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FIRST REVISION

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 096

WEIGHTS AND STABILITY

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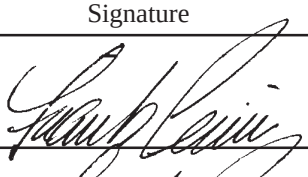
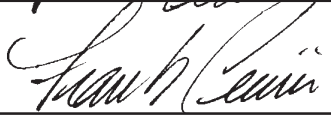
Acquisition	FRANK PERRINI		NAVSEASYSCOM	O3H33	8/2/96
Technical	FRANK PERRINI		NAVSEASYSCOM	O3H33	8/2/96
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TABLE OF CONTENTS

CHAPTER 096
WEIGHTS AND STABILITY

SECTION 1. GENERAL

SECTION 2. STABILITY: INCLINING EXPERIMENTS AND TRIM DIVES AND DEADWEIGHT DETERMINATION

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

CHAPTER 096
WEIGHTS AND STABILITY

SECTION 1.
GENERAL

096–1.1 STABILITY AND LOADING DATA

096–1.1.1 In addition to the Inclining Experiment Data, a discussion of stability and loading is prepared for inclusion in the Damage Control Books. For ships which do not have Damage Control Books, a discussion of stability and loading will be issued as a separate booklet.

a. The discussion provides operating personnel with the information pertaining to stability and buoyancy necessary to:

1. Permit proper control of loading.

2. Avoid danger of capsizing or foundering due to storms, high speed turning, etc.

3. Maintain an adequate margin of stability and reserve buoyancy to permit survival of damage within the limits imposed by the design of the ship.

4. Determine action to be taken after damage.

5. Evaluate probability of survival after damage.

b. The scope of this discussion will vary with the type of ship. However, in all cases it will contain the following material:

1. Basic data and instructions necessary to evaluate stability under any conditions of loading.

2. Criteria of adequate stability and reserve buoyancy.

3. Routine precautions to be observed, such as ballasting, limiting draft, handling of liquids, limiting deck loads, etc.

4. Discussion of the effects of damage.

096–1.2 WEIGHT CONTROL

096–1.2.1 Many naval vessels have suffered from increased weight to such an extent that it has become necessary to take drastic steps in order to avoid compromising their power of survival.

a. In some cases, the overweight condition has been so serious that the ship has been unable to carry the desired armament.

b. When conditions are such that additional weights will seriously impair survival of a ship, the Naval Sea Systems Command (NAVSEA) will not authorize any alterations involving an increase in weight unless compensating weight removals are made. This procedure is not completely effective in preventing serious weight growth unless increases in weight from other sources are also controlled. The Commanding Officer is in the best position to exercise this control. The following measures should be employed to the fullest extent:

1. Eliminate unauthorized alterations and installation of unauthorized equipment.

2. Avoid loading excessive quantities of stores, water, ammunition, fuel, and repair parts.

3. Avoid carrying extraneous items which are not assigned to the ship and do not contribute to its function.

4. Prevent excessive accumulation of paint and deck tile.

5. Survey the ship to locate unnecessary equipment, structure, fittings, stores, and miscellaneous items which may be removed or replaced by lighter installations.

c. Many of the individual items will appear to be trivial when compared to the weight of the ship, and in fact, most items have an insignificant effect in themselves. The danger lies in the cumulative effect of many weight increases which occur over a period of years. This is conclusively demonstrated by the almost invariable increase in displacement which is apparent from the results of successive inclining experiments on the same ship. All such accumulations decrease the military effectiveness of the ship and in many cases jeopardize its safety.

096–1.3 BALLAST INSTALLATION (SOLID OR LOCKED LIQUIDS)

096–1.3.1 PURPOSE. The use of ballast is most prevalent on converted merchant types and submarines. Solid ballast, particularly lead, may cause hull corrosion. See **NSTM Chapter 631**, for preventive action. Ballast is installed on ships for one or more of the following purposes:

a. To improve transverse stability.

b. To adjust trim.

c. To provide adequate immersion.

d. To eliminate an inherent list.

e. To permit submarines to submerge with neutral buoyancy and zero trim.

096–1.3.2 NAVSEA RECORDS. NAVSEA maintains a record of the solid ballast installed in each ship. These records are valuable in evaluating the ship's stability and seaworthiness, in determining the deadweight and space available for cargo, and in locating valuable material such as lead or iron in the ballast installation when a ship is scheduled for disposal.

096–1.3.3 REPORT OF CHANGES. Occasionally, the permanent ballast on a ship may be increased, decreased, relocated, or replaced. Changes in ballast may result from alterations issued by NAVSEA or may become necessary in connection with repairs or alterations. In order to maintain the accuracy of NAVSEA records, each activity installing or rearranging ballast shall furnish NAVSEA a report, with copies to the Commanding Officer of the ship involved, containing the following data pertaining to the ballast installed, removed or relocated:

a. Material and approximate density.

b. Weight installed at each location.

c. Vertical, longitudinal, and transverse position of center of gravity of ballast at each location.

d. Principal dimensions of each ballast location.

096–1.4 REPORTS DESIRED BY NAVSEA

096–1.4.1 UNUSUAL CONDITIONS. NAVSEA desires to receive reports of any unusual conditions encountered involving heavy rolling, excessive heel on turns, heavy pounding, or lack of propeller immersion which are considered dangerous or which seriously affect the operation of the ship.

096–1.4.1.1 Excessive Rolling. When excessive rolling is encountered, the following information should be included in the report:

a. General statement of condition of loading (approximate displacement, tank loading, and similar data).

b. Velocity of the wind.

c. Bearing of the wind relative to the ship.

d. Direction of approach (bearing) of the sea relative to the ship.

e. Length of waves (between crests).

f. Height of waves (from trough to crest).

g. Time interval between meeting successive crests.

h. Speed of ship.

i. Average angle of roll (upright to one side).

j. Angle of maximum roll (upright to one side).

k. Whether this roll was toward or away from wave crest.

l. Average complete period (as from port to starboard and back to port).

m. Whether rolling was regular. If not, explain. Pendulum or bubble type inclinometers, if located high above the waterline, will give readings that are too high when rolling, due to acceleration forces. In extreme cases, when inclinometers are the only instruments available, an inclinometer or temporary pendulum located as near the waterline as practicable should be used.

096–1.4.1.2 Heeling Due To Rudder Action. When reporting heel due to rudder action, it should be clearly stated whether the heel is toward or away from the center of turn, and whether it is steady heel (average around circle), initial heel inward on first moving rudder, or heel in righting the rudder to steer straight course. The speed of the ship and the angle and direction of rudder producing the heel should always be given. The speed and direction of wind and the condition of the sea relative to the ship at the point of maximum heel should also be included in cases where the effect of wind or sea is superimposed on the steady heel due only to turning.

096–1.4.1.3 Excessive Pounding. When heavy pounding is encountered, the following data should be included in the report:

a. Drafts forward and aft.

b. General statement of conditions of loading (approximate displacement, longitudinal disposition of oil, water, cargo, or other heavy loads, and so on).

c. Velocity of the wind.

d. Bearing of the wind relative to the ship.

e. Direction of approach (bearing) of the sea relative to the ship.

f. Length of waves (between crests).

g. Height of waves (from trough to crest).

h. Time interval between meeting successive crests.

i. Speed of ship.

j. Average total angle of pitch (angle included between bow up and bow down position or vice versa).

k. Angle of maximum pitch (angle included between maximum bow up position and maximum bow down position or vice versa).

l. Average complete period of pitch (as from bow up to bow down and back up).

m. Whether pitching was regular. If not, explain.

n. Severity, including statement of damage, if any.

o. Whether it was necessary to reduce speed or change course.

096–1.4.1.4 Inadequate Propeller Immersion. When inadequate propeller immersion occurs, the following data should be included in the report:

a. Drafts forward and aft.

b. Effect on speed and efficiency.

c. Any excessive vibration due to inadequate propeller immersion.

d. Longitudinal disposition of oil, water, cargo, or other heavy loads.

096–1.5 TONNAGE AND DISPLACEMENT

096–1.5.1 DEFINITIONS. The tonnage and displacement of a ship will have different values under the various definitions which have been established.

096–1.5.1.1 Displacement. The displacement of a ship at any time is the total weight of the ship with all loads that are aboard and is equivalent to the weight of water displaced by the underwater hull volume. Displacement is measured in tons of 2240 pounds, and may be determined by computation when the drafts are known or estimated by adding the variable load to the light ship displacement.

096–1.5.1.2 Conditions of Loading. For convenient reference, certain conditions such as Light Ship, Minimum Operating Condition, Capacity Load Condition, Optimum Battle Condition, and Full Load Condition, have been defined for surface ships. The displacement in any of these conditions is determined by adding the loads specified in the definition to the light ship displacement. Detailed definitions of these conditions are given in paragraph NO TAG. For submarines, surface and submerged conditions N and M are described in NO TAG through NO TAG. Equilibrium conditions for submarines are described in NO TAG.

096–1.5.1.3 Standard Displacement. The Washington treaty, proclaimed August 21, 1923, defines standard displacement as follows: “The displacement of the ship, fully manned, engined, and equipped ready for sea,

including all armament and ammunition, equipment, outfit, provisions and fresh water for the crew, miscellaneous stores and implements of every description that are intended to be carried in war, but without fuel or reserve feed water on board." See **NSTM Chapter 022**, for definition as regards submarines.

096–1.5.1.4 Deadweight Tonnage. The deadweight tonnage of a ship is the difference in tons of 2240 pounds between the displacement at the limiting draft and the light ship displacement. It represents the total load which the ship can carry at the limiting draft, including crew, passengers, ammunition, provisions, stores, water, oil, and cargo.

096–1.5.1.5 Cargo Deadweight. The cargo deadweight represents the total weight of cargo in tons of 2240 pounds which the ship can carry at the limiting draft when otherwise fully loaded. The cargo deadweight is equal to the deadweight tonnage minus the weight of a full load consisting of crew, passengers, ammunition, provisions, stores, water, and oil.

096–1.5.1.6 Admeasurement Tonnage. Gross and net tons as used for tonnage admeasurement and certification purposes are measures of volume rather than weight. They are used world–wide by national administrations and maritime industries for applying regulations, assessing canal tolls and determining pilotage, wharfage, harbor, drydocking and other such fees charged to ships. Under the Suez Canal rules, a ton is equivalent to 100 cubic feet. A ton as used in the 1969 International Tonnage Convention on Measurement of Ships (ITC 69) and the Panama Canal/Universal Measurement (PC/UMS) System varies from vessel to vessel depending upon a logarithmic function of the vessel's volume.

a. **Gross Tonnage** is based on the total volume within the enclosed portion of a ship's structure, including deckhouses, with certain exceptions.

b. **Net Tonnage** is intended to be a measure of a vessel's earning capacity, such as space available for passengers and cargo. It takes into account the volume of spaces used for propulsion, fuel, crew, operation of the vessel, etc., that do not contribute to the earning capacity.

096–1.5.2 TONNAGE CERTIFICATES. Excluding the Military Sealift Command ships, tonnage certificates applicable to U. S. Navy Ships are as follows:

a. **Suez Canal Tonnage Certificate (SCTC).** The Suez Canal Authority requires SCTCs for all U.S. Navy vessels transiting the Suez Canal, since all Canal dues and charges are based on Suez tonnage. The SCTC must be issued specifically for the ship in transit in order to avoid possible overcharges and delays. A SCTC issued for a sister vessel is no longer acceptable as evidence of a ship's Suez tonnage. Additional guidance regarding SCTCs and Canal transit procedures can be provided by the Defense Attache Office in Cairo, Egypt and is also published in:

1. Suez Canal Authority **Rules of Navigation**,

2. Defense Mapping Agency, Publication 172, **Sailing Directions (Enroute), Red Sea and Persian Gulf.**

b. **Panama Canal Tonnage.** Since 1 October, 1994, the Panama Canal Commission has required Navy auxiliary ships transiting the Canal to have a copy of one of the following documents for toll assessment purposes:

1. Panama Canal/Universal Measurement System (PC/UMS) Net Tonnage Certificate issued by the Panama Canal Commission.

2. PC/UMS Documentation of Total Volume issued by the U.S. Coast Guard (USCG).

3. Panama Canal Tonnage Certificate, if a ship qualifies under all the following transitional relief provisions:

(a) A Panama Canal Tonnage Certificate is already on board.

(b) The ship transited the Panama Canal between 23 March 1976 and 30 September 1994, inclusive.

(c) The ship has not had any volume changes greater than ten (10) percent since issuance of the Panama Canal Tonnage Certificate.

Auxiliary ships include transports, oil tankships, hospital ships, supply ships, repair ships and tenders. Amphibious ships categorized as auxiliaries by the Panama Canal Commission are the LSD 36 (ANCHORAGE) and LKA 113 (CHARLESTON) Classes.

Panama Canal tonnage certificates are not required for warships (combatants), naval training ships, floating drydocks and dredges since Canal tolls are based upon their displacement tonnage. Warships include submarines, battleships, cruisers, aircraft carriers, destroyers, frigates, mine warfare ships, and amphibious ships except as noted above. Displacement tonnage is derived from a vessel's displacement curves or draft diagram and is determined upon arrival at the Canal Zone before any replenishment loads are taken on board.

Additional guidance regarding Panama Canal Certificates and transit procedures can be obtained from the Port Services Officer of the Naval Station Panama Canal (NAVSTAPANCANAL) and from "Fleet Guide Panama Canal" Defense Mapping Agency Publication 940/941 Chapter 6.

c. **U.S. Tonnage Certificates.** As of January, 1996, these certificates are no longer required to be held on board U.S. Navy ships. Formerly known as U.S. Certificates of Admeasurement, these certificates document U.S. register (volume) tonnage. Domestic and foreign service fees charged to Navy ships are more often based on estimated vessel tonnage parameters rather than register tonnage. However, since U.S. regulations (pollution, navigation, communication, etc.) applicable to Navy ships are based on register tonnage, the USCG assigns and maintains register tonnage records for reference as required.

NOTE

International Tonnage Certificates (ITC 69) are required for Military Sealift Command ships, but are not required for U.S. Navy ships, since they are excluded as "warships" under Convention provisions.

096–1.5.2.1 Certificate Security and Disposition. Suez and Panama Canal tonnage certificates, as applicable, are required to be retained on board **in a secure place** as part of the vessel's official papers.

In case tonnage certificates on in–service ships are lost or become invalid, replacement tonnage certificates can be obtained by letter or telefax request to NAVSEA. New certificates for vessels under construction are obtained by submitting applications directly to the USCG.

Tonnage certificates for ships scheduled for inactivation are treated as follows:

a. For ships designated as "mobilization assets," Suez and Panama Canal certificates should be retained on board in a secure place. USCG will not reissue misplaced certificates until ship reactivation.

b. Ships which are to be "stricken," do not need original or replacement tonnage certificates for inactivation. Any tonnage certificates found on board may be discarded or destroyed, but not returned to NAVSEA or USCG.

c. Ships which are to be sold to other governments (foreign military sales) must have their tonnage certificates removed from the ship and destroyed.

096–1.5.3 CALCULATION OF ACTUAL DISPLACEMENT. When the actual displacement of the ship is required, it is determined by observing density of the water and the drafts forward and aft. The displacement may then be established from a displacement curve similar to that described in paragraph NO TAG or from a draft diagram.

096–1.5.3.1 Draft Marks. On ships which have projections below the keel, the Arabic draft marks designated by the letters PROJ are not suitable for use in determining the displacement without correction. The remaining draft marks, either Arabic or Roman, are for calculative purposes.

096–1.5.3.2 Draft Diagram. There are several forms of draft diagrams. The simplest form has the forward and after draft marks and the longitudinal center of flotation plotted in their relative locations with a scale for displacement plotted along the longitudinal center of flotation. The displacement in salt water is determined by connecting the drafts forward and aft by a straight line and reading the displacement on the scale. A second form is similar and is used in the same manner, except that the displacement is indicated for each inch of draft rather than plotted as a scale. A third form, similar to the second except that the longitudinal center of flotation is not shown, is used by connecting the drafts forward and aft, reading the displacement at the midship perpendicular, and applying a correction to displacement for trim as given on the diagram. The displacement will be different if the density of water in which the ship is floating is different than 64 lbs/ft^3.

096–1.5.3.3 Displacement and Other Curves. To determine the displacement by use of the displacement and other curves, the draft at the longitudinal center of flotation is calculated from the observed drafts, and the displacement in salt water read from the curves at that draft. As read, displacements should be corrected for density if different than 64 lbs/ft^3. The position of the longitudinal center of flotation is plotted as a curve, sometimes labeled Center of Gravity of Waterplane on the displacement and other curves.

096–1.6 COMPARTMENT TIGHTNESS AND TESTING

096–1.6.1 Refer to **NSTM Chapter 079, Volume 4 (9880),** for information on compartment tightness and testing.

SECTION 2.
STABILITY: INCLINING EXPERIMENTS AND TRIM DIVES AND DEADWEIGHT DETERMINATION

096–2.1 GENERAL

096–2.1.1 PURPOSE. The inclining experiment provides the basic data concerning weight and center of gravity for use in all considerations of stability, reserve buoyancy, immersion, trim, and in determining compliance with the requirements of the weight control program, after the ship is completed. An inclining experiment is the only satisfactory method of accurately determining the location of the center of gravity of a ship.

a. The information calculated or recorded in connection with an inclining experiment is as follows:

1. Displacement in light condition.
2. Location of the center of gravity of the ship in light condition.
3. Data relative to weight and location of items of variable load.

b. For submarines, in addition to an inclining experiment, a trim dive is conducted to determine the proper weight and location of the lead ballast. The information obtained is the weight and the longitudinal location of this weight required to be added to the light ship to cause the submarine to submerge with neutral buoyancy and zero trim. From this, the weight and location of lead ballast which will permit the ship to submerge under any probable condition of loading and in water of any density, is determined.

c. At times it is desirable to determine only displacement, and the longitudinal and transverse coordinates of the center of gravity. Commonly used terms for this procedure are deadweight determination or compensation check for submarines. The procedures for a deadweight determination are the same as for an inclining experiment except that inclining weights are not used and no observations and calculations are made for vertical locations of inventory items, KG, GM, and free surface. Inclining experiment forms are used for recording observed data and calculating displacements, LCG and TCG. Specific data required will be indicated in the NAVSEA authorization.

096–2.1.2 NORMAL INCLINING METHOD. An inclining experiment consists of moving one or more large weights across the ship and measuring the angle of list produced (Figure 096–2–1). This angle of list usually need not exceed 2°. As indicated in paragraph 096–2.3.11, an inclination of 1–1/2 to 3° is generally satisfactory.

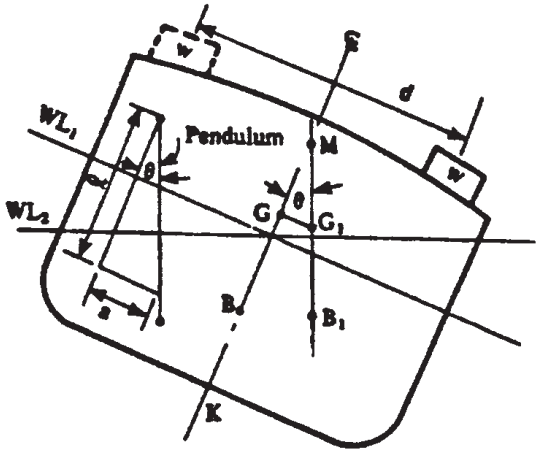

Figure 096–2–1. Effect of Weight(s) on Angle of List

096–2.1.2.1 Calculating Inclining Experiment Data. The metacentric height is derived from the formula:

$$GM = \frac{wd}{W \tan \theta}$$

where:

w = inclining weight (tons)
d = distance weight moved athwartships (feet)
W = displacement of ship including weight w (tons)
$\tan \theta$ = tangent of angle of list = a/l

a. The inclining experiment measures GM accurately. Since the ships draft is known, KM can be found from the displacement and other curves drawing. Then from Figure 096–2–1:

KG = KM – GM

b. The KG obtained from the inclining experiment is that for the ship in the condition of loading in which the ship was inclined. This is known as the As-Inclined Condition. The ship may have been in any condition of loading at the time of inclining, not necessarily an operating condition. Therefore, in order to convert the data thus obtained to practical use, the KG must be found for operating conditions. These conditions include an extreme light ship, a fully loaded ship, and one or two intermediate conditions.

096–2.1.2.2 Availability of Data. The results of the experiment are furnished to each ship as a BOOKLET OF INCLINING EXPERIMENT DATA, Part 2 (see paragraph 096–2.2). This booklet contains data on displacement, KG, and over–all stability for the operating conditions of load.

096–2.1.3 WHEN REQUIRED. Ships under construction are inclined as required by the Ship Specifications, Section 9290–3.

a. For ships in service, NAVSEA will authorize inclining experiments as considered necessary to maintain current data representative of the ship or class of ships. In cases where an inclining experiment is considered desirable by another activity, NAVSEA should be informed before the experiment is conducted since equivalent data may be available from other sources.

b. As required by the Ship Specifications, Section 9290–3, a trim dive is conducted for each submarine under construction at approximately the same time the inclining experiment is performed. On the first ship of a class, the inclining experiment must precede the trim dive. On follow ships of the same class, the inclining experiment may follow the trim dive provided that a stability check is made on each ship prior to sea trials by means of sallying ship to determine the period of roll (see paragraph 096–2.4.7). Trim dives are also conducted for each submarine prior to and after conversion and regular overhaul and when authorized for restricted availabilities (RAV) by NAVSEA.

096–2.1.4 PRELIMINARY DATA FOR NEW SHIPS. Each new ship must be furnished data regarding its stability before it joins the fleet.

a. For surface types, the standard source of stability information is the Stability and Loading Data which is issued by NAVSEA as Chapter II(a) of the Damage Control Book or as a separate publication for ships for which Damage Control Books are not prepared. If this publication has not been issued, the booklet of stability data, described in paragraph 096–2.1.2.2 is a satisfactory source of preliminary information.

b. For submarines, the standard source of stability information is the booklet of Stability and Equilibrium Data (Part 2 of the inclining experiment report) described herein. Selected sheets are to be included in the appropriate Damage Control Book.

c. If applicable data are not available, data for an earlier ship of the class may be issued and significant differences between the ships noted. If no reasonably applicable data are available, steps should be taken to obtain them (such as expediting preparation of data for inclining experiments which have already been performed). In special instances a plot of estimated righting arms for various conditions of loading will suffice if nothing better can be provided. NAVSEA should be furnished a copy of the letter forwarding the data in each case. Upon request, NAVSEA will assist in furnishing data; however, the responsibility of delivering such data rests with the Supervisor of Shipbuilding or Commander, Naval Shipyard.

096–2.1.5 PREPARATION OF STABILITY DATA FOR THE BOARD OF INSPECTION AND SURVEY. For new construction, the Supervisor of Shipbuilding or Commander, Naval Shipyard must furnish the Board of Inspection and Survey, prior to the trials, an estimate of the stability characteristics, including curves of statical stability, for the ship in the trial conditions.

096–2.1.6 PRELIMINARY REPORT OF INCLINING EXPERIMENT AND TRIM DIVE. Within one week (two weeks for CV and submarine pre–shipyard availability trim dives) of the inclining or trim dive experiment, a preliminary report of the results should be furnished NAVSEA and NAVSEC. In addition, the inclining or trim dive activity shall furnish an opinion as to the reliability of the experiment.

a Items to be included in the report are:

1. For As-Inclined Condition:

Displacement
Location of the center of gravity
Metacentric height
Free surface correction
Period of roll
Trim
Brief statement of weight to complete, weight to deduct, and weight to relocate.

2. For Condition A:

Displacement
Location of the center of gravity
Metacentric height
Statement of armament, boats, locked water ballast, solid ballast, water in non–free flooding sonar dome and salvage gear included in Condition A. For ballast and water in sonar dome, include material and center of gravity if available (normal liquids in anti–roll tank shall be treated as a load item and not part of Condition A).

3. For submarines (in addition to applicable data above): Weight and longitudinal center of gravity of load to submerge. Condition N Surface, N–Sub, M–Surface and M–Sub (where applicable) including vertical and longitudinal centers of gravity for each condition. GM and BG for appropriate conditions. Equilibrium polygon (paragraph 096–2.8.19) and equilibrium conditions as defined by paragraph 096–2.8.21 and Table 096–2–3.

4. Displacement and other curves drawing.

5. Photographs required by paragraph 096–2.3.14.

b The purpose in providing an early preliminary report is to permit evaluation of the ships stability and reserve buoyancy as soon as practicable. The preliminary report may indicate the necessity for action to improve the ship, a change in policy on weight control or additional inclining experiments.

c It is not necessary that the data in the preliminary report be checked in detail, but a broad check should be made to ensure that the figures reported are sufficiently accurate to form the basis for any necessary action. It will be satisfactory to report Condition A with installed armament and boats rather than ultimate allowances, if the

preliminary report will be expedited by this procedure. The preliminary report shall be submitted on the appropriate forms designated in paragraph 096–2.13.1.

096–2.1.7 CONTRACTOR'S RESPONSIBILITY FOR NEW SHIPS. When ships are building at a private shipyard the contractor's responsibilities are covered by Section 9290–3 of the Ship Specifications (or superseding number).

096–2.2 BOOKLET OF INCLINING EXPERIMENT DATA

a The BOOKLET OF INCLINING EXPERIMENT DATA is prepared by the inclining activity. In the case of ships which are built or converted at a private shipyard, the BOOKLET OF INCLINING EXPERIMENT DATA is prepared by the contractor under the supervision of the Supervisor of Shipbuilding.

b The BOOKLET OF INCLINING EXPERIMENT DATA consists of two parts. Inclining Experiment Report (Part 1) contains the observations and calculations leading to the determination of the displacement and location of the center of gravity of the ship in the light condition. Stability Data (Part 2) for surface ships and Stability and Equilibrium Data (Part 2) for submarines contain data relative to the characteristics of the ship in the operating conditions. The contents of the BOOKLET OF INCLINING EXPERIMENT DATA are discussed in detail in paragraphs 096–2.5, 096–2.6, and 096–2.8 and subordinate paragraphs thereto.

096–2.2.1 REFERENCE LINES. The reference lines used for longitudinal, vertical, and transverse centers in the BOOKLET OF INCLINING EXPERIMENT DATA shall be the same as those used on the displacement and other curves drawing.

096–2.2.2 ADDITIONAL INFORMATION. Additional information, other than specifically requested in this chapter, which is necessary to interpret the inclining and stability data should be included in the appropriate part of the BOOKLET OF INCLINING EXPERIMENT DATA.

096–2.3 SHIPBOARD PREPARATIONS FOR INCLINING EXPERIMENT

096–2.3.1 IMPORTANCE OF PREPARATION. Inclining experiments will interfere with productive work and with operations aboard ship. Since the safety of the ship or a class of ships depends upon reliable stability data, this interference must be accepted. The effort of inclining may be wasted when unknown or unsatisfactory conditions exist. Undetected errors may jeopardize the safety of the ship. No production work or other testing shall be done during the inclining experiment.

096–2.3.2 COOPERATION OF SHIPS FORCE. If the ship is in commission when inclined, it is essential that the ships force cooperate in obtaining favorable conditions for the experiment. Arrangements should be made with the Commanding Officer, well in advance, to have the ship in the best possible condition in regard to trim, list, and disposition of liquid. In preparation for and during the experiment, the Commanding Officer should assist by preventing transfer or discharge of liquids, securing swinging weights such as boats or booms, pumping down bilges, and reducing ships personnel aboard to a minimum. Although the inclining activity is responsible for the accuracy of all observations, the ships force when requested can assist materially by furnishing information regarding quantity and location of all loads and repair parts and providing access as required.

096–2.3.3 STABILITY AT TIME OF INCLINING. It is essential that the ship have positive metacentric height when inclined, taking into account the correction for free surface and the effect of inclining weights. If stability is in question, ship may be sallied per paragraph 096–2.4.7 to estimate GM.

096–2.3.4 FREE SURFACE AT TIME OF EXPERIMENT. Correction for free surface existing when the ship is inclined may be an extremely important factor.

a Any error in determining the free surface correction is reflected directly as an equal error in the height of the center of gravity of the ship.

b To calculate the free surface correction the following conditions must be met.

1. Actual moment of inertia of free surface must be known.

2. Moment of inertia of free surface must not change appreciably during the inclination.

c Favorable conditions obtained before the experiment will do much toward establishing an accurate free surface correction and simplifying the calculations. If a tank can be completely filled or completely emptied, the correction is eliminated. A tank cannot be assumed completely emptied unless it is definitely known that the liquid below the suction has been removed. A tank cannot be assumed completely full unless the sounding is above the highest point of the tank and it is known that no air pockets exist. To eliminate air pockets, an air escape must be available at the highest point of the tank. It may be possible to heel the ship so that the air escape will be at the highest point while the tank is filling.

d If a tank is nearly full or nearly empty, the effect of the free surface cannot be determined since the moment of inertia of the surface will change rapidly as the liquid touches the top or as the bottom is uncovered. This condition must be avoided.

e Accordingly, liquid in all tanks having a significant free surface correction should be adjusted so that the tanks are completely full, completely empty, or filled to a level at which the moment of inertia will be constant throughout the angle of inclination. Trim should be considered in determining whether or not the liquid will touch the top or uncover the bottom of the tank.

f In view of the difficulty encountered in completely filling or completely draining tanks, it is recommended that tanks be generally between 20 and 80 percent full, provided that this will not produce negative metacentric height during the experiment.

g Bilges should be pumped down to the bottom of the suctions. Bilge water below this level is considered as part of the light ship displacement. No correction is made for the free surface effect of bilge water in determining the vertical center of gravity of the ship if this level is obtained.

h Sufficient details of tank dimensions shall be included to permit examination of the free surface calculations.

096–2.3.5 LIST AND TRIM. The ship should be nearly upright at the time of inclining. A list of less than one degree is desirable. While not essential, it is desirable that trim be such that the displacement and other curves drawing can be readily used. These conditions will simplify calculations in several respects. If trim is sufficient to change form characteristics from the displacement and other curves drawing, it will be necessary to calculate displacement, position of metacenter, and longitudinal center of buoyancy corresponding to actual draft and trim. Excessive trim will also make it necessary to correct observed tank capacities and vertical centers of tanks and make it difficult to obtain a determinate free surface at time of inclining. Excessive trim is defined in paragraph 096–2.5.5.

096–2.3.6 FORCES WHICH AFFECT HEEL. Insofar as possible, inclination of the ship should not be influenced by forces other than the inclining weights. Effect of gangways, floats, fenders, appendages, swinging weights, submerged obstacles, and shifting of personnel or liquids aboard shall be eliminated. A check of water depth shall be made for the entire ships length to ensure that a sufficient depth of clear water exists below the ship bottom. If possible, the experiment should be performed when the tide is slack. Effect of wind, pier, mooring lines, cable, and hose should be reduced to a minimum. Lines and essential cable and hose should be well slacked when readings are taken.

096–2.3.7 WEIGHT TO COMPLETE AND WEIGHT TO DEDUCT. The ship should be as nearly complete as possible at time of inclining in order to reduce the weight to complete.

a The weight to deduct, and the possibility of error, can be substantially reduced by removing foreign items to the greatest possible extent. Weights and centers of gravity of staging and yard equipment are particularly difficult to estimate.

b. On–board repair parts and equipment should be stowed and secured in their proper locations.

c. Water and oil in machinery should be brought to the working level, if possible. Any difference from normal conditions must be entered as a weight to complete or a weight to deduct including any significant vertical moment caused by changes in free surface.

096–2.3.8 PERSONNEL ABOARD. The number of men aboard during the experiment should be reduced to a minimum. This applies to both ship and yard personnel.

096–2.3.9 CHANGES DURING EXPERIMENT. The possibility of liquid flowing from one tank to another or being pumped overboard should be eliminated.

a. All valves in oil and water systems adjacent to the tanks and all sluice valves should remain closed during the experiment. Attention should be given to the possibility of leaking valves.

b. Personnel aboard during the experiment should be in the same position each time the inclination is measured.

c. Swinging weights such as boats and booms should be secured.

096–2.3.10 CHECKING OF DRAFT MARKS. If possible, the keel should be surveyed in drydock and an arbitrary baseline for determining the corrections to draft readings for calculative purposes established. This arbitrary baseline is a straight line if the keel is substantially straight with local irregularities, or a fair curve if the ship has a permanent hog or sag. The intent is to establish a baseline such that the displacement, as determined from draft readings corrected to this baseline, will be as accurate as possible. Corrections to draft mark readings found by this method correct only for errors in placement of the marks and for local irregularities of the keel. The effect of permanent hog or sag is taken care of in the “As Inclined” calculations. If corrections to draft readings for calculative purposes have already been entered on the docking drawing, these figures may be used and the procedure above will not be necessary.

096–2.3.11 INCLINING WEIGHTS. Solid inclining weights should be used. Weights should be selected which will produce an angle of heel sufficient to insure accurate results. Inclinations should not be carried beyond the angle at which the statical stability curve departs from the tangent at zero degrees. An inclination of 1–1/2 to 3° is generally satisfactory.

a. An arrangement by which the weights are rolled across the deck is preferable to lifting the weights and setting them down in another position. Self–propelled equipment is effective on carriers.

b. The weight of each of the inclining weights should be accurately determined and recorded.

c. Missile tube doors may be used as inclining weights on SSBM submarines.

096–2.3.12 MEASURING INCLINATION. Provisions should be made for measuring angles of inclination independently at three stations. Measurements may be made by pendulums or other devices which, in the opinion of the inclining activity, will ensure accurate results. If pendulums are used, they should be free to swing throughout the range of inclinations. Pendulum vibrations should be damped by suitable means, such as a bucket of liquid in which the bob is immersed. Rigid horizontal transverse battens should be provided at the lower ends of the pendulums for recording deflections. The length of each pendulum, from the point of suspension to the batten, should be recorded.

096–2.3.13 MIDSHIP DRAFTS FOR SURFACE SHIPS. Provisions should be made for reading the draft amidships at the time the ship is inclined to permit a correction for hog or sag and list determination. If midship draft marks are not installed, a datum point should be established on each side at or near amidships above the anticipated waterline. When the datum points mentioned above have been established, a single permanent draft mark should be fitted on each side of the ship approximately amidships for future use. This mark is an Arabic numeral, 6 inches high, similar to the draft marks required by the Ship Specifications. This mark should indicate the draft above the bottom of the keel, and its location should be indicated on the docking drawing.

096–2.3.14 PHOTOGRAPHS. Arrangements should be made to obtain photographs of the ship at the time of inclining. The intent is to record the important topside installations and the reading of the draft marks. These photographs should be forwarded with the preliminary report mentioned in paragraph 096–2.1.6. Photographs of the draft readings should be taken with zero inclining moment.

096–2.4 CONDUCTING THE INCLINING EXPERIMENT AND SUBMARINE TRIM DIVE

096–2.4.1 INVENTORY. An accurate inventory is conducted to determine the weight to complete, weight to deduct, and weight to relocate. Reference should be made to the definition of Condition A (see paragraph 096–2.5.3) and an inventory taken to determine the weight and coordinates of the center of gravity of all items included in Condition A which are not aboard at the time of inclining and of all items aboard which are not part of the Condition A weight. Any variation of the depth of bilge water from the level of the bottom of the suction should be recorded and accounted for as required by paragraph 096–2.5.10.b.

a. In preparing the list or weight to complete, the various shops, planning sections, and the ships force should be consulted in order to determine the scope of the work remaining to be done and the weight still to go aboard. The effect of authorized allowance list changes should be included.

b. The weight to deduct is determined by a thorough survey of the ship by the inclining activity. Each tank should be sounded before and after the experiment unless there is definite assurance that no change in loading has occurred. It is advisable to check the overall length and general positioning of sounding tubes versus information given in tank capacity tables and curves. If for any reason significant differences are noted, further inspections should be made to define the level of the liquid in the tank.

c. Voids and cofferdams should be investigated. Consideration should be given to the possibility of small quantities of oil below the zero sounding and to the possibility of air pockets as discussed in connection with free surface in paragraph 096–2.3.4. The actual specific gravity of liquids aboard should be determined. The weight and center of gravity of items of oil and water in machinery which differ from the normal operating condition should be recorded. Solid weights to deduct include ammunition, provisions, stores, personnel, yard equipment, cargo, aircraft, aircraft stores, yellow gear, inclining gear, and dunnage.

d. If any weights which are part of Condition A are aboard but not in their proper location, their weight and the location of their center of gravity should be recorded, together with the position of their center of gravity in their final location. Such items are labeled weights to relocate.

e. In addition to changes necessary to bring the ship to Condition A, the weight and the vertical and longitudinal position of the center of gravity of items of boats, armament, storage batteries on submarines, liquid and solid ballast, water in non–free flooding sonar, salvage gear, and other similar large items which are included in Condition A should be recorded. Ships records should be consulted for information on solid ballast and the ballast examined to ensure that the records are complete and reasonably accurate. Identification and location by frame and level may be used for armament if weights and centers are not readily available.

096–2.4.2 DRAFT READINGS. Draft readings should be taken on all available draft marks at the time the ship is inclined. It is essential that the drafts forward, aft, and amidships (where amidships draft marks are installed) be determined. Where both calculative and navigational draft marks are fitted, the navigational draft marks should be used as an approximate check on the readings taken on the calculative marks.

a. In taking the midship drafts, readings port and starboard should be taken simultaneously.

b. Use of a glass tube with a small hole in the bottom or a similar device, is recommended in order to damp out wave action. Draft readings should be taken to the nearest one-quarter of an inch.

096–2.4.3 DENSITY OF WATER. The density of the water is determined when the ship is inclined. Several samples should be taken at various locations and depths as a check against variations in density due to local conditions. The hydrometer reading must first be corrected for temperature and then the corrected specific gravity

converted to density. The hydrometer scale may be based on pure water at either 4_C or 60_F having a specific gravity of 1.0000. If it is based on 4_C, the corrected specific gravity should be divided into 35.922 to obtain the specific volume of the water sample in cubic feet per ton. If it is based on 60_F, the corrected specific gravity should be divided into 35.955 to obtain the specific volume.

096–2.4.4 WEIGHT MOVEMENTS. The inclining weights are moved transversely to produce at least two inclinations to port and two to starboard, the intermediate inclinations being about one–half of the maximum inclination (see paragraph 096–2.3.11). The weights are returned to their original position after the extreme weight movement to port and again after the extreme weight movement to starboard.

a. Measurement of the transverse distance of each weight from its original position is recorded after each movement.

b. Motion of the weights across the deck should be steady and slow to avoid inducing a roll. If weights are handled by a crane alongside, they should be lifted and set down as slowly as possible.

096–2.4.5 MEASUREMENT OF INCLINATION. Readings to determine the inclination of the ship should be taken with the inclining weights in their initial position, after each movement of the weights and with the weights returned to their original position at the conclusion of the experiment. Readings should be taken simultaneously at all three stations. The signal to read the inclination should be given after allowing sufficient time for the ship to come to a position of equilibrium after movement of the weights. All personnel should be in their original positions. The ship should be clear of the pier and all lines well slacked. The signal to read should be given at a time when the external forces are at a minimum and the ship is as steady as practicable. If the ship is not absolutely steady, the reading of inclination should be taken at the midpoint of the vibration.

096–2.4.6 PLOT OF TANGENTS. During the inclination, the tangents of the angles of inclination should be plotted against he transverse moments of the inclining weights, using the initial positions of the weights and pendulums as the zero points for each. The tangents of the angles of inclination for the two cases of weights returned to their original positions should also be plotted. Variations of the resulting plot from a straight line indicate that conditions are not favorable or that an error has been made, in which case a check should be made to determine the cause. After any corrections have been made, the experiment should be repeated to obtain a correct set of readings.

096–2.4.7 DETERMINATION OF PERIOD OF ROLL CONSTANT. Prior to the weight movements, the ship should be sallied (induced rolling) and the complete period of roll determined. As soon as the slope of the Plot of Tangents can be determined, the roll constant for the ship should be calculated and compared to the values for other ships of the same class. If the roll constant is not in line with values for the class, the reliability of the results obtained up to that point should be questioned. The ship should be sallied again later during the experiment to confirm that the period of roll used in the calculations is correct.

a. The following methods of inducing a roll are suggested:

1. By landing a weight on one side of the ship and lifting it rapidly by means of a crane. Cribbing should be provided if necessary to avoid damage to the ship.

2. By taking a lift, on a suitable fitting on one side of the ship near amidships, by means of a crane and slacking off rapidly.

3. For small ships, by a group of men moving across the deck in synchronism with the period of roll of the ship. After an adequate roll has been built up, the group should remain on the centerline while the period of roll is timed. For aircraft carriers, the use of trucks on the flight deck in the same manner is effective. If trucks are not available a large group of men can be used.

b. After rolling has been induced, the total time of three or more rolls is measured by means of a stopwatch, and the period of roll is determined by dividing the total elapsed time by the number of rolls. The roll constant is then calculated from the formula:

$$C = \frac{T\,(GM)^{1/2}}{B}$$

Where

C=roll constant
T=average time of one complete roll (port to starboard to port) in seconds.
GM="as inclined" metacentric height (GM =slope of Plot of Tangents divided by the displacement)
B=maximum beam to the outside of plating on DWL for surface ships
=maximum beam of ships hull for submarines.

c The value of sally constants for surface ships varies from 0.40 to 0.50. For submarines, the value for a body of revolution hull is about 0.40 to 0.45. For other submarines, it varies from 0.32 to 0.37.

d. Sallying gives fairly accurate results for ships in calm water, however, it is not practical for use at sea or after damage.

096–2.4.8 SUBMARINE TRIM DIVE. An area should be selected for performing the dive which is free from strong currents and sharp density gradients. Insofar as practicable, tanks should be dry or completely full.

a. The information to be obtained from the trim dive is the weight and longitudinal center of gravity of the load to submerge and the density of the water in which the dive was made. The load to submerge is defined as the total load, including all water ballast, required to be added to Condition A to submerge the ship in water of a specified density in a condition of neutral buoyancy and zero trim.

b. The ship is completely submerged and the variable ballast is carefully adjusted to obtain neutral buoyancy and zero trim. The ship should be stopped and held at rest long enough to make certain that these conditions are obtained.

c. The density of the water in which the dive is made is determined from a sample taken while the ship is submerged. Sea water should be drawn from a fitting or piping system which is in direct communication with the sea, preferably a circulating water system. See paragraph 096–2.4.3 for information on density calculations.

d. Reference should be made to the definition of Condition A (see paragraph 096–2.5.3) and an inventory taken to determine the weight and longitudinal center of gravity of all items aboard which are not part of the Condition A weight. The inventory should include, as a negative load, any variation of the air in banks from the weight of the full charge or missing light ship items. The total obtained from this inventory is the Load to Submerge corresponding to the water density observed at the time.

096–2.5 CONTENTS OF INCLINING EXPERIMENT REPORT (PART 1) FOR SURFACE SHIPS AND SUBMARINES

096–2.5.1 GENERAL. The ships name and identification number; place; date and time of inclining; supervising office; and data regarding wind, tide, and mooring conditions are entered on the title page. Direction of wind and tide should be given relative to the ship. All drawings and other data used in preparing Part 1 are listed under References. The various pages comprising this Part, are listed under Contents and in the order listed in paragraph 096–2.13.1 (Table 096–2–7A).

096–2.5.2 ARMAMENT, BOATS, SUBMARINE BATTERIES, BALLAST. Significant items of weight which are included in Condition A but which are subject to change or readily removable are listed. Such items as boats, armament, ballast, salvage gear, and storage batteries on submarines are included. The weight, center of gravity, and the vertical, transverse, and longitudinal moments of these items are listed. Where there is a difference between peacetime and wartime allowances, a listing of both shall be given. Armament may be listed by item and location identification if weights and centers of gravity are not readily available.

096–2.5.3 SHIP IN CONDITION A–LIGHT SHIP. The weight and location of the center of gravity of the ship in Condition A as obtained from the inclining experiment are entered on this sheet and modified if necessary to conform to any changes in Condition A since the inclining experiment.

a. From the above, the draft at the longitudinal center of flotation, metacentric height, moment to heel one degree, trim, drafts forward and aft, and curve of statical stability are obtained.

b. The Light Ship Condition, designated as Condition A, includes the weight of the ship with all those items which are not consumable and not subject to frequent change. Included are items which are expected to be aboard post delivery and weight reservations. It is intended primarily to serve as a basic condition to which the items of variable load may be added in order to arrive at the other conditions of loading.

096–2.5.3.1 Semi-Permanent Weight Items. The following are examples of items which are considered to be reasonably permanent and are therefore included in Condition A:

8254)	Permanent ballast (solid or liquid)
8255)	Boats (including fuel)
8256)	Liquids in machinery at operating levels
8257)	Liquids in all piping systems which normally contain liquid (drainage systems are assumed to be dry)
8258)	Air in banks (full charge)
8259)	Electrolyte in storage batteries at minimum operating level
8260)	Bilge water (to level of bottom of suction)
8261)	Armament
8262)	Salvage gear
8263)	Tools
8264)	Equipment and outfit
8277)	Water in the emergency heat exchanger tank
8265)	On-board repair parts (except aircraft onboard repair parts)
8266)	Foamite cans
8267)	Emergency rations and fresh water
8268)	Water in torpedo impulse tanks
8269)	Water in charging water day tanks
8270)	Water in surge tanks
8271)	Liquid in bilge sump (collecting) tanks and dirty drain tanks
8272)	Waste oil collecting in non-compensated tanks
8273)	Oil in sludge tanks and waste lube oil tanks which are considered empty in conditions N and M
8274)	Hydraulic oil in main and vital hydraulic oil systems, (not including reserve tanks)
8275)	Water in fuel oil overflow or salt water expansion tanks associated with the low pressure compensated fuel oil system
8276)	Water in NFO expansion tanks, (these are tanks full of salt water at all times as compared to the expansion tank in the fuel oil system that can carry fuel oil or water)

NOTE

Any of the above items which are carried for issue to other ships or activities are considered as cargo and are included in the variable load rather than in Condition A.

096–2.5.3.2 Transverse Moments. Transverse moments are entered and the list is calculated on this sheet for all new construction surface ships, older ships which are known or suspected of having a list problem as determined by consultation with ships force, and for paragraph 096–2.11.1). Transverse moments are not required for submarines.

096–2.5.4 CHANGES IN CONDITION A WEIGHT SINCE INCLINING. All significant details of the changes in Condition A since the inclining experiment, with weights, centers of gravity and the longitudinal,

vertical, and transverse (if required) moments of the various items are included. Separate summations are made for weights added, weights removed, and weights relocated so that the totals may be entered under Ship in Condition A.

096–2.5.5 DISPLACEMENT AND CENTER OF GRAVITY AS INCLINED. The displacement and the location of the center of gravity as inclined are calculated from the observed drafts, density of water, slope of the plot of tangents, and the vertical moment of free surface. If the ship does not have a large trim when inclined, the form entitled, Displacement and Center of Gravity As Inclined – Trim Not Excessive, is used. If the trim is large, the forms entitled, Displacement and Center of Gravity As Inclined – Trim Excessive, and, Functions of Wedge Areas, are used and the displacement and center of gravity determined by the method indicated thereon. Use of the latter forms will not be necessary unless the trim differs from the displacement and other curves trim by an amount in excess of 1/150 of the length between perpendiculars or unless there is an abrupt change in the shape of the waterplane due to trim. List and off-center moment calculations are made only for those ships described in paragraph 096–2.5.3.1 above.

096–2.5.6 FUNCTIONS OF WEDGE AREAS. This form is used to determine hydrostatic functions for an inclined water line for a ship with an excessive trim.

096–2.5.7 DISPLACEMENT AND CENTER OF GRAVITY IN CONDITIONS A AND A–1. The displacement and the center of gravity in Condition A are calculated by modifying the as inclined condition to take into account the weight to complete, weight to deduct, and the weight to relocate. The displacement and center of gravity in Condition A–1 are calculated by deducting the permanent ballast, solid and liquid, from Condition A. Transverse moments are included only for those ships described in paragraph 096–2.5.3.1.

096–2.5.8 WEIGHT MOVEMENTS AND INCLINATIONS. Each inclining weight or group of weights which are moved as a unit is assigned an identifying number and its weight (in pounds or tons) and its location (including whether port or starboard) are tabulated. If pendulums are used, their lengths and locations are given, or if other devices are used, their locations are given. For each position of the weights, including the final position, the total inclining moment is calculated, and the tangent of the angle of inclination, as determined from each pendulum or other device, is entered. The inclining moment is calculated using the distance of each weight from its original position prior to the first weight movement, not the distance from an intermediate position. If pendulums are used, the deflection of each pendulum is entered in addition to the tangent of the angle of inclination.

a. Identifying symbol. An identifying symbol is assigned to each tangent reading on each device to correlate these figures with the plot of tangents.

b. Plot of tangents. Refer to paragraph 096–2.4.6.

096–2.5.9 WEIGHT TO COMPLETE, WEIGHT TO DEDUCT, AND WEIGHT TO RELOCATE. The total weight and the vertical, longitudinal, and transverse moments of each of these items, as described in paragraph 096–2.4.1 are calculated. A summary sheet should be included for a group whenever the number of sheets in the tabulation of that group exceeds five.

096–2.5.10 VERTICAL MOMENT OF FREE SURFACE AS INCLINED. For each tank which was not completely full or completely empty at the time of the inclining experiment, the moment of inertia of the actual Free surface about longitudinal axis through its centroid is calculated.

a. The vertical movement of the free surface is calculated by dividing this moment of inertia by the specific volume of the liquid in cubic feet per ton. The sum of the vertical moments for each of these tanks is the total vertical moment of free surface as inclined.

b. If the level of the water in the bilges is at the bottom of the suction, no correction for free surface of bilge water is made since this quantity of bilge water with its free surface is considered as part of Condition A. If the level of the water in the bilges is above or below this level, a correction is made for the difference in free surface effect of the water at the actual and normal levels. When the configuration of the bilges and quantity of water are

such that a substantial transverse motion of bilge water occurs at the angles of heel obtained during the experiment, the free surface effect cannot be evaluated in terms of vertical moment of free surface. In such cases, it is necessary to determine, for each angle of inclination obtained during the inclining experiment, the actual transverse position of the center of gravity of that portion of the bilge water which exceeds the normal quantity. The free surface effect of the excess bilge water is then taken into account by adding its transverse moments to the transverse moments of the inclining weights at the various angles of heel.

096–2.5.11 DIAGRAM SHOWING LOCATION OF DRAFT MARKS. A sketch shall be made of the profile of the hull to show the location of the draft marks relative to the perpendiculars. The reference line for longitudinal centers shall also be included, as well as the relationship of the molded baseline to the bottom of the keel amidships.

096–2.5.12 REMARKS AND MISCELLANEOUS CALCULATIONS. All calculations leading to the determination of Condition A should be included in the report.

a. Calculations such as the determination of the moment of inertia of free surface, which cannot be presented on the other forms, should be furnished on the form entitled Remarks and Miscellaneous Calculations.

b. In determining the capacity, center of gravity, and free surface effect of tanks in the as inclined condition, consideration should be given to the list and trim at the time the tanks were sounded. In a long tank, the liquid level at one end may be several inches above or below the level at the other end. Similarly, a free surface may not extend throughout the length of a tank, or a free surface may exist which is not apparent from the soundings.

c. Any explanatory remarks or information that would be useful in evaluating the Inclining Experiment Report should be included on the form Remarks and Miscellaneous Calculations.

096–2.6 CONTENTS OF INCLINING EXPERIMENT REPORT, (PART 2) STABILITY DATA FOR SURFACE SHIPS ONLY

096–2.6.1 STABILITY DATA FOR SURFACE SHIPS ONLY. The ships name, identification number, and general measurements are entered on the title sheet. Under References, all plans and other data used in preparing the booklet are listed. The various pages of this Part are listed under Contents, and in the order listed in paragraph 096–2.13.1 (NO TAGB).

096–2.6.1.1 Armament, Boats, Submarine Batteries, Ballast. Refer to paragraph 096–2.5.2.

096–2.6.1.2 Ship In Condition A-Light Ship. Refer to paragraph 096–2.5.3.

096–2.6.1.3 Changes in Condition A Weight Since Inclining. Refer to paragraph 096–2.5.4.

096–2.6.2 LOADING CONDITIONS INCLUDED IN REPORT. The definitions of loading conditions for surface ships are given in paragraph 096–2.7.2. The document authorizing an inclining experiment will indicate the loading conditions required for the particular experiment.

a. Two forms are provided for each of these conditions; one entitled Ship in Condition____(Small Free Surface Effect) and the other Ship in Condition____(Large Free Surface Effect). As specified in paragraph 096–2.10.2, the former is used when the total moment of inertia of all slack tanks in feet to the fourth is numerically less than twenty times the displacement in tons. Otherwise, the latter form is used.

b. The title of the appropriate condition should appear at the top of the sheet.

096–2.6.3 EXCESSIVE TRIM IN LOADING CONDITION. Should the trim in the loading condition exceed 1/150 of the length between perpendiculars or there is an abrupt change in the shape of the waterplane due to trim, the required form characteristics should be determined manually with the aid of Bonjean curves or by computer means, utilizing a program approved by NAVSEA. The righting arm curve trim corrections need only be determined if a suitable computer program is readily available or specifically required by NAVSEA.

096–2.6.4 DISPLACEMENT AND OTHER CURVES. The following form characteristics are plotted against draft and included in the stability data:

8278) Displacement in salt water & Delta;SW
8279) Transverse metacenter. KM
8280) Moment to trim one inch. MTI
8281) Tons per inch immersion. TPI
8282) Longitudinal center of flotation. LCF
8283) Longitudinal center of buoyancy. LCB

a. A statement as to whether the curves are based on even keel or (x) feet trim between drafts or perpendiculars should be included.

b. Wherever possible, separate scales should be provided for each of these functions so that their values may be read directly. It is not necessary to plot the functions for drafts below the light ship draft. A sample sheet showing a satisfactory arrangement is shown on Figure 096–2–2. A copy of an applicable diagram for a sister ship may be used.

096–2.6.5 CROSS CURVES OF STABILITY. A set of cross curves of stability is included, covering approximately the same range of displacement as the form characteristics. A statement of the assumed axis and the extent of watertightness of the hull is included. A sister ship diagram may be used.

096–2.6.6 DIAGRAM SHOWING LOCATION OF DRAFT MARKS. Refer to paragraph 096–2.5.11.

096–2.6.7 APPROXIMATE CHANGE IN METACENTRIC HEIGHT DUE TO ADDED WEIGHT. A diagram is included showing the approximate change in metacentric height due to adding a fixed weight at levels between the keel and the highest level of the superstructure. The fixed weight considered is a round number of tons, about one percent of the full load displacement. The effect of this added weight is shown by a straight line for each condition of loading included in the stability data, plotted so that ordinates represent heights of the added weight and the abscissae represent the increase or decrease in metacentric height. The effect of the added weight in changing the position of the transverse metacenter and the vertical position of the center of gravity of the ship are taken into account. The heights of the various deck levels amidships are indicated on the diagram.

096–2.6.8 SUMMARY OF LOAD ITEMS. The weights and locations of the center of gravity of each item of load as defined in paragraph 096–2.7.3 are tabulated. The load items are added to the ship in Condition A to obtain the displacement and center of gravity for the ship in the applicable conditions outlined in paragraph 096–2.6.3. Transverse moments are included only for new construction and ships with a list problem as described in paragraph 096–2.5.3.2.

096–2.6.9 DETAILS OF LOAD ITEMS. Details of the items of load for each load condition are included. The weight, location of the center of gravity, and the associated moments are tabulated and separate summations made for each type of load. For ships having a small free surface effect, as discussed in paragraph 096–2.6.2, the vertical moment of free surface is included in this tabulation as specified in paragraph 096–2.10.2.a For ships which have a large free surface effect, the tabulation of vertical moment of free surface is not made on these sheets since the free surface effect is determined by a separate calculation as discussed in paragraph 096–2.10.2.b

096–2.6.10 CORRECTION TO RIGHTING ARMS FOR FREE SURFACE. This calculation, details of which are discussed in paragraph 096–2.10.1, is included only for ships which have a large free surface effect.

096–2.6.11 TANK CAPACITIES. A tabulation is made of all tanks or voids fitted for carrying liquids in bulk, including salt water ballast. Tanks are grouped according to the type of liquid carried. The vertical moment of free surface, capacity in gallons and tons, and the vertical, longitudinal and transverse position of the center of gravity are tabulated. Capacities of oil tanks correspond to the 95 percent full condition, and capacities of water tanks to 100 percent full. Capacities of gasoline tanks correspond to the rated gasoline capacity and, in addition, the weight of salt water at the rated capacity is shown. The vertical moment of free surface is the moment of inertia at the

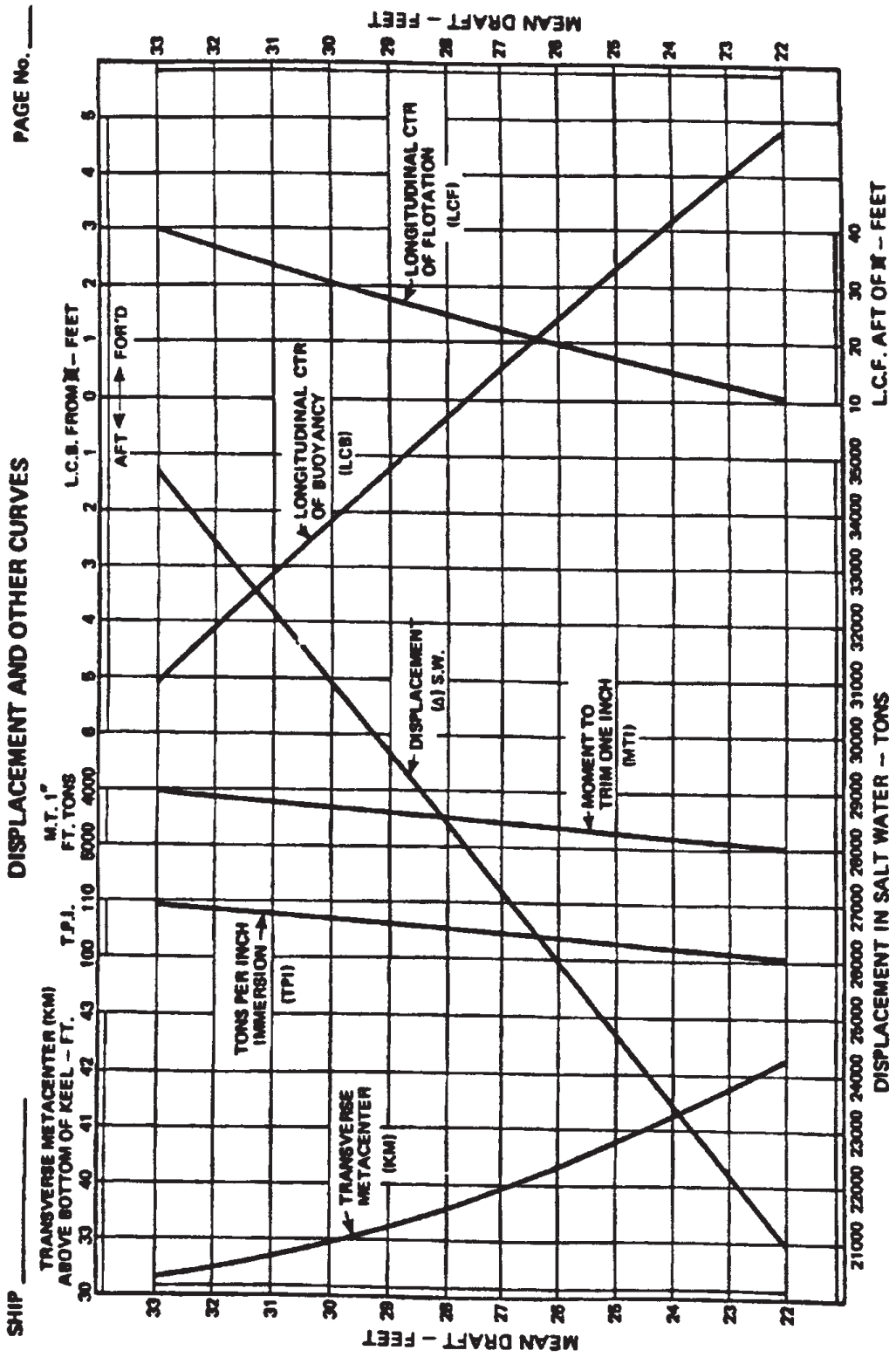

Figure 096−2−2. Sample Sheet for Plotting Displacement and Other Curves

level at which this figure is a maximum divided by the specific volume of the liquid in cubic feet per ton. In the case of compensated gasoline tanks, the vertical moment is I/& delta;S.W. minus I/& delta;GAS. Where tanks are fitted for fuel oil or ballast, the weight of fuel oil is entered but the fact that they are fitted for ballast is indicated. Tanks normally used for carrying liquids as cargo or for issue to other ships are so designated. The density factors for liquid loads are listed in Table 096–2–1.

Table 096–2–1. DENSITY FACTORS FOR LIQUID LOADS

LIQUID	#/FT^3	#/FT^3 / TON	GALLONS / TON
Saltwater	64.00	35.0	261.8
Freshwater	62.22	36.0	269.3
NSFO	59.00	38.0	284.0
Hydraulic oil	58.18	38.5	288.0
Lube oil (Propulsion)	57.50	39.0	291.4
Lube oil (Aviation)	56.18	39.9	298.7
Navy Distaillate			
Fuel	52.97	42.3	316.4
Diesel Oil	52.04	43.0	322.0
JP–5	50.80	44.1	329.9
Alcohol	50.50	44.4	331.8
Gasoline (Automobile)	45.37	49.4	369.5
Gasoline (Aviation)	43.75	51.2	383.0

096–2.6.12 COMPARTMENT CAPACITIES. A list of all compartments intended for stowing ammunition, provisions, stores, or dry cargo is prepared, giving the bale capacity and the vertical and longitudinal position of the center of gravity of each space. Compartments containing the same type of material are listed together. For ammunition stowages, the maximum capacity of each space in rounds is also included. In all cases, the type of material stowed is indicated.

096–2.6.13 TABLE OF FRAME SPACINGS. One sheet shall be filled out indicating the distance of each frame from the longitudinal reference point in feet and decimals. The frame spacings should also be included on this sheet.

096–2.6.14 REMARKS AND MISCELLANEOUS CALCULATIONS. Refer to paragraph 096–2.5.12.

096–2.7 CONDITIONS OF LOADING FOR SURFACE SHIPS

096–2.7.1 DISTINCTIONS BETWEEN LIGHT SHIP AND VARIABLE LOAD. To permit calculation of the characteristics of a ship under any condition of loading, and to permit comparison of the characteristics of similar ships, the total displacement is considered to consist of light ship displacement and variable load.

096–2.7.1.1 Light Ship. The light ship condition, designated as Condition A, includes the weight of the ship with all those items which are not consumable and not subject to frequent change. It is intended primarily to serve as a basic condition to which the items of variable load may be added in order to arrive at the other conditions of loading. Items which are considered to be reasonably permanent and are therefore included in Condition A are identified in paragraph 096–2.5.3.1.

096–2.7.1.2 Variable Load. The variable load includes all items, other than those in Condition A, which are aboard. In general, these are the loads which are subject to change during a voyage.

a. The variable load includes:

1. Crew and effects
2. Ammunition
3. Provisions and personnel stores
4. General stores
5. Liquids in storage tanks
6. Airplanes and aviation stores, aviation and mobile support equipment
7. Cargo
8. Passengers
9. Salt water ballast

b For ships with anti-roll tanks, the normal liquid carried in the tank is treated as a load item with free surface.

c. The distinction outlined above between Condition A weights and the variable load is adequate for all practical purposes. It is important that any weight which will normally be carried in service in a particular condition of loading be included either in Condition A or in the variable load, and that no weight be included both in Condition A and as an item of variable load.

096–2.7.2 DEFINITIONS OF CONDITIONS OF LOADING FOR SURFACE SHIPS. Certain significant conditions of loading have been defined and assigned identifying letters for convenient reference.

a Condition A–Light Ship. Ship complete, ready for service in every respect, including permanent ballast (solid and liquid), on–board repair parts, aviation mobile support equipment as assigned and liquids in machinery at operating levels, without any items of variable load. This condition represents the ship under wartime conditions, with ultimate armament but peacetime boat allowance aboard.

b. Condition A–1–Light Ship. Condition A without permanent ballast (solid or liquid).

c. Condition B–Minimum Operating Condition. A condition in which the ship has the minimum stability characteristics likely to exist in normal operation. For combatant ships it represents, approximately, conditions which would exist toward the end of an engagement, after a long period at sea. Liquids are included in amounts and locations which will provide satisfactory stability and trim and limitation of list in case of underwater damage. The components of load will depend on the type of ship and its service.

d. Condition C–Optimum Battle Condition. This condition is applicable only to those ships which have extensive underwater defense systems, such as battleships and aircraft carriers. This is the condition which provides the optimum amount and distribution of liquids from the standpoint of resistance to underwater damage and represents, approximately, the loading which would be most favorable at the beginning of an engagement.

e. Condition D–Full Load Condition. Condition D consists of:

1. Full load (contractual). Ship complete, ready for service in every respect. It is Condition A (light ship) plus the following variable loads: authorized complement of officers, men, and passengers, and their effects; full allowances of ammunition in magazines and ready service spaces; full allowance of aircraft and vehicles (empty weight with full allowance of repair parts and stores); full supply of provisions and stores for the periods specified in the design characteristics; fuel in amount necessary to meet endurance requirements; anti–roll tank liquid; all other liquids in tanks to required capacity in accordance with characteristics and existing liquid loading instructions. The ammunition, stores, fuel, and other liquids referred to above are for the ship’s own use; cargo (liquids and solid) is included in amounts normally carried or to the specified portion of the full capacity of the assigned spaces. This condition applies to weight estimating and weight reporting.

2. Full load (departure). Same as full load (contractual) except fuel and lube oil tanks are 95& pct; full, potable and reserve feed water tanks are 100& pct; full. This condition applies to inclining reports.

f. Condition E–Capacity Load Condition. Ship complete, ready for service in every respect. It is Condition A (light ship) plus the following variable loads: maximum number of officers, men, and passengers that can be accommodated, and their effects; maximum stowage of ammunition in magazines and ready service spaces; full allowance of aircraft and vehicles (empty weight with full allowance of repair parts and stores); maximum amount of provisions and stores that can be carried in the assigned spaces; maximum capacity of liquids in tanks. Fuel oil, JP–5, diesel oil, gasoline, and lube oil shall not exceed 95 percent of tank capacity, unless such tanks are compensating. Compensating tanks shall be considered filled with 95 percent fuel and 5 percent salt water. Maximum amounts of cargo and supplies, other than for ships own use. However, Condition E loading shall not exceed the limiting drafts.

096–2.7.3 DETAILED DESCRIPTION OF CONDITIONS OF LOADING FOR SURFACE SHIPS. Distinct conditions of loading are described in the following subparagraphs.

096–2.7.3.1 Condition D–Full Load (Contractual). The condition is determined by adding the following variable load to Condition A:

a. Crew and effects. The weight of crew and effects is based on the wartime complement as currently authorized by the Chief of Naval Personnel. Total weights are obtained by allowing following pounds per man. The center of gravity is taken as berthed.

Officers (commissioned or warrent)	400
Chief Petty Officers	330
Other Enlisted Personnel	230

b. Ammunition. A full load of ammunition consists of the full allowance. This item includes torpedoes, mines, depth charges, bombs, guided missiles, pyrotechnics, and aircraft ammunition. Maximum quantities are assumed in the ready-service stowage and the remainder in magazines.

c. Provisions and personnel stores. The weight of this item is based on the complement and the number of days endurance specified in the Design Characteristics. Quantities should not exceed the capacities of the available spaces. The weight, density, and utilization factors used are given in Table 096–2–2. Because of the perishable nature of the food items stored in chill, a 30 day upper limit is recommended. The utilization factor is the ratio of the volume the load item occupies to the total volume of the space, assuming compact stowage. The density factor should be applied to the net volume of each compartment to determine its capacity in pounds for any load item. Medical stores and troops stores are included in the amounts normally carried.

Table 096–2–2. PROVISION DATA

Provisions	Pounds Per Man Per Day	Density Lbs. Per Cu. Ft.	Utilization Factor
Dry	3.20	34	0.7
Freeze	1.11	39	0.7
Chill	1.65	29	0.7
Clothing and Small Stores	0.07	13	0.5
Ships Store Stock	0.80	25	0.6
General Stores	1.06	18	0.5

d. General stores. This item includes all stores, other than personnel stores, which are of a consumable nature. The quantity required is for the period specified in the Design Characteristics. Table 096–2–2 may be used.

e. Lubricating oil. Amount necessary to meet endurance requirements, distributed in storage tanks and settling tanks.

f. Potable water. Amount necessary to meet endurance requirements.

g. Reserve feed water. Amount necessary to meet endurance requirements.

h. Fuel oil. Amount necessary to meet endurance requirements, distributed in storage and service tanks or settling tanks equivalent to service tanks.

i. Diesel oil. Amount necessary to meet endurance requirements, distributed in storage and service tanks. Overflow oil tanks shall be filled to an amount necessary to meet endurance requirements. Contaminated oil tanks are assumed empty.

j. Aviation and vehicle fuel. 95& pct; capacity of fuel tanks.

k. Compensating water in aviation and vehicle fuel tanks. Sufficient salt water to completely fill the compensating tanks in conjunction with 95& pct; fuel.

l. Miscellaneous liquids. Fog oil, hydraulic oil, cleaning fluid, etc; amount necessary to meet endurance requirements. The sewage collecting, holding, and transfer tanks are assumed to be 25& pct; full and of salt water density.

m. Airplanes and aviation stores. Full design complement of aircraft, unloaded, with full allowance of repair parts and stores. The distribution of aircraft, between hangar and flight decks, shall be the most unfavorable, from the stability standpoint, which is likely to be encountered in service.

n. Cargo. Cargo includes all items of ammunition, stores. provisions, fuel, water, etc. which are normally carried for issue to other activities. If the portion of these items for the ships own use is not physically segregated from the portion carried for issue, a reasonable portion is allocated to the ship and the remainder considered cargo. The design estimate weights should be used.

o. Passengers. Passengers include troops in the case of transports and patients on hospital ships. Number of passengers should be the authorized complement. For passengers and effects, other than troops, the following weights expressed as pounds per man are applicable.

Officers (commissioned or warrent)	400
Chief Petty Officers	330
Other Enlisted Personnel	230

For embarked troops, a figure of 240 pounds per man is used for both officer and enlisted personnel unless troops are equipped for arctic operation, in which case a figure of 290 pounds per man is used. The center of gravity is taken as berthed except that, in the case of ships carrying large numbers of passengers, a realistic assumption as to distribution is made if this consideration has a significant effect on stability.

1. Salt water ballast, and other liquid loads. Amount and distribution in accordance with ballasting instructions, liquid loading instructions of Damage Control Book.

2. Aviation mobile support equipment. Amount necessary to meet design requirements. All self–propelled and portable equipment for service and maintenance of aircraft such as tractors, crash cranes, fire engines, dollies, fork lifts, portable power and air conditioning units, tow bars, jacks, etc. Distribution shall be that as normally stowed when not in service.

096–2.7.3.2 Condition D–Full Load (Departure). Load details same as for Full Load (contractual) except fuel and lube oil tanks are 95& pct; full, potable and reserve feed water tanks are 100& pct; full, contaminated fuel oil settling tanks and lube oil settling tanks are empty in this condition. If design characteristics are not available, endurance information should be obtained from NAVSEC Code 6134.

096–2.7.3.3 Condition E-Capacity Load Condition. This condition is determined by adding the following variable load to Condition A:

a. Crew and effects. The weight of the maximum number of crew and their effects which can be accommodated. Weights are obtained using the same factors as for full load.

b. Ammunition. Maximum stowage of ammunition in magazines and ready service spaces. This item includes torpedoes, mines, depth charges, bombs, guided missiles, pyrotechnics, and aircraft ammunition.

c. Provisions and personnel stores. This item includes the maximum amount of provisions and personnel stores that can be carried in the assigned spaces. Weights may be obtained by using the same factors as for full load.

d. General stores. This item includes all stores, other than personnel stores, which are of a consumable nature. The quantity required is the maximum amount that can be carried in the assigned spaces. Weights may be obtained by using the same factors as for full load.

e. Lubricating oil. Ninety five percent of the total net volume of each tank.

f. Potable water. One hundred percent of the total net volume of each tank.

g. Reserve feed water. One hundred percent of the total net volume of each tank.

h. Fuel oil. Ninety five percent of the total net volume of each tank.

i. Diesel oil. Ninety five percent of the total net volume of each tank.

j. Overflow fuel oil tanks are considered 95 percent of the total net volume of each tank. Contaminated tanks are assumed empty.

k. Compensating water in aviation and vehicle fuel tanks. Sufficient salt water to completely fill the compensating tanks in conjunction with 95& pct; fuel.

l. Miscellaneous liquids. Fog oil, hydraulic oil, cleaning fluid, etc; ninety five percent of the total net volume of each tank.

m. Airplanes and aviation stores. Full complement of aircraft unloaded, with maximum repair parts and stores. The distribution of aircraft, between hangar and flight decks, shall be the most unfavorable from the stability standpoint, which is likely to be encountered in service.

n. Cargo. Includes the maximum amount of ammunition, stores, provisions, fuel, water, etc; which are carried for issue to other activities. If the portion of these items for the ships own use is not physically separated from the portion carried for issue, a reasonable portion is allocated to the ship and the remainder considered cargo.

o. Passengers. Maximum amount of passengers which can be accommodated including troops in the case of transports and patients in hospital ships. Weights are obtained using the same factors as for Full Load Condition (Condition D).

p. Salt water ballast and other liquids. Amount and distribution in accordance with ballasting instructions, liquid loading instructions of Damage Control Book.

q. Aviation mobile support equipment. Maximum amount carried in assigned spaces. All self–propelled and portable equipment for service and maintenance of aircraft such as tractors, crash cranes, fire engines, dollies, fork lifts, portable power and air conditioning units, tow bars, jacks, etc. Distribution shall be that as normally stowed when not in service.

096–2.7.3.4 Condition B–Minimum Operating Condition. This condition is determined by adding the following variable load to Condition A: (percentages are of full load departure)

a. Crew and effects. Same as Full Load Condition.

b. Ammunition. One–third of the ammunition excluding missiles, depth charges, torpedoes, and mines) included in Full Load with maximum quantities in ready-service stowages and the remainder in magazines. For missiles, depth charges, torpedoes and mines, use full load. One-third the quantity of aircraft ammunition is included for aircraft carriers.

c. Provisions and personnel stores. One-third of the amount in full load.

d. General Stores. One-third of the amount in full load.

e. Lubricating oil. One-third of the amount in full load distributed in storage and settling tanks.

f. Potable water. Two-thirds of the amount in full load or that amount required by the liquid loading instructions for stability or underwater protection, whichever is larger.

g. Reserve feed water. Two-thirds of the amount in full load, or that amount required by the liquid loading instructions for stability or underwater protection, whichever is larger.

h. Fuel oil. One-third of the amount in full load. Fuel oil service, contaminated, and settling tanks are assumed to be half full.

i. Diesel oil. For ships of destroyer size and smaller, one-half the amount in full load. For larger ships, one–third of the amount in full load. For diesel-driven ships, diesel oil is treated in the manner described above for fuel oil.

j. Aviation or vehicle fuel. One-third of the amount in full load.

k. Compensating water in aviation and vehicle fuel tanks. Sufficient salt water to completely fill the compensating tanks in conjunction with the fuel.

l. Fog oil. One-third of the amount in full load.

m. Aircraft and aviation stores. Same as for full load.

n. Cargo. For ships whose normal function requires that they unload all cargo, no cargo is included in the Minimum Operating Condition. For ships, such as tenders and replenishment ships, which carry cargo for issue to other ships or activities and do not normally unload completely, the cargo assumed in the Minimum Operating Condition is one–third of the amount in full load.

o. Passengers. Same as for full load.

p. Salt water ballast and other liquids. Amount and distribution in accordance with liquid loading instructions of Damage Control Book. Assume sewage collecting, holding, and transfer tanks are empty.

q. Aviation mobile support equipment. Same as full load.

r. All loading in the Minimum Operating Condition should conform to all loading instructions issued to the ship.

096–2.7.3.5 Condition C–Optimum Battle Condition. This condition is determined by adding the following variable load to Condition A: (Percentages are of full load departure)

a. Crew and effects. Same as for full load.

b. Ammunition. Same as for full load, reduced by aircraft ammunition.

c. Provisions and personnel stores. Two-thirds of the amount in full load.

d. General stores. Two-thirds of the amount in full load.

e. Lubricating oil. Two-thirds of the amount in full load distributed in storage and settling tanks.

f. Potable water. Two-thirds of the amount in full load.

g. Reserve feed water. Two-thirds of the amount in full load.

h. Fuel oil. All tanks required to be ballasted are assumed to be full of fuel to 95% of the net volume of the tank. One half of the fuel oil service and settling tanks are assumed to be half full. The remaining fuel oil service and settling tanks are considered full. All other tanks are assumed empty if this is consistent with the ships loading instructions.

i. Diesel oil. Two-thirds of the amount in full load.

j. Aviation fuel. Two-thirds of the amount in full load.

k. Compensating water in aviation fuel tanks. Sufficient salt water to completely fill the compensating tanks in conjunction with the fuel.

l. Fog oil. Two-thirds of the amount in full load.

m. Aircraft. Full complement of aircraft, fully loaded. The distribution on the flight and hangar decks shall be the most unfavorable from the standpoint of stability, trim, and list which is likely to be encountered during major launching operations.

n. Aviation stores. Same as full load.

o. Aviation mobile support equipment. Same as full load.

p. Salt water ballast and other liquids. Amount and distribution in accordance with liquid loading instructions of Damage Control Book. Assume sewage collecting, holding, and transfer tanks are empty.

q. Aviation mobile support equipment. Same as full load.

096–2.8 CONTENTS OF INCLINING EXPERIMENT REPORT, (PART 2) DATA FOR SUBMARINES

096–2.8.1 STABILITY AND EQUILIBRIUM DATA FOR SUBMARINES. The ships name and identification number, date of trim dive, activity by which prepared and general measurements are entered on this sheet. Under References all drawings and data used in preparing this booklet are listed. The various pages of this part and their order are listed in paragraph 096–2.13.1, NO TAGC.

096–2.8.2 LOAD TO SUBMERGE DETERMINATION. On this sheet the Condition A weight and longitudinal moment for the ship at the time of trim dive and at present are calculated from the Condition A data in the most

recent Inclining Experiment Report. Using the load at the time of the trim dive, the submerged displacement is then calculated and compared to that given on the displacement and other curves drawing. Finally the present load to submerge is calculated for three water densities: 64.3, 64.0 and 63.6 lbs/cu.ft.

096–2.8.2.1 Armament, Boats, Submarine Batteries, Ballast. Refer to paragraph 096–2.5.2.

096–2.8.2.2 Condition A–Light Ship. Refer to paragraph 096–2.5.3.

096–2.8.3 DETAILED CHANGES IN CONDITION A AND SUBMERGED DISPLACEMENT SINCE LAST INCLINING AND TRIM DIVE. Details of the changes in Condition A since the inclining experiment, with weights, centers of gravity, and the vertical and longitudinal moments of the various items are included. Separate summations are made for weights added, weights removed, and weights relocated so that the totals can be added on the sheet entitled Ship in Condition A. If the weight changes since the inclining experiment and the changes since the trim dive are identical, the total change in weight and longitudinal moment may be taken from these figures for the purpose of modifying the load to submerge. If the changes are not identical, a separate calculation of change in Condition A weight and longitudinal moment since the trim dive is made. Detailed calculation of the displacement (in tons) and the longitudinal center of buoyancy of any alterations made since the trim dive which affect the submerged modify the load to submerge as discussed in paragraph 096–2.8.2.

096–2.8.4 LOAD TO SUBMERGE AT TIME OF TRIM DIVE. This sheet contains a summary of the weight and longitudinal moment of the items of load at the time of the trim dive.

096–2.8.5 DETAILS OF LOAD ON TRIM DIVE. Details of the calculation of weight and longitudinal moment of the load to submerge at the time of the trim dive are included. Separate summations are made for each type of load.

096–2.8.6 SHIP IN CONDITION N–SURFACE, DIVING TRIM. The displacement, vertical moment of free surface, and the vertical and longitudinal position of the center of gravity are determined.

a. The foregoing factors are calculated by adding:

1. Ship in Condition A

2. Variable load in Condition N

3. Variable ballast in Condition N

4. Residual water in main ballast, fuel ballast, and safety tanks

b. The free surface correction is determined by dividing the total vertical moment of free surface by the displacement. The metacentric height, moment to heel one degree, drafts forward and aft, and the statical stability curve are determined.

096–2.8.7 SHIP IN CONDITION N–SUBMERGED. The displacement and the vertical and longitudinal position of the center of gravity are determined.

a. The foregoing are calculated by adding:

1. Ship in Condition N.

2. Water ballast in main ballast, fuel ballast, and safety tanks above the level of the residual water.

b. The vertical moment of free surface in Condition N–Sub is calculated by deducting the vertical moment of free surface of the residual water in the main ballast, fuel ballast, and safety tanks from the vertical moment of free surface in condition N Surface. This figure, divided by the displacement, is the free surface correction. From the foregoing, BG, moment to heel one degree, and the statical stability curve are determined.

096–2.8.8 VARIABLE BALLAST IN CONDITION. The weight and longitudinal moment or the variable ballast in Condition N are determined.

a. The foregoing are calculated by deducting the following items from the load to submerge:

1. Variable load in Condition N.

2. Residual water in main ballast, fuel ballast, and safety tanks.

3. Water ballast in main ballast, fuel ballast, and safety tanks above the level of the residual water.

b. After the total weight and longitudinal moment of the variable ballast have been determined, the disposition of ballast in the individual tanks is established on the following basis:

1. The weight of variable fuel or variable fresh water is determined in accordance with the definition of paragraph 096–2.9.5.2.b The remaining weight of the variable ballast consists of variable water.

2. The disposition of variable ballast (both water and fuel oil) is that which produces the maximum metacentric height consistent with the proper longitudinal moment.

c. When the disposition of the variable ballast has been determined, the vertical position of its center of gravity is calculated, together with the moment of free surface.

096–2.8.9 CONDITION M–SURFACE DIVING TRIM. With the submarine surfaced:

a. The displacement, vertical moment of free surface, and the vertical and longitudinal positions of the center of gravity in Condition M are calculated by adding:

1. Ship in Condition A.

2. Variable load in Condition M.

3. Variable ballast in Condition M.

4. Residual water in main ballast, fuel ballast, and safety tanks.

5. Water seal in fuel ballast tanks.

b. In entering the value for the vertical moment of free surface of the residual water, the effect of the fuel ballast tanks should not be included since these tanks are filled in this condition. From the foregoing, the metacentric height, moment to heel one degree, drafts forward and aft, and the statical stability curve are determined.

096–2.8.10 CONDITION M–SUBMERGED. When submerged:

a. The displacement and the vertical and longitudinal positions of the center of gravity in Condition M-Sub are calculated by adding:

1. Ship in Condition M.

2. Water ballast in main ballast and safety tanks above the level of the residual water.

b. The vertical moment of free surface in Condition M-Sub is calculated by deducting the vertical moment of free surface of the residual water in the main ballast and safety tanks from the vertical moment of free surface in Condition M. This figure, divided by the displacement, is the free surface correction. From the foregoing, BG, moment to heel one degree, and the statical stability curve are determined.

096–2.8.11 VARIABLE BALLAST IN CONDITION M. In Condition M:

a. The weight and longitudinal moment of the variable ballast are calculated by deducting the following items from the load to submerge.

1. Variable load in Condition M.

2. Residual water in main ballast, fuel ballast, and safety tanks.

b. Water ballast in main ballast and safety tanks above the level of the residual water.

c. Water seal in fuel ballast tanks.

d. Disposition of the variable ballast is determined in the manner described in paragraph 096–2.9.5.b The vertical position of the center of gravity and the vertical moment of free surface are determined.

096–2.8.12 DISPLACEMENT AND OTHER CURVES. Refer to paragraph 096–2.6.4.

096–2.8.13 CROSS CURVES OF STABILITY. Refer to paragraph 096–2.6.5.

096–2.8.14 DIAGRAM SHOWING LOCATION OF DRAFT MARKS. Refer to paragraph h 096–2.5.11.

096–2.8.15 VARIABLE LOAD IN CONDITIONS N AND M. The weight, center of gravity, the vertical moment of free surface, and the vertical and longitudinal moments of the variable load in Conditions N and M, as defined in paragraph 096–2.9.5.a, are calculated.

096–2.8.16 DETAILS OF VARIABLE LOAD IN CONDITION N AND M. Details of weight, center of gravity, vertical moment of free surface, and vertical and longitudinal moments of items of variable load, as defined in paragraph 096–2.9.3.c, are included. Separate summations are made for fuel oil in the normal, clean fuel oil, collecting, and expansion tanks and for oil in the fuel ballast tanks. Separate summations are also made for each of the other items of load.

096–2.8.17 WATER BALLAST IN MAIN BALLAST, FUEL BALLAST, AND SAFETY TANKS. Details of the weight, center of gravity, and the vertical and longitudinal moments of the water ballast in the main ballast, fuel ballast, and safety tanks are included. Two summations are required, one for the main ballast, fuel ballast, and safety tanks and the other for the main ballast and safety tanks. In addition, the total weight and longitudinal moment for each of these summations are calculated at densities of 64.3 and 63.6 pounds per cubic foot for use in calculating the equilibrium conditions. These figures represent the water above the level of the residual water.

096–2.8.18 RESIDUAL WATER, WATER SEAL AND MBT LEAD CORRECTIONS. The details of the weight and moments of the residual water and the water seal are included. The following summations are required:

a. For condition N: Weight, vertical moment, vertical moment of free surface, and longitudinal moment of the residual water in main ballast, fuel ballast, and safety tanks.

b. For condition M: Summation same as for Condition N except that the vertical moment of free surface of residual water in fuel ballast tanks is not included.

c. For condition M: Weight and vertical and longitudinal moments of water seal in fuel ballast tanks.

096–2.8.19 EQUILIBRIUM POLYGON. The equilibrium polygon, illustrated in Figure 096–2–3, is a graphic representation of the range of weight and longitudinal moment which can be obtained by adjusting the liquids in the variable water and variable fuel tanks and, if necessary, the negative tank and the balance of the depth control system capacity not used as a variable load item. The diagram consists of a polygon, plotted on a horizontal scale

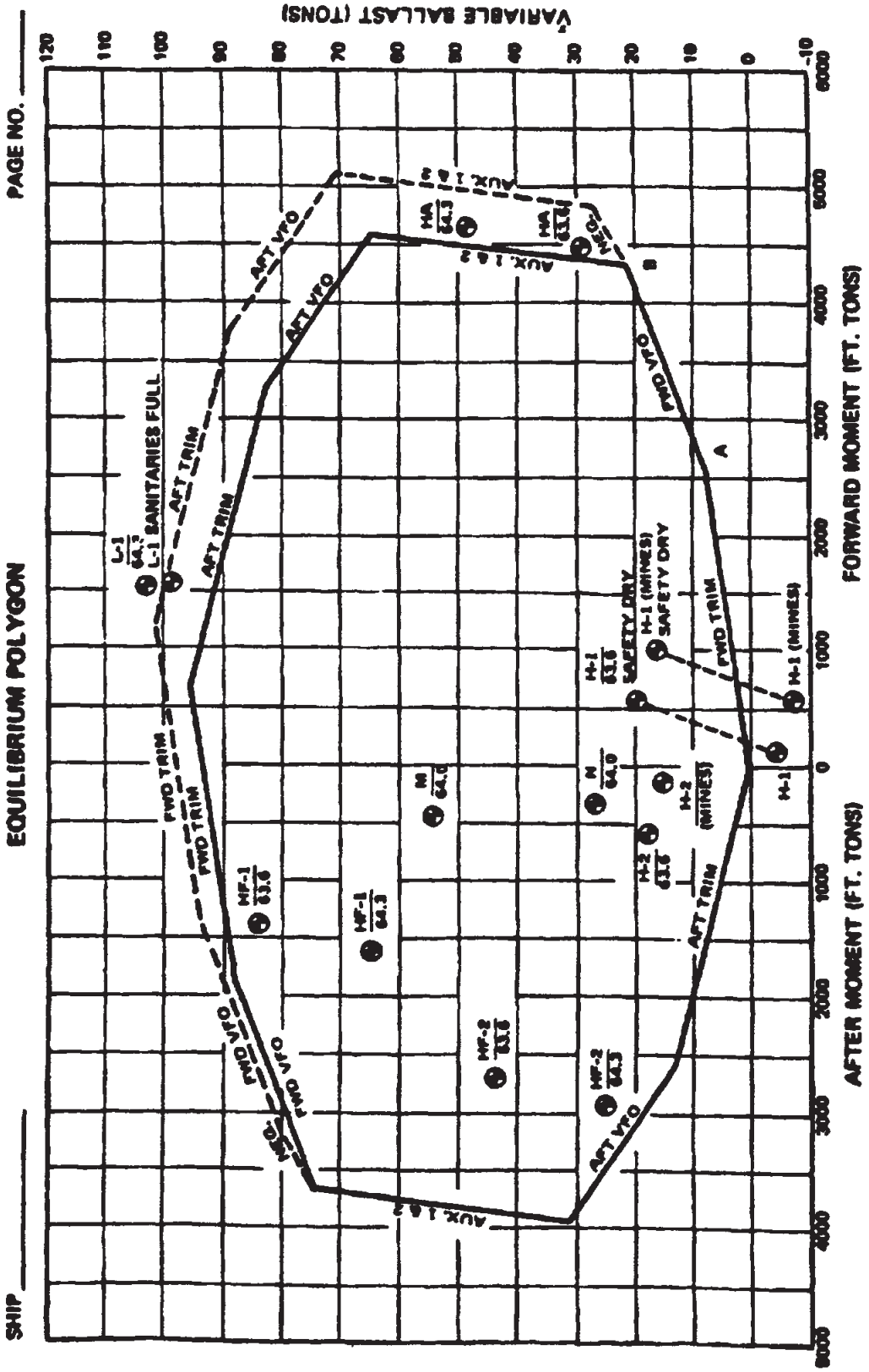

Figure 096–2–3. Equilibrium Polygon

of longitudinal moment and a vertical scale of weight, which encloses all points representing combinations of weight and longitudinal moment to which these liquids can be adjusted. The weight and moment of the variable ballast to balance for each of the equilibrium conditions defined in paragraph 096–2.8.21 are plotted on this diagram to determine whether the necessary adjustment can be obtained. The ship can submerge with neutral buoyancy and zero trim in any condition for which the variable ballast to balance falls within the polygon. Notes on the polygon shall indicate any remedial action available for points falling outside the polygon.

a. The coordinates of the points for plotting the equilibrium polygon may be obtained by starting with the weight and longitudinal moment of the tank farthest forward and adding successively the weight and moment of each of the remaining tanks in order of longitudinal position. The same process may be repeated, starting with the aftermost tank and proceeding forward. Thus, on Figure 096–2–3 point A represents the weight and moment of the forward trim tank, and point B the combined weight and moment of the forward trim and forward variable fuel oil tank. Successive points represent the cumulative effect of additional tanks. Ships fitted with a Trim/W.R.T. tank combined shall use for the outline the total capacity of the tank less the maximum W.R.T. required in any of the equilibrium conditions. On those submarines in which the sanitary flush water is obtained from a pressurized auxiliary tank, the minimum amount of required flush water should be deducted from the auxiliary tankage in constructing the equilibrium polygon.

b. The effect of flooding the negative tank or the balance of the depth control system is added to the polygon as a broken line if necessary to satisfy any of the equilibrium conditions. The water in the depth control system may not be used for FBM submarine polygon outlines. If a regulating tank is fitted, the portion not considered as safety tank in calculating the equilibrium conditions is considered to be the negative tank.

c. The density of water in the variable water tanks is taken at 64 pounds per cubic foot. The weight for the variable fuel oil tanks is based on the assumption that they are filled with fuel oil to 95 percent of the total net volume of the tanks.

d. Sides of the polygon are labeled to correspond to the various tanks as necessary to clarify the diagram.

e. Reballasting (adjustment of lead ballast in Condition A, Light Ship) may be necessary to bring all equilibrium points not only within the polygon outline but to optimum locations. Detailed instructions for obtaining an acceptable distribution of the equilibrium points within the polygon are given in NAVSEAINST 09290.39.

096–2.8.20 POINTS FOR EQUILIBRIUM POLYGON. The calculation of the coordinates for the equilibrium polygon, as described in paragraph 096–2.8.19.a, is included.

096–2.8.21 EQUILIBRIUM CONDITIONS. To demonstrate that the ship can submerge under certain conditions of loading and density of sea water which are considered to be extreme, the weight and longitudinal moment of the variable ballast necessary to bring the ship to diving trim under these conditions are calculated and compared graphically with the possible adjustment of the variable ballast.

a. The equilibrium conditions calculated represent situations in which the ship is normal, maximum fuel, light, heavy, heavy forward, and heavy aft. For conditions N, N–Sub, M, and M–Sub, the sea water is assumed to be at 64.0 pounds per cubic foot. For the light conditions, it is assumed to be 64.3 pounds per cubic foot (a probable maximum) and for the heavy conditions 63.6 pounds per cubic foot (a probable minimum). The heavy forward and heavy aft conditions are calculated for both probable maximum and minimum densities. A description of each equilibrium condition is as follows:

1. Light no. 1 (Diesel powered submarines only): At the beginning of a short sea passage or training exercise. Fuel at maximum, but no torpedoes; submarine is diving in heavy density water.

2. Light no. 2 (Submarines, other than diesel–powered): At the end of a prolonged patrol with all missiles, torpedoes, provisions, and general stores exhausted; submarine is diving in heavy density water.

3. Heavy no. 1: At the end of a fast, unsuccessful patrol. All fuel oil consumed, but no torpedoes, missiles, or other group 6 items expended. Submarine is diving in light density water.

4. Heavy no. 1 (Mines): Same as Heavy No. 1 except that a full load of mines is being carried rather than torpedoes.

5. Heavy no. 2: Leaving for patrol (same as Condition N–Sub except WRT at required amount). Submarine is diving in light density water.

6. Heavy no. 2 (Mines): Same as Heavy No. 2 except that a full load of mines is being carried rather than torpedoes.

7. Heavy forward no. 1 (Diesel powered submarines only): Early in the patrol with all torpedoes at the after end of the ship expended; fuel oil in the FBT's partially expended (see footnote 1 to Table 096–2–3) and NFO tanks full of fuel. This condition is calculated for heavy and light density water.

8. Heavy forward no. 2: For diesel powered submarines, late in the patrol with all torpedoes at the after end of the ship expended, fuel oil in the NFO tanks partially expended (see footnote 2 to Table 096–2–3) and the FBT's rigged as ballast tanks. For other submarines; early in the patrol with maximum probable forward moment. This condition is calculated for heavy and light density water.

9. Heavy aft: For diesel powered submarines, late in the patrol with all torpedoes at the forward end of ship expended, fuel oil in the NFO tanks partially expended (see footnote 3 to Table 096–2–3), and FBT's rigged as ballast tanks. For other submarines, early in the patrol with maximum probable after moment. This condition is calculated for heavy and light density water.

b. The equilibrium condition included in the Stability and Equilibrium Data, together with the quantities of the various items of load assumed to be aboard in each condition, are listed in Table 096–2–3. All sea water aboard in the equilibrium conditions is assumed to have a density of 64 pounds per cubic foot except that the water admitted to the main ballast and safety tanks upon diving will have the same density as that assumed for the sea water. In addition, the density of the water in FBT shall also be the same as the assumed sea water density except for condition HF No. 1 which shall be 64.0 pounds per cubic foot. The terms normal and full as used in the tabulation refer to the normal quantities of the various items as defined in paragraph 096–2.9.5. Where a regulating tank, which combines the functions of the safety and negative tank, is fitted, the amount included in the equilibrium conditions as water in the safety tank is the full capacity of the regulating tank less ten tons.

c. The loads assumed in the various equilibrium conditions are based on the following considerations:

1. Group 1. These loads do not normally vary appreciably and are therefore assumed constant for all conditions. Oxygen candles are put in this group when the ship is fitted with at least one oxygen generator.

2. Group 2. Since these items can be replenished by distillation, it is assumed that the quantity of each item can be kept up to one-half the normal quantity when a light condition is approached and that the tanks may be full in the heavy conditions.

3. Groups 3, 4, and 5. The quantities of items in these groups are interrelated. For example, the Light No. 1 condition is basically light because of a maximum load of fuel and, with this fuel load, three-quarters of the normal load of provisions, stores, oxygen, and lubricating oil is considered to be the reasonable minimum load. In the Light No. 2 condition, the provisions, stores, and oxygen are assumed to be depleted and a normal load of fuel with one–half the normal load of lubricating oil is considered to be the reasonable minimum weight of these items consistent with this assumption. A similar consistency is maintained for the other equilibrium conditions. Oxygen candles are assumed to be in Group 3 when no oxygen generator is fitted.

Table 096–2–3. EQUILIBRIUM CONDITIONS

GROUP	Items		Cond. N	Cond. M	Light No. 1	Light No. 2	Heavy No. 1	Heavy No. 2	Heavy No. 1 (Mines)	Heavy No. 2 (Mines)	Heavy Foward No. 1	Heavy Forward No. 2	Heavy Aft
	Water Density		64.0	64.0	64.3	64.3	63.6	63.6	63.6	63.6	64.3 63.6	64.3 63.6	64.3 63.6
1	Fixed Loads: Crew and effects Ballistic Missiles and/or Missile compensating water Sanitary tanks Sanitary Flush water Lub. oil sumps Depth Control Water Hovering water Residual water Clean Fuel Oil Water seal in low pressure compensated F.O. system Nitrogen Oxygen candles, see paragraph 096–2.8.19.c		Normal										
2	Potable water Battery fresh water Reserve feed water Pure water Reserve for special propulsion plant fluids		Normal		1/2 Normal		Normal				Full to 1/2 Full Maximum Fwd Moment		Full to 1/2 Full Max Aft Moment
3	Provisions General stores Oxygen for air revitalization Oxygen candles. See paragraph 096–2.8.19.c		Normal		3/4 Normal	None	1/2 Normal	Normal	1/2 Normal	Normal	3/4 Normal	3/4 Normal (Nuclear) 1/2 Normal (Diesel)	3/4 Normal (Nuclear) 1/2 Normal (Diesel)
4	Lubricating oil in storage and reserve tanks		Normal		3/4 Normal	1/2 Normal		Normal	1/2 Normal	Normal	3/4 Normal	1/2 to 3/4 Max Fwd Moment	1/2 to 3/4 Max Aft Moment
5	Oil and water in compensating	Normal tanks	Normal				Water	Normal	Water	Normal	Normal	See note 2	See note 3
		Collecting										Normal	
		Expansion										Water	
	Oil in fuel ballast tanks		None	Full		None					See Note 1	None	

Table 096–2–3. EQUILIBRIUM CONDITIONS (CONT)

GROUP	Items		Cond. N	Cond. M	Light No. 1	Light No. 2	Heavy No. 1	Heavy No. 2	Heavy No. 1 (Mines)	Heavy No. 2 (Mines)	Heavy Foward No. 1	Heavy Forward No. 2	Heavy Aft
6	Torpedoes Ammunition Landing craft Vehicles Dry Cargo Liquid cargo in non-compensating tanks Reserve hydraulic oil		Normal		Normal		Normal		Full load of mines		Normal fwd None aft		Normal aft none fwd
7	Passengers Electrolyte above minimum operating level		Normal		None		Normal				Normal load or none Max fwd Moment (for each item)		Normal or none Max aft Moment (for each item)
8	Waste lub oil in compensating tank		None								Normal aft None fwd		Normal fwd None aft see note 4
	Liquid cargo in compensating tank		Normal				None				See note 4		
	Compensating water for waste lub oil		Full								Normal fwd None aft		Normal aft none fwd
	Compensating water for liquid cargo		Normal				None						
9	Water in WRT tanks or WRT water in Trim & WRT tank combined	Fwd	Normal		Full		Amount required to fill tubes around torpedoes or mines carried				Required Amount		Full
		Aft									Full		Req'd amount
	Water in torpedo tube drain tank	Fwd	None		Full		None				None		Full
		Aft									Full		None
	Water in torpedo tubes	Fwd									None		Full
		Aft									Full		None
10	Water in MBT's & safety tank (above residual water)		Full										

Table 096–2–3. EQUILIBRIUM CONDITIONS (CONT)

GROUP	Items	Cond. N	Cond. M	Light No. 1	Light No. 2	Heavy No. 1	Heavy No. 2	Heavy No. 1 (Mines)	Heavy No. 2 (Mines)	Heavy Foward No. 1	Heavy Forward No. 2	Heavy Aft
10	Water in FBT's (above residual water)	Full	None		Full					See Note 1	Full	
	Water seal in FBT's above residual water	None	In all tanks		None					In aft FBT's	None	In fwd FBT's

1. In Heavy Forward No. 1, FBT's aft of L.C.B. are full of fuel oil, and FBT's forward of L.C.B. are full of salt water.
2. In Heavy Forward No. 2, Normal Fuel Oil Tank's aft of L.C.B. are full of fuel oil, and Normal Fuel Oil Tanks forward of L.C.B. are full of salt water.
3. In Heavy Aft Normal Fuel Oil Tanks aft of L.C. B. are full of salt water and Normal Fuel Oil Tanks forward of L.C.B. are full of Fuel Oil.
4. The notations for cargo in this tabulation apply to ships which carry a moderate amount. For ships which are engaged primarily in carrying large amounts of cargo in point-to-point service, it is assumed, in developing the Heavy Forward and the Heavy Aft conditions, that either a normal load or no cargo is aboard, whichever is less favorable. For ships which carry a large amount of cargo which is used for replenishment purposes, it is assumed, for the Heavy Forward and the Heavy Aft conditions, that the cargo is issued in the most favorable manner from the standpoint of longitudinal moment. For example, in the Heavy Forward conditions, include the maximum forward moment of cargo and compensating water which would be obtained at any stage if the cargo is issued so as to develop minimum longitudinal moments in either direction.

4. Group 6. The nature of these items is such that, at any time, they may be aboard in normal quantities or none may be aboard. Also, for any of these items, it is reasonable to expect that all of the material at one end of the ship might be expended while a normal load remained at the other end. For each equilibrium condition, the least favorable quantity and disposition is assumed.

5. Group 7. As in the case of the items in Group 6, these items may be aboard in normal quantities at any time, or may be completely depleted. It is considered unreasonable, however, to assume that either of these items would be completely expended at one end of the ship while a normal quantity remained at the other end. Each item is treated as a unit and considered to be aboard or not, whichever is the less favorable.

6. Group 8. These items, like the items of Group 6, may be aboard in normal quantities or completely depleted, and may be expended at one end of the ship while normal quantities are carried at the other end. Since they are carried in compensating tanks, quantities and disposition of these items are adjusted to produce the least favorable conditions in conjunction with the effect of the compensating water.

7. Group 9. For all equilibrium conditions, it is assumed that the salt water in the W.R.T. tanks, torpedo tubes, and torpedo tube drain tank has been adjusted to produce the most favorable conditions, provided that the W.R.T. tanks carry at least the required amount of water when torpedoes or mines are carried in the adjacent tubes.

8. Group 10. The quantities of these items are determined by the assumptions made as to the loads in the fuel oil tanks and the fuel ballast tanks.

9. The final result of the calculation for each equilibrium condition is the weight and longitudinal moment of the variable ballast to balance. This is the variable ballast which would be necessary to bring the ship to diving trim with the assumed loading. These figures are obtained by deducting the load, as defined in the preceding paragraph, from the load to submerge at the appropriate sea water density.

096–2.8.22 DETAILS OF LOAD FOR EQUILIBRIUM CONDITIONS. Wherever possible, the weights and longitudinal moments of the items of load in the equilibrium conditions are taken from the details of variable load

in Conditions N and M described in paragraph 096–2.8.16. For the remaining items, calculations of weight and longitudinal moment are included under this heading.

096–2.8.23 PLOT OF MINIMUM GM WHILE TRIMMING DOWN. From the conditions described in paragraph 096–2.8.24, a plot is made to illustrate the minimum GM. Heights of virtual center of gravity are plotted against displacement and a curve of height of transverse metacenter added. The values of minimum GM while trimming down for both Conditions N and M are indicated on the plot.

096–2.8.24 CONDITIONS WHILE TRIMMING DOWN. In order to determine the minimum metacentric height while trimming down, a number of conditions are calculated to establish the displacement and virtual height of the center gravity of the ship with ballast tanks filled to various levels. An adequate number of conditions are calculated to permit Plotting a curve of virtual height of the center of gravity against displacement, for both Conditions N and M. In each trimming down condition, all ballast tanks are assumed filled to the same waterline. To determine the free surface effect while trimming down, the figure for the vertical moment of free surface in Condition N or M, as appropriate, plus the figure for the water ballast in the flooded tanks, minus the figure for the residual water in the flooded tanks is divided by the total displacement. In calculating the free surface effect for a pair of ballast tanks, each side shall be considered as a separate tank, even though there is no water tight centerline subdivision since it is assumed that water is entering each side at the same rate.

096–2.8.25 SHIP IN CONDITION___SURFACE, DIVING TRIM BALLAST TANKS FLOODED, ONE SIDE ONLY. The displacement and the vertical and transverse positions of the center of gravity are calculated for Conditions N and M with all ballast tanks on one side flooded. Ballast tanks without centerline division are considered empty. The free surface correction is calculated by deducting the vertical moment of free surface of the residual water in the flooded tanks from the vertical moment of free surface in the surface condition and dividing the result by the total displacement. From this, a curve of statical stability is drawn to illustrate the resulting angle of heel and the righting arms.

096–2.8.26 TABLE OF FRAME SPACING. Refer to paragraph 096–2.6.13.

096–2.8.27 REMARKS AND MISCELLANEOUS CALCULATIONS. Refer to paragraph 096–2.5.12.

096–2.9 CONDITIONS OF LOADING FOR SUBMARINES

096–2.9.1 DIVING TRIM. A submarine is said to be in diving trim in any condition of loading when it is so compensated for loads such that complete flooding of the main ballast tanks, fuel ballast tanks being employed as main ballast tanks, and safety tank will cause the vessel to submerge with neutral buoyancy and zero–force–and–aft trim.

096–2.9.2 SUBMERGED CONDITION. The term submerged condition designates the condition in which all fixed portions of the vessel are completely submerged and the variable ballast is adjusted so that the submarine has neutral buoyancy and zero fore-and-aft trim.

096–2.9.3 COMPONENTS OF TOTAL DISPLACEMENT. Condition A, variable load, fuel and water ballast, and residual water comprise the total displacement of a submarine.

a. To permit calculation of the characteristics of a submarine under any condition of loading, and to permit comparison of the characteristics of similar ships, the total displacement is considered to consist of:

1. Light ship displacement (Condition A)
2. Variable load
3. Variable ballast (variable water and variable fuel)
4. Water ballast in main ballast, fuel ballast (less water seal), and safety tanks

5. Residual water in main ballast, fuel ballast, and safety tanks
6. Water seal in fuel ballast tanks

b. The Light Ship Displacement (Condition A) is defined in paragraph 096–2.5.3.

c. The Variable Load includes all items aboard ship, other than those in Condition A, except the water ballast used to cause the ship to submerge and the variable ballast (water or fuel oil) used to maintain diving trim. The following items are considered part of the Variable Load:

1. Crew and effects
2. Contents of sanitary tanks
3. Lubricating oil in sump tanks
4. Water in hovering tanks
5. Water in depth control tanks
6. Sanitary flush water
7. Nitrogen
8. Ballistic missiles
9. Water in ballistic missile compensating tanks
10. Water seal in fuel oil low pressure compensated tank
11. Oxygen candles
12. Potable water
13. Battery fresh water
14. Reserve feed water
15. Reserve for special propulsion plant fluids (if any)
16. Provisions
17. General stores
18. Oxygen for air revitalization
19. Lubricating oil in storage tanks–including reserve
20. Fuel oil in sea pressure compensated tanks
21. Fuel oil in low pressure compensated tanks
22. Clean fuel oil
23. Ammunition and pyrotechnics
24. Torpedoes, mines, and subroc
25. Guided missiles
26. Special fuels for aircraft, guided missiles, etc.
27. Hydraulic oil in reserve or external storage tanks
28. Passengers
29. Water in compensated waste, lubricating oil, or waste oil collecting tanks

30. Water in water round torpedo tanks

31. WRT water in forward trim and WRT tank combined

32. Water in torpedo tube drain tanks

33. Battery electrolyte (above minimum operating level)

d Variable Ballast includes the variable water and variable fuel oil. Variable water is defined as the water in those tanks which are used primarily for compensation for the variable load and for trimming the vessel submerged. Variable fuel oil is the oil carried in the variable fuel oil tanks to compensate for variations in the load in the other types of fuel tanks.

e Water Ballast in Main Ballast, Fuel Ballast, and Safety Tanks includes the water in these tanks above the level of the top of the flood opening, i.e., the quantity which is expelled when the tank is blown.

f. Residual Water in Main Ballast, Fuel Ballast, and Safety Tanks includes the water which remains in these tanks, below the top of the flood opening, when the tanks are blown.

g Water Seal in Fuel Ballast Tanks includes the water in these tanks above the level of the flood opening and below the level of the compensating water pipe.

h The distinction outlined above between Condition A weights and the variable load is adequate for all practical purposes. It is important that any weight which will normally be carried in service be included under one of the above headings and that there is no duplication of any item under different headings.

096–2.9.4 DEFINITIONS OF CONDITIONS OF LOADING FOR SUBMARINES. Certain significant conditions of loading have been defined and assigned identifying letters for convenient reference, as follows:

8284) NOTE 1

Conditions M and M–Sub are not appropriate for ships which are not fitted with fuel ballast tanks.

8285) NOTE 2

In all the conditions defined in this paragraph, all salt water is assumed to have a density of 64 pounds per cubic foot.

a. Condition A–Light ship. Ship complete, ready for service in every respect, including lead ballast, liquids in machinery at operating levels, air in banks at full charge, electrolyte in storage batteries at minimum operating level, water in torpedo impulse tanks, and emergency rations and fresh water but without any items of consumable or variable load.

b. Condition N–Surface diving trim with normal fuel. An operating condition with normal fuel oil tanks full; normal quantities of other items of variable load; main ballast, fuel ballast, and safety tanks empty and with variable ballast adjusted to bring ship to diving trim.

c. Condition N–Submerged, with normal fuel. A condition identical to Condition N, except that main ballast, fuel ballast, and safety tanks are flooded. In this condition, ship will have neutral buoyancy and zero fore–and–aft trim.

d. Condition M–Surface, diving trim with maximum fuel. An operating condition with a full load of oil in normal fuel tanks and fuel ballast tanks; normal quantities of other items of variable load; main ballast and safety tanks empty and with variable ballast adjusted to bring ship to diving trim.

e. Condition M–Submerged, with maximum fuel. A condition identical to Condition M, except that the main ballast and safety tanks are flooded. In this condition, ship will have neutral buoyancy and zero fore-and-aft trim.

096–2.9.5 DETAILED DESCRIPTION OF CONDITIONS OF LOADING FOR SUBMARINES. The variable load is assumed to be the same in Condition N, N–Sub, M, and M–Sub except that in conditions M and M–Sub the fuel ballast tanks are used for fuel oil only.

a. Quantities of the various items of load for Conditions N and N–Sub which are designated as normal quantities are determined as follows:

1. Crew and effects: Wartime complement as currently authorized by the Bureau of Naval Personnel, or the number of berths, whichever is larger. Unit weight for men is taken as 160 pounds and the complement is assumed to be at battle stations submerged. The unit weight for effects is taken at 240 pounds for commissioned officers, 170 pounds for chief petty officers and 70 pounds for other enlisted personnel.

2. Contents of sanitary tanks. Tanks filled with salt water to one–third of the total net volume.

3. Lubricating oil in sump tanks. Seventy–five percent of the total net volume of the tanks.

4. Water in hovering tanks. Fifty percent of the total net volume of the tanks.

5. Water in depth control tanks (pneumatic systems). Ninety-five percent of the total net volume of the smaller Depth Control Tank plus five percent of the total net volume of the larger Depth Control Tank.

6. Sanitary flush water. On those submarines in which sanitary flush water is obtained from a pressurized auxiliary tank, the minimum amount required. Ships with separate sanitary flush tanks, 60& pct; of full capacity.

7. Nitrogen. Full charge in flasks not associated with main propulsion power system.

8. Ballistic missiles. Ballistic missiles assigned to the ship, in their stowed position, fully equipped.

9. Water in ballistic missile compensating tanks. An amount of water such that the weight of compensating water plus missiles (pre–fire) equals the back flooded weight (post–fire).

10. Oxygen candles. Total weight as specified in the Allowance Parts/Equipage List.

11. Potable water. One hundred percent of the net volume of the tanks.

12. Battery fresh water. One hundred percent of the total volume of the tanks.

13. Reserve feed water. One hundred percent of the total net volume of the tanks.

14. Reserve coolant (pure water). One hundred percent of the total net volume of the storage tanks.

15. Provisions. The weight of provisions is based on the complement and the number of days endurance given in the estimated weights. The rates of consumption used are given in Table 096–2–4.

Table 096–2–4. CONSUMPTION RATE

Provisions	Utilization Factor	Pounds per Man Per day	Density lbs. Per Cu. Ft.
Dry	0.7	4.52	35
Freeze	0.5	1.62	39
Chill	0.5	0.87	23

(a) The utilization factor is the ratio of the volume the load item occupies to the total volume of the space, assuming compact stowage. The density factor should be applied to the net volume of each compartment to determine its capacity in pounds for any load item.

(b) Because of the perishable nature of food items stored in chill, a 30 day upper limit is recommended.

(c) If the freeze spaces will not accommodate the amount indicated above, assume a capacity load of frozen provisions. If the dry provision and chill stowage will not accommodate the amounts indicated, assume the quantity specified above is aboard, with storerooms filled to capacity and the remainder distributed throughout the ship in accordance with actual practice. Medical stores are included in the amounts normally carried, or if this information is not available, the figures in the design estimated weights are used.

16. General stores. This item includes all stores, other than personnel stores, which are of a consumable nature. Garbage weights, cans, and bags are included. The quantity included in the design estimated weights should be used. If the estimated weights are not available or have become obsolete, the weight should be that which the ship normally loads.

17. Oxygen for air revitalization. Full charge in flasks.

18. Lubricating oil. Ninety-five percent of the total net volume of the storage tanks. Settling tanks empty

19. Fuel oil in sea pressure compensation tanks. One hundred percent of the total net volume of the Normal Fuel Tanks and collecting tank.

20. Sea water in sea pressure compensated fuel expansion tank. One hundred percent of the total net volume of the fuel expansion tank.

21. Fuel oil in low pressure compensated tanks. One hundred percent of the total net volume of the Collecting Tank and one hundred percent of the total net volume of the Normal Fuel Oil tanks less the volume of sea water required in tanks for fuel expansion purpose.

22. Sea water in low pressure fuel expansion or overflow tanks. Fifty percent of the total net volume of the fuel expansion or overflow tanks.

23. Clean fuel oil. Ninety-five percent of the total net volume of the tank.

24. Ammunition and pyrotechnics. Maximum amount that can be stored in magazine and ready service spaces.

25. Torpedoes, mines, subroc. Maximum stowage in all tubes and racks. Use weight, ready for war shot, of heaviest weapon mix which ship can fire, unless otherwise specified in the detail specifications.

26. Guided missiles. Guided missiles assigned to ship, in their stowed position, fully fueled and equipped.

27. Cargo. For cargo types, full load of cargo is included. The design estimated weights may be used for guidance. For special types assigned aircraft, landing craft and vehicles are included in this category.

28. Special Fuels for Aircraft, Guided Missiles, etc. Rated capacity of the tanks assigned, less the quantities assumed drawn off to fuel the craft or the missiles. Any compensating water in these tanks is included under this heading.

29. Hydraulic oil in reserve or reserve external storage tanks. Ninety–five percent of the total net volume of the tanks assigned.

30. Passengers. Weights used for passengers and their effects, other than troops, are determined by allocating the following pounds per man (lb/man):

Officers (commissioned or warrent)	400 lb/man
Chief Petty Officers	330 lb/man
Other Enlisted Personnel	230 lb/man

For embarked troops and their equipment, a figure of 240 pounds per man is used for both officer and enlisted personnel unless troops are equipped for arctic operation in which case a figure of 290 pound per man is used. The center of gravity is taken as berthed.

31. Electrolyte in storage batteries. This item is the weight of the electrolyte between the minimum and normal operating levels.

32. Water in compensated waste lubricating oil or waste oil collecting tanks. One hundred percent of the total net volume of the tanks.

33. Water in water round torpedoes tanks. One hundred percent of the total net volume of the tanks, but not to exceed one hundred and twenty percent of the amount required to fill torpedo tubes with water around the smallest torpedo carried.

34. WRT water in forward trim and WRT tank combined. One hundred and twenty percent of the amount of water required to flood torpedo tubes around all torpedoes or mines assigned.

35. Water in torpedo tube drain tanks. This special sump tank is empty in Conditions N and N–Sub.

36. Torpedo tubes. Contain no water. The variable load in Conditions N and M is calculated by adding the following items:

37. Fuel oil in fuel ballast tanks. One hundred percent of the total net volume of the Fuel Ballast Tanks above the bottom of the compensating water pipes or water seal.

38. Lubricating oil in reserve (Emergency lube oil tanks). Ninety-five percent of the total net volume of the tanks.

b. The variable ballast in Condition N, N–Sub, M, and M–Sub consists of the following:

1. Variable water in auxiliary tanks (excluding sanitary flush tank if auxiliary and sanitary flush tanks are combined), after and forward trim tank (excluding amount for WRT if forward trim and WRT tanks are combined). Tanks loaded as necessary to bring the ship to diving trim with maximum metacentric height.

2. Variable fuel in variable fuel oil tanks. The weight of variable fuel oil in each of the above conditions is equivalent to the increase in weight which will occur when oil in the fuel oil tanks is replaced by salt water, subject to the following:

(a) The quantity of variable fuel oil does not exceed 95& pct; of the total net volume of the tank.

(b) The quantity of variable fuel oil is limited to the amount which will permit the ship to be brought to diving trim in conjunction with a reasonable quantity of variable water.

3. Variable fresh water in variable fresh water tanks. The weight of variable fresh water in each of the above conditions is limited to the amount which will permit the ship to be brought to diving trim in conjunction with a reasonable quantity of variable water in the auxiliary, forward, and aft trim tanks.

c. The Water Ballast in Condition N–Sub and M–Sub consists of the following:

1. Main ballast and safety tanks. One hundred percent of the total net volume of the tanks minus residual water.

2. Fuel ballast tanks. In Condition N–Sub, one hundred percent of the total net volume of the tanks, minus residual water.

3. Negative tank. The negative tank is assumed empty of all conditions of loading.

4. Regulating tank. This tank, when fitted, combines the functions of the safety and negative tanks. In conditions N–Sub and M–Sub, it is assumed to be filled to within ten tons of its capacity.

d. The residual water in Condition N and Condition M is the amount of water remaining in the main ballast, fuel ballast, and safety tanks below the level of the highest point of the flood openings when the tanks are blown. It also includes the water held in those topside cavity drain pipes which extend below the residual water line. This quantity of residual water is included in all conditions of loading.

e. Water Seal is the quantity of water in the fuel ballast tanks in Conditions M and M–Sub between the level of the top of the flood opening and the bottom of the compensating water pipe.

096–2.10 FREE SURFACE EFFECT IN LOADED CONDITIONS

096–2.10.1 EFFECT OF FREE SURFACE ON RIGHTING ARM. Free liquids in a ship have the effect of reducing the righting arm at various angles of heel. The decrease in righting arm at any angle of inclination is given by the formula:

$$\text{Decrease in righting arm (in feet)} = \frac{M}{\Delta}$$

Where:

M = Moment of transference of free liquid parallel to the inclined waterline (in foot tons).

Δ = displacement of ship (in tons)

For a rectangular tank, the moment of transference (M) may be expressed in the following manner:

$$\text{Moment of transference (in foot tons)} = Cx\ \frac{1}{\delta}$$

Where

C = a coefficient determined by the angle of inclination, the ratio of depth to breadth of the tank, and the degree of fullness.

I = the moment of inertia of the free surface at zero inclination about a longitudinal axis through its center of gravity (in feet^4).

δ = specific volume of liquid (in cubic feet per ton).

Values of the coefficient C within certain limits are given in Table 096–2–5 and Table 096–2–6. These coefficients may be used as described in paragraph 096–2.10.2 to give a reasonable approximation of reduction in righting arm due to free liquids in practically all tanks.

096–2.10.2 DETERMINATION OF FREE SURFACE EFFECT FOR LOADED CONDITIONS. It must be recognized that a theoretically accurate correction to righting arms for free surface would involve an unreasonable amount of calculation. The application of the following principles, however, will provide an adequate degree of accuracy for practical purposes.

a. Where the total moment of inertia for all slack tanks in feet^4 is numerically less than twenty times the displacement in tons, the value of I/(delta) is calculated for each slack tank. This quantity is designated as the Vertical Moment of Free Surface. The summation of the vertical moment of free surface for all slack tanks, divided by the displacement of the ship is designated as the Free Surface Correction, and is considered as a virtual rise in the center of gravity of the ship and as a virtual reduction in metacentric height. In drawing a curve of righting arms, the height of the center of gravity of the ship is taken at the virtual height.

b. Where the total moment of inertia of all slack tanks is numerically greater than twenty times the displacement, the coefficients in Table 096–2–5 and Table 096–2–6 are used or the actual moment of transference calculated. Although these coefficients are strictly applicable only to rectangular tanks, they may be used as outlined below with a satisfactory degree of accuracy for all tanks except in rare cases where the tank is very irregular and also has a large free surface. In such cases, the actual moment of transference should be calculated for several angles of inclination.

c. For tanks which are approximately trapezoidal in plan view, the value of breadth used in determining the depth to breadth ratio for application of Table 096–2–5 and Table 096–2–6 should generally be the breadth of the narrow end. This will be sufficiently accurate in most cases, since tanks which have a substantial variation in breadth will usually have a small free surface effect. If this procedure is not considered sufficiently accurate, the breadth in feet may be taken as:

d. For tanks which are not rectangular in transverse section, the depth used for application of Table 096–2–5 and Table 096–2–6 should generally be taken as the greatest depth. If this is not considered sufficiently accurate, the depth should be taken as twenty times the distance from the free surface to the tank top for tanks 95 percent full or two times this distance for tanks 50 percent full.

e. The next larger value of the depth to breadth ratio should be used in entering Table 096–2–5 and Table 096–2–6 unless an interpolation is made. Interpolation will not generally be necessary and should not be employed unless a substantial difference in righting arms would result.

f. A form entitled Correction to Righting Arms for Free Surface is provided for making this correction for ships having a large free surface effect. See paragraph 096–2.13.1. For each slack tank, the depth to breadth ratio, percent full, vertical moment of free surface and applicable coefficients from Table 096–2–5 and Table 096–2–6 are entered in the appropriate columns. The moments of transference are then obtained by multiplying the vertical moment of free surface by the coefficients. To reduce the amount of work tanks having the same values of depth to breadth and percent full may be grouped and the total vertical moment of free surface obtained before applying the coefficients. The total moment of transference for each ten degrees of inclination is obtained and divided by the displacement in tons to obtain the correction to righting arms in feet. When this method is used, the metacentric height corrected for free surface is considered to be 5.73 times the corrected righting arm at ten degrees.

Table 096–2–5. FACTORS FOR MOMENT OF TRANSFERENCE OF FREE LIQUID IN RECTANGULAR TANKS–95 PERCENT FULL

Ratio of depth to breadth	Angle of Inclination (degrees)								
	10	20	30	40	50	60	70	80	90
0.1 ---	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00
0.15 ---	.04	.04	.04	.03	.03	.02	.02	.01	.01
0.2 ---	.05	.05	.05	.04	.04	.03	.03	.02	.01
0.25 ---	.06	.06	.06	.06	.05	.04	.03	.03	.02
0.3 ---	.06	.07	.07	.07	.06	.05	.04	.04	.03
0.4 ---	.08	.09	.09	.09	.08	.07	.06	.05	.05
0.5 ---	.10	.11	.11	.11	.10	.09	.08	.07	.07
0.6 ---	.11	.13	.13	.13	.12	.11	.10	.09	.10
0.7 ---	.12	.14	.15	.15	.14	.13	.12	.11	.14
0.8 ---	.13	.16	.17	.17	.16	.14	.13	.14	.18
0.9 ---	.14	.18	.19	.18	.18	.16	.15	.16	.23
1.0 ---	.15	.19	.20	.20	.20	.18	.17	.18	.28
1.2 ---	.16	.22	.24	.24	.24	.23	.22	.23	.41
1.5 ---	.17	.25	.28	.29	.29	.29	.28	.31	.64
2.0 ---	.18	.30	.35	.38	.38	.38	.39	.45	1.14
3.0 ---	.18	.36	.46	.52	.56	.58	.62	.77	2.6
4.0 ---	.18	.36	.53	.64	.71	.78	.87	1.12	4.6
5.0 ---	.18	.36	.57	.74	.85	.96	1.12	1.5	7.1
6.0 ---	.18	.36	.58	.80	.97	1.14	1.36	1.9	10.3
7.0 ---	.18	.36	.58	.85	1.09	1.30	1.6	2.3	14.0
8.0 ---	.18	.36	.58	.87	1.16	1.46	1.9	2.7	18.2
9.0 ---	.18	.36	.58	.87	1.22	1.6	2.1	3.2	23.0
10.0 ---	.18	.36	.58	.87	1.27	1.7	2.3	3.6	28.5

096–2.10.3 ASSUMED CONDITION OF TANKS WITH RESPECT TO FREE SURFACE. When the effect of free surface is calculated for any condition of loading, the level of the liquid in each tank is assumed to be the same as that used in calculating the weight and center of gravity of the tankage in that condition, except as follows:

a. One pair of tanks or one centerline tank in each system is assumed to be on suction and 50 percent full. The tank or pair of tanks on suction is selected to produce the largest free surface effect. A system is defined as a group of tanks containing the same type of liquid, where the tanks are drawn down in pairs or successively as the liquid is consumed. On ships employing split–plant operation, each section is considered a system.

b. Tanks which are usually partially filled, such as service tanks, contaminated oil tanks or overflow tanks are assumed to be 50 percent full.

c. When a tank is neither empty, full, 95 percent full, nor 50 percent full, as in the case of tanks which are filled to the waterline in certain conditions, the tank is assumed to be 50 percent full for the purpose of free surface calculations unless this would result in a substantial error.

Table 096–2–6. FACTORS FOR MOMENT OF TRANSFERENCE OF FREE LIQUID IN RECTANGULAR TANKS–50 PERCENT FULL

Ratio of depth to breadth	Angle of Inclination (degrees)								
	10	20	30	40	50	60	70	80	90
0.1	0.13	0.14	0.14	.12	0.11	0.09	0.06	0.04	0.02
0.15	.17	.21	.21	.19	.16	.14	.10	.07	.03
0.2	.18	.27	.27	.26	.23	.20	.16	.11	.06
0.25	.18	.31	.34	.33	.30	.26	.21	.16	.09
0.3	.18	.35	.40	.40	.37	.33	.27	.21	.14
0.4	.18	.36	.50	.53	.51	.47	.41	.33	.24
0.5	.18	.36	.57	.65	.66	.63	.56	.47	.38
0.6	.18	.36	.58	.74	.80	.79	.74	.65	.54
0.7	.18	.36	.58	.83	.94	.96	.92	.85	.74
0.8	.18	.36	.58	.87	1.06	1.13	1.12	1.06	.96
0.9	.18	.36	.58	.87	1.16	1.30	1.34	1.30	1.22
1.0	.18	.36	.58	.87	1.24	1.47	1.56	1.56	1.50
1.2	.18	.36	.58	.87	1.31	1.7	2.0	2.1	2.2
1.5	.18	.36	.58	.87	1.31	2.0	2.7	3.1	3.4
2.0	.18	.36	.58	.87	1.31	2.2	3.7	5.0	6.0
3.0	.18	.36	.58	.87	1.31	2.2	4.5	9.3	13.5

Table 096–2–6. FACTORS FOR MOMENT OF TRANSFERENCE OF FREE LIQUID IN RECTANGULAR TANKS–50 PERCENT FULL (CONT)

Ratio of depth to breadth	Angle of Inclination (degrees)								
	10	20	30	40	50	60	70	80	90
4.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	13.4	24.0
5.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.2	37.0
6.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.8	54.0
7.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.8	73.0
8.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.8	96.0
9.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.8	121.0
10.0 ----	.18	.36	.58	.87	1.31	2.2	4.5	16.8	150.0

Where:

I = moment of inertia of the free surface at zero inclination in feet^4

$\int$ = length of the tank in feet

d. For Submarines. In determining free surface for Condition N, N–Sub, M, and M–Sub, if a system is designated full and there is more than one tank in the system, the largest tank of the system shall require a free surface correction for a slack tank even though its weight shall be at 100& pct; capacity. The exceptions to this are compensated tanks and main ballast tanks.

096–2.11 SHIPS WITH LIST

096–2.11.1 CONDITIONS REQUIRING DETERMINATION OF TRANSVERSE MOMENT. Additional calculations to determine heeling moments are made for ships which are not upright in Condition A, or which have unsymmetrical items of load which might cause an undesirable list. It is not intended that transverse moment calculations be made for ships which have only a slight list. Consideration of this factor is necessary only for ships on which special control of loading is necessary to maintain an upright position. When transverse moment calculations are made, it is not intended that they be elaborate. Only items having a significant transverse moment and not counter–balanced by similar items on the opposite side are considered. Calculations should not be more extensive or exact than necessary to show that the list can be removed in the loaded conditions. Transverse moment calculations are not required for submarines.

096–2.11.2 DETERMINATION OF TRANSVERSE MOMENT IN CONDITION A. The unsymmetrical moment in the as–inclined condition is determined. This may be determined from the midship port and starboard draft readings or by moving the inclining weights transversely to bring the ship exactly to the upright position and calculating the off–center moment of the inclining weights in this location. The transverse moment of any unsymmetrical items in the weight to complete, weight to deduct, or weight to relocate, is also calculated. From the above data the transverse moment and the distance from the centerline in Condition A are computed and included in the report of the inclining experiment. In plotting the right arm curve for Condition A in the Stability Data, a correction is made by deducting this distance multiplied by the cosine of the angle of inclination from the value of the righting arms.

096–2.11.3 DETERMINATION OF TRANSVERSE MOMENT IN LOADED CONDITIONS. For ships which are not upright in Condition A and for ships which would not be upright in the loaded conditions without special distribution of the load, a calculation is made and included in the Stability Data to demonstrate that the list can be removed in the loaded conditions or, if this is not possible, to indicate what the residual moment would be

after the maximum reasonable list correction has been applied. The displacement and transverse moment in Condition A are entered on the form entitled Transverse Moment in Condition and modified as necessary to take into account any changes since inclining. To this are added the weight and transverse moment of any items of load which must be located unsymmetrically due to the nature of their stowages. Next, the items of load which may be loaded unsymmetrically in order to remove the list are added. The most practical method of list correction should be assumed in this calculation. If the transverse moment thus calculated cannot be brought very nearly to zero, the residual moment is used to modify the righting arm curve for the particular condition as described in the preceding paragraph.

096–2.12 ACCURACY

096–2.12.1 The importance of accuracy in observing and calculating data relative to a particular item can be judged by considering the effect of that item on the ships displacement and center of gravity.

a. An error in measurement of pendulum length, pendulum deflection, inclining weight or weight movement will be reflected as a proportional error in the metacentric height in the as inclined condition.

b. Inaccuracy in draft reading will result in an error in displacement and, at the lighter drafts, may also cause a substantial error in the position of the transverse metacenter with a corresponding error in the vertical center of gravity.

c. Errors in weight-to-complete and weight-to-deduct affect the Condition A displacement directly. The degree of accuracy required to determine the center of gravity of any item depends upon the weight of the item.

d. The importance of various tanks in determining the total free surface correction varies widely. For a bottom tank whose width is about half the ships beam it is essential that the size and shape of the free surface be determined accurately and that precise methods of calculating the moment of inertia be used. For narrow tanks, less precise measurement and calculations are acceptable. There are many small tanks for which the free surface correction is negligible. The criterion in each case is the effect on the vertical center of gravity of the ship.

e. There are certain areas in which the substitution of a reasonable approximation for a precise calculation would save a great deal of time with no significant reduction in the accuracy of the final result. An example is the determination of the weight, moment of inertia of free surface, and the vertical and longitudinal position of the center of gravity of liquids in tanks which are partially filled at the time of inclining. In most cases, sufficient accuracy will be obtained by using the tank capacity tables for weight and vertical center of gravity, assuming that the surface is trapezoidal for the purpose of obtaining moment of inertia and assuming a linear variation of section area along the length of the tank to locate the longitudinal center of gravity. If the vertical center of gravity is not shown on the tank capacity tables, an approximate formula for vertical center of buoyancy may be used for satisfactory accuracy.

096–2.13 PROCESSING INCLINING EXPERIMENT DATA

096–2.13.1 FORMS. NAVSEA Forms 9290/6–1 through 9290/6–52 (Rev. 4–74) are available in the Cognizance Symbol “I” supply system. Users should obtain the current revised forms from the COG–I system. The forms are enumerated in Table 096–2–7. Computer printout sheets may be substituted for NAVSEA 9290/6 sheets, if desired. All basic information specified herein shall be shown if computer processing is utilized. Format and arrangement of data may vary to suit computer process used.

096–2.13.2 SECURITY CLASSIFICATION. The Inclining Experiment Report (Part 1) is unclassified. The Stability Data (Part 2) and the Stability and Equilibrium Data (Part 2) are assigned a Confidential security classification for: warships, BB, CA, CG, CGN, CC, CV, CVN, CVS, CVT, DD, DDG, DL, FF, FFG, PCE, PCER, PG and Submarines; Amphibious Warfare ships, LCC, LFR, LHA, LKA, LPA, LPD, LPH, LPR, LPSS, LSD, and LST; Mine Warfare Ships, MCS, MHC, MMC, MMD, MMF, MSC, MSCO, MSF, MSO and MSS; and experimental and future combatant ships designated by NAVSEA.

Table 096–2–7. FORMS FOR PROCESSING INCLINING EXPERIMENT DATA

Form Title	Form Number NAVSEA 9290/6–
Table 7A. Inclining Experiment Report, (Part–1) For Surface Ships and Submarines	
Title Sheet—Inclining Experiment Report, (Part–1), For Surface and Submarines	1
Armament, Boats, Submarine Batteries, Ballast	2
Ship in Condition A—Light Ship	3
Change In Condition A Weight Since Inclining	4
Displacement and Center of Gravity, “As Inclined,” Trim Not Excessive	5
Displacement and Center of Gravity, “As Inclined,” Trim Excessive	6
Functions of Wedge Areas	7
Displacement and Center of Gravity in Conditions A and A–1	8
Weight Movements and Inclinations	9
Plot of Tangents	10
Weight To Complete	11
Weight To Deduct	12
Weight To Relocate	13
Vertical Moment of Free Surgace, “As Inclined”	14
Diagram Showing Location of Draft Marks	15
Remarks and Miscellaneous Calculations	16
Summary of Load Items in Condition_____	23
Details of Load Items in Condition_____	24
Correction to Righting Arms for Large Free Surface Effect in Condition_____	25
Tank Capacities	26
Compartment Capacities	27
Table of Frame Spacing	28
Remarks and Miscellaneous Calculations	16
Table 7B. Inclining Experiment Report, (Part–2) Stability Data—For Surface Ships Only	
Title Sheet—Inclining Experiment Report, (Part–2), Stability Data—For Surface Ships Only	17
Armament, Boats, Submarine Batteries, Ballast	2
Ship In Condition A—Light Ship	3
Change in Conditions A Weight Since Inclining	4
Ship in Condition_____(Small Free Surface Effect)	18
Ship in Condition_____(Large Free Surface Effect)	19
Displacement and Other Curves	20
Cross Curves of Stability	21
Diagram Showing Location of Draft Marks	15
Approximate Change in Metacentric Height Due to Added Weight	22

Table 096–2–7. FORMS FOR PROCESSING INCLINING EXPERIMENT DATA (Continued)

Form Title	Form Number NAVSEA 9290/6–
Table 7C. Inclining Experiment Report, (Part–2) Stability and Equilibrium Data For Submarines	
Title Sheet—Inclining Experiment Report, (Part–2), For Stability and Equilibrium Data for Submarines	29
Load to Submerge—Determination	30
Armament, Boats, Submarine Batteries, Ballast	2
Ship In Condition A—Light Ship	3
Detailed Change In Condition A and Submerged Displacement Since Last Inclining & Trim Dive	31
Load to Submerge at Time of Trim Dive	32
Details of Load on Trim Dive	33
Ship in Condition_____Surface Diving Trim	34
Ship in Condition_____Submerged	35
Variable Ballast in Condition_____	36
Displacement and Other Curves	20
*Cross Curves of Stability	21
Diagram Showing Location of Draft Marks	15
Variable Load in Conditions N and M	37
Details of Variable Load in Conditions N and M	38
Water Ballast in Main Ballast, Fuel Ballast, and Safety Tanks	39
Residual Water, Water Seal and MBT Lead Corrections	40
*Equilibrium Polygon	41
Points for Equilibrium Polygon	42
Equilibrium Conditions– Light No. 1 & Light No. 2	43
Heavy No. 1 & Heavy No. 2	44
Neavy No. 1 (With Mines) & Heavy No. 2 (With Mines)	45
Heavy FWD No. 1	46
Heavy FWD No. 2	47
Heavy AFT	48
Detail of Loads for Equilibrium Conditions	49
*Plot of Minimum GM While Trimming Down	50
Conditions While Trimming Down	51
*Ship in Condition_____Surface Diving Trim, Ballast Tanks Flooded, One Side Only	52
Table of Frame Spacing	28
Remarks and Miscellaneous Calculations	16
*A copy of these sheets when completed also becomes apart of the appropriate Damage Control Book for submarines.	

096–2.13.3 APPROVAL, RESPONSIBILITY AND SIGNATURE. Inclining Experiment reports are neither acknowledged nor approved by the Naval Sea Systems Command. Responsibility for preparation is as follows:

a. NAVSEA Field Activity Performed Inclining Experiments. An experienced Engineering Duty Officer or supervisory civilian shall be assigned the responsibility of actively supervising the performance of the experiments, preparation of calculations, and the timely reporting of the results. The Commander of the field activity may delegate the signature of final reports (Parts 1 and 2) to a qualified staff member, military, or civilian.

b. Contractor Performed Inclining Experiments. An experienced Engineering Duty Officer or supervisory civilian of the Supervisor's staff shall be assigned the task of witnessing Contractor performed experiments. The Supervisor's staff shall be satisfied that the inclining or trim dive was conducted under favorable conditions, that the calculations were adequately checked by the Contractor, and that the reports are in accordance with the Ship Specifications as to content and timeliness. Final reports (Parts 1 and 2) shall be signed by an appropriate supervisory member of the Contractor's staff and by the Supervisor of Shipbuilding. The latter may delegate signature to a qualified staff member, military or civilian.

096–2.13.4 DISTRIBUTION. In general, distribution shall be the responsibility of the inclining activity. In the case of a private contractor, distribution shall be according to the specifications or contract for performing the experiment. The distribution of the completed, approved Inclining Experiment Data is delineated in Table 096–2–8.

Table 096–2–8. DISTRIBUTION OF APPROVED INCLINING EXPERIMENT DATA

Inclining Experiment Data for ↓ / Distribution →	OneCopy of Part 2 to the Commanding Officer of Each Ship to Which It Applies	One Copy of Part 1 and One Reproducible Copy[3] of Part 2 to Naval Shipyards as Indicated Below[1]	Part 1 and Part 2 Originals to NAVSEA and Copies to NAVSEC	One Copy of Part 1 and Part 2 to the Supervisor of Shipbuiling of the Lead Yard	Two Copies of Part 1 and Part 2 to each Supervisor of Shipbuilding of each Following yard	One Copy of Part 1 and Part 2 to the Supervisor of the Shipbuilding of the Inclining Activity
New Construction Lead Ship Built in a Naval Shipyard	X	X	X		X	
New Construction Lead Ship Built in a Private Shipyard	X	X	X	X	X	X
New Construction Follow Ship Built in a Naval Shipyard	X	X	X	X	X	
New Construction Follow Ship Built in a Private Shipyard	X	X	X	X	X	X
Active Ship Inclined in Naval Shipyard	X	X	X			
Active Ship Inclined in a Private Shipyard	X	X	X			X

[1]Naval Shipyard	Furnish Data for
Charleston	All Ships except BB, CVA, CVAN and CVS
Long Beach	All Ships except submarines

Mare Island	All Ships except BB, CVA, CVAN and CVS
Norfolk	All Ships
Pearl Harbor	All Ships
Philadelphia	All surface ships and diesel submarines
Portsmouth	Submarines, AS and ASR
Puget Sound	All Ships

[2]In addition, NAVSEA should be informed of the distribution of all copies, including any retained by the inclining activity.

[3]Reproducible copies may be any legible copy from which clear copies may be produced using modern reproduction devices.

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