SPECIFICATION

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SPECIFICATION FOR DESIGN AND TEST CRITERIA FOR SHOCK RESISTANT EQUIPMENT IN NAVAL SHIPS

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DEPARTMENT OF NATIONAL DEFENCE

SPECIFICATION

FOR

DESIGN AND TEST CRITERIA

FOR

SHOCK RESISTANT EQUIPMENT IN NAVAL SHIPS

Date Approved .... __________________________________ Cmdre

Director General Maritime Engineering and Maintenance

List of Amendments

Amdt. No.	Date	Description	Amended By

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INTRODUCTION

Shock Design Considerations

Shock requirements for the Canadian Forces (Sea Element) are directly related to a ship's intended ability to fight and survive. Fortunately most equipment designed to take advantage of today's materials, is already inherently highly resistant to shock. Because of the vital necessity for this property in ship's equipment, this specification requires a physical determination of shock resistance. For the quidance of manufacturers the required physical criteria to carry out a simple stress analysis are included. This may be used either to check or improve shock resistance.

It is most important to understand that the requirement to withstand shock is not unduly difficult to meet. Shock loads result from an acceleration acting on the mass of a unit or part, and since in good design the working stress in a part is high in relation to its mass, even very high shock accelerations may not impose stresses equal to the normal working stress. Even if a part is required to withstand an acceleration of 120 "g's" this force of 120 times its weight may not cause great additional stress. This is an important point since there is a popular misconception that the imposition of 120 "g's" means that there must be a factor of safety of 120.

The first step in the design will be to calculate the dimensions using appropriate design working stresses. Then using this design, three additional calculations are made on appropriate parts of the unit, i.e. when the unit is subjected separately to the indicated UPWARD, DOWNWARD and ATHWARTSHIPS accelerations.* The stress obtained in each case is added to the design working stress and it is only necessary that the combined stress in each case be less than the yield strength of the material. The shock stresses for upward, downward and athwartships accelerations do not have to be withstood simultaneously and calculations may be made by considering them separately.

In many cases the shock condition will be met without any alteration, in others it may be necessary to dispose material differently, but it is clear that since the shock load is simply a mass-acceleration effect it is not the massive design which wins and the use of light sections will often solve the more difficult problems.

* NOTE: Some equipment (particularly electronic) may be mounted in any direction, and in these cases will be designed and tested to withstand maximum shock in any direction. The end product specification will define the three mutually normal planes for test purposes.

General Principles

a. Materials having less than 10% elongation shall not be used unless unavoidable or the stresses can be proven to be acceptable by experiment.

b. All parts should be as light as possible.

c. Stress concentrations should be avoided by eliminating sharp corners, sudden changes in section, unsuitable welding design, etc.

d. Fixed portions should be rigidly secured, and moving parts designed so that undesirable movements will not occur.

e. Moving parts shall be mass balanced when possible.

f. Knife edge supports should be avoided wherever possible.

g. Items which might become misaligned should be mounted on a common bed plate, preferably not of cast material.

h. Clearance between fixed and moving (or elastic) parts shall be sufficient to prevent damage due to displacement under shock.

j. Unit assemblies should be used wherever possible to avoid associated parts being independently mounted on the ship's structure, so that shock is reduced by being transmitted via the greater mass of an assembly.

k. Overhung and cantilevered components should be avoided, when possible.

m. Thermal, electrical and acoustic insulation should be well fitted and supported.

n. Switchgear, relays, and other electrical contacts, should be so designed that they cannot change their open or closed position under shock. In some applications, momentary opening or closing might be permissible.

Equipment carried in ships is subjected to an abnormal shock environment when the ship suffers shell-fire, bombing or an underwater explosion. The ship is rather like a girder, partly damped by flotation forces which are unevenly distributed throughout its length. Underwater shock has a greater intensity at the ship's bottom than at intermediate decks. The heavier the equipment the more the shock effect is reduced, as considerable weight increases the ship's shock impedance at the point of mounting, for example, where the equipment weight is several times the weight of the ship's hull structure below the projected area of the equipment. Figures 1 to 6 take account of this reduction. The intensity of shock is also greater for items, such as pumps, which have a rigid connection with the ship's structure than for those which are mounted on resilient supports.

It would be desirable to have all equipment in the ship capable of withstanding shock up to the level at which the ship's hull would be fractured. However, for reasons of economy and practical limits to design, the shock resistance value is determined on the basis of how important it is that the equipment should continue to function satisfactorily after shock. Equipment is therefore divided into three grades. Grade 1 equipment is that which must be able to operate after sustaining shock up to the maximum specified level. Grade 2 equipment is all other equipment, the loss of which, accompanied by the application of reasonable expedients, will not prevent the operation of the ship. Grade 3 equipment is ancillary equipment whose failure does not affect the combat operation of the ship.

The reaction of equipment to shock is extremely complex and a number of design methods have been originated. The Shock Spectrum Method is preferred, and will produce the optimum design; it may, however, be uneconomic in the case of limited quantity production runs. The Base Acceleration Method is simpler and may in many cases be the best method, although the resulting design may be somewhat heavier, and there is less certainty (but nevertheless a good chance) of passing the shock test that is the criterion of acceptance.

The minimum required Design Acceleration for any equipment is dependent upon:

a. the type of the ship;

b. the grade and weight of the equipment;

c. the position of the equipment in the ship; and

d. the mounting, as specified by the "Military Design Authority".

Whatever grade the equipment is, no significant part of the equipment shall become detached nor shall the tensile strength of the holding down bolts be exceeded under the actual shock. The yield strength of the holding down bolts shall be designed to conform to the applicable grade of the equipment, but the tensile strength of the bolts shall always exceed the stress from the maximum actual shock receivable at the point of mounting. (Maximum as the result of shock tests or as given in this specification.)

SECTION 1

General

1.01 Scope

This specification states the requirements of the Department of National Defence (Canadian Forces Headquarters), hereinafter referred to as the Department, for the criteria of shockproof designing and testing of equipment for Naval Ships.

Machinery and equipment for installation in naval ships are required to withstand various degrees of shock, caused by non-contact underwater explosions, without suffering operational failure, in order that the ship's intended ability to fight and survive under action conditions will not be impaired.

1.02 Priority of Documents

In the event of any inconcistency in contract documents, specifications, drawings, or patterns, the following order of significance shall prevail:

a. contract;

b. end product specification;

c. drawings;

d. patterns or sealed samples; and

e. this specification taken in the order of:

(1) Shock test,

(2) Shock design calculations,

(3) Contents, and

(4) Applicable Specifications.

NOTE: This is a basic specification which may be cited in end product specifications. The latter may modify the requirements of this specification.

1.03 Applicable Specifications, Standards and Drawings

The following specifications, standards, drawings and other documents form part of this specification.

a. Specifications

D-03-003-006/SF-000		Machinery Vibration Criteria
D-03-003-021/SF-001		The Design/Installation of Noise, Shock, and Vibration Reduction in Ships
	Part 1	Theory and Practise of Noise, Shock, and Vibration Isolation - Hull
	Part 2	Theory and Practise of Noise, Shock and Vibration Isolation - Machinery and Equipment
	Part 3	Accoustic Hardware
	Part 4	Acoustic Treatment of Spaces
	Part 5	Component Selection Schedule - Acoustic Hardware Standards and Specifications

b. Standards

ASTM A194-69	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
ASTM A325-70	High Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers
ASTM A354-66	Quenched and Tempered Alloy Steel Bolts and Studs with Suitable Nuts

c. Drawings

* Curator's Manufacturing Drawings for Mountings

Buships 10-T-2145-L(13)

Buships 807-655947(5)

d. Other Documents

DND 677	Instructions to Contractors on the Design Change Procedure

* These items will be supplied on loan to contractors only on proof of requirement.

e. Equipment shock qualified according to the American MIL-S-901C Specification or NAVSEA 0908-LP-000-3010, the equivalent NATO specifications or the British specification BR 3021 can be considered as having passed the requirements of this specification.

1.04 Inspection

Inspection shall be carried out by the Authority designated in the Contract or Order.

1.05 Design Change or Deviation

The procedure required by DND 677 shall be followed in applying for any change or deviation from this specification, except insofar as this specification may have been altered for a particular contract (see Article 1.02).

1.06 Warning - Patent Infringement

Attention is drawn to the possibility of patent-infringement if gauges or testing machines fabricated from information contained in this specification are used for any purpose not definitely related to a Canadian Government contract. The Government of Canada assumes no responsibility for such use.

SECTION 2

Requirements to Comply with this Specification

2.01 General

All equipment ordered to this specification shall pass the shock machine test and remain operable to the equipment specification. This is the criterion of acceptance.

2.02 Allocation of Equipment to Shock Test Machines

Equipment up to 114 kg (250 lb) shall be tested on an approved light weight Shock Machine; equipment 114 kg to 2720 kg (250 to 6000 lb) shall be tested on an approved Medium Weight Machine; and equipment 2720 kg to 13600 kg (6000 lb to 30,000 lb) shall be tested on a Floating Shock Platform.

2.03 Methods of Calculating Shock Resistance

1. This specification sets out the method of calculating the minimum strengths required which should enable the equipment to pass the test. The Shock Spectrum Method is preferred and will produce the most economic equipment, however the Base Acceleration Method is simpler to calculate though there is less certainty of passing the test (which is the criterion). Normally the choice of design method will be up to the manufacturer, but in rare cases the Department may require the Shock Spectrum Method to be used.

2. Whether the Shock Spectrum Method, or the Base Acceleration Method of design is used, calculations shall conform to the requirements of Section 4 of this specification.

2.04 Use of Mountings

In the few cases where it can be shown that built-in shock resistance is impossible or really uneconomic, yielding or resilient mountings may be prescribed with the Department's prior approval. Yielding mountings often do not return to original shape and may require replacement after one shock, which may not be convenient or may be prohibited by the ship specification. Resilient mountings require flexible connections and some special design in the foundations, and shall be designed to suit the equipment. This is fairly expensive if noise reduction is not a prime object also. The yielding mountings are designed to crush at a "g" level a little below the rating of the equipment so that alignment can be retained up to that shock level. Resilient mounts generally reduce shock levels from ½ to 1/10 the maximum depending on the design. Mounts shall only be selected from D-03-003-021/SF-001 Part 5. Resilient mounts are not normally to be used for shock, and will usually be fitted only where the Vibration Specification D-03-003-006/SF-000 requires the noise reduction qualities. Yielding mounts shall only be used where it is uneconomic to build in any more shock resistance.

Equipment designed for installation on resilient or yielding mountings may be tested to the requirements of this specification using the mountings. However, if the equipment utilizing such mountings passes the shock tests the equipment without mountings will not be considered to be in compliance with this specification. Manufacturers desiring shock proof qualification for a product shall submit the equipment for test with direct mounting (hard mounted).

2.05 Subsequent Modifications

1. In the event of failure or damage to the equipment under shock test, the manufacturer shall repair and modify the equipment as necessary to pass the test without added cost to the Department.

2. If modifications are made to the design of any equipment after shock testing, for any reason, during the production run, then a retest may be required by the Department. Insignificant changes may be accepted at the discretion of the Department.

2.06 Waiving of Shock Test

At the sole discretion of the Department shock testing of any equipment or component may be waived if an approved test record is supplied showing that an identical unit has satisfactorily passed a test equivalent to this specification.

2.07 Disposition of Equipment That Has Been Subjected to Shock Test

The equipment shall be sufficiently dismantled to allow the Inspection Authority to adequately examine any constituent part. Any equipment which exhibits any crack, or has deformed out of specification or drawings tolerances shall be rejected by the Inspection Authority. Ball or roller bearings in an equipment which has been shock tested shall be replaced by new ones after test. Equipment which has been satisfactorily shock tested, labelled as such under Article 8.04 (2) and reconditioned by the manufacturer to specification, shall normally be accepted for service.

SECTION 3

Shock Grading of Equipment

3.01 Assignment of Shock Grade

Every equipment for use in ships will be assigned a shock grade which will determine the testing required by this specification.

a. Grade 1 items are machinery, equipment and systems essential for the safety and continued combat capability of the ship. Design shall be suitable to withstand Grade 1 shock loadings without significant effect on performance and without any portion of the equipment coming adrift or otherwise creating a hazard to personnel or the ship.

b. Grade 2 items are machinery, equipment and systems necessary for all the ship's operational requirements not essential for the safety or continued combat capability of the ship. Design shall be suitable to withstand Grade 2 shock loadings without significant effect on performance and without the equipment or any external portion of the equipment coming adrift or otherwise creating a hazard to personnel or grade 1 systems. Its securing arrangements and supports shall be calculated to withstand Grade 1 shock without exceeding ultimate stress.

c. Grade 3 items are ancillary commercial and "housekeeping" equipment which have no effect on the combat operation of the ship and do not seriously affect the habitability of the ship. Grade 1 shock shall be a factor in the design of supports and securing arrangements. Failure to operate even at Grade 2 levels is allowed but it shall not become a missile under shock conditions. No test is required.

NOTE: (1) The word "Grade" in Canadian Forces and Royal Navy shock designations is different from the United States Navy use of the word "Grade".

(2) Any ancillary system required to support the capabilities of Grade 1 equipment or systems shall be given the same shock grade if the ancillary system is necessary for the effectiveness of the main system.

(3) Any item that is specified to be mounted in a compartment or deck wholly above the waterline may be designed to the accelerations given in Figures 2, 3, 5 and 6. These items will be graded 1A, 1B, 2A or 2B and defined in paragraph 4.4. of Section 4. Equipment tested in this special category shall not be granted a grade 1 or 2 certificate unless it is put through the maximum grade 1 or 2 test. Armaments shall be a full grade 2.

TABLE 1

Typical Examples of Grade 1 Equipment

- Propulsion and manoeuverability equipment and systems.
- Sonar.
- Communication equipment.
- Radars.
- Navigation equipment.
- Electronic warfare equipment.
- Weapons control.
- Weapons stowage, reloading and firing or launching mechanisms.
- Interior communication systems necessary to support the capabilities of Grade 1 equipment.
- Emergency and damage control systems.
- Aircraft arming, refuelling and controlling.
- Visual reconnaissance.
- Replenishment at sea.

SECTION 4

Design Requirements

General Requirements

The necessary conditions to be fulfilled if the equipment is to be considered as capable of withstanding successfully the shock motion represented by a given standard shock are the following:

a. the calculated maximum stresses induced by the shock in the various points of equipment shall not exceed the permissible stresses dealt with in Appendix C;

b. the relative movements of adjacent parts of the equipment shall not be such as to endanger the equipment function (e.g. contacts between rotating and stationary components of rotating machinery); and

c. there are not other shock effects which cause malfunction of the equipment e.g. a transient motion of a component which causes an unacceptable interruption of vital supplies.

4.01 Evaluation of the Maximum Stresses

The stress analysis shall consider three mutually independent shocks acting along the three principal directions, vertical, transverse and longitudinal respectively. This analysis shall combine the working stress and the stress due to shock accelerations.

4.01.1 When the analysis method is such as to yield the actual response of the oscillating system, either completely as a time history (as in the case of dynamic analyses in the time domain) or more simply in the form of response maxima (as in the case of simplified analyses such as the "quasi-static" methods, the "g" method, etc.), then the calculated stresses must not exceed the permissible stresses given in Appendix C. Stresses are to be compared on the basis of a currently accepted yield criterion, such as Tresca's, Hencky-von Mises, maximum principal stress criterion, etc.

4.01.2 When the analysis chosen is a modal one, i.e. one in which the stresses are obtained through superposition of the individual contribution of the various modes, the following formula for the stress shall be used to account for the phase relationship between modes:

$$\sigma_i = \sigma_{max_{ib}} + \sqrt{\sum_{b=1}^{n} \sigma_{ib}^2 - \sigma_{max_{ib}}^2}$$

where the index i refers to the i^{th} mass of the oscillating system the index b to the b^{th} mode. $\sigma_{max_{ib}}$ is the maximum stress at mass i among those relating to the various modes.

4.01.3 The contractor should complete such stress analysis, modifying the design of the equipment as necessary, before submitting equipment for shock testing.

4.01.4 The minimum design accelerations which should be used in shock stress analysis of equipment for use by the Department are related to the overall weight of an equipment, for any grade of equipment. Figures 1 to 6 shall be used in the Base Acceleration Design Method. For the Shock Spectrum Design Method see appendix C.

4.02 Base Design Values

All equipment or any external parts of the equipment shall remain captive and shall not become a hazard to personnel or vital systems under grade 1 shock conditions.

4.03 Holding Down Bolt Design Values

When the contract or the equipment specification citing this specification calls for supply of holding down bolts, they shall be designed and supplied in accordance with Section 5. When such supply is not required, it may be assumed that the holding down bolts to be used in actual installation will have the characteristics of those in Section 5.

4.04 Base Acceleration Curves

The base acceleration curves in Figures 1 to 6 are related to equipment and position in the ship as follows:

Figure 1 Design accelerations for Grade 1 equipment located on the ship's bottom or on decks below the waterline. It shall pass a Grade 1 test.

Figure 2 Design accelerations for Grade 1 equipment specified to be mounted on bulkheads, decks above the waterline and ship's side positions above the waterline. It shall pass a Grade IA test.

Figure 3 Design accelerations for Grade 1 equipment specified to be mounted on upper deck and superstructure. It shall pass a Grade 2A test.

Figure 4 Design accelerations for Grade 2 equipment located on the ship's bottom or on decks below the waterline. It shall pass a Grade 2 test.

Figure 5 Design accelerations for Grade 2 equipment specified to be mounted on bulkheads, decks above the waterline and ship's side positions above the waterline. It shall pass a Grade 2A test.

Figure 6 Design accelerations for Grade 2 equipment specified to be mounted on upper deck and superstructure. It shall pass a Grade 2B test, which is a modified 2A test, see paragraphs 6.04 e. and 6105 e.

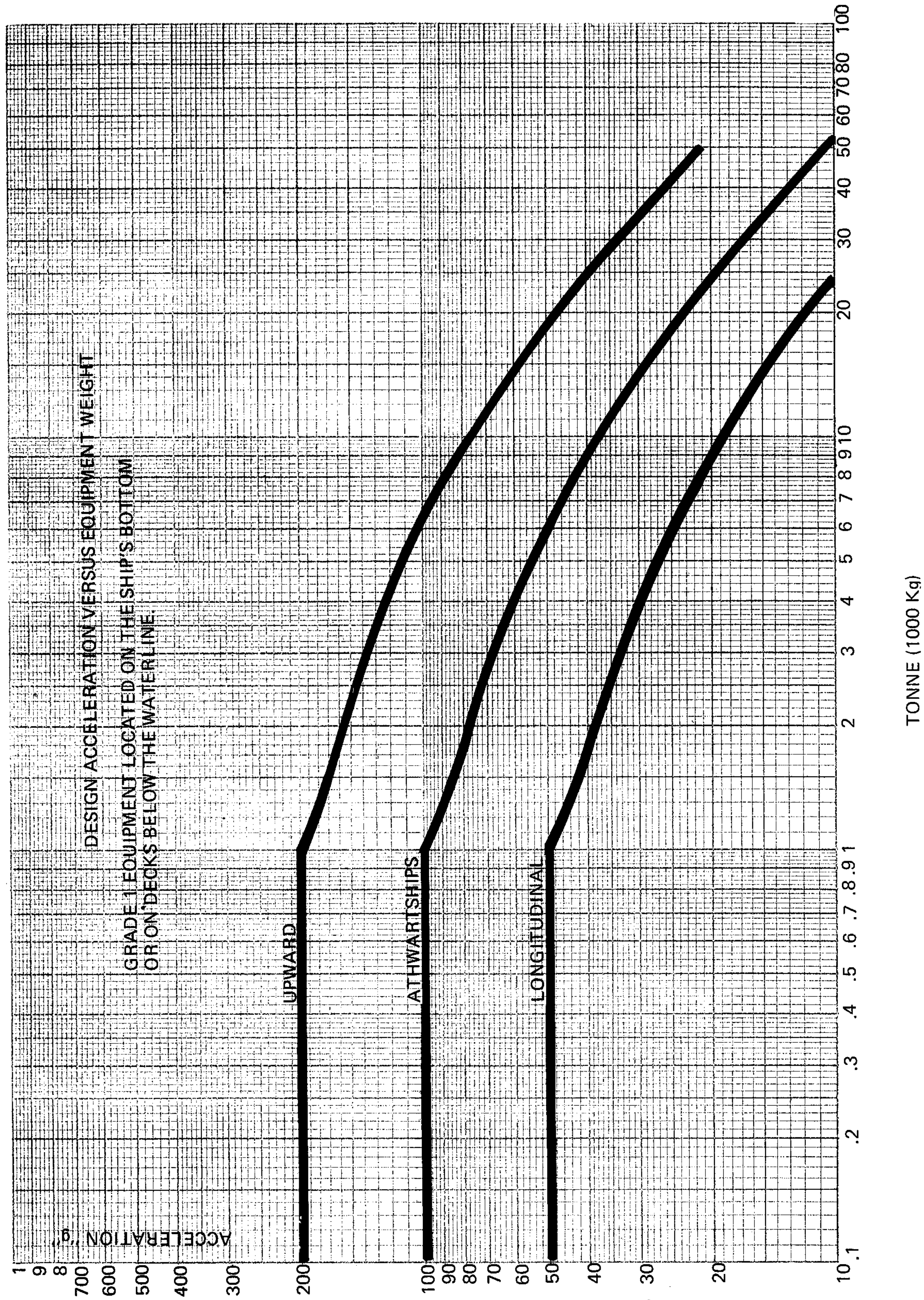

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT
GRADE 1 EQUIPMENT LOCATED ON THE SHIP'S BOTTOM
OR ON DECKS BELOW THE WATERLINE.
UPWARD
ATHWARTSHIPS
LONGITUDINAL
ACCELERATION "g"
TONNE (1000 Kg)
.1 .2 .3 .4 .5 .6 .7 .8 .9 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 100
10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 700 8 9 1

Figure 1

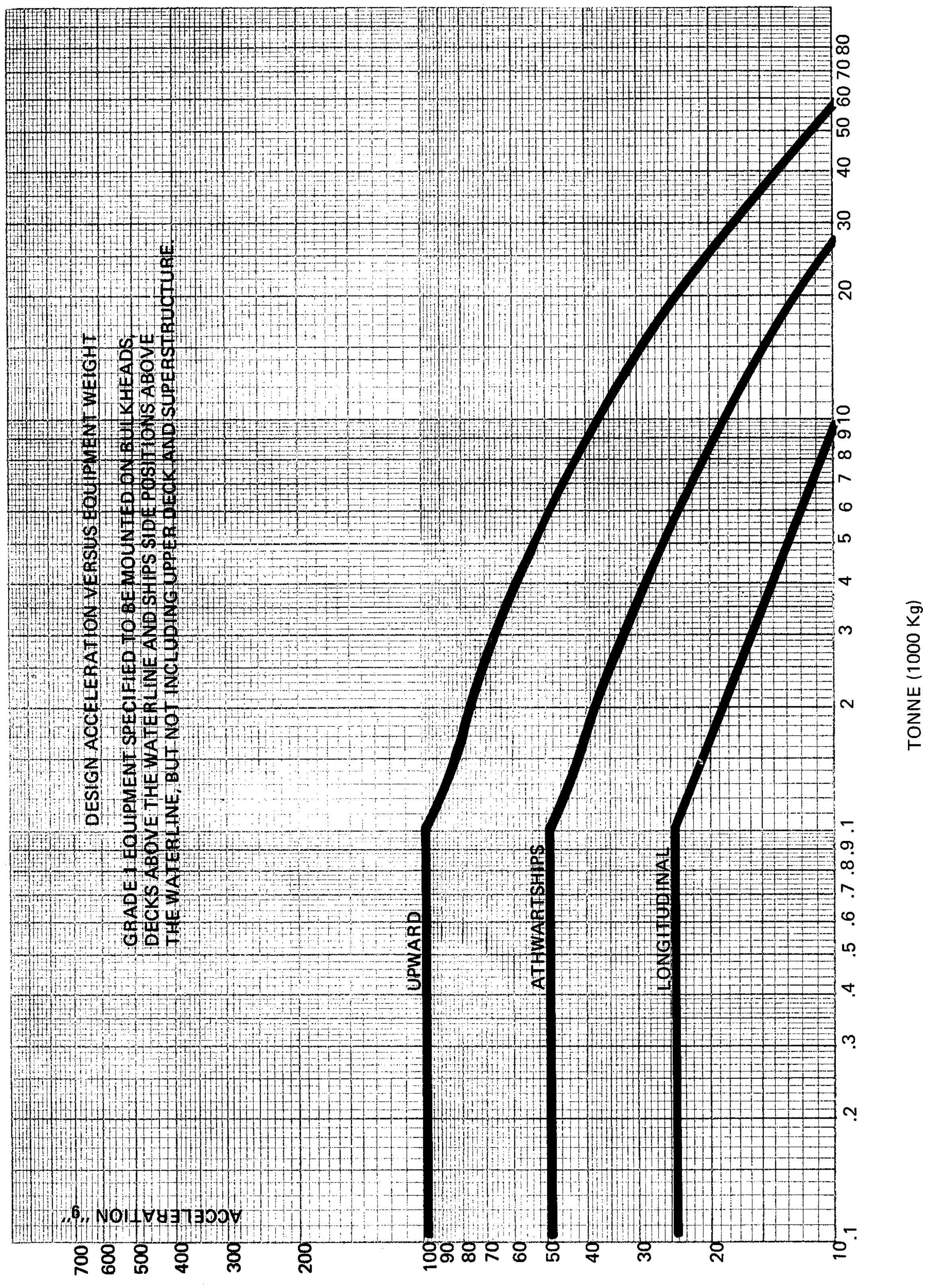

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT
GRADE 1 EQUIPMENT SPECIFIED TO BE MOUNTED ON BULKHEADS, DECKS ABOVE THE WATERLINE AND SHIPS SIDE POSITIONS ABOVE THE WATERLINE, BUT NOT INCLUDING UPPER DECK AND SUPERSTRUCTURE
UPWARD
ATHWARTSHIPS
LONGITUDINAL
ACCELERATION "g"
TONNE (1000 Kg)

Figure 2

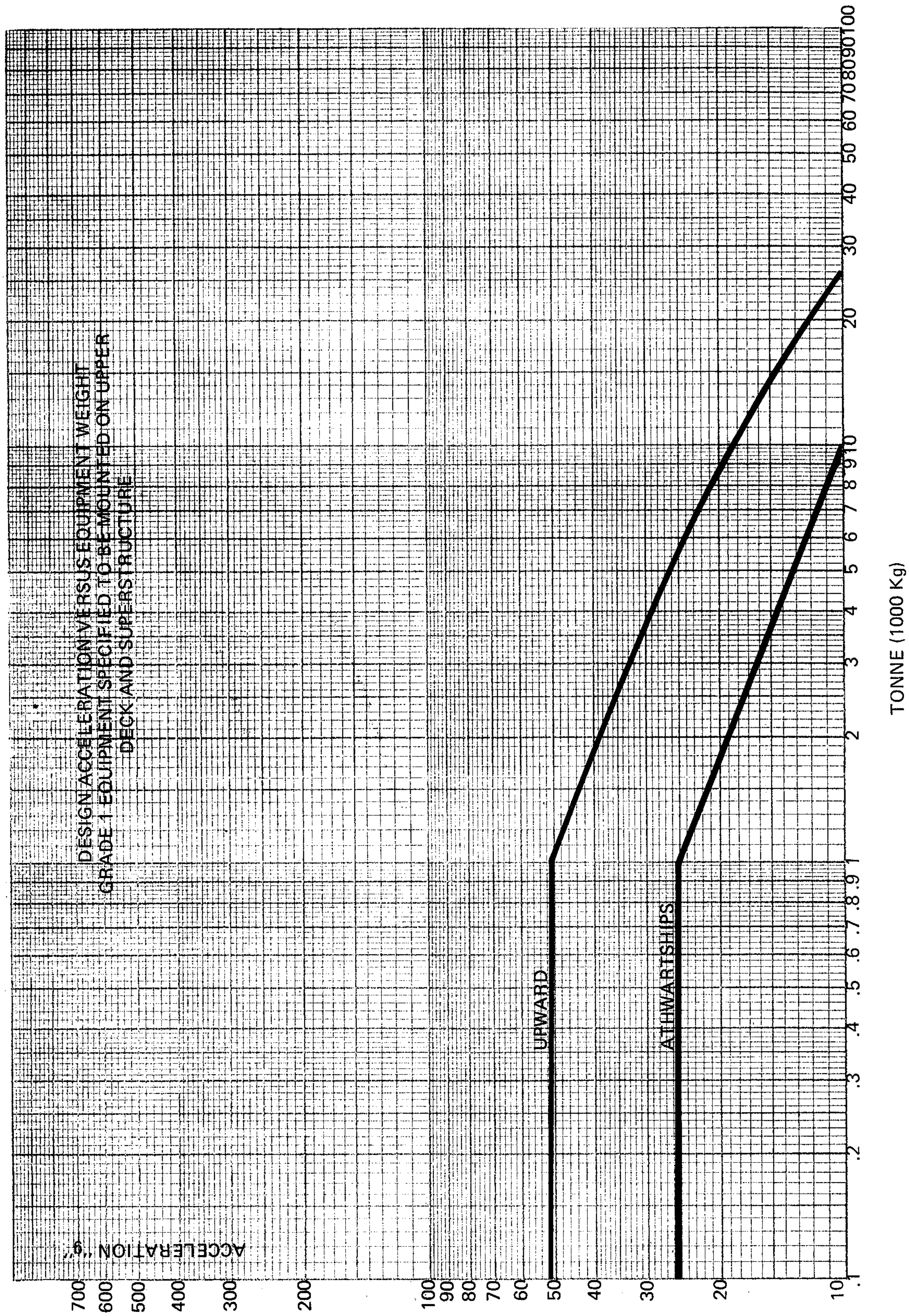

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT
GRADE 1 EQUIPMENT SPECIFIED TO BE MOUNTED ON UPPER
DECK AND SUPERSTRUCTURE
UPWARD
ATHWARTSHIPS
ACCELERATION "g"
TONNE (1000 Kg)

Figure 3

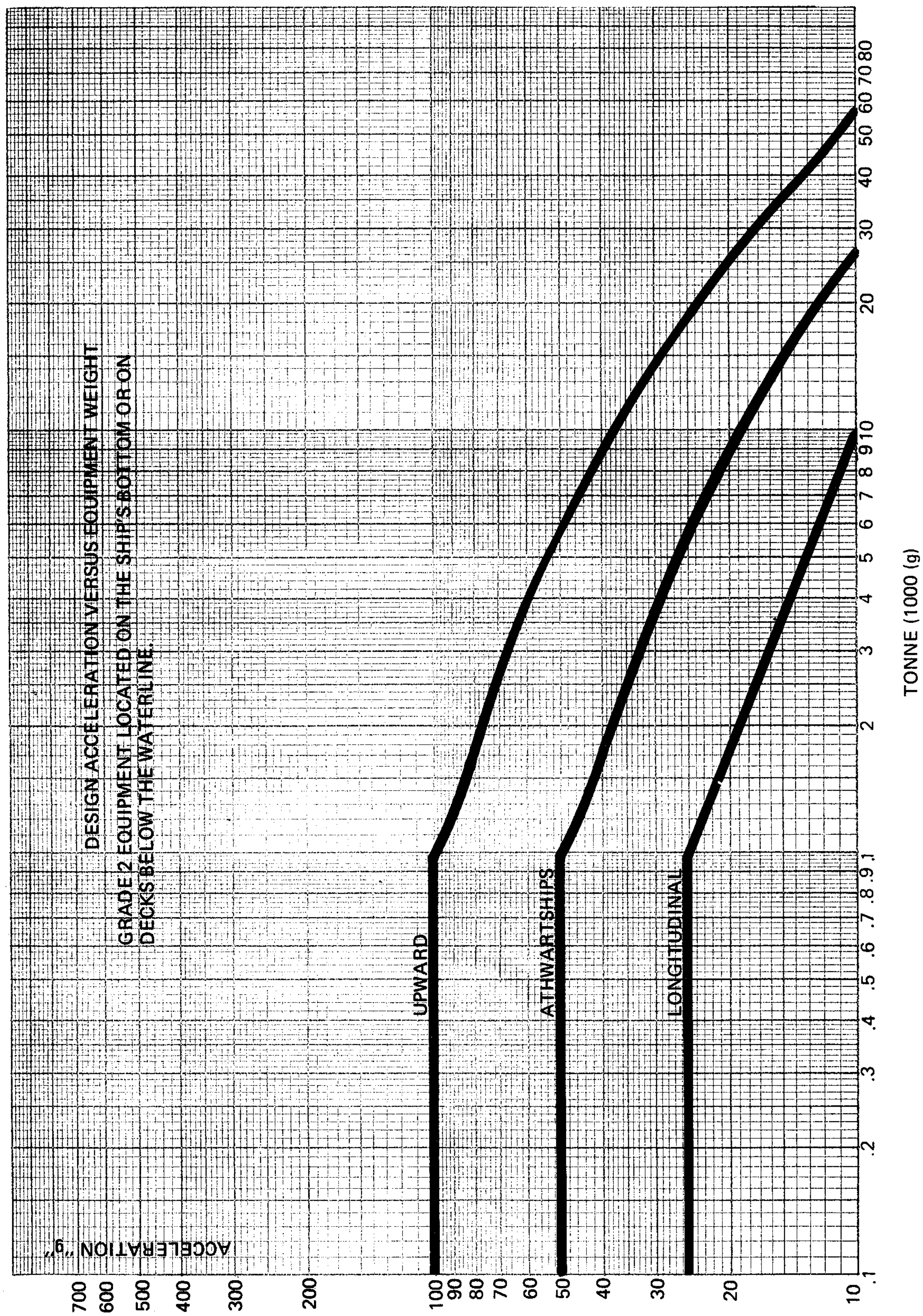

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT
GRADE 2 EQUIPMENT LOCATED ON THE SHIP'S BOTTOM OR ON DECKS BELOW THE WATERLINE.
UPWARD
ATHWARTSHIPS
LONGITUDINAL
ACCELERATION "g"
TONNE (1000 (g)
700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10
.1 .2 .3 .4 .5 .6 .7 .8 .9 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80

Figure 4

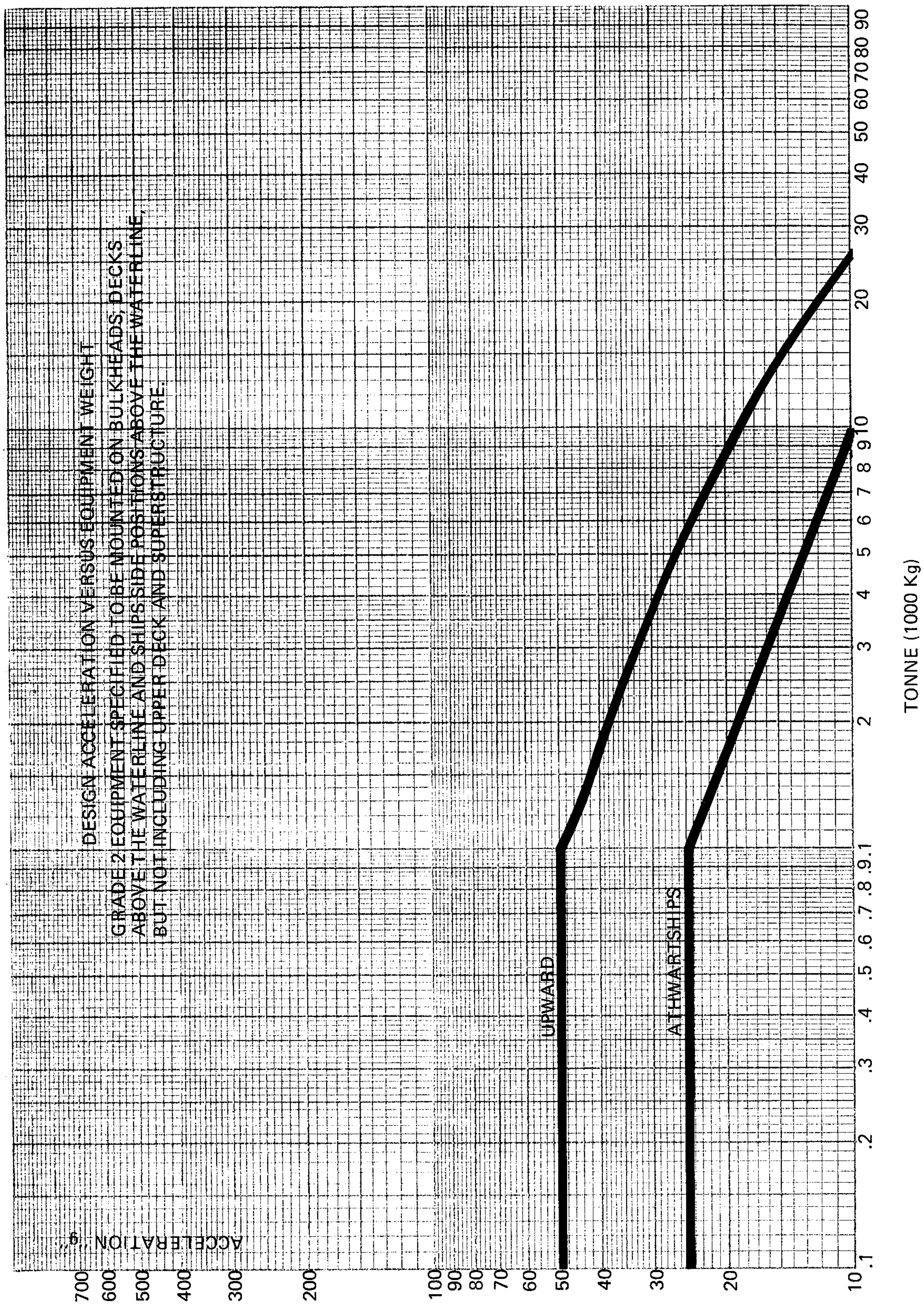

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT.
GRADE 2 EQUIPMENT SPECIFIED TO BE MOUNTED ON BULKHEADS, DECKS ABOVE THE WATERLINE AND SHIPS SIDE POSITIONS ABOVE THE WATERLINE, BUT NOT INCLUDING UPPER DECK AND SUPERSTRUCTURE.
UPWARD
ATHWARTSHIPS
ACCELERATION "g"
TONNE (1000 Kg)
700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10
.1 .2 .3 .4 .5 .6 .7 .8 .9 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90

Figure 5

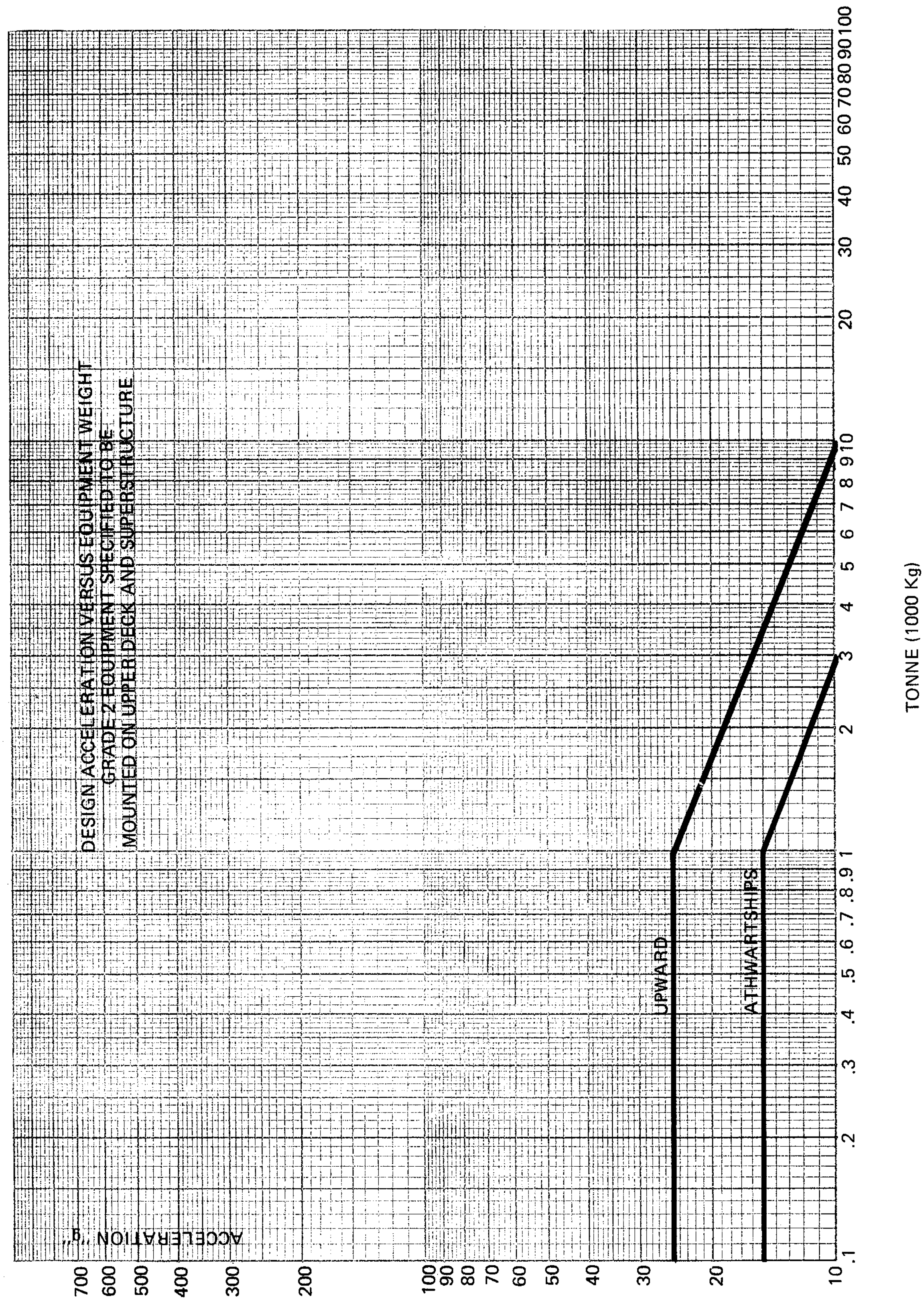

DESIGN ACCELERATION VERSUS EQUIPMENT WEIGHT
GRADE 2 EQUIPMENT SPECIFIED TO BE
MOUNTED ON UPPER DECK AND SUPERSTRUCTURE
ACCELERATION "g"
700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10
.1 .2 .3 .4 .5 .6 .7 .8 .9 1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100
UPWARD
ATHWARTSHIPS
TONNE (1000 Kg)

Figure 6

SECTION 5

Design of Securing or Holding Down Bolts

5.01 General

1. Shock shall be considered in the following directions: vertical, upwards or downwards, and horizontal athwartships. Bolts shall be considered separately and not combined.

2. The shock design accelerations shall be calculated according to this specification unless modified by the Department, and supplied to the manufacturer and shipbuilder. The actual shock received by the equipment, according to its position in the ship, shall be determined from the information given in this specification and the yield strength of the holding down bolts shall at least equal the calculated shock or Grade 1 shock, whichever is the lower, providing that the tensile strength exceeds whichever is the higher by at least 5 percent. Resilient mountings and yielding mountings modify the stress values, but the principle of yielding at the specified design stress and yet not letting the machinery loose at the maximum possible shock shall be adhered to. In the absence of information to the contrary the "Design Acceleration at Maximum Load at Grade 1 Shock" given in D-03-003-021/SF-001 Part 5 shall be used.

3. The type and size of all holding down and securing bolts shall be chosen from Table 2 when the stresses have been calculated.

4. All holding down bolts shall be designed by the equipment manufacturer and shown on the general arrangement drawings, but supplied by the shipbuilder.

5.02 Vertical Upward Shock

1. In most cases this imposes no immediate stress on the holding down bolts. However, in some cases where the seatings are vertical brackets (e.g. some air receivers) or bulkhead mountings (e.g. separators) the full upward shock is taken by bolts in shear stress.

2. If, with horizontal bolts, the centre of gravity of the equipment is in line with the securing bolts then the shear stress calculation is straight forward, being the weight of the equipment times the actual shock in "g's" divided by the total of the cross-sectional areas of the smallest section in the shanks of the bolts.

3. If, with horizontal bolts, the centre of gravity is offset, the overturning effect produces a tensile stress in some bolts as well as the shear stress.

5.03 Vertical Downward Shock

1. The centroid of the holding down bolts should usually be vertical above or below the centre of gravity of the equipment. If the two centres are offset horizontally, extra bolts should be fitted on the side nearest the centre of gravity to distribute shock stresses in all the bolts evenly. Larger bolts could be used in certain cases, but more of the same size is preferred.

2. Providing the stress is evenly distributed between the bolts, the yield strength of each bolt should be equal to the weight of all the equipment secured by these bolts, times the actual shock acceleration in "g's" and divided by the minimum total cross-sectional area of the bolts.

3. It should also be noted that where various parts of an equipment are held together by bolts or located with spigots, these sections should be calculated for shock resistance so that the equipment does not disintegrate.

5.04 Athwartships Shock

1. In most cases, this imposes a shear stress in all vertical holding down bolts unless the feet or bed-plates are spigoted to their seatings. Providing the stress is evenly distributed, the equipment weight times the actual athwartship shock acceleration in "g's" divided by the total cross-sectional area of the bolts gives the shear stress. However, since in most cases the centre of gravity of the equipment is offset to the plane of seating, an additional effect shall be considered. This condition will impose an overturning effect and produce a tensile stress in the bolts farthest from the applied force, see Figure 7.

2. In the case of horizontal securing bolts, the athwartship shock produces a direct tensile stress or a shear which is automatically covered if the bolts are designed to take a full upward shock in shear providing the horizontal loading is evenly distributed.

5.05 Bolt Design

Figure 8 and Table 2 describe the characteristics of holding down bolts to meet the requirements of this specification.

TABLE 2

Holding Down Bolt Characteristics

Bolt Size (UNC)	Shank Area (Sq/in)	Maximum Shear at Shank (lb)	Tensile	Type I Neck Max. Dia. (in)	Type I Min. Yield Force (lb)	Type II Range of Bore Diameters (in)	Type II Range of Min Yield Forces (lb)
No. 4	0.00985	480	500	0.080	375		
No. 6	0.01496	700	760	0.099	570		
No. 8	0.02112	1,000	1,200	0.125	900		
No. 10	0.02385	1,350	1,500	0.138	1,100		
1/4	0.0491	2,350	2,750	0.188	2,050		
5/16	0.0765	3,650	4,600	0.244	3,450		
3/8	0.110	5,250	7,000	0.298	5,250		
7/16	0.150	7,200	9,500	0.349	7,100	9/32	6,600
1/2	0.196	9,400	13,000	0.409	9,750	5/16- 9/32	9,000- 9,750
9/16	0.248	11,800	17,500	0.472	13,100	11/32- 9/32	11,600- 12,800
5/8	0.316	15,000	21,500	0.526	16,000	13/32-13/32	14,000- 15,400
3/4	0.440	21,000	32,000	0.641	24,000	17/32-13/32	16,400- 23,400
7/8	0.600	28,500	44,500	0.754	33,000	5/8 - 7/16	22,000- 33,600
1	0.786	37,500	58,500	0.864	44,000	3/4 - 1/2	26,000- 44,000
1-1/8	0.990	47,500	76,000	0.989	57,000	27/32-17/32	32,200- 56,000
1-1/4	1.220	58,500	97,000	1.114	72,000	31/32- 9/18	36,000- 72,000
1-3/8	1.480	71,000	120,000	1.239	90,000	1-1/16-19/32	44,500- 90,000
1-1/2	1.760	84,500	146,000	1.364	110,000	1-3/16- 5/8	48,500-108,000
1-3/4	2.400	95,000	171,000	1.614	122,000	1-7/16-11/16	47,000-122,000
2	3.140	120,000	225,000	1.864	160,000	1-5/8-23/32	64,000-160,000

The neck diameter of Type I should not be reduced below 75% of the maximum given in the Table (i.e. 56% of minimum yield force). Normally there is no point in reducing it below the maximum neck diameter of the next smaller size bolt.

Holding down bolts and nuts shall be manufactured from heat treated carbon steel as SAE Grade 5 bolts, or to ASTM A325 or ASTM 354 Grade BD, having the following minimum properties.

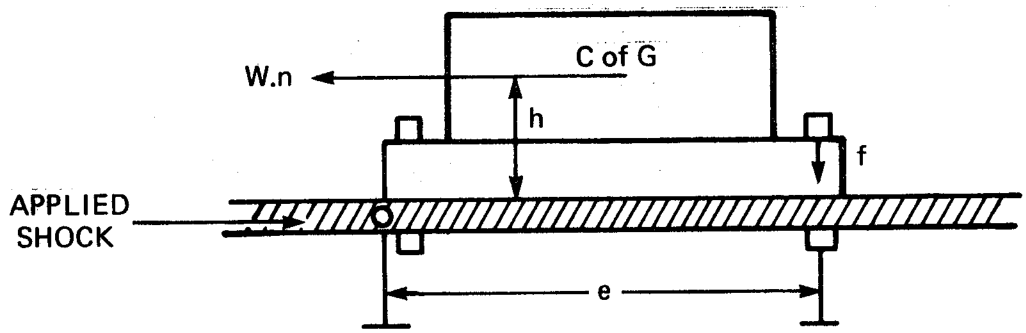
<u>BOLTS:</u> Yield strength 75,000 psi. TS 100,000 psi. Elongation 14%.

<u>NUTS:</u> Specification ASTM A-194-2H may also be used for nuts. ESNA, Tork-Lok nuts, or equal nut may be used.

<u>THREADS:</u> Class 2 fit, Unified National Course

<u>TOLERANCES:</u> Bore +0.00" to -0.005"; neck +0.005" to -0.000".

<u>MARKING:</u> The heads of all holding down bolts shall have three radial lines 120 degrees apart, or the letters "BO" marked on them as called for in the appropriate specifications.



SIMPLE EXAMPLE

W WEIGHT OF EQUIPMENT

n ACCELERATION DUE TO SHOCK IN *g' s* HORIZONTALLY

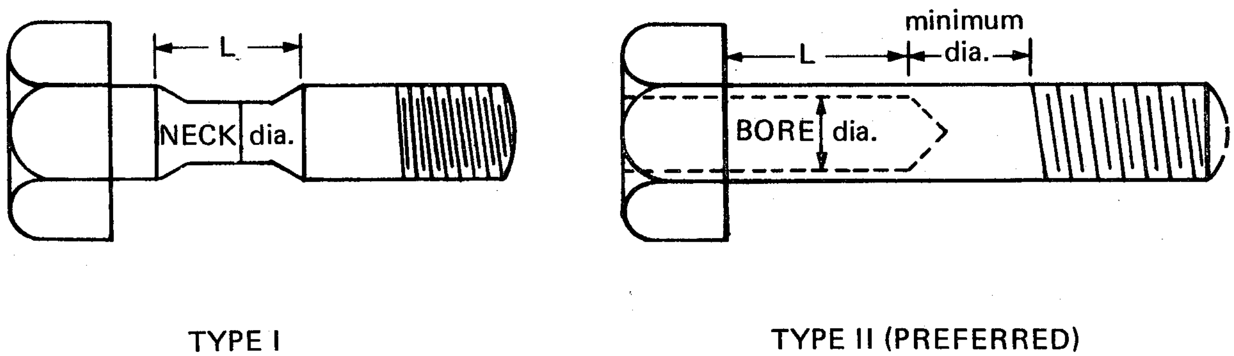
h HEIGHT OF C. of G. ABOVE JOINT OF MACHINE AND SEATING

e DISTANCE FROM EDGE OF EQUIPMENT TO HOLDING DOWN BOLTS

f RESULTING TENSILE FORCE IN HOLDING DOWN BOLTS DUE TO HORIZONTAL SHOCK.

f.e. W.n.h. (TAKING MOMENTS ABOUT 0)

Figure 7 – Horizontal Shock Effect



L = 1 - 1/2 x BOLT dia. (TOTAL LENGTH OF BORE IS NORMALLY 2 - 1/2 x BOLT dia., PROVIDING THAT THE END OF THE BORE DOES NOT COME WITHIN A MINIMUM DISTANCE TO THE THREADS, EQUAL TO THE BOLT DIAMETER)

Figure 8 – Holiday Down Bolts Shape

SECTION 6

Shock Tests

6.01 General

1. A sample of every equipment for use in ships, the specification for which cites this specification for shockproof testing, shall be shock tested in accordance with this section.

2. The manufacturer shall perform the tests of this section to the satisfaction of the Inspection Authority. In those cases where the manufacturer cannot perform the tests, the Department's testing facilities may, at the discretion of the Department, carry out these tests or may be used to amplify or verify part or all of the contractor's tests.

6.02 Test Requirements

1. During any of the tests on a shock machine the equipment and its mountings shall be superficially inspected and holding down bolts tightened after each blow. After the tests are complete the equipment tested shall be dismantled by the contractor (usually at his factory) in the presence of the Inspection Authority and examined as specified in Article 2.07 and the equipment specification to ascertain whether failure or deformation has occurred.

2. Any failure shall be recorded in accordance with Article 9 and directions for retest sought from the Department.

6.03 Type of Test Assembly

The application of any of the tests detailed in Articles 6.04, 6.05 and 6.06 of this specification to an equipment shall be governed by the type of test (A or B) as cited in the specification for the equipment:

Type A - requires that the complete assembly be mounted and tested as a unit.

Type B - allows a sub-assembly to be mounted and tested separately from the equipment. This may be permitted in cases where the performance of similar equipment has been previously established but new components have been added, or when an equipment is too large for testing as a unit.

6.04 Light-Weight Test

For units up to 114 kg (250 lb) Weight -

a. The Units shall be tested on a machine similar to that shown in Figure 9. Buships drawing 10-T-2145-L(13).

b. The equipment under test shall be complete with any auxiliary gear which might affect the test, or might itself be susceptible to damage under shock.

c. All appropriate electrical and mechanical connections, required by the equipment for operation, shall be made.

d. For equipment that may be oriented in any position in a ship the tests shall normally consist of 9 blows delivered by a weight of 181 kg. (400 lb) in three mutually perpendicular planes as shown in fig. 8. The 9 blows shall consist of 3 blows parallel to each of the 3 principal axes of the equipment under test with one blow from each of the following heights: 15", 30" and 60" for grade 1 equipment and 9", 18" and 36" for grade 2 equipment.

e. If the equipment has been designed to figure 1 to 6 values and will only be fitted in one direction in the ship as stated in the End Product Specification, then table 3 may be used with the equipment mounted as shown in figure 8a. Grade 1 equipment specified to be mounted on the upper deck or superstructure may be tested according to Grade 2A in Table 3. Grade 2 equipment specified to be mounted on the upper deck or superstructure may be tested according to Grade 2A except that the 36" blow will be omitted.

TABLE 3

Light Weight Test Heights

	Grade I	IA	Grade 2	2A
	Below Waterline (inch)	Above Waterline (inch)	Below Waterline (inch)	Above Waterline (inch)
Vertically Down	15, 30	9, 15	9, 15	9
Vertically Up	15, 30, 60	9, 18, 36	9, 18, 36	9, 18, 36
Athwartship	15, 30	9, 15	9, 15	9

f. The equipment shall not be operating at the first lowest height of blow in each set of blows, but shall be operating at its maximum condition during the second and third in each set of blows. If the equipment has any other normal operating condition which is different from the above (apart from speed only) the three maximum height blows (according to direction) shall be repeated on the same equipment operating at each of the other normal operating conditions.

g. For equipment with electrical connections, a further test of one maximum height blow in each direction shall be repeated with all electrical contacts in the "OFF" position to ensure that they will not momentarily energize the equipment as a result of the shock.

h. Instructions shall be obtained from the Inspection Authority before arrangements are made to test apparatus containing coils, relays, and overload devices in order to obtain exact conditions for the tests.

j. Holding down bolts shall be retightened after every blow. Any noticeable retightening movement which may indicate a permanent set in elongation of the bolts shall be noted in the test report.

k. Any departures from the foregoing requirements will be included in the end product specification or contract.

6.05 Medium-Weight Test

For Units between 114 kg and 2720 kg (250 and 6,000 lb) Weight - (total weight of equipment plus test fixture on the anvil not to exceed 3400 kg (7500 lb)).

a. Units shall be tested on a machine similar to that shown in Figure 11 Buships drawing No. 807-655947(5).

b. Tests shall consist of:

i. Two blows from the 1360 kg (3000 lb) hammer falling from the heights given in column 1 of Table 4.

ii. Two blows from the 1360 kg (3000 lb) hammer falling from the heights given in column 2 of Table 4.

iii. Two blows from the 1360 kg (3000 lb) hammer falling from the heights given in column 3 of the Table 4.

c. The equipment shall not be operating for the test detailed in sub-paragraph b.i., but shall be operating at its maximum condition during tests detailed in sub-paragraphs b.ii. and iii. If the equipment has any other normal operating condition which is different from the above (apart from speed only), one blow as per column 3 of Table 4 shall be repeated on the same equipment, operating at each of the other normal operating conditions.

d. One blow of each section of paragraph b. above shall be carried out with the equipment on an inclined base support at 30° to the horizontal, and the orientation shall be such that the equipment is stressed in the athwartships direction. The second blow of each section of paragraph b. above will be with the equipment turned around through 180°. Normally equipment is designed to operate at up to 20° inclination (ship's roll). Any equipment which ceases to function normally at 30° may use the 20° base support.

e. Equipment that has passed tests according to sub-paragraphs b., c. and d. shall be classified as Grade 1. Equipment specified as Grade 1A shall be tested as for Grade 2. Equipment specified as Grade 1B shall be tested as Grade 2A. Equipment that is specified as Grade 2 shall be tested as per paragraphs b., c. and d., in each case, but omitting the b.iii. test. Equipment specified as Grade 2A shall be tested as for Grade 2 except that the blows defined in column 2 (Table 4) shall have the anvil travel distance doubled and the whole test shall be carried out on a 20° inclined base support, as per sub-paragraph d. Equipment specified as Grade 2B shall be tested as Grade 2A except that both tests b.ii. and b.iii. be omitted and the equipment will be operating during the b.i. test.

f. Instructions shall be obtained from the Inspection Authority before arrangements are made to test apparatus containing coils, relays, and overload devices in order to obtain exact conditions for the tests.

g. Weight of unit for the purpose of this paragraph includes that of the unit together with all fixtures mounted on the anvil.

h. Holding down bolts shall be retightened after every blow. Any significant retightening movement which indicates a permanent set of elongation of the bolts, shall be noted in the test report.

TABLE 4

Medium Weight Test Heights

	1	2	3
Total Weight of Equipment and its mounting carried by the anvil table (lb)	Height of hammer drop with 3 inch anvil table travel (inch)	Height of hammer drop with $1\frac{1}{2}$ inch anvil table travel (inch)	Height of hammer drop with $1\frac{1}{2}$ inch anvil table travel (inch)
250 - 1000	11	15	24
1000 - 2000	13	17	28
2000 - 3000	14	19	31
3000 - 3500	16	21	34
3500 - 4000	18	23	38
4000 - 4400	20	27	45
4400 - 4600	22	29	48
4600 - 4800	24	31	51
4800 - 5000	26	33	55
5000 - 5200	29	37	62
5200 - 5400	32	41	69
5400 - 6000	35	45	72
6000 - 7500	36	46	72

6.06 Heavy Weight Units

1. Machinery weighing 2720 kg to 13600 kg (6,000 to 30,000 lb) shall be tested on a Floating Shock Platform, refer to Figures 12 and 13.

2. At the discretion of the Department these heavy units may be dealt with by design only, and the calculations shall be submitted to the Department for approval before manufacture. Alternatively, a type B test may be specified, requiring sub-assemblies to be tested individually, as per Article 6.03.

3. The equipment tested on the floating shock platform is to be installed on a seating, foundation or substructure which as closely as possible is representative of the manner in which it would normally be installed in the ship.

4. When the equipment is to be resiliently mounted on board ship it should be fitted into the shock test vehicle with the same mountings. Such mountings will constitute a part of the equipment. The equipment is in actual operation during the shock test.

5. The shock test vehicle is to be subjected to a series of five underwater explosion attacks of increasing severity as shown in Figure 12. A charge of 36 to 50 kg of TNT or its equivalent is employed for each of these attacks, the explosion severity being governed by the stand-off of the charge from the shock test vehicle as shown in figure 12.

6. The equipment is to be thoroughly examined for any evidence of damage and, if possible, its operation is to be checked in detail after each attack and before proceeding to the next more severe attack.

7. If necessary or if desired an attack may be repeated to check a result or to confirm the efficiency of repair before proceeding to the next more severe attack.

8. At the discretion of the purchasing or acceptance authority or the customer, tests at intermediate stand-offs may be employed but such procedure must be clearly and specifically stated in the test report issued in accordance with the requirements specified below.

6.07 Compliance Acceptability

1. Equipment capable of withstand the shock tests specified herein without significant impairment of function during and after these tests will be identified as complying with this specification. However, the following should be noted:

a. Minor damage or distortion may be permitted provided that does not in any way impair the ability of the equipment to perform its specified functions, or present a hazard aboard ship.

b. Maloperation and damage which reduces operation below specification may be cause for rejection of the equipment.

c. Any significant modification of the equipment design which affects its operation or integrity may require all shock tests to be repeated.

2. Equipment which has been tested may be used on board of a ship after refurbishing specified items, e.g. ball and roller bearings, flexible mountings etc.

6.08 Test Report

1. A test report shall be submitted to the customer giving a description of the equipment and the tests performed against it in the following detail:

a. Description of the equipment.

b. The name and address of the supplier or manufacturer.

c. References to drawings and full description of equipment as accepted.

d. The weight and general overall dimensions of the equipment as tested.

e. Description of any resilient mounting system used to support the equipment during the test including the number of mounts fitted, their load range, their location, the type number and/or name of manufacturer of the mountings.

f. A sketch or photographs showing how the equipment was installed in the Shock Test Vehicle together with any seating, foundation or substructure fitted.

g. The state of the equipment for the test, i.e. fully operating, part operating etc. together with, in the latter case, what was and what was not operating normally.

h. Vehicle used for the tests.

j. The severity of the explosions tests applied with details of charge (material and mass) and stand-off if not a standard test as defined in figure 12.

k. Details of any damage or malfunction resulting from the test including details of any performance checks and tests performed before and after each explosion test including all functions controlled and any changes noted.

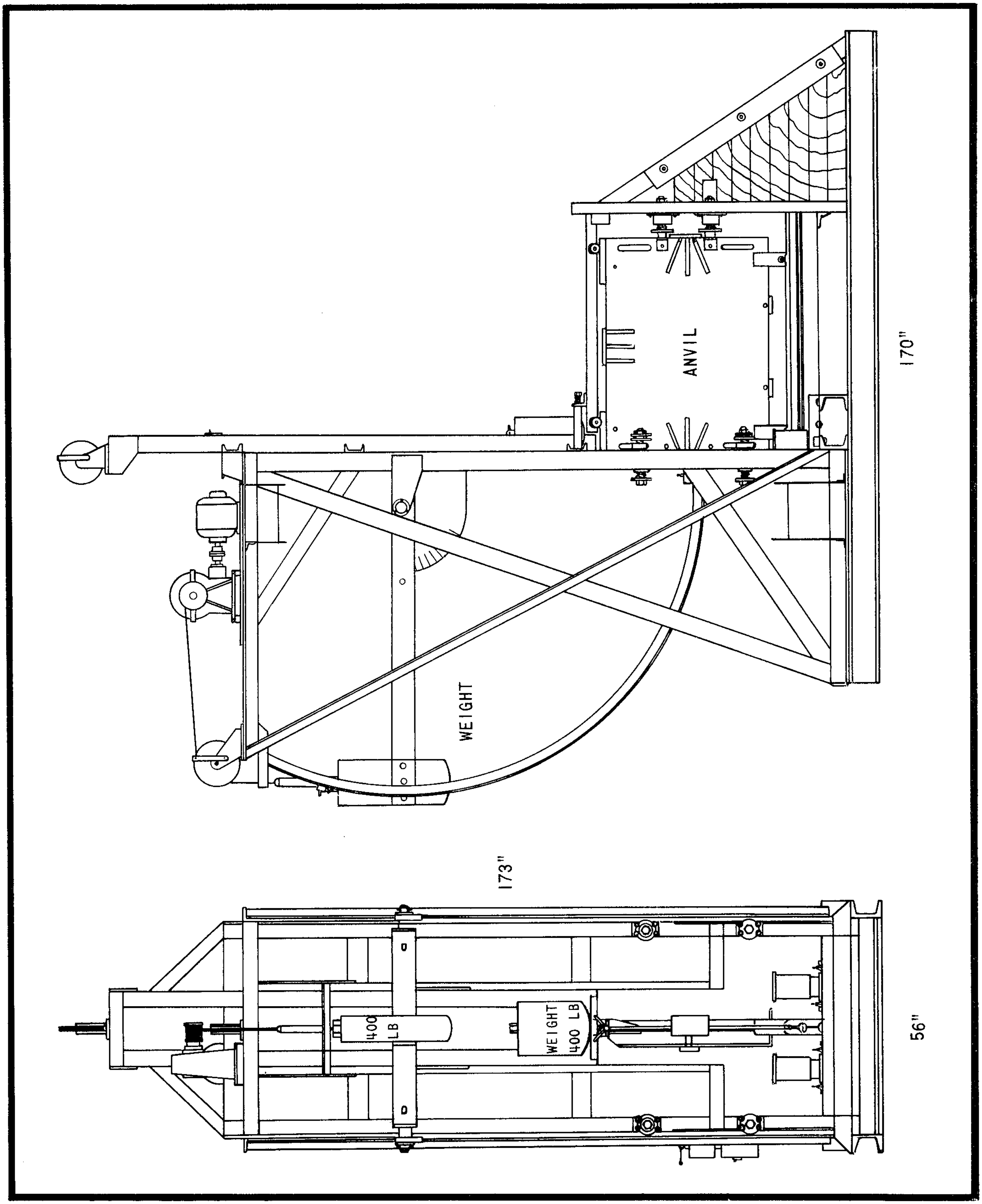


Figure 9 – Shock Testing Machine for Light Weight Equipment

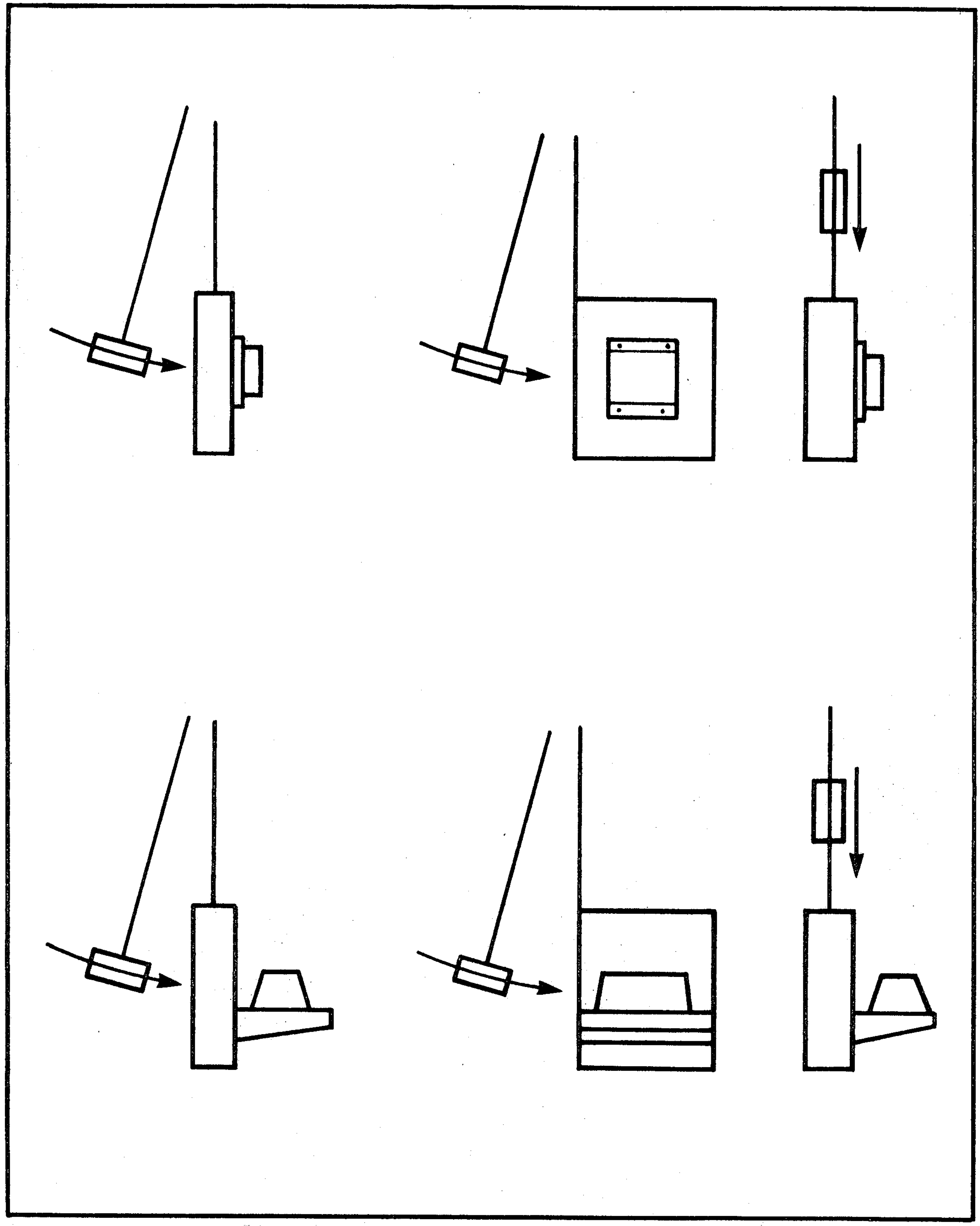


Figure 10 – Direction of Blows on Light Weight Machine for Tests According to Para. 6.04d

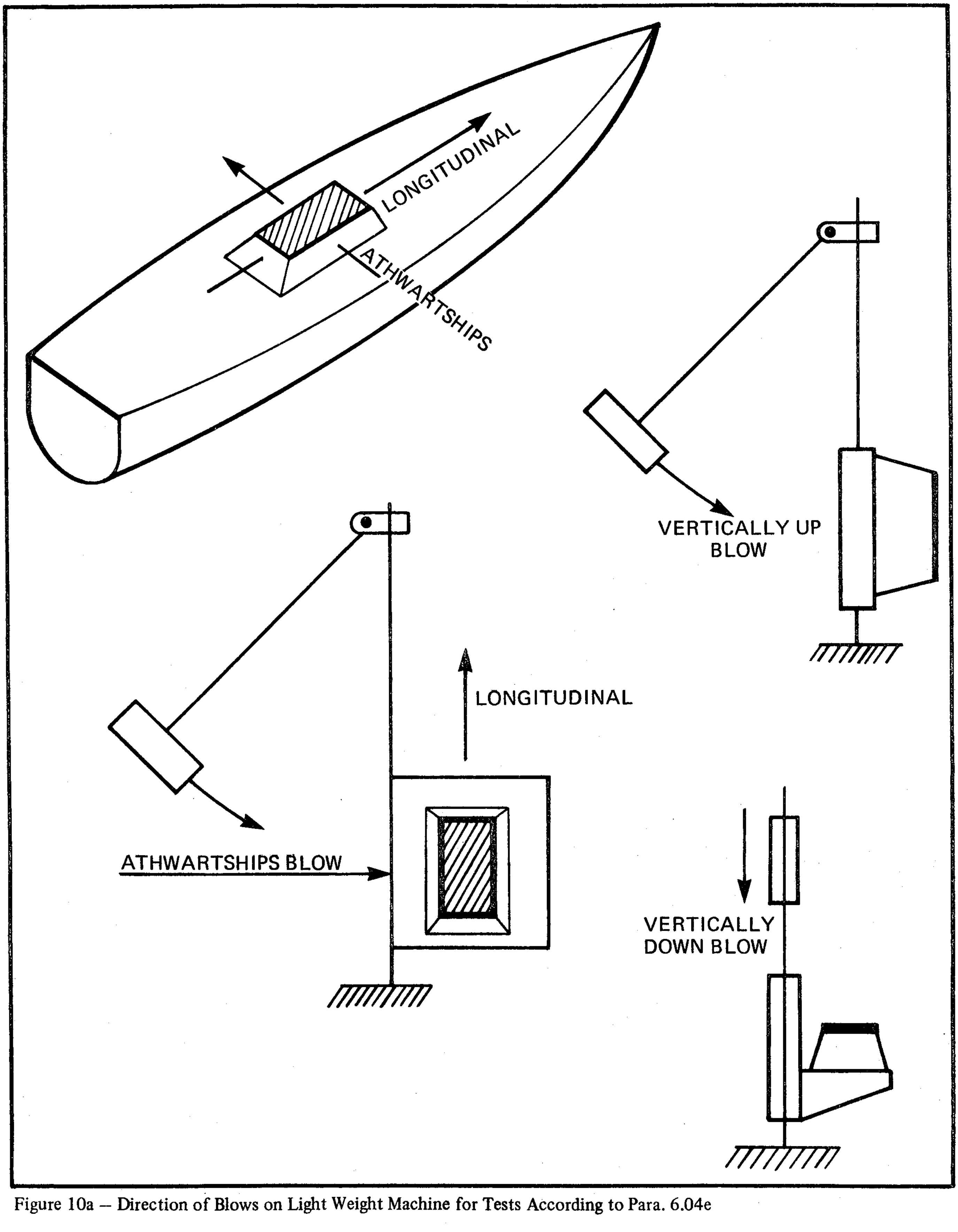


Figure 10a – Direction of Blows on Light Weight Machine for Tests According to Para. 6.04e

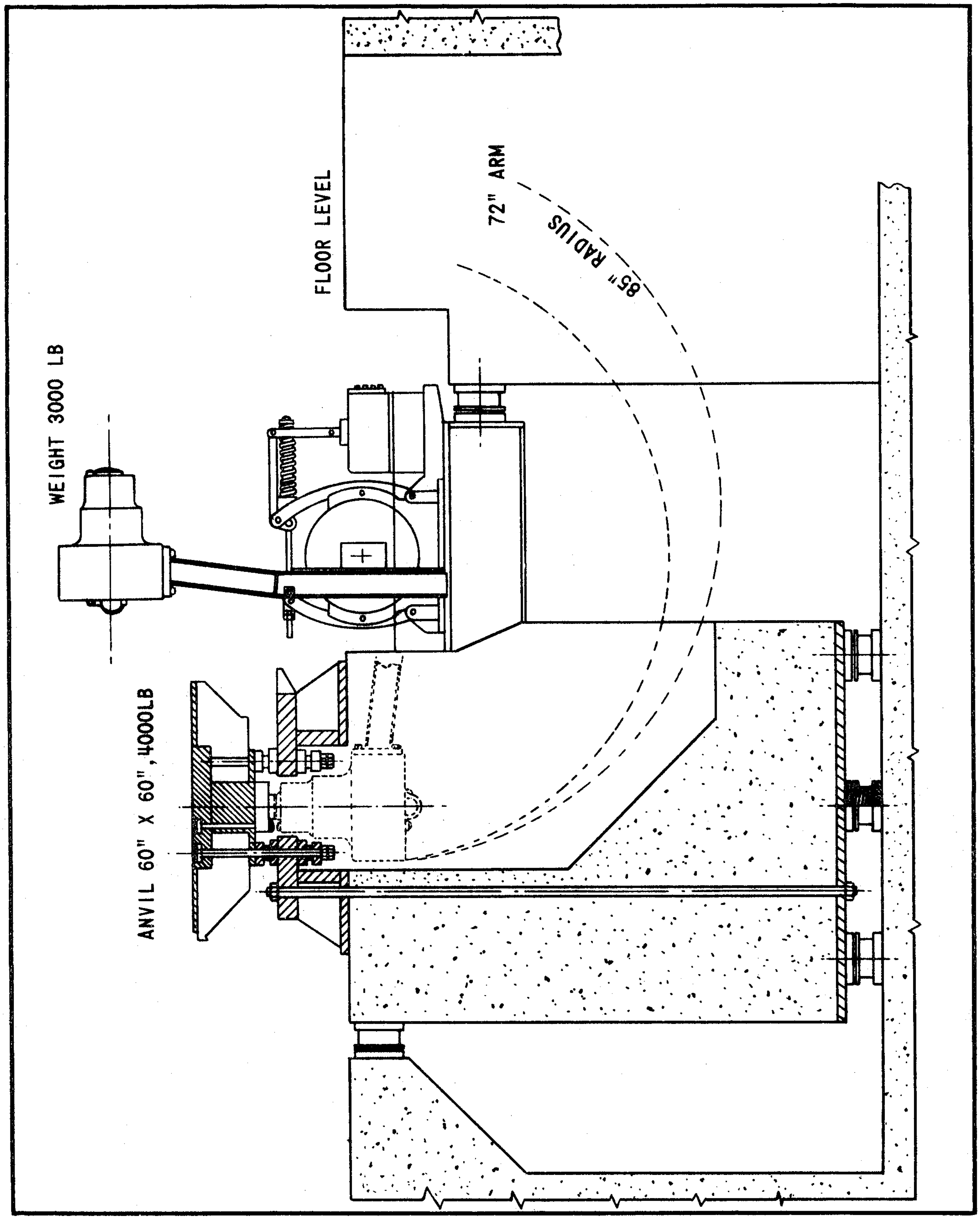
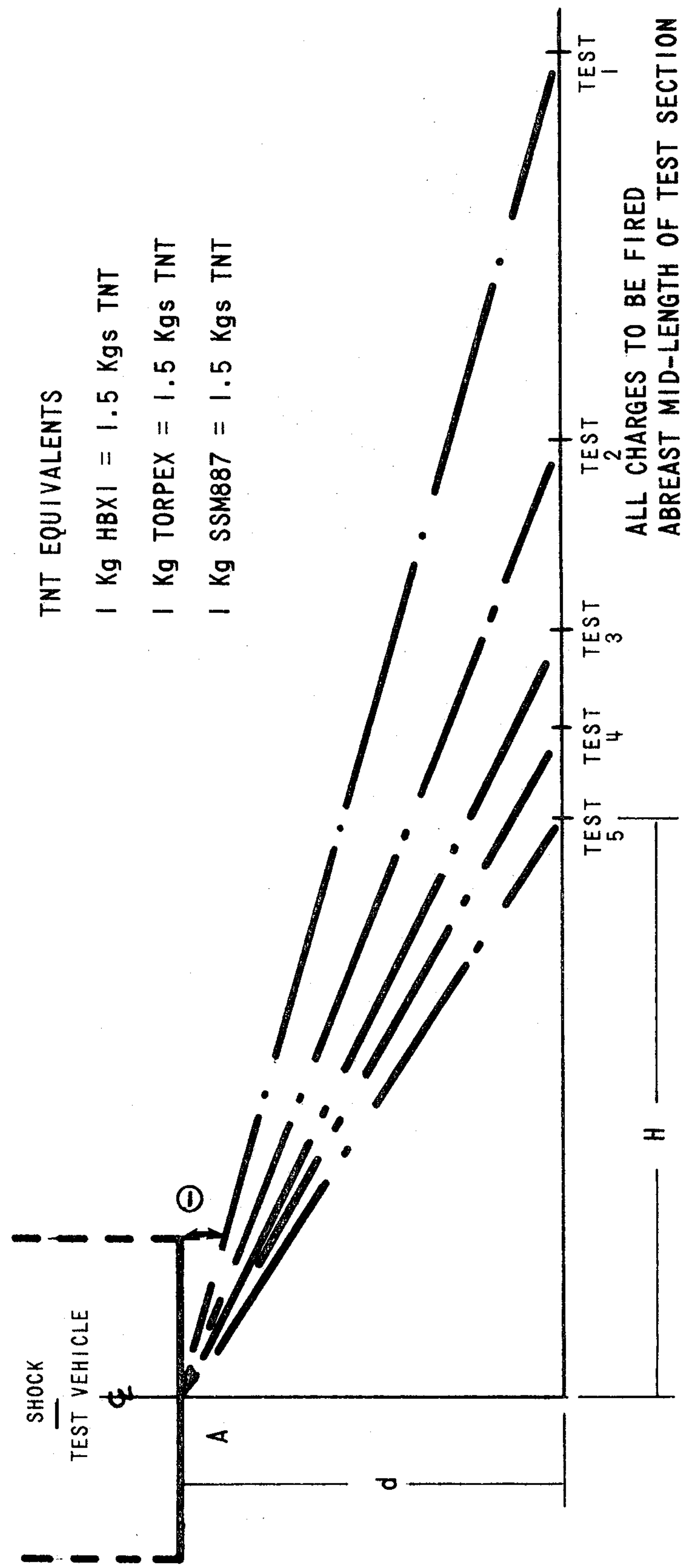


Figure 11 – Shock Testing Machine For Medium Weight Equipment



NOTES

(1) THIS TEST MAY BE CONDUCTED WITH THE CHARGE ALONG THE FORE AND AFT AXIS OF THE VEHICLE.

(2) WHERE POSSIBLE TESTS ARE TO BE CONDUCTED IN A MINIMUM OF 10 m OF WATER.

CHARGE GEOMETRIES IN METRES. (See Note (2))

	W = 36 Kgs TNT		W = 40 Kgs TNT		W = 45 Kgs TNT		W = 50 Kgs TNT	
	d	H	d	H	d	H	d	H
TEST 1	5.5	19.0	6.0	20.0	6.5	21.5	6.75	22.5
TEST 2 (1)	5.5	14.0	6.0	15.0	6.5	16.0	6.75	17.0
TEST 3	5.5	11.5	6.0	12.0	6.5	12.5	6.75	13.5
TEST 4	5.5	10.0	6.0	10.5	6.5	11.0	6.75	12.0
TEST 5	5.5	8.5	6.0	9.0	6.5	9.5	6.75	10.0

NOMINAL TEST REQUIREMENTS

Figure 12 – Raft Test Parameters

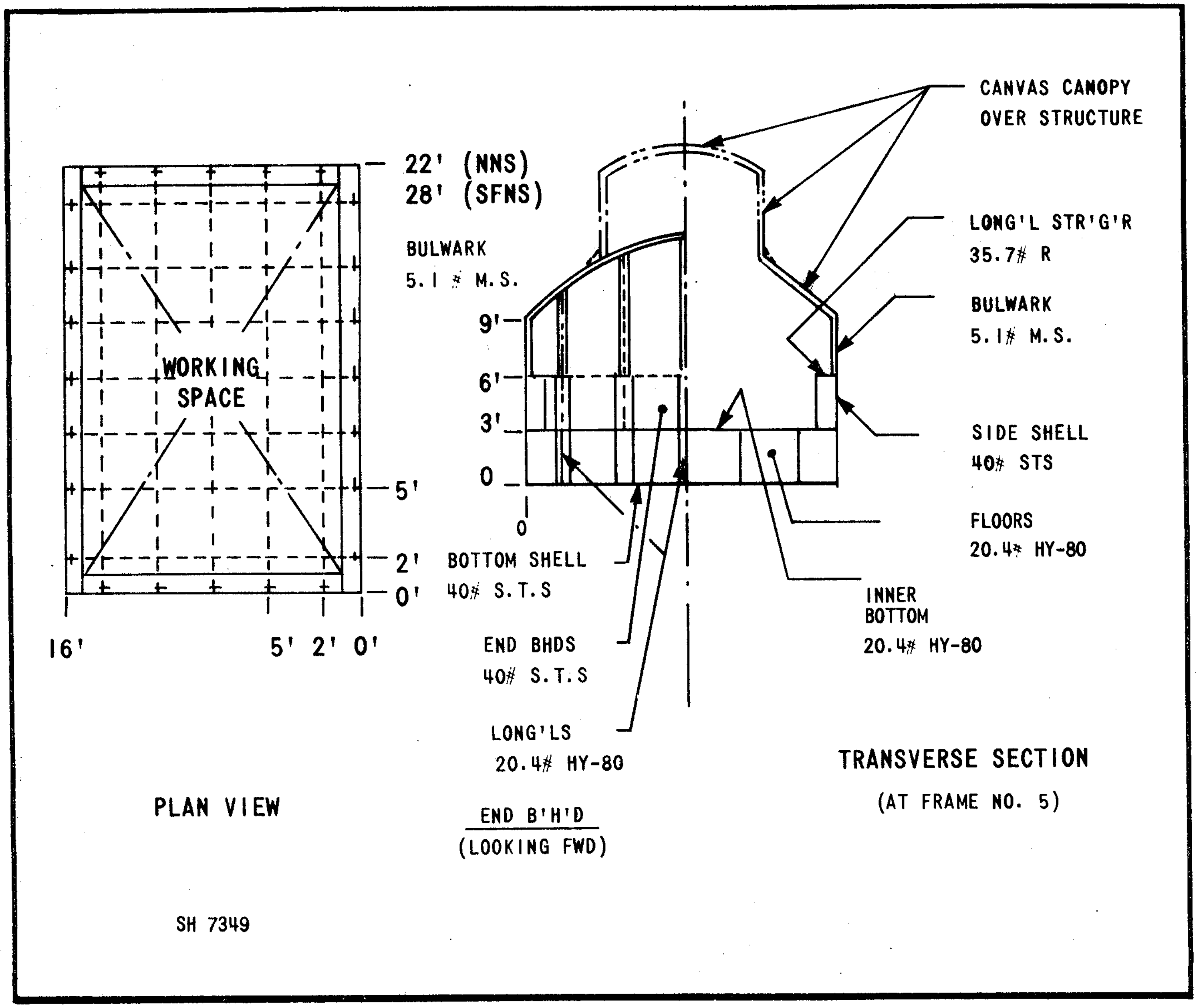


Figure 13 – Floating Shock Test Platform
(See Buships DWG. No. 645-1973904 For Construction Details)

SECTION 7

Methods of Mounting for Test

7.01 General

1. Equipment may be mounted directly on the anvil plate of the light-weight shock machine, or by means of approved standard mountings.

2. Any questions regarding the use of, or deviations from standard mountings, shall be decided by the Department. It is the intent of these standard mountings to approximate the actual rigidity encountered aboard ship by the particular equipment.

3. The arrangement on the anvil shall be such that the direction of the blow upon impact shall pass approximately through the centre of gravity, of the anvil plus every thing mounted on it, and also as close as possible through the centre of gravity of the item of equipment. Approval of the mounting by the Inspection Authority is necessary.

7.02 Light Weight Equipment

Mounting shall be in such a way that the blows are equivalent to shocking the equipment:

a. vertically upwards;

b. vertically downwards; and

c. horizontally athwartships in the actual athwartships direction.

7.03 Medium-Weight Equipment

Mounting conditions shall be as directed in Article 6.05 of this specification except that the approved standard shock machine mounting plates and brackets for medium-weight machines may be required.

7.04 Holding Down Bolts

Holding down bolts shall be of the same material and design as those used in service in the ship. See Figure 8 and Table 2.

SECTION 8

Test Requisition, Recording the Marking After Test

8.01 Requisitioning

When Departmental assistance is needed to shock test an equipment, a request shall be submitted on the appropriate form provided by the Inspection Authority. For location of Departmental facilities see Appendix A.

8.02 Recording

The details of the shock test carried out on any equipment shall be recorded on a form similar to Appendix B or as the Department shall direct.

8.03 Qualification

An equipment whose specification requires it to be shock tested with resilient or yielding mounts shall be deemed satisfactory if it passes the appropriate test under Section 7, but by virtue of this alone it shall not be considered shockproof and shall not be marked, as in Article 8.04. Manufacturers desiring shockproof qualification for a product shall submit the equipment for test with direct mounting.

8.04 Marking After Test

1. Every item of equipment of a type and production source which has satisfactorily passed the tests in Section 7 without resilient or yielding mounts shall be marked with a stamp or label plate as follows:

Shockproof Grade 1 (or 2 or 3 as applicable).

The label shall be of a similar type, and placed near the nameplate of the equipment.

2. The unit which has actually been subjected to the shock test shall be labelled as follows:

This unit was shock tested on the .... weight machine on .... (date) ....

The label shall be of a similar type, and placed near the nameplate of the equipment.

3. After successful test, all drawings shall be noted as follows:

This equipment has been tested and passed as Shockproof Grade 1 (or 2) in accordance with

Specification D-03-003-007/SF-000 at .... by .... date ....

SECTION 9

Ordering of Equipment

9.01 Items to be Defined When Ordering Equipment

End product specifications for machinery or equipment in War Ships shall cite this specification defining the following:

a. The required shockproof grade of the equipment (1, 2, 3, 1A, 1B, 2A or 2B).

b. Whether type A or B test is required.

c. Orientation of the equipment for the athwartships shock test or a statement that the maximum shock resistance is required in all directions.

d. The number of items in any batch to be tested. Normally the first unit only is selected, though the Department may select other units if a doubt exists.

e. A description of the extent of dismantling and inspection after shock tests.

f. Mode of equipment operation during the shock test.

9.02 Sample Clause for an End Product Specification for Shock Resistance

The unit shall comply with Shock Specification D-03-003-007/SF-000, Grade 2 with type A test. The narrow dimension across the base is athwartships and shall be the direction for the athwartships test, (alternatively full shock resistance is required in all three directions). Only the first unit shall be tested unless complications arise. Dismantling for inspection shall be far enough to reveal the main shaft. All ball and roller bearings shall be replaced with new ones after shock test.

9.03 Test Costs

The contract shall define the contractor's responsiblities with regard to the provision of facilities for power loading the equipment and other simulation of operating conditions and transportation to an from the place of test and the cost of tests at the Department's test establishment.

SECTION 10

AIR BLAST

Introduction

The previous chapters have considered the effects of non-contact underwater explosions on the design of Naval Ship equipment. However, the effects of air blast, on the ship's superstructure and equipment inside or outside the superstructure caused either by the ship's own guns or by an air-burst weapon, should also be considered in the design stage.

Since the blast effects caused by the ship's guns on the superstructure or decks are different from those caused by an air-burst weapon the two phenomena will be considered separately. It is important to realize that equipment and superstructures that are satisfactory for resistance to underwater shock at the weather deck level may have to be re-assessed for air blast resistance. For underwater shock and air blast it is impossible to exactly predict and formulate the responses of equipment, systems and structures. For underwater shock the criteria, although based on actual test results on different types of vessels, are necessarily arbitrary in order to cover the broad range of equipment types and systems that should survive the effects of shock. Ships are rarily subjected to underwater shocks of a severity that forms the basis for the shock design criteria. In the case of gun blast the nature of the blast-wave is known and the gun can be fired as often as one wants. No arbitrary standard is therefore required. The response of equipment and its mountings can be verified in practice. For a nuclear air blast the design criteria are simply based on a chosen static over-pressure. The 10 psi survivability criterion coincides with similar criteria with respect to radiation.

Gun Blast

The peak pressure is less and the pulse duration longer than for an underwater explosion. However, the sudden rise in air pressure is sufficiently abrupt to cause damage to equipment directly exposed to the blast and to equipment attached to the inside walls of structures that are exposed to gun-blast. The latter equipment will undergo sudden and rapid displacements caused by the impingement of the blast wave on the structure. The item will then be subjected to a shock that can be compared with the effect of a non-contact underwater explosion.

Pressure Zones

Fig. 14 shows overpressure versus distance from muzzle for the 5"/54 gun as used on the DDH-280.

Recommendations

a. No items should be located in the 15 to 20 psi zone unless they are designed to an acceleration of up to 200 g.

b. In the zone where over-pressures can be expected of 7.5 to 10 psig items should be designed to withstand an acceleration of up to 50 g or should be resiliently mounted.

c. Items in the zone where the over-pressure is less than 7.5 psi do not need special design considerations if they are designed to withstand the ordinary forces of shipboard use.

In order that equipment survive the accelerations mentioned above the following points require special attention:

(1) Resilient mounting of lights or light fixtures.

(2) Piping and ducting to use hangers with resilient bushes while hanger spacing should not be over 1 metre.

(3) Equipment mounted on bulkheads and deckheads exposed to gunblast should use resilient mounts.

(4) Locking devices are recommended for nuts and studs holding fittings to deckheads or bulkheads.

(5) Brittle materials should be avoided.

Note: For the structural design of superstructures the peak free field pressures shown in fig. 14 are modified to an equivalent static load which in general is lower than the peak recorded impulsive loads. For design guidance in this respect one is referred to the applicable structural design manual.

Blast Due to a Nuclear Airburst Weapon

Results from nuclear bomb blast trials have shown that shock damage to ships situated outside the sinking range was almost exclusively limited to superstructures, directors and equipment within superstructures. It was observed that blast waves could be amplified, due to reflection and due to the configuration of the superstructure, producing a reflected pressure of at least twice the incident overpressure.

The duration of the blast wave is in general long compared with the natural period of superstructures. The effect of this blast loading can therefore be considered as a static load. It can be assumed that equipment mounted on any structure directly exposed to nuclear blast should be designed to an acceleration of 50 g. Resilient mounting is not recommended because of the long duration of the blast overpressure. This is contrary to the recommendation for equipment subject to gun blast. Based on results from full scale trials a blast overpressure of 10 psi caused a horizontal shock acceleration in the superstructure to about twice the horizontal acceleration resulting from a lethal underwater shock.

General Recommendations

a. For a blast resistant design structural bulkheads should be continuous up through all levels of superstructure and line up with the supporting transverse bulkheads in the main hull.

b. Because proper alignment is important for radar antennas and their supports they must be designed for elastic deformations at the 3.5 psi to 4 psi blast overpressure level.

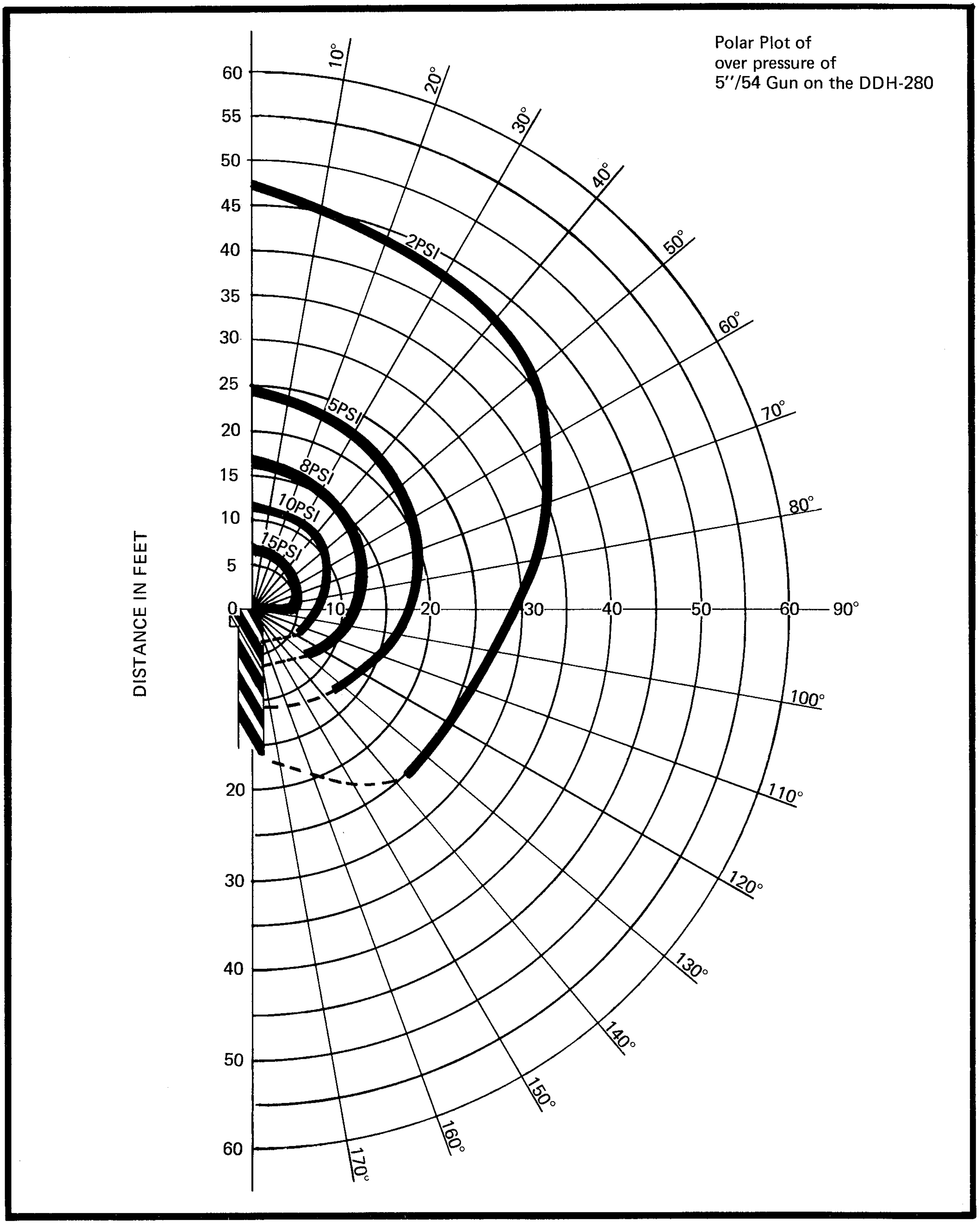
c. Protection against interior blast penetration will require assessment of the vulnerability of each compartment and installation of blast shutters in any ventilation system open to the effects of blast.

d. The use of recirculating air-conditioning is important to reduce the number of weather openings.

e. To keep the top weight to a minimum weight saving possibilities for equipment should be investigated instead of compromising the strength of the deckhouses.

f. The superstructure should be reduced to the bare minimum required for handling the ship and for antenna supports with the rest of the facilities inside the hull.

g. Large flat surfaces and re-entrant angles should be avoided.



Polar Plot of
over pressure of
5"/54 Gun on the DDH-280
DISTANCE IN FEET
2PSI
5PSI
8PSI
10PSI
15PSI
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
0
5
10
15
20
25
30
35
40
45
50
55
60

Figure 14

APPENDIX A

Shock Testing Facilities in Canada

Light-Weight Shock Testing Machines are Available at:

1. Officer in Charge
   Naval Engineering Test Establishment
   161 Wanklyn Street
   La Salle 650, PQ

2. Commanding Officer
   Land Engineering Test Establishment
   Department of National Defence
   Ottawa, Ontario
   K1A 0K2

3. Superintendent
   Quality Engineering Test Establishment
   Department of National Defence
   Ottawa, Ontario
   K1A 0K2

4. Stark Electronic Instruments Ltd
   P.O. Box 670
   Ajax, Ontario

5. Bach-Simpson Ltd
   P.O. Box 2484
   London, Ontario

6. Valeriote Electronics (Guelph) Ltd
   P.O. Box 603
   Guelph, Ontario

7. Hermes Electronics Ltd
   P.O. Box 1005
   Dartmouth, Nova Scotia

Medium-Weight Shock Testing Machine

1. Naval Engineering Test Establishment.

Contractors in the United States of America should consult BUSHIPS publication 9690.7B Ser 423-93.

NOTE: This appendix is furnished as a convenience to tendering contractors or Departmental contractors. The postal addresses of the facilities listed are accurate at time of printing but no obligation exists to maintain these facilities or their locations. Contractors are advised to obtain up-to-date information on facilities and their locations if these affect production schedules (including shipping addresses) or cost. Consult the Inspection Authority.

APPENDIX B

Canadian Forces (Sea Element)
Record of H.I. Shock Test
.... Weight Machine

Test No .... Date .... File No ....

Shock Test to Specification No .... Project No ....

Type of Test - Complete .... Sub Assy .... Component ....

Equipment Model .... Weight ....(lb) Rev ....(rpm)

Rating (volts, gpm, etc.) ....

Drawings: Gen Arrgt .... Mounting Dwg ....

Major Parts or Reason for Test	Manufacturer	Correspondence Address

Contract No .... Contractor ....

Weight of Individual Parts ....

Weight of Assy. Tested ....kg (lb) Total Weight on Anvil ....kg (lb)

Anvil Continuous Plate or Bracket Type ....

Conditions

Blow	Height of Drop	Blow Direction or Table Travel	ON or OFF	NIL	Damage Incurred
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Velocity of Support Plate under feet or base ....m/sec

Acceleration of feet (a) .... m/sec/sec (b) .... m/sec/sec

Notes:

APPENDIX C

1. Permissible Stresses

1.1 Normal Stress

The maximum permissible normal stress σ shall be the 0.2% offset static yield strength for materials having an elongation of more than 10% before rupture.

Material having less than 10% elongation shall not be used unless unavoidable or the stresses can be proved acceptable by experiment.

1.2 Shear Stress

The maximum permissible shear stress shall be 60% of the maximum permissible normal stress σ or some other experimentally proved value.

1.3 Permissible Plastic Yield

If the stress distribution in some component part of the equipment is such that appreciable areas within the material are lightly stressed (e.g. a beam of circular cross section stressed in pure bending) and if small plastic deformations of this component part do not impair the function of equipment, then a certain amount of plastic yield may be asumed.

The supplier must satisfy the purchasing authority that the amount of plastic deformation assumed is acceptable.

2. Shock Data

2.1 Symbols, Abbreviations and Nomenclature

Throughout Section 2 abbreviation DRS stands for Design Response Spectrum (or Spectra)

a	= absolute acceleration	g
a_o	= constant value of the acceleration characterizing a standard grade DRS for $f = f_s$ (see Figure C1)	g
f	= frequency	Hz
f_i	= lower transition frequency (see Figure C1)	Hz
f_s	= upper transition (or "cut-off") frequency	Hz
d	= relative displacement	m(or cm)

d_o = constant value of the relative displacement characterizing a standard grade DRS for $f = f_i$ (see Figure C1). m(or cm)

v = spectral (or "pseudo") velocity = $2\pi fd$. m s^{-1}

v_o = constant value of the spectra velocity characterizing a standard grade DRS in the interval $f_i < f < f_s$ m s^{-1}

W = modal mass or equipment mass tonnes

DRS Parameters = the quantities d_o, v_o, and a_o characterizing a given standard grade DRS.

2.2 Shock Description

2.2.1 Spectral Description

2.2.1.1 General

2.2.1.1.1 Standard Grade DRS Composition

For a given equipment mass, shock direction and shock standard grade, the Design Response Spectrum (DRS) is composed by three distinct curves, each valid in a certain frequency interval, namely:

for $f \leqslant f_i$ by a constant relative displacement curve, i.e.

$$d_o = \text{const.}$$

for $f_i \leqslant f \leqslant f_s$ by a constant spectral velocity curve, i.e.

$$v_o = \text{const.}$$

for $f > f_s$ by a constant absolute acceleration curve, i.e.

$$a_o = \text{const.}$$

In a logarithmic plotting with the frequencies as abscissae a standard grade DRS is a polygonal, the vertices of which correspond to the lower (f_i) and upper (f_s) transition frequencies (Figure C1).

2.2.1.1.2 Direction of the Shock

A standard grade shock is a set of three shocks, each acting along a principal ship direction, namely:

- a vertical shock,
- a transverse (i.e. athwarthships) shock, and
- a longitudinal (i.e. fore and aft) shock.

The DRS parameters d_o, v_o and a_o given in the following Section 2.2.1.2 refer to a vertical shock.

The DRS parameters d_o, v_o and a_o of the transverse shock are obtained by multiplying the corresponding vertical shock DRS parameters by 0.5.

The DRS parameters d_o, v_o and a_o of the longitudinal shock are obtained by multiplying the corresponding vertical shock DRS parameters by 0.25.

2.2.1.1.3 Direction of the Acceleration

The parameter a_o represents both a maximum acceleration and a maximum deceleration.

2.2.1.1.4 Use of Design Response Spectra in Modal Analyses

If a standard grade DRS is used in a modal analysis, then:

a. the mass to which the spectrum refers is to be considered as a modal effective mass and the frequency as a modal frequency; and

b. the effect of the dynamic reaction of the oscillating equipment on the foundation motion is to be considered as having been accounted for in the standard grade DRS formulation.

2.2.1.2 Grade One Shock

The grade 1 vertical shock DRS are represented graphically in Figure C1. The values of the spectrum parameters d_o, v_o and a_o, as well as those of the lower (f_i) and upper (f_s) transistion frequencies, as a function of the equipment mass W are given tabularly on Table 1 and analytically by the following correlations:

Relative Displacement	$d_o = 0.035$	(m)
Spectral Velocity	$v_o = 3.93/W^{0.16} + 0.0037\ W$	(m/s)
Absolute Acceleration	$a_o = 200/W^{0.32} + 0.0074\ W$	(g)
Lower Transition	$f_i = 17.9/W^{0.16} + 0.0037\ W$	(Hz)
Upper Transition Frequency	$f_s = 79.5/W^{0.16} + 0.0037\ W$	(Hz)

4.2.1.3 Grade Two Shock

For a given equipment mass the grade 2 vertical shock DRS parameters v_o and a_o are obtained from the corresponding grade 1 vertical shock DRS parameters by multiplying the latter by 0.5, the upper transition frequency remaining unchanged. d_o remains unchanged and the lower transition frequency will vary accordingly.

TABLE C1 - STANDARD GRADE 1 DRS PARAMETERS

W (t)	d_o (m)	v_o (m/s)	a_o (g)	f_i (Hz)	f_s (Hz)
1	.035	3,93	200	17,9	79,5
2	.035	3,50	159	15,9	70,8
3	.035	3,26	137	14,8	65,8
4	.035	3,08	123	14,0	62,4
5	.035	2,95	113	13,4	59,6
6	.035	2,84	104	12,9	57,3
7	.035	2,74	97	12,4	55,3
8	.035	2,65	91	12,0	53,6
9	.035	2,57	86	11,7	52,0
10	.035	2,50	81	11,4	50,5
11	.035	2,43	76	11,0	49,1
12	.035	2,36	72	10,8	47,8
13	.035	2,30	69	10,5	46,6
14	.035	2,25	65	10,2	45,4
15	.035	2,19	62	10,0	44,3
16	.035	2,14	59	9,7	43,3
17	.035	2,09	57	9,5	42,3
18	.035	2,04	54	9,3	41,3
19	.035	1,99	52	9,1	40,3
20	.035	1.95	49	8,9	39,4

2.2.2 Time - Domain Description

The choice of the analytical equations describing the equipment foundation motion is left with the supplier. This choice shall however comply with the following requirements.

For a given standard grade, equipment mass and shock direction, the severity of the excitation described in the form of a time history of the foundation motion shall be such that the shock response spectrum is comparable with that of the corresponding standard grade DRS over the frequency range 5 to 300 Hz.

This condition shall be considered as fulfilled when the DRS derived from the chosen foundation time history (consideration being given where necessary to the effects of the equipment reaction on the foundation motion) approximates in a satisfactory way the standard grade DRS, in the sense that for the same frequency the accelerations (both positive and negative) for the DRS relating to the chosen foundation motion time history equal or exceed those of the standard grade DRS.

For limited intervals of the frequencies small deviations from the preceding requirements are tolerated, provided that the reduction of the accelerations of the DRS relating to the chosen foundation motion time history with respect to those of the standard grade DRS does not exceed 15%. A comparison of the two spectra is to be given in the analysis report.

When it proves impossible to satisfy the preceding requirements with one foundation motion time history, the analysis is to be carried out on the basis of two or more different foundation motions, so that the envelope of their DRS satisfies the conditions specified above.

3. Analysis Report

3.1 In applying for the shock resistance qualification of a piece of equipment, the supplier shall submit to the purchasing authority a full report on the equipment shock analyses carried out on equipment. This report shall contain:

3.1.1 A description of the theoretical model (or models) simulating the dynamic behaviour under shock of the actual piece of equipment, complete with all the relevant numerical data (masses and/or moments of inertia of the inertial components, coefficients of influence or stiffnesses of the resilient component, fractions of the critical damping of the eventual dissipative components, etc.).

The description of the model (or models) shall be completed with an account of the criteria followed in deducing it (or them) from the actual constructional design of equipment (e.g. criteria at the basis of the choice of the spatial distribution of the masses, etc.).

3.1.2 A description of the dynamic analysis method used, including:

a. the theoretical background for the analytical method;

b. the critical assumptions, if any, made for simplifying the analysis, together with their theoretical and/or experimental justification;

c. the procedure used for taking account of the dynamic reaction of the oscillating equipment on the foundation motion, together with its theoretical and/or experimental basis where applicable;

d. an account of the numerical procedures used for calculating the response of equipment, with reference to the computer programmes (if any) used in connection with those procedures;

e. a complete quantitative description of the basis of the analysis showing that all the requirements of Section 2 are satisfied;

f. the results of the actual shock motion calculations carried out on the equipment model (or models) on the basis of the chosen standard grade shock;

g. the results of the actual calculation of the stresses induced in the various equipment parts by its shock motion, together with the criterion used for determining the "equivalent" stresses to be compared with the permissible ones. The assumptions made in these calculations, as concerns the stress raisers, the eventual design into the plastic field (according to point 1.4), etc. must be clearly stated and justified; and

h. a summary sheet of calculated values compared with permissible values. Calculated values that are greater than 75% of the permissible values should be identified.

The evidence required by a, b, c and d above can be dispensed with if full documentary material is already available for example in the form of technical reports describing the dynamic analaysis method used for the specific equipment considered, national standards, etc. In this case the analysis report shall contain a complete list of this background material, and, if so requested by the purchasing authority, a copy of the relevant technical documents shall be annexed to this report.

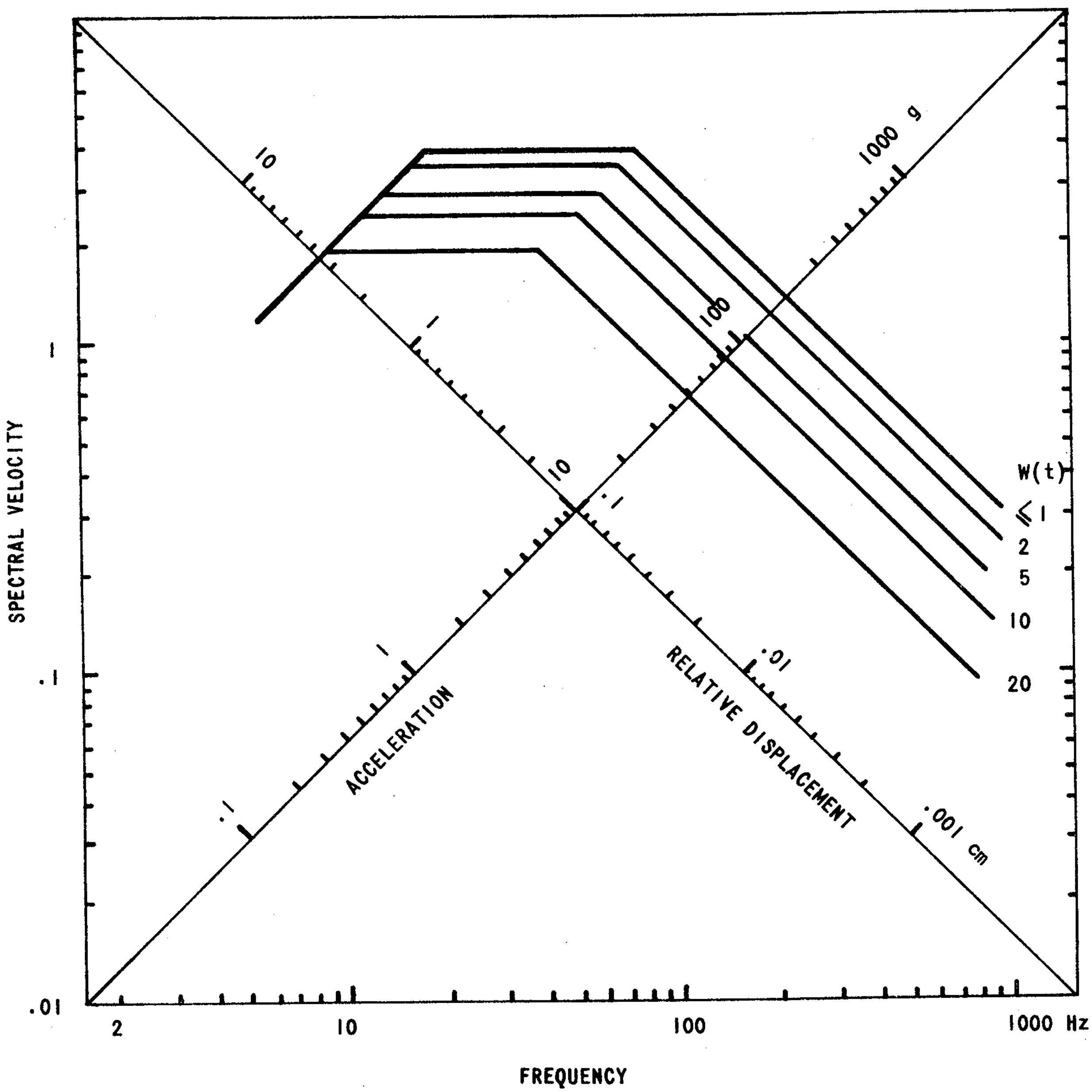


Figure C1 – Standard Grade 1 Vertical Shock Design Spectrum