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AMPHIBIOUS HOVERCRAFT SKIRT STABILITY

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Amphibious Hovercraft Skirt Stability

1 INTRODUCTION

After the publication of CAA Paper 75017, "Report of the ARB Special Committee on Hovercraft Stability and Control" the Ship and Marine Technology Requirements Board (SMTRB) agreed to sponsor a programme of research into hovercraft capsizing, based on recommendations made in the CAA Paper.

The research programme commenced in mid-July 1977 with the British Hovercraft Corporation (BHC) as the main contractor. Contributions to the programme were also made by Vosper Thornycroft (UK) Ltd., and Hovermarine International. The main objective of the programme was to provide more quantitative information on hovercraft capsizing tendencies. However, as it is generally believed that all capsizes on amphibious craft have followed a skirt tuck-under, the main effort was spent in analysing this phenomenon, as this represents the first major indication that a capsizing situation is occurring. Once this boundary has been exceeded the craft structure must ultimately provide further righting forces to prevent capsizing and the applicable requirements are contained in the British Hovercraft Safety Requirements (BHSR) Chapter B5-1.

The research programme was completed in December 1979 and the final report, Ref. 1 was submitted to the SMTRB in April 1980.

2 DESIGN ASSESSMENT

The Tuck-under analysis was carried out by BHC who utilised the results from a considerable number of model tests in deriving the method presented in Ref. 2. This combines a number of skirt section design parameters with craft geometric and operating parameters in order to produce a steady state Restoring Moment Coefficient (RMC) applicable for still air, central CG conditions. When this has been estimated it may be compared with the craft's known overturning moments (due to cross winds, CG shift etc.), or to similarly evaluated coefficients obtained for other craft. A further benefit is that the method gives the separate contributions to the over-turning and restoring moments and not merely the nett result. This should enable the reason for an inadequate nett result to be established and remedied.

It has been assumed that the craft under analysis is being controlled by a trained commander who will not apply control inputs which will directly make the situation worse. Based on this assumption, the lift fan RPM is assumed to remain constant and the skirt shift system (if fitted) will be used to minimise adverse roll.

In the event of the analysis producing a critical restoring moment balance without the beneficial use of skirt shift, sea trials should be used to examine the effects of skirt shift operation and to confirm safe operation of the craft.

3 EFFECT ON CRAFT SPEED

It has already been postulated in CAA Paper 75017 that there is a low speed (the critical speed) at which a hovercraft moving beam-on is most sensitive to overturning. This critical speed is typically slightly below the primary hump speed for beam-on motion. Therefore in view of the greater probability of capsizes during beam-on motion at the critical speed the main effort has been concentrated on producing a method for this speed condition.

4 ANALYSIS LIMITATIONS

The following limitations to the RMC analysis should be noted:

(i) The RMC system is based on a steady state, skirt equilibrium moment balance analysis. It may not therefore correlate completely with the skirt behaviour in waves, where inertias, water structural contact and waveform parameters are also involved. However, it is considered that the critical speed assessment system should provide a good guide to skirt behaviour under these conditions.

(ii) The RMC system incorporates a predication of differential pressure based on the research model and theoretical flow considerations. However, keel configuration variation is not included. If the end gaps at bow and rear, and/or the keel depth differ significantly from the research model (see Fig. 15), and particularly if less effective, an independent assessment of the differential rate and starting point should be made.

5 RESTORING MOMENT COEFFICIENT

The assessment is based on the tabular and graphical data provided. The user completes the calculations in the appropriate tables using the particulars for the craft concerned and the information provided. The derived restoring moment capability can then be compared to the likely applied moments due to the craft controls, weather conditions or offset craft loading.

A method of assessing these is included, in the same tabular form, following the evaluation of the Restoring Moment Coefficient.

Fig. 1 shows the mathematical model on which the system is based. Fig. 2 helps to define the sideskirt geometric parameters required (see also NOTATION). Fig. 3 traces the various routes which may be followed, as instructed in Tables 1 to 5, in arriving at the restoring moment coefficient just before leading sideskirt tuck-under.

The system has been extended to include assessment of the (maximum) restoring moment coefficient after tuck-under, and with structure water contact. Skirt parameters are then unimportant, and a single route is followed. For a skirt configuration having segments only, along the sides, much of the tabulation is bypassed since it is concerned with tuck-under. This phenomenon is associated with the loop or bag part of a composite skirt.

The procedure is as follows:

(i) Complete Table 1, ESSENTIAL PARAMETERS AND PREDICTION OF DATUM ROLL ANGLE, for all types of craft.

(ii) Bag/Finger Skirts

Calculate the roll angle at Tuck-under using Table 2A if the skirt utilises an anti-bounce web and keel. For similar skirts without keels use Table 2B. For craft not using an anti-bounce web use Table 4A.

(iii) Loop/Segment Skirts

For Loop/Segment skirts without anti-bounce webs or ties, calculate the roll angle at tuck-under from Table 4.

(iv) Loop/Segment Skirt with Anti-bounce Webs or Ties

For Loop/Segment skirts with anti-bounce webs or ties, follow the Table 2. route, Table 2B being for cushion systems without keels.

(v) Tapered Cushions

For cushion systems whose skirt depths decrease significantly from bow to stern, the roll angle analysis should be carried out for two skirt sections, these being at the most forward point of the straight side skirt and the most rearward point on the straight side skirt.

General input values for the craft configuration such as craft weight, C.G. height, cushion flow, cushion planform dimensions and cushion inflow characteristic slope are likely to remain the same. Skirt section parameters such as skirt depth, hinge dimensions and %finger depth are likely to differ.

The two skirt sections will give different values of roll angle at tuck-under. If the two values are within 10% of one another, the analysis should be carried out for a mean skirt section mid-way between the two original extremes. All subsequent analysis should be carried out as if the craft has a parallel cushion based on this mean skirt section.

If the roll angles at tuck-under are at variance by more than 10%, the section which tucks under first (usually the aft section) should be analysed for its nett restoring moment at tuck-under. If this value is positive, the nett restoring moment for the whole side skirt section should be the mean of the restoring moments from both sections.

Should the variance be more than 10% and the aft section has a negative nett restoring moment at tuck-under, the pessimistic assumption that the entire side skirt will then tuck-under should be made and that the nett restoring moment for the whole side skirt should be based on the aft skirt section results.

(vi) Insufficient Restoring Moment from the Skirt at Tuck-under

When the nett restoring moment coefficient at tuck-under is insufficient to counter the applied overturning moments calculated in TABLE 8, the total nett restoring moments due at structural contact need to be calculated (Tables 6 and 7).

Where craft are designed with a structural shape or dimensions which vary along the side of the hull, the contact analysis should be applied at sufficient number of stations (probably two or three) to cover adequately the change of profile. The overall nett restoring moment coefficient (given in equation [191]), should be aggregated, taking into account the proportion of the hull length to which each profile applies.

The righting moment provided by the use of a skirt shift system (see Section 2 above) may be taken into account but due notice should be taken of the fact that no beneficial outboard movement of the leading skirt can be relied on after tuck-under.

6 EXPLANATORY NOTES ON TABLES 1 TO 7

6.1 General

A list of symbols used in the stability analysis is contained in Section 7, "Notation".

(i) The tables are designed to be photo-copied to assist in carrying out calculations for various craft types and configurations.

(ii) Each item on the tables has an entry number for easy identification. Entry No's marked with an asterisk have an additional explanatory note listed below. It is essential that these are referred to during the calculation procedure.

(iii) Tables 3, 4 and 5 subdivide into cases with perimeter ratio referred to as 'high' or 'low', and pressure ratio less or greater than 1.5. The division is somewhat arbitrary as the treatment is based on four different mathematical models for the skirt shape, which unfortunately, cannot give exactly the same result at the perimeter or pressure ratio where they meet.

Hence if the actual perimeter ratio 20 cannot clearly be classified initially as high (>3.5) or low (< 2.5), it may be necessary to follow both routes and take an interpolated mean. Its validity may later be checked against the subsequent classification (by Fig. 10). If the pressure ratio is close to 1.5, it is advisable again to average two results.

6.2 **Table 1.**

Entry No.

2 The mass densities of sea water are quoted. If analysing model test results use the fresh water values (= 1025 kg/m^3 or 1.94 slugs/ft^3) if appropriate.

3 The weight densities of sea water are quoted. For fresh water the values are 9,807 N/m^3 or 62.43 lb/ft^3.

10 If analysing for other than design conditions use appropriate value.

11/12 For a skirt having hemline cut-out(s) of appreciable length, e.g. at rear, use h_G and H_{SK} measured from the reduced depth skirt.

16 Hemline span is from inner hinge (or inner attachment to structure) to design hemline (effective, see fig. 2).

22 The % Finger Depth is the height of the outer finger attachment point P, above finger tip, expressed as a percentage of skirt depth, H_{SK}.

23 The effective face angle is measured to the horizontal and is less by $57.3 \times \frac{1}{2} \left\{ \left(1 - \frac{\pi}{4}\right) \cdot \frac{\text{finger pitch}}{\text{outer face length}} \right\}$ degrees than the inclination of the line directly joining the finger or segment outer face centreline tip point to the finger outer attachment point, P.

24 The cushion feed location determines that assumed feed closure, in Table 9. Alternative feed arrangements not covered by the table might be considered to produce other % feed closures, which may then be used with discretion.

25 For loop/segment skirts, use supply duct area if any open loop skirt; if with inner segments, use $SF = Q\left\{0.65\sqrt{\frac{2}{\rho_A}} \cdot \sqrt{p_{C_o}} \cdot \sqrt{\frac{(p_B)}{(p_C)_o} - 1}\right\}^{-1}$

29/30 If analysing for other than design conditions use appropriate value.

34/38 If only the P_{Bmax} and corresponding volume flow $(Q)_{PBmax}$ at the R.P.M. used are known, then:-

$$\frac{\rho_A N \sigma Q}{D P_{C0}} = 2 \frac{Q}{P_{C0}} \frac{(P_{B_{max}} - P_B)}{(Q - (Q)_{P_{B_{max}}})}$$

When even these are not known, assume

$$\frac{\Delta P_B}{P_{C0}} = 0.$$

40 This is the pressure coefficient used in Figs. 7 to 14.

42/44 For Table 1: Normally, assume tuck-under after bag or loop contact.

For Table 4: Assume that tuck-under is prevented by scooping unless returned to [37] at [101].

6.3 **Table 2.**

General Note

The early tuck-under case or trailing side scooping condition will not normally apply in TABLE 2. If it were used for comparative purposes, or if suspected that an early tuck-under might occur, TABLE 2C. should be used as well as, or instead of TABLE 2A. or 2B.

Entry No.

53 A full length keel is assumed. The differential pressure rate $\partial\left\{\frac{\Delta P}{P_C}\right\}/\partial\phi$ should be taken pro-rata for a part length keel (terminated at effective transverse dividers). The keel depth relative to peripheral skirt should be as good as, and end gaps no greater than is shown in Fig. 15. Keel pressure should be ≥ bag pressure. (See also 4(ii)).

54 The pressure ratio at tuck-under, P_B/P_C is used in Figures 7 to 14 (except Fig. 13). Higher pressure coefficients, $P_C/\rho gb$, and pressure ratios, can generally be extrapolated in these figures.

NOTE: In Figs. 7 and 9, low perimeter ratio may be taken as less than 2.5. Interpolate as necessary for the parameter $\left\{\frac{Z_H/X_H}{b/X_H} - \frac{H_{SK}}{b}\right\}$.

In Fig. 8 high perimeter ratio may be taken as greater than 3.5. Similar initial classification may be employed in Figs. 11 and 12. If an intermediate ratio applies, it is advisable to proceed using both results and taking the mean roll angle.

59 If this condition is satisfied, evaluate $(h_G)_{T/b}$ and check that the stability parameter, item[61], is positive then enter TABLE 3. If [61] is negative enter TABLE 2B. and continue on TABLE 3 with this roll angle and appropriate $(h_G)_{T/b}$ item [67].

63A If perimeter ratio has initially been classified as low, and other parameters in Fig. 11 are also low, such that ϕ_{ADD} cannot be read from the curves for low perimeter ratio (or gives an unrealistic ϕ) use curves for high perimeter ratio, obtain ϕ at [66] and return to [61] A to E. If Fig.10 then indicates that "high" perimeter ratio is inappropriate assume early tuck-under, and obtain the appropriate ϕ at [70] in Table 2C.

6.4 Table 3.

Entry No.

75 A $R_{1/b}$ cannot be large. If greater than 0.5 put equal to 0.5.

76 A/B $2R_{/b}$ cannot be negative or large. If negative put equal to zero.
If greater than: $\dfrac{(Z_H / X_H)}{(b / X_H)} + \left\{1 - \dfrac{\%\text{Finger Depth}}{100}\right\} \cdot \left\{\dfrac{H_{SK}}{b}\right\}$
put equal to that value.

80 A/B If the water surface slope θ_B exceeds about 36°, it may be necessary to calculate f_1, f_2, f_3 or f_6 from the expressions given in Figs. 16, 17 and 18, but it is more likely that with a large θ_B, early tuck-under has already been selected, i.e. these figures will not be used.

85 $\dfrac{\Delta P}{P_{C0}}$ cannot be negative. It is zero if $\phi < (\phi)_{\Delta p} = 0$.

86 The value of $\dfrac{\Delta P_C}{P_{C0}}$ calculated here is used subsequently (and not the value assumed at [37]). This applies also at [134].

87 The value of this item cannot be greater than unity and values less than 0.7 would be abnormal.

6.5 **Table 5.**

Entry No.

125 The value of this item cannot be less than zero or very large. If greater than:

$$\left\{ p/X_H \right\} \Big/ 4 \left\{ b/X_H \right\}$$

put equal to that value.

6.6 **Table 6.**

Entry No.

157 Use 40% feed closure unless the cushion feed configuration makes it unlikely that flow will be reduced by water contact. In that case, $\Delta P_B / P_{C0} = 0$.

6.7 **Table 7.**

Entry No.

179 For a sideskirt consisting of segments only, there is no skirt contact moment. Then, [182]= [185]= 0.

7 NOTATION

b = Maximum width of cushion, i.e. Cushion Beam (if width varies significantly over sideskirt length, a mean width over this length should be used)

b_{CHINE} = Width across side structure chines (which may be lower (b_L), intermediate (b_c), or upper/top side, (b_u))

C_M = Rolling moment coefficient about axis through C.G.

C_Δ = Cushion loading coefficient = $\dfrac{W}{\rho g S^{3/2}}$

CG = Centre of Gravity

C_Q = Cushion volume flow coefficient = $\dfrac{Q}{S}\sqrt{\dfrac{\rho_A}{2p_C}}$

$\bar{c}$ = Overall width of craft

D = Fan Diameter

D_{WET} = Drag due to wetting

$(f)^{-1}$ = A factor used in predicting roll just before tuck-under

= $\left\{2.25 + 10.5\,\dfrac{p_B}{\rho g b}\right\} - 1$

f_1 to f_8 = Functions used in evaluating incremental beam increase ratio and factor on water contact length. The functions are given in figures 16, 17 and 18.

G = Acceleration due to gravity.

H_{SK} = Skirt depth, see Fig. 2.

H_G = Height of CG above hemline (or mean water plane approx.) under normal operating conditions.

$(h_G)_T$ = Height of CG above mean water plane when rolled, normally just before leading sideskirt tuck-under.

L = Cushion Length.

L_B = Deformed skirt water contact length.

L_C = Distance between consecutive chines (or upper chine and top of side structure)

M	=	Rolling moment about the OX axis
$M_{APPLIED}$	=	Applied overturning moment in roll
N	=	Fan revolutions per minute (RPM)
P (or p)	=	Cross sectional perimeter of sideskirt bag or loop (see Fig. 2)
$\overline{P}$	=	Mean hydrodynamic pressure on structure surface between chines
P_B	=	Mean bag or loop pressure
P_C	=	Mean cushion pressure
P_S	=	Pressure at supply ducts to sideskirt, with open loop skirt configuration
		NOTE: All pressures are gauge pressures.
ΔP	=	Pressure differential between leading and trailing side compartments of cushion compartmented by a centre keel
ΔP_B	=	Increment in bag (or loop) pressure caused by change in cushion volume flow
ΔP_C	=	Increment in mean cushion pressure due to change in effective beam when rolled, and to bag or loop water contact
Q	=	Cushion air volume flow
R	=	Radius of outer loop of leading sideskirt with craft rolled, just before tuck-under
R_1	=	Radius of inner loop of leading sideskirt with craft rolled, just before tuck-under
S	=	Cushion planform area at normal operating conditions
S_F	=	Cushion feed hole or gap area
S_P	=	Span from inner skirt attachment to effective tip of finger, or segment
S_T	=	Overall craft planform area
V	=	Relative velocity of following wind when moving beam on at critical speed, V_{CRIT}
V_{CRIT}	=	Critical overturning speed $= 0.46\sqrt{gb}$
V_L	=	Local water surface relative velocity at leading sideskirt

W = Craft weight

w = A number, depending on pressure ratio, which is used in evaluating the roll angle at tuck-under (see TABLE 2B)

X_C = Horizontal spacing between upper and lower chines (see Fig.2)

X_H = Horizontal spacing between inner and outer sideskirt hinges, or attachment points to structure (see Fig. 2)

y_G = Lateral offset of craft C.G. from longitudinal centre line

Z_C = Vertical spacing between upper and lower chines (see Fig. 12)

Z_H = Vertical spacing between inner and outer sideskirt hinges, or attachment points to structure (see Fig. 2)

α = Incidence of structural surface between chines to the local water flow direction

δ = Increase in cushion beam due to water contact with the leading sideskirt

ρ = Water density

ρ_A = Air density

ϕ = Roll angle, commonly just before tuck-under, positive when leading side down

ϕ_{ADD} = A (negative) increment to ϕ given by one of Figs. 7 to 9 and 11 to 14, used in evaluating ϕ just before tuck-under

ϕ_{DAT} = Datum roll angle

$$= 57.3\left\{\frac{H_{SK}}{b} + \frac{Z_H}{b} + C_Q + .0285\right\}$$

ϕ_{SCOOP} = The maximum leading side down roll angle at which trailing sideskirt scooping is likely to occur

$(\phi)_{\Delta P=0}$ = The roll angle at which differential cushion pressure, Δp, commences at critical speed, beam on

ψ_o = Inclination to the horizontal of structural surface between chines (see Fig. 2)

σ = Slope of the fan characteristic curve at the operating point (N.B. characteristic with fan speed in RPM)

θ_B = Mean slope of the bag (or loop) water contact length

θ_F = Inclination of the effective finger outer face to the horizontal (see Fig. 2)

θ_W = Slope of mean water plane for surface level beneath the cushion periphery, at critical speed

χ = A function used in the assessment procedures

$$= b/X_H \left\{ 0.0175 \, (\phi_{DAT} - \phi) - 1.96 \, \frac{p_c}{\rho g b} \right\}$$

ζ = A function used in the assessment procedure

$$= \chi - 0.86 \, b/X_H \cdot \frac{p_B}{\rho g b}$$

Suffix $_0$ denotes values at normal operating condition, without roll e.g. $\left\{ \frac{P_B}{P_C} \right\}_0 = \frac{P_{B0}}{P_{C0}}$

8 REFERENCES

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2. D G Gerry — "A System for the Assessment of Restoring Moment Coefficient in Roll" - British Hovercraft Corporation Report TFA/DGG/PC/2519, December 1979

3. D G Gerry — Supplementary data for use in Restoring Moment Coefficient assessment - British Hovercraft Corporation Note TFA/DGG/PC/2725, 26 March 1981

TABLE 1
ESSENTIAL PARAMETERS AND PREDICTION OF DATUM ROLL ANGLE

No.	PARAMETER	SYMBOL	VALUE	UNITS
	DENSITIES			
1	Air Density (mass)	ρ_A	1.225	Kg/m^3
			0.00238	$slugs/ft^3$
2*	Water Density (mass)	ρ	1025	Kg/m^3
			1.99	$slugs/ft^3$
3	Water Density (weight)	ρg	10,054	N/m^3
			64	lb/ft^3

CRAFT PARAMETERS

A consistent system of units must be used. With densities in either the imperial or S.I. system, as above, weight must be in pounds or Newtons and length in feet or metres. Pressures are then in $lb./ft^2$ or $Newton/m^2$. The unit of time is one second (the exception being in fan speed , where revolutions per minute are designated, to conform with common practice.)

4	Craft Weight	W			
5	Datum Cushion Area	S			
6	Datum Cushion Beam	b			
7	Datum Cushion Length	L			
8	Cushion Length /Beam Ratio $=[7]/[6]$	L/b			ND
9	$(\text{Datum Cushion Area})^{3/2}$ $[5]^{3/2}$	$S^{3/2}$			
10*	Datum Cushion Loading $=\frac{[4]}{[3][9]}$	$C_\Delta = \frac{W}{\rho g S^{3/2}}$			ND

*These items are described in paragraph 6, explanatory notes.

11*	CG Height (above hemline)	h_G		
11_A	$[11]/[6]$	h_G/b		

No.	PARAMETER	SYMBOL	VALUE	UNITS
	SKIRT PARAMETERS			
12*	Skirt Depth	H_{SK}		
13	Horizontal Hinge Spacing	X_H		
14	Vertical Hinge Spacing	Z_H		
15	Sideskirt Bag or Loop Perimeter	P		
16*	Hemline Span	S_P		
17	Skirt Depth Ratio [12]/[6]	H_{SK}/b		ND
18	Hinge Beam Ratio [6]/[13]	b/X_H		"
19	Hinge Spacing Ratio [14]/[13]]	Z_H/X_H		"
20	Sectional Perimeter Ratio [15]/[13]	P/X_H		"
21	Hemline Span Ratio [16]/[13]	S_P/X_H		"
22*	% Finger Depth	%		"
23*	Finger Effective Face Angle	θ_F		Deg.
24*	Cushion Feed Location			
25	Cushion Feed Area	S_F		
26	Feed Area Ratio [25]/[5]	S_F/S		ND

No.	PARAMETER	SYMBOL	VALUE	UNITS
	CUSHION AIR PARAMETERS			
27	Fan Type			
28	Fan Diameter	D		
29*	Fan Speed	N		RPM
30*	Design Volume Flow	Q		
31	Nominal Cushion Pressure $[4]/[5]$	P_{C0}		
32	Volume Flow Coefficient = $\frac{[30]}{[5]}\sqrt{\frac{[1]}{2 \times [31]}}$	$C_Q = \frac{Q}{S}\sqrt{\frac{\rho_A}{2P_{C0}}}$		ND
33	Inflow Characteristic Slope	$\sigma \quad \left(= \frac{D}{\rho_A N}\frac{\Delta P_B}{\Delta Q}\right)$		"
34*	$\frac{[1][29][30][33]}{[28][31]}$	$\frac{\rho_A N Q \sigma}{D P_{C0}}$		"
35	Design Pressure Ratio	$\left(\frac{P_B}{P_C}\right)_0$		"
	FROM TABLE 9 USING [20] AND [35]			
36	Assumed % Feed Closure at Tuck- Under			
37	Assumed $\Delta P_C/P_{C0}$ at Tuck-Under	$\frac{\Delta P_C}{P_{C0}}$		ND
	FROM FIG.4 USING [34], [35] AND [36]			
38*	$\Delta P_B/P_{C0}$ at Tuck-Under	$\frac{\Delta P_B}{P_{C0}}$		ND
39	Actual Cushion Pressure = [31] (1+[37])	$P_C = P_{C0}\left(1+\frac{\Delta P_C}{P_{C0}}\right)$		
40*	$\frac{[39]}{[3][6]}$	$\frac{P_C}{\rho g b}$		ND
41	[35] + [38]	$\frac{P_B}{P_{C0}}$		"

No.	PARAMETER	SYMBOL	VALUE	UNITS
	EARLY TUCK- UNDER			
42*	[40]	$\frac{P_C}{\rho g b}$		"
43	NOT ALLOTTED		0	"
	TUCK- UNDER AFTER BAG LOOP CONTACT			
44*	$\frac{[40][41]}{1+[37]}$	$\frac{P_B}{\rho g b}$		"
45	$[44]\sqrt{1-\frac{1}{[41]}}$	$\frac{P_B}{\rho g b}\sqrt{1-\left(\frac{P_B}{P_{C0}}\right)^{-1}}$	(or 0 if neg've)	"
	FROM FIG.5. USING [42] AND ZERO OR [44] AND [45]			
46*	Water Surface Slope	θ_B		Deg.
46A		Sine θ_B		ND
46B		Cosine θ_B		"
46C		Tangent θ_B		"
47	Datum Roll Angle = $57.3\left\{[17]+\frac{[14]}{[6]}+[32]+0.0285\right\}$	$\phi_{DAT} = 57.3\left\{\frac{H_{SK}}{b}+\frac{Z_H}{b}+C_Q+0.0285\right\}$		Deg.

NOTE: For a sideskirt consisting of segments only, along the sides, continue to [51] in TABLE 2A, (if with keel) then go to TABLE 6.

TABLE 2A

ROLL ANGLE AT TUCK- UNDER FOR SIDESKIRT WITH ANTI- BOUNCEWEB INITIALLY CARRYING LOAD WITH KEEL

No.	PARAMETER	SYMBOL	VALUE	UNITS
48	$0.91\left(\frac{[31]}{[3][6]}\right)$	$0.91\left(\frac{P_{C0}}{\rho g b}\right)$		ND
49	1.1 [35]	$1.1\left(\frac{P_B}{P_C}\right)_0$		"
50	FROM FIG. 6. USING [22] , [24] AND [48]	$\frac{H_{SK}}{b}(\phi)_{\Delta P=0}$		Deg.
51	$\frac{[50]}{[17]}$	$(\phi)_{\Delta P=0}$		Deg.
52	FROM FIG.6. USING [24] AND [49]	$\frac{\partial\left(\frac{\Delta P}{P_{C0}}\right)}{7.\left(S_F/S\right).(C_\Delta)^{-1}}\Big/\partial\phi$		$Deg.^{-1}$
53*	$\frac{[52][26]}{[10]}$	$7.\frac{\partial\left(\frac{\Delta P}{P_{C0}}\right)}{\partial\phi}$		"
54*	$\frac{[41]}{(1+[37])}$ Refer To Explanatory Note 6 (iii)	$\frac{P_B}{P_C}$		ND

NOTE

If [54] > 1.5 and:
if [20] < 2.5 use Fig. 2, if [20] > 3.5 use Fig. 4a , then continue at [55] and omit [56] and [57].
If [54] < 1.5 use Fig. 8b or Fig. 9 and go to [56], (unless [53] is zero or small compared with [11A], in which case go to TABLE 2B).

No.	PARAMETER	SYMBOL	VAL.	UNITS
55	FROM FIG.7 USING ([19] /[18]-[17]), [40] &[54] OR FROM FIG.8 USING [40] & [54]	ϕ_{ADD} ϕ_{ADD}		Deg. "
56A	$10.5\left\{\frac{[47]}{57.3}-\frac{[13]}{[6]}\sqrt{1+[19]^2}\right\}$ $+0.86$	$10.5\left\{\frac{\phi_{DAT}}{57.3}-\left(\frac{X_H}{b}\right)\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}\right\}$ $+0.86$		ND
56B	FROM FIG. 9. USING [40] , [54] AND [56A]	ϕ_{ADD}		Deg.
57	$\frac{1}{2.25+10.5\,[44]}$	$\frac{1}{f}$		ND
58	Roll Angle at Tuck-Under = [47] + [55] OR $=\{[47]+[56B]\}[57]$	$\phi=\phi_{DAT}+\phi_{ADD}$ OR $=\{\phi_{DAT}+\phi_{ADD}\}\frac{1}{f}$		Deg.
59*	<u>CHECK</u> [58]>[51],(IF [58] < [51] USE TABLE 2B)	$\phi\chi(\phi)_{\Delta P=0}$		
60	C G Height Ratio at Tuck-Under $=[11A]-\frac{[58]}{115}$	$\frac{(h_G)_T}{b}=\frac{h_G}{b}-\frac{\phi}{115}$		ND
61	CHECK FOR POSITIVE [53] - [60] (IF [61] IS NEGATIVE USE TABLE 2B)	$7.\frac{\partial\left(\frac{\Delta P}{P_C}\right)}{\partial\phi}-\frac{(h_G)_T}{b}$		Deg.
61A	$[18]\{0.0175[47]-1.96[40]\}$	$\frac{b}{X_H}\left\{0.0175\left(\phi_{DAT}\right)-1.96\frac{P_C}{\rho g b}\right\}$		ND
61B	0.86 [18] [44]	$0.86\,{}^{b}/_{X_H}\frac{P_B}{\rho g b}$		
61C	$[61A]-0.0175([18][58]\text{or}[66])$	$\chi=[61A]-0.0175\,{}^{b}/_{X_H}.\phi$		
61D	[61C]-[61B]	$\zeta=\chi-[61B]$		
61E	$\frac{[58]\text{or}[66]}{57.3}-[19]$	${}^{\phi}/_{57.3}-{}^{Z_H}/_{X_H}$		

NOTE:

If [54] <1.5 refer to Fig.10a and using [46] with [61C] or [61D] and [61E], classify as 'high' or 'low' perimeter ratio according to which dependent P/X_H value is close to the true ratio, [20].

If [54] > 1.5, refer to Fig.10b and classify similarly.

Continue in TABLE 3 if 'low' perimeter ratio and TABLE 5 if 'high' perimeter ratio.

TABLE 2B

ROLL ANGLE AT TUCK- UNDER FOR SIDESKIRT WITH ANTI-BOUNCE WEB INITIALLY CARRYING LOAD WITHOUT KEEL

(Or before commencement of differential pressure)

No.	PARAMETER	SYMBOL	VALUE	UNITS
62	$\frac{1-[21]}{[18]}$	$\left(1-\frac{S_P}{X_H}\right) \Big/ \frac{b}{X_H}$		ND
63A*	FROM FIG.11 USING [40] AND [62] IF [54] < 1.5	ϕ_{ADD}		Deg.
63B	FROM FIG.12. USING [40] AND [62] IF [54] > 1.5	ϕ_{ADD}		
64	$[11A]-\frac{1}{2}\left([17]+\frac{[14]}{[6]}\right)$	$\frac{h_G}{b}-\frac{1}{2}\left(\frac{H_{SK}}{b}+\frac{Z_H}{b}\right)$		ND
65	FACTOR From FIG. 11 or FIG. 12			"
66	Roll Angle at Tuck- Under $=[65]\{[47]+[63]+50(w-[54])[40]\}$ Where: w =1.15 for [54] <1.5 w = 2.0 for [54] >1.5	$\phi = [65]\{\phi_{DAT}+\phi_{ADD}+50\left(w-\frac{P_B}{Pc}\right)\frac{Pc}{\rho g b}\}$		Deg.
67	CG Height Ratio at Tuck-Under $=[11A]-\frac{[66]}{115}$	$\frac{(h_G)_T}{b} = \frac{h_G}{b}-\frac{\phi}{115}$		ND
	RETURN TO [61A] TO [61E] AND SUBSEQUENT NOTE IN TABLE 2A.			

TABLE 2C

ROLL ANGLE AT TUCK- UNDER FOR SIDESKIRT WITH ANTI- BOUNCE WEB INITIALLY CARRYING LOAD, WITH AND WITHOUT KEEL EARLY TUCK- UNDER CHECK

No.	PARAMETER	SYMBOL	VALUE	UNITS
	WITHOUT TRAILING SIDE SCOOPING			
68	$57.3\left\{\frac{[17][22]}{100}+[32]+0.0285\right\}$	$57.3\left\{\left(\frac{H_{SK}}{b}\right)\left(\frac{\%FING.}{100}\right)+C_Q+0.0285\right\}$		ND
69	FROM FIG. 13 USING [35] AND [40]	ϕ_{ADD}		Deg.
70	Roll Angle at Tuck-Under = [68] + [69]	$\phi = [68] + \phi_{ADD}$		"
	FROM FIG.15. USING [40] AND [23]			
71	Maximum Roll Angle for Trailing Side Scooping	ϕ_{SCOOP}		"

NOTE

The bag/finger configuration should be assumed not to be protected by trailing side scooping.

GO TO TABLE 5, [121A] OR [121B].

TABLE 3A

RESTORING MOMENT COEFFICIENT FOR SIDESKIRT WITH ANTI BOUNCE WEB INITIALLY CARRYING LOAD

'LOW' PERIMETER RATIO

No.	PARAMETER	SYMBOL	VALUE	UNITS
	PRESSURE RATIO < 1.5 AT TUCK UNDER			
72A	$[61C]/[18]$ Note: use [58] or [66] as appropriate for ϕ	$0.0175(\phi_{DAT} - \phi) - 1.96\frac{Pc}{\rho g b}$	or 0 if neg've	Deg.
73A	$\sqrt{1+[19]^2}$	$\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}$		ND
74A	$\frac{(1-[21])+[19]\sin\phi}{[18]}+[17]\sin\phi$	$\frac{\left(1-\frac{S_P}{X_H}\right)+\left(\frac{Z_H}{X_H}\right)\sin\phi}{b/X_H} + \frac{H_{SK}}{b}\sin\phi$		"
75A*	$\frac{[72A]}{[46B]-[46A]}$	$\frac{R_1}{b}$ If [75A] >0.5 put = 0.5)		"
76A*	$\frac{[72A]}{[46B]}-\left\{\frac{[73A]}{[18]}-[75A]\right\}[46C]$	$\frac{2R}{b}$		"
77A	[76A] [46A] +[74A]	$\frac{2R}{b}\sin\theta_B + [74A]$		"
	FROM FIG.16a. USING [46]			
78A		f_1		ND
79A		f_2		"
80A*	[78A] [18] [72A] + [79A] [73A]	$f_1\left(\frac{b}{X_H}\right)[72A] + f_2[73A]$		"
81A	[20]-[80A]	$\frac{P}{X_H}-[80A]$		"
82A	FROM FIG. 16b. USING [46] AND [81A]	$\left(\frac{\delta}{b}\right)_{INC}$		"
83A	[77A] + [82A]	$\frac{\delta}{b}$		"
84A	$=\frac{[73A]}{[18]}-[75A]$	$L_B/b = \frac{[73A]}{b/X_H} - \frac{R_1}{b}$	or 0 if value is neg've	"

NOTE

Continue at [85] on TABLE 3C

TABLE 3B

RESTORING MOMENT COEFFICIENT FOR SIDESKIRT WITH ANTI-BOUNCE WEB INITIALLY CARRYING LOAD

'LOW' PERIMETER RATIO

No.	PARAMETER	SYMBOL	VAL.	UNITS
	PRESSURE RATIO > 1.5 AT TUCK- UNDER			
72B	[61D] / [18]	$0.0175(\phi_{DAT} - \phi) - \left(1.96 + 0.86\frac{P_B}{P_C}\right)\frac{Pc}{\rho g b}$		ND
73B	$\sqrt{1+[19]^2}$	$\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}$		"
74B	$\frac{(1-[21])+[19]\sin\phi}{[18]}+[17]\sin\phi$	$\frac{\left(1-\frac{Sp}{X_H}\right)+\left(\frac{Z_H}{X_H}\right)\sin\phi}{b/X_H} + \frac{H_{SK}}{b}\sin\phi$		"
75B	Not Required			
76B*	$\frac{[72B]}{[46B]}$	$\frac{2R}{b}$		"
77B	Not Required			
78B	" "			
79B	" "			
80B	$\frac{\pi}{[46B]}\{[18][72B]+\left(\frac{[46A]}{2}+\frac{[46B]}{\pi}\right)[73B]\}$	$\frac{\pi}{\cos\theta_B}\left\{\frac{b[72B]}{X_H}+\left(\frac{\sin\theta_B}{2}+\frac{\cos\theta_B}{\pi}\right)[73B]\right\}$		"
81B	[20]-[80B]	$\frac{P}{X_H}-[80B]$		
82B	FROM FIG. 16c USING [46] AND [81B]	FACTOR		ND
83B	[76B] [46A] + [74B]	$\frac{\delta}{b}$		"
84B	$\frac{[82B][73B]}{[18]}$	$\frac{L_B}{b}$		"

TABLE 3C
RESTORING MOVEMENT COEFFICIENT FOR SIDESKIRT WITH ANTI-BOUNCE WEB INITIALLY CARRYING LOAD *'LOW'* PERIMETER RATIO

No.	PARAMETER	SYMBOL	VALUE	UNITS
85*	WITH KEEL $=([58]-[51])\frac{[53]}{7}$	$\Delta P/P_{C0}$ $=(\phi-(\phi)_{\Delta P=0})\frac{\partial(\Delta P/P_{C0})}{\partial\phi}$	NB [85]>0	ND
86*	$=\left[\frac{1-\left\{[41]-[85]/2\right\}[84]}{1+[83]-[84]}\right]-1$	$\Delta P_C/P_{C0}=$ $\left[\frac{1-\left\{P_B/P_{C0}-\Delta P/2P_{C0}\right\}\frac{L_B}{b}}{1+\delta/b-L_B/b}\right]-1$		"

CHECK:

Repeat calculation from [36] if $([37]-[86])>+0.05$ OR <-0.05

87*	$(1+[83])(1+[86])$	$\left(1+\frac{\delta}{b}\right)\left(1+\frac{\Delta P_C}{P_{C0}}\right)$		"
88A	$0.467[46B]-\frac{(h_G)_T}{b}[46A]+\frac{[75A]}{2}$	$\left(\frac{ARM}{b}\right)_1$ (Low Press. Ratio)		"
88B	$0.467[46B]-\frac{(h_G)_T}{b}[46A]$	$\left(\frac{ARM}{b}\right)_1$ (High Press. Ratio)		"
	NOTE: Use [60] or [67] as appropriate for $(h_G)_T/b$			
89	$=94.5\left(\frac{[31]}{[3][6]}\right)$	$\theta_W=94.5\left(\frac{P_{C0}}{\rho g b}\right)$		Deg.
90	$\frac{[46A]}{2}+\frac{(h_G)_T}{b}[46B]$	$\left(\frac{ARM}{b}\right)_2$		ND
	NOTE: Use [60] or [67] as appropriate for $\left((h_G)_T/b\right)$			

No.	PARAMETER	SYMBOL	VAL.	UNITS
	RESTORING MOMENT COEFFICIENTS			
91	Increased Cushion Beam $=\frac{[83][87]}{2}$	$=\frac{1}{2}\left(\frac{\delta}{b}\right)\left(1+\frac{\delta}{b}\right)\left(1+\frac{\Delta P_C}{P_{C0}}\right)$		ND
92	Differential Cushion Press. $=\frac{(1+[83])^2[85]}{8}$	$=\frac{1}{8}\left(1+\frac{\delta}{b}\right)^2\frac{\Delta P}{P_{C0}}$		"
93	Leading Sideskirt Contact = $\left\{[41]-(1+[86])-\frac{[85]}{2}\right\}[84][88]$	$=\left\{\left(\frac{P_B}{P_{C0}}\right)-\left(1+\frac{\Delta P_C}{P_{C0}}\right)-\frac{\Delta P}{2P_{C0}}\right\}\cdot\frac{L_B}{b}\left(\frac{ARM}{b}\right)_1$		"
	OVERTURNING MOMENT COEFFICIENTS			
94	CG Height $=\frac{-(h_G)_T}{b}\{\sin(\phi+[89])\}[87]$	$=\frac{-(h_G)_T}{b}\{\sin(\phi+\theta w)\}[87]$		ND
	NOTE: Use [60] or [67] for $(h_G)_T/b$ and [58] or [66] for ϕ			
95	Wetting Drag (Low Press. Ratio) $=\frac{-0.0089[17]\frac{[22]}{100}[90]}{[10]\sqrt{[8]}}$	$=\frac{-0.0089\frac{H_{SK}}{b}\frac{\%FING.}{100}\left(\frac{ARM}{b}\right)_2}{C_\Delta\sqrt{L/b}}$		ND
	(High pressure Ratio) $=\frac{-0.0063[84B][90]}{[10]\sqrt{[8]}}$	$=\frac{-0.0063\left(\frac{L_B}{b}\right)\left(\frac{ARM}{b}\right)_2}{C_\Delta\sqrt{L/b}}$		"

96	Total Restoring Moment Coeff. [91] + [92] + [93]			ND
97	Total Overturning Moment Coeff. [94] + [95]			"
98	Nett Restoring Moment Coeff. [96] + [97]			"

TABLE 4

ROLL ANGLE AT TUCK- UNDER FOR SIDESKIRT WITHOUT ANTI-BOUNCE WEB

No.	PARAMETER	SYMBOL	VALUE	UNITS
	FROM FIG.15. USING [23] &[40]			
99	Maximum Roll Angle For Trailing Side Scooping	ϕ_{SCOOP}		Deg.
	EARLY TUCK- UNDER ROLL			
	FROM FIG.13. USING [35] & [40]			
100		ϕ_{ADD}		Deg.
101	$=57.3\left\{[17]\frac{[22]}{100}+[32]+0.0285\right\}+[100]$	$\phi = 57.3\left\{\left(\frac{H_{SK}}{b}\right)\left(\frac{\%FING.}{100}\right)+C_Q+0.0285\right\}+\phi_{ADD}$		Deg.

NOTE:

If [101] < [99] continue at [102].
If [101] > [99] return to [36] and assume % closure to be zero. Put [37] = -0.1 and re-calculate (assuming early tuck under) to [46] , then return to [102] ,but use the ϕ at [101], (in place of [103] or [115] or [117]) and in [118]. Proceed to TABLE 5 at [121] to [124A] or [124B] and from [134A] or [134B] onward.

No.	PARAMETER	SYMBOL	VALUE	UNITS
102	$\frac{[41]}{1+[37]}$	$\frac{P_B}{P_C}$		ND
	WITH KEEL			
103	= [47] - 57.3 [40] x $\{0.86[102]+1.96\}$	$\phi = \phi_{DAT} - 57.3\frac{P_C}{\rho g b} \times \left\{0.86\frac{P_B}{P_C}+1.96\right\}$		Deg.
104	$0.91\frac{[31]}{[3][6]}$	$0.91\frac{P_{C0}}{\rho g b}$		ND
105	FROM FIG.6 USING [22], [24] AND [104]	$\frac{H_{SK}}{b}(\phi)_{\Delta P=0}$		Deg.
106	$\frac{[105]}{[17]}$	$(\phi)_{\Delta P=0}$		"
107	1.1 [102]	$1.1\left(\frac{P_B}{P_C}\right)$		ND
108	FROM FIG. 6 USING [24] AND [107]	$7\frac{\partial\left(\frac{\Delta P}{P_{C0}}\right)/\partial\phi}{S_F/S\,C_\Delta^{-1}}$		Deg.
109	$\frac{[108][26]}{[10]}$	$7\frac{\partial\left(\Delta P/P_{C0}\right)}{\partial\phi}$		"
110	$=\{[103]-[106]\}\frac{[109]}{7}$	$\frac{\Delta P}{P_{C0}} = \left\{\phi-(\phi)_{\Delta P=0}\right\}\frac{\partial\left(\Delta P/P_{C0}\right)}{\partial\phi}$ OR 0 IF NEGATIVE		ND
	WITHOUT KEEL OPEN LOOP CONFIGURATION			
111	FROM FIG. 14 USING [40] AND [35]	ϕ_{ADD}		Deg.
112	$([18]-[21])^{-1}$	$\left(\frac{b}{X_H}-\frac{Sp}{X_H}\right)^{-1}$		ND

No.	PARAMETER	SYMBOL	VALUE	UNITS
113	[112] [18] ([47] + [111])	$[112]\frac{b}{X_H}(\phi_{DAT}+\phi_{ADD})$		Deg.
114	[19] + 0.1 [17] [18] $-1.33\sqrt{1+[19]^2}.[46A]$	$\frac{Z_H}{X_H}+0.1\frac{H_{SK}}{b}\frac{b}{X_H}-1.33\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}\sin\theta_B$		ND
115	[113] - 57.3 [112] [114]	ϕ		Deg.
	CONTINUE AT [118]			
	WITHOUT KEEL INNER LOOP CONFIGURATION			
116	FROM FIG.14 USING [40] AND [102]	ϕ_{ADD}		Deg.
117	[47] + [116]	ϕ		Deg.
118	= [11A] - $\frac{\phi}{115}$	$\frac{(h_G)_T}{b}=\frac{h_G}{b}-\frac{\phi}{115}$		
	NOTE: Use [101], [103], [115] or [117] as appropriate for ϕ			

TABLE 5A

RESTORING MOMENT CO-EFFICIENT FOR SIDESKIRT WITHOUT ANTI-BOUNCE WEB

(Or with anti-bounce, if 'high' perimeter ratio or early tuck under)

No.	PARAMETER	SYMBOL	VALUE	UNITS
	PRESSURE RATIO < 1.5 AT TUCK-UNDER			
119A	0.0175 ([47] - ϕ) - [40](0.86[102] + 1.96) OR $[61D]/[18]$ IF [61D] ALREADY CALCULATED Note: Use [101], [103], [115] or [117] for ϕ as appropriate	$0.0175(\phi_{DAT} - \phi) - \frac{P_C}{\rho g b}\left(0.86\frac{P_B}{P_C} + 1.96\right)$	or 0 if neg've	ND
120A	$\sqrt{1+[19]^2}$	$\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}$		"
121A	$\left\{\frac{(1-[21])+[19]\sin\phi}{[18]}\right\} + [17]\sin\phi$	$\left\{\frac{\left(1-Sp/X_H\right)+\left(Z_H/X_H\right)\sin\phi}{b/X_H}\right\} + \frac{Hsk}{b}\sin\phi$		"
	EARLY TUCK UNDER ONLY			
122A	0.389 [20]- 0.7	$0.389\frac{P}{X_H} - 0.7$		"
123A	$[121A] + \frac{[122A]}{[18]}$	$\frac{\delta}{b}$		"
124A		$\frac{L_B}{b}$	0.05	ND
	CONTINUE AT [134A]			

No.	PARAMETER	SYMBOL	VALUE	UNITS
	EARLY TUCK UNDER PREVENTED BY TRAILING SIDE SCOOPING			
125A*	$[119A]\frac{[46B]+[46A]}{[46B]-[46A]}$	$[119A]\frac{\cos\theta_B+\sin\theta_B}{\cos\theta_B-\sin\theta_B}$		ND
126A	[121A] + [125A]			"
	FROM FIG. 17a USING [46]	f_6 f_7 f_8		"
127A	$f_6[18]\,[119A] + f_7\left\{\frac{\phi}{57.3}-[19]\right\} + f_8[120A]$	$f_6\frac{b}{X_H}[119A]+f_7\left\{\frac{\phi}{57.3}-\frac{Z_H}{X_H}\right\}+f_8[120A]$		"
128A	[20]-[127A]	$\frac{P}{X_H}-[127A]$		"
129A	FROM FIG 17b USING [128A]	$\left(\frac{\delta}{b}\right)_{INC}$		"
130A	"	$\left(\frac{L_B}{b}\right)_{INC}$		"
131A	= [126A] + [129A]	$\delta/b=[126A]+\left(\delta/b\right)_{INC}$		"
132A	$\frac{[119A]}{[46B]-[46A]}$	$\frac{[119A]}{\cos\theta_B-\sin\theta_B}$		"
133A	$\frac{\left(\frac{[120A]}{[18]}\right)[46B]+[132A][46A]}{[46A]+[46B]}$ +[130A]	$\left(\frac{L_B}{b}\right)$		"
134A	$=\left\{\frac{1-\left([41]-[110]/2\right)L_B/b}{\left(1+\delta/b-L_B/b\right)}\right\}-1$	$\Delta P_C/P_{C0}=\left\{\frac{1-\left(\frac{P_B}{P_{C0}}-\frac{\Delta P}{2P_{C0}}\right)\left(\frac{L_B}{b}\right)}{\left(1+\delta/b-L_B/b\right)}\right\}-1$		"
	NOTE: Use [124A] or [133A]for L_B/b and [123A] or [131A] for δ/b as appropriate. [110] = 0 if without a keel.			

No.	PARAMETER	SYMBOL	VALUE	UNITS
	CHECK: Repeat calculation from [36] if $([37]-[134A])>$ +0.05 or < -0.05			
135A	$\left(1+\delta/b\right)(1+[134A])$ NOTE: use [123A] or [131A] for δ/b as appropriate.	$\left(1+\delta/b\right)\left(1+\Delta Pc/Pc_0\right)$		ND
136A	$(0.467+[132A]+[130A])\times$ [46B]- [118][46A]	$\left(\frac{ARM}{b}\right)_3$		"
	NOTE: [132A] + [130A] = 0 if early Tuck- under			
137A	$\frac{[46A]}{2}+[118][46B]$	$\left(\frac{ARM}{b}\right)_4$		ND
138A	$94.5\ \frac{[31]}{[3][6]}$	θ_W		Deg.
	NOTE: Continue at [139] on TABLE 5C			

TABLE 5B

RESTORING MOMENT COEFFICIENT
FOR SIDE-SKIRT WITHOUT ANTI-BOUNCE WEB
(or with anti-bounce web, if 'high' perimeter ratio or early tuck-under)

No.	PARAMETER	SYMBOL	VALUE	UNITS
	PRESSURE RATIO >1.5 AT TUCK- UNDER			
119B	$0.0175\,([47]-\phi)-[40](0.86[102]+1.96)$ or $[61D]/[18]$ if [61D] already calculated. NOTE: Use [103], [115] or [117] for ϕ as appropriate	$0.0175\,(\phi_{DAT}-\phi)-\frac{Pc}{\rho g b}\left(0.86\frac{P_B}{Pc}+1.96\right)$	or 0 if neg've	ND
120B	$\sqrt{1+[19]^2}$	$\sqrt{1+\left(\frac{Z_H}{X_H}\right)^2}$		
121B	$\left\{\frac{(1-[21])+[19]\sin\phi}{[18]}\right\}+[17]\sin\phi$	$\left\{\frac{\left(1-Sp/X_H\right)+\left(Z_H/X_H\right)\sin\phi}{b/X_H}\right\}+\frac{H_{SK}}{b}\sin\phi$		"
	EARLY TUCK-UNDER ONLY			
122B	0.2 [20]- 0.35	$0.2\,\frac{P}{X_H}-0.35$		"
123B	$[121B]+\frac{[122B]}{[18]}$	$\frac{\delta}{b}$		"
124B		$\frac{L_B}{b}$	0.05	ND
	CONTINUE AT [134B]			

No.	PARAMETER	SYMBOL	VALUE	UNITS
	EARLY TUCK- UNDER PREVENTED BY TRAILING SIDE SCOOPING.			
125B*	$[119B]\frac{[46B]+[46A]}{[46B]-[46A]}$	$[119B]\frac{\cos\theta_B+\sin\theta_B}{\cos\theta_B-\sin\theta_B}$		ND
126B	[121B] + [125B]			"
	FROM FIG.18a USING [46]	f_3 f_4 f_5		" " "
127B	f_3 [18] [119B] + $f_4\left\{\frac{\phi}{57.3}-[19]\right\}$ + f_5[120B]	$f_3\frac{b}{X_H}[119B]+f_4\left\{\frac{\phi}{57.3}-\frac{Z_H}{X_H}\right\}$ + f_5[120B]		"
128B	[20]-[127B]	$\frac{P}{X_H}-[127B]$		"
129B	FROM FIG 18 USING [128B]	$\left(\frac{\delta}{b}\right)_{INC}$		"
130B	"	$\left(\frac{L_B}{b}\right)_{INC}$		ND
131B	= [126B] + [129B]	$\delta/b = [126B] + \left(\delta/b\right)_{INC}$		"
132B	$\frac{[119B]}{[46B]-[46A]}$	$\frac{[119B]}{\cos\theta_B-\sin\theta_B}$		"
133B	$\frac{[120B]}{[18]}+[132B]+[130B]$	$\left(\frac{L_B}{b}\right)$		"
134B	$= \left\{\frac{1-\left([41]-\frac{[110]}{2}\right)L_B/b}{\left(1+\delta/b-L_B/b\right)}\right\} -1$	$\frac{\Delta Pc}{P_{C0}} = \left\{\frac{1-\left(\frac{P_B}{P_{C0}}-\frac{\Delta P}{2P_{C0}}\right)\left(\frac{L_B}{b}\right)}{\left(1+\delta/b-L_B/b\right)}\right\}-1$		"
	NOTE: Use [124B] or [133B] for L_B/b and [123B] or [131B] for δ/b as appropriate.			

No.	PARAMETER	SYMBOL	VALUE	UNITS
	CHECK: Repeat calculation from [36] if $([37]-[134B]) > +0.05$ or < -0.05			
135B	$\left(1+\delta/b\right)(1+[134B])$	$\left(1+\delta/b\right)\left(1+\Delta Pc/P_{co}\right)$		ND
	NOTE: Use [123B] or [131B] for δ/b as appropriate.			
136B	(0.467 + [132B] + [130B]) [46B] - [118] [46A]	$\left(\frac{ARM}{b}\right)_3$		"
137B	$\frac{[46A]}{2}+[118][46B]$	$\left(\frac{ARM}{b}\right)_4$		ND
138B	$94.5\ \frac{[31]}{[3][6]}$	θ_w		Deg.
	NOTE: Continue at [139] on TABLE 5C			

TABLE 5C

RESTORING MOMENT CO-EFFICIENT
FOR SIDE SKIRT WITHOUT ANTI-BOUNCE WEB
(or with anti-bounce web, if 'high' perimeter ratio or early tuck-under)

No.	PARAMETER	SYMBOL	VALUE	UNIT
	RESTORING MOMENT COEFFICIENTS			
139	Increased Cushion Beam $= \frac{(\delta/b)[135]}{2}$ NOTE: Use [123] or [131] for δ/b as appropriate.	$= \frac{1}{2}\left(\frac{\delta}{b}\right)\left(1+\frac{\delta}{b}\right)\left(1+\frac{\Delta Pc}{Pc0}\right)$		ND
140	Differential Cushion Pressure $= \frac{\left(1+\delta/b\right)^2[110]}{8}$	$= \frac{1}{8}\left(1+\frac{\delta}{b}\right)^2 \frac{\Delta P}{Pc0}$		"
141	Leading Sideskirt Contact $= \left[[41]-\left(1+[134]\right)-\frac{[110]}{2}\right] [136]\left(\frac{LB}{b}\right)$ NOTE: Use [124] or [133] for LB/b as appropriate.	$= \left[\frac{PB}{Pc0}-\left(1+\frac{\Delta Pc}{Pc0}\right)-\left(\frac{\Delta P}{2Pc0}\right)\right] \left(\frac{ARM}{b}\right)_3\left(\frac{LB}{b}\right)$		"

No.	PARAMETER	SYMBOL	VALUE	UNIT
	OVERTURNING MOMENT COEFFICIENTS			
142	CG Height = -[118]$\left[\sin(\phi + [138])\right]$[135]	$= -\frac{(h_G)_T}{b}\left[\sin(\phi + \theta w)\right]$[135]		ND
	NOTE: Use [101], [103], [115] or [117] as appropriate for ϕ.			
143	Wetting Drag $= \frac{-0.0063\left(\frac{L_B}{b}\right)[137]}{[10]\sqrt{[8]}}$ NOTE: Use [124] or [133] for L_B/b as appropriate.	$= \frac{-0.0063\left(\frac{L_B}{b}\right)\left(\frac{ARM}{b}\right)_4}{C_\Delta\sqrt{\left(L/b\right)}}$		ND
144	Total Restoring Moment coefficient [139] + [140] + [141]			"
145	Total Overturning Moment coefficient [142] + [143]			"
146	Nett Restoring Moment coefficient [144] + [145]			"

TABLE 6

RESTORING MOMENT COEFFICIENT DUE TO STRUCTURAL CONTACT ALL SKIRT CONFIGURATIONS

No.	PARAMETER	SYMBOL	VALUE	UNITS
	STRUCTURAL PARAMETERS			
147	Horizontal Chine Spacing	X_C		
148	Vertical Chine Spacing	Z_C		
148A	Upper Chine to Top of Side Structure			
149	Chine Beam Ratio $[6]/[147]$	b/Xc		ND
150	Chine Spacing Ratio $[148]/[147]$	Zc/Xc		ND
151	Hull Width Across Lower Chines	b_L		
152	Slope Outb'd of Lower Chines	Ψ_{OL} (must be < 90°)		Deg.
153	Hull Width Across Intermed. Chines	b_C		
154	Slope Outb'd of Intermed. Chines	Ψ_{OC} (must be < 90°)		Deg.
155	Hull Width Across Upper Chines	b_U		
156	Slope Outb'd of Upper Chines	Ψ_{OU}		Deg.
	FROM FIG 4. USING [34], [35] AND 40% FEED CLOSURE. ASSUME $\Delta P_C/P_{C0} = 0$			
157*	Bag Pressure Rise Ratio	$\Delta P_B/P_{C0}$		ND
158	$[31]/[3][6]$	$\frac{P_{C0}}{\rho g b}$		ND
159	[35] + [157]	P_B/P_{C0}		ND
160	[158] [159]	$\frac{P_B}{\rho g b}$		ND
161	$[160]\sqrt{1-1/[159]}$	$\frac{P_B}{\rho g b}\sqrt{1-\frac{1}{(P_B/P_{C0})}}$		ND
162	FROM FIG. 5, USING [160] AND [161]. WATER SLOPE BENEATH LEADING SKIRT	θ_B		Deg.
163	$[158]\{1.96+0.86[159]\}$	$\frac{P_{C0}}{\rho g b}\left\{1.96+0.86\frac{P_B}{P_{C0}}\right\}$		ND

No.	PARAMETER	SYMBOL	VALUE	UNITS
164	[17] + [32] + 0.0285	$H_{SK}/_{b} + C_{Q} + 0.0285$		ND
165	$2(-[163]+[164])$			ND

NOTE: If no intermediate chine , omit [166B] to [169B] and put $^{bC}/_{b} = {}^{bU}/_{b}$ at [167A].

No.	PARAMETER	SYMBOL	VALUE	UNITS
	LOWER TO INTERMEDIATE CHINE			
166A	Beam Ratio $[151]/[6]$	b_L/b		ND
167A	Contact Length/Cushion Beam $\left([153]/[6]-[166A]\right)/2\cos[152]$	$L_C/b=\dfrac{\frac{1}{2}\left(b_C/b-b_L/b\right)}{\cos\psi_{OL}}$		ND
168A	Roll at Intermed. Chine Immersion $57.3\left\{\dfrac{[165]+2\tan[162]/[149]}{(1+[166A])}+[167A]\sin[152]\right\}$	ϕ		Deg.
169A	Moment Arm/Cushion Beam $\left\{\dfrac{[166A]}{2\tan[152]}-[11A]+[17]\right\}\sin[152]+\frac{1}{2}[167A]$	$\left\{\dfrac{b_L/b}{2\tan\Psi_{OL}}-\dfrac{h_G}{b}+\dfrac{H_{SK}}{b}\right\}\sin\psi_{OL}+\dfrac{L_C}{2b}$		ND
	INTERMEDIATE TO UPPER CHINE			
166B	Beam Ratio $[153]/[6]$	b_C/b		ND
167B	Contact Length/Cushion Beam $\left([155]/[6]-[166B]\right)/2\cos[154]$	$L_C/b=\dfrac{\frac{1}{2}\left(b_U/b-b_C/b\right)}{\cos\psi_{OC}}$		ND
168B	Roll at Upper Chine Immersion 57.3 $\left\{\dfrac{[165]+([166B]-[166A])\tan[152]}{(1+[166B])}+\dfrac{\left([155]/6-[166B]\right)\tan[162]}{(1+[166B])}+[167B]\sin[154]\right\}$	ϕ		Deg.

No.	PARAMETER	SYMBOL	VALUE	UNITS
169B	Moment Arm / Cushion Beam $\sin[154]\left\{\frac{[166B]}{2\tan[154]}-[11A]+[17]+\frac{1}{2}([166B]-[166A])\tan[152]\right\}+\frac{1}{2}[167B]$	$\sin\psi_{OC}\left\{\frac{b_C/b}{2\tan\Psi_{OC}}-\frac{h_G}{b}+\frac{H_{SK}}{b}+\frac{1}{2}\left(\frac{b_C}{b}-\frac{b_L}{b}\right)\tan\psi_{OL}\right\}+L_C/2b$		ND
	<u>UPPER CHINE TO TOP OF SIDE STRUCTURE</u>			
166C	Beam Ratio $[155]/[6]$	b_U/b		ND
167C	Contact Length/ Cushion Beam $[148A]/[6]$	L_C/b		ND
168C	Roll at Top Side Immersion $57.3\left\{\frac{[165]+2[150]/[149]}{(1+[166C])}+[167C]\right\}$	ϕ		Deg.
169C	Moment Arm/Cushion Beam $\left\{\frac{[166C]}{2\tan[156]}-[11A]+[17]+\frac{[150]}{[149]}\right\}\sin[156]+\frac{1}{2}[148A]/[6]$	$\left\{\frac{b_U/b}{2\tan\Psi_{OL}}-\frac{h_G}{b}+\frac{H_{SK}}{b}+\frac{Z_C/X_C}{b/X_C}\right\}\sin\Psi_{OU}+\frac{1}{2}[148A]/b$		ND

No.	PARAMETER	SYMBOL	VALUE	UNITS
170	Incidence to Local Flow Direction Ψ_O -[162] -[168] for Ψ_O use [152], [154] or [156]	$\alpha = \Psi_O - \theta_B - \phi$		Deg.
	CONTINUE ONLY IN CASE(S) FOR WHICH [170] IS POSITIVE			
171	EITHER :- $0 < \alpha < 10°$ sin(2.5[170]) OR	$\left(\frac{\bar{P}}{\frac{1}{2}\rho V_L^2}\right) = \sin(2.5\alpha)$		ND
172	$10° < \alpha$ $[170]/70$	$\alpha/70$		ND
173	$0.8[172]\sqrt{\frac{2}{[172]} - 1}$	$\left(\frac{\bar{P}}{\frac{1}{2}\rho V_L^2}\right)$ $= 0.8\left(\alpha/70\right)\sqrt{\frac{2}{\left(\alpha/70\right)} - 1}$		ND
	MOMENT COEFFICIENT DUE TO STRUCTURAL CONTACT			
174	$\frac{0.047[167][169]\left(\frac{\bar{P}}{\frac{1}{2}\rho V_L^2}\right)}{[158]}$ FOR $\left(\frac{\bar{P}}{\frac{1}{2}\rho V_L^2}\right)$ USE [171] OR [173] AS APPROPRIATE.	$0.047 \times \frac{\frac{Lc}{b}\left(\frac{ARM}{b}\right)\left(\frac{\bar{P}}{\frac{1}{2}\rho V_L^2}\right)}{Pc0/\rho gb}$		ND

TABLE 7

NETT RESTORING MOMENT COEFFICIENT , INCLUDING STRUCTURAL CONTACT

ALL SKIRT CONFIGURATIONS

No.	PARAMETER	SYMBOL	VALUE	UNITS
175	[168]-[51] (= 0 IF NO KEEL)	$\phi-(\phi)_{\Delta P=0}$		Deg.
176	EITHER:- [175] < 5° FACTOR = 1.0 OR :- [175]>5° FACTOR= $\dfrac{\left(1+5^{\circ}/[175]\right)}{2}$			
177	Pressure Differential Ratio $[53]/7$ [175] [176]	$\dfrac{\Delta P}{P_{C0}}=\dfrac{\partial\left(\frac{\Delta P}{P_{C0}}\right)}{\partial\phi}\left(\phi-(\phi)_{\Delta\rho=0}\right)$ × FACTOR		ND
178	Cushion Beam Increase Ratio $\text{TAN}[168]\left\{\left(\dfrac{b_{CHINE}}{b}-1\right)\Big/2\sin[168]\right.$ $\left.+4.7[158]+0.0285\right\}$ $\dfrac{b_{CHINE}}{b}$ USE [166] A, B OR C AS APPROPRIATE.	$\delta/b=\tan\phi\left\{\dfrac{\frac{b_{CHINE}}{b}-1}{2\sin\phi}\right.$ $\left.+4.7\dfrac{P_{C0}}{\rho g b}+0.0285\right\}$		ND
179*	[162] + [168]	$\theta_B+\phi$		Deg.
180	$\frac{1}{2}\left([166].\cos[179]-L_B/b\right)$ L_B/b, USE [84]OR [133] OR 0.06[20], IF EARLY T'-UNDER	$\dfrac{1}{2}\left(\dfrac{b_{CHINE}}{b}\cos(\theta_B+\phi)-\dfrac{L_B}{b}\right)$		ND
181	$\sin[179]\left\{[11A]-[17]-\dfrac{[19]}{[18]}\right\}$	$\sin(\theta_B+\phi)\left\{\dfrac{hc}{b}-\dfrac{H_{SK}}{b}\right.$ $\left.-\dfrac{Z_H/X_H}{b/X_H}\right\}$		ND
182	Skirt Contact Mom't Arm Ratio [180] - [181]	$\left(\dfrac{ARM}{b}\right)$		ND

No.	PARAMETER	SYMBOL	VALUE	UNITS
	RESTORING MOMENT COEFFICIENTS			
183	Increased cushion beam $\frac{1}{2}$[178]	$\frac{1}{2}\frac{\delta}{b}$		ND
184	Differential Cushion Pressure $\frac{1}{8}(1+[178])^2[177]$	$\frac{1}{8}\left(1+\frac{\delta}{b}\right)^2\frac{\Delta P}{P_{C0}}$		ND
185	Leading Sideskirt Contact $\left\{[159]-1-\frac{1}{2}[177]\right\}\frac{L_B}{b}[182]$ $\frac{L_B}{b}$ as used at [180]	$\left\{\frac{P_B}{P_{C0}}-1-\frac{1}{2}\frac{\Delta P}{P_{C0}}\right\}\frac{L_B}{b}\left(\frac{ARM}{b}\right)$		ND
186	Leading Sidestructure Contact [174]	COEFF. AS OBTAINED IN TABLE 6.		ND
187	Total Restoring Moment Coefficient [183] + [184] + [185] + [186]			ND
	OVERTURNING MOMENT COEFFICIENTS			
188	C.G Height Loss $-\left([11A]-\frac{[168]}{115}\right)\sin([168]+\theta_w)$ θ_w USE [89] OR [138]	$-\left(\frac{hc}{b}-\frac{\phi}{115}\right)\sin(\phi+\theta w)$		ND
189	Wetting Drag as [95] or [143]	COEFF. AS OBTAINED IN TABLE 3 OR 5		ND
190	Total Overturning Moment Coefficient [188] + [189]			ND
191	Nett Restoring Moment Coefficient With Structural Contact [187] + [190]			ND

TABLE 8

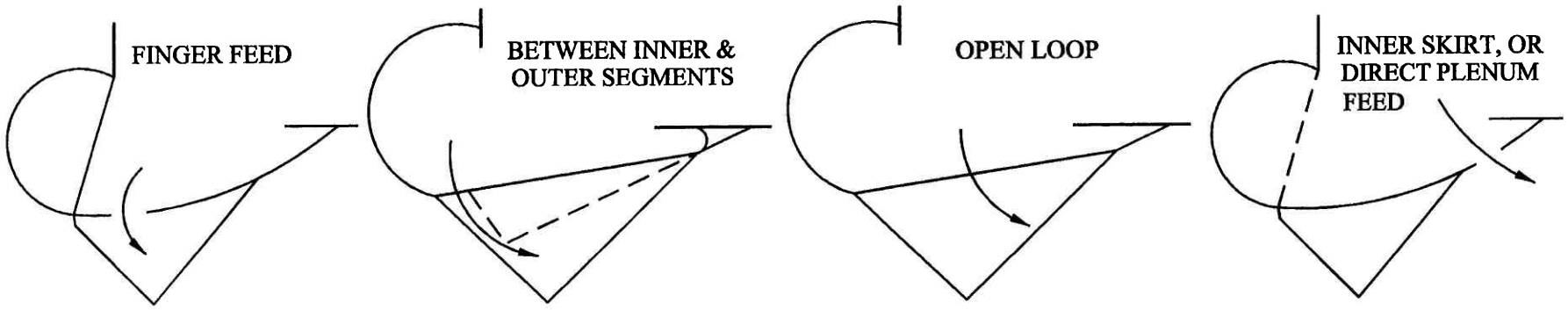
APPLIED OVERTURNING MOMENT COEFFICIENT DUE TO FOLLOWING WIND, ADVERSE CONTROL APPLICATION AND LATERAL C.G. OFFSET

No.	PARAMETER	SYMBOL	VALUE	UNITS
192	Craft Overall Planform Area	S_T		
193	Craft Overall Width	$\overline{C}$		
194	$\frac{[192][193]}{[5][6]}$	$\frac{S_T\overline{C}}{S.b}$		ND
195	OPERATORS HANDBOOK LIMITATIONS Gust Speed			
196	C.G. Lateral Offset			
197	Critical Overturning Water Speed $0.46\sqrt{[3]\frac{[6]}{[2]}}$	$V_{CRIT} = 0.46\sqrt{gb}$		
198	Relative Wind Speed = [195] - [197]	V		
199	Air Dynamic Pressure $\frac{1}{2}[1]([198])^2$	$\frac{1}{2}\rho_A V^2$		
200	$\frac{\text{Dynamic Pressure}}{\text{Cushion Pressure}} = \frac{[199]}{[31]}$	$\frac{1}{2}\rho_A V^2 / P_{C0}$		ND
	WIND OVERTURNING MOMENT COEFF. FROM FIG 19, USING TUCK-UNDER ROLL ϕ AND [11A]			
201	Body	C_m		ND
202	Momentum Drag $[30]/(5.[192][198])$			ND
203	Total = [201] + [202] + 0.01			ND
	CONTROL OVERTURNING MOMENT COEFF. (Moments About C.G.)			
204	Nett Propeller Torque $\frac{\text{Torque}}{[4][6]}$			ND
205	NON VECTORED THRUST Rudder(S) In Slipstream $\frac{\text{Sideforce Mom.}}{[4][6]}$			ND
206	Propeller fin effect $\frac{\text{Sideforce Mom.}}{[4][6]}$			ND

207	VECTORED THRUST Max Thrustline Rotation			Deg.
208	$\frac{\text{(Max. Thrust)(Thrust Line Height)}}{[4][6]}$			ND
209	TOTAL CONTROL MOMENT COEFF. NON VECTORED THRUST [204] + [205] + [206]			ND
	TOTAL CONTROL MOMENT COEFF. VECTORED THRUST			
210	sin[207] {[204] + [208]}			ND
211	C.G. Offset Overturning Moment Coeff. [196] / [6]	y_G / b		ND
212	Wind Overturning Moment Coeff. [194] [200] [203]			ND
213	Control Overturning Moment Coeff. [209] or [210]			ND
214	TOTAL APPLIED OVERTURNING MOMENT COEFFICIENT [211] + [212] + [213]	$M_{APPLIED}$		ND

TABLE 9

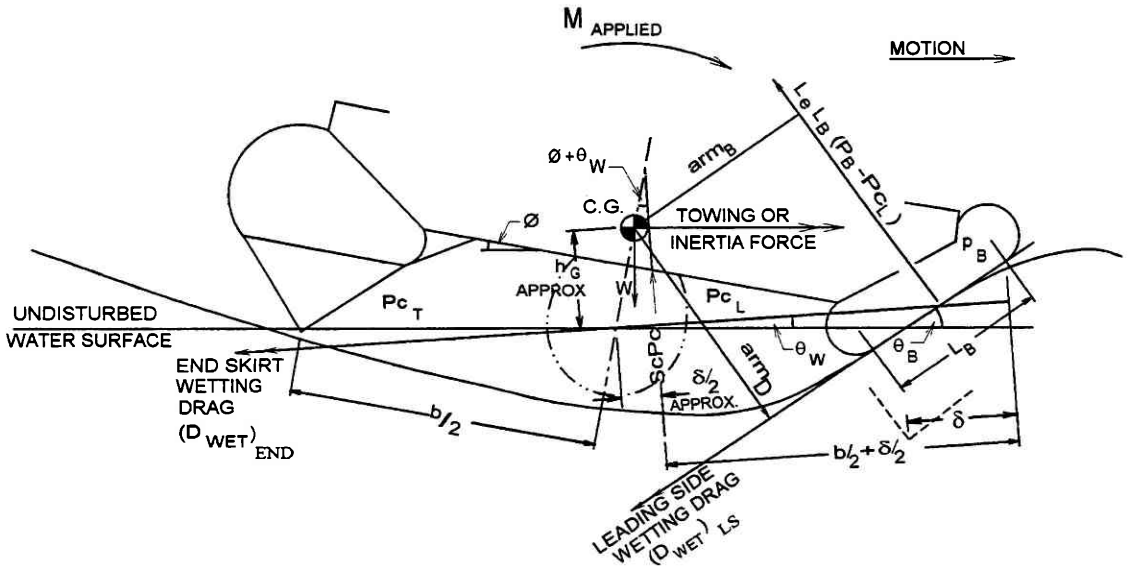
ASSUMPTIONS FOR PERCENTAGE CUSHION FEED CLOSURE AND CUSHION INCREASE RATIO AT TUCK-UNDER (IN TABLE 1.)



Initial Classification				
	High $(P_B/P_C)_0$	above 1.5	High P/X_H	above 3.5
	Low $(P_B/P_C)_0$	below 1.2	Low P/X_H	below 2.5

% FEED CLOSURE — 20 / -0.2 — CUSHION PRESSURE INCREASE RATIO $\Delta P_C/P_{C0}$

	WITH ANTI-BOUNCE WEB			WITHOUT ANTI-BOUNCE WEB (OR WEB INITIALLY SLACK)							
	NO TRAILING SIDE SCOOPING ASSUMED			PROTECTED BY TRAILING SIDE SCOOPING				UNPROTECTED BY TRAILING SIDE SCOOPING			
CUSHION FEED LOCATION	FINGER	INNER SKIRT OR DIRECT PLENUM	OPEN LOOP CONFIG'N	BETWEEN INNER & OUTER SEG'NTS	THRO' INNER LOOP OR DIRECT PLENUM	OPEN LOOP CONFIG'N	FINGER	BETWEEN INNER & OUTER SEG'NTS	THRO' INNER LOOP OR DIRECT PLENUM	OPEN LOOP CONFIG'N	FINGER
HIGH $(P_B/P_C)_0$ HIGH P/X_H	20 / -0.3	0 / -0.2		70 / -0.3	0 / -0.2		0 / -0.1	20 / -0.1	0 / -0.1	0 / -0.1	0 / -0.1
HIGH $(P_B/P_C)_0$ LOW P/X_H	20 / -0.25	0 / -0.15		70 / -0.2	0 / -0.15		0 / -0.1	20 / -0.1	0 / -0.1	0 / -0.1	0 / -0.1
LOW $(P_B/P_C)_0$ HIGH P/X_H	20 / -0.25	0 / -0.15	0 / -0.2	70 / -0.3	0 / -0.15	0 / -0.2	0 / -0.1	20 / -0.1	0 / -0.1	0 / -0.1	0 / -0.1
LOW $(P_B/P_C)_0$ LOW P/X_H	20 / -0.1	0 / -0.1	0 / -0.1	70 / -0.2	0 / -0.1	0 / -0.1	0 / -0.1	20 / -0.1	0 / -0.1	0 / -0.1	0 / -0.1



(Note: $P_{CL} = P_C + \Delta P/2$ and $P_{CT} = P_C - \Delta P/2$, for compartmented cushion)

Moment Equation

$$(D_{WET})_{LS}/W * arm_D/b + M_{APPLIED}/Wb + (D_{WET})_{END}/W * h_{GT}/b \cong$$

$$\tfrac{1}{2}((b+\delta)/2)^2 * \Delta P * L_e/Wb - S_C P_C/W * h_{GT}/b * (\phi+\theta_w) + S_C P_C/W * \delta/2b + (P_B - P_{CL}) * L_e L_B/W * arm_B/b$$

$$\text{Differential Pressure Moment} = (1 + \delta/b)^2/8 * Sb\Delta P$$

$$P_C = P_{C0} + \Delta P_C$$

$$S_C P_C/W = (Sp_C)_0(1 + \delta/b)(1 + \Delta P_C/P_{C0}) * 88/(Sp_C)_0$$

Note: In the assessment method, for simplicity $(D_{WET})_{END}/W * h_{GT}/b$ has been taken as equal to 0.5 times $(D_{WET})_{LS}/W * arm_D/b$ with some experimental justification, and because wetting drag is not usually a major overturning component.

At full scale, $M_{APPLIED}$ may be composed of wind, control and lateral C.G.-offset moments (see TABLE 8.).

Restoring Moment Coefficient, RMC (nett, just before tuck-under) = $M_{APPLIED}/Wb$
Moment Arm notation used in tables is:

	TABLE 3C	TABLE 5 (A & B)
arm_B/b	$(ARM/b)_1$	$(ARM/b)_3$
arm_D/b	$(ARM/b)_2$	$(ARM/b)_4$

FIGURE 1.
Mathematical model for Rolling Moment Equation at Critical Overturn Speed before Tuck-under.

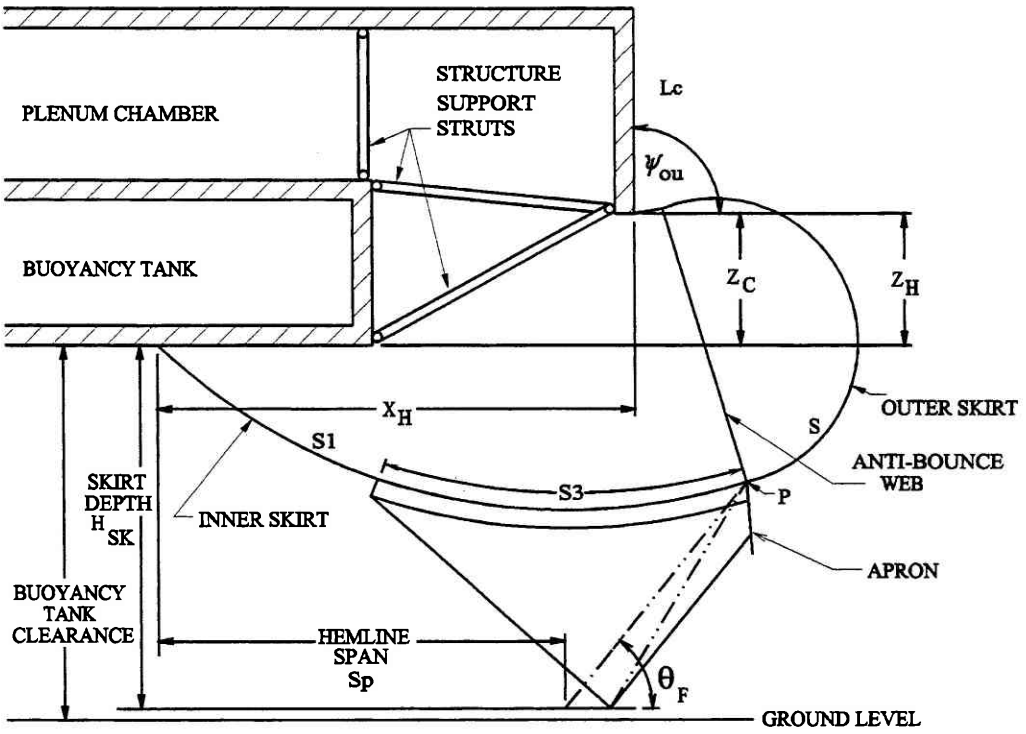
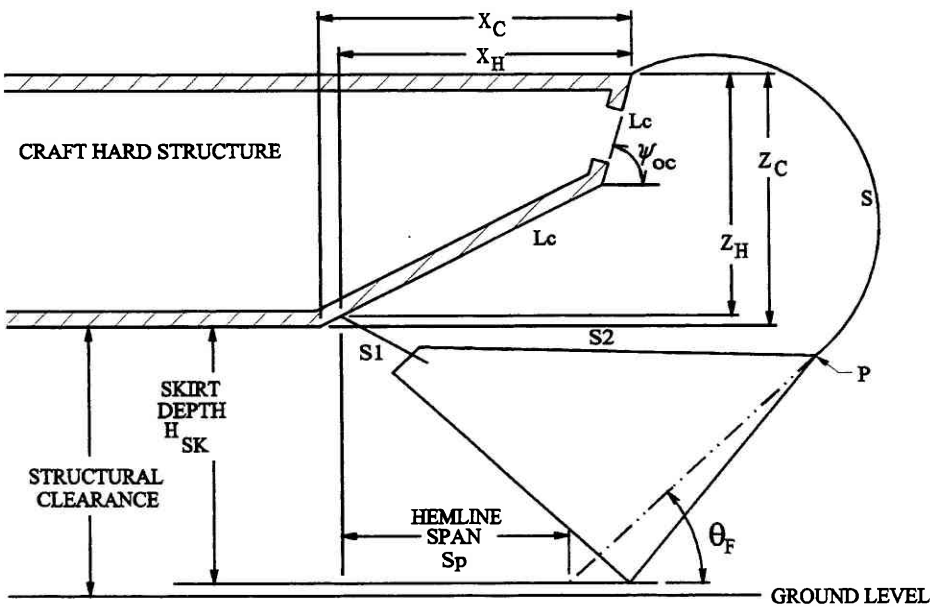


Fig 2a Bag/Finger Skirt (shown with Anti-Bounce Web)

Bag or Loop Perimeter, P = S1 + S3 + S

θ_F is the effective finger-face angle. See Section 6., explanatory note 23.



Loop Perimeter, P = S1 + S2 + S

Fig 2b. Loop/Segment Skirt (shown without Inner Loop and Inner Segments, i.e. "Open Loop")

FIGURE 2
Sideskirt Sectional Geometry

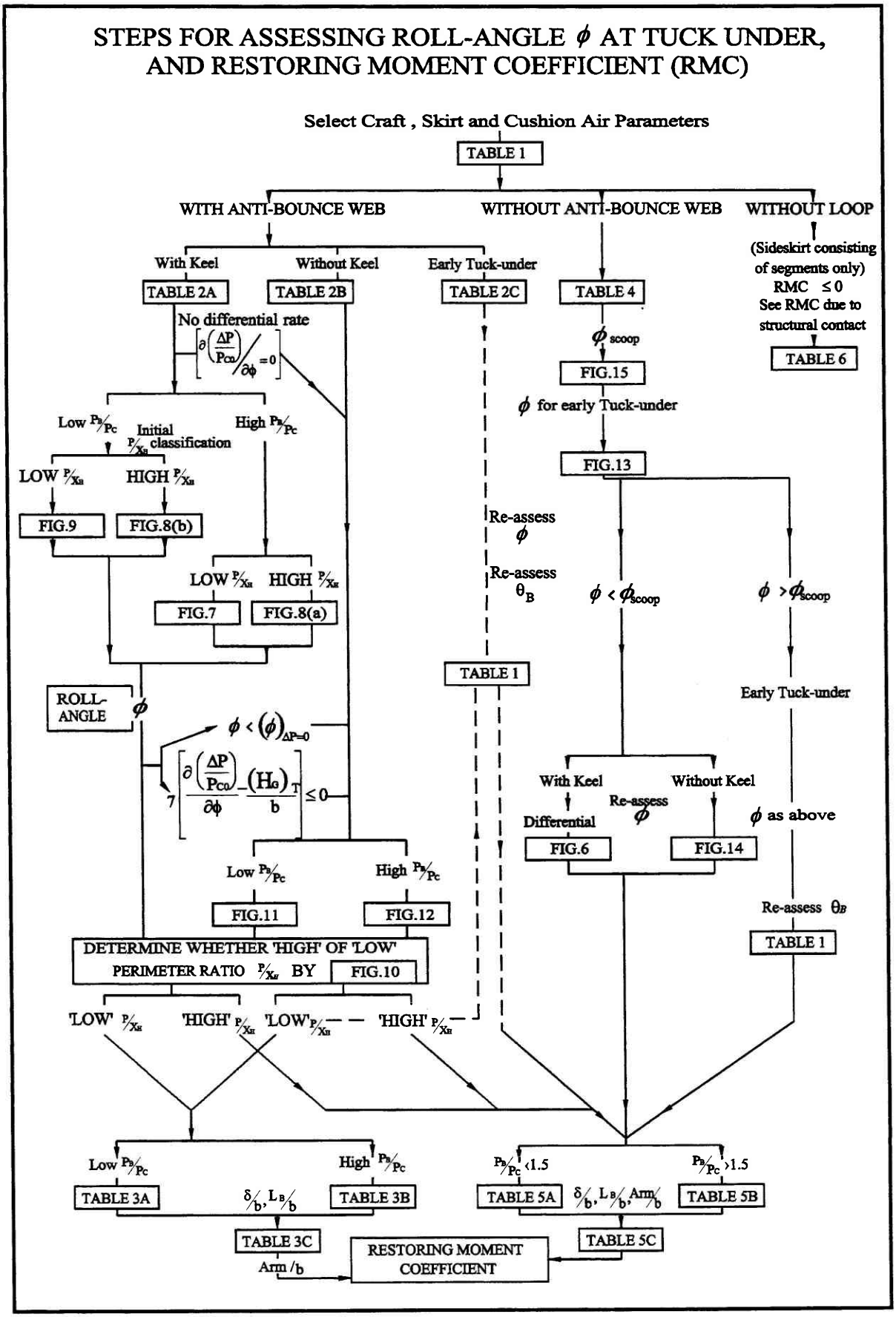


FIGURE 3
Parameter Selection and Processing

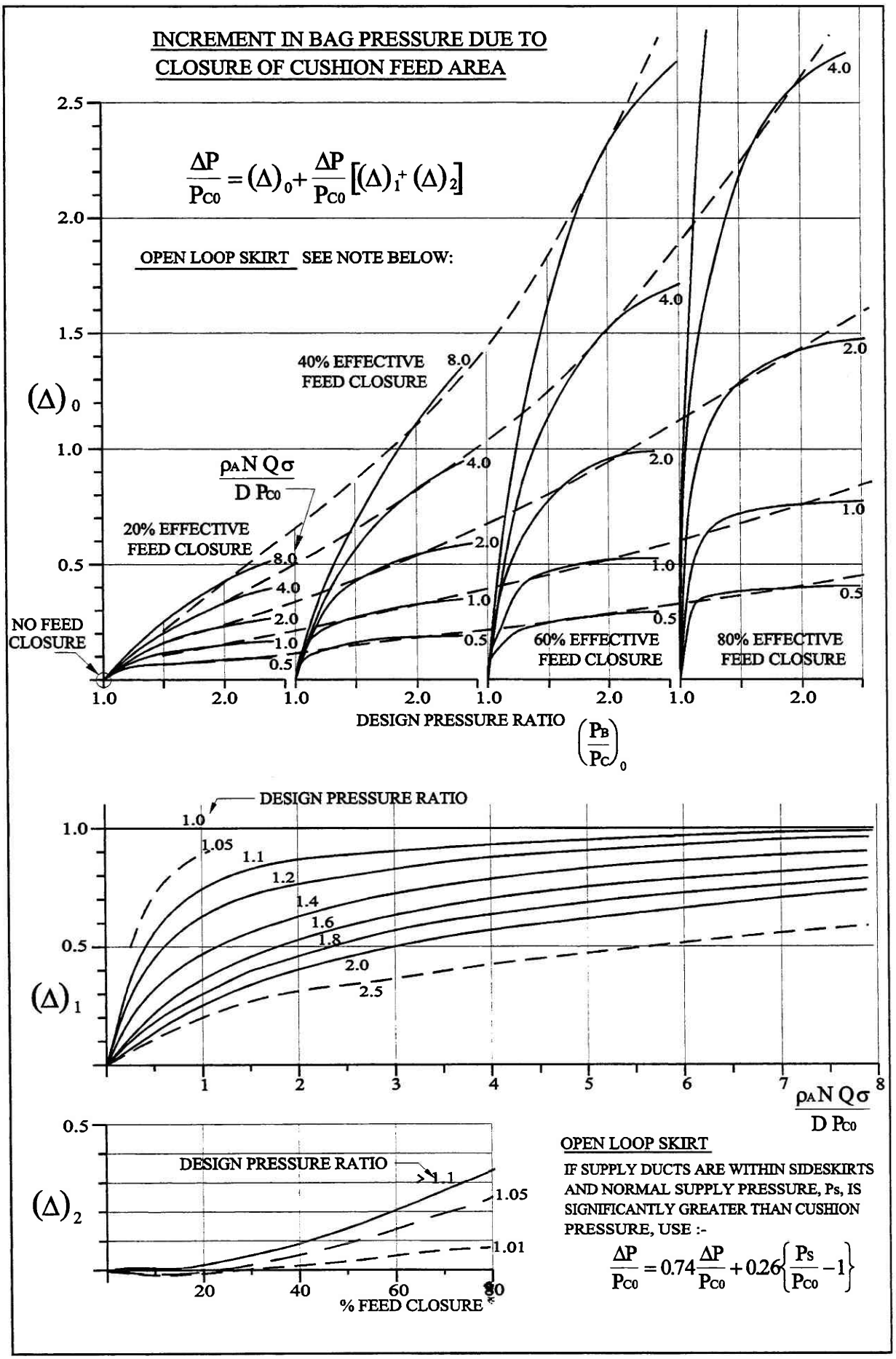

INCREMENT IN BAG PRESSURE DUE TO CLOSURE OF CUSHION FEED AREA
$\frac{\Delta P}{P_{C0}} = (\Delta)_0 + \frac{\Delta P}{P_{C0}}[(\Delta)_1 + (\Delta)_2]$
OPEN LOOP SKIRT SEE NOTE BELOW:
$(\Delta)_0$
$\frac{\rho_A N Q \sigma}{D P_{C0}}$
NO FEED CLOSURE
20% EFFECTIVE FEED CLOSURE
40% EFFECTIVE FEED CLOSURE
60% EFFECTIVE FEED CLOSURE
80% EFFECTIVE FEED CLOSURE
DESIGN PRESSURE RATIO $\left(\frac{P_B}{P_C}\right)_0$
$(\Delta)_1$
DESIGN PRESSURE RATIO
$(\Delta)_2$
% FEED CLOSURE
OPEN LOOP SKIRT
IF SUPPLY DUCTS ARE WITHIN SIDESKIRTS AND NORMAL SUPPLY PRESSURE, Ps, IS SIGNIFICANTLY GREATER THAN CUSHION PRESSURE, USE :-
$\frac{\Delta P}{P_{C0}} = 0.74\frac{\Delta P}{P_{C0}} + 0.26\left\{\frac{P_S}{P_{C0}} - 1\right\}$

FIGURE 4.

WATER CONTACT SLOPE - θ_B°

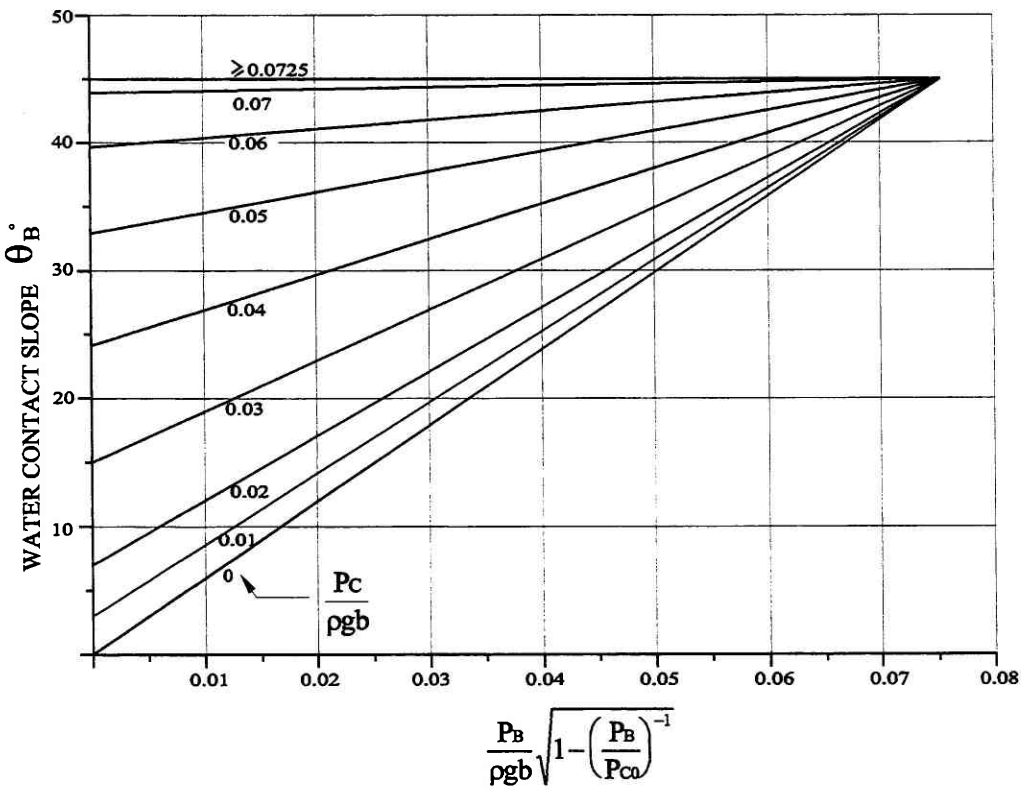


FIGURE 5

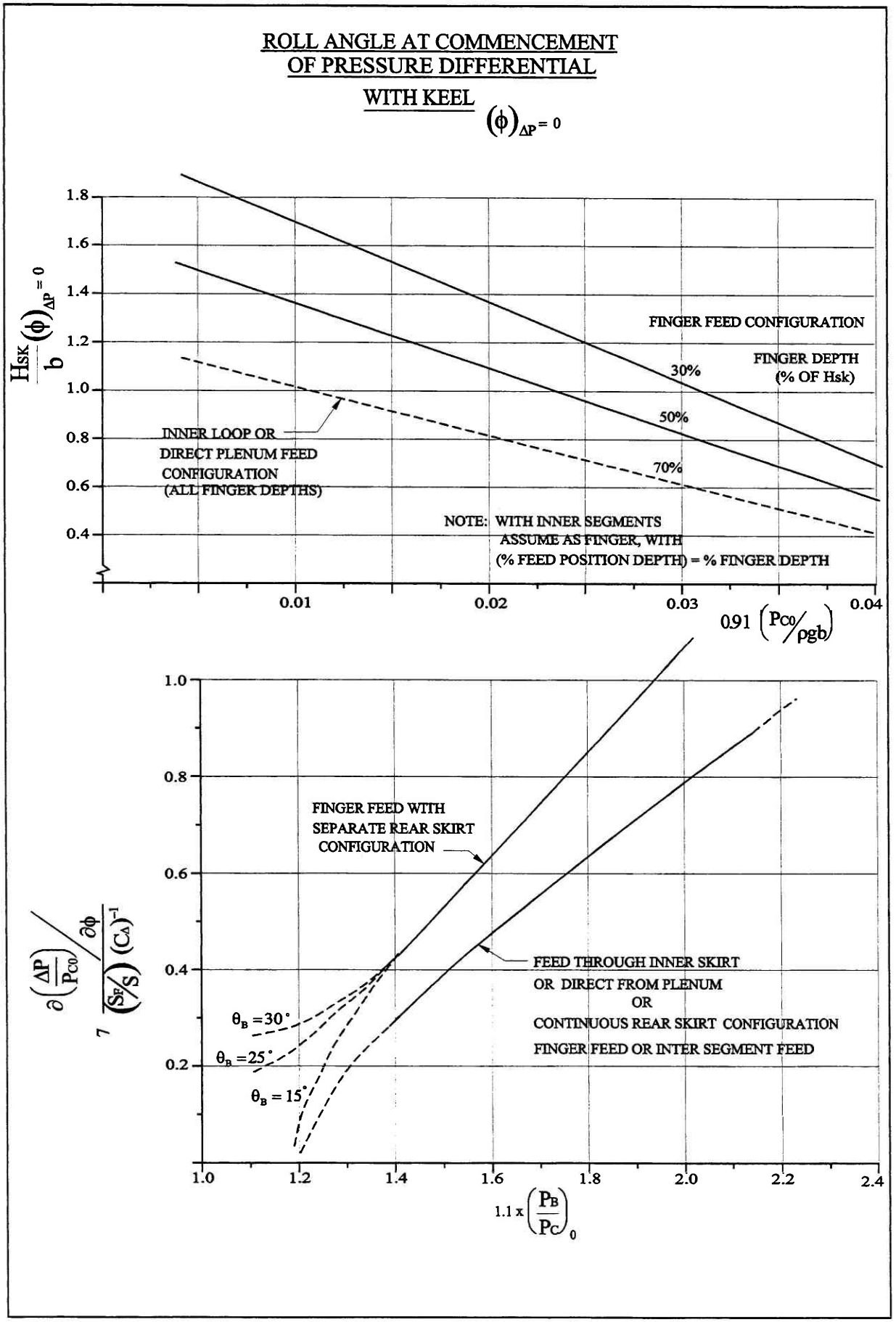

ROLL ANGLE AT COMMENCEMENT
OF PRESSURE DIFFERENTIAL
WITH KEEL
$(\phi)_{\Delta P = 0}$
$\frac{H_{SK}}{b}(\phi)_{\Delta P = 0}$
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
FINGER FEED CONFIGURATION
FINGER DEPTH
(% OF Hsk)
30%
50%
70%
INNER LOOP OR
DIRECT PLENUM FEED
CONFIGURATION
(ALL FINGER DEPTHS)
NOTE: WITH INNER SEGMENTS
ASSUME AS FINGER, WITH
(% FEED POSITION DEPTH) = % FINGER DEPTH
0.01
0.02
0.03
0.04
$0.91\left(P_{C0}/\rho g b\right)$
$\frac{\partial\left(\frac{\Delta P}{P_{C0}}\right)}{7\left(\frac{S_F}{S}\right)(C_A)^{-1}} \Big/ \frac{\partial\phi}{}$
1.0
0.8
0.6
0.4
0.2
FINGER FEED WITH
SEPARATE REAR SKIRT
CONFIGURATION
FEED THROUGH INNER SKIRT
OR DIRECT FROM PLENUM
OR
CONTINUOUS REAR SKIRT CONFIGURATION
FINGER FEED OR INTER SEGMENT FEED
$\theta_B = 30°$
$\theta_B = 25°$
$\theta_B = 15°$
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
$1.1 \times \left(\frac{P_B}{P_C}\right)_0$

FIGURE 6.

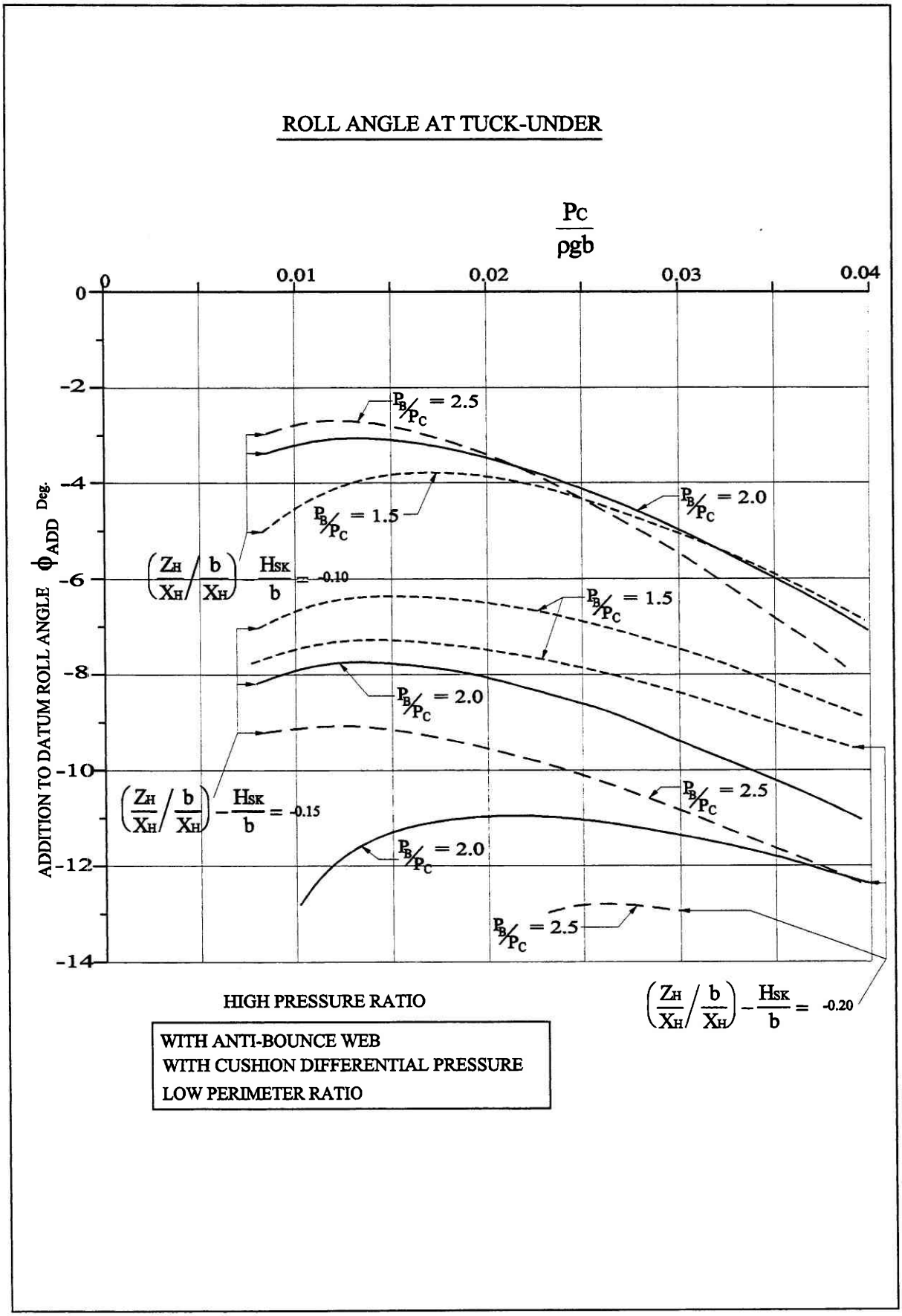

ROLL ANGLE AT TUCK-UNDER
Pc / ρgb
0
0.01
0.02
0.03
0.04
-2
-4
-6
-8
-10
-12
-14
ADDITION TO DATUM ROLL ANGLE φADD Deg.
PB/PC = 2.5
PB/PC = 1.5
PB/PC = 2.0
(ZH/XH / b/XH) HSK/b = -0.10
PB/PC = 1.5
PB/PC = 2.0
PB/PC = 2.5
(ZH/XH / b/XH) HSK/b = -0.15
PB/PC = 2.0
PB/PC = 2.5
(ZH/XH / b/XH) HSK/b = -0.20
HIGH PRESSURE RATIO
WITH ANTI-BOUNCE WEB
WITH CUSHION DIFFERENTIAL PRESSURE
LOW PERIMETER RATIO

FIGURE 7.

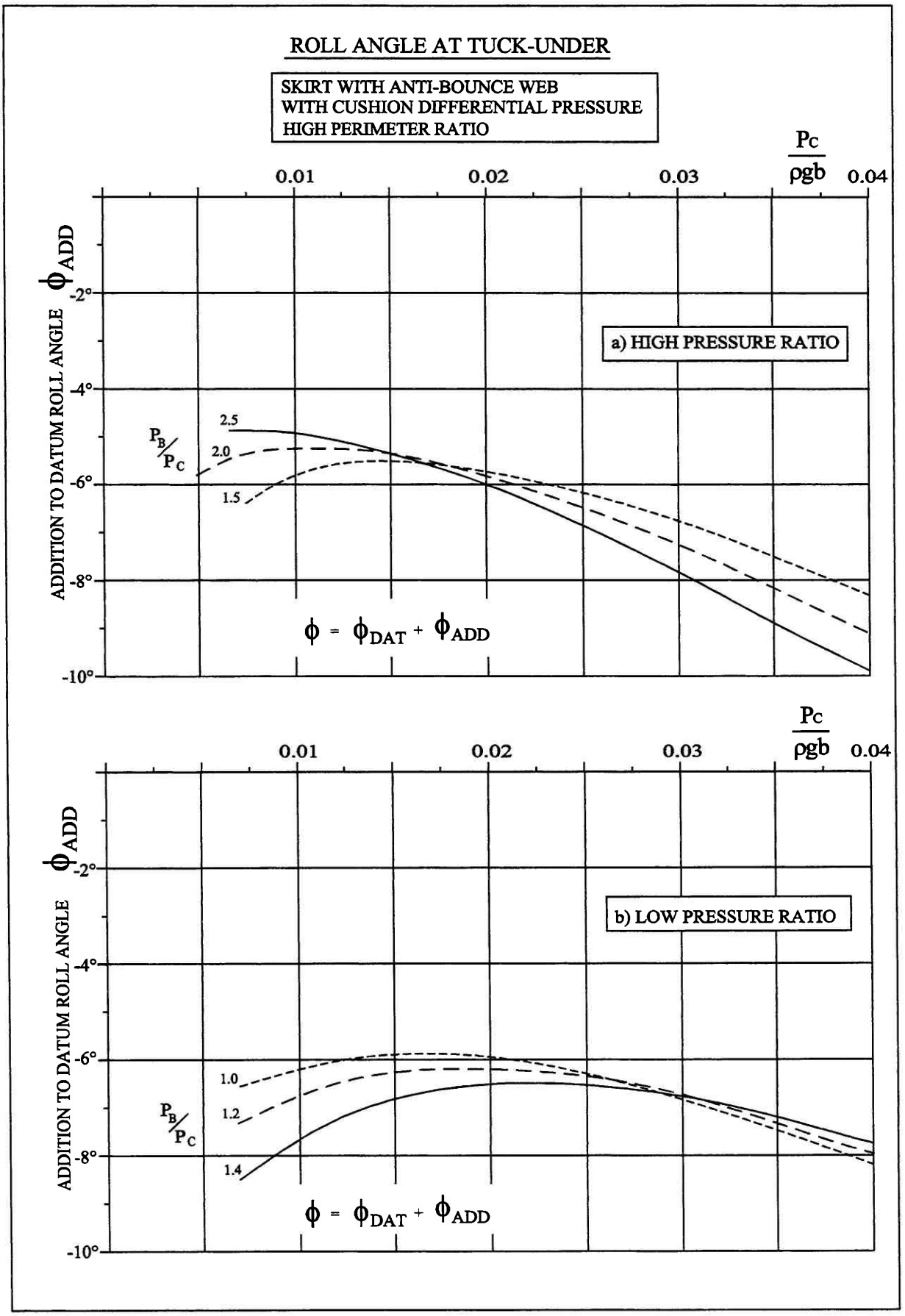
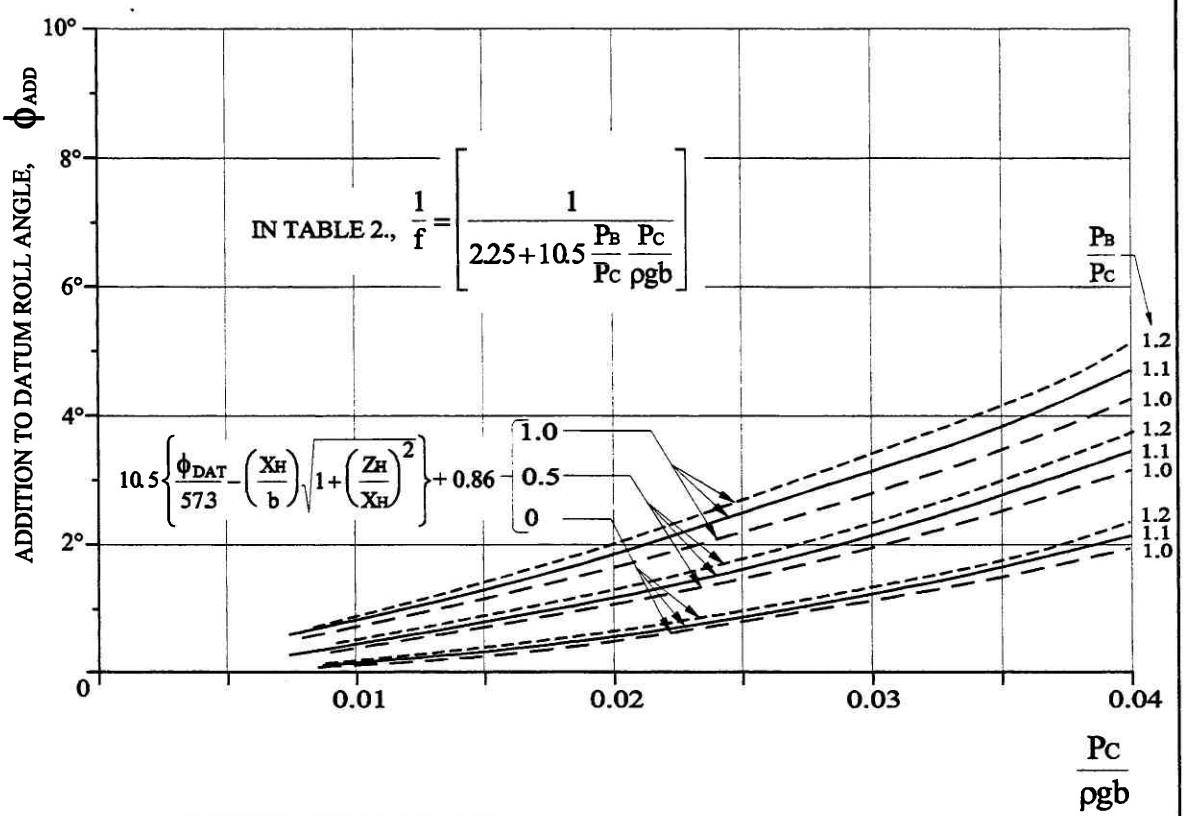

ROLL ANGLE AT TUCK-UNDER
SKIRT WITH ANTI-BOUNCE WEB
WITH CUSHION DIFFERENTIAL PRESSURE
HIGH PERIMETER RATIO
Pc / ρgb
0.01
0.02
0.03
0.04
ADDITION TO DATUM ROLL ANGLE ϕADD
-2°
-4°
-6°
-8°
-10°
a) HIGH PRESSURE RATIO
PB/PC
2.5
2.0
1.5
ϕ = ϕDAT + ϕADD
b) LOW PRESSURE RATIO
1.0
1.2
1.4

FIGURE 8.

ROLL UNDER AT TUCK-UNDER

$$\text{ROLL ANGLE AT TUCK-UNDER} = \frac{\phi_{DAT} + \text{ADDITIONAL ROLL}}{2.25 + 10.5 \frac{P_B}{P_C} \frac{P_C}{\rho g b}}$$



LOW PRESSURE RATIO

WITH ANTI-BOUNCE WEB
WITH CUSHION DIFFERENTIAL PRESSURE
LOW PERIMETER RATIO

FIGURE 9.

CLASSIFICATION AS 'HIGH' OR 'LOW' PERIMETER RATIO

FIG. 10a LOW PRESSURE RATIO

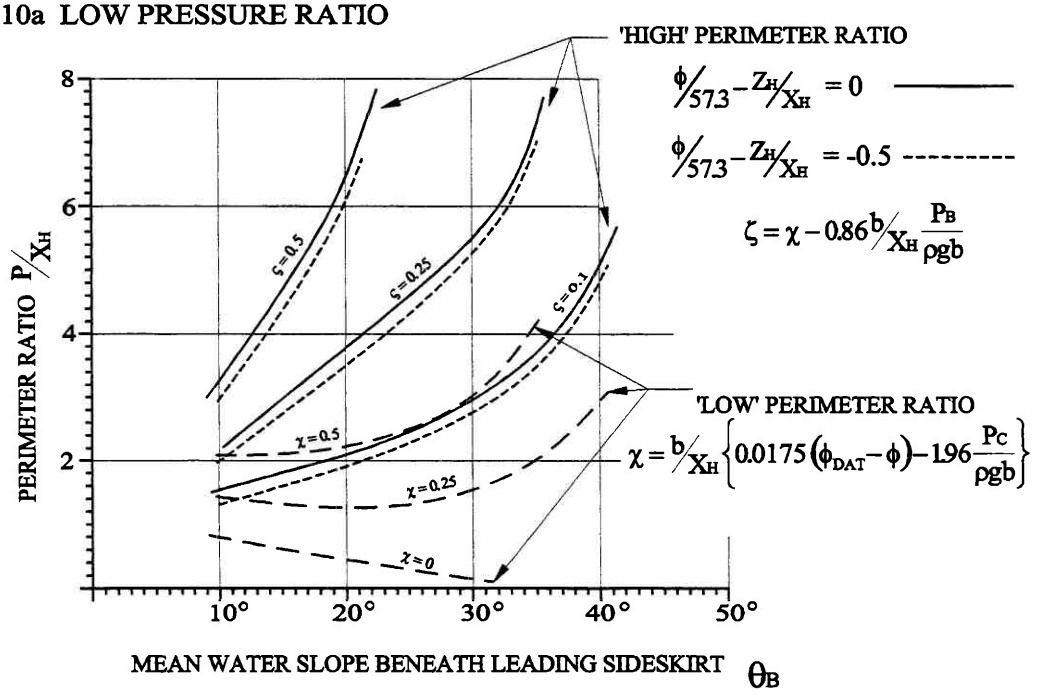


FIG. 10b HIGH PRESSURE RATIO

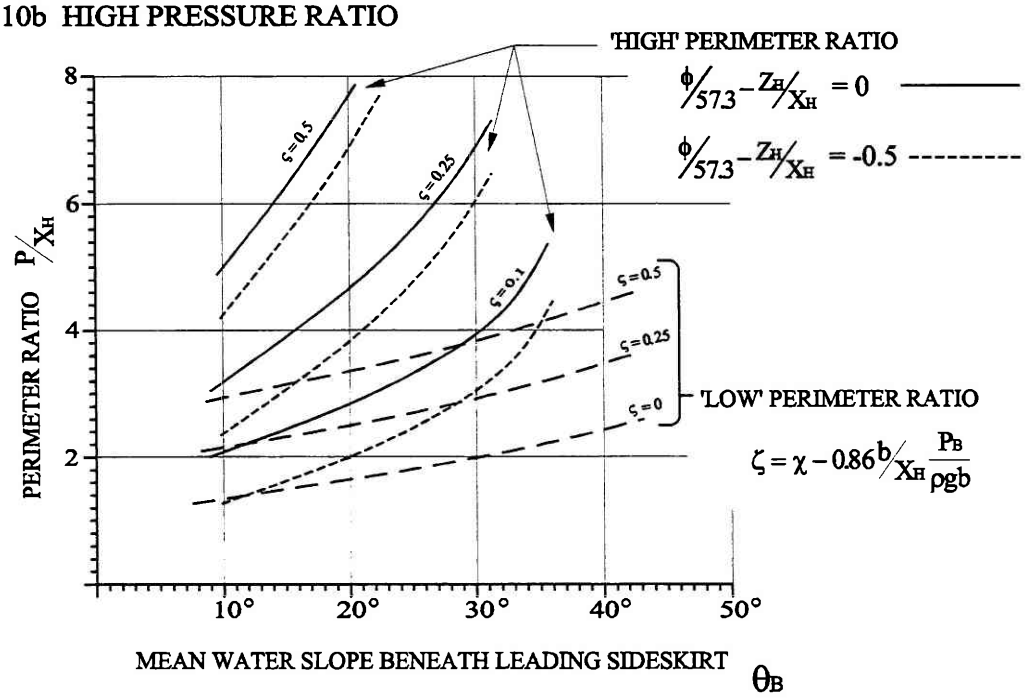


FIGURE 10.

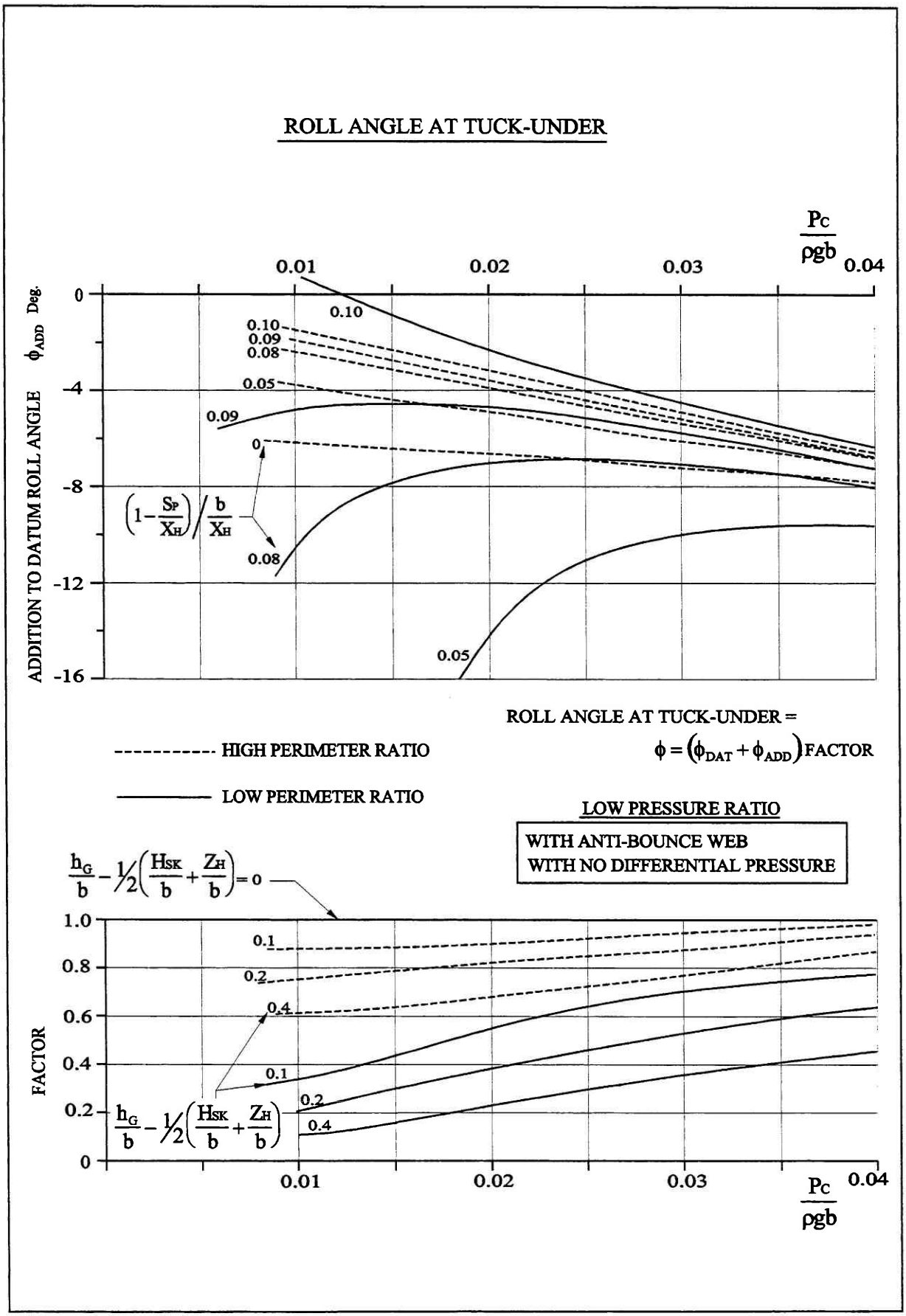

ROLL ANGLE AT TUCK-UNDER
Pc / ρgb
0.01
0.02
0.03
0.04
0
-4
-8
-12
-16
ADDITION TO DATUM ROLL ANGLE φADD Deg.
0.10
0.09
0.08
0.05
0
(1 − SP/XH) / b/XH
ROLL ANGLE AT TUCK-UNDER =
φ = (φDAT + φADD) FACTOR
---------- HIGH PERIMETER RATIO
———— LOW PERIMETER RATIO
LOW PRESSURE RATIO
WITH ANTI-BOUNCE WEB
WITH NO DIFFERENTIAL PRESSURE
hG/b − 1/2(HSK/b + ZH/b) = 0
1.0
0.8
0.6
0.4
0.2
0
FACTOR
0.1
0.2
0.4
hG/b − 1/2(HSK/b + ZH/b)

FIGURE 11.

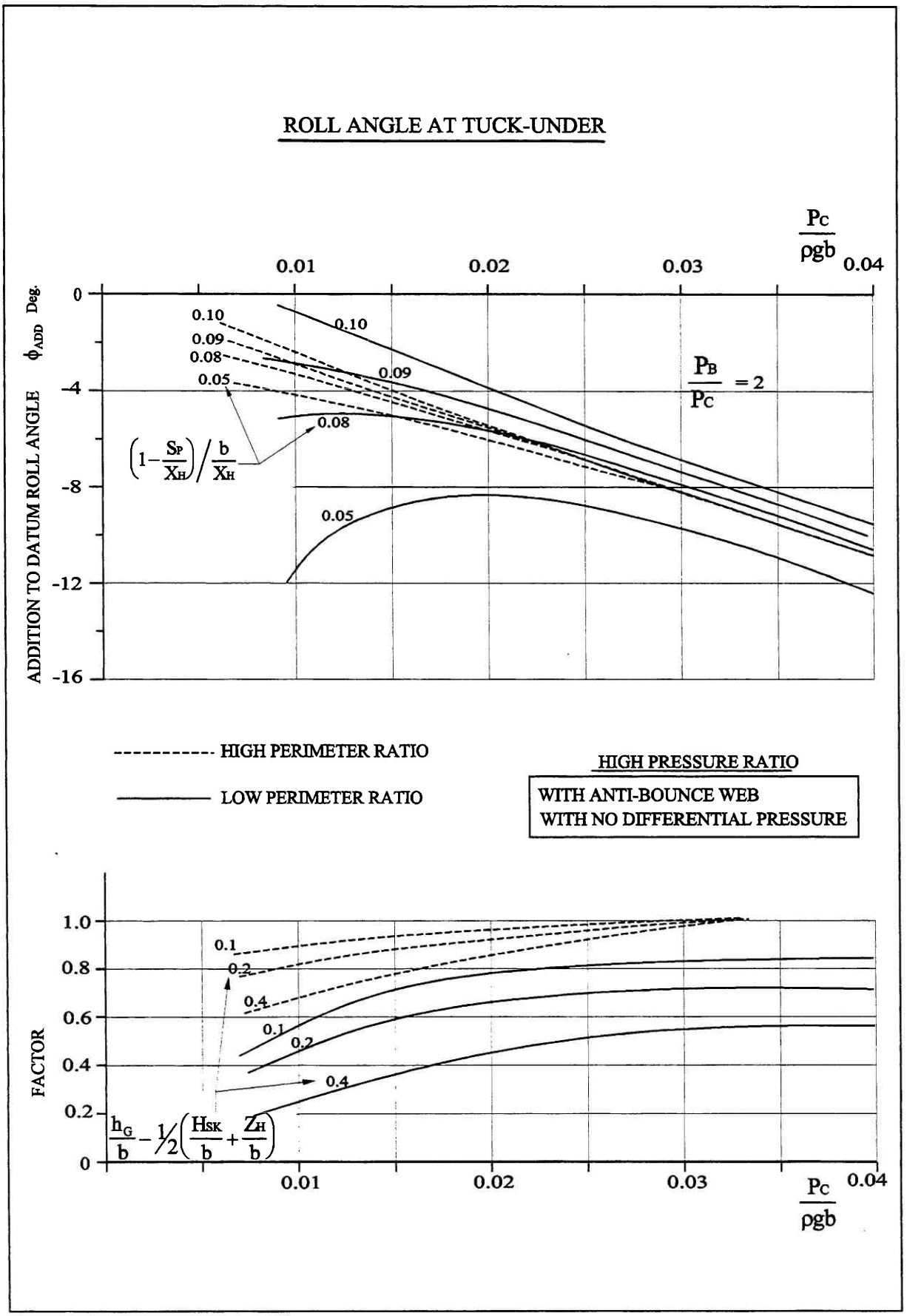
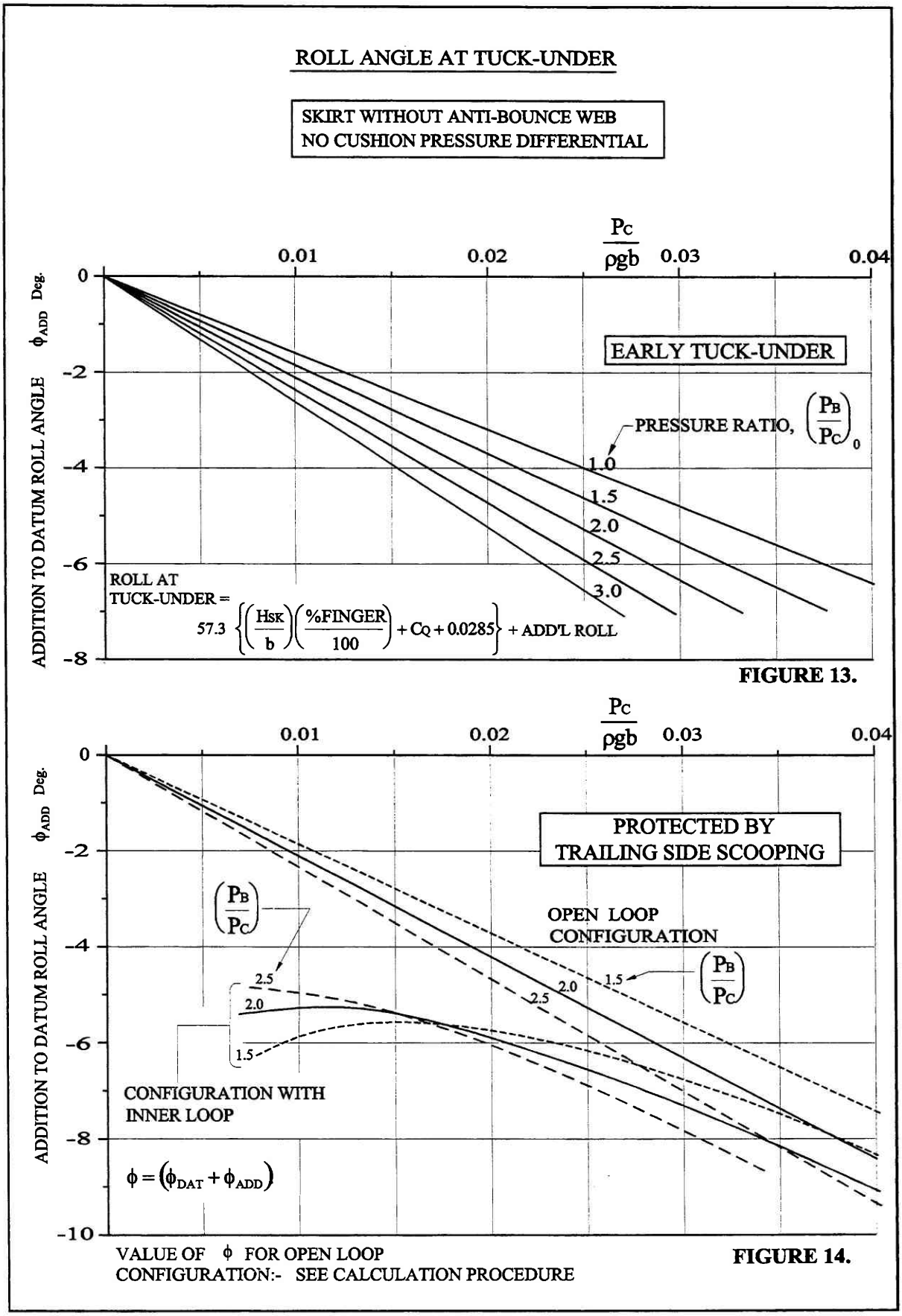

ROLL ANGLE AT TUCK-UNDER
ADDITION TO DATUM ROLL ANGLE ϕ_{ADD} Deg.
0
-4
-8
-12
-16
0.01
0.02
0.03
0.04
$\frac{P_C}{\rho g b}$
0.10
0.09
0.08
0.05
$\frac{P_B}{P_C} = 2$
$\left(1-\frac{S_P}{X_H}\right)\Big/\frac{b}{X_H}$
HIGH PERIMETER RATIO
LOW PERIMETER RATIO
HIGH PRESSURE RATIO
WITH ANTI-BOUNCE WEB
WITH NO DIFFERENTIAL PRESSURE
FACTOR
1.0
0.8
0.6
0.4
0.2
0
0.1
0.2
0.4
$\frac{h_G}{b} - \frac{1}{2}\left(\frac{H_{SK}}{b} + \frac{Z_H}{b}\right)$

FIGURE 12.



FIGURES 13 and 14.

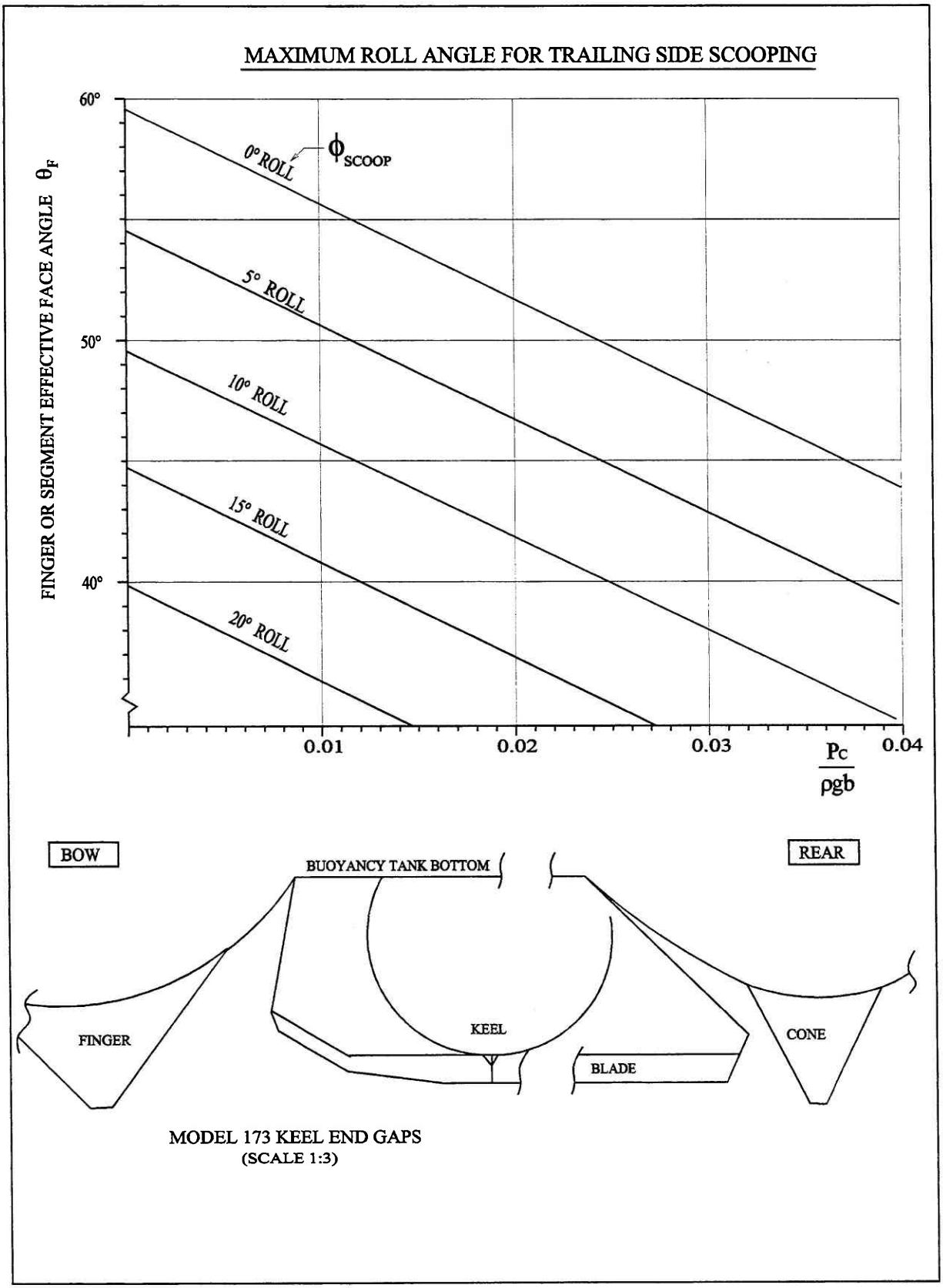

MAXIMUM ROLL ANGLE FOR TRAILING SIDE SCOOPING
FINGER OR SEGMENT EFFECTIVE FACE ANGLE θ_F
60°
50°
40°
0° ROLL
ϕ_{SCOOP}
5° ROLL
10° ROLL
15° ROLL
20° ROLL
0.01
0.02
0.03
0.04
$\frac{P_C}{\rho g b}$
BOW
REAR
BUOYANCY TANK BOTTOM
FINGER
KEEL
BLADE
CONE
MODEL 173 KEEL END GAPS
(SCALE 1:3)

FIGURE 15.

FIGURE (a) FACTORS f_1 AND f_2 USED TO EVALUATE 'IDEALISED' PERIMETER RATIO

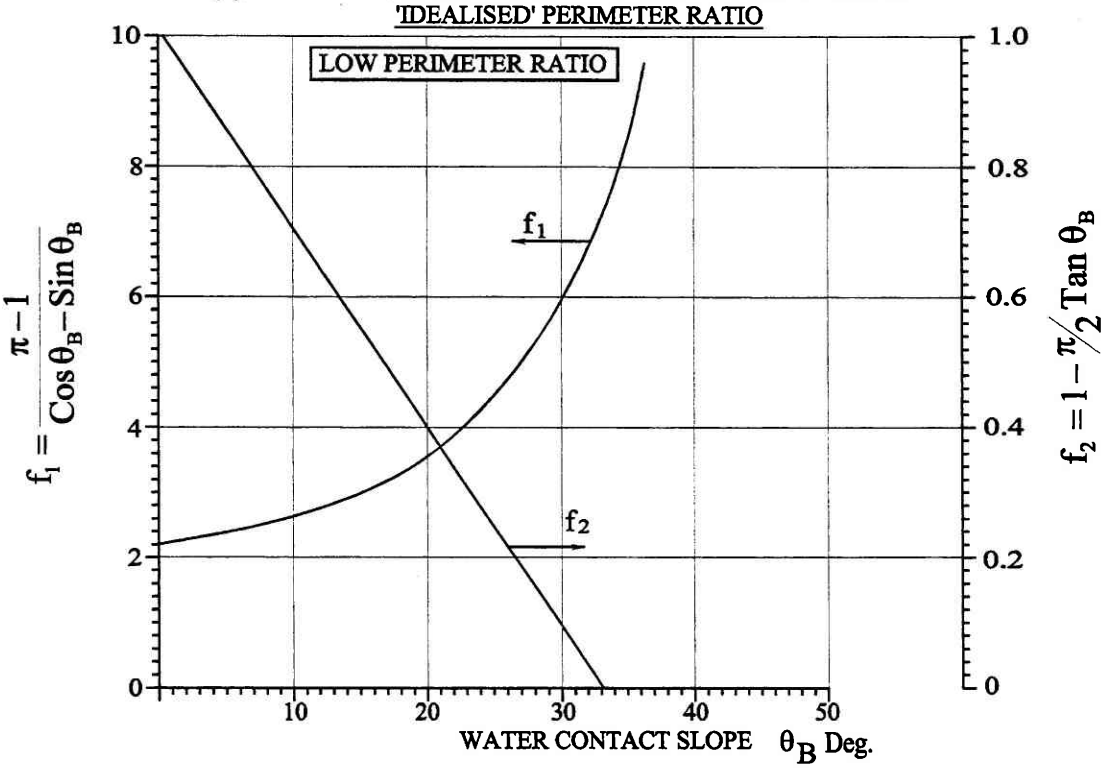


FIGURE (b)

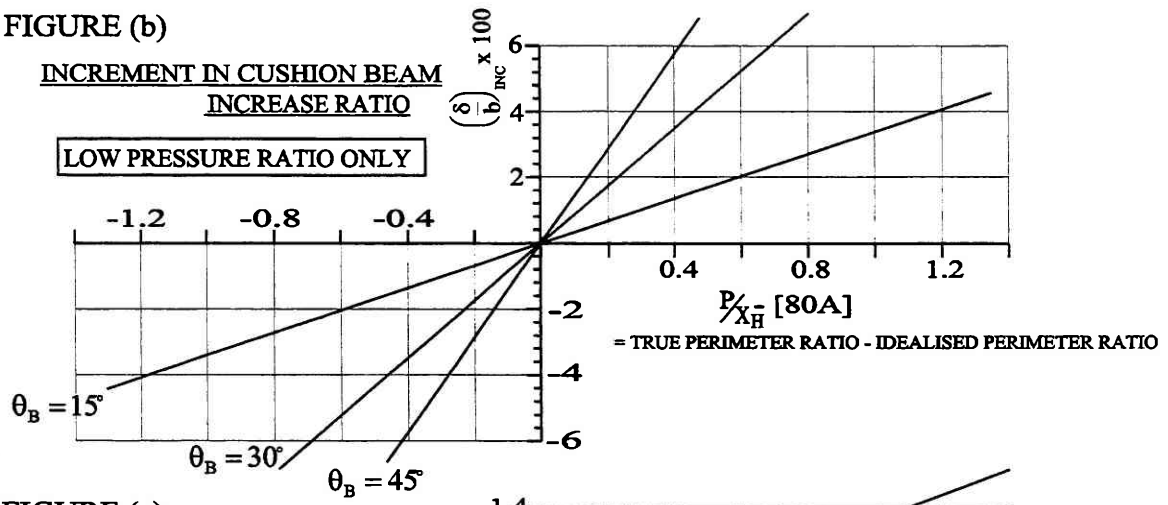


FIGURE (c)

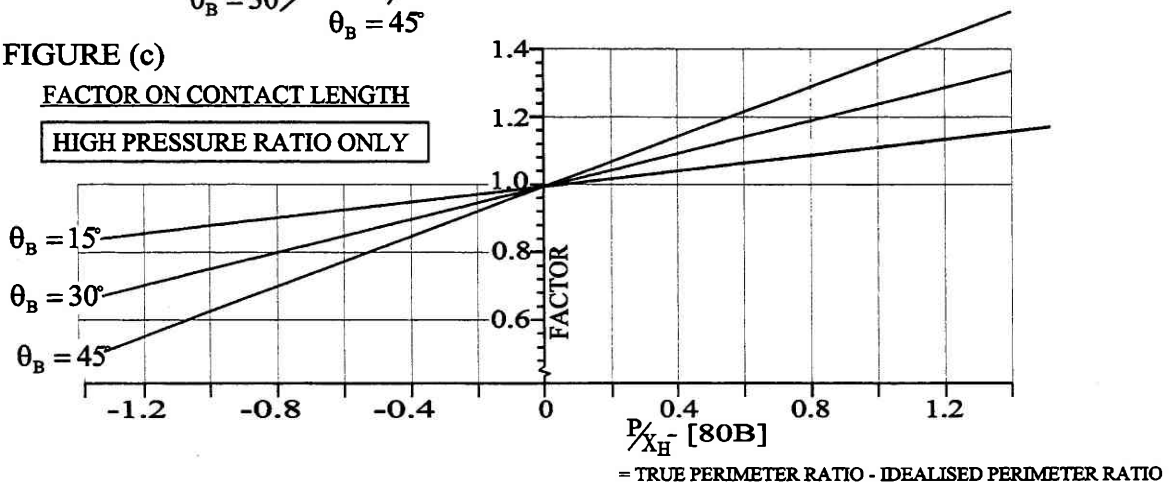


FIGURE 16.

FIGURE (a)

FACTORS f_6, f_7 AND f_8 USED IN EVALUATING 'IDEALISED' PERIMETER RATIO

HIGH PERIMETER RATIO, LOW PRESSURE RATIO

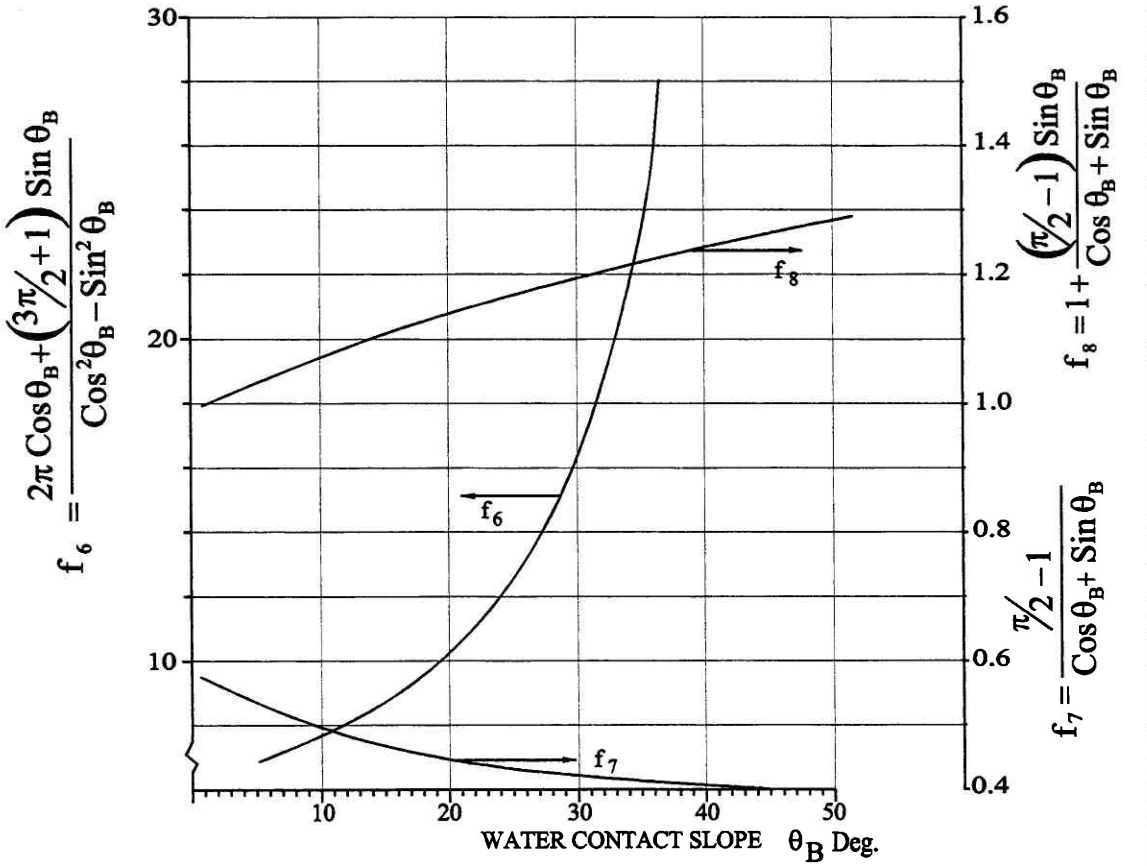


FIGURE (b)

INCREMENT IN CUSHION BEAM INCREASE RATIO

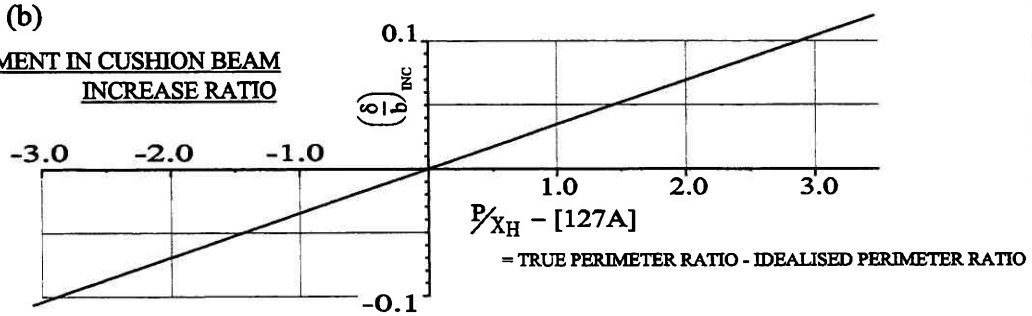


FIGURE (c)

INCREMENT IN CONTACT LENGTH TO BEAM RATIO

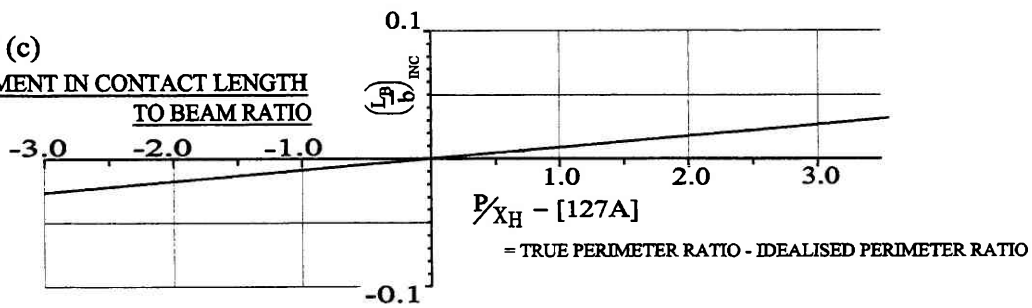


FIGURE 17.

FIGURE (a)

FACTORS f_3, f_4 AND f_5 USED IN EVALUATING 'IDEALISED' PERIMETER RATIO

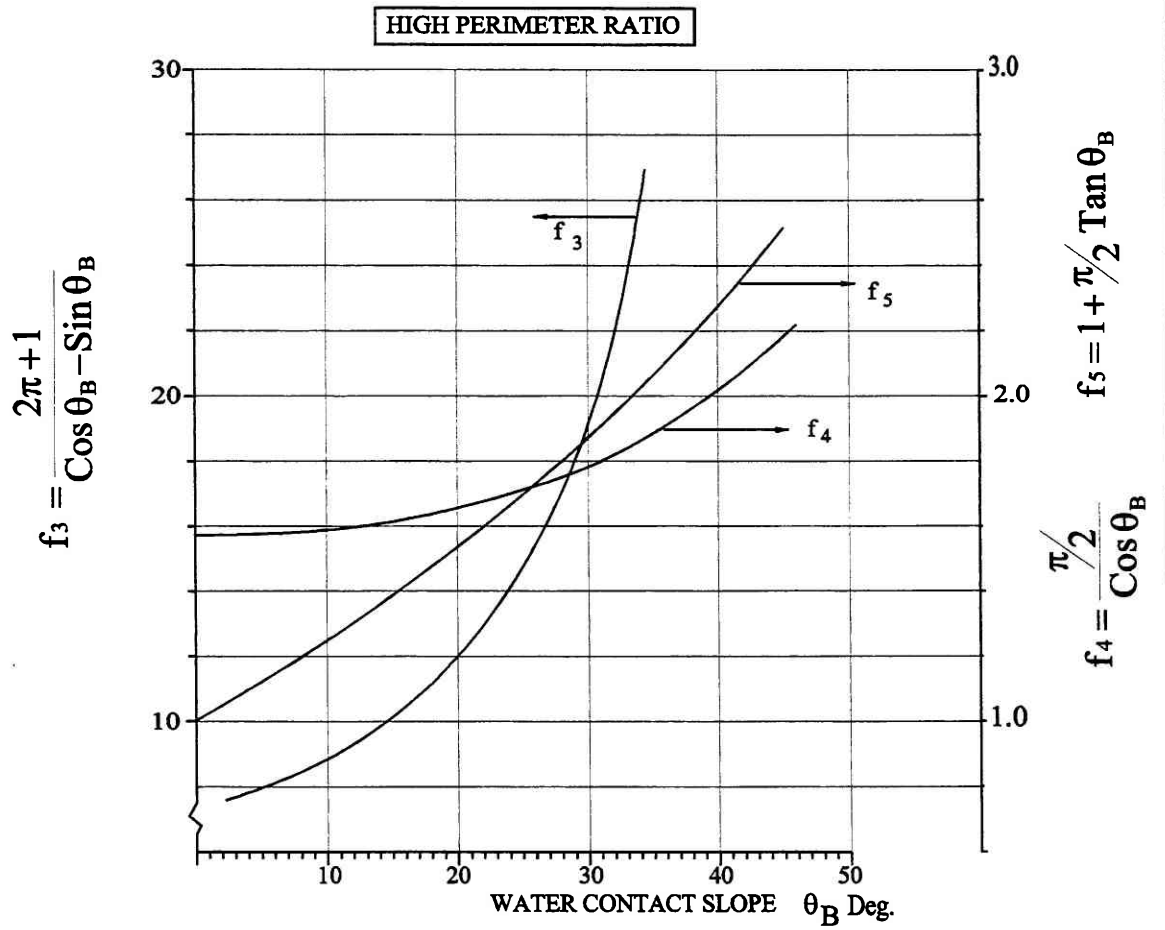


FIGURE (b)

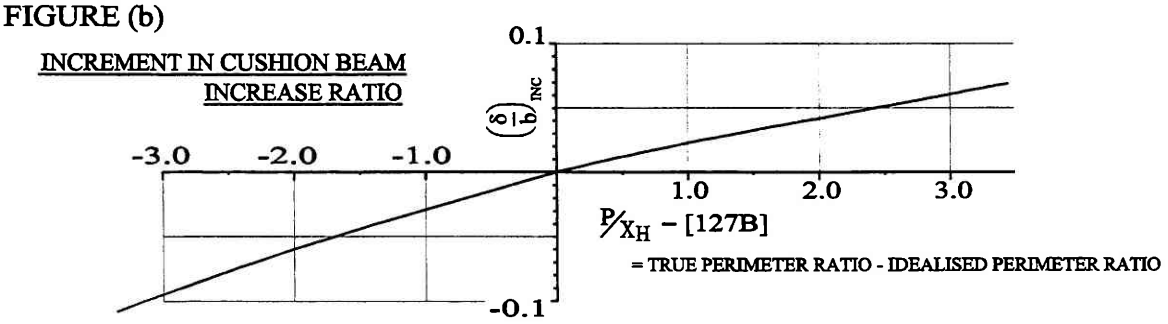


FIGURE (c)

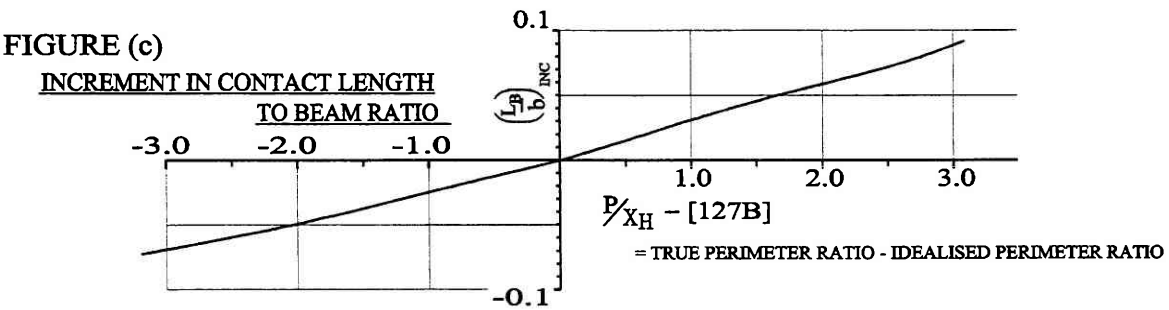


FIGURE 18.

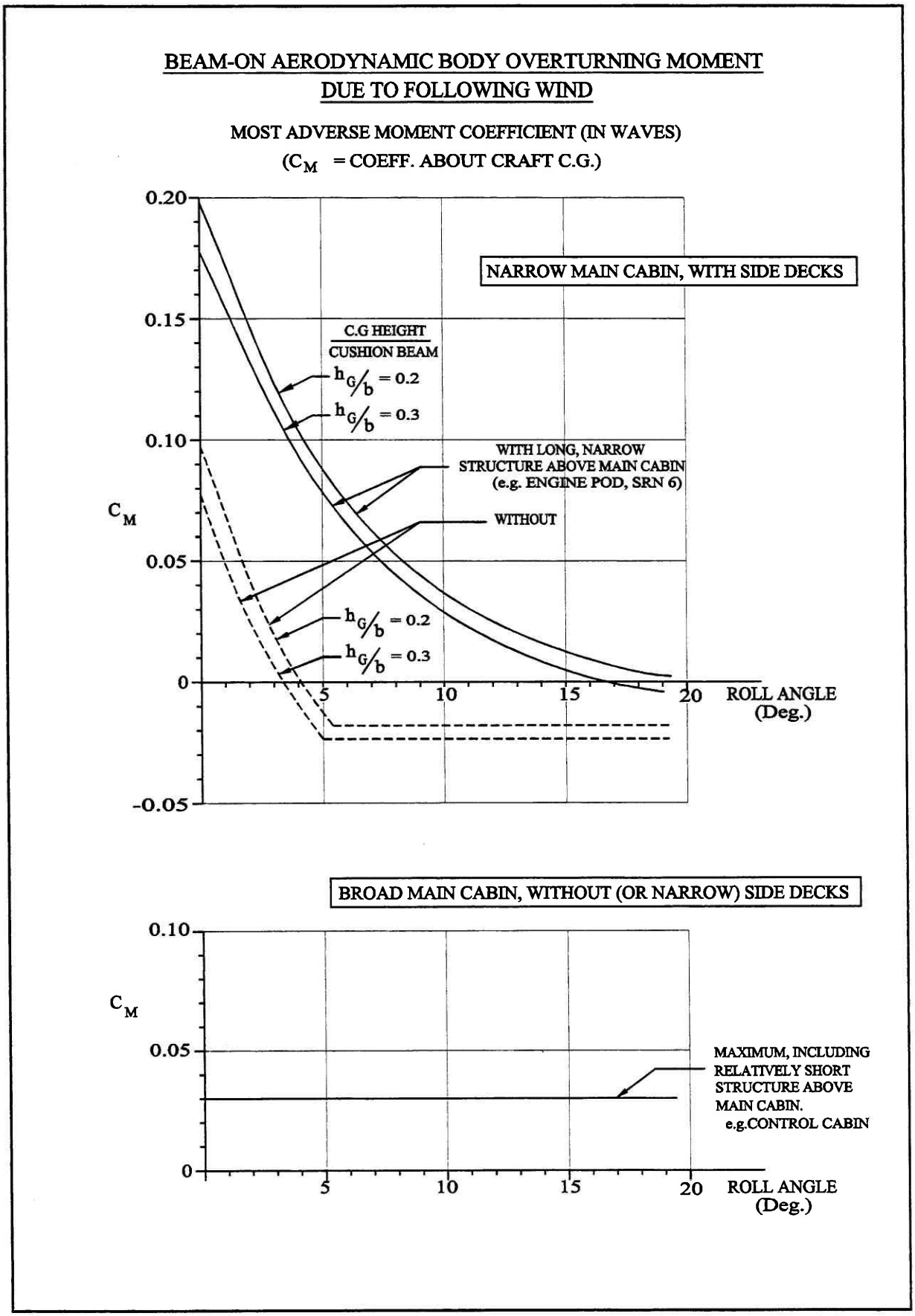

BEAM-ON AERODYNAMIC BODY OVERTURNING MOMENT
DUE TO FOLLOWING WIND
MOST ADVERSE MOMENT COEFFICIENT (IN WAVES)
(C_M = COEFF. ABOUT CRAFT C.G.)
NARROW MAIN CABIN, WITH SIDE DECKS
C.G HEIGHT / CUSHION BEAM
h_G/b = 0.2
h_G/b = 0.3
WITH LONG, NARROW STRUCTURE ABOVE MAIN CABIN (e.g. ENGINE POD, SRN 6)
WITHOUT
h_G/b = 0.2
h_G/b = 0.3
C_M
0.20
0.15
0.10
0.05
0
-0.05
5
10
15
20
ROLL ANGLE (Deg.)
BROAD MAIN CABIN, WITHOUT (OR NARROW) SIDE DECKS
C_M
0.10
0.05
0
MAXIMUM, INCLUDING RELATIVELY SHORT STRUCTURE ABOVE MAIN CABIN.
e.g.CONTROL CABIN
5
10
15
20
ROLL ANGLE (Deg.)

FIGURE 19.