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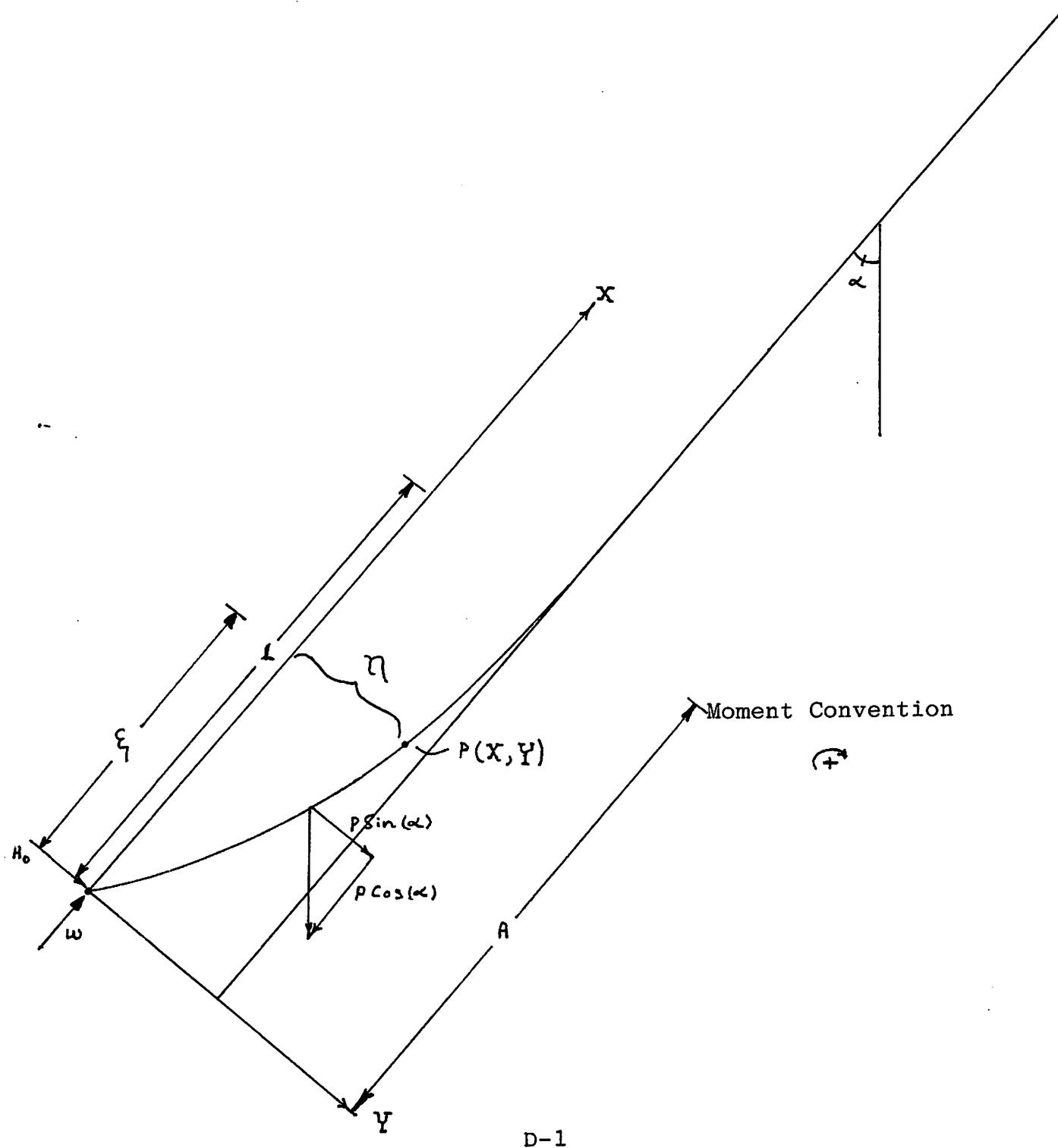
## Appendix D

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APPENDIX D  
DRILL COLLARS WITH NO STABILIZER PRESENT



SIGN CONVENTION FOR  
FORCES APPLIED TO THE DRILL STRING

$H_O$  - The side force at the bit. This vector will be considered to be the reaction force of the formation against the bit. It will be positive when pointed in the positive Y direction. For example, if  $H_O > 0$ , as computed by the model, the bit will be exerting an upward force against the formation at  $X = 0, Y = 0$ , which results in an increase in hole inclination as drilling proceeds.

$W$  - The weight on bit. This force vector will be considered to be the reaction force of the formation on the bit. It will always be positive and pointing in the +X direction.

$H_1$  - The side force at the stabilizer. This force will be considered the reaction force of the formation on the stabilizer. It will have a positive sign when pointing in a negative Y direction. This means the computed value for  $H_1$  is positive when the stabilizer exerts a force on the low side of the hole.

$+ \curvearrowright$  The moment applied in the clock-wise manner will be considered positive.

$$\sum M_i = EI \frac{d^2Y}{dX^2}$$

### Moments

$$+ WY$$

$$- H_O X$$

$$+ \int_0^X (\xi - X) p \sin(\alpha) d\xi$$

$$+ \int_0^X (\eta - Y) p \cos(\alpha) d\xi$$

Summing Moments:

$$- EI \frac{d^2Y}{dX^2} = WY + H_O X + \int_0^X (\xi - X)p \sin(\alpha) + (\eta - Y)p \cos(\alpha) d\xi \quad (D-1)$$

Taking the derivative of (1) w/r to X

$$- EI \frac{d^3Y}{dX^3} = W \frac{dY}{dX} + H_O + \frac{\partial \left[ \int_0^X (\xi - X)p \sin(\alpha) + (\eta - Y)p \cos(\alpha) d\xi \right]}{\partial X} \quad (D-2)$$

Using Leibniz's Rule to take the derivative of the integral

$$\text{Let part i} = \int_0^X (\xi - X)p \sin(\alpha) d\xi$$

$$\text{Let part ii} = \int_0^X (\eta - Y)p \cos(\alpha) d\xi$$

For part i

$$\frac{\partial \left[ \int_0^X (\xi - X)p \sin(\alpha) d\xi \right]}{\partial X} = \int_0^X -pX \sin(\alpha) \quad (D-3)$$

For part ii

$$\frac{\partial \left[ \int_0^X (\eta - Y) P \cos(\alpha) d\xi \right]}{\partial X} = \int_0^X Y' P \cos(\alpha) d\xi = -Y' P X \cos(\alpha) \quad (D-4)$$

Substituting (D-3) and (D-4) into (D-2)

$$\begin{aligned} -EI \frac{d^3Y}{dX^3} &= WY' - H_O - PX \sin(\alpha) - Y' P X \cos(\alpha) \\ -EI Y''' + Y' \left[ -W + PX \cos(\alpha) \right] &= -H_O - PX \sin(\alpha) \\ EI Y''' + Y' \left[ W - PX \cos(\alpha) \right] &= H_O + PX \sin(\alpha) \end{aligned} \quad (D-5)$$

Dropping  $PX \cos(\alpha)$ , (assume negligible effect)

$$-EI Y''' + Y' W = H_O + PX \sin(\alpha) \quad (D-6)$$

#### Dimensionless Conversions

Three quantities must be converted into dimensionless form,  
they are  $X$ ,  $Y$ ,  $h$ .

$$\frac{Y}{M_1} = y ; \frac{X}{M_2} = x ; \frac{H}{M_3} = h \quad (D-6a)$$

$$\frac{L}{M_2} = \ell ; \frac{C_{dc}}{M_1} = C_{dc}$$

$$y' = \frac{dy}{dX} \cdot \frac{dx}{dx} ; \frac{dx}{dX} = M_2 ; \frac{dy}{dX} = \frac{dY}{dX} \frac{1}{M_1}$$

$$y' = \frac{dY}{dX} \frac{1}{M_1} \cdot M_2$$

$$y'' = \frac{d(dy/dx)}{dx} = \frac{d(dy/dx)}{dX} \frac{dX}{dx}$$

$$\frac{d(dy/dx)}{dX} = \frac{d\left(\frac{dY}{dX} \frac{M_2}{M_1}\right)}{dX} = \frac{d^2Y}{dX^2} \frac{M_2}{M_1}$$

$$y'' = \frac{d^2Y}{dX^2} \frac{M_2^2}{M_1}$$

$$y''' = \frac{d(d^2y/dX^2)}{dx} = \frac{d\left(\frac{d^2Y}{dX^2} \frac{M_2^2}{M_1}\right)}{dX} \cdot \frac{dX}{dx}$$

$$y''' = \frac{d^3Y}{dX^3} \frac{M_2^2}{M_1} \cdot M_2 = \frac{d^3Y}{dX^3} \frac{M_2^3}{M_1}$$

Dividing (D-6) by  $EI P \sin(\alpha)$

$$\frac{Y'''}{P \sin(\alpha)} + \frac{Y'W}{EI P \sin(\alpha)} = \frac{H_O}{EI P \sin(\alpha)} + \frac{X}{EI} \quad (D-7)$$

$$Y''' = \frac{M_1}{M_2^3} y''' \quad H_O = M_3 h$$

$$Y'' = \frac{M_1}{M_2} y'$$

$$X = M_2 x$$

$$\frac{M_1}{M_2^3} y''' \frac{1}{P \sin(\alpha)} + \frac{M_1}{M_2} y' \frac{W}{EI P \sin(\alpha)} = \frac{M_3 h}{EI P \sin(\alpha)} + \frac{X}{EI} M_2$$

$$\frac{M_1}{M_2^2} y''' \frac{W}{P \sin(\alpha)} + M_1 y' \frac{W^2}{EI P \sin(\alpha)} = \frac{M_3 M_2 h W}{EI P \sin(\alpha)} + \frac{X W M_2^2}{EI} \quad (D-8)$$

From (D-8)

$$M_1 = \frac{EI P \sin(\alpha)}{W^2} ; M_2 = \sqrt{\frac{EI}{W}}$$

$$M_2 M_3 = \frac{EI P \sin(\alpha)}{W}$$

$$M_3 = \frac{EI P \sin(\alpha)}{W} \sqrt{\frac{W}{EI}} = \sqrt{\frac{EI}{W}} P \sin(\alpha)$$

Substituting into  $M_1$ ,  $M_2$ ,  $M_3$  into (D-8)

$$y'''' + y' = h + x \quad (D-9)$$

#### Solution to the Differential Equation

Equation (D-9) may be broken down such that there is an homogenous, linear constant coefficient portion as follows:

$$\text{let } h + x = F(x)$$

$$y'''' + y' = 0$$

and the non-homogenous term is

$$h + x$$

The solution to the homogenous:

$$\text{let } y'''' = M^3 ; y' = M$$

$$M(M^2 + 1) = 0$$

$$M_1 = 0 \quad \text{root (1)}$$

$$M_2 = +j \quad \text{root (2)}$$

$$M_3 = -j \quad \text{root (3)}$$

$$y_C = c_1 e^{mx} + e^{ax} [C_2 \cos(bx) + C_3 \sin(bx)]$$

where  $a = 0$ ;  $b = 1$

$$y_C = C_1 + [C_2 \cos(x) + C_3 \sin(x)]$$

The particular solution

From (D-9)  $F(x) = h + x$

The uc =  $x$ ; the uc set is  $\{x, 1\}$

Since the complimentary solution already has 1 as a term ( $c_1 e^{0x}$ ),  
the uc set is multiplied by  $x$  which yields  $\{x^2, x\}$

The particular function is:

$$y_p = C'_1 x^2 + C_2 x = h + x$$

$$y'_p = 2C'_1 x + C_2$$

$$y''_p = 2C'_1$$

$$y'''_p = 0$$

$$2C'_1 x + C_2 = h + x$$

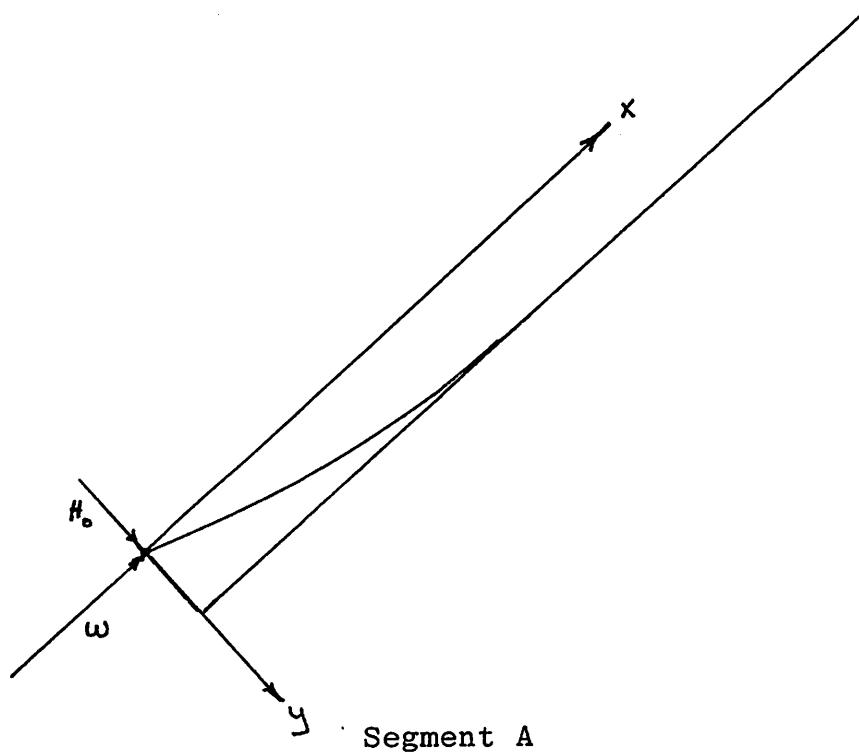
$$C'_1 = 1/2; C_2 = h$$

$$y_p = 1/2x^2 + hx$$

The solution to (D-9)

$$y = y_p + y_C = C_1 + C_2 \cos(x) + C_3 \sin(x) + 1/2x^2 + hx \quad (D-10)$$

NO STABILIZER PRESENT  
 (Slick String)



B. C.

$$x = 0 \quad y_A = 0 \quad (D-11)$$

$$x = 0 \quad y''_A = 0 \quad (D-12)$$

$$x = \ell \quad y_A = C_{dc} \quad (D-13)$$

$$x = \ell \quad y'_A = 0 \quad (D-14)$$

$$x = \ell \quad y''_A = 0 \quad (D-15)$$

Rewriting (D-10)

$$y = C_1 + C_2 \cos(x) + C_3 \sin(x) + 1/2 x^2 + hx \quad (D-10)$$

Using (D-11)  $x = 0$   $y_A = 0$

$$0 = C_1 + C_2 \quad C_1 = -C$$

Using (D-12)  $x = 0$   $y''_A = 0$

$$0 = C_2 + 1 \quad C_2 = 1 \quad C_1 = -1$$

Now

$$y_A = -1 \cos(x) + C_3 A \sin(x) + h_O x + x \quad (D-16)$$

Using (D-15)  $x = \ell$   $y''_A = 0$

$$0 = -\cos(\ell) - C_3 A \sin(\ell) + 1$$

$$C_3 A \sin(\ell) = [-\cos(\ell) + 1]$$

$$C_3 A = \frac{[1-\cos(\ell)]}{\sin(\ell)} \quad (D-17)$$

Using (D-14)  $x = \ell$   $y'_A = 0$

$$0 = -\sin(\ell) + C_3 A \cos(\ell) + h_O + \ell \quad (D-18)$$

Solving for  $h_O$

$$h_O = \sin(\ell) - C_3 A \cos(\ell) - \ell$$

$$h_O = \sin(\ell) - [1 - \cos(\ell)] \cot(\ell) - \ell \quad (D-19)$$

Using (D-13)  $x = \ell$   $y_A = C_{dc}$

$$C_{dc} = -1 + \cos(\ell_1) + C_3 A \sin(\ell_1) + 1/2\ell_1^2 + h_O \ell_1 \quad (D-20)$$

Putting (D-17) into (D-20)

$$C_{dc} = -1 + \cos(\ell) + [1 - \cos(\ell)] + 1/2\ell^2 + h_O \ell_1$$

$$C_{dc} = 1/2\ell^2 + h_O \ell \quad (D-21)$$

Rearranging (D-19)

$$h_O = \sin(\ell) - \frac{\cos(\ell) + \cos^2(\ell)}{\sin(\ell)} - \ell$$

$$[h_O + (\ell)] = \frac{1}{\sin(\ell)} [\sin^2(\ell) - \cos(\ell) + \cos^2(\ell)]$$

$$[h_O + (\ell)] = \frac{1}{\sin(\ell)} [1 - \cos(\ell)]$$

After rearrangements

$$h_O = \tan \ell/2 - \ell \quad (D-22)$$

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10 CLS
20 INPUT "Dh(in) = "; DH; DH=DH/12
30 INPUT "ODdc(in) = "; OD; OD=OD/12
40 INPUT "IDdc(in) = "; ID; ID=ID/12
50 INPUT "MW (PPg) = "; MW
60 INPUT "alfa(deg) = "; AA; AO=AA
70 INPUT "FORMATION DIP gamma(deg) = "; GA
80 INPUT "WOB(1000's lb) = "; W; W=W*1000
90 INPUT "DRILL ANISOTROPY INDEX a = "; DAI
100 WU = 3.14159*((OD/2)^2-(ID/2)^2)*489
110 C=(DH-OD)/2
120 SUML=0
130 AA=AO
140 P=WU*(1-MW/65.4)
150 I=3.14*(OD^4-ID^4)/64
160 PRINT "Dh (in) = "; DH*12
170 PRINT "ODdc (in) = "; OD*12
180 PRINT "IDdc (in) = "; ID*12
190 PRINT "MW (PPg) = "; MW
200 PRINT "ALPHA (deg) = "; AA
210 PRINT "GAMA (deg) = "; GAMA
220 PRINT "FAI = "; FAI
230 PRINT "WOB (lb's) = "; W
240 PRINT "I (ft^4) = "; I
250 PRINT "P (lb's/ft) = "; P
260 INPUT "DO YOU WANT A HARD COPY 1-YES, 2-NO "; HARD
270 IF (HARD=1) THEN GOSUB 1170
280 EI=4176*10^6*I
290 XX=0
300 XX=XX+1
310 CD=W^2*C/(EI*P*SIN(AA/57.29))
320 GOSUB 330
330 LL=.1; LH=2.5; L=(LL+LH)/2
340 LV=L*TAN(L/2)-L^2/2
350 T=ABS((CD-LV)/2)
360 IF T<.00001 THEN GOTO 400
370 IF LV>CD GOTO 390
380 LL=L; L=(LL+LH)/2; GOTO 340
390 LH=L; L=(LL+LH)/2; GOTO 340
400 FDD=2*TAN(L/2)-L
410 FD=(SQR(EI)*P*SIN(AA/57.29)*FDD)/(W^1.5)
420 BA=57.29*ATN(FD)
430 H=TAN(L/2)-L
440 HH=H*SQR(EI/W)*P*SIN(AA/57.29)
450 LLL=L*SQR(EI/W)
460 SUML=SUML+LLL
470 PF=LLL*P*SIN(AA/57.29)/2
480 FI=57.29*ATN(HH/W)+AA
490 AAN2=GA+57.29*ATN((1-DAI)*TAN((FI-GA)/57.29))
500 PRINT
510 CLS
520 PRINT "-----"
530 PRINT "CLEARANCE (ft) = "; C
540 PRINT "UNIT WEIGHT (lb/ft) = "; P

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550 PRINT "MOMENT OF INERTIA = ";I
560 PRINT "STIFFNESS = ";EI
570 PRINT "-----"
580 PRINT
590 PRINT "DIMENSIONLESS CLEARANCE = ";CD
600 PRINT
610 PRINT "TILT ANGLE, BETA = ";BA
620 PRINT
630 PRINT "SIDE FORCE AT THE BIT = ";HH
640 PRINT
650 PRINT "DISTANCE TO THE TANGENCY POINT = ";LLL
660 PRINT
670 PRINT "PENDULUM FORCE = ";PF
680 PRINT
690 PRINT "RESULTANT FORCE ANGLE = ";FI
700 PRINT
710 PRINT "NEW HOLE INCLINATION ANGLE, ITERATION # ";XX; " ALPHA = ";AAN2
720 PRINT
730 PRINT "TOTAL FOOTAGE DRILLED = ";SUML
740 DA=ABS(AA-AAN2)
750 AA=AAN2
760 IF (DA>.1) THEN GOTO 300
770 LPRINT"EQUILIBRIUM ANGLE ALPHA = ";AA
780 LPRINT"FOOTAGE DRILLED = ";SUML
790 LPRINT"HO = ";HH
800 LPRINT"# OF ITERATIONS = ";XX
810 INPUT "DO YOU WISH TO CONTINUE WITH ANOTER RUN ? 1-YES, 0-NO";DEC1
820 IF (DEC1=0) THEN GOTO 1160
830 PRINT
840 INPUT "WOULD YOU LIKE TO CHANGE ANY VARIABLES ? 1-YES, 0-NO";DEC2
850 IF (DEC2=0) GOTO 110
860 CLS
870 PRINT "CODE #      VARIABLE"
880 PRINT "-----"
890 PRINT " 1      ----- Dh"
900 PRINT " 2      ----- ODdc"
910 PRINT " 3      ----- IDdc"
920 PRINT " 4      ----- Wdc"
930 PRINT " 5      ----- MW"
940 PRINT " 6      ----- ALPHA"
950 PRINT " 7      ----- GAMA"
960 PRINT " 8      ----- WOB"
970 PRINT " 9      ----- h"
980 PRINT
990 PRINT "INPUT THE CORRESPONDING CODE FOR THE VARIABLES YOU WISH TO CHANGE,"
1000 PRINT "ENTER THEM ONE PER LINE ----ENTER 0 WHEN FINISHED"
1010 INPUT "CODE # = ";CN
1020 IF (CN=0) THEN GOTO 110
1030 IF (CN=1) THEN INPUT "Dh (in) = ";DH:DH=DH/12
1040 IF (CN=2) THEN INPUT "ODdc (in) = ";OD:OD=OD/12
1050 IF (CN=3) THEN INPUT "IDdc (in) = ";ID:ID=ID/12
1060 IF (CN=4) THEN INPUT "Wdc (in) = ";WU
1070 IF (CN=5) THEN INPUT "MW (PPg) = ";MW

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1080 IF (CN=6) THEN INPUT "ALPHA (deg) = ";AA:AO=AA
1090 IF (CN=7) THEN INPUT "GAMA (deg) = ";GA
1100 IF (CN=8) THEN INPUT "WOB (1000'S lbs) = ";W:W=1000*W
1110 IF (CN=9) THEN INPUT " h = ";DAI
1120 IF (CN<0)OR(CN>9) THEN GOTO 1140
1130 GOTO 1010
1140 PRINT "INPUT VALUE MUST BE BETWEEN 0 AND 8 INCLUSIVE"
1150 GOTO 1010
1160 END
1170 REM ***** HARD COPY OF INPUT DATA *****
1180 LPRINT "Dh (in)           = ";DH*12
1190 LPRINT "ODdc (in)         = ";OD*12
1200 LPRINT "IDdc (in)         = ";ID*12
1210 LPRINT "MW (Ppg)          = ";MW
1220 LPRINT "GAMA (deg)        = ";GAMA
1230 LPRINT "ALPHA (deg)       = ";ALPHA
1240 LPRINT "FAI                = ";FAI
1250 LPRINT "WOB (lb's)         = ";W
1260 LPRINT "I (ft^4)          = ";I
1270 LPRINT "P (lb's)           = ";P
1280 RETURN
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## **APPENDIX E**

APPENDIX E  
ONE STABILIZER REAMER, CONTACT  
POINT AND NO CONTACT POINT  
CONSIDERED.

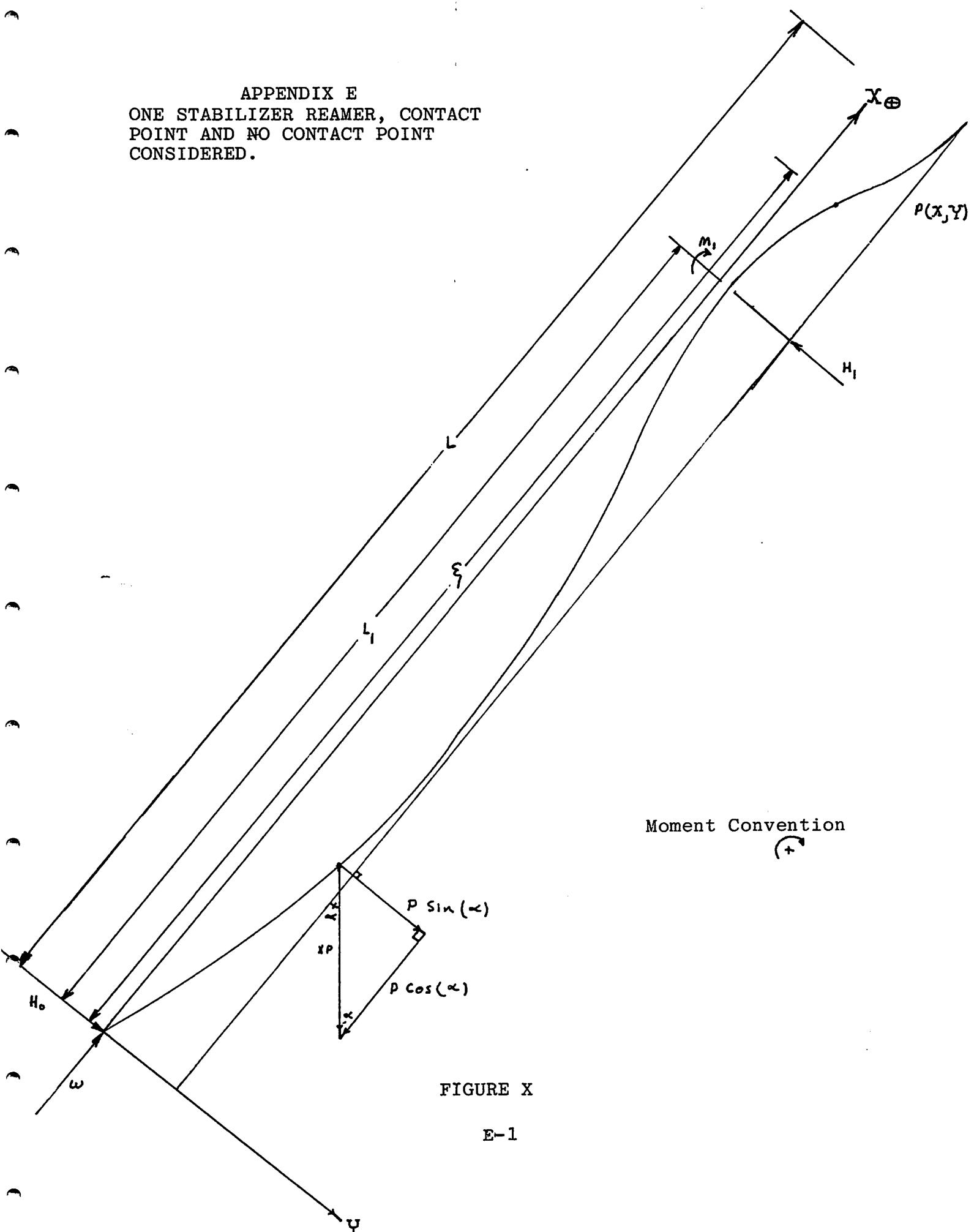


FIGURE X

E-1

### Moments

$$\sum M_i = -EIY'' = [WY - H_0X + H_1(X-\ell_1) + M] \\ + \int_0^X [(\xi - X)p \sin(\alpha) + (\eta - Y)p \cos(\alpha)] d\xi \quad (E-1)$$

$$+ WY \\ - H_0X \\ + H_1(X - \ell_1) \\ + M_1 \\ + (\xi - X) p \sin(\alpha) d\xi \\ + (\eta - Y) p \cos(\alpha) d\xi$$

Taking the derivative of the summation of moments to w/r x yields:

$$EI Y''' = W Y' - H_0 + H_1 + \frac{\partial \left\{ \int_0^X [(\xi - X)p \sin(\alpha) + (\eta - Y)p \cos(\alpha)] d\xi \right\}}{\partial X} \quad (E-2)$$

$$\text{part i} = (\xi - X)p \sin(\alpha)$$

$$\text{part ii} = (\eta - Y)p \cos(\alpha)$$

Liebnitz Rule for differentiation of integrals is:

$$\frac{\partial}{\partial \alpha} \left\{ \int_{u_O(\alpha)}^{u_1(\alpha)} F[x, (\alpha)] dx \right\} = F[u_1, (\alpha)] \frac{du}{d(\alpha)} - F[u_O, (\alpha)] \frac{du_O}{d(\alpha)} \\ + \int_{u_O(\alpha)}^{u_1(\alpha)} F_\alpha [x, (\alpha)] dx \quad (E-3)$$

let  $\xi = X$  [From formula (E-3)]

let  $X = \alpha$  E-2

$$\begin{aligned}
 \text{let } F(\xi, X) &= (\xi - X)P\sin(\alpha) && \text{part i} \\
 \text{let } F(\xi, X) &= (\eta - Y)P\cos(\alpha) && \text{part ii} \\
 F_X(\xi, X) &= -P\sin(\alpha) && \text{part i} \\
 F_X(\xi, X) &= -Y' P\cos(\alpha) && \text{part ii}
 \end{aligned}$$

For part i

$$\frac{\partial}{\partial X} \left[ \int_0^X (\xi - X)P\sin(\alpha) d\xi \right] = 0 - 0 + \int_0^X -P\sin(\alpha) d\xi = -Px \sin(\alpha) \quad (E-4)$$

For part ii

$$\frac{\partial}{\partial X} \left[ \int_0^X (\eta - Y)P\cos(\alpha) d\xi \right] = F(X, X) - 0 + \int_0^X -Y' P\cos(\alpha) d\xi = -YPX \cos(\alpha) \quad (E-5)$$

Substituting (E-4) and (E-5) into (E-2)

$$EI Y'''' = W Y' + (H_1 - H_O) - Y' P X \cos(\alpha) - PX \sin(\alpha)$$

$$EI Y'''' + Y' [-W + PX \cos(\alpha)] = (H_1 - H_O) - PX \sin(\alpha)$$

$$EI Y'''' - Y' [W - PX \cos(\alpha)] = (H_1 - H_O) - PX \sin(\alpha)$$

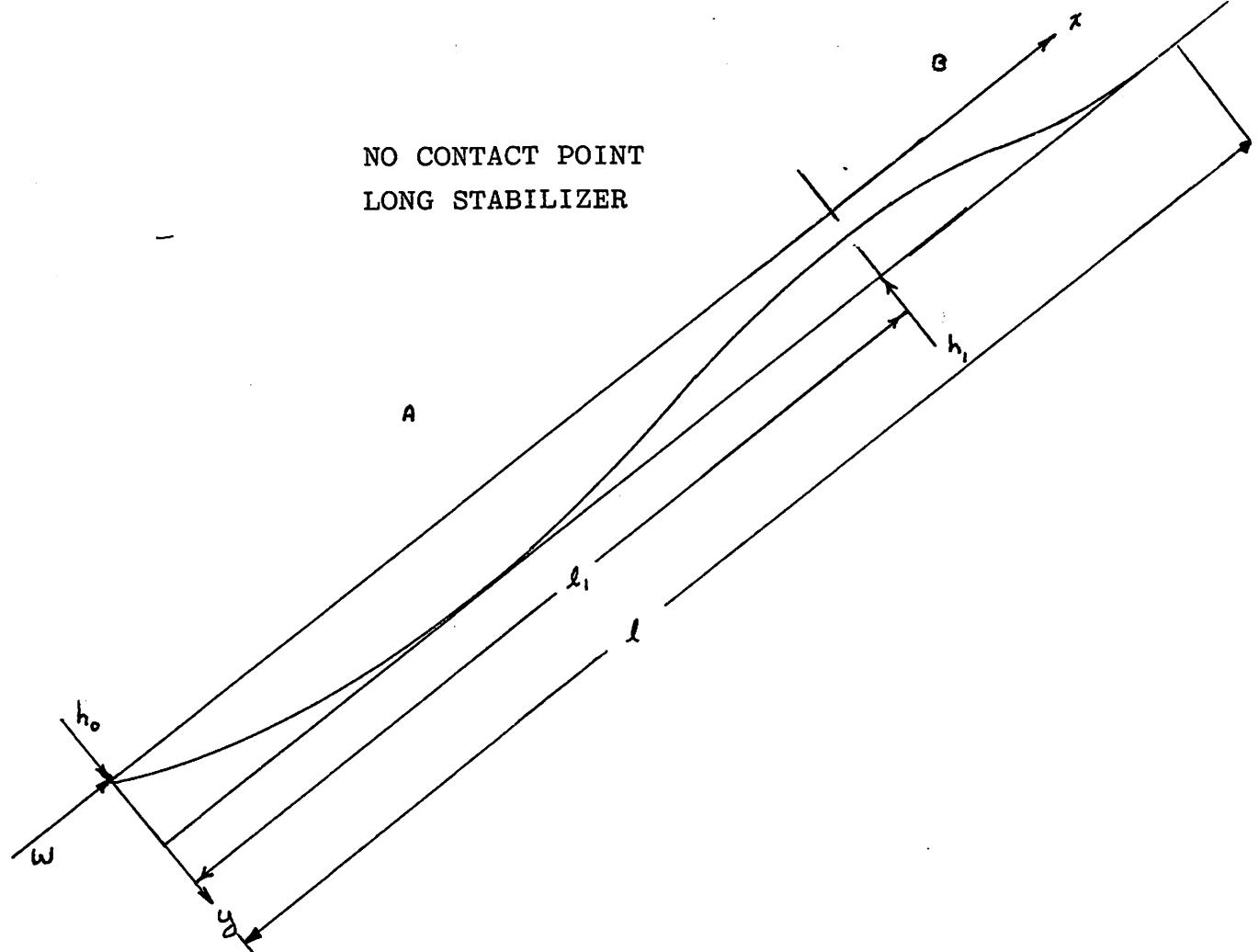


FIGURE XI

Segment A

$$y_A = -l + \cos(x) + C_{3A} \sin(x) + 1/2x^2 + h_O x$$

B.C.

$$\left. \begin{array}{ll} x = 0 & y_A = 0 \\ x = 0 & y''_A = 0 \end{array} \right\} \text{produce same constants } C_{A1} \text{ and } C_{A2} \text{ as (E-6)} \\ \text{derived in point stabilizer case (E-7)} \\ C_{1A} = -l ; C_{2B} = l ; h_A = h_O$$

Segment B

$$x = l_1 \quad y_B = C_{st1} \quad (E-8)$$

$$x = l \quad y_B = C_{dc} \quad \left. \right\} h_B = (h_1 - h_O) \quad (E-9)$$

$$x = l \quad y'_B = 0 \quad \left. \right\} \text{produce same constants } C_{B1}, C_{B2}, C_{B3} \quad (E-10)$$

$$x = l \quad y''_B = 0 \quad \left. \right\} \text{as derived in point stabilizer case} \quad (E-11)$$

## Continuity Conditions

$$X = \ell_1$$

$$y_A = y_B = C_{st_1} \quad (E-12)$$

$$Y'_A = Y'_B = 0 \quad (E-13)$$

### Segment A

Determination of  $C_{sA}$ ,  $h_o$

using (E-7)  $X = \ell_1$ ;  $y_A = C_{st_1}$  to determine  $C_{sA}$

$$C_{st_1} = -1 + \cos(\ell_1) + C_{sA} \sin(\ell_1) + 1/2 \ell_1^2 + h_o \ell_1$$

$$C_{sA} = \frac{[C_{st_1} + 1 - \cos(\ell_1) - 1/2 \ell_1^2 - h_o \ell_1]}{\sin(\ell_1)} \quad (E-14)$$

using (E-13)  $X = \ell_1$ ;  $Y'_A = 0$  to determine  $h_o$

$$0 = \sin(\ell_1) + C_{sA} \cos(\ell_1) + \ell_1 + h_o \quad (E-15)$$

substituting (E-14) into (E-15)

$$\begin{aligned} 0 &= -\sin(\ell_1) + \left[ \frac{[C_{st_1} + 1 - \cos(\ell_1) - 1/2 \ell_1^2 - h_o \ell_1]}{\sin(\ell_1)} \right] \cos(\ell_1) + \ell_1 + h_o \\ &= -\sin(\ell_1) + [C_{st_1} + 1 - \cos(\ell_1) - 1/2 \ell_1^2] \tan(\ell_1) - h_o \ell_1 + \ell_1 + h_o \\ &= \sin(\ell_1) - [C_{st_1} + 1 - \cos(\ell_1) - 1/2 \ell_1^2] \tan(\ell_1) - \ell_1 = h_o [1 - \ell_1 \tan(\ell_1)] \end{aligned}$$

$$h_o = \frac{\sin(\ell_1) - [C_{st_1} + 1 - \cos(\ell_1) - 1/2 \ell_1^2] \cot(\ell_1) - \ell_1}{1 - \ell_1 \cot(\ell_1)} \quad (E-16)$$

### Segment B

$C_{1B}$ ,  $C_{2B}$  and  $C_{3B}$  are obtained from the boundary conditions at the point of tangency.

$$X = \ell_1 \quad y'_B = y'_A = 0 \\ a = (\ell + h_B)$$

$$\bar{y}_B = C_{1B} + C_{2B} \cos(x) + C_{3B} \sin(x) + 1/2 x^2 + h_B x$$

$$0 = -[\cos(\ell) + a \sin(\ell)]\sin(\ell_1) + [\sin(\ell) - a \cos(\ell)\cos(\ell_1)] + h_B + \ell_1$$

$$= -\cos(\ell)\sin(\ell_1) - a \sin(\ell)\sin(\ell_1) + \sin(\ell)\cos(\ell_1) - a \cos(\ell)\cos(\ell) \\ + h + \ell_1$$

$$0 = +\sin(\ell - \ell_1) - a \cos(\ell - \ell_1) + h_B + \ell_1 \\ = +\sin(\ell - \ell_1) - \ell \cos(\ell - \ell_1) + h_B[1 - \cos(\ell - \ell_1)] + \ell_1$$

$$h_B = \frac{+\sin(\ell - \ell_1) - \ell \cos(\ell - \ell_1) + \ell_1}{-[1 - \cos(\ell - \ell_1)]}$$

$$h_B = \frac{\sin(\ell - \ell_1) - \cos(\ell - \ell_1) + \ell_1}{[\cos(\ell - \ell_1) - 1]} \quad (E-17)$$

$$X = \ell_1 \quad \bar{y}_B = C_{st}$$

$$C_{st} = C_1 + C_{2B} \cos(\ell_1) + C_{3B} \sin(\ell_1) + h_B \ell_1 + 1/2 \ell_1^2 \\ = [\cos(\ell) + a \sin(\ell)\cos(\ell_1)] + [\sin(\ell) - a \cos(\ell)\sin(\ell_1)] \\ + h_B (\ell_1 - \ell) \\ = \cos(\ell)\cos(\ell_1) + a \sin(\ell)\cos(\ell_1) + \sin(\ell)\sin(\ell_1) \\ - a \cos(\ell)\sin(\ell) + h \ell_1 - h \ell$$

$$= \cos(\ell - \ell_1) + a \sin(\ell - \ell_1) + h_B(\ell_1 - \ell)$$

$$= \cos(\ell - \ell_1) + \ell \sin(\ell - \ell_1) + h_B[\ell_1 - \ell - \sin(\ell - \ell_1)]$$

$$M = - C_{dc} + 1 - 1/2 \ell_1^2$$

$$0 = -M - 1/2 \ell^2 + \cos(\ell - \ell_1) + \ell \sin(\ell - \ell_1) + h_B[\ell_1 - \ell - \sin(\ell - \ell_1)]$$

$$0 = M + 1/2 \ell^2 - \cos(\ell - \ell_1) - \ell \sin(\ell - \ell_1) - h_B[\ell - \ell_1 + \sin(\ell - \ell_1)] \quad (E-18)$$

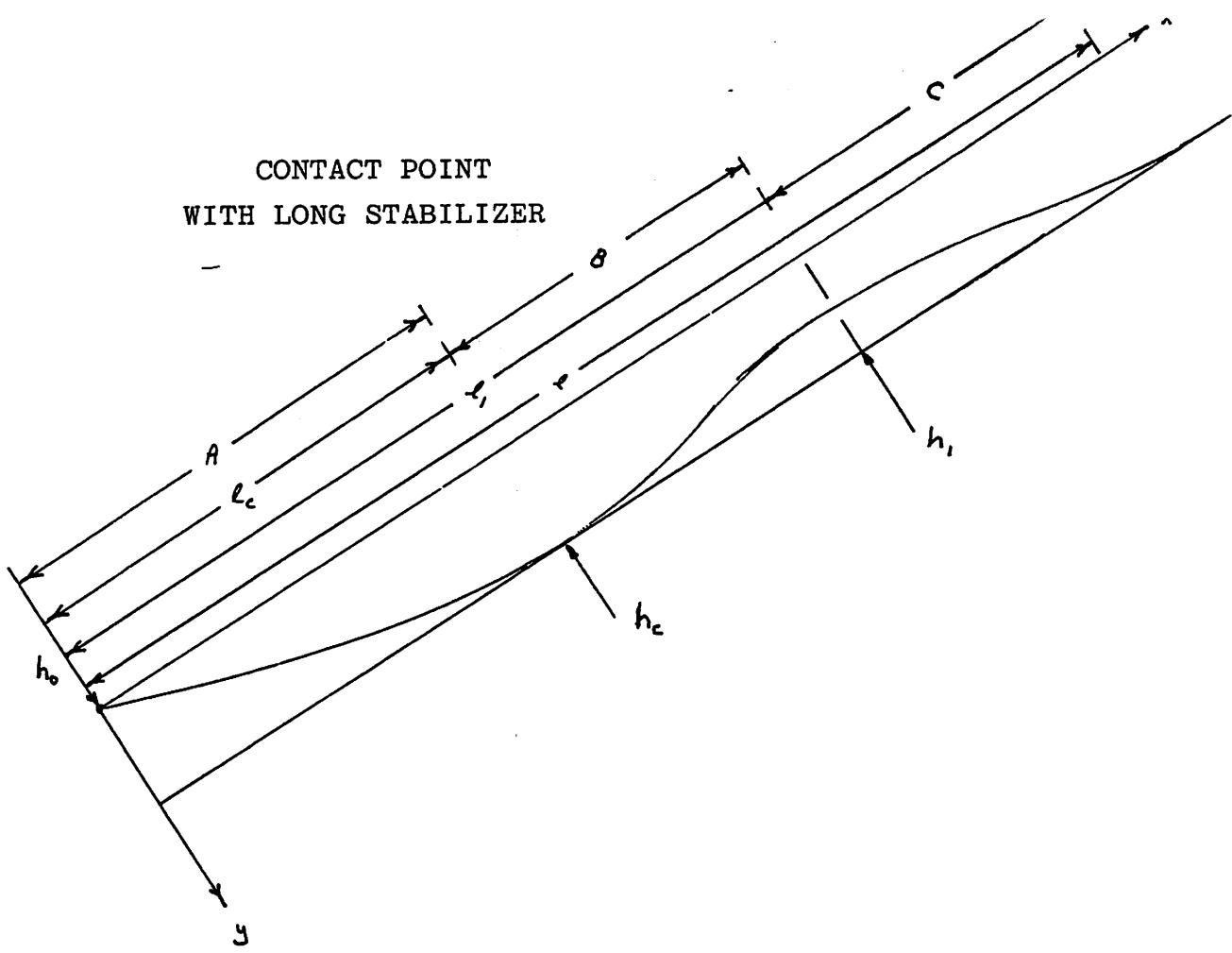


FIGURE XII  
Segment A  
Long Stabilizer

$$0 \leq x < l_c$$

Boundary Conditions

$$x = 0 \quad y_A = 0 \quad (\text{bit is centered in the bore hole}) \quad (\text{E-19})$$

$$x = 0 \quad y''_A = 0 \quad (\text{no moment exists at the bit}) \quad (\text{E-20})$$

Continuity Conditions

$$x = l_c \quad y_A = y_B = C_{dc} \quad (\text{E-21})$$

$$x = l_c \quad y'_A = y'_B = 0 \quad (\text{E-22})$$

From boundary condition (E-19, E-20)  $C_1 = -1, C_2 = 1$

$$y_A = -1 + \cos(x) + C_{3A} \sin(x) + 1/2 x^2 + h_0 x$$

$$y'_A = -\sin(x) + C_{3A} \cos(x) + x + h_0$$

using B.C. (E-21)

$$C_{dc} = -1 + \cos(\ell_c) + C_{3A} \sin(\ell_c) + 1/2(\ell_c^2) + h_0 \ell_c$$

$$C_{3A} \sin(\ell_c) + h_0 \ell_c = 1 + C_{dc} - \cos(\ell_c) - 1/2 \ell_c^2 \quad (E-23)$$

using (E-22)

$$C_{3A} \cos(\ell_c) + h_0 = \sin(\ell_c) - \ell_c$$

$$h_0 = \sin(\ell_c) - \ell_c - C_{3A} \cos(\ell_c) \quad (E-24)$$

substituting (E-24) into (E-23)

$$C_{3A} \sin(\ell_c) + [\sin(\ell_c) - \ell_c - C_{3A} \cos(\ell_c)] \ell_c = 1 + C_{dc} - \cos(\ell_c) - 1/2 \ell_c^2$$

$$C_{3A} = \frac{1 + C_{dc} - \cos(\ell_c) + 1/2 \ell_c^2 - \ell_c \sin(\ell_c)}{[\sin(\ell_c) - \ell_c \cos(\ell_c)]} \quad (E-25)$$

substituting (E-25) into (E-24)

$$h_0 = \sin(\ell_c) - \ell_c - \left[ \frac{1 + C_{dc} - \cos(\ell_c) - 1/2 \ell_c^2 - \ell_c \sin(\ell_c)}{\sin(\ell_c) - \ell_c \cos(\ell_c)} \right] \cos(\ell_c)$$

$$h_0 = \sin^2(\ell_c) - \ell_c \cos(\ell_c) \sin(\ell_c) - \ell_c \sin(\ell_c) + \ell_c^2 \cos(\ell_c)$$

$$\frac{-\cos(\ell_c) - C_{dc} \cos(\ell_c) - 1/2 \ell_c^2 \cos(\ell_c) + \ell_c \sin(\ell_c) \cos(\ell_c) + \cos^2 \ell_c}{[\sin(\ell_c) - \ell_c \cos(\ell_c)]}$$

$$h_o = \frac{1 + 1/2 \ell_c^2 \cos(\ell_c) - \cos(\ell_c) - C_{dc} \cos(\ell_c) - \ell_c \sin(\ell_c)}{[\sin(\ell_c) - \ell_c \cos(\ell_c)]}$$

$$h_o = \frac{1 - \ell_c \sin(\ell_c) + \cos(\ell_c)[1/2 \ell_c^2 - 1 - C_{dc}]}{[\sin(\ell_c) - \ell_c \cos(\ell_c)]}$$

(E-26)

CONTACT POINT  
Segment B

Long Stabilizer

$$l_C \leq x < l_1$$

Boundary Conditions

$$x = l_C \quad y_B = C_{dc} \quad (E-27)$$

$$x = l_C \quad y'_B = 0 \quad (E-28)$$

Continuity Conditions

$$x = l_1 \quad y_B = y_C = C_{st_1} \quad (E-29)$$

$$x = l_1 \quad y'_B = y'_C = 0 \quad (E-30)$$

using (E-28) and (E-30)

$$0 = -C_{2B} \sin(l_C) + C_{3B} \cos(l_C) + (l_C + h_B) \quad (E-31)$$

$$0 = -C_{2C} \sin(l_1) + C_{3B} \cos(l_1) + (l_1 + h_B) \quad (E-32)$$

Multiply (E-32) by  $-\sin(l_C)$  and (E-31) by  $\sin(l_1)$

$$0 = -C_{2B} \sin(l_C) \sin(l_1) + C_{3B} \cos(l_C) \sin(l_1) + (l_C + h_B) \sin(l_1)$$

$$0 = C_{2B} \sin(l_C) \sin(l_1) - C_{3B} \cos(l_1) \sin(l_C) - (l_1 + h_B) \sin(l_C)$$

$$0 = C_{3B} [-\cos(l_C) \sin(l_1) + \cos(l_1) \sin(l_C)] + \sin(l_1) (l_C + h_B) - (l_1 + h) \sin(l_C)$$

$$-C_{3B} [\cos(l_C) \sin(l_1) - \cos(l_1) \sin(l_C)] = \sin(l_1) (l_C + h_B) \sin(l_C) (l_1 + h)$$

$$C_{3B} = \frac{\sin(l_1) (l_C + h_B) - \sin(l_C) (l_1 + h_B)}{-(\cos(l_C) \sin(l_1) - \cos(l_1) \sin(l_C))}$$

$$C_{3B} = \frac{\sin(\ell_1)(\ell_C + h_B) - \sin(\ell_C)(\ell_1 + h_B)}{[\cos(\ell_1)\sin(\ell_C) - \sin(\ell_1)\cos(\ell_C)]}$$

$$C_{3B} = \frac{\sin(\ell_C)(\ell_1 + h_B) - \sin(\ell_1)(\ell_C + h_B)}{\sin(\ell_1 - \ell_C)} \quad (E-33)$$

multiply (E-32) by  $\cos(\ell_C)$  and (E-31) by  $\cos(\ell_1)$

$$0 = - C_{2B} \sin(\ell_C)\cos(\ell_1) + C_{3B} \cos(\ell_C)\cos(\ell_1) + (\ell_C + h_B)\cos(\ell_1) \quad (E-34)$$

$$0 = - C_{2B} \sin(\ell_1)\cos(\ell_C) + C_{3B} \cos(\ell_1)\cos(\ell_C) + (\ell_1 + h_B)\cos(\ell_C) \quad (E-35)$$

subtracting (E-34) from (E-35)

$$0 = C_{2B} [\sin(\ell_1)\cos(\ell_C) - \sin(\ell_C)\cos(\ell_1)] + (\ell_C + h_B)\cos(\ell_1) - (\ell_1 + h_B)\cos(\ell_C)$$

$$C_{2B} = \frac{(\ell_C + h_B)\cos(\ell_1) - (\ell_1 + h_B)\cos(\ell_C)}{[\sin(\ell_C)\cos(\ell_1) - \sin(\ell_1)\cos(\ell_C)]}$$

$$= \frac{(\ell_C + h_B)\cos(\ell_1) - (\ell_1 + h_B)\cos(\ell_C)}{\sin(\ell_1 + \ell_C)}$$

$$C_{2B} = \frac{(\ell_1 + h_B)\cos(\ell_C) - (\ell_C + h_B)\cos(\ell_1)}{\sin(\ell_1 - \ell_C)} \quad (E-36)$$

To solve for  $h$ , and  $C_{1B}$  in Segment B, boundary conditions, (E-27)(E-29) are used:

$$C_{st_1} = C_1 + C_2 \cos(\ell_1) + C_3 \sin(\ell_1) + 1/2\ell_1^2 + h \ell_1 \quad (E-37a)$$

$$-C_{dc} = -C_1 - C_2 \cos(\ell_C) - C_3 \sin(\ell_C) - 1/2\ell_C^2 - h \ell_C \quad (E-37b)$$

$$\begin{aligned} C_{st} - C_{dc} &= C_2 [\cos(\ell_1) - \cos(\ell_C)] + C_3 [\sin(\ell_1) - \sin(\ell_C)] \\ &\quad + 1/2(\ell_1^2 - \ell_C^2) + h(\ell_1 - \ell_C) \end{aligned}$$

$$\begin{aligned} C_{st} - C_{dc} - 1/2(\ell_1^2 - \ell_C^2) &= C_2 (\cos(\ell_1) - \cos(\ell_C)) + C_3 [\sin(\ell_1) - \sin(\ell_C)] \\ &\quad + h (\ell_1 - \ell_C) \end{aligned} \quad (E-38)$$

Expanding the terms in the numerator of the r.h.s. of equations (E-37):

(E-38a)

$$C_{2B}[\cos(\ell_1)] = \frac{\ell_1 \cos(\ell_C) \cos(\ell_1) + h \cos(\ell_C) \cos(\ell_1) - \ell_C \cos(\ell_1) - h \cos^2(\ell_1)}{\sin(\ell_1 - \ell_C)} \quad (E-38b)$$

$$C_{2B}[-\cos(\ell_C)] = \frac{-\ell_1 \cos^2(\ell_C) - h \cos^2(\ell_C) + \ell_C \cos(\ell_1) \cos(\ell_C) + h \cos(\ell_1) \cos(\ell_C)}{\sin(\ell_1 - \ell_C)} \quad (E-38c)$$

$$C_{3B}[\sin(\ell_1)] = \frac{\ell_1 \sin(\ell_C) \sin(\ell_1) + h \sin(\ell_C) \sin(\ell_1) - (\ell_C) \sin^2(\ell_1) - h \sin^2(\ell_1)}{\sin(\ell_1 - \ell_C)} \quad (E-38d)$$

$$C_{3B}[-\sin(\ell_C)] = \frac{-\ell_1 \sin^2(\ell_C) - h \sin^2(\ell_C) + \ell_C \sin(\ell_1) \sin(\ell_C) + h \sin(\ell_1) \sin(\ell_C)}{\sin(\ell_1 - \ell_C)} \quad (E-38e)$$

Adding similar terms in equation (E-38a,b,c,d) yields:

(E-38e)

$$-\ell_C[\cos^2(\ell_1) + \sin^2(\ell_1)] - h[\cos^2(\ell_1) + \sin^2(\ell_1)] - h[\cos^2(\ell_C) + \sin^2(\ell_C)]$$

$$-\ell_1[\cos^2(\ell_C) + \sin^2(\ell_C)] + \ell_1[\cos(\ell_C) \cos(\ell_1) + \sin(\ell_C) \sin(\ell_1)]$$

Continuation of (E-38e)

$$+ 2h[\cos(\ell_c)\cos(\ell_1) + \sin(\ell_c)\sin(\ell_1)] + \ell_c[\cos(\ell_1)\cos(\ell_c) + \sin(\ell_1)\sin(\ell_c)]$$

Simplifying (E-38e) and substituting back into Equation (E-38)  
yields:

(E-39)

$$C_{st} - C_{dc} - 1/2(\ell_1^2 - \ell_c^2) = \frac{-(\ell_c - 2h + \ell_1) + \cos(\ell_1 - \ell_c)[\ell_1 + 2h + \ell_c]}{\sin(\ell_1 - \ell_c)} = h(\ell_1 - \ell_c)$$

isolating h on the r.h.s. of (E-38)

$$\begin{aligned} & [C_{st} - C_{dc} - 1/2(\ell_1^2 - \ell_c^2)] \sin(\ell_1 - \ell_c) + (\ell_c + \ell_1) - \cos(\ell_1 - \ell_c)[\ell_1 + \ell_c] \\ &= h[(\ell_1 - \ell_c)\sin(\ell_1 - \ell_c) + 2\cos(\ell_1 - \ell_c) - 2] \end{aligned}$$

solving for h, which will be designated  $h_B$  for the second segment  
of the string.

$$h_B = \frac{[C_{st} - C_{dc} - 1/2(\ell_1^2 - \ell_c^2)] \sin(\ell_1 - \ell_c) + (\ell_c + \ell_1)[1 - \cos(\ell_1 - \ell_c)]}{[2\cos(\ell_1 - \ell_c) + (\ell_1 - \ell_c)\sin(\ell_1 - \ell_c) - 2]} \quad (E-40)$$

multiplying (E-37a) by  $\ell_c$  and (E-37b) by  $\ell_1$

$$\begin{aligned} C_{st} \ell_c &= C_1 B \ell_c + C_2 B \ell_c \cos(\ell_1) + C_3 B \ell_c \sin(\ell_1) + 1/2 \ell_1^2 \ell_c + h_B \ell_1 \ell_c \\ - C_{dc} \ell_1 &= C_1 B \ell_1 - C_2 B \ell_1 \cos(\ell_c) - C_3 B \ell_1 \sin(\ell_c) - 1/2 \ell_c^2 \ell_1 - h_B \ell_1 \ell_c \end{aligned}$$

adding the two equations above yields:

$$\begin{aligned} C_{st} \ell_c - C_{dc} \ell_1 &= C_1 B(\ell_c - \ell_1) + C_2 [\ell_c \cos(\ell_1) - \ell_1 \cos(\ell_c)] \\ &+ C_3 [\ell_c \sin(\ell_1) - \ell_1 \sin(\ell_c)] + 1/2 \ell_1 \ell_c (\ell_1 - \ell_c) \end{aligned} \quad (E-41)$$

solving for  $C_{1B}$

$$C_{1B} = C_{dc} \ell_1 - C_{st} \ell_C + C_2 [\ell_C \cos(\ell_1) - \ell_1 \cos(\ell_C)] + C_3 [\ell_C \sin(\ell_1) - \ell_1 \sin(\ell_C)] + 1/2 \ell_1 \ell_C (\ell_1 - \ell_C) \quad (E-42)$$

To solve for  $\ell_C$  in Segments A and B, we use  $X = \ell_C$   $Y''_A = Y''_B$  and solve for 0.

$$-\cos(\ell_C) - C_{3A} \sin(\ell_C) = -C_{2B} \cos(\ell_C) - C_{3B} \sin(\ell_C)$$

$$0 = (C_{3A} - C_{3B}) \sin(\ell_C) + (1 - C_{2B}) \cos(\ell_C) \quad (E-43)$$

THE INFLUENCE OF WOB

$D_h = 12.25\text{in.}$   $\alpha = 25^\circ$   $OD_{dc} = 8.25\text{in.}$   $ID_{dc} = 2.5\text{in.}$   
 $MW = 10 \text{ ppg.}$   $D_1 = 60 \text{ ft.}$

WOB x 1000       $H_O$        $H_1$        $\phi$        $\beta$        $l_c$        $H_c$

20	-1488	4927	20.7	0.006	-	-
30	-1476	4907	22.2	0.008	-	-
40	-1463	4887	22.9	0.009	-	-
50	-1449	4869	23.3	0.011	-	-
60	-1434	4850	23.6	0.012	-	-
70	-1418	4834	23.8	0.013	-	-
80	-1401	4818	24.0	0.015	-	-

TABLE VI-E

THE INFLUENCE OF HOLE INCLINATION

$D_h = 12.15 \text{ in.}$   $OD_{dc} = 8.75 \text{ in.}$   $ID_{dc} = 2.5 \text{ in.}$   $MW = 10 \text{ ppg.}$   
 $WOB \times 1000 = 60$        $D_1 = 60 \text{ ft.}$

$\alpha$        $H_O$        $H_1$        $\phi$        $\beta$        $l_c$        $H_c$

5	-296	1151	4.72	0.002	-	-
10	-589	2167	9.43	0.005	-	-
15	-878	3113	14.2	0.007	-	-
20	-1160	4006	18.9	0.010	-	-
25	-1434	4850	23.6	0.012	-	-
30	-1697	5647	28.4	0.014	-	-
35	-1946	6394	33.1	0.016	-	-

TABLE VII-E  
E-17

THE INFLUENCE OF STABILIZER PLACEMENT

$D_h = 12.25$  in.  $\alpha = 25^\circ$   $OD_{dc} = 8.75$   $ID_{dc} = 2.5$

$MW = 10$  ppg.  $W \times 1000 = 60$

$D_1$	$H_O$	$H_I$	$\phi$	$\beta$	$l_c$	$H_C$
20	-501	3098	24.5	0.0004	-	-
30	-747	3523	24.3	0.001	-	-
40	-987	3955	24.1	0.003	-	-
50	-1217	4396	23.9	0.006	-	-
60	-1434	4850	23.6	0.012	-	-
70	-1369	4859	23.7	0.471	0.947	727
80	-1178	4600	23.9	0.436	1.09	1848

TABLE VIII-E

THE INFLUENCE OF I

$D_h = 12.25$  in.  $\alpha = 25^\circ$   $MW = 10$  ppg.  $W \times 1000 = 60$

$D_1 = 60$  ft.

$*10^{-2}$	$I$	$H_O$	$H_I$	$\phi$	$\beta$	$l_c$	$H_C$
8.25 x 2.25 1.091	-1493	5,043	28.6	0.019	-	-	-
8.5 x 2.5 1.226	-1579	5,298	28.5	0.016	-	-	-
8.75 x 2.5 1.378	-1696	5,647	28.4	0.014	-	-	-
9.25 x 2.25 1.727	-1967	6,447	28.1	0.011	-	-	-
9.5 x 2.25 1.919	-2091	6,806	28.0	0.010	-	-	-
10 x 2.5 2.358	-2318	7,434	27.8	0.007	-	-	-
10.25 x 2.75 2.599	-2417	7,689	27.7	0.007	-	-	-

TABLE IX-E  
E-18

## DRILL COMPARISON

### Standard Data

$D_h = 12.25$       MW = 10 ppg.      WOB = 60,000

$OD_{dc} = 8.75$        $\gamma = 25^\circ$        $h = 0.15$

$ID_{dc} = 2.50$        $\alpha = 30^\circ$

Case 1      DI = 30 ft.      (no contact point)

Case 2      DI = 90 ft.      (contact point)

Case 3      DI = 0      (slick string)

	(Δα<0.05)				(Δα<0.10)			
	Equil. Angle (α)	Footage Drilled	$H_O$	#of iter- ations	Equil. Angle (α)	Footage Drilled	$H_O$	#of iter- ations
Case 1	21.7	1594	-655	19	21.9	1339	-662	16
Case 2	20.1	2898	-945	20	20.34	2309	-955	16
Case 3	20.2	814	-932	20	20.4	647	-943	16

TABLE X-E

```

10 REM ONE STABILIZER
20 REM
30 REM ZERO CLEARANCE
40 REM
50 REM CONTACT POINT BETWEEN BIT AND STABILIZER WILL BE CONSIDERED IF PRESENT
60 REM
70 REM THIS PROGRAM CALCULATES BETA, H0, H1, HC, PHI, LC FOR A SPECIFIED
80 REM
90 REM DISTANCE TO THE STABILIZER, WOB, AND MOMENT OF INERTIA.
100 CLS
110 DEFDBL F,L,X,N
120 DIM Y(450),YD(450),YDD(450)
130 INPUT "DISTANCE TO STABILIZER 1 (ft) : ";D11
140 INPUT "Dh=";DH:DH=DH/12
150 INPUT "ODdc(in)=";OD:OD=OD/12
160 INPUT "IDdc(in)=";ID:ID=ID/12
170 INPUT "MW(ppg)(";MW
180 INPUT "Hole inclination ALFA(deg)(";AA
190 INPUT "WOB(1000 lb)(";W:W=1000*W
200 DST1=DH
210 REM ***** PRINT INPUT DATA *****
220 CLS
230 PRINT " D1 (ft)= ";D11
240 PRINT " Dh (in) = ";DH*12
250 PRINT " ODdc (in) = ";OD*12
260 PRINT " IDdc (in) = ";ID*12
270 PRINT " ODst (in) = ";DH*12
280 PRINT " MW (ppg) = ";MW
290 PRINT " ALPHA (deg) = ";AA
300 PRINT " WOB (lb's) = ";W
310 REM ***** CALCULATE DIMENSIONLESS QUANTITIES *****
320 WU=3.14159*((OD/2)^2-(ID/2)^2)*489
330 C=(DH-OD)/2
340 CST1=(DH-DST1)/2
350 P=WU*(1-MW/65.4)
360 I=3.14*(OD^4-ID^4)/64
370 PRINT "P (lb's/ft) = ";P
380 PRINT "I (ft^4) = ";I
390 PRINT:PRINT
400 EI=4176*10^6*I
410 D1=(D11*SQR(W/EI))
420 CD=(W^2*C)/(EI*P*SIN(AA/57.29))
430 REM**** DIMENSIONLESS CONVERSION FACTORS *****
440 M1=EI*P*SIN(AA/57.29)/(W^2)
450 M2=SQR(EI/W)
460 M3=SQR(EI/W)*P*SIN(AA/57.29)
470 REM **** SOLVES FOR DISTANCE TO TANGENCY POINT *****
480 CST1=(W^2*CST1)/(EI*P*SIN(AA/57.29))
490 INPUT "DO YOU WANT A HARD COPY, 1- YES, 2-NO";HARD
500 IF (HARD=1) THEN GOSUB 3570
510 REM **** SOLVES FOR DISTANCE TO TANGENCY POINT *****
520 L=D1+.01
530 POS1=1
540 COUNT=0
550 XTERM= CD-CST1-1+.5*D1^2
560 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)

```

```

570 F=XTERM-.5*L^2+COS(L-D1)+L*SIN(L-D1)+H*(D1-L+SIN(L-D1))
580 IF F<0 THEN POS1=2
590 DX=.1
600 ITER =1
610 LPR=L
620 L=LPR+DX
630 IF L>15 THEN 890
640 XTERM=C0-CST1-1+.5*D1^2
650 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)
660 F=XTERM-.5*L^2+COS(L-D1)+L*SIN(L-D1)+H*(D1-L+SIN(L-D1))
670 IF F<0 THEN 700
680 POS2=1
690 GOTO 710
700 POS2=2
710 IF POS2<>POS1 THEN 740
720 LPR=L
730 GOTO 620
740 IF ITER=1 THEN 790
750 IF ITER=2 THEN 810
760 IF ITER=3 THEN 830
770 IF ITER=4 THEN 850
780 IF ITER=5 THEN 870
790 DX=.01: ITER=2
800 GOTO 620
810 DX=.001: ITER=3
820 GOTO 620
830 DX=.0001: ITER=4
840 GOTO 620
850 DX=.00001: ITER=5
860 GOTO 620
870 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
880 GOTO 620
890 FOR I=1 TO COUNT
900 PRINT "ROOT(";I;") = ";ROOT(I)
910 NEXT I
920 REM ***** DETERMINATION OF BETA, PHI, HO, AND H1 *****
930 I=0
940 L=ROOT(1)
950 PRINT "L= ";L
960 I=I+2
970 DX=D1/I
980 IF(DX>.025)THEN GOTO 960
990 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)
1000 HO=(SIN(D1)-(CST1+1-COS(D1)-.5*D1^2)*1/TAN(D1)-D1)/(1-D1*I/TAN(D1))
1010 H1=HO-H
1020 C3A=(CST1+1-COS(D1)-.5*D1^2-HO*D1)/SIN(D1)
1030 Y(0)=(C3A+HO)*SQR(W/EI)*M1/M2
1040 BB=57.29*ATN(Y(0))
1050 HOU=HO*M3:H1U=H1*M3
1060 PHI = 57.29*(ATN((SQR(EI/W)*P*SIN(AA/57.29)*HO)/W))+AA

```

```

1070 PRINT
1080 REM ***** DETERMINES IF POINT OF CONTACT IS PRESENT *****
1090 PRINT
1100 I=-1 : DX=.01:X=0
1110 I=I+1
1120 Y(I)=-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2
1130 X=X+DX
1140 IF (Y(I)>CD) OR (Y(I)=CD) THEN GOTO 2380
1150 IF (X<D1) THEN GOTO 1110
1160 IF (HARD=1) THEN GOSUB 3700
1170 INPUT"DO YOU WANT A HARD COPY OF Y, SLOPE, MOMENT Vs X, 1-YES, 2-NO";HC
1180 PRINT"BETA (deg) = ";BB
1190 PRINT"PHI (deg) = ";PHI
1200 PRINT"H0 (lb's) = ";H0*M3
1210 NN=D1/.01
1220 FOR I=0 TO NN
1230 Y(I)=0
1240 NEXT I
1250 REM ***** SOLVE FOR 0 SLOPE POINT BETWEEN BIT AND TANGENCY *****
1260 X=0:POS1=1:COUNT=0
1270 F=-SIN(X)+C3A*COS(X)+X+H0
1280 IF (F<0) THEN POS1=2:DX=.1
1290 ITER=1
1300 XPR=X
1310 X=XPR+DX
1320 F=-SIN(X)+C3A*COS(X)+X+H0
1330 IF -(F<0) THEN 1360
1340 POS2=1
1350 GOTO 1370
1360 POS2=2
1370 IF (POS2<>POS1) THEN 1400
1380 XPR=X
1390 GOTO 1310
1400 IF (ITER =1) THEN 1440
1410 IF (ITER =2) THEN 1450
1420 IF (ITER =3) THEN 1460
1430 IF (ITER=4) THEN 1470
1440 DX=.01:ITER=2:GOTO 1310
1450 DX=.001: ITER=3: GOTO 1310
1460 DX=.0001: ITER=4: GOTO 1310
1470 SLP0=X:DX1=SLP0/5:DX2=(D1-SLP0)/5
1480 REM***** DETERMINE VALUE OF Y, SLOPE, MOMENT FOR BIT TO 0 SLOPE POINT"***
1490 X=0:J=0
1500 FOR J=0 TO 5
1510 Y(J)=(-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2)*M1
1520 YD(J)=(-SIN(X)+C3A*COS(X)+H0+X)*M1/M2
1530 YDD(J)=-EI*(-COS(X)-C3A*SIN(X)+1)*M1/(M2^2)
1540 X=X+DX1:LSJ=J
1550 NEXT J
1560 REM ***** DETERMINE VALUES OF Y, SLOPE, MOMENT FOR 0 SLOPE TO STAB1 "*****
1570 X=SLP0+DX2: LSJ=LSJ+1

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1580 FOR K=LSJ TO 10
1590 Y(K)=(-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2)*M1
1600 YD(K)=(-SIN(X)+C3A*COS(X)+H0+X)*M1/M2
1610 YDD(K)=(-EI*(-COS(X)-C3A*SIN(X)+1))*M1/(M2^2)
1620 X=X+DX2
1630 NEXT K
1640 PRINT " X Y SLOPE MOMENT "
1650 PRINT " ----- ----- ----- -----"
1660 DIMX=.000001
1670 FOR I=0 TO 5
1680 PRINT " ";DIMX; " ;Y(I); " ;YD(I); " ;YDD(I)
1690 DIMX=DIMX+DX1*M2
1700 NEXT I
1710 DIMX=SLP0*M2
1720 FOR I=6 TO 10
1730 DIMX=DIMX+DX2*M2
1740 PRINT " ";DIMX; " ;Y(I); " ;YD(I); " ;YDD(I)
1750 NEXT I
1760 IF (HC=1) THEN GOSUB 3760
1770 REM ***** DETERMINE Y, SLOPE, MOMENT FOR SEGMENT B *****
1780 C1B=CD-H*L-.5*L^2-1
1790 C2B=COS(L)+(L+H)*SIN(L)
1800 C3B=SIN(L)-(L+H)*COS(L)
1810 DX3=(L-D1)/10:X=D1
1820 FOR I= 11 TO 21
1830 Y(I)=(C1B+C2B*COS(X)+C3B*SIN(X)+H*X+.5*X^2)*M1
1840 YD(I)=(-C2B*SIN(X)+C3B*COS(X)+H+X)*M1/M2
1850 YDD(I)=(-EI*(-C2B*COS(X)-C3B*SIN(X)+1))*M1/(M2^2)
1860 X=X+DX3
1870 NEXT I
1880 PRINT
1890 DIMX=D1*M2
1900 PRINT:PRINT "SEGMENT B ";PRINT
1910 PRINT " X Y SLOPE MOMENT "
1920 PRINT "----- ----- ----- -----"
1930 FOR I=11 TO 21
1940 PRINT " ";DIMX; " ;Y(I); " ;YD(I); " ;YDD(I)
1950 DIMX=DIMX+DX3*M2
1960 NEXT I
1970 IF (HC=1) THEN GOSUB 3910
1980 INPUT "DO YOU WISH TO CONTINUE WITH ANOTHER RUN ? 1-YES, 0-NO";DEC1
1990 IF (DEC1=0) THEN GOTO 3560
2000 PRINT
2010 INPUT "WOULD YOU LIKE TO CHANGE ANY VARIABLES ? 1-YES, 0-NO";DEC2
2020 IF (DEC2=0) GOTO 220
2030 REM ***** DATA CHANGE SECTION *****
2040 CLS
2050 PRINT "CODE # VARIABLE"
2060 PRINT "----- -----"
2070 PRINT " 1 ----- Dh"
2080 PRINT " 2 ----- ODdc"
2090 PRINT " 3 ----- IDdc"
2100 PRINT " 4 ----- Wdc"
2110 PRINT " 5 ----- MW"

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2120 PRINT " 6      ----- ALPHA"
2130 PRINT " 7      ----- GAMA"
2140 PRINT " 8      ----- WOB"
2150 PRINT " 9      ----- h"
2160 PRINT " 10     ----- ODst"
2170 PRINT " 11     ----- Dst1 "
2180 PRINT
2190 PRINT "INPUT THE CORRESPONDING CODE FOR THE VARIABLES YOU WISH TO CHANGE,"
2200 PRINT "ENTER THEM ONE PER LINE ----ENTER 0 WHEN FINISHED"
2210 INPUT "CODE # = ";CN
2220 IF (CN=0) THEN GOTO 220
2230 IF (CN=1) THEN INPUT "Dh (in) = ";DH;DH=DH/12
2240 IF (CN=2) THEN INPUT "ODdc (in) = ";OD;OD=OD/12
2250 IF (CN=3) THEN INPUT "IDdc (in) = ";ID;ID=ID/12
2260 IF (CN=4) THEN INPUT "Wdc (in) = ";WU
2270 IF (CN=5) THEN INPUT "MW (PPg) = ";MW
2280 IF (CN=6) THEN INPUT "ALPHA (deg) = ";AA;AO=AA
2290 IF (CN=7) THEN INPUT "GAMA (deg) = ";GA
2300 IF (CN=8) THEN INPUT "WOB (1000'S lbs) = ";W;W=1000*W
2310 IF (CN=9) THEN INPUT " h = ";DAI
2320 IF (CN=10) THEN INPUT " ODst(in) = ";DST1;DST1=DST1/12
2330 IF (CN=11) THEN INPUT " Dst1(ft) = ";D11
2340 IF (CN<0)OR(CN>11) THEN GOTO 2360
2350 GOTO 2210
2360 PRINT "INPUT VALUE MUST BE BETWEEN 0 AND 10 INCLUSIVE"
2370 GOTO 2210
2380 L=.01
2390 IF (HARD=1) THEN LPRINT"***** CONTACT POINT BETWEEN BIT AND STABILIZER ***"
2400 IF (HARD=1) THEN LPRINT:LPRINT
2410 PRINT "***** CONTACT POINT BETWEEN THE BIT AND STABILIZER *****"
2420 GOSUB 2900
2430 POS1=1
2440 COUNT=0
2450 IF F<0 THEN POS1=2
2460 DX=.1
2470 ITER =1
2480 LPR=L
2490 L=LPR+DX
2500 IF (L>D1) GOTO 2790
2510 GOSUB 2900
2520 IF F<0 THEN 2550
2530 POS2=1
2540 GOTO 2560
2550 POS2=2
2560 IF POS2<>POS1 THEN 2590
2570 LPR=L
2580 GOTO 2490
2590 IF ITER=1 THEN 2660
2600 IF ITER=2 THEN 2680
2610 IF ITER=3 THEN 2700
2620 IF ITER=4 THEN GOTO 2720
2630 IF ITER=5 THEN GOTO 2740
2640 IF ITER=6 THEN GOTO 2760
2650 IF ITER=7 THEN 2780
2660 DX=.01: ITER=2

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2670 GOTO 2490
2680 DX=.001: ITER=3
2690 GOTO 2490
2700 DX=.0001 : ITER = 4
2710 GOTO 2490
2720 DX=.00001:ITER=5
2730 GOTO 2490
2740 DX=.000001:ITER=6
2750 GOTO 2490
2760 DX=.0000001:ITER=7
2770 GOTO 2490
2780 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
2790 FOR I=1 TO COUNT
2800 PRINT "CONTACT POINT = ";ROOT(1)
2810 NEXT I
2820 REM ***** DETERMINES HO, HC, H1, BETA, PHI *****
2830 L=ROOT(1)
2840 X=0
2850 N3A=(1+CD-COS(L)+.5*L^2-L*SIN(L))/(SIN(L)-L*COS(L))
2860 HO=SIN(L)-L-N3A*COS(L)
2870 YD(0)=(-SIN(X)+N3A*COS(X)+X+HO)*M1/M2
2880 BB=57.29*ATN(YD(0))
2890 GOTO 3000
2900 REM ***** FUNCTION FOR CONTACT POINT BETWEEN BIT AND STABILIZER *****
2910 N3A=(1+CD-COS(L)+.5*L^2-L*SIN(L))/(SIN(L)-L*COS(L))
2920 NUMER=((CST1-CD-.5*(D1^2-L^2))*SIN(D1-L)+(L+D1)*(1-COS(D1-L)))
2930 DENOM=(2*COS(D1-L)+(D1-L)*SIN(D1-L)-2)
2940 HB=NUMER/DENOM
2950 X=0
2960 N3B=((D1+HB)*SIN(L)-(L+HB)*SIN(D1))/SIN(D1-L)
2970 N2B=((D1+HB)*COS(L)-(L+HB)*COS(D1))/(SIN(D1-L))
2980 F=COS(L)*(1-N2B)+SIN(L)*(N3A-N3B)
2990 RETURN
3000 X=0
3010 NUMER=((CST1-CD-.5*(D1^2-L^2))*SIN(D1-L)+(L+D1)*(1-COS(D1-L)))
3020 DEN=(2*COS(D1-L)+(D1-L)*SIN(D1-L)-2)
3030 HB=NUMER/DEN
3040 HC=HO-HB
3050 PRINT "BETA (deg) = ";BB
3060 PHI=57.29*ATN((SQR(EI/W)*P*SIN(AA/57.29)*HO)/W)+AA
3070 PRINT "PHI (deg) = ";PHI
3080 PRINT "HO (lb's) = ";HO*M3
3090 PRINT "HC (lb's) = ";HC*M3
3100 IF (HARD=1) THEN GOTO 3120
3110 GOTO 3150
3120 LPRINT " CONTACT POINT PRESENT AT X = ";X/M1:LPRINT:LPRINT
3130 GOSUB 3700
3140 REM ***** DETERMINE Y, SLOPE, MOMENT FOR SEGMENT A *****
3150 PRINT " X Y SLOPE
OMENT"
3160 PRINT " ----- ----- ----- "

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3170 DXA=(L/5):I=0:X=0
3180 FOR Q=0 TO 5
3190 Y(Q)=(-1+COS(X)+N3A*SIN(X)+HO*X+.5*X^2)*M1
3200 YD(Q)=(-SIN(X)+N3A*COS(X)+HO+X)*M1/M2
3210 YDD(Q)=(-EI*(-COS(X)-N3A*SIN(X)+1))*M1/(M2^2)
3220 X=X+DXA
3230 LSTX=X
3240 NEXT Q
3250 DIMX=0
3260 FOR I= 0 TO 5
3270 PRINT " ";DIMX;" ";Y(I);";YD(I);";YDD(I)
3280 DIMX=DIMX+DXA*M2
3290 NEXT I
3300 PRINT:PRINT
3310 X=L
3320 N2B=((D1+HB)*COS(L)-(L+HB)*COS(D1))/SIN(D1-L)
3330 N3B=((D1+HB)*SIN(L)-(L+HB)*SIN(D1))/SIN(D1-L)
3340 N1=(CST1*L-CD*D1)+.5*(L^2*D1-D1^2*L)+N2B*(D1*COS(L)-L*COS(D1))
3350 N2=N3B*(D1*SIN(L)-L*SIN(D1))
3360 DEN=(L-D1)
3370 N1B=(N1+N2)/DEN
3380 DXB=(D1-L)/5
3390 PRINT" X Y SLOPE MOMENT"
3400 PRINT" ----- ----- ----- -----"
3410 I=6
3420 Y(I)=(N1B+N2B*COS(X)+N3B*SIN(X)+HB*X+.5*X^2)*M1
3430 YD(I)=(-N2B*SIN(X)+N3B*COS(X)+HB+X)*M1/M2
3440 YDD(I)=-EI*(-N2B*COS(X)-N3B*SIN(X)+1)*M1/(M2^2)
3450 X=X+DXB:I=I+1
3460 IF (I<12) GOTO 3420
3470 DIMX=L*M2
3480 FOR I= 6 TO 11
3490 PRINT " ";DIMX;" ";Y(I);";YD(I);";YDD(I)
3500 DIMX=DIMX+DXB*M2
3510 NEXT I
3520 INPUT "DO YOU WANT A HARD COPY OF Y, SLOPE, MOMENT Vs X; 1-YES,2-NO";CH
3530 IF (CH=1) THEN GOSUB 4010
3540 GOSUB 4180
3550 GOTO 1980
3560 END
3570 REM ***** HARD COPY OF INPUT DATA *****
3580 LPRINT " D1 (ft) = ";D11
3590 LPRINT " DH (in) = ";DH*12
3600 LPRINT " ODdc (in) = ";OD*12
3610 LPRINT " IDdc (in) = ";ID*12
3620 LPRINT " Dh (in) = ";DH*12
3630 LPRINT " MW (PPg) = ";MW
3640 LPRINT " ALPHA (deg) = ";AA
3650 LPRINT " WOB (lb's) = ";W
3660 LPRINT " P (lb's/ft in fluid) = ";P
3670 LPRINT " I (in^4) = ";I
3680 LPRINT:LPRINT
3690 RETURN
3700 REM ***** HARD COPY OF HO, BETA, HC, PHI *****

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3710 LPRINT "BETA (deg) =           ";BB
3720 LPRINT "HO (lb's) =           ";HO*M3
3730 LPRINT "HC (lb's) =           ";HC*M3
3740 LPRINT "PHI (deg) =           ";PHI
3750 RETURN
3760 REM ***** HARD COPY SEGMENT A NO CONTACT POINT *****
3770 LPRINT;LPRINT" SEGMENT A BIT TO STABILIZER "
3780 LPRINT"      X          Y          SLOPE
      MOMENT"
3790 LPRINT"      -----      -----      -----
      -----"
3800 DIMX=.000001
3810 FOR K=0 TO 5
3820 LPRINT"      ";DIMX;"      ";Y(K);"      ";YD(K);"      ";YDD(K)
3830 DIMX=DIMX+DX1*M2
3840 NEXT K
3850 DIMX=SLP0*M2
3860 FOR J=6 TO 10
3870 DIMX=DIMX+DX2*M2
3880 LPRINT"      ";DIMX;"      ";Y(J);"      ";YD(J);"      ";YDD(J)
3890 NEXT J
3900 RETURN
3910 REM ***** HARD COPY OF SEGMENT B NO CONTACT PRESENT *****
3920 LPRINT;LPRINT" SEGMENT B STABILIZER TO TANGENCY POINT "
3930 LPRINT"      X          Y          SLOPE      M
      MOMENT"
3940 LPRINT"      -----      -----      -----
      -----"
3950 DIMX=D1*M2
3960 FOR I=11 TO 21
3970 LPRINT"      ";DIMX;"      ";Y(I);"      ";YD(I);"      ";YDD(I)
3980 DIMX=DIMX+DX3*M2
3990 NEXT I
4000 RETURN
4010 REM ***** HARD COPY OF SEGMENT A AND B CONTACT POINT PRESENT *****
4020 LPRINT;LPRINT
4030 LPRINT"SEGMENT A AND B (BIT TO STABILIZER)":LPRINT
4040 DIMX=0
4050 LPRINT"      X          Y          SLOPE
      MOMENT"
4060 LPRINT"      -----      -----      -----
      -----"
4070 FOR J=0 TO 5
4080 LPRINT"      ";DIMX;"      ";Y(J);"      ";YD(J);"      ";
YDD(J)
4090 DIMX=DIMX+DXA*M2
4100 NEXT J
4110 DIMX=L*M2
4120 FOR I= 6 TO 11
4130 LPRINT"      ";DIMX;"      ";Y(I);"      ";YD(I);"      ";
YDD(I)
4140 DIMX=DIMX+DXB*M2
4150 NEXT I
4160 RETURN
4170 REM
4180 REM THIS SECTION CALCULATES THE DISTANCE TO TANGENCY CONTACT POINT PRESENT

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4190 FOR I= 1 TO COUNT
4200 ROOT(I)=0
4210 NEXT I
4220 POS1=1:L=D1+.01
4230 COUNT =0
4240 NUMC=(COS(L-D1)+L*SIN(L-D1)-.5*L^2-(CST1-.5*D1^2-CD+1))
4250 DENC=(L-D1-SIN(L-D1))
4260 HC=NUMC/DENC
4270 C1C=-HC*L-.5*L^2+CD-1
4280 C2C=COS(L)+(L+HC)*SIN(L)
4290 C3C=SIN(L)-(L+HC)*COS(L)
4300 F=-C2C*SIN(D1)+C3C*COS(D1)+D1+HC
4310 IF F<0 THEN POS1=2
4320 DX=.1
4330 ITER =1
4340 LPR=L
4350 L=LPR+DX
4360 IF L>12 THEN 4620
4370 NUMC=COS(L-D1)+L*SIN(L-D1)-.5*L^2-(CST1-.5*D1^2-CD+1)
4380 DENC=L-D1-SIN(L-D1)
4390 HC=NUMC/DENC
4400 C2C=COS(L)+(HC+L)*SIN(L)
4410 C3C=SIN(L)-(HC+L)*COS(L)
4420 F=-C2C*SIN(D1)+C3C*COS(D1)+D1+HC
4430 IF F<0 THEN 4460
4440 POS2=1
4450 GOTO 4470
4460 POS2=2
4470 IF POS2<>POS1 THEN 4500
4480 LPR=L
4490 GOTO 4350
4500 IF ITER=1 THEN 4540
4510 IF ITER=2 THEN 4560
4520 IF ITER=3 THEN 4580
4530 IF ITER=4 THEN 4600
4540 DX=.01: ITER=2
4550 GOTO 4350
4560 DX=.001: ITER=3
4570 GOTO 4350
4580 DX=.0001: ITER=4
4590 GOTO 4350
4600 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
4610 GOTO 4350
4620 FOR I=1 TO COUNT
4630 PRINT "ROOT(";I;") = ";ROOT(I)
4640 NEXT I
4650 L=ROOT(1)
4660 DXC=(L-D1)/10

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4670 NUMC=COS(L-D1)+L*SIN(L-D1)-.5*L^2-(CST1-.5*D1^2-CD+1)
4680 DENC=L-D1-SIN(L-D1)
4690 HC=NUMC/DENC
4700 C1C=-HC*L-.5*L^2+CD-1
4710 C2C=COS(L)+(L+HC)*SIN(L)
4720 C3C=SIN(L)-(L+HC)*COS(L)
4730 X=D1
4740 FOR J=12 TO 22
4750 Y(J)=M1*(C1C+C2C*COS(X)+C3C*SIN(X)+.5*X^2+HC*X)
4760 YD(J)=M1/M2*(-C2C*SIN(X)+C3C*COS(X)+HC+X)
4770 YDD(J)=-EI*M1/(M2^2)*(-C2C*COS(X)-C3C*SIN(X)+1)
4780 X=X+DXC
4790 NEXT J
4800 PRINT:PRINT
4810 PRINT " SEGMENT C STABILIZER TO TANGENCY POINT(CONTACT POINT PRESENT)"
4820 DIMX=D1*M2
4830 PRINT " X Y SLOPE MOME
NT"
4840 PRINT " ----- ----- ----- -----
4850 FOR I=12 TO 22
4860 PRINT " ;DIMX; ";Y(I); ";YD(I); ";YDD(I)
)
4870 DIMX=DIMX+DXC*M2
4880 NEXT I
4890 IF (CH=1) THEN GOTO 4910
4900 GOTO 5000
4910 LPRINT:LPRINT
4920 LPRINT " SEGMENT C STABILIZER TO TANGENCY POINT(CONTACT POINT PRESENT)":LPRI
NT
4930 LPRINT " X Y SLOPE MOME
NT"
4940 LPRINT " ----- ----- ----- -----
4950 DIMX=D1*M2
4960 FOR I= 12 TO 22
4970 LPRINT " ;DIMX; ";Y(I); ";YD(I); ";YDD(I)
4980 DIMX=DIMX+DXC*M2
4990 NEXT I
5000 RETURN

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```

10 REM THIS PROGRAM WILL DRILL A HOLE BASED ON FORCES PRESENT AT THE BIT,
20 REM WHICH IN TURN IS DEPENDENT UPON PLACEMENT OF THE ZERO CLEARANCE
30 REM STABILIZER.
40 REM
50 REM
60 REM
70 REM FIRST, THE PROGRAM CALCULATES L, HO, BETA, PHI, THEN PSI, WHICH IS
80 REM THE NEW TRAJECTORY OF THE BORE HOLE. CONVERGENCE TO THE EQUILIBRIUM
90 REM ANGLE IS REACHED WHEN DELTA ALPHA IS LESS THAN .01 deg.
94 REM
100 CLS
110 DEFDBL F,L,X,N
120 DIM Y(450),YD(450),YDD(450)
130 INPUT "DISTANCE TO STABILIZER 1 (ft) : ";D11
140 INPUT "Dh=";DH;DH=DH/12
150 INPUT "ODdc(in)=";OD;OD=OD/12
160 INPUT "IDdc(in)=";ID;ID=ID/12
170 INPUT "MW(ppg)=";MW
179 INPUT "HOLE INCLINATION (deg)= ";AA
180 INPUT "FORMATION DIP GAMA(deg)=";GAMA
182 INPUT "FORMATION ANISOTROPY INDEX, FAI=";FAI
190 INPUT "WOB(1000 lb)=";W;W=1000*W
200 DST1=DH
210 REM ***** PRINT INPUT DATA *****
220 CLS
230 PRINT " D1 (ft)=      ";D11
240 PRINT " Dh (in) =     ";DH*12
250 PRINT " ODdc (in) =    ";OD*12
260 PRINT " IDdc (in) =    ";ID*12
270 PRINT " ODst (in) =    ";DH*12
280 PRINT " MW (ppg) =     ";MW
290 PRINT " ALPHA (deg) =  ";AA
300 PRINT " WOB (lb's) =   ";W
310 REM ***** CALCULATE DIMENSIONLESS QUANTITIES *****
312 XX=1
320 WU=3.14159*((OD/2)^2-(ID/2)^2)*489
330 C=(DH-OD)/2
340 CST1=(DH-DST1)/2
350 P=WU*(1-MW/65.4)
360 I=3.14*(OD^4-ID^4)/64
370 PRINT "P (lb's/ft) =   ";P
380 PRINT "I (ft^4) =      ";I
390 PRINT:PRINT
400 EI=4176*10^6*I
410 D1=(D11*SQR(W/EI))
412 INPUT "DO YOU WANT A HARD COPY, 1-YES, 2-NO";HARD
414 IF (HARD=1) THEN GOSUB 3570
420 CD=(W^2*C)/(EI*P*SIN(AA/57.29))
430 REM**** DIMENSIONLESS CONVERSION FACTORS ****
440 M1=EI*P*SIN(AA/57.29)/(W^2)
450 M2=SQR(EI/W)
460 M3=SQR(EI/W)*P*SIN(AA/57.29)

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470 REM *****
480 CST1=(W^2*CST1)/(EI*P*SIN(AA/57.29))
510 REM ***** SOLVES FOR DISTANCE TO TANGENCY POINT *****
520 L=D1+.01
530 POS1=1
540 COUNT=0
550 XTERM= CD-CST1-1+.5*D1^2
560 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)
570 F=XTERM-.5*L^2+COS(L-D1)+L*SIN(L-D1)+H*(D1-L+SIN(L-D1))
580 IF F<0 THEN POS1=2
590 DX=.1
600 ITER=1
610 LPR=L
620 L=LPR+DX
530 IF L>15 THEN 890
540 XTERM=CD-CST1-1+.5*D1^2
550 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)
560 F=XTERM-.5*L^2+COS(L-D1)+L*SIN(L-D1)+H*(D1-L+SIN(L-D1))
570 IF F<0 THEN 700
580 POS2=1
590 GOTO 710
600 POS2=2
710 IF POS2<>POS1 THEN 740
720 LPR=L
730 GOTO 620
740 IF ITER=1 THEN 790
750 IF ITER=2 THEN 810
760 IF ITER=3 THEN 830
770 IF ITER=4 THEN 850
780 IF ITER=5 THEN 870
790 DX=.01: ITER=2
800 GOTO 620
810 DX=.001: ITER=3
820 GOTO 620
830 DX=.0001: ITER=4
840 GOTO 620
850 DX=.00001: ITER=5
860 GOTO 620
870 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
880 GOTO 620
890 FOR I=1 TO COUNT
900 PRINT "ROOT(";I;") = ";ROOT(I)
910 NEXT I
920 REM ***** DETERMINATION OF BETA, PHI, HO, AND H1 *****
930 I=0
940 L=ROOT(1)
950 PRINT "L= ";L
960 I=I+2
970 DX=D1/I
980 IF(DX>.025)THEN GOTO 960
990 H=(SIN(L-D1)-L*COS(L-D1)+D1)/(COS(L-D1)-1)
1000 HO=(SIN(D1)-(CST1+1-COS(D1)-.5*D1^2)*1/TAN(D1)-D1)/(1-D1*I/TAN(D1))

```

```

1010 H1=H0-H
1020 C3A=(CST1+1-COS(D1)-.5*D1^2-H0*D1)/SIN(D1)
1030 Y(0)=(C3A+H0)*SQR(W/EI)*M1/M2
1040 BB=57.29*ATN(Y(0))
1050 HOU=H0*M3:H1U=H1*M3
1060 PHI=57.29*ATN(HOU/W)+AA
1070 PRINT
1080 REM ***** DETERMINES IF POINT OF CONTACT IS PRESENT *****
1090 PRINT
1100 I=-1 : DX=.01:X=0
1110 I=I+1
1120 Y(I)=-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2
1130 X=X+DX
1140 IF (Y(I)>CD) OR (Y(I)=CD) THEN GOTO 2380
1150 IF (X<D1) THEN GOTO 1110
1160 PRINT"BETA (deg) = ";BB
1170 PRINT"PHI (deg) = ";PHI
1180 PRINT"H0 (lb's) = ";H0*M3
1190 NN=D1/.01
1200 FOR I=0 TO NN
1210 Y(I)=0
1220 NEXT I
1230 PSI=GAMA+57.29*ATN((1-FAI)*TAN((PHI-GAMA)/57.29))
1240 PRINT "PSI = ";PSI
1250 PRINT "ITERATION # ";XX
1255 DA=ABS(PSI-AA)
1260 AA=PSI
1265 XX=XX+1
1270 SUML=L+SUML
1272 PRINT "FOOTAGE DRILLED = ";SUML*M2
1273 PRINT:PRINT
1280 IF (DA>.1) THEN GOTO 420
1288 PRINT:PRINT
1290 PRINT "EQUILIBRIUM ANGLE REACHED AT ALPHA = ";AA
1300 PRINT "FOOTAGE DRILLED = ";SUML*M2
1310 PRINT "HO = ";H0*M3
1320 PRINT "# OF ITERATIONS = ";XX-1
1330 GOTO 4731
1340 INPUT "DO YOU WISH TO CONTINUE WITH ANOTHER RUN ? 1-YES, 0-NO";DEC1
1350 IF (DEC1=0) THEN GOTO 4740
1360 PRINT
1370 INPUT "WOULD YOU LIKE TO CHANGE ANY VARIABLES ? 1-YES, 0-NO";DEC2
1380 IF (DEC2=0) GOTO 220
1390 REM ***** DATA CHANGE SECTION *****
1400 CLS
1410 PRINT "CODE #      VARIABLE"
1420 PRINT "-----"
1430 PRINT " 1      ----- Oh"
1440 PRINT " 2      ----- ODDc"
1450 PRINT " 3      ----- IDdc"
1460 PRINT " 4      ----- Wdc"
1470 PRINT " 5      ----- MW"
1480 PRINT " 6      ----- ALPHA"
1490 PRINT " 7      ----- GAMA"
1500 PRINT " 8      ----- WOB"
1510 PRINT " 9      ----- h"
1520 PRINT " 10     ----- ODst"
1530 PRINT " 11     ----- Dst1 "

```

```

2180 PRINT
2190 PRINT "INPUT THE CORRESPONDING CODE FOR THE VARIABLES YOU WISH TO CHANGE,"
2200 PRINT "ENTER THEM ONE PER LINE ----ENTER 0 WHEN FINISHED"
2210 INPUT "CODE # = ";CN
2220 IF (CN=0) THEN GOTO 220
2230 IF (CN=1) THEN INPUT "Dh (in) = ";DH:DH=DH/12
2240 IF (CN=2) THEN INPUT "ODdc (in) = ";OD:OD=OD/12
2250 IF (CN=3) THEN INPUT "IDdc (in) = ";ID:ID=ID/12
2260 IF (CN=4) THEN INPUT "Wdc (in) = ";WU
2270 IF (CN=5) THEN INPUT "MW (PPg) = ";MW
2280 IF (CN=6) THEN INPUT "ALPHA (deg) = ";AA:AO=AA
2290 IF (CN=7) THEN INPUT "GAMA (deg) = ";GA
2300 IF (CN=8) THEN INPUT "WOB (1000'S lbs) = ";W:W=1000*W
2310 IF (CN=9) THEN INPUT " h = ";DAI
2320 IF (CN=10) THEN INPUT " ODst(in) = ";DST1:DST1=DST1/12
2330 IF (CN=11) THEN INPUT " Dst1(ft) = ";D11
2340 IF (CN<0)OR(CN>11) THEN GOTO 2360
2350 GOTO 2210
2360 PRINT "INPUT VALUE MUST BE BETWEEN 0 AND 10 INCLUSIVE"
2370 GOTO 2210
2380 L=.01
2390 IF (HARD=1) THEN LPRINT"***** CONTACT POINT BETWEEN BIT AND STABILIZER ****"
2400 IF(HARD=1) THEN LPRINT:LPRINT
2410 PRINT "***** CONTACT POINT BETWEEN THE BIT AND STABILIZER *****"
2420 GOSUB 2900
2430 POS1=1
2440 COUNT=0
2450 IF F<0 THEN POS1=2
2460 DX=.1
2470 ITER =1
2480 LPR=L
2490 L=LPR+DX
2500 IF (L>D1) GOTO 2790
2510 GOSUB 2900
2520 IF F<0 THEN 2550
2530 POS2=1
2540 GOTO 2560
2550 POS2=2
2560 IF POS2<>POS1 THEN 2590
2570 LPR=L
2580 GOTO 2490
2590 IF ITER=1 THEN 2660
2600 IF ITER=2 THEN 2680
2610 IF ITER=3 THEN 2700
2620 IF ITER=4 THEN GOTO 2720
2630 IF ITER=5 THEN GOTO 2740
2640 IF ITER=6 THEN GOTO 2760
2650 IF ITER=7 THEN 2780
2660 DX=.01: ITER=2
2670 GOTO 2490
2680 DX=.001: ITER=3
2690 GOTO 2490
2700 DX=.0001 : ITER = 4

```

```

2710 GOTO 2490
2720 DX=.00001:ITER=5
2730 GOTO 2490
2740 DX=.000001:ITER=6
2750 GOTO 2490
2760 DX=.0000001:ITER=7
2770 GOTO 2490
2780 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
2790 FOR I=1 TO COUNT
2800 PRINT "CONTACT POINT = ";ROOT(1)
2810 NEXT I
2820 REM ***** DETERMINES HQ, HC, H1, BETA, PHI *****
2830 L=ROOT(1)
2840 X=0
2850 N3A=(1+CD-COS(L)+.5*L^2-L*SIN(L))/(SIN(L)-L*COS(L))
2860 HO=SIN(L)-L-N3A*COS(L)
2870 YD(0)=(-SIN(X)+N3A*COS(X)+X+HO)*M1/M2
2880 BB=57.29*ATN(YD(0))
2890 GOTO 3000
2900 REM ***** FUNCTION FOR CONTACT POINT BETWEEN BIT AND STABILIZER *****
2910 N3A=(1+CD-COS(L)+.5*L^2-L*SIN(L))/(SIN(L)-L*COS(L))
2920 NUMER=((CST1-CD-.5*(D1^2-L^2))*SIN(D1-L)+(L+D1)*(1-COS(D1-L)))
2930 DENOM=(2*COS(D1-L)+(D1-L)*SIN(D1-L)-2)
2940 HB=NUMER/DENOM
2950 X=0
2960 N3B=((D1+HB)*SIN(L)-(L+HB)*SIN(D1))/SIN(D1-L)
2970 N2B=((D1+HB)*COS(L)-(L+HB)*COS(D1))/SIN(D1-L)
2980 F=COS(L)*(1-N2B)+SIN(L)*(N3A-N3B)
2990 RETURN
3000 X=0
3010 NUMER=((CST1-CD-.5*(D1^2-L^2))*SIN(D1-L)+(L+D1)*(1-COS(D1-L)))
3020 DEN=(2*COS(D1-L)+(D1-L)*SIN(D1-L)-2)
3030 HB=NUMER/DEN
3040 HC=HO-HB
3045 PRINT:PRINT
3050 PRINT "BETA (deg) = ";BB
3060 PHI=57.29*ATN((SQR(EI/W)*P*SIN(AA/57.29)*HO)/W)+AA
3070 PRINT "PHI (deg) = ";PHI
3080 PRINT "HO (lb's) = ";HO*M3
3090 PRINT "HC (lb's) = ";HC*M3
3095 GOTO 4180
3570 REM ***** HARD COPY OF INPUT DATA *****
3580 LPRINT " D1 (ft) = ";D11
3590 LPRINT " DH (in) = ";DH*12
3600 LPRINT " ODdc (in) = ";OD*12
3610 LPRINT " IDdc (in) = ";ID*12
3620 LPRINT " Dh (in) = ";DH*12
3630 LPRINT " MW (PPg) = ";MW
3640 LPRINT " ALPHA (deg) = ";AA
3650 LPRINT " WOB (lb's) = ";W
3660 LPRINT " P (lb's/ft in fluid) = ";P
3670 LPRINT " I (in^4) = ";I
3680 LPRINT:LPRINT
3690 RETURN
3700 REM ***** HARD COPY OF HO, BETA, HC, PHI *****
3710 LPRINT "BETA (deg) = ";BB
3720 LPRINT "HO (lb's) = ";HO*M3
3730 LPRINT "HC (lb's) = ";HC*M3

```

```

3740 LPRINT "PHI (deg) =           "; PHI
3750 RETURN
4180 REM THIS SECTION CALCULATES THE DISTANCE TO TANGENCY CONTACT POINT PRESENT
4190 FOR I= 1 TO COUNT
4200 ROOT(I)=0
4210 NEXT I
4220 POS1=1:L=D1+.01
4230 COUNT =0
4240 NUMC=(COS(L-D1)+L*SIN(L-D1)-.5*L^2-(CST1-.5*D1^2-CD+1))
4250 DENC=(L-D1-SIN(L-D1))
4260 HC=NUMC/DENC
4270 C1C=-HC*L-.5*L^2+CD-1
4280 C2C=COS(L)+(L+HC)*SIN(L)
4290 C3C=SIN(L)-(L+HC)*COS(L)
4300 F=-C2C*SIN(D1)+C3C*COS(D1)+D1+HC
4310 IF F<0 THEN POS1=2
4320 DX=.1
4330 ITER =1
4340 LPR=L
4350 L=LPR+DX
4360 IF L>12 THEN 4620
4370 NUMC=COS(L-D1)+L*SIN(L-D1)-.5*L^2-(CST1-.5*D1^2-CD+1)
4380 DENC=L-D1-SIN(L-D1)
4390 HC=NUMC/DENC
4400 C2C=COS(L)+(HC+L)*SIN(L)
4410 C3C=SIN(L)-(HC+L)*COS(L)
4420 F=-C2C*SIN(D1)+C3C*COS(D1)+D1+HC
4430 IF F<0 THEN 4460
4440 POS2=1
4450 GOTO 4470
4460 POS2=2
4470 IF POS2<>POS1 THEN 4500
4480 LPR=L
4490 GOTO 4350
4500 IF ITER=1 THEN 4540
4510 IF ITER=2 THEN 4560
4520 IF ITER=3 THEN 4580
4530 IF ITER=4 THEN 4600
4540 DX=.01: ITER=2
4550 GOTO 4350
4560 DX=.001: ITER=3
4570 GOTO 4350
4580 DX=.0001: ITER=4
4590 GOTO 4350
4600 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
4610 GOTO 4350
4620 FOR I=1 TO COUNT
4630 PRINT "ROOT(";I;") = ";ROOT(I)
4640 NEXT I
4650 L=ROOT(1)
4670 PSI=GAMA+57.29*ATN((1-FAI)*TAN((PHI-GAMA)/57.29))
4673 PRINT "PSI = ";PSI
4674 PRINT "ITERATION # ";XX
4675 XX=XX+1
4680 SUML=L+SUML
4682 PRINT "FOOTAGE DRILLED = ";SUML*M2
4684 PRINT:PRINT

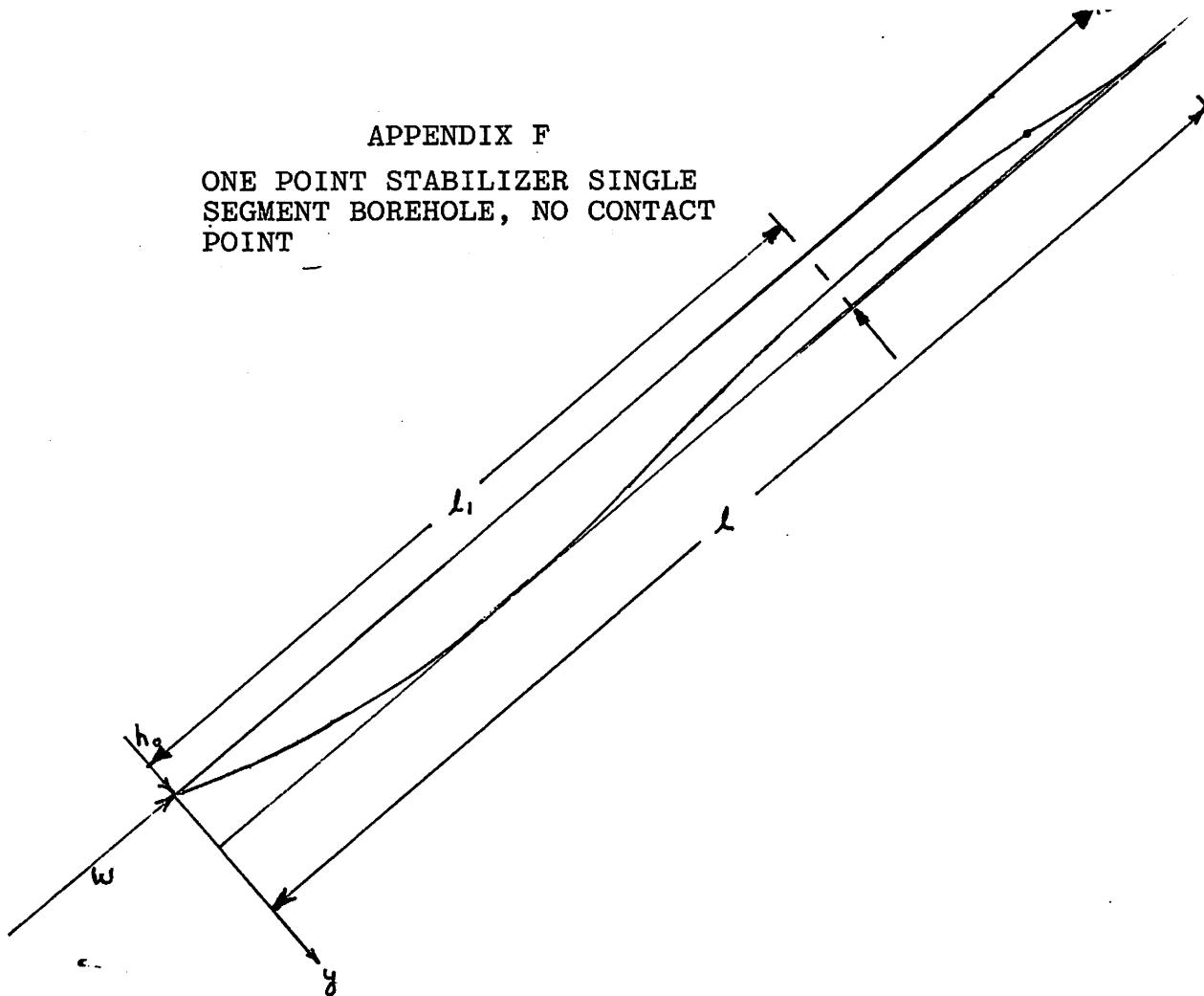
```

```
4690 DA=ABS(PSI-AA)
4700 AA=PSI
4710 IF (DA>.1) THEN GOTO 420
4720 PRINT "EQUILIBRIUM ANGLE REACHED AT ALPHA = ";AA
4730 PRINT "FOOTAGE DRILLED = ";SUML*M2
4731 LPRINT "EQUILIBRIUM ANGLE REACHED AT ALPHA = ";AA
4732 LPRINT "FOOTAGE DRILLED = ";SUML*M2
4733 LPRINT "HO = ";HO*M3
4734 LPRINT "# OF ITERATIONS = ";XX-1
4735 GOTO 1980
4740 END
```

**APPENDIX F**

APPENDIX F

ONE POINT STABILIZER SINGLE  
SEGMENT BOREHOLE, NO CONTACT  
POINT



Segment A      Range:  $0 \leq x < l_1$  ;  $h_A = h_o$

$$\text{B.C. } x = 0 \quad y_A = 0 \quad \text{bit centered in hole} \quad C_{1A} \quad (\text{F-1})$$

$$x = 0 \quad y''_A = 0 \quad \text{no moment at bit} \quad C_{2A} \quad (\text{F-2})$$

Segment B      Range:  $l_1 \leq x \leq \ell$  ;  $h_B = h - h_o$

$$\text{B.C. } x = l_1 \quad y_B = C_{st} \quad h_B \quad (\text{F-3})$$

$$x = \ell \quad y_B = C_{dc} \quad C_{1B} \quad (\text{F-4})$$

$$x = \ell \quad y'_B = 0 \quad C_{2B} \quad (\text{F-5})$$

$$x = \ell \quad y''_B = 0 \quad C_{3B} \quad (\text{F-6})$$

$$y = C_1 + C_2 \cos(x) + C_3 \sin(x) + \frac{1}{2} x^2 + hx$$

$$y' = -C_2 \sin(x) + C_3 \cos(x) + x + h$$

$$y'' = -C_2 \cos(x) - C_3 \sin(x) + 1$$

### Segment A

$$x = 0 \quad y_A = 0$$

$$0 = C_1 + C_2 \quad C_1 = -C_2$$

$$x = 0 \quad y''_A = 0$$

$$0 = -C_2 + 1 \quad C_2 = 1 \quad C_1 = -1$$

We now have

$$y_A = -1 + \cos(x) + C_{3A} \sin(x) + \frac{1}{2} x^2 + h_0 x \quad (F-7)$$

### Segment B

$$x = \ell \quad y''_B = 0$$

$$0 = -C_{2B} \cos(\ell) - C_{3B} \sin(\ell) + 1$$

$$C_{2B} = \frac{-C_{3B} \sin(\ell) + 1}{-\cos(\ell)} = \frac{C_{3B} \sin(\ell) - 1}{\cos(\ell)} \quad (F-8)$$

$$x = \ell \quad y'_B = 0$$

$$0 = -C_{2B} \sin(\ell) + C_{3B} \cos(\ell) + \ell + h$$

$$C_{3B} = \frac{-C_{2B} \sin(\ell) + (\ell + h)}{-\cos(\ell)} = \frac{-(\ell + h) + C_{2B} \sin(\ell)}{\cos(\ell)} \quad (F-9)$$

Substituting (F-9) into (F-8)

$$C_{2B} = \frac{[-C_{2B} \sin(\ell) + a]}{\cos^2(\ell)} \sin(\ell) + 1/\cos(\ell)$$

$$C_{2B} \cos^2(\ell) = - C_{2B} \sin^2(\ell) + (\ell + h_B) \sin(\ell) + \cos(\ell)$$

$$C_{2B} = \cos(\ell) + (\ell + h_B) \sin(\ell)$$

(F-10)

substituting (F-10) into (F-9)

$$C_{3B} = \frac{(-\cos(\ell) - (\ell + h_B) \sin(\ell)) \sin(\ell) + (\ell + h_B)}{-\cos(\ell)}$$

$$- C_{3B} \cos(\ell) = - \cos(\ell) \sin(\ell) - a \sin^2(\ell) + (\ell + h_B)$$

$$C_{3B} = \sin(\ell) - (\ell + h_B) \cos(\ell)$$

(F-11)

$$x = \ell \quad y_B = C_{dc}$$

$$C_{dc} = C_1 + [\cos(\ell) + (\ell + h_B) \sin(\ell)] \cos(\ell) + [\sin(\ell) - (\ell + h_B) \cos(\ell)] \sin(\ell) + \frac{1}{2}\ell^2 + h_B \ell$$

$$C_{1B} = - h_B \ell - \frac{1}{2}\ell^2 + C_{dc} - 1 + (\ell + h_B) \cos(\ell) \sin(\ell) - (\ell + h_B) \cos(\ell) \sin(\ell)$$

$$C_{1B} = C_{dc} - 1 - \frac{1}{2}\ell^2 - h_B \ell$$

(F-12)

$$x = \quad y_B = C_{st}$$

$$C_{st} = (C_{dc} - 1 - \frac{1}{2}\ell^2 - h_B \ell) + [\cos(\ell) + (\ell + h_B) \sin(\ell)] \cos(\ell) + [\sin(\ell) - (\ell + h_B) \cos(\ell)] \sin(\ell) + \frac{1}{2}\ell^2 + h_B \ell$$

$$(C_{st} - C_{dc} + 1 + \frac{1}{2}\ell^2 - \frac{1}{2}\ell_1^2) = \cos(\ell) \cos(\ell_1) + \\ + (\ell + h_B) \cos(\ell_1) \sin(\ell) + \sin(\ell) \sin(\ell_1) - (\ell + h_B) \\ \cos(\ell) \sin(\ell_1) + h_B(\ell_1 - \ell)$$

$$[C_{st} - C_{dc} + 1 + \frac{1}{2}(\ell^2 - \ell_1^2)] = \cos(\ell - \ell_1) + (\ell + h_B) \\ \sin(\ell - \ell_1) + h_B(\ell_1 - \ell)$$

$$h_B = \frac{C_{st} - C_{dc} + 1 + \frac{1}{2}(\ell^2 - \ell_1^2) - \cos(\ell - \ell_1) - \ell \sin(\ell - \ell_1)}{[(\ell_1 - \ell) + \sin(\ell - \ell_1)]} \quad (F-13)$$

### Continuity Conditions

$$X = \ell_1 \quad y_A = B = C_{st} \quad (F-14)$$

$$X = \ell_1 \quad y'_A = y'_B \quad (F-15)$$

$$X = \ell_1 \quad y''_A = y''_B \quad (F-16)$$

$$X = \ell_1 \quad y_A = C_{st}$$

$$C_{st} = -1 + \cos(\ell_1) + C_{3A} \sin(\ell_1) + \frac{1}{2}\ell_1^2 + h_O \ell_1$$

$$C_{3A} = \frac{[1 + C_{st} - \frac{1}{2}\ell_1^2 - \cos(\ell_1) - h_O \ell_1]}{\sin(\ell_1)} \quad (F-17)$$

$$X = \ell_1 \quad y''_A = y''_B$$

$$\cos(\ell_1) + C_{3A} \sin(\ell_1) + 1 = [\cos(\ell) + (\ell + h_B) \sin(\ell)] \\ \cos(\ell_1) + [\sin(\ell) - (\ell + h_B) \cos(\ell)] \sin(\ell_1) + 1$$

$$\begin{aligned}
 C_3 A \sin(\ell_1) &= \cos(\ell) \cos(\ell_1) + (\ell + h_B) \sin(\ell) \sin(\ell_1) \\
 &+ \sin(\ell) \sin(\ell_1) - (\ell + h_B) \cos(\ell) \sin(\ell_1) - \cos(\ell_1) \\
 - h_O \ell_1 &= (\frac{1}{2} \ell_1^2 - C_{st} - 1) + \cos(\ell - \ell_1) + (\ell + h_B) \sin(\ell - \ell_1)
 \end{aligned}$$

$$h_O = \frac{(1+C_{st}-\frac{\ell_1^2}{2})-\cos(\ell - \ell_1)-(\ell + h_B)\sin(\ell - \ell_1)}{\ell_1}$$

(F-18)

$$X = \ell_1 \quad y'_A = y'_B$$

$$\begin{aligned}
 -\sin(\ell_1) + C_3 A \cos(\ell_1) + \ell_1 + h_O &= -[\cos(\ell) + (\ell + h_B) \sin(\ell)] \\
 \sin(\ell_1) + [\sin(\ell) - (\ell + h_B) \cos(\ell)] \cos(\ell_1) + \ell_1 + h_B
 \end{aligned}$$

Solving for 0 on the l.h.s.

$$\begin{aligned}
 0 &= -C_2 B \sin(\ell_1) + C_3 B \cos(\ell_1) + h - h_O - C_3 A \cos(\ell_1) \\
 &+ \sin(\ell_1)
 \end{aligned}$$

$$0 = (1 - C_2 B) \sin(\ell_1) + (C_3 B - C_3 A) \cos(\ell_1) + h_B - h_O$$

(F-19)

NUMBERIC VERIFICATION OF RESULTS  
FOR THE SINGLE SEGMENT POINT STABILIZER MODEL

Starting with the simplified differential equation for bending.

$$EI \ Y''' + W \ Y' = H + XP \ sin(\alpha) \quad (F-20)$$

Integrating (F-20)

$$EI \ Y'' + WY ]_0^{d_1} = \frac{H_O X + X^2 P \ sin(\alpha)}{2} ]_0^{d_1}$$

$$Y''(0) = 0 @ X = 0 \quad Y(d_1) = C_{st}$$

$$Y(0) = 0 \quad X = d_1$$

$$EI \ Y''(d_1) + W \ C_{st} = H_O \ d_1 + \frac{d_1^2 \ P \ sin(\alpha)}{2} \quad (F-21)$$

Integrating (F-20) from  $d_1$  to L

$$EI \ Y'' + WY ]_{d_1}^L = H_1 X + \frac{X^2 P \ sin(\alpha)}{2} ]_{d_1}^L$$

$$Y''(l) = 0 \quad Y(l) = C_{dc}$$

$$Y'(d_1) = 0 \quad Y(d_1) = C_{st}$$

$$- EI \ Y''(d_1) + W(C_{dc} - C_{st}) = H_1(l - d_1) + \frac{P \ sin(\alpha)}{2} (L - d_1^2) \quad (F-22)$$

Adding F-21) and (F-22)

$$W \ C_{dc} = H_O d_1 + H_1(L - d_1) + \frac{L^2 P \ sin(\alpha)}{2} \quad (F-23)$$

$$H_1 = H_O - H_1$$

$$EI Y''' + W Y' = H + X P \sin(\alpha) \quad (F-24)$$

Integrating (F-24) using B.C. for the slick assembly

$$EI Y'' + W Y \Big|_0^L = H X + \frac{X^2 P \sin(\alpha)}{2} \Big|_0^L$$

$$Y(0) = 0 \quad Y(L) = C_{dc}$$

$$Y'(0) = 0 \quad Y''(L) = 0$$

$$+ W C_{dc} = H L + \frac{L^2 P \sin(\alpha)}{2} \quad (F-25)$$

Callas's data (1 - pt. stabilizer) From (F-23)

$$D_1 = 10 \text{ ft.} \quad 2084 \text{ lb/ft} = 6930 - 65233$$

$$C_{dc} = 0.1042 \text{ ft.} \quad + 60351$$

$$H_O = 693 \text{ lb.} \quad 2084 \text{ lb/ft} = 2048 \text{ lb/ft}$$

$$H_1 = 2694 \text{ lb.} \quad 1.75\% \text{ difference}$$

$$\lambda = 41.48 \text{ ft.}$$

$$P = 76.8 \text{ lb/ft.}$$

$$\alpha = 60^\circ$$

$$W = 20 \text{ m lb's}$$

Slick string data

From (F-25)

$$C_{dc} = 0.1042 \text{ ft.} \quad 2,084 = -15,572 + 17,650$$

$$P = 76.8 \text{ lb/ft.} \quad 2084 = 2078 \text{ lb/ft.}$$

$$H_O = -513.6 \quad 0.29 \% \text{ difference}$$

$$\alpha = 30^\circ$$

$$W = 20 \text{ m lb's}$$

$$l = 30.32 \text{ ft.}$$

 $C_{st} = 0$  (1 - pt. Stabilizer) From (F-23)

$$D_1 = 20 \text{ ft.} \quad +3646 = 1,480 - 36,440 +$$

$$\alpha = 15^\circ \quad + 38,560$$

$$W = 35 \text{ m lb's} \quad 3646 = 3600$$

$$P = 76.815 \quad 1.28\% \text{ difference}$$

$$H_O = 74.0 \text{ lb.}$$

$$H_1 = 934 \text{ lb.}$$

$$C_{dc} = 0.1042$$

```

10 REM                      ONE STABILIZER
20 REM
30 REM                      POINT SUPPORT
40 REM
50 REM      A CONTACT POINT BETWEEN BIT AND STABILIZER IS NOT CONSIDERED.
60 REM
70 REM      THIS PROGRAM CALCULATES BETA, PHI, HO, AND H1, FOR A SPECIFIED
80 REM
90 REM      DISTANCE TO THE STABILIZER, CLEARANCE, WOB, AND MOMENT OF INERTIA.
100 CLS
110 DEFDBL F,L,X,N
120 DIM Y(450),YD(450),YDD(450)
130 INPUT "DISTANCE TO STABILIZER 1 (ft) : ";D11
140 INPUT "Dh=";DH:DH=DH/12
150 INPUT "ODdc(in)=";OD:OD=OD/12
160 INPUT "IDdc(in)=";ID:ID=ID/12
170 INPUT "ODst (in) =      ";DST1:DST1=DST1/12
180 INPUT "MW(ppg)=";MW
190 INPUT "Hole inclination ALFA(deg)=";AA
200 INPUT "WOB(1000 lb)=";W:W=1000*KW
210 REM ***** PRINT INPUT DATA *****
220 CLS
230 PRINT " D1 (ft)=           ";USING"##.##";D11
240 PRINT " Dh (in) =          ";DH*12
250 PRINT " ODdc (in) =         ";OD*12
260 PRINT " IDdc (in) =         ";ID*12
270 PRINT " ODst (in) =         ";DST1*12
280 PRINT " MW (ppg) =          ";MW
290 PRINT " ALPHA (deg) =        ";AA
300 PRINT " WOB (lb's) =         ";W
310 REM ***** CALCULATE DIMENSIONLESS QUANTITIES *****
320 WU=3.14159*((OD/2)^2-(ID/2)^2)*489
330 C=(DH-OD)/2
340 CST1=(DH-DST1)/2
350 P=WU*(1-MW/65.4)
360 I=3.14*(OD^4-ID^4)/64
370 PRINT "P (lb's/ft) =       ";P
380 PRINT "I (ft^4) =           ";I
390 PRINT:PRINT
400 EI=4176*10^6*I
410 D1=(D11*SQR(W/EI))
420 CD=(W^2*C)/(EI*P*SIN(AA/57.29))
430 PRINT "CD = ";CD
440 M1=EI*P*SIN(AA/57.29)/(W^2)
450 M2=SQR(EI/W)
460 M3=SQR(EI/W)*P*SIN(AA/57.29)
470 PRINT "m3= ";M3
480 CST1=(W^2*CST1)/(EI*P*SIN(AA/57.29))
490 PRINT "CST1= ";CST1
500 INPUT "DO YOU WANT A HARD COPY, 1- YES, 2-NO";HARD
510 IF (HARD=1) THEN GOSUB 2710

```

```

520 GOTO 1150
530 REM ***** SOLVES FOR DISTANCE TO TANGENCY POINT *****
540 L=D1+.01
550 POS1=1
560 COUNT=0
570 NUMB=(CST1+.5*L^2-CD+1-.5*D1^2)-COS(L-D1)-L*SIN(L-D1)
580 DENB=D1-L+SIN(L-D1)
590 HB=NUMB/DENB
600 C1B=-HB*L-.5*L^2+CD-1
610 C2B=COS(L)+(L+HB)*SIN(L)
620 C3B=SIN(L)-(L+HB)*COS(L)
630 H0=((CST1-.5*D1^2+1)-COS(L-D1)-(L+HB)*SIN(L-D1))/D1
640 C3A=(1+CST1-.5*D1^2-COS(D1)-H0*D1)/SIN(D1)
650 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-H0)
660 IF F<0 THEN POS1=2
670 DX=.01
680 ITER =1
690 LPR=L
700 L=LPR+DX
710 IF L>15 THEN 1120
720 NUMB=(CST1+.5*L^2-CD+1-.5*D1^2)-COS(L-D1)-L*SIN(L-D1)
730 DENB=D1-L+SIN(L-D1)
740 HB=NUMB/DENB
750 C1B=-HB*L-.5*L^2+CD-1
760 C2B=COS(L)+(L+HB)*SIN(L)
770 C3B=SIN(L)-(L+HB)*COS(L)
780 H0=((CST1-.5*D1^2+1)-COS(L-D1)-(L+HB)*SIN(L-D1))/D1
790 C3A=(1+CST1-.5*D1^2-COS(D1)-H0*D1)/SIN(D1)
800 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-H0)
810 IF F<0 THEN 840
820 POS2=1
830 GOTO 850
840 POS2=2
850 IF POS2<>POS1 THEN 880
860 LPR=L
870 GOTO 700
880 IF ITER=1 THEN 960
890 IF ITER=2 THEN 980
900 IF ITER=3 THEN 1000
910 IF ITER=4 THEN 1020
920 IF ITER=5 THEN 1040
930 IF ITER=6 THEN 1060
940 IF ITER=7 THEN 1080
950 IF ITER=8 THEN 1100
960 DX=.001: ITER=2
970 GOTO 700
980 DX=.0001: ITER=3
990 GOTO 700
1000 DX=.00001:ITER=4
1010 GOTO 700

```

```

1020 DX=.000001:ITER=5
1030 GOTO 700
1040 DX=.0000001:ITER=6
1050 GOTO 700
1060 DX=1E-08:ITER=7
1070 GOTO 700
1080 DX=1E-09:ITER=8
1090 GOTO 700
1100 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
1110 GOTO 700
1120 FOR I=1 TO COUNT
1130 PRINT "ROOT(";I;") = ";ROOT(I)
1140 NEXT I
1150 REM ***** DETERMINATION OF BETA, PHI, H0, AND H1 *****
1160 I=0
1170 L=1.90608
1180 NUMB=(CST1+.5*L^2-CD+1-.5*D1^2)-COS(L-D1)-L*SIN(L-D1)
1190 DENB=D1-L+SIN(L-D1)
1200 HB=NUMB/DENB
1210 C1B=-HB*L-.5*L^2+CD-1
1220 C2B=COS(L)+(L+HB)*SIN(L)
1230 C3B=SIN(L)-(L+HB)*COS(L)
1240 H0=((CST1-.5*D1^2+1)-COS(L-D1)-(L+HB)*SIN(L-D1))/D1
1250 C3A=(1+CST1-.5*D1^2-COS(D1)-H0*D1)/SIN(D1)
1260 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-H0)
1270 H1=H0-HB
1280 YD(0)=(C3A+H0)
1290 BB=57.29*ATN(YD(0)*M1/M2)
1300 HOU=H0*M3:H1U=H1*M3
1310 PHI = 57.29*(ATN((M3*H0)/W))+AA
1320 PRINT
1330 REM ***** DETERMINES IF POINT OF CONTACT IS PRESENT *****
1340 PRINT
1350 I=-1 : DX=.01:X=0
1360 I=I+1
1370 Y(I)=-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2
1380 X=X+DX
1390 IF (Y(I)>CD) OR (Y(I)=CD) THEN GOTO 2660
1400 IF (X<D1) THEN GOTO 1360
1410 IF (HARD=1) THEN GOSUB 2840
1420 INPUT"DO YOU WANT A HARD COPY OF Y, SLOPE, MOMENT Vs X, 1-YES, 2-NO";HZ
1430 PRINT"BETA (deg) = ";BB
1440 PRINT"PHI (deg) = ";PHI
1450 PRINT"H0 (lb's) = ";H0*M3
1460 PRINT "H1 (lb's) = ";H1*M3
1470 NN=D1/.01
1480 FOR I=0 TO NN
1490 Y(I)=0
1500 NEXT I
1510 REM ***** SOLVE FOR 0 SLOPE POINT BETWEEN BIT AND TANGENCY *****
1520 X=0:POS1=1:COUNT=0
1530 F=-SIN(X)+C3A*COS(X)+X+H0
1540 IF (F<0) THEN POS1=2:DX=.1

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```

1550 ITER=1
1560 XPR=X
1570 X=XPR+DX
1580 IF (X>D1) THEN GOTO 1750
1590 F=-SIN(X)+C3A*COS(X)+H0+H
1600 IF (F<0) THEN 1630
1610 POS2=1
1620 GOTO 1640
1630 POS2=2
1640 IF (POS2<>POS1) THEN 1670
1650 XPR=X
1660 GOTO 1570
1670 IF (ITER =1) THEN 1710
1680 IF (ITER =2) THEN 1720
1690 IF (ITER =3) THEN 1730
1700 IF (ITER=4) THEN 1740
1710 DX=.01:ITER=2:GOTO 1570
1720 DX=.001: ITER=3: GOTO 1570
1730 DX=.0001: ITER=4: GOTO 1570
1740 SLP0=X:DX1=SLP0/5:DX2=(D1-SLP0)/5:GOTO 1770
1750 DX1=D1/10:DX2=D1/10:SLP0=D1/2
1760 PRINT "DX1= ";DX1
1770 REM***** DETERMINE VALUE OF Y, SLOPE, MOMENT FOR BIT TO 0 SLOPE POINT *****
1780 X=0:J=0
1790 FOR J=0 TO 5
1800 Y(J)=(-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2)*M1
1810 YD(J)=(-SIN(X)+C3A*COS(X)+H0+X)*M1/M2
1820 YDD(J)=-EI*(-COS(X)-C3A*SIN(X)+1)*M1/(M2^2)
1830 X=X+DX1:LSJ=J
1840 NEXT J
1850 REM ***** DETERMINE VALUES OF Y, SLOPE, MOMENT FOR 0 SLOPE TO STAB1 *****
1860 X=SLP0+DX2: LSJ=LSJ+1
1870 FOR K=LSJ TO 10
1880 Y(K)=(-1+COS(X)+C3A*SIN(X)+H0*X+.5*X^2)*M1
1890 YD(K)=(-SIN(X)+C3A*COS(X)+H0+X)*M1/M2
1900 YDD(K)=(-EI*(-COS(X)-C3A*SIN(X)+1))*M1/(M2^2)
1910 X=X+DX2
1920 NEXT K
1930 PRINT "      X          Y          SLOPE          MOMENT"
1940 PRINT "      (ft)        (ft)        (ft/ft)        (ft-lb"
" "
1950 PRINT "-----"
1960 DIMX=.000001
1970 FOR I=0 TO 5
1980 PRINT USING "+#####.#####";DIMX;Y(I);YD(I);YDD(I)
1990 DIMX=DIMX+DX1*M2
2000 NEXT I
2010 DIMX=SLP0*M2
2020 FOR I=6 TO 10
2030 DIMX=DIMX+DX2*M2
2040 PRINT USING "+#####.#####";DIMX;Y(I);YD(I);YDD(I)
2050 NEXT I

```

```

2060 IF (HZ=1) THEN GOSUB 2910
2070 REM ***** DETERMINE Y, SLOPE, MOMENT FOR SEGMENT B *****
2080 DX3=(L-D1)/10:X=D1
2090 FOR I= 11 TO 21
2100 Y(I)=(C1B+C2B*COS(X)+C3B*SIN(X)+HB*X+.5*X^2)*M1
2110 YD(I)=(-C2B*SIN(X)+C3B*COS(X)+HB+X)*M1/M2
2120 YDD(I)=(-EI*(-C2B*COS(X)-C3B*SIN(X)+1))*M1/(M2^2)
2130 X=X+DX3
2140 NEXT I
2150 PRINT
2160 DIMX=D1*M2
2170 PRINT:PRINT "SEGMENT B ":PRINT
2180 PRINT" X Y SLOPE MOMENT"
2190 PRINT" (ft) (ft) (ft/ft) (ft-lb)"
2200 PRINT" -----"
2210 FOR I=11 TO 21
2220 PRINT USING "# #####.#####";DIMX;Y(I);YD(I);YDD(I)
2230 DIMX=DIMX+DX3*M2
2240 NEXT I
2250 IF (HZ=1) THEN GOSUB 3070
2260 INPUT "DO YOU WISH TO CONTINUE WITH ANOTHER RUN ? 1-YES, 0-NO";DEC1
2270 IF (DEC1=0) THEN GOTO 3550
2280 PRINT
2290 INPUT "WOULD YOU LIKE TO CHANGE ANY VARIABLES ? 1-YES, 0-NO";DEC2
2300 IF (DEC2=0) GOTO 220
2310 REM ***** DATA CHANGE SECTION *****
2320 CLS
2330 PRINT "CODE # VARIABLE"
2340 PRINT" -----"
2350 PRINT" 1 ----- Dh"
2360 PRINT" 2 ----- ODdc"
2370 PRINT" 3 ----- IDdc"
2380 PRINT" 4 ----- Wdc"
2390 PRINT" 5 ----- MW"
2400 PRINT" 6 ----- ALPHA"
2410 PRINT" 7 ----- GAMA"
2420 PRINT" 8 ----- WOB"
2430 PRINT" 9 ----- h"
2440 PRINT" 10 ----- ODst"
2450 PRINT" 11 ----- Dst1"
2460 PRINT
2470 PRINT "INPUT THE CORRESPONDING CODE FOR THE VARIABLES YOU WISH TO CHANGE, "
2480 PRINT "ENTER THEM ONE PER LINE ----ENTER 0 WHEN FINISHED"
2490 INPUT "CODE # = ";CN
2500 IF (CN=0) THEN GOTO 220
2510 IF (CN=1) THEN INPUT "Dh (in) = ";DH:DH=DH/12
2520 IF (CN=2) THEN INPUT "ODdc (in) = ";OD:OD=OD/12
2530 IF (CN=3) THEN INPUT "IDdc (in) = ";ID:ID=ID/12
2540 IF (CN=4) THEN INPUT "Wdc (in) = ";WU
2550 IF (CN=5) THEN INPUT "MW (ppg) = ";MW
2560 IF (CN=6) THEN INPUT "ALPHA (deg) = ";AA:AA=AA
2570 IF (CN=7) THEN INPUT "GAMA (deg) = ";GA

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2580 IF (CN=8) THEN INPUT "WOB (1000'S lbs) = ";W:W=1000*W
2590 IF (CN=9) THEN INPUT " h = ";DAI
2600 IF (CN=10) THEN INPUT " ODst(in) = ";DST1:DST1=DST1/12
2610 IF (CN=11) THEN INPUT " Dst1(ft) = ";D11
2620 IF (CN<0)OR(CN>11) THEN GOTO 2640
2630 GOTO 2490
2640 PRINT "INPUT VALUE MUST BE BETWEEN 0 AND 10 INCLUSIVE"
2650 GOTO 2490
2660 L=.01
2670 PRINT "***** CONTACT POINT BETWEEN THE BIT AND STABILIZER *****"
2680 END
2690 GOTO 3550
2700 REM
2710 REM ***** HARD COPY OF INPUT DATA *****
2720 LPRINT " D1 (ft) = " ;D11
2730 LPRINT " DH (in) = " ;DH*12
2740 LPRINT " ODdc (in) = " ;OD*12
2750 LPRINT " IDdc (in) = " ;ID*12
2760 LPRINT " ODst (in) = " ;DST1*12
2770 LPRINT " MW (ppg) = " ;MW
2780 LPRINT " ALPHA (deg) = " ;AA
2790 LPRINT " WOB (lb's) = " ;W
2800 LPRINT " P (lb's/ft in fluid) = " ;P
2810 LPRINT " I (in^4) = " ;I
2820 LPRINT:LPRINT
2830 RETURN
2840 REM ***** HARD COPY OF HO, BETA, HC, PHI *****
2850 LPRINT "BETA (deg) = " ;BB
2860 LPRINT "HO (lb's) = " ;HO*M3
2870 LPRINT "HC (lb's) = " ;HC*M3
2880 LPRINT "hi (lb's) = " ;H1*M3
2890 LPRINT "PHI (deg) = " ;PHI
2900 RETURN
2910 REM ***** HARD COPY SEGMENT A NO CONTACT POINT *****
2920 LPRINT:LPRINT" SEGMENT A BIT TO STABILIZER "
2930 LPRINT" X Y SLOPE MOME
T"
2940 LPRINT" (ft) (ft) (ft/ft) (ft-
b)"
2950 LPRINT" ----- -----
2960 DIMX=.000001
2970 FOR K=0 TO 5
2980 LPRINT USING"+#####.####;" ;DIMX;Y(K);YD(K);YDD(K)
2990 DIMX=DIMX+DX1*M2
3000 NEXT K
3010 DIMX=SLP0*M2
3020 FOR J=6 TO 10
3030 DIMX=DIMX+DX2*M2
3040 LPRINT USING"+#####.####;" ;DIMX;Y(J);YD(J);YDD(J)
3050 NEXT J
3060 RETURN
3070 REM ***** HARD COPY OF SEGMENT B NO CONTACT PRESENT *****
3080 LPRINT:LPRINT" SEGMENT B STABILIZER TO TANGENCY POINT "

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**APPENDIX G**

APPENDIX G  
ONE POINT STABILIZER, TWO SEGMENT BOREHOLE,  
WITH CONTACT POINT CONSIDERED

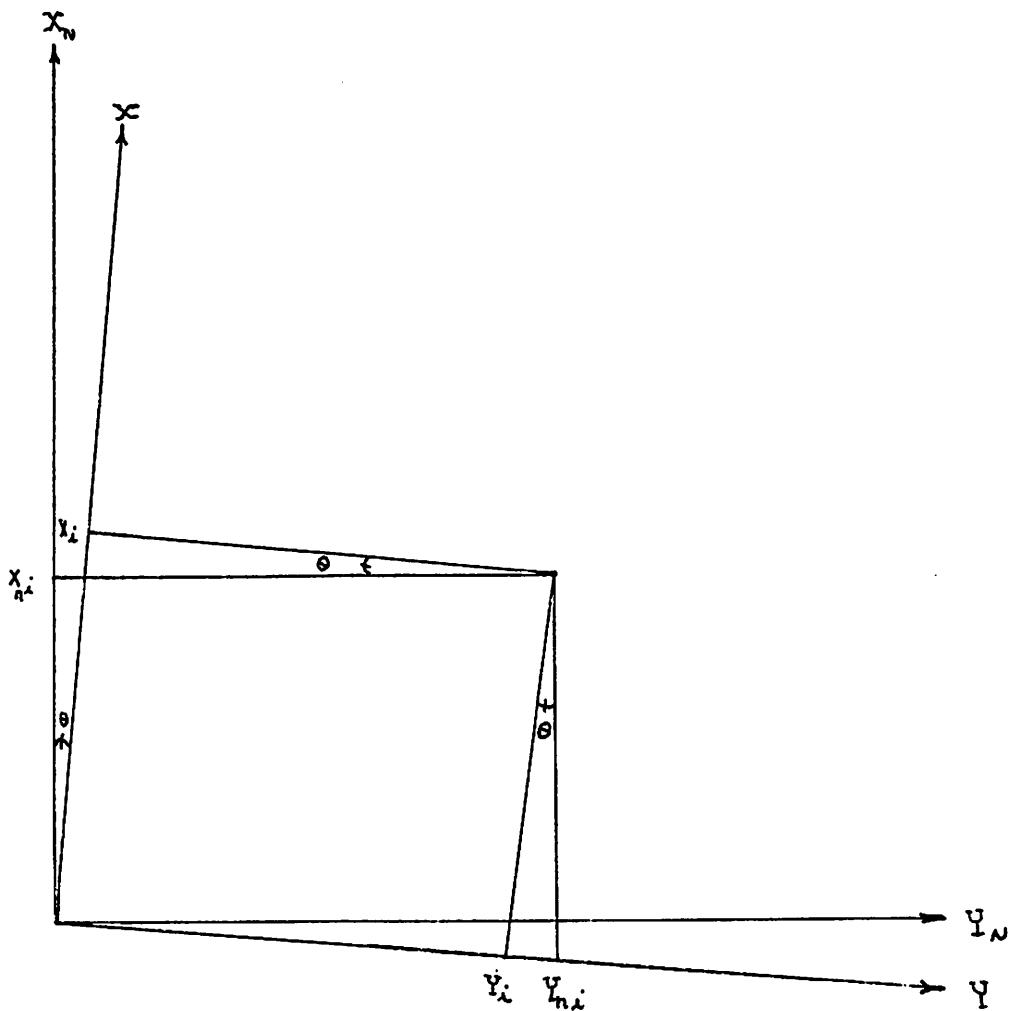


FIGURE XIV-G

$X_n, Y_n$  - The new coordinate system

$$Y_{ni} = Y_i \cos\theta + X_i \sin\theta \quad (G-1)$$

$$X_{ni} = -Y_i \sin\theta + X_i \cos\theta + D_1 \quad (G-2)$$

expressing (G-1) and (G-2) in the general coordinate systems:

$$Y_n = Y \cos\theta + X \sin\theta \quad (G-3)$$

$$X_n = -Y \sin\theta + X \cos\theta + D_1 \quad (G-4)$$

$D_1$  - distance to first stabilizer

$$\frac{dY_n}{dX_n} = \frac{dY_n/dX}{dX_n/dX}$$

$$dY_n/dX = \cos\theta \cdot dY/dX + \sin\theta$$

$$dX_n/dX = -dY/dX \sin\theta + \cos\theta$$

$$dY_n/dX_n = \frac{\cos\theta \cdot dY/dX + \sin\theta}{-\sin\theta \cdot dY/dX + \cos\theta} \quad (G-5)$$

Assuming  $\sin\theta$  in the denominator is small:

$$dY_n/dX_n = \tan\theta + dY/dX \quad (G-6)$$

$$\frac{d^2Y_n}{dX_n^2} = \frac{d(dY_n/dX_n)}{dX} = \frac{d(\tan\theta + dY/dX)}{dX} \quad (G-7)$$

$$\text{let } u = \cos\theta \cdot dY/dX + \sin\theta$$

$$v = -dY/dX \sin\theta + \cos\theta$$

$$\frac{d(u/v)}{dx} = \frac{(v \ du/dx - u \ dv/dx)}{v^2} \quad (G-8)$$

$$du/dx = \cos\theta \ d^2Y/dx^2$$

$$dv/dx = -d^2Y/dx^2 \ \sin\theta$$

Applying rule (G-8) to the numerator of (G-7)

$$\frac{d(dY_n/dX_n)}{dx} = \frac{-\sin\theta\cos\theta \ d^2Y/dx^2 \ dY/dx + \cos^2\theta \ d^2Y/dx^2}{+\sin\theta\cos\theta \ dY/dx \ d^2Y/dx^2 + \sin^2\theta \ d^2Y/d^2x} \\ \frac{d(dY_n/dX_n)}{dx} = \frac{(-dY/dx \ \sin\theta + \cos\theta)^2}{d^2Y/dx^2}$$

$$\frac{d(dY_n/dX_n)}{dx} = \frac{d^2Y/dx^2}{(-dY/dx \ \sin\theta + \cos\theta)^2}$$

$$\frac{d^2Y_n}{dX_n^2} = \frac{d^2Y/dx^2}{(-dY/dx \ \sin\theta + \cos\theta)^3} \quad (G-8a)$$

Assuming that the  $\sin\theta$  term can be approximately equal to 0

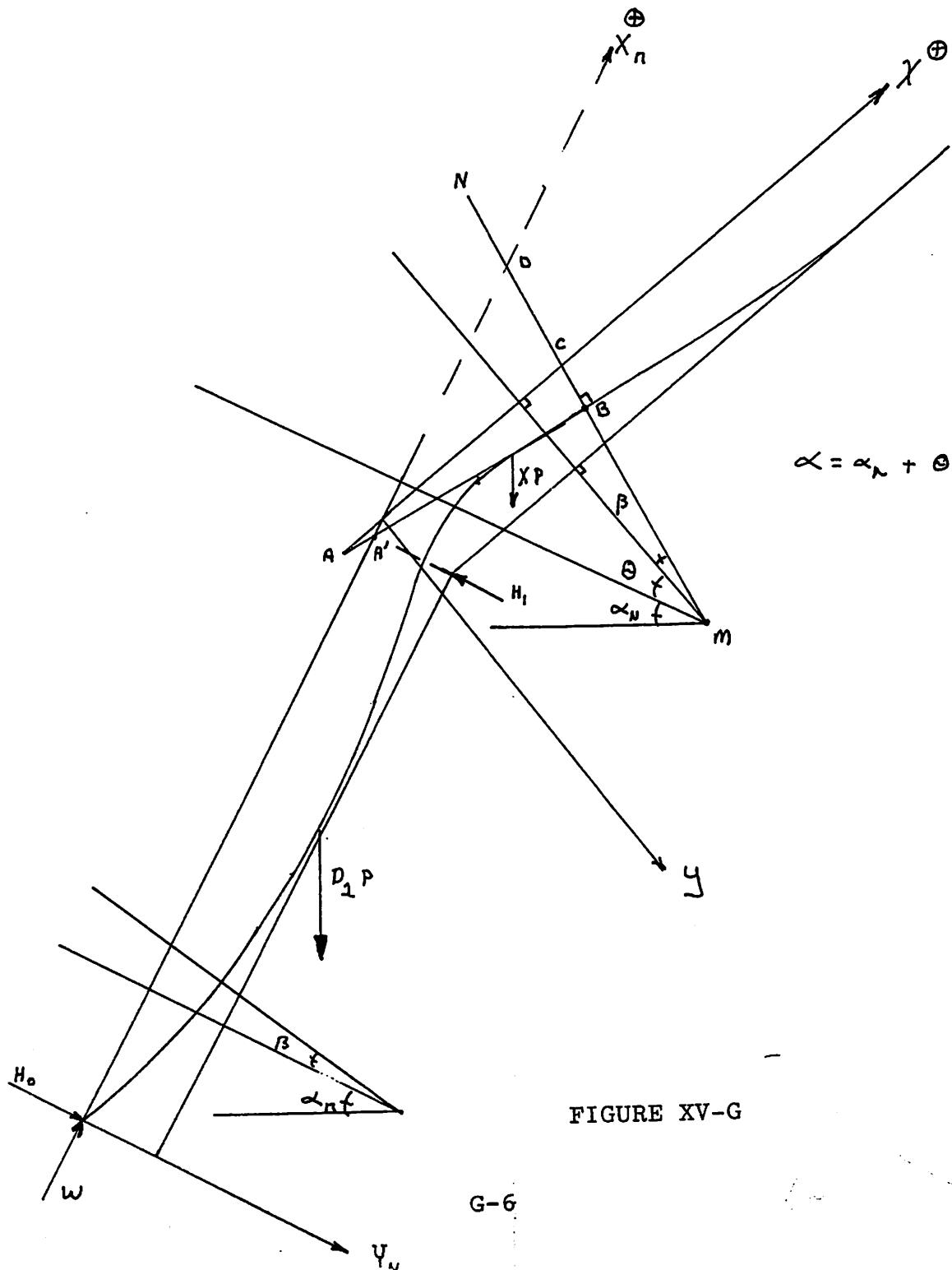
$$d^2Y_n/dX_n^2 = \frac{d^2Y/dx^2}{\cos^3\theta} \quad (G-9)$$

$$\frac{d(d^2Y_n/dX_n^2)}{dx} = \frac{\frac{d(d^2Y_n/dX_n^2)}{dX}}{dX_n/dX} \quad (G-10)$$

$$\text{let } v = (-dY/dx \ \sin\theta + \cos\theta)^3$$

$$\text{let } u = d^2Y/d^2x$$

DERIVATION OF THE  
DIFFERENTIAL EQUATION OF BENDING



Superimposing forces on the NM axis to obtain shear at that point yields:

$$\begin{aligned}
 & -W \sin(\beta + \theta) \\
 & + H_O \cos(\beta + \theta) \\
 & - H_1 \cos(\beta + \theta) \\
 & + D_1 P \sin(\alpha_n + \beta + \theta) \\
 & + X P \sin(\alpha_n + \beta + \theta)
 \end{aligned}$$

$$\sum S_i = EI d^3 Y_n / dX_n^3$$

$$\begin{aligned}
 EI d^3 Y_n / dX_n^3 = & -W \sin(\beta + \theta) + (H_O - H_1) \cos(\beta + \theta) \\
 & + (D_1 + X) P \sin(\alpha_n + \beta + \theta)
 \end{aligned} \tag{G-14}$$

$$\begin{aligned}
 X = \frac{(X_n - D_1)}{\cos(\theta)} ; \quad \sin(\alpha_n + \beta + \theta) = \sin(\alpha_n) \cos(\beta + \theta) + \\
 & + \cos(\alpha_n) \sin(\beta + \theta)
 \end{aligned}$$

$$\begin{aligned}
 EI d^3 Y_n / dX_n^3 = & -W \sin(\beta + \theta) + (H_O - H_1) \cos(\beta + \theta) \\
 & + \frac{[D_1 \cos(\theta) + X_n - D_1]}{\cos(\theta)} P \sin(\alpha_n + \beta + \theta)
 \end{aligned} \tag{G-15}$$

$$\begin{aligned}
 & = -W \sin(\beta + \theta) + (H_O - H_1) \cos(\beta + \theta) \\
 & + [D_1 (1 - \frac{1}{\cos \theta}) + \frac{X_n}{\cos \theta}] P \sin(\alpha_n + \beta + \theta)
 \end{aligned}$$

assuming that  $D_1(1 - \frac{1}{\cos \theta})P$  small in comparison to  $\frac{X_n P}{\cos \theta}$

we obtain:

$$EI \frac{d^3Y_n}{dX_n^3} = -W \sin(\beta + \theta) + (H_O - H_1) \cos(\beta + \theta) + \\ + (X_n / \cos\theta) P \sin(\alpha_n + \beta + \theta) \quad (G-16)$$

dividing by  $\cos(\beta + \theta)$

$$\frac{EI}{\cos(\beta + \theta)} \frac{d^3Y_n}{dX_n^3} = -W \tan(\beta + \theta) + (H_O - H_1) + \\ + \frac{X_n}{\cos(\theta)} \frac{P \sin(\alpha_n + \beta + \theta)}{\cos(\beta + \theta)} = -W \tan(\beta + \theta) + \\ + (H_O - H_1) + \frac{X_n P}{\cos(\theta)} \frac{[\sin(\alpha_n) \cos(\beta + \theta) + \sin(\beta + \theta) \cos\alpha_n]}{\cos(\beta + \theta)} \\ = -W \tan(\beta + \theta) + (H_O - H_1) + \frac{X_n P}{\cos(\theta)} [\sin\alpha + \\ + \tan(\beta + \theta) \cos\alpha_n]$$

Per equation (G-12) in the coordinate transformation section

$$\frac{dY_n}{dX_n} = \tan(\beta + \theta)$$

$$\frac{EI \frac{d^3Y_n}{dX_n^3}}{\cos(\beta + \theta) dX_n^3} = \frac{-W}{\cos(\beta + \theta)} \frac{dY}{dX_n} + (H_O - H_1) + \frac{X_n}{\cos(\theta)} P [\sin\alpha_n + \\ + \frac{dY_n}{dX_n} \cos\alpha_n]$$

$$\frac{EI}{\cos(\beta + \theta)} \frac{d^3Y_n}{dX_n^3} + \frac{dY_n}{dX_n} (W - \frac{X_n P}{\cos\theta} \cos\alpha_n) = H_O - H_1 + \\ + \frac{X_n P}{\cos(\theta)} \sin\alpha_n$$

assuming that  $\frac{X_n P \cos(\alpha_n)}{\cos(\theta)}$  is small in comparison to  $W$

$$\frac{EI}{\cos(\beta + \theta)} \frac{d^3Y}{dX^3} + \frac{dY_n}{dX_n} W = (H_O - H_1) + \frac{X_n P}{\cos(\theta)} \sin(\alpha_n) \quad (G-17)$$

Assuming  $\cos(\beta + \theta) \approx \cos(\theta)$  per the derivation in the coordinate transformation section

$$\boxed{\frac{EI}{\cos(\theta)} \frac{d^3Y_n}{dX_n^3} + \frac{dY_n}{dX_n} W = (H_O + H_1) + \frac{X_n P}{\cos(\theta)} \sin(\alpha_n)} \quad (G-18)$$

For the case when the stabilizer is located just above the dog-leg in the hole, Equation (G-18a) applies.

$$\frac{EI}{\cos(\theta)} \frac{d^3Y_n}{dX_n^3} + \frac{dY_n}{dX_n} W = [H_O + H_1/\cos(\theta)] + \frac{X_n P}{\cos(\theta)} \sin(\alpha_n) \quad (G-18a)$$

DERIVATION OF DIMENSIONLESS CONVERSIONS  
 (Valid for  $X_n > D_1$ )

Given:

$$\frac{Y_n}{M_1} = y_n \quad ; \quad \frac{X_n}{M_2} = x_n \quad ; \quad \frac{H}{M_3} = h$$

$$y'_n = dy_n/dX_n \cdot dX_n/dx \quad ; \quad dX_n/dx_n = M_2$$

$$dy_n/dX_n = dY_n/dX_n \cdot \frac{1}{M_1}$$

$$dy_n/dx_n = (dY_n/dX_n)(M_2/M_1) \quad (G-19)$$

$$d^2y_n/dx_n^2 = \frac{d(dY_n/dX_n)}{dX_n} \cdot dX_n/dx_n$$

$$d^2y_n/dx_n^2 = d^2Y_n/dX^2 \cdot M_2^2/M_1 \quad (G-20)$$

$$d^3y_n/dx_n^3 = \frac{d(d^2y_n/dx_n^2)}{dX_n} \cdot dX_n/dx_n$$

$$= d^3Y_n/dX_n^3 \cdot M_2^2/M_1 \cdot M_2$$

$$d^3y_n/dx_n^3 = d^3Y_n/dX_n^3 \cdot M_2^3/M_1 \quad (G-21)$$

Solving for the dimensional form of the function and its derivatives yeilds:

$$Y_n = y_n M_{1B} : X_n = x_n M_{2B} : H = h_B M_{3B}$$

$$\frac{dY_n}{dX_n} = \frac{dy_n}{dx_n} \cdot \frac{M_1}{M_2}^2 \quad (G-22)$$

$$\frac{d^2Y_n}{dX_n^2} = \frac{d^2y}{dx^2} \cdot \frac{M_1}{M_2}^2 \quad (G-23)$$

$$\frac{d^3Y_n}{dX_n^3} = \frac{d^3y}{dx^3} \cdot \frac{M_1}{M_2}^3 \quad (G-24)$$

let  $\frac{EI}{\cos(\theta)} = EI^*$  ;  $\frac{P}{\cos(\theta)} = P^*$

(G-18) becomes

$$EI^* \frac{d^3Y_n}{dX_n^3} + \frac{dY_n}{dX_n} W = (h_O - h_1) + X_n P^* \sin(\alpha_n) \quad (G-25)$$

substituting (G-22), (G-23) and (G-24) into (G-25) yields:

$$EI^* \frac{M_1 B}{M_2 B^3} \frac{d^3 y_n}{dX_n^3} + W \frac{M_1 B}{M_2 B} \frac{dy}{dX_n^2} = (h_O - h_1) M_3 B + \\ + X_n P^* M_2 B \sin(\alpha_n) \quad (G-26)$$

dividing (G-13) by  $\frac{EI^* P^* \sin(\alpha_n)}{W}$

$$\frac{M_1 B}{M_2 B^3} \frac{W}{P \sin(\alpha_n)} \frac{d^3 y_n}{dX_n^3} + \frac{W^2}{EI^* P^* \sin(\alpha_n)} \frac{M_1}{M_2} \frac{dy}{dX_n^2} = \frac{(h_O - h_1)}{EI^* P^* \sin(\alpha_n)} * \\ * M_3 B + \frac{X_n W}{EI^*} M_2 B$$

Multiplying by  $M_2 B$  yields:

$$\frac{M_1 B}{M_2 B^2} \frac{W}{P^* \sin(\alpha_n)} \frac{d^3 y_n}{dX_n^3} + \frac{W^2}{EI^* P^* \sin(\alpha_n)} M_1 B \frac{dy_n}{dX_n} = \\ = \frac{(h_O - h_1) W M_3 B M_2 B}{EI^* P^* \sin(\alpha_n)} + \frac{X_n W M_2^2 B}{EI^*} \quad (G-24)$$

From (G-27)

$$M_{2B} = \sqrt{\frac{EI^*}{W}} \quad (G-28)$$

$$M_{1B} = \left[ \frac{EI^* P^* \sin(\alpha_n)}{W^2} \right] \quad (G-29)$$

$$M_{3B} = \left[ \frac{EI^* P^* \sin(\alpha_n)}{W M_2} \right] = \frac{EI^* P^* \sin(\alpha_n)}{W \sqrt{\frac{EI^*}{W}}} \quad (G-30)$$

$$M_{3B} = \left[ \sqrt{\frac{EI^*}{W}} \cdot P^* \sin(\alpha_n) \right] \quad (G-30)$$

Substituting back in for  $EI^*$  and  $P^*$  yields:

$$M_{1B} = \left[ \frac{EI P \sin(\alpha_n)}{\cos^2 \theta W^2} \right] \quad (G-30a)$$

$$M_{2B} = \left[ \frac{EI}{W \cos(\theta)} \right]^{\frac{1}{2}} \quad (G-30b)$$

$$M_{3B} = \sqrt{\frac{EI}{W \cos \theta}} \cdot \frac{P \sin(\alpha_n)}{\cos(\theta)} \quad (G-30c)$$

For the case in which the stabilizer is just above the dog-leg in the hole, the dimensionless differential equation becomes:

$$\frac{d^3 y_n}{dx_n^3} + \frac{dy_n}{dx_n} = h_B = x_n \quad (G-31)$$

DETERMINATION OF INTEGRATION  
CONSTANTS AND FORCING FUNCTION

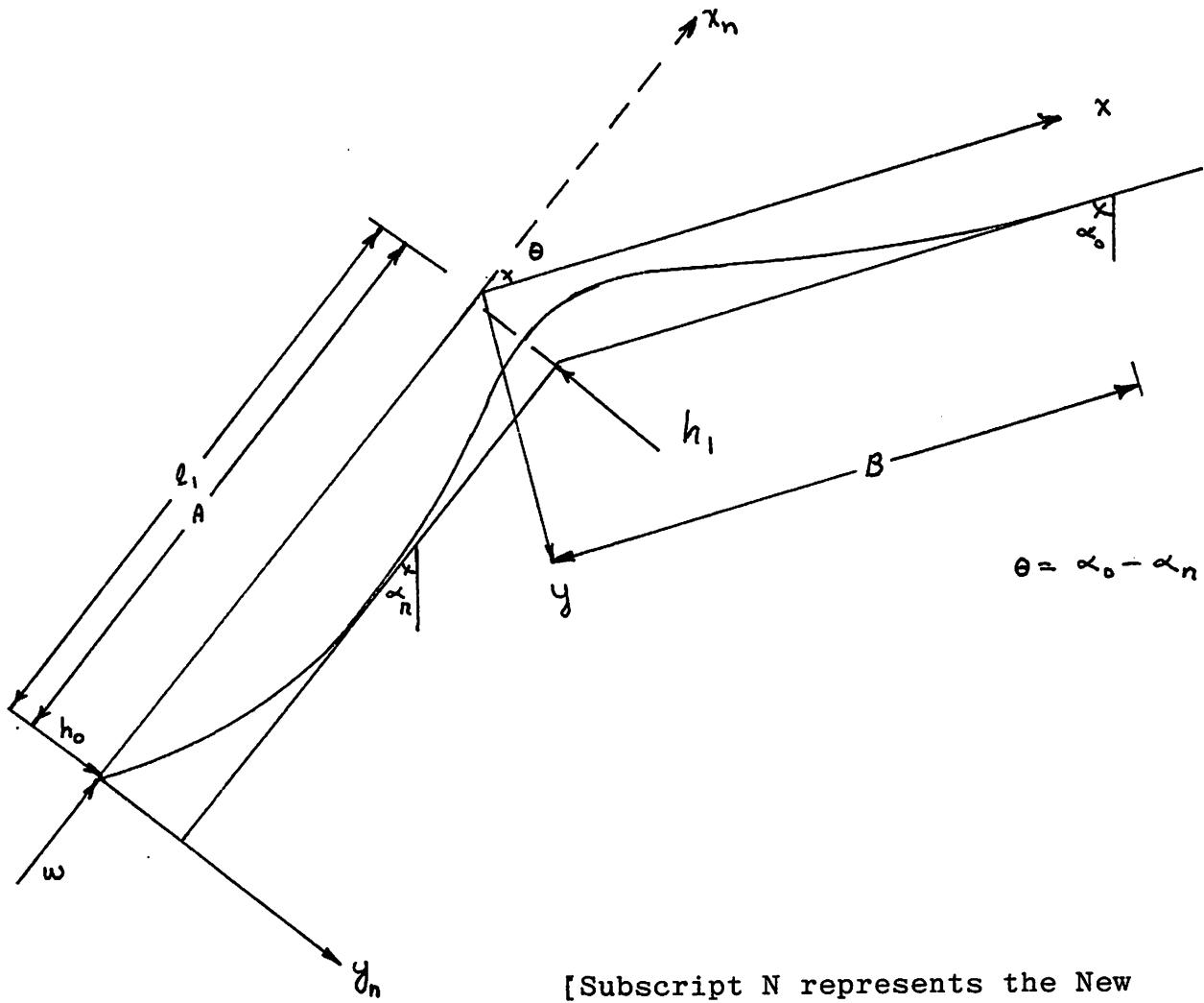


FIGURE XVI-G  
[Dimensionless Coordinates]

Segment A

B.C.

$$x = 0 \quad y_A = 0 \quad (G-32)$$

$$x = 0 \quad y''_A = 0 \quad (G-33)$$

### Continuity Conditions

$$X_n = \ell_1 \quad y_A = y_{Bn} = C_{st_1} \quad (G-34)$$

$$X_n = \ell_1 \quad y'_A = y'_{Bn} \quad (G-35)$$

$$X_n = \ell_1 \quad y''_A = y''_{Bn} \quad (G-36)$$

using B.C. (G-32), (G-33) yields:

$$C_{1A} = -1 \quad ; \quad C_{2A} = 1$$

$$\text{using B.C. (G-34)} \quad X = \ell_1 \quad Y_A = C_{st_1}$$

$$C_{st_1} = -1 + \cos \ell_1 + C_{3A} \sin \ell_1 + h_O \ell_1 + \frac{1}{2} \ell_1^2$$

$$(C_{st_1} + 1) - h_O \ell_1 - \frac{1}{2} \ell_1^2 = C_{3A} \sin \ell_1 + \cos \ell_1$$

$$C_{3A} = \frac{C_{st} + 1 - h_O \ell_1 - \frac{1}{2} \ell_1^2 - \cos \ell_1}{\sin \ell_1} \quad (G-37)$$

$$\text{using B.C (G-36)} \quad X = \ell_1 \quad y''_A = y''_{Bn}$$

$$-\cos \ell_1 - C_{3A} \sin \ell_1 + 1 = -C_{2B} \cos \ell_1 - C_{3B} \sin \ell_1 + 1$$

$$-C_{3A} = -C_{2B} \cos \ell_1 - C_{3B} \sin \ell_1 + \cos \ell_1$$

$$-(C_{st} + 1 - h_O \ell_1 - \frac{1}{2} \ell_1^2 - \cos \ell_1) = (-C_{2B} + 1) \cos \ell_1 - C_{3B} \sin \ell_1$$

$$h_O \ell_1 = (1 - C_{2B}) \cos \ell_1 - C_{3B} \sin \ell_1 + (C_{st} + 1 - \frac{1}{2} \ell_1^2 - \cos \ell_1)$$

$$h_O = \frac{(-C_2B)\cos\ell_1 - C_3B \sin\ell_1 + (C_{st} + 1 - \frac{1}{2}\ell_1^2)}{\ell_1} \quad (G-38)$$

using B.C. (G-35)  $X = \ell_1$   $Y'A = Y'B_n$

$$-\sin\ell_1 + C_3A \cos\ell_1 + h_O + \ell_1 = -C_2B \sin\ell_1 + C_3B \cos\ell_1 + h_B + \ell_1$$

Solving for 0

$$0 = (1 - C_2B) \sin\ell_1 + (C_3B - C_3A) \cos\ell_1 + (h_B - h_O) \quad (G-39)$$

### Segment B

#### B.C.

$$X_n = \ell_1 \quad Y_{Bn} = C_{st_1} \quad (G-40)$$

$$X_n = \ell_1 \quad Y'A_n = Y'B_n \quad (G-41)$$

$$X_n = \ell_1 \quad Y''A_n = Y''B_n \quad (G-42)$$

$$X_n = \ell \quad Y_{Bn} = Y \cos\theta + X \sin\theta \quad (G-43)$$

$$X_n = \ell \quad Y'B_n = \tan\theta + dY/dX \quad (G-44)$$

$$X_n = \ell \quad Y''B_n = 0 \quad (G-45)$$

Converting B.C. (G-43) to dimensionless units

$$Y = C_{dc} \text{ (in ft.)}$$

$$X_n = -Y \sin\theta + X \cos\theta ; \quad X_n = L \text{ (in ft.)}$$

$$x_n = X/M_2B \quad y_n = Y_n/M_1B \quad \text{For } x_n > l_1$$

$$x_n = X_n/M_2B = 1/M_2B [ -Y \sin\theta + X \cos\theta + D_1 ]$$

$$y_n = Y_n/M_1B = 1/M_1B [ +Y \cos\theta + X \sin\theta ] \quad (G-46)$$

Solving for X in (G-46)

$$\text{Given: } x_n = l \text{ @ B.C. (G-43) : } \frac{x_n}{M_2B} = l$$

$$\frac{l M_2B + Y \sin(\theta) - D_1}{\cos(\theta)} = X \quad (G-47)$$

putting (G-47) into (G-46)

$$y_n = \frac{1}{M_1B} [ Y \cos(\theta) + \frac{(l M_2B - D_1 + Y \sin\theta)}{\cos(\theta)} \sin(\theta) ]$$

$$y_n = \frac{1}{M_1B} [ Y \cos(\theta) + (l M_2B - D_1 + Y \sin\theta) \tan\theta ]$$

$$y_n = \frac{1}{M_1B} [ C_{dc} \cos(\theta) + (l M_2B - D_1 + C_{dc} \sin\theta) \tan\theta ]$$

$$y_{Bn} = y_n$$

$$y_{Bn} = \frac{1}{M_1B} [ C_{dc} \cos\theta + (M_2B (l - l_1) + C_{dc} \sin\theta) \tan\theta ] \quad (G-48)$$

To convert B.C. (G-44)

$$\frac{x_n}{M_2B} = x_n = l$$

$$\frac{y' B_n M_2}{M_1} = y' B_n = \frac{M_2}{M_1} [\tan\theta + \frac{dy}{dx}]$$

$$\frac{dy}{dx} = 0$$

$$y' B_n = \frac{M_2}{M_1} \tan\theta$$

(G-49)

using (G-45)  $y'' B_n = 0 @ x_n = \ell$

$$0 = -C_2 B \cos \ell - C_3 B \sin \ell + 1$$

$$C_2 B = \frac{1 - C_3 B \sin \ell}{\cos \ell}$$

$$\text{using (G-49)} \quad x_n = \ell \quad y' B_n = \frac{M_2}{M_1} \tan\theta$$

$$\frac{M_2}{M_1} \tan\theta = -C_2 B \sin \ell + C_3 B \cos \ell + \ell + h_B$$

$$C_3 B = [ \frac{M_2/M_1 \tan\theta + C_2 B \sin \ell - \ell - h_B}{(\cos \ell)} ] \quad (\text{G-51})$$

putting (G-50) to (G-51)

$$C_3 B = \left[ \frac{M_2/M_1 + \tan\theta + \frac{\sin \ell - C_3 B \sin^2 \ell}{\cos \ell} - \ell - h_B}{\cos \ell} \right]$$

$$C_3B \cos^2 \ell = M_2/M_1 \tan \theta \cos \ell + \sin \ell - C_3B \sin^2 \ell$$

$$- \ell \cos \ell - h_B \cos \ell$$

$$C_3B(\cos^2 \ell + \sin^2 \ell) = M_2/M_1 \tan \theta \cos \ell + \sin \ell - (\ell + h_B) \cos \ell$$

$$C_3B = (M_2/M_1) \tan \theta \cos \ell + \sin \ell - (\ell + h_B) \cos \ell \quad (G-52)$$

putting (G-52) into (G-50)

$$C_2B = \frac{1}{\cos \ell} - \frac{[M_2/M_1 \tan \theta \cos \ell + \sin \ell - (\ell + h_B) \cos \ell] \sin \ell}{\cos \ell}$$

$$C_2B = \frac{1}{\cos \ell} - [\frac{M_2}{M_1} \tan \theta + \tan \ell - (\ell + h_B)] \sin \ell \quad (G-53)$$

using (G-48)  $X_n = \ell$   $y_{Bn} = C_{dc} \cos \theta + [M_2/M_1 (\ell - \ell_1) + C_{dc} \sin \theta] \tan \theta$

$$C_{dc} \cos \theta + [M_2/M_1 (\ell - \ell_1) + C_{dc} \sin \theta] \tan \theta = C_{1B} + C_{2B} \cos \ell$$

$$+ C_3B \sin \ell + h_B \ell + \frac{1}{2} \ell^2$$

Solving for  $C_{1B}$

$$C_{1B} = C_{dc} \cos \theta + [M_2/M_1 (\ell - \ell_1) + C_{dc} \sin \theta] \tan \theta$$

$$- C_{2B} \cos \ell - C_3B \sin \ell - h_B \ell - \frac{1}{2} \ell^2 \quad (G-54)$$

using (G-40)  $x_n = \ell_1$   $y_{Bn} = C_{St_1}$  (dimensionless)

$$C_{St_1} = C_{1B} + C_{2B} \cos \ell_1 + C_{3B} \sin \ell_1 + h_B \ell_1 + \frac{1}{2} \ell_1^2$$

$$\begin{aligned} C_{St_1} - \frac{1}{2} \ell_1^2 + \frac{1}{2} \ell^2 - & [C_{dc} \cos \theta + [M_2/M_1 (\ell - \ell_1) + \\ & + C_{dc} \sin \theta] \tan \theta] = C_{2B} \cos \ell_1 - C_{2B} \cos \ell + C_{3B} \sin \ell_1 - (G-55) \\ & - C_{3B} \sin \ell + h_B (\ell_1 - \ell) \end{aligned}$$

let:

$$JB = C_{St_1} + \frac{1}{2} (\ell^2 - \ell_1^2) - [C_{dc} \cos \theta + [M_2/M_1 (\ell - \ell_1) + \\ + C_{dc} \sin \theta] \tan \theta]$$

(E-55) becomes:

$$JB = C_{2B} (\cos \ell_1 - \cos \ell) + C_{3B} (\sin \ell_1 - \sin \ell) + h_B (\ell_1 - \ell) \quad (G-56)$$

$$\text{let } a_1 = [1/\cos \ell - (M_2/M_1 \tan \theta + \tan \ell - \ell) \sin \ell] \quad (G-57)$$

$$\text{let } b_2 = [M_2/M_1 \tan \theta \cos \ell + \sin \ell - \ell \cos \ell] \quad (G-58)$$

substituting (G-57), (G-58) into (E-56)

$$\begin{aligned} JB = a_1 (\cos \ell_1 - \cos \ell) + b_2 (\sin \ell_1 - \sin \ell) \\ + h_B \sin \ell (\cos \ell_1 - \cos \ell) - h_B \cos \ell (\sin \ell_1 - \sin \ell) \\ + h_B (\ell_1 - \ell) \end{aligned}$$

$$h_B = \frac{JB - a_1 (\cos \ell_1 - \cos \ell) - b_2 (\sin \ell_1 - \sin \ell)}{[\sin \ell (\cos \ell_1 - \cos \ell) - \cos \ell (\sin \ell_1 - \sin \ell) + (\ell_1 - \ell)]} \quad (G-59)$$

THE EFFECT OF DOG LEG  
SEVERITY ON SIDE FORCE AT THE BIT

Input data:

$D_h = 12.25$       MW = 10 ppg.

$OD_{dc} = 8.75$        $D_1 = 40$  ft.

$ID_{dc} = 2.50$       0 - difference in inclination between two

$OD_{st} = 12.25$       successive segments of borehole

$\alpha = 5^\circ$        $\beta$  - tilt angle of the bit

$\phi$  - angle of resultant force at the bit w/r  
to verticle

$\theta$ (deg)	$\beta$ (deg)	$H_o$ (lb's)	$\phi$ (deg)
-1.5	-0.2825	803	6.315
-1.25	-0.2508	697	6.142
-1.00	-0.2159	580	5.951
-0.75	-0.1774	452	5.740
-0.50	-0.1349	310	5.507
-0.25	-0.0892	151	5.217
0.00	-0.0361	-20.1	4.967
0.25	0.0216	-213	4.651
0.50	0.0854	-426	4.302
0.75	0.1552	-659	3.920
1.00	0.2303	-910	3.510
1.25	0.3098	-1176	3.075
1.50	0.3932	-1455	2.619

TABLE XI-G

Standard Data for String Dimensions

$\alpha = 30^\circ$

$D_1 = 10$  ft.

$\theta$	$\beta$	$H_O$	$\phi$
-1.5	-0.1683	9870	45.75
-1.25	-0.1511	8842	44.18
-1.00	-0.1329	7754	42.49
-0.75	-0.1136	6596	40.67
-0.50	-0.0981	5354	38.70
-0.25	-0.0704	4011	26.54
0.00	-0.0458	+2541	34.15
0.25	0.0186	+913	31.49
0.50	0.0119	-912	28.51
0.75	0.0463	-2969	25.15
1.00	0.0839	-5279	21.42
1.25	0.1277	-7836	17.38
1.50	0.1743	-10629	13.11

TABLE XIII-G

$\alpha = 30^\circ$

$D_1 = 40 \text{ ft}$

$\theta$	$\beta$	$H_O$	$\phi$
-1.5	-0.339	329	30.54
-1.25	-0.2818	134	30.22
-1.00	-0.2218	-65.9	29.89
-0.75	-0.1599	-273	29.55
-0.50	-0.0959	-487	29.20
-0.25	-0.0297	-708	28.84
0.00	-0.0389	-938	28.47
0.25	0.1102	-1175	28.08
0.50	0.1841	-1423	27.67
0.75	0.2607	-1679	27.25
1.00	0.3403	-1945	26.82
1.25	0.4224	-2219	26.37
1.50	0.5071	-2503	25.91

TABLE XIV-G

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.168312
HO (lb's) =	9870.74
HC (lb's) =	0
h1 (lb's) =	14054
PHI (deg) =	45.748

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00294	+0.01557
+1.15712	-0.00385	-0.00282	-11592.20000
+2.31423	-0.00644	-0.00247	-23281.20000
+3.47135	-0.00898	-0.00188	-35057.70000
+4.62846	-0.01071	-0.00106	-46412.00000
+5.78558	-0.01134	+0.00000	-58834.40000
+6.62846	-0.01096	+0.00093	-67556.40000
+7.47135	-0.00974	+0.00198	-76305.70000
+8.31423	-0.00758	+0.00316	-85078.40000
+9.15712	-0.00437	+0.00448	-93870.80000
+10.00000	+0.00000	+0.00592	%-102679.00000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00000	+0.00591	%-102679.00000
+17.61300	+0.09224	+0.01772	-75984.80000
+25.22590	+0.26119	+0.02611	-51175.30000
+32.83890	+0.48192	+0.03139	-29157.60000
+40.45190	+0.73233	+0.03399	-19705.60000
+48.06480	+0.99388	+0.03441	+3532.36000
+55.67780	+1.25227	+0.03326	+13055.80000
+63.29080	+1.49792	+0.03118	+17530.20000
+70.90380	+1.72636	+0.02885	+16798.20000
+78.51670	+1.93831	+0.02696	+10885.50000
+86.12970	+2.13971	+0.02619	+0.00000

D1 (ft) =	10
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.151121
HO (lb's) =	8842.28
HC (lb's) =	0
h1 (lb's) =	12956.4
PHI (deg) =	44.1769

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00264	+0.01557
+1.15712	-0.00301	-0.00253	-10390.10000
+2.31423	-0.00578	-0.00222	-20878.10000
+3.47135	-0.00807	-0.00169	-31455.50000
+4.62846	-0.00962	-0.00095	-42113.60000
+5.78558	-0.01019	+0.00000	-52843.70000
+6.62846	-0.00985	+0.00083	-60700.30000
+7.47135	-0.00875	+0.00178	-68587.10000
+8.31423	-0.00681	+0.00284	-76500.70000
+9.15712	-0.00393	+0.00402	-84437.60000
+10.00000	+0.00000	+0.00532	-92394.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00000	+0.00532	-92394.50000
+17.25010	+0.07696	+0.01539	-67739.50000
+24.50010	+0.21596	+0.02248	-45067.20000
+31.75020	+0.39634	+0.02687	-25122.10000
+39.00030	+0.59993	+0.02895	-8540.22000
+46.25030	+0.81162	+0.02918	+4149.70000
+53.50040	+1.01984	+0.02808	+12543.00000
+60.75050	+1.21696	+0.02621	+16372.20000
+68.00050	+1.39947	+0.02415	+15515.10000
+75.25060	+1.56817	+0.02250	+9999.10000
+82.50070	+1.72807	+0.02182	+0.00000

D1 (ft) =	10
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in <sup>4</sup> ) =	.013777

BETA (deg) =	-132941
HO (lb's) =	754.52
HC (lb's) =	0
h1 (lb's) =	1176.1
PHI (deg) =	42.4913

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00232	+0.01557
+1.15793	-0.00265	-0.00223	-9125.21000
+2.31585	-0.00509	-0.00195	-18349.50000
+3.47378	-0.00710	-0.00149	-27665.30000
+4.63171	-0.00847	-0.00084	-37055.10000
+5.78963	-0.00597	+0.00000	-46541.10000
+6.63171	-0.00867	+0.00073	-53475.70000
+7.47378	-0.00770	+0.00157	-60443.70000
+8.31585	-0.00600	+0.00250	-67441.90000
+9.15793	-0.00346	+0.00354	-74467.30000
+10.00000	-0.00000	+0.00468	-81516.90000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	+0.00468	-81516.90000
+16.85890	+0.06233	+0.01305	-59079.50000
+23.71780	+0.17311	+0.01885	-38671.20000
+30.57670	+0.31569	+0.02237	-20887.00000
+37.43550	+0.47557	+0.02395	-6234.51000
+44.29440	+0.64078	+0.02400	+4867.84000
+51.15330	+0.80228	+0.02295	+12103.20000
+58.01220	+0.95415	+0.02128	+15265.00000
+64.87110	+1.09383	+0.01947	+14263.00000
+71.73000	+1.22213	+0.01804	+9125.79000
+78.58890	+1.34324	+0.01746	+0.01557

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-.75
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-,113576
HO (lb's) =	6596.11
HC (lb's) =	0
hi (lb's) =	10495.3
PHI (deg) =	40.6717

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00198	+0.01557
+1.15793	-0.00227	-0.00190	-7770.34000
+2.31585	-0.00435	-0.00167	-15640.90000
+3.47378	-0.00607	-0.00127	-23605.10000
+4.63171	-0.00724	-0.00072	-31656.60000
+5.78963	-0.00767	+0.00000	-39788.80000
+6.63171	-0.00741	+0.00063	-45749.60000
+7.47378	-0.00659	+0.00134	-51747.00000
+8.31585	-0.00513	+0.00214	-57778.40000
+9.15793	-0.00296	+0.00303	-63841.20000
+10.00000	+0.00000	+0.00401	-69932.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	+0.00401	-69932.80000
+16.43410	+0.04850	+0.01069	-49908.20000
+22.86830	+0.13303	+0.01523	-31904.90000
+29.30240	+0.24066	+0.01792	-16381.40000
+35.73660	+0.36026	+0.01902	-3727.80000
+42.17070	+0.48273	+0.01887	+5737.88000
+48.60490	+0.60128	+0.01786	+11777.80000
+55.03900	+0.71157	+0.01637	+14240.20000
+61.47320	+0.81182	+0.01481	+13063.20000
+67.90730	+0.90250	+0.01359	+8276.39000
+74.34150	+0.98823	G-2601309	+0.01557

D1 (ft) =	10
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-3
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-0.0928121
HO (lb's) =	5353.79
HC (lb's) =	0
h1 (lb's) =	9091.73
RHI (deg) =	38.696

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00162	+0.01557
+1.15874	-0.00185	-0.00156	-6321.80000
+2.31748	-0.00356	-0.00136	-12745.10000
+3.47621	-0.00457	-0.00104	-19264.60000
+4.63495	-0.00592	-0.00059	-25875.10000
+5.79369	-0.00628	+0.00000	-32571.00000
+6.63495	-0.00607	+0.00051	-37482.90000
+7.47621	-0.00539	+0.00110	-42434.80000
+8.31748	-0.00420	+0.00175	-47424.60000
+9.15874	-0.00242	+0.00248	-52450.30000
+10.00000	+0.00000	+0.00325	-57509.60000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	+0.00329	-57509.60000
+15.97060	+0.03560	+0.00834	-40106.40000
+21.94110	+0.09615	+0.01168	-24659.50000
+27.91170	+0.17210	+0.01353	-11505.30000
+33.88230	+0.25531	+0.01416	-928.53500
+39.85290	+0.33924	+0.01382	+6841.70000
+45.82340	+0.41908	+0.01284	+11637.30000
+51.79400	+0.49188	+0.01152	+13354.50000
+57.76460	+0.55556	+0.01018	+11956.00000
+63.73510	+0.61999	+0.00914	+7472.13000
+69.70570	+0.66695	+0.00873	-0.01557

D1 (ft) =	10
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.0703579
HO (lb's) =	4011
HC (lb's) =	0
h1 (lb's) =	7536.14
PHI (deg) =	36.5369

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00123	+0.01357
+1.16036	-0.00141	-0.00118	-4756.90000
+2.32072	-0.00270	-0.00104	-9616.86000
+3.48108	-0.00377	-0.00079	-14575.90000
+4.64144	-0.00450	-0.00045	-19629.90000
+5.80180	-0.00477	+0.00000	-24774.90000
+6.64144	-0.00451	+0.00039	-28552.00000
+7.48108	-0.00410	+0.00089	-32372.90000
+8.32072	-0.00319	+0.00138	-36236.00000
+9.16036	-0.00184	+0.00189	-40139.40000
+10.00000	-0.00000	+0.00251	-44081.70000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00000	+0.00250	-44081.70000
+15.46410	+0.02382	+0.00559	-29512.80000
+20.92820	+0.06304	+0.00817	-16776.30000
+26.39230	+0.11105	+0.00924	-6103.52000
+31.85640	+0.16233	+0.00940	+2311.87000
+37.32050	+0.21251	+0.00887	+8317.24000
+42.78460	+0.25849	+0.00790	+11803.80000
+48.24870	+0.29845	+0.00671	+12708.30000
+53.71270	+0.33193	+0.00557	+11014.20000
+59.17680	+0.35980	+0.00470	+6752.33000
+64.64090	+0.38428	+0.00436	+0.00000

D1 (ft) =	10
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	0
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.01377

BETA (deg) =	-.0458009
HO (lb's) =	2541.25
HC (lb's) =	0
h1 (lb's) =	5781.02
PHI (deg) =	34.1524

#### SEGMENT A BII TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00000	+0.01557
+1.16360	-0.00092	-0.00077	-3042.92000
+2.32721	-0.00176	-0.00068	-6190.88000
+3.49081	-0.00247	-0.00052	-9441.31000
+4.65441	-0.00294	-0.00029	-12791.50000
+5.81802	-0.00312	+0.00000	-16238.70000
+6.65441	-0.00302	+0.00025	-18774.80000
+7.49081	-0.00268	+0.00055	-21358.60000
+8.32721	-0.00209	+0.00088	-23988.90000
+9.16360	-0.00121	+0.00124	-26664.40000
+10.00000	+0.00000	+0.00165	-29384.30000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	+0.00165	-29384.30000
+14.91270	+0.01343	+0.00365	-17859.20000
+19.82530	+0.03441	+0.00475	-7986.97000
+24.73800	+0.05881	+0.00507	+87.60320
+29.65070	+0.08323	+0.00479	+6246.11000
+34.56340	+0.10511	+0.00406	+10398.30000
+39.47600	+0.12269	+0.00307	+12483.20000
+44.38870	+0.13511	+0.00199	+12470.30000
+49.30140	+0.14238	+0.00100	+10359.80000
+54.21410	+0.14537	+0.00028	+6182.62000
+59.12670	+0.14583	+0.00000	-0.00778

D1 (ft) =	10
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.019777

BETA (deg) =	-.0185778
HO (lb's) =	912.579
HC (lb's) =	0
h1 (lb's) =	8762.89
PHI (deg) =	31.4934

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00032	+0.01537
+1.17739	-0.00038	-0.00031	-1142.72000
+2.35478	-0.00073	-0.00028	-2394.59000
+3.53216	-0.00102	-0.00021	-3754.54000
+4.70955	-0.00122	-0.00012	-5221.43000
+5.88694	-0.00129	+0.00000	-6794.03000
+6.70955	-0.00125	+0.00011	-7954.81000
+7.53216	-0.00112	+0.00023	-9166.04000
+8.35477	-0.00087	+0.00037	-10427.30000
+9.17739	-0.00051	+0.00053	-11737.90000
+10.00000	-0.00000	+0.00070	-13097.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	+0.00070	-13097.50000
+14.32680	+0.00470	+0.00137	-4780.65000
+18.65370	+0.01100	+0.00146	+2104.99000
+22.98050	+0.01666	+0.00109	+7480.96000
+27.30740	+0.01992	+0.00037	+11286.10000
+31.63420	+0.01956	-0.00057	+13477.10000
+35.96100	+0.01485	-0.00161	+14029.00000
+40.28790	+0.00563	-0.00264	+12935.50000
+44.61470	-0.00777	-0.00352	+10209.20000
+48.94150	-0.02444	-0.00413	+5880.90000
+53.26840	-0.04298	-0.00436	+0.00000

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.01377

BETA (deg) =	.0114236
HO (lb's) =	-912.23
HQ (lb's) =	0
h1 (lb's) =	1397.73
PHI (deg) =	28.5072

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00021	+0.01557
+1.11495	+0.00023	+0.00020	+975.71400
+2.22990	+0.00044	+0.00017	+1851.96000
+3.34485	+0.00060	+0.00013	+2628.05000
+4.45980	+0.00071	+0.00007	+3303.42000
+5.57475	+0.00076	-0.00000	+3877.55000
+6.45980	+0.00073	-0.00006	+4260.91000
+7.34485	+0.00064	-0.00013	+4580.05000
+8.22990	+0.00050	-0.00020	+4834.78000
+9.11495	+0.00028	-0.00028	+5024.96000
+10.00000	+0.00000	-0.00036	+5150.56000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	-0.00036	+5150.56000
+13.73780	-0.00218	-0.00086	+10184.80000
+17.47560	-0.00681	-0.00166	+14023.30000
+21.21340	-0.01482	-0.00265	+16633.70000
+24.95120	-0.02684	-0.00379	+17993.80000
+28.68890	-0.04320	-0.00497	+18092.10000
+32.42670	-0.06394	-0.00611	+16927.70000
+36.16450	-0.08876	-0.00714	+14510.60000
+39.90230	-0.11708	-0.00797	+10861.30000
+43.64010	-0.14801	-0.00853	+6010.65000
+47.37790	-0.18037	-0.00973	+0.00000

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.75
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.0463024
HO (lb's) =	-2968.99
HC (lb's) =	0
h1 (lb's) =	-1412.34
PHI (deg) =	25.1518

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00081	+0.01557
+1.14495	+0.00091	+0.00077	+3379.23000
+2.28991	+0.00175	+0.00067	+6651.62000
+3.43486	+0.00243	+0.00051	+9814.59000
+4.57981	+0.00289	+0.00028	+12865.60000
+5.72476	+0.00306	-0.00000	+15802.30000
+6.57981	+0.00296	-0.00025	+17919.30000
+7.43486	+0.00252	-0.00053	+19970.30000
+8.28991	+0.00204	-0.00084	+21954.40000
+9.14495	+0.00117	-0.00119	+23870.60000
+10.00000	+0.00000	-0.00155	+25718.10000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	-0.00156	+25718.10000
+13.19500	-0.00731	-0.00304	+27494.70000
+16.39000	-0.01948	-0.00459	+28288.00000
+19.58490	-0.03666	-0.00616	+28095.30000
+22.77990	-0.05881	-0.00769	+26917.80000
+25.97490	-0.08572	-0.00913	+24762.50000
+29.16990	-0.11701	-0.01043	+21643.60000
+32.36480	-0.15213	-0.01152	+17579.70000
+35.55980	-0.19035	-0.01236	+12596.30000
+38.75480	-0.23079	-0.01290	+6724.23000
+41.94980	-0.27242	-0.01309	+0.00000

D1 (ft) =	10
DH (in) =	12.25
ODdc (in) =	5.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in <sup>4</sup> ) =	1013777

BETA (deg) =	.0849065
HO (lb's) =	-3278.6
HC (lb's) =	0
h1 (lb's) =	-4754.88
PHI (deg) =	21.4243

#### SEGMENT A BII TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00148	+0.01557
+1.14901	+0.00168	+0.00142	+6071.50000
+2.29801	+0.00322	+0.00124	+12033.30000
+3.44702	+0.00448	+0.00094	+17880.50000
+4.59603	+0.00534	+0.00053	+23608.50000
+5.74504	+0.00565	-0.00000	+29212.70000
+6.59603	+0.00546	-0.00046	+33280.80000
+7.44702	+0.00485	-0.00048	+37276.80000
+8.29801	+0.00377	-0.00157	+41198.90000
+9.14901	+0.00217	-0.00220	+45043.20000
+10.00000	-0.00000	-0.00290	+48814.20000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00000	-0.00240	+48814.20000
+12.73850	-0.01109	-0.00519	+47394.40000
+15.47710	-0.02836	-0.00740	+45155.60000
+18.21560	-0.05150	-0.00948	+42115.40000
+20.95410	-0.08012	-0.01139	+38287.60000
+23.69260	-0.11372	-0.01311	+33689.70000
+26.43120	-0.15171	-0.01459	+28342.70000
+29.16970	-0.19338	-0.01580	+22271.00000
+31.90820	-0.23795	-0.01670	+15502.20000
+34.64670	-0.28453	-0.01726	+8067.23000
+37.38580	-0.33216	-0.01746	-0.01557

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (PPg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.127668
HO (lb's) =	-7836.85
HC (lb's) =	0
hi (lb's) =	-8679.43
PHI (deg) =	17.3803

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00223	+0.01557
+1.15063	+0.00253	+0.00214	+5053.25000
+2.30126	+0.00485	+0.00187	+17994.00000
+3.45189	+0.00676	+0.00142	+26815.20000
+4.60252	+0.00805	+0.00080	+35509.60000
+5.75315	+0.00852	-0.00000	+44070.20000
+6.90252	+0.00823	-0.00070	+50299.60000
+7.45189	+0.00731	-0.00149	+55449.70000
+8.30126	+0.00568	-0.00236	+62517.70000
+9.15063	+0.00327	-0.00333	+68500.90000
+10.00000	-0.00000	-0.00439	+74396.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00000	-0.00439	+74396.80000
+12.37740	-0.01402	-0.00737	+69807.40000
+14.75470	-0.03489	-0.01015	+64511.60000
+17.13210	-0.06210	-0.01269	+58545.30000
+19.50940	-0.09505	-0.01498	+51929.00000
+21.88680	-0.13309	-0.01698	+44685.40000
+24.26410	-0.17552	-0.01865	+36839.40000
+26.64150	-0.22157	-0.02001	+28418.00000
+29.01890	-0.27040	-0.02101	+19450.20000
+31.39620	-0.32114	-0.02161	+9966.63000
+33.77360	-0.37286	-0.02182	+0.00000

D1 (ft) =	10
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DOst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.019777

BETA (deg) =	,174339
HO (lb's) =	-10629
HC (lb's) =	0
h1 (lb's) =	-13209.9
PHI (deg) =	13.1089

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00304	+0.01557
+1.15144	+0.00346	+0.00292	+12307.00000
+2.30288	+0.00663	+0.00255	+24498.80000
+3.45432	+0.00924	+0.00194	+36565.50000
+4.60576	+0.01101	+0.00109	+48497.40000
+5.75720	+0.01165	-0.00000	+60284.90000
+6.90576	+0.01126	-0.00055	+68873.80000
+7.45432	+0.01000	-0.00203	+77375.30000
+8.30288	+0.0078	-0.00323	+85785.80000
+9.15144	+0.00448	-0.00455	+94101.40000
+10.00000	-0.00000	-0.00501	+102319.00000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00000	-0.00602	+102319.00000
+12.05690	-0.01644	-0.00961	+94525.60000
+14.19370	-0.04009	-0.01290	+86095.60000
+16.29060	-0.07032	-0.01588	+77086.20000
+18.38750	-0.10644	-0.01851	+67521.50000
+20.48440	-0.14772	-0.02079	+57427.20000
+22.58120	-0.19338	-0.02269	+46830.10000
+24.67810	-0.24262	-0.02420	+35758.70000
+26.77500	-0.29458	-0.02530	+24242.50000
+28.87180	-0.34840	-0.02596	+12312.30000
+30.96870	-0.40316	-0.02619	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.282538
HO (lb's) =	803.782
HC (lb's) =	0
h1 (lb's) =	1604.61
PHI (deg) =	6.31545

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00493	+0.00271
+4.63820	-0.02259	-0.00475	-4667.60000
+9.27639	-0.04342	-0.00417	-9571.74000
+13.91460	-0.06067	-0.00320	-14648.30000
+18.55280	-0.07244	-0.00181	-19830.90000
+23.19100	-0.07680	+0.00000	-25051.80000
+26.55280	-0.07421	+0.00158	-28821.20000
+29.91460	-0.06596	+0.00337	-32548.90000
+33.27640	-0.05132	+0.00538	-36209.30000
+36.63820	-0.02957	+0.00760	-39777.40000
+40.00000	-0.00000	+0.01002	-43228.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.01002	-43228.50000
+52.33830	+0.17751	+0.01845	-35039.00000
+64.67670	+0.44748	+0.02498	-25707.40000
+77.01500	+0.78541	+0.02946	-16105.80000
+89.35330	+1.16610	+0.03193	-7116.33000
+101.69200	+1.56593	+0.03261	+435.20900
+114.03000	+1.96509	+0.03190	+5855.08000
+126.36800	+2.34934	+0.03029	+8645.34000
+138.70700	+2.71135	+0.02839	+8349.67000
+151.04500	+3.05137	+0.02683	+5576.86000
+163.38300	+3.37721	+0.02619	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.250815
HO (lb's) =	697.731
HC (lb's) =	0
h1 (lb's) =	1583.99
PHI (deg) =	6.14194

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00438	+0.00271
+4.64630	-0.02009	-0.00421	-4094.47000
+9.29261	-0.03864	-0.00371	-8433.82000
+13.93890	-0.05401	-0.00285	-12961.10000
+18.58520	-0.06452	-0.00161	-17617.00000
+23.23150	-0.06841	+0.00000	-22340.30000
+26.58520	-0.06612	+0.00140	-23756.60000
+29.93890	-0.05879	+0.00300	-29152.40000
+33.29260	-0.04576	+0.00480	-32504.60000
+36.64630	-0.02638	+0.00679	-35790.00000
+40.00000	-0.00000	+0.00897	-38986.40000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00897	-38986.40000
+51.61800	+0.14693	+0.01605	-30926.50000
+63.23590	+0.36629	+0.02142	-22192.10000
+74.85390	+0.63772	+0.02502	-13504.40000
+86.47180	+0.94098	+0.02692	-5571.83000
+98.08980	+1.25759	+0.02736	+958.50000
+109.70800	+1.57233	+0.02657	+5555.05000
+121.32600	+1.87449	+0.02527	+7842.17000
+132.94400	+2.15874	+0.02367	+7633.69000
+144.56200	+2.42557	+0.02236	+4946.60000
+156.18000	+2.68124	+0.02182	+0.00000

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.01377

BETA (deg) =	-215858
HO (lb's) =	580.867
HC (lb's) =	0
h1 (lb's) =	1544.09
PHI (deg) =	5.95071

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00377	+0.00271
+4.65928	-0.01734	-0.00363	-3463.68000
+9.31855	-0.03337	-0.00320	-7181.93000
+13.97780	-0.04668	-0.00246	-11105.70000
+18.63710	-0.05579	-0.00140	-15183.20000
+23.29640	-0.05918	+0.00000	-19360.70000
+26.63710	-0.05720	+0.00121	-22386.80000
+29.97780	-0.05087	+0.00260	-25415.50000
+33.31860	-0.03962	+0.00416	-28426.10000
+36.65930	-0.02286	+0.00590	-31398.30000
+40.00000	-0.00000	+0.00781	-34311.90000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00781	-34311.90000
+50.84750	+0.11722	+0.01356	-26588.70000
+61.69490	+0.28878	+0.01782	-18588.30000
+72.54240	+0.49840	+0.02059	-10484.90000
+83.38990	+0.73043	+0.02198	-4026.70000
+94.23730	+0.97092	+0.02219	+1498.39000
+105.08500	+1.20865	+0.02152	+5297.30000
+115.93200	+1.43588	+0.02032	+7099.72000
+126.78000	+1.64895	+0.01898	+6777.44000
+137.62700	+1.84852	+0.01790	+4353.38000
+148.47500	+2.03952	+0.01745	-0.00136

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-75
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.019777

BETA (deg) =	-17.36
HO (lb's) =	452.171
HC (lb's) =	0
h1 (lb's) =	1481.58
PHI (deg) =	5.7401

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00310	+0.00271
+4.67793	-0.01431	-0.00259	-2767.61000
+9.35585	-0.02756	-0.00264	-5801.09000
+14.03380	-0.03860	-0.00204	-9060.10000
+18.71170	-0.04618	-0.00116	-12501.30000
+23.38960	-0.04901	+0.00000	-16078.90000
+26.71170	-0.04738	+0.00100	-18676.40000
+30.03380	-0.04217	+0.00216	-21301.30000
+33.35590	-0.03287	+0.00346	-23936.00000
+36.67790	-0.01598	+0.00492	-26552.70000
+40.00000	-0.00000	+0.00653	-29164.00000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00653	-29164.00000
+50.01800	+0.08879	+0.01099	-21989.70000
+60.03590	+0.21595	+0.01419	-14859.80000
+70.05390	+0.36910	+0.01619	-8209.92000
+80.07180	+0.53669	+0.01710	-2443.94000
+90.08980	+0.70873	+0.01711	+2087.89000
+100.10800	+0.87735	+0.01646	+5110.34000
+110.12600	+1.03730	+0.01543	+6439.83000
+120.14400	+1.18628	+0.01432	+5995.59000
+130.16200	+1.32505	+0.01345	+3804.62000
+140.18000	+1.45742	+0.01309	+0.00000

D1 (ft) =	40
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.655
I (in^4) =	.013777

BETA (deg) =	-,134925
HO (lb's) =	310.31
HC (lb's) =	0
hi (lb's) =	1391.78
PHI (deg) =	5.50792

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00236	+0.00271
+4.71036	-0.01097	-0.00228	-1999.22000
+9.42072	-0.02116	-0.00202	-4278.37000
+14.13110	-0.02969	-0.00157	-6806.70000
+18.84140	-0.03559	-0.00090	-9530.14000
+23.55180	-0.03780	+0.00000	-12471.70000
+26.84140	-0.03656	+0.00077	-14596.70000
+30.13110	-0.03257	+0.00167	-16775.50000
+33.42070	-0.02543	+0.00269	-18993.70000
+36.71040	-0.01471	+0.00384	-21236.60000
+40.00000	-0.00000	+0.00512	-23489.60000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00512	-23489.60000
+49.12170	+0.06216	+0.00834	-17078.30000
+58.24340	+0.14905	+0.01055	-10352.50000
+67.36510	+0.23186	+0.01184	-5421.97000
+76.48670	+0.36261	+0.01232	-763.38500
+85.60840	+0.47460	+0.01214	+2782.53000
+94.73010	+0.58272	+0.01150	+5042.95000
+103.85200	+0.68372	+0.01062	+5301.94000
+112.97300	+0.77636	+0.00971	+5316.21000
+122.09500	+0.86148	+0.00901	+3315.28000
+131.21700	+0.94197	+0.00873	+0.00271

D1 (ft) =	40
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	-125
WOB (lb's) =	40000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-0.0891982
HO (lb's) =	151.796
HC (lb's) =	0
h1 (lb's) =	1232.36
PHI (deg) =	5.21741

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00156	+0.00237
+4.76946	-0.00735	-0.00151	-1175.61000
+9.53893	-0.01423	-0.00135	-2647.22000
+14.30840	-0.02006	-0.00106	-4391.57000
+19.07790	-0.02413	-0.00052	-6381.13000
+23.84730	-0.02568	+0.00000	-8584.46000
+27.07780	-0.02486	+0.00053	-10189.80000
+30.30840	-0.02218	+0.00114	-11847.70000
+33.53890	-0.01736	+0.00186	-13573.10000
+36.76950	-0.01007	+0.00267	-15344.50000
+40.00000	-0.00000	+0.00358	-17149.10000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00358	-17149.10000
+48.11490	+0.03785	+0.00562	-11817.10000
+56.22980	+0.08925	+0.00693	-6854.37000
+64.34460	+0.14856	+0.00758	-2487.35000
+72.45950	+0.21080	+0.00767	+1084.79000
+80.57440	+0.27188	+0.00732	+3699.11000
+88.68930	+0.32883	+0.00668	+5236.39000
+96.80410	+0.37990	+0.00590	+5626.49000
+104.91900	+0.42464	+0.00515	+4851.65000
+113.03400	+0.46393	+0.00458	+2947.20000
+121.14900	+0.49995	+0.00436	+0.00237

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	0
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.036088
HO (lb's) =	-20.1018
HC (lb's) =	0
hi (lb's) =	1100.58
PHI (deg) =	4.9671

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00063	+0.00271
+5.01363	-0.00315	-0.00062	-183.53200
+10.02730	-0.00621	-0.00059	-711.87000
+15.04090	-0.00894	-0.00049	-1576.95000
+20.05450	-0.01098	-0.00030	-2765.55000
+25.06810	-0.01179	+0.00000	-4259.52000
+28.05450	-0.01144	+0.00025	-5285.33000
+31.04090	-0.01026	+0.00055	-6405.91000
+34.02730	-0.00809	+0.00091	-7615.18000
+37.01360	-0.00473	+0.00134	-8906.59000
+40.00000	-0.00000	+0.00184	-10273.10000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	+0.00184	-10273.10000
+47.14180	+0.01704	+0.00284	-5981.67000
+54.28350	+0.03943	+0.00335	-2209.50000
+61.42530	+0.06382	+0.00342	+926.63300
+68.56710	+0.08744	+0.00315	+3329.68000
+75.70880	+0.10817	+0.00263	+4925.27000
+82.85060	+0.12460	+0.00196	+5664.00000
+89.99230	+0.13607	+0.00126	+5523.04000
+97.13410	+0.14271	+0.00062	+4506.72000
+104.27600	+0.14541	+0.00017	+2646.52000
+111.41800	+0.14583	+0.00000	-0.00136

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.0216094
HO (lb's) =	-212.983
HC (lb's) =	0
h1 (lb's) =	876.294
PHI (deg) =	4.65138

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00038	+0.00271
+3.48351	+0.00129	+0.00036	+702.99100
+6.96702	+0.00243	+0.00030	+1232.87000
+10.45050	+0.00332	+0.00021	+1585.73000
+13.93400	+0.00387	+0.00011	+1758.97000
+17.41760	+0.00406	-0.00000	+1751.31000
+21.93400	+0.00376	-0.00013	+1472.32000
+25.45050	+0.00293	-0.00022	+892.91800
+30.96700	+0.00183	-0.00026	+20.29270
+35.48350	+0.00071	-0.00022	-1134.75000
+40.00000	+0.00000	-0.00008	-2557.87000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00008	-2557.87000
+46.12780	+0.00003	+0.00003	+463.96300
+52.25560	-0.00022	-0.00016	+2956.29000
+58.38340	-0.00237	-0.00058	+4862.27000
+64.51120	-0.00766	-0.00117	+6138.45000
+70.63900	-0.01691	-0.00186	+6755.73000
+76.76680	-0.03054	-0.00258	+6700.03000
+82.89460	-0.04851	-0.00327	+5972.63000
+89.02240	-0.07033	-0.00383	+4590.10000
+95.15020	-0.09512	-0.00422	+2583.98000
+101.27800	-0.12157	-0.00456	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in <sup>4</sup> ) =	.013777

BETA (deg) =	.0854251
HO (lb's) =	-426.318
HC (lb's) =	0
hi (lb's) =	580.346
PHI (deg) =	4.30221

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00149	+0.00271
+4.31141	+0.00632	+0.00142	+1830.59000
+8.62283	+0.01203	+0.00121	+3582.22000
+12.93420	+0.01658	+0.00089	+4936.24000
+17.24570	+0.01955	+0.00048	+5977.35000
+21.55710	+0.02066	-0.00000	+6693.80000
+25.24570	+0.01979	-0.00044	+7942.83000
+28.93420	+0.01732	-0.00090	+7145.33000
+32.62280	+0.01317	-0.00135	+7000.48000
+36.31140	+0.00736	-0.00179	+6699.47000
+40.00000	+0.00000	-0.00220	+5975.52000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00220	+5975.52000
+43.20390	-0.01298	-0.00282	+7690.49000
+50.40780	-0.02955	-0.00357	+8904.25000
+55.61160	-0.05030	-0.00441	+9597.07000
+60.81550	-0.07554	-0.00529	+9757.57000
+66.01940	-0.10536	-0.00616	+9383.08000
+71.22330	-0.13557	-0.00697	+8479.77000
+76.42710	-0.17776	-0.00768	+7062.51000
+81.63100	-0.21924	-0.00824	+5154.62000
+86.83490	-0.26314	-0.00850	+2787.47000
+92.03880	-0.30883	-0.00873	+0.00271

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	.75
WQB (lb's) =	33000
P (lb's/ft in fluid) =	158.855
I (in <sup>4</sup> ) =	.013777

BETA (deg) =	.155205
HO (lb's) =	-659.593
HC (lb's) =	0
h1 (lb's) =	200.382
PHI (deg) =	3.92047

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00271	+0.00271
+4.43142	+0.01182	+0.00258	+3200.64000
+8.86284	+0.02255	+0.00222	+6091.45000
+13.29430	+0.03122	+0.00165	+8637.91000
+17.72570	+0.03645	+0.00090	+10809.60000
+22.15710	+0.03900	-0.00000	+12580.70000
+25.72570	+0.03756	-0.00082	+13701.20000
+29.29430	+0.03310	-0.00169	+14539.40000
+32.86280	+0.02542	-0.00261	+15088.80000
+36.43140	+0.01440	-0.00356	+15345.20000
+40.00000	-0.00000	-0.00451	+15306.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	-0.00451	+15306.50000
+44.44170	-0.02270	-0.00571	+15736.40000
+48.88350	-0.05079	-0.00693	+15703.40000
+53.32520	-0.08425	-0.00813	+15209.20000
+57.76700	-0.12291	-0.00927	+14239.80000
+62.20870	-0.16645	-0.01032	+12866.50000
+66.65050	-0.21439	-0.01124	+11046.00000
+71.09220	-0.26610	-0.01201	+8820.24000
+75.53400	-0.32083	-0.01260	+6215.79000
+79.97570	-0.37768	-0.01296	+3263.91000
+84.41750	-0.43564	-0.01309	+0.00271

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	5
DELTA ALPHA =	1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.230275
HO (lb's) =	-910.551
HC (lb's) =	0
h1 (lb's) =	-269.747
PHI (deg) =	3.5099

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00402	+0.00271
+4.47764	+0.01773	+0.00384	+4558.81000
+8.95528	+0.03388	+0.00332	+8784.75000
+13.43290	+0.04698	+0.00248	+12626.30000
+17.91060	+0.05369	+0.00136	+16036.70000
+22.38820	+0.05883	-0.00000	+18974.40000
+25.91060	+0.05670	-0.00122	+20929.50000
+29.43290	+0.05007	-0.00256	+22555.10000
+32.95530	+0.03858	-0.00398	+23838.80000
+36.47760	+0.02196	-0.00547	+24771.10000
+40.00000	-0.00000	-0.00701	+25344.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00701	+25344.80000
+43.85190	-0.03024	-0.00868	+24522.70000
+47.70390	-0.06679	-0.01028	+23270.40000
+51.55580	-0.10933	-0.01179	+21602.80000
+55.40780	-0.15744	-0.01317	+19535.20000
+59.25970	-0.21058	-0.01440	+17086.10000
+63.11160	-0.26812	-0.01545	+14277.60000
+66.96360	-0.32933	-0.01630	+11135.00000
+70.81550	-0.39340	-0.01693	+7686.77000
+74.66750	-0.45946	-0.01732	+3963.91000
+78.51940	-0.52653	-0.01746	+0.00271

D1 (ft) =	40
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	5
DELTA ALPHA =	1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.30984
HO (lb's) =	-1176.71
HC (lb's) =	0
H1 (lb's) =	-831.647
PHI (deg) =	3.07462

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00541	+0.00271
+4.50116	+0.02399	+0.00517	+5995.98000
+9.00231	+0.04588	+0.00448	+11637.90000
+13.50350	+0.06364	+0.00336	+16856.20000
+18.00460	+0.07557	+0.00286	+21586.80000
+22.50580	+0.07986	-0.00000	+25771.30000
+26.00460	+0.07702	-0.00156	+28613.60000
+29.50350	+0.06808	-0.00347	+31073.60000
+33.00230	+0.05255	-0.00543	+33132.90000
+36.50120	+0.02997	-0.00749	+34776.20000
+40.00000	+0.00000	-0.00965	+35991.20000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	-0.00965	+35991.20000
+43.40280	-0.03641	-0.01172	+38935.10000
+46.80570	-0.07964	-0.01366	+31471.30000
+50.20850	-0.12919	-0.01544	+28625.80000
+53.61130	-0.18451	-0.01704	+25418.50000
+57.01410	-0.24493	-0.01844	+21872.20000
+60.41700	-0.30975	-0.01962	+18011.60000
+63.81980	-0.37819	-0.02056	+13864.00000
+67.22260	-0.44942	-0.02126	+9458.63000
+70.62550	-0.52254	-0.02168	+4826.43000
+74.02830	-0.59664	-0.02182	+0.00271

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.393201
HO (lb's) =	-1455.23
HC (lb's) =	0
hi (lb's) =	-1482.39
PHI (deg) =	2.61937

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00686	+0.00271
+4.51575	+0.03055	+0.00657	+7499.36000
+9.03150	+0.05844	+0.00570	+14623.70000
+13.54730	+0.08117	+0.00428	+21284.80000
+18.06300	+0.09637	+0.00237	+27400.00000
+22.57880	+0.10188	-0.00000	+32893.60000
+26.06300	+0.09827	-0.00211	+36664.20000
+29.54730	+0.08693	-0.00443	+39996.20000
+33.03150	+0.06716	-0.00695	+42863.00000
+36.51580	+0.03835	-0.00962	+45249.40000
+40.00000	+0.00000	-0.01242	+47131.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	-0.01242	+47131.80000
+43.05750	-0.04173	-0.01484	+43846.50000
+46.11500	-0.09058	-0.01708	+40166.40000
+49.17250	-0.14594	-0.01911	+36128.80000
+52.23010	-0.20718	-0.02091	+31756.50000
+55.28760	-0.27357	-0.02248	+27074.30000
+58.34510	-0.34436	-0.02378	+22108.90000
+61.40260	-0.41873	-0.02482	+16888.50000
+64.46010	-0.49585	-0.02557	+11442.70000
+67.51760	-0.57482	-0.02603	+5802.55000
+70.57520	-0.65474	-0.02619	+0.00271

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.339945
HO (lb's) =	329.023
HC (lb's) =	0
h1 (lb's) =	6316.06
PHI (deg) =	30.5385

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00593	+0.01557
+4.86605	-0.02866	-0.00580	-3544.68000
+9.73210	-0.05580	-0.00528	-8917.00000
+14.59810	-0.07922	-0.00424	-16039.70000
+19.46420	-0.09597	-0.00252	-24810.20000
+24.33020	-0.10246	+0.00000	-35102.40000
+27.46420	-0.09926	+0.00211	-42468.40000
+30.59810	-0.08879	+0.00464	-50360.50000
+33.73210	-0.06973	+0.00761	-58731.70000
+36.86610	-0.04063	+0.01104	-67532.00000
+40.00000	+0.00000	+0.01497	-76708.70000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.01497	-76708.70000
+46.68210	+0.12704	+0.02263	-55298.20000
+53.36420	+0.29712	+0.02790	-35878.40000
+60.04620	+0.49522	+0.03106	-19028.30000
+66.72830	+0.70828	+0.03244	-5204.73000
+73.41040	+0.92560	+0.03240	+5217.62000
+80.09250	+1.13911	+0.03137	+11956.10000
+86.77450	+1.34359	+0.02978	+14828.00000
+93.45660	+1.53682	+0.02808	+13755.60000
+100.13900	+1.71963	+0.02673	+8767.84000
+106.82100	+1.89587	+0.02619	-0.00779

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	- .281773
HO (lb's) =	134.55
HC (lb's) =	0
hi (lb's) =	6086.82
PHI (deg) =	30.2202

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00432	+0.01557
+4.91714	-0.02405	-0.00483	-2463.47000
+9.83427	-0.04699	-0.00444	-6808.99000
+14.75140	-0.06701	-0.00361	-12972.70000
+19.66850	-0.08151	-0.00218	-20854.10000
+24.58570	-0.08720	+0.00000	-30367.20000
+27.66850	-0.08450	+0.00181	-37085.90000
+30.75140	-0.07568	+0.00399	-44344.90000
+33.83430	-0.05952	+0.00657	-52102.20000
+36.91710	-0.03474	+0.00958	-60313.00000
+40.00000	-0.00000	+0.01304	-68929.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	+0.01304	-68929.70000
+46.39600	+0.10554	+0.01959	-49134.90000
+52.79210	+0.24614	+0.02404	-31331.90000
+59.18810	+0.40916	+0.02665	-15995.80000
+65.58410	+0.58373	+0.02771	-3507.45000
+71.98020	+0.76098	+0.02755	+5822.81000
+78.37620	+0.93428	+0.02654	+11763.20000
+84.77220	+1.09944	+0.02506	+14166.30000
+91.16820	+1.25473	+0.02352	+12972.20000
+97.56430	+1.40101	+0.02231	+8210.67000
+103.96000	+1.54166	+0.02182	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.221812
HO (lb's) =	-65.9015
HC (lb's) =	0
h1 (lb's) =	5837.79
PHI (deg) =	29.8921

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00387	+0.01557
+4.99011	-0.01926	-0.00383	-1334.24000
+9.98023	-0.03787	-0.00358	-4623.82000
+14.97030	-0.05441	-0.00297	-9818.97000
+19.96050	-0.06664	-0.00183	-16841.10000
+24.95060	-0.07151	+0.00000	-25583.90000
+27.96050	-0.06934	+0.00149	-31634.90000
+30.97030	-0.06218	+0.00332	-38230.80000
+33.98020	-0.04900	+0.00550	-45335.40000
+36.99010	-0.02867	+0.00807	-52909.70000
+40.00000	+0.00000	+0.01105	-60911.70000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.01105	-60911.70000
+46.09760	+0.08507	+0.01653	-42799.60000
+52.19530	+0.19790	+0.02019	-26651.80000
+58.29290	+0.32808	+0.02226	-12851.50000
+64.39050	+0.46671	+0.02301	-1710.16000
+70.48820	+0.60660	+0.02273	+6520.45000
+76.58580	+0.74245	+0.02174	+11654.60000
+82.68340	+0.87094	+0.02037	+13576.30000
+88.78110	+0.99083	+0.01897	+12242.30000
+94.87870	+1.10298	+0.01789	+7682.50000
+100.97600	+1.21033	+0.01746	+0.01557

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.75
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.15992
HO (lb's) =	-272.806
HC (lb's) =	0
hi (lb's) =	5566.2
PHI (deg) =	29.5535

SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00279	+0.01557
+5.10445	-0.01428	-0.00280	-142.02800
+10.20890	-0.02841	-0.00271	-2348.76000
+15.31330	-0.04141	-0.00232	-6585.28000
+20.41780	-0.05134	-0.00148	-12784.50000
+25.52220	-0.05542	+0.00000	-20848.40000
+28.41780	-0.05377	+0.00118	-26204.10000
+31.31330	-0.04830	+0.00265	-32092.00000
+34.20890	-0.03815	+0.00442	-38482.00000
+37.10440	-0.02238	+0.00653	-45341.50000
+40.00000	-0.00000	+0.00899	-52635.50000

SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00899	-52635.50000
+45.78670	+0.06573	+0.01345	-36268.70000
+51.57350	+0.15266	+0.01635	-21811.40000
+57.36020	+0.25240	+0.01791	-9566.61000
+63.14700	+0.35782	+0.01836	+216.60100
+68.93370	+0.46325	+0.01796	+7339.24000
+74.72050	+0.56454	+0.01698	+11656.50000
+80.50720	+0.65919	+0.01571	+13080.50000
+86.29390	+0.74636	+0.01444	+11582.30000
+92.08070	+0.82694	+0.01348	+7192.35000
+97.86740	+0.90346	+0.01309	-0.00778

D1 (ft) =	40
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.0959443
HO (lb's) =	-486.677
HC (lb's) =	0
h1 (lb's) =	5268.73
PHI (deg) =	29.2034

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00167	+0.01557
+5.30311	-0.00902	-0.00174	+1148.23000
+10.60620	-0.01851	-0.00182	+46.05860
+15.90930	-0.02793	-0.00168	-3287.65000
+21.21240	-0.03566	-0.00114	-8795.92000
+26.51550	-0.03900	+0.00000	-16384.70000
+29.21240	-0.03787	+0.00088	-21001.80000
+31.90930	-0.03407	+0.00198	-26103.50000
+34.60620	-0.02698	+0.00333	-31667.30000
+37.30310	-0.01587	+0.00495	-37668.50000
+40.00000	+0.00000	+0.00687	-44080.70000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00687	-44080.70000
+45.46380	+0.04767	+0.01035	-29514.30000
+50.92770	+0.11073	+0.01253	-16777.50000
+56.39150	+0.18258	+0.01360	-6104.49000
+61.85530	+0.25770	+0.01376	+2311.14000
+67.31920	+0.33172	+0.01324	+8316.74000
+72.78300	+0.40154	+0.01226	+11803.50000
+78.24680	+0.46535	+0.01108	+12708.00000
+83.71070	+0.52267	+0.00993	+11014.10000
+89.17450	+0.57439	+0.00907	+6752.33000
+94.63840	+0.62271	+0.00873	+0.01557

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	-.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	-.0297178
HO (lb's) =	-708.072
HC (lb's) =	0
hi (lb's) =	4941.36
PHI (deg) =	28.8412

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00052	+0.01557
+5.69557	-0.00326	-0.00067	+2630.28000
+11.39110	-0.00789	-0.00095	+2636.11000
+17.08670	-0.01387	-0.00111	+17.43350
+22.78230	-0.01974	-0.00087	-5174.17000
+28.47790	-0.02259	+0.00000	-12836.40000
+30.78230	-0.02194	+0.00059	-16605.80000
+33.08670	-0.01975	+0.00134	-20743.30000
+35.39110	-0.01565	+0.00226	-25235.50000
+37.69560	-0.00921	+0.00336	-30067.90000
+40.00000	+0.00000	+0.00467	-35224.90000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00467	-35224.90000
+45.13040	+0.03101	+0.00723	-22502.80000
+50.26090	+0.07238	+0.00873	-11508.30000
+55.39130	+0.11908	+0.00934	-2417.78000
+60.52170	+0.16697	+0.00923	+4623.24000
+65.65210	+0.21283	+0.00858	+9502.27000
+70.78260	+0.25443	+0.00760	+12141.20000
+75.91300	+0.29055	+0.00648	+12497.90000
+81.04340	+0.32105	+0.00544	+10566.70000
+86.17380	+0.34680	+0.00466	+6378.39000
+91.30430	+0.36972	+0.00436	+0.00000

D1 (ft) =	40
DH (in) =	12.25
DDdc (in) =	8.75
IDdc (in) =	2.5
DDst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	0
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.0389259
HO (lb's) =	-937.547
HC (lb's) =	0
h1 (lb's) =	4579.37
PHI (deg) =	28.4657

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00068	+0.01557
+2.15936	+0.00144	+0.00064	+1889.71000
+4.31871	+0.00273	+0.00054	+3403.78000
+6.47806	+0.00375	+0.00039	+4537.87000
+8.63742	+0.00440	+0.00021	+5288.80000
+10.79680	+0.00462	-0.00000	+5654.44000
+15.63740	+0.00297	-0.00055	+4708.39000
+22.47810	-0.00134	-0.00086	+959.74400
+28.31870	-0.00608	-0.00065	-5513.90000
+34.15940	-0.00742	+0.00035	-14578.40000
+40.00000	-0.00000	+0.00239	-26045.90000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00239	-26045.90000
+44.78960	+0.01589	+0.00409	-15195.60000
+49.57920	+0.03789	+0.00496	-5953.57000
+54.36870	+0.06232	+0.00513	+1551.30000
+59.15830	+0.08619	+0.00476	+7214.42000
+63.94790	+0.10726	+0.00399	+10956.90000
+68.73750	+0.12401	+0.00299	+12726.40000
+73.52710	+0.13576	+0.00192	+12498.50000
+78.31670	+0.14260	+0.00096	+10276.30000
+83.10620	+0.14540	+0.00027	+6090.63000
+87.89580	+0.14583	-0.00000	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.110146
HO (lb's) =	-1175.63
HC (lb's) =	0
hi (lb's) =	4177.29
PHI (deg) =	28.0764

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00192	+0.01557
+3.35945	+0.00633	+0.00181	+3722.78000
+6.71889	+0.01194	+0.00151	+6524.02000
+10.07830	+0.01629	+0.00107	+8384.52000
+13.43780	+0.01902	+0.00055	+9291.53000
+16.79720	+0.01993	-0.00000	+9238.79000
+21.43780	+0.01827	-0.00069	+7589.26000
+26.07830	+0.01363	-0.00118	+4131.69000
+30.71890	+0.00790	-0.00131	-1088.70000
+35.35950	+0.00243	-0.00095	-8003.58000
+40.00000	-0.00000	+0.00002	-16522.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	+0.00002	-16522.40000
+44.44640	+0.00241	+0.00094	-7550.09000
+48.89280	+0.00746	+0.00123	-55.65590
+53.33930	+0.01257	+0.00099	+5870.49000
+57.78570	+0.01571	+0.00036	+10157.20000
+62.23210	+0.01541	-0.00053	+12752.80000
+66.67850	+0.01077	-0.00156	+13626.40000
+71.12490	+0.00151	-0.00259	+12767.20000
+75.57130	-0.01210	-0.00349	+10185.70000
+80.01780	-0.02915	-0.00412	+5912.83000
+84.46420	-0.04820	-0.00436	+0.00000

D1 (ft) =	40
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.184069
HO (lb's) =	-1422.76
HC (lb's) =	0
h1 (lb's) =	3729.08
PHI (deg) =	27.6724

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00321	+0.01557
+3.83705	+0.01209	+0.00303	+5297.58000
+7.67410	+0.02285	+0.00253	+9379.10000
+11.51120	+0.03124	+0.00181	+12208.00000
+15.34820	+0.03653	+0.00093	+13759.10000
+19.18530	+0.03832	-0.00000	+14018.30000
+23.34820	+0.03625	-0.00098	+12836.20000
+27.51120	+0.03035	-0.00182	+10143.40000
+31.67410	+0.02143	-0.00241	+5968.35000
+35.83710	+0.01075	-0.00265	+355.05100
+40.00000	-0.00000	-0.00243	-6637.42000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00243	-6637.38000
+44.10820	-0.00938	-0.00222	+475.59700
+48.21630	-0.01886	-0.00247	+6244.59000
+52.32450	-0.03015	-0.00308	+10609.90000
+56.43260	-0.04450	-0.00395	+13526.70000
+60.54080	-0.06280	-0.00497	+14965.20000
+64.64900	-0.08544	-0.00605	+14910.50000
+68.75710	-0.11242	-0.00707	+13363.20000
+72.86530	-0.14329	-0.00792	+10339.20000
+76.97340	-0.17715	-0.00851	+5869.52000
+81.08160	-0.21270	-0.00873	-0.01557

DI (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	.75
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in <sup>4</sup> ) =	.013777

BETA (deg) =	.260774
HO (lb's) =	-1679.19
HC (lb's) =	0
hi (lb's) =	3228.52
PHI (deg) =	27.2535

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00455	+0.01557
+4.06329	+0.01815	+0.00430	+6802.66000
+8.12657	+0.03439	+0.00362	+12226.70000
+12.18990	+0.04715	+0.00261	+16217.60000
+16.25310	+0.05529	+0.00137	+18735.30000
+20.31640	+0.05809	-0.00000	+19754.70000
+24.25310	+0.05543	-0.00135	+19303.40000
+28.18990	+0.04761	-0.00261	+17440.10000
+32.12660	+0.03511	-0.00370	+14182.50000
+36.06330	+0.01883	-0.00452	+9561.17000
+40.00000	-0.00000	-0.00498	+3619.67000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00498	+3619.70000
+43.78340	-0.01952	-0.00540	+8916.31000
+47.56680	-0.04123	-0.00613	+12998.20000
+51.35030	-0.06615	-0.00708	+15830.40000
+55.13370	-0.09499	-0.00818	+17388.40000
+58.91710	-0.12812	-0.00934	+17658.50000
+62.70050	-0.16562	-0.01047	+16638.50000
+66.48390	-0.20723	-0.01150	+14337.10000
+70.26740	-0.25239	-0.01233	+10774.40000
+74.05080	-0.30020	-0.01289	+5981.50000
+77.83420	-0.34947	-0.01309	-0.00778

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.340252
HO (lb's) =	-1944.89
HC (lb's) =	0
hi (lb's) =	2669.88
PHI (deg) =	26.8198

SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00594	+0.01557
+4.18897	+0.02444	+0.00563	+8305.49000
+8.37794	+0.04638	+0.00477	+15129.80000
+12.56690	+0.06375	+0.00346	+20400.00000
+16.75590	+0.07494	+0.00183	+24050.10000
+20.94490	+0.07883	-0.00000	+26070.90000
+24.75590	+0.07550	-0.00175	+26449.10000
+28.56690	+0.06553	-0.00347	+25440.90000
+32.37790	+0.04916	-0.00509	+23055.30000
+36.18900	+0.02701	-0.00650	+19313.20000
+40.00000	+0.00000	-0.00762	+14247.80000

SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.00762	+14247.80000
+43.48060	-0.02815	-0.00859	+17790.00000
+46.96120	-0.06004	-0.00975	+20234.70000
+50.44180	-0.09616	-0.01102	+21568.10000
+53.92240	-0.13680	-0.01234	+21780.60000
+57.40290	-0.18201	-0.01363	+20370.40000
+60.88350	-0.23160	-0.01484	+18844.30000
+64.36410	-0.28513	-0.01589	+15717.20000
+67.84470	-0.34196	-0.01672	+11512.20000
+71.32530	-0.40119	-0.01726	+6260.24000
+74.80590	-0.46172	-0.01746	-0.01557

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1.25
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.422423
HO (lb's) =	-2219.6
HC (lb's) =	0
hi (lb's) =	2048.37
PHI (deg) =	26.3717

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00737	+0.01557
+4.26763	+0.03093	+0.00700	+9831.56000
+8.53525	+0.05879	+0.00595	+18108.90000
+12.80290	+0.08096	+0.00435	+24740.40000
+17.07050	+0.09534	+0.00233	+29652.70000
+21.33810	+0.10038	-0.00000	+32791.40000
+25.07050	+0.09634	-0.00218	+34054.70000
+28.20290	+0.08408	-0.00439	+33923.80000
+32.53530	+0.06364	-0.00655	+32399.90000
+36.26760	+0.03538	-0.00856	+29495.70000
+40.00000	+0.00000	-0.01035	+25236.10000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	-0.00000	-0.01035	+25236.10000
+43.20580	-0.03550	-0.01181	+27095.10000
+46.41160	-0.07582	-0.01335	+27956.30000
+49.61740	-0.12113	-0.01491	+27826.20000
+52.82320	-0.17138	-0.01643	+26705.70000
+56.02900	-0.22640	-0.01787	+24601.70000
+59.23480	-0.28579	-0.01916	+21527.40000
+62.44060	-0.34902	-0.02025	+17502.10000
+65.64640	-0.41536	-0.02109	+12550.80000
+68.85220	-0.48392	-0.02163	+6704.65000
+72.05800	-0.55368	-0.02182	+0.00000

D1 (ft) =	40
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPG) =	10
ALPHA (deg) =	30
DELTA ALPHA =	1.5
WOB (lb's) =	35000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

BETA (deg) =	.507132
HO (lb's) =	-2502.8
HC (lb's) =	0
hi (lb's) =	1360.6
PHI (deg) =	25.9102

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00885	+0.01557
+4.32114	+0.03762	+0.00841	+11389.80000
+8.64228	+0.07158	+0.00718	+21168.60000
+12.96340	+0.09871	+0.00528	+29225.30000
+17.28460	+0.11642	+0.00284	+35468.50000
+21.60570	+0.12266	-0.00000	+39827.40000
+25.28460	+0.11787	-0.00263	+42015.70000
+28.96340	+0.10322	-0.00535	+42784.00000
+32.64230	+0.07853	-0.00807	+42125.90000
+36.32110	+0.04396	-0.01070	+40046.90000
+40.00000	-0.00000	-0.01316	+36564.00000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+40.00000	+0.00000	-0.01316	+36564.10000
+42.96180	-0.04180	-0.01506	+36810.50000
+45.92360	-0.08920	-0.01694	+36138.30000
+48.88540	-0.14209	-0.01877	+34575.90000
+51.84720	-0.20025	-0.02049	+32131.80000
+54.80900	-0.26330	-0.02206	+28819.10000
+57.77080	-0.33073	-0.02344	+24655.30000
+60.73260	-0.40191	-0.02458	+19662.80000
+63.69440	-0.47607	-0.02545	+13868.00000
+66.65620	-0.55235	-0.02600	+7302.13000
+69.61800	-0.62972	-0.02619	+0.00000

D1 (ft) =	50
OH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	.0368924
HO (lb's) =	-100.711
HC (lb's) =	0
H1 (lb's) =	443.392
PHI (deg) =	4.71152

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00064	+0.00059
+3.18036	+0.00201	+0.00061	+326.61500
+6.36073	+0.00380	+0.00051	+581.13100
+9.54109	+0.00520	+0.00036	+760.07900
+12.72150	+0.00608	+0.00019	+861.02000
+15.90180	+0.00638	-0.00000	+882.57600
+22.72150	+0.00506	-0.00037	+661.26400
+29.54110	+0.00177	-0.00055	+88.90780
+36.36070	-0.00173	-0.00040	-798.76800
+43.18040	-0.00265	+0.00022	-1946.33000
+50.00000	+0.00258	+0.00142	-3282.21000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+50.00000	+0.00258	+0.00142	-3282.21000
+55.58370	+0.01349	+0.00241	-1999.62000
+61.16740	+0.02863	+0.00294	-841.23000
+66.75110	+0.04556	+0.00306	+144.40200
+72.33470	+0.06223	+0.00286	+915.95900
+77.91840	+0.07702	+0.00241	+1441.10000
+83.50210	+0.08882	+0.00181	+1697.82000
+89.08580	+0.09710	+0.00116	+1675.34000
+94.66950	+0.10190	+0.00058	+1374.62000
+100.25300	+0.10386	+0.00016	+808.26100
+105.83700	+0.10417	+0.00000	+0.00000

D1 (ft) =	50
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	20
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	.329727
HO (lb's) =	-473.052
HC (lb's) =	0
H1 (lb's) =	1583.97
PHI (deg) =	18.6452

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00576	+0.00232
+4.24647	+0.02396	+0.00542	+2231.07000
+8.49295	+0.04523	+0.00452	+3974.65000
+12.73940	+0.06173	+0.00320	+5128.88000
+16.98590	+0.07205	+0.00163	+5685.73000
+21.23240	+0.07551	-0.00000	+5631.69000
+26.98590	+0.06950	-0.00202	+4588.58000
+32.73940	+0.05345	-0.00342	+2474.75000
+38.49290	+0.03205	-0.00381	-615.74500
+44.24650	+0.01218	-0.00284	-4545.39000
+50.00000	+0.00258	-0.00020	-9139.32000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+50.00000	+0.00258	-0.00020	-9139.32000
+54.43890	+0.00706	+0.00206	-6009.37000
+58.87770	+0.01956	+0.00343	-3236.57000
+63.31660	+0.03641	+0.00404	-894.49000
+67.75550	+0.05451	+0.00402	+954.76000
+72.19430	+0.07140	+0.00352	+2262.12000
+76.63320	+0.08534	+0.00272	+2992.91000
+81.07210	+0.09537	+0.00179	+3127.76000
+85.51090	+0.10131	+0.00091	+2663.07000
+89.94980	+0.10378	+0.00025	+1611.19000
+94.38870	+0.10417	-0.00000	+0.00232

D1 (ft) =	50
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	25
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	.425762
HO (lb's) =	-592.126
HC (lb's) =	0
h1 (lb's) =	1936.99
PHI (deg) =	23.3044

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00743	+0.00287
+4.29439	+0.03129	+0.00700	+2869.20000
+8.58878	+0.05907	+0.00583	+5069.65000
+12.88320	+0.08063	+0.00413	+6546.72000
+17.17760	+0.09412	+0.00211	+7263.74000
+21.47190	+0.09865	-0.00000	+7202.89000
+27.17760	+0.09109	-0.00257	+5924.07000
+32.88320	+0.07075	-0.00439	+3332.95000
+38.58880	+0.04332	-0.00498	-457.07500
+44.29440	+0.01708	-0.00391	-5280.15000
+50.00000	+0.00258	-0.00081	-10925.20000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+50.00000	+0.00258	-0.00081	-10925.20000
+54.30810	+0.00515	+0.00182	-7272.99000
+58.61630	+0.01686	+0.00346	-4040.33000
+62.92440	+0.03369	+0.00422	-1308.03000
+67.23250	+0.05221	+0.00427	+855.63300
+71.54060	+0.06973	+0.00378	+2396.60000
+75.84870	+0.08431	+0.00294	+3276.35000
+80.15690	+0.09486	+0.00193	+3472.92000
+84.46500	+0.10114	+0.00099	+2981.38000
+88.77310	+0.10376	+0.00028	+1814.02000
+93.08120	+0.10417	+0.00000	+0.00287

D1 (ft) =	50
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	35
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

INITIAL INPUT DATA TO THE DRILL PROGRAM

D1 (ft) =	30
OH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (ppg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	0
WOB (lb's) =	40000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

ITERATION # =	1
BETA (deg) =	-.0358951
ALPHA (deg) =	30
HO (lb's) =	-379.137
HC (lb's) =	0
h1 (lb's) =	4269.98
PHI (deg) =	29.457
PSI (deg) =	29.457
THETA (deg) =	0

ITERATION # =	2
BETA (deg) =	-.036355
ALPHA (deg) =	29.457
HO (lb's) =	-366.37
HC (lb's) =	0
h1 (lb's) =	4214.09
PHI (deg) =	28.9323
PSI (deg) =	28.9323
THETA (deg) =	0

ITERATION # =	3
BETA (deg) =	-.0368024
ALPHA (deg) =	28.9323
HO (lb's) =	-353.968
HC (lb's) =	0
h1 (lb's) =	4159.73
PHI (deg) =	28.4253
PSI (deg) =	28.4253
THETA (deg) =	0

ITERATION # = 4  
BETA (deg) = -.0372307  
ALPHA (deg) = 28.4253  
HO (lb's) = -341.959  
HC (lb's) = 0  
H1 (lb's) = 4106.82  
PHI (deg) = 27.9356  
PSI (deg) = 27.9356  
THETA (deg) = 0

ITERATION # = 5  
BETA (deg) = -.0376374  
ALPHA (deg) = 27.9356  
HO (lb's) = -330.364  
HC (lb's) = 0  
H1 (lb's) = 4055.3  
PHI (deg) = 27.4624  
PSI (deg) = 27.4624  
THETA (deg) = 0

ITERATION # = 6  
BETA (deg) = -.038026  
ALPHA (deg) = 27.4624  
HO (lb's) = -319.146  
HC (lb's) = 0  
H1 (lb's) = 4005.18  
PHI (deg) = 27.0053  
PSI (deg) = 27.0053  
THETA (deg) = 0

ITERATION # = 7  
BETA (deg) = -.0383972  
ALPHA (deg) = 27.0053  
HO (lb's) = -308.3  
HC (lb's) = 0  
H1 (lb's) = 3956.44  
PHI (deg) = 26.5638  
PSI (deg) = 26.5638  
THETA (deg) = 0

ITERATION # = 8  
BETA (deg) = -.038758  
ALPHA (deg) = 26.5638  
HO (lb's) = -297.778  
HC (lb's) = 0  
H1 (lb's) = 3909.12  
PHI (deg) = 26.1373  
PSI (deg) = 26.1373  
THETA (deg) = 0

ITERATION # = 9  
BETA (deg) = -.0390947  
ALPHA (deg) = 26.1373  
HO (lb's) = -287.656  
HC (lb's) = 0  
H1 (lb's) = 3863.04  
PHI (deg) = 25.7253  
PSI (deg) = 25.7253  
THETA (deg) = 0

ITERATION # = 10  
BETA (deg) = -.0394241  
ALPHA (deg) = 25.7253  
HO (lb's) = -277.823  
HC (lb's) = 0  
H1 (lb's) = 3818.35  
PHI (deg) = 25.3274  
PSI (deg) = 25.3274  
THETA (deg) = 0

ITERATION # = 11  
BETA (deg) = -.0397321  
ALPHA (deg) = 25.3274  
HO (lb's) = -268.365  
HC (lb's) = 0  
H1 (lb's) = 3774.87  
PHI (deg) = 24.943  
PSI (deg) = 24.943  
THETA (deg) = 0

ITERATION # = 12  
BETA (deg) = -.040025  
ALPHA (deg) = 24.943  
HO (lb's) = -259.234  
HC (lb's) = 0  
H1 (lb's) = 3732.63  
PHI (deg) = 24.5717  
PSI (deg) = 24.5717  
THETA (deg) = 0

ITERATION # = 13  
BETA (deg) = -.0403099  
ALPHA (deg) = 24.5717  
HO (lb's) = -250.381  
HC (lb's) = 0  
H1 (lb's) = 3691.66  
PHI (deg) = 24.2131  
PSI (deg) = 24.2131  
THETA (deg) = 0

ITERATION # = 14  
BETA (deg) = -.0405808  
ALPHA (deg) = 24.2131  
HO (lb's) = -241.833  
HC (lb's) = 0  
h1 (lb's) = 3631.89  
PHI (deg) = 23.8668  
PSI (deg) = 23.8668  
THETA (deg) = 0

ITERATION # = 15  
BETA (deg) = -.040837  
ALPHA (deg) = 23.8668  
HO (lb's) = -233.597  
HC (lb's) = 0  
h1 (lb's) = 3613.25  
PHI (deg) = 23.5322  
PSI (deg) = 23.5322  
THETA (deg) = 0

ITERATION # = 16  
BETA (deg) = -.0410779  
ALPHA (deg) = 23.5322  
HO (lb's) = -225.663  
HC (lb's) = 0  
h1 (lb's) = 3575.71  
PHI (deg) = 23.209  
PSI (deg) = 23.209  
THETA (deg) = 0

ITERATION # = 17  
BETA (deg) = -.0413127  
ALPHA (deg) = 23.209  
HO (lb's) = -217.97  
HC (lb's) = 0  
h1 (lb's) = 3539.35  
PHI (deg) = 22.8968  
PSI (deg) = 22.8968  
THETA (deg) = 0

ITERATION # = 18  
BETA (deg) = -.0415353  
ALPHA (deg) = 22.8968  
HO (lb's) = -210.552  
HC (lb's) = 0  
h1 (lb's) = 3504.05  
PHI (deg) = 22.5952  
PSI (deg) = 22.5952  
THETA (deg) = 0

ITERATION # = 19  
BETA (deg) = -.0417447  
ALPHA (deg) = 22.5952  
HO (lb's) = -203.405  
HC (lb's) = 0  
H1 (lb's) = 3469.77  
PHI (deg) = 22.3039  
PSI (deg) = 22.3039  
THETA (deg) = 0

ITERATION # = 20  
BETA (deg) = -.0419318  
ALPHA (deg) = 22.3039  
HO (lb's) = -196.463  
HC (lb's) = 0  
H1 (lb's) = 3436.6  
PHI (deg) = 22.0225  
PSI (deg) = 22.0225  
THETA (deg) = 0

ITERATION # = 21  
BETA (deg) = -.0421387  
ALPHA (deg) = 22.0225  
HO (lb's) = -189.826  
HC (lb's) = 0  
H1 (lb's) = 3404.32  
PHI (deg) = 21.7507  
PSI (deg) = 21.7507  
THETA (deg) = 0

ITERATION # = 22  
BETA (deg) = -.042323  
ALPHA (deg) = 21.7507  
HO (lb's) = -183.378  
HC (lb's) = 0  
H1 (lb's) = 3373.08  
PHI (deg) = 21.488  
PSI (deg) = 21.488  
THETA (deg) = 0

ITERATION # = 23  
BETA (deg) = -.0424975  
ALPHA (deg) = 21.488  
HO (lb's) = -177.164  
HC (lb's) = 0  
H1 (lb's) = 3342.78  
PHI (deg) = 21.2343  
PSI (deg) = 21.2343  
THETA (deg) = 0

ITERATION # =	24
BETA (deg) =	-.0426634
ALPHA (deg) =	21.2343
HO (lb's) =	-171.169
HC (lb's) =	0
H1 (lb's) =	3313.39
PHI (deg) =	20.9891
PSI (deg) =	20.9891
THETA (deg) =	0

ITERATION # =	25
BETA (deg) =	-.0428193
ALPHA (deg) =	20.9891
HO (lb's) =	-163.393
HC (lb's) =	0
H1 (lb's) =	3284.87
PHI (deg) =	20.7522
PSI (deg) =	20.7522
THETA (deg) =	0

ITERATION # =	26
BETA (deg) =	-.0429705
ALPHA (deg) =	20.7522
HO (lb's) =	-159.804
HC (lb's) =	0
H1 (lb's) =	3257.23
PHI (deg) =	20.5234
PSI (deg) =	20.5233
THETA (deg) =	0

ITERATION # =	27
BETA (deg) =	-.0431133
ALPHA (deg) =	20.5233
HO (lb's) =	-154.415
HC (lb's) =	0
H1 (lb's) =	3230.46
PHI (deg) =	20.3022
PSI (deg) =	20.3022
THETA (deg) =	0

ITERATION # =	28
BETA (deg) =	-.0432479
ALPHA (deg) =	20.3022
HO (lb's) =	-149.223
HC (lb's) =	0
H1 (lb's) =	3204.48
PHI (deg) =	20.0885
PSI (deg) =	20.0885
THETA (deg) =	0

ITERATION # = 29  
BETA (deg) = -.0433784  
ALPHA (deg) = 20.0885  
HO (lb's) = -144.198  
HC (lb's) = 0  
H1 (lb's) = 3179.32  
PHI (deg) = 19.8819  
PSI (deg) = 19.8819  
THETA (deg) = 0

ITERATION # = 30  
BETA (deg) = -.0433018  
ALPHA (deg) = 19.8819  
HO (lb's) = -139.353  
HC (lb's) = 0  
H1 (lb's) = 3154.92  
PHI (deg) = 19.6823  
PSI (deg) = 19.6823  
THETA (deg) = 0

ITERATION # = 31  
BETA (deg) = -.0436171  
ALPHA (deg) = 19.6823  
HO (lb's) = -134.69  
HC (lb's) = 0  
H1 (lb's) = 3131.25  
PHI (deg) = 19.4894  
PSI (deg) = 19.4894  
THETA (deg) = 0

ITERATION # = 32  
BETA (deg) = -.0437294  
ALPHA (deg) = 19.4894  
HO (lb's) = -130.175  
HC (lb's) = 0  
H1 (lb's) = 3108.33  
PHI (deg) = 19.303  
PSI (deg) = 19.303  
THETA (deg) = 0

ITERATION # = 33  
BETA (deg) = -.043834  
ALPHA (deg) = 19.303  
HO (lb's) = -125.829  
HC (lb's) = 0  
H1 (lb's) = 3086.1  
PHI (deg) = 19.1228  
PSI (deg) = 19.1228  
THETA (deg) = 0

ITERATION # = 34  
BETA (deg) = -.043935  
ALPHA (deg) = 19.1228  
HO (lb's) = -121.624  
HC (lb's) = 0  
h1 (lb's) = 3064.57  
PHI (deg) = 18.9486  
PSI (deg) = 18.9486  
THETA (deg) = 0

ITERATION # = 35  
BETA (deg) = -.0440285  
ALPHA (deg) = 18.9486  
HO (lb's) = -117.584  
HC (lb's) = 0  
h1 (lb's) = 3043.67  
PHI (deg) = 18.7802  
PSI (deg) = 18.7802  
THETA (deg) = 0

ITERATION # = 36  
BETA (deg) = -.0441229  
ALPHA (deg) = 18.7802  
HO (lb's) = -113.648  
HC (lb's) = 0  
h1 (lb's) = 3023.48  
PHI (deg) = 18.6174  
PSI (deg) = 18.6174  
THETA (deg) = 0

ITERATION # = 37  
BETA (deg) = -.0442062  
ALPHA (deg) = 18.6174  
HO (lb's) = -109.891  
HC (lb's) = 0  
h1 (lb's) = 3003.84  
PHI (deg) = 18.46  
PSI (deg) = 18.46  
THETA (deg) = 0

ITERATION # = 38  
BETA (deg) = -.0442895  
ALPHA (deg) = 18.46  
HO (lb's) = -106.237  
HC (lb's) = 0  
h1 (lb's) = 2984.86  
PHI (deg) = 18.3078  
PSI (deg) = 18.3078  
THETA (deg) = 0

ITERATION # = 39  
BETA (deg) = -.04437  
ALPHA (deg) = 18.3078  
HO (lb's) = -102.705  
HC (lb's) = 0  
H1 (lb's) = 2966.47  
PHI (deg) = 18.1607  
PSI (deg) = 18.1607  
THETA (deg) = 0

ITERATION # = 40  
BETA (deg) = -.0444427  
ALPHA (deg) = 18.1607  
HO (lb's) = -99.3171  
HC (lb's) = 0  
H1 (lb's) = 2948.61  
PHI (deg) = 18.0185  
PSI (deg) = 18.0185  
THETA (deg) = 0

ITERATION # = 41  
BETA (deg) = -.0445147  
ALPHA (deg) = 18.0185  
HO (lb's) = -96.0289  
HC (lb's) = 0  
H1 (lb's) = 2931.34  
PHI (deg) = 17.881  
PSI (deg) = 17.881  
THETA (deg) = 0

ITERATION # = 42  
BETA (deg) = -.044584  
ALPHA (deg) = 17.881  
HO (lb's) = -92.8487  
HC (lb's) = 0  
H1 (lb's) = 2914.61  
PHI (deg) = 17.748  
PSI (deg) = 17.748  
THETA (deg) = 0

ITERATION # = 43  
BETA (deg) = -.0446456  
ALPHA (deg) = 17.748  
HO (lb's) = -89.8044  
HC (lb's) = 0  
H1 (lb's) = 2898.35  
PHI (deg) = 17.6194  
PSI (deg) = 17.6193  
THETA (deg) = 0

ITERATION # =	44
BETA (deg) =	-.0447099
ALPHA (deg) =	17.6194
HO (lb's) =	-86.8317
HC (lb's) =	0
H1 (lb's) =	2882.67
PHI (deg) =	17.495
PSI (deg) =	17.495
THETA (deg) =	0

ITERATION # =	45
BETA (deg) =	-.0447663
ALPHA (deg) =	17.495
HO (lb's) =	-83.9885
HC (lb's) =	0
H1 (lb's) =	2867.42
PHI (deg) =	17.3747
PSI (deg) =	17.3747
THETA (deg) =	0

ITERATION # =	46
BETA (deg) =	-.0448216
ALPHA (deg) =	17.3747
HO (lb's) =	-81.2335
HC (lb's) =	0
H1 (lb's) =	2852.65
PHI (deg) =	17.2584
PSI (deg) =	17.2584
THETA (deg) =	0

ITERATION # =	47
BETA (deg) =	-.0448768
ALPHA (deg) =	17.2584
HO (lb's) =	-78.5562
HC (lb's) =	0
H1 (lb's) =	2838.37
PHI (deg) =	17.1459
PSI (deg) =	17.1459
THETA (deg) =	0

ITERATION # =	48
BETA (deg) =	-.0449272
ALPHA (deg) =	17.1459
HO (lb's) =	-75.9839
HC (lb's) =	0
H1 (lb's) =	2824.52
PHI (deg) =	17.037
PSI (deg) =	17.037
THETA (deg) =	0

ITERATION # =	49
BETA (deg) =	-.0449753
ALPHA (deg) =	17.037
HO (lb's) =	-73.4992
HC (lb's) =	0
h1 (lb's) =	2811.09
PHI (deg) =	16.9317
PSI (deg) =	16.9317
THETA (deg) =	0

ITERATION # =	50
BETA (deg) =	-.0450188
ALPHA (deg) =	16.9317
HO (lb's) =	-71.1135
HC (lb's) =	0
h1 (lb's) =	2798.05
PHI (deg) =	16.8299
PSI (deg) =	16.8299
THETA (deg) =	0

ITERATION # =	51
BETA (deg) =	-.0450636
ALPHA (deg) =	16.8299
HO (lb's) =	-68.7871
HC (lb's) =	0
h1 (lb's) =	2785.46
PHI (deg) =	16.7314
PSI (deg) =	16.7314
THETA (deg) =	0

ITERATION # =	52
BETA (deg) =	-.0451072
ALPHA (deg) =	16.7314
HO (lb's) =	-66.5349
HC (lb's) =	0
h1 (lb's) =	2773.27
PHI (deg) =	16.6361
PSI (deg) =	16.6361
THETA (deg) =	0

ITERATION # =	53
BETA (deg) =	-.0451443
ALPHA (deg) =	16.6361
HO (lb's) =	-64.386
HC (lb's) =	0
h1 (lb's) =	2761.41
PHI (deg) =	16.5438
PSI (deg) =	16.5438
THETA (deg) =	0

ITERATION # =	54
BETA (deg) =	-.0451827
ALPHA (deg) =	16.5438
HO (lb's) =	-62.2908
HC (lb's) =	0
h1 (lb's) =	2749.95
PHI (deg) =	16.4546
PSI (deg) =	16.4546
THETA (deg) =	0

ITERATION # =	55
BETA (deg) =	-.0452182
ALPHA (deg) =	16.4546
HO (lb's) =	-60.2726
HC (lb's) =	0
h1 (lb's) =	2738.84
PHI (deg) =	16.3683
PSI (deg) =	16.3683
THETA (deg) =	0

ITERATION # =	56
BETA (deg) =	-.0452538
ALPHA (deg) =	16.3683
HO (lb's) =	-58.3116
HC (lb's) =	0
h1 (lb's) =	2728.09
PHI (deg) =	16.2848
PSI (deg) =	16.2848
THETA (deg) =	0

ITERATION # =	57
BETA (deg) =	-.045287
ALPHA (deg) =	16.2848
HO (lb's) =	-56.4197
HC (lb's) =	0
h1 (lb's) =	2717.68
PHI (deg) =	16.204
PSI (deg) =	16.204
THETA (deg) =	0

ITERATION # =	58
BETA (deg) =	-.0453166
ALPHA (deg) =	16.204
HO (lb's) =	-54.6066
HC (lb's) =	0
h1 (lb's) =	2707.56
PHI (deg) =	16.1238
PSI (deg) =	16.1238
THETA (deg) =	0

ITERATION # = 59  
BETA (deg) = -.0453455  
ALPHA (deg) = 16.1258  
HO (lb's) = -52.8482  
HC (lb's) = 0  
h1 (lb's) = 2697.76  
PHI (deg) = 16.0501  
PSI (deg) = 16.0501  
THETA (deg) = 0

ITERATION # = 60  
BETA (deg) = -.045374  
ALPHA (deg) = 16.0501  
HO (lb's) = -51.1426  
HC (lb's) = 0  
h1 (lb's) = 2688.28  
PHI (deg) = 15.9769  
PSI (deg) = 15.9769  
THETA (deg) = 0

ITERATION # = 61  
BETA (deg) = -.0454026  
ALPHA (deg) = 15.9769  
HO (lb's) = -49.4855  
HC (lb's) = 0  
h1 (lb's) = 2679.11  
PHI (deg) = 15.906  
PSI (deg) = 15.906  
THETA (deg) = 0

ITERATION # = 62  
BETA (deg) = -.0454261  
ALPHA (deg) = 15.906  
HO (lb's) = -47.9072  
HC (lb's) = 0  
h1 (lb's) = 2670.18  
PHI (deg) = 15.8374  
PSI (deg) = 15.8374  
THETA (deg) = 0

ITERATION # = 63  
BETA (deg) = -.0454515  
ALPHA (deg) = 15.8374  
HO (lb's) = -46.3625  
HC (lb's) = 0  
h1 (lb's) = 2661.56  
PHI (deg) = 15.771  
PSI (deg) = 15.771  
THETA (deg) = 0

ITERATION # = 64  
BETA (deg) = -.0454766  
ALPHA (deg) = 15.771  
HO (lb's) = -44.865  
HC (lb's) = 0  
h1 (lb's) = 2653.22  
PHI (deg) = 15.7067  
PSI (deg) = 15.7067  
THETA (deg) = 0

ITERATION # = 65  
BETA (deg) = -.0454993  
ALPHA (deg) = 15.7067  
HO (lb's) = -43.4246  
HC (lb's) = 0  
h1 (lb's) = 2645.12  
PHI (deg) = 15.6445  
PSI (deg) = 15.6445  
THETA (deg) = 0

ITERATION # = 66  
BETA (deg) = -.0455197  
ALPHA (deg) = 15.6445  
HO (lb's) = -42.0381  
HC (lb's) = 0  
h1 (lb's) = 2637.27  
PHI (deg) = 15.5843  
PSI (deg) = 15.5843  
THETA (deg) = 0

ITERATION # = 67  
BETA (deg) = -.045542  
ALPHA (deg) = 15.5843  
HO (lb's) = -40.6823  
HC (lb's) = 0  
h1 (lb's) = 2629.68  
PHI (deg) = 15.526  
PSI (deg) = 15.526  
THETA (deg) = 0

ITERATION # = 68  
BETA (deg) = -.0455613  
ALPHA (deg) = 15.526  
HO (lb's) = -39.3817  
HC (lb's) = 0  
h1 (lb's) = 2622.32  
PHI (deg) = 15.4696  
PSI (deg) = 15.4696  
THETA (deg) = 0

ITERATION # = 69  
BETA (deg) = -.0455786  
ALPHA (deg) = 15.4696  
HO (lb's) = -38.1335  
HC (lb's) = 0  
h1 (lb's) = 2615.16  
PHI (deg) = 15.415  
PSI (deg) = 15.415  
THETA (deg) = 0

ITERATION # = 70  
BETA (deg) = -.0455961  
ALPHA (deg) = 15.415  
HO (lb's) = -36.9172  
HC (lb's) = 0  
h1 (lb's) = 2608.24  
PHI (deg) = 15.3621  
PSI (deg) = 15.3621  
THETA (deg) = 0

ITERATION # = 71  
BETA (deg) = -.0456134  
ALPHA (deg) = 15.3621  
HO (lb's) = -35.7383  
HC (lb's) = 0  
h1 (lb's) = 2601.55  
PHI (deg) = 15.3109  
PSI (deg) = 15.3109  
THETA (deg) = 0

ITERATION # = 72  
BETA (deg) = -.0456311  
ALPHA (deg) = 15.3109  
HO (lb's) = -34.5924  
HC (lb's) = 0  
h1 (lb's) = 2595.07  
PHI (deg) = 15.2614  
PSI (deg) = 15.2614  
THETA (deg) = 0

ITERATION # = 73  
BETA (deg) = -.0456451  
ALPHA (deg) = 15.2614  
HO (lb's) = -33.4997  
HC (lb's) = 0  
h1 (lb's) = 2588.76  
PHI (deg) = 15.2134  
PSI (deg) = 15.2134  
THETA (deg) = 0

ITERATION # = 74  
BETA (deg) = -.045662  
ALPHA (deg) = 15.2134  
HO (lb's) = -32.4217  
HC (lb's) = 0  
h1 (lb's) = 2582.69  
PHI (deg) = 15.167  
PSI (deg) = 15.167  
THETA (deg) = 0

ITERATION # = 75  
BETA (deg) = -.0456747  
ALPHA (deg) = 15.167  
HO (lb's) = -31.4009  
HC (lb's) = 0  
h1 (lb's) = 2576.77  
PHI (deg) = 15.122  
PSI (deg) = 15.122  
THETA (deg) = 0

ITERATION # = 76  
BETA (deg) = -.0456907  
ALPHA (deg) = 15.122  
HO (lb's) = -30.3897  
HC (lb's) = 0  
h1 (lb's) = 2571.07  
PHI (deg) = 15.0785  
PSI (deg) = 15.0785  
THETA (deg) = 0

ITERATION # = 77  
BETA (deg) = -.0457019  
ALPHA (deg) = 15.0785  
HO (lb's) = -29.4377  
HC (lb's) = 0  
h1 (lb's) = 2565.5  
PHI (deg) = 15.0363  
PSI (deg) = 15.0363  
THETA (deg) = 0

ITERATION # = 78  
BETA (deg) = -.0457148  
ALPHA (deg) = 15.0363  
HO (lb's) = -28.5009  
HC (lb's) = 0  
h1 (lb's) = 2560.14  
PHI (deg) = 14.9955  
PSI (deg) = 14.9955  
THETA (deg) = 0

ITERATION # =	79
BETA (deg) =	-.0457266
ALPHA (deg) =	14.9955
HO (lb's) =	-27.6019
HC (lb's) =	0
h1 (lb's) =	2554.93
PHI (deg) =	14.956
PSI (deg) =	14.956
THETA (deg) =	0

ITERATION # =	80
BETA (deg) =	-.0457367
ALPHA (deg) =	14.956
HO (lb's) =	-26.734
HC (lb's) =	0
h1 (lb's) =	2549.87
PHI (deg) =	14.9177
PSI (deg) =	14.9177
THETA (deg) =	0

ITERATION # =	81
BETA (deg) =	-.0457476
ALPHA (deg) =	14.9177
HO (lb's) =	-25.8898
HC (lb's) =	0
h1 (lb's) =	2544.98
PHI (deg) =	14.8806
PSI (deg) =	14.8806
THETA (deg) =	0

ITERATION # =	82
BETA (deg) =	-.04576
ALPHA (deg) =	14.8806
HO (lb's) =	-25.059
HC (lb's) =	0
h1 (lb's) =	2540.26
PHI (deg) =	14.8447
PSI (deg) =	14.8447
THETA (deg) =	0

ITERATION # =	83
BETA (deg) =	-.0457704
ALPHA (deg) =	14.8447
HO (lb's) =	-24.265
HC (lb's) =	0
h1 (lb's) =	2535.68
PHI (deg) =	14.8099
PSI (deg) =	14.8099
THETA (deg) =	0

ITERATION # =	84
BETA (deg) =	-.0457781
ALPHA (deg) =	14.8099
HO (lb's) =	-23.5124
HC (lb's) =	0
hi (lb's) =	2531.21
PHI (deg) =	14.7763
PSI (deg) =	14.7763
THETA (deg) =	0

ITERATION # =	85
BETA (deg) =	-.0457897
ALPHA (deg) =	14.7763
HO (lb's) =	-22.7561
HC (lb's) =	0
hi (lb's) =	2526.93
PHI (deg) =	14.7437
PSI (deg) =	14.7437
THETA (deg) =	0

ITERATION # =	86
BETA (deg) =	-.0457988
ALPHA (deg) =	14.7437
HO (lb's) =	-22.0376
HC (lb's) =	0
hi (lb's) =	2522.75
PHI (deg) =	14.7121
PSI (deg) =	14.7121
THETA (deg) =	0

ITERATION # =	87
BETA (deg) =	-.0458046
ALPHA (deg) =	14.7121
HO (lb's) =	-21.36
HC (lb's) =	0
hi (lb's) =	2518.68
PHI (deg) =	14.6815
PSI (deg) =	14.6815
THETA (deg) =	0

ITERATION # =	88
BETA (deg) =	-.0458139
ALPHA (deg) =	14.6815
HO (lb's) =	-20.6801
HC (lb's) =	0
hi (lb's) =	2514.77
PHI (deg) =	14.6519
PSI (deg) =	14.6519
THETA (deg) =	0

ITERATION # =	89
BETA (deg) =	-.0458226
ALPHA (deg) =	14.6319
HO (lb's) =	-20.0227
HC (lb's) =	0
h1 (lb's) =	2510.98
PHI (deg) =	14.6232
PSI (deg) =	14.6232
THETA (deg) =	0

ITERATION # =	90
BETA (deg) =	-.045828
ALPHA (deg) =	14.6232
HO (lb's) =	-19.406
HC (lb's) =	0
h1 (lb's) =	2507.28
PHI (deg) =	14.5954
PSI (deg) =	14.5954
THETA (deg) =	0

EQUILIBRIUM ANGLE REACHED AT 14.5954 degrees

INITIAL INPUT DATA TO THE DRILL PROGRAM

D1 (ft) =	10
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	60
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

ITERATION # =	1
BETA (deg) =	-.0411439
ALPHA (deg) =	60
HO (lb's) =	693.327
HC (lb's) =	0
h1 (lb's) =	2694.79
PHI (deg) =	61.9852
PSI (deg) =	61.9852
THETA (deg) =	0

ITERATION # =	2
BETA (deg) =	-.0415227
ALPHA (deg) =	61.9852
HO (lb's) =	695.885
HC (lb's) =	0
h1 (lb's) =	2730.02
PHI (deg) =	63.9778
PSI (deg) =	63.9778
THETA (deg) =	0

ITERATION # =	3
BETA (deg) =	-.0418443
ALPHA (deg) =	63.9778
HO (lb's) =	697.748
HC (lb's) =	0
h1 (lb's) =	2762.33
PHI (deg) =	63.9757
PSI (deg) =	63.9757
THETA (deg) =	0

ITERATION # =	4
BETA (deg) =	-.0421613
ALPHA (deg) =	65.9757
HO (lb's) =	699.746
HC (lb's) =	0
h1 (lb's) =	2792.79
PHI (deg) =	67.9793
PSI (deg) =	67.9793
THETA (deg) =	0

ITERATION # =	5
BETA (deg) =	-.0424518
ALPHA (deg) =	67.9793
HO (lb's) =	701.551
HC (lb's) =	0
h1 (lb's) =	2820.95
PHI (deg) =	69.9881
PSI (deg) =	69.9881
THETA (deg) =	0

ITERATION # =	6
BETA (deg) =	-.0427066
ALPHA (deg) =	69.9881
HO (lb's) =	703.049
HC (lb's) =	0
h1 (lb's) =	2846.55
PHI (deg) =	72.0012
PSI (deg) =	72.0012
THETA (deg) =	0

ITERATION # =	7
BETA (deg) =	-.0429516
ALPHA (deg) =	72.0012
HO (lb's) =	704.576
HC (lb's) =	0
h1 (lb's) =	2870.06
PHI (deg) =	74.0186
PSI (deg) =	74.0186
THETA (deg) =	0

ITERATION # =	8
BETA (deg) =	-.04315
ALPHA (deg) =	74.0186
HO (lb's) =	705.619
HC (lb's) =	0
h1 (lb's) =	2890.7
PHI (deg) =	76.039
PSI (deg) =	76.039
THETA (deg) =	0

ITERATION # =	9
BETA (deg) =	-.0433378
ALPHA (deg) =	76.039
HO (lb's) =	706.742
HC (lb's) =	0
h1 (lb's) =	2909.24
PHI (deg) =	78.0626
PSI (deg) =	78.0626
THETA (deg) =	0

ITERATION # = 10  
BETA (deg) = -.043491  
ALPHA (deg) = 78.0626  
HO (lb's) = 707.575  
HC (lb's) = 0  
h1 (lb's) = 2925.13  
PHI (deg) = 80.0886  
PSI (deg) = 80.0886  
THETA (deg) = 0

ITERATION # = 11  
BETA (deg) = -.0436272  
ALPHA (deg) = 80.0886  
HO (lb's) = 708.363  
HC (lb's) = 0  
h1 (lb's) = 2938.7  
PHI (deg) = 82.1169  
PSI (deg) = 82.1169  
THETA (deg) = 0

ITERATION # = 12  
BETA (deg) = -.0437418  
ALPHA (deg) = 82.1169  
HO (lb's) = 709.053  
HC (lb's) = 0  
h1 (lb's) = 2949.85  
PHI (deg) = 84.1471  
PSI (deg) = 84.1471  
THETA (deg) = 0

ITERATION # = 13  
BETA (deg) = -.0438147  
ALPHA (deg) = 84.1471  
HO (lb's) = 709.342  
HC (lb's) = 0  
h1 (lb's) = 2958.12  
PHI (deg) = 86.1782  
PSI (deg) = 86.1782  
THETA (deg) = 0

ITERATION # = 14  
BETA (deg) = -.043877  
ALPHA (deg) = 86.1782  
HO (lb's) = 709.745  
HC (lb's) = 0  
h1 (lb's) = 2964.22  
PHI (deg) = 88.2104  
PSI (deg) = 88.2104  
THETA (deg) = 0

ITERATION # =	15
BETA (deg) =	- .043909
ALPHA (deg) =	88.2104
H0 (lb's) =	709.879
HC (lb's) =	0
h1 (lb's) =	2967.63
PHI (deg) =	90.243
PSI (deg) =	-89.7388
THETA (deg) =	0

INITIAL INPUT DATA TO THE DRILL PROGRAM

D1 (ft) =	30
DH (in) =	12.25
ODdc (in) =	8.75
IDdc (in) =	2.5
ODst (in) =	12.25
MW (PPg) =	10
ALPHA (deg) =	30
DELTA ALPHA =	0
WOB (lb's) =	40000
P (lb's/ft in fluid) =	158.855
I (in^4) =	.013777

ITERATION # =	1
BETA (deg) =	-.0358951
ALPHA (deg) =	30
HO (lb's) =	-379.137
HC (lb's) =	0
h1 (lb's) =	4269.98
PHI (deg) =	29.457
PSI (deg) =	29.457
THETA (deg) =	0

ITERATION # =	2
BETA (deg) =	-.157193
ALPHA (deg) =	29.457
HO (lb's) =	383.988
HC (lb's) =	0
h1 (lb's) =	5263.55
PHI (deg) =	30.007
PSI (deg) =	30.0069
THETA (deg) =	-.542999

ITERATION # =	3
BETA (deg) =	.101382
ALPHA (deg) =	30.0069
HO (lb's) =	-1231.7
HC (lb's) =	0
h1 (lb's) =	2879.89
PHI (deg) =	28.2434
PSI (deg) =	28.2434
THETA (deg) =	.549946

ITERATION # =	4
BETA (deg) =	-.387479
ALPHA (deg) =	28.2434
HO (lb's) =	1836.35
HC (lb's) =	0
h1 (lb's) =	6750.12
PHI (deg) =	30.8717
PSI (deg) =	30.8717
THETA (deg) =	-1.76355

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

ITERATION #	5
BETA (deg) =	.749954
ALPHA (deg) =	30.8717
PHI (deg) =	23.3686
PSI (deg) =	23.3686
H0 (lb's) =	-5268.81
HC H(lb's) =	73.6088
H1 (lb's) =	6857.49
THETA (deg) =	2.62827

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

DISTANCE TO TANGENCY OUT OF SEARCH RANGE 379.251 ft

INITIAL INPUT DATA TO THE DRILL PROGRAM

D1 (ft) =	10
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	60
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

ITERATION # =	1
BETA (deg) =	-.0411439
ALPHA (deg) =	60
HO (lb's) =	693.327
HC (lb's) =	0
h1 (lb's) =	2694.79
PHI (deg) =	61.9852
PSI (deg) =	61.9852
THETA (deg) =	0

ITERATION # =	2
BETA (deg) =	.357822
ALPHA (deg) =	61.9852
HO (lb's) =	-5406.42
HC (lb's) =	0
h1 (lb's) =	-7712.71
PHI (deg) =	46.8601
PSI (deg) =	46.8601
THETA (deg) =	1.98524

ITERATION # =	3
BETA (deg) =	-.731016
ALPHA (deg) =	46.8601
HO (lb's) =	11261.8
HC (lb's) =	0
h1 (lb's) =	10921
PHI (deg) =	76.2406
PSI (deg) =	76.2406
THETA (deg) =	-15.1252

**APPENDIX H**

APPENDIX H  
ONE POINT STABILIZER, TWO SEGMENT BOREHOLE,  
WITH CONTACT POINT CONSIDERED

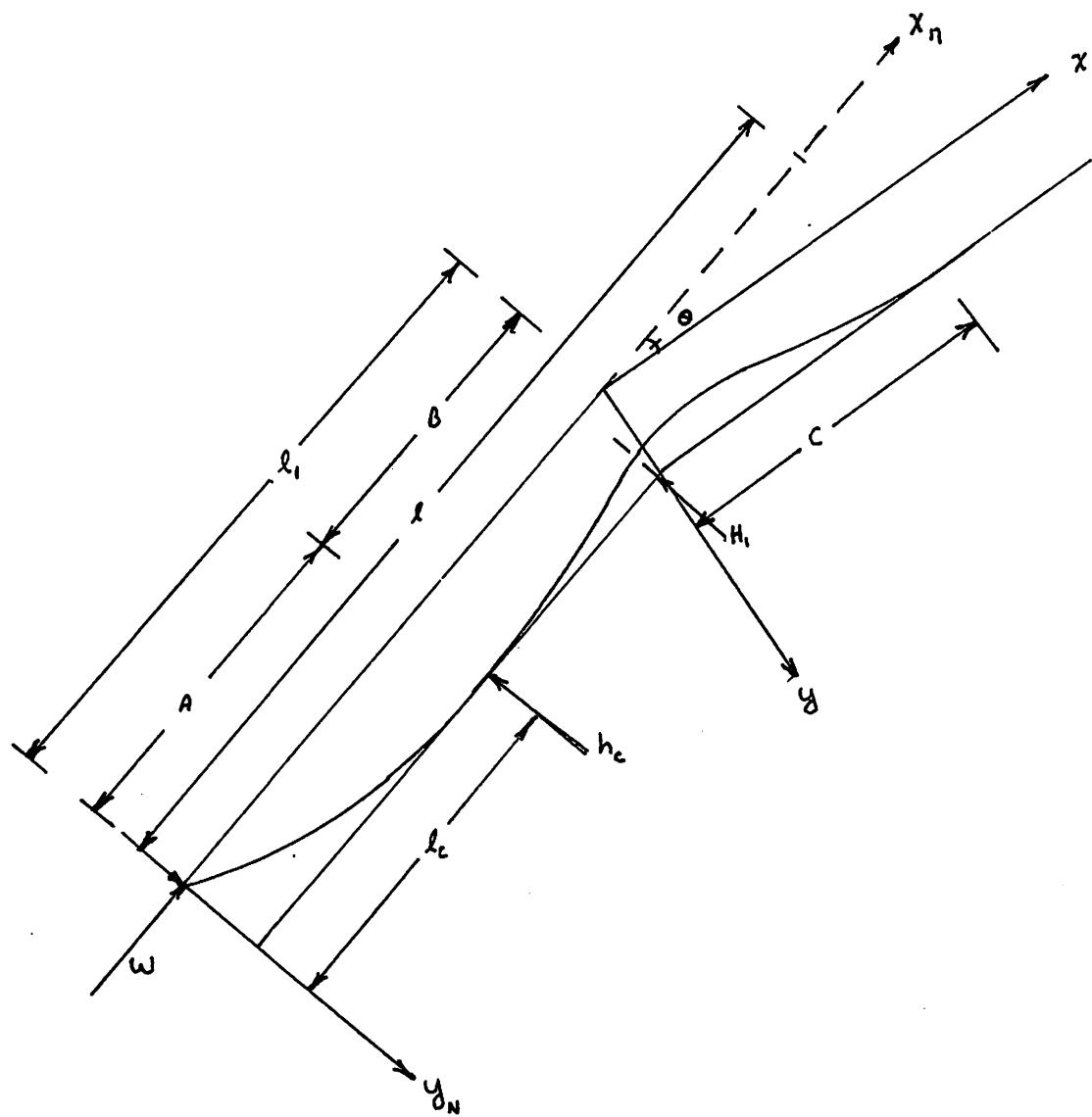


FIGURE XVII-H

Segment A

B.C.

$$x = 0 \quad y_A = 0 \quad (H-1)$$

$$C_{1A} = -1 \quad C_{2A} = 1$$

$$x = 0 \quad y''_A = 0 \quad (H-2)$$

Continuity

$$x = \ell_c \quad y_A = y_B = C_{dc} \quad (H-3)$$

$$x = \ell_c \quad y'_A = y'_B = 0 \quad (H-4)$$

$$x = \ell_c \quad y''_A = y''_B \quad (H-5)$$

Using (H-4) to solve for  $C_{3A}$

$$0 = -C_{2A} \sin \ell_c + C_{3A} \cos \ell_c + h_o + \ell_c$$

$$C_{3A} = \frac{\sin \ell_c - h_o - \ell_c}{\cos \ell_c} \quad (H-6)$$

Using (H-3) to solve for  $h_o$

$$C_{dc} = -1 + \cos \ell_c + C_{3A} \sin \ell_c + h_o \ell_c + \frac{1}{2} \ell_c^2$$

$$C_{dc} + 1 - \cos \ell_c - \frac{1}{2} \ell_c^2 = [\sin \ell_c - (h_B + \ell_c)] \tan \ell_c + h_o \ell_c$$

$$C_{dc} + 1 - \cos \ell_c - \frac{1}{2} \ell_c^2 - \sin \ell_c \tan \ell_c + \ell_c \tan \ell_c =$$

$$= h_o (\ell_c - \tan \ell_c)$$

$$h_o = \frac{C_{dc} + 1 - \cos \ell_c - \frac{1}{2} \ell_c^2 - \sin \ell_c \tan \ell_c + \ell_c \tan \ell_c}{(\ell_c - \tan \ell_c)} \quad (H-7)$$

### Segment B

#### B.C.

$$X = \ell_c \quad y_B = C_{st} \quad (H-8)$$

$$X = \ell_c \quad y'_B = 0 \quad (H-9)$$

#### Continuity

$$X = \ell_1 \quad y_B = y_C = C_{st} \quad (H-10)$$

$$X = \ell_1 \quad y'_B = y'_C \quad (H-11)$$

$$X = \ell_1 \quad y''_B = y''_C \quad (H-12)$$

Using (H-10)

$$C_{st} = C_{1B} + C_{2B} \cos \ell_1 + C_{3B} \sin \ell_1 + h_B \ell_1 + \frac{1}{2} \ell_1^2$$

Using (H-8)

$$C_{dc} = C_{1B} + C_{2B} \cos \ell_c + C_{3B} \sin \ell_c + h_B \ell_c + \frac{1}{2} \ell_c^2$$

Subtracting (H-8) from (H-10)

$$(C_{st} - C_{dc}) = C_2 B (\cos \ell_1 - \cos \ell_C) + C_3 B (\sin \ell_1 - \sin \ell_C) + h_B (\ell_1 - \ell_C) + \frac{1}{2} (\ell_1^2 - \ell_C^2) \quad (H-13)$$

Using (H-9)

$$0 = -C_2 B \sin \ell_C + C_3 B \cos \ell_C + h_B + \ell_C \quad (H-14)$$

Multiplying (H-13) by  $\sin \ell_C$  and (H-14) by  $(\cos \ell_1 - \cos \ell_C)$

$$\begin{aligned} (C_{st} - C_{dc}) \sin \ell_C &= C_2 B \sin \ell_C (\cos \ell_1 - \cos \ell_C) + \\ &+ C_3 B \sin \ell_C (\sin \ell_1 - \sin \ell_C) + h_B \sin \ell_C (\ell_1 - \ell_C) + \\ &+ \frac{1}{2} \sin \ell_C (\ell_1^2 - \ell_C^2) \end{aligned} \quad (H-15)$$

$$\begin{aligned} 0 &= -C_2 B \sin \ell_C (\cos \ell_1 - \cos \ell_C) + C_3 B \cos \ell_C (\cos \ell_1 - \cos \ell_C) \\ &+ h_B (\cos \ell_1 - \cos \ell_C) + \ell_C (\cos \ell_1 - \cos \ell_C) \end{aligned}$$

$$\begin{aligned} (C_{st} - C_{dc}) \sin \ell_C &= C_3 B [\sin \ell_C \sin \ell_1 - \sin^2 \ell_C + \cos \ell_C \cos \ell_1 - \\ &- \cos^2 \ell_C] + h_B (\cos \ell_1 - \cos \ell_C) + \ell_C (\cos \ell_1 - \cos \ell_C) + \\ &+ h_B (\sin \ell_C) (\ell_1 - \ell_C) + \frac{1}{2} \sin \ell_C (\ell_1^2 - \ell_C^2) \end{aligned}$$

$$\begin{aligned} (C_{st} - C_{dc}) \sin \ell_C - h_B (\cos \ell_1 - \cos \ell_C) - h_B \sin \ell_C (\ell_1 - \ell_C) \\ - \ell_C (\cos \ell_1 - \cos \ell_C) - \frac{1}{2} \sin \ell_C (\ell_1^2 - \ell_C^2) = \\ = C_3 B [\cos(\ell_1 - \ell_C) - 1] \end{aligned}$$

$\begin{aligned} (C_{st} - C_{dc}) \sin \ell_C - h_B (\cos \ell_1 - \cos \ell_C) - \\ C_3 B = \frac{-h_B \sin \ell_C (\ell_1 - \ell_C) - \ell_C (\cos \ell_1 - \cos \ell_C) - \\ - \frac{1}{2} \sin \ell_C (\ell_1^2 - \ell_C^2)}{[\cos(\ell_1 - \ell_C) - 1]} \end{aligned}$	(H-16)
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Multiplying (H-13) by  $\cos\ell_C$  and (H-14) by  $(\sin\ell_1 - \sin\ell_C)$

$$\begin{aligned} (C_{st} - C_{dc}) \cos\ell_C &= C_2B \cos\ell_C(\cos\ell_1 - \cos\ell_C) + \\ &+ C_3B \cos\ell_C(\sin\ell_1 - \sin\ell_C) + h_B(\ell_1 - \ell_C) \cos\ell_C + \\ &+ \frac{1}{2}(\ell_1^2 - \ell_C^2) \cos\ell_C \end{aligned} \quad (H-17)$$

$$\begin{aligned} 0 &= -C_2B \sin\ell_C(\sin\ell_1 - \sin\ell_C) + C_3B \cos\ell_C(\sin\ell_1 - \sin\ell_C) + \\ &+ h_B(\sin\ell_1 - \sin\ell_C) + \ell_C(\sin\ell_1 - \sin\ell_C) \end{aligned} \quad (H-18)$$

Subtracting (H-18) from (H-17)

$$\begin{aligned} (C_{st} - C_{dc}) \cos\ell_C &= C_2B(\cos\ell_C \cos\ell_1 - \cos^2\ell_C + \sin\ell_1 \sin\ell_C - \\ &- \sin^2\ell_C) + h_B(\ell_1 - \ell_C) \cos\ell_C - h_B(\sin\ell_1 - \sin\ell_C) + \\ &+ \frac{1}{2}(\ell_1^2 - \ell_C^2) \cos\ell_C - \ell_C(\sin\ell_1 - \sin\ell_C) \\ (C_{st} - C_{dc}) \cos\ell_C - h_B(\ell_1 - \ell_C) \cos\ell_C + h_B(\sin\ell_1 - \sin\ell_C) \\ + \frac{1}{2}(\ell_1^2 - \ell_C^2) \cos\ell_C + \ell_C(\sin\ell_1 - \sin\ell_C) &= C_2B[\cos(\ell_1 - \ell_C) - 1] \end{aligned}$$

$$C_2B = \frac{(C_{st} - C_{dc}) \cos\ell_C - h_B(\ell_1 - \ell_C) \cos\ell_C + h_B(\sin\ell_1 - \sin\ell_C)}{[\cos(\ell_1 - \ell_C) - 1]} \quad (H-19)$$

Using (H-5) to solve for  $h_B$

$$\begin{aligned} -\cos\ell_C - C_3A \sin\ell_C + 1 &= -C_2B \cos\ell_C - C_3B \sin\ell_C + 1 \\ \cos\ell_C + C_3A \sin\ell_C &= C_2B \cos\ell_C + C_3B \sin\ell_C \end{aligned}$$

$$\text{let } a_{2B} = \frac{(C_{st}-C_{dc})\cos\ell_C - \frac{1}{2}(\ell_1^2 - \ell_C^2)\cos\ell_C + \ell_C(\sin\ell_1 - \sin\ell_C)}{[\cos(\ell_1 - \ell_C) - 1]}$$

$$\text{let } a_{3B} = \frac{(C_{st}-C_{dc})\sin\ell_C - \ell_C(\cos\ell_1 - \cos\ell_C) - \frac{1}{2}(\ell_1^2 - \ell_C^2)\sin\ell_C}{[\cos(\ell_1 - \ell_C) - 1]}$$

$$(1-a_{2B})\cos\ell_C + (C_{3A}-a_{3B})\sin\ell_C = \frac{h_B[-(\cos\ell_1 - \cos\ell_C) - \sin\ell_C(\ell_1 - \ell_C) - (\ell_1 - \ell_C) - (\ell_1 - \ell_C)\cos\ell_C + (\sin\ell_1 - \sin\ell_C)]}{[\cos(\ell_1 - \ell) - 1]}$$

$$(a_{2B}-1)\cos\ell_C + (a_{3B}-C_{3A})\sin\ell_C = \frac{h_B[(\cos\ell_1 - \cos\ell_C) - (\sin\ell_1 - \sin\ell_C) + (\ell_1 - \ell_C)\cos\ell_C + \sin\ell_C(\ell_1 - \ell_C)]}{[\cos(\ell_1 - \ell_C) - 1]}$$

$$h_B = \frac{[(a_{2B}-1)\cos\ell_C + (a_{3B}-C_{3A})\sin\ell_C][\cos(\ell_1 - \ell_C) - 1]}{[(\cos\ell_1 - \cos\ell_C) + \sin\ell_C(\ell_1 - \ell_C)]\sin\ell_C} + \\ + [(\ell_1 - \ell_C)\cos\ell_C - (\sin\ell_1 - \sin\ell_C)] \cos\ell_C$$
(H-20)

### Segment C

From a previous derivation

$$C_{1C} = C_{dc} \cos\theta + [M_2/M_1 (\ell - \ell_1) + C_{dc} \sin\theta] \tan\theta - \\ - C_{2C} \cos\ell - C_{3C} \sin\ell - h_C \ell - \frac{1}{2} \ell^2$$

$$C_{2C} = 1/\cos\ell - [M_2/M_1 \tan\theta + \tan\ell - (\ell + h_C)] \sin\ell$$

$$C_{3C} = M_2/M_1 \tan\theta \cos\ell + \sin\ell - (\ell + h_C) \cos\ell$$

$$h_C = \frac{JB-a_1(\cos\ell_1 - \cos\ell) - b_2(\sin\ell_1 - \sin\ell)}{[\sin\ell(\cos\ell_1 - \cos\ell) - \cos\ell(\sin\ell_1 - \sin\ell) + \ell_1 - \ell]}$$

### Equations for Solution

$$X = \ell_C \quad y''_B = y''_C$$

$$-C_{2B} \cos\ell_1 - C_{3B} \sin\ell_1 = -C_{2C} \cos\ell_1 - C_{3C} \sin\ell_1$$

$$F_2 = 0 = (C_{2B} - C_{2C}) \cos\ell_1 + (C_{3B} - C_{3C}) \sin\ell_1 \quad (H-21)$$

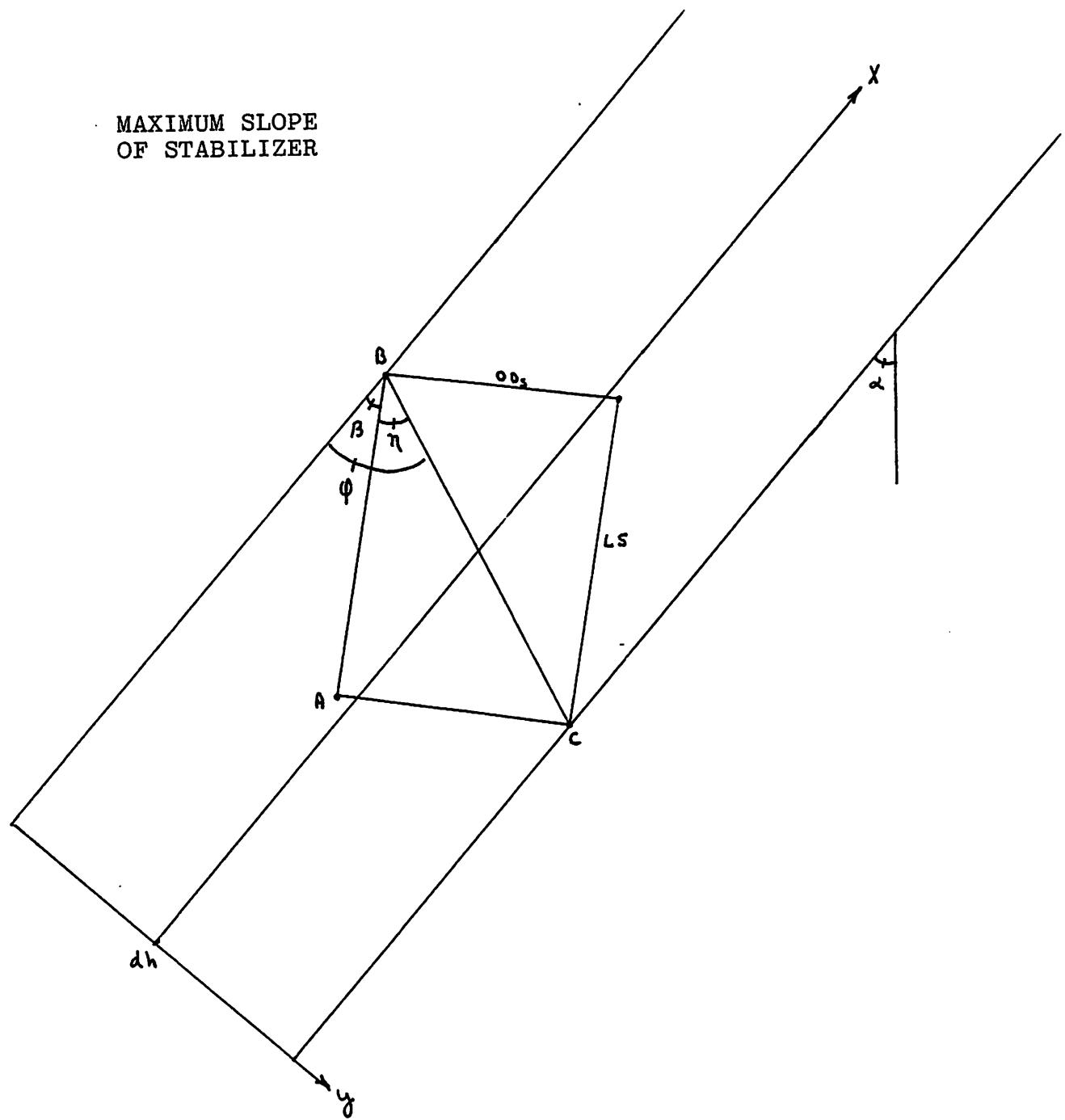
$$X = \ell_1 \quad y'_B = y'_C$$

$$-C_{2B} \sin\ell_1 + C_{3B} \cos\ell_1 + h_B + \ell_1 = -C_{2C} \sin\ell_1 + \\ + C_{3C} \cos\ell_1 + h_C + \ell_1$$

$$(C_{2B} - C_{2C}) \sin\ell_1 + (C_{3C} - C_{3B}) \cos\ell_1 + (h_C - h_B) = 0$$

$$F_1 = 0 = (C_{2B} - C_{2C}) \sin\ell_1 + (C_{3C} - C_{3B}) \cos(\ell_1) + h_C - h_B \quad (H-22)$$

MAXIMUM SLOPE  
OF STABILIZER



$OD_s$  - outside diameter of stabilizer

$L.S.$  - length of stabilizer

$d_h$  - diameter of borehole

$\phi$  - angle between diagonal of stabilizer and borehole wall

$\beta$  - angle between wall of stabilizer and borehole wall

$\eta$  - angle between diagonal of stabilizer and stabilizer wall

$\alpha$  - inclination of the borehole with respect to vertical

The maximum slope of the stabilizer is the slope of line  $\overline{AB}$  relative to the x y axis.

$$\text{Slope } \overline{AB} = - \tan \beta$$

$$B = \phi - \eta \quad ; \quad \overline{BC} = \sqrt{OD_s^2 + LS^2}$$

$$\phi = \sin^{-1} \left( \frac{D_h}{\sqrt{OD_s^2 + LS^2}} \right)$$

$$\eta = \tan^{-1} \left( \frac{WS}{LS} \right)$$

$$-\tan \beta = -\tan \left[ \sin^{-1} \left( \frac{D_h}{\sqrt{OD_s^2 + LS^2}} \right) + \tan^{-1} \left( \frac{WS}{LS} \right) \right]$$

$$-\tan(\phi - \eta) = \frac{-(\tan \phi - \tan \eta)}{(1 + \tan \phi \tan \eta)}$$

$$-\tan(\phi - \eta) = \frac{\frac{D_h}{\sqrt{WS^2 + LS^2 - D_h^2}} - \frac{WS}{LS}}{\left( 1 + \frac{D_h}{\sqrt{WS^2 + LS^2 - D_h^2}} \frac{WS}{LS} \right)} \quad (H-23)$$

A Case for a Drilling Assembly  
With no Equilibrium Angle in  
The 0 - 90° Range

**Input data:**

$$D_h = 8.75 \text{ in.} \quad OD_{st} = 8.688 \text{ in.}$$

$$OD_{dc} = 6.25 \text{ in.} \quad MW = 10 \text{ ppg.}$$

$$ID_{dc} = 2.25 \text{ in.} \quad D_1 = 10 \text{ ft.}$$

$\alpha$ [deg]	$H_o$ [lb]
5°	+332
20°	+545
35°	+633
50°	+677
60°	+693
75°	+706
90°	+710

Comparison of Point Stabilizer  
Program with Walker and  
Friedman and N.P. Callas

Walker and Fiedman	N.P. Callas	Point Stabilizer Program
$\beta$	-0.043	-0.0405
$\phi$	62.15	62.04
$H_O$	749.3	713.0
$H_1$	2801.	2735.
		2694.8

Run #1

$D_h = 8.75$  in  $D_1 = 10$  ft.  
 $OD_{dc} = 6.25$  in  
 $ID_{dc} = 2.25$  in  
 $OD_{st} = 8.688$  in  
 $MW = 10$  ppg  
 $\alpha = 60^\circ$   
 $W = 20,000$  lb's

Walker and Fiedman	N.P. Callas	Point Stabilizer Program
$\beta$	0.303	0.3147
$\phi$	$18.65^\circ$	$18.64^\circ$
$H_O$	-469.9	-474.6
$H_1$	-1614.	-1593.
		1584.

Run #2

$D_h = 8.75$  in  $D_1 = 50$  ft.  
 $OD_{dc} = 6.25$  in  
 $ID_{dc} = 2.25$  in  
 $OD_{st} = 8.688$  in  
 $MW = 10$  ppg  
 $\alpha = 20^\circ$   
 $W = 20,000$  lb's

```

10 REM UNE STABILIZER
20 REM POINT SUPPORT
40 REM
50 REM A CONTACT POINT BETWEEN BIT AND STABILIZER IS CONSIDERED.
60 REM
70 REM THIS PROGRAM CALCULATES BETA, PHI, H0, HC, AND H1, FOR A SPECIFIED
80 REM DISTANCE TO THE STABILIZER, CLEARANCE, WOB, AND MOMENT OF INERTIA.
100 CLS
110 DEFDBL F,L,X,N
120 DIM Y(450),YD(450),YDD(450),YO(450),YDO(450),YDDD(450)
130 INPUT "DISTANCE TO STABILIZER 1 (ft) : ";D11
140 INPUT "Dh=";DH:DH=DH/12
150 INPUT "ODdc(in)=";OD:OD=OD/12
160 INPUT "IDdc(in)=";ID:ID=ID/12
170 INPUT "ODst (in) = ";DST1:DST1=DST1/12
180 INPUT "MW(ppg)(";MW
190 INPUT "Hole inclination ALFA(deg)";AA
200 PRINT:PRINT"drop in angle is negative and build-up is positive":PRINT
210 INPUT "CHANGE IN ALPHA (deg) ";TT:TT=TT/57.29
220 INPUT "WOB(1000 lb)";W:W=1000*W
230 REM ***** PRINT INPUT DATA *****
240 CLS
250 PRINT " D1 (ft)= ";USING"##.##";D11
260 PRINT " Dh (in) = ";DH*12
270 PRINT " ODdc (in) = ";OD*12
280 PRINT " IDdc (in) = ";ID*12
290 PRINT " ODst (in) = ";DST1*12
300 PRINT " MW (ppg) = ";MW
310 PRINT " ALPHA (deg) = ";AA
320 PRINT " DELTA ALPHA = ";TT*57.29
330 PRINT " WOB (lb's) = ";W
340 REM ***** CALCULATE DIMENSIONLESS QUANTITIES *****
350 TT=-TT
360 WU=3.14159*((OD/2)^2-(ID/2)^2)*489
370 C=(DH-OD)/2
380 CST1=(DH-DST1)/2
390 P=WU*(1-MW/65.4)
400 I=3.14*(OD^4-ID^4)/64
410 PRINT "P (lb's/ft) = ";P
420 PRINT "I (ft^4) = ";I
430 PRINT:PRINT
440 EI=4176*10^6*I
450 D1=(D11*SQR(W/EI))
460 CD=(W^2*C)/(EI*P*SIN(AA/57.29))
470 M1= EI*P*SIN(AA/57.29)/(W^2)
480 M2=SQR(EI/W)
490 M3=SQR(EI/W)*P*SIN(AA/57.29)
500 M1B=EI*P*SIN(AA/57.29)/(W^2*COS(TT))
510 M2B=SQR(EI/W*COS(TT))
520 M3B=SQR(EI/(COS(TT)*W))*P*SIN(AA/57.29)
530 CST1=(W^2*CST1)/(EI*P*SIN(AA/57.29))
540 INPUT "DO YOU WANT A HARD COPY, 1- YES, 2-NO";HARD
550 IF (HARD=1) THEN GOSUB 2920
560 REM ***** SOLVES FOR DISTANCE TO TANGENCY POINT *****

```

```

570 L=D1+.1
580 POS1=1
590 COUNT=0
600 A1=1/COS(L)-((M2B/M1B)*TAN(TT)-L+TAN(L))*SIN(L)
610 B2=(M2B/M1B*TAN(TT))*COS(L)+SIN(L)-L*COS(L))
620 JB=CST1+.5*(L^2-D1^2)-CD*COS(TT)-TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))
630 NUMB=JB-A1*(COS(D1)-COS(L))-B2*(SIN(D1)-SIN(L))
640 DENB=(SIN(L)*(COS(D1)-COS(L))-COS(L)*(SIN(D1)-SIN(L))+D1-L)
650 HB=NUMB/DENB
660 C2B=1/COS(L)-((M2B/M1B)*TAN(TT)-HB-L+TAN(L))*SIN(L)
670 C3B=(M2B/M1B)*TAN(TT)*COS(L)+SIN(L)-(L+HB)*COS(L)
680 C1B=CD*COS(TT)+TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))-C2B*COS(L)-C3B*SIN(L)
690 ZZ=-HB*L-.5*L^2
700 C1B=C1B+ZZ
710 HO=(-C2B*COS(D1)-C3B*SIN(D1)+(CST1+1-.5*D1^2))/D1
720 C3A=(CST1+1-HO*D1-.5*D1^2-COS(D1))/SIN(D1)
730 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-HO)
740 IF F<0 THEN POS1=2
750 DX=.1
760 ITER =1
770 LPR=L
780 L=LPR+DX
790 IF L>10 THEN 1190
800 A1=1/COS(L)-((M2B/M1B)*TAN(TT)-L+TAN(L))*SIN(L)
810 B2=M2B/M1B*TAN(TT)*COS(L)+SIN(L)-L*COS(L)
820 JB=CST1+.5*(L^2-D1^2)-CD*COS(TT)-TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))
830 NUMB=JB-A1*(COS(D1)-COS(L))-B2*(SIN(D1)-SIN(L))
840 DENB=(SIN(L)*(COS(D1)-COS(L))-COS(L)*(SIN(D1)-SIN(L))+D1-L)
850 HB=NUMB/DENB
860 C2B=1/COS(L)-((M2B/M1B)*TAN(TT)-HB-L+TAN(L))*SIN(L)
870 C3B=(M2B/M1B)*TAN(TT)*COS(L)+SIN(L)-(L+HB)*COS(L)
880 C1B=CD*COS(TT)+TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))-C2B*COS(L)-C3B*SIN(L)
890 ZZ=-HB*L-.5*L^2
900 C1B=C1B+ZZ
910 HO=(-C2B*COS(D1)-C3B*SIN(D1)+(CST1+1-.5*D1^2))/D1
920 C3A=(CST1+1-HO*D1-.5*D1^2-COS(D1))/SIN(D1)
930 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-HO)
940 IF F<0 THEN 970
950 POS2=1
960 GOTO 980
970 POS2=2
980 IF POS2<>POS1 THEN 1010
990 LPR=L
1000 GOTO 780
1010 IF ITER=1 THEN 1070
1020 IF ITER=2 THEN 1090
1030 IF ITER=3 THEN 1110
1040 IF ITER=4 THEN 1130
1050 IF ITER=5 THEN 1150
1060 IF ITER=6 THEN 1170
1070 DX=.01:ITER=2
1080 GOTO 780
1090 DX=.001:ITER=3
1100 GOTO 780
1110 DX=.0001:ITER=4
1120 GOTO 780
1130 DX=.00001:ITER=5

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```

1140 GOTO 780
1150 DX=.000001:ITER=6
1160 GOTO 780
1170 LPR=L : POS1=POS2 : DX=.1 : ITER=1 : COUNT=COUNT+1 : ROOT(COUNT)=LPR
1180 GOTO 780
1190 FOR I=1 TO COUNT
1200 PRINT "ROOT("I;") = ";ROOT(I)
1210 NEXT I
1220 REM ***** DETERMINATION OF BETA, PHI, H0, AND H1 *****
1230 I=0
1240 L=ROOT(1)
1250 A1=1/COS(L)-((M2B/M1B)*TAN(TT)-L*TAN(L))*SIN(L)
1260 B2=M2B/M1B*TAN(TT)*COS(L)+SIN(L)-L*COS(L)
1270 JB=CST1+.5*(L^2-D1^2)-CD*COS(TT)-TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))
1280 NUMB=JB-A1*(COS(D1)-COS(L))-B2*(SIN(D1)-SIN(L))
1290 DENB=(SIN(L)*(COS(D1)-COS(L))-COS(L)*(SIN(D1)-SIN(L))+D1-L)
1300 HB=NUMB/DENB
1310 C2B=1/COS(L)-((M2B/M1B)*TAN(TT)-HB-L*TAN(L))*SIN(L)
1320 C3B=(M2B/M1B)*TAN(TT)*COS(L)+SIN(L)-(L+HB)*COS(L)
1330 C1B=CD*COS(TT)+TAN(TT)*((L-D1)*(M2B/M1B)+CD*SIN(TT))-C2B*COS(L)-C3B*SIN(L)
1340 ZZ=-HB*L-.5*L^2
1350 C1B=C1B+ZZ
1360 H0=(-C2B*COS(D1)-C3B*SIN(D1)+(CST1+1-.5*D1^2))/D1
1370 C3A=(CST1+1-H0*D1-.5*D1^2-COS(D1))/SIN(D1)
1380 F=(SIN(D1)*(1-C2B)+COS(D1)*(C3B-C3A)+HB-H0)
1390 H1=H0-HB
1400 YD(0)=(C3A+H0)
1410 BB=57.29*ATN(YD(0)*M1/M2)
1420 H0U=H0*M3:H1U=H1*M3
1430 PHI = 57.29*(ATN((M3*H0)/W))+AA
1440 PRINT
1450 REM ***** DETERMINES IF POINT OF CONTACT IS PRESENT *****
1460 PRINT
1470 I=-1 : DX=.01:X=0
1480 I=I+1
1490 Y(I)=-1+COS(X)+C3A*SIN(X)+HU*X+.5*X^2
1500 X=X+DX
1510 IF (ABS(Y(I))>CD) OR (ABS(Y(I))=CD) THEN GOTO 2880
1520 IF (X<D1) THEN GOTO 1480
1530 IF (HARD=1) THEN GOSUB 3060
1540 INPUT "DO YOU WANT A HARD COPY OF Y, SLOPE, MOMENT VS X, 1-YES, 2-NO";HZ
1550 PRINT "BETA (deg) = " ;BB
1560 PRINT "PHI (deg) = " ;PHI
1570 PRINT "H0 (lb's) = " ;H0*M3
1580 PRINT "H1 (lb's) = " ;H1*M3
1590 NN=D1/.01
1600 FOR I=0 TO NN
1610 Y(I)=0
1620 NEXT I
1630 REM ***** SOLVE FOR 0 SLOPE POINT BETWEEN BIT AND TANGENCY *****
1640 X=0:POS1=1:COUNT=0
1650 F=-SIN(X)+C3A*COS(X)+X+HU
1660 IF (F<0) THEN POS1=2:DX=.1
1670 ITER=1

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```

1680 XPR=X
1690 X=XPR+DX
1700 IF(X>D1) THEN GOTO 1870
1710 F=-SIN(X)+C3A*COS(X)+X+HO
1720 IF (F<0) THEN 1750
1730 POS2=1
1740 GOTO 1760
1750 POS2=2
1760 IF (POS2<>POS1) THEN 1790
1770 XPR=X
1780 GOTO 1690
1790 IF (ITER =1) THEN 1830
1800 IF (ITER =2) THEN 1840
1810 IF (ITER =3) THEN 1850
1820 IF (ITER=4) THEN 1860
1830 DX=.01:ITER=2:GOTO 1690
1840 DX=.001: ITER=3: GOTO 1690
1850 DX=.0001: ITER=4: GOTO 1690
1860 SLP0=X:DX1=SLP0/5:DX2=(D1-SLP0)/5:GOTO 1890
1870 DX1=D1/10:DX2=D1/10:SLP0=D1/2
1880 PRINT "DX1= ";DX1
1890 REM***** DETERMINE VALUE OF Y, SLOPE, MOMENT FOR BIT TO 0 SLOPE POINT *****
1900 X=0:J=0
1910 FOR J=0 TO 5
1920 Y(J)=(-1+COS(X)+C3A*SIN(X)+HO*X+.5*X^2)*M1
1930 YD(J)=(-SIN(X)+C3A*COS(X)+HO+X)*M1/M2
1940 YDD(J)=-EI*(-COS(X)-C3A*SIN(X)+1)*M1/(M2^2)
1950 X=X+DX1:LSJ=J
1960 NEXT J
1970 REM ***** DETERMINE VALUES OF Y, SLOPE, MOMENT FOR 0 SLOPE TO STAB1 *****
1980 X=SLP0+DX2: LSJ=LSJ+1
1990 FOR K=LSJ TO 10
2000 Y(K)=(-1+COS(X)+C3A*SIN(X)+HO*X+.5*X^2)*M1
2010 YD(K)=(-SIN(X)+C3A*COS(X)+HO+X)*M1/M2
2020 YDD(K)=(-EI*(-COS(X)-C3A*SIN(X)+1))*M1/(M2^2)
2030 X=X+DX2
2040 NEXT K
2050 PRINT " X Y SLOPE MOMENT "
2060 PRINT " (ft) (ft) (ft/ft) (ft-lb) "
2070 PRINT "-----"
2080 DIMX=.000001
2090 FOR I=0 TO 5
2100 PRINT USING "+#####.#####";DIMX;Y(I);YD(I);YDD(I)
2110 DIMX=DIMX+DX1*M2
2120 NEXT I
2130 DIMX=SLP0*M2
2140 FOR I=6 TO 10
2150 DIMX=DIMX+DX2*M2
2160 PRINT USING "+#####.#####";DIMX;Y(I);YD(I);YDD(I)
2170 NEXT I
2180 IF (HZ=1) THEN GOSUB 3130
2190 REM ***** DETERMINE Y, SLOPE, MOMENT FOR SEGMENT B *****

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2200 DX3=(L-D1)/10:X=D1
2210 FOR I= 11 TO 21
2220 IF (I>11) GOTO 2290
2230 REM THE VALUES OF Y, YD, YDD ARE IN THE NEW COORDINATE SYSTEM, HENCE VALUES
2240 REM OF Y WILL EXCEED THE DIAMETER OF THE NEW BORE HOLE
2250 Y(I)=(C1B+C2B*COS(X)+C3B*SIN(X)+HB*X+.5*X^2)*M1
2260 YD(I)=(-C2B*SIN(X)+C3B*COS(X)+HB+X)*M1/M2
2270 YDD(I)=(-EI*(-C2B*COS(X)-C3B*SIN(X)+1))*M1/M2^2
2280 GOTO 2320
2290 Y(I)=(C1B+C2B*COS(X)+C3B*SIN(X)+HB*X+.5*X^2)*M1B
2300 YD(I)=(-C2B*SIN(X)+C3B*COS(X)+HB+X)*M1B/M2B
2310 YDD(I)=-EI*(-C2B*COS(X)-C3B*SIN(X)+1)*M1B/M2B^2
2320 X=X+DX3
2330 NEXT I
2340 PRINT
2350 DIMX=D1*M2
2360 PRINT:PRINT "SEGMENT B ";PRINT
2370 PRINT" X Y SLOPE MOMENT"
2380 PRINT" (ft) (ft) (ft/ft) (ft-lb)"
2390 PRINT" ----- ----- ----- -----"
2400 FOR I=11 TO 21
2410 PRINT USING "# #####,###";DIMX;Y(I);YD(I);YDD(I)
2420 DIMX=DIMX+DX3*M2B
2430 NEXT I
2440 IF (HZ=1)THEN GOSUB 3290
2450 INPUT "DO YOU WISH TO CONTINUE WITH ANOTHER RUN ? 1-YES, 0-NO";DEC1
2460 IF (DEC1=0) THEN GOTO 5470
2470 PRINT
2480 INPUT "WOULD YOU LIKE TO CHANGE ANY VARIABLES ? 1-YES, 0-NO";DEC2
2490 IF (DEC2=0) GOTO 240
2500 REM ***** DATA CHANGE SECTION *****
2510 CLS
2520 PRINT "CODE # VARIABLE"
2530 PRINT" -----"
2540 PRINT" 1 ----- Dh"
2550 PRINT" 2 ----- DDdc"
2560 PRINT" 3 ----- IDdc"
2570 PRINT" 4 ----- Wdc"
2580 PRINT" 5 ----- MW"
2590 PRINT" 6 ----- ALPHA"
2600 PRINT" 7 ----- GAMA"
2610 PRINT" 8 ----- WOB"
2620 PRINT" 9 ----- h"
2630 PRINT" 10 ----- DDst"
2640 PRINT" 11 ----- Dst1"
2650 PRINT "A DROP IN ANGLE IS NEGATIVE AND BUILD-UP IS POSITIVE"
2660 PRINT" 12 ----- THETA"
2670 PRINT
2680 PRINT "INPUT THE CORRESPONDING CODE FOR THE VARIABLES YOU WISH TO CHANGE,"
2690 PRINT "ENTER THEM ONE PER LINE ----ENTER 0 WHEN FINISHED"
2700 INPUT "CODE # = ";CN
2710 IF (CN=0)THEN GOTO 240
2720 IF (CN=1)THEN INPUT "Dh (in) = ";DH:DH=DH/12

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2730 IF (CN=2) THEN INPUT "DDdc (in) = ";DD:DD=DD/12
2740 IF (CN=3) THEN INPUT "IDdc (in) = ";ID:ID=ID/12
2750 IF (CN=4) THEN INPUT "Wdc (in) = ";WU
2760 IF (CN=5) THEN INPUT "MW (PPg) = ";MW
2770 IF (CN=6) THEN INPUT "ALPHA (deg) = ";AA:AO=AA
2780 IF (CN=7) THEN INPUT "GAMA (deg) = ";GA
2790 IF (CN=8) THEN INPUT "WOB (1000'S lbs) = ";W:W=1000*W
2800 IF (CN=9) THEN INPUT " h = ";DAI
2810 IF (CN=10) THEN INPUT " ODst(in) = ";DST1:DST1=DST1/12
2820 IF (CN=11) THEN INPUT " Dst1(ft) = ";D11
2830 IF (CN=12) THEN INPUT "THETA = ";TT:TT=TT/57.29
2840 IF (CN<0)OR(CN>12) THEN GOTO 2860
2850 GOTO 2700
2860 PRINT "INPUT VALUE MUST BE BETWEEN 0 AND 10 INCLUSIVE"
2870 GOTO 2700
2880 PRINT "***** CONTACT POINT BETWEEN THE BIT AND STABILIZER *****"
2890 LPRINT:LPRINT "***** CONTACT POINT BETWEEN BIT AND STABILIZER *****"
*****":LPRINT
2900 GOTO 3410
2910 REM
2920 REM ***** HARD COPY OF INPUT DATA *****
2930 LPRINT " D1 (ft) = ";D11
2940 LPRINT " DH (in) = ";DH*12
2950 LPRINT " DDdc (in) = ";DD*12
2960 LPRINT " IDdc (in) = ";ID*12
2970 LPRINT " ODst (in) = ";DST1*12
2980 LPRINT " MW (PPg) = ";MW
2990 LPRINT " ALPHA (deg) = ";AA
3000 LPRINT " DELTA ALPHA = ";-TT*57.29
3010 LPRINT " WOB (lb's) = ";W
3020 LPRINT " P (lb's/ft in fluid) = ";P
3030 LPRINT " I (in^4) = ";I
3040 LPRINT:LPRINT
3050 RETURN
3060 REM ***** HARD COPY OF HO, BETA, HC, PHI *****
3070 LPRINT "BETA (deg) = ";BB
3080 LPRINT "HO (lb's) = ";HO*M3
3090 LPRINT "HC (lb's) = ";HC*M3
3100 LPRINT "h1 (lb's) = ";H1*M3
3110 LPRINT "PHI (deg) = ";PHI
3120 RETURN
3130 REM ***** HARD COPY SEGMENT A NO CONTACT POINT *****
3140 LPRINT:LPRINT " SEGMENT A BIT TO STABILIZER "
3150 LPRINT " X Y SLOPE MOMEN
T"
3160 LPRINT" (ft) (ft) (ft/ft) (ft-l
b)"
3170 LPRINT" ----- -----
3180 DIMX=.000001
3190 FOR K=0 TO 5
3200 LPRINT USING "+#####.####";DIMX;Y(K);YD(K);YDD(K)
3210 DIMX=DIMX+DX1*M2
3220 NEXT K
3230 DIMX=SLP0*M2
3240 FOR J=6 TO 10

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3250 DIMX=DIMX+DX2*M2
3260 LPRINT USING "+#####.#####";DIMX;Y(J);YD(J);YDD(J)
3270 NEXT J
3280 RETURN
3290 REM ***** HARD COPY OF SEGMENT B NO CONTACT PRESENT *****
3300 LPRINT:LPRINT" SEGMENT B STABILIZER TO TANGENCY POINT "
3310 LPRINT" X Y SLOPE MOMENT"
3320 LPRINT" (ft) (ft) (ft/ft) (ft-lb)"
3330 LPRINT" ----- -----
3340 DIMX=D1*M2
3350 FOR I=11 TO 21
3360 LPRINT USING "+#####.#####";DIMX;Y(I);YD(I);YDD(I)
3370 DIMX=DIMX+DX3*M2B
3380 NEXT I
3390 LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT:LPRINT
3400 RETURN
3410 REM ***** DETERMINATION OF CONTACT POINT *****
3420 CLS
3430 WU=3.14159*((OD/2)^2-(ID/2)^2)*489
3440 C=(DH-OD)/2
3450 PRINT "C=";C
3460 CST1=(DH-DST1)/2
3470 P=WU*(1-MW/65.4)
3480 I=3.14*(OD^4-ID^4)/64
3490 EI=4176*10^6*I
3500 D1=(D11*SQR(W/EI))
3510 CD=(W^2*C)/(EI*P*SIN(AA/57.29))
3520 M1= EI*P*SIN(AA/57.29)/(W^2)
3530 M2=SQR(EI/W)
3540 M3=SQR(EI/W)*P*SIN(AA/57.29)
3550 M1C=EI*P*SIN(AA/57.29)/(W^2*COS(TT))
3560 M2C=SQR(EI/W*COS(TT))
3570 M3C=SQR(EI/(COS(TT)*W))*P*SIN(AA/57.29)
3580 CST1=(W^2*CST1)/(EI*P*SIN(AA/57.29))
3590 VLC=.6*D1:LLC=.25*D1:PLOT=2 → ?
3600 SINE=1:SINL=1:SINU=1
3610 ITER2=1:LC=LLC
3620 ITER1=1:SIGN1=1:SIGN1=1:SIGN2=1:ITER=1
3630 I=1
3640 I=I+1
3650 DL=(4*D1-1.25*D1)/I
3660 IF (DL>.3) THEN GOTO 3640
3670 LLLOW=1.01*D1
3680 LPR=LLLOW-DL
3690 L=LPR+DL
3700 IF (L>4*D1) THEN 4550
3710 L=LPR+DL
3720 A1=(1/COS(L)-(M2C/M1C*TAN(TT)+TAN(L)-L)*SIN(L))
3730 REM
3740 B2=(M2C/M1C*TAN(TT)*COS(L)+SIN(L)-L*COS(L))
3750 REM
3760 JB=CST1+.5*(L^2-D1^2)-(CD*COS(TT)+(M2C/M1C*(L-D1)+CD*SIN(TT))*TAN(TT))
3770 REM
3780 NUMC=JB-A1*(COS(D1)-COS(L))-B2*(SIN(D1)-SIN(L))
3790 REM

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3800 DENC=(SIN(L)*(COS(D1)-COS(L))-COS(L)*(SIN(D1)-SIN(L))+D1-L)
3810 HC=NUMC/DENC
3820 REM
3830 C3C=M2C/M1C*TAN(TT)*COS(L)+SIN(L)-(L+HC)*COS(L)
3840 REM
3850 C2C=1/COS(L)-(M2C/M1C*TAN(TT)+TAN(L)-(L+HC))*SIN(L)
3860 REM
3870 C1C=CD*COS(TT)+(M2C/M1C*(L-D1)+CD*SIN(TT))*TAN(TT)-C2C*COS(L)-C3C*SIN(L)-HC
* $L - .5*L^2$ 
3880 NUMA3B=(CST1-CD)*SIN(LC)-LC*(COS(D1)-COS(LC))- .5*SIN(LC)*(D1^2-LC^2)
3890 REM
3900 A3B=NUMA3B/(COS(D1-LC)-1)
3910 REM
3920 NUMA2B=(CST1-CD)*COS(LC)- .5*(D1^2-LC^2)*COS(LC)+LC*(SIN(D1)-SIN(LC))
3930 REM
3940 A2B=NUMA2B/(COS(D1-LC)-1)
3950 H0=(CD+1-COS(LC)- .5*LC^2-TAN(LC)*SIN(LC)+LC*TAN(LC))/(LC-TAN(LC))
3960 REM
3970 C3A=(SIN(LC)-(H0+LC))/COS(LC)
3980 NUMB=((A2B-1)*COS(LC)+(A3B-C3A)*SIN(LC))
3990 REM
4000 DENB=((SIN(LC)*(D1-LC)+COS(D1)-COS(LC))*SIN(LC)+(COS(LC)*(D1-LC)-SIN(D1)+SIN(LC))*COS(LC))
4010 REM
4020 HB=NUMB/DENB*(COS(D1-LC)-1)
4030 C2B=(CST1-CD)*COS(LC)-HB*(COS(LC)*(D1-LC)-SIN(D1)+SIN(LC))- .5*(D1^2-LC^2)*COS(LC)+LC*(SIN(D1)-SIN(LC))
4040 REM
4050 C2B=C2B/(COS(D1-LC)-1)
4060 REM
4070 C3B=(CST1-CD)*SIN(LC)-HB*(SIN(LC)*(D1-LC)+COS(D1)-COS(LC))-LC*(COS(D1)-COS(LC))- .5*SIN(LC)*(D1^2-LC^2)
4080 REM
4090 C3B=C3B/(COS(D1-LC)-1)
4100 REM
4110 C1B=CST1-C2B*COS(D1)-C3B*SIN(D1)-HB*D1-.5*D1^2
4120 REM
4130 REM
4140 F1=(C2B-C2C)*SIN(D1)+(C3C-C3B)*COS(D1)+HC-HB
4150 REM
4160 F2=(C2B-C2C)*COS(D1)+(C3B-C3C)*SIN(D1)
4170 IF(PLOT=1) THEN GOTO 4590
4180 IF(ITER1=1) THEN GOTO 4260
4190 IF(F1<0) THEN GOTO 4220
4200 SIGN1=1
4210 GOTO 4230
4220 SIGN1=2
4230 IF(SIGN1<>SIGN) THEN GOTO 4290
4240 LPR=L
4250 GOTO 3690
4260 IF (F1<0) THEN SIGN=2
4270 ITER1=2;LPR=L
4280 GOTO 3690
4290 REM
4300 IF ITER=1 THEN 4340
4310 IF ITER=2 THEN 4350
4320 IF ITER=3 THEN 4360

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4330 IF ITER=4 THEN 4370
4340 DL=.1:ITER=2:GOTO 3690
4350 DL=.01:ITER=3:GOTO 3690
4360 DL=.001:ITER=4:GOTO 3690
4370 REM ***** DETERMINING LC *****
4380 PRINT "lc = ";LC
4390 PRINT "l = ";L; " f2 = ";F2; " f1 = ";F1
4400 IF (ITER2=1) THEN GOTO 4450
4410 IF (ITER2=2) THEN GOTO 4460
4420 IF (ABS(F2)<.01) THEN 4550
4430 IF (F2<0) THEN GOTO 4500
4440 SINE=1:GOTO 4510
4450 LC=ULC:IF (F2<0) THEN SINL=2:ITER2=2:GOTO 3620
4460 IF (F2<0) THEN SINU=2
4470 ITER2=3
4480 LC=(ULC+LLC)/2
4490 GOTO 3620
4500 SINE=2
4510 IF (SINE<>SINL) THEN 4540
4520 IF (SINE<>SINU) THEN 4530
4530 LLC=LC:LC=(ULC+LLC)/2:GOTO 3620
4540 ULC=LC:LC=(ULC+LLC)/2:GOTO 3620
4550 PRINT " root(l,lc) = ";L; " ";LC
4560 REM ***** DETERMINE SHAPE OF STRING *****
4570 PLOT=1
4580 GOTO 3720
4590 DXA=(LC/5):DXB=(D1-LC)/5:DXC=(L-D1)/10
4600 X=0
4610 FOR J=0 TO 5
4620 Y(J)=M1*(-1+COS(X)+C3A*SIN(X)+.5*X^2+HO*X)
4630 YD(J)=M1/M2*(-SIN(X)+C3A*COS(X)+HO+X)
4640 YDD(J)=-EI*M1/M2^2*(-COS(X)-C3A*SIN(X)+1)
4650 X=X+DXA
4660 NEXT J
4670 X=X-DXA
4680 FOR J=6 TO 11
4690 Y(J)=M1*(C1B+C2B*COS(X)+C3B*SIN(X)+HB*X+.5*X^2)
4700 YD(J)=M1/M2*(-C2B*SIN(X)+C3B*COS(X)+HB+X)
4710 YDD(J)=-EI*M1/M2^2*(-C2B*COS(X)-C3B*SIN(X)+1)
4720 X=X+DXB
4730 NEXT
4740 X=D1+DXC
4750 FOR J=12 TO 21
4760 Y(J)=M1C*(C1C+C2C*COS(X)+C3C*SIN(X)+HC*X+.5*X^2)
4770 YD(J)=M1C/M2C*(-C2C*SIN(X)+C3C*COS(X)+HC+X)
4780 YDD(J)=-EI*M1/M2^2*(-C2C*COS(X)-C3C*SIN(X)+1)
4790 X=X+DXC
4800 NEXT J
4810 REM ***** DETERMINE BETA, HO, HC, H1, PHI *****
4820 BB=57.29*(ATN(YD(0))):DHO=HO*M3
4830 PHI=57.29*ATN((SQR(EI/W)*P*SIN(AA/57.29)*HO)/W)+AA
4840 DHCON=(HO-HB)*M3:HCON=HO-HB
4850 DH1=(HC-HB)*M3
4860 CLS:PRINT "BETA (deg)= "
4870 PRINT "PHI (deg)= ";PHI
4880 PRINT "HO (lb's)= ";DHO

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4890 PRINT "HC (lb's) = " ; DHCON
4900 PRINT "H1 (lb's) = " ; DH1
4910 PRINT " BIT TO STABILIZER"
4920 PRINT" X Y SLOPE MOMENT"
4930 PRINT" ----- ----- -----
"
4940 X=0
4950 FOR J=0 TO 5
4960 PRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)
4970 X=X+DXA*M2
4980 NEXT J
4990 X=LC*M2
5000 FOR J= 6 TO 11
5010 PRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)
5020 X=X+DXB*M2
5030 NEXT J
5040 PRINT " STABILIZER TO TANGENCY POINT "
5050 PRINT" X Y SLOPE MOMENT"
5060 PRINT" ----- ----- -----
"
5070 X=D1*M2
5080 FOR J=11 TO 21
5090 PRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)
5100 X=X+DXC*M2
5110 NEXT J
5120 INPUT "DO YOU WANT A HARD COPY OF THE DATA 1-YES; 2-NO"; HZ
5130 IF (HZ=1) THEN GOTO 5150
5140 GOTO 5460
5150 ME=L:MC=LC
5160 LPRINT" L = ";ME;" LC = ";MC;" (DIMENSIONLESS UNITS)"
5170 LPRINT"-----"
5180 LPRINT" BETA (deg) = " ; BB
5190 LPRINT" PHI (deg) = " ; PHI
5200 LPRINT" HO (LB'S) = " ; DHO
5210 LPRINT" HC H(lb's) = " ; DHCON
5220 LPRINT" H1 (lb's) = " ; DH1
5230 LPRINT
5240 LPRINT" BIT TO STABILIZER"
5250 LPRINT
5260 LPRINT" X Y SLOPE MOMENT"
5270 LPRINT" ----- ----- -----
"
5280 X=0
5290 FOR J= 0 TO 5
5300 LPRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)
5310 X=X+DXA*M2
5320 NEXT J
5330 X=LC*M2
5340 FOR J=6 TO 11
5350 LPRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)
5360 X=X+DXB*M2
5370 NEXT J
5380 LPRINT:LPRINT" STABILIZER TO TANGENCY":LPRINT
5390 LPRINT" X Y SLOPE MOMENT"
5400 LPRINT" ----- ----- -----
"
5410 X=D1*M2
5420 FOR J=11 TO 21
5430 LPRINT USING "+#####.#####" ; X;Y(J);YD(J);YDD(J)

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5440 X=X+DXC\*M2C  
5450 NEXT J  
5460 GOTO 2450  
5470 END

**Comparison of Point Stabilizer  
Program with Lubinski  
and Woods Model**

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**Input Data:**

$D_h = 8.75$  in.  
 $OD_{dc} = 6.00$  in.  
 $ID_{dc} = 2.25$  in.  
 $MW = 10$  ppg.

Lubinski and Woods'  
Dimensionless Units

$M = 57.5$  ft. length of one  
dimensionless unit

$M_p = 4000$  lb weight of one  
dimensionless unit

$r =$  collar clearance in ft.

$$C_{st} = 0$$

Run #	Msina r	Slick String $X_2/WOB(1b)$	Point Stabilizer $WOB/X_2$	$\alpha$	Ideal Stabilizer Position	Slick String $H_o/W$	Point Stabilizer $H_o/W$	% Difference
1	20	4/16,000	22720/5.68	2.284	77.6	$-2.46 \times 10^{-3}$	$-3.49 \times 10^{-3}$	27.9
2	50	5/20,000	27400/6.85	5.718	66.1	$-4.87 \times 10^{-3}$	$-4.70 \times 10^{-3}$	3.6
3	150	7/28,000	38080/9.52	17.39	51.75	$-9.018 \times 10^{-3}$	$-8.69 \times 10^{-3}$	3.7

$$C_{st} = 0.0573 \text{ ft.}$$

4	20	6/24,000	31200/7.8	2.284	64.98	$-6.36 \times 10^{-4}$	$-7.05 \times 10^{-4}$	10.3
5	50	5/20,000	24600/6.15	5.718	61.53	$-4.87 \times 10^{-3}$	$-4.76 \times 10^{-3}$	2.3
6	150	9/36,000	44600/11.16	17.37	48.88	$-5.99 \times 10^{-3}$	$-5.31 \times 10^{-3}$	12.0

TABLE XV-G

D1 (ft) = 77.6  
 DH (in) = 8.75  
 ODdc (in) = 6  
 IDdc (in) = 2.25  
 ODst (in) = 8.75  
 MW (ppg) = 10  
 ALPHA (deg) = 2.284  
 DELTA ALPHA = 0  
 WOB (lb's) = 22720  
 P (lb's/ft in fluid) = 69.8961  
 I (in^4) = 3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 6.57309 LC = 1.42118 (DIMENSIONLESS UNITS)

BETA (deg) = .316845  
 PHI (deg) = 2.14461  
 HO (LB'S) = -55.2802  
 HC H(lb's) = 16.621  
 H1 (lb's) = -261.252

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00553	+0.00018
+6.68088	+0.03625	+0.00522	+1130.84000
+13.36175	+0.06855	+0.00436	+2047.43000
+20.04263	+0.09365	+0.00309	+2676.21000
+26.72350	+0.10934	+0.00158	+2966.72000
+33.40438	+0.11458	-0.00000	+2895.65000
+33.40438	+0.11458	-0.00000	+2895.65000
+42.24350	+0.10593	-0.00190	+2403.10000
+51.08263	+0.08260	-0.00325	+1359.60000
+59.92175	+0.05102	-0.00372	-89.03500
+68.76088	+0.02010	-0.00308	-1740.33000
+77.60000	-0.00000	-0.00128	-3363.49000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+77.60001	-0.00000	-0.00128	-3363.49000
+85.28982	-0.00247	+0.00056	-2600.64000
+92.97964	+0.00726	+0.00189	-1727.10000
+100.66946	+0.02312	+0.00267	-833.61700
+108.35927	+0.04694	+0.00292	-14.97270
+116.04909	+0.06889	+0.00272	+641.98700
+123.73890	+0.08791	+0.00218	+1067.57000
+131.42872	+0.10201	+0.00147	+1216.63000
+139.11854	+0.11050	+0.00075	+1073.36000
+146.80835	+0.11403	+0.00021	+652.94900
+154.49817	+0.11458	+0.00000	+0.00018

D1 (ft) = 66.1  
 DH (in) = 8.75  
 ODdc (in) = 6  
 IDdc (in) = 2.25  
 ODst (in) = 8.75  
 MW (ppg) = 10  
 ALPHA (deg) = 5.718  
 DELTA ALPHA = 0  
 WOB (lb's) = 27400  
 P (lb's/ft in fluid) = 69.8961  
 I (in^4) = 3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 5.94988 LC = 1.32097 (DIMENSIONLESS UNITS)

---

BETA (deg)= .375807  
 PHI (deg)= 5.44882  
 HO (LB'S)= -128.741  
 HC H(lb's)= 40.414  
 H1 (lb's)= -538.023

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00656	+0.00038
+5.65465	+0.03638	+0.00619	+1613.42000
+11.30930	+0.06872	+0.00516	+2893.48000
+16.96395	+0.09378	+0.00364	+3751.35000
+22.61860	+0.10938	+0.00185	+4127.50000
+28.27324	+0.11458	-0.00000	+3995.83000
+28.27325	+0.11458	-0.00000	+3995.83000
+35.83860	+0.10580	-0.00226	+3345.91000
+43.40395	+0.08207	-0.00387	+1887.81000
+50.96930	+0.04998	-0.00441	-198.18700
+58.53465	+0.01892	-0.00356	-2654.16000
+66.10001	-0.00000	-0.00119	-5176.45000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+66.10001	-0.00000	-0.00119	-5176.45000
+72.22477	-0.00026	+0.00100	-3819.57000
+78.34953	+0.01089	+0.00252	-2394.41000
+84.47429	+0.02920	+0.00333	-1034.01000
+90.59905	+0.05065	+0.00356	+151.00900
+96.72381	+0.07172	+0.00325	+1064.26000
+102.84858	+0.08969	+0.00257	+1631.48000
+108.97334	+0.10289	+0.00172	+1806.52000
+115.09810	+0.11078	+0.00088	+1575.16000
+121.22286	+0.11407	+0.00025	+956.20300
+127.34762	+0.11458	+0.00000	+0.00000

D1 (ft) =	51.75
DH (in) =	8.75
DDdc (in) =	6
IDdc (in) =	2.25
DDst (in) =	8.75
MW (ppg) =	10
ALPHA (deg) =	17.39
DELTA ALPHA =	0
WOB (lb's) =	38080
P (lb's/ft in fluid) =	69.8961
I (in^4) =	3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 5.42639    LC = 1.21725 (DIMENSIONLESS UNITS)

BETA (deg)=	,480629
PHI (deg)=	16.8919
HO (LB'S)=	-331.117
HC H(lb's)=	64.9039
H1 (lb's)=	-1270.47

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00839	+0.00082
+4.41998	+0.03636	+0.00791	+2644.21000
+8.83995	+0.06869	+0.00659	+4726.34000
+13.25993	+0.09374	+0.00466	+6123.58000
+17.67990	+0.10937	+0.00237	+6753.53000
+22.09988	+0.11458	+0.00000	+6579.05000
+22.09988	+0.11458	+0.00000	+6579.05000
+28.02990	+0.10572	-0.00290	+5484.46000
+33.95993	+0.08179	-0.00498	+3081.78000
+39.88995	+0.04948	-0.00565	-374.91700
+45.81997	+0.01838	-0.00451	-4520.15000
+51.75000	-0.00000	-0.00134	-8915.60000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+51.75000	-0.00000	-0.00134	-8915.60000
+56.42692	+0.00072	+0.00149	-6352.61000
+61.10383	+0.01251	+0.00339	-3851.59000
+65.78075	+0.03104	+0.00439	-1350.85000
+70.45767	+0.05233	+0.00459	+397.76800
+75.13458	+0.07299	+0.00415	+1865.67000
+79.81150	+0.09049	+0.00327	+2755.98000
+84.48842	+0.10327	+0.00218	+3009.96000
+89.16533	+0.11091	+0.00111	+2610.84000
+93.84225	+0.11409	+0.00031	+1584.95000
+98.51917	+0.11458	-0.00000	+0.00000

D1 (ft) =	64.98
OH (in) =	8.75
ODdc (in) =	6
IDdc (in) =	2.25
ODst (in) =	7.375
MW (ppg) =	10
ALPHA (deg) =	2.284
DELTA ALPHA =	0
WOB (lb's) =	31200
P (lb's/ft in fluid) =	69.8961
I (in^4) =	3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 6.59571    LC = 1.64039    (DIMENSIONLESS UNITS)

BETA (deg)=	.325781
PHI (deg)=	2.24352
HO (LB'S)=	-22.0476
HC H(lb's)=	2.77915
H1 (lb's)=	-261.536

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00569	+0.00013
+6.58049	+0.03669	+0.00536	+1229.40000
+13.16099	+0.06921	+0.00444	+2208.11000
+19.74148	+0.09421	+0.00310	+2831.71000
+26.32198	+0.10956	+0.00155	+3033.68000
+32.90247	+0.11458	+0.00000	+2792.49000
+32.90247	+0.11458	+0.00000	+2792.49000
+39.31797	+0.11029	-0.00128	+2172.51000
+45.73348	+0.09897	-0.00216	+1218.48000
+52.14898	+0.08372	-0.00249	+27.16070
+58.56449	+0.06841	-0.00217	-1280.60000
+64.97999	+0.05729	-0.00118	-2572.15000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+64.98000	+0.05729	-0.00118	-2572.15000
+71.71145	+0.05366	+0.00006	-2034.10000
+78.44291	+0.05734	+0.00098	-1399.60000
+85.17437	+0.06606	+0.00155	-733.98600
+91.90583	+0.07744	+0.00177	-111.53100
+98.63729	+0.08926	+0.00169	+398.31600
+105.36874	+0.09970	+0.00138	+738.66900
+112.10020	+0.10753	+0.00094	+871.34800
+118.83166	+0.11228	+0.00048	+782.13100
+125.56312	+0.11427	+0.00014	+480.39200
+132.29458	+0.11458	-0.00000	+0.00000

D1 (ft) = 61.53  
 DH (in) = 8.75  
 ODdc (in) = 6  
 IDdc (in) = 2.25  
 ODst (in) = 7.375  
 MW (PPg) = 10  
 ALPHA (deg) = 5.718  
 DELTA ALPHA = 0  
 WOB (lb's) = 24600  
 P (lb's/ft in fluid) = 69.8961  
 I (in^4) = 3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 5.0646 LC = 1.35319 (DIMENSIONLESS UNITS)

BETA (deg)= .353824  
 PHI (deg)= 5.44453  
 HO (LB'S)= -117.427  
 HC H(lb's)= 24.3893  
 HI (lb's)= -515.35

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00618	+0.00042
+6.11334	+0.03697	+0.00580	+1497.31000
+12.22668	+0.06958	+0.00478	+2626.91000
+18.34003	+0.09448	+0.00331	+3306.57000
+24.45337	+0.10966	+0.00164	+3486.81000
+30.56671	+0.11458	+0.00000	+3154.52000
+30.56671	+0.11458	-0.00000	+3154.52000
+36.75937	+0.11005	-0.00141	+2469.39000
+42.95202	+0.09809	-0.00236	+1334.42000
+49.14468	+0.08215	-0.00266	-165.64200
+55.33734	+0.06677	-0.00216	-1918.75000
+61.52999	+0.05729	-0.00075	-3793.96000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+61.52999	+0.05729	-0.00075	-3793.96000
+66.81725	+0.05709	+0.00060	-2656.43000
+72.10450	+0.06282	+0.00149	-1598.78000
+77.39176	+0.07212	+0.00136	-647.74400
+82.67901	+0.08290	+0.00206	+144.80900
+87.96627	+0.09340	+0.00187	+735.65400
+93.25352	+0.10229	+0.00147	+1092.57000
+98.54078	+0.10881	+0.00098	+1196.09000
+103.82803	+0.11270	+0.00050	+1040.57000
+109.11528	+0.11433	+0.00014	+634.49300
+114.40254	+0.11458	-0.00000	+0.00000

D1 (ft) =	48.88
DH (in) =	8.75
ODdc (in) =	6
IDdc (in) =	2.25
ODst (in) =	7.375
MW (ppg) =	10
ALPHA (deg) =	17.39
DELTA ALPHA =	0
WOB (lb's) =	44600
P (lb's/ft in fluid) =	69.8961
I (in^4) =	3.00577E-03

\*\*\*\*\* CONTACT POINT BETWEEN BIT AND STABILIZER \*\*\*\*\*

L = 5.27815    LC = 1.43151    (DIMENSIONLESS UNITS)

BETA (deg) =	.456348
PHI (deg) =	17.0858
HO (LB'S) =	-236.84
HC H(lb's) =	179.443
H1 (lb's) =	-1113.98

BIT TO STABILIZER

X	Y	SLOPE	MOMENT
+0.00000	+0.00000	+0.00797	+0.00070
+4.80303	+0.03743	+0.00746	+2565.90000
+9.60607	+0.07025	+0.00609	+4444.23000
+14.40910	+0.09503	+0.00416	+5482.06000
+19.21213	+0.10988	+0.00201	+5594.92000
+24.01516	+0.11458	+0.00000	+4773.61000
+24.01516	+0.11458	+0.00000	+4773.61000
+28.98813	+0.11010	-0.00175	+3890.23000
+33.96110	+0.09809	-0.00297	+2154.60000
+38.93407	+0.08194	-0.00336	-281.86800
+43.90703	+0.06644	-0.00268	-3206.65000
+48.88000	+0.05729	-0.00079	-6364.62000

STABILIZER TO TANGENCY

X	Y	SLOPE	MOMENT
+48.88000	+0.05729	-0.00079	-6364.62000
+52.84667	+0.05771	+0.00090	-4437.76000
+56.81333	+0.06370	+0.00202	-2644.53000
+60.78000	+0.07302	+0.00260	-1031.35000
+64.74666	+0.08366	+0.00270	+312.03300
+68.71333	+0.09393	+0.00243	+1310.85000
+72.67999	+0.10264	+0.00191	+1909.52000
+76.64666	+0.10898	+0.00127	+2074.74000
+80.61333	+0.11276	+0.00065	+1797.30000
+84.57999	+0.11434	+0.00018	+1092.65000
+88.54666	+0.11458	-0.00000	+0.00000

D1 (ft) =	10
OH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (pog) =	10
ALPHA (deg) =	60
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0411425
HO (lb's) =	693.304
HC (lb's) =	0
h1 (lb's) =	2694.75
PHI (deg) =	61.9852

SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00072	+0.00588
+1.02037	-0.00072	-0.00069	-756.54000
+2.04075	-0.00139	-0.00061	-1581.28000
+3.06112	-0.00195	-0.00047	-2473.06000
+4.08149	-0.00234	-0.00027	-3430.62000
+5.10187	-0.00248	+0.00000	-4452.62000
+6.08149	-0.00233	+0.00033	-5493.11000
+7.06112	-0.00182	+0.00073	-6590.33000
+8.04075	-0.00088	+0.00120	-7742.85000
+9.02037	+0.00056	+0.00175	-8949.18000
+10.00000	+0.00258	+0.00239	-10207.80000

SEGMENT B. STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00238	-10207.80000
+13.26380	+0.01350	+0.00415	-5982.77000
+16.52750	+0.02876	+0.00506	-2379.69000
+19.79130	+0.04577	+0.00525	+549.72600
+23.05500	+0.06243	+0.00487	+2763.44000
+26.31880	+0.07714	+0.00409	+4229.68000
+29.58250	+0.08896	+0.00307	+4927.38000
+32.84630	+0.09709	+0.00198	+4846.55000
+36.11000	+0.10188	+0.00099	+3988.33000
+39.37380	+0.10385	+0.00028	+2365.94000
+42.63750	+0.10417	+0.00000	-9.00294

D1 (ft) =	16.8
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	60
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0444735
HO (lb's) =	1.99119
HC (lb's) =	0
h1 (lb's) =	2416.15
PHI (deg) =	60.0057

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00078	+0.00588
+1.97868	-0.00153	-0.00077	-164.80600
+3.95735	-0.00301	-0.00072	-389.09200
+5.93602	-0.00433	-0.00060	-1270.62000
+7.91470	-0.00531	-0.00037	-2205.79000
+9.89337	-0.00571	+0.00000	-3389.67000
+11.27470	-0.00547	+0.00036	-4360.29000
+12.65600	-0.00467	+0.00082	-5446.58000
+14.03730	-0.00316	+0.00138	-6645.77000
+15.41870	-0.00080	+0.00206	-7954.78000
+16.80000	+0.00258	+0.00287	-9370.21000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+16.80000	+0.00258	+0.00287	-9370.21000
+20.01040	+0.01455	+0.00444	-5311.42000
+23.22080	+0.03025	+0.00521	-1863.75000
+26.43120	+0.04728	+0.00530	+924.91000
+29.64160	+0.06371	+0.00486	+3015.85000
+32.85200	+0.07808	+0.00405	+4380.01000
+36.06240	+0.08945	+0.00302	+4998.44000
+39.27280	+0.09739	+0.00193	+4862.56000
+42.48320	+0.10199	+0.00096	+3974.26000
+45.69360	+0.10387	+0.00027	+2345.86000
+48.90400	+0.10417	+0.00000	+0.00000

D1 (ft) =	50
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	20
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	.329727
HO (lb's) =	-473.052
HC (lb's) =	0
H1 (lb's) =	1583.97
PHI (deg) =	18.6452

SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	+0.00576	+0.00232
+4.24647	+0.02396	+0.00542	+2251.07000
+8.49295	+0.04523	+0.00452	+3974.65000
+12.73940	+0.06173	+0.00320	+5128.88000
+16.98590	+0.07205	+0.00163	+5685.73000
+21.23240	+0.07551	-0.00000	+5631.69000
+26.98590	+0.06950	-0.00202	+4588.58000
+32.73940	+0.05345	-0.00342	+2474.75000
+38.49290	+0.03205	-0.00381	-615.74500
+44.24650	+0.01218	-0.00284	-4545.39000
+50.00000	+0.00258	-0.00020	-9139.32000

SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+50.00000	+0.00258	-0.00020	-9139.32000
+54.43890	+0.00706	+0.00206	-6009.37000
+58.87770	+0.01956	+0.00343	-3236.57000
+63.31660	+0.03641	+0.00404	-894.49000
+67.75550	+0.05451	+0.00402	+954.76000
+72.19430	+0.07140	+0.00352	+2262.12000
+76.63320	+0.08534	+0.00272	+2992.91000
+81.07210	+0.09537	+0.00179	+3127.76000
+85.51090	+0.10131	+0.00091	+2663.07000
+89.94980	+0.10378	+0.00025	+1611.19000
+94.38870	+0.10417	-0.00000	+0.00232

D1 (ft) =	21.3
DH (in) =	8.75
DDdc (in) =	6.25
IDdc (in) =	2.25
DDst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	20
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0366835
HO (lb's) =	-.21384
HC (lb's) =	0
h1 (lb's) =	1182.37
PHI (deg) =	19.9994

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00064	+0.00232
+2.50574	-0.00160	-0.00063	-113.93700
+5.01148	-0.00314	-0.00059	-391.76400
+7.51722	-0.00452	-0.00049	-831.13400
+10.02300	-0.00553	-0.00030	-1428.32000
+12.52870	-0.00594	+0.00000	-2178.28000
+14.28300	-0.00569	+0.00029	-2790.88000
+16.03720	-0.00487	+0.00066	-3472.73000
+17.79150	-0.00332	+0.00112	-4221.00000
+19.54570	-0.00089	+0.00166	-5032.58000
+21.30000	+0.00258	+0.00231	-5904.10000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+21.30000	+0.00258	+0.00231	-5904.10000
+25.30580	+0.01457	+0.00356	-3379.86000
+29.31160	+0.03024	+0.00417	-1203.44000
+33.31740	+0.04726	+0.00424	+578.12900
+37.32330	+0.06368	+0.00390	+1926.34000
+41.32910	+0.07807	+0.00323	+2812.06000
+45.33490	+0.08945	+0.00242	+3216.15000
+49.34070	+0.09740	+0.00155	+3129.87000
+53.34650	+0.10200	+0.00077	+2555.09000
+57.35240	+0.10388	+0.00021	+1504.23000
+61.35820	+0.10417	-0.00000	+0.00000

D1 (ft) =	10
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	5
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-7.68695E-03
HO (lb's) =	332.005
HC (lb's) =	0
h1 (lb's) =	617.6
PHI (deg) =	5.95094

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00013	+0.00059
+0.68225	-0.00009	-0.00013	-229.87400
+1.36449	-0.00017	-0.00011	-462.71900
+2.04674	-0.00024	-0.00009	-698.39000
+2.72898	-0.00029	-0.00005	-936.73900
+3.41123	-0.00031	+0.00000	-1177.62000
+4.72898	-0.00023	+0.00013	-1649.47000
+6.04674	+0.00004	+0.00029	-2129.07000
+7.36449	+0.00056	+0.00050	-2615.32000
+8.68225	+0.00139	+0.00076	-3107.07000
+10.00000	+0.00258	+0.00106	-3603.16000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00106	-3603.16000
+15.70860	+0.01208	+0.00219	-2274.14000
+21.41720	+0.02660	+0.00282	-1062.91000
+27.12580	+0.04349	+0.00303	-22.50320
+32.83440	+0.06047	+0.00287	+801.48800
+38.54310	+0.07573	+0.00244	+1372.97000
+44.25170	+0.08802	+0.00185	+1666.91000
+49.96030	+0.09671	+0.00119	+1670.42000
+55.66890	+0.10177	+0.00060	+1383.36000
+61.37750	+0.10385	+0.00017	+818.30500
+67.08610	+0.10417	-0.00000	+0.00000

D1 (ft) =	10
DH (in) =	8.75
DDdc (in) =	6.25
IDdc (in) =	2.25
DDst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	20
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0248772
HO (lb's) =	545.621
HC (lb's) =	0
h1 (lb's) =	1462.65
PHI (deg) =	21.5625

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00043	+0.00232
+0.93162	-0.00040	-0.00042	-527.70200
+1.86324	-0.00077	-0.00037	-1077.59000
+2.79487	-0.00107	-0.00028	-1649.02000
+3.72649	-0.00128	-0.00016	-2241.32000
+4.65811	-0.00136	+0.00000	-2853.80000
+5.72649	-0.00124	+0.00023	-3580.09000
+6.79486	-0.00084	+0.00052	-4330.87000
+7.86324	-0.00012	+0.00086	-5104.96000
+8.93162	+0.00101	+0.00125	-5901.18000
+10.00000	+0.00258	+0.00171	-6718.29000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00171	-6718.29000
+14.11290	+0.01292	+0.00319	-4042.83000
+18.22590	+0.02790	+0.00398	-1718.90000
+22.33880	+0.04488	+0.00418	+200.55900
+26.45170	+0.06167	+0.00391	+1671.83000
+30.56460	+0.07661	+0.00330	+2661.38000
+34.67760	+0.08855	+0.00248	+3146.69000
+38.79050	+0.09695	+0.00160	+3116.69000
+42.90340	+0.10185	+0.00080	+2572.06000
+47.01640	+0.10365	+0.00022	+1525.22000
+51.12930	+0.10417	-0.00000	+0.00000

D1 (ft) =	10
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	35
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0335162
HO (lb's) =	633.052
HC (lb's) =	0
h1 (lb's) =	2049.18
PHI (deg) =	36.8128

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00059	+0.00389
+0.98498	-0.00057	-0.00056	-656.30400
+1.96996	-0.00109	-0.00050	-1354.49000
+2.95494	-0.00153	-0.00038	-2093.65000
+3.93993	-0.00183	-0.00022	-2872.82000
+4.92491	-0.00194	+0.00000	-3690.97000
+5.93993	-0.00181	+0.00026	-4573.73000
+6.95494	-0.00135	+0.00063	-5495.51000
+7.96996	-0.00051	+0.00104	-6455.06000
+8.98498	+0.00078	+0.00151	-7451.02000
+10.00000	+0.00258	+0.00206	-8482.02000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00206	-8482.02000
+13.61860	+0.01325	+0.00370	-5027.27000
+17.23720	+0.02839	+0.00455	-2059.96000
+20.85580	+0.04539	+0.00475	+367.56000
+24.47440	+0.06211	+0.00442	+2212.47000
+28.09300	+0.07693	+0.00372	+3442.22000
+31.71160	+0.08874	+0.00279	+4035.12000
+35.33020	+0.09704	+0.00180	+3980.71000
+38.94880	+0.10188	+0.00090	+3279.95000
+42.56740	+0.10386	+0.00025	+1945.19000
+46.18600	+0.10417	+0.00000	+0.00389

D1 (ft) = 10  
 DH (in) = 8.75  
 DDdc (in) = 6.25  
 IDdc (in) = 2.25  
 DDst (in) = 8.688  
 MW (PPG) = 10  
 ALPHA (deg) = 50  
 DELTA ALPHA = 0  
 WOB (lb's) = 20000  
 P (lb's/ft in fluid) = 76.8151  
 I (in^4) = 3.54967E-03

BETA (deg) = -.0388163  
 HO (lb's) = 677  
 HC (lb's) = 0  
 h1 (lb's) = 2482.6  
 PHI (deg) = 51.9385

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00068	+0.00520
+1.01057	-0.00068	-0.00065	-727.73300
+2.02115	-0.00130	-0.00058	-1514.55000
+3.03172	-0.00182	-0.00045	-2359.39000
+4.04229	-0.00218	-0.00025	-3261.07000
+5.05286	-0.00232	+0.00000	-4218.34000
+6.04229	-0.00217	+0.00031	-5208.18000
+7.03172	-0.00167	+0.00070	-6248.75000
+8.02115	-0.00076	+0.00115	-7338.67000
+9.01057	+0.00063	+0.00168	-8476.50000
+10.00000	+0.00258	+0.00228	-9660.74000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00228	-9660.74000
+13.36620	+0.01343	+0.00401	-5680.05000
+16.73250	+0.02866	+0.00491	-2278.62000
+20.09870	+0.04567	+0.00510	+491.61300
+23.46490	+0.06235	+0.00473	+2588.35000
+26.83120	+0.07710	+0.00397	+3979.58000
+30.19740	+0.08885	+0.00298	+4644.05000
+33.56360	+0.09709	+0.00192	+4571.63000
+36.92980	+0.10189	+0.00096	+3763.41000
+40.29610	+0.10386	+0.00027	+2231.74000
+43.66230	+0.10417	+0.00000	+0.00520

D1 (ft) =	10
DH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	60
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0411425
HO (lb's) =	693.304
HC (lb's) =	0
h1 (lb's) =	2694.75
PHI (deg) =	61.9852

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00072	+0.00588
+1.02037	-0.00072	-0.00069	-756.54000
+2.04075	-0.00139	-0.00061	-1581.28000
+3.06112	-0.00195	-0.00047	-2473.06000
+4.08149	-0.00234	-0.00027	-3430.62000
+5.10187	-0.00248	+0.00000	-4452.62000
+6.08149	-0.00233	+0.00033	-5493.11000
+7.06112	-0.00182	+0.00073	-6590.33000
+8.04075	-0.00088	+0.00120	-7742.85000
+9.02037	+0.00056	+0.00175	-8949.18000
+10.00000	+0.00258	+0.00239	-10207.80000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00238	-10207.80000
+13.26380	+0.01350	+0.00415	-5982.77000
+16.52750	+0.02876	+0.00506	-2379.63000
+19.79130	+0.04577	+0.00525	+549.72600
+23.05500	+0.06243	+0.00487	+2763.44000
+26.31880	+0.07714	+0.00409	+4229.68000
+29.58250	+0.08886	+0.00307	+4927.38000
+32.84630	+0.09709	+0.00198	+4846.55000
+36.11000	+0.10188	+0.00099	+3988.33000
+39.37380	+0.10385	+0.00028	+2365.04000
+42.63750	+0.10417	+0.00000	-0.00294

D1 (ft) = 10  
 DH (in) = 8.75  
 ODdc (in) = 6.25  
 IDdc (in) = 2.25  
 ODst (in) = 8.688       $C_{st1} = - .031 \text{ ft}$   
 MW (PPg) = 10  
 ALPHA (deg) = 60  
 DELTA ALPHA = 0  
 WOB (lb's) = 20000  
 P (lb's/ft in fluid) = 76.8151  
 I (in^4) = 3.54967E-03

BETA (deg) = -.0768406  
 HO (lb's) = 776.145  
 HC (lb's) = 0  
 h1 (lb's) = 2823.69  
 PHI (deg) = 62.2222

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00134	+0.00588
+1.29915	-0.00172	-0.00129	-1098.92000
+2.59830	-0.00332	-0.00115	-2307.59000
+3.89746	-0.00465	-0.00089	-3623.28000
+5.19661	-0.00557	-0.00051	-5042.98000
+6.49576	-0.00591	+0.00000	-6563.47000
+7.19661	-0.00580	+0.00033	-7424.37000
+7.89746	-0.00544	+0.00070	-8313.01000
+8.59830	-0.00480	+0.00112	-9228.83000
+9.29915	-0.00386	+0.00158	-10171.20000
+10.00000	-0.00258	+0.00208	-11139.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	-0.00258	+0.00208	-11139.50000
+13.34650	+0.00800	+0.00408	-6674.62000
+16.69310	+0.02366	+0.00514	-2853.14000
+20.03960	+0.04153	+0.00542	+267.27500
+23.38620	+0.05924	+0.00508	+2639.52000
+26.73270	+0.07500	+0.00429	+4227.80000
+30.07920	+0.08762	+0.00323	+5008.16000
+33.42580	+0.09651	+0.00209	+4968.80000
+36.77230	+0.10170	+0.00105	+4110.32000
+40.11890	+0.10383	+0.00029	+2445.70000
+43.46540	+0.10417	+0.00000	+0.00000

D1 (ft) =	10
OH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (PPG) =	10
ALPHA (deg) =	75
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.9432451
HO (lb's) =	706.205
HC (lb's) =	0
h1 (lb's) =	2900.94
PHI (deg) =	77.0221

SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00075	+0.00656
+1.02909	-0.00077	-0.00073	-781.38900
+2.05817	-0.00148	-0.00064	-1640.23000
+3.08726	-0.00207	-0.00050	-2575.30000
+4.11634	-0.00248	-0.00029	-3585.26000
+5.14543	-0.00264	+0.00000	-4668.67000
+6.11634	-0.00247	+0.00034	-5756.78000
+7.08726	-0.00195	+0.00076	-6907.51000
+8.05817	-0.00098	+0.00125	-8119.40000
+9.02909	+0.00050	+0.00182	-9390.91000
+10.00000	+0.00258	+0.00248	-10720.40000

SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00248	-10720.40000
+13.17580	+0.01358	+0.00429	-6263.86000
+16.35170	+0.02888	+0.00521	-2469.71000
+19.52750	+0.04589	+0.00540	+610.46300
+22.70340	+0.06254	+0.00500	+2934.81000
+25.87920	+0.07723	+0.00419	+4471.73000
+29.05510	+0.08893	+0.00314	+5200.31000
+32.23090	+0.09713	+0.00203	+5110.58000
+35.40680	+0.10190	+0.00101	+4204.05000
+38.58260	+0.10386	+0.00028	+2492.73000
+41.75850	+0.10417	+0.00000	+0.00000

D1 (ft) =	10
OH (in) =	8.75
ODdc (in) =	6.25
IDdc (in) =	2.25
ODst (in) =	8.688
MW (ppg) =	10
ALPHA (deg) =	90
DELTA ALPHA =	0
WOB (lb's) =	20000
P (lb's/ft in fluid) =	76.8151
I (in^4) =	3.54967E-03

BETA (deg) =	-.0439181
HO (lb's) =	709.945
HC (lb's) =	0
h1 (lb's) =	2968.61
PHI (deg) =	92.0328

#### SEGMENT A BIT TO STABILIZER

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+0.00000	+0.00000	-0.00077	+0.00679
+1.03126	-0.00078	-0.00074	-788.60800
+2.06253	-0.00151	-0.00065	-1657.78000
+3.09379	-0.00211	-0.00051	-2606.25000
+4.12505	-0.00253	-0.00029	-3632.66000
+5.15632	-0.00268	+0.00000	-4735.55000
+6.12505	-0.00252	+0.00035	-5839.81000
+7.09379	-0.00199	+0.00076	-7008.77000
+8.06253	-0.00102	+0.00126	-8240.93000
+9.03127	+0.00048	+0.00184	-9534.73000
+10.00000	+0.00258	+0.00251	-10888.50000

#### SEGMENT B STABILIZER TO TANGENCY POINT

X (ft)	Y (ft)	SLOPE (ft/ft)	MOMENT (ft-lb)
+10.00000	+0.00258	+0.00251	-10888.50000
+13.14830	+0.01360	+0.00433	-6356.26000
+16.29660	+0.02891	+0.00526	-2499.61000
+19.44490	+0.04593	+0.00544	+629.89800
+22.59330	+0.06257	+0.00504	+2990.46000
+25.74160	+0.07725	+0.00423	+4550.53000
+28.88990	+0.08894	+0.00317	+5289.29000
+32.03820	+0.09714	+0.00204	+5196.84000
+35.18650	+0.10190	+0.00102	+4274.45000
+38.33480	+0.10386	+0.00028	+2534.42000
+41.48320	+0.10417	+0.00000	+0.00000

## **APPENDIX I**

APPENDIX I  
DERIVATION OF THE  
FORMATION BIT FACTOR

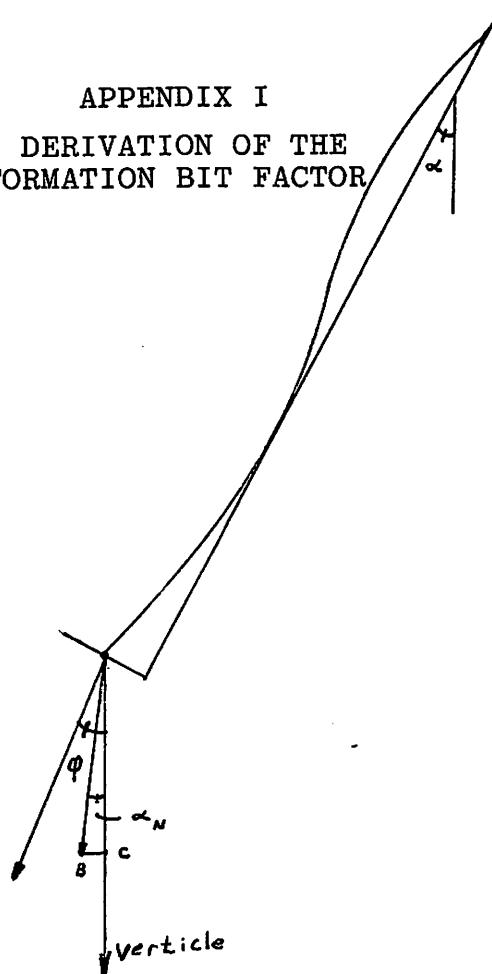


FIGURE XVIII-I

By definition:

$$FBF = \frac{K_v - K_h}{K_v} \quad (I-1)$$

Considering the triangle ABC in the diagram above:

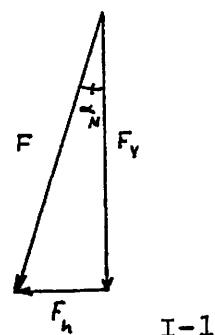


FIGURE XIX-I

R - Resultant force vector at the bit  
 $\alpha_N$  - inclination of the new segment of borehole  
 F - footage drilled  
 $F_v, F_h$  - vertical and horizontal components of footage vector  
 $\phi$  - angle between the resultant force at the bit and vertical  
 $K_v, K_e$  - reliability of the formation in the vertical and horizontal directions.  
 $\gamma$  - Dip angle of the formation relative to horizontal

by definition

$$F_v = K_v R \cos\phi \quad (I-2)$$

$$F_h = K_e R \sin\phi \quad (I-3)$$

Solving (I-1) for  $K_h$

$$K_h = K_v (1 - FBF) \quad (I-4)$$

Substituting into (I-3) and rearranging

$$FBF = 1 - \frac{\tan\alpha_N}{\tan\phi} \quad (I-5)$$

The FBF will be split into two factors which will segregate out the influence of the formation and the bit. Lubinski and Woods originally defined h as a drilling Anisotropy Index. In this paper it is redefined as the Formation Anisotropy Index, FAI.

$$h = FAI = \frac{K_d - K_e}{K_d} \quad (I-5a)$$

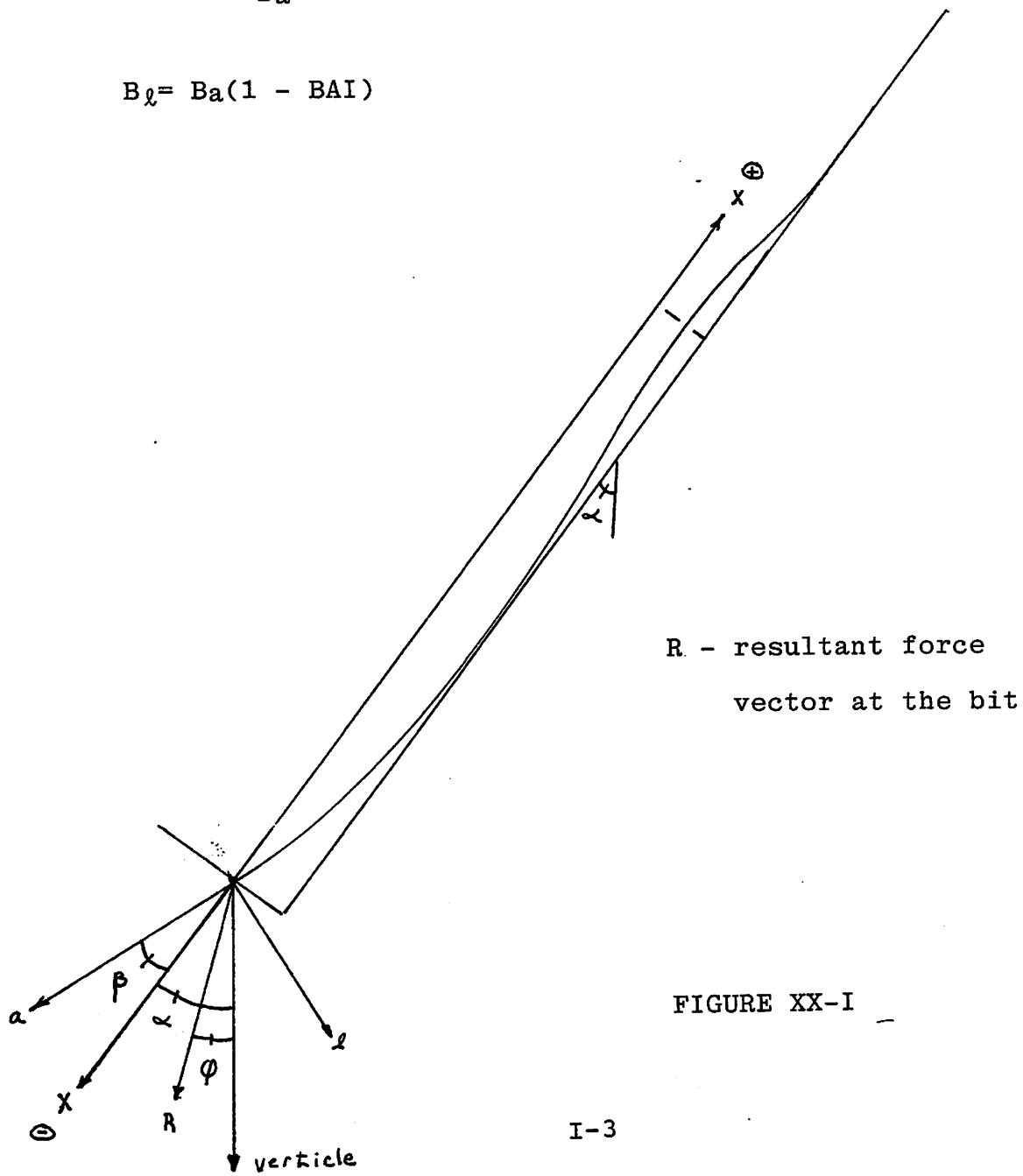
$$\Psi = \gamma + \text{ATN}[(1 - \text{FAI}) * \tan(\phi - \gamma)] \quad (\text{I-6})$$

where  $K_d$ ,  $K_e$  are the drillability of the formation parallel and perpendicular to the bedding plane.

by definition:

$$\text{BAI} = \frac{B_a - B_\ell}{B_a} \quad (\text{I-6a})$$

$$B_\ell = B_a(1 - \text{BAI})$$



where:

a - axis that is tangent to the drill string  
at the bit

$\ell$  - axis that is perpendicular to the slope  
at the bit

$B_a$ ,  $B_\ell$  - rock bits ability to drill along its axis  
and laterally on its side

From the assumption that the displacement is proportional  
to the force.

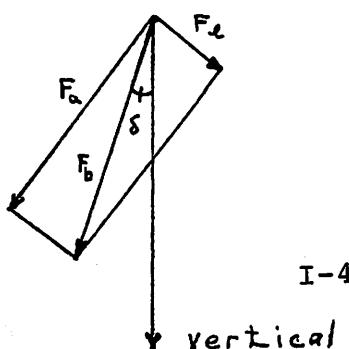
$$F_a = B_a R \cos[(\alpha + \beta) - \phi] \quad (I-7)$$

$$F_\ell = B_\ell R \sin[(\alpha + \beta) - \phi] \quad (I-8)$$

$$F_\ell = B_a(1 - BAI) R \sin[(\alpha + \beta) - \phi]$$

$$\frac{F_\ell}{F_a} = (1 - BAI) \tan(\alpha + \beta - \phi)$$

FIGURE XXI-I



where:

$F_a$ ,  $F_\ell$  - are the footage vector components along the  $a$  and  $\ell$  axis

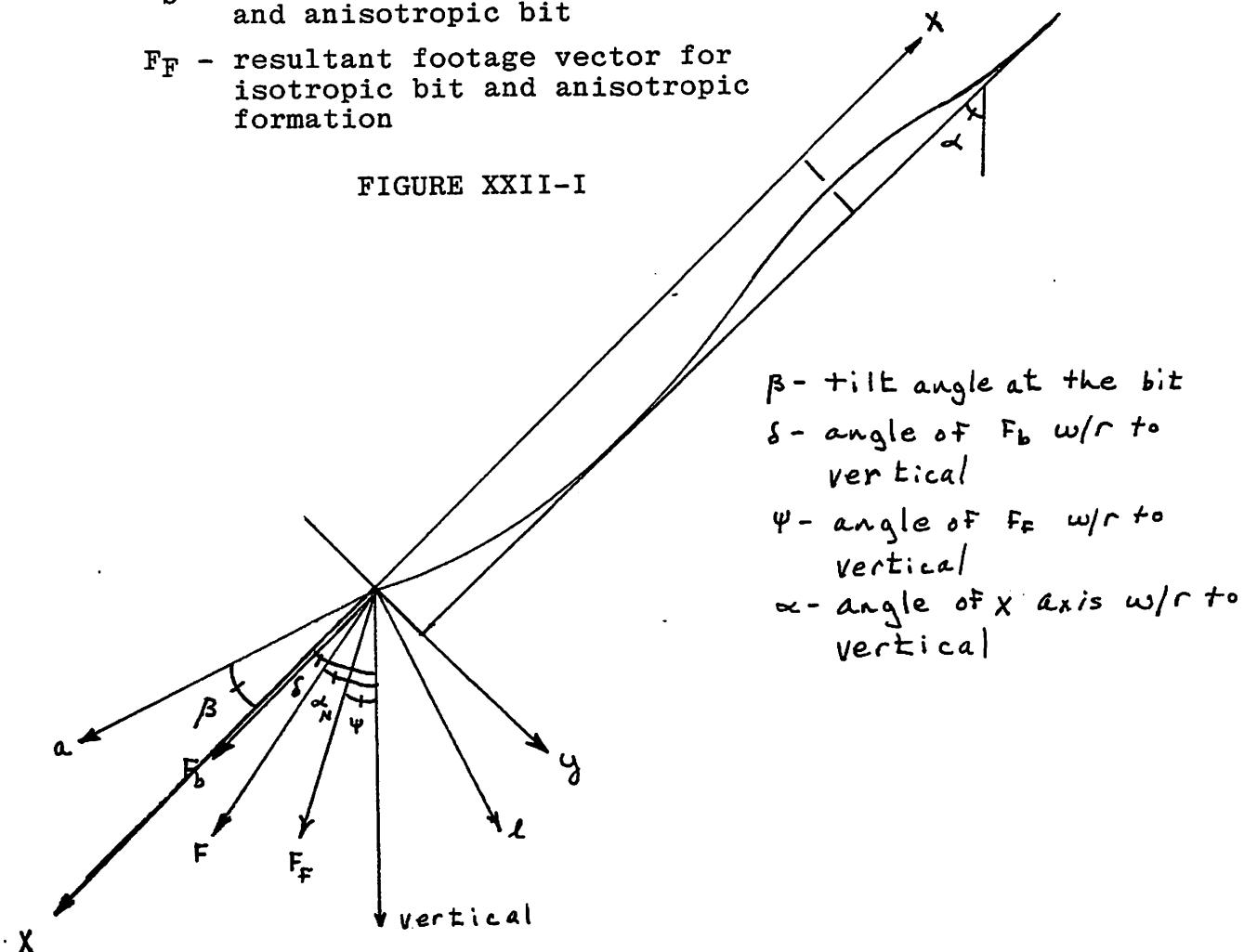
$F_b$  - resultant footage angle  $\delta$  from the vertical

$F_F$  - resultant footage vector angle  $\psi$  from vertical

$F_b$  - resultant footage vector for isotropic formation and anisotropic bit

$F_F$  - resultant footage vector for isotropic bit and anisotropic formation

FIGURE XXII-I



From Figure E

$$\tan(\alpha + \beta - \delta) = \frac{F_\ell}{F_a} = (1 - BAI) * \tan(\alpha + \beta - \phi) \quad (I-9)$$

which yields the following expression for  $\delta$

$$\delta = (\alpha + \beta) - \text{ATN}[(1-BAI)*\tan(\alpha + \beta - \phi)] \quad (I-10)$$

per Lubinski and Wood's definition of  $\Delta e$ ,  $\Delta d$

$$|F_F| = K_d R [\cos^2(\phi - \gamma) + (1 - F_{ai})^2 \sin^2(\phi - \gamma)]^{\frac{1}{2}} \quad (I-11)$$

in an analogous manner

(I-12)

$$|F_b| = B_a R [\cos^2[(\alpha + \beta) - \phi] + (1 - B_{ai})^2 \sin^2[(\alpha + \beta) - \phi]]^{\frac{1}{2}}$$

Resolving  $F_F$  and  $F_b$  onto the verticle and horizontal axis  
(per diagram E) and dividing the two components yields:

$$\tan \alpha_n = \frac{F_h}{F_v} = \frac{F_F \sin(\psi) + F_b \sin(\delta)}{F_F \cos(\psi) + F_b \cos(\delta)} \quad (I-13)$$

Let:

(I-14)

$$\frac{K_d}{B_a} \sqrt{C} = \frac{|F_F|}{|F_b|} = \left[ \frac{\cos^2(\phi - \gamma) + (1 - F_{ai})^2 \sin^2(\phi - \gamma)}{\cos^2(\alpha + \beta - \phi) + (1 - B_{ai})^2 \sin^2[(\alpha + \beta) - \phi]} \right]^{\frac{1}{2}}$$

Upon rearrangement (I-13) yields

$$\tan(\alpha_n) = \left[ \frac{\frac{K_d}{B_a} \sqrt{C} \sin(\psi) + \sin(\delta)}{\frac{K_d}{B_a} \sqrt{C} \cos(\psi) + \cos(\delta)} \right] \quad (I-15)$$

This thesis is accepted on behalf of the faculty of the  
Institute by the following committee:

W. L. Wilson  
Adviser

Ruth C. Y.

David Siegel

Nicholas P. Cahn

12/5/84  
Date