DDS 100-6

LONGITUDINAL STRENGTH CALCULATION

DEPARTMENT OF THE NAVY

NAVAL SEA SYSTEMS COMMAND

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DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

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LONGITUDINAL STRENGTH CALCULATION

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100-6-a. References

(a) CASDAC No. 230021, Ship Design Weight Estimate Program (SDWE) User's Manual, vol. II, NAVSEC.

(b) Expanded Ship Work Breakdown Structure for All Ships and Ship/Combat Systems, NAVSEA publication, S9040-AA-IDX-010/SWBS 5D

(c) CASDAC No. 231072, Ship Hull Characteristics Program (SHCP) User's Manual, NAVSEC, 1976.

(d) Ferris, L.W., "The Effect of an Added Weight on Longitudinal Strength," SNAME Transactions, 1940.

100-6-b. Purpose and scope

This Design Data Sheet (DDS) describes the traditional static balance method of calculating longitudinal hull shear forces, bending moments, and hull deflections; it also describes the accepted Navy method of calculating the effective hull section properties and related stresses. For simplicity, traditional manual solutions are described throughout this DDS. The referenced computer programs employ the same underlying assumptions and procedures and, therefore, give similar results.

100-6-c. Symbols and abbreviations

A	=	sectional area	(in^2)
a	=	unit area of shape elements	(in^2)
AP	=	after perpendicular of ship	
b	=	elemental width	(in)
c_b	=	block coefficient	
D	=	depth of ship's section	(ft)
d	=	moment arm or lever arm	(ft)
E	=	Young's modulus of elasticity	(ksi)

FP	=	forward perpendicular of ship	
f_{1c}	=	calculated primary hull bending stress	(tons/in^2)
h_w	=	standard trochoidal wave height measured from crest to trough	(ft)
h	=	projected height of plate elements	(ft)
I	=	moment of inertia	(in^2-ft^2)
I_{BL}	=	moment of inertia about baseline	(in^2-ft^2)
I_{NA}	=	moment of inertia about neutral axis of hull	(in^2-ft^2)
i_o		moment of inertia about neutral axis of individual elements or sections	(in^2-ft^2)
kip	=	thousand pounds	(lb or lbf)
ksi	=	thousand pounds per square inch	(lbf/in^2)
LBP or L	=	ship length between perpendiculars	(ft)
LCB	=	longitudinal center of buoyancy	
LCG	=	longitudinal center of gravity	
LOA	=	length overall	(ft)
LWL	=	length on design waterline	(ft)
M	=	bending moment	(ft-tons)
ΔM	=	change in bending moment due to added or removed weight	(ft-tons)
m	=	moment of area of section above shear plane, with respect to neutral axis	(in^2 - ft)
n	=	number of shape elements	
P	=	added weight	(tons)
Q	=	shearing force	(tons)
SDWE	=	Ship Design Weight Estimate	
SHCP	=	Ship Hull Characteristics Program	
SM	=	section modulus	(in^2-ft)
SM_{DK}	=	section modulus, deck	(in^2-ft)
SM_{KL}	=	section modulus, keel	(in^2-ft)
t	=	plate thickness	(in)
x	=	distance from origin along x axis	(ft, in)
y	=	distance from origin along y axis	(ft, in)

y_d	=	distance of deck from neutral axis of ship	(ft)
y_k	=	distance of keel from neutral axis of ship	(ft)
y_o	=	distance of baseline of ship from neutral axis	(ft)
z	=	distance from origin along z axis	(ft, in)
$\bar{z}$	=	distance from baseline to keel	(ft)
Δ DELTA	=	ship's displacement	(tons)
$\triangle$ Delta	=	a finite increment	
δ delta	=	hull deflection	(in)
λ lambda	=	wave length	(ft)
τ tau	=	shear stress	(tons/in^2)
ϕ phi	=	trochoidal wave profile generating parameter	(radians)
⊗ MSHP	=	midships	

100-6-d. General design principles

The hull is assumed to be a girder which is loaded statically and which behaves in accordance with the theory of flexure. The downward loads on the girder are the weights of the component parts of the ship and any weights carried by the ship. The upward loads on the girder are the forces of buoyancy (and grounding or beaching loads in special cases). Longitudinal hull girder flexure is described as hogging when excess buoyancy amidships causes the middle portion of the ship to deflect (hog) upwards, and as sagging when less buoyancy amidships allows the middle portion of the ship to deflect (sag) downward.

The ship is statically balanced in the following conditions:

(a) Still water condition

(b) Waveborne condition wherein the ship is balanced on a stationary, "standard" trochoidal wave in both hogging and sagging.

Past designs for ships of standard size, construction, and hull form have shown that the static longitudinal strength analysis, which is mainly empirically derived, allows sufficient safety margin to account for all primary hull loadings. Once the weight and buoyancy distributions are determined so that the ship is statically balanced, the hull girder load curve can be calculated by algebraically summing the opposing weight and buoyancy forces along the length of the hull. Successive integrations of the load curve with respect to ship length provide the longitudinal shear, longitudinal bending moment, and deflection of the hull girder along the length. Given the hull scantlings, then the section moduli and shear areas along the length can be calculated, and the primary bending and shear stresses can be determined. Based on the calculated stresses, hull scantlings are revised and section moduli recalculated until the specified acceptable stress levels are achieved.

In design and analysis, measurements and properties may be expressed in either US customary or International System (SI) metric units, unless a particular unit system is specified in the ship specifications. The example problems have been completed in US customary units. Appendix D has been provided for conversion to SI-metric.

100-6-e. Prerequisite data

The following data are required for performing the longitudinal strength calculations:

(a) Weight distribution - The ship's weight, consisting of fixed (light ship) weights and variable weights, broken down by ship stations or other convenient increments to give a realistic representation of their distribution along the length of the ship. Fixed and variable components of the weight distribution must be readily separable in order to facilitate manipulation to simulate the various hog and sag inducing loading conditions anticipated in service.

(b) Table of offsets or body plan - For use with the computer-aided approach, or Bonjean curves for the hand calculation method.

(c) Drawings - Sufficiently complete structural drawings to allow calculation of the various section properties for any chosen transverse section, and general arrangement drawings for outlining the ineffective shadow areas throughout the length of the hull.

600-6-f. Steps in calculation

Steps in calculation are:

(a) Tabulation of longitudinal distribution of weights

(b) Definition of wave height, wave length, and wave center

(c) Balancing of ship on wave and still water

(d) Tabulation of the forces of buoyancy

(e) Determination of loads from weights and buoyancy

(f) Integration of loads to give shearing forces

(g) Integration of shearing forces to give bending moments

(h) Determination of effective structure

(i) Calculation of moments of inertia and section moduli

(j) Calculation of bending stresses

(k) Calculation of shearing stresses

(l) Calculation of deflections

(m) Assembly of work in suitable form for record in a longitudinal strength drawing.

100-6-g. Longitudinal strength drawing

The longitudinal strength drawing summarizes the results of the longitudinal strength calculations and is developed as standard background strength data for each ship class of the Navy. It is intended for various future uses such as evaluating the ship's strength against other known hulls, assessing hull damage effects, evaluating future growth and modifications, and evaluating special service loadings. To satisfy these ends, the following items are generally included as standard information in all longitudinal strength drawings. Additional data of background value are to be included to document any special features in individual ship designs.

(a) Weight distribution tables:

(1) Full load

(2) Light ship

(3) Special loads, such as bow sheave or stern roller heavy-lift loads on salvage ships

(4) Special beaching or grounding design loadings

(b) Table of hull section properties (Stations 3 through 17 inclusive):

(1) Net effective area

(2) Moment of inertia

(3) Height of neutral axis

(4) Section moduli to keel and upper strength deck

(c) Table of principal results - Full load

(d) Table of general data

(e) Table of calculated results - Full load condition, Stations 3 to 17 inclusive:

(1) Hull bending moments for hogging, sagging, and still water conditions

(2) Bending stresses at keel and upper strength deck for hogging, sagging, and still water conditions

(f) Table of calculated results for other special design-critical hull loading conditions (such as heavy lift condition for salvage ships, beaching conditions for landing ships, or off-loaded conditions for oilers) or for the design envelope of maximum moments and shears where such curves are developed as part of the design. This additional table, required on a case basis, would include bending moments and stresses similar to those tabulated for the basic full load condition.

(g) Diagrams of weight distribution, shear, bending moments, and bending stresses for full load and special loading conditions. In order to standardize the size of the drawing regardless of the size of ship, the following scaling criteria shall be used for the diagrams on longitudinal strength drawings:

(1) Base length for all curves shall be drawn 20 inches. Since this corresponds to the length between perpendiculars of the ship, the horizontal scale becomes 1 inch = L/20 feet.

(2) The mean heights of the weight curve and the buoyancy curve are made 3 inches for the full load condition. Therefore, the vertical scale for either the weight or the buoyancy curve is 1 inch = Δ/3 L tons per foot of length.

(3) One square inch of area under either the weight curve or the buoyancy curve represents Δ/60 tons.

(4) The shear curve is drawn so that an inch of ordinate represents two square inches under the weight or buoyancy curve; therefore, the vertical scale of the shear curve is 1 inch = Δ/30 tons.

(5) One square inch of area under the shear curve represents Δ/30 x L/20 = Δ L/600 foot-tons.

(6) The bending moment curve is drawn so that an inch of ordinate represents three square inches under the shear curve; therefore, the vertical scale of the bending moment curve is 1 inch = Δ L/200 foot-tons.

(h) Typical section views of effective hull girder structure for stations 3 through 17 inclusive. Other relevant sections may be substituted or more section views added depending on individual designs. Principal sections 5, 10, and 15 are preferred shown on sheet 1 of the drawing together with the tabulated study results, while the remaining section views are shown on sheet 2. The longitudinal strength drawing shall be of standard Navy drawing size. A typical format of the drawing is shown in appendix B. For brevity, drawing sheet 2, which contains only representative section views, is omitted from appendix B. Figures B-1 and B-2 taken together give the overall view of the first sheet of the drawing, while the remaining figures in appendix B show enlarged (and somewhat simplified) views of individual components of the drawing.

PART II. LOADING

100-6-h. Weight

100-6-h.1 General

The ship's weight consists of fixed (light ship) weights and variable weights. The fixed weights consist primarily of hull, hull engineering, machinery, fittings, equipment, permanent ballast, etc. Variable weights consist of cargo, fuel, water, lubricants, water ballast, crew, provisions, ship's stores, etc. Weight distributions under light ship and full load conditions are obtained as standard outputs of the computer generated weight estimates. The longitudinal strength analysis process requires manipulation of these distributions by adding and subtracting variable weights to simulate maximum hogging and sagging hull loading conditions. In the design process, as the weight estimates are refined with each cycle of weight estimate, longitudinal strength is recalculated and structural scantlings are adjusted in an iterative process.

100-6-h.2 Weight distribution

The Navy light ship and full load weight distributions are divided into 22 segments corresponding to the standard 20 ship segments between perpendiculars, plus one forward and one aft of the perpendiculars. To facilitate manipulation of variable weights to arrive at critical hull loading conditions, it is convenient to base all the calculations on this uniform segmentation; this has been found to give sufficiently accurate results. The stations (cross-sections of the hull) are numbered consecutively from zero at the FP to 20 at the AP. Segments are identified by the stations that bound them.

In certain cases such as oilers and cargo ships where a wide range of cargo loadings by compartments must be investigated, it may be more convenient to segment the ship by compartments. Modification of the light ship distribution to match the ship's cargo compartmentation would be required in such cases, or alternatively, the compartmentation stations may be superimposed on standard zero-to-20 ship's stations so as to give calculated results both at compartment end bulkheads and at regular ship's stations. Other high weight items such as nuclear reactors should be similarly treated.

For a complete longitudinal strength analysis, the full range of displacements from full load to minimum operating condition, including all possible intermediate off-loaded conditions, in both hog and sag inducing distributions of variable weights, should be investigated. Variable weights amidship would be off-loaded to form hog inducing distributions, while variable weights forward and aft would be off-loaded to form sag inducing distributions.

Following are some of the loading conditions that should be investigated:

(a) Full load

(b) Combat load

(c) Min-op (minimum operations with partial payload as applicable but with one-third of fuel and stores retained onboard)

(d) Ballast departure/ballast arrival

(e) Any other distribution of cargo and consumables which could occur in service including intermediate conditions that may occur in the loading and off-loading sequence of replenishment ships and fleet oilers

(f) Special external hull loadings such as heavy salvage lifts, beaching, or grounding.

100-6-h.3 <u>Computer applications</u>

The light ship and full load weight distributions are standard outputs generated by the Ship Design Weight Estimate (SDWE) program (references (a) and (b)) specifically for longitudinal strength calculation purposes. The weight distributions are divided into the standard 22 segments (20 equal-length ship segments and one each forward and aft of the perpendiculars). The weight and longitudinal center of gravity of each segment are given. For use as input to the Ship Hull Characteristics Program (SHCP) (reference (c)) for longitudinal strength calculations, the longitudinal center of gravity (LCG) of each station weight must fall within the mid one-third length of the station. For stations in which this condition is not satisfied, manual shift of the LCG to fall within the mid one-third length is necessary. As noted for manual solutions in 100-6-k.1, the LCG of weights in a segment can be assumed at the mid-length of the segment with sufficient accuracy for calculated results. The same assumption would be equally acceptable in computer solutions and indeed may be preferable for consistency of results with comparable existing ship strength data.

100-6-i. Buoyancy

100-6-i.1 General

The buoyancy distribution is dependent upon the immersed hull form. Static balancing of the ship requires that the buoyancy forces of the immersed hull equal the ship's weight in magnitude, and that the longitudinal center of buoyancy (LCB) and the longitudinal center of gravity (LCG) of the weights be aligned vertically, that is, both the sum of the vertical forces shall be zero and the sum of the applied moments shall be zero. The balancing procedure thus requires a trial and error process to arrive at the appropriate displacement and trim to satisfy these conditions of static balance. Centers of gravity of ship segments, and their centers of buoyancy, are assumed to lie in the ship's vertical centerline plane, so that heeling (athwartships) moments may be ignored.

100-6-i.2 Wave profile

The standard wave for longitudinal strength purposes is of trochoidal form with wavelength equal to the length between perpendiculars, L, and wave height, h_w, equal to $1.1 \sqrt{L}$. The trochoidal profile is defined by the following formulas, with the origin of coordinates taken at the lowest point of the wave trough, and with phi in radians. (To use phi in degrees, substitute 360^{o} for 2π in the formula for x.)

$$x = L\frac{\phi}{2\pi} + h_w\frac{\sin\phi}{2}$$

$$y = h_w\frac{1 - \cos\phi}{2}$$

Having determined h_w in a particular case, one may conveniently develop the coordinates for the wave profile by choosing values of the parameter phi at 15-degree intervals in the formulas for x and y. Note that since the curvature of the crest of the wave differs from the curvature of the trough, both hogging and sagging portions of the profile need to be developed.

100-6-i.3 Static balance procedure

The following outlines the basic hand calculation procedure for statically balancing a ship:

(a) The standard hogging and sagging wave profiles are plotted to the same horizontal and vertical scales as the Bonjean curves (a flat wave or straight line would represent the still water condition). To avoid appreciable errors when the Bonjean curves are trimmed relative to the wave profile, the vertical scale should not be expanded to more than twice the horizontal scale.

(b) The wave profile is superimposed on the Bonjean curves, with the highest point of wave crest placed at the midship station for the hogging condition, and lowest point of wave trough at the midship station for the sagging condition. Readings are taken at the levels where the wave crosses the Bonjean stations. The readings are used to plot a trial buoyancy curve, which is integrated (with respect to ship length) by any convenient means to determine the total buoyant force and the center of buoyancy. Successive trial calculations are made, moving the wave up or down and trimming it forward or aft, until a position is found where buoyancy equals weight and the center of buoyancy is in vertical alignment with the center of gravity (within one foot). The precision of balancing should be such that the curves of shear and bending moment will close within the limits given in 100-6-k.

(c) When the final position of the ship on the wave is determined, the Bonjean curve readings, converted to buoyancy forces, are used to plot a precise buoyancy curve. From this curve, the buoyant forces acting on each segment of the length are derived.

A weight summary for a sample ship of 770-foot length and 38.5-foot station spacing at full load is tabulated on figure 1. Figure 2 shows an example of hand calculated balance of a ship on a hogging wave. Sagging and still water balances would follow similar steps.

100-6-j. Hull girder loading

While total weight and opposing buoyancy forces are equal in a statically balanced ship, inevitable differences in their distribution, even in still water, result in excess weight over buoyancy and vice-versa in individual hull segments throughout the ship's length. The algebraic sum of weight and buoyancy at each of the hull segments, with weight considered positive and buoyancy negative, constitutes the net loading on the hull which gives rise to shear, bending moments, and deflection in the hull girder. To simulate maximum service hogging conditions, a hog inducing weight distribution, with cargo and consumable weights removed from the midship region, is balanced with the wave crest centered amidships. For maximum sagging conditions, a sag inducing weight distribution, with cargo and consumable weight removed from the end regions, is balanced with the wave trough amidships.

PART III. ANALYSIS METHOD

100-6-k. Bending moments and shear forces

100-6-k.1 Calculation of shear

The vertical shear force at any section along the hull girder is the algebraic sum of the vertical forces to one side of the section. Therefore, the shear curve can be determined by numerical integration of the load curve with respect to ship length, starting from either end of the ship. The total positive area under the shear curve should equal the total negative area. This is a condition of static equilibrium. The shear force should be zero at each end of the ship, and for many ships will be maximum at about the quarter-length point and change sign at a point close to midship. The error of closure of the shearing force curve should not exceed 0.2 percent of the maximum ordinate of the curve.

Figure 3 shows an example of the development of ordinates for the weight and buoyancy curves. The ordinates are used in columns (1) and (2) of figure 4, which shows a convenient method of manual integration in developing ordinates for the shear and moment curves. For simplicity in the hand calculations, the centers of weight and buoyancy are assumed to lie at the midlength of each hull segment. This procedure historically has shown sufficient accuracy for static balance purposes.

100-6-k.2 Calculation of bending moment

The bending moment acting at any section of the hull girder is the algebraic sum of the moments of forces about the section. Therefore, the bending moment curve can be determined by integration of the shear curve with respect to ship length (see figure 4). The bending moment should be a maximum at the point where the shearing force changes from plus to minus and should be zero at each end. The error of closure of the bending moment curve should not exceed 0.2 percent of the maximum ordinate of the curve.

100-6-k.3 Computer methods

The longitudinal strength subprogram of SHCP performs static balance calculations of shear and bending moments based on the same basic principles as outlined for the manual method, but it has greater versatility in that it can readily accommodate any wave length and wave position relative to the ship length, and can readily accept nonuniform hull segmentation and any LCG location within the middle one-third length of each hull segment.

As noted earlier, however, the midlength LCG location of station weights, that is, a stepped weight distribution curve, is consistent with existing ship strength data and therefore may be preferable to the middle-one-third LCG location. Similarly, the bending moment standards established by the static balance method are predicated on a midship alignment of the standard hogging and sagging waves. Positioning of waves with crest or trough at other than midship should therefore be used for special conditions only.

100-6-1. Section properties

100-6-1.1 Moments of inertia and section modulus

Moments of inertia are calculated for stations 3 through 17 to determine the strength of the hull girder. Other sections may be added or substituted on a case basis. The hull section property calculations are based on commonly accepted principles of beam flexure theory. Sample worksheets for section property calculations are shown in appendix E.

The following formulas are used:

$$I_{BL} = \sum Ad^2 + \sum i_o$$

$$I_{NA} = I_{BL} - \sum Ay^2$$

$$SM_{DK} = \frac{I_{NA}}{y_d}$$

$$SM_{KL} = \frac{I_{NA}}{y_k}$$

100-6-1.2 Effective hull girder structure

Hull girder structure typically consists of the shell, decks, inner bottom, and longitudinal bulkheads specifically designed for strength; these structures are usually identified in the detail specifications. In calculating the moment of inertia, only the net cross-sectional area of longitudinally continuous components of these structures, excluding openings and ineffective shadow areas forward and aft of openings and other discontinuities, are considered effective in strength. The shadow area of an opening is that area forward and aft of the opening between converging lines drawn tangent to the radiused corners of the opening and sloped 1:4 (transverse units to longitudinal units). All structures, including longitudinal framing and other connected structures lying within this area, are considered ineffective and are not included in hull section property calculations. Shadow areas forward and aft of discontinuities such as those at the ends of longitudinal bulkheads, strength decks, and inner bottom are determined by using the same 1:4 slope. Figures 5 and 6 illustrate this rule.

100-6-1.3 Computer methods

Many computer programs are available to calculate the structural properties of a ship's transverse cross-sections, about the section's centroidal (or other) axis. Appendix C shows a sample midship section and computer calculations of its hull section properties.

100-6-m. Stresses and deflections

100-6-m.1 Bending stress

The bending stress is obtained by using simple beam theory. The bending stress of any part of a given section is proportional to its vertical distance from the neutral axis. Therefore, the maximum longitudinal bending stresses occur at the extreme fibers of the section, which are the uppermost deck and the keel.

At each of the inertia stations the bending stresses are calculated for both the uppermost strength deck and the keel, in hogging and sagging conditions, by using the beam formula:

$$f_{1c} = \frac{M}{SM}$$

$$\text{where} \quad SM = \frac{I}{y}$$

100-6-m.2 Shear stress

The maximum shear stress at a section is determined by the standard formula:

$$\tau = \frac{Q\ m}{12\ t\ I_{NA}}$$

The thickness, t, in this formula is ordinarily the sum of shell plating thickness for both sides of the ship at the neutral axis plus any effective longitudinal bulkheads that extend from the strength deck to the bottom of the ship.

Where a more detailed analysis is indicated, as in the case of multicelled hull sections, a shear flow analysis should be performed.

100-6-m.3 Deflections

The deflection of the hull girder is a function of the fourth integral of the load curve with respect to the ship length. Thus, the deflection may be determined by double integration of the bending moment curve divided by the product EI. The deflection will be zero at each end of the ship and reach a maximum at some point nearly amidships.

The quantity $\frac{M}{EI}$ is calculated for each of the inertia stations and a curve of $\frac{M}{EI}$ is drawn. This curve is integrated from its left extremity to each inertia station, by any convenient means of integration. This first integration gives the ordinates required for plotting the first integral curve. A similar integration of this curve provides ordinates for the second integral curve. A straight line is constructed joining the two ends of this latter curve. The vertical intercepts between the straight line and the second integral curve represent the hull deflection curve (see figure 7).

100-6-m.4 Computer methods

The foregoing manual solution of hull deflection may be programmed for computer solution for cases where the bending moment diagram and hull inertia are known.

Alternatively, hull deflections may be computed by ordinary finite element methods if net hull girder loads as described in 100-6-j are available. This loading information can be obtained from station weight and buoyancy values tabulated in SHCP printouts (see appendix A).

Note that hogging and sagging waveborne conditions are theoretical conditions, and that deflection under the still water condition would be the best indicator of real hull deflections.

PART IV. ESTIMATING CHANGES IN BENDING MOMENT DUE TO SMALL CHANGES IN WEIGHT

100-6-n. Ferris method

The following summarizes the Ferris method, reference (d), which gives an approximate method for estimating the change in longitudinal bending moment at midship due to small changes in weights at any point along the length of the hull girder. The method provides a quick means of estimating changes in bending moment without redoing the entire longitudinal strength calculation. Since it assumes a constant waterplane area, it is valid only if the change in weight is a small percentage of the ship's displacement.

The change in longitudinal bending moment for the hogging or sagging condition is:

$$\Delta M = \frac{P\,x}{2} - \frac{P\,K\,L}{4}$$

where:

ΔM = change in bending moment (ft-tons)

P = change in weight (tons)

L = length between perpendiculars (ft)

x = distance of point P from midship (ft)

K = hull shape coefficient (dimensionless)

The above formula is so constructed that P is positive for added weights and negative for removed weights, and x is always taken positive whether forward or aft. The first term of the expression accounts for the change in moment caused by the change in weight, while the second term accounts for the effects of the opposing buoyancy wedge. Thus, a positive answer indicates that the hogging moment is increased or sagging moment reduced; and a negative answer indicates the opposite.

Plots of the coefficient K, figure 8, obtained from reference (d), are based on a percentage of length from midship. The coefficient K is nondimensional and applies to all ships similar in shape to those included in the plots, regardless of size.

As noted in reference (d), the average K value is about 0.35 for hogging and about 0.45 for sagging. Where specific curves for a given ship are not available, these average values may be used for reasonable results. Data for DD-963 and FFG-7 show similar trends.

For the hogging condition, a weight added in the midlength of the vessel reduces the longitudinal bending stress, while a weight added near either end increases it. There is, therefore, a point in the forebody and one in the afterbody at which weight can be added without changing the stress. For sagging, the effects are similar but opposite to those for hogging.

The following example, adapted from reference (d), illustrates this method:

<u>EXAMPLE</u>: Assume a ship of L = 341 ft. with I_{NA} = 45,000 in^2-ft^2 and y_k = 10.5 ft. The weight changes are 1 ton of chain added at 148 feet forward, 5 tons of ammunition added at 112 feet forward, 5 tons of ammunition added at 110 feet aft, and 8 tons of machinery removed at 7 feet aft. Estimate the change in stress at the keel for the hogging condition.

Item	P (tons)	x (ft)	$\frac{P\,x}{2}$ (ft-tons)	K ---	$\frac{P\,K\,L}{4}$ (ft-tons)	$\frac{P\,x}{2} - \frac{P\,K\,L}{4}$ (ft-tons)
Chain	1	148	74	0.34	29.0	45.0
Ammunition	5	112	280	0.33	140.7	139.3
Ammunition	5	110	275	0.34	144.9	130.1
Machinery	-8	7	-28	0.37	-252.3	224.3
						+538.7

ΔM_B = 539 foot-tons (increase)

Increase in stress = $\frac{539 \times 10.5}{45\ 000}$ = 0.13 ton/inch^2, hogging.

If the average value of K = 0.35 had been used throughout, the anwer would be 0.12 ton/inch^2, hogging.

WEIGHT SUMMARY - TONS/STATION

SHIP ____________________ CALC.BY __________ DATE ______

CHKD.BY __________ DATE ______

CONDITION:

STATION	WEIGHT (TONS)	ARM (STATIONS)	MOMENT
AFT 20	19.49	10.10	196.8
20-19	567.37	9.5	5390.0
19-18	1460.10	8.5	12410.8
18-17	2161.42	7.5	16 210.6
17-16	3046.88	6.5	19 804.7
16-15	2444.90	5.5	13 447.0
15-14	1901.77	4.5	8 558.0
14-13	1923.09	3.5	6730.8
13-12	3930.60	2.5	9826.5
12-11	4968.11	1.5	7452.2
11-10	4715.09	0.5	2357.5
10-9	4597.17	-0.5	-2298.6
9-8	3638.13	-1.5	-5457.2
8-7	4702.80	-2.5	-11 757.0
7-6	3779.65	-3.5	-13 228.8
6-5	2387.20	-4.5	-10 742.4
5-4	2119.06	-5.5	-11 654.8
4-3	2684.45	-6.5	-17 448.9
3-2	1473.59	-7.5	-11 051.9
2-1	890.44	-8.5	-7568.7
1-0	189.94	-9.5	-1804.4
FWD 0	22.69	-10.05	-228.0
TOTAL	53624	—	9144.2

FIGURE 1. Weight summary.

BUOYANCY

CALC.BY __________ DATE __________

SHIP ____________________ CHKD.BY __________ DATE __________

CONDITION:

BONJEAN STATION	SHIP LEVEL					SHIP TRIMMED					STATION
	SECTION AREAS IN FT² — BL OF WAVE AT			ARM FROM STA 10	MOM. ABOUT STA 10	BL OF WAVE AT F 15.5 A 25.5 FT²	MOM. ABOUT STA 10	BL OF WAVE AT F 15.4 A25.6 FT²	MOM. ABOUT STA 10	MEAN ORD TO BUOY. CURVE FT²	
	21'-0"	20'-0"									
20	½ × 0	½ × 0	½ ×	9.75	0	½ × 0	0	½ × 0	0	0	AFT 20
19	0	0		9	0	5	45	0	0	0	20-19
18	90	50		8	720	180	1440	175	1440	88	19-18
17	500	450		7	3500	700	4900	690	4830	432	18-17
16	1280	1200		6	7680	1510	9060	1490	8940	1090	17-16
15	2300	2230		5	11500	2520	12600	2520	12600	2005	16-15
14	3320	3270		4	13280	3510	14040	3515	14060	3017	15-14
13	4240	4170		3	12720	4380	13140	4360	13080	3938	14-13
12	4925	4850		2	9850	4980	9960	4990	9980	4675	13-12
11	5420	5250		1	5420	5400	5400	5390	5390	5190	12-11
10	5480	5330		0	0	5420	0	5445	0	5417	11-10
9	5190	5120		1	-5190	5090	-5090	5145	-5145	5295	10-9
8	4600	4460		2	-9200	4500	-9000	4460	-8920	4803	9-8
7	3760	3600		3	-11280	3590	-10770	3575	-10725	4017	8-7
6	2850	2730		4	-11400	2950	-11800	2640	-10560	3108	7-6
5	1990	1910		5	-9950	1780	-8900	1785	-8925	2213	6-5
4	1310	1260		6	-7860	1130	-6780	1120	-6720	1453	5-4
3	800	750		7	-5600	640	-4480	635	-4445	878	4-3
2	490	460		8	-3920	370	-2960	375	-3000	505	3-2
1	310	290		9	-2790	230	-2070	230	-2070	303	2-1
0	125	125		9.75	-1219	110	-1073	105	-1024	168	1-0
	½ × 250	½ × 250	½ ×			½ × 220		½ × 210		53	FWD 0
TOTAL	48980	47505			-3739	48995	+ 7662	48645	8786	48648	
	TONS 53876	TONS 58509	TONS	FT	2.95' FWD ⊗	TONS 53895	CG AT 605 AFT	TONS 53510	CG AT 674 AFT	TONS 53513	

FIGURE 2. Buoyancy calculations.

ORDINATES TO WEIGHT & BUOYANCY CURVES

CALC.BY ________ DATE ________

SHIP ______________________ CHKD.BY ________ DATE ________

CONDITION:

STATION	ARM FROM STA 10	ORD TO WT CURVE		ORDINATES TO BUOYANCY CURVES							
				HOGGING				SAGGING			
		TONS/STA X 60/Δ	MOM. ABOUT STA 10	FT2/STA X 60/ΣFT2	MOM. ABOUT STA 10	CORR TO ORD FOR MOM.	FINAL ORD TO BUOY. CURVE	FT2/STA X 60/ΣFT2	MOM. ABOUT STA 10	CORR TO ORD FOR MOM.	FINAL ORD TO BUOY. CURVE
		IN	IN2	IN	IN2	IN	IN	IN	IN2	IN	IN
AFT 20		0.02	0.20	0,00	0,00		0,00				
20-19	9.5	.63	5.99	.06	.00		.00				
19-18	8.5	1,63	13.86	.11	.94		.11				
18-17	7.5	2.42	18.15	.53	3.98		.53				
17-16	6.5	3.41	22.17	1.34	8.71		1.34				
16-15	5.5	2.74	15.07	2.47	13.59		2.47				
15-14	4.5	2.13	9.59	3.72	16.74		3.72				
14-13	3.5	2.15	7.53	4.86	17.01	-.01	4.85				
13-12	2.5	4.40	11.00	5.77	14.43	-.02	5.75				
12-11	1.5	5.56	8.34	6.41	9.62	-.03	6.38				
11-10	0.5	5.28	2.64	6.69	3.35	-.03	6.66				
10-9	0.5	5.14	-2.57	6.53	-3.27	.03	6.56				
9-8	1.5	4.07	-6.11	5.92	-8.88	.03	5.95				
8-7	2.5	5.26	-13.15	4.95	-12.38	.02	4.97				
7-6	3.5	4.23	-14.81	3.83	-13.41	.01	3.84				
6-5	4.5	2.67	-12.02	2.73	-12.29		2.73				
5-4	5.5	2.37	-13.04	1.79	-9.85		1.79				
4-3	6.5	3.00	-19.50	1.08	-7.02		1.08				
3-2	7.5	1.65	-12.38	.62	-4.65		.62				
2-1	8.5	1.00	-8.50	.37	-3.15		.37				
1-0	9.5	.21	-2.00	.21	-2.00		.21				
FWD 0		.03	-.31	.07	-.72		.07				
TOTAL		60.00	10.15	60.00	10.75	0.00	60.00			0.00	

FIGURE 3. Ordinates to weight and buoyancy curves.

ORDINATES TO SHEAR & MOMENT CURVES

CALC.BY __________ DATE __________

SHIP ______________________ CHKD.BY __________ DATE __________

CONDITION:

STATION	ORD TO WT CURVE IN (1)	ORD TO BUOY. CURVE IN (2)	ORD TO LOAD CURVE (1)-(2) IN (3)	Σ AREA UNDER LOAD CURVE IN^2 (4)	ORD TO SHEAR CURVE (4) x $\frac{1}{2}$ IN (5)	MEAN ORD TO SHEAR CURVE IN (6)	Σ AREA UNDER SHEAR CURVE IN^2 (7)	ORD TO MOM. CURVE (7) x $\frac{1}{3}$ IN (8)	BENDING MOM. (8) x $\frac{\Delta L}{200}$ FT-TONS (9)
AFT 20	0.02	0.00	0.02	0.02	0.01	0.00	0.00	0.00	0
20-19	.63	.00	.63	.65	.33	.17	.17	.06	12 387
19-18	1.63	.11	1.52	2.17	1.09	.71	.88	.29	59871
18-17	2.42	.53	1.89	4.06	2.03	1.56	2.44	.81	167226
17-16	3.41	1.34	2.07	6.13	3.07	2.55	4.99	1.66	342710
16-15	2.74	2.47	.27	6.40	3.20	3.14	8.13	2.71	559484
15-14	2.13	3.72	-1.59	4.81	2.41	2.80	10.93	3.64	751485
14-13	2.15	4.85	-2.70	2.11	1.05	1.73	12.66	4.22	871227
13-12	4.40	5.75	-1.35	.76	.38	.72	13.38	4.46	920776
12-11	5.56	6.38	-.82	-.06	.93 FWD 12 -.03	.18 .00	13.56 13.56	4.52 4.52	933163 933163
11-10	5.28	6.66	-1.38	-1.44	-.72	-.38	13.18	4.39	906 324
10-9	5.14	6.56	-1.42	-2.86	-1.43	-1.07	12.11	4.04	834066
9-8	4.07	5.95	-1.88	-4.74	-2.37	-1.90	10.21	3.40	701 937
8-7	5.26	4.97	.29	-4.45	-2.22	-2.29	7.92	2.64	545 033
7-6	4.23	3.84	.39	-4.06	-2.03	-2.13	5.79	1.93	398 452
6-5	2.67	2.73	-.06	-4.12	-2.06	-2.05	3.74	1.25	258 065
5-4	2.37	1.79	.58	-3.54	-1.77	-1.92	1.82	.61	125935
4-3	3.00	1.08	1.92	-1.62	-.81	-1.29	.53	.18	37161
3-2	1.65	.62	1.03	-.59	-.29	-.55	-.02	-.01	2065
2-1	1.00	.37	.63	.04	DAT .935 .02	FWD2 -.13 .00	-.15	-.05	10322
1-0	.21	.21	.00	.04	.02	.02	-.13	-.04	8258
FWD 0	.03	.07	-.04	.00	.00	.01	-.12	-.04	8258

FIGURE 4. Ordinates to shear and moment curves.

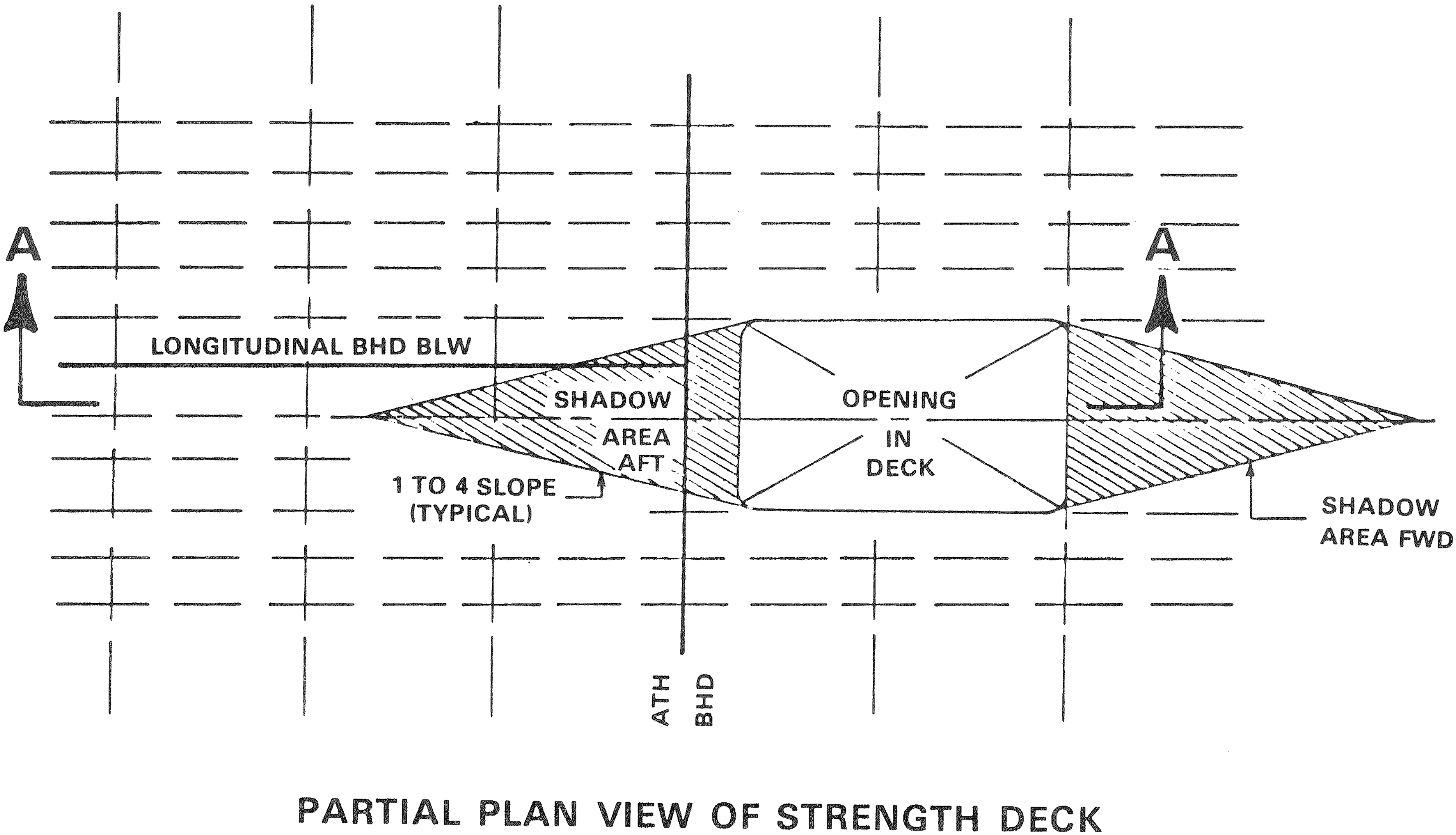
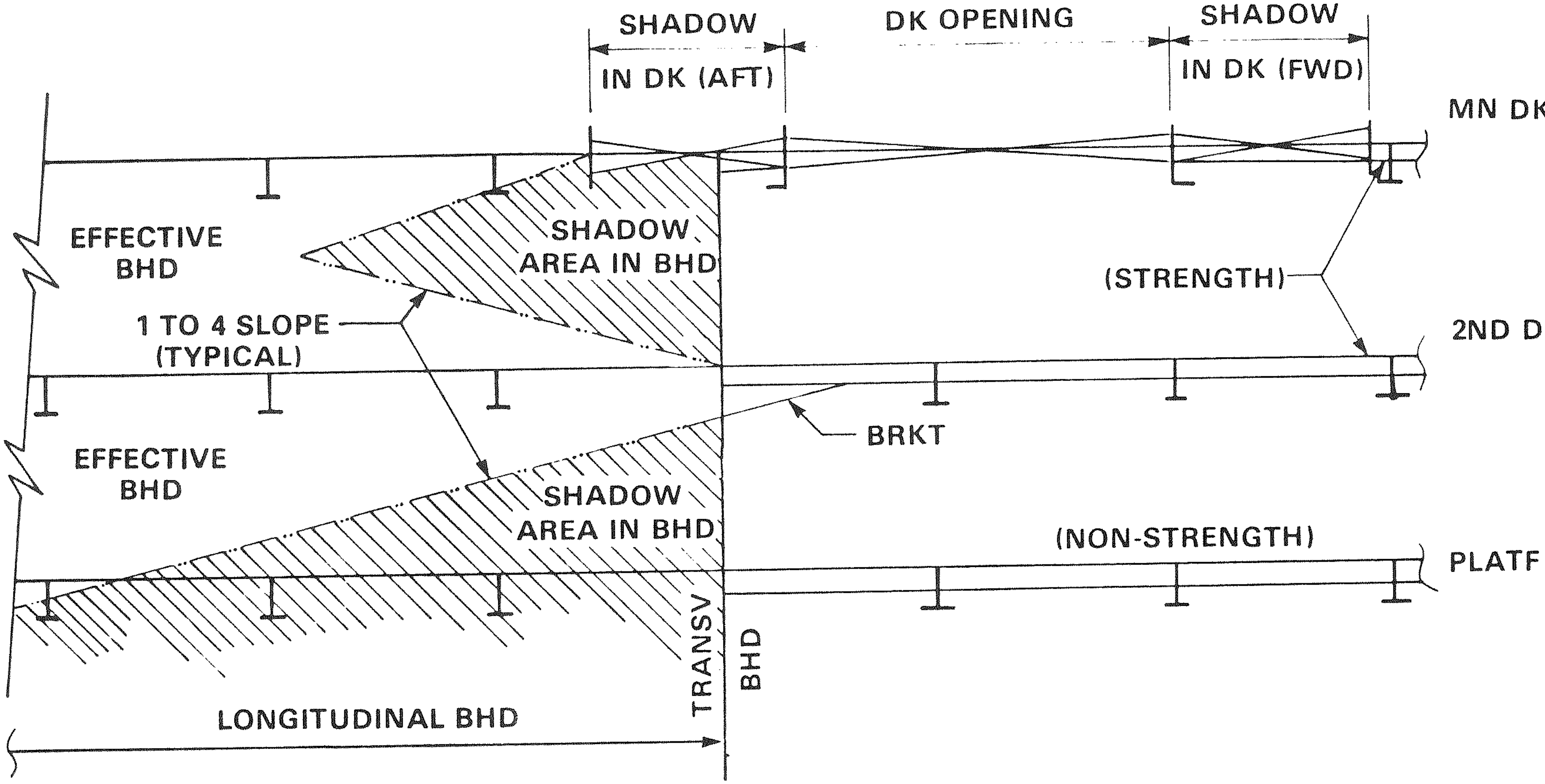
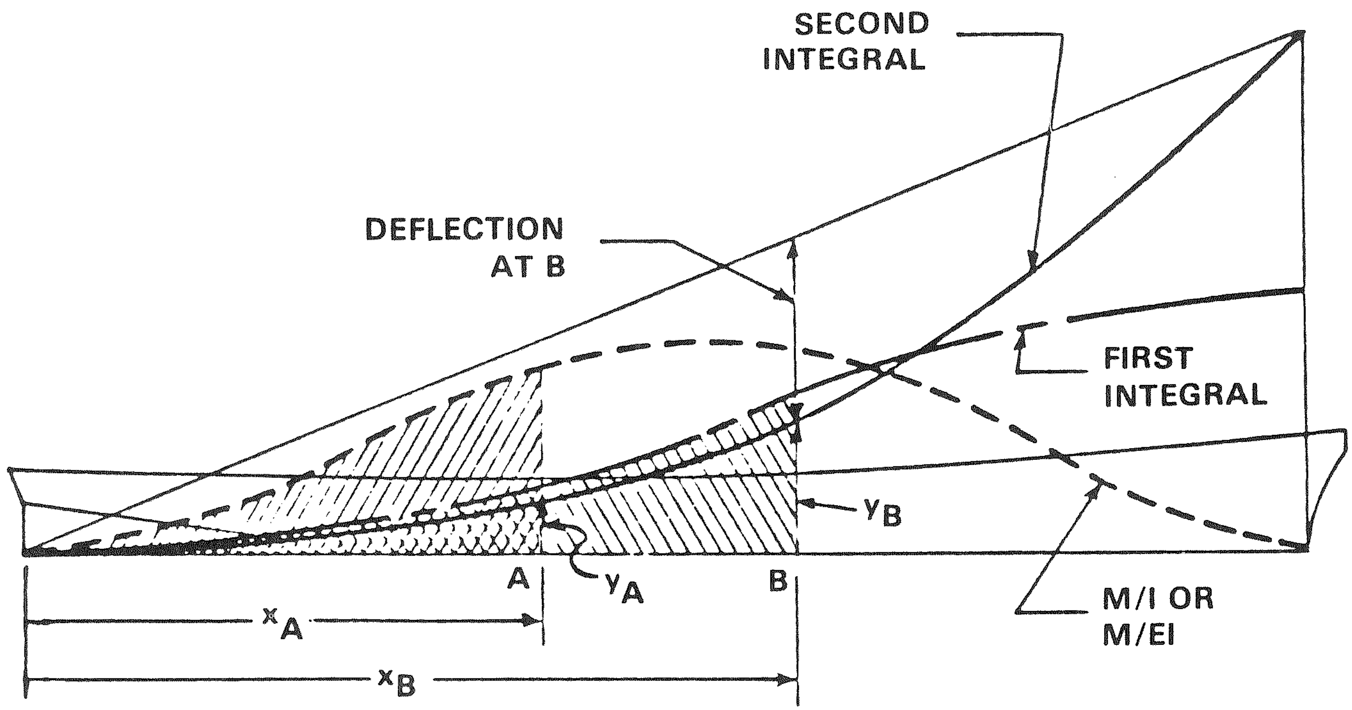


FIGURE 5. Ineffective shadow area at openings.



SECT A-A

FIGURE 6. Ineffective shadow area at discontinuities.



PROCEDURE FOR CALCULATING DEFLECTION

(DOUBLE INTEGRATION)

FIGURE 7. Hull deflection - procedure for calculating deflection.

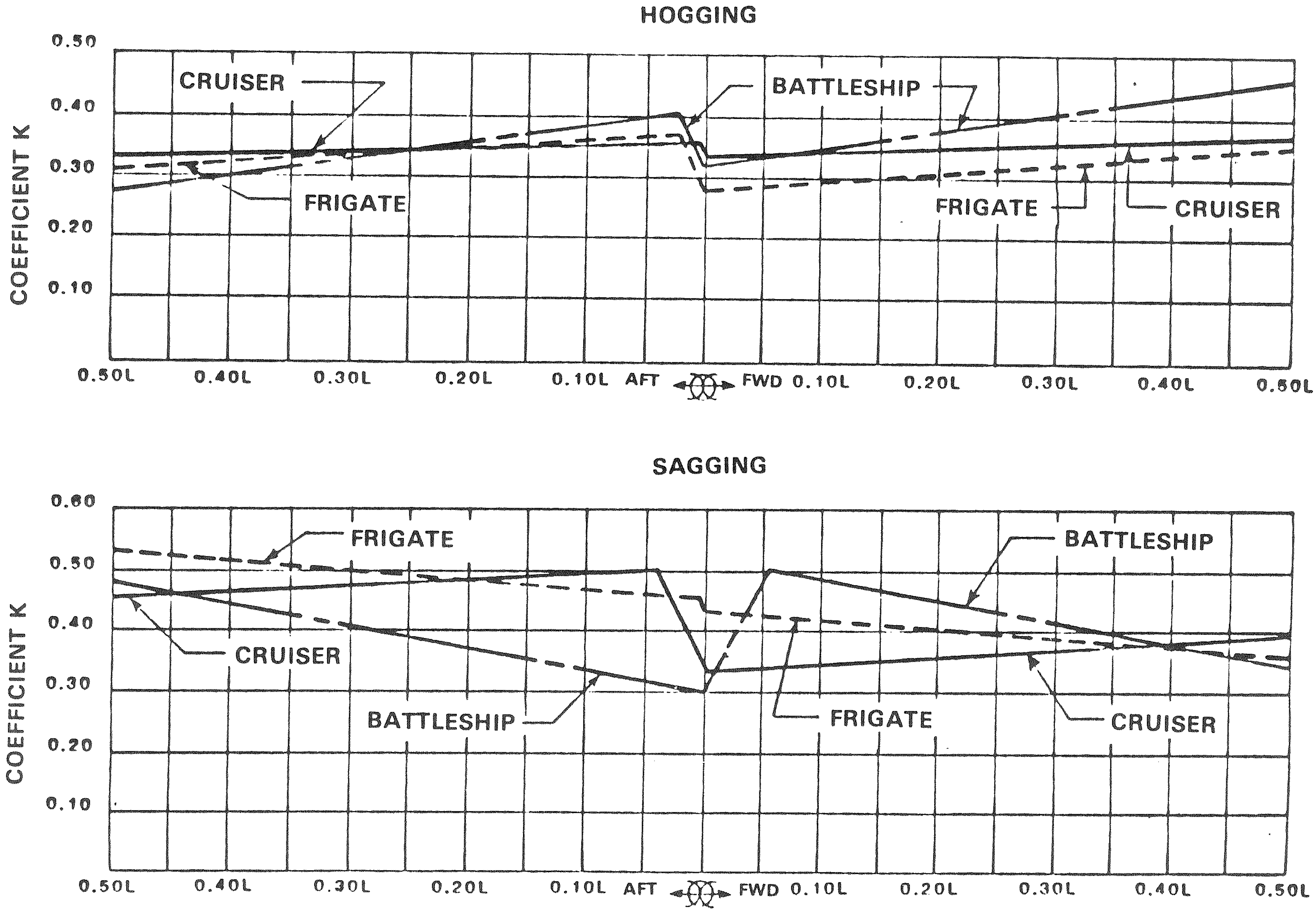


FIGURE 8. Hull deflection bending coefficient.

APPENDIX A

EXAMPLE OF LONGITUDINAL STRENGTH CALCULATIONS

USING THE SHIP HULL CHARACTERISTICS PROGRAM

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

DESIGN DISPLACEMENT	48489.871	TONS SW
DESIGN LCG	-6.137	FEET FROM AMIDSHPS (+ FWD)
DESIGN DRAFT	37.931	FEET
DESIGN TRIM	0.000	FEET (+ BY STERN)
LENGTH OVERALL	745.330	FEET
LENGTH BETWEEN PERPENDICULARS	730.000	FEET
LENGTH ON DESIGN WATERLINE	730.000	FEET
STATION OF MAX AREA (AT DWL)	379.134	FEET FROM FP
BEAM AT STATION OF MAX AREA	107.190	FEET
SECTION AREA COEFFICIENT	0.9890	
PRISMATIC COEFFICIENT	0.5782	
BLOCK COEFFICIENT	0.5718	

APPENDAGE PROPERTIES AT DESIGN CONDITION

N	TITLE	VOLUME	DISPL	TCB	VCB	LCB
1	PROPELLERS (2)	270.00	7.7	0.000	14.670	-329.000
2	SHAFTS & STRUTS (2)	1674.00	47.8	0.000	16.070	-289.500
3	RUDDERS (2)	2317.00	66.2	0.000	24.200	-347.720
4	BILGE KEELS (2)	729.00	20.8	0.000	4.090	1.640

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS

WAVE CENTER FROM AMIDSHIPS 0.00 (+ FWD)
WAVE LENGTH/LBP 1.000
WAVE HEIGHT=1.1*SQRT(LBP) 29.72 FEET

WEIGHT STATION (FT FROM FP)	WEIGHT (TONS)	LCG OF WEIGHT FROM AMIDSHIPS (FT,+FWD)	SECT.MODUL
-15.33			
0.00	76.27	372.67	
36.50	260.35	346.75	
73.00	948.38	310.25	
109.50	1231.22	273.75	
146.00	1838.27	237.25	
182.50	2331.39	200.75	
219.00	2479.91	164.25	
255.50	3356.40	127.75	
292.00	3888.66	91.25	
328.50	4543.85	54.75	
365.00	4322.69	18.25	
401.50	3951.76	-18.25	
438.00	4129.03	-54.75	
474.50	2153.69	-91.25	
511.00	2153.27	-127.75	
547.50	1643.44	-164.25	
584.00	1837.96	-200.75	
620.50	2751.05	-237.25	
657.00	2067.78	-273.75	
693.50	1387.41	-310.25	
730.00	1090.52	-346.75	
735.00	46.52	-367.25	

SHIP AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - SAGGING

WAVE HEIGHT 29.72 FT CENTER 0.00 FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000

DISPLACEMENT 48489.82 TONS SW LCG -5.782 FT FROM AMIDSHIPS (+ FWD)

LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-15.33			0.00	0.0			0.000	0.000
	76.27	128.77			0.22	0.38		
0.00			-52.50	-119.5			-0.032	-0.001
	260.35	819.23			0.32	1.01		
36.50			-611.38	-10822.7			-0.378	-0.061
	948.38	1284.18			1.17	1.59		
73.00			-947.17	-37783.8			-0.586	-0.213
	1231.22	1810.47			1.52	2.24		
109.50			-1526.42	-81252.7			-0.944	-0.459
	1838.27	2306.69			2.27	2.85		
146.00			-1994.84	-144269.7			-1.234	-0.815
	2331.39	2635.66			2.88	3.26		
182.50			-2298.89	-221876.3			-1.422	-1.254
	2479.91	2822.92			3.07	3.49		
219.00			-2641.89	-311611.1			-1.635	-1.761
	3356.40	2931.97			4.15	3.63		
255.50			-2217.46	-400065.6			-1.372	-2.260
	3888.66	2982.99			4.81	3.69		
292.00			-1311.79	-464351.8			-0.812	-2.624
	4543.85	3016.98			5.62	3.73		
328.50			215.07	-484283.0			0.133	-2.736
	4322.69	3023.31			5.35	3.74		
365.00			1514.46	-452770.5			0.937	-2.558
	3951.76	3008.54			4.89	3.72		
401.50			2457.67	-380318.0			1.521	-2.149
	4129.03	3016.70			5.11	3.73		
438.00			3570.00	-270247.0			2.209	-1.527
	2153.69	3017.38			2.66	3.73		
474.50			2706.31	-155766.0			1.674	-0.880
	2153.27	2955.63			2.66	3.66		
511.00			1903.95	-71950.0			1.178	-0.407
	1643.44	2824.47			2.03	3.49		
547.50			722.93	-24484.0			0.447	-0.138
	1837.96	2641.28			2.27	3.27		
584.00			-80.39	-13402.0			-0.050	-0.076
	2751.05	2395.13			3.40	2.96		
620.50			275.53	-10694.0			0.170	-0.060
	2067.78	2080.00			2.56	2.57		
657.00			263.31	-1953.0			0.163	-0.011
	1387.41	1622.30			1.72	2.01		
693.50			28.42	1921.0			0.018	0.011
	1090.52	1165.46			1.35	1.44		
730.00			-46.52	152.0			-0.029	0.001
	46.52	0.00			0.42	0.00		
735.00			0.00	46.0			0.000	0.000

MOMENT AT ZERO SHEAR = -484841.5 LOCATED 323.315 FT FROM FP

MOMENT AT ZERO SHEAR = -13235.0 LOCATED 579.841 FT FROM FP

MOMENT AT ZERO SHEAR = -13879.0 LOCATED 595.265 FT FROM FP

MOMENT AT ZERO SHEAR = 1972.0 LOCATED 697.153 FT FROM FP

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - SAGGING

DRAFTS AND SECTIONAL AREAS AT INPUT STATIONS

STATION NUMBER	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-0.420	-15.330	62.820	29.81
-0.280	-10.220	62.836	211.62
-0.140	-5.110	62.815	392.41
0.000	0.000	62.756	521.60
0.500	18.250	62.238	780.59
1.000	36.900	61.252	1005.48
1.500	54.750	59.833	1222.68
2.000	73.000	58.035	1474.79
3.000	109.500	53.575	2002.58
4.000	146.000	48.457	2395.36
5.000	182.500	43.236	2633.06
6.000	219.000	38.360	2769.97
7.000	255.500	34.159	2842.20
8.000	292.000	30.860	2877.65
9.000	328.500	28.606	2907.39
10.000	365.000	27.476	2891.36
11.000	401.500	27.494	2879.08
12.000	438.000	28.636	2899.71
13.000	474.5000	30.823	2880.39
14.000	511.000	33.912	2779.60
15.000	547.500	37.676	2628.88
16.000	584.000	41.785	2425.66
17.000	620.500	45.791	2156.79
17.250	629.625	46.713	2081.88
18.000	657.000	49.139	1812.34
18.250	666.125	49.804	1663.57
18.500	675.250	50.382	1543.86
18.750	684.375	50.864	1443.46
19.000	693.500	51.244	1339.42
19.250	702.625	51.516	1231.60
19.500	711.750	51.674	1119.93
19.750	720.875	51.715	1004.70
20.000	730.000	51.636	886.24

SHIP- AOE 6 FULL LOAD SERIAL NUMBER 5511- DATE - 10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DISPLACEMENT 48489.82 TONS SW LCG -5.782 FT FROM AMIDSHPS (+ FWD)

LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-15.33			0.00	0.0			0.000	0.000
	76.27	112.58			0.22	0.33		
0.00			-36.31	-64.4			-0.022	0.000
	260.35	485.04			0.32	0.60		
36.50			-261.00	-5308.5			-0.161	-0.030
	948.38	621.45			1.17	0.77		
73.00			65.93	-8140.1			0.041	-0.046
	1231.22	998.43			1.52	1.24		
109.50			298.72	36.5			0.185	0.000
	1838.27	1539.67			2.27	1.91		
146.00			597.32	18035.6			0.370	0.102
	2331.39	2073.69			2.88	2.57		
182.50			855.02	46143.1			0.529	0.261
	2479.91	2597.62			3.07	3.21		
219.00			737.32	76776.7			0.456	0.434
	3356.40	3096.06			4.15	3.83		
255.50			997.65	109898.6			0.617	0.621
	3888.66	3547.44			4.81	4.39		
292.00			1338.87	153801.4			0.828	0.869
	4543.85	3917.71			5.62	4.85		
328.50			1965.01	215088.5			1.216	1.215
	4322.69	4143.41			5.35	5.13		
365.00			2144.29	290442.8			1.327	1.641
	3951.76	4195.81			4.89	5.19		
401.50			1900.24	364215.0			1.176	2.058
	4129.03	4139.22			5.11	5.12		
438.00			1890.05	433069.5			1.169	2.447
	2153.69	3953.61			2.66	4.89		
474.50			90.13	468397.5			0.056	2.646
	2153.27	3587.89			2.66	4.44		
511.00			-1344.48	444116.5			-0.832	2.509
	1643.44	3075.90			2.03	3.81		
547.50			-2776.94	367176.0			-1.718	2.075
	1837.96	2647.82			2.27	3.05		
584.00			-3406.80	252403.0			-2.108	1.426
	2751.05	1832.42			3.40	2.27		
620.50			-2488.17	142871.0			-1.539	0.807
	2067.78	1219.41			2.56	1.51		
657.00			-1639.80	65780.0			-1.015	0.372
	1387.41	636.06			1.72	0.79		
693.50			-888.46	18104.0			-0.550	0.102
	1090.52	248.59			1.35	0.31		
730.00			-46.52	102.0			-0.029	0.001
	46.52	0.00			0.42	0.00		
735.00			0.00	-2.0			0.000	0.000

MOMENT AT ZERO SHEAR = -8509.1 LOCATED 62.641 FT FROM FP
MOMENT AT ZERO SHEAR = 468487.0 LOCATED 476.503 FT FROM FP

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - STILL WATER

DRAFTS AND SECTIONAL AREAS AT INPUT STATIONS

STATION NUMBER	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-0.420	-15.330	37.875	26.42
-0.280	-10.220	37.877	205.59
-0.140	-5.110	37.879	340.13
0.000	0.000	37.881	405.73
0.500	18.250	37.887	453.98
1.000	36.500	37.893	502.87
1.500	54.750	37.899	579.28
2.000	73.000	37.905	736.01
3.000	109.500	37.918	1215.73
4.000	146.000	37.930	1734.75
5.000	182.500	37.942	2239.87
6.000	219.000	37.955	2735.85
7.000	255.500	37.967	3195.79
8.000	292.000	37.979	3593.35
9.000	328.500	37.992	3905.89
10.000	365.000	38.004	4019.31
11.000	401.500	38.016	4006.39
12.000	438.000	38.029	3905.98
13.000	474.500	38.041	3650.43
14.000	511.000	38.053	3212.70
15.000	547.500	38.066	2668.55
16.000	584.000	38.078	2063.01
17.000	620.500	38.091	1449.96
17.250	629.625	38.094	1307.35
18.000	657.000	38.103	895.94
18.250	666.125	38.106	722.55
18.500	675.250	38.109	590.18
18.750	684.375	38.112	489.09
19.000	693.500	38.115	396.24
19.250	702.625	38.118	311.14
19.500	711.750	38.121	233.41
19.750	720.875	38.124	163.01
20.000	730.000	38.128	100.81

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - HOGGING

WAVE HEIGHT 29.72 FT CENTER 0.00 FT FROM AMIDSHIPS (+ FWD) LENGTH/LBP 1.000

DISPLACEMENT 48489.82 TONS SW LCG -5.782 FT FROM AMIDSHPS (+ FWD)

LOCATION FT FM FP	WEIGHT TONS	BUOYANCY TONS	SHEAR TONS	BENDING MOM FOOT-TONS	WEIGHT ORD	BUOYANCY ORD	SHEAR ORD	MOMENT ORD
-15.33			0.00	0.0			0.000	0.000
	76.27	49.82			0.22	0.15		
0.00			26.45	314.2			0.016	0.002
	260.35	219.51			0.32	0.27		
36.50			67.28	1994.4			0.042	0.011
	948.38	246.75			1.17	0.31		
73.00			768.92	17472.1			0.476	0.099
	1231.22	436.09			1.52	0.54		
109.50			1564.04	61012.2			0.968	0.345
	1838.27	850.75			2.27	1.05		
146.00			2551.56	137637.9			1.579	0.778
	2331.39	1438.01			2.88	1.78		
182.50			3444.94	249130.2			2.131	1.408
	2479.91	2212.34			3.07	2.74		
219.00			3712.51	382360.3			2.297	2.160
	3356.40	3111.18			4.15	3.85		
255.50			3957.73	525203.4			2.449	2.967
	3888.66	4052.20			4.81	5.01		
292.00			3794.19	669399.1			2.347	3.782
	4543.85	4851.26			5.62	6.00		
328.50			3486.78	804414.5			2.157	4.545
	4322.69	5351.71			5.35	6.62		
365.00			2457.76	913731.3			1.521	5.163
	3951.76	5450.85			4.89	6.74		
401.50			958.68	975854.5			0.593	5.514
	4129.03	5231.69			5.11	6.47		
438.00			-143.98	989689.5			-0.089	5.592
	2153.69	4724.38			2.66	5.85		
474.50			-2714.67	935466.0			-1.680	5.285
	2153.27	3917.30			2.66	4.85		
511.00			-4478.70	801383.0			-2.771	4.528
	1643.44	2946.12			2.03	3.65		
547.50			-5781.38	611033.0			-3.577	3.452
	1837.96	1919.56			2.27	2.38		
584.00			-5862.98	395533.0			-3.627	2.235
	2751.05	1033.46			3.40	1.28		
620.50			-4145.39	210481.0			-2.565	1.189
	2067.78	400.78			2.56	0.50		
657.00			-2478.39	88197.0			-1.533	0.498
	1387.41	46.06			1.72	0.06		
693.50			-1137.04	21680.0			-0.703	0.122
	1090.52	0.00			1.35	0.00		
730.00			-46.52	80.0			-0.029	0.000
	46.52	0.00			0.42	0.00		
735.00			0.00	-24.0			0.000	0.000

MOMENT AT ZERO SHEAR = 990048.5 LOCATED 432.391 FT FROM FP

SHIP- AOE 6 FULL LOAD SERIAL NUMBER- 5511 DATE-10-25-85

LONGITUDINAL STRENGTH CALCULATIONS - SAGGING

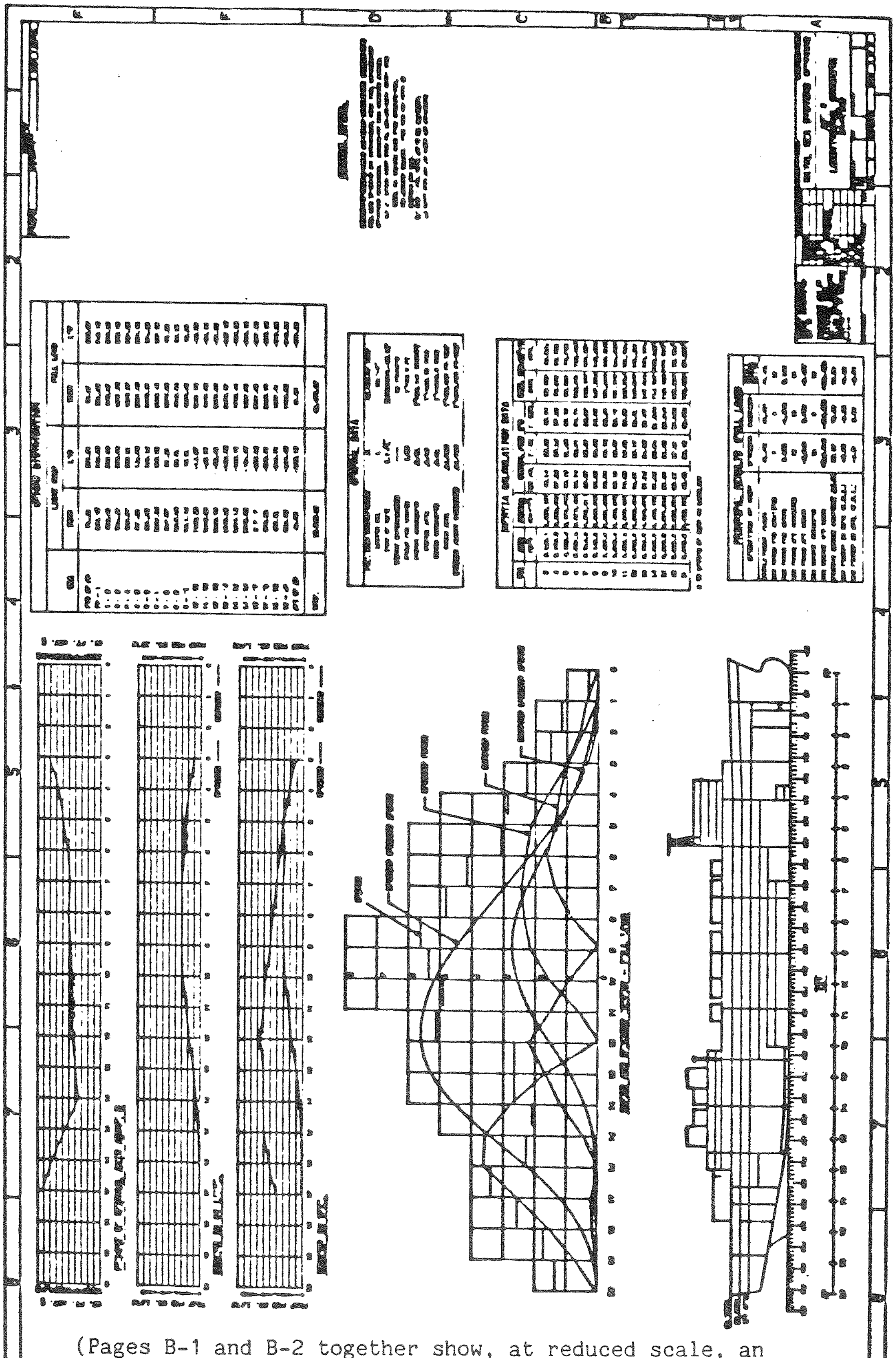
DRAFTS AND SECTIONAL AREAS AT INPUT STATIONS

STATION NUMBER	LOCATION FT FROM FP	DRAFT FEET	SECTIONAL AREA SQUARE FEET
-0.420	-15.330	15.375	3.01
-0.280	-10.220	15.377	83.21
-0.140	-5.110	15.401	156.57
0.000	0.000	15.448	194.96
0.500	18.250	15.801	201.13
1.000	36.900	16.441	211.82
1.500	54.750	17.362	229.52
2.000	73.000	18.557	287.21
3.000	109.500	21.718	591.01
4.000	146.000	25.780	1068.96
5.000	182.500	30.518	1717.25
6.000	219.000	35.601	2538.98
7.000	255.500	40.581	3441.04
8.000	292.000	44.903	4299.54
9.000	328.500	47.982	4973.50
10.000	365.000	49.348	5234.68
11.000	401.500	48.819	5163.63
12.000	438.000	46.575	4821.60
13.000	474.500	43.089	4190.70
14.000	511.000	38.945	3306.31
15.000	547.500	34.697	2328.15
16.000	584.000	30.796	1384.52
17.000	620.500	27.569	628.76
17.250	629.625	26.896	491.49
18.000	657.000	25.244	187.99
18.250	666.125	24.822	76.57
18.500	675.250	24.467	17.04
18.750	684.375	24.181	5.54
19.000	693.500	23.964	0.00
19.250	702.625	23.817	0.00
19.500	711.750	23.742	0.00
19.750	720.875	23.739	0.00
20.000	730.000	23.807	0.00

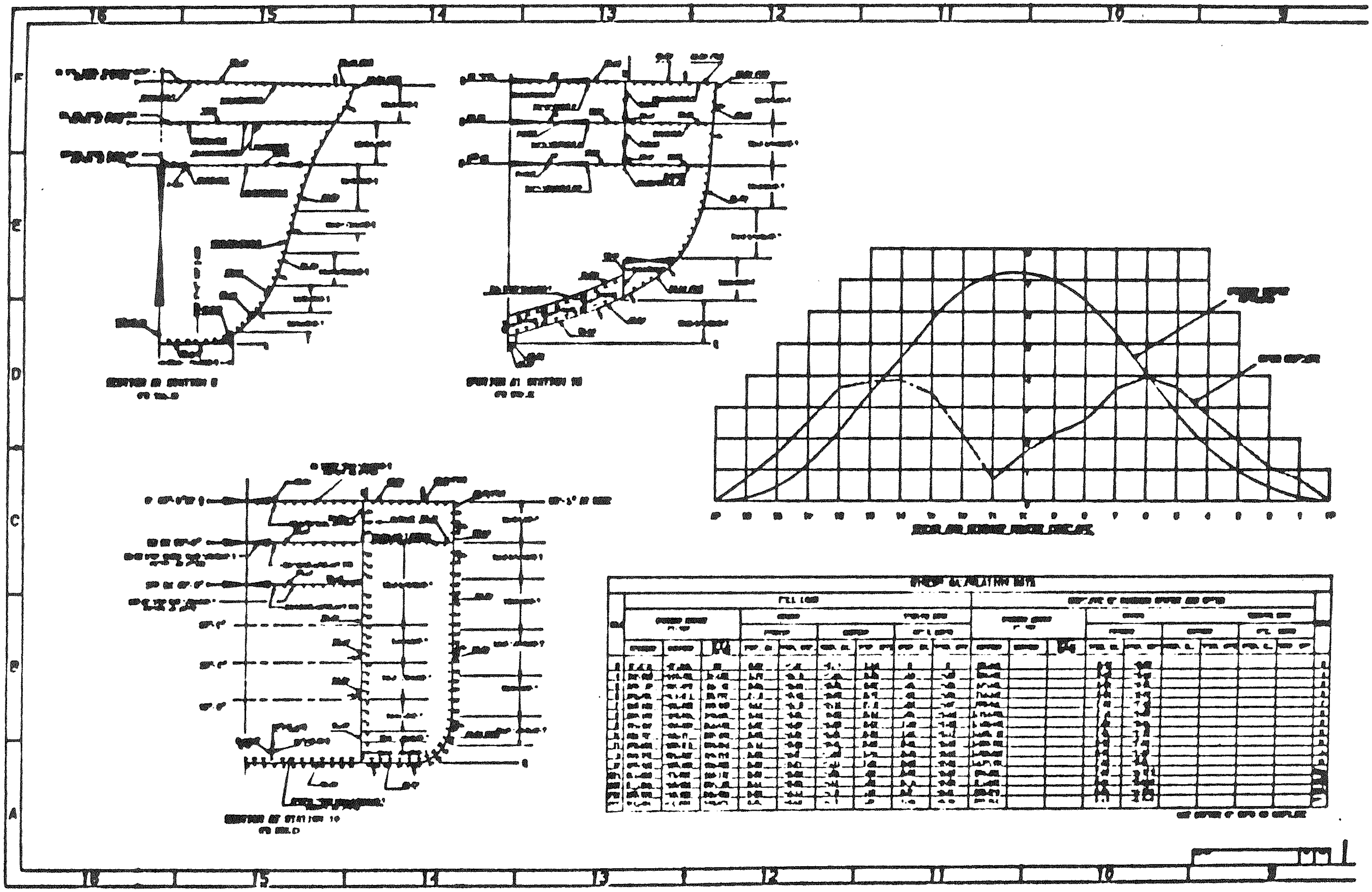
APPENDIX B

TYPICAL LONGITUDINAL STRENGTH DRAWING

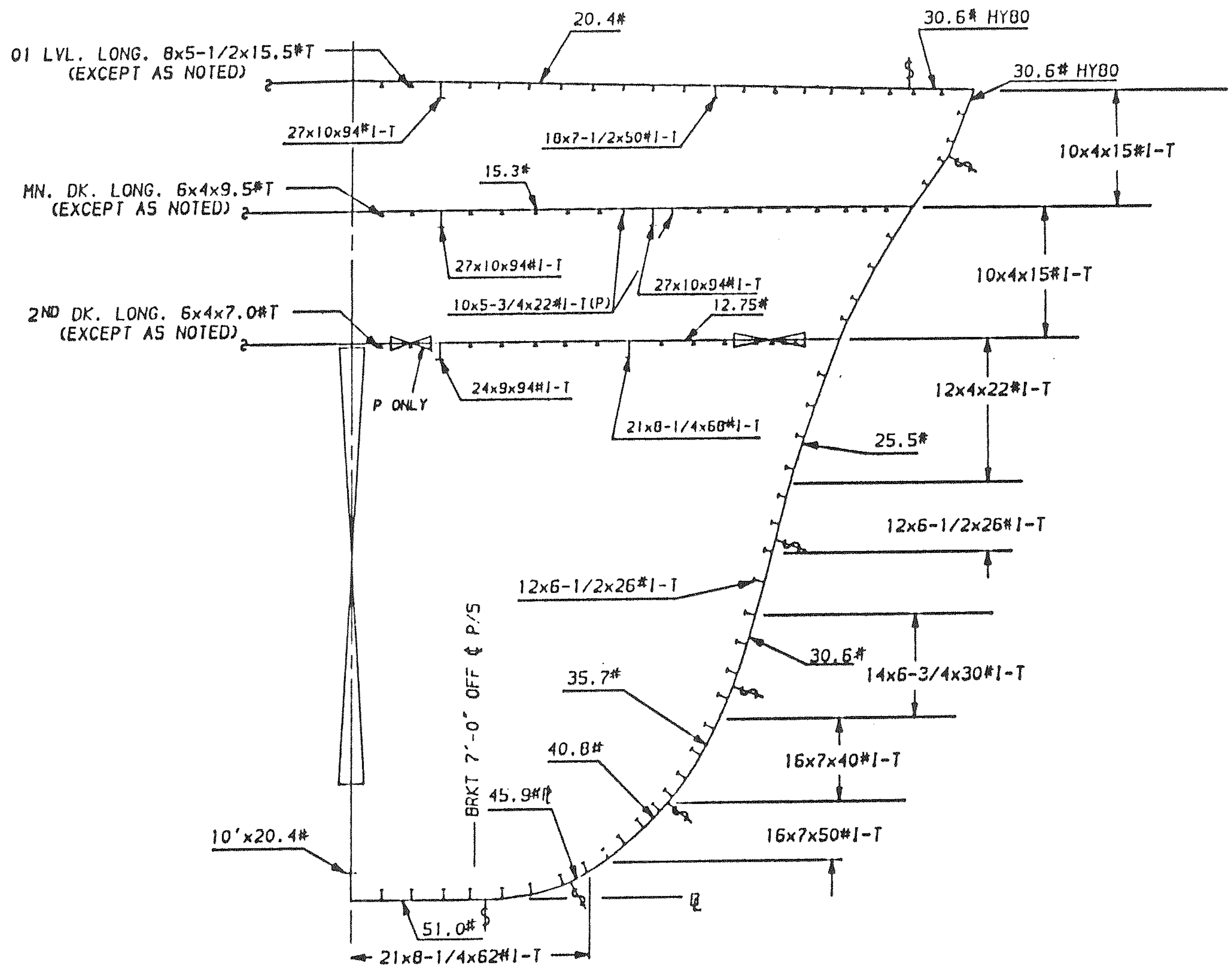
(FOR A FAST COMBAT SUPPORT SHIP)



(Pages B-1 and B-2 together show, at reduced scale, an overall view of the drawing sheet, whose separate parts are shown at larger scale on pages B-3 through B-10.)

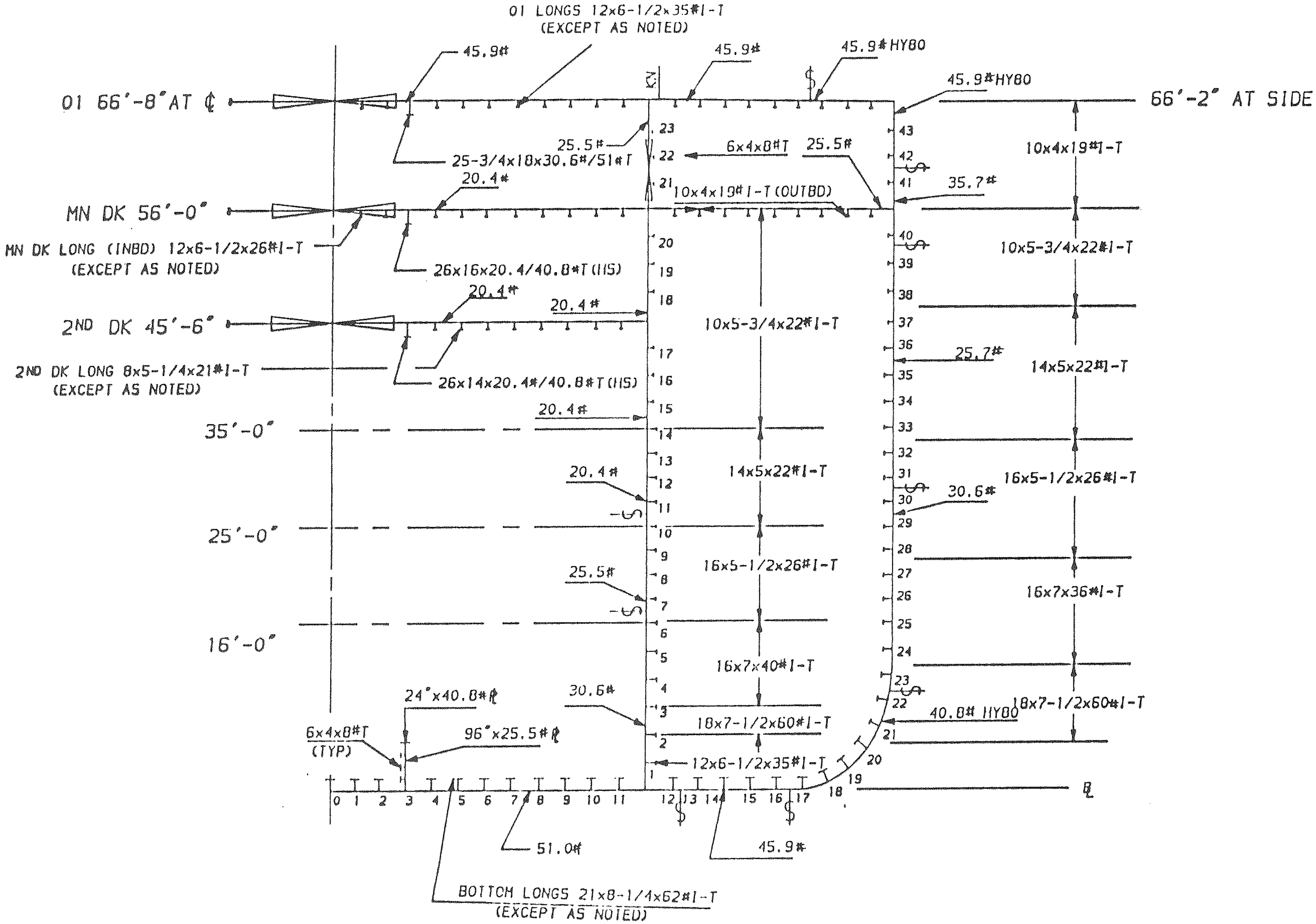


(Pages B-1 and B-2 together show, at reduced scale, an overall view of the drawing sheet, whose separate parts are shown at larger scale on pages B-3 through B-10.)

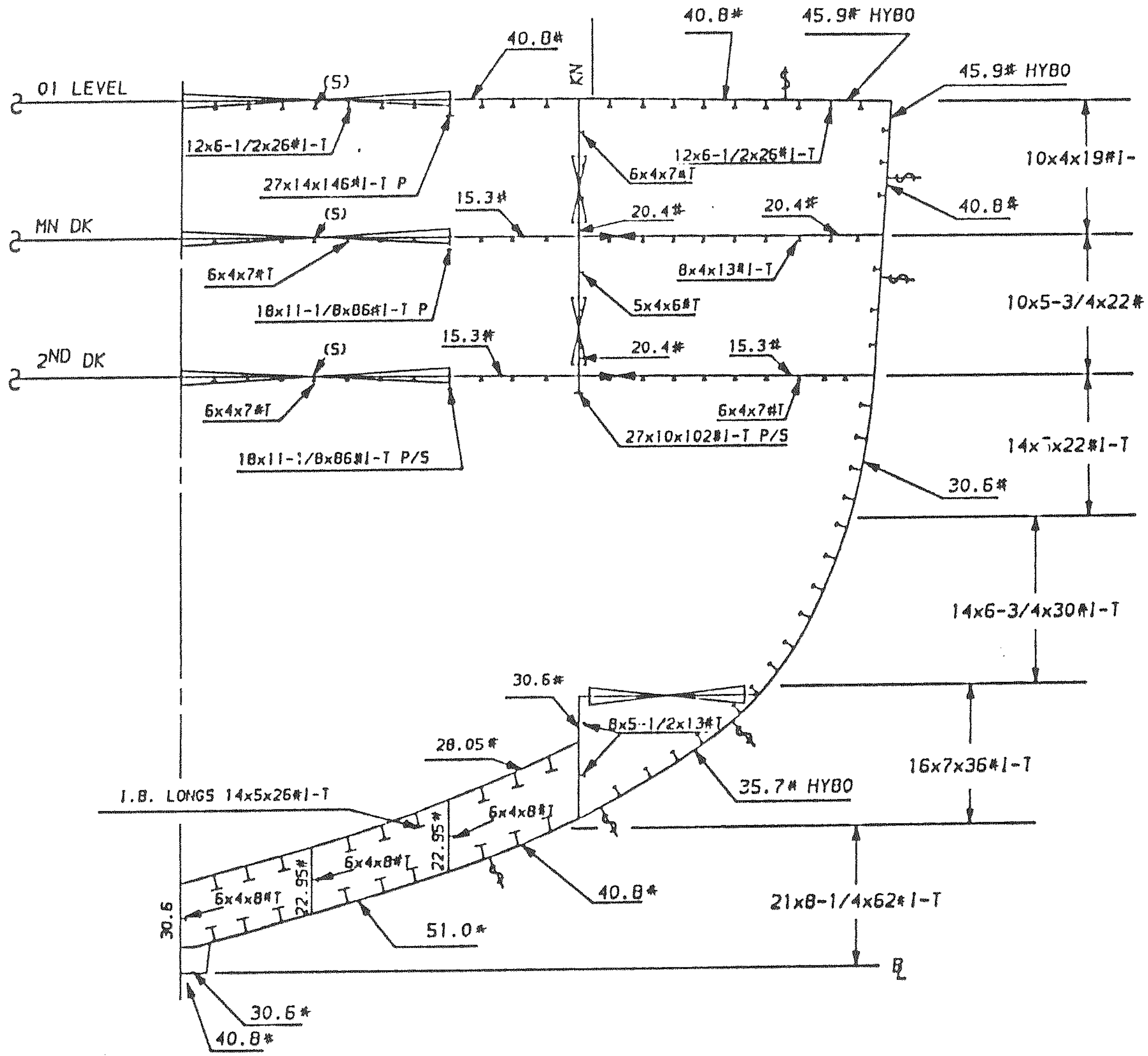


SECTION AT STATION 5

(FR 182.5)

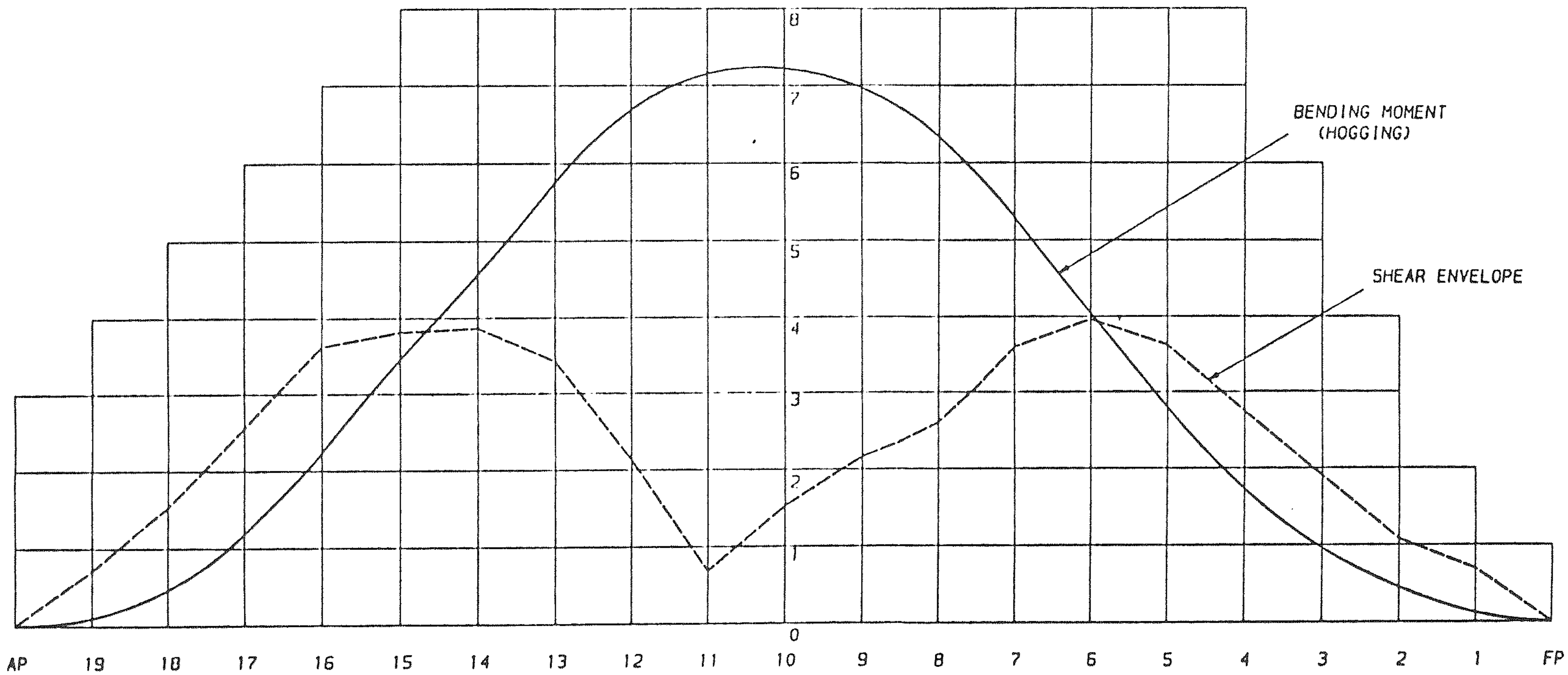


SECTION AT STATION 10
(FR 365.0)



SECTION AT STATION 15

(FR 547.5)

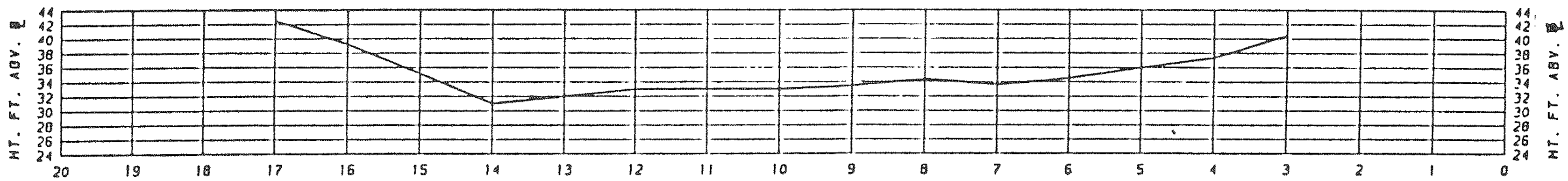


SHEAR AND BENDING MOMENT ENVELOPE

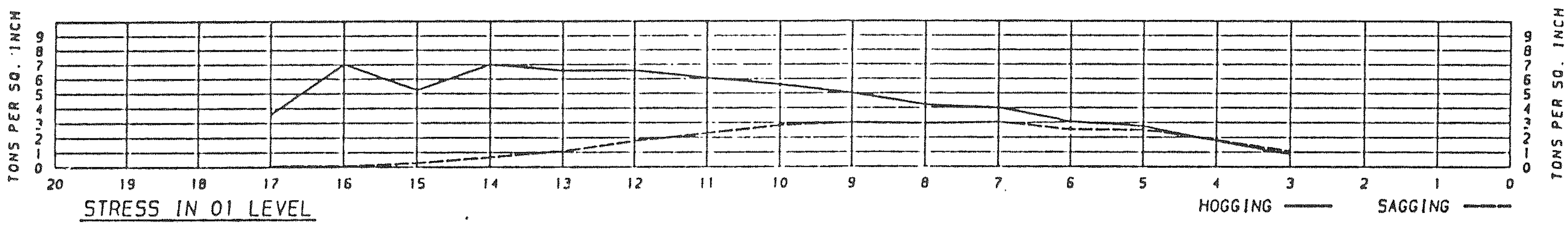
STRESS CALCULATION DATA

STA	FULL LOAD — BENDING MOMENT FT-TON — HOGGING	FULL LOAD — BENDING MOMENT FT-TON — SAGGING	FULL LOAD — BENDING MOMENT FT-TON — STILL WATER	FULL LOAD — STRESS TONS/SQ INCH — HOGGING — TENS. DK.	FULL LOAD — STRESS — HOGGING — COMP. KEEL	FULL LOAD — STRESS — SAGGING — COMP. DK.	FULL LOAD — STRESS — SAGGING — TENS. KEEL	FULL LOAD — STRESS — STILL WATER — COMP. DK.	FULL LOAD — STRESS — STILL WATER — TENS. KEEL	ENVELOPE OF MAXIMUM MOMENT AND SHEAR — BENDING MOMENT FT-TON — HOGGING	ENVELOPE — BENDING MOMENT — SAGGING	ENVELOPE — BENDING MOMENT — STILL WATER	ENVELOPE — STRESS TONS/SQ INCH — HOGGING — TENS. DK.	ENVELOPE — STRESS — HOGGING — COMP. KEEL	ENVELOPE — STRESS — SAGGING — COMP. DK.	ENVELOPE — STRESS — SAGGING — TENS. KEEL	ENVELOPE — STRESS — STILL WATER — COMP. DK.	ENVELOPE — STRESS — STILL WATER — TENS. KEEL	STA
3	61,012	-81,252	36	0.87	-1.21	-1.17	1.74	0	0	170,050			2.45	-3.66					3
4	137,638	-144,270	18,035	1.74	-2.18	-1.82	2.28	.23	-.29	306,680			3.08	-4.06					4
5	249,130	-221,876	46,143	2.82	-3.23	-2.51	2.97	.52	-.62	493,200			5.58	-6.60					5
6	382,360	-311,611	76,777	3.13	-3.40	-2.55	2.77	.63	-.68	715,150			5.86	-6.36					6
7	525,203	-400,065	109,899	4.07	-4.15	-3.10	3.16	.85	-.87	935,860			7.25	-7.39					7
8	669,399	-464,362	153,801	4.26	-4.60	-2.95	3.19	.98	-1.06	1,119,960			7.12	-7.69					8
9	804,415	-484,203	215,089	4.97	-5.03	-2.99	3.03	1.23	-1.25	1,234,300			7.63	-7.72					9
10	913,731	-452,771	290,443	5.65	-5.57	-2.80	2.76	1.80	-1.77	1,278,100			7.90	-7.79					10
11	975,854	-380,318	364,215	6.19	-6.06	-2.41	2.26	2.31	-2.26	1,265,000			8.02	-7.85					11
12	989,640	-270,247	433,070	6.69	-6.51	-1.83	1.78	2.93	-2.85	1,183,000			8.00	-7.79					12
13	935,466	-155,766	468,390	6.64	-6.07	-1.11	1.01	3.22	-3.04	1,017,400			7.22	-6.60					13
*14	801,383	-71,950	444,117	6.96	-6.06	-.63	.54	3.86	-3.36	806,210			7.00	-6.10 *					*14
*15	611,033	-24,484	367,176	5.21	-5.88	-.21	.24	3.13	-3.53	611,000			5.21	-5.88 *					*15
*16	395,523	-13,402	252,403	6.96	-5.19	-.12	.18	2.31	-3.31	395,530			3.62	-5.19 *					*16
*17	210,481	-10,694	142,871	3.62	-4.03	-.11	.21	1.42	-2.73	210,500			2.09	-3.68 *					*17

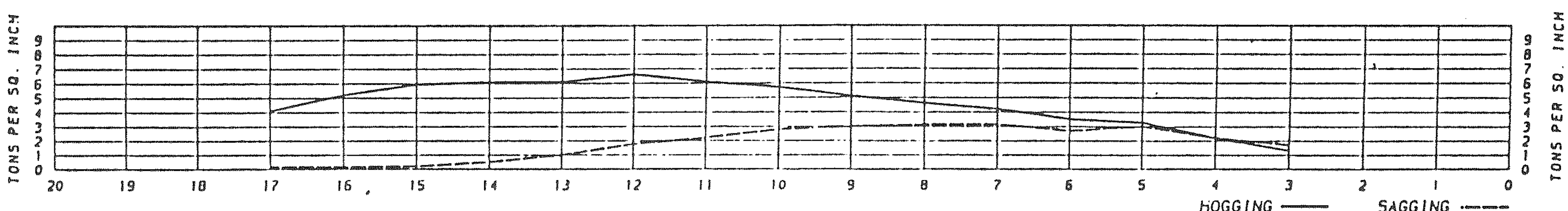
*AT BOTTOM OF SKEG ON BASELINE



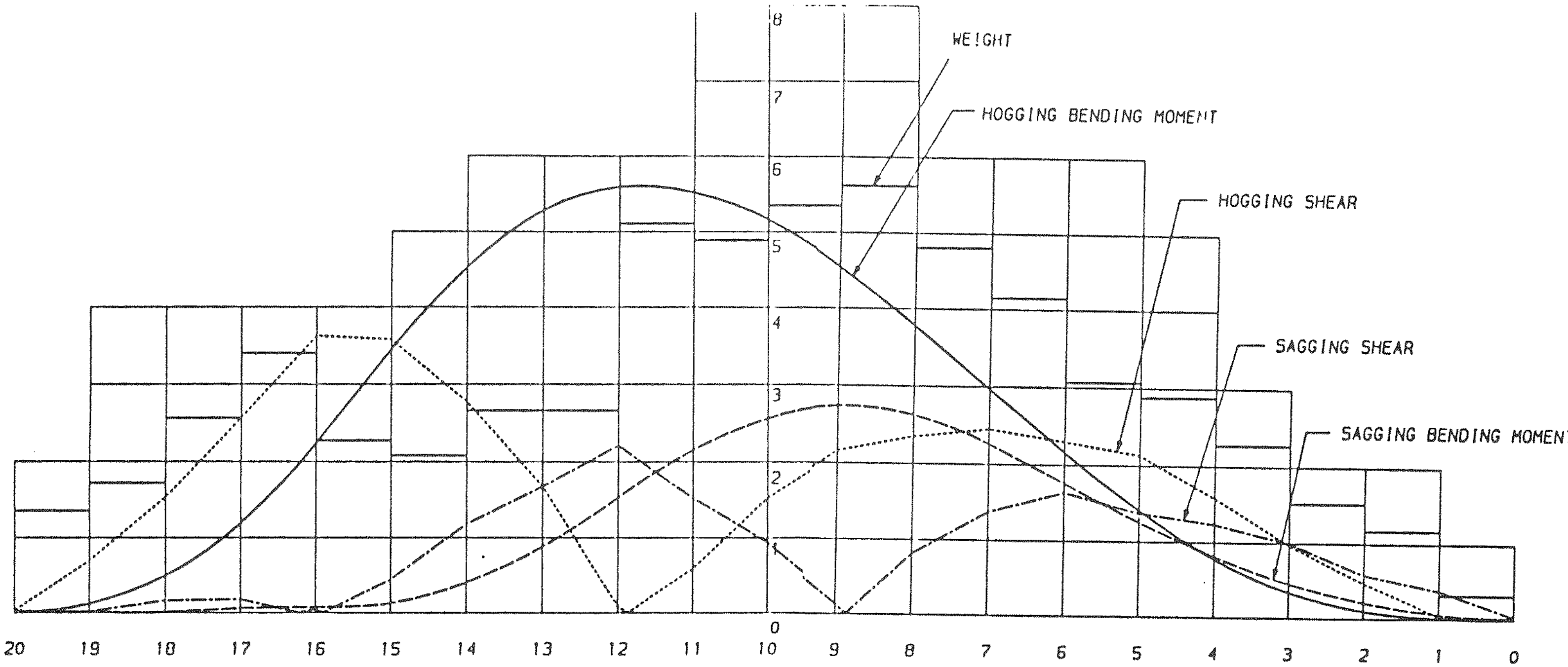
HEIGHT OF NEUTRAL AXIS ABOVE ℄



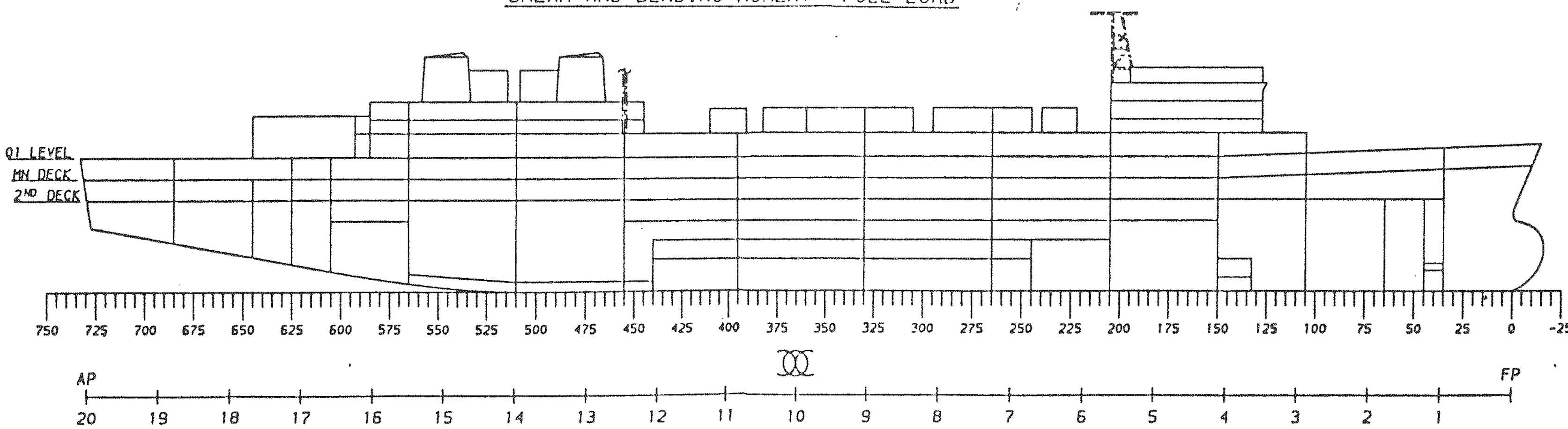
STRESS IN 01 LEVEL



STRESS IN KEEL



SHEAR AND BENDING MOMENT - FULL LOAD



WEIGHT DISTRIBUTION				
	LIGHT SHIP		FULL LOAD	
STA	TONS	LCG	TONS	LCG
FWD OF FP	71.96	371.81	76.27	372.67
FP - 1	244.15	343.65	260.35	346.75
1 - 2	469.68	313.69	948.38	310.25
2 - 3	364.90	272.09	1231.22	273.75
3 - 4	879.97	235.31	1838.27	237.25
4 - 5	851.31	198.92	2331.39	200.75
5 - 6	867.85	163.16	2479.91	164.25
6 - 7	1205.06	128.26	3356.40	127.75
7 - 8	987.57	91.96	3888.66	91.25
8 - 9	1329.82	55.50	4543.85	54.75
9 - 10	1301.15	16.90	4322.69	18.25
10 - 11	1152.23	-19.57	3951.76	-18.25
11 - 12	1373.06	-55.76	4129.03	-54.75
12 - 13	1263.76	-92.43	2153.69	-91.25
13 - 14	1840.25	-126.56	2153.27	-127.75
14 - 15	1544.79	-166.71	1643.44	-164.25
15 - 16	1046.99	-198.97	1837.96	-200.75
16 - 17	917.17	-236.80	2751.05	-237.25
17 - 18	665.28	-273.31	2069.78	-273.75
18 - 19	480.60	-310.71	1387.41	-310.25
19 - AP	663.75	-344.45	1090.52	-346.75
AFT OF AP	43.92	-369.10	46.55	-367.25
TOTAL	19,565.21		48,489.87	

GENERAL DATA		
FULL LOAD DISPLACEMENT	Δ	48,489.87 TONS
LENGTH DWL	L	730'-0"
TYPE OF WAVE	$1.1\sqrt{L}$	TROCHOIDAL-29.72'
WEIGHT DISTRIBUTION	——	20 STATION
SCALE FOR LENGTH	L/20	1"=36.5 FT
WEIGHT ORDINATES	Δ/3L	1"=22.141 TONS/FT
WEIGHT AREA	Δ/60	1"=808.15 TONS
SHEAR ORDINATES	Δ/30	1"=1616.3 TONS
SHEAR AREA	ΔL/600	1"=58,995 FT-TONS
BENDING MOMENT ORDINATES	ΔL/200	1"=176,985 FT-TONS

INERTIA CALCULATION DATA							
STA	AREA	INERTIA	NEUTRAL AXIS (FT)			SECT. MOD. ($IN^2 \cdot FT$)	
	(IN^2)	($IN \cdot FT^2$)	HGT ABL	Y · DK	Y · KEEL	DECK	KEEL
3	3,254.7	1,901,101	40.74	27.26	40.74	69,739	46,664
4	3,779.6	2,352,837	37.25	29.75	37.25	79,079	63,168
5	4,196.5	2,701,825	36.16	30.59	36.16	88,333	74,712
6	5,637.3	3,907,429	34.74	32.01	34.74	122,060	112,484
7	6,389.3	4,260,911	33.67	33.00	33.67	129,100	126,567
8	7,148.9	5,045,526	34.66	32.09	34.66	157,206	145,593
9	7,487.9	5,360,803	33.54	33.13	33.54	161,812	159,832
10	7,535.4	5,429,673	33.10	33.57	33.10	161,750	164,030
11	7,338.2	5,313,856	32.99	33.68	32.99	157,785	161,064
12	6,832.3	4,997,484	32.90	33.77	32.90	147,966	151,921
13	6,785.5	4,909,683	31.85	34.82	31.85	140,982	154,174
14	6,313.3	4,103,173	31.05	35.64	31.05*	115,130	132,230*
15	6,205.3	3,671,906	35.34	31.33	35.34*	117,189	103,912*
16	5,880.0	2,992,594	39.30	27.37	39.30*	109,324	76,154*
17	6,013.6	2,433,195	42.48	24.19	42.48*	100,590	57,278*

* TO BOTTOM OF SKEG ON BASELINE

PRINCIPAL RESULTS (FULL LOAD)			
CONDITION OF WAVE	HOGGING	SAGGING	STILL WATER
DISPLACEMENT (TONS)	48,490	48,490	48,490
MAX SHEAR FWD (STATION)	7	6	10
MAX SHEAR FWD (TONS)	3,958	-2,642	2,144
MAX SHEAR AFT (STATION)	16	13	16
MAX SHEAR AFT (TONS)	-5,863	2,706	-3,407
MAX MOMENT (STATION)	12	9	13
MAX MOMENT (FT-TONS)	+989,640	-484,283	+468,398
BENDING MOMENT CONSTANT ΔL/M	35.77	73.09	75.57
MAX STRESS IN DECK (T.S.I.)	+6.69	-2.99	+3.32
MAX STRESS IN KEEL (T.S.I.)	-6.51	3.03	-3.04

APPENDIX C

SECTION PROPERTIES CALCULATIONS

TOTALS (ONE SIDE)	3767.71	2582007	32830	2714837

STRUCTURAL PROPERTIES OF SECTION WITH REMOVALS

STA 10

PROPERTIES AT STA10 AOE6

TOTAL AREA =	7535.42 SQ. IN.
MOMENT OF INERTIA ABT N,A, =	5429673 SQ.IN.FT-SQ
MOMENT OF INERTIA ABT VERT AXIS =	6728149 SQ.IN.FT-SQ
DISTANCE FROM N.A. TO DECK =	23.57 FEET
DISTANCE FROM N.A. TO KEEL =	33.10 FEET
SECTION MODULUS DECK =	161750. SQ. IN. - FT
SECTION MODULUS KEEL =	164030. SQ. IN. - FT.

STA 10

PROPERTIES AT STA10 A0E6

ELEMENT NO.	DESCRIPTION	Y1 (FT)	Z1 (FT)	Y2 (FT)	Z2 (FT)	Y3 (FT)	Z3 (FT)	PLATE THICKNESS OR LUMP AREA	ID	K	AREA (IN^2)	DISTANCE FROM NEUTRAL AXIS (FT)	INERTIA DUE TO DISTANCE FROM NEUTRAL AXIS (IN^2FT^2)	INERTIA OF ELEMENT ABOUT OWN AXIS (IN^2FT^2)	TOTAL INERTIA (IN^2FT^2)
1	BOT PL 0-12.5	0.00	0.00	35.75	0.00	0.00	0.00	51.000	0	0	536.25	33.10	587581	0	587587
2	BOT PL 12.5-16	35.75	0.00	43.20	0.00	0.00	0.00	45.900	0	0	100.58	33.10	110202	0	110202
3	BILGE PL 16-19	43.20	0.00	49.40	2.00	47.20	0.50	40.800	0	0	67.31	32.48	71019	27	71045
4	BILGE PL 19-21	49.40	2.00	52.30	6.25	51.00	4.00	40.800	0	0	61.98	29.05	52301	94	52395
5	BILGE PL 21-22.5	52.30	6.25	53.25	9.50	52.80	7.75	40.800	0	0	40.67	25.24	25902	35	25937
6	SIDE PL 22.5-30	53.25	9.50	53.50	28.30	0.00	0.00	30.600	0	0	169.21	14.28	34129	4984	39113
7	SIDE PL 30-39. 5	53.50	28.30	53.50	52.67	0.00	0.00	25.500	0	0	182.77	7.38	9954	9046	19000
8	SIDE PL 39.5-41. 5	53.50	52.67	53.50	59.67	0.00	0.00	35.700	0	0	73.50	23.07	39113	300	39413
9	SHEER STR	53.50	59.67	53.50	66.17	0.00	0.00	45.900	0	0	87.75	29.82	78021	309	78330
10	BOT LONG 0	0.00	1.18	0.00	0.00	0.00	0.00	13.220	0	0	6.61	31.92	6736	0	6736
11	BOT LONG 1-17	1.00	1.18	0.00	0.00	0.00	0.00	......	0	0	211.52	31.92	215538	0	215538
12	BILGE LONG 18-20	1.00	3.00	0.00	0.00	0.00	0.00	39.660	0	0	39.65	30.10	35936	0	35936
13	BILGE LONG 21-23	1.00	8.80	0.00	0.00	0.00	0.00	37.590	0	0	37.59	24.30	22200	0	22200
14	SIDE LONG 24-27	1.00	17.00	0.00	0.00	0.00	0.00	33.040	0	0	33.04	16.10	8566	0	8566
15	SIDE LONG 28-32	1.00	27.75	0.00	0.00	0.00	0.00	28.650	0	0	28.65	5.35	821	0	821
16	SIDE LONG 33-37	1.00	40.25	0.00	0.00	0.00	0.00	23.800	0	0	23.80	7.15	1216	0	1216
17	SIDE LONG 38-40	1.00	50.50	0.00	0.00	0.00	0.00	13.260	0	0	13.26	17.40	4014	0	4014
18	SIDE LONG 41-43	1.00	61.00	0.00	0.00	0.00	0.00	12.150	0	0	12.15	27.90	9457	0	9457
19	KEELSON WEB	1.00	0.00	1.00	8.00	0.00	0.00	25.500	0	0	60.00	29.10	50815	320	51135
20	KEELSON FLG	1.00	8.00	0.00	0.00	0.00	0.00	24.000	0	0	24.00	25.10	15122	0	15122
21	KEELSON STIFF	1.00	4.00	0.00	0.00	0.00	0.00	6.960	0	0	6.96	29.10	5894	0	5894
22	BHD PL BL-16	1.00	0.00	1.00	17.00	0.00	0.00	30.600	0	0	153.00	24.60	92602	3685	96287
23	BHD PL 16-25.5	1.00	17.00	1.00	26.50	0.00	0.00	25.500	0	0	71.25	11.35	9181	536	9717
24	BHD PL 25.5-MN DK	1.00	26.50	1.00	56.00	0.00	0.00	20.400	0	0	177.00	8.15	11752	12836	24588
25	BHD PL MN-01	1.00	56.00	1.00	66.67	0.00	0.00	25.500	0	0	80.02	28.23	63789	759	64549

ELEMENT NO.	DESCRIPTION	GEOMETRY Y1 (FT)	Z1	Y2	Z2	Y3	Z3	PLATE THICKNESS OR LUMP AREA	ID	K	AREA (IN^2)	DISTANCE FROM NEUTRAL AXIS (FT)	INERTIA DUE TO DISTANCE FROM NEUTRAL AXIS (IN^2FT^2)	INERTIA OF ELEMENT ABOUT OWN AXIS (IN^2FT^2)	TOTAL INERTIA (IN^2FT^2)
26	BHD L1	1.00	2.67	0.00	0.00	0.00	0.00	7.010	0	0	7.01	30.43	6492	0	6492
27	BHD L2-3	1.00	6.67	0.00	0.00	0.00	0.00	25.060	0	0	25.06	26.43	17508	0	17508
28	BHD L4-6	1.00	13.33	0.00	0.00	0.00	0.00	24.780	0	0	24.78	19.77	9687	0	9687
29	BHD L7-10	1.00	21.94	0.00	0.00	0.00	0.00	22.920	0	0	22.92	11.16	2855	0	2855
30	BHD L11-14	1.00	31.43	0.00	0.00	0.00	0.00	19.040	0	0	19.04	1.67	53	0	53
31	BHD L15-17	1.00	40.25	0.00	0.00	0.00	0.00	13.260	0	0	13.26	7.15	678	0	678
32	BHD L18-20	1.00	50.20	0.00	0.00	0.00	0.00	13.260	0	0	13.26	17.10	3877	0	3877
33	BHD L23	1.00	64.00	0.00	0.00	0.00	0.00	2.320	0	0	2.32	30.90	2215	0	2215
34	01 LVL PL INBD	7.00	66.67	30.50	66.67	0.00	0.00	45.900	0	0	317.25	33.57	357487	0	357487
35	01 LVL PL OUTBD	30.50	66.67	45.50	66.36	0.00	0.00	45.900	0	0	202.54	33.41	226129	2	226131
36	STRINGER STR	45.50	66.36	53.50	66.19	0.00	0.00	45.900	0	0	108.02	33.17	118877	0	118878
37	MN DK PL INBD	7.00	56.00	30.00	56.00	0.00	0.00	20.400	0	0	138.00	22.90	72358	0	72358
38	MN DK PL OUTBD	30.00	56.00	53.50	56.00	0.00	0.00	25.500	0	0	176.25	22.90	92414	0	92414
39	2ND DK PL	7.00	45.50	30.00	45.50	0.00	0.00	20.400	0	0	138.00	12.40	21213	0	21213
40	01 LONGS INBD	1.00	65.92	0.00	0.00	0.00	0.00	56.000	0	0	56.00	32.82	60314	0	60314
41	01 LONGS OUTBD	1.00	65.67	0.00	0.00	0.00	0.00	63.090	0	0	63.09	32.57	66919	0	66919
42	01 GIRD	1.00	64.99	0.00	0.00	0.00	0.00	41.810	0	0	41.81	31.89	42515	0	42515
43	MN DK LONG INBD	1.00	55.25	0.00	0.00	0.00	0.00	41.520	0	0	41.52	22.15	20368	0	20368
44	MN DK LONG OUTBD	1.00	55.42	0.00	0.00	0.00	0.00	32.400	0	0	32.40	22.32	16139	0	16139
45	MN DK GIRD	1.00	54.30	0.00	0.00	0.00	0.00	29.000	0	0	29.00	21.20	13032	0	13032
46	2ND DK LONG	1.00	45.00	0.00	0.00	0.00	0.00	32.640	0	0	32.64	11.90	4621	0	4621
47	2ND DK GIRD	1.00	43.99	0.00	0.00	0.00	0.00	25.000	0	0	25.00	10.89	2964	0	2964
48	SYM MN DK PL	33.50	56.00	36.00	56.00	0.00	0.00	25.500	0	0	-18.75	22.90	-9831	0	-9831
49	SYM BHD PL	1.00	56.75	1.00	62.25	0.00	0.00	25.500	0	0	-41.25	26.40	-28746	-104	-128850

APPENDIX D

SELECTED MEASUREMENT UNITS AND CONVERSION FACTORS

APPENDIX D

SELECTED MEASUREMENT UNITS AND CONVERSION FACTORS

(US Customary and SI (metric) Units)

Category	To convert from inch-pound units	To SI units	Multiply by 1/
Length	foot (ft)	meter (m)	0.3048
	inch (in)	meter (m)	2.54×10^{-2}
	inch (in)	millimeter (mm)	25.4
Area	square foot (ft^2)	square meter (m^2)	9.290×10^{-2}
	square inch (in^2)	square millimeter (mm^2)	6.452×10^{2}
Force	pound force (lbf)	newton (N)	4.448
Mass	pound (lb)	kilogram (kg)	0.4536
	ton (long, 2240 lb) 2/	metric ton (t)	1.016
Stress (force/area)	pound/square inch (lbf/in^2, psi)	pascal (Pa)	6.895×10^{3}
Second moment of area 3/	$inch^2$-$foot^2$ (in^2-ft^2)	$meter^2$-$centimeter^2$ (m^2-cm^2)	0.5994

SI uses 16 prefixes to designate decimal multiples. The five prefixes in most frequent use are these:

mega	M	1 000 000	$= 10^{6}$
kilo	k	1 000	$= 10^{3}$
centi	c	0.01	$= 10^{-2}$
milli	m	0.001	$= 10^{-3}$
micro	μ	0.000 001	$= 10^{-6}$

1/ Conversion factors listed for length are exact; others are approximate.

2/ The long ton is also used as a unit of force of 2240 pounds force.

3/ The second moment of area as listed here is also termed the moment of inertia. Strictly, moment of inertia has dimensions of mass times length squared, instead of area times length squared or length to the fourth power. Nevertheless, the second moment of area is customarily called moment of inertia in longitudinal strength calculations.

APPENDIX E

BLANK CALCULATION FORMS

WEIGHT SUMMARY - TONS/STATION

CALC.BY ____________ DATE ________

SHIP ______________________________ CHKD.BY ____________ DATE ________

CONDITION:

STATION	WEIGHT (TONS)	ARM (STATIONS)	MOMENT
AFT 20			
20-19			
19-18			
18-17			
17-16			
16-15			
15-14			
14-13			
13-12			
12-11			
11-10			
10-9			
9-8			
8-7			
7-6			
6-5			
5-4			
4-3			
3-2			
2-1			
1-0			
FWD 0			
TOTAL			

BUOYANCY

SHIP ______________________ CALC.BY __________ DATE ________

CHKD.BY __________ DATE ________

CONDITION:

BONJEAN STATION	SHIP LEVEL: SECTION AREAS IN FT² — BL OF WAVE AT			ARM FROM STA 10	MOM. ABOUT STA 10	SHIP TRIMMED: BL OF WAVE AT F A FT²	MOM. ABOUT STA 10	BL OF WAVE AT F A FT²	MOM. ABOUT STA 10	MEAN ORD TO BUOY. CURVE FT²	STATION
20	$\frac{1}{2}$ x	$\frac{1}{2}$ x	$\frac{1}{2}$ x	9.75		$\frac{1}{2}$ x		$\frac{1}{2}$ x			AFT 20
19				9							20-19
18				8							19-18
17				7							18-17
16				6							17-16
15				5							16-15
14				4							15-14
13				3							14-13
12				2							13-12
11				1							12-11
10				0							11-10
9				1							10-9
8				2							9-8
7				3							8-7
6				4							7-6
5				5							6-5
4				6							5-4
3				7							4-3
2				8							3-2
1				9							2-1
0				9.75							1-0
	$\frac{1}{2}$ x	$\frac{1}{2}$ x	$\frac{1}{2}$ x			$\frac{1}{2}$ x		$\frac{1}{2}$ x			FWD 0
TOTAL											
	TONS	TONS	TONS	FT		TONS	CG AT	TONS	CG AT	TONS	

ORDINATES TO WEIGHT & BUOYANCY CURVES

CALC.BY ________ DATE ________

SHIP ______________________ CHKD.BY ________ DATE ________

CONDITION:

STATION	ARM FROM STA 10	ORD TO WT CURVE		ORDINATES TO BUOYANCY CURVES							
				HOGGING				SAGGING			
		TONS/STA $\times \frac{60}{\Delta}$ IN	MOM. ABOUT STA 10 IN^2	FT^2/STA $\times \frac{60}{\Sigma FT^2}$ IN	MOM. ABOUT STA 10 IN^2	CORR TO ORD FOR MOM. IN	FINAL ORD TO BUOY. CURVE IN	FT^2/STA $\times \frac{60}{\Sigma FT^2}$ IN	MOM. ABOUT STA 10 IN^2	CORR TO ORD FOR MOM. IN	FINAL ORD TO BUOY. CURVE IN
AFT 20											
20-19	9.5										
19-18	8.5										
18-17	7.5										
17-16	6.5										
16-15	5.5										
15-14	4.5										
14-13	3.5										
13-12	2.5										
12-11	1.5										
11-10	0.5										
10-9	0.5										
9-8	1.5										
8-7	2.5										
7-6	3.5										
6-5	4.5										
5-4	5.5										
4-3	6.5										
3-2	7.5										
2-1	8.5										
1-0	9.5										
FWD 0											
TOTAL						0.00				0.00	

ORDINATES TO SHEAR & MOMENT CURVES

CALC.BY __________ DATE __________

SHIP ______________________ CHKD.BY __________ DATE __________

CONDITION:

STATION	ORD TO WT CURVE IN (1)	ORD TO BUOY. CURVE IN (2)	ORD TO LOAD CURVE (1)-(2) IN (3)	Σ AREA UNDER LOAD CURVE IN^2 (4)	ORD TO SHEAR CURVE (4) x $\frac{1}{2}$ IN (5)	MEAN ORD TO SHEAR CURVE IN (6)	Σ AREA UNDER SHEAR CURVE IN^2 (7)	ORD TO MOM. CURVE (7) x $\frac{1}{3}$ IN (8)	BENDING MOM. (8) x $\frac{\Delta L}{200}$ FT-TONS (9)
AFT 20									
20-19									
19-18									
18-17									
17-16									
16-15									
15-14									
14-13									
13-12									
12-11									
11-10									
10-9									
9-8									
8-7									
7-6									
6-5									
5-4									
4-3									
3-2									
2-1									
1-0									
FWD 0									

SHIP: ______________ STA: ________ FR: ________ BY: ________ DATE: ________ PAGE: ________

$\Sigma Ad =$ ________ in²-ft

$\Sigma A =$ ________ in²

$\bar{y} = \Sigma Ad / \Sigma A =$ ________ ft

$\Sigma Ad^2 =$ ________ in²-ft²

$\Sigma i_o =$ ________ in²-ft²

$I_{BL} = \Sigma Ad^2 + \Sigma i_o =$ ________ in²-ft²

$I_{NA} = I_{BL} - Ay^2 =$ ________ in²-ft²

$D =$ ________ ft
baseline to strength dk

$\bar{z} =$ ________ ft *
to structure below BL

$\bar{y}_k = \bar{y} - \bar{z} =$ ________ ft *

$\bar{y}_d = D - \bar{y}_k =$ ________ ft

$SM_{KL} = \dfrac{I_{NA}}{\bar{y}_k} =$ ________ in²-ft

$SM_{DK} = \dfrac{I_{NA}}{\bar{y}_d} =$ ________ in²-ft

* NOTE: $\bar{z}$ = zero if baseline coincides with keel bottom.

$M_{HOG} =$ ________ ft-ton

$M_{SAG} =$ ________ ft-ton

$M_{STILL\ WATER} =$ ________ ft-ton

$\dfrac{M_{HOG}}{SM_{DK}} =$ ________ tons/in²
DECK, TNSN

$\dfrac{M_{HOG}}{SM_{KL}} =$ ________ tons/in²
KEEL, CPRSN

$\dfrac{M_{SAG}}{SM_{DK}} =$ ________ tons/in²
DECK, CPRSN

$\dfrac{M_{SAG}}{SM_{KL}} =$ ________ tons/in²
KEEL, TNSN

$\dfrac{M_{SW}}{SM_{DK}} =$ ________ tons/in²

$\dfrac{M_{SW}}{SM_{KL}} =$ ________ tons/in²

SHIP: ______________ STA: ________ FR: ________ BY: ________ DATE: ________ PAGE: ______

MEMBER	b (IN) OR n	t (IN) OR a (IN^2)	h (FT)	A = bt OR na (IN^2)	d (FT)	Ad (IN^2-FT)	Ad^2 (IN^2-FT^2)	$i_o = Ah^2/12$ (IN^2-FT^2)
TOTAL ONE SIDE								
TOTAL BOTH SIDES								

a = UNIT AREA OF ELEMENTS n = NUMBER OF ELEMENTS h = PROJECTED HEIGHT OF PLATES