DESIGN DATA SHEET
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

DDS 130-2
1 July 1984

STRUCTURAL DESIGN AND ANALYSIS OF HELICOPTER HANDLING DECKS

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PART I: INTRODUCTION

130-2-a. References

(a) DDS 130-1, Structural Design of Aircraft Handling Decks.
(b) DDS 100-4, Strength of Structural Members.
(c) MIL-STD-1399, Interface Standard for Shipboard Systems, Section 301, Ship Motion and Attitude.
(d) Design of Deck Structures Under Wheel Loads, Jackson and Frieze, RINA, 1980.
(e) Design Manual for Orthotropic Steel Plate Deck Bridges, A.I.S.C., 1963.
(f) Individual Ships Specifications, General Specifications for Ships of the U.S. Navy or General Overhaul Specifications for Surface Ships, as appropriate.
(g) MIL-HDBK-264 (SH), Properties of Steel Shapes, and Plate-Beam Combinations Used in Shipbuilding.
(h) Structural Design Manual for Surface Ships of the U.S. Navy.
(i) NAVAIR Technical Manual 17-1-537, Aircraft Securing and Handling.

130-2-b. Purpose and Scope

This Design Data Sheet provides uniform standards and simplified methods for the analysis of aircraft handling deck structures. The method incorporated in this Design Data Sheet is to be used to analyze plate deck structures with thin plate, (less than one inch thick), and flexible stiffener supports for longitudinally or transversely framed decks. For deck structures with thick plate or rigid bents, see Reference (a).

This Design Data Sheet deals with only those loads resulting from aircraft operations. Other local loadings and the requirements for hull girder bending, as applicable, should be addressed separately in accordance with References (f) and (h).

The method presented herein is based primarily on the previous edition, Reference (a) and, in addition, References (d) and (e). This version takes advantage of the later and more refined techniques of structural analysis, employing accepted principles of structural mechanics with empirical constants determined from static and dynamic tests. Other documents used in the development of this Design Data Sheet are listed in Appendix J.

130-2-c. Symbols, Abbreviations and Definitions

η_{xs} = storm sea ship motion factor, longitudinal to ship
η_{ys} = storm sea ship motion factor, transverse to ship
η_{zs} = storm sea ship motion factor, vertical to ship
X = longitudinal distance from specified center of motion (ft)
Y = transverse distance from specified center of motion (ft)
Z = vertical distance above specified center of motion (ft)
θ_P = pitch angle (rad)
θ_R = roll angle (rad)
T_P = pitch period (sec)

T_R = roll period (sec)
S = surge acceleration (g's)
H = heave acceleration (g's)
η_{xm} = moderate sea ship motion factor, longitudinal to ship
η_{ym} = moderate sea ship motion factor, transverse to ship
η_{zm} = moderate sea ship motion factor, vertical to ship
F_x = ship motion load, longitudinal to ship (kips)
F_y = ship motion load, transverse to ship (kips)
F_z = ship motion load, vertical to ship (kips)
W_P = parked weight of aircraft (kips)
W_M = maximum weight of aircraft (kips)
W_L = light weight of aircraft (kips)
F_w = wind load (kips)
a_s = sail area of aircraft (ft^2)
R_A = auxiliary gear reaction, tail or nose gear (kips)
R_M = total main gear reaction (kips)
F_F = tire friction force (kips)
F_D = ship motion force, vertical to aircraft (kips)
F_L = ship motion force, longitudinal to aircraft (kips)
F_T = ship motion force, transverse to aircraft (kips)
X_G = longitudinal distance from main gear to CG of aircraft (in)
Z_G = height of aircraft CG above deck
CP = center of pressure of sail area
CG = center of gravity of aircraft
Z_P = height of CP above deck (in)
Z_T = height of tiedown above deck (in)
Y_T = transverse distance from centerline of aircraft tiedown (in)
T = tiedown force (kips)
Z_O = equivalent tiedown lever arm (in)
M = aircraft overturning moment (in-k)
Ω = tiedown angle to deck (deg)
R = critical gear reaction (kips)
R_1 = main gear reaction nearest tiedown (kips)
R_2 = main gear reaction farthest from tiedown (kips)
s = distance between main gear (in)
r = distance between main and auxiliary gear (in)
P_b = bottoming load of tire (kips)
A = contact length of tire (in)
B = contact width of tire (in)
L_S = stiffener span length (in)
L_B = beam span length (in)
b = stiffener spacing (in)
b_e = effective breadth of plating (in)
t = plating thickness (in)
d = depth of stiffener (in)
b_f = breadth of flange (in)
t_w = web thickness (in)
t_f = flange thickness (in)
Ψ = dual pitch equivalent load factor, plating
A' = patch length of load on deck (along stiffener) (in)
B' = patch width of load on deck (perpendicular to stiffener (in)

b' = dual tire spacing, center to center (in)

E = modulus of elasticity (ksi)

F_y = yield strength of material (ksi)

F_b = allowable working strength of material (ksi)

b'' = dual patch spacing, center to center

C_1 = non-dimensionalized bending moment coefficient of plating

C_O = deck function coefficient

P = patch load (kips)

P_T = tire load (kips)

σ_P = plate allowable bending stress (ksi)

Φ_1 = patch width load distribution factor, stiffener

Φ_2 = plating load distribution factor, stiffener

Φ_3 = dual patch equivalent load factor, stiffener

Φ_4 = beam loading coefficient

I_S = moment of inertia of plate-stiffener combination (in^4)

I_B = moment of inertia of plate-beam combination (in^4)

γ_{PS} = relative rigidity coefficient of plate-stiffener

γ_{SB} = relative rigidity coefficient of stiffener-beam

M_C = stiffener bending moment correction for elastic supports (in-k)

M_O = stiffener bending moment over rigid supports due to load (in-k)

M_D = stiffener bending moment due to dead load of structure (in-k)

w_D = dead load of plating and stiffener (k/in)

w_S = dead load of stiffener (lb/ft)

w_P = dead load of plating (lb/ft^2)

M_S = total bending moment in stiffener (in-k)

f_{SB} = calculated bending stress in stiffener (ksi)

SM_{MIN} = minimum section modulus of stiffener-plate combination (in^3)

V_O = stiffener shear due to load (kips)

σ_S = stiffener allowable bending stress (ksi)

$\sigma_{primary}$ = hull girder design primary stress (ksi)

V_D = stiffener shear due to dead load (kips)

V_S = total shear in stiffener (kips)

f_{SV} = calculated stiffener shear stress (ksi)

P_O = operational tire pressure (psi)

A_S = shear area of stiffener ($d \times t_w$) (in^2)

e_S = effective span length factor, stiffener

f_P = calculated bending stress in plating (ksi)

e_B = effective span length factor, beam

R_O = unit gear load, beam (k/in)

B_O = unit gear load width, beam (in)

F_r = RAST system holddown force per gear (kips)

F_{T_M} = proportion of ship motion force, transverse to aircraft, acting on main gear, skids (kips)

F_{T_A} = proportion of ship motion force, transverse to aircraft, acting on auxiliary gear, skids (kips)

F_{W_M} = proportion of wind load acting on main gear, skids (kips)

F_{W_A} = proportion of wind load acting on auxiliary gear, skids (kips)

t_{REQD} = required plating thickness (in)

SM_{REQD} = required minimum section modulus of stiffener-plate combination (in^3)
AS_{REQD} = required shear area of stiffener (in^2)

130-2-d. General

Parts II and III provide a detailed description of the assumptions, rationale, and methods for determining the loading and load distribution.

Part IV provides general guidance and considerations for the design of aircraft handling decks.

Part V provides a detailed description of the assumptions, rationale, and methods for analyzing the structural response.

Part VI provides the design criteria to be used for determining the adequacy of the structure.

Appendices A and B provide the necessary data on existing and notional helicopters.

Appendices C, D, and E provide summaries of the analysis methods for easy reference.

Appendix F provides nomographs of two of the functions in Parts III and V which can be used in lieu of the equations.

Appendix G provides standard work sheets for documenting the analysis.

Appendix H provides a complete example.

Appendix I provides selected measurement units and conversion factors.

Appendix J provides a list of other documents that are applicable to the design and analysis of aircraft handling decks.

PART II: LOADING

139-2-e. General

Aircraft handling decks are exposed to two types of loads in addition to but separate from the standard design loads for all decks. These two types of loads are the landing and parking loads imposed by the aircraft which operate on the deck.

Once the aircraft is on the deck it is subject to the inertial loads produced by the ship's motion accelerations. The ship specifications specify two conditions, storm seas and moderate seas, and provide equations to determine the ship motion factors for that ship for any point on the ship. Although ship motion factors and their corresponding sea states and chance of exceedance are dependent on ship size and the particular seaway, the following approximations that apply to most Navy ships and operational seaways, are offered as background information. The storm sea factors relate to a sea state

7, which for the average service of a ship, correlates fo a 0.05 percent chance of exceedance. The moderate sea factors relate to a sea state 5, which for the average service of a ship, correlates to a 30 percent chance of exceedance.

The aircraft loading conditions which must be considered, if applicable, are:

(a) landing, fore and aft orientation
(b) landing, athwartships orientation
(c) parking, storm sea condition, fore and aft orientation
(d) parking, storm sea condition, athwartships orientation
(e) parking, moderate sea condition, fore and aft orientation
(f) parking, moderage sea condition, athwartships orientation

Special consideration must be given to assure that those loading conditions investigated are realistic. This is especially critical on small decks.

Aircraft elevators are only used during moderate sea conditions; therefore, storm sea parking should not be considered for aircraft elevators.

Generally, all aircraft are parked in the hangar during storm seas, if possible. Those ships with large flight decks or without hangars should be capable of storm sea parking on the flight deck.

Most aircraft handling decks, especially small ships, are marked for angled landings. It is assumed that either fore and aft or athwartships orientations produce the worst loading condition; therefore, for those decks designated for angled landings both orientations must be considered.

Although tiedowns are normally applied immediately upon touchdown, it is assumed that the tiedowns are not being used in the moderate sea condition.

Some small decks are equipped with Recovery Assist, Securing, and Traversing (RAST) systems which are used to enable the LAMPS MK III (SH-60B) helicopter to operate in heavy seas. This system is used not only to aid in the landing of the aircraft but also in moving the aircraft into the hangar.

The shipboard recovery assist system consists of a cable which is attached to the helicopter and a winch which applies constant tension to the cable. This system provides centering guidance and a 4 kip hauldown load to the helicopter to reduce landing dispersions.

The securing system consists of a main probe on the bottom of the aircraft which is captured immediately after touchdown by the Rapid Securing Device in the deck. This system prevents the helicopter from sliding or overturning once on the deck, and is released after tiedowns have been applied. A secondary probe at the helicopter tail wheel engages the RAST track on the deck to provide directional control while the helicopter is being traversed.

It is assumed that the landing reactions are not increased by the RAST system. The parking reactions are decreased due to the vertical restraint to the helicopter by the system.

Appendix C is a summary of the methods for determining the load and load distribution for easier reference. Appendix G contains standard work sheets for documenting the calculations.

130-2-f. Landing Loads

Landing loads are imposed on the landing area of the flight deck. They are probabilistic, and depend in any given instance upon such factors as the rate and attitude of descent, the aircraft gear configuration, the tire characteristics, and the aircraft landing weight. Nominal landing loads are provided by the aircraft manufacturers and are included on the Helicopter Data Sheets of Appendix A for existing helicopters and Appendix B for notional helicopters. These landing loads represent the landing gear reactions measured during landings at various sink rates, with specified tire pressures, and at maximum weight. They predict nominal landing loads rather than maximum or gear collapse loads.

R_L = Nominal Landing Load per Gear

For aircraft not included in Appendix A, a load factor of 2.67 can be applied to the static gear loads.

130-2-g. Parking Loads

The loads experienced by a deck due to a parked aircraft include inertia loads resulting from the motion of the ship, aircraft tiedown forces, and wind forces if exposed to the weather.

Ship motion inertia loads depend on the location of the aircraft's center of gravity relative to the assumed center of motion of the ship and response characteristics of the ship. This information is available in the ship specifications, corresponding to Sect. 070 (Sect. 9020-01 for older ships) of Reference (f).

For those ships whose specifications do not provide the ship motion factors, but do give the ship motion parameters, Reference (c) can be used to develop the vertical, transverse and fore-aft factors.

The equivalent location of all tiedown fittings on the helicopter and maximum allowable angle to the deck of the tiedown are included on the Helicopter Data Sheets of Appendix A.

The wind force exerted on the aircraft is assumed to be 15 pounds per square foot in the storm sea condition applied to the folded sail area as a concentrated load at the center of pressure. For the moderate sea condition, 7.5 pounds per square foot is applied to the unfolded sail area. Both loads are applied in a horizontal transverse direction with respect to the aircraft. The wind force does not apply for parking in a hangar.

It is intuitively considered that the storm sea parking loads predicted by this method are the maximum load that a parked aircraft would be subjected to. The moderate sea parking loads are considered to be the loads which would be experienced most frequently.

Specifically, the weight conditions to be investigated when an aircraft is parked are as shown in Table I.

SEA CONDITION	FLIGHT DECK	HANGAR DECK	ELEVATOR PLATFORM
Storm	W_P	W_P	N/A
Moderate	W_M	W_P	W_P

<u>Table I</u>   <u>Aircraft Weight Conditions</u>

Aircraft orientation and location, with respect to the ship, will also affect the loading imposed on the deck. On small decks, such as those on frigates, destroyers, and auxiliaries, the aircraft is only allowed to be parked longitudinally with respect to the ship and variations of the location are limited. However, on large decks such as those on amphibious assault ships, the aircraft can be parked either longitudinally or transversely with respect to the ship, and location can vary over a considerable portion of the ship's length and breadth. This not only affects the magnitude of the load, but also the loading of the individual structural members. All cases should be examined in the analyses.

To determine gear reactions, two dimensional free body diagrams can be used. A longitudinal free body diagram, (with respect to the aircraft), see Figure 1, will balance the loads between the main and auxiliary gears, and a transverse free body diagram, see Figure 2, will balance the loads between each main gear and the tiedowns.

Moderate sea tiedowns act to restrain the aircraft from sliding. Storm sea tiedowns act to restrain the aircraft from sliding and overturning.

There are four configurations for tiedowns, as described in Reference (i): initial, intermediate, permanent and heavy weather. Initial tiedowns (4 chains for helicopters) are required just prior to aircraft movement, immediately after parking, after recovery, or after respot. Intermediate tiedowns (6 chains for helicopters) are required during flight quarters when the aircraft may be expected to be moved. Permanent tiedowns (12 chains for helicopters) are required when not at flight quarters. Heavy weather tiedowns (18 chains for helicopters) are applied at the direction of the Aircraft Handling Officer.

For the moderate sea parking condition, it is assumed that no tiedowns have been applied.

For the storm sea parking condition, it is assumed that the heavy weather tiedowns have been applied. An equivalent heavy weather tiedown attachment location is provided in Appendix A for existing Navy helicopters.

130-2-g.1 Ship Motion Factors

The Ship Specifications provide storm and moderate sea ship motion equations in a form such that the dimensions from the motion axes of the vessel to the center of gravity of the aircraft are substituted into these equations to obtain the motion factors in each of the directions.

η_x = fore and aft factor
η_y = athwartships factor
η_z = vertical factor

If these equations are not available, Reference (c) can be used to obtain the motion factors.

If not otherwise specified, the ship motion factors for the moderate sea condition can be related to the storm sea factors by the following:

$$\eta_{xm} = 1/2\ \eta_{xs} \qquad \text{G.1-1}$$

$$\eta_{ym} = 1/2\ \eta_{ys} \qquad \text{G.1-2}$$

$$\eta_{zm} = \frac{1 + \eta_{zs}}{2} \qquad \text{G.1-3}$$

130-2-g.2 Ship Motion Loads

The loads produced on the aircraft acting at the center of gravity are the product of the ship motion factor and the appropriate weight of the aircraft.

F_i = Ship motion force in i direction
η_i = Ship Motion factor in i direction
W_j = Weight of aircraft in j condition

$$F_i = \eta_i\ W_j \qquad \text{G.2-1}$$

130-2-g.3 Wind Loads

The wind load on the aircraft acts at the center of pressure of the sail area and is defined as follows:

Storm Seas

$$F_w = 0.015a_s \qquad \text{G.3-1}$$

Moderate Seas

$$F_w = 0.0075a_s \qquad \text{G.3-2}$$

Where a_s is the sail area in square feet of the aircraft. In the storm sea condition the area of the folded aircraft should be used. In the moderate sea condition the area of the unfolded aircraft should be used.

If the aircraft is in a hangar the wind force is zero, i.e., $F_w = 0$.

130-2-g.4 Ship Motion Forces

Aircraft orientation with respect to the ship will also affect the loading imposed on the deck. Therefore, each ship motion load must be oriented to the aircraft for each loading condition.

F_L = Ship motion force longitudinal to aircraft
F_T = Ship motion force transverse to aircraft
F_D = Downward ship motion force.

Aircraft Oriented Longitudinally

$$F_L = F_x \tag{G.4-1}$$
$$F_T = F_y \tag{G.4-2}$$
$$F_D = F_z \tag{G.4-3}$$

Aircraft Oriented Athwartships

$$F_L = F_y \tag{G.4-4}$$
$$F_T = F_x \tag{G.4-5}$$
$$F_D = F_z \tag{G.4-6}$$

130-2-g.5 Gear Reactions

Maximum total main gear reaction, R_M:

$$R_M = F_D \left(1 - \frac{X_G}{r}\right) + F_L \left(\frac{Z_G}{r}\right) \tag{G.5-1}$$

Maximum auxiliary gear reaction, R_A:

$$R_A = F_D \left(\frac{X_G}{r}\right) + F_L \left(\frac{Z_G}{r}\right) \tag{G.5-2}$$

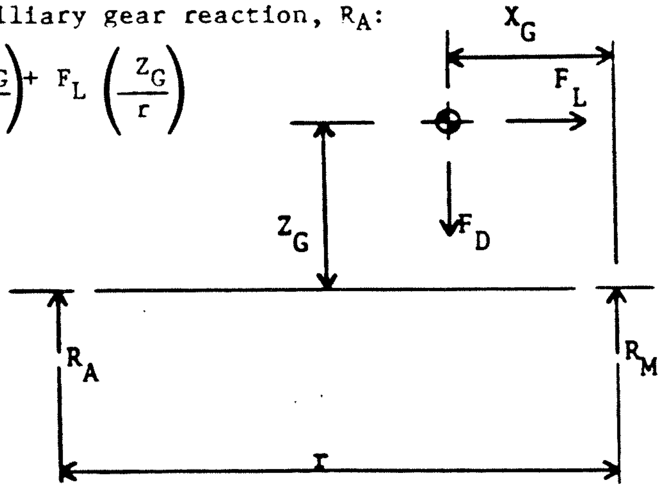


Figure 1 Aircraft Longitudinal Free Body Diagram

NOTE: Figure 1 shows the direction of ship motion forces that produce the maximum main gear reaction, R_M. The direction of the longitudinal ship motion force is reversed to produce the maximum auxiliary gear reaction, R_A.

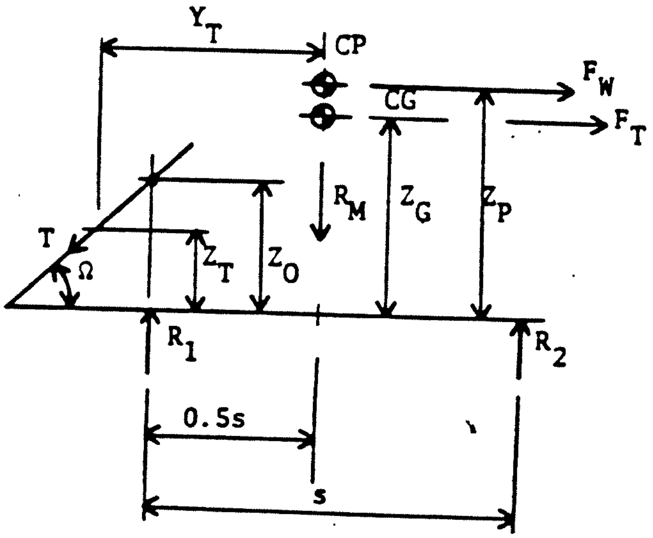
These loads represent maximum values used to determine the most critical gear reaction to be used in the plating analysis, Section 130-2-p., and in the stiffener analysis for regular structural scantlings, Section 130-2-q.1. If the structural scantlings are irregular, as discussed in Section 130-2-q.2., then a grillage analysis will be required. In order to have consistent gear loads to apply to the model, the following equations can be used depending on which gear is critical.

Main Gear Critical:

$$R_A = F_D - R_M \qquad \text{G.5-3}$$

Auxiliary Gear Critical:

$$R_M = F_D - R_A \qquad \text{G.5-4}$$



Equivalent tiedown lever arm, Z_O:

$$Z_O = Z_T + \left(Y_T - \frac{s}{2}\right)\tan\Omega \qquad \text{G.5-5}$$

Aircraft overturning moment, M:

$$M = F_W Z_P + F_T Z_G - R_M\left(\frac{s}{2}\right) \qquad \text{G.5-6}$$

Figure 2 Aircraft Transverse Free Body Diagram

If $M \leq 0$ (Tiedown not resisting overturning of aircraft (i.e., T = 0))

In moderate seas tiedowns are assumed not to be applied. In storm seas the tiedowns are slack due to both main gear being depressed.

Main gear reaction #2, R_2:

$$R_2 = 1/2\ R_M + F_W\left(\frac{Z_P}{s}\right) + F_T\left(\frac{Z_G}{s}\right) \qquad \text{G.5-7}$$

Main gear reaction #1, R_1:

$$R_1 = R_M - R_2 \qquad \text{G.5-8}$$

If $M > 0$ (Storm Sea Condition Only)

If this condition exists in the moderate sea condition, aircraft operations will be hazardous, due to possible overturning of the aircraft.

The tiedown is assumed to act so as to prevent R_1 from reducing below the minimum load at the time the tiedowns are applied.

Since the tiedown has a horizontal component, it is necessary to include an estimate of the tire friction force, otherwise, the tiedown force would be over predicted and the maximum main gear reaction would be under-predicted. This produces a force system which has more unknowns than equations; therefore, an estimate is made for the value of the main gear reaction adjacent to the acting tiedown. It is assumed that this gear reaction (main gear reaction #1) is equal to the static gear load (no ship motion loads) at the parking weight.

Main gear reaction #1, R_1:

$$R_1 = 1/2\, W_P \left(1 - \frac{X_G}{r}\right) \qquad \text{G.5-9}$$

Friction force, F_F:

$$F_F = \frac{1/2\, R_M - R_1 + F_W\left(\tan\Omega - \left(\frac{Z_P - Z_o}{s}\right)\right) + F_T\left(\tan\Omega - \left(\frac{Z_G - Z_o}{s}\right)\right)}{2\tan\Omega + \frac{Z_o}{s}} \qquad \text{G.5-10}$$

Main gear reaction #2, R_2:

$$R_2 = 1/2\, R_M + F_W\left(\frac{Z_P - Z_o}{s}\right) + F_T\left(\frac{Z_G - Z_o}{s}\right) + F_F\left(\frac{Z_o}{s}\right) \qquad \text{G.5-11}$$

Tiedown force, T:

$$T = (F_W + F_T - F_F)/\cos\Omega \qquad \text{G.5-12}$$

130-2-g.6 Critical Gear Load

The critical gear load is that gear reaction which when applied over that gear load distribution, creates the worst load for that load condition. The maximum gear reaction will often be the main gear reaction, R_2: however, it is possible that the auxiliary gear reaction, R_A, could be the most critical. The gear load distribution effects can vary between gears due to number of wheels, tire size, or operational pressure. Both load magnitude and distribution affect the strength analysis. Typically, load magnitude will have the larger effect. It may be necessary to perform the strength analysis on both gear reactions, R_2 and R_A, if the critical load is not obvious.

130-2-h. Variation in Loading due to RAST System

The RAST System is comprised of airborne and shipboard equipment which together perform the functions of helicopter recovery assist, securing, deck maneuvering, aircraft traversing into and out of the hangar, and helicopter launch assist. The RAST system is designed to support helicopter operations in upper sea state five conditions (significant wave height of 13 feet and surface winds of 26 knots).

130-2-h.1 Landing Loads

The RAST system tends to increase landing loads; however, landing loads do not exceed the nominal landing load, R_L. The nominal landing load for the SH-60B is provided in Appendix A.

130-2-h.2 Parking Loads

During parking (securing and traversing), the two probes which hold the aircraft to the deck resist the longitudinal ship motion force, F_L, the transverse ship motion force, F_T, and the wind force, F_W. The probes act as vertical tiedowns applied at the centerline of the aircraft. The gear reactions produced are determined as follows (see Figure 3).

Maximum total main gear reaction, R_M:

$$R_M = F_D \quad 1 - \left(\frac{X_G}{r}\right) \qquad \text{H.2-1}$$

Maximum auxiliary gear reaction, R_A:

$$R_A = F_D\left(\frac{X_G}{r}\right) \qquad \text{H.2-2}$$

Aircraft overturning moment, M:

$$M = F_W Z_P + F_T Z_G - R_M\left(\frac{S}{2}\right) \qquad \text{H.2-3}$$

If $M \leq 0$

Probe force, $F_P = 0$

Main gear reaction #2, R_2:

$$R_2 = 1/2\ R_M + F_W\left(\frac{Z_P}{S}\right) + F_T\left(\frac{Z_G}{S}\right) \qquad \text{H.2-4}$$

Main gear reaction #1, R_1:

$$R_1 = R_M - R_2 \qquad \text{H.2-5}$$

If $M > 0$

Main gear reaction #1, R_1:

$$R_1 = 1/2\, W_P \left(1 - \frac{X_G}{r}\right) \qquad \text{H.2-6}$$

Probe force, F_P:

$$F_P = 2R_1 + 2F_T \left(\frac{Z_G}{S}\right) + 2F_W \left(\frac{Z_P}{S}\right) - R_M \qquad \text{H.2-7}$$

Main gear reaction #2, R_2:

$$R_2 = 1/2\, R_M + 1/2\, F_P + F_T \left(\frac{Z_G}{S}\right) + F_W \left(\frac{Z_P}{S}\right) \qquad \text{H.2-8}$$

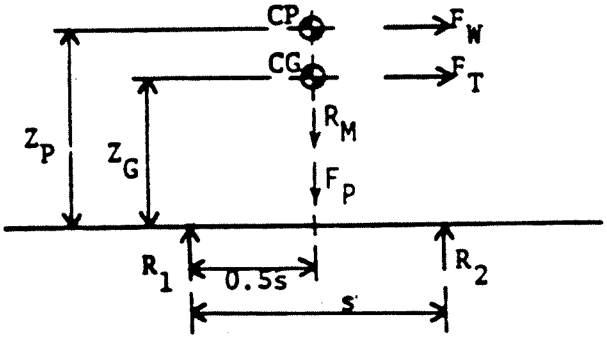


Figure 3 Aircraft Transverse Free Body Diagram for RAST

130-2-i. Variation in Loading due to Skids

Since both the main and auxiliary gears (forward and aft crossbars respectively) are capable of resisting aircraft overturning moments produced by the ship motion and wind forces acting transversely to the aircraft, it is necessary that these forces be proportioned between the main and auxiliary gears. It is assumed that this proportion is based on the longitudinal CG of the aircraft, X_G.

$$F_{T_M} = F_T \left(1 - \frac{X_G}{r}\right) \qquad \text{I-1}$$

$$F_{T_A} = F_T \left(\frac{X_G}{r}\right) \qquad \text{I-2}$$

$$F_{W_M} = F_W \left(1 - \frac{X_G}{r}\right) \qquad \text{I-3}$$

$$F_{W_M} = F_W \left(\frac{X_G}{r}\right) \qquad \text{I-4}$$

These forces are then used in each of two aircraft transverse force balances, as in Section 130-2-g.5, to determine the four skid loads as shown in Section 130-2-1.

PART III: LOAD DISTRIBUTION

130-2-j. General

Aircraft gear load distribution depends on the number of wheels per gear, tire size and construction, and tire pressure. It is assumed that the tire load, P_T, is the critical gear load, R, divided by the number of wheels on the gear.

For single wheeled gear:

$$P_T = R \qquad \text{J-1}$$

For dual wheeled gear:

$$P_T = 1/2\ R \qquad \text{J-2}$$

Appendix C is a summary of the methods for determining the load and load distribution for easier reference. Appendix G contains standard work sheets for documenting the calculations.

130-2-k. Tire Footprint

The tire footprint is assumed to be a rectangular area of uniform pressure, see Figure 4. The length, A, and width, B, can be determined for the footprint by linear interpolation from load tables found in Appendix A for each aircraft and gear.

For the following footprint load table:

P_T	A	B
P_{T_1}	A_1	B_1
P_{T_2}	A_2	B_2

Calculate the footprint dimensions.

$$A = A_1 + \left(\frac{A_2 - A_1}{P_{T_2} - P_{T_1}}\right)\left(P_T - P_{T_1}\right) \qquad \text{K-1}$$

$$B = B_1 + \left(\frac{B_2 - B_1}{P_{T_2} - P_{T_1}}\right)\left(P_T - P_{T_1}\right) \qquad \text{K-2}$$

When a calculated value of P_T is greater than the tire bottoming load, P_b, A and B are equal to the A and B dimensions at P_b. That is, the tire contact dimensions do not increase for any tire load greater than P_b.

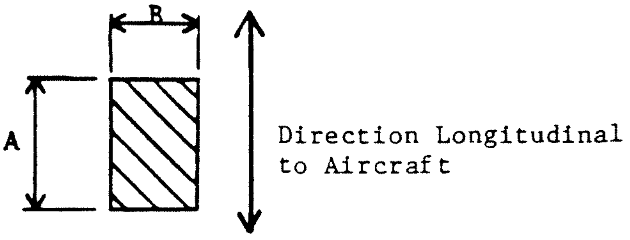


Figure 4 Tire Footprint

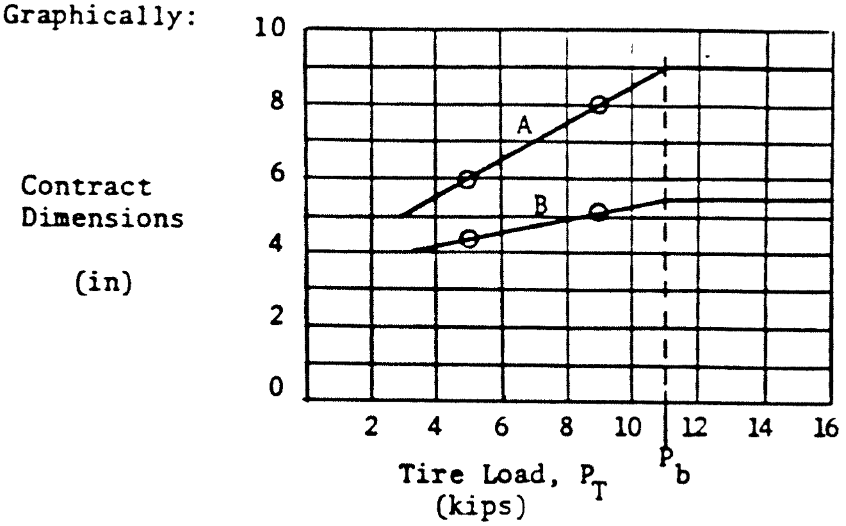
The following example demonstrates the method graphically.

Sample data from Appendix A:

$P_b = 11.0$ kips

P_T	A	B
5	6	4.5
9	8	5

Graphically:



As an alternative approach, if the load table for a particular aircraft is not known, but the bottoming load, P_b and the operational tire pressure, P_o, are given, then the contract width and length of a tire can be determined from the nomograph in Appendix F.

130-2-1. Skid Footprint

The skid footprint is assumed not to vary with respect to the load. The contact dimensions are assumed to be: contact length, A, equal to 8 inches, and contact width, B, equal to 1.5 inches. A contact area is at each intersection of the skids and crossbars, see Figure 5. The distance between skids and the distance between crossbars is provided in Appendix A for existing Navy helicopters.

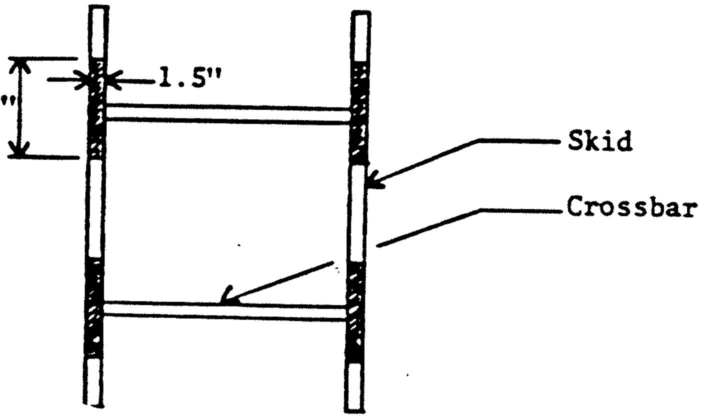


Figure 5 Skid Footprints

130-2-m. Variation in Load and Load Pattern Due to Aircraft Orientation

The orientation of the aircraft with respect to the stiffeners and the number of wheels per gear are resolved into patch(es) with associated loads with respect to the stiffeners. The tire contact dimensions, length, A, width, B, and dual wheel spacing, b', are resolved into patch dimensions, length in direction of stiffeners, A', width perpendicular to stiffeners, B', and dual patch spacing, b", with a load that is modified as applicable.

When the aircraft is alined with the stiffeners:

A' = A M-1

B' = B M-2

For single wheeled gear, see Figure 6-A:

P = R M-3

b" is not applicable M-4

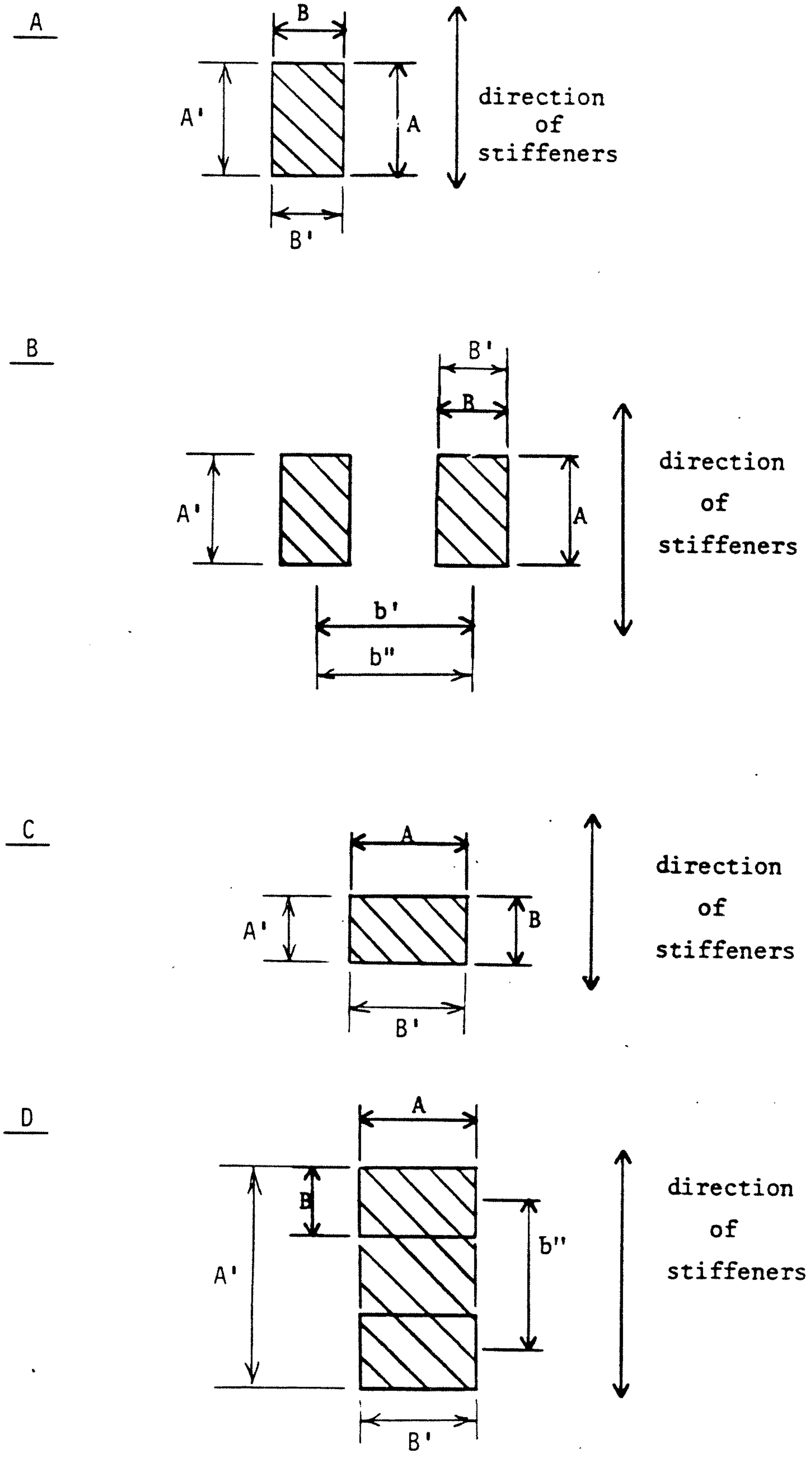


Figure 6 Load Pattern vs. Aircraft Orientation

For dual wheeled gear, see Figure 6-B:

$P = 1/2\ R$ M-5

$b'' = b'$ M-6

When the aircraft is alined perpendicular to the stiffeners:

$B' = A$ M-7

$P = R$ M-8

b'' is not applicable

For single wheeled gear, see Figure 6-C:

$A' = B$ M-9

For dual wheeled gear, see Figure 6-D:

$A' = b' + B$ M-10

PART IV: NEW DESIGN CONSIDERATIONS

130-2-n. General

For the design of aircraft handling decks it is suggested that a notional aircraft be specified in lieu of specific aircraft. This will allow for the typical weight increases in existing aircraft as well as for new aircraft in the future. Appendix B contains four (4) notional helicopters for design purposes. Each notional helicopter represents a class of helicopter operational scenarios. Those existing helicopters which fall into each class are listed in Appendix B for guidance in selecting a notional helicopter.

For determining the plating thickness, it is important that all aircraft which will operate on the deck be analyzed. Due to smaller patches, the lighter aircraft could control the design.

For determining the stiffener size, the aircraft with the largest gear reaction (generally the heaviest) will often control the design, due to the lesser dependence on patch effects.

PART V: ANALYSIS METHOD

130-2-o. Structural Parameters

The typical structure of modern Navy aircraft handling decks is a plate deck grillage of continuously welded construction. Stiffeners are continuous members of uniform size. This causes the individual structural elements to interact; therefore, the structural parameters of each member are altered to account for these effects.

130-2-o.1 Geometry

The aircraft handling deck consists of a flat plate and mutually perpendicular stiffeners supported by beams and/or girders and/or bulkheads. This is a statically indeterminate structural system. For design purposes, it may be treated as a grid, where the deck plate acts as a common top flange for the stiffeners, beams, and girders.

A typical deck scantling arrangement is shown in Figure 7. The structural model of this arrangment for finite element purposes is shown in Figure 8.

130-2-o.2 Effective Span

The effective span length factor, e_S or e_B, is a function of the number of spans of the member.

Where: e_S = effective span length factor of stiffener

e_B = effective span length factor of beam

See Table II for values of factors.

Number of Spans	e_S or e_B
1	1.0
2	0.842
3	0.700
4	0.692
5 or more	0.684

Table II Effective Span Length Factor

130-2-o.3 Member Properties

The properties of the stiffeners, beams and girders are those of the actual member itself plus that portion of deck plating which acts as the upper flange. The effective breadth of the deck plating which may be assumed for this upper flange is a function of the plate thickness and material, span length, or spacing, whichever is less.

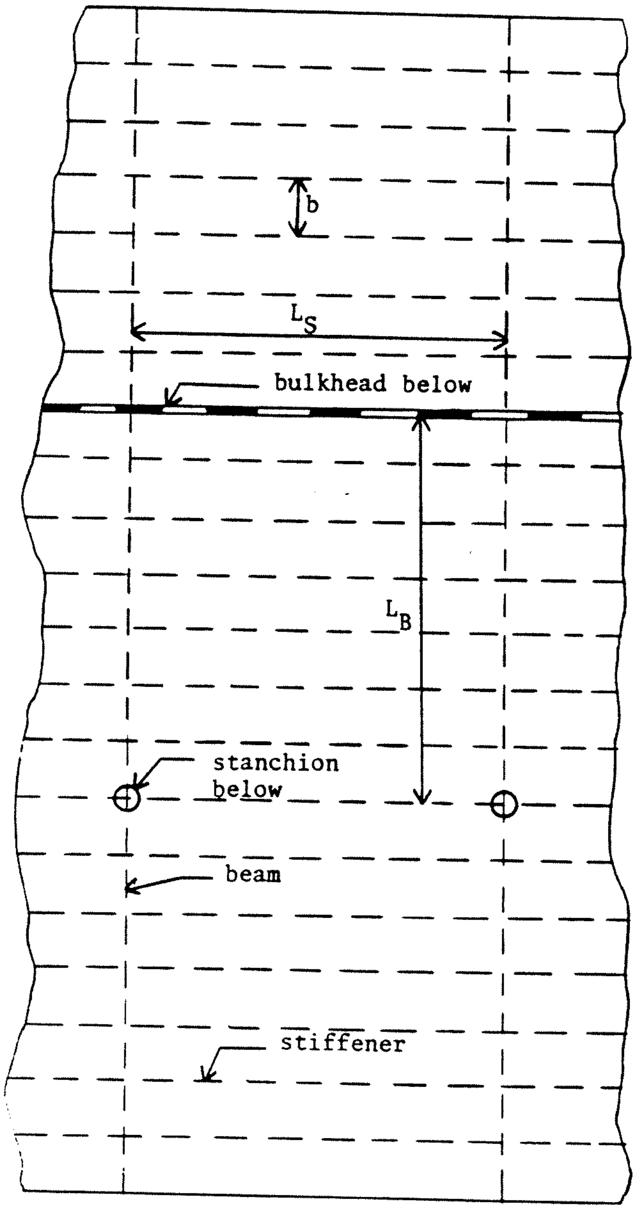


Figure 7 Typical Deck Scantlings

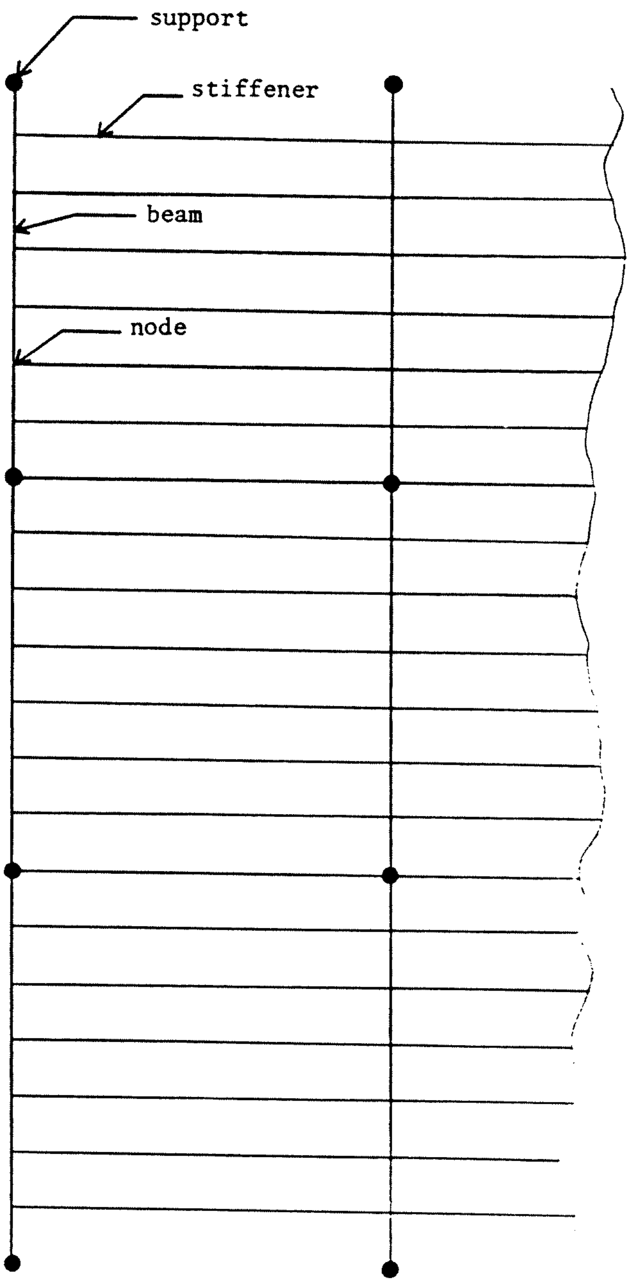


Figure 8 Typical Finite Element Model

$$b_e = \left\{ \begin{array}{c} 2t\sqrt{\frac{E}{F_y}} \\ 1/3\ L_s \\ b \end{array} \right\}, \text{ minimum of} \qquad 0.3\text{-}1$$

The combined properties of the member and associated plating can be found in Reference (g) or by direct calculation. Figure 9 provides graphical definitions of those dimensions which define a member's size. Figure 10 shows the common structural members used in aircraft handling decks.

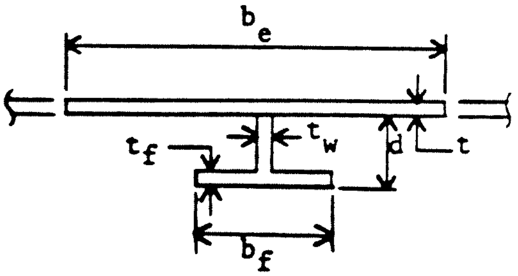


Figure 9 Member Dimensional Variables

It is assumed that the section modulus at the flange will be the minimum and the section modulus at the plate will be the maximum.

130-2-p. Plating

The following analysis procedure utilizes the elastic-plastic behavior of the plating so as to take advantage of the reserve energy absorption capability of a plate deck structure over that determined by first order flexural theory. The approach is a simplified approximation to the complex theory of elastic-plastic behavior, which is beyond the scope of a design data sheet. The strength values determined by this approach are based primarily on Reference (d) with support from those documents listed in the bibliography.

The load applied to the plating panel is a single or dual patch load of length, A', (along the stiffener), width, B', (perpendicular to the stiffener), magnitude, P, and dual patch spacing, b", as described in Section 130-2-m.

First, determine the non-dimensionalized bending moment of the plating, C_1, by

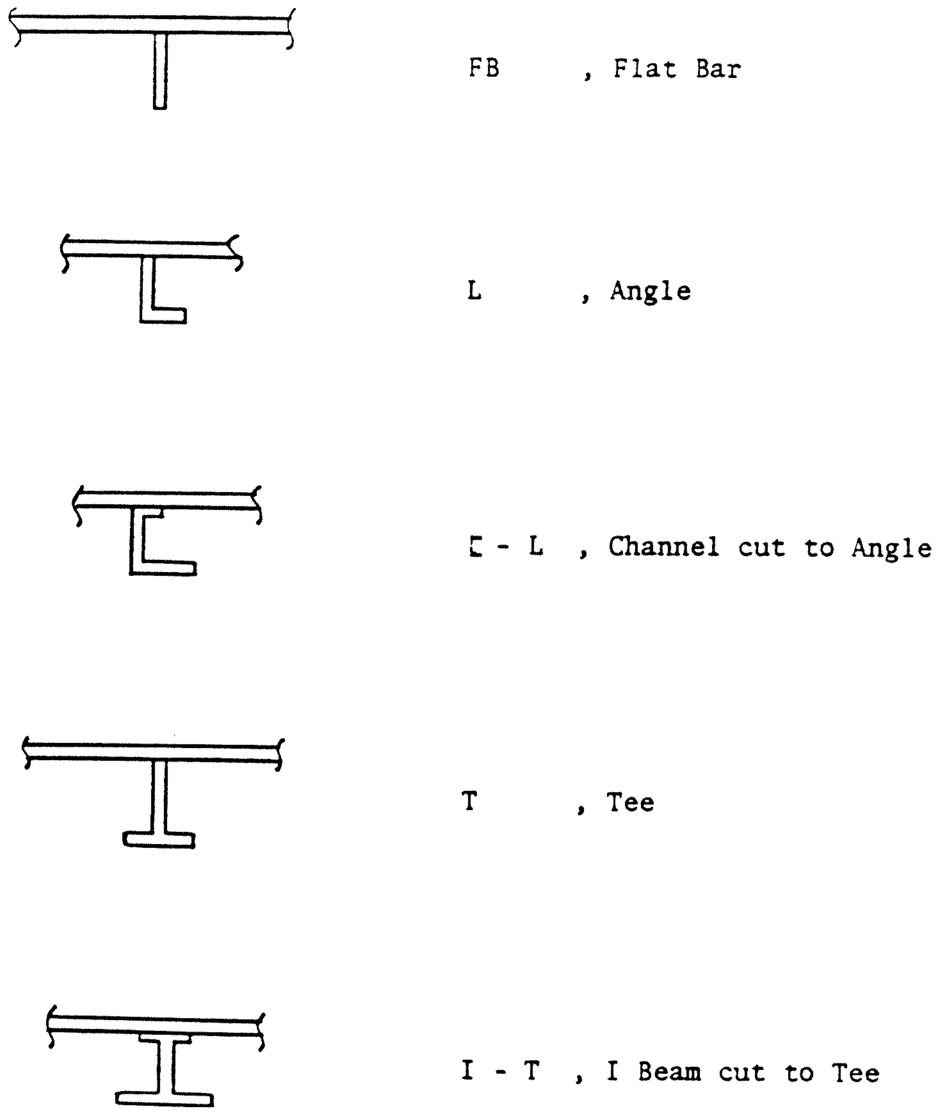


Figure 10 Common Structural Members

$$C_1 = \frac{0.25 - 0.125\left(\frac{B'}{b}\right)}{0.94 + 0.45\left(\frac{A'}{b}\right)} - \frac{0.079 - 0.026\left(\frac{B'}{b}\right)^2}{1.75 + 0.15\left(\frac{A'}{b}\right)^2} \text{, when } \frac{A'}{b} \leq .5 \qquad \text{P - 1}$$

or

$$C_1 = \frac{0.25 - 0.125\left(\frac{B'}{b}\right)}{\left(\frac{A'}{b}\right) + \frac{0.6}{\left(\left(\frac{A'}{b}\right) + 0.4\right)}} - \frac{0.079 - 0.026\left(\frac{B'}{b}\right)^2}{1.75 + 0.15\left(\frac{A'}{b}\right)^2} \text{, when } \frac{A'}{b} \geq .5 \qquad \text{P - 2}$$

The nomograph in Appendix F may also be used to determine C_1.

After determining the ratios of $\frac{B'}{b}$ and $\frac{b''}{b}$, the equivalent tire reaction factor, Ψ, can be obtained from Figure 11. Note that for single patches $\psi = 1.0$.

A deck function coefficient, C_o, is used to provide a relationship between allowable permanent set, load probability, and deck function. Where deck function is determined by the deck's contribution to the hull girder strength and by the type of aircraft operations performed on the deck. For a particular sea condition and deck function, C_o is given by Table III.

C_o (Steel or Aluminum)

Deck Function	Landing and Moderate Sea Parking	Storm Sea Parking
Uppermost Strength Deck High Speed Rolling of Aircraft	2.0	1.7
Uppermost Strength Deck Low Speed Handling of Aircraft	3.4	2.8
Non-Uppermost Strength Deck High Speed Rolling of Aircraft	3.4	2.8
Non-Uppermost Strength Deck Low Speed Handling of Aircraft	4.2	3.5

Table III Deck Function Coefficient, C_o

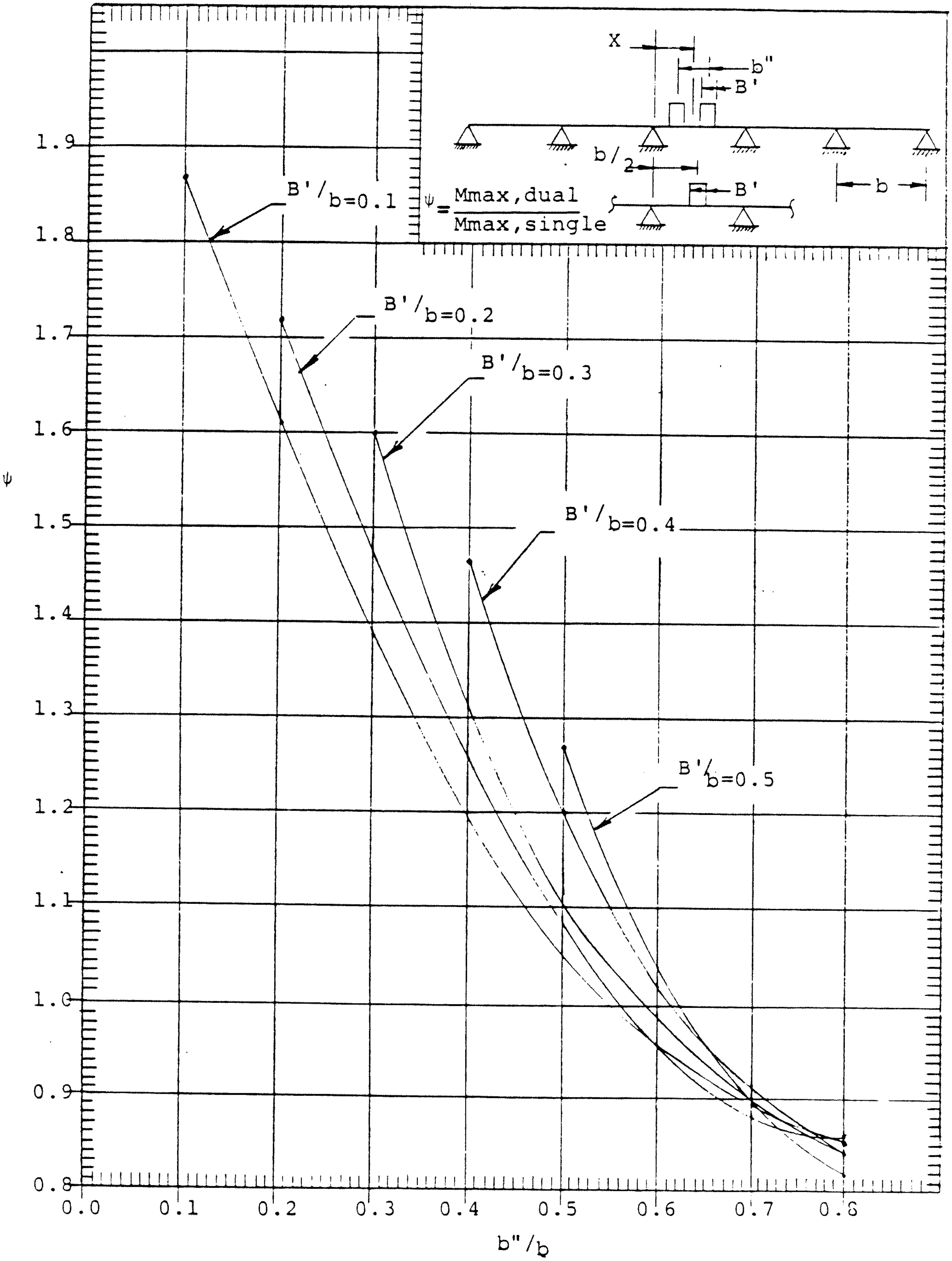


Figure 11 Dual Patch Equivalent Load Factor, Plating, ψ

The maximum plate bending stress is then calculated to be

$$f_p = \frac{6\ C_1\ P\Psi}{C_o\ t^2} \qquad P - 3$$

For transversely framed decks subject to parking loads, the plating should be checked with the combined primary and secondary stresses for buckling in accordance with Reference (b).

The required plating thickness, t_{REQD} can be determined as follows:

$$t_{REQD} = \sqrt{\frac{6\ C_1\ P\Psi}{C_o\ \sigma_p}} \qquad P - 4$$

where the allowable plating stress, σ p is as defined in Section 130-2-t.

Appendix D is an abridged description of the plating analysis method and criteria for easier reference. Appendix G contains standard calculation sheets.

130-2-q. Stiffeners

The following analysis procedures incorporate the grillage effects into the stiffener analysis. Acting as continuous members, the stiffeners react on beams which carry the load to the supports. The beams deflect proportionately to the loads they carry and thus provide elastic supports for the stiffeners.

130-2-q.1 Regular Structural Scantlings

The following analysis is based on strip theory and the use of influence lines. The strength values determined by this approach are based primarily on Reference (e) with support from those documents listed in the bibliography.

The analysis procedure is applicable to longitudinal or transverse framing where the longitudinal or transverse stiffeners are continuous beams over equally spaced supports. For simplicity, the term stiffener will refer to either longitudinal or transverse stiffeners, and the term beam will refer to the members which support the longitudinal or transverse stiffeners.

The analysis procedure determines the maximum bending moment and shear force in a stiffener for a single or dual patch loading.

Maximum Bending Moment and Stress

The loading condition which produces the maximum bending moment is when the patch load is placed at midspan directly over the stiffener. This maximum moment is the summation of (1) the moment due to the live load, M_O, assuming the stiffener as a continuous beam on rigid supports; (2) the added moment due to the flexibility of the beam supports, M_C; and (3) the moment due to the dead weight of the plating and stiffener, M_D.

The load applied to the stiffener is a single or dual patch load of length, A', (along the stiffener) width, B', (perpendicular to the stiffener), magnitude, P, and dual patch spacing, b", as described in Section 130-2-m.

To account for the distribution effects of the patch width, B', the patch width load factor, ϕ_1, is used. To determine the patch width load factor, ϕ_1, calculate $\frac{B'}{b}$ and use Figure 12. Note that the curve marked i = 0 must be used because the stiffener in question is that one directly under the load.

To account for the distribution effects of the plating, the plating load distribution factor, ϕ_2, is used. To determine the patch width load factor, ϕ_2, calculate the relative rigidity between the plating and stiffener and use Figure 13. The relative rigidity between the plating and stiffener is calculated by the following equation.

$$\gamma_{PS} = \frac{(e_S L_S)^4\ t^3}{3.49\ b^3\ \pi^4\ I_S} \qquad \text{Q.1-1}$$

To account for the combined effects of dual patches, the dual patch equivalent load factor, ϕ_3, is used. To determine the dual patch equivalent load factor, ϕ_3, calculate $\frac{b''}{b}$ and use Figure 14. Note that for single patches $\phi_3 = 1.0$.

The moment due to the live load over rigid supports, M_O, is determined by using the influence line coefficient then applying the appropriate load factors. The influence line coefficient for the moment at midspan of a continuous beam over equally spaced rigid supports for a patch load at midspan is calculated by the following equation.

$$\frac{M_O}{PL_S} = 0.1708 - 0.125\left(\frac{A'}{L_S}\right) + 0.0264\left(\frac{A'}{L_S}\right)^2 \qquad \text{Q.1-2}$$

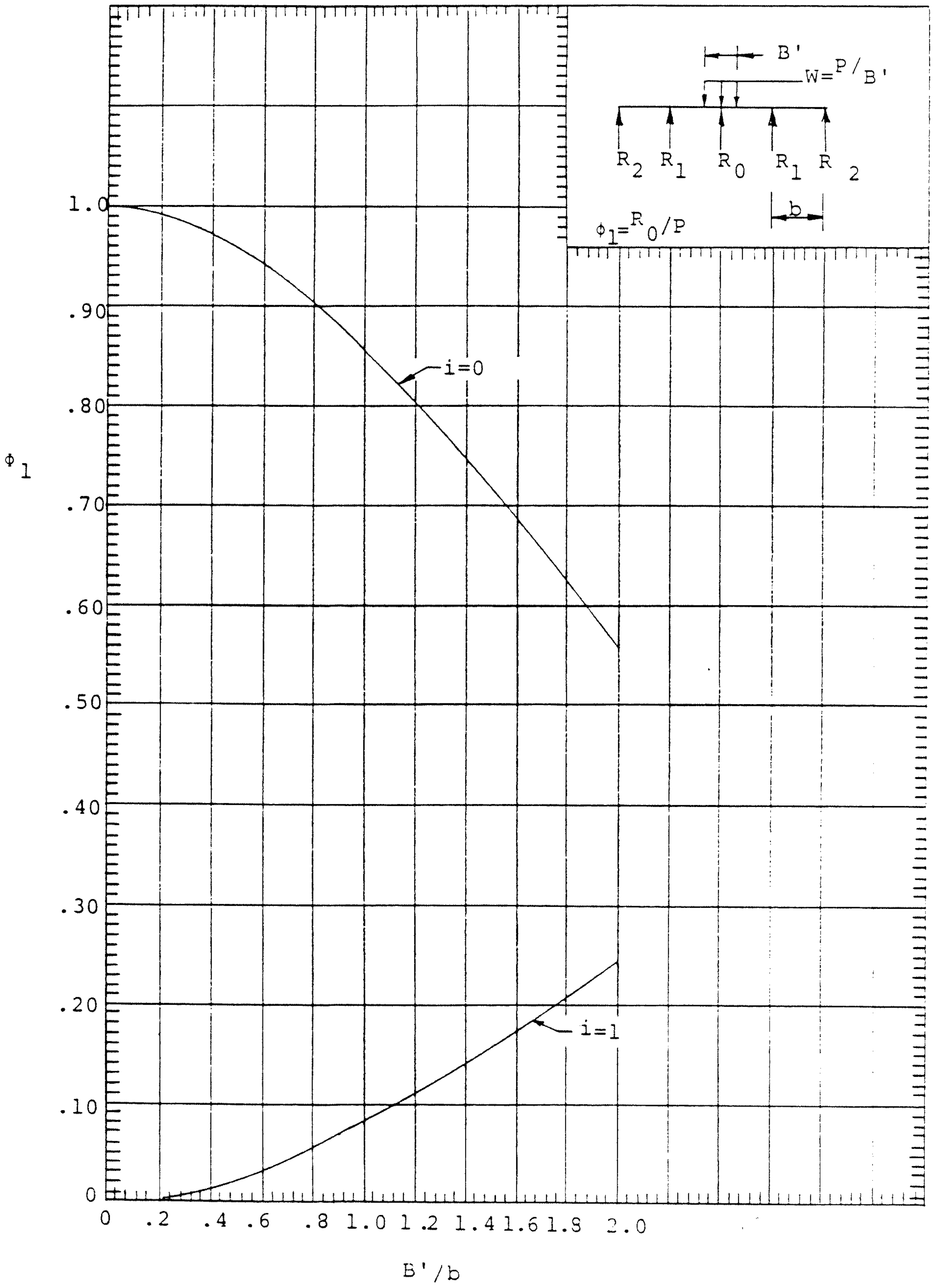


Figure 12 Patch Width Load Distribution Factor, Stiffener, Φ_1

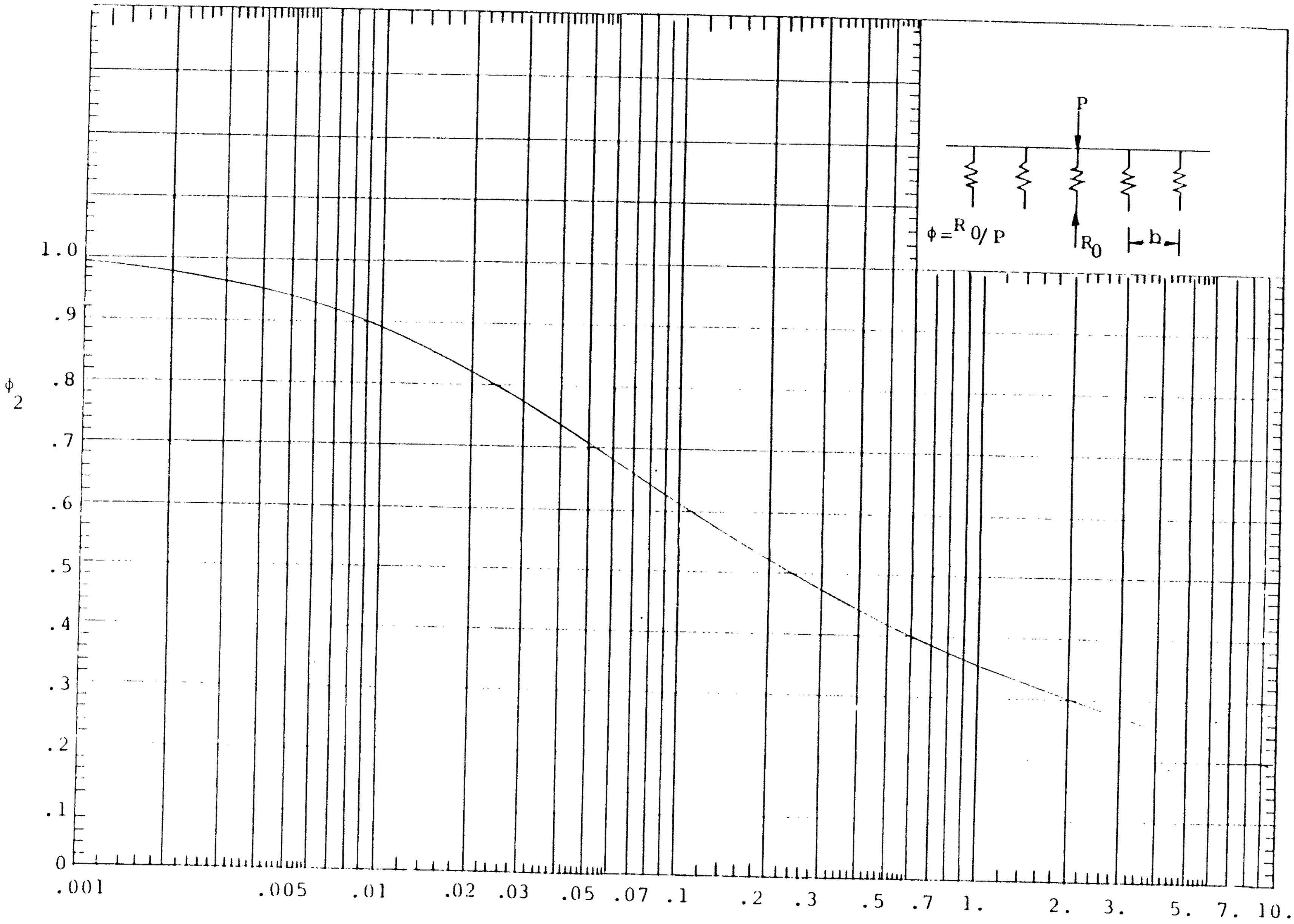


Figure 13 Plating Load Distribution Factor, Stiffener, ϕ_2

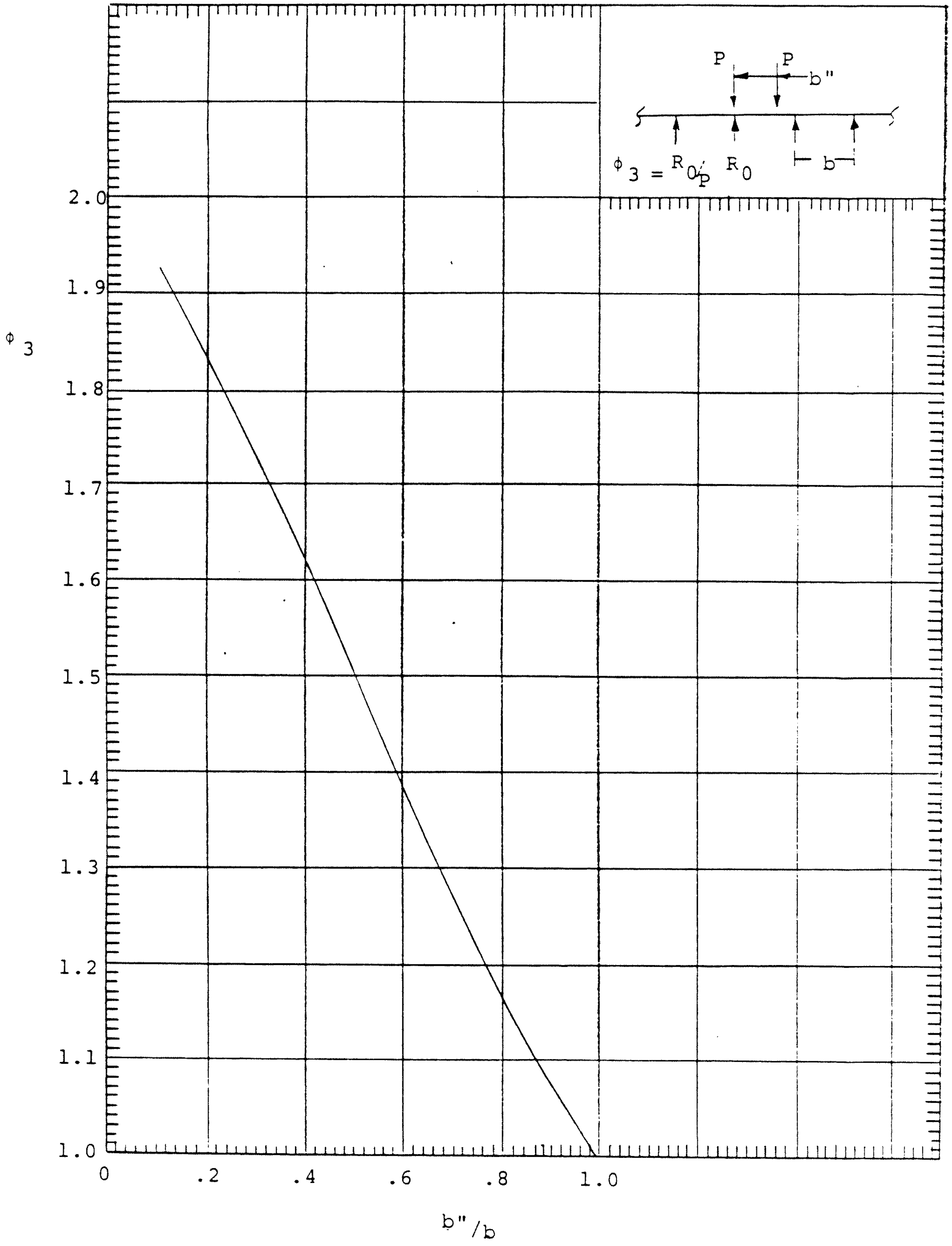


Figure 14 Dual Patch Equivalent Load Factor, Stiffener, ϕ_3

The moment due to the live load over rigid supports, M_o is then calculated by applying the appropriate load factors using the following equation.

$$M_o = \left(\frac{M_o}{PL_S}\right) PL_S \, \phi_1 \, \phi_2 \, \phi_3 \qquad \text{Q.1-3}$$

The moment due to flexibility of the beam supports, M_c, is determined by calculating the relative rigidity between the stiffener and the beam to obtain the moment correction coefficient due to flexure of the beams then applying the appropriate load factors. If bulkheads are supporting stiffeners in lieu of beams, then the stiffener supports are considered rigid; therefore, $M_c = 0$.

The relative rigidity between the stiffener and beam is calculated by the following equation.

$$\gamma_{SB} = \frac{(e_B L_B)^4 \, I_S}{.684 \, b \, (e_s L_S)^3 \, \pi^4 \, I_B} \qquad \text{Q.1-4}$$

The moment correction coefficent due to flexure of the beams, $\frac{M_c}{RL_S}$ is obtained from Figure 15 using the relative rigidity, γ_{SB}.

To account for multiple gear loads, and plating and stiffener load distributions, the load on the transverse beam for determining the moment in the stiffeners due to beam flexture is assumed to be the Fourier Series component representation of the load. This representation consists of a characteristic loading (characteristic load, R_o, and characteristic load width, B_o) and a shape function (beam loading coefficient, ϕ_4).

The beam characteristic load, R_o is calculated based on the total gear load as follows:

$$R_o = \begin{cases} \dfrac{R}{B'} & \text{, single patch} \qquad \text{Q.1-5} \\[2ex] \dfrac{R}{(b'' + B')} & \text{, dual patch} \qquad \text{Q.1-6} \end{cases}$$

The beam characteristic load width, B_o is calculated based on the total gear distribution as follows:

$$B_o = \begin{cases} \dfrac{B'}{2} & \text{, single patch} \qquad \text{Q.1-7} \\[2ex] \dfrac{1}{2}(b'' + B') & \text{, dual patch} \qquad \text{Q.1-8} \end{cases}$$

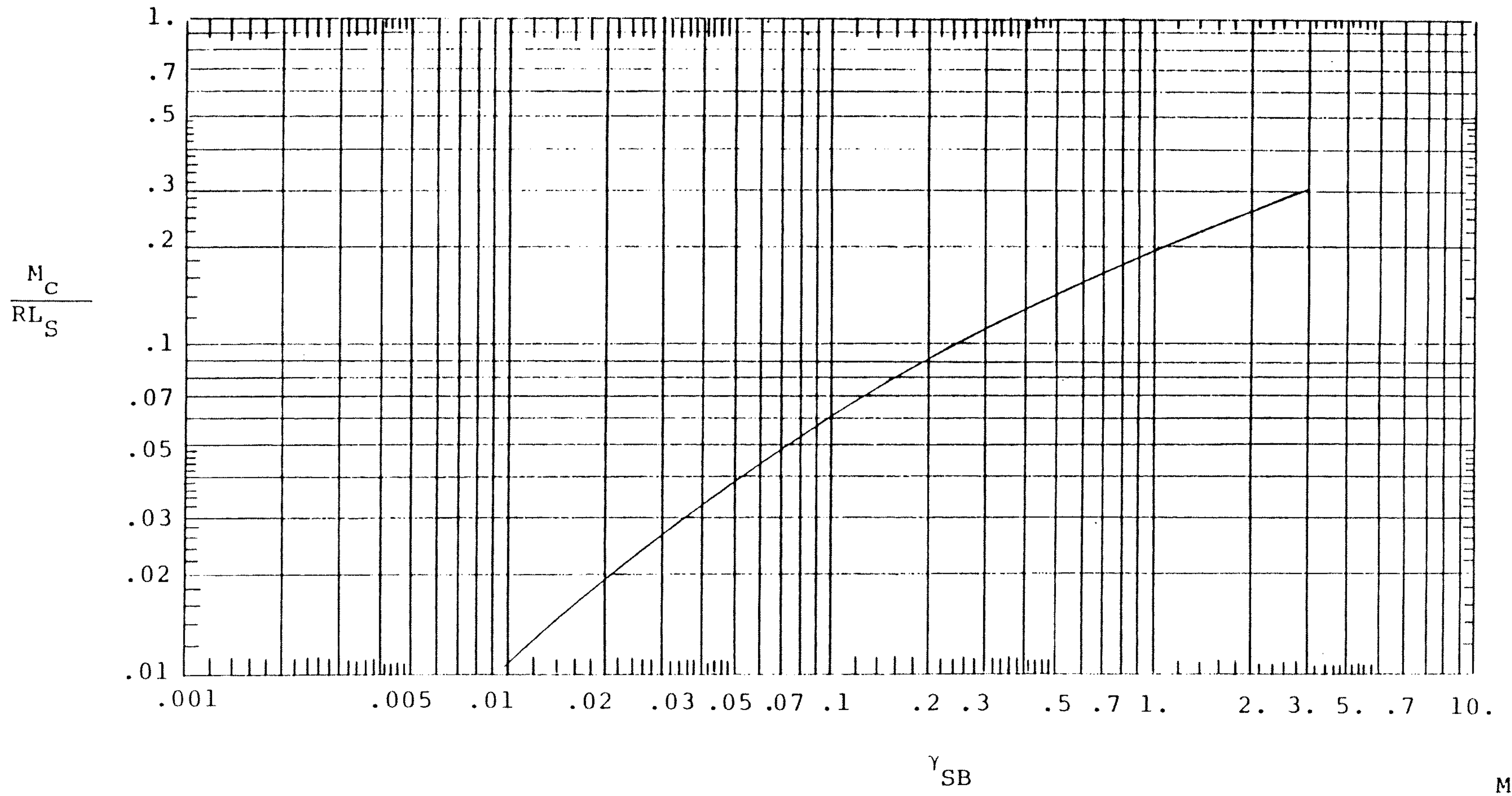


Figure 15 Stiffener Bending Moment Correction for Elastic Supports Coefficient, $\frac{M_C}{RL_S}$

The beam load coefficient, ϕ_4, is calculated by one of the following equations, depending on the aircraft's orientation to the stiffeners.

For the aircraft alined with the stiffeners and where:

$$L_B \geq 1.5\ s \qquad \text{Q.1-9}$$

the beam loading coefficient is:

$$\phi_4 = \frac{4}{\pi} \cos\left(\frac{\pi s}{2 L_B}\right) \sin\left(\frac{\pi B_o}{L_B}\right)\left(1 + \cos\left(\frac{\pi s}{2 L_B}\right)\right) \qquad \text{Q.1-10}$$

And for the aircraft alined perpendicular to the stiffeners, or, for the aircraft alined with the stiffeners where:

$$L_B < 1.5\ s \qquad \text{Q.1-11}$$

the beam loading coefficient is:

$$\phi_4 = \frac{4}{\pi} \sin\left(\frac{\pi B_o}{L_B}\right) \qquad \text{Q.1-12}$$

The moment due to flexibility of the beam supports, M_c, is then calculated by applying the appropriate load factors using the following equation.

$$M_c = \left(\frac{M_c}{RL_S}\right) R_o b L_S\ \phi_4 \qquad \text{Q.1-13}$$

The moment due to the dead weight of the plating and stiffener, M_D, is determined by calculating the midspan moment of a single span beam with fixed supports under that distributed load. The distributed load due to the weight of the plating and stiffener is calculated using the following equation.

$$w_D = \frac{1}{12{,}000}\left(w_s + \left(\frac{b}{12}\right) w_p\right) \qquad \text{Q.1-14}$$

The moment due to the dead weight of the plating and stiffener, M_D, is then calculated using the following equation.

$$M_D = \frac{\eta_z w_D L_S{}^2}{12} \qquad \text{Q.1-15}$$

The maximum bending moment in the stiffener, M_S, is the sum of these components, and is calculated using the following equation.

$$M_S = M_o + M_c + M_D \qquad \text{Q.1-16}$$

The bending stress is then calculated using one of the following equations depending on type of aircraft operations and deck function.

For the landing condition or the parking condition on a non-strength deck, the bending stress is calculated using the following equation.

$$f_{SB} = \frac{M_S}{SM_{MIN}} \qquad Q.1\text{-}17$$

For the parking condition on a strength deck, the bending stress is calculated using the following equation.

$$f_{SB} = \frac{M_S}{SM_{MIN}} + \sigma_{primary} \qquad Q.1\text{-}18$$

The value of the design primary stress ($\sigma_{primary}$) for the storm sea condition and its variation along the length of the vessel may be taken from the detail specifications for that vessel. The primary stress values to be used in the various loading conditions are as shown in Table IV.

	Percent of Design Primary
Storm Sea Parking	100
Moderate Sea Parking	50
Landing	0

Table IV Design Primary Stress versus Sea Condition

For those decks utilizing a RAST system for operations in heavier seas, it may be appropriate to include the primary stress for the landing condition. Depending upon the sea state specified in the vessel's detailed specifications for flight operations, and estimate can be made of the primary stress.

In addition, it may be necessary to determine ($\frac{M_S}{SM_{MAX}} + \sigma_{primary}$) where high hull girder deck compressive stresses occur. Check the plate stiffener combination, for buckling as a column in accordance with Reference (b).

An estimate of the required section modulus, SM_{REQD}, can be determined as follows:

$$SM_{REQD} = \frac{M_S}{(\sigma_{SB} - \sigma_{primary})} \qquad \text{Q.1-19}$$

where the allowable bending stress, σ_{SB}, is as defined in Section 130-2-u.

Maximum Shear Force and Stress

The loading condition which produces the maximum shear force is when the patch load is placed adjacent to the stiffener support directly over the stiffener. This maximum shear force is the summation of (1) the shear due to the live load, V_o, (assuming the stiffener as a continuous beam on rigid supports) and (2) the shear due to the dead weight of the plating and stiffener, V_D.

The load applied to the stiffener is a single or dual patch load of length, A', (along the stiffener), width, B', (perpendicular to the stiffener), magnitude, P, and dual patch spacing, b", as described in Section 130-2-m.

To account for the distribution effects of the patch width, B', the patch width load factor, ϕ_1, calculate $\frac{B'}{b}$ and use Figure 12. Note that the curve marked i = 0 must be used because the stiffener in question is that one directly under the load.

To account for the combined effects of dual patches, the dual patch equivalent load factor, ϕ_3, is used. To determine the dual patch equivalent load factor, ϕ_3, calculate $\frac{b''}{b}$ and use Figure 14. Note that for single patches $\phi_3 = 1.0$.

The shear due to the live load over rigid supports, V_o, is determined by using the influence line coefficient and applying the appropriate load factors. The influence line coefficient for the shear at the support of a continuous beam over equally spaced rigid supports for a patch load adjacent to the support is calculated by the following equation.

$$\frac{V_o}{P} = 1 - 0.7321\left(\frac{A'}{L_S}\right)^2 + 0.2990\left(\frac{A'}{L_S}\right)^3 \qquad \text{Q.1-20}$$

The shear due to the live load over rigid supports, V_o, is then calculated by applying the appropriate load factors using the following equation.

$$V_o = \left(\frac{V_o}{P}\right) P \, \phi_1 \, \phi_3 \qquad \text{Q.1-21}$$

The shear due to the dead weight of the plating and stiffener, V_D, is determined by using the distributed load due to the weight of the plating and stiffener, and then calculating the shear at the support of a single span beam under the distributed load. The shear due to the dead weight of the plating and stiffener, V_D, is calculated using the following equation.

$$V_D = \frac{n_z w_D L_S}{2} \qquad \text{Q.1-22}$$

The maximum shear force in the stiffener, V_S, is the sum of these components and is calculated using the following equation.

$$V_S = V_o + V_D \qquad \text{Q.1-23}$$

The shear stress is then calculated using the following equation.

$$f_{SV} = \frac{V_S}{A_S} \qquad \text{Q.1-24}$$

An estimate of the required shear area, $A_{S_{REQD}}$, can be determined as follows:

$$A_{s_{REQD}} = \frac{V_s}{\sigma_{SV}} \qquad \text{Q.1-25}$$

Where the allowable shear stress, σ_{SV}, is as defined in Section 130-2-u.

Appendix E is an abridged description of the stiffener analysis methods and criteria for both bending and shear for easier reference. Appendix G contains standard calculation sheets.

130-2-q.2 Irregular Structural Scantlings

Where the structural arrangement of the deck scantlings cannot be characterized as equally spaced or sized stiffeners or beams due to unique design considerations, a grid analysis of the deck may be performed using an accepted Finite Element Program. Figure 8 shows a typical grid model.

The modeling of the deck is left to the discretion of the engineer, but some suggestions follow:

Plating - Generally it is not necessary to model the plate. Panels are usually regular in size or a given set of panels will control the design. If this is not the case, and analysis is necessary, the analysis must allow for the membrane as well as the bending behavior of the plating, and must allow for plastic as well as elastic deformations. The design criteria must account for permanent set as well as stress limit criteria.

Stiffeners - Beam elements are adequate. The effective plate should be included in the beam properties. Generally, five spans are sufficient to achieve the effects of continuous beams.

Beams and Girders - Beam elements are adequate. The effective plate should be included in the beam properties. Generally three spans are sufficient to achieve the continuity effects for these beams.

Stanchions and Bulkheads - Generally it is not necessary to model the supports other than rigid. If sway of the deck is critical, then modeling may be necessary.

Loading - (1) Live Load.

If only the stiffeners will be designed or analyzed based on the results obtained, then only one gear load need be applied. If the beams and girders will be designed or analyzed based on the results obtained, then the other gears should be included and the critical loading conditions for these members should be used. Only those loading conditions pertaining to the stiffener design or analysis will be discussed.

Two loading conditions will be needed, (1) to determine the maximum bending moment and stress and (2) to determine the maximum shear force and stress. As described before, the maximum shear force occurs when the load is adjacent to the support.

To properly distribute the loads so that the effects of patch width distribution, plating distribution, dual patches, and beam flexibility are accurately modeled, the gear load should be distributed between the three stiffeners nearest midspan of the beams. The loads are distributed using the patch width load factor, Φ_1, the plating distribution load factor, Φ_2, and the dual patch equivalent load factor, Φ_3, as described in Section 130-2-q.1. The loads applied to each stiffener should be distributed along the length of the stiffeners for a distance equal to the patch length, A'. Figure 16 shows the proposed distribution of the gear load, where L_0 is the load on the stiffener in question, L_{1L} is the load on the stiffener directly to the left, and L_{1R} is the load directly to the right.

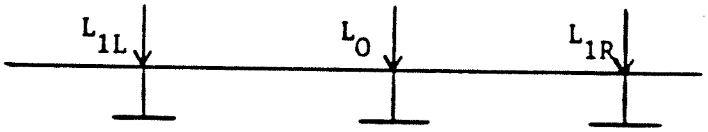


Figure 16

The magnitude of these loads should be as shown in Table V.

Loading Condition for		Bending Moment	Shear Force
Single patch	L_0	$P \Phi_1 \Phi_2$	$P \Phi_1$
	L_{1L}	$1/2P \Phi_1(1-\Phi_2)$	$1/2P \Phi_1$
	L_{1R}	$1/2P \Phi_1(1-\Phi_2)$	$1/2P \Phi_1$
Dual patch	L_0	$P \Phi_1 \Phi_2 \Phi_3$	$P \Phi_1 \Phi_3$
	L_{1L}	$1/2P \Phi_1(1-\Phi_2)$	$1/2P \Phi_1$
	L_{1R}	$1/2P \Phi_1(1-\Phi_2)+P(2-\Phi_3)$	$1/2P \Phi_1+P(2-\Phi_3)$

Table V F.E.M. Model Loadings

Note that the patch width load factor, ϕ_1, is different for L_0 than for L_{1L} of L_{1R}. For L_0 the ϕ_1, curve marked i = 0 should be used and for L_{1L} and L_{1R} the ϕ_1, curve marked i = 1 should be used.

(2) Dead Load.

The dead load of the plating and stiffeners can be modeled as distributed loads of magnitude, w_D, applied to each of the stiffeners over the entire length.

(3) Primary Stress.

The effects due to the hull girder bending (primary stress) can be either added as an additional stress or as an axial load in the longitudinal direction.

130-2-r. Beams, Girders and Stanchions

Beams, girders, and stanchions supporting aircraft handling decks must be designed to withstand the maximum bending, shear, or compressive stress induced by the aircraft gear loads or any other loading requirements of the deck. Special consideration is required where more than one aircraft may be parked on the deck at a time. Due to the relatively large span of the beams and girders, the gear load may be considered as a concentrated load, regardless of single or dual wheeled gear. It is essential that the most critical loading condition for each of these members be determined, since the aircraft could be at almost any location on the deck.

Longitudinal beams or girders must also be designed or analyzed with primary stress considered, if applicable.

For both beams and girders, any acceptable linear analysis method such as moment distribution may be utilized. The method chosen should be based on the structural geometry and the engineer's discretion.

Stanchions provide intermediate support for beams or girders where their spans would otherwise be excessive. Likewise, where deck stiffeners, beams, or girders are supported by bulkheads, the vertical stiffener under the beams may be considered as a column using the appropriate plate-stiffener combination.

The maximum reaction into a stanchion or bulkhead support must be obtained. Reference (b) should be used to determine the adequacy or required size of the stanchion or bulkhead support.

PART VI: DESIGN CRITERIA

130-2-s. General

The yield stress, F_y, and allowable working stress, F_b, for each material are as provided in the ship specifications, corresponding to Section 100 (Section 9110-0 for older ships) of Reference (f).

130-2-t. Plating

The allowable stress levels for the plating are a function of the probability of the occurence of the loading. In deck parking areas, when severe ship motions (storm sea) are assumed, the plating allowable stress is taken as the welded yield strength of the material, that is,

$$\sigma_p = F_y \qquad T - 1$$

For landing and moderate sea parking, (the most common and frequent load magnitudes), the allowable stress is the allowable working strength of the material or

$$\sigma_p = F_b \qquad T - 2$$

For those decks utilizing a RAST system for operation in heavy seas (see state 5), greater than the moderate sea condition, the allowable stress is the allowable working strength of the material or

$$\sigma_p = F_b \qquad T - 3$$

The calculated stress in the plating, f_p, must be less than or equal to the allowable stress or

$$f_p \leq \sigma_p \qquad T - 4$$

130-2-u. Stiffeners

The allowable bending stress level for the stiffeners is the allowable working strength of the material or

$$\sigma_{SB} = F_b \qquad U-1$$

The calculated bending stress in the stiffener, f_{SB}, must be less than or equal to the allowable bending stress or

$$f_{SB} \leq \sigma_{SB} \qquad U-2$$

The allowable shear stress level for the stiffeners is sixty percent (60%) of the allowable working strength of the material or

$$\sigma_{SV} = 0.6\ F_b \qquad U-3$$

The calculated shear stress in the stiffener, f_{SV}, must be less than or equal to the allowable shear stress or

$$f_{SV} \leq \sigma_{SV} \qquad U-4$$

130-2-v. Beams, Girders and Stanchions

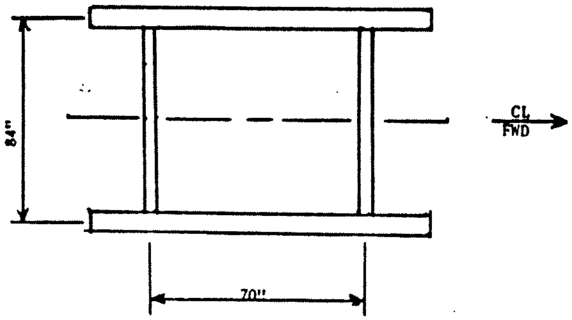
The allowable stress levels for beams, girders and stanchions are as per the design criteria in the ship specifications, corresponding to Section 100 (Section 9110-0 for older ships) of Reference (f) or Reference (b).

APPENDIX A

DATA SHEETS FOR EXISTING NAVY HELICOPTERS

	HELICOPTER H-1			
WEIGHT	Maximum Landing	W_M	10.5 K	
	Parking	W_P	10.5 K	
	Light	W_L	6.7 K	
CENTER OF GRAVITY	Vertical	Z_G	92"	
	Longitudinal Aft of Fwd Crossbar	X_G	67"	
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	24"	24"
	Transverse	Y_T	42"	42"
	Angle to Deck	Ω	45°	45°
CONFIGURATION			OPERATIONAL	BLADES REMOVED
	Sail Area	a_s	190 ft^2	199 ft^2
	Vertical Center of Pressure	Z_p	64"	69"
	Overall Length		57'-2"	44'-7"
	Overall Width		48'-0"	10'-4"
	Overall Height		14'-4"	13'-1"
	Forward Extent from Fwd Crossbar		20'-8"	11'-4"
SKIDS				
	Nominal Landing Load Fwd/Skid		3.5 K	
	Nominal Landing Load Aft/Skid		7.0 K	

SKID CONFIGURATION



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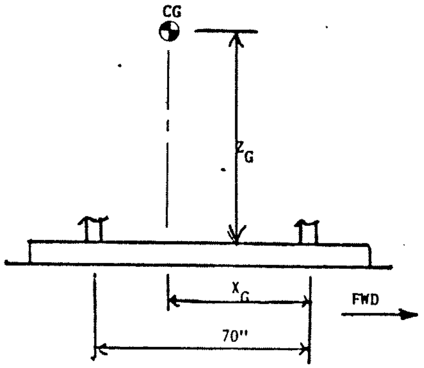

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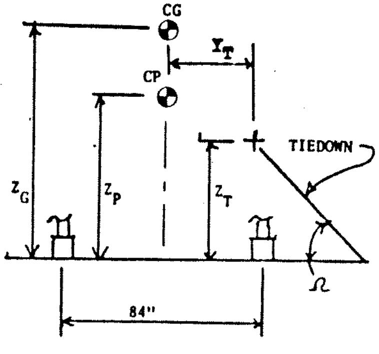
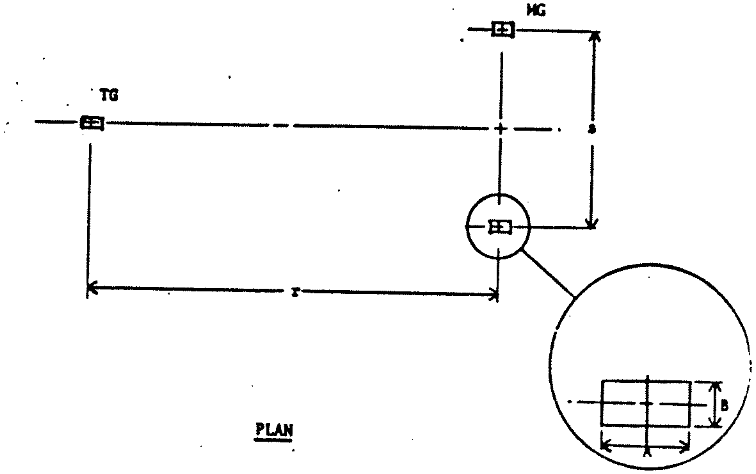


SECTION

HELICOPTER UH-2

WEIGHT	Maximum Landing	W_M		11.7K
	Parking	W_P		11.7K
	Light	W_L		7.6K
CENTER OF GRAVITY	Vertical	Z_G		103"
	Longitudinal Aft of MG	X_G		32"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	84"	9"
	Transverse .	Y_T	30"	68"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	200#	205#
	Vertical Center of Pressure	Z_P	70"	72"
	Overall Length		52'-7"	40'-6"
	Overall Width		44'-0"	11'-7"
	Overall Height		15'-6"	13'-7"
	Forward Extent from MG		18'-0"	9'-4"
	Distance between MG and TG	r		221"
	Distance between MG	s		126"
MAIN GEAR	Nominal Landing Load/Gear	R		18.7K
	Tire Size & Ply			17.5 x 6.25 8 ply
	Tire Bottoming Load	P_b		11.7K
TAIL GEAR	Nominal Landing Load/Gear	R		18.0K
	Tire Size & Ply			5.0 x 5.0 10 ply
	Tire Bottoming Load	P_b		9.3K

GEAR CONFIGURATION



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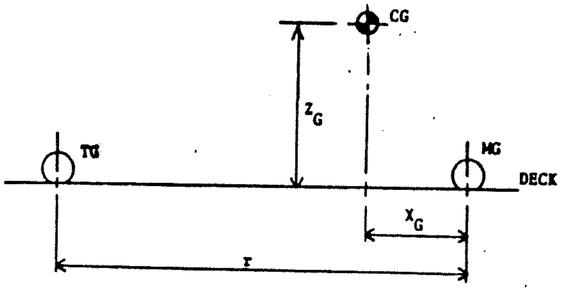

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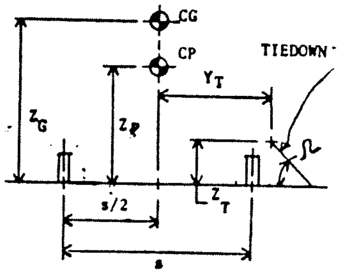


SECTION

TIRE FOOTPRINT DATA

Tail Gear

P_T	A	B
1.2	6.7	4.7
9.0	9.7	5.7

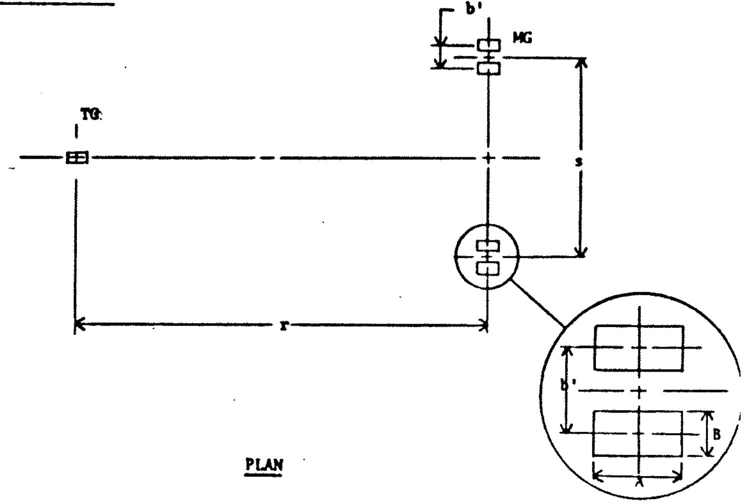
Main Gear

P_T	A	B
3.2	5.3	4.3
10.5	8.5	5.3

HELICOPTER HH-2 and SH-2

WEIGHT	Maximum Landing	W_M		14.0 K
	Parking	W_P		14.0 K
	Light	W_L		8.9 K
CENTER OF GRAVITY	Vertical	Z_G		103"
	Longitudinal Aft of MG	X_G		32"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	96"	9"
	Transverse	Y_T	30"	68"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	200 ft^2	205 ft^2
	Vertical Center of Pressure	Z_P	70"	72"
	Overall Length		52'-7"	40'-6"
	Overall Width		44'-0"	12'-5"
	Overall Height		15'-8"	13'-7"
	Forward Extent from MG		18'-8"	9'-4"
	Distance between MG and TG	r		201"
	Distance between MG	s		120"
	Dual Wheel Spacing	b'		10.5"
MAIN GEAR	Nominal Landing Load/Gear	R		21.0 K
	Tire Size & Ply		17.5 x 6.25	8 ply
	Tire Bottoming Load	P_b		18.0 K
TAIL GEAR	Nominal Landing Load/Gear	R		18.0 K
	Tire Size & Ply		5.0 x 5.0	10 ply
	Tire Bottoming Load	P_b		9.3 K

GEAR CONFIGURATION



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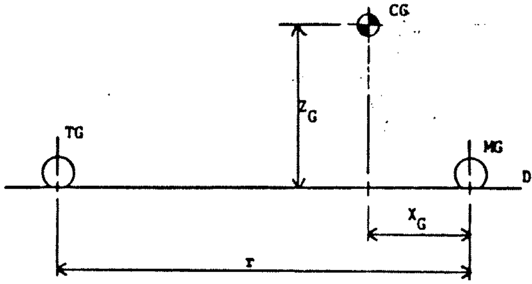

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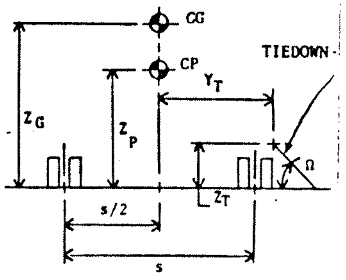


SECTION

TIRE FOOTPRINT DATA

Tail Gear

P_T	A	B
1.2	6.7	4.7
9.0	9.7	5.7

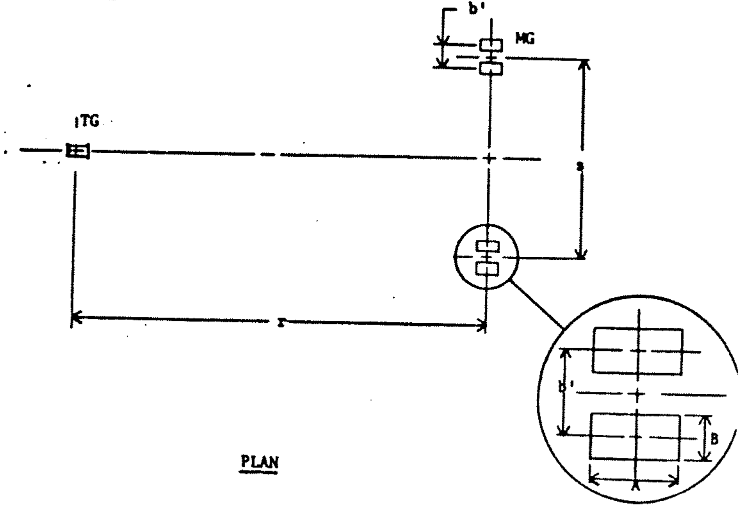
Main Gear

P_T	A	B
3.2	5.3	4.3
10.5	8.5	5.3

HELICOPTER H-3

WEIGHT	Maximum Landing	W_M		21.0 K
	Parking	W_P		21.0 K
	Light	W_L		11.9 K
CENTER OF GRAVITY	Vertical	Z_G		80"
	Longitudinal Aft of MG	X_G		31"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	108"	11"
	Transverse.	Y_T	42"	88"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	465 ft^2	475 ft^2
	Vertical Center of Pressure	Z_p	95"	100"
	Overall Length		72'-8"	47'-3"
	Overall Width		62'-0"	16'-4"
	Overall Height		16'-10"	15'-7"
	Forward Extent from MG		26'-8"	11'-2"
	Distance between MG and TG	r		282.5"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		13"
MAIN GEAR	Nominal Landing Load/Gear	R		20.0 K
	Tire Size & Ply		6.50 x 10	10 ply
	Tire Bottoming Load	P_b		13.3 K
TAIL GEAR	Nominal Landing Load/Gear	R		10.0 K
	Tire Size & Ply		6.00 x 6	8 ply
	Tire Bottoming Load	P_b		8.1 K

GEAR CONFIGURATION



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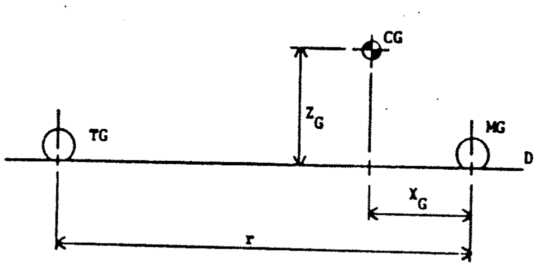

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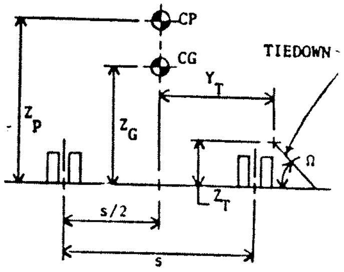


SECTION

TIRE FOOTPRINT DATA

Tail Gear

P_T	A	B
1.7	7.6	4.9
5.0	13.0	7.8

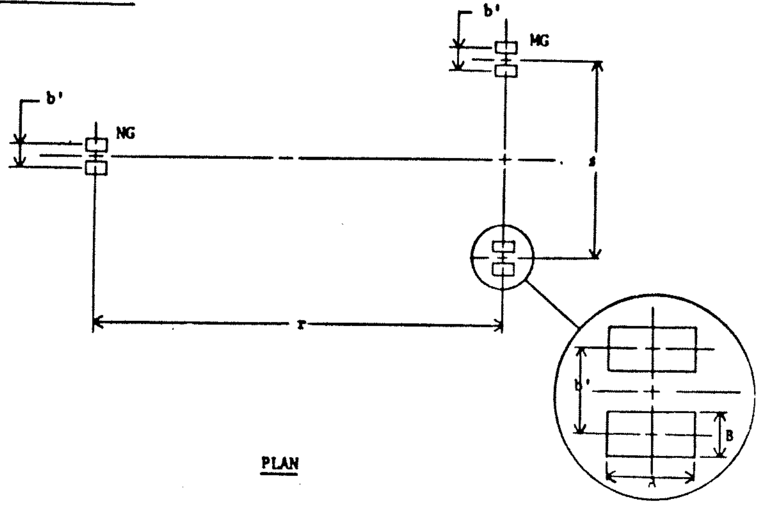
Main Gear

P_T	A	B
4.7	9.6	5.2
10.0	15.0	7.4

HELICOPTER H-46

WEIGHT	Maximum Landing	W_M		23.0 K
	Parking	W_P		20.0 K
	Light	W_L		13.1 K
CENTER OF GRAVITY	Vertical	Z_G		85"
	Longitudinal FWD of MG	X_G		86"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	45"	9"
	Transverse	Y_T	85"	85"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	444 ft^2	440 ft^2
	Vertical Center of Pressure	Z_p	93"	92"
	Overall Length		84'-4"	45'-8"
	Overall Width		51'-0"	14'-9"
	Overall Height		18'-10"	16'-9"
	Forward Extent from MG		51'-6"	31'-0"
	Distance between MG and NG	r		298"
	Distance between MG	s		154.5"
	Dual Wheel Spacing	b'		10"
MAIN GEAR	Nominal Landing Load/Gear	R		30.0 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K
NOSE GEAR	Nominal Landing Load/Gear	R		20.0 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K

GEAR CONFIGURATION



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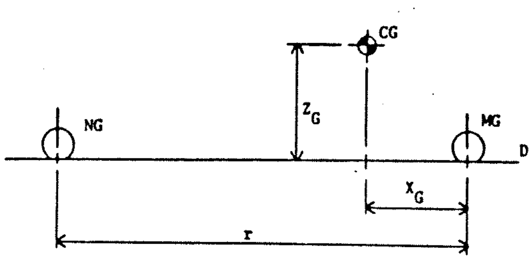

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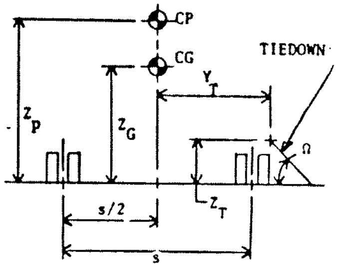


SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

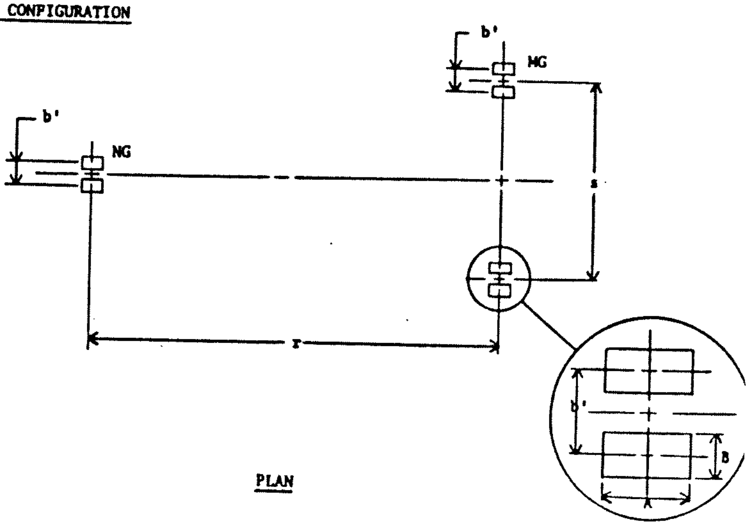
Main Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

HELICOPTER CH - 53A

WEIGHT	Maximum Landing	W_M		42.0 K
	Parking	W_P		29.0 K
	Light	W_L		23.1 K
CENTER OF GRAVITY	Vertical	Z_G		116"
	Longitudinal FWD of MG	X_G		84"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	51"	12"
	Transverse	Y_T	93"	87"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	644 ft^2	687 ft^2
	Vertical Center of Pressure	Z_p	122"	127"
	Overall Length		88'-2"	56'-6"
	Overall Width		72'-3"	15'-8"
	Overall Height		24'-11"	17'-2"
	Forward Extent from MG		37'-1"	26'-0"
	Distance between MG and NG	r		324"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		17"
MAIN GEAR	Nominal Landing Load/Gear	R		33.0 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		21.7 K
NOSE GEAR	Nominal Landing Load/Gear	R		25.5 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		21.7 K

GEAR CONFIGURATION



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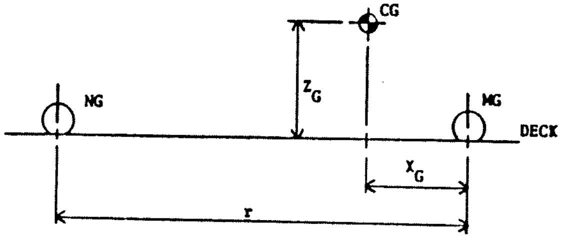

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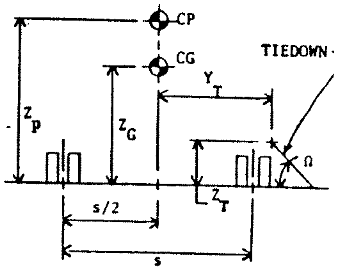


SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
5.75	10.0	5.4
12.75	15.3	7.7

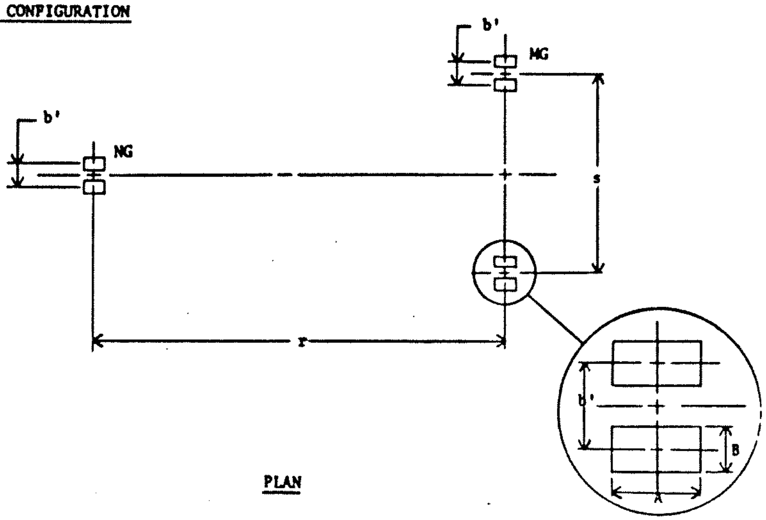
Main Gear

P_T	A	B
7.63	10.2	5.5
16.5	15.4	7.7

HELICOPTER RH - 53D

WEIGHT	Maximum Landing	W_M		50.0 K
	Parking	W_P		32.0 K
	Light	W_L		25.7 K
CENTER OF GRAVITY	Vertical	Z_G		116"
	Longitudinal FWD of MG	X_G		84"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	51"	12"
	Transverse	Y_T	93"	87"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	644 ft^2	687 ft^2
	Vertical Center of Pressure	Z_p	122"	127"
	Overall Length		88'-2"	56'-10"
	Overall Width		72'-3"	23'-11"
	Overall Height		24'-11"	17'-2"
	Forward Extent from MG		37'-1"	26'-0"
	Distance between MG and NG	r		324"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		17"
MAIN GEAR	Nominal Landing Load/Gear	R		50.5 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	R_b		25.5 K
NOSE GEAR	Nominal Landing Load/Gear	R		33.6 K
	Tire Size & Ply		8.50 x10	12 ply
	Tire Bottoming Load	P_b		23.2 K

GEAR CONFIGURATION



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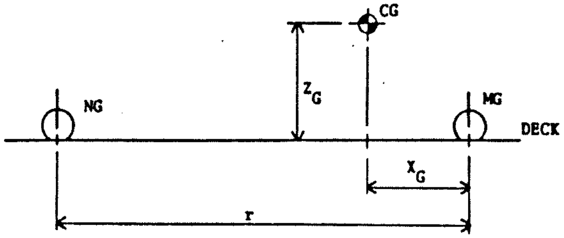

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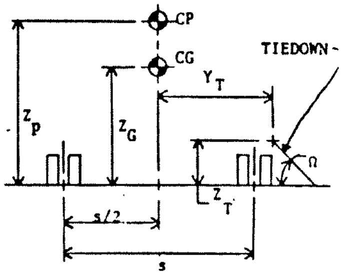


SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
7.14	10.8	5.9
16.8	16.3	8.1

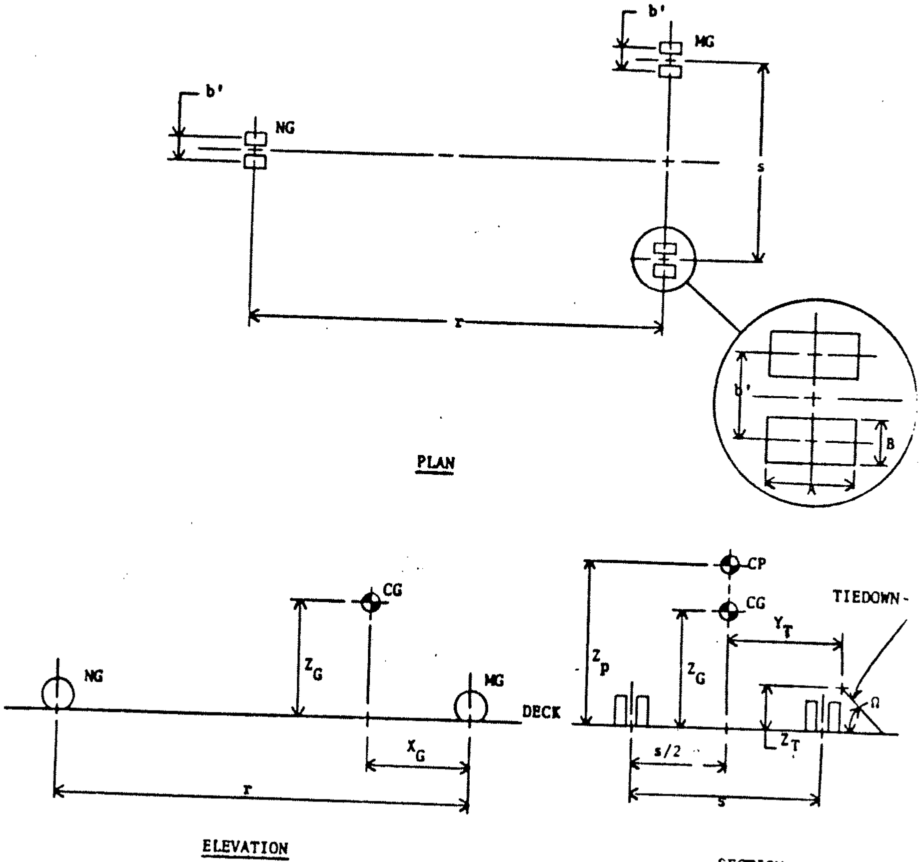
Main Gear

P_T	A	B
9.73	12.7	6.5
25.25	19.8	9.3

HELICOPTER CH - 53E

WEIGHT	Maximum Landing	W_M		70.0 K
	Parking	W_P		60.0 K
	Light	W_L		33.3 K
CENTER OF GRAVITY	Vertical	Z_G		90"
	Longitudinal FWD of MG	X_G		83"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	51"	12"
	Transverse	Y_T	93"	87"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	674 ft^2	702
	Vertical Center of Pressure	Z_P	122"	127"
	Overall Length		99'-0"	60'-3"
	Overall Width		79'-0"	28'-5"
	Overall Height		28'-5"	18'-7"
	Forward Extent from MG		47'-11"	29'-9"
	Distance between MG and NG	r		327"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		17"
MAIN GEAR	Nominal Landing Load/Gear	R		51.2 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		32.2 K
NOSE GEAR	Nominal Landing Load/Gear	R		33.9 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		23.2 K

GEAR CONFIGURATION



PLAN

ELEVATION

SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
9.95	11.5	6.2
16.95	15.8	8.1

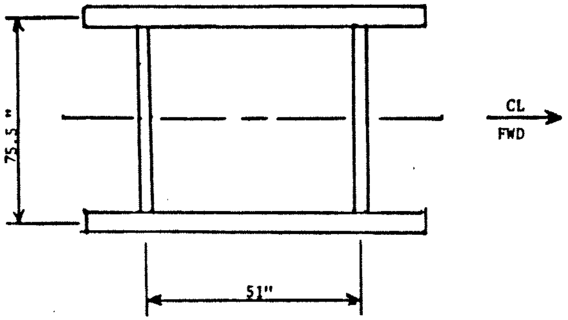
Main Gear

P_T	A	B
13.3	12.9	7.0
25.6	16.2	8.1

HELICOPTER TH - 57A

WEIGHT	Maximum Landing	W_M	2.9 K	
	Parking	W_P	2.9 K	
	Light	W_L	1.55 K	
CENTER OF GRAVITY	Vertical	Z_G	46"	
	Longitudinal Aft of Fwd Crossbar	X_G	48"	
TIEDOWNS			STORM	MODERATE
		Z_T	24"	24"
	Transverse	Y_T	22"	22"
	Angle to Deck	Ω	45°	45°
CONFIGURATION			OPERATIONAL	BLADES REMOVED
	Sail Area	a_s	106 ft²	103 ft²
	Vertical Center of Pressure	Z_p	60"	58"
	Overall Length		39'-1"	31'-2"
	Overall Width		33'-4"	6'-4"
	Overall Height		11'-8"	10'-0"
	Forward Extent from Fwd Crossbar		30'-6"	7'-0"
SKIDS				
	Nominal Landing Load Fwd/Skid		1.0 K	
	Nominal Landing Load Aft/Skid		2.0 K	

SKID CONFIGURATION



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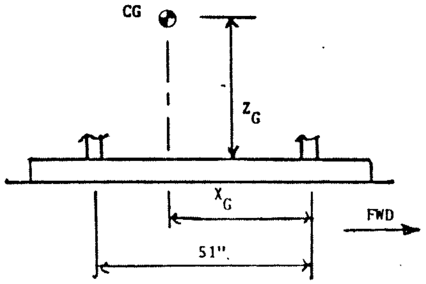

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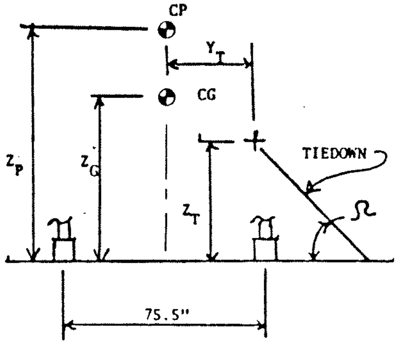
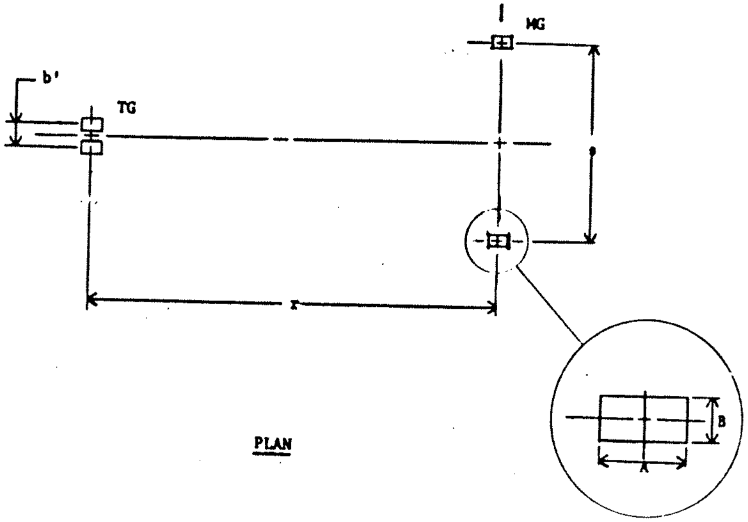


SECTION

HELICOPTER SH-60B

WEIGHT	Maximum Landing	W_M		21.9 K
	Parking	W_P		21.9 K
	Light	W_L		21.9 K
CENTER OF GRAVITY	Vertical	Z_G		66"
	Longitudinal Aft of MG	X_G		50"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	59.5"	12"
	Transverse	Y_T	29.6"	58"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	268 ft^2	271 ft^2
	Vertical Center of Pressure	Z_p	76"	76"
	Overall Length		64'-10"	40'-11"
	Overall Width		53'-8"	10'-9"
	Overall Height		17'-0"	13'-3"
	Forward Extent from MG		50'-0"	11'-1"
	Distance between MG and TG	r		185.7"
	Distance between MG	s		106.6"
	Dual Wheel Spacing	b'		12.5"
MAIN GEAR	Nominal Landing Load/Gear	R		18.2 K
	Tire Size & Ply			26 x 10-11 10 ply
	Tire Bottoming Load	P_b		25.0 K
TAIL GEAR	Nominal Landing Load/Gear	R		19.0 K
	Tire Size & Ply			6.00 x 6 8 ply
	Tire Bottoming Load	P_b		10.8 K

GEAR CONFIGURATION



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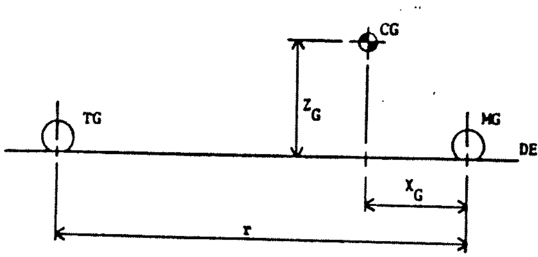

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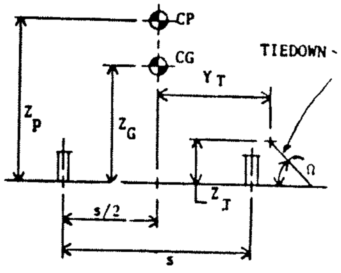


SECTION

TIRE FOOTPRINT DATA

Tail Gear

P_T	A	B
3.2	9.0	5.6
9.5	14.0	6.2

Main Gear

P_T	A	B
6.5	11.2	7.7
18.2	17.6	10.9

APPENDIX B

DATA SHEETS FOR NOTIONAL HELICOPTERS

HELICOPTER DESIGN CHARACTERISTICS

In the early stages of structural design, the exact helicopter type may not be specified but it will be required to develop scantlings. Given the nominal characteristics for an anticipated helicopter type, the following may be used for the structural analysis and design:

Example of the use of these characteristics from each category are given below and the other additional needed data are itemized in the succeeding pages:

A. Similar to H-1 (max W = 10,500 lb., skid landing gear) or H-2 (max W = 14,000 lb., single or dual tire main landing gear).

Weight = 17,000 pounds (maximum weight)
W_P = 17,000 pounds (maximum parking weight)
R_L = 23,000 pounds (landing gear reaction)

B. Similar to H-3 (max W = 21,000 lb., dual main landing gear) or H-46 (max W = 23,000 lb., dual main landing gear)

Weight = 29,000 pounds
W_P = 29,000 pounds
R_L = 37,500 pounds

C. Similar to CH-53A (max W = 42,000 lb., dual landing gear)

Weight = 56,000 pounds
W_P = 44,000 pounds
R_L = 51,000 pounds

Use CH-53A landing gear configuration

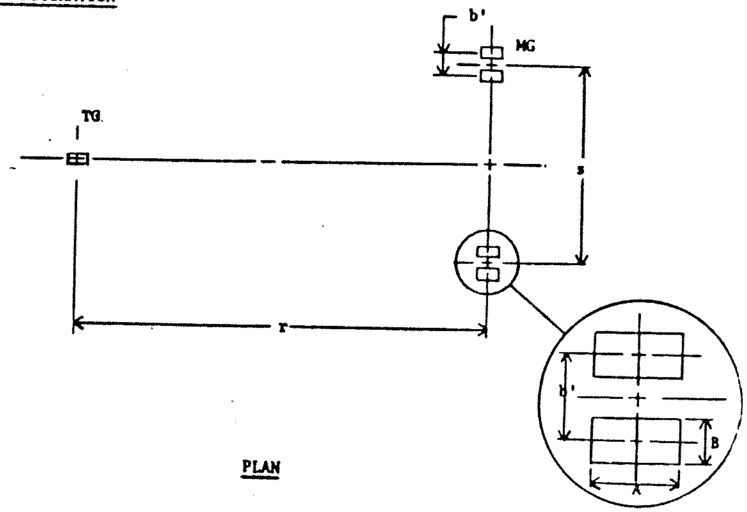
D. Similar to CH-53E (max W = 70,000 lb., dual landing gear)

Weight = 80,000 pounds
W_P = 65,000 pounds
R_L = 60,000 pounds

Use CH-53E landing gear configuration

	HELICOPTER		A	
WEIGHT	Maximum Landing	W_M		17.0 K
	Parking	W_P		17.0 K
	Light	W_L		9.0 K
CENTER OF GRAVITY	Vertical	Z_G		103"
	Longitudinal Aft of MG	X_G		32"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	96"	9"
	Transverse	Y_T	30"	68"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	200 ft^2	205 ft^2
	Vertical Center of Pressure	Z_P	70"	72"
	Overall Length		52'-7"	40'-6"
	Overall Width		44'-0"	12'-5"
	Overall Height		15'-8"	13'-7"
	Forward Extent from MG		18'-8"	9'-4"
	Distance between MG and TG	r		201"
	Distance between MG	s		120"
	Dual Wheel Spacing	b'		10.5"
MAIN GEAR	Nominal Landing Load/Gear	R		23.0 K
	Tire Size & Ply		17.5 x 6.25	8 ply
	Tire Bottoming Load	P_b		18.0 K
TAIL GEAR	Nominal Landing Load/Gear	R		18.0 K
	Tire Size & Ply		5.0 x 5.0	10 ply
	Tire Bottoming Load	P_b		9.3 K

GEAR CONFIGURATION



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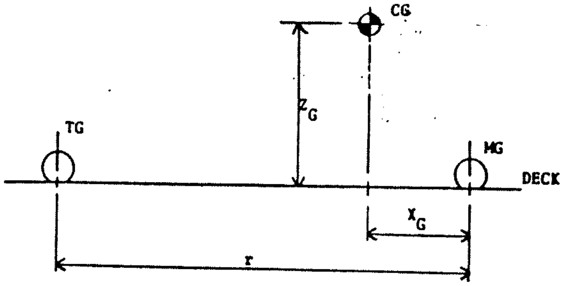

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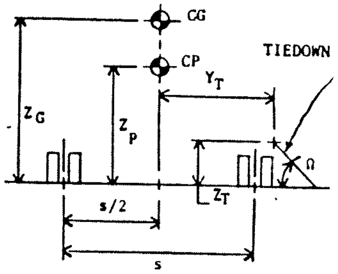


SECTION

TIRE FOOTPRINT DATA

Tail Gear

P_T	A	B
1.2	6.7	4.7
9.0	9.7	5.7

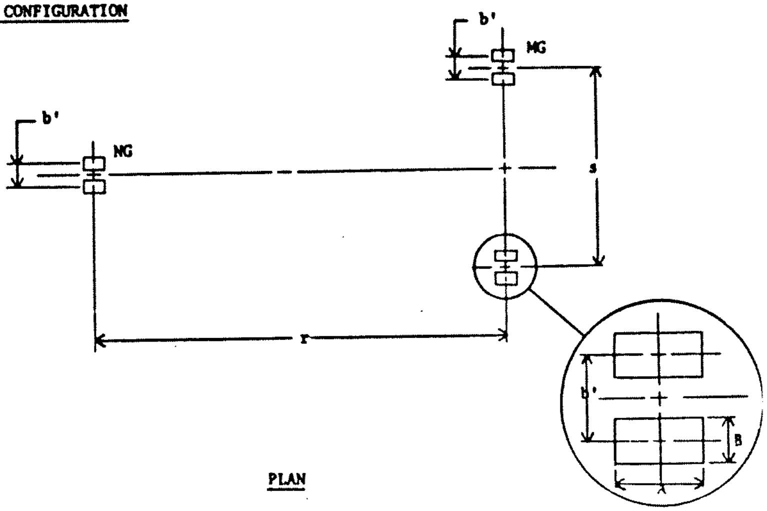
Main Gear

P_T	A	B
3.2	5.3	4.3
10.5	8.5	5.3

HELICOPTER B

WEIGHT	Maximum Landing	W_M		29.0 K
	Parking	W_P		29.0 K
	Light	W_L		14.0 K
CENTER OF GRAVITY	Vertical	Z_G		85"
	Longitudinal FWD of MG	X_G		86"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	45"	9"
	Transverse	Y_T	85"	85"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	444 ft^2	440 ft^2
	Vertical Center of Pressure	Z_p	93"	92"
	Overall Length		84'-4"	45'-8"
	Overall Width		51'-0"	14'-9"
	Overall Height		18'-10"	16'-9"
	Forward Extent from MG		51'-6"	31'-0"
	Distance between MG and NG	r		298"
	Distance between MG	s		154.5"
	Dual Wheel Spacing	b'		10"
MAIN GEAR	Nominal Landing Load/Gear	R		37.5 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K
NOSE GEAR	Nominal Landing Load/Gear	R		25.0 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K

GEAR CONFIGURATION



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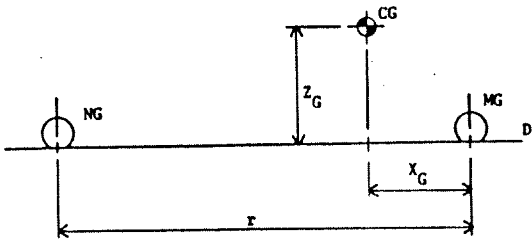

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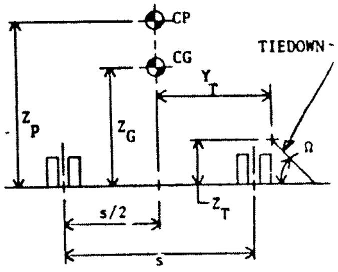


SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

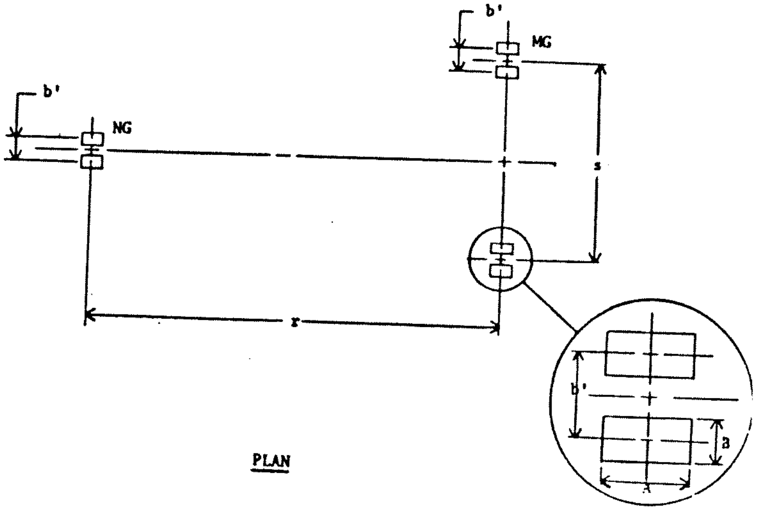
Main Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

HELICOPTER C

WEIGHT	Maximum Landing	W_M		56.0 K
	Parking	W_P		44.0 K
	Light	W_L		25.0 K
CENTER OF GRAVITY	Vertical	Z_G		116"
	Longitudinal FWD of MG	X_G		84"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	51"	12"
	Transverse	Y_T	93"	87"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	644 ft^2	687 ft^2
	Vertical Center of Pressure	Z_p	122"	127"
	Overall Length		88'-2"	56'-6"
	Overall Width		72'-3"	15'-8"
	Overall Height		24'-11"	17'-2"
	Forward Extent from MG		37'-1"	26'-0"
	Distance between MG and NG	r		324"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		17"
MAIN GEAR	Nominal Landing Load/Gear	R		51.0 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		25.5 K
NOSE GEAR	Nominal Landing Load/Gear	R		25.5 K
	Tire Size & Ply		8.50 x 10	12 ply
	Tire Bottoming Load	P_b		23.2 K

GEAR CONFIGURATION



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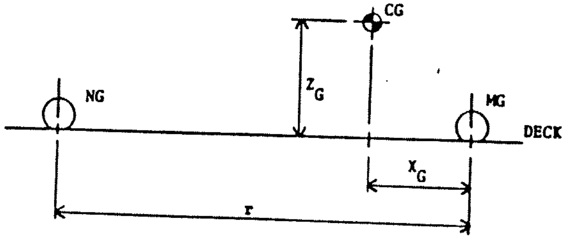

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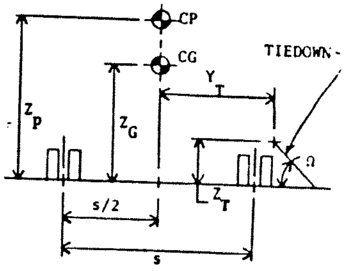


SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
5.75	10.0	5.4
12.75	15.3	7.7

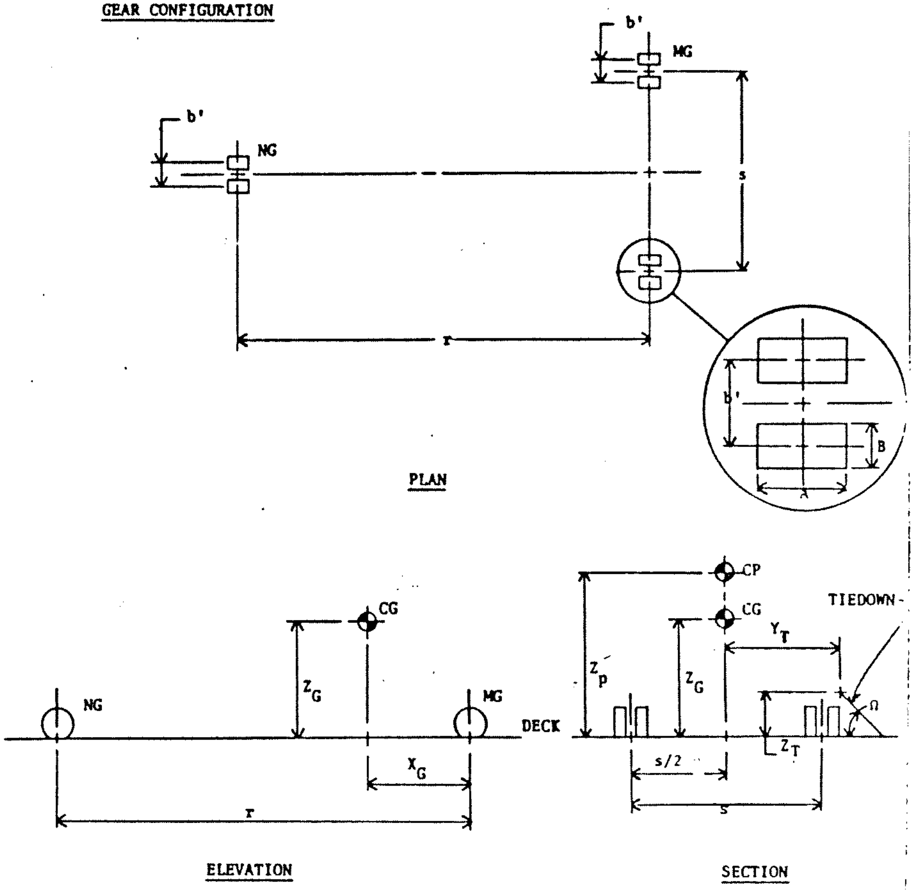
Main Gear

P_T	A	B
7.63	10.2	5.5
16.5	15.4	7.7

HELICOPTER D

WEIGHT	Maximum Landing	W_M		80.0 K
	Parking	W_P		65.0 K
	Light	W_L		35.0 K
CENTER OF GRAVITY	Vertical	Z_G		90"
	Longitudinal FWD of MG	X_G		83"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	51"	12"
	Transverse,	Y_T	93"	87"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	674 ft^2	702
	Vertical Center of Pressure	Z_p	122"	127"
	Overall Length		99'-0"	60'-3"
	Overall Width		79'-0"	28'-5"
	Overall Height		28'-5"	18'-7"
	Forward Extent from MG		47'-11"	29'-9"
	Distance between MG and NG	r		327"
	Distance between MG	s		156"
	Dual Wheel Spacing	b'		17"
MAIN GEAR	Nominal Landing Load/Gear	R		60.0 K
	Tire Size & Ply			8.50 x 10 12 ply
	Tire Bottoming Load	P_b		32.2 K
NOSE GEAR	Nominal Landing Load/Gear	R		35.0 K
	Tire Size & Ply			8.50 x 10 12 ply
	Tire Bottoming Load	P_b		23.2 K

GEAR CONFIGURATION



TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
9.95	11.5	6.2
16.95	15.8	8.1

Main Gear

P_T	A	B
13.3	12.9	7.0
25.6	16.2	8.1

APPENDIX C

SUMMARY OF LOAD AND LOAD DISTRIBUTION METHODS

Summary of Load and Load Distribution Methods

Landing Loads

Gear Reaction: R_L = Nominal Landing Load per Gear

Parking Loads

Aircraft Weight Conditions: W_j = Aircraft Weight in the j condition

SEA CONDITION	FLIGHT DECK	HANGAR DECK	ELEVATOR PLATFORM
Storm	W_P	W_P	N/A
Moderate	W_M	W_P	W_P

Table I Aircraft Weight Conditions

Ship Motion Factors: η_i = Ship Motion Factor in the i direction

η_x = fore and aft factor

η_y = athwartships factor

η_z = vertical factor

Ship Motion Loads: F_i = Ship Motion Load in the i direction

$$F_i = \eta_i W_j \qquad \text{G.2-1}$$

Wind Motion Loads: F_w = Wind Load

a_s = Aircraft Sail Area

Storm Seas: $F_w = 0.015a_s$ G.3-1

Moderate Seas : $F_w = 0.0075a_s$ G.3-2

In Hangar : $F_w = 0$

Ship Motion Forces: F_L = Ship Motion Force Longitudinal to Aircraft

F_T = Ship Motion Force Transverse to Aircraft

F_D = Motion Force Downward to Aircraft

Aircraft Oriented Longitudinally:

$$F_L = F_x \qquad \text{G.4-1}$$

$$F_T = F_y \qquad \text{G.4-2}$$

$$F_D = F_z \qquad \text{G.4-3}$$

Aircraft Oriented Athwartships:

$$F_L = F_y \qquad \text{G.4-4}$$

$$F_T = F_x \qquad \text{G.4-5}$$

$$F_D = F_z \qquad \text{G.4-6}$$

Gear Reactions:

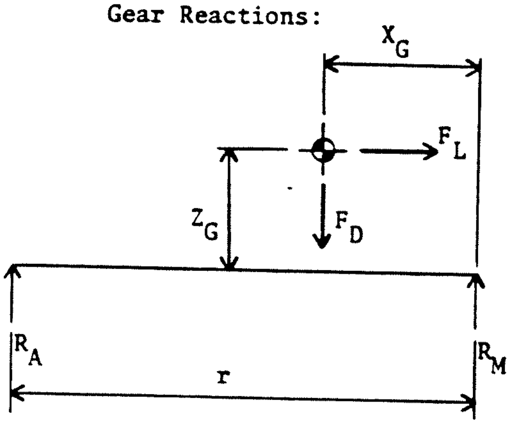


Figure 1 Aircraft Longitudinal Free Body Diagram

Maximum total main gear reaction, R_M :

$$R_M = F_D\left(1 - \frac{X_G}{r}\right) + F_L\left(\frac{Z_G}{r}\right) \qquad \text{G.5-1}$$

Maximum auxiliary gear reaction, R_A :

$$R_A = F_D\left(\frac{X_G}{r}\right) + F_L\left(\frac{Z_G}{r}\right) \qquad \text{G.5-2}$$

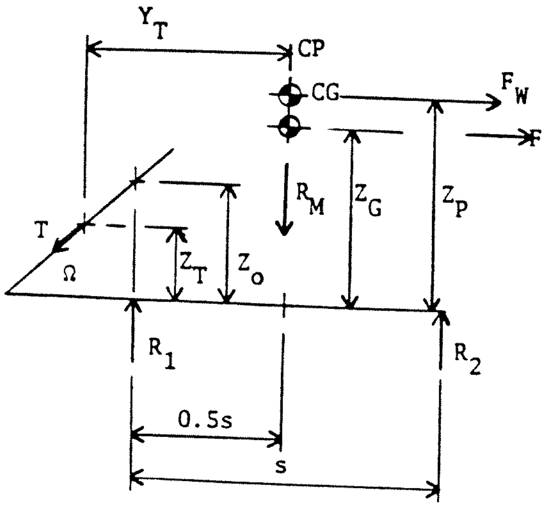


Figure 2 Aircraft Transverse Free Body Diagram

Equivalent tiedown lever arm, Z_O:

$$Z_O = Z_T + \left(Y_T - \frac{-s}{2}\right) \operatorname{Tan} \Omega \qquad \text{G.5-5}$$

Aircraft overturning moment, M:

$$M = F_w Z_P + F_T Z_G - R_M\left(\frac{s}{2}\right) \qquad \text{G.5-6}$$

If $M \leq 0$

Main gear reaction #2, R_2:

$$R_2 = 1/2\ R_M + F_w \left(\frac{Z_P}{s}\right) + F_T \left(\frac{Z_G}{s}\right) \tag{G.5-7}$$

Main gear reaction #1, R_1:

$$R_1 = R_M - R_2 \tag{G.5-8}$$

<u>If $M > 0$ (Storm Sea Condition Only)</u>

Main gear reaction #1, R_1:

$$R_1 = 1/2\ W_P \left(1 - \frac{X_G}{r}\right) \tag{G.5-9}$$

Friction force, F_F:

$$F_F = \frac{1/2\ R_M - R_1 + F_w \left(\tan \Omega - \left(\frac{Z_P - Z_o}{S}\right)\right) + F_T \left(\tan \Omega - \left(\frac{Z_G - Z_o}{S}\right)\right)}{2 \tan \Omega + \frac{Z_o}{S}} \tag{G.5-10}$$

Main gear reaction #2, R_2:

$$R_2 = 1/2\ R_M + F_w \left(\frac{Z_P - Z_o}{S}\right) + F_T \left(\frac{Z_G - Z_o}{S}\right) + F_F \left(\frac{Z_o}{S}\right) \tag{G.5-11}$$

Tiedown force, T:

$$T = (F_w + F_T - F_F)/\cos \Omega \tag{G.5-12}$$

Critical Gear Load:

$R = R_2$ or R_A, whichever produces the worst loading.

Tire Load, P_T:

Single Wheeled Gear: $P_T = R$ J-1

Dual Wheeled Gear: $P_T = 1/2\ R$ J-2

Tire Footprint: P_b = Tire Bottoming Load

P_T	A	B
P_{T_1}	A_1	B_1
P_{T_2}	A_2	B_2

$$A = A_1 + \left(\frac{A_2 - A_1}{P_{T_2} - P_{T_1}}\right)(P_T - P_{T_1}) \qquad \text{K-1}$$

$$B = B_1 + \left(\frac{B_2 - B_1}{P_{T_2} - P_{T_1}}\right)(P_T - P_{T_1})$$

Note P_T must be less than or equal to P_b

Variation in Load and Load Pattern due to Aircraft Orientation

If the aircraft is alined with the stiffeners:

$A' = A$ M-1

$B' = B$ M-2

For single wheeled gear, see Figure 6-A:

$P = R$ M-3

b' is not applicable M-4

For dual wheeled gear, see Figure 6-B:

$P = 1/2R$ M-5

$b'' = b'$ M-6

If the aircraft is alined perpendicular to the stiffeners:

$B' = A$ M-7

$P = R$ M-8

b" is not applicable

For single wheeled gear, see Figure 6-C:

$A' = B$ M-9

For dual wheeled gear, see Figure 6-D:

$A' = b' + B$ M-10

APPENDIX D

SUMMARY OF PLATING ANALYSIS METHOD AND CRITERIA

Summary of Plating Analysis Method and Criteria

Analysis Method -

Non-dimensional bending moment per unit width of plating, C_1:

$$\text{For } \frac{A'}{b} \leq .5,\ C_1 = \frac{0.25 - 0.125\left(\frac{B'}{b}\right)}{0.94 + 0.45\left(\frac{A'}{b}\right)} - \frac{0.079 - 0.026\left(\frac{B'}{b}\right)^2}{1.75 + 0.15\left(\frac{A'}{b}\right)^2} \qquad \text{P-1}$$

$$\text{For } \frac{A'}{b} > .5,\ C_1 = \frac{0.25 - 0.125\left(\frac{B'}{b}\right)}{\left(\frac{A'}{b}\right) + \frac{.6}{\left(\left(\frac{A'}{b}\right) + 0.4\right)}} - \frac{0.079 - 0.026\left(\frac{B'}{b}\right)^2}{1.75 + 0.15\left(\frac{A'}{b}\right)^2} \qquad \text{P-2}$$

Equivalent tire reaction factor, Ψ:

Use $\frac{B'}{b}$ and $\frac{b''}{b}$ on Figure 11 to obtain Ψ.

Note $\Psi = 1$ for single patch loadings.

Deck function coefficient, C_o:

DECK FUNCTION	C_o (Steel or Aluminum)	
	Landing and Moderate Sea Parking	Storm Sea Parking
UPPERMOST STRENGTH DECK HIGH SPEED ROLLING OF AIRCRAFT	2.0	1.7
UPPERMOST STRENGTH DECK LOW SPEED HANDLING OF AIRCRAFT	3.4	2.8
NON UPPERMOST STRENTH DECK HIGH SPEED ROLLING OF AIRCRAFT	3.4	2.8
NON UPPERMOST STRENGTH DECK LOW SPEED HANDLING OF AIRCRAFT	4.2	3.5

Table III Deck Function Coefficient, C_o

Maximum plate bending stress, f_p:

$$f_p = \frac{6C_1 \; P\Psi}{C_o \; t^2} \qquad \text{P-3}$$

Design criteria

Storm Sea Parking Allowable Stress:

$$\sigma_p = F_Y \qquad \text{T-1}$$

Landing and Moderate Sea Parking Allowable Stress

$$\sigma_p = F_b \qquad \text{T-2}$$

Stress Criteria:

$$f_p \leq \sigma_p \qquad \text{T-4}$$

APPENDIX E

SUMMARY OF STIFFENER ANALYSIS METHOD AND CRITERIA

Summary of Stiffener Analysis Method and Criteria

Analysis Method

Maximum Bending Moment and Stress:

Patch width load distribution factor, ϕ_1:

Use $\frac{B'}{b}$ on Figure 12 curve i = 0 to obtain ϕ_1.

Plating load distribution factor, ϕ_2:

Calculate the relative rigidity coefficient of plate - stiffener, γ_{PS}

$$\gamma_{PS} = \frac{(e_s\ L_S)^4 t^3}{3.49\ b^3\ \pi^4\ I_S} \qquad \text{Q.1-1}$$

Use γ_{PS} on Figure 13 to obtain ϕ_2.

Dual patch equivalent load factor, ϕ_3:

Use $\frac{b''}{b}$ on Figure 14 to obtain ϕ_3.

Note $\phi_3 = 1$ for single patch loadings.

Moment due to the live load over rigid supports, M_o:

Calculate the influence line coefficient, $\frac{M_o}{PL_S}$:

$$\frac{M_o}{PL_S} = 0.1708 - 0.125\left(\frac{A'}{L_S}\right) + 0.0264\left(\frac{A'}{L_S}\right)^2 \qquad \text{Q.1-2}$$

Calculate M_o:

$$M_o = \left(\frac{M_o}{PL_S}\right) PL_S \phi_1\ \phi_2\ \phi_3 \qquad \text{Q.1-3}$$

Moment due to flexibility of the beam supports, M_c:

Calculate the relative rigidity coefficient of stiffener - beam, γ_{SB}:

$$\gamma_{SB} = \frac{(e_B L_B)^4 I_S}{0.684b\ (e_S L_S)^3\ \pi^4 I_B} \qquad \text{Q.1-4}$$

Moment correction coefficient, $\frac{M_c}{RL_S}$:

Use γ_{SB} on Figure 15 to obtain $\frac{M_c}{RL_S}$.

Calculate the beam characteristic load, R_o:

$$R_o = \begin{cases} \dfrac{R}{B'} & \text{, single patch} \qquad \text{Q.1-5} \\ \dfrac{R}{(b' + B')} & \text{, dual patch} \qquad \text{Q.1-6} \end{cases}$$

Calculate the beam characteristic load width, B_o:

$$B_o = \begin{cases} \dfrac{B'}{2} & \text{, single patch} \qquad \text{Q.1-7} \\ 1/2\ (b'' + B') & \text{, dual patch} \qquad \text{Q.1-8} \end{cases}$$

Calculate the beam loading coefficient, ϕ_4:

Aircraft alined with stiffeners and

$$L_B \geq 1.5s \qquad \text{Q.1-9}$$

$$\phi_4 = \frac{4}{\pi} \cos\left(\frac{\pi s}{2L_B}\right) \sin\left(\frac{\pi B_o}{L_B}\right)\left(1 + \cos\left(\frac{\pi s}{2L_B}\right)\right) \qquad \text{Q.1-10}$$

Aircraft perpendicular to stiffeners or aircraft alined with stiffeners and

$$L_B < 1.5s \qquad \text{Q.1-11}$$

$$\phi_4 = \frac{4}{\pi} \sin\left(\frac{\pi B_o}{L_B}\right) \qquad \text{Q.1-12}$$

Calculate M_c:

$$M_c = \left(\frac{M_c}{RL_S}\right) R_o\ b\ L_S\ \phi_4 \qquad \text{Q-1.13}$$

Moment due to dead weight of plating and stiffener, M_D:

Calculate the dead load of plating and stiffener, w_D:

$$w_D = \frac{1}{12000} \left(w_S + \frac{b}{12} w_p\right) \qquad \text{Q.1-14}$$

Calculate M_D:

$$M_D = \frac{\eta_z w_D L_S^2}{12} \qquad \text{Q.1-15}$$

Maximum bending moment in stiffener, M_S:

$$M_S = M_o + M_c + M_D \qquad \text{Q.1-16}$$

Landing or parking on a non-strength deck

$$f_{SB} = \frac{M_S}{SM_{MIN}} \qquad \text{Q.1-17}$$

Parking on a strength deck

$$f_{SB} = \frac{M_S}{SM_{MIN}} + \sigma_{primary} \qquad \text{Q.1-18}$$

Maximum Shear Force and Stress:

Patch width load distribution factor, ϕ_1:

Use $\frac{B'}{b}$ on Figure 12 curve i = 0 to obtain ϕ_1.

Dual patch equivalent load factor, ϕ_3:

Use $\frac{b''}{b}$ on Figure 14 to obtain ϕ_3.

Note $\phi_3 = 1$ for single patch loadings.

Shear due to live load, V_o:

Calculate the influence line coefficient, $\frac{V_o}{P}$:

$$\frac{V_o}{P} = 1 - 0.7321 \left(\frac{A'}{L_S}\right)^2 + 0.2990 \left(\frac{A'}{L_S}\right)^3 \qquad \text{Q.1-20}$$

Calculate V_o :

$$V_o = \left(\frac{V_o}{P}\right) P\phi_1\phi_3 \qquad \text{Q.1-21}$$

Shear due to dead weight of plating and stiffener, V_D:

$$V_D = \frac{\eta_z w_D L_S}{2} \qquad \text{Q.1-22}$$

Maximum shear force in stiffener, V_S:

$$V_S = V_o + V_D \qquad \text{Q.1-23}$$

Maximum shear stress in stiffener, f_{SV}:

$$f_{SV} = \frac{V_S}{A_S} \qquad \text{Q.1-24}$$

Design Criteria -

Allowable Bending Stress:

$$\sigma_{SB} = F_b \qquad \text{U-1}$$

Bending Stress Criteria:

$$f_{SB} \leq \sigma_{SB} \qquad \text{U-2}$$

Allowable Shear Stress:

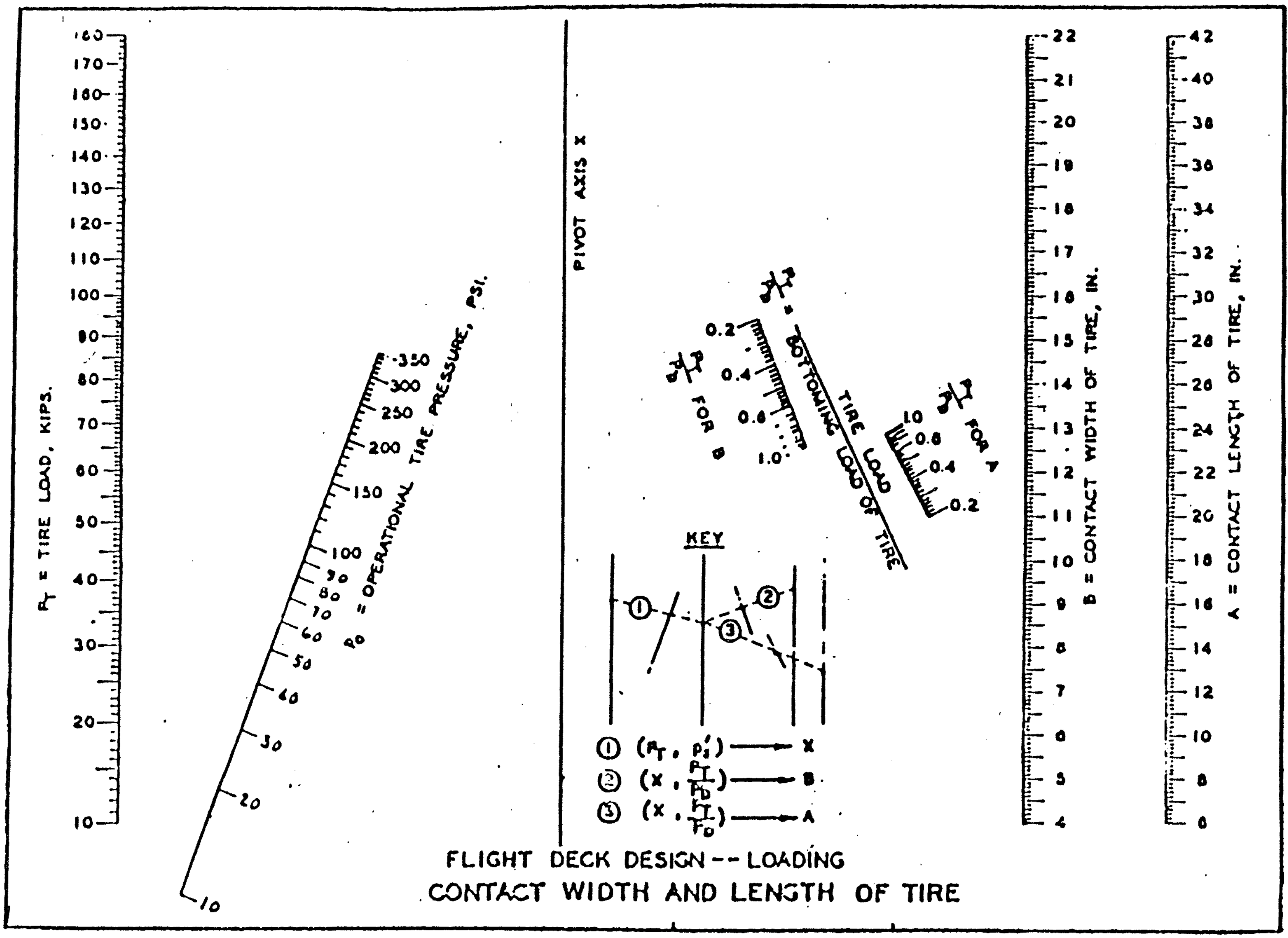
$$\sigma_{SV} = 0.6\ F_b \qquad \text{U-3}$$

Shear Stress Criteria:

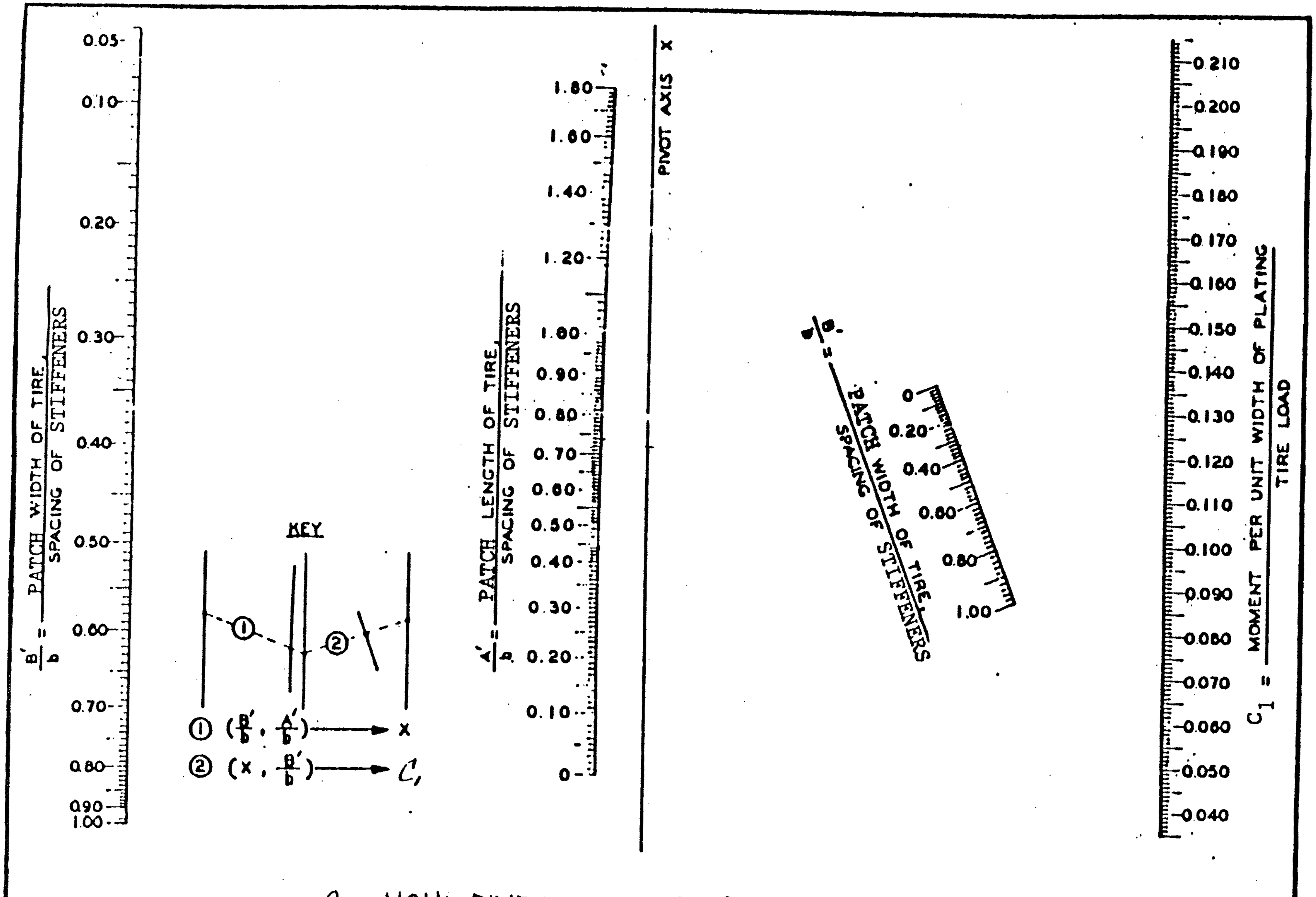
$$f_{SV} \leq \sigma_{SV} \qquad \text{U-4}$$

APPENDIX F

NOMOGRAPHS



FLIGHT DECK DESIGN -- LOADING
CONTACT WIDTH AND LENGTH OF TIRE



C_1, NON-DIMENSIONALIZED BENDING MOMENT COEFFICIENT OF PLATING

APPENDIX G

STANDARD WORK SHEETS

STRUCTURAL PROPERTIES			SHIP OR PROJECT:		
DECK STRUCTURE					
PLATE	t				
	material				
	w_p				
STIFFENER	size				
	material				
	w_S				
	A				
	A_S				
	b_e				
	I_s				
	SM_{MIN}				
BEAM	size				
	material				
	w_B				
	A				
	A_S				
	b_e				
	I_B				
	SM_{MIN}				
GEOMETRY	b				
	L_S				
	L_B				
PARAMETERS	γ_{PS}				
	γ_{SB}				
	w_D				
	e_S				
	e_B				
$\sigma_{PRIMARY}$					
REMARKS					

SHIP MOTION FACTORS AND LOADS					SHIP OR PROJECT:						
	SPOT	1	2	3	4	5	6	7	8	9	10
LOCATION	X										
	Y										
	Z										
STORM SEA CONDITION	n_{xs}										
	n_{ys}										
	n_{zs}										
	W										
	F_{xs}										
	F_{ys}										
	F_{zs}										
	F_w										
MODERATE SEA CONDITION	n_{xm}										
	n_{ym}										
	n_{zm}										
	W										
	F_{xm}										
	F_{ym}										
	F_{zm}										
	F_w										
REMARKS											

SHIP MOTION EQUATIONS:

n_{xs} =

n_{ys} =

n_{zs} =

n_{xm} =

n_{ym} =

n_{zm} =

GEAR REACTIONS AND DISTRIBUTIONS					SHIP OR PROJECT:			
SPOT								
ORIENT	LONGITUDINAL		TRANSVERSE		LONGITUDINAL		TRANSVERSE	
SEA COND	STORM	MOD	STORM	MOD	STORM	MOD	STORM	MOD
F_L								
F_T								
F_D								
R_M								
R_A								
M								
R_1								
F_F								
R_2								
T								
R								
P_T								
A								
B								
P								
b"								
A'								
B'								
Remarks								

PLATE AND STIFFENER STRESS ANALYSIS

SHIP OR PROJECT:

DECK STRUCTURE:

SEA CONDITION:

SPOT:

ORIENTATION:

ANALYSIS PARAMETERS:

REMARKS

$R =$

$P =$

$A' =$

$B' =$

$\frac{B'}{b} =$

$\frac{A'}{b} =$

$\frac{A'}{L_S} =$

$\frac{b''}{b} =$

PLATE ANALYSIS:

REMARKS

$t =$

$F_y =$

$F_b =$

$C_1 =$

$\psi =$

$f_p =$

$C_o =$

$\sigma_p =$

$t_{reqd} =$

STIFFENER ANALYSIS:

REMARKS

$SM_{MIN} =$

$A_s =$

$f_b =$

$\phi_1 =$

$\phi_2 =$

$\phi_3 =$

$\frac{M_o}{PL_S} =$

$M_o =$

$R_o =$

$B_o =$

$\phi_4 =$

$\frac{M_c}{RL_S} =$

$M_c =$

$M_D =$

$M_S =$

$f_{SB} =$

$\sigma_{SB} =$

$\frac{V_o}{P} =$

$SM_{reqd} =$

$V_D =$

$V_o =$

$V_S =$

$f_{SV} =$

σ_{SV}

$A_{s_{reqd}}$

APPENDIX H

EXAMPLE

The following is a numerical example to demonstrate the analysis methods presented in this Design Data Sheet. The storm sea parking condition for the longitudinal orientation is given in detail. The entire analysis is summarized on the Standard Work Sheets of Appendix G.

Ship: Fleet Oiler

Scantlings: Main Deck, Flight and Hangar Deck Areas

Plating	30.6# OS
Longitudinal Stiffeners	12" x 6½" x 30# I-T OS
Transverse Beams	16" x 7" x 36# I-T OS
Stiffener Spacing	30"
Stiffener Span	10'- 0"
Beam Span	20'- 0"
Number of Stiffener Spans	>15
Number of Beam Spans	5

Ship Motion Factors:

Storm Seas

Fore and Aft: $n_{xs} = 0.20 + 0.0002X + 0.002\ Z$

Transverse: $n_{ys} = 0.50 + 0.001X + 0.002Y + 0.004\ Z$

Downward: $n_{zs} = 1.30 + 0.002X + 0.004Y$

Moderate Seas

Fore and Aft: $n_{xm} = 0.50\ n_{xs}$

Transverse: $n_{ym} = 0.50\ n_{ys}$

Downward: $n_{zm} = 0.50\ (1 + n_{zs})$

Spotting:

1) Landing Circle	X = 350'	Y = 0'	Z = 28'
2) Extreme Aft Athwartships	X = 375'	Y = 30'	Z = 28'
3) Hangar	X = 275'	Y = 20'	Z = 28'

Primary Stress: Storm

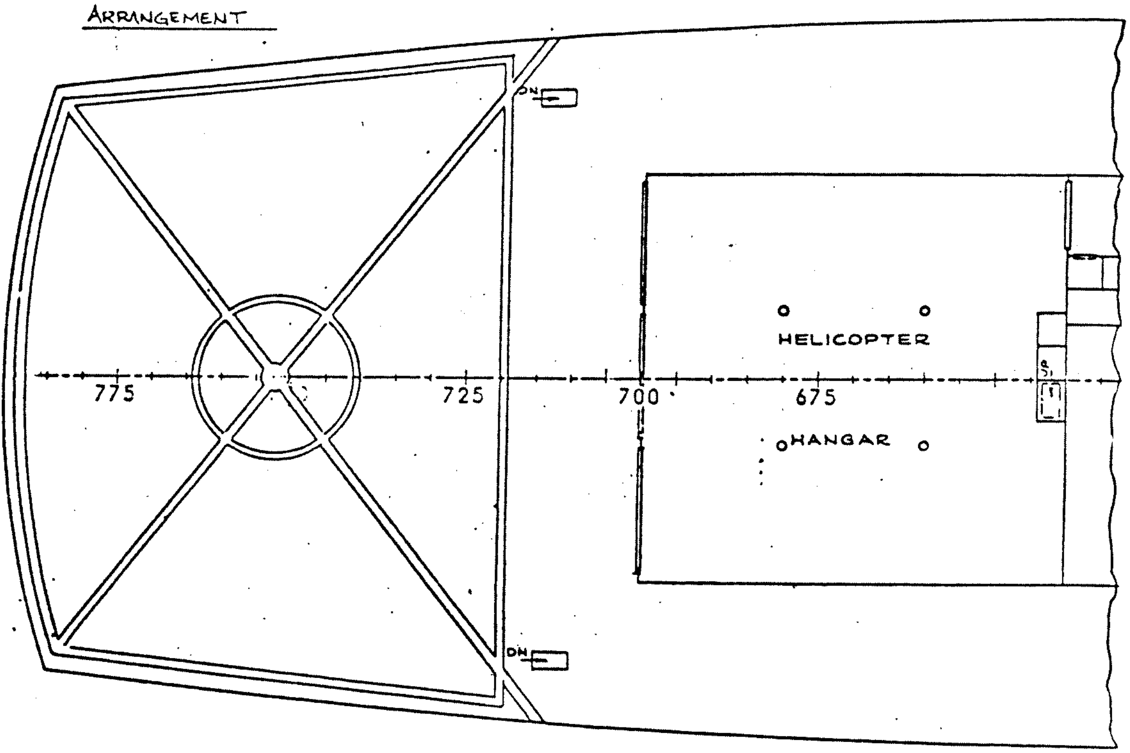
Spot

1) $^{\sigma}$primary = 1.3 tsi = 2.9 ksi

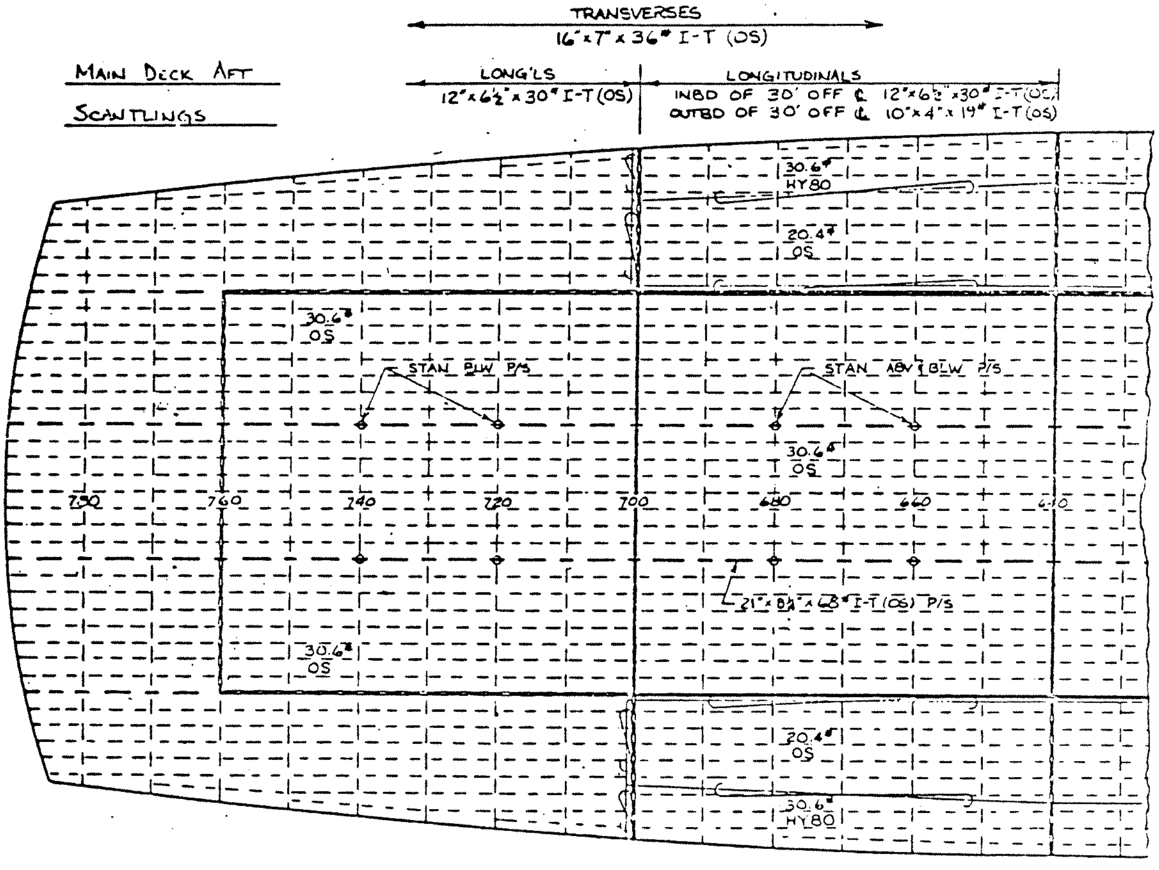
2) $^{\sigma}$primary = 0.7 tsi = 1.6 ksi

3) $^{\sigma}$primary = 3.3 tsi = 7.4 ksi

MAIN DECK AFT
ARRANGEMENT



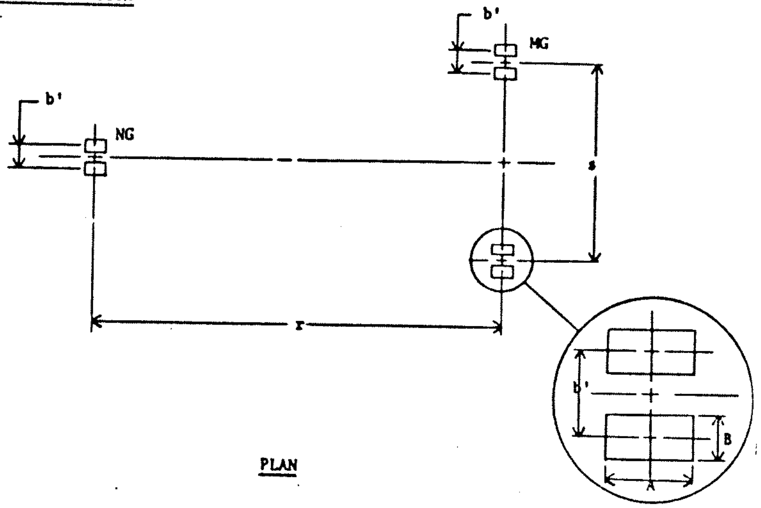
MAIN DECK AFT
SCANTLINGS



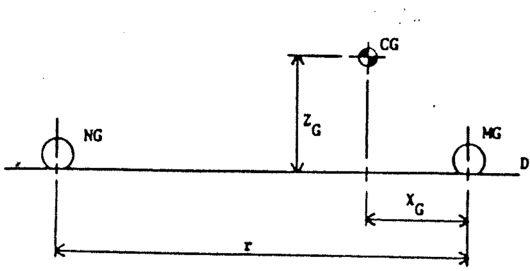
HELICOPTER CH-46

WEIGHT	Maximum Landing	W_M		23.0 K
	Parking	W_P		20.0 K
	Light	W_L		13.1 K
CENTER OF GRAVITY	Vertical	Z_G		85"
	Longitudinal FWD of MG	X_G		86"
TIEDOWNS			STORM	MODERATE
	Vertical	Z_T	45"	9"
	Transverse	Y_T	85"	85"
	Angle to Deck	Ω	45°	15°
CONFIGURATION			UNFOLDED	FOLDED
	Sail Area	a_s	444 ft^2	440 ft^2
	Vertical Center of Pressure	Z_p	93"	92"
	Overall Length		84'-4"	45'-8"
	Overall Width		51'-0"	14'-9"
	Overall Height		18'-10"	16'-9"
	Forward Extent from MG		51'-6"	31'-0"
	Distance between MG and NG	r		298"
	Distance between MG	s		154.5"
	Dual Wheel Spacing	b'		10"
MAIN GEAR	Nominal Landing Load/Gear	R		30.0 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K
NOSE GEAR	Nominal Landing Load/Gear	R		20.0 K
	Tire Size & Ply		18 x 5.5	8 ply
	Tire Bottoming Load	P_b		10.8 K

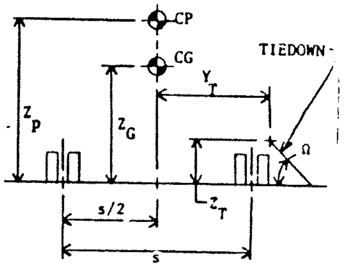
GEAR CONFIGURATION



PLAN



ELEVATION



SECTION

TIRE FOOTPRINT DATA

Nose Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

Main Gear

P_T	A	B
3.9	7.2	4.2
10.0	10.5	5.3

Detailed Analysis:

Sea Condition: Storm

Spot: 1

Ship Motion Factors:

$\eta_{xs} = 0.20 + 0.0002\ (350) + 0.002\ (28 + \frac{85}{12}) = 0.34$

$\eta_{ys} = 0.50 + 0.001\ (350) + 0.002\ (0) + 0.004\ (28 + \frac{85}{12}) = 0.99$

$\eta_{zs} = 1.30 + 0.002\ (350) + 0.004\ (0) = 2.0$

Aircraft Weight Condition:

$W_p = 20.0$ kips

Ship Motion Loads:

$F_x = 0.34\ (20.00) = 6.8$ kips G.2-1

$F_y = 0.99\ (20.0) = 19.8$ kips G.2-1

$F_z = 2.0\ (20.0) = 40.0$ kips G.2-1

Wind Load:

$F_w = 0.015\ (440) = 6.6$ kips G.3-1

Aircraft Oriented Longitudinally

Ship Motion Forces

$F_L = 6.8$ kips G.4-1

$F_T = 19.8$ kips G.4-2

$F_D = 40.0$ kips G.4-3

Gear Reactions:

$R_M = 40.0\ (1 - \frac{86}{298}) + 6.8\ (\frac{85}{298}) = 30.4$ kips G.5-1

$R_A = 40.0\ (\frac{86}{298}) + 6.8\ (\frac{85}{298}) = 13.5$ kips G.5-2

$Z_o = 45 + (85 - \frac{154.5}{2})\ \tan\ (45^o) = 52.8$ inches G.5-5

$M = 6.6\ (92) + 19.8\ (85) - 30.4\ (\frac{154.5}{2}) = -58.2$ in-kips G.5-6

$R_2 = \frac{1}{2}(30.4) + 6.6\ (\frac{92}{154.5}) + 19.8\ (\frac{85}{154.5}) = 30.0$ kips G.5-7

$R_1 = 30.4 - 30.0 = 0.4$ kips G.5-8

Critical Gear Load:

$R = 30.0$ kips

Tire Load:

$P_T = \frac{1}{2}(30.0) = 15.0$ kips J-1

Tire Footprint: $P_T > P_b = 10.8$ kips

$A = 7.2 + (\frac{10.5 - 7.2}{10 - 3.9})(10.8 - 3.9) = 10.9$ inches K-1

$B = 4.2 + (\frac{5.3 - 4.2}{10 - 3.9})(10.8 - 3.9) = 5.4$ inches K-2

Variation in Load and Load Pattern Due to Aircraft Orientation:

Aircraft alined with stiffeners

$A' = A = 10.9$ inches M-1

$B' = B = 5.4$ inches M-2

Dual Wheeled Gear

$P = \frac{1}{2}(30.0) = 15.0$ kips M-5

$b'' = b' = 12.5$ inches M-6

Structural Parameters:

Effective Span:

Stiffener; > 15 spans, $e_s = 0.684$ Table 2

Beam; 5 spans, $e_B = 0.684$ Table 2

Effective Breadth:

Stiffener, $b_e = b = 30$ inches 0.3-1

Beam, $b_e = 60(0.75) = 45$ inches 0.3-1

Member Properties:

See standard work sheet

Taken From Reference (g)

Plating Analysis:

Non-dimensional Bending Moment:

$$\frac{A'}{b} = \frac{10.9}{30} = 0.36 < 0.5$$

$$\frac{B'}{b} = \frac{5.4}{30} = 0.18$$

$$C_1 = \frac{0.25 - 0.125(0.18)}{0.94 + 0.45(0.36)} - \frac{0.079 - 0.026(0.18)^2}{1.75 + 0.15(0.36)^2} \qquad \text{P - 1}$$

$$C_1 = 0.16$$

Equivalent Tire Reaction Factor:

$$\frac{B'}{b} = \frac{5.4}{30} = 0.18$$

$$\frac{b''}{b} = \frac{12.5}{30} = 0.42$$

$$\psi = 1.22 \qquad \text{Figure 11}$$

Deck Function Coefficient:

Uppermost Strength Deck

Low Speed Handling of Aircraft

$C_o = 2.8$ Table 3

Maximum Plate Bending Stress:

$$f_p = \frac{6(0.16)\ 15.0\ (1.22)}{2.8\ (0.75)^2} = 11.2 \text{ ksi} \qquad \text{P-3}$$

Allowable Stress:

$$\sigma_p = F_Y = 34 \text{ ksi} \qquad \text{T-1}$$

Stress Criteria:

$$f_p = 11.2 < \sigma_p = 34 \qquad \text{T-4}$$

Plating is Adequate

Stiffener Analysis:

Bending:

Patch Width Load Distribution Factor:

$$\frac{B'}{b} = \frac{5.4}{30} = 0.18$$

$\phi_1 = 0.99$ Figure 12

Plating Load Distribution Factor:

$$\gamma_{PS} = \frac{((0.684)\ 120)^4\ (0.75)^3}{3.49(30)^3\pi^4\ (496.9)} = 0.0042$$ Q.1-1

$\phi_2 = 0.94$ Figure 13

Dual Patch Equivalent Load Factor:

$$\frac{b''}{b} = \frac{12.5}{30} = 0.42$$

$\phi_3 = 1.59$ Figure 14

Live Load Moment:

$$\frac{A'}{L_S} = \frac{10.9}{120} = 0.091$$

$$\frac{M_o}{PL_S} = 0.1708 - 0.125\ (0.091) + 0.0264\ (0.091)^2$$ Q.1-2

$$\frac{M_o}{PL_S} = 0.160$$

$M_o = 0.160\ (15.0)\ 120\ (0.99)\ 0.94\ (1.59)$ Q.1-3

$M_o = 426.1$ in-kips

Moment Correction:

$$\gamma_{SB} = \frac{((0.684)240)^4\ (496.9)}{0.684(30)((0.684)120)^3\pi^4(986.0)} = 0.33 \tag{Q.1-4}$$

$$\frac{M_c}{RL_S} = 0.12 \tag{Figure 15}$$

$$R_o = \frac{30.0}{(12.5 + 5.4)} = 1.68 \text{ kips/in} \tag{Q.1-6}$$

$$B_o = \tfrac{1}{2}(12.5 + 5.4) = 8.95 \text{ inches} \tag{Q.1-8}$$

$$L_B = 240 > \tfrac{1}{2}(240 + 1.5(154.5)) = 235.9 \tag{Q.1-9}$$

$$\phi_4 = \frac{4}{\pi}\cos\left(\frac{\pi(154.5)}{2(240)}\right)\ \sin\left(\frac{\pi(8.95)}{240}\right)\left(1 + \cos\left(\frac{\pi(154.5)}{2(240)}\right)\right) \tag{Q.1-10}$$

$$\phi_4 = 0.121$$

$$M_c = 0.12\,(1.68)30(120)0.121 = 87.8 \text{ in-kips} \tag{Q.1-13}$$

Dead Load Moment:

$$w_D = \frac{1}{12000}(20.27 + (\frac{30}{12})30.6) = 0.0081 \text{ kips/ in} \tag{Q.1-14}$$

$$M_D = \frac{2.0(0.0081)(120)^2}{12} = 19.4 \text{ in-kips} \tag{Q.1-15}$$

Maximum Bending Moment:

$$M_S = 426.1 + 87.8 + 19.4 = 533.3 \text{ in-kips} \tag{Q.1-16}$$

Maximum Stiffener Bending Stress:

$$f_{SB} = \frac{533.3}{46.5} + 2.9 = 14.4 \text{ kips/in}^2$$ Q. 1-17

Allowable Bending Stress

$$\sigma_{SB} = F_b = 28 \text{ kips/in}^2$$ U-5

Stress Criteria:

$$f_{SB} = 14.8 < \sigma_{SB} = 28$$ U-6

Stiffener is Adequate in Bending

Shear:

Patch Width Load Distribution Factor:

$$\frac{B'}{b} = \frac{5.4}{30} = 0.18$$

$$\phi_1 = 0.99$$ Figure 12

Dual Patch Equivalent Load Factor:

$$\frac{b''}{b} = \frac{12.5}{30} = 0.42$$

$\phi_3 = 1.59$ Figure 14

Live Load Shear:

$$\frac{A'}{L_S} = \frac{10.9}{120} = 0.091$$

$$\frac{V_o}{P} = 1 - 0.7321(0.091)^2 + 0.299(0.091)^3 \qquad \text{Q.1-19}$$

$$\frac{V_o}{P} = 0.99$$

$$V_o = 0.99(15.0)0.99(1.59) = 23.4 \text{ kips} \qquad \text{Q.1-20}$$

Dead Load Shear:

$$V_D = \frac{2.0(0.0081)120}{2} = 0.97 \text{ kips} \qquad \text{Q.1-21}$$

Maximum Shear Force:

$$V_S = 23.4 + 0.97 = 24.4 \text{ kips} \qquad \text{Q.1-22}$$

Maximum Stiffener Shear Stress:

$$f_{SV} = \frac{24.4}{3.21} = 7.6 \text{ kips/in}^2 \qquad \text{Q.1-23}$$

Allowable Shear Stress

$\sigma_{SV} = 0.6F_b = 0.6(28) = 16.8$ kips/in^2 U-7

Stress Criteria:

$f_{SV} = 7.6 < \sigma_{SV} = 16.8$ U-8

Stiffener is Adequate in Shear

STRUCTURAL PROPERTIES

SHIP OR PROJECT: FLEET OILER

DECK STRUCTURE		MAIN DECK		
PLATE	t	0.75"		
	material	OS		
	w_P	30.6 # / ft^2		
STIFFENER	size	12" x 6½ x 30# I-T		
	material	OS		
	w_S	20.27#/ft		
	A	5.96 in^2		
	A_S	3.21 in^2		
	b_e	30"		
	I_s	496.9 in^4		
	SM_{MIN}	46.5 in^3		
BEAM	size	16" x 7' x 36# I-T		
	material	OS		
	w_B	25.69#/ft		
	A	7.56 in^2		
	A_S	4.68 in^2		
	b_e	45"		
	I_B	986.0 in^4		
	SM_{MIN}	69.5 in^3		
GEOMETRY	b	30"		
	L_S	120"		
	L_B	240"		
PARAMETERS	γ_{PS}	0.0042		
	γ_{SB}	0.33		
	w_D	0.0081 k/in		
	e_S	0.684		
	e_B	0.684		
$\sigma_{PRIMARY}$		2.9 1.6 7.4		
REMARKS	SPOT	1 2 3		

SHIP MOTION FACTORS AND LOADS		SHIP OR PROJECT: FLEET OILER								
SPOT		1	2	3	4	5	6	7	8	9	10
LOCATION	X	350	375	275							
	Y	0	30	20							
	Z	35	35	35							
STORM SEA CONDITION	n_{xs}	0.34	0.35	0.33							
	n_{ys}	0.99	1.08	0.96							
	n_{zs}	2.00	2.17	1.93							
	W	20.0	20.0	20.0							
	F_{xs}	6.80	7.00	6.60							
	F_{ys}	19.8	21.6	19.2							
	F_{zs}	40.0	43.4	38.6							
	F_w	6.60	6.60	—							
MODERATE SEA CONDITION	n_{xm}	0.17	0.18	0.17							
	n_{ym}	0.50	0.54	0.48							
	n_{zm}	1.50	1.59	1.47							
	W	23.0	23.0	20.0							
	F_{xm}	3.91	4.14	3.40							
	F_{ym}	11.5	12.4	9.60							
	F_{zm}	34.5	36.6	29.4							
	F_w	3.33	3.33	—							
REMARKS											

SHIP MOTION EQUATIONS:

$n_{xs} = 0.20 + 0.0002 + 0.002Z$

$n_{ys} = 0.50 + 0.001X + 0.002Y + 0.004Z$

$n_{zs} = 1.30 + 0.002X + 0.004Y$

$n_{xm} = 0.5n_{xs}$

$n_{ym} = 0.5n_{ys}$

$n_{zm} = 0.5\ (1 + n_{zs})$

GEAR REACTIONS AND DISTRIBUTIONS					SHIP OR PROJECT: FLEET OILER			
SPOT	1				1			
ORIENT	LONGITUDINAL		TRANSVERSE		LONGITUDINAL		TRANSVERSE	
SEA COND	STORM	MOD	STORM	MOD	STORM	MOD	STORM	MOD
F_L					6.80	3.91	19.8	11.5
F_T					19.8	11.5	6.80	3.91
F_D					40.0	34.5	40.0	34.5
K_M					30.4	25.7	34.1	27.8
R_A					13.5	11.1	17.2	13.2
M					-58.2	-698	-1449	-1506
R_1					0.40	4.10	9.40	9.7
F_F					—	—	—	—
R_2					30.0	21.6	24.7	18.1
T					—	—	—	—
R		30.0		30.0	30.0	21.6	24.7	18.1
P_T		10.8		10.8	10.8	10.8	10.8	9.1
A		10.9		10.9	10.9	10.9	10.9	10.0
B		5.40		5.40	5.40	5.40	5.40	5.1
P		15.0		30.0	15.0	10.8	24.7	18.1
b''		12.5		—	12.5	12.5	—	—
A'		10.9		17.9	10.9	10.9	17.9	17.6
B'		5.40		10.9	5.40	5.40	10.9	10.0
Remarks	N/A	Landing	N/A	Landing	Parking	Parking	Parking	Parking

GEAR REACTIONS AND DISTRIBUTIONS					SHIP OR PROJECT: FLEET OILER			
SPOT	2				3			
ORIENT	LONGITUDINAL		TRANSVERSE		LONGITUDINAL		TRANSVERSE	
SEA COND	STORM	MOD	STORM	MOD	STORM	MOD	STORM	MOD
F_L	7.0	4.14	21.6	12.4	6.6	3.4		
F_T	21.6	12.4	7.0	4.14	19.2	9.6		
F_D	43.4	36.6	43.4	36.6	38.6	29.4		
K_M	32.9	27.2	37.0	29.6	29.3	21.9		
R_A	14.5	11.7	18.7	14.1	13.0	9.5		
M	-98	-738	-1656	-1625	-631	-876		
R_1	0.6	4.8	10.7	10.5	4.1	5.7		
F_F	—	—	—	—	—	—		
R_2	32.3	22.4	26.3	19.1	25.2	16.2		
T	—	—	—	—	—	—		
R	32.3	22.4	26.3	19.1	25.2	16.2		
P_T	10.8	10.8	10.8	9.6	10.8	8.1		
A	10.9	10.9	10.9	10.3	10.9	9.5		
B	5.4	5.4	5.4	5.2	5.4	5.0		
P		11.2	26.3	19.1	12.6	8.1		
b''	12.5	12.5	—	—	12.5	12.5		
A'	10.9	10.9	17.9	17.7	10.9	9.5		
B'	5.4	5.4	10.9	10.3	5.4	5.0		
Remarks	Parking	Parking	Parking	Parking	Parking	Parking	N/A	N/A

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 1	ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

$R = 30.0$ kips $P = 15.0$ kips $A' = 10.9$ in $B' = 5.4$ in

$\frac{B'}{b} = 0.18$ $\frac{A'}{b} = 0.36$ $\frac{A'}{L_S} = 0.091$ $\frac{b''}{b} = 0.42$

REMARKS: Landing

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.16$

$\psi = 1.22$ $C_o = 3.4$

$f_p = 9.2$ ksi $<$ $\sigma_p = 28$ ksi

$t_{reqd} = 0.430$ in

REMARKS: Landing

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5$ in^3 $A_s = 3.21$ in^2 $F_b = 28$ ksi

$\phi_1 = 0.99$ $\phi_2 = 0.94$ $\phi_3 = 1.59$

$\frac{M_o}{PL_S} = 0.160$ $M_o = 426.1$ in-kips

$R_o = 1.68$ kips/in $B_o = 8.95$ in $\phi_4 = 0.121$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 87.8$ in-kips

$M_D = 14.6$ in-kips $M_S = 528.5$ in-kips

$f_{SB} = 11.4$ ksi $<$ $\sigma_{SB} = 28$ ksi

$SM_{reqd} = 18.9$ in^3

$\frac{V_o}{P} = 0.99$ $V_o = 23.4$ kips

$V_D = 0.73$ kips $V_S = 24.1$ kips

$f_{SV} = 7.5$ ksi $<$ $\sigma_{SV} = 16.8$ ksi

$A_{s_{reqd}} = 21.44$ in^2

REMARKS: Landing

OK

OK

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 1	ORIENTATION: TRANSVERSE

ANALYSIS PARAMETERS:

$R = 30.0$ kips $P = 30.0$ kips $A' = 17.9$ in $B' = 10.9$ in

$\frac{B'}{b} = 0.36$ $\frac{A'}{b} = 0.60$ $\frac{A'}{L_S} = 0.149$ $\frac{b''}{b} =$ N/A

REMARKS: Landing

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.129$

$\psi = 1.0$ $C_o = 3.4$

$f_p = 12.1$ ksi $<$ $\sigma_p = 28$ ksi

$t_{reqd} = 0.494$ in

REMARKS: Landing

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5$ in^3 $A_s = 3.21$ in^2 $F_b = 28$ ksi

$\phi_1 = 0.98$ $\phi_2 = 0.94$ $\phi_3 = 1.0$

$\frac{M_o}{PL_S} = 0.153$ $M_o = 507.4$ in-kips

$R_o = 2.75$ kips/in $B_o = 5.45$ in $\phi_4 = 0.091$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 108.1$ in-kips

$M_D = 14.6$ in-kips $M_S = 630.1$ in-kips

$f_{SB} = 13.6$ ksi $<$ $\sigma_{SB} = 28$ ksi

$SM_{reqd} = 22.5$ in^3

$\frac{V_o}{P} = 0.99$ $V_o = 29.1$ kips

$V_D = 0.73$ kips $V_S = 29,8$ kips

$f_{SV} = 9.3$ ksi $<$ $\sigma_{SV} = 16.8$ ksi

$A_{s_{reqd}} = 1.77$ in^2

REMARKS: Landing

OK

OK

PLATE AND STIFFENER STRESS ANALYSIS

SHIP OR PROJECT: FLEET OILER

DECK STRUCTURE: MAIN DECK

SEA CONDITION: STORM

SPOT: 1

ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

$R = 30.0$ kips $P = 15.0$ kips $A' = 10.9$ in $B' = 5.4$ in

$\frac{B'}{b} = 0.18$ $\frac{A'}{b} = 0.36$ $\frac{A'}{L_s} = 0.091$ $\frac{b''}{b} = 0.42$

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$\zeta_1 = 0.16$

$\psi = 1.22$

$C_o = 2.8$

$f_p = 11.2$ ksi $<$ $\sigma_p = 34$ ksi

$t_{reqd} = 0.430$ in

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5$ in^3 $A_s = 3.21$ in^2 $F_b = 28$ ksi

$\phi_1 = 0.99$ $\phi_2 = 0.94$ $\phi_3 = 1.59$

$\frac{M_o}{PL_s} = 0.160$ $M_o = 426.1$ in-kips

$R_o = 1.68$ kips /in $B_o = 8.95$ in $\phi_4 = 0.121$

$\frac{M_c}{RL_s} = 0.12$ $M_c = 87.8$ in-kips

$M_D = 19.4$ in-kips $M_S = 533.3$ in-kips

$f_{SB} = 14.4$ ksi $<$ $\sigma_{SB} = 28$ ksi

$\frac{V_o}{P} = 0.99$ $SM_{reqd} = 21.3$ in^3

$V_o = 23.4$ kips

$V_D = 0.97$ kips $V_S = 24.4$ kips

$f_{SV} = 7.6$ ksi $<$ $\sigma_{SV} = 16.8$ ksi

$A_{s_{reqd}} = 1.45$ in^2

REMARKS: Parking

OK

OK

PLATE AND STIFFENER STRESS ANALYSIS

SHIP OR PROJECT: FLEET OILER

DECK STRUCTURE: MAIN DECK

SEA CONDITION: MODERATE

SPOT: 1

ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

$R = 21.6$ kips $P = 10.8$ kips $A' = 10.9$ in $B' = 5.4$ in

$\frac{B'}{b} = 0.18$ $\frac{A'}{b} = 0.36$ $\frac{A'}{L_s} = 0.091$ $\frac{b''}{b} = 0.42$

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$\zeta_1 = 0.16$

$\psi = 1.22$

$C_o = 3.4$

$f_p = 6.6$ ksi $<$ $\sigma_p = 28$ ksi

$t_{reqd} = 0.365''$

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5$ in^3 $A_s = 3.21$ in^2 $F_b = 28$ ksi

$\phi_1 = 0.99$ $\phi_2 = 0.94$ $\phi_3 = 1.59$

$\frac{M_o}{PL_s} = 0.160$ $M_o = 306.8$ in-kips

$R_o = 1.21$ kips/in $B_o = 8.95$ in $\phi_4 = 0.121$

$\frac{M_c}{RL_s} = 0.12$ $M_c = 63.2$ in-kips

$M_D = 14.6$ in-kips $M_S = 384.6$ in-kips

$f_{SB} = 9.7$ ksi $<$ $\sigma_{SB} = 28$ ksi

$\frac{V_o}{P} = 0.99$ $SM_{reqd} = 14.5$ in^3

$V_o = 16.9$ kips

$V_D = 0.73$ kips $V_S = 17.6$ kips

$f_{SV} = 5.5$ ksi $<$ $\sigma_{SV} = 16.8$ ksi

$A_{s_{reqd}} = 1.10$ in^2

REMARKS: Parking

OK

OK

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: STORM
SPOT: 1	ORIENTATION: TRANSVERSE

ANALYSIS PARAMETERS:

$R = 24.7$ kips $P = 24.7$ kips $A' = 17.9$ in $B' = 10.9$ in

$\frac{B'}{b} = 0.36$ $\frac{A'}{b} = 0.60$ $\frac{A'}{L_S} = 0.149$ $\frac{b''}{b} =$ N/A

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.129$

$\psi = 1.0$

$C_o = 2.8$

$f_p = 12.1$ ksi $<$ $\sigma_p = 34$ ksi

$t_{reqd} = 0.448$ in

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5\ in^3$ $A_s = 3.21\ in^2$ $F_b = 28$ ksi

$\phi_1 = 0.98$ $\phi_2 = 0.94$ $\phi_3 = 1.0$

$\frac{M_o}{PL_S} = 0.153$ $M_o = 417.8$ in-kips

$R_o = 2.27$ kips/in $B_o = 5.45$ in $\phi_4 = 0.091$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 89.2$ in-kips

$M_D = 19.4$ in-kips $M_S = 526.4$ in-kips

$f_{SB} = 14.2$ ksi $<$ $\sigma_{SB} = 28$ ksi   OK

$\frac{V_o}{P} = 0.99$ $SM_{reqd} = 21.0\ in^3$

$V_o = 24.0$ kips

$V_D = 0.97$ kips $V_S = 25.0$ kips

$f_{SV} = 7.8$ ksi $<$ $\sigma_{SV} = 16.8$ ksi   OK

$A_{s_{reqd}} = 1.49\ in^2$

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 1	ORIENTATION: TRANSVERSE

ANALYSIS PARAMETERS:

$R = 18.1$ kips $P = 18.1$ kips $A' = 17.6$ in $B' = 10.0$ in

$\frac{B'}{b} = 0.33$ $\frac{A'}{b} = 0.59$ $\frac{A'}{L_S} = 0.147$ $\frac{b''}{b} =$ N/A

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.132$

$\psi = 1.0$

$C_o = 3.4$

$f_p = 7.5$ ksi $<$ $\sigma_p = 28$ ksi

$t_{reqd} = 0.388$ in

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5\ in^3$ $A_s = 3.21\ in^2$ $F_b = 28$ ksi

$\phi_1 = 0.98$ $\phi_2 = 0.94$ $\phi_3 = 1.0$

$\frac{M_o}{PL_S} = 0.153$ $M_o = 306.1$ in-kips

$R_o = 1.81$ kips/in $B_o = 5.0$ in $\phi_4 = 0.083$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 65.1$ in-kips

$M_D = 14.6$ in-kips $M_S = 385.8$ in-kips

$f_{SB} = 9.8$ ksi $<$ $\sigma_{SB} = 28$ ksi   OK

$\frac{V_o}{P} = 0.99$ $SM_{reqd} = 14.5\ in^3$

$V_o = 17.6$ kips

$V_D = 0.73$ kips $V_S = 18.3$ kips

$f_{SV} = 5.7$ ksi $<$ $\sigma_{SV} = 16.8$ ksi   OK

$A_{s_{reqd}} = 1.09\ in^2$

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: STORM
SPOT: 2	ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

R = 32.3 kips P = 16.2 kips A' = 10.9 in B' = 5.4 in

$\frac{B'}{b}$ = 0.18 $\frac{A'}{b}$ = 0.36 $\frac{A'}{L_s}$ = 0.091 $\frac{b''}{b}$ = 0.42

REMARKS: Parking

PLATE ANALYSIS:

t = 0.75 in F_y = 34 ksi F_b = 28 ksi

C_1 = 0.16

ϕ = 1.22

C_o = 2.8

f_p = 12.1 ksi   < σ_p = 34 ksi   OK

t_{reqd} = 0.446 in

REMARKS: Parking

STIFFENER ANALYSIS:

SM_{MIN} = 46.5 in^3 A_s = 3.21 in^2 F_b = 28 ksi

ϕ_1 = 0.99 ϕ_2 = 0.94 ϕ_3 = 1.59

$\frac{M_o}{PL_s}$ = 0.160 M_o = 460.2 in-kips

R_o = 1.81 kips/in B_o = 8.95 in ϕ_4 = 0.121

$\frac{M_c}{RL_s}$ = 0.12 M_c = 94.6 in-kips

M_D = 21.1 in-kips M_S = 575.9 in-kips

f_{SB} = 14.0 ksi   < σ_{SB} = 28 ksi   OK

$\frac{V_o}{P}$ = 0.99 SM_{reqd} = 21.8 in^3

V_D = 1.05 kips V_o = 25.3 kips V_S =

f_{SV} = 8.2 ksi   < σ_{SV} = 16.8 ksi   OK

$A_{s_{reqd}}$ = 1.57 in^2

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	SHIP OR PROJECT: FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 2	ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

R = 22.4 kips P = 11.2 kips A' = 10.9 in B' = 5.4 in

$\frac{B'}{b}$ = 0.18 $\frac{A'}{b}$ = 0.36 $\frac{A'}{L_s}$ = 0.091 $\frac{b''}{b}$ = 0.42

REMARKS: Parking

PLATE ANALYSIS:

t = 0.75 in F_y = 34 ksi F_b = 28 ksi

C_1 = 0.16

ϕ = 1.22

C_o = 3.4

f_p = 6.9 ksi   < σ_p = 28 ksi   OK

t_{reqd} = 0.371 in

REMARKS: Parking

STIFFENER ANALYSIS:

SM_{MIN} = 46.5 in^3 A_s = 3.21 in^2 F_b = 28 ksi

ϕ_1 = 0.99 ϕ_2 = 0.94 ϕ_3 = 1.59

$\frac{M_o}{PL_s}$ = 0.160 M_o = 318.2 in-kips

R_o = 1.25 kips/in B_o = 8.95 in ϕ_4 = 0.121

$\frac{M_c}{RL_s}$ = 0.12 M_c = 65.3 in-kips

M_D = 15.4 in-kips M_S = 398.9 in-kips

f_{SB} = 9.4 ksi   < σ_{SB} = 28 ksi   OK

$\frac{V_o}{P}$ = 0.99 SM_{reqd} = 14.7 in^3

V_D = 0.77 kips V_o = 17.5 kips V_S = 18.3 kips

f_{SV} = 5.7 ksi   < σ_{SV} = 16.8 ksi   OK

$A_{s_{reqd}}$ = 1.09 in^2

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	**SHIP OR PROJECT:** FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: STORM
SPOT: 2	ORIENTATION: TRANSVERSE

ANALYSIS PARAMETERS:

R = 26.3 kips　P = 26.3 kips　A' = 17.9 in　B' = 10.9 in

$\frac{B'}{b}$ = 0.36　$\frac{A'}{b}$ = 0.60　$\frac{A'}{L_s}$ = 0.149　$\frac{b''}{b}$ = N/A

REMARKS: Parking

PLATE ANALYSIS:

t = 0.75 in　F_y = 34 ksi　F_b = 28 ksi

C_1 = 0.129

ψ = 1.0　C_o = 2.8

f_p = 12.9 ksi $<$ σ_p = 34 ksi　OK

t_{reqd} = 0.462 in

REMARKS: Parking

STIFFENER ANALYSIS:

SM_{MIN} = 46.5 in^3　A_s = 3.21 in^2　F_b = 28 ksi

ϕ_1 = 0.98　ϕ_2 = 0.94　ϕ_3 = 1.0

$\frac{M_o}{PL_s}$ = 0.153　M_o = 444.8 in-kips

R_o = 2.41 kips/in　B_o = 5.45 in　ϕ_4 = 0.091

$\frac{M_c}{RL_s}$ = 0.12　M_c = 94.7 in-kips

M_D = 21.1 in-kips　M_S = 558.9 in-kips

f_{SB} = 13.6 ksi $<$ σ_{SB} = 28 ksi　OK

$\frac{V_o}{P}$ = 0.99　SM_{reqd} = 21.2 in^3

V_o = 25.5 kips

V_D = 1.05 kips　V_S = 26.5 kips

f_{SV} = 8.3 ksi $<$ σ_{SV} = 16.8 ksi　OK

$A_{s_{reqd}}$ = 1.58 in^2

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	**SHIP OR PROJECT:** FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 2	ORIENTATION: TRANSVERSE

ANALYSIS PARAMETERS:

R = 19.1 kips　P = 19.1 kips　A' = 17.7 in　B' = 10.3 in

$\frac{B'}{b}$ = 0.34　$\frac{A'}{b}$ = 0.59　$\frac{A'}{L_s}$ = 0.147　$\frac{b''}{b}$ = N/A

REMARKS: Parking

PLATE ANALYSIS:

t = 0.75 in　F_y = 34 ksi　F_b = 28 ksi

C_1 = 0.132

ψ = 1.0　C_o = 3.4

f_p = 7.9 ksi $<$ σ_p = 28 ksi　OK

t_{reqd} = 0.399 in

REMARKS: Parking

STIFFENER ANALYSIS:

SM_{MIN} = 46.5 in^3　A_s = 3.21 in^2　F_b = 28 ksi

ϕ_1 = 0.98　ϕ_2 = 0.94　ϕ_3 = 1.0

$\frac{M_o}{PL_s}$ = 0.153　M_o = 323.0 in-kips

R_o = 1.85 kips/in　B_o = 5.15 in　ϕ_4 = 0.086

$\frac{M_c}{RL_s}$ = 0.12　M_c = 68.7 in-kips

M_D = 15.4 in-kips　M_S = 407.1 in-kips

f_{SB} = 9.6 ksi $<$ σ_{SB} = 28 ksi　OK

$\frac{V_o}{P}$ = 0.99　SM_{reqd} = 15.0 in^3

V_o = 18.5 kips

V_D = 0.77 kips　V_S = 19.3 kips

f_{SV} = 6.0 ksi $<$ σ_{SV} = 16.8 ksi　OK

$A_{s_{reqd}}$ = 1.15 in^2

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	**SHIP OR PROJECT:** FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: STORM
SPOT: 3	ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

$R = 25.2$ kips $P = 12.6$ kips $A' = 10.9$ in $B' = 5.4$ in

$\frac{B'}{\bar{b}} = 0.18$ $\frac{A'}{\bar{b}} = 0.36$ $\frac{A'}{L_s} = 0.091$ $\frac{b''}{\bar{b}} = 0.42$

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.160$

$\nu = 1.22$

$C_o = 2.8$

$f_p = 9.4$ ksi $<$ $\sigma_p = 34$ ksi

$t_{reqd} = 0.394$ in

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5\ in^3$ $A_s = 3.21\ in^2$ $F_b = 28$ ksi

$\phi_1 = 0.99$ $\phi_2 = 0.94$ $\phi_3 = 1.59$

$\frac{M_o}{PL_S} = 0.160$ $M_o = 357.9$ in-kips

$R_o = 1.41$ kips/in $B_o = 8.95$ in $\phi_4 = 0.121$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 73.7$ in-kips

$M_D = 18.7$ in-kips $M_S = 450.3$ in-kips

$f_{SB} = 17.1$ ksi $<$ $\sigma_{SB} = 28$ ksi OK

$SM_{reqd} = 21.9\ in^3$

$\frac{V_o}{P} = 0.99$ $V_o = 19.7$ kips

$V_D = 0.94$ kips $V_S = 20.6$ kips

$f_{SV} = 6.4$ ksi $<$ $\sigma_{SV} = 16.8$ ksi OK

$A_{s_{reqd}} = 1.23\ in^2$

REMARKS: Parking

PLATE AND STIFFENER STRESS ANALYSIS	**SHIP OR PROJECT:** FLEET OILER
DECK STRUCTURE: MAIN DECK	SEA CONDITION: MODERATE
SPOT: 3	ORIENTATION: LONGITUDINAL

ANALYSIS PARAMETERS:

$R = 16.2$ kips $P = 8.1$ kips $A' = 9.5$ in $B' = 5.0$ in

$\frac{B'}{\bar{b}} = 0.17$ $\frac{A'}{\bar{b}} = 0.32$ $\frac{A'}{L_s} = 0.079$ $\frac{b''}{\bar{b}} = 0.42$

REMARKS: Parking

PLATE ANALYSIS:

$t = 0.75$ in $F_y = 34$ ksi $F_b = 28$ ksi

$C_1 = 0.17$

$\phi = 1.22$

$C_o = 3.4$

$f_p = 5.3$ ksi $<$ $\sigma_p = 28$ ksi

$t_{reqd} = 0.325$ in

REMARKS: Parking

OK

STIFFENER ANALYSIS:

$SM_{MIN} = 46.5\ in^3$ $A_s = 3.21\ in^2$ $F_b = 28$ ksi

$\phi_1 = 0.99$ $\phi_2 = 0.94$ $\phi_3 = 1.59$

$\frac{M_o}{PL_S} = 0.161$ $M_o = 231.6$ in-kips

$R_o = 0.93$ kips/in $B_o = 8.75$ in $\phi_4 = 0.118$

$\frac{M_c}{RL_S} = 0.12$ $M_c = 47.4$ in-kips

$M_D = 14.3$ in-kips $M_S = 293.3$ in-kips

$f_{SB} = 10.0$ ksi $<$ $\sigma_{SB} = 28$ ksi OK

$SM_{reqd} = 12.1\ in^3$

$\frac{V_o}{P} = 0.99$ $V_o = 12.6$ kips

$V_D = 0.71$ kips $V_S = 13.3$ kips

$f_{SV} = 4.2$ ksi $<$ $\sigma_{SV} = 16.8$ ksi OK

$A_{s_{reqd}} = 0.79\ in^2$

REMARKS: Parking

APPENDIX I

SELECTED MEASUREMENT UNITS AND CONVERSION FACTORS

SELECTED SI CONVERSION FACTORS

CATEGORY	TO CONVERT FROM INCH POUND UNITS	TO SI UNITS	MULTIPLY BY
Length:	foot (ft)	meter (m)	0.3048
	inch (in)	meter (m)	2.540×10^{-2}
	inch (in)	mm	25.4
Area:	foot^2 (ft^2)	meter^2 (m^2)	9.290×10^{-2}
	inch^2 (in^2)	mm^2	6.542×10^3
Force:	kip	newton (N)	4.448×10^3
	pound-force (lbf)	newton (N)	4.448
Mass:	pound (lb)	kilogram (kg)	.454
	ton (long, 2240 lb)	metric ton	1.016
Stress (Force/ Area):	kip/inch^2 (ksi)	pascal (Pa)	6.895×10^6
	lbf/in^2 (lb/in^2)	pascal (Pa)	6.895×10^3

SI makes extensive use of prefixes to form decimal multiples; it officially establishes 16 prefixes. Those 5 prefixes most frequency used are as follows:

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	$0.000001 = 10^{-6}$

APPENDIX J

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