundation system and must also be shock designed.

II. Pre-Contract Award - A conference of interested bidders shall be convened to permit the purchasing agency to present the intent of the shock requirement and to outline the extent and nature of the analysis that is anticipated as being necessary. The following items will be discussed.

a. The points of interest for stress and deflection checking shall be broadly outlined. This need not be in complete detail but should be comprehensive enough to leave no doubt in any one's mind of the scope of the problem involved.

b. Since design is always an iterative procedure (whether for shock or not) the number of formal "run-throughs" shall be decided upon. Unless otherwise specified this shall be at least three, one of which may be crude and preliminary to get the design started. The results of the second go around shall be detailed and sufficiently complete so that corrective measures may be applied, and the third analysis shall be the basis of judging the design. If additional formal run throughs are desirable and/or necessary, the cost shall be a matter of negotiation.

c. The kind and availability of computational routines and services shall be described for the potential bidders. These include normal-mode determinations and related special services.

d. When other parties are involved (such as the shipbuilder), their involvement and responsibilities shall be stated. It is desirable that the shipbuilder attend this conference, if he is to construct the foundation (this may not always be possible, however).

e. The types of progress and engineering reports to be sent by the contractor to the purchasing agency shall be discussed.

f. To avoid future misunderstanding, confusion, etc., the prospective bidders should use this opportunity to clarify any points they may have concerning methods, criteria, or procedures.

III. Bid Submission

a. The submitted bids shall include as much information as possible concerning the proposed method of shock analysis. This should include a statement concerning facilities and personnel available for this effort, and any other such information as may be deemed desirable which indicates a capability in the field of dynamic shock analysis.

b. If possible, a proposed or hypothetical mathematical model of the equipment shall be included to illustrate general approach and scope of the analysis.

IV. Post Contract Award

As soon as practicable following contract award the contractor shall submit to the purchaser the following information.

a. The proposed mathematical models to be analyzed shall be approximately defined. Statements justifying the proposed modeling should be included. These statements should make clear how the models will permit check of stress and deflection at critical locations.

b. Liaison procedures between the contractor(s) (including shipbuilder) and the purchasing agency shall be outlined in detail. It is especially important that the party responsible for this liaison be clearly identified.

c. The form and proposed content of the progress and engineering reports shall be outlined, along with an estimated time schedule.

It must be clearly understood that the purchasing agency is responsible for the determination of the acceptance of the equipment on a shock proof basis, following submission of the engineering reports.

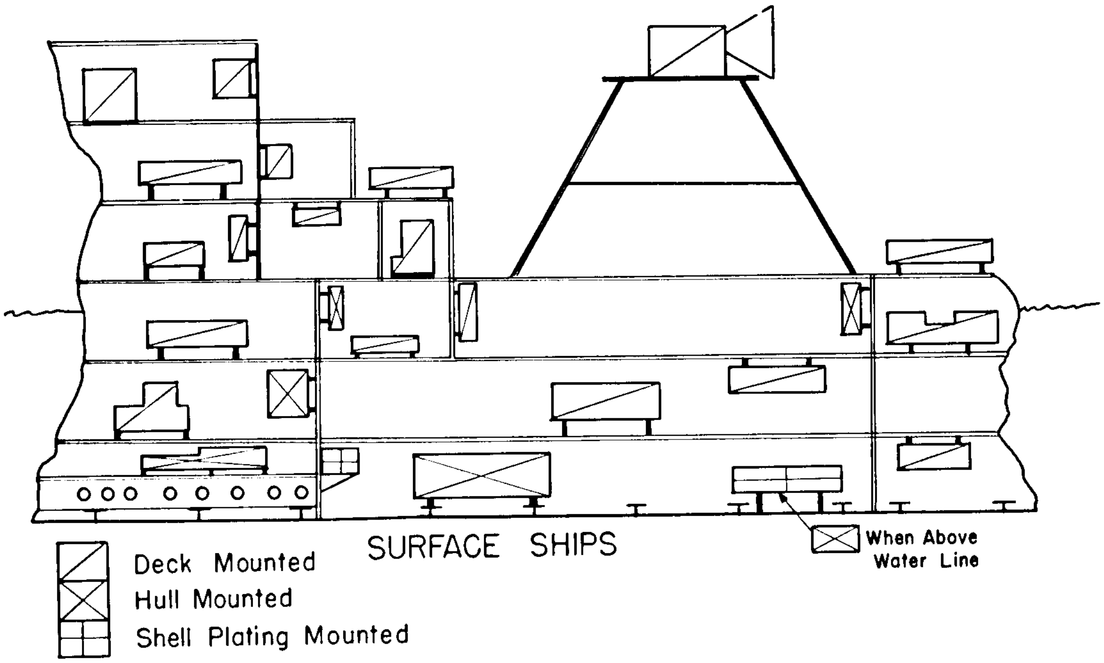

Figure 1 - Surface Ship Equipment-and-Foundation Classification

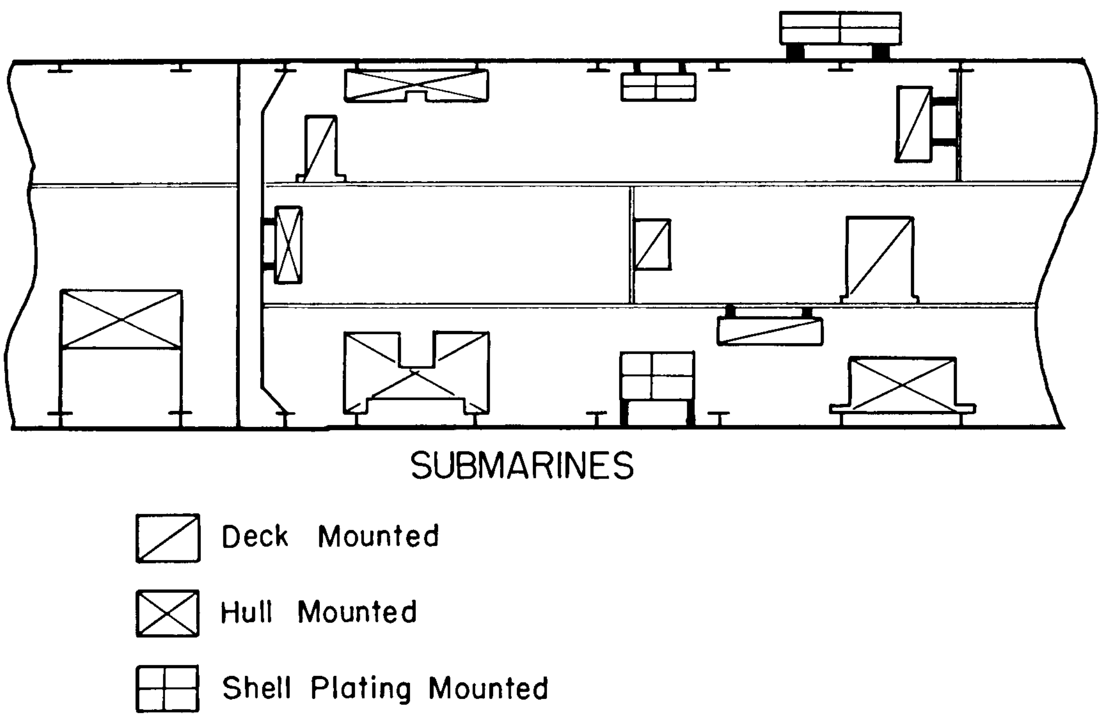

Figure 2 - Submarine Equipment-and-Foundation Classification

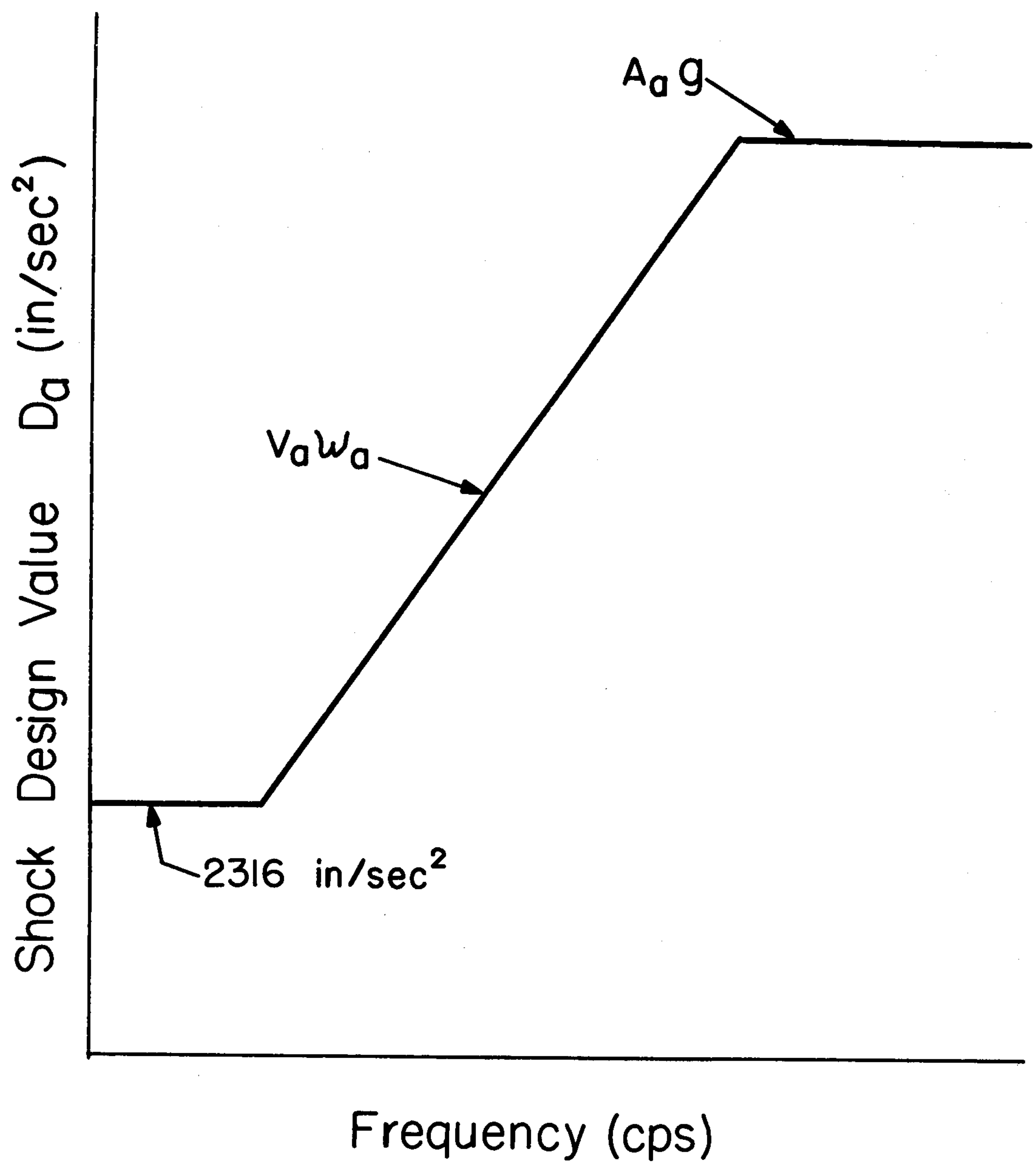

Figure 3 - A Design Shock Spectrum

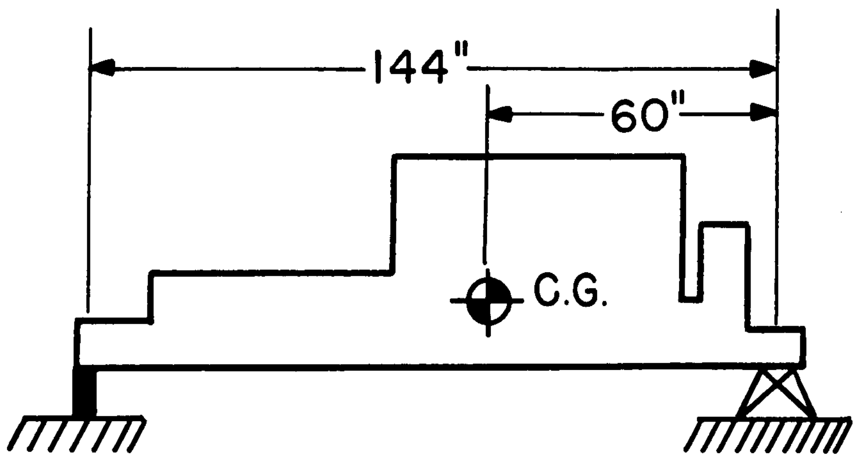

Figure A-1a - Rigid Equipment on Foundation

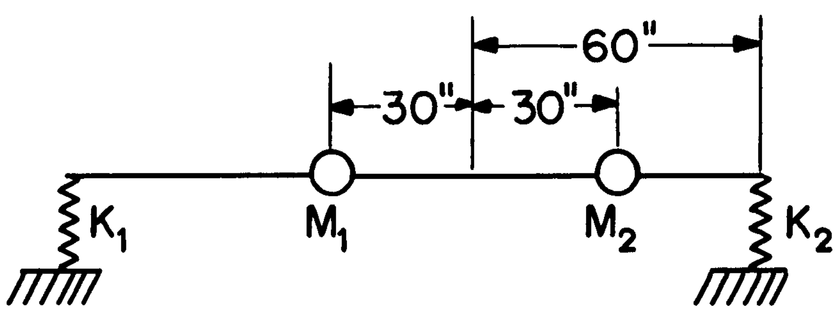

Figure A-1b - Schematic of System

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