DDS130-1

(9110-6/1106-1)
1 November 1957

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS
WASHINGTON 25, D. C.

DESIGN DATA SHEET

DDS1106-1

STRUCTURAL DESIGN OF AIRCRAFT HANDLING DECKS

By

A. W. Fischer and Y. Park

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ACKNOWLEDGMENT

The nomographs used in this design sheet were developed by Dr. N. M. Newmark and associates of the University of Illinois under Contract NObs 65546 Index NS 731-940. These nomographs were developed from the Bureau of Ships fundamental equations as given in Appendix D.

DDS1106-1-a. General

1. Purpose and Brief Discussion

This Design Data Sheet is issued for guidance in structural design and rating of flight decks, hangar decks, and platforms which are constructed of steel plating, aluminum planking or wood planking, stiffened with steel longitudinals. These longitudinals, in turn, are supported by transverse bents or structural bulkheads. The transverse bents, which are not discussed in this design data sheet, are the primary supporting structures for the flight deck. In some cases additional stiffness is added by using intermediate transverses. The design problem is complicated by the varying and dynamic nature of loads and the complex interaction of the deck structural components. The procedure described herein uses accepted principles of structural mechanics with empirical constants determined from static and dynamic tests conducted on aircraft carriers and other structures.

2. Procedure applies to elastic range

No permanent set in the flight deck can be tolerated; hence, this design method is based on the assumption that stresses will not exceed the elastic range. Therefore the deformations of the structure contemplated do not approach those which might be developed at failure of the structure. It is recognized that in terms of loading, there is a considerable margin of safety, beyond the point at which first yielding occurs in the metallic structure, and to a smaller degree in wood planking.

3. Nomographs and formulas

The procedure is reduced to a series of nomographs (Appendix E). The empirical formulas on which the nomographs are based have been included in Appendix D for use when data exceeds the range of the nomographs.

4. Nomenclature

Symbols and definitions used in this Design Data Sheet are given in Appendix A.

DDS1106-1-b. Loading.

1. Landing reaction

The magnitude of loading on various parts of the decks and platforms depends on aircraft operations. The landing area of the flight deck (consult applicable detail specifications) is designed for the landing gear reaction, which is furnished by the Bureau of Aeronautics. This reaction takes into consideration the mission and type of aircraft, since an aircraft might be landed with certain bombs and fuel aboard.

2. Catapulting reaction

The catapult area (consult detail specifications) is designed for the catapulting reaction, (also furnished by Bureau of Aeronautics) which is based on the catapult characteristics and the aircraft considered.

3. Parking reaction

The parking area of the flight deck in the moderate sea condition is considered as the entire flight deck, including deck edge elevators. In the storm condition, the deck edge elevators, the angled deck sponson, the starboard sponson (if any) and the foremost 50 feet of the flight deck are not used for parking. The parking area is designed for the maximum parking wheel reaction.

(a) The maximum parking wheel reaction occurs during storms. When the aircraft carrier is heaving, pitching, and rolling, the resulting inertia forces increase the wheel reactions above those due to the weight of aircraft alone. Ship motions vary with the characteristics of each ship and the roughness of the sea. Unless otherwise directed, the amplitudes and periods of roll and pitch listed for various classes in Appendix B may be used for design. This parking reaction is further increased by the wind forces acting on the aircraft parked on the flight deck (this is not included for aircraft parked on the hangar deck) and the heave factor. A maximum design wind force of 15 p.s.f. is used on the projected area of the aircraft with the wings folded. For heave factors consult applicable detail specifications.

4. Wheel Loads

The wheel loads are applied to the deck structure through high-pressure pneumatic tires (for tire characteristics, see Appendix C) in two ways: by air pressure acting on the inside of the tire casing, and by compression due to the rigidity of the wheel rims. The air pressure acting on the inside of the casing is assumed uniformly distributed over the entire contact area. The size of this contact area varies with the applied wheel load, (see example

No. 2). If the tire pressure is insufficient or if the applied wheel load is excessive, the tire will bottom so that the rims of the wheels will bear against the deck through solid rubber. When this condition occurs, the deck members must resist both the wheel and rim loads. For the illustration of rim load, see FIGS. 1-1 and 1-2.

(a) If the total load carried by the tire is designated as P, the portion of load carried by the tire alone is referred to as P_T and the portion of the load transmitted to the deck directly through the rims is known as rim load or P_R then

$$P = P_T + P_R$$

(b) When the wheel load is less than the bottoming load P_b, the entire load is carried by the tire, i.e.

$$P < P_b; \; P_T = P; \; P_R = 0$$

(c) When the wheel load is greater than the bottoming load, the tire carries a load equal to the bottoming load and the excess over the bottoming load will be carried by the rims,

$$P > P_b; \; P_T = P_b; \; P_R = P - P_b$$

(d) The tire load P_T is considered to be uniformly distributed over a rectangular area of contact length A and contact width B, (see FIG. 1-1). The values of A and B vary with the magnitude of tire load P_T. For loads greater than the bottoming load, the values of A and B will remain constant since the load carried by the tire does not change after the wheel bottoms.

(e) The rim load P_R is considered to be distributed uniformly over two rectangular strips of length A_R and width of 1½ inches each and spacing, center to center of rectangles, of B_R. The contact length of rim A_R is taken as ¼ of the rim diameter (See Appendix C for rim diameter). As shown on FIG. 1-2, the rim load will add bending and shearing stresses on the planking or steel plating to those caused by the tire load.

5. Example No. 1

Determine the maximum parking wheel reaction of a 40,000 pound aircraft to be parked on a given carrier flight deck when the aircraft and ship characteristics are as follows:

T_P = period of pitch = 8 seconds full period

θ_P = angle of pitch = 4 degrees

Z = longitudinal distance from aircraft center of gravity to ship center of flotation = 440 feet

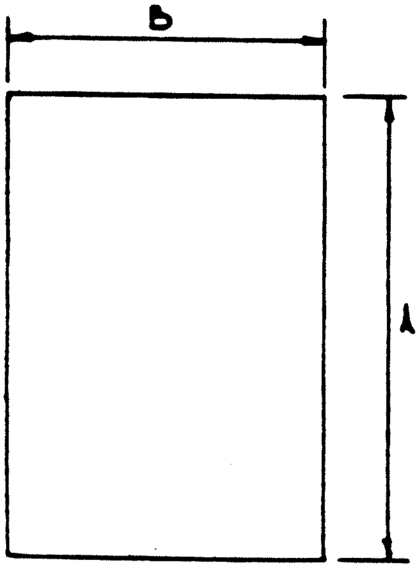


FIGURE 1-1
Below bottoming load

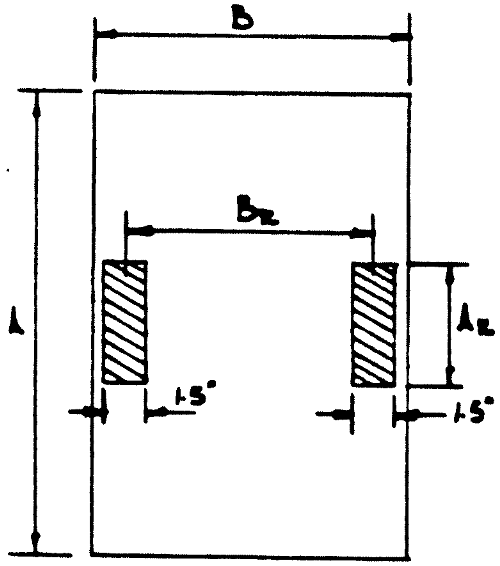


FIGURE 1-2
Above bottoming load

C_z = longitudinal distance from main wheel axis to aircraft center of gravity = 73.0 inches

S_z = distance from nose wheel to main wheel axis = 320.5 inches

H_F = heave factor = 0

T_R period of roll = 15 seconds full period

θ_R angle of roll = 30 degrees

Y vertical distance from aircraft center of gravity to ship center of flotation = 59.46 feet

C_y = vertical distance from deck to aircraft center of gravity = 92.9 inches

S = distance between main wheels = 127.5 inches

A = maximum sail area of aircraft wings folded = 680 square feet

C_y' vertical distance from deck line to center of pressure of sail area = 134.5 inches (assumed wings folded)

From FIG. A1-1, $C_z/S_z = 0.228$

$\Omega = 0.588$

$P_1/W = 0.69$

$P_1 = 0.69 \times 40.0 = 27.6$ kips if heave factor = 0.20g.

$P_1 = (27.6)\ (1 + 0.588)/(1.20 + 0.588) = 24.5$ kips for 0 heave

From FIG. A1-2, $C_y/S_x = 0.722$, $P_2/W = 0.70$

$P_2 = 0.70 \times 40.0 = 28.0$ kips

From FIG. A1-3, $P_3 = 10.8$ kips

Then maximum parking wheel reaction $= P_1 + P_2 + P_3$
$= 63.3$ kips

6. Example No. 2

If the main wheels of aircraft in example No. 1 are operated on tire size of 44 x 13, 26-ply with operational pressure of 190.0 p.s.i., find the contact width and contact length under maximum parking wheel reaction.

FIG. A2, $p_g' = 190.0$ p.s.i.

$$\left.\begin{array}{l} p_R = 200.0 \text{ p.s.i.} \\ P_R = 35.0 \text{ kips} \end{array}\right\} \begin{array}{l} \text{from MIL-C-5041A} \\ \text{table VI} \end{array}$$

Bottoming load, $P_b = 94.6$ kips. Therefore there will be no rim load when parked.

From FIG. A3, $P_T = 63.3$ kips; $p_g' = 190$ p.s.i.;

$P_T/P_b = 63.3/94.6 = 0.669$

Contact width B = 13.83 inches

Contact length A = 22.88 inches

DDS1106-1-c. Allowable Stresses

1. Allowable Stresses for Existing Carriers

The strengthening of the flight decks to handle aircraft larger than originally specified is costly and time consuming. To minimize these costly alterations, the following allowable stresses may be specified:

(a) In the parking area, when severe ship motions are assumed, it is permissible to increase the allowable bending and shearing stresses of the longitudinals, intermediate transverse girders and steel plate or aluminum plank decking to the tensile yield and shear yield of the material respectively. The shear yield for steel and aluminum alloy may be assumed to be 0.6 of the tensile yield strength. For Douglas fir planking in the parking area, the allowable bending and shearing stresses shall not exceed 7,500 p.s.i. and 750 p.s.i. respectively when the planking is supported on 4.2 lb. or heavier plating. If there is no plating under the wood planking then the allowable bending and shearing stresses shall not exceed 4,500 p.s.i. and 270 p.s.i. respectively.

(b) In the landing and catapulting areas, the allowable stresses (excluding wood) are the tensile yield and shear yield of the material. For wood planking in the landing area, the allowable bending and shearing stresses may be assumed to be 12,000 p.s.i. and 1,200 p.s.i. respectively.

2. Allowable Stresses for New Designs

(a) In recent carrier designs, the flight deck has been designed as a ballistic deck to provide maximum shipboard protection. The presence of ballistic material at the flight deck level makes it possible to consider the flight deck as a strength deck. By utilizing the flight deck as strength deck, a greater depth is added to the ship's hull girder. This added depth increases the moment of inertia, hence the rigidity of the hull girder to resist bending. By considering the flight deck as the strength deck of the hull, the longitudinal members supporting the deck are subjected to both primary and secondary stresses. The primary stresses, determined from longitudinal strength calculations, are the stresses due to bending of the ship's hull girder by wave actions. The secondary stresses are the stresses resulting from aircraft operations on the flight deck. For these new designs, the allowable stresses for this type of structural arrangement are defined in the appropriate specifications.

(1) The longitudinals in the parking area of the flight and hangar decks (defined in applicable detail specifications) are designed for storm condition. Under this load condition, use a working stress equal to the allowable stresses specified in the detail specifications.

(2) Since landings and catapulting are made in moderate sea condition, the primary stresses are neglected, because they are usually small. Therefore, use a working stress equal to the allowable stress specified in the detail specifications.

(3) After the longitudinal members have been designed for the above stresses, the ratio of their span length (L) to the radius of gyration (longitudinal plus plating) should be investigated. This ratio generally should not exceed 60, but as this slenderness ratio may change for any specified ship, consult the applicable detail specifications.

DDS1106-1-d. Design of Plate Decks Without Transverse Girders

1. Type of Structure Considered

(a) The design procedure for plate decks, without transverse girders within the bent spacing, is based on the assumption that the solid metal plate is supported by a series of identical longitudinal girders uniformly spaced, and continuous over nondeflecting supports. These supports (bents or bulkheads) are also uniformly spaced, and are assumed to provide no restraint against the rotation of the longitudinals. Although the design procedure applies strictly to uniform and symmetrical conditions, for practical purposes it can be applied to conditions which deviate somewhat from these assumptions.

(b) The plate deck, which is integrally connected to the longitudinal girders by welding, serves a three-fold purpose: It acts as a watershed; it acts as a deck to support the wheel reactions and distribute the loads to the longitudinal girders; and in recent designs it acts as the top flange for the hull girder.

2. Effective Section of Longitudinal Girders

The effective section of the longitudinal girder for the moment of inertia calculation consists of the actual longitudinal girder plus that portion of the deck plating which acts with it. The effective flange width of the plating is taken equal to the spacing of the longitudinals, or 60t (t is the thickness of plate) plus the width of the upper flange of the longitudinal, whichever is less (see FIG. D1).

3. Design of Longitudinal Girders

The longitudinal girders are designed to resist a single landing gear reaction. The other landing gear reaction in most cases occurs far enough away from the point in question as to have a negligible effect in the determination of the strength of the longitudinal under consideration. Generally a landing gear has single tires. For the case where a landing gear has dual tires, which are spaced quite close, then the following procedure must be used to arrive at the deck reaction: Place one of the tires directly over the midspan of the longitudinal. Knowing the ratio b'/b (b' = distance from c-c of dual tires), the equivalent tire reaction (summation of the two tire loads) can be obtained directly from FIG. 2.7 (Appendix E). This reaction is to act over the contact area of the original tire load. The use of dual tires is a favorable factor since the design load is not as severe as that caused by the same aircraft with single tires. The percentage of applied load transferred to other longitudinals depends on the stiffness of the given longitudinal and the transverse flexural rigidity of the members (steel plating, aluminum or wood planking, transverse girders) between the longitudinals. FIGS. 2.2 or 2.3 (Appendix E) gives distribution factors. Equation 2.5 (Appendix D) illustrates the use of this figure.

(a) *Determination of Structural Parameters*

The first step in the design of longitudinal girders and plating is to determine parameters from FIG. B1. These parameters are required to determine the bending stresses of the longitudinals and steel plating (see example 3).

(b) *Maximum Moment and Bending Stress in Longitudinals*

(1) The maximum moment occurs when the wheel reaction is directly over the longitudinal

girder, at the center of the span between bents or structural bulkheads. This positive moment is considerably greater than the negative moment in the longitudinal.

(2) In calculating the maximum moment for the longitudinals, the wheel reaction times r_c (see FIGS. 2.2 or 2.3 Appendix E) is assumed uniformly distributed along a line of no width and of contact length A in the direction of the longitudinals. For loads greater than the bottoming load use the contact length corresponding to the bottoming load. This simplified load distribution makes the computation of the maximum bending moment in the longitudinals independent of the actual contact width B of the tire and makes it unnecessary to determine the effect of the rim load separately from that of the wheel load. As long as the contact width B is less than ¼ of spacing of longitudinals, this assumed load distribution gives results very close to the true ones. If the contact width B is greater than ¼ the spacing of the longitudinals, c-c, this assumption might be over-conservative and a more economical design may be achieved by applying a correction due to the contact width B.

(3) Correction due to contact width is determined from FIG. 2.6. Using the ratio of contact width to spacing of longitudinals, the correction factor ϕ_3 is obtained directly from the graph.

(4) The maximum moment and bending stress in the longitudinals caused by the live and dead loads are calculated by using FIG. B2. Multiply the moment from B2 by ϕ_3 from FIG. 2.6 to get the corrected values.

(c) *Maximum Shear and Shearing Stress*

(1) Maximum shear in a longitudinal occurs at a point adjacent to the support, when the wheel is directly over the longitudinal and one end of the rectangular area (contact width or contact length) is at the support.

(2) Use FIG. D2 for calculating shear and shearing stress.

4. Design of Plating

(a) The maximum design moment for the plating is the transverse moment under a load applied at the center of a panel of the plate. The wheel is oriented so that the contact length of the tire extends in the direction of the longitudinal. If the tire load is greater than the bottoming load, the effect of the rim load must be calculated separately from the tire load, considering the appropriate contact area for each component loading.

(b) When the distance from c-c of the dual tires is greater than 0.586b, a single tire positioned in the center between the longitudinals will cause the maximum bending stress. If the dual tires are spaced closer than 0.586b, the two tires must be considered and so placed as to cause the maximum bending stress. Knowing the ratios b′/b and B/b, the equivalent tire reaction can be obtained directly from FIG. 2.8 (Appendix E). This equivalent reaction is to be placed in the center between the longitudinals and is considered to act over a contact area equal to that of the original tire load.

(c) The maximum bending moment and bending stress are determined by using FIGS. B3-1, B3-2 and B3-3.

(d) The design of plating is not governed by shear.

5. Example No. 3

If the flight deck of the carrier in example No. 1 consists of 25 lbs. STS plate with 12 x 6½ x 31 lbs. I-T HTS longitudinal spaced 22.5 inches c-c and transverse bents 12 feet apart, determine if it is feasible to park the 40.0 kip aircraft on the flight deck of the carrier.

Maximum bending stress in longitudinal

FIG. B1, span = 12.0 ft.; $I = 447.3$ inches^4;
$h = 0.6127$ inches; $b/L = 22.5/144$
$= 0.1562$; $H = 147.5$; $\lambda = 1.01$

FIG. B2, $\lambda = 1.01$; $A/L = 22.88/144 = 0.1589$
$M/PL = 0.1391$

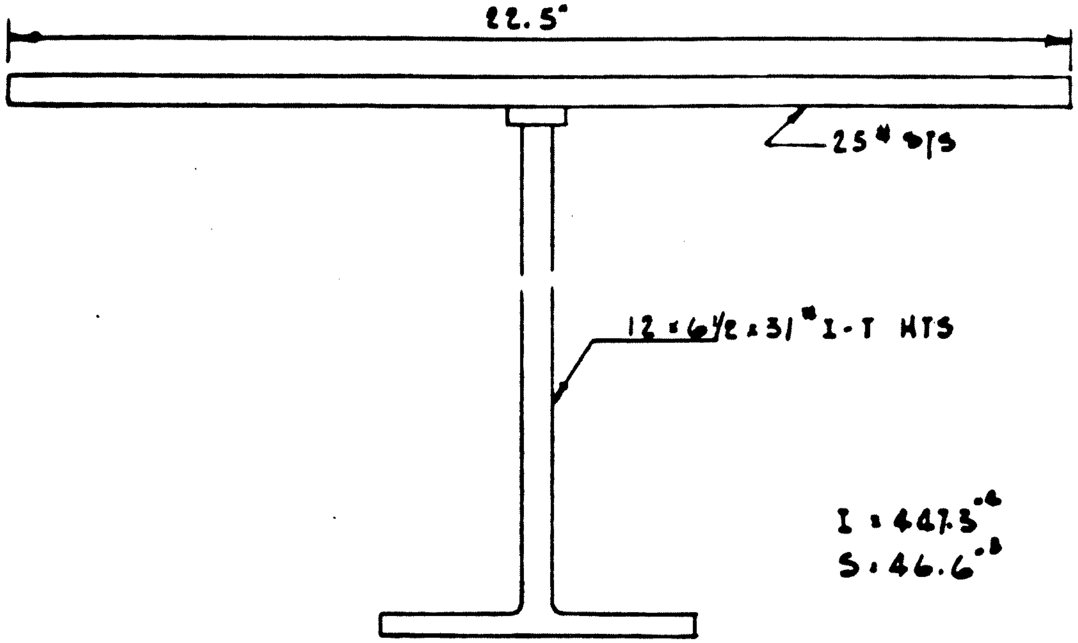
FIG. 2.6, $B/b = 13.83/22.5 = 0.615$; $\phi_3 = 0.94$

Corrected $M = 0.1391 \times 63.3 \times 144 \times 0.94 = 1191$ inch-kips

Dead load moment:

25 x 22.5 / 12 = 46.9 lb. per ft.
beam = 21.5 lb. per ft.
total = 68.4 lb. per ft.

Note: This is a static dead load moment. The effect of ship motions is not considered. This applies to parking area only.



$M_d = wL^2/24 = (68.4 \times 12 \times 144)/24 = 4.9$ inch-kips

Total moment = 1196 inch-kips

$f_b = 1196/46.6 = 25.7$ ksi., allowable 48.0 ksi.

Maximum shearing stress in longitudinal

FIG. D2, $A/L = 22.88/144 = 0.1589$;

$B/b = 13.83/22.5 = 0.615$

$V/P = 0.885$

$V = 0.885 \times 63.3 = 56.0$ kips

Shear due to D. L. $= qL/2 = 68.4 \times 12/2 = 0.4$ kips

$v_s = 56.4/(11.16 \times 0.265) = 19$ ksi. allowable 28.8 ksi.

Maximum bending stress in plating

FIG. B3-1, $B/b = 13.83/22.5 = 0.615$;

$A/b = 22.88/22.5 = 1.017$

$m_o/P = 0.084$

$m_o = 0.084 \times 63.3 = 5.31$ inch-kips per inch

FIG. B3-3, $b/L = 22.5/144 = 0.1562$,

$\lambda = 1.01$,

$m_c/P = 0.001$

$m_c = 0.001 \times 63.3 = 0.06$ inch-kips per inch

$f_b = 6\,(m_o + m_c)/(0.6127)^2 = 85.8$ ksi. allowable 100 ksi.

Therefore, this 40.0 kip aircraft can park on the flight deck of this carrier. It should be noted that the calculations are based on the most unfavorable sea condition.

DDS1106-1-e. Design of Aluminum Plank Decks Without Transverse Girders

1. Type of Structure Considered

(a) The assumptions and structural arrangement of the flight decks with aluminum planking are basically the same as the structure considered for the plate decking (section 1-a), page 6.

(b) Aluminum planks require no membrane plating because watertightness of the deck is obtained by welding the seams between planks (see FIG. 1-3). They are connected to the top flanges of longitudinal by steel clips or stud bolts.

2. Effective Section of Longitudinal Girders

The effective section of the longitudinal consists of the actual longitudinal girder only. The

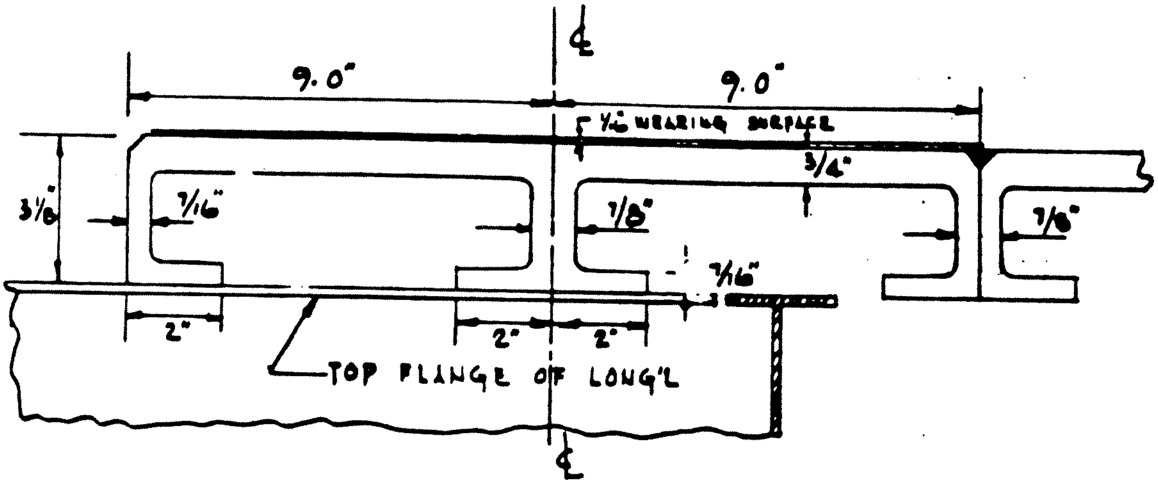


FIGURE 1-3
Typical Aluminum Planking Section

aluminum planking is not considered to act integrally with the top flange of the longitudinal girder because it is not continuously connected to it.

3. Design of Longitudinal Girders

In the design of longitudinal girders, it is assumed that the aluminum planks do not give lateral support to the compression flanges of the longitudinal girders. If

$$Ld/bt > 600$$

lateral support must be provided.

L = span length in inches
d = depth of beam
b = compression flange width
t = thickness of web

The longitudinal girders are designed to resist a single wheel reaction only. The other wheel reactions are considered far enough away so that they can be neglected with the exception of dual tires as indicated in section d-3, page 6.

(a) *Determination of Structural Parameters*

The first step in the design of the longitudinal girders is to determine β from FIG. C1. This parameter β is required to calculate the bending moment in the longitudinals and planking. It should be noted that FIG. C1, is based on 12 inch wide aluminum planks only. If other widths are used, corrections must be made, (see FIG. C1 and example No. 4 for 18 inch aluminum plank correction).

(b) *Maximum moment and bending stress in longitudinals*

1. See section d-3 paragraph b, page 6.

2. Maximum moment and bending stress in the longitudinals due to the live load and dead load are calculated by using FIG. C2 and FIG. 2.6.

(c) *Maximum Shear and Shearing Stress in Longitudinals*

1. See section d-3, paragraph c, page 7.

2. Use FIG. D2 for calculating shear and shearing stress.

4. Design of Aluminum Planking

In the design of aluminum planking, it is important that the top wearing surface should have sufficient thickness to carry tire and rim loads.

(a) *Maximum Moment and Bending Stress*

The maximum moment in the aluminum plank occurs when the wheel reaction is placed midway between two longitudinals on that plank which is midway between the supporting bents or structural bulkheads. The wheel is assumed to be oriented so that the contact length A extends in the longitudinal direction of the ship. In some cases such as the deck edge elevator platform, the wheel may be oriented parallel to the planking. This condition should be investigated for planking stress.

(b) *The maximum bending moment and stress are determined by using FIGS. C3-1, C3-2 and C3-3.*

(c) *Maximum Shear and Shearing Stress in Aluminum Planks*

(1) Maximum shear in the aluminum planks occurs when the wheel reaction is close to the support of the longitudinal. When the wheel reaction is applied to these planks, the relative deflection of the longitudinals is rather small so that they can be considered as nondeflecting supports. The planks are therefore analyzed as continuous beams over rigid supports.

(2) The maximum shearing stress is calculated by using FIGS. C5-1 and C5-2. It is assumed that the shearing force due to the tire load is resisted by the entire width of the plank, but that due to the rim load is resisted by the effective section of the weakest web only.

5. Example No. 4

So far only parking conditions have been illustrated. This example is for a landing condition.

If the landing area of the flight deck of the carrier in example No. 1 consists of aluminum planks (cross section is shown on FIG. 1-3) with 12 x 6½ x 36 lbs. I HTS longitudinals spaced at 22.5 inches c-c and the transverse bents 20 feet apart, determine if it is feasible to land the aircraft mentioned in example No. 1 with a landing reaction of 115.0 kips per main landing wheel.

landing wheel load = 115.0 kips
bottoming load = 94.6 kips (example 2)
rim load P_R = 20.4 kips

FIG. A-3, P_T = 94.6 kips; p'_a = 190 psi; P_T/P_b = 1
B = 15.14 inches
A = 29.23 inches
B_R = 12.0 inches

For section see paragraph 1 (b), page 8.

Note: 1/16 inch should be added to the depth for wearing surface. Calculations for I_A do not include fillets.

Item	A_o	y	A_oy	A_oy^2	I_o
Top flange, 18 x 3/4	13.50	2.75	37.12	102.1	.6
Webs, 4 – 1.9375 x 7/16	3.39	1.406	4.77	6.7	4.4
Bottom flange 4 – 2 x 7/16	3.50	.219	.76	0.0	0.0
Total	20.39		42.65		113.8

$$\begin{array}{r} 113.8 \\ -\ \underline{89.1} \\ 24.7 \text{ inches}^4 \end{array}$$

$\bar{y}$ = 42.65/20.39 $\doteq$ 2.09 inches distance from top of section to neutral axis = 1.035 inches
Section modulus = 24.7/2.09 = 11.82 inches^3
Section modulus of weakest rib = 11.82/2 = 5.91 inches^3

Statical moment of top section above neutral axis:

$$\begin{aligned} Q_p &= 13.50 \times 0.66 = 8.91 \\ &\quad 0.499 \times 0.142 = 0.07 \\ &\qquad 8.98 \text{ inches}^3 \end{aligned}$$

I_p = 24.7 inches^4
t_p = 4 x 7/16 = 1.75 inches

Statical moment of weakest web above neutral axis:

Q'_p = 4.49 inches^3

I'_p = 12.35 inches^4
t'_p = 0.88 inches

Maximum Bending Moment and Bending Stress in Longitudinal

FIG. C1, L = 20.0 feet; I = 280.8 inches^4; I_A (for 12 inch width) = 24.7 x (12/18) = 16.47 inches^4;
b/L = 22.5/240 = 0.0938;
H = 2.56; β = 0.358

FIG. C2, β = 0.358; A/L = 29.23/240 = 0.122;
M/PL = .0597

FIG. 2.6, B/b = 15.14/22.5 = 0.673; ϕ_3 = 0.92
M = 0.0597 x 115.0 x 240 x 0.92 = 1516 inch-kips

Dead load for 18 inch aluminum
planking = 17.0 psf. x 22.5/12 = 31.85 lb. per ft.
beam = <u>36.0</u>
q = 67.85 psf.

Dead load moment = qL2/24 =
67.85 x 20 x 240/24 =
13.6 inch-kips

f_b = (1516 + 14)/45.9 = 33.3 ksi. < 48.0 ksi., (if the compression flanges are laterally supported, see section e-3), page 9.

Maximum Shear and Shearing Stress in Longitudinal

FIG. D2, A/L = 29.23/240 = 0.122;
B/b = 15.14/22.5 = 0.673; V/p = 0.891
V = 0.891 x 115.0 = 102.5 kips

Shear due to dead load = qL/2 = 67.85 x 20/2 = 0.68 kips

v_s = (102.5 + 0.7)/(11.16 x 0.305) = 30.3 ksi. (average) allowable 28.8 ksi. slightly overstressed, but acceptable with discretion for an existing ship.

Maximum Moment and Bending Stress in Aluminum Planking

FIG. C3-1, B/b_e = 15.14/19.25 = 0.786;
w_o/A = 18/29.23 = 0.616; M_o/P_Tb_e = 0.055
M_o = 0.055 x 94.0 x 19.25 = 99.5 inch-kips

FIG. C3-2, w'_o/A_R = (23.75/4)/23.75/4) = 1;
B_R/b_e = 12.0/19.25 = 0.623;
M'_o/P_Rb_e = 0.046
M'_o = 0.046 x 21.0 x 19.25 = 18.6 inch-kips

FIG. C3-3, w/L = 18/240 = 0.075; β = 0.358 (FIG. C1);

M_c/P_b = 0.054
M_c = 0.054 x 115.0 x 22.5 = 139.7 inch-kips

Moment taken by one rib = (99.5/2) + 18.6 + (139.7/2) = 138.2 inch-kips

f_b = 138.2/5.91 = 23.38 ksi. allowable 35.0 ksi.

Maximum Shear and Shearing Stress in Aluminum Planking

FIG. C5-1, B/b_e = 15.14/19.25 = 0.786;
w_o/A = 18.0/29.23 = 0.616;
B_R/b_e = 12.0/19.25 = 0.623;

V_T due to P_T = 0.381 x 94.0 = 35.8 kips
V_R due to P_R = 0.678 x 21.0 = 14.24 kips
$v_T = V_TQ_p/I_pt_p$ = (35.8 x 8.98)/(24.7 x 1.75) = 7.44 ksi.
$v_R = V_RQ'_p/I'_pt'_p$ = (14.24 x 4.49)/(12.35 x 0.88) = 5.89 ksi.

total = 13.33 ksi. allowable 21.0 ksi.

Therefore with the maximum landing wheel reaction of 115.0 kips which is a severe landing reaction, the aircraft can land on the flight deck of this carrier.

DD1106-1-f. Design of Wood Plank Decks Without Transverse Girders

1. Type of Structure Considered

(a) The assumptions and structural arrangement of the flight deck with wood plank decking are basically the same as for the structure considered for plate decking (refer to d-1a.), page 6.

(b) The wood planks which are nominally 6 inches in width and 3 inches in thickness run transversely to the longitudinals and are connected to their top flanges by means of stud bolts. A thin steel plate is used between the wood planks and longitudinals. This plating acts as a waterproofing shield and as an additional top flange to the longitudinals. (See FIG. 1-4.)

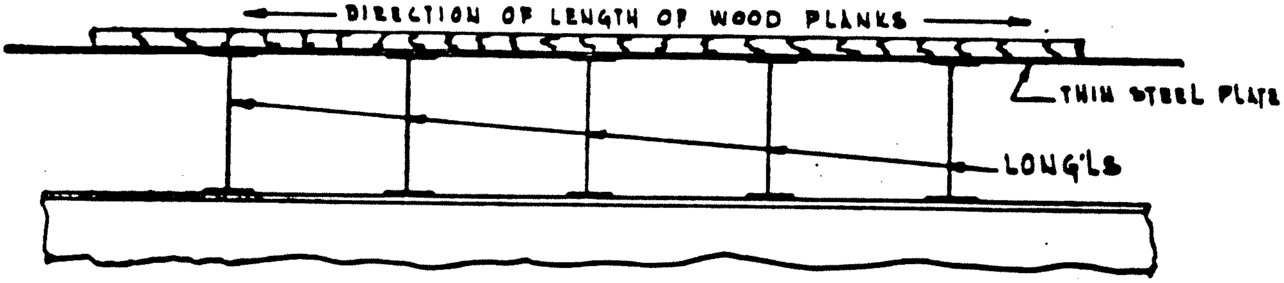


FIGURE 1-4
Typical Wood Plank Decking

2. Effective Section of Longitudinal Girders

Refer to section e-2, page 8 for the effective section of longitudinal girder. The wood planking is neglected in considering strength of longitudinals because shrinkage in the planking may take place to cause cracks and the modulus of wood across the grain is low.

3. Design of Longitudinal Girders

Refer to e-3 paragraphs a, b and c, page 9.

4. Design of Wood Planking

(a) *Maximum Moment and Bending Stress*

Refer to section e-4, paragraph a, page 9.

(b) *Maximum Shear and Shearing Stress in Wood Planks*

(1) The maximum shearing stress is determined by the two-beam theory, which is an ultimate strength theory for wooden beams failing in shear. The assumption is made that the wood planks are simply supported between longitudinals.

(2) In the two-beam theory, the maximum end reaction is computed by the ordinary shear formula. However, in figuring the maximum end reaction the wheel reaction is placed at some distance, d_0, away from the support, this distance is the function of the width over which the load is spread and the thickness and length of the plank. For the determination of d_0 see equation (6.7).

(3) The rim load is considered to be supported by a single plank if the contact length of rims is less than the width of the plank. If the contact length of rims is greater than the width of plank, the load is considered to be supported by a width of plank equal to the contact length of rims.

(4) The wheel load is assumed to be positioned so that only the shear due to the tire load is maximum. This arrangement does not produce the maximum shear in the plank but it gives satisfactory results for all practicable purposes.

(5) The maximum shear and shearing stress are calculated by using FIGS. C4-1, C4-2 and C4-3.

5. Example No. 5

Work example No. 4 with wood planks and a 5.1 lb. steel plate between the wood planks and the longitudinals.

Maximum Moment and Bending Stress in Longitudinal

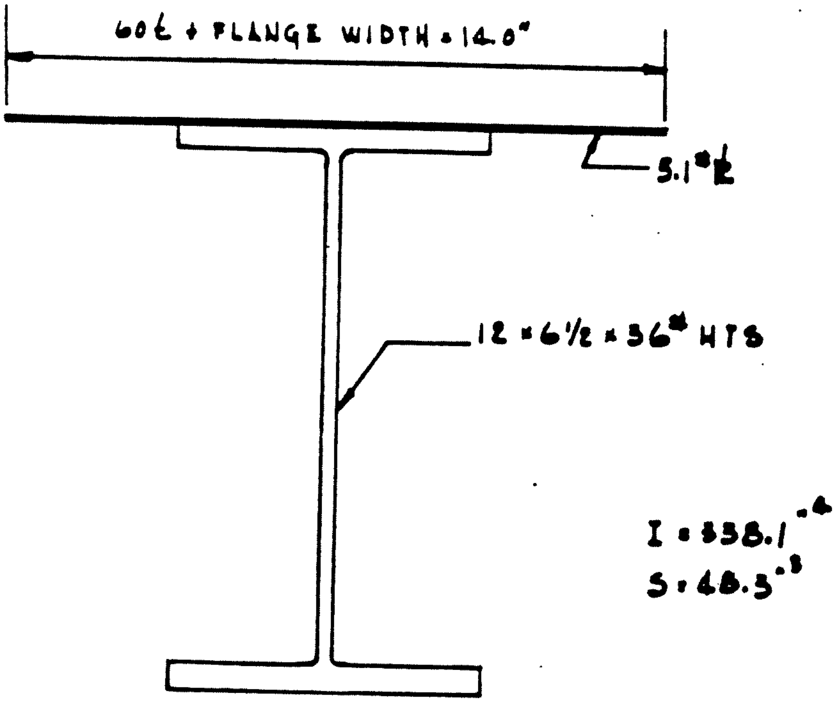
FIG. C1, $L = 20.0$ ft.; $I = 338.1$ inches^4;
$h = 3$ inches; $E_w = 1.6 \times 10^6$;
$b/L = 22.5/240 = 0.0938$; $H = 11.7$;
$\beta = 0.459$

FIG. C2, $\beta = 0.459$; $A/L = 29.23/240 = 0.122$;
$M/_{PL} = 0.079$

FIG. 2.6, $B/b = 15.14/22.5 = 0.673$, $\phi_3 = 0.93$
Corrected $M = 0.0790 \times 115.0 \times 240 \times 0.93$
$= 2028$ inch-kips
$q = 36.0$ lb./ft. + 5.1 lb./sq. ft. x 22.5/12 +
10 lb./sq. ft. x 22.5/12 = 64.34 lb./ft.
$M_d = qL^2/24 = 64.34 \times 20 \times 20 \times 12/24 = 12.9$ inch-kips
Total moment = 2028 + 13 = 2041
$f_b = 2041/48.3 = 42.3$ ksi. allowable 48.0 ksi.

Maximum Shear and Shearing Stress in Longitudinal

FIG. D2, $A/L = 29.23/240 = 0.122$;
$B/_b = 15.14/22.5 = 0.673$; $V/P = 0.891$
$V = 0.891 \times 115.0 = 102.5$ kips
D.L.S. $= qL/2 = 64.34 \times 20/2 = 0.6$ kips, total $=$
103.1 kips



v_s = 103.1/(11.16 x 0.305) = 30.3 ksi., (average) > 28.8 acceptable but with discretion for existing ships.

Maximum Moment and Bending Stress in Wood Planking

FIG. C3-1, B/b_e = 15.14/19.25 = 0.786;
w_o/A = 6.00/29.23 = 0.2053;
$M_o/P_T b_e$ = 0.018
M_o = 0.018 x 94.0 x 19.25 = 32.6 inch-kips

FIG. C3-2, w_o'/A_R = (23.75/4)/(23.75/4) = 1;
B_R/b_e = 12.0/19.25 = 0.623
$M_o'/P_R b_e$ = 0.046
M_o' = 0.046 x 21.0 x 19.25 = 18.6 inch-kips

FIG. C3-3, w/L = 6.00/240 = 0.025; β = 0.459;
M_c/Pb = 0.009
M_c = 0.009 x 115.0 x 22.5 = 23.3 inch-kips
$M_o + M_o' + M_c$ = 74.5 inch-kips

Section modulus = $bd^2/6 = 5.75(3)^2/6$ = 8.62 inches^3
f_b = 74.5/8.62 = 8.64 ksi. allowable 12.0 ksi.

Maximum Shear and Shearing Stress in Wood Planking

FIG. C4-1, b/h = 22.5/3 = 7.5;
B/b = 15.14/22.5 = 0.673;
hA = 3 x 29.23 = 87.7 sq. inches;
V_T/P_T = 6.9
v_T = 6.9 x 94.0 = 649 p.s.i.

FIG. C4-2, B/b = 15.14/22.5 = 0.673;
b/h = 22.5/3 = 7.5;
B_R/h = 12/3 = 4
x_1 = 1.3; x_2 = 5.3; where A_e = 3 x 5.75 or h (A_R – ½") whichever is larger.
$(v_R)_1$ = 16.2 x 21.0 = 340 p.s.i.; $(v_R)_2$ = 11.8 x 21.0 = 248 p.s.i.
Total v_s = 649 + 340 + 248 = 1,237 > 1,200 p.s.i. overstressed, not acceptable.

DDS1106-1-g. Design of Plate Decks With Transverse Girders

1. Type of Structure Considered

(a) The characteristics of the flight decks with transverse girders are the same as those without transverses, therefore refer to sections d-1 and d-2, page 6.

(b) The transverse girders may be rigidly connected or welded underneath the longitudinals or placed intercostally between the longitudinals. The rigidity of the connections between the transverses and longitudinals is very important for unless the connections are fairly rigid-a great portion of the effectiveness of the transverses may be lost.

2. Design of Longitudinal Girders

(a) The transverse girders will increase the transverse stiffness of the flight deck structure to distribute the wheel reaction to various longitudinals, thus causing a moment reduction in the loaded longitudinals. The effectiveness of the transverses in reducing the design moment depends on the relative stiffness between the transverses and the deck structure. If the deck structure is very stiff, the addition of transverses will have little further effect.

(b) Experience and tests have demonstrated that a suitable design moment for the loaded longitudinal with transverses may be obtained by averaging the upper and lower limits, i.e., $M_x = (M + M_n)/2$ if the transverses are not stiffer than the longitudinals.

(1) When a wheel reaction is applied on the longitudinal, with transverses underneath, midway between the two supports or bents, the longitudinals and the transverses will deflect equally. In this condition, consider the transverses as being removed. Then the maximum moment M, forms the upper limit. This moment M is determined from FIG. B2.

(2) The maximum effectiveness of the transverses occurs when the wheel reaction is applied at a point over a transverse girder. The transverse girder will distribute the wheel reaction to other longitudinals, causing a moment reduction in the loaded longitudinal. The effectiveness of the transverses will diminish as the load moves away from the transverse. Therefore, the maximum moment for the loaded longitudinal occurs only when the applied load is not directly over a transverse. The lower limit then must be the moment, M_n, when the load is directly over a transverse.

(3) Thus far only the transverses which are not too stiff have been considered. If the transverses are infinitely stiff, each transverse will act to distribute the wheel reaction to a large number of longitudinals, thereby reducing the deflection of all longitudinal at their intersections with the transverses to zero. The maximum moment M_{in} in this case occurs when the wheel reaction is applied at midpoint of the span between the support or bent and the new transverse.

(4) The design procedure is to determine the moments due to the two conditions mentioned above, namely $M_x = (M + M_n)/2$ and M_{in} from FIGS. B2, E1, E2, and E3 and use the larger moment as the design moment for the longitudinal.

(c) Maximum shear and shearing stress in the longitudinals are calculated by using FIG. D2. With the presence of the transverses the effective span length is used instead of the true span length. The effective span is as follows:

One transverse at center of span, use 3/4 span length

Two transverses equally spaced, use 5/8 span length

Three transverses equally spaced, use 1/2 span length

3. Design of Transverse Girders

(a) The maximum stresses in the transverse girders are obtained in that transverse girder nearest the midspan of the longitudinals, for a load over the intersection of a longitudinal and the transverse.

(b) The maximum moment and bending stress are computed by using FIG. E4.

(c) The maximum shear and shearing stress are computed by using FIG. E5.

4. Design of Plating

(a) The effect of transverse girders on the maximum bending stresses in the plating is very small and is presently neglected. Therefore, the maximum stresses for plate are computed as described in section d-4, page 7.

5. Example No. 6

Analyze example No. 3 with a 12 x 4 x 16.5 lb.

I HTS transverse girder underneath the longitudinals at the center of the span between the two bents.

Maximum Bending Stress in Longitudinal

FIG. E1, $\lambda = 1.01$; (from example No. 3); $r_o = 0.925$;
$A/L = 22.88/144 = 0.1589$; $M_{in}/PL = 0.073$

FIG. 2.6, $B/b = 13.83/22.5 = 0.615$, $\phi_3 = 0.94$
Corrected $M_{in} = 0.073 \times 63.3 \times 144 \times 0.94$
$= 625$ inch-kips
$H = 147.5$ (from example 3)

FIG. E2, $H(n+1)\ (E_tI_t/EI) =$
$147.5(2)\ (105.3/447.3) = 69.4$
$r_o = 0.925$; $r_n = 0.53$;
$A/L = 22.88/144 = 0.1589$; $M_n/PL = 0.073$
Corrected $M_n = 0.073 \times 63.3 \times 144 \times 0.94$
$= 625$ inch-kips

FIG. B2, $\lambda = 1.01$; $A/L = 22.88/144 = 0.1589$;
$M/PL = 0.1391$
Corrected $M = 0.1391 \times 63.3 \times 144 \times 0.94$
$= 1192$ inch-kips
$M_x = (625 + 1192)/2 = 908.5$ inch-kips
Total moment $= M_x + 4.9$ (dead load moment)$=$
913.4 inch-kips
$f_b = 913.4/46.6 = 19.6$ ksi. allowable 48.0 ksi.

Maximum Shearing Stress in Longitudinal

FIG. D2, effective span $= (3/4)\ (144)$ 108.0 inches
$A/L = 22.88/108 = 0.212$;
$B/b = 13.83/22.5 = 0.615$; $V/P = 0.87$
$V = 0.87 \times 63.3 = 55.1$ kips
dead load = 0.6 kips (example 3)
total = 55.7 kips
$v_s = 55.7/(11.16 \times 0.265) = 18.8$ ksi. allowable
28.8 ksi.

Maximum Bending Stress in Transverse

FIG. E4, $b/L = 22.5/144 = 0.1562$;
$E_tI_t/EI = 105.3/447.3 = 0.235$;
$r_n/r_o = 0.53/0.925 = 0.573$; $M_t/Pb = 0.31$
$M_t = 0.31 \times 63.3 \times 22.5 = 441.5$ inch-kips
$f_b = 441.5/17.5 = 25.2$ ksi. allowable 48.0 ksi.

Maximum Shearing Stress in Transverse

FIG. E5, $r_n = 0.53$; $r_n/r_o = 0.53/0.925 = 0.573$;
$V_t/P = 0.226$
$V_t = 0.226 \times 63.3 = 14.3$ kips
$v_s = V_t/\ (d_w \times t_w)$
$v_s = 14.3/(11.46 \times 0.23) = 5.4$ ksi. allowable
28.8 ksi.

Maximum Bending Stress in Plating

$$\left.\begin{array}{l}\text{FIG. B3-1}\\ \\ \text{FIG. B3-3}\end{array}\right\}\ \text{same as example No. 3}$$

$f_b = 85.82$ ksi. allowable 100 ksi.

Comparing results with those of example 3, it is seen that the transverse girder has only a limited effect in the plating stress.

DDS1106-1-h. Design of Aluminum Plank Decks with Transverse Girders

1. Type of Structure Considered

Refer to g-1, 2 and 3, page 14 for the design of longitudinals and transverses; except, use FIG. C2 to replace B2 to determine the moment M for the longitudinals.

2. Design of Aluminum Planking

(a) The maximum moment is determined in three parts: (1) Moment M_o due to tire load, assuming that the longitudinals are nondeflecting. (2) Moment M_o' due to rim load, assuming that the longitudinals are nondeflecting. (3) Correction moment M_c' due to the deflections of the longitudinals. In this case however, only the correction moment is affected by the introduction of transverses.

(b) The moments M_o and M_c' are calculated by using FIGS. C3-1 and C3-2 and M_c' by using FIG. E6.

(c) The maximum shearing stress is not affected by the presence of transverses because the maximum shear occurs in the planks near the bulkheads where longitudinals act practically as nondeflecting supports. Maximum shear and shearing stresses are determined by using FIGS. C5-1 and C5-2.

3. Example No. 7

Analyze example No. 4 with a 12 x 6½ x 27.

lb. wide flange HTS transverse girder underneath the longitudinals at the center of the span between the two bents.

Maximum Bending Stress in Longitudinal

FIG. E1, β = 0.358 (example No. 5); r_o = 0.425;
A/L = 29.23/240 = 0.122

FIG. 2.6, B/b = 15.14/22.5 = 0.673; ϕ_3 = 0.93;
M_{in}/PL = 0.051
Corrected M_{in} = 0.051 x 115.0 x 240 x 0.93
= 1309 inch-kips
H = 2.56 (example No. 4)
$H(n+1)(E_tI_t/EI)$ = 2.56(2) (204.1/280.8) = 3.72

FIG. E2, r_o = 0.425; r_n = 0.33;
A/L = 29.23/240 = 0.122; M_n/PL = 0.043
Corrected M_n = 0.043 x 115.0 x 0.93 x 240
= 1104 inch-kips

FIG. C2, β = 0.371; A/L = 29.23/240 = 0.122;
M/PL = 0.0597
Corrected M = 0.0597 x 115.0 x 240 x 0.93
= 1516 inch-kips
M_x = (1104 + 1516)/2 = 1310 inch-kips
Total maximum moment M_s = 1310 + 14 (see example No. 4) = 1324 inch-kips
f_b = 1324/45.9 = 28.8 ksi. allowable 48.0 ksi.

Maximum Shearing Stress in the Longitudinal

FIG. D2, Effective span length = (3/4) (240) = 180 inches
A/L = 29.23/180 = 0.162;
B/b = 15.14/22.5 = 0.673; V/P = 0.875
V = 0.875 x 115.0 = 100.6 kips
dead load = 0.7 kips (example No. 4)
total = 101.3 kips
v_s = 101.3/(11.16 x 0.305) = 29.8 ksi. allowable 28.8 ksi. acceptable but with discretion for existing ships.

Maximum Bending Stress in Transverse

FIG. E3, b/L = 22.5/240 = 0.0937;
E_tI_t/EI = 204.1/280.8 = 0.728;
r_n/r_o = 0.330/0.425 = 0.776; M_t/Pb = 0.49
M_t = 0.49 x 115.0 x 22.5 = 1268 inch-kips
f_b = 1268/34.1 = 37.2 ksi. allowable 48.0 ksi.

Maximum Shearing Stress in Transverse

FIG. E5, r_n = 0.330; r_n/r_o = 0.33/0.425 = 0.776;
V_t/P = 0.262
V_t = 0.262 x 115.0 = 30.1 kips
v_s = 30.1/(11.16 x 0.240) = 11.24 ksi. allowable 28.8 ksi.

Maximum Bending Stress in Aluminum Planking

FIG. C3-1 } same as example No. 4
FIG. C3-2 }

FIG. E6, M_x/PL = 1310/(115.0 x 240) = 0.475;
A/L 29.23/240 = 0.122
R_n = 0.304; R_n/r_o = 0.304/0.425 = 0.715;
w/L = 18/240 = 0.075
M_c'/PL = 0.014
M_c' = 0.014 x 115.0 x 22.5 = 36.2
M_o = 99.5 } example No. 4
M_o' = 18.6 }

$$\text{Total moment} = \frac{99.5}{2} + 18.6 + \frac{36.2}{2} = 86.5$$

inch-kips
f_b = 86.5/5.91 = 14.64 ksi. allowable 35.0 ksi.

Maximum Shearing Stress in Aluminum Planking

FIG. C5-1 same as example No. 4

v_s = 13.33 ksi. allowable 21.0 ksi.

Therefore it is permissible to land the aircraft even in a severe landing condition.

DDS1106-1-i. Design of Wood Plank Decks With Transverse Girder

1. Design Procedure

The design procedure for wood plank decks with transverses is similar to that of aluminum plank with transverses with the exception of using FIGS. C4-1, C4-2 and C4-3 to determine the shear and shearing stress in wood planking. The effective section of the longitudinal (section f-2, page 12) is used for the calculation of the moment of inertia of the longitudinal.

2. Example No. 8

Solve example No. 5 with a 12 x 6½ x 27.0 lb. I HTS transverse girder underneath the longitudinal at the center of the span between the two bents.

Maximum Bending Stress in Longitudinal

FIG. E1, $\beta = 0.459$ (example No. 5);
$r_o = 0.542$; A/L 29.23/240 = 0.122
$r_n = 0.345$

FIG. 2.6, B/b = 15.14/22.5 = 0.673; $\phi_3 = 0.93$;
$M_{in}/PL = 0.0588$
Corrected $M_{in} = 0.0588 \times 115.0 \times 240 \times 0.93$
= 1509 inch-kips
$H_n = 11.7$ (example No. 5)

FIG. E2, $H(N+1)(E_tI_t)/EI = 11.7(2)(204.1/338.1) =$
14.12; $M_n/PL = 0.0452$
Corrected $M_n = 0.0452 \times 115.0 \times 240 \times 0.93$
= 1160 inch-kips

FIG. C2, $\beta = 0.459$; A/L = 29.23/240 = 0.122;
M/PL = 0.079
Corrected M = 0.079 x 115.0 x 240 x 0.93
= 2028 inch-kips
$M_x = (M_n + M)/2 = 1594$
Dead load moment $\underline{= \quad 13}$ (example No. 5)
Total = 1607
$f_b = 1607/48.3 = 33.3$ ksi. allowable 48.0 ksi.

Maximum Shearing Stress in Longitudinal

FIG. D2, effective span length = (3/4) (240) = 180 inches
A/L = 29.23/180 = 0.162;
B/b = 15.14/22.5 = 0.673; V/P = 0.875
V = 0.875 x 115.0 = 100.6 kips
dead load = 0.6 kips (example No. 5)
$v_s = 1012/(11.16 \times 0.305) = 29.7$ kips > 28.8, but acceptable with discretion for existing ships.

Maximum Bending Stress in Transverse

FIG. E4, b/L = 22.5/240 = 0.0938;
$E_tI_t/EI = 204.1/338.1 = 0.604$
$r_n/r_o = 0.345/0.542 = 0.636$; $M_t/Pb = 0.562$
$M_t = 0.562 \times 115.0 \times 22.5 = 1454$ inch-kips
$f_b = 1454/34.1 = 42.6$ ksi. allowable 48.0 ksi.

Maximum Shearing Stress in Transverse

FIG. E5, $r_n = 0.345$; $r_n/r_o = 0.345/0.542 = 0.637$
$V_t/P = 0.305$
$Vt = 0.305 \times 115.0 = 35.1$ kips
$v_s = (35.1)/(11.16 \times 0.24) = 13.11$ ksi. allowable = 28.8 ksi.

Maximum Bending Stress in Wood Planking

FIG. C3-1
FIG. C3-2
} same as example No. 5

FIG. E6, $M_x/PL = 1594/(115.0 \times 240) = 0.0578$
A/L = 29.23/240 = 0.122
$R_n = 0.369$; $R_n/r_o = 0.369/0.542 = 0.681$; w/L = 6.00/240 = 0.025
$M_c'/Pb = 0.00238$
$M_c' = 0.00238 \times 115.0 \times 22.5 = 6.2$ inch-kips
$M_o = 32.6$ inch-kips; $M' = 18.6$ inch-kips (example No. 5) page 12.
Total moment = 32.6 + 18.6 + 6.2 = 57.4 inch-kips
$f_b = 57.4/8.62 = 6.66$ ksi. allowable 12.0 ksi.

Maximum Shearing Stress in Wood Planking

FIG. C4-1
FIG. C4-2
FIG. C4-3
} Same as example No. 5

$v_s = 1237$ p.s.i. allowable 1200 p.s.i., not acceptable.

APPENDIX A

NOMENCLATURE

A = contact length of tire

A_c = contact area of tire

A_e = effective area of plank, defined as the actual area of the plank or the product $h(A_R - ½")$ whichever is larger

A_o = area of each component of a composite girder

A_R = contact length of wheel rims

A_s = maximum sail area of aircraft with wings folded

A_e' = actual area of plank or the product hA, whichever is larger

a = equivalent simple span of longitudinals between points of contraflexure. For a series of equal spans $a = 0.683L$.

B = contact width of tire

B_R = distance from center to center of rims

b = spacing of longitudinals

b' = distance from center to center of dual tires

b_e = effective span length of planking, taken as the average of the clear span and the span center to center of longitudinals

C_y = vertical distance from deck line to center of gravity of aircraft

C_z = longitudinal distance from main wheel axis to center of gravity of aircraft

C_y' = vertical distance from deck line to center of sail area with wings folded

c = distance from reference axis to extreme fiber of a girder, as shown in FIG. D1.

d = distance from support to point of application of a concentrated load on a wood plank

d_w = depth of the web of a girder

d_o = distance from support to center of gravity of tire when the wheel is positioned so that the value of v_T in a wood plank is maximum

$d_1 = d_o - B_R/2$ = distance from support to the rim nearest to the support, when the wheel is positioned so that the value of v_T in a wood plank is maximum

$d_2 = d_o + B_R/2$ = distance from support to the rim furthest away from the support, when the wheel is positioned so that the value of v_T in a wood plank is maximum

E = modulus of elasticity for longitudinals or steel plating

E_A = modulus of elasticity for aluminum planking or plating

E_t = modulus of elasticity for transverse girders

E_w = modulus of elasticity for wood plank

F_x = transverse force (athwartship) acting at center of gravity of aircraft

f_b = maximum bending stress

$f_1(B/b)$, $f_2(B/b)$ = functions defined by equations (2.7) and (2.8), respectively

$f_3(\beta)$ = function defined by equation (4.7)

$f_4(b/h)$ = function defined by equation (6.2)

$f_5(B/b)$ = function defined by the curves in FIG. (2.5)

$f_1(B_R/b)$, $f_2(B_R/b)$ = functions defined by equations (2.13) and (2.14)

g = acceleration due to gravity = 32.2 ft./sec.^{2}

H = EI/LN, a dimensionless parameter

H_F = heave factor

H_n = $H\ [1 + H(n + 1)\ E_tI_t/EI]^{-1}$, a dimensionless parameter

$\bar{H}$ = EI/aN, a dimensionless parameter

h = thickness of deck plate or wood plank

I = moment of inertia of effective section of longitudinals

I_A = moment of inertia of a 12 inch wide aluminum plank

I_o = moment of inertia of each component of a girder about its own centroid

I_p = moment of inertia of one plank

I_t = moment of inertia of a transverse girder

I_p' = moment of inertia of the effective section of the weakest web of an aluminum plank

K = $E_tI_tL^3/EIb^3$ = relative stiffness of transverse to longitudinal girders

K_1, K_2 = dimensionless factors defined in FIG. 2.1

L = span length of continuous longitudinals, equal to distance between bulkheads or supporting beats

M = maximum moment in a longitudinal due to wheel load for a deck without transverse girders

M_c = correction moment per plank due to deflection of longitudinals for a deck without transverse girders

M_d = positive maximum moment in a longitudinal due to dead load

M_{in} = maximum moment in a longitudinal due to wheel load for a deck with rigid transverses
M_n = moment in a longitudinal under a wheel load for a deck with n transverses of equal stiffness and the wheel placed directly over the transverse at or nearest to midspan
M_o = maximum moment per plank due to tire load for planking continuous over rigid longitudinals
M_p = total maximum moment per plank. It is equal to $M_o + M_o' + M_c$ for a structure without transverses or $M_o + M_o' + M_c'$ for a structure with transverses
M_s = total maximum moment in longitudinals, equal to $M + M_d$ for deck without transverses or $M_x + M_d$ for deck with transverses
M_t = maximum moment in a transverse girder
M_x = maximum moment in a longitudinal due to wheel load for a deck with transverses. It is equal to M_{in} or $(M + M_n)/2$, whichever is larger
M_c' = correction moment per plank due to deflection of longitudinals for a deck with transverses
M_o' = maximum moment per plank due to rim load for planks continuous over rigid longitudinals
$m = m_o + m_o' + m_c$ = total maximum moment per unit width of plating
m_c = correction moment per unit width of plating due to deflection of longitudinals
m_o = maximum moment per unit of width of plating due to tire load for plating continuous over rigid longitudinals
m_o' = maximum moment per unit of width of plating due to rim load for plating continuous over rigid longitudinals
n = number of equally spaced transverse girders
N = $E_d h^3/12(1 - \mu^2)$, where E_d is modulus of elasticity of deck material
P = wheel load
P_b = bottoming load of tire
P_R = rim load, defined as the portion of wheel load carried by the rims
P_s = manufacturer's rated load of tire corresponding to pressure p_s
P_T = tire load, defined as the portion of wheel load carried by the tire
P_w = maximum wind pressure
P_1 = component of parking wheel load due to vertical forces
P_2 = component of parking wheel load due to transverse forces (athwartship)
P_3 = component of parking wheel load due to wind forces
P_s' = rated load of tire corresponding to pressure p_s'
p = tire pressure corresponding to tire load P_T
p_s = manufacturer's rated inflation pressure of tire
p_s' = initial operational pressure of tire
Q_p = statical moment of the cross section of an aluminum plank about its centrodial axis
Q_p' = statical moment for the effective section of the weakest web of an aluminum plank about the section centrodial axis
q = weight per unit of length of the effective section of a longitudinal girder
q' = function defined by equation (1.8)
R = reaction of equivalent tire load when dual tires are used
R_n = dimensionless factor defined by equation (5.2)
R_R = the rim reaction that should be used in computing the shearing stress v_R in wood planking
R_T = the tire reaction that should be used in computing the shearing stress v_T in wood planking
$\overline{R}_n$ = dimensionless factor equal to the quantity in brackets in equations (5.1a) and (5.1b)
r = proportion of the total moment across midspan carried by the loaded longitudinal for a concentrated load at midspan. (See FIG. 2.2) This symbol is used only for decks without transverses
r_c = proportion of the total moment across midspan carried by the loaded longitudinal for a distributed load at midspan
r_n = proportion of the total moment carried by the loaded longitudinal across a transverse section directly under a concentrated load. This symbol is for a deck with transverse girders and a concentrated load applied over the transverse at or nearest to midspan
r_o = dimensionless factor for a deck with transverses, equal to the value of r for the deck with the transverses removed
r_s = proportion of maximum moment carried by the loaded longitudinal for a deck with infinitely rigid transverse girders
r_n' = dimensionless factor equivalent to r_n but applicable to a distributed load
S = section modulus of a longitudinal girder
S_p = section modulus of a plank
S_t = section modulus of a transverse girder
S_x = distance between main wheels of an aircraft

S_ℓ = distance from nose or tail wheel to main wheel axis of an aircraft

$s = L/(n+1)$ = span length between transverse supports, either transverse girders or bulkheads

T_p period of pitch of aircraft carrier (See Appendix B)

T_R = period of roll of aircraft carrier (See Appendix B)

t_p - total thickness of the cross section of an aluminum plank across its centrodial axis

t_w thickness of the web of a girder

t_p = thickness of the effective section of the weakest web of an aluminum plank across the section centrodial axis

V = maximum shear in loaded longitudinal due to wheel load

V_d = maximum shear in a longitudinal due to dead load

V_R = maximum shear in an aluminum plank due to rim load

$V_s = V + V_d$ = total maximum shear in loaded longitudinal

V_T = maximum shear in an aluminum plank due to tire load

V_t = maximum shear in a transverse girder

v = maximum shearing stress due to total wheel load

v_R = maximum shearing stress due to rim load

$(v_R)_1$ = shearing stress in wood planking due to a rim load $P_R/2$ applied at a distance d_1 from the support

$(v_R)_2$ = shearing stress in wood planking due to a rim load $P_R/2$ applied at a distance d_2 from the support

v_T = maximum shearing stress due to tire load

W = weight of aircraft

w = spacing of planks

w_o = spacing of planks or contact length of tire A, whichever is less

w_o = spacing of planks or contact length of rims A_R, whichever is less

$x = d/h$ = dimensionless parameter

$x_1 = d_1/h$ = dimensionless parameter

$x_2 = d_2/h$ = dimensionless parameter

Y = vertical distance from center of gravity of aircraft to center of flotation of ship

y = distance from a reference axis to the centroid of each component of a girder

$\bar{y}$ = distance from a reference axis to the centroid of a girder

Z = longitudinal distance from center of gravity of aircraft to center of flotation of ship

$\beta = H^{1/6}(b/L)^{1/2}$ = a dimensionless parameter used for plank decks

$\beta_n = H_n^{1/6}(b/L)^{1/2}$ = a dimensionless parameter used for decks with transverse girders

β_{nf} = effective value of β (corresponding to $r = R_n$) for a deck with transverse girders

$\beta_s = (n+1)^{2/3}\beta$ = a dimensionless parameter

θ_p = angle of pitch of aircraft carrier, degrees (See Appendix B)

θ_R = angle of roll of aircraft carrier, degrees (See Appendix B)

$\lambda = H^{3/16}(b/L)^{1/2}$ = a dimensionless parameter used for plate decks

μ = Poisson's ratio

$\phi_1(A/b)$, $\phi_2(A/b)$ = functions defined by equations (2.9b) and (2.11), respectively

$\phi_1(A_R/b)$, $\phi_2(A_R/b)$ = functions similar to $\phi_1(A/b)$ and $\phi_2(A/b)$ with the quantity A_R taking the place of A

$\phi_2(A/L)$, $\phi_3(B/b)$ = functions defined by the curves in FIG. 2.6

Ω = parameter defined by equation (1.2)

APPENDIX B

SHIP MOTION DESIGN PARAMETERS (storm condition)

Assumed for various classes of Aircraft Carriers

Ship Class	Roll		Pitch		Maximum Longitudinal Distance from C.F. of Ship to C.G. of Aircraft		Vertical Distance from C.F. to		Horizontal Distance of C.F. Aft of Midships
	θ_R	Period T_R	θ_P	Period T_P	On Flight Deck	On Hangar Deck	Flight Deck	Hangar Deck	
	Degrees	Seconds	Degrees	Seconds	feet	feet	feet	feet	feet
CVE 6	30	15	4	8	230	158	45.0	19.0	4.2
CVE 26	30	15	4	8	236	167	40.2	19.0	17.9
CVE 55	30	15	4	10	218	172	42.2	16.0	32.0
CVE 105	25	16	4	8	240	168	40.2	18.8	17.6
CVL 22	30	15	4	8	254	162	42.3	21.8	42.0
CVL 48	30	12	4	8	284	198	46.3	23.1	48.5
CVA 9	30	15	4	8	418	350	51.8	24.7	41.7
CVA 41	30	17	4	8	444	380	49.3	22.3	50.3
CVA 59	25	16	4	9	531	431	62.3	25.8	50.0

NOTES:
(1) Angle of roll is the transverse angle of inclination measured from the vertical.
(2) Angle of pitch is the longitudinal angle of inclination measured from the vertical.
(3) Periods of roll or pitch are complete periods from port to starboard to port or up to down to up.

APPENDIX C

AIRCRAFT TIRE CHARACTERISTICS

(Type VII Tires)

TIRE SIZE		PLY RATING	RATED LOAD P_s	RATED INFLATION PRESSURE P_s	DISTANCE C to C OF RIMS	RIM DIAMETER
O.D.	CASING DEPTH					
Inches			Pounds	p.s.i.	Inches	Inches
18	5.5	12	5,050	170		
20	4.4	10	3,750	150	4.50	13.625
22	5.5	8	4,400	120	4.91	13.750
24	5.5	12	7,000	205	4.91	15.750
24	5.5	14	8,000	235	4.91	15.750
24	7.7	10	5,100	85		
26	6.6	12	8,000	160	5.69	16.000
26	6.6	14	10,000	225	5.69	16.000
30	7.7	12	10,000	165	6.85	18.000
30	8.8	18	15,500	180		
32	8.8	12	11,000	135	7.81	18.250
34	9.9	14	14,000	140	8.81	18.500
36	11	14	14,000	110	9.94	18.750
38	11	14	12,000	95	9.94	20.750
40	12	14	14,500	95	10.94	21.000
42	12	14	16,000	100	11.00	23.000
44	13	26	35,000	200	12.00	23.750
46	14	20	20,000	95	13.06	23.500
52	16	22	32,000	110	14.19	27.250
56	16	24	45,000	178	14.00	32.500
56	16	32	60,000	240	14.00	32.500
64	19	24	43,000	115	16.88	34.750

NOTES: (1) The tire sizes rated load and rated inflation pressure are tabulated from MIL-C-5041A.
(2) The distance c-c of rims and rim diameter are tabulated from 1950-1951 Year Book of the "Tire and Rim Associated Inc."

APPENDIX D

THEORY AND PRINCIPLES

1. Loading Charts

(a) *Parking Wheel Reaction*

The parking wheel load reaction caused by the vertical component due to pitching, heaving and rolling (normal to the deck) is given by

$$P_1/W = (1 + H_F + \Omega) \text{ Cos } \theta_R \, (0.5 + C_z/2S_z)$$

See FIG. A1-1 (1.1)

where

$$\Omega = 0.0214 \, \theta_P Z/T_P^2 \qquad (1.2)$$

The vertical reaction per main wheel due to horizontal forces parallel to the deck when the ship is pitching equals to W $[(0.0214 \, Y \, \theta_P/(T_P)^2) + \sin \theta_P] \, (C_y/2S_z)$. Since this reaction is so small, it can be neglected.

The parking wheel load reaction caused by the horizontal component due to pitching, heaving and rolling is given by

$$P_2/W = (F_x/W) \, (C_y/S_x) \quad \text{See FIG. A1-2} \qquad (1.3)$$

where

$$F_x/W = (0.0214 \, Y \, \theta_R)/T^2{}_R + (1 + \Omega + H_F) \sin \theta_R \qquad (1.4)$$

by replacing θ_R by sin θ_R and assuming that sin $\theta_R = 0.960 \, \theta_R$ (radians), $= 0.01676 \, \theta_R$ (degrees) then equation (1.4) reduces to

$$F_x/W = (1 + \Omega + H_F + 1.277 \, Y/T_R^2) \sin \theta_R \qquad (1.5)$$

The component of parking wheel due to wind is

$$P_3 = P_w A_s C_y'/S_x \quad \text{See FIG. A1-3} \qquad (1.6)$$

(b) *The bottoming load of tire is*

$$P_b = 2.8 \, P_s \, (q') \quad \text{See FIG. A2} \qquad (1.7)$$

where

$$q' = (0.7 \, p_s'/p_s) + 0.3 \qquad (1.8)$$

(c) *The contact width of tire*

$$A_c = P_T/p \qquad (1.9)$$

where

$$p = K_1 \, p_s' \qquad (1.10)$$

where K_1 values can be read from FIG. 2.1

$$B = K_2(A_c)^{1/2}, \text{ See FIG. A3} \qquad (1.11)$$

where K_2 values can be read from FIG. 2.1

$$A = A_c/B, \text{ See FIG. A3} \qquad (1.12)$$

2. Plate Decks Without Transverses

(a) *Plate Deck Design Charts*

$$\lambda = (H)^{3/16} \, (b/L)^{1/2}, \text{ See FIG. B1} \qquad (2.1)$$

$$H = 10.92 \, I/(Lh^3), \text{ See FIG. B1} \qquad (2.2)$$

(b) *Aluminum Plate Deck*

$$H = 10.92 \, I/(Lh^3/3) = 10.92 \, I/\left[(L)\,(0.693h)^3\right] \qquad (2.3)$$

(c) *Maximum Bending Moment in Longitudinals (no transverses)*

$$M/PL = r_c \, (0.1708 - 0.1250 \, A/L + 0.0264 \, A^2/L^2), \text{ See FIG. B2} \qquad (2.4)$$

The value of r_c is determined from the expression

$$(1 - r_c) \, / \, (1 - r) = (1 - 0.89 \, A^2/L^2) \, / \, (1 - 0.73 \, A/L) \qquad (2.5)$$

where r is shown in FIG. (2.2). After the bending moment M is calculated, then apply a correction factor ϕ_3 from FIG. (2.6) due to the contact width. This will give the corrected moment.

(d) *Maximum Shear in Longitudinals*

$(V/P)(\phi_2)(\phi_3)$, for values of ϕ_2 and ϕ_3 See FIG. 2.6 (2.6)

(e) *Maximum Bending Moment Per Unit Width of Plating*

$$m_o/P_T = \left[f_1(B/b)/\phi_1(A/b)\right] - \left[f_2(B/b)/\phi_2(A/b)\right], \quad \text{See FIG. B3-1} \tag{2.7}$$

where

$$f_1(B/b) = (1/8)(2 - B/b) \tag{2.8}$$

$$f_2(B/b) = (1/38)\left[3 - (B/b)^2\right] \tag{2.9}$$

and

$$\phi_1(A/b) = 0.45(A/b) + 0.94 \quad \text{for } A/b \leq 0.5 \tag{2.10a}$$

$$\phi_1(A/b) = A/b + 0.6/(A/b + 0.4) \quad \text{for } A/b \geq 0.5 \tag{2.10b}$$

and

$$\phi_1(A/b) = 1.75 + 0.15(A/b)^2 \quad \text{for } A/b \leq 3.0 \tag{2.11}$$

The plate bending moment m_o' from rim load is given approximately by the equation

$$m_o'/P_R = \left[f_1'(B_R/b)/\phi_1(A_R/b)\right] - \left[f_2'(B_R/b)/\phi_2(A_R/b)\right] \tag{2.12}$$

See FIG. B3-2

where

$$f_1'(B_R/b) = (1/4)(1 - B_R/b) \tag{2.13}$$

$$f_2'(B_R/b) = (3/38)\left[1 - (B_R/b)^2\right] \tag{2.14}$$

The functions ϕ_1 and ϕ_2 in equation (2.12) are similar to those given in equation (2.10) and (2.11)

The correction moment m_c from wheel load due to the deflection of the beam is

$$m_c = P/\left[9 + 32\bar{H}(b/a)^{3/2}\right] \tag{2.15}$$

where

$$\bar{H} = H/0.683 \tag{2.16}$$

or

$$m_c = P/\left\{9 + 83.09\left[\lambda(b/L)^{-7/32}\right]^{16/3}\right\} \tag{2.17}$$

The nomograph shown in FIG. B3-3 was constructed by using a quantity $(b/L)^{-1/4}$, in place of $(b/L)^{-7/32}$, see FIG. 2.4 for a plot of m_c/P in terms of $(b/L)^{-1/4}$. Since the values calculated by equation (2.17) or by using $(b/L)^{-1/4}$ in place of $(b/L)^{-7/32}$, do not exactly agree with the values given in FIG. B3-3, it is recommended that values from FIG. B3-3 be used and for values of m_c/P less than 0.001 be omitted.

(f) *Maximum Bending Moment Per Unit Width of Plating in the Long Direction*

The longitudinal simple span moments m_L^s at the center of the panels under the load are given by the following empirical relations:

For $B/A \leq 1.0$

$$m_L^s = \left[f_1(B/b)/\phi_1(A/b)\right] - \left[P/9(1 + B/A)\right] \tag{2.18}$$

and for $B/A \geq 1.0$

$$m_L^s = \left[f_1(B/b)/\phi_1(A/b)\right] - \left[0.09P/(0.62 + B/A)\right] \tag{2.19}$$

The correction moment in the plate due to continuity, in the longitudinal direction under the load is given by the approximate relation:

$$m_L^{c+} = \left[f_2(B/b)/\phi_2(A/b)\right] + \left[0.04P/(2 + B/b)\right] \tag{2.20}$$

This correction moment from equation (2.20) is a subtractive moment.

The correction moments in the long direction under a concentrated load, due only to deflection of beams, is given by the approximate relation:

$$m_L^{d+} = P/\left[8 + 14.2H(b/L)^{1/2}\right] \tag{2.21}$$

This correction moment from equation (2.21) is an additive moment.

Equations (2.7) to (2.21) inclusive for moments in a transverse or longitudinal strip are limited in applicability by the range of values of the variables considered in their derivation. They are applicable, generally for values of B/b ranging from 0 to 1.0, and for values of A/b from 0 to 2.0. Because they are for an infinitely long strip, they should be limited to cases defined by the following relationship between the length of the loaded area, A, and the aspect ratio, b/a: $A/a \geq 1 - 2b/a$ (where $a = 0.683L$.)

3. Plate Deck With Transverses

(a) *Maximum Bending Moment in Longitudinals*

$$M_{in}/Pa = (n+1)\,M_{in}/PL = r_a(0.1708 - 0.1250A/a + 0.0264A^2/a^2) \quad \text{See FIG. E1} \tag{3.1}$$

Where r_a is given in FIG. 2.3 (but never exceeds unity). For the value of β in FIG. 2.3, use

$$\beta_a = (n+1)^{2/3}(EI/LN)^{1/6}\,(b/L)^{1/2} \tag{3.2}$$

(b) *Maximum Bending Moment in Longitudinals for Load over Transverse*

$$M_n/PL = r_n'(0.1708 - 0.1250A/L + 0.0264A^2/L^2), \text{ See FIG. E2} \tag{3.3}$$

where

$$(1 - r_n')/(1 - r_n) = (1 - 0.89A^2/L^2)/(1 - 0.73A/L) \tag{3.4}$$

and

$$r_n = 1.18H^{1/6}\,(b/L)^{1/2}\left[1 + H(n+1)E_tI_t/EI\right]^{-1/6} \tag{3.5}$$

(c) *Maximum Bending Moment in Transverse Girders*

$$M_t/Pb = 0.115K^{1/4}(1 - r_n^6/r_o^6), \quad \text{See FIG. E4} \tag{3.6}$$

where

$$K = E_tI_tL^3/EIb^3, \quad \text{and the value of } r_o \text{ in FIG. 2.2} \tag{3.7}$$

(d) *Maximum Shear in Transverse Girders*

$$V_t/P = (1/2)\,(1 - r_n)\,(1 - r_n^6/r_o^6), \quad \text{See FIG. E5} \tag{3.8}$$

4. Aluminum Plank Decks Without Transverses

(a) *Moment per Plank Due to Tire Load for Deck with Nondeflecting Longitudinals*

$$M_o/P_Tb_e = (w_o/A)\,(0.1708 - 0.1250B/b_e + 0.0264B^2/b_e^2), \text{ See FIG. C3-1} \tag{4.1}$$

Equation (4.1) applies to tire oriented normal to the plank. If tire is parallel to the plank

$$M_o/P_Tb_e = (w_o/B)\,\left[0.1708 - 0.215A/b_e + 0.0264A^2/b_e^2\right] \tag{4.2}$$

(b) *Moment per Plank Due to Rim Load for Deck with Nondeflecting Longitudinals*

$$M_o'/P_Rb_e = (w_o'/A_R)\,\left[0.1708 - 0.250B_R/b_e + 0.0792B_R^2/b_e^2\right], \text{ See FIG. C3-2} \tag{4.3}$$

Equation (4.3) applies to tire oriented normal to plank.

(c) *Correction Moment Which Takes Into Account the Effect of Deflection of the Longitudinals*

$$M_c/Pb = (w/L)f_3(\beta), \text{ See FIG. C3-3} \tag{4.4}$$

where, for

$$\beta \leq 0.5,\ f_3(\beta) = (0.24/\beta^{3/2}) - 0.407 \tag{4.5}$$

for

$$\beta \geq 0.5,\ f_3(\beta) = 0.017/\beta^4 \tag{4.6}$$

and where

$$\beta = H^{1/6}(b/L)^{1/2} \tag{4.7a}$$

and for aluminum

$$H = 12(EI/LE_AI_A) = 36I/LI_A \tag{4.7b}$$

for wood

$$H = 12EI/LE_wh^3 \tag{4.7c}$$

(d) *Maximum Shearing Stress in Aluminum Plank*

The maximum shearing force V_T in the plank due to the tire load is given by equation

$$V_T/P_T = \left[1 - B/2b_e + 0.1830\left(1 - B^3/b_e^2\right)\left(B/b_e\right)\right] w_o/A \tag{4.8}$$

In this expression w_o denotes the distance from center to center of planks or the contact length of tire A, whichever is less. b_e is defined in the nomenclature.

The maximum shear V_R due the rim load is given by the equation

$$V_R/P_R = \left(1 - B_R/2b_e\right) + \left(0.1830 B_R/b_e\right)\left(1 - 2B_R/b_e\right)\left(1 - B_R/b_e\right) \tag{4.9}$$

For calculating unit shearing stress after V_T and V_R are solved from equations (4.8) and (4.9), see FIG. C5-2.

5. Aluminum Plank Decks With Transverses

(a) *Correction Moment M_c' Due to the Presence of Transverse Girders*

for $0 < \beta_{nf} < 0.8$

$$M_c'/Pb = (w/L)\left[0.240/\beta_{nf}^{3/2} - 0.407\right]\left(R_n^6/r_o^6\right) \quad \text{See FIG. E6} \tag{5.1a}$$

for $\beta_{nf} \geq 0.8$

$$M_c'/Pb = (w/L)\left[0.017/\beta_{nf}^4\right]\left(R_n^6/r_o^6\right) \tag{5.1b}$$

where

$$R_n = M_x/(PL)\left(0.1708 - 0.1250A/L + 0.0264A^2/L^2\right) \tag{5.2}$$

Using FIG. 2.3, find the value of $\beta = \beta_{nf}$ which corresponds to $r = R_n$

For M_x/PL value, see FIG. E3

6. Wood Plank Decks Without Transverses

(a) *Maximum Shearing Stress in Wood Plank*

The reaction R_T that should be considered in computing the maximum shearing stress due to the tire load P_T can be expressed approximately by the equation

$$R_T/P_T = f_4(b/h)\, f_5(B/b) \tag{6.1}$$

where

$$f_4(b/h) = 0.50 + (h/b)^2 \log_e\left[0.50(b/h)^2 + 1\right] - \sqrt{2}(h/b)\tan^{-1}\left[0.707(b/h)\right] \tag{6.2}$$

and $f_5(B/b)$ is given by the curve shown in FIG. 2.5

The resulting maximum shearing stress is determined from the equation

$$v_T = (3/2)\left(R_T/A_e'\right) \quad \text{See FIG. C4-1} \tag{6.3}$$

where $A_e' = hA$ is the area resisting the reaction R_T

For a concentrated rim load $P_R/2$ applied at a distance d from the support, the reaction R_R which must be used to compute, by means of the two-beam theory, the resulting shearing stress, is given by the equation

$$R_R/P_R = (0.5)(x)^2\left[1 - (x)(h/b)\right] + \left[2 + (x)^2\right] \tag{6.4}$$

where $x = d/h$

The parameters x_1 and x_2 define the locations of the rims when the wheel load is positioned so that the shear arising from the tire is a maximum.

Let d_o be the distance from the support to the center of gravity of the tire. Similarly, let d_1 and d_2 be the corresponding distances to rim nearest to and farthest away from the support. Then

$$x_1 = d_1/h = d_o/h - B_R/2h \tag{6.5}$$

and

$$x_2 = d_2/h = d_o/h + B_R/2h \tag{6.6}$$

where B_R is the distance center to center of rims

and

$d_o/h = 0.50\, b/h - b/h\, f$ [illegible]

The functions $f_6(b/h)$ and $f_7(B/b)$ are given by the curves shown in FIG. 2.9 and 2.10 respectively. Equation (6.7) is solved graphically in FIG. C4-2.

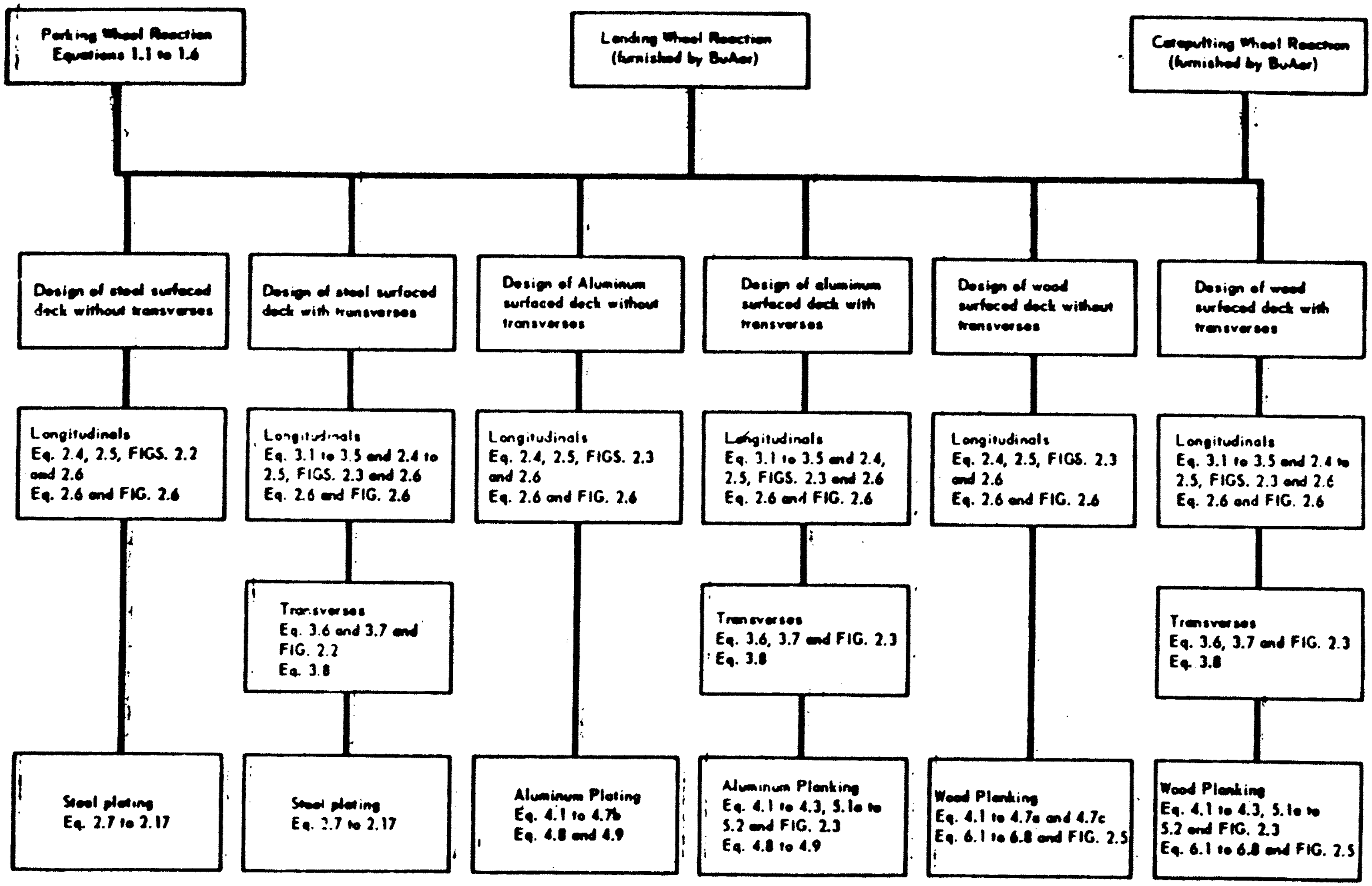
The shearing stress v_R is computed from the relation

$$v_R = 1500\,(\Sigma R_R A_e), \text{ See FIG. C4-3} \tag{6.8}$$

where A_e is the area of the plank or the product of the thickness of the plank and contact length of rim, (A_R – 1/2"), whichever is larger. In equation (6.8), v_R is expressed in psi., R_R in kips and A_e in square inches. The total shearing stress is equal to the sum of v_T and v_R.

Appendix D

Summary of Theory and Principles



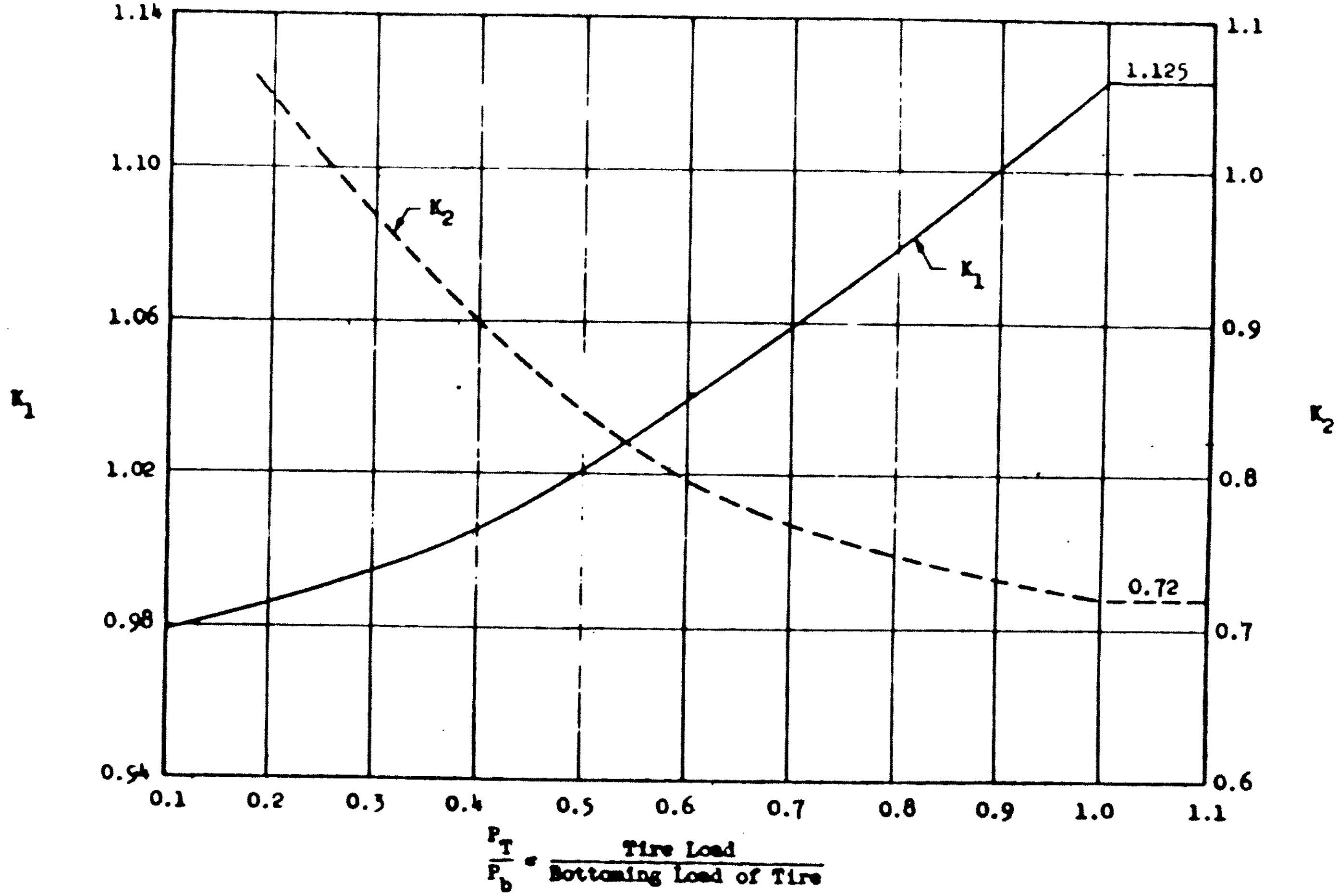


FIG. 2.1 DIMENSIONLESS FACTORS K_1 AND K_2 IN EQS. (1.10) AND (1.11)

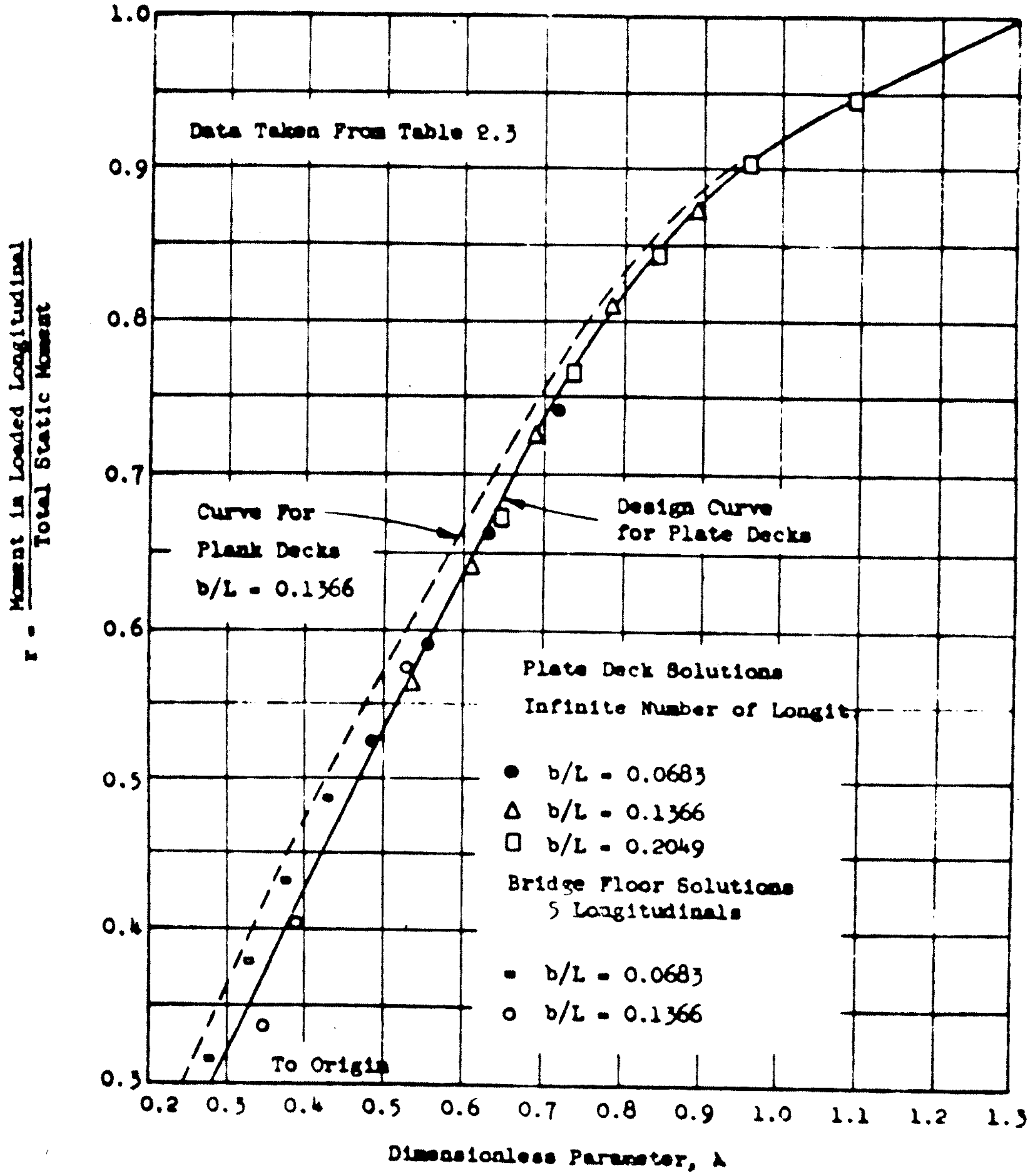


FIG. 2.2 CURVES OF MOMENT RATIO r vs. λ FOR PLANK DECK AND PLATE DECK SOLUTIONS

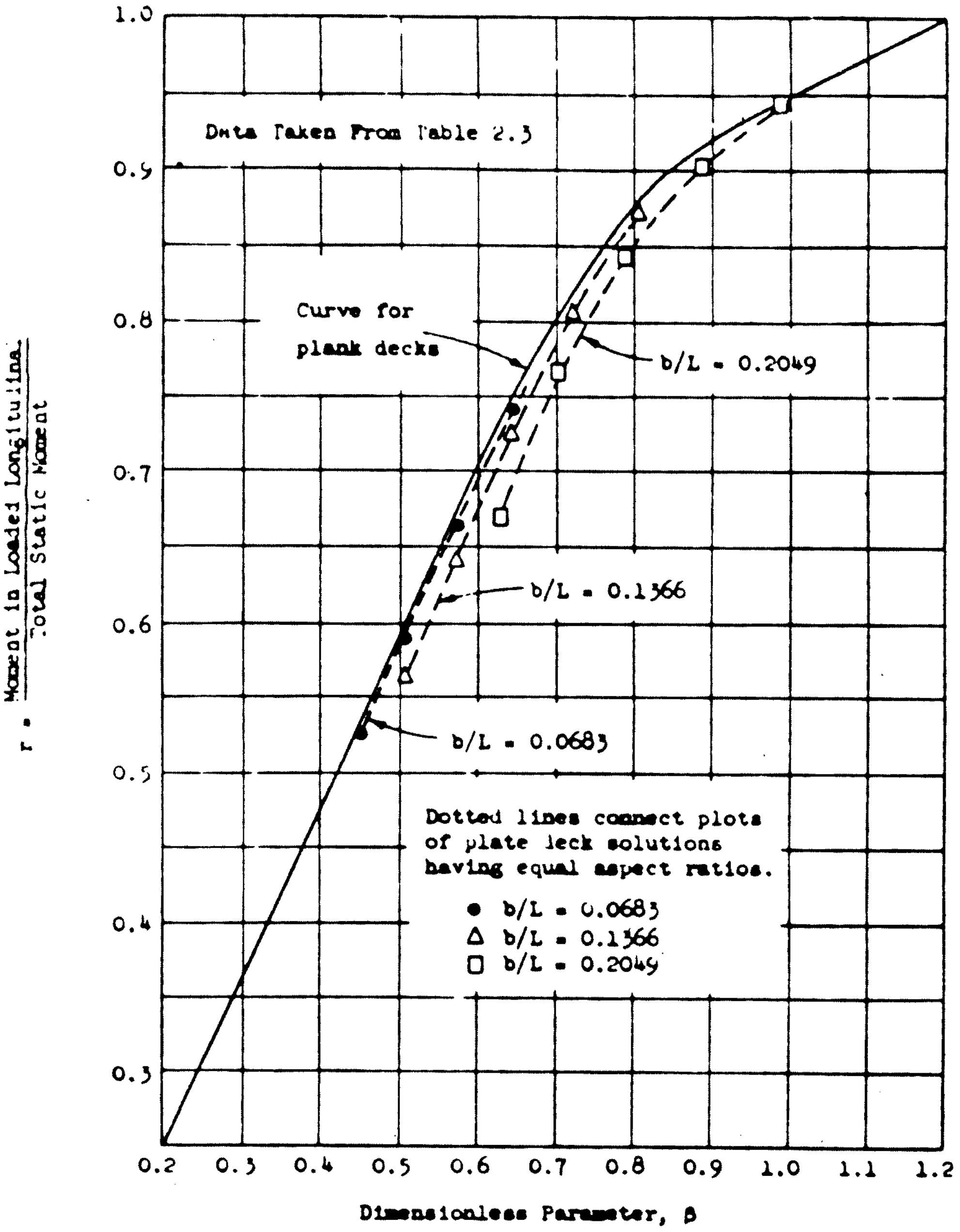


FIG. 2.3 CURVES OF MOMENT RATIO r vs. β FOR PLANK DECK AND PLATE DECK SOLUTIONS

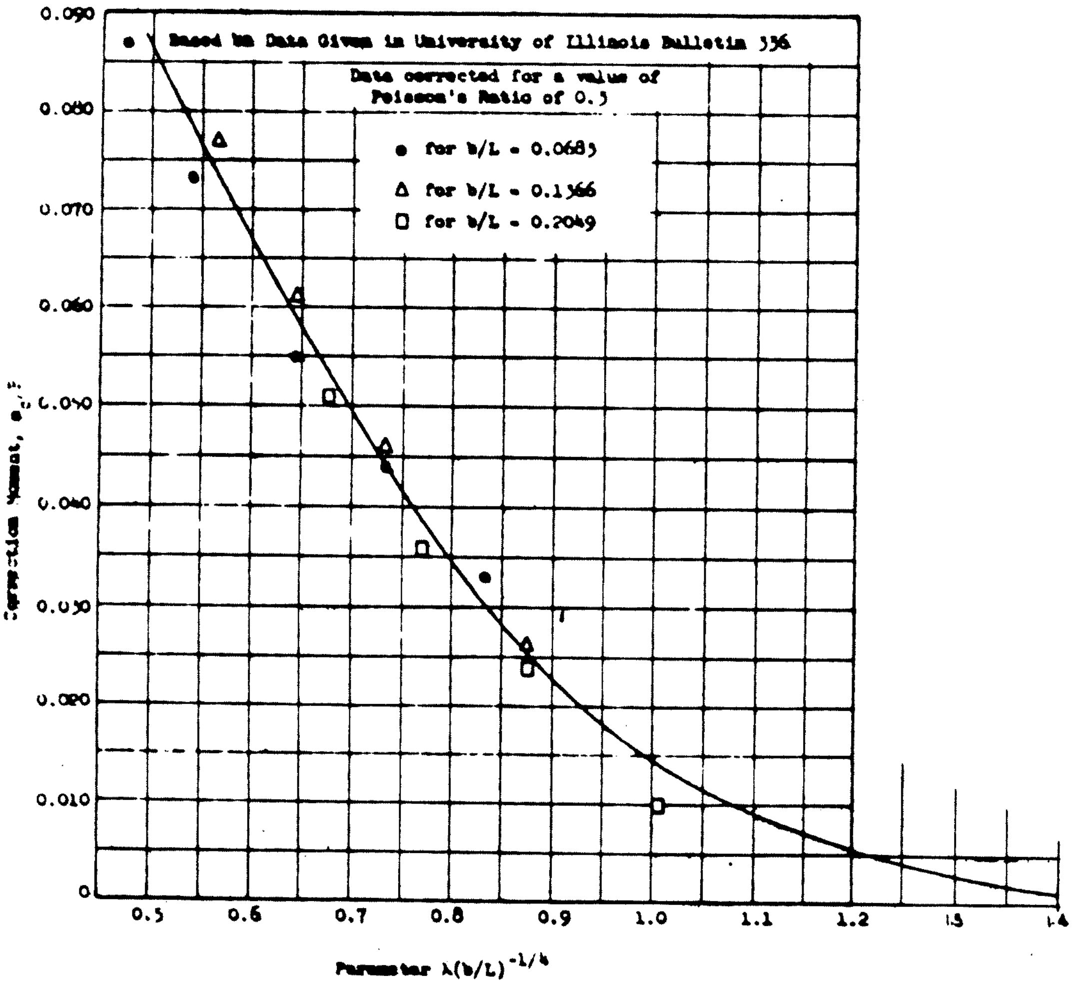


FIG. 2.4 CORRECTION MOMENT m_c/P DUE TO DEFLECTION OF LONGITUDINALS

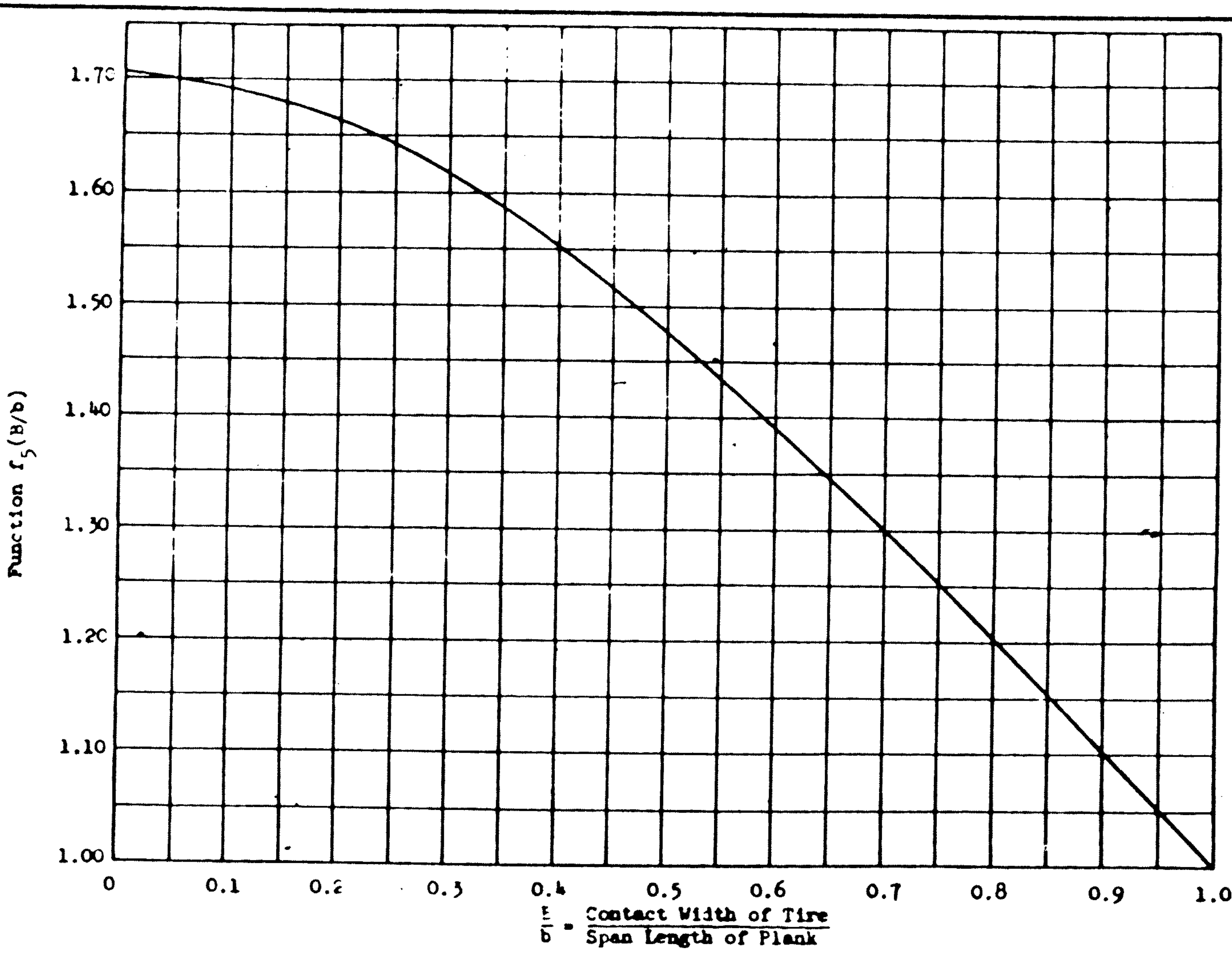


FIG.(2.5) FUNCTION $f_5(B/b)$ IN EQ. (6.1)

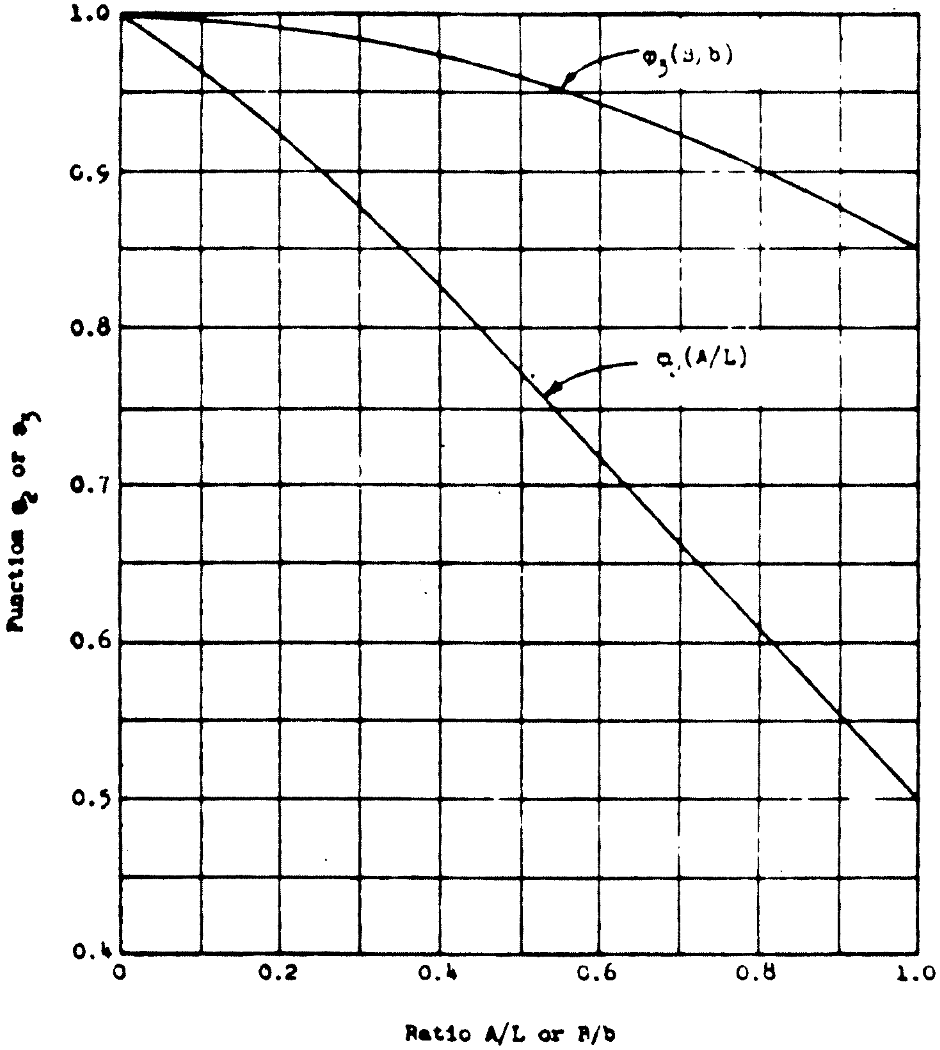
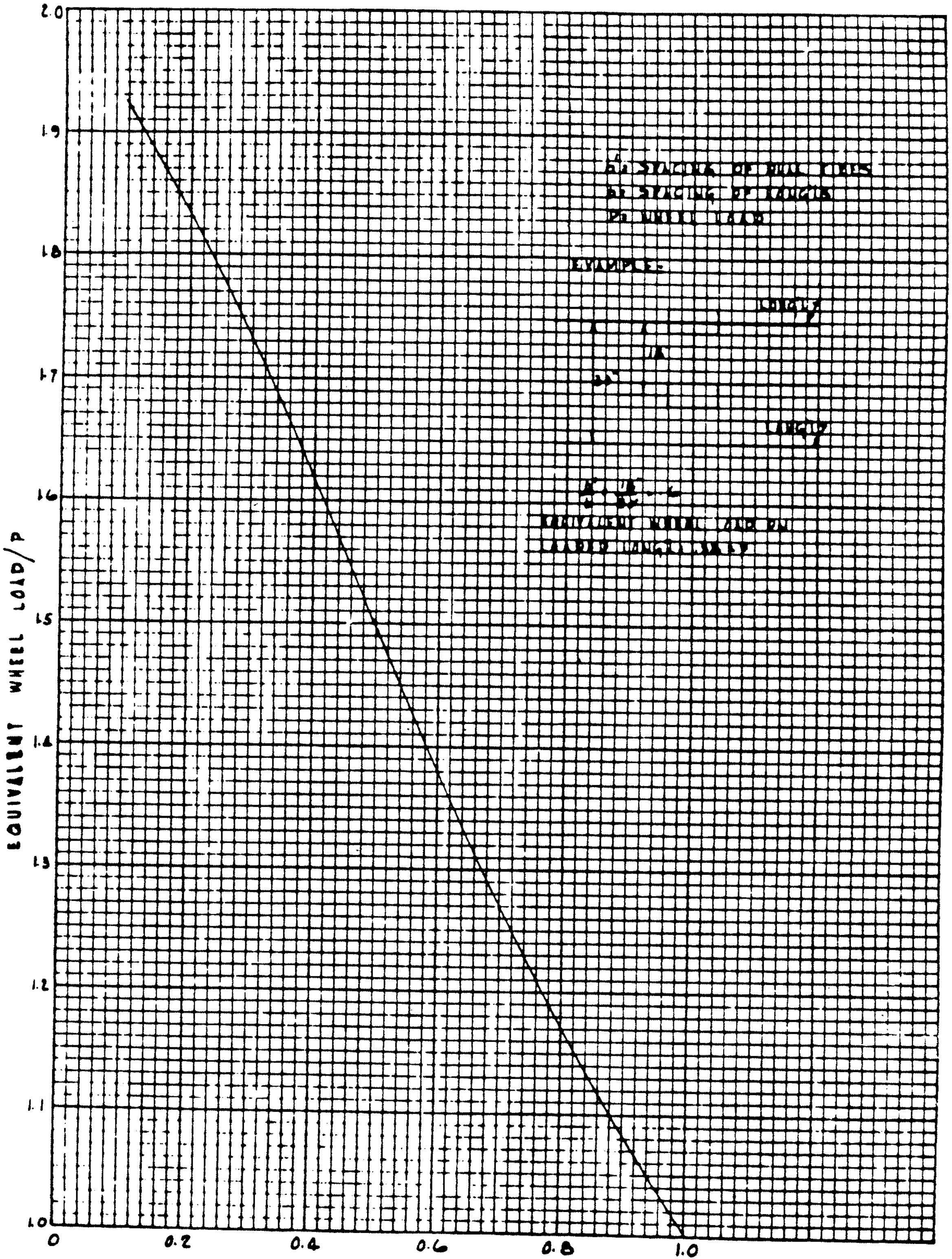


FIG. 2.6 FUNCTIONS $\varphi_2(A/L)$ AND $\varphi_3(B/b)$ IN EQ 2.8



2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
EQUIVALENT WHEEL LOAD/P
0
0.2
0.4
0.6
0.8
1.0
b'/b
b' = SPACING OF DUAL TIRES
b = SPACING OF LONGLS
P = WHEEL LOAD
EXAMPLE:-
LONGL
18"
24"
LONGL
b'/b = 18/24 = [illegible]
EQUIVALENT WHEEL LOAD ON
LOADED LONGL. [illegible]

FIG. 2.7

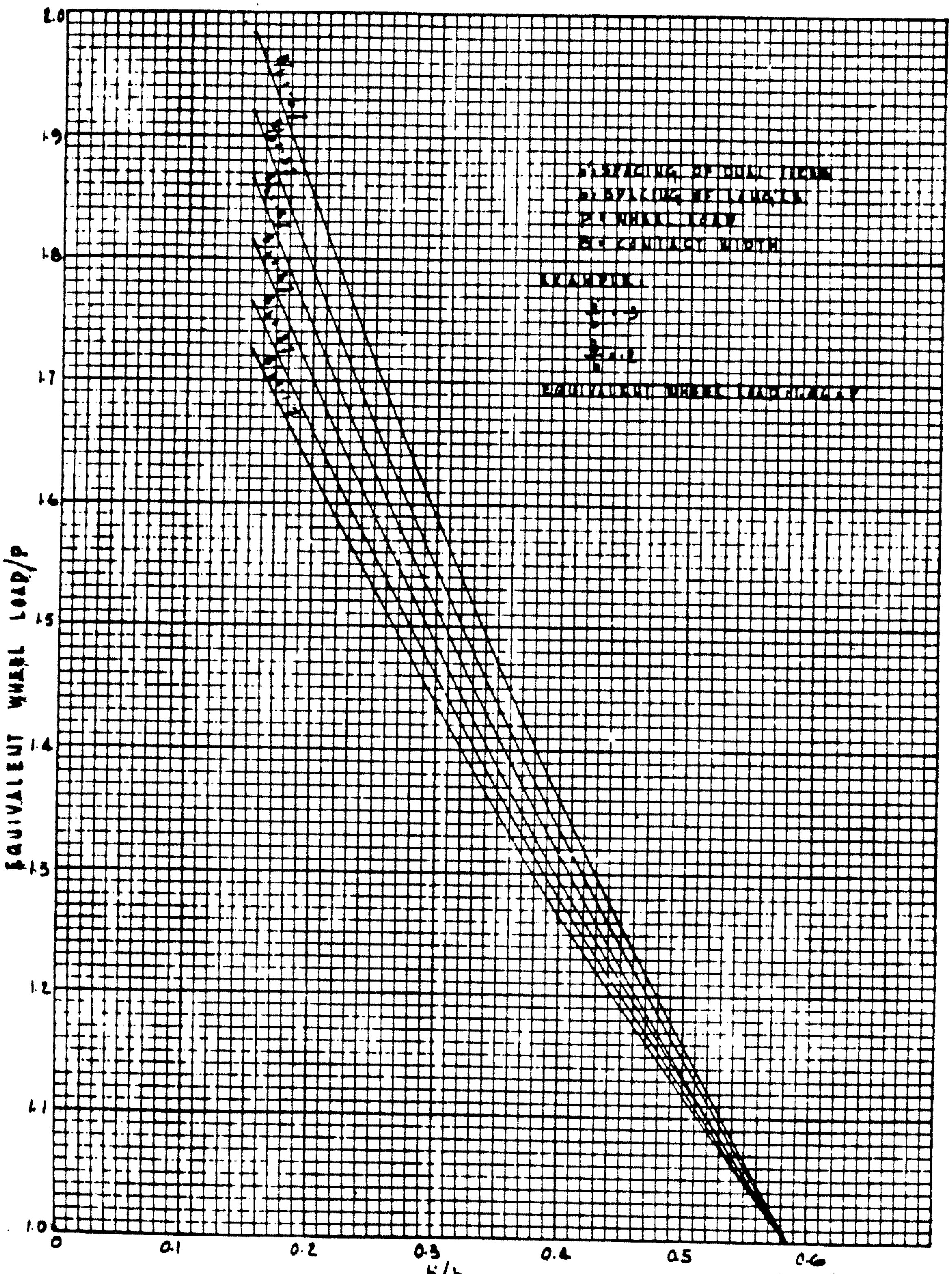
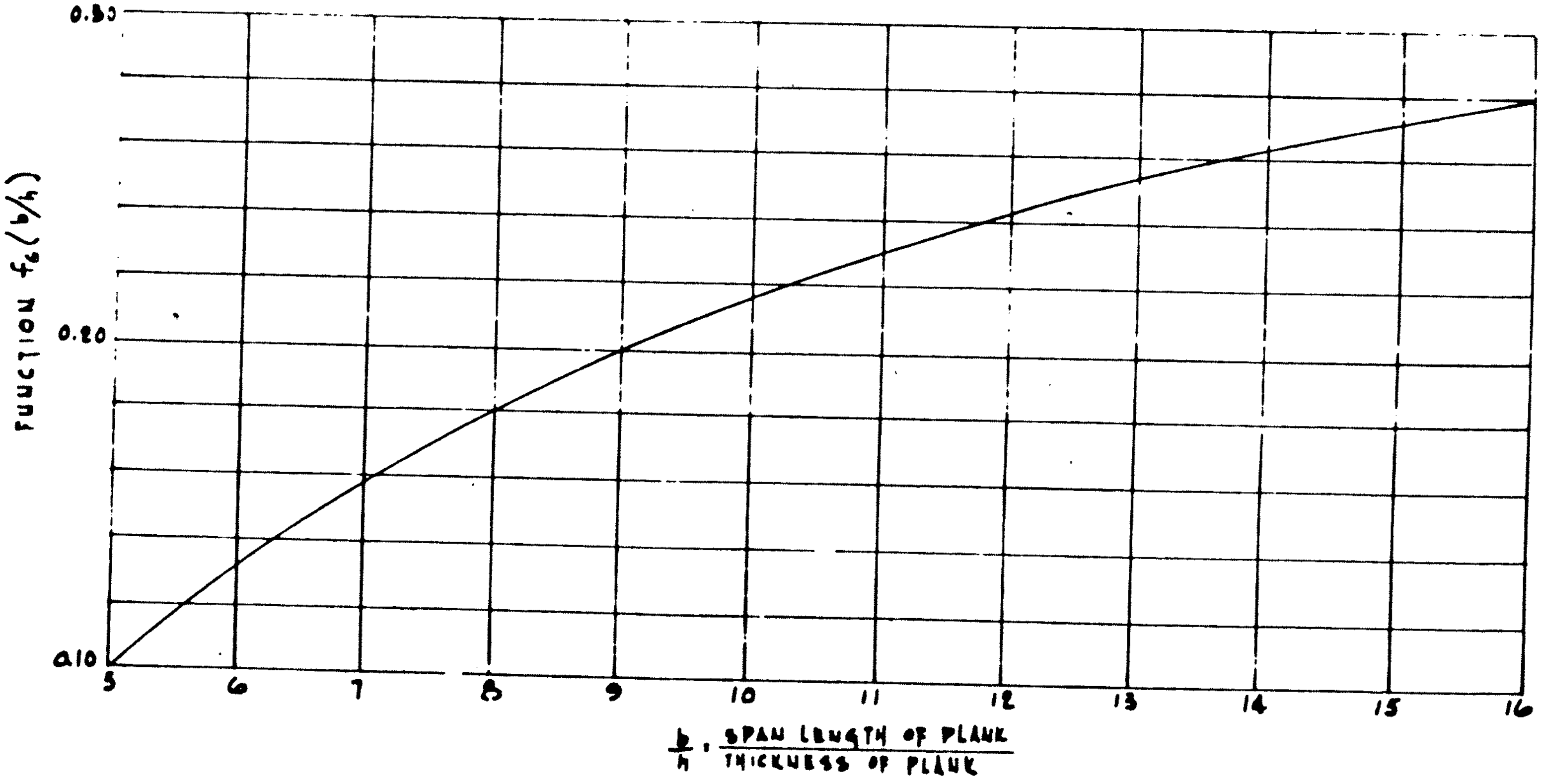
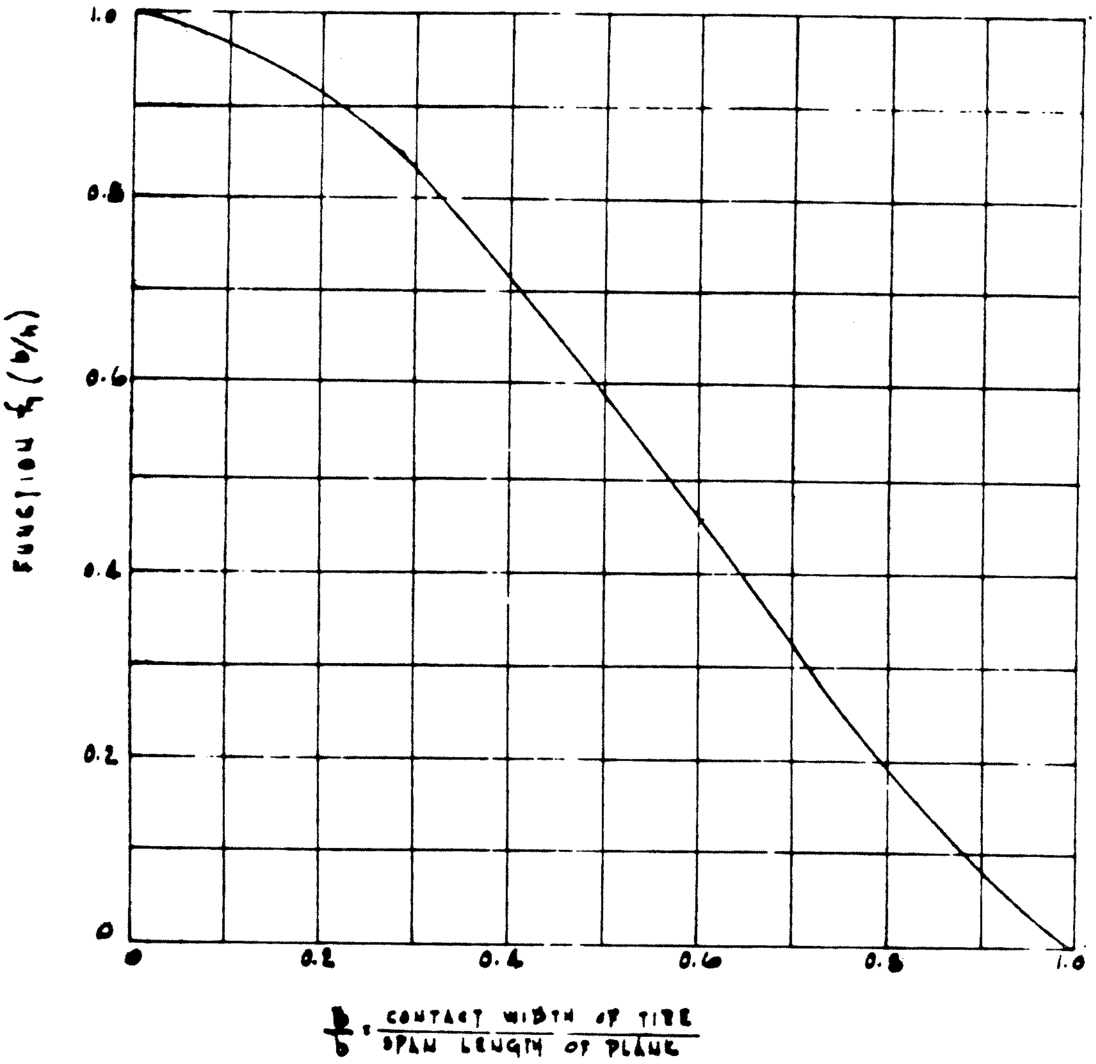

2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
0.1
0.2
0.3
0.4
0.5
0.6
EQUIVALENT WHEEL LOAD/P
b'/b
b' = SPACING OF DUAL TIRES
b = SPACING OF [illegible]
P = WHEEL LOAD
B = CONTACT WIDTH
EXAMPLE:
b'/b = ·3
B/b = ·2
EQUIVALENT WHEEL LOAD = [illegible] P

FIG. 2.8



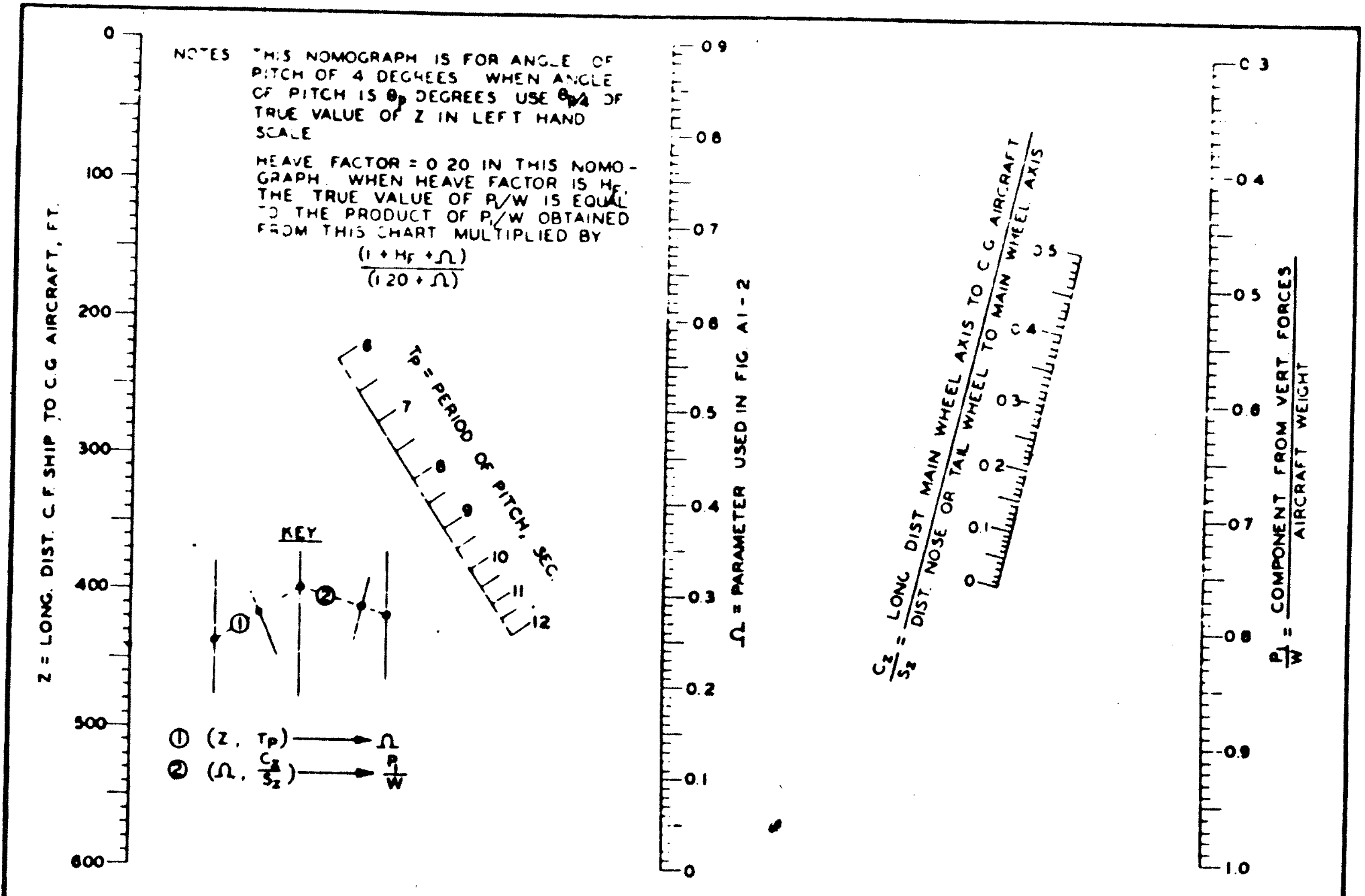
FUNCTION $f_6(b/h)$

FIG. 2.9



FUNCTION f_η (b/h)

FIG. 2.10



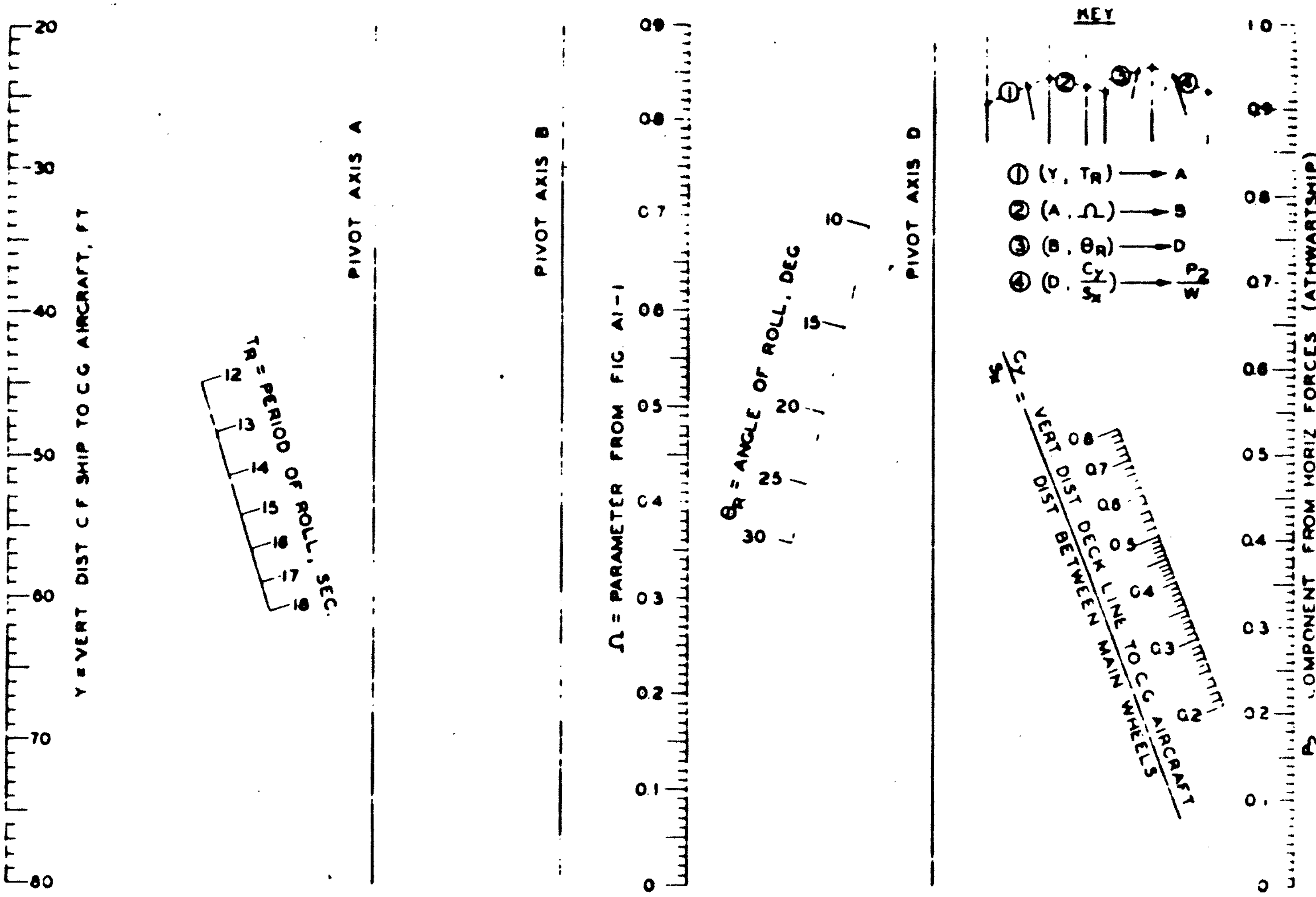
NOTES THIS NOMOGRAPH IS FOR ANGLE OF PITCH OF 4 DEGREES. WHEN ANGLE OF PITCH IS θ_p DEGREES USE $\theta_p/4$ OF TRUE VALUE OF Z IN LEFT HAND SCALE.

HEAVE FACTOR = 0.20 IN THIS NOMOGRAPH. WHEN HEAVE FACTOR IS H_F, THE TRUE VALUE OF P/W IS EQUAL TO THE PRODUCT OF P/W OBTAINED FROM THIS CHART MULTIPLIED BY

$$\frac{(1 + H_F + \Omega)}{(1.20 + \Omega)}$$

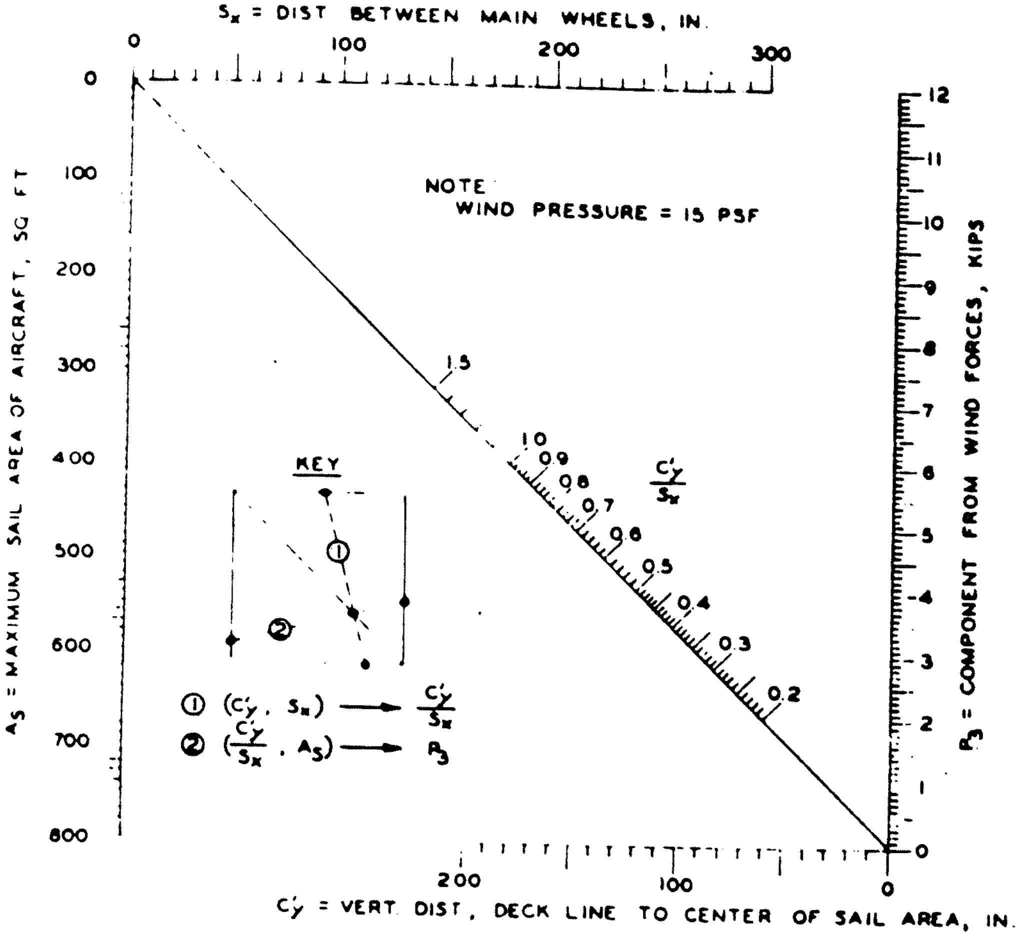
FLIGHT DECK DESIGN -- LOADING

FIG. A1-1 PARKING WHEEL LOAD -- PART I



FLIGHT DECK DESIGN -- LOADING

FIG. A1-2 PARKING WHEEL LOAD -- PART 2



SUMMARY OF CALCULATIONS FOR MAXIMUM PARKING WHEEL LOAD

AIRCRAFT WEIGHT, W = ____________ KIPS

FROM FIG A1-1, $\frac{P_1}{W}$ = ____________, P_1 = ____________ KIPS

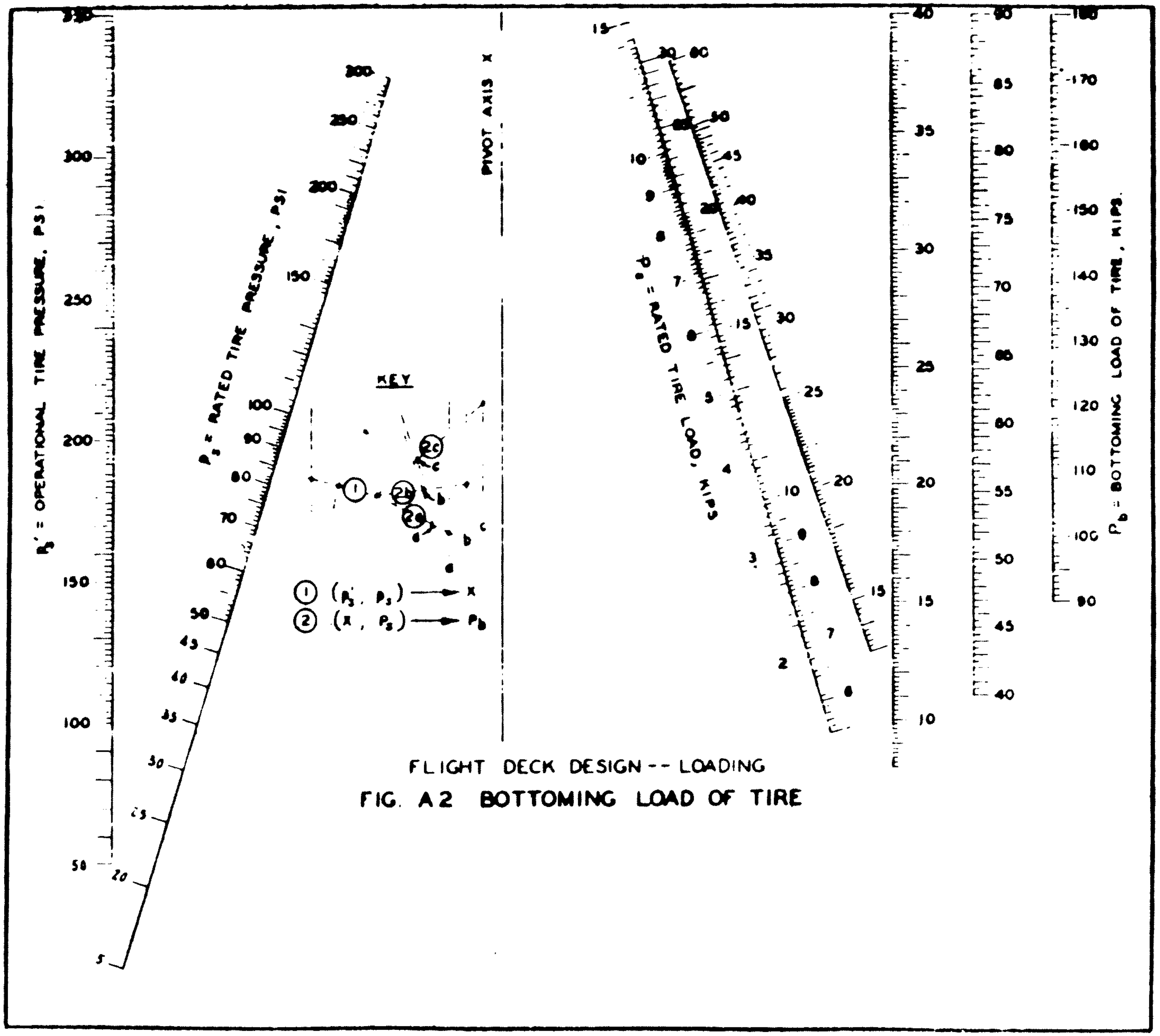
FROM FIG A1-2, $\frac{P_2}{W}$ = ____________, P_2 = ____________ KIPS

FROM FIG A1-3, P_3 = ____________ KIPS

MAXIMUM PARKING WHEEL LOAD, $P = P_1 + P_2 + P_3$ = ____________ KIPS

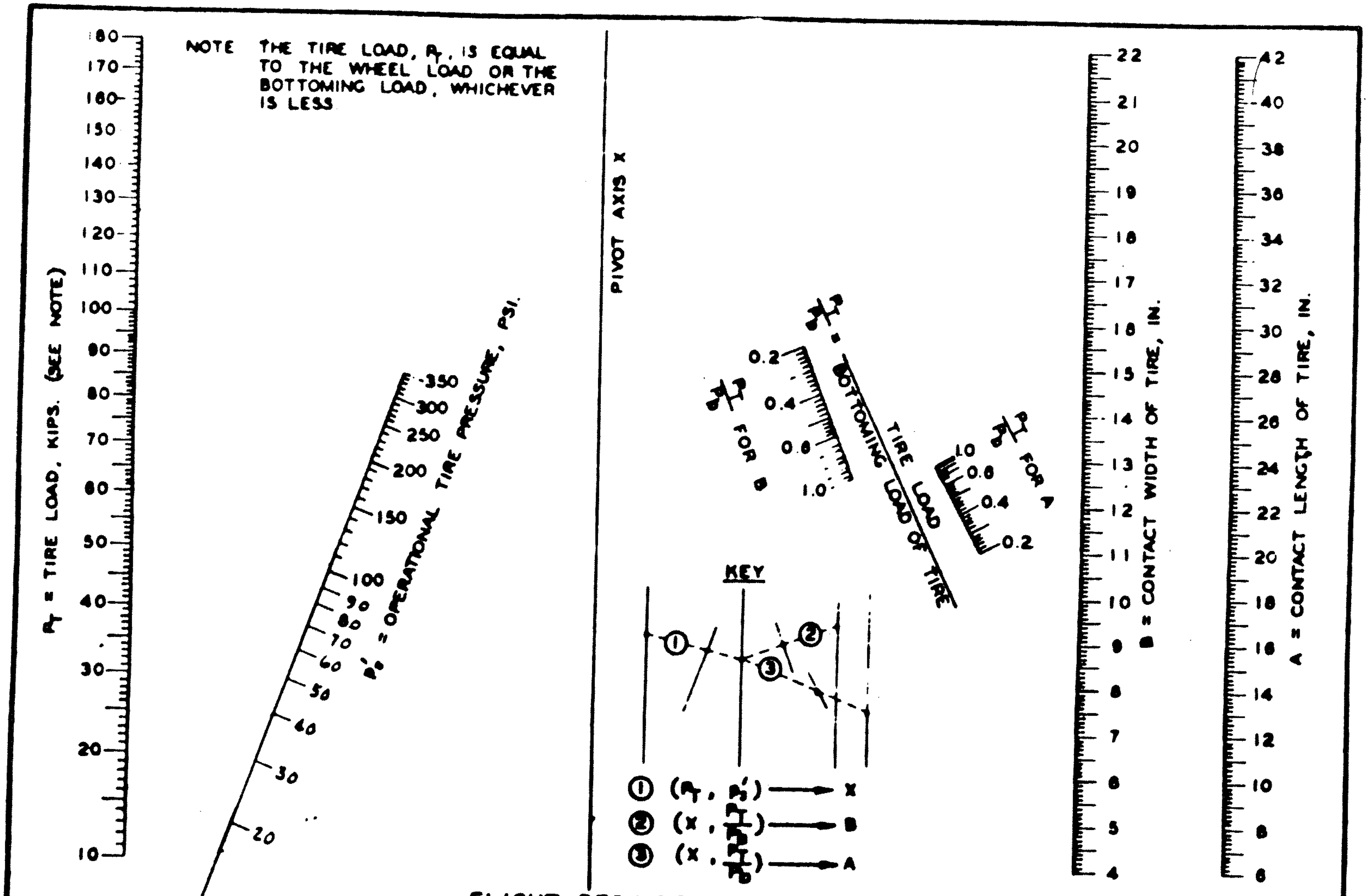
FLIGHT DECK DESIGN -- LOADING

FIG. A1-3 PARKING WHEEL LOAD -- PART 3 AND TOTAL



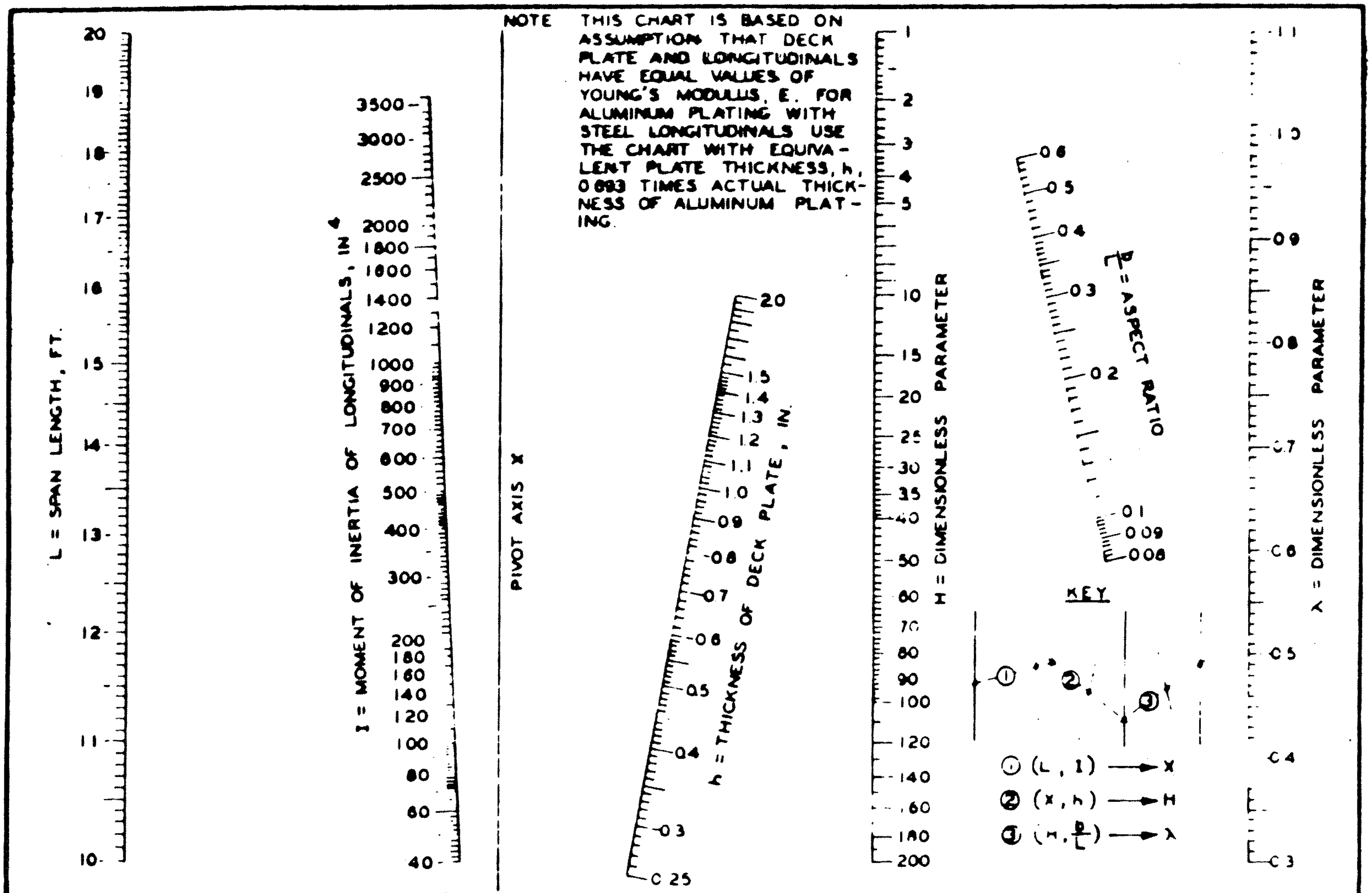
FLIGHT DECK DESIGN -- LOADING

FIG. A2 BOTTOMING LOAD OF TIRE



FLIGHT DECK DESIGN -- LOADING

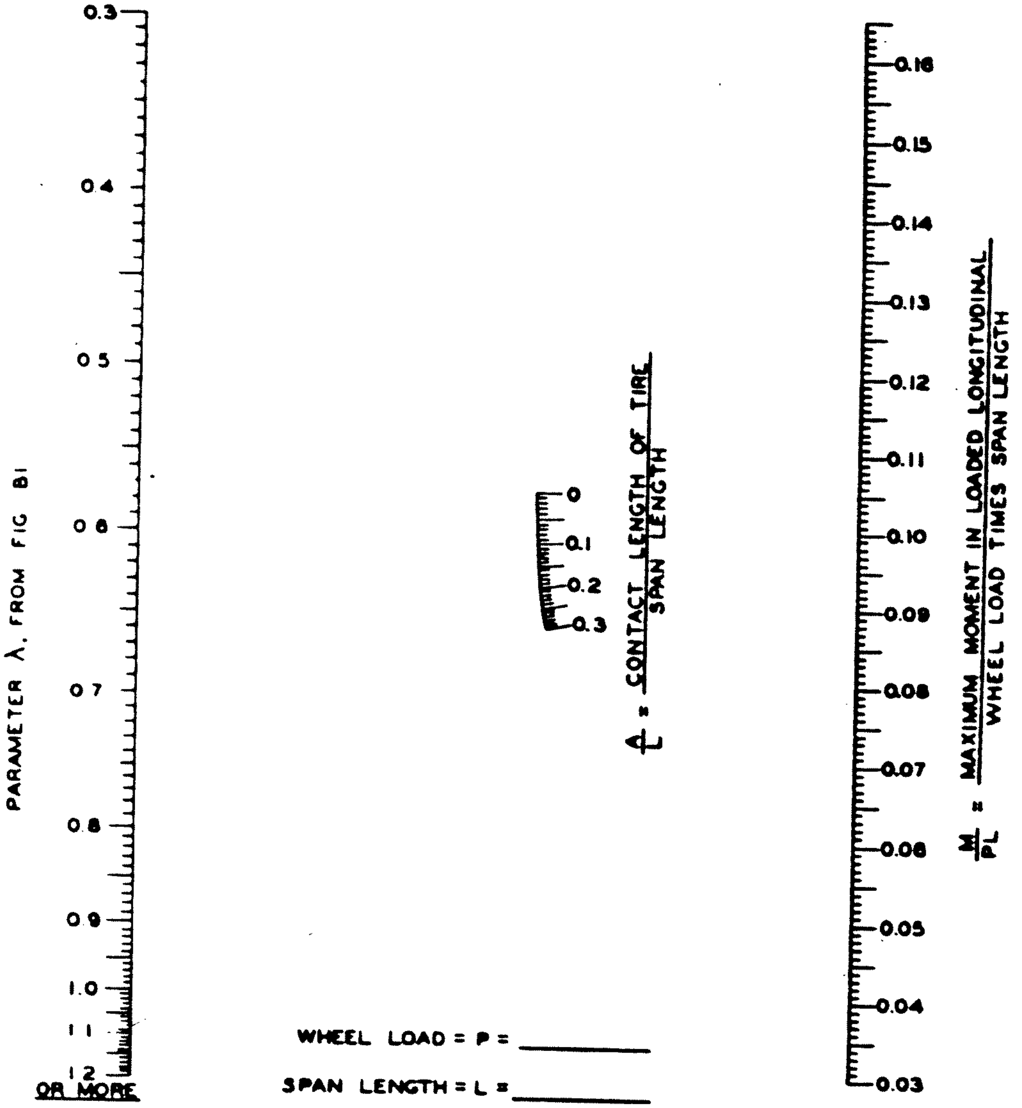
FIG. A3 CONTACT WIDTH AND LENGTH OF TIRE



NOTE THIS CHART IS BASED ON ASSUMPTION THAT DECK PLATE AND LONGITUDINALS HAVE EQUAL VALUES OF YOUNG'S MODULUS, E. FOR ALUMINUM PLATING WITH STEEL LONGITUDINALS USE THE CHART WITH EQUIVALENT PLATE THICKNESS, h, 0.693 TIMES ACTUAL THICKNESS OF ALUMINUM PLATING.

FLIGHT DECK DESIGN -- PLATE DECK

FIG. B1 DIMENSIONLESS PARAMETERS H AND λ



WHEEL LOAD = P = __________

SPAN LENGTH = L = __________

FROM FIG. D1, SECTION MODULUS = S = __________

FROM ABOVE NOMOGRAPH, $\frac{M}{PL}$ = __________ ; M = __________

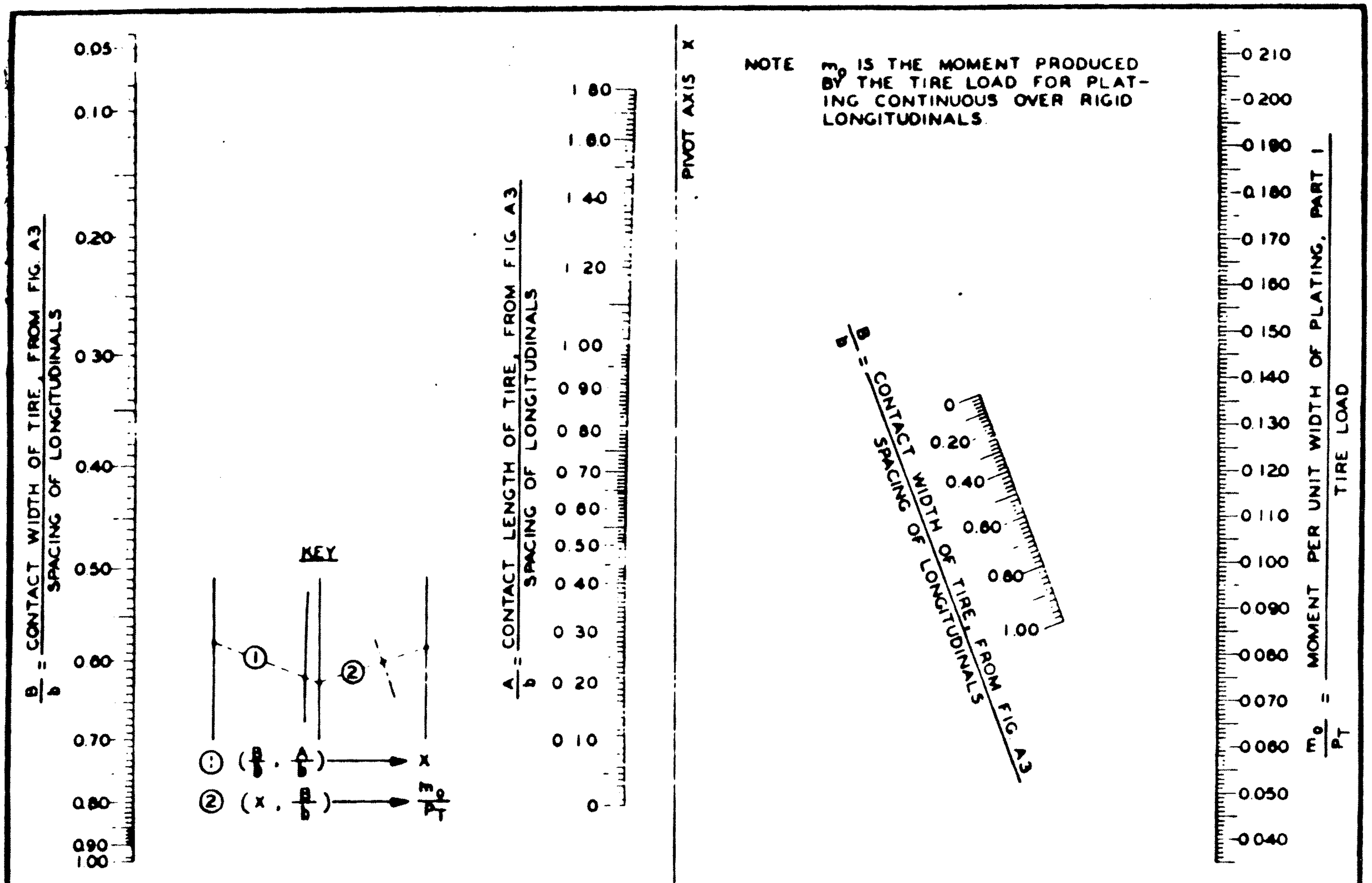
POSITIVE DEAD LOAD MOMENT = $\frac{1}{24}qL^2 = M_d$ = __________

TOTAL MOMENT = $M_s = M + M_d$ = __________

MAXIMUM BENDING STRESS = $\frac{M_s}{S}$ = __________

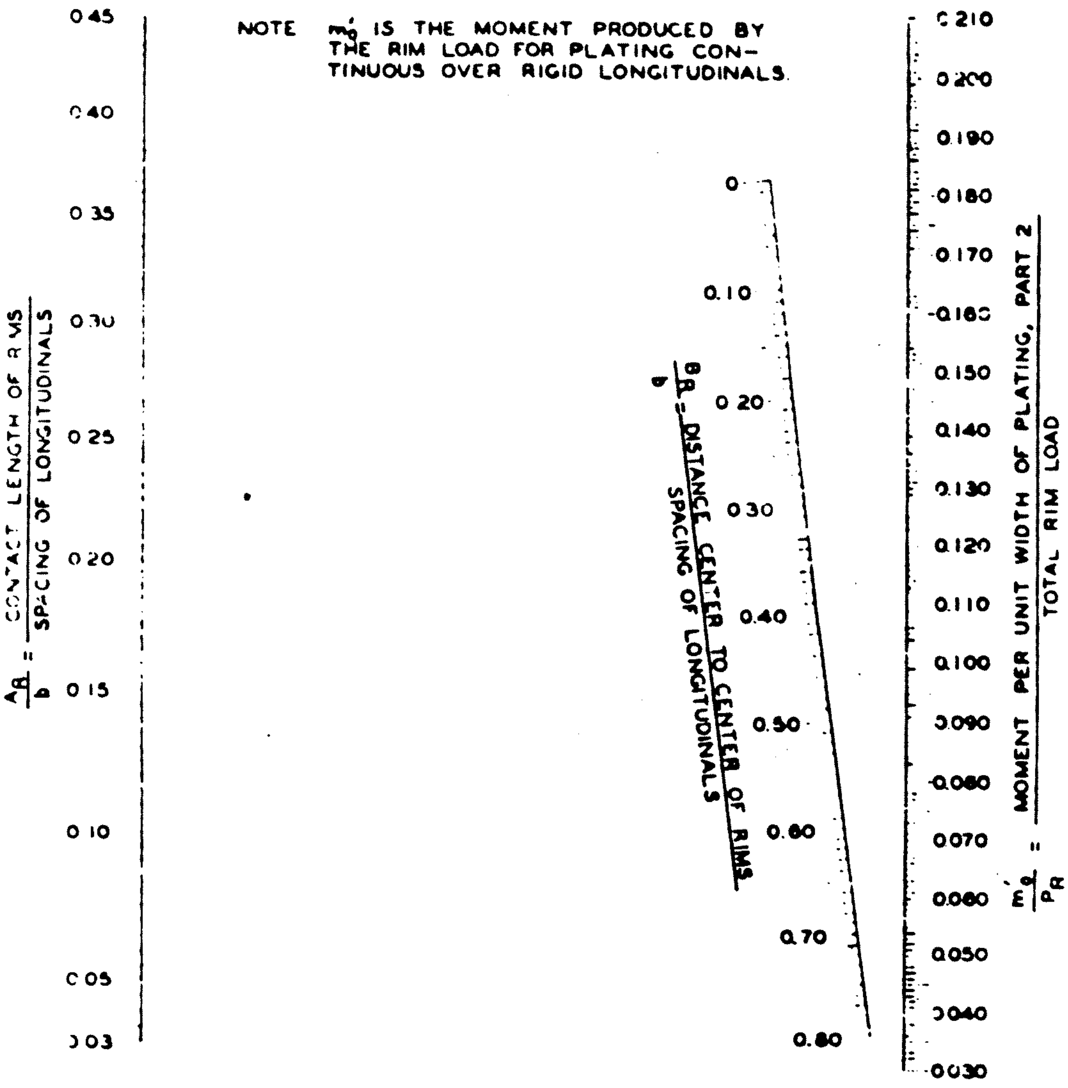
FLIGHT DECK DESIGN -- PLATE DECK

FIG. B2 MAXIMUM MOMENT AND BENDING STRESS IN LONGITUDINALS



FLIGHT DECK DESIGN -- PLATE DECK

FIG. B3-1 MAXIMUM BENDING MOMENT PER UNIT WIDTH OF PLATING -- PART I

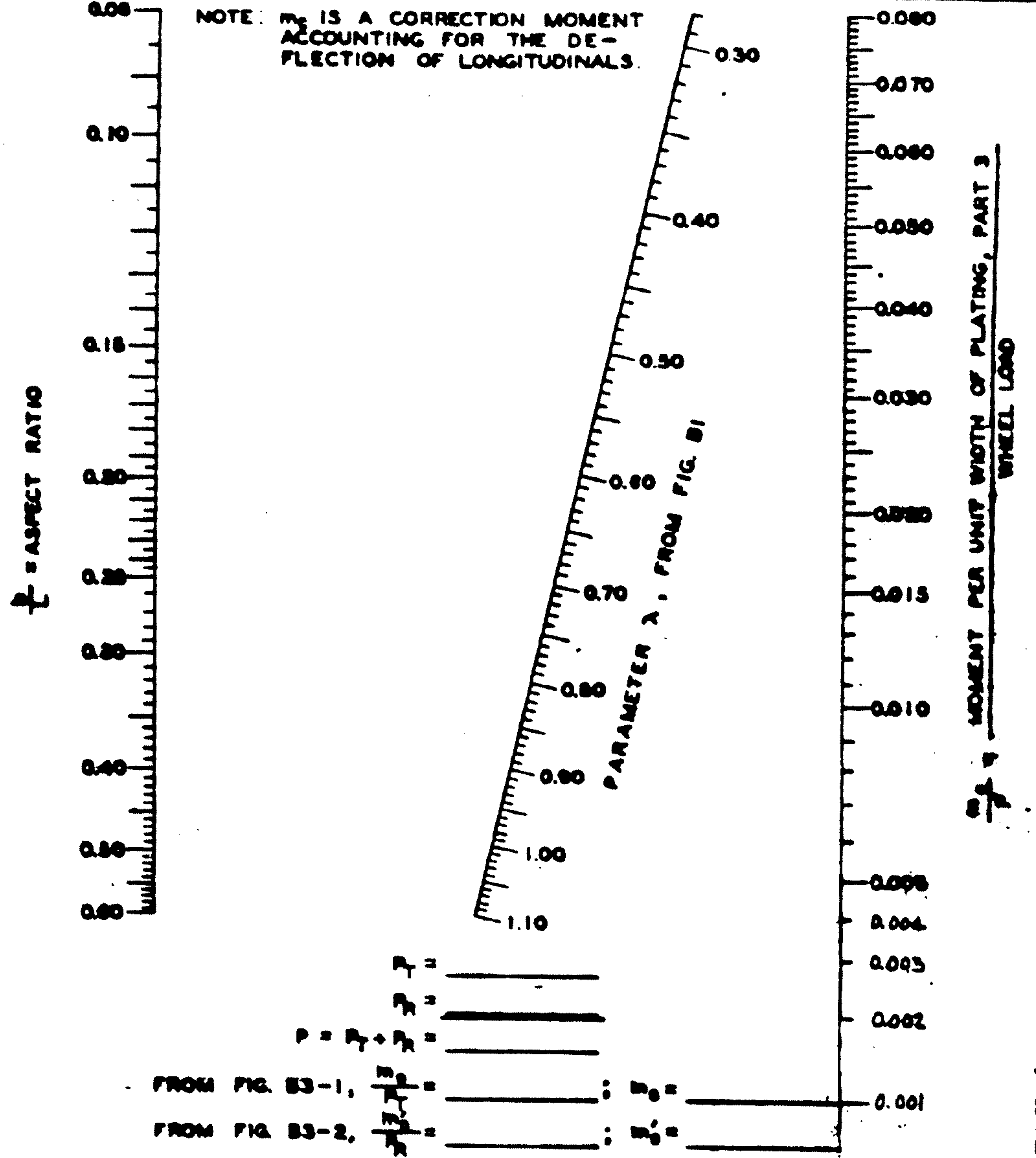


NOTE m_o' IS THE MOMENT PRODUCED BY THE RIM LOAD FOR PLATING CONTINUOUS OVER RIGID LONGITUDINALS.

FLIGHT DECK DESIGN --PLATE DECK

FIG. B3-2 MAXIMUM BENDING MOMENT PER UNIT WIDTH OF PLATING --PART 2

NOTE: m_e IS A CORRECTION MOMENT ACCOUNTING FOR THE DEFLECTION OF LONGITUDINALS.



P_T = ____________

P_R = ____________

$P = P_T + P_R$ = ____________

FROM FIG. B3-1, $\frac{m_a}{P_T}$ = ____________ ; m_a = ____________

FROM FIG. B3-2, $\frac{m_b'}{P_R}$ = ____________ ; m_b' = ____________

FROM THIS FIG., $\frac{m_e}{P}$ = ____________ ; m_e = ____________

TOTAL MAXIMUM MOMENT, $m = m_a + m_b' + m_e$ = ____________

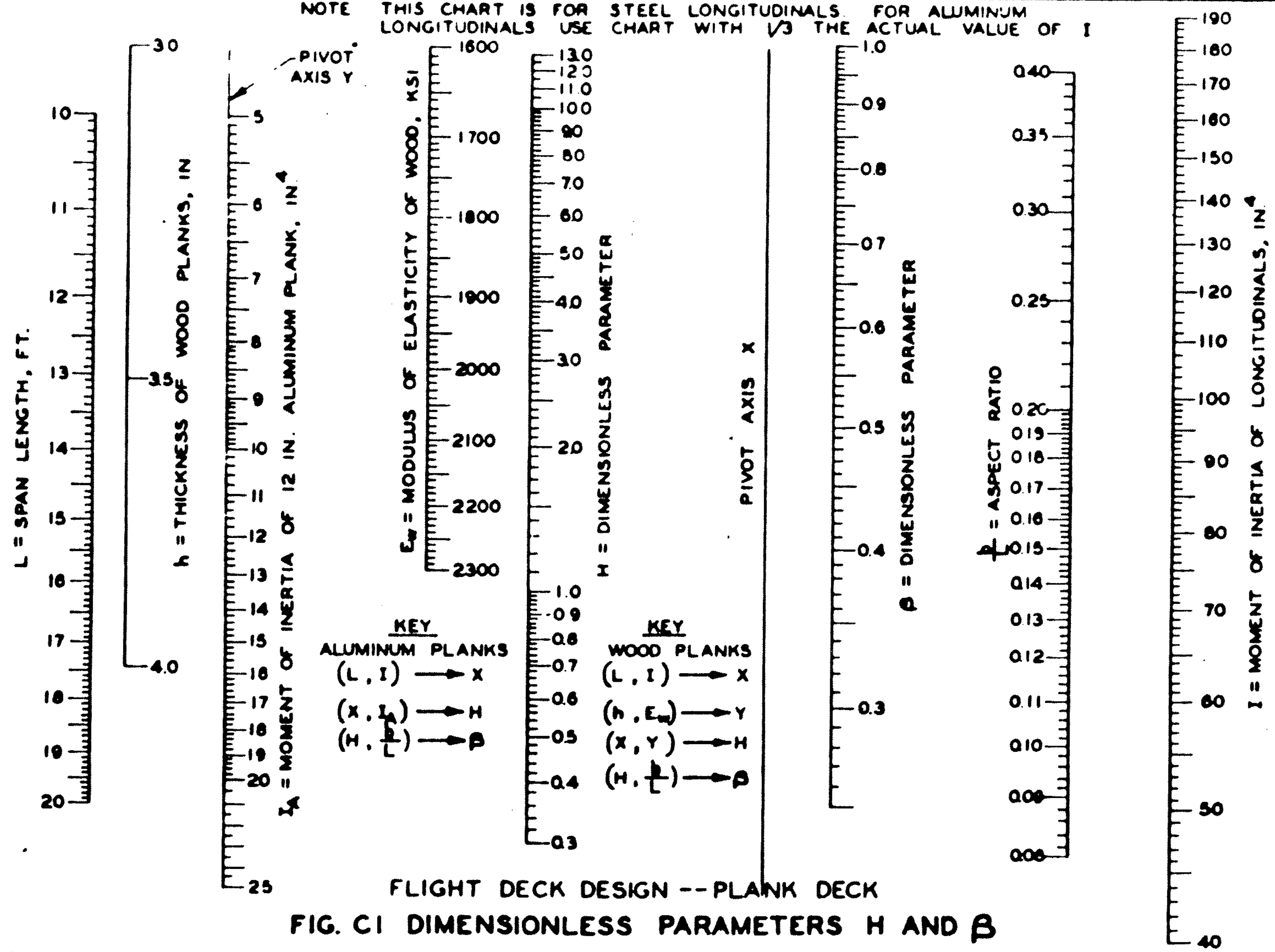
PLATE THICKNESS, h = ____________

MAX. BENDING STRESS = $\frac{6m}{h^2}$ = ____________

FLIGHT DECK DESIGN -- PLATE DECK

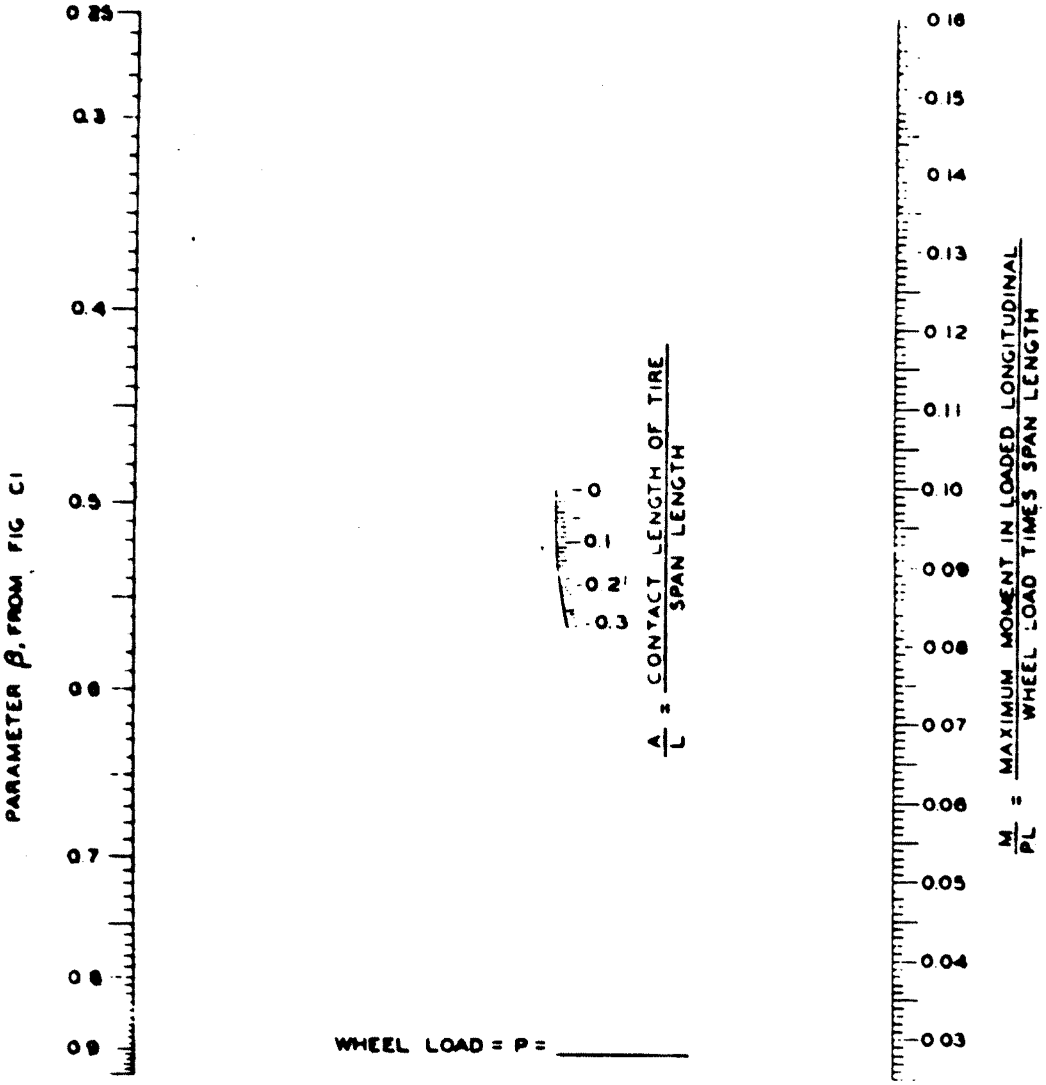
FIG. B3-3 MAXIMUM BENDING MOMENT PER UNIT WIDTH OF PLATING -- PART 3 AND TOTAL

NOTE THIS CHART IS FOR STEEL LONGITUDINALS. FOR ALUMINUM LONGITUDINALS USE CHART WITH 1/3 THE ACTUAL VALUE OF I



FLIGHT DECK DESIGN -- PLANK DECK

FIG. C1 DIMENSIONLESS PARAMETERS H AND β



WHEEL LOAD = P = __________

SPAN LENGTH = L = __________

FROM FIG. D1, SECTION MODULUS = S = __________

FROM ABOVE NOMOGRAPH, $\frac{M}{PL}$ = __________ , M = __________

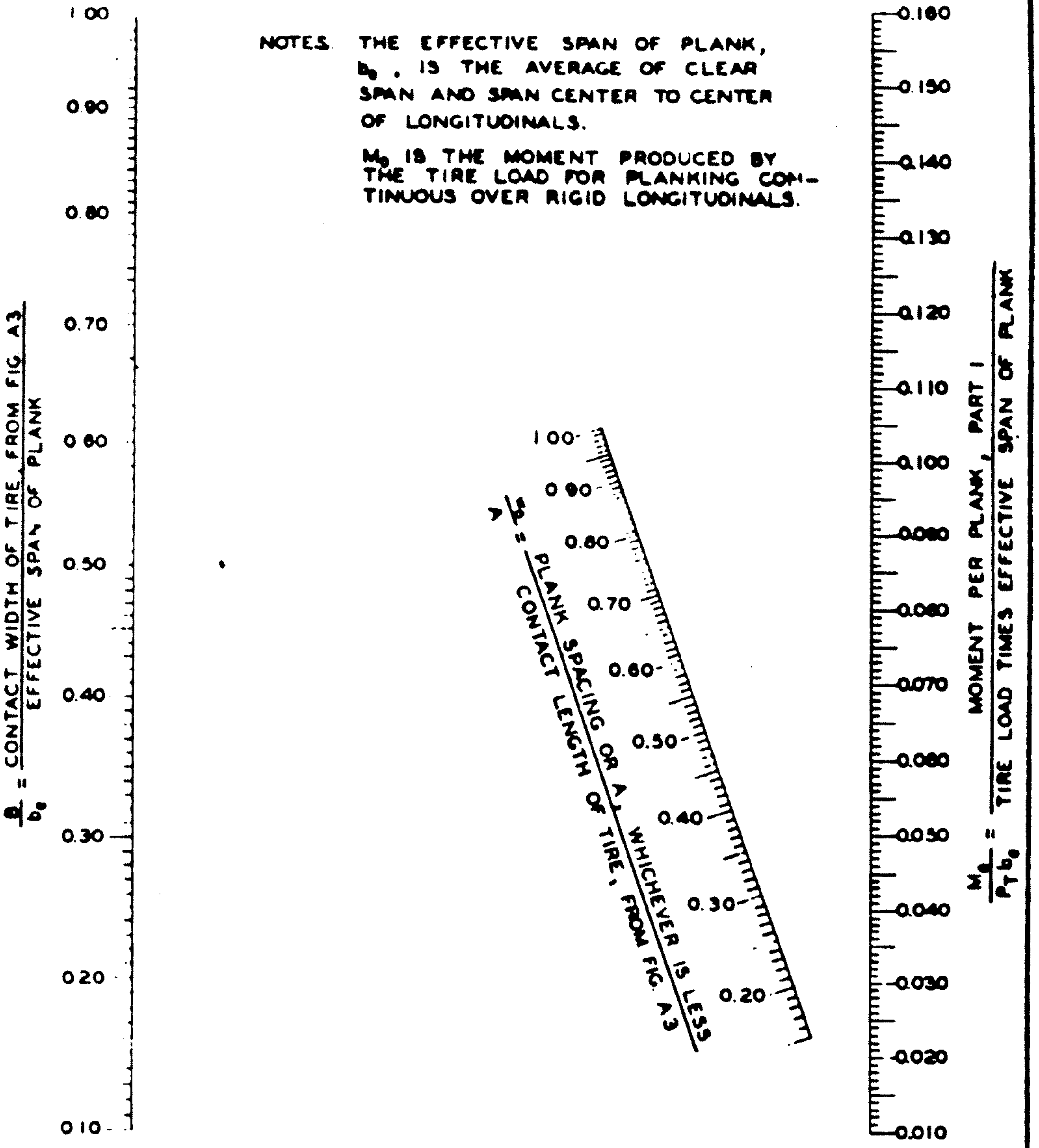
POSITIVE DEAD LOAD MOMENT = $\frac{1}{24} qL^2 = M_d$ = __________

TOTAL MOMENT = $M_s = M + M_d$ = __________

MAXIMUM BENDING STRESS = $\frac{M_s}{S}$ = __________

FLIGHT DECK DESIGN -- PLANK DECK

FIG. C2 MAXIMUM MOMENT AND BENDING STRESS IN LONGITUDINALS



NOTES. THE EFFECTIVE SPAN OF PLANK, b_e, IS THE AVERAGE OF CLEAR SPAN AND SPAN CENTER TO CENTER OF LONGITUDINALS.

M_o IS THE MOMENT PRODUCED BY THE TIRE LOAD FOR PLANKING CONTINUOUS OVER RIGID LONGITUDINALS.

P_T = ____________

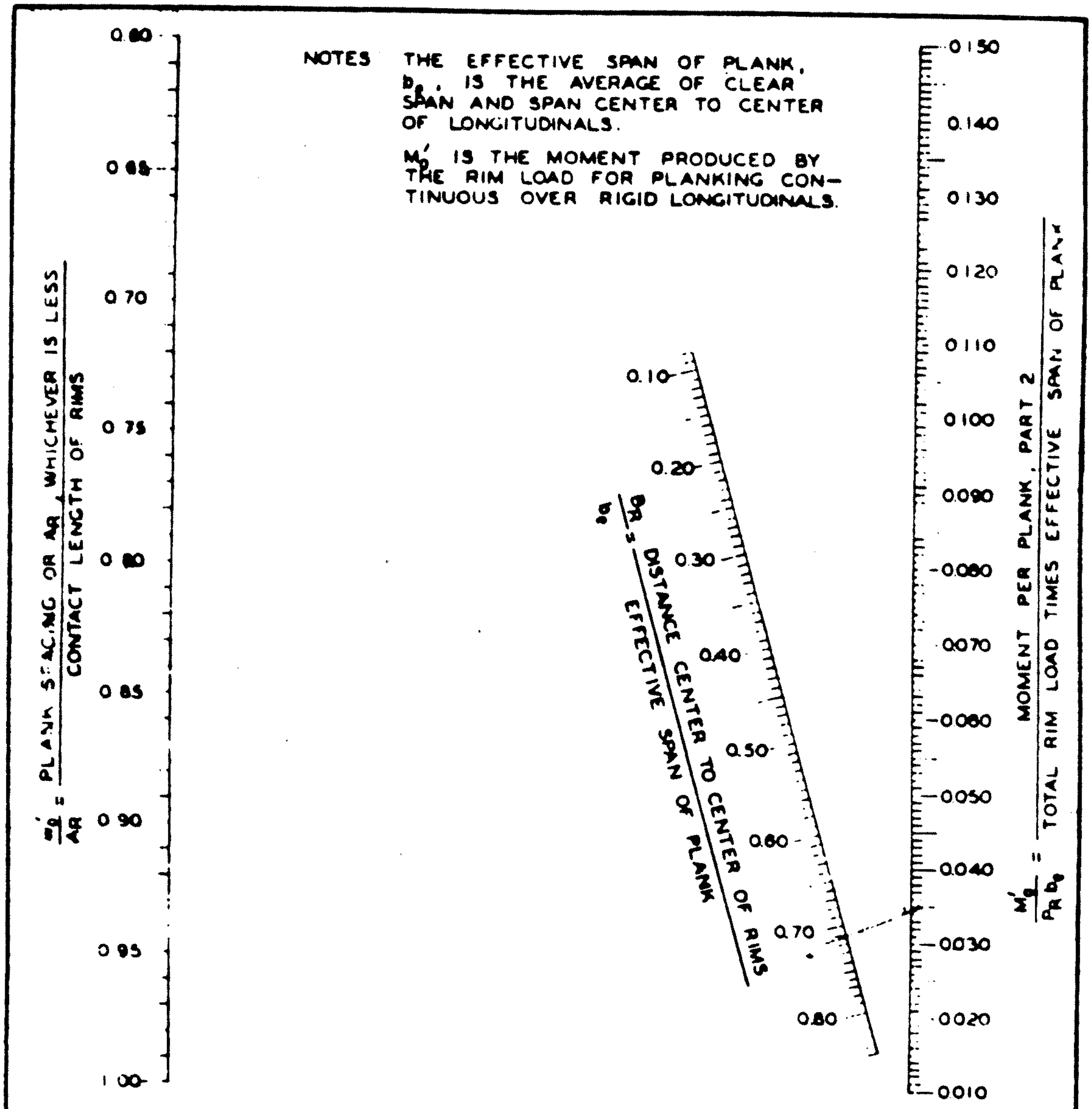
b_e = ____________

$\frac{M_o}{P_T b_e}$ = ____________

M_o = ____________

FLIGHT DECK DESIGN -- PLANK DECK

FIG. C3-1 MAXIMUM BENDING MOMENT PER PLANK -- PART I



NOTES THE EFFECTIVE SPAN OF PLANK, b_e, IS THE AVERAGE OF CLEAR SPAN AND SPAN CENTER TO CENTER OF LONGITUDINALS.

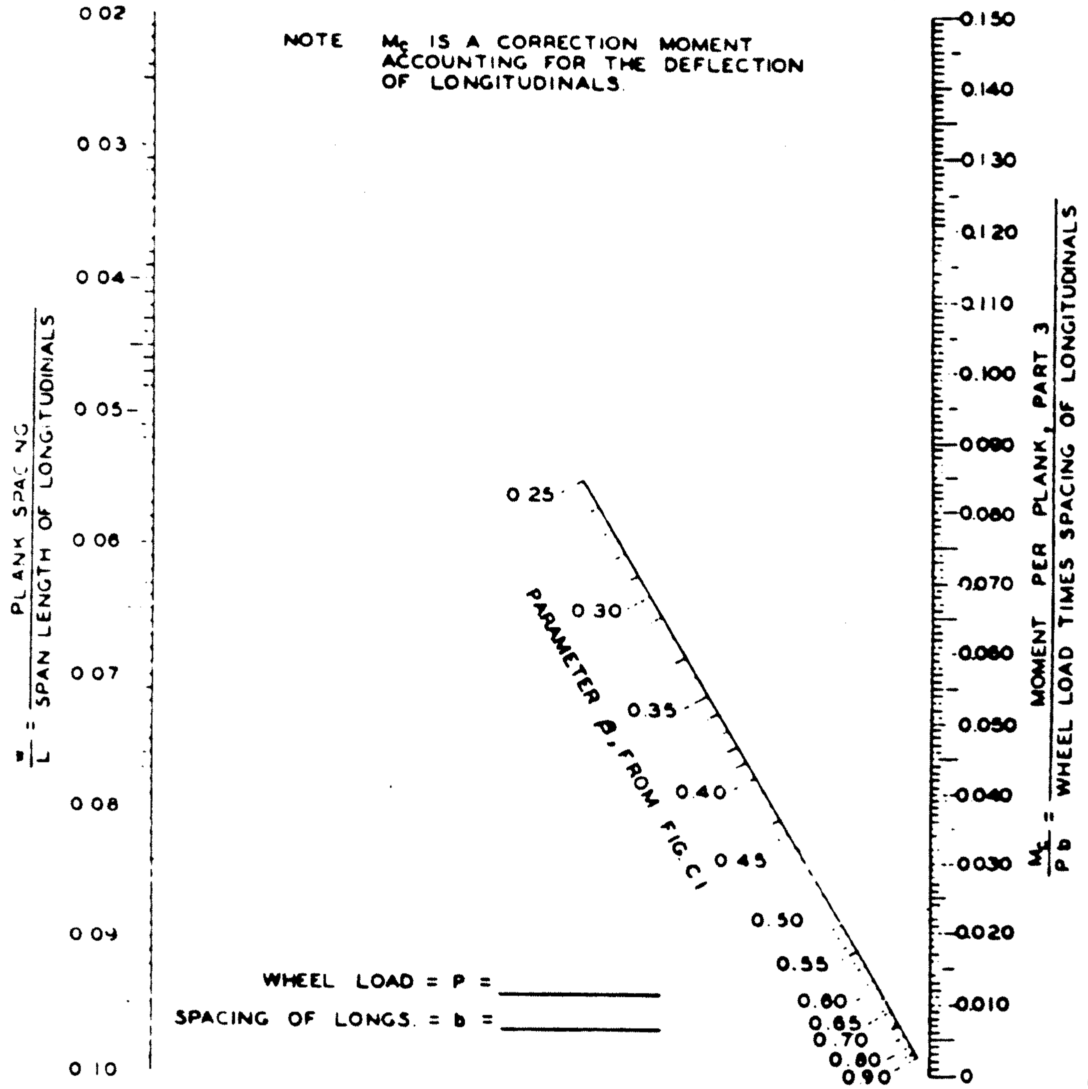
M'_e IS THE MOMENT PRODUCED BY THE RIM LOAD FOR PLANKING CONTINUOUS OVER RIGID LONGITUDINALS.

P_R = ____________ b_e = ____________

$\frac{M'_e}{P_R b_e}$ = ____________ ; M'_e = ____________

FLIGHT DECK DESIGN -- PLANK DECK

FIG. C3-2 MAXIMUM BENDING MOMENT PER PLANK -- PART 2



NOTE M_c IS A CORRECTION MOMENT ACCOUNTING FOR THE DEFLECTION OF LONGITUDINALS.

WHEEL LOAD = P = ____________

SPACING OF LONGS. = b = ____________

FROM FIG. C3-1, M_o = ____________

FROM FIG. C3-2, M_o' = ____________

FROM ABOVE NOMOGRAPH, $\frac{M_c}{P\,b}$ = ____________ ; M_c = ____________

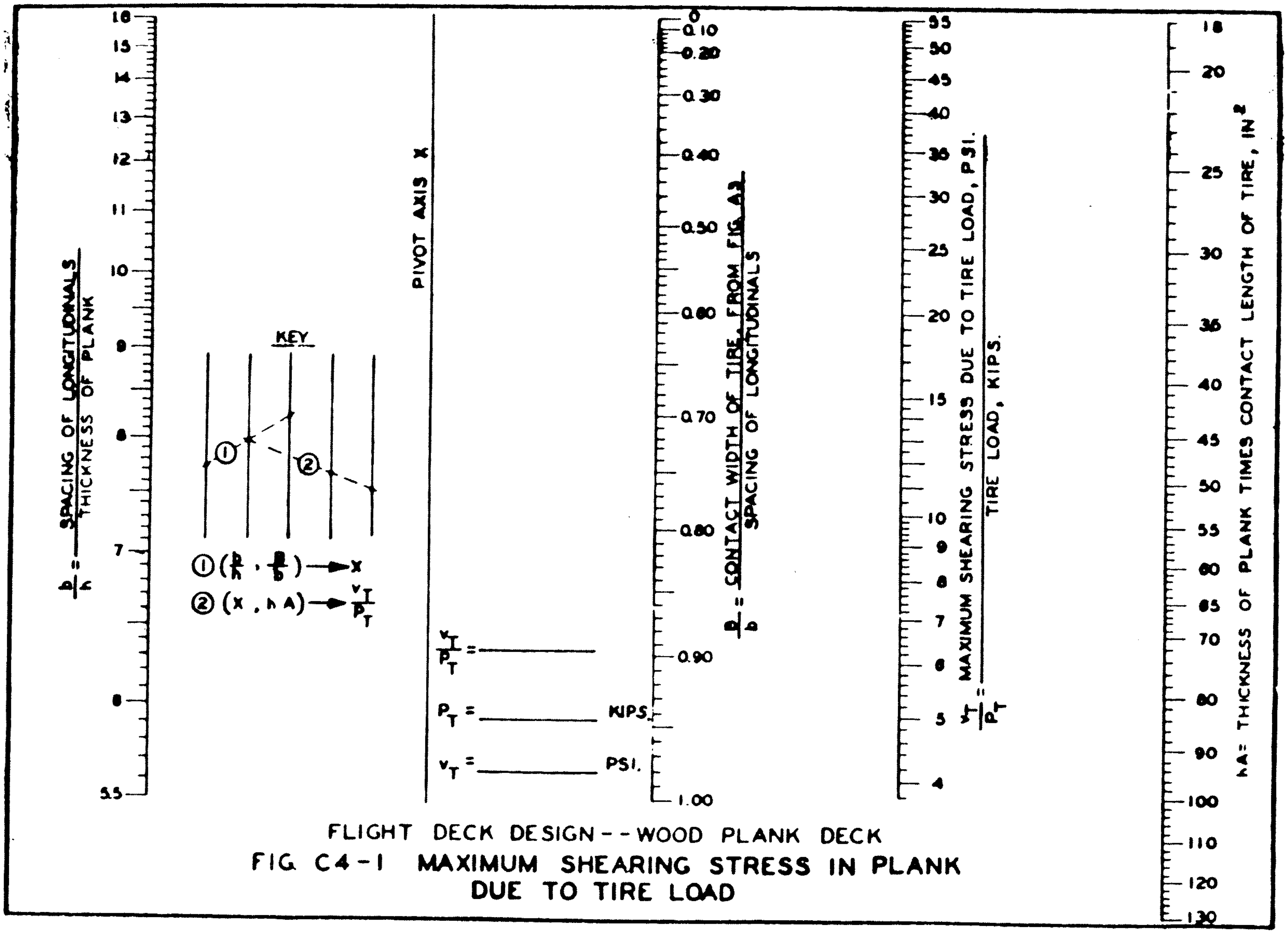
TOTAL MAX. MOMENT PER PLANK = $M_p = M_o + M_o' + M_c$ = ____________

SECTION MODULUS OF PLANK = S_p = ____________

MAX. BENDING STRESS IN PLANK = $\frac{M_p}{S_p}$ = ____________

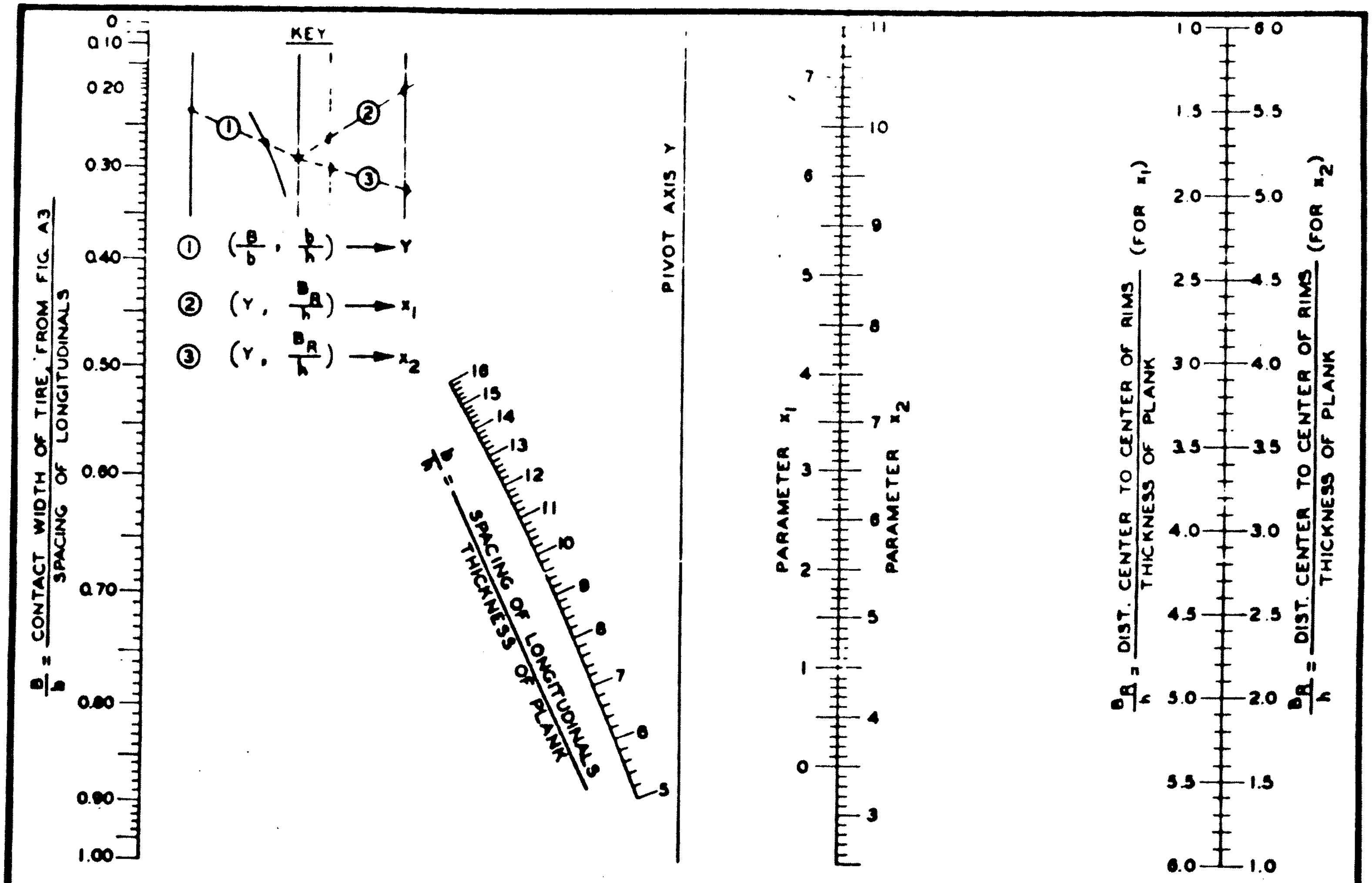
FLIGHT DECK DESIGN -- PLANK DECK

FIG. C3-3 MAXIMUM BENDING MOMENT PER PLANK -- PART 3 AND TOTAL



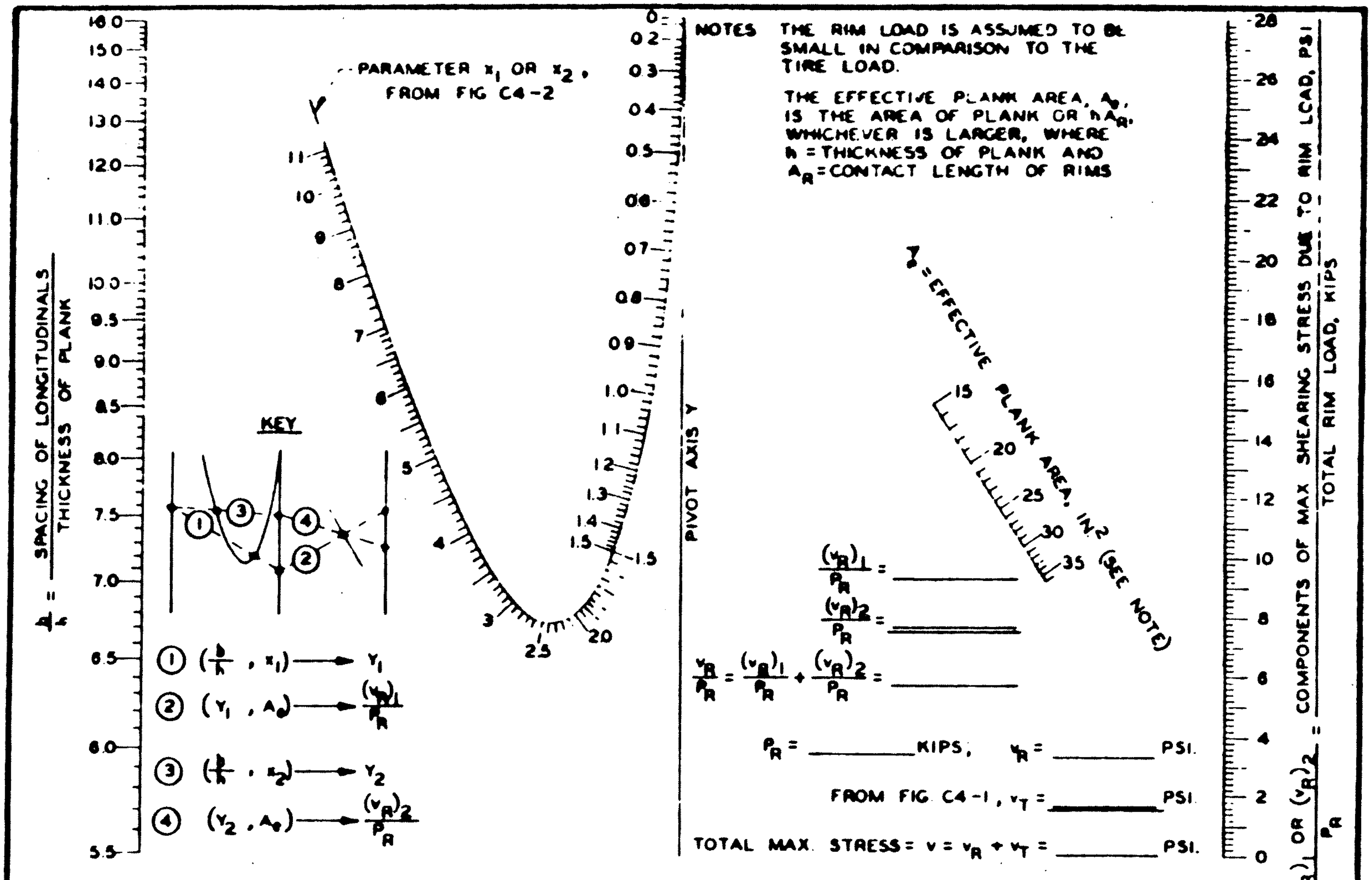
FLIGHT DECK DESIGN--WOOD PLANK DECK

FIG. C4-1 MAXIMUM SHEARING STRESS IN PLANK DUE TO TIRE LOAD



FLIGHT DECK DESIGN--WOOD PLANK DECK

FIG. C4-2 DIMENSIONLESS PARAMETERS x_1 AND x_2 FOR USE IN FIG. C4-3



NOTES THE RIM LOAD IS ASSUMED TO BE SMALL IN COMPARISON TO THE TIRE LOAD.

THE EFFECTIVE PLANK AREA, A_e, IS THE AREA OF PLANK OR hA_R, WHICHEVER IS LARGER, WHERE h = THICKNESS OF PLANK AND A_R = CONTACT LENGTH OF RIMS

① $(\frac{b}{h}, x_1) \longrightarrow Y_1$

② $(Y_1, A_e) \longrightarrow \frac{(v_R)_1}{P_R}$

③ $(\frac{b}{h}, x_2) \longrightarrow Y_2$

④ $(Y_2, A_e) \longrightarrow \frac{(v_R)_2}{P_R}$

$\frac{(v_R)_1}{P_R}$ = ________

$\frac{(v_R)_2}{P_R}$ = ________

$\frac{v_R}{P_R} = \frac{(v_R)_1}{P_R} + \frac{(v_R)_2}{P_R}$ = ________

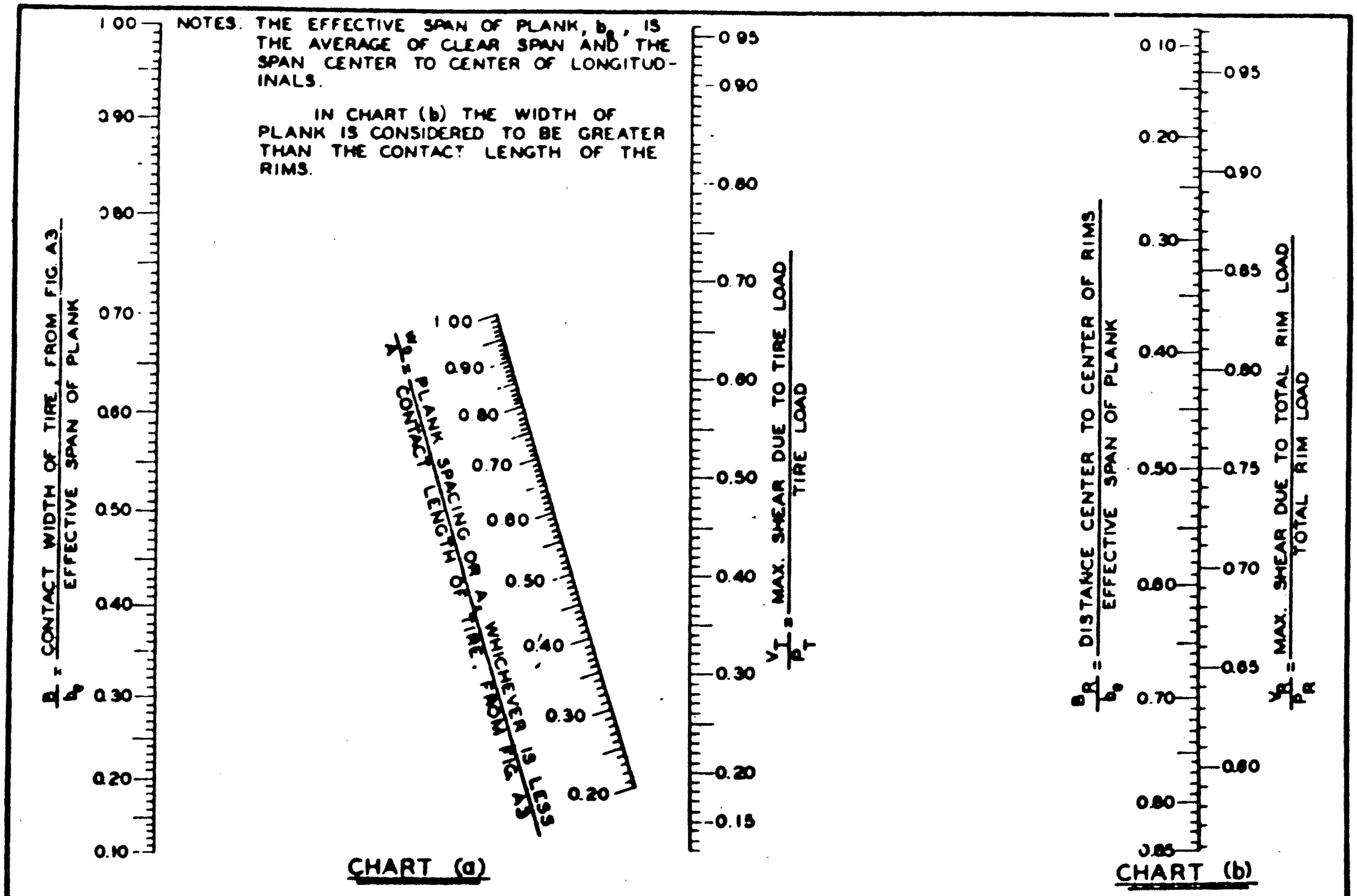
P_R = ________ KIPS, v_R = ________ PSI.

FROM FIG. C4-1, v_T = ________ PSI.

TOTAL MAX. STRESS = $v = v_R + v_T$ = ________ PSI.

FLIGHT DECK DESIGN -- WOOD PLANK DECK

FIG. C4-3 MAXIMUM SHEARING STRESS IN PLANK DUE TO RIM LOAD AND TOTAL



NOTES. THE EFFECTIVE SPAN OF PLANK, b_e, IS THE AVERAGE OF CLEAR SPAN AND THE SPAN CENTER TO CENTER OF LONGITUDINALS.

IN CHART (b) THE WIDTH OF PLANK IS CONSIDERED TO BE GREATER THAN THE CONTACT LENGTH OF THE RIMS.

FLIGHT DECK DESIGN--ALUMINUM PLANK DECK
FIG. C5-1 MAXIMUM SHEAR PER PLANK

NOMENCLATURE Q_p = STATICAL MOMENT OF CROSS SECTION OF PLANK ABOUT ITS NEUTRAL AXIS

I_p = MOMENT OF INERTIA OF PLANK ABOUT ITS NEUTRAL AXIS

t_p = TOTAL THICKNESS OF CROSS SECTION OF PLANK ACROSS ITS NEUTRAL AXIS

THE SYMBOLS Q'_p, I'_p AND t'_p DENOTE THE CORRESPONDING QUANTITIES FOR THE EFFECTIVE SECTION OF THE WEAKEST WEB OF THE PLANK

FROM CHART (a) OF FIG C5-1, $\frac{V_T}{P_T}$ = ______________

TIRE LOAD = P_T = ______________

MAX SHEAR DUE TO TIRE LOAD = V_T = ______________

MAX SHEARING STRESS DUE TO TIRE LOAD = $v_T = \frac{V_T Q_p}{I_p t_p}$ = ______________

FROM CHART (b) OF FIG C5-1, $\frac{V_R}{P_R}$ = ______________

RIM LOAD = P_R = ______________

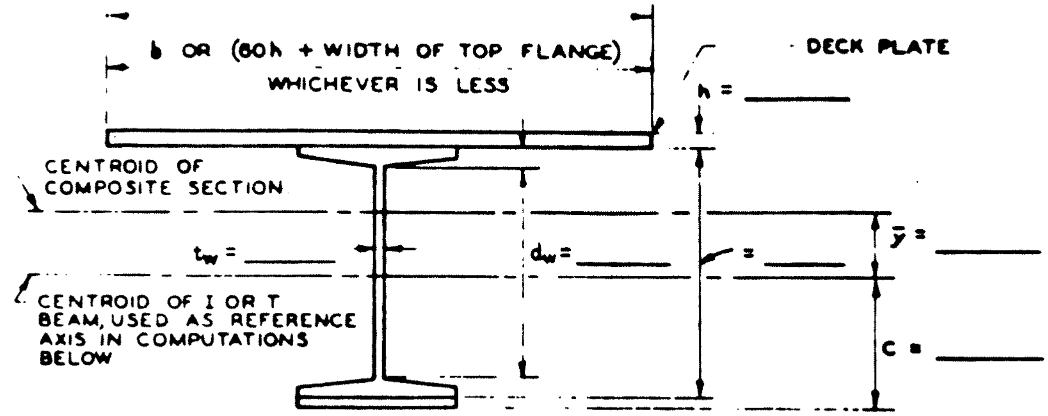
MAX SHEAR DUE TO RIM LOAD = V_R = ______________

MAX SHEARING STRESS DUE TO RIM LOAD = $v_R = \frac{V_R Q'_p}{I'_p t'_p}$ = ______________

TOTAL MAX. SHEARING STRESS = $v = v_R + v_T$ = ______________

FLIGHT DECK DESIGN--ALUMINUM PLANK DECK

FIG. C5-2 SUMMARY SHEET FOR MAXIMUM SHEARING STRESS IN PLANK



SECTION	A_o IN^2 (1)	y IN (2)	$A_o y$ IN^3 (3)	$A_o y^2$ IN^4 (4)	I_o IN^4 (5)
I OR T					
DECK PLATE					
COVER PLATE					
SUMS					

NOMENCLATURE

A_o = AREA OF EACH COMPONENT OF COMPOSITE BEAM.

y = DISTANCE FROM CENTROID OF EACH COMPONENT TO REFERENCE AXIS, WHICH IS TAKEN HERE AS CENTROID OF ROLLED SECTION.

I_o = MOMENT OF INERTIA OF EACH COMPONENT ABOUT OWN CENTROID.

PROCEDURE

1 - LIST A_o, y AND I_o IN COLUMNS (1), (2) AND (5) FOR EACH COMPONENT.
2 - COMPUTE PRODUCTS FOR COLUMNS (3) AND (4).
3 - SUM COLUMNS (1), (3), (4) AND (5).
4 - COMPUTE $\bar{y}$, I AND S AS INDICATED BELOW.

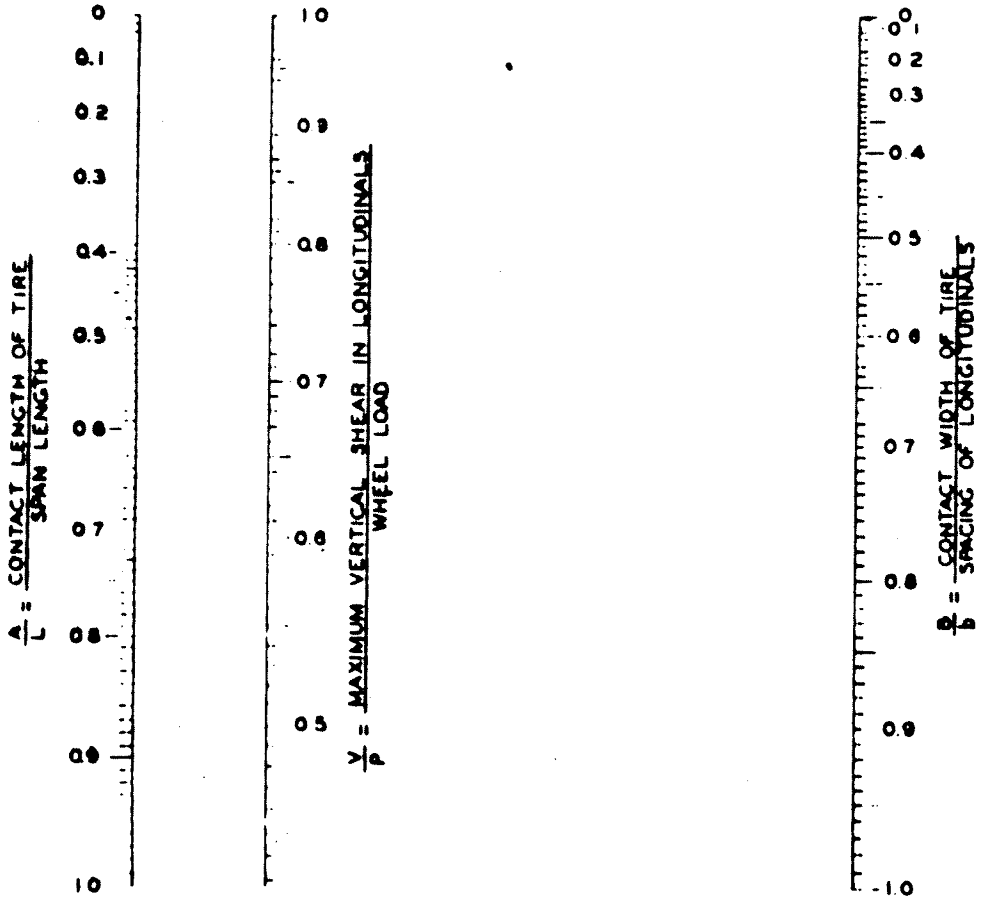
DISTANCE CENTROID OF ROLLED SECTION TO CENTROID OF COMPOSITE BEAM $= \bar{y} = \dfrac{\text{SUM (3)}}{\text{SUM (1)}} =$ ______

MOMENT OF INERTIA OF COMPOSITE BEAM $= I = \text{SUM}(4) + \text{SUM}(5) - \bar{y}\ \text{SUM}(3) =$ ______

SECTION MODULUS OF COMPOSITE BEAM $= S = \dfrac{I}{c + \bar{y}} =$ ______

FLIGHT DECK DESIGN

FIG. D1 SECTION PROPERTIES OF LONGITUDINALS



WHEEL LOAD = P = ____________

FROM FIG. D1 { THICKNESS OF WEB = t_w = ____________

DEPTH OF WEB = d_w = ____________

FROM ABOVE NOMOGRAPH, $\frac{V}{P}$ = ____________ ; V = ____________

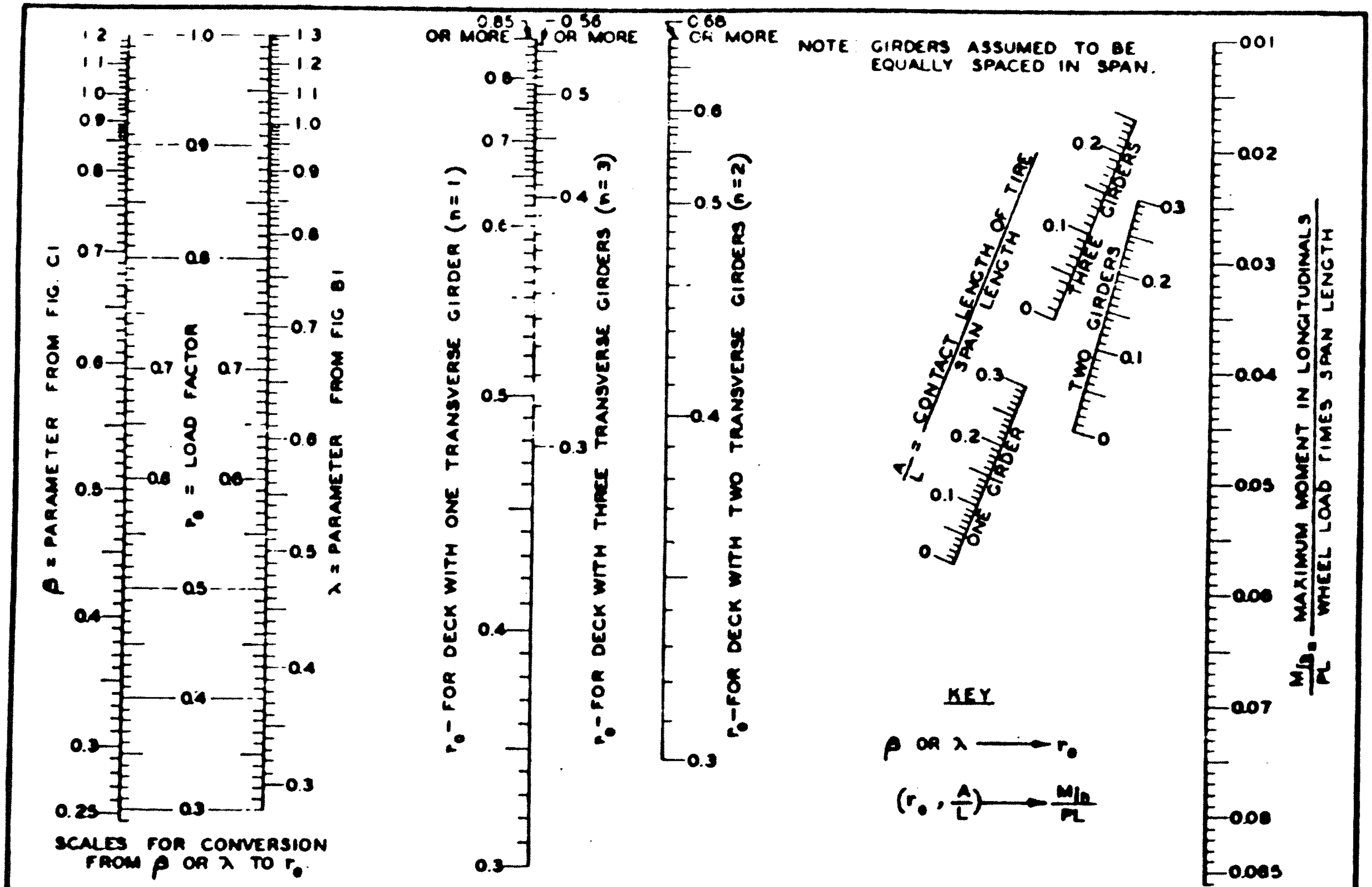
SHEAR DUE TO DEAD LOAD = $V_d = \frac{1}{2} qL$ = ____________

TOTAL SHEAR = $V_s = V + V_d$ = ____________

APPROX. MAXIMUM SHEARING STRESS = $\frac{V_s}{t_w d_w}$ = ____________

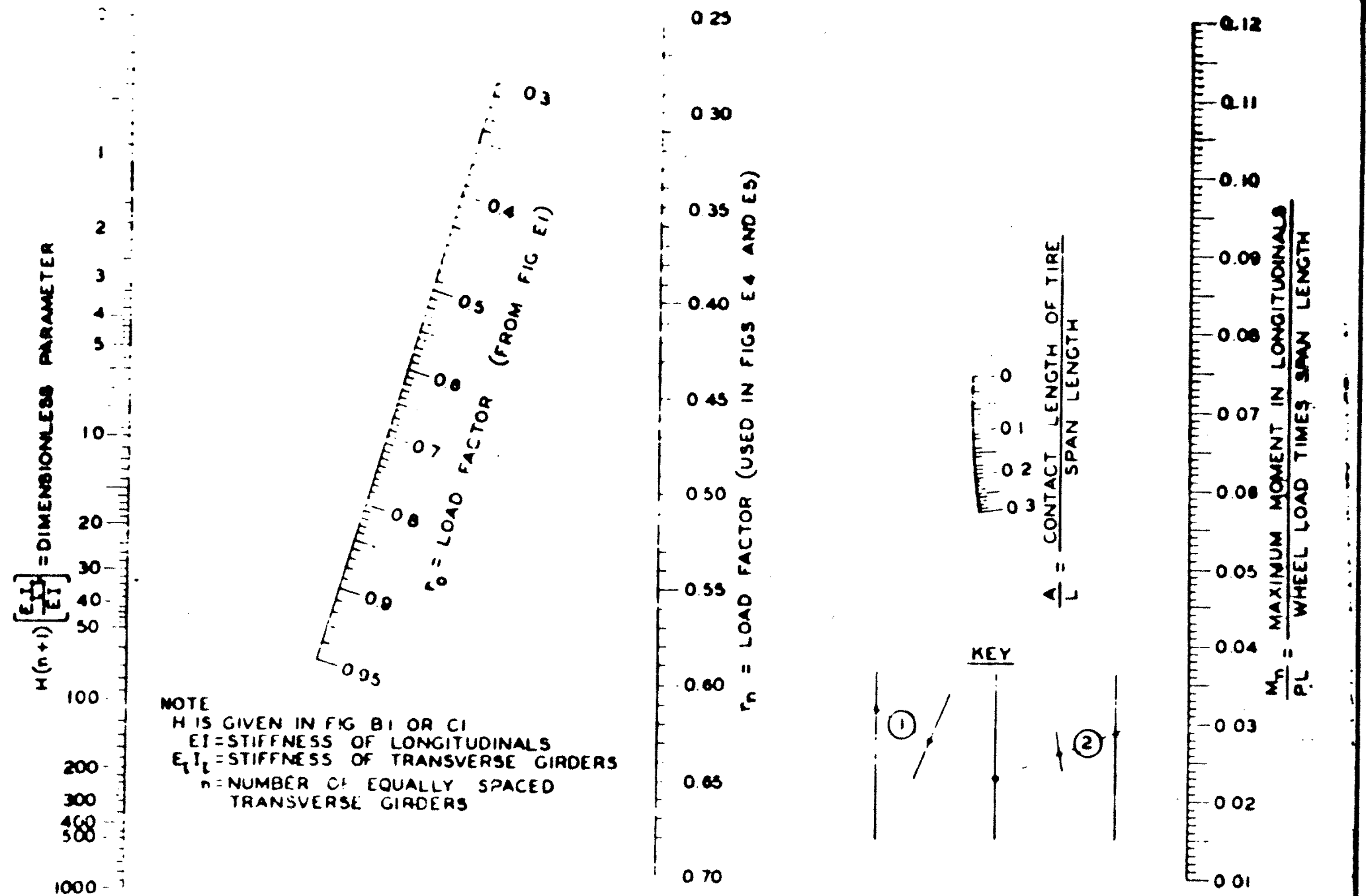
FLIGHT DECK DESIGN

FIG. D2 MAXIMUM SHEAR AND SHEARING STRESS IN LONGITUDINALS



FLIGHT DECK DESIGN--TRANSVERSE GIRDERS

FIG. E1 MAXIMUM MOMENT IN LONGITUDINALS FOR RIGID TRANSVERSE GIRDERS



NOTE
H IS GIVEN IN FIG B1 OR C1
EI = STIFFNESS OF LONGITUDINALS
$E_t I_t$ = STIFFNESS OF TRANSVERSE GIRDERS
n = NUMBER OF EQUALLY SPACED TRANSVERSE GIRDERS

FLIGHT DECK DESIGN -- TRANSVERSE GIRDERS

FIG. E2 MAXIMUM MOMENT IN LONGITUDINALS FOR LOAD OVER TRANSVERSE GIRDERS

WHEEL LOAD = P = __________

SPAN LENGTH = L = __________

FROM FIG D1, SECTION MODULUS = S = __________

FROM FIG B2 OR C2, $\frac{M}{PL}$ = __________

FROM FIG E2, $\frac{M_n}{PL}$ = __________

$\frac{1}{2}\left(\frac{M}{PL} + \frac{M_n}{PL}\right)$ = __________

FROM FIG E1, $\frac{M_m}{PL}$ = __________

$\frac{M_x}{PL} = \frac{M_m}{PL}$ OR $\frac{1}{2}\left(\frac{M}{PL} + \frac{M_n}{PL}\right)$, WHICHEVER IS LARGER

$\frac{M_x}{PL}$ = __________ ; M_x = __________

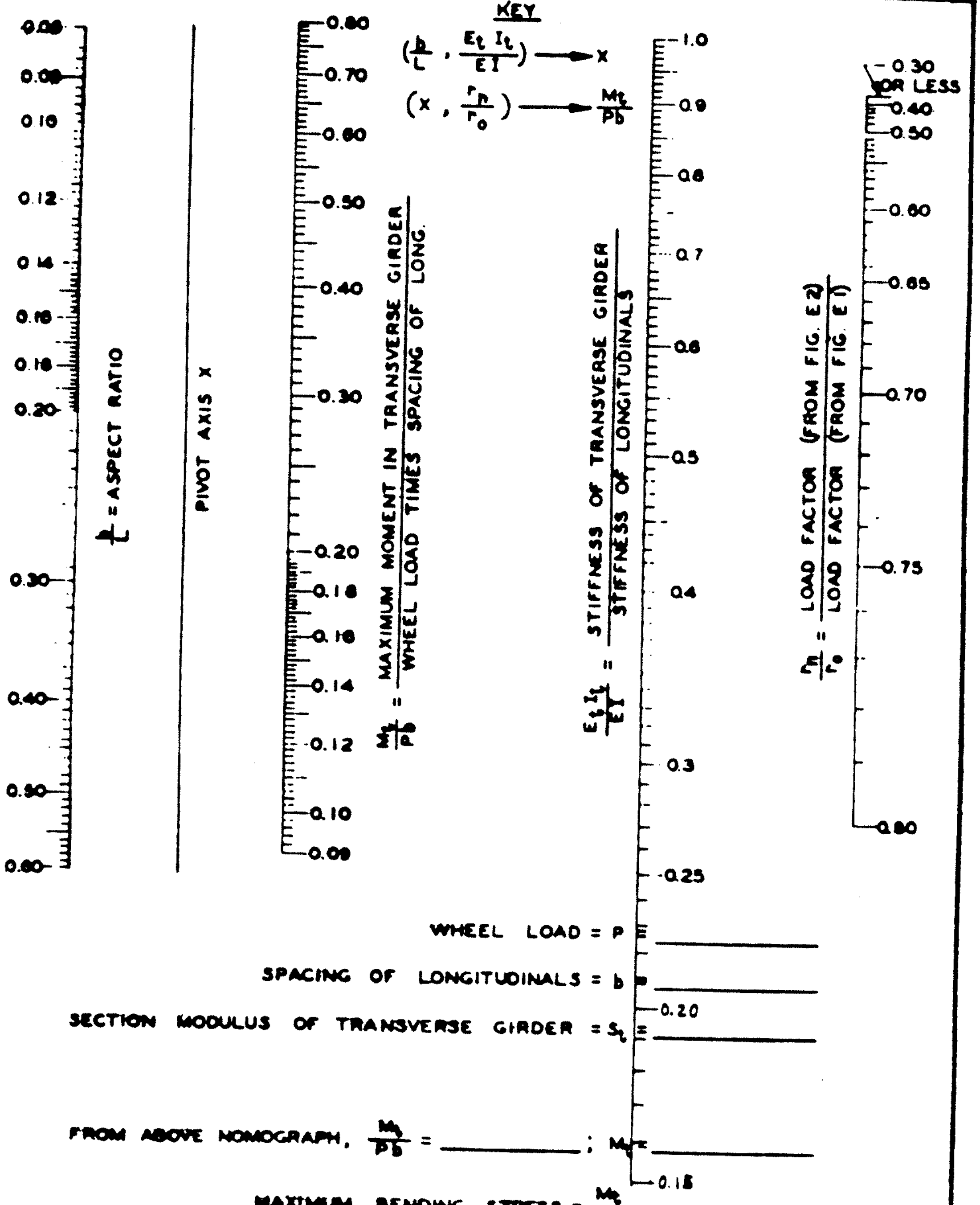
POSITIVE DEAD LOAD MOMENT = $\frac{1}{24} qL^2 = M_d$ = __________

TOTAL MOMENT = $M_s = M_x + M_d$ = __________

MAXIMUM BENDING STRESS = $\frac{M_s}{S}$ = __________

FLIGHT DECK DESIGN - TRANSVERSE GIRDERS

FIG. E3 SUMMARY SHEET FOR MAXIMUM MOMENT IN LONGITUDINALS



WHEEL LOAD = P = ____________

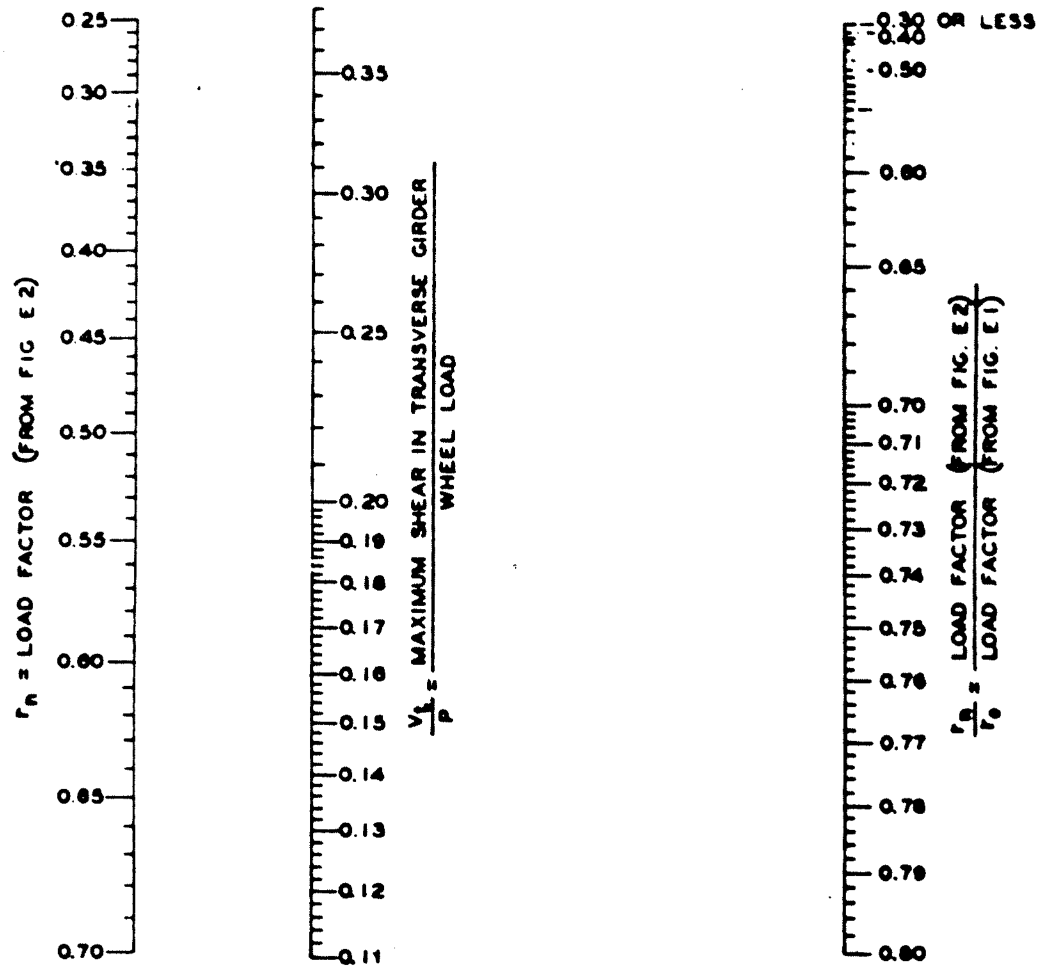
SPACING OF LONGITUDINALS = b = ____________

SECTION MODULUS OF TRANSVERSE GIRDER = S_t = ____________

FROM ABOVE NOMOGRAPH, $\frac{M_t}{Pb}$ = ____________ ; M_t = ____________

MAXIMUM BENDING STRESS = $\frac{M_t}{S_t}$ = ____________

FLIGHT DECK DESIGN -- TRANSVERSE GIRDERS
FIG. E4 MAXIMUM MOMENT AND BENDING STRESS IN TRANSVERSE GIRDERS



WHEEL LOAD = P = ____________

THICKNESS OF WEB OF TRANSVERSE GIRDER = t_w = ____________

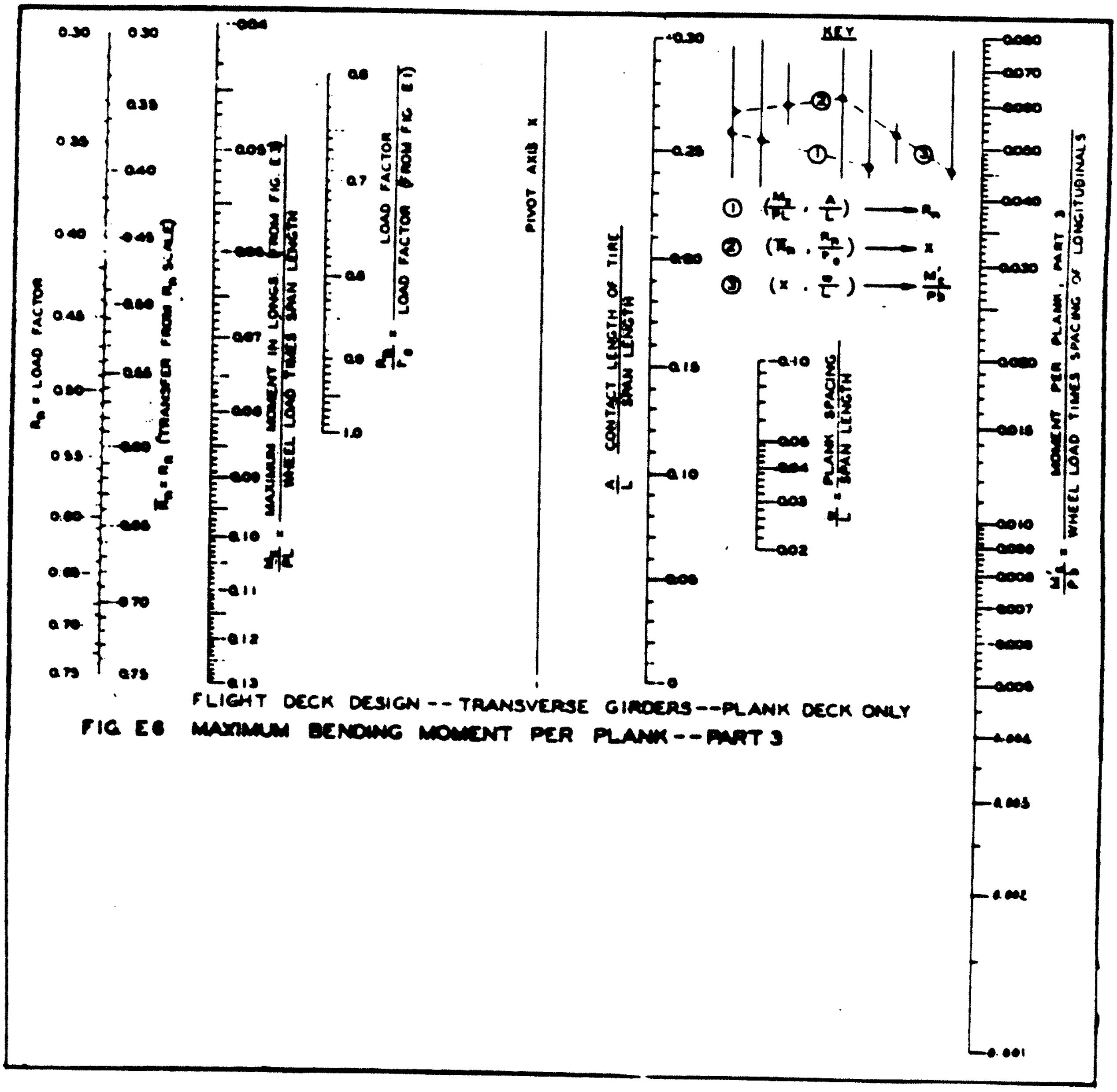
DEPTH OF WEB OF TRANSVERSE GIRDER = d_w = ____________

FROM ABOVE NOMOGRAPH, $\frac{V_\ell}{P}$ = ____________ ; V_ℓ = ____________

APPROXIMATE MAXIMUM SHEARING STRESS = $\frac{V_\ell}{d_w t_w}$ = ____________

FLIGHT DECK DESIGN -- TRANSVERSE GIRDERS

FIG. E5 MAXIMUM SHEAR AND SHEARING STRESS IN TRANSVERSE GIRDERS



FLIGHT DECK DESIGN -- TRANSVERSE GIRDERS--PLANK DECK ONLY

FIG. E6 MAXIMUM BENDING MOMENT PER PLANK--PART 3

WHEEL LOAD = P = ______________

SPACING OF LONGITUDINALS = b = ______________

SECTION MODULUS OF PLANK = S_p = ______________

FROM FIG. C3-1, M_0 = ______________

FROM FIG. C3-2, M'_0 = ______________

FROM FIG. E6, $\frac{M'_c}{Pb}$ = ______________ ; M'_c = ______________

TOTAL MAX. MOMENT PER PLANK = $M_p = M_0 + M'_0 + M'_c$ = ______________

MAX. BENDING STRESS IN PLANK = $\frac{M_p}{S_p}$ = ______________

FLIGHT DECK DESIGN -- TRANSVERSE GIRDERS -- PLANK DECK ONLY

FIG. E7 SUMMARY SHEET FOR MOMENT IN PLANKING (REPLACES FIG. C3-3)