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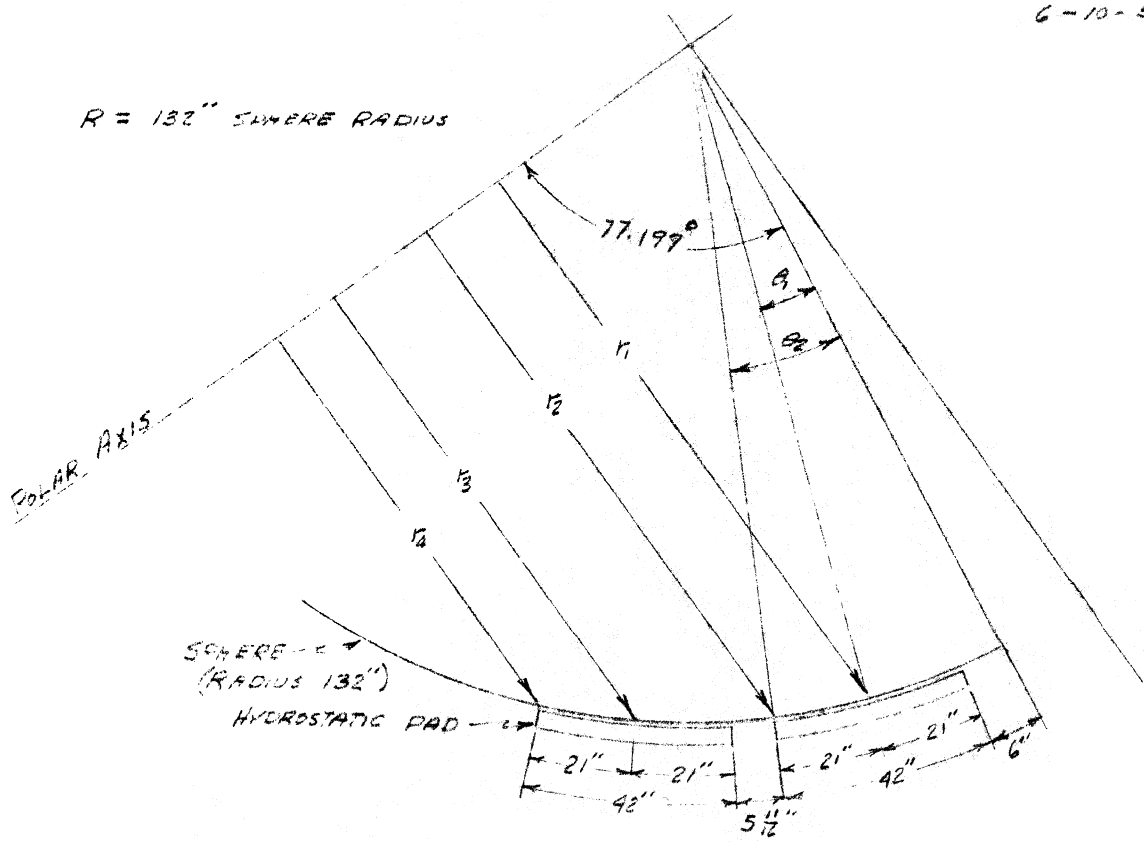
6-13-57	Laboratories for Research and Development	1
ENGINEER	PHILADELPHIA 3, PA.	PROJECT NO.
RC HERRICK		A-2062

TITLE: POSITIONS OF HYDROSTATIC PADS.

REFERENCE: LAYOUT OF POLAR AXIS BEARING by NED L. ASHTON 6-10-57

R = 132" SPHERE RADIUS



$\theta_1 = \frac{arc}{R} = \frac{6+21}{132} = \frac{27}{132} = 0.20455$ rad. or $11.720°$

$\theta_2 = \frac{arc}{R} = \frac{6+42}{132} = \frac{48}{132} = 0.36364$ rad. or $20.835°$

$\theta_3 = \frac{arc}{R} = \frac{6+42+5\frac{11}{16}+21}{132} = \frac{74\frac{11}{16}}{132} = 0.56581$ rad. or $32.418°$

$\theta_4 = \frac{arc}{R} = \frac{6+42+5\frac{11}{16}+42}{132} = 0.72491$ rad. or $41.534°$

$r_1 = R \sin(77.197° - \theta_1) = 132 \sin(77.197° - 11.720°) = 132 \cdot \sin(65.477°)$

$r_1 = 132 (0.909794) = 120.09$ inches.

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TITLE POSITIONS OF HYDROSTATIC PADS.

$r_2 = 132 \sin(77.197^\circ - 20.835') = 132 \sin(56.362^\circ) = 132(0.832554)$

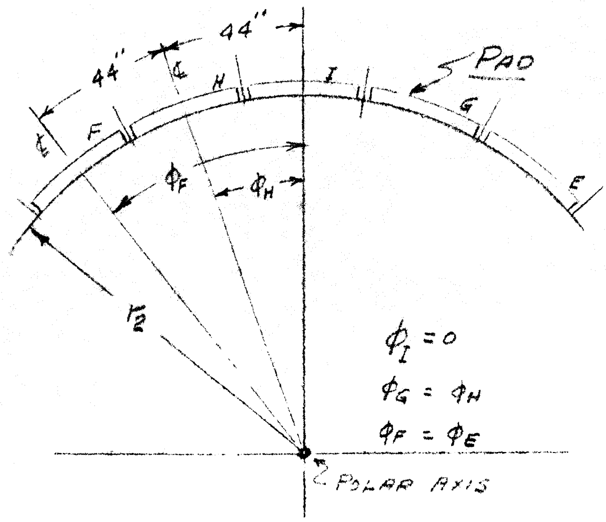
$r_2 = 109.89$ inches.

SIMILARLY

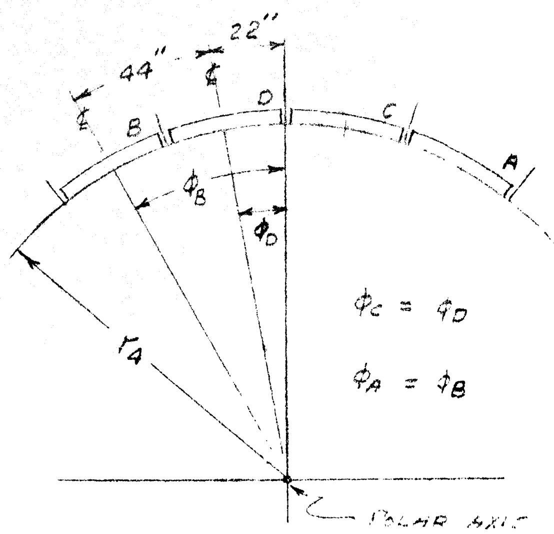
$r_3 = 132 \sin(44.719) = 132(0.704374) = 92.977$ inches.

$r_4 = 132 \sin(35.663) = 132(0.583017) = 76.958$ inches.

HYDROSTATIC PAD IS 42" X 42". LET THERE BE 2" BETWEEN CORNERS OF ADJACENT PADS BEFORE CORNERS ARE ROUNDED. THEN THERE MUST BE 44" OF ARC PER PAD ON CIRCLE OF RADIUS r_2 FOR FRONT PAD AND THE SAME ARC ON A CIRCLE OF RADIUS OF r_4 FOR THE REAR PADS.



FRONT PADS



REAR PADS

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TITLE POSITION OF HYDROSTATIC PADS

POSITIONS OF PAD CENTERS WITH REF TO POLAR AXIS

FRONT PADS: ON CIRCLE OF RADIUS $r_1 = 120.39$ inches.

$$\phi_I = 0$$

$$\phi_E = \phi_F = \frac{44+44}{r_2} = \frac{88}{109.89} = 0.8008 \text{ rad.} = \underline{45.882^\circ}$$

$$\phi_G = \phi_H = \frac{44}{r_2} = \frac{44}{109.89} = 0.40040 \text{ rad.} = \underline{22.941^\circ}$$

REAR PADS: ON CIRCLE OF RADIUS $r_3 = 92.927$ inches.

$$\phi_C = \phi_D = \frac{22}{r_4} = \frac{22}{76.958} = 0.28587 \text{ rad. or } \underline{16.379^\circ}$$

$$\phi_A = \phi_B = \frac{66}{r_4} = \frac{66}{76.958} = 0.85761 \text{ rad. or } \underline{49.137^\circ}$$

POSITION OF PADS ON THE SPHERE ARE LOCATED BY THE ABOVE PARAMETERS BUT THE LOCATIONS MUST BE REFERENCED TO THE [illegible] FOR FURTHER ANALYTICAL WORK OF FINDING PAD LOADS. THIS WILL BE DONE BY FINDING DIRECTION COSINES FOR EACH PAD.

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Laboratories for Research and Development

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ENGINEER R. C. HERRICK

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TITLE POSITIONS OF HYDROSTATIC PADS

LET a = DISTANCE FROM YZ PLANE

b = DISTANCE FROM XZ PLANE

c = DISTANCE FROM XY PLANE

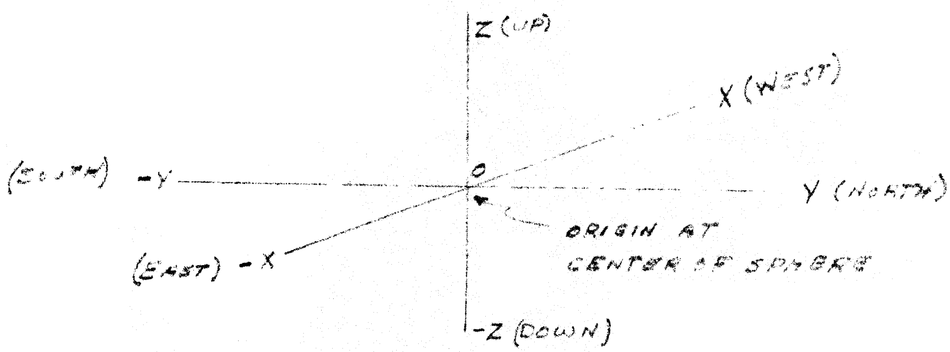
DIRECTION COSINES.

$$\cos \alpha = \frac{a}{R} = l$$

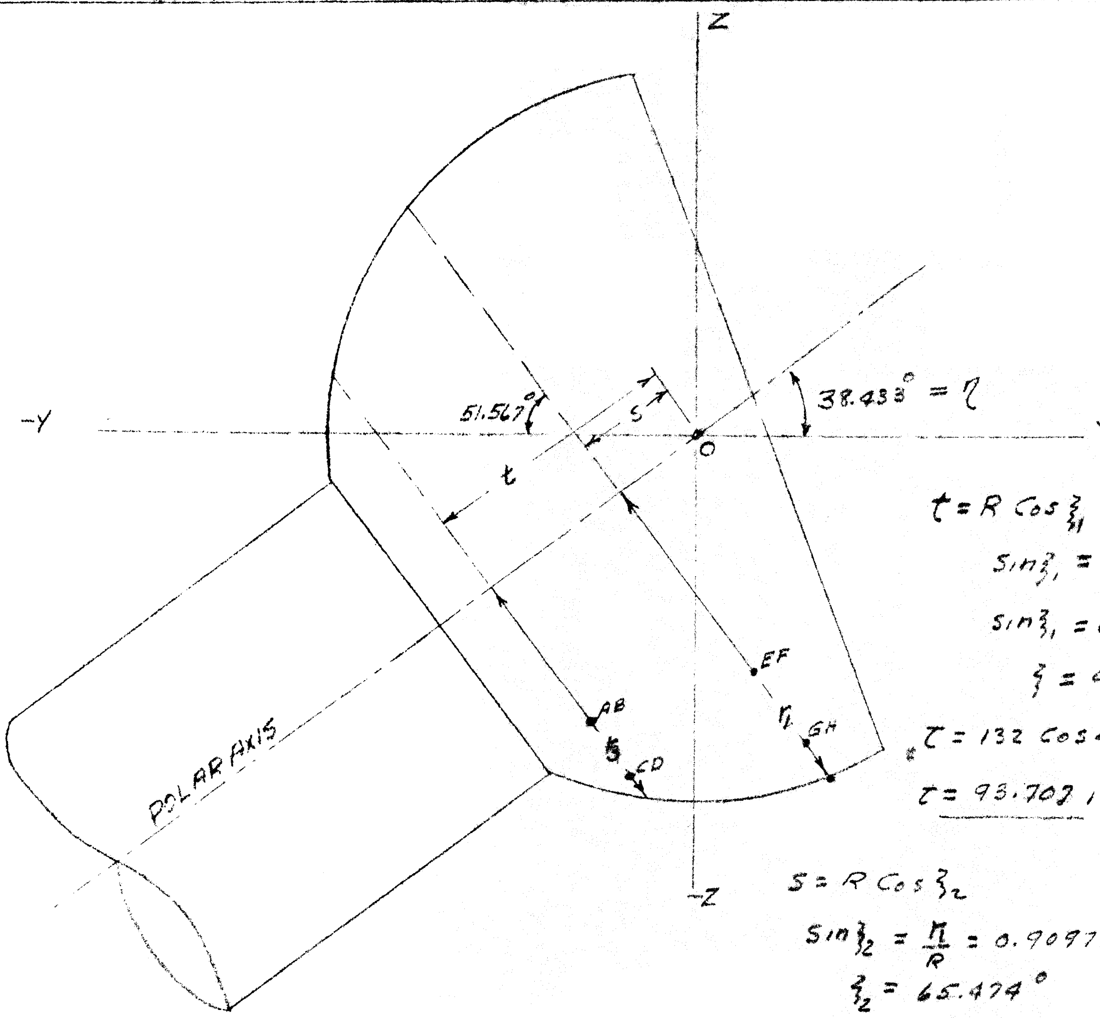
$$\cos \beta = \frac{b}{R} = m$$

$$\cos \gamma = \frac{c}{R} = n$$

COORDINATE AXIS TO BE USED



TITLE POSITIONS OF HYDROSTATIC PADS



$t = R \cos \xi_1$

$\sin \xi_1 = \frac{r_3}{R} = \frac{92.977}{132}$

$\sin \xi_1 = 0.70437$

$\xi = 44.773$

$t = 132 \cos 44.773$

$t = 93.707$ inches

$S = R \cos \xi_2$

$\sin \xi_2 = \frac{r_1}{R} = 0.909772$

$\xi_2 = 65.474°$

$S = 132 \cos \xi_2 = 54.794$ IN.

POLAR AXIS LIES IN YZ PLANE, THEN a WILL BE EQUAL TO $r_1 \sin\phi$ or $r_3 \sin\phi$.

DETERMINATION OF DIRECTION COSINES

PAD "A"

$a_A = -r_3 \sin\phi_A = -92.977 \sin 49.137° = -92.977(0.756276)$

$a_A = -70.316$ inches

PAD "A" (Cont.)

$$b_A = -t\cos\eta + r_3\cos\phi_A\sin\eta$$

$$b = -93.707\cos 38.433^\circ + 92.977\cos 49.137^\circ \sin 38.433^\circ$$

$$b = -93.707(0.78334) + 92.977(0.65425)(0.62160)$$

$$b = -73.404 + 37.812$$

$$b_A = -35.592 \text{ inches.}$$

$$c_A = -t\sin\eta - r_3\cos\phi_A\cos\eta$$

$$c = -93.707\sin 38.433^\circ - 92.977\cos 49.137^\circ\cos 38.433^\circ$$

$$c = -93.707(0.62160) - 92.977(0.65425)(0.78334)$$

$$c = -58.248 - 47.650$$

$$c_A = -105.90 \text{ inches,}$$

$$\ell_A = \cos\alpha_A = \frac{a}{R} = \frac{-70.316}{132} = -0.53270$$

$$m_A = \cos\beta_A = \frac{b}{R} = \frac{-35.592}{132} = -0.26964$$

$$n_A = \cos\gamma_A = \frac{c}{R} = \frac{-105.90}{132} = -0.80227$$

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TITLE

POSITIONS OF HYDROSTATIC PADS

PAD "B" (PADS A & B SYMMETRIC ABOUT YZ PLANE)

$a_B = +\ 70.316$ inches.

$b_B = -35.592$ inches

$c_B = -105.90$ inches

$l_B = \cos \alpha_B = 0.53270$

$m_B = \cos \beta_B = -0.26964$

$n_B = \cos \gamma_B = -0.80227$

PAD "C"

$a_c = -r_3 \sin \phi_c = -92.977 \sin 16.379^\circ$

$a_c = -92.977(0.28199) = -26.218$ inches.

$b_c = -t \cos \eta + r_3 \cos \phi_c \sin \eta$

$b_c = -93.707 \cos 38.433^\circ + 92.977 \cos 16.379^\circ \sin 38.433^\circ$

$b_c = -93.707(0.78334) + 92.977(0.95942)(0.62160)$

$b_c = -73.404 + 55.449$

$b_c = -17.955$ IN.

$c_c = -t \sin \eta - r_3 \cos \phi_c \cos \eta$

$c_c = -93.707(0.62160) - 92.977(0.95942)(0.78334)$

$c_c = -58.248 - 69.877$

$c_c = -128.125$ IN.

PAD "C" (Cont)

$$l_c = \cos\alpha_c = \frac{a_c}{R} = \frac{-26.218}{132} = -0.19862$$

$$m_c = \cos\beta_c = \frac{b_c}{R} = \frac{-17.955}{132} = -0.13602$$

$$n_c = \cos\gamma_c = \frac{c_c}{R} = -\frac{128.125}{132} = -0.97064$$

PAD "D" (PADS C & D SYMMETRIC ABOUT YZ PLANE)

$$l_D = \cos\alpha_D = +0.19862$$

$$m_D = \cos\beta_D = -0.13602$$

$$n_D = \cos\gamma_D = -0.97064$$

PAD "E"

$$a_E = -r_1 \sin\phi_E = -120.09 \sin 45.882^\circ$$

$$a_E = -120.09(0.71791) = -86.214$$

$$b_E = -S\cos\eta + r_1\cos\phi_E \sin\eta$$

$$b_E = -54.794\cos 38.433 + 120.09\cos 45.882 \sin 38.433^\circ$$

$$b_E = -54.794(0.78334) + 120.09(0.69614)(0.62160)$$

$$b_E = -42.922 + 51.965$$

$$b_E = +9.043 \text{ inches.}$$

TITLE POSITIONS OF HYDROSTATIC PADS

PAD E (Cont.)

$$c_E = -S \sin \eta - r \cos \phi_E \cos \eta$$

$$c_E = -54.794 \sin 38.433^\circ - 120.09 \cos 45.882^\circ \cos 38.433^\circ$$

$$c_E = -54.794(0.62160) - 120.09(0.69614)(0.78334)$$

$$c_E = -34.060 - 65.486$$

$$c_E = -99.546 \text{ inches.}$$

$$l_E = \cos \alpha_E = \frac{a_E}{R} = \frac{-86.214}{132} = -0.65314$$

$$m_E = \cos \beta_E = \frac{b_E}{R} = \frac{9.043}{132} = 0.06851$$

$$n_E = \cos \gamma_E = \frac{c_E}{R} = \frac{-99.546}{132} = -0.75414$$

PAD "F" (PADS E & F SYMMETRIC ABOUT YZ PLANE)

$a_F = +86.214$ in.

$b_F = 9.043$ in.

$c_F = -99.546$ in.

$l_F = \cos \alpha_F = 0.65314$

$m_F = \cos \beta_F = 0.06851$

$n_F = \cos \gamma_F = -0.75414$

TITLE: POSITIONS OF HYDROSTATIC PADS

PAD G

$a_G = -r_1 \sin \phi_G = -120.09 \sin 22.941^\circ$

$a_G = -120.09(0.38988) = -46.821$ inches.

$b_G = -S \cos \eta + r_1 \cos \phi_G \sin \eta$

$b_G = -54.774 \cos 38.433^\circ + 120.09 \cos 22.941^\circ \sin 38.433^\circ$

$b_G = -54.774(0.78334) + 120.09(0.92757)(0.62160)$

$b_G = -42.922 + 69.241$

$b_G = 26.319$ inches.

$c_G = -S \sin \eta - r_1 \cos \phi_G \cos \eta$

$c_G = -54.774(0.62160) - 120.09(0.92757)(0.78334)$

$c_G = -34.060 - 87.258$

$c_G = -121.32$ inches.

$l_G = \cos \alpha_G = \frac{a_G}{R} = \frac{-46.821}{132} = -0.35470$

$m_G = \cos \beta_G = \frac{b_G}{R} = \frac{26.319}{132} = 0.19939$

$n_G = \cos \gamma_G = \frac{c_G}{R} = \frac{-121.32}{132} = -0.91909$

TITLE POSITIONS OF HYDROSTATIC PADS

PAD H (PADS G & H' SYMMETRIC ABOUT YZ PLANE)

$\ell_H = \cos\alpha_H = 0.35470$

$m_H = \cos\beta_H = 0.19939$

$n_H = \cos\gamma_H = -0.91909$

PAD I

$a_I = r_1 \sin\phi_I = r_1(0) = 0$

$b_I = -s\cos\eta + r_1\cos\phi_I \sin\eta$

$b_I = -54.794(0.78334) + 120.09(1.000)(0.6216)$

$b_I = -42.922 + 74.648$

$b_I = 31.726$

$c_I = -s\sin\eta - r_1\cos\phi_I\cos\eta$

$c_I = -54.794(0.6216) - 120.09(1.000)(0.78334)$

$c_I = -34.060 - 94.071$

$c_I = -128.13$

$\ell_I = \cos\alpha_I = \frac{a_I}{R} = \frac{-0}{132} = 0$

$m_I = \cos\beta_I = \frac{b_I}{R} = \frac{31.726}{132} = 0.24035$

$n_I = \cos\gamma_I = \frac{c_I}{R} = \frac{-128.13}{132} = -0.97068$

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ENGINEER R.C. HERRICK
PROJECT NO. A-2062

TITLE FORCES ON HYDROSTATIC PADS

AT ASSEMBLY THE NINE PADS WILL BE ADJUSTED MECHANICALLY OR HYDRAULICALLY TO SHARE THE LOAD UNDER A NO-WIND CONDITION.

NO-WIND

LET FORCES ON THE PADS BE AS FOLLOWS:

$$F_A = F_B = F_{AB}$$

$$F_C = F_D = F_E = F_F = F_G = F_H = F_I = F_0$$

$\sum F_y = 0$ SOLVE FOR F_{AB}

$$0 = F_{AB}(m_A + m_B) + F_0(m_C + m_D + m_E + m_F + m_G + m_H + m_I) = 0$$

$$0 = F_{AB}(-0.26964 - 0.26964) + F_0(-0.13602 - 0.13602 + 0.06851 + 0.06851 + 0.19939 + 0.19939 + 0.24035)$$

$$F_{AB}(-0.53928) + F_0(0.50411) = 0$$

$$F_{AB} = F_0\left(\frac{0.50411}{0.53928}\right)$$

$$F_{AB} = 0.9348\, F_0$$

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TITLE FORCES ON HYDROSTATIC PADS.

NO WIND CONDITION $\qquad W = 4{,}283{,}000$ LBS.

$$\sum F_z = 0$$

$$W + 0.9348 F_0 (n_A + n_B) + F_0 (n_C + n_D + n_E + n_F + n_G + n_H + n_I) = 0$$

$$W + 0.9348 F_0 (-0.80227 - 0.80227) + F_0 (-0.97064 - 0.97064 - 0.75414$$
$$- 0.75414 - 0.91909 - 0.91909 - 0.97068) = 0$$

$$W = 1.4999 F_0 + 6.2584 F_0$$

$$F_0 = \frac{W}{7.7583} = \frac{4{,}283{,}000}{7.7583} = 552{,}000 \text{ LBS.}$$

EFFECTIVE AREA OF EACH PAD = 1186 IN.^{2}

THEN PAD PRESSURE IS:

$$P_C = P_E = (etc) = P_0 = \frac{552\,000}{1186} = 465 \text{ psi}$$

ALSO FOR PADS A & B:

$$P_A = P_B = 0.9348 (465 \text{ psi}) = 435 \text{ psi}$$

FORCES ON THE PADS DURING WIND LOADS ARE CALCULATED BY ASSUMING THE SPHERE TO BE MOUNTED ON ELASTIC SUPPORTS OF SPRING CONSTANT, K. PAD FORCES HAVE BEEN DETERMINED FOR THE NO WIND CONDITION. THIS ANALYSIS IS BASED UPON THE FACT THAT THE CHANGE IN FORCES FROM THE NO WIND CONDITION MUST BE IN EQUILIBRIUM.

ASSUMING A RIGID SPHERE, THE DEFLECTION OF PAD A, FOR EXAMPLE, IS $(\Delta X \ell_A + \Delta Y m_A + \Delta Z n_A)$ WHERE ΔX, ΔY & ΔZ IS THE MOVEMENT OF THE SPHERE CENTER, AND ℓ_A, m_A & n_A ARE DIRECTION COSINES OF THE PAD POSITION.

THEN: PAD FORCE = $F_o + \Delta F$ OR $F_{AB} + \Delta F$

$$\Delta F = K(\Delta X \ell + \Delta Y m + \Delta Z n)$$

SOUTH WIND

$$\sum F_z = 0$$

$$0 = \Delta W + K_A(\Delta X \ell_A + \Delta Y m_A + \Delta Z n_A) n_A + K_B n_B (\Delta X \ell_B + \Delta Y m_B + \Delta Z n_B)$$

$$+ K_C n_C (\Delta X \ell_C + \Delta Y m_C + \Delta Z n_C) + \text{------}$$

SOUTH WIND (Cont.)

$\Sigma F_Z = 0$

$$0 = \Delta W + \Delta X\left(\sum_{i=A}^{I} K_i l_i n_i\right) + \Delta Y\left(\sum_{i=A}^{I} K_i m_i n_i\right) + \Delta Z\left(\sum_{i=A}^{I} K_i n_i^2\right)$$

$\Sigma F_Y = 0$ F_S = SOUTH WIND FORCE $F_T \sin\eta$ = TAIL FORCE COMPONENT

$$0 = -(F_S + F_T \sin\eta) + \Delta X\left(\sum_{i=A}^{I} K_i l_i m_i\right) + \Delta Y\left(\sum_{i=A}^{I} K_i m_i^2\right) + \Delta Z\left(\sum_{i=A}^{I} K_i m_i n_i\right)$$

$\Sigma F_X = 0$

$$0 = \Delta X\left(\sum_{i=A}^{I} K_i l_i^2\right) + \Delta Y\left(\sum_{i=A}^{I} K_i l_i m_i\right) + \Delta Z\left(\sum_{i=A}^{I} K_i l_i n_i\right)$$

SOLVE FOR ΔX, ΔY & ΔZ AND SUBSTITUTE INTO EQUATION FOR ΔF ON PAGE 14.

$$\Delta X = \frac{\begin{vmatrix} 0 & (\Sigma K_i l_i m_i) & (\Sigma K_i l_i n_i) \\ +(F_S + F_T \sin\eta) & (\Sigma K_i m_i^2) & (\Sigma K_i m_i n_i) \\ -\Delta W & (\Sigma K_i m_i n_i) & (\Sigma K_i n_i^2) \end{vmatrix}}{\begin{vmatrix} (\Sigma K_i l_i^2) & (\Sigma K_i l_i m_i) & (\Sigma K_i l_i n_i) \\ (\Sigma K_i l_i m_i) & (\Sigma K_i m_i^2) & (\Sigma K_i m_i n_i) \\ (\Sigma K_i l_i n_i) & (\Sigma K_i m_i n_i) & (\Sigma K_i n_i^2) \end{vmatrix}}$$

SOUTH WIND (Cont.)

$$\Delta Y = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & 0 & \Sigma K_i l_i n_i \\ \Sigma K_i l_i m_i & +(F_3 + F_4 \sin\eta) & \Sigma K_i m_i n_i \\ \Sigma K_i l_i n_i & -\Delta W & \Sigma K_i n_i^2 \end{vmatrix}}{D}$$

$$\Delta Z = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & \Sigma K_i l_i m_i & 0 \\ \Sigma K_i l_i m_i & \Sigma K_i m_i^2 & +(F_3 + F_4 \sin\eta) \\ \Sigma K_i l_i n_i & \Sigma K_i m_i n_i & -\Delta W \end{vmatrix}}{D}$$

Now:

$$\Delta F_i = K_i(\Delta X l_i + \Delta Y m_i + \Delta Z n_i)$$

SIMILARLY, THE FORCES DUE TO WINDS FROM OTHER DIRECTIONS MAY BE STUDIED.

NORTH WIND

$$\Delta X = \frac{\begin{vmatrix} 0 & \Sigma K_i l_i m_i & \Sigma K_i l_i n_i \\ -(F_N + F_T \sin\eta) & \Sigma K_i m_i^2 & \Sigma K_i m_i n_i \\ -\Delta W & \Sigma K_i m_i n_i & \Sigma K_i n_i^2 \end{vmatrix}}{D}$$

$$\Delta Y = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & 0 & \Sigma K_i l_i n_i \\ \Sigma K_i l_i m_i & -(F_N + F_T \sin\eta) & \Sigma K_i m_i n_i \\ \Sigma K_i l_i n_i & -\Delta W & \Sigma K_i n_i^2 \end{vmatrix}}{D}$$

$$\Delta Z = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & \Sigma K_i l_i m_i & 0 \\ \Sigma K_i l_i m_i & \Sigma K_i m_i^2 & -(F_N + F_T \sin\eta) \\ \Sigma K_i l_i n_i & \Sigma K_i m_i n_i & -\Delta W \end{vmatrix}}{D}$$

AND

$$\Delta F = K_i(\Delta X\, l_i + \Delta Y\, m_i + \Delta Z\, n_i)$$

WEST WIND

$$\Delta X = \frac{\begin{vmatrix} -F_W & \Sigma K_i l_i m_i & \Sigma K_i l_i n_i \\ 0 & \Sigma K_i m_i^2 & \Sigma K_i m_i n_i \\ -\Delta W & \Sigma K_i m_i n_i & \Sigma K_i n_i^2 \end{vmatrix}}{D}$$

$$\Delta Y = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & -F_W & \Sigma K_i l_i n_i \\ \Sigma K_i l_i m_i & 0 & \Sigma K_i m_i n_i \\ \Sigma K_i l_i n_i & -\Delta W & \Sigma K_i n_i^2 \end{vmatrix}}{D}$$

$$\Delta Z = \frac{\begin{vmatrix} \Sigma K_i l_i^2 & \Sigma K_i l_i m_i & -F_W \\ \Sigma K_i l_i m_i & \Sigma K_i m_i^2 & 0 \\ \Sigma K_i l_i n_i & \Sigma K_i m_i n_i & -\Delta W \end{vmatrix}}{D}$$

AND

$$\Delta F = K_i(\Delta X \, l_i + \Delta Y \, m_i + \Delta Z \, n_i)$$

EAST WIND

DUE TO SYMMETRY ABOUT YZ PLANE, THE EAST WIND WILL PRODUCE THE SAME CHANGE IN THE FORCES ON PADS A, C, E, & G AS THE WEST WIND PRODUCED ON PADS B, D, F & H. PAD "I" WILL BE THE SAME FOR BOTH.

TITLE COMPUTATION of FORCES

l' = CONSTANT

TABLE '

P_{A_D}	ℓ	m	n	ℓm	ℓn	mn	ℓ^2	m^2	n^2
A	−0.53270	−0.26964	−0.80227	+0.14364	+0.42737	+0.21632	+0.28377	+0.07270	+0.64364
B	+0.53270	−0.26964	−0.80227	−0.14364	−0.42737	+0.21632	+0.28377	+0.07270	+0.64364
C	−0.19862	−0.13602	−0.97064	+0.02702	+0.19279	+0.13202	+0.03945	+0.01850	+0.94214
D	+0.19862	−0.13602	−0.97064	−0.02702	−0.19279	+0.13203	+0.03945	+0.01850	+0.94214
E	−0.65314	+0.06851	−0.75414	−0.04475	+0.49256	−0.05167	+0.42659	+0.00469	+0.56873
F	+0.65314	+0.06851	−0.75414	+0.04475	−0.49256	−0.05167	+0.42659	+0.00469	+0.56873
G	−0.35470	+0.19939	−0.91909	−0.07072	+0.32600	−0.18326	+0.12581	+0.03976	+0.84413
H	+0.35470	+0.19939	−0.91909	+0.07072	−0.32600	−0.18326	+0.12581	+0.03976	+0.84473
I	0	+0.24035	−0.97068	0	0	−0.23330	0	+0.05777	+0.94222
		Σ ⟵⟶		0	0	−0.00646	1.75124	+0.32907	+6.94070

SOUTH WIND $\Delta W = 287{,}600^{\#}$
$F = 680{,}000^{\#}$

NORTH WIND $\Delta W = -287{,}600$
$F = 680{,}000$

WEST & EAST WINDS $\Delta W = 0$
$F = 1{,}100{,}000$

CALCULATION of THE DETERMINANTS

D = DENOMINATOR

$$D = K^3\left[(1.75124)(0.32907)(6.94070) - (-0.00646)^2(1.75124)\right]$$

$$D = 1.75124\,K^3\left[2.28398 - 0.00004\right]$$

$$D = 3.99973\,K^3 \leftarrow$$

SOUTH WIND:

$\Delta X = 0$ ←

$$D \cdot \Delta Y = K^2 \left[(1.75124)(680,000)(6.94070) - (-287,600)(-0.00646)(1.75124) \right]$$

$$D \cdot \Delta Y = K^2 (1.75124) \left[4,719,676 - 1,858 \right]$$

$$\Delta Y = \frac{K^2}{K^3} \frac{(1.75124)}{(3.99973)} \left[4,717,818 \right]$$

$$\Delta Y = \frac{0.43784}{K} (4,717,818) = \frac{2,065,649}{K}$$ ←

$$D \cdot \Delta Z = K^2 \left[(1.75124)(0.32907)(-287,600) - (1.75124)(-0.00646)(680,000) \right]$$

$$D \cdot \Delta Z = K^2 (1.75124)(-94,640 + 4,393)$$

$$\Delta Z = \frac{0.43784}{K} (-90,247) = -\frac{39,514}{K}$$ ←

$$\Delta F = K \left(\Delta X \, \ell + \Delta Y \, m + \Delta Z \, n \right)$$

ΔF_A, ΔF_B WILL DESIGNATE FORCE ON PAD A, PAD B, etc.

$$\Delta F_A = K \left[\left(\frac{2,065,649}{K} \right)(-0.26964) + \left(-\frac{39,514}{K} \right)(-0.80227) \right]$$

$$\Delta F_A = -556,982 + 31,701$$

$$\Delta F_A = \Delta F_B = -525,281 \text{ \#}$$

$$\Delta F_C = K \left[\left(\frac{2,065,649}{K} \right)(-0.13602) + \left(-\frac{39,514}{K} \right)(-0.97064) \right]$$

$$\Delta F_C = -280,970 + 38,354$$

$$\Delta F_C = \Delta F_D = -242,616 \text{ \#}$$ ←

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TITLE: COMPUTATION OF FORCES

SOUTH WIND - CONT. -

$$\Delta F_E = K\left[\left(\frac{2,065,649}{K}\right)(0.06851) + \left(-\frac{39,514}{K}\right)(-0.75414)\right]$$

$$\Delta F_E = 141,518 + 29,799$$

$$\Delta F_E = \Delta F_F = 171,317^{\#} \longleftarrow$$

$$\Delta F_G = K\left[\left(\frac{2,065,649}{K}\right)(0.19939) + \left(\frac{-39,514}{K}\right)(-0.91909)\right]$$

$$\Delta F_G = 411,870 + 36,317$$

$$\Delta F_G = \Delta F_H = 448,187^{\#} \longleftarrow$$

$$\Delta F_I = K\left[\left(\frac{2,0[illegible]}{K}\right)(0.74035) + \left(\frac{-39,514}{K}\right)(-0.97068)\right]$$

$$\Delta F_I = 496,479 + 38,355$$

$$\Delta F_I = 534,834^{\#} \longleftarrow$$

NORTH WIND:

$$\Delta X = 0 \longleftarrow$$

$$D \cdot \Delta Y = K^2\left[(1.75124)(-680,000)(6.94070) - (1.75124)(287,600)(-0.00646)\right]$$

$$D \cdot \Delta Y = 1.75124\,K^2\left[-4,719,676 + 1,858\right]$$

$$\Delta Y = \frac{0.43784}{K}(-4,717,818)$$

$$\Delta Y = -\frac{2,065,649}{K} \longleftarrow$$

$$D \cdot \Delta Z = K^2\left[(1.75124)(0.32907)(287,600) - (1.75124)(-680,000)(-0.00646)\right]$$

$$\Delta Z = \frac{0.43784}{K}\left[94,640 - 4,393\right]$$

$$\Delta Z = \frac{39,514}{K} \longleftarrow$$

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TITLE: COMPUTATION of FORCES

AFTER ANALYZING THE FORCE DUE TO THE NORTH WIND, ΔW, ΔX, ΔY, ΔZ & THE DIRECTION COSINES, IT CAN BE SEEN THAT THE FORCES ON THE PADS DUE TO THE NORTH WIND ARE EQUAL & OPPOSITE TO THOSE PRODUCED BY THE SOUTH WIND.

BY THE SAME REASONING, THE EAST & WEST WIND FORCES PRODUCE EQUAL & OPPOSITE FORCES ON THE NINE HYDROSTATIC PADS.

WEST WIND:

$\Delta Y = 0$ ←

$\Delta Z = 0$ ←

$$D \cdot \Delta X = K^2\left[(-1{,}100{,}000)(0.32907)(6.24070) - (-1{,}100{,}000)(-0.00646)^2\right]$$

$$\Delta X = \frac{K^2}{K^3}\left(\frac{1{,}100{,}000}{3.59913}\right)\left[-2.25398 + .00004\right]$$

$\Delta X = \dfrac{-628{,}122}{K}$ ←

$\Delta F = \Delta X \, \ell + \Delta Y \, m + \Delta Z \, n$

$$\Delta F_A = K\left[\left(\frac{-628{,}122}{K}\right)(-0.53270)\right]$$

$\Delta F_A = 334{,}600^{\#}$ ←

$\Delta F_B = -334{,}600^{\#}$ ←

$$\Delta F_C = K\left[\left(\frac{-628{,}122}{K}\right)(-0.19862)\right]$$

$\Delta F_C = 124{,}758^{\#}$ ←

$\Delta F_D = -124{,}758^{\#}$ ←

$$\Delta F_E = K\left[\left(\frac{-628{,}122}{K}\right)(-0.65314)\right]$$

$\Delta F_E = 410{,}252^{\#}$ ←

$\Delta F_F = -410{,}252^{\#}$ ←

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WEST WIND - CONT. -

$$\Delta F_G = K\left[\left(\frac{-628,124}{12}\right)(-0.35470)\right]$$

$\Delta F_G = 222,795$ # ←

$\Delta F_H = -222,795$ # ←

$\Delta F_I = 0$ ←

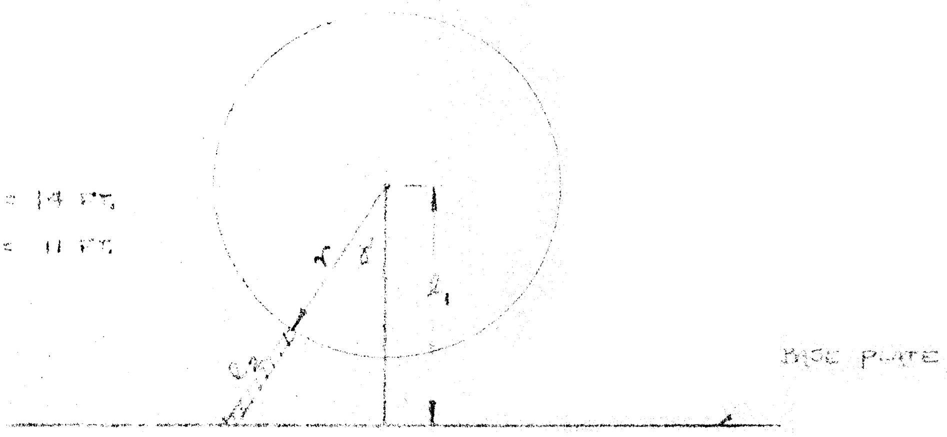
SUMMARY of CHANGE in FORCES
DUE TO THE FOUR WINDS

PADS	# ΔF DUE TO FOUR WINDS			
	SOUTH	NORTH	WEST	EAST
A	-525,281	525,281	334,600	-334,600
B	-525,281	525,281	-334,600	334,600
C	-242,616	242,616	124,758	-124,758
D	-242,616	242,616	-124,758	124,758
E	171,317	-171,317	410,252	-410,252
F	171,317	-171,317	-410,252	410,252
G	448,187	-448,187	222,795	-222,795
H	448,187	-448,187	-222,795	222,795
I	534,834	-534,834	0	0

TITLE COMPUTATION OF FORCES

WE CAN NOW SHOW AND COMPUTE THE CHANGE IN FORCES WHEN 'K' DOES NOT EQUAL A CONSTANT. THE REASON WHY 'K' IS NOT A CONSTANT FOR ALL PADS IS DUE TO THE COMPRESSIVE DEFORMATION CAUSED BY THE APPLIED FORCES. SINCE THE SUPPORTING MEMBERS UNDER EACH PAD ARE OF DIFFERENT LENGTHS AND ARE PLACED AT DIFFERENT ANGLES, THE DEFORMATIONS SHALL BE DIFFERENT. HENCE, $K \neq$ CONSTANT.

$\ell_1 = 14$ FT.
$r = 11$ FT.



$$\ell_2 = \frac{\ell_1}{\cos\theta} - r$$

$$\therefore \ell_i' = 12\left(\frac{14'}{\cos\theta_i} - 11'\right) \text{ INS.}$$

$$\delta = \frac{P\ell}{AE}$$

$$\frac{P}{\delta} = \frac{AE}{\ell}$$

$$\therefore K_i = \frac{k}{\ell_i'}$$

Computations of k_i^a

$$l'_i = 12\left(\frac{14}{\cos\theta_i} - 11\right) \qquad k_i = \frac{k}{l'_i}$$

$$l'_A = 12\left(\frac{14}{0.80229} - 11\right) = 77.40 \text{ in.} \leftarrow$$

$$l'_B = 77.40 \text{ in.} \leftarrow$$

$$l'_C = 12\left(\frac{14}{0.97068} - 11\right) = 41.04 \text{ in.} \leftarrow$$

$$l'_D = 41.04 \text{ in.} \leftarrow$$

$$l'_E = 12\left(\frac{14}{0.75431} - 11\right) = 90.72 \text{ in.} \leftarrow$$

$$l'_F = 90.72 \text{ in.} \leftarrow$$

$$l'_G = 12\left(\frac{14}{0.91923} - 11\right) = 50.76 \text{ in.} \leftarrow$$

$$l'_H = 50.76 \text{ in.} \leftarrow$$

$$l'_I = 12\left(\frac{14}{0.97068} - 11\right) = 41.04 \text{ in.} \leftarrow$$

X

TITLE COMPUTATION of FORCES

K = k/...

TABLE

Pad	k/K	ℓ	m	n	Kℓo/k	Kℓn/k	Kmn/k	Kℓ²/k	Km²/k	Kn²/k
A	71.40	0.53270	0.2[illegible]364	0.80221	.001856	.005522	.002795	.003666	.000939	.008316
B	71.40	0.53270	[illegible]	0.80221	.001856	.005522	.002795	.003666	.000939	.008316
C	41.[illegible]	0.13862	0.13[illegible]	0.97664	.000658	.004698	.003317	.000961	.000451	.022957
D	41.[illegible]	0.13862	0.13[illegible]	0.97664	.000658	.004688	.003717	.000961	.000451	.022957
E	90.[illegible]	0.67314	0.06251	0.75414	.004453	.005429	.000570	.004[illegible]	.000052	.006269
F	[illegible].72	0.65314	0.06[illegible]	0.75414	.004492	.005429	.000570	.004[illegible]	.000052	.006269
G	50.[illegible]	0.37470	0.19939	0.91903	.001393	.006422	.003610	.002478	[illegible]	.016642
H	50.[illegible]	0.37470	0.19939	0.91903	.001393	.006422	.003610	.002478	.000793	.016642
I	41.04	0	0.24[illegible]	0.96668	0	0	.005485	0	.001405	.022358
		Σ →			0	0	.002021	.023614	.005858	.131326

CALCULATION of THE DETERMINANT

$$D = k^2\left[(.023614)(.005858)(.131326) - (.002021)^2(.023614)\right]$$

$$D = .023614\,k^2\left[.000769 - .000004\right]$$

$$D = .000018\,k^2 \leftarrow$$

SOUTH WIND:

$$\Delta X = 0 \leftarrow$$

$$D \cdot \Delta Y = k^2\left[(.023614)(680,000)(.131326) - (.023614)(-297,000)(.002021)\right]$$

$$\Delta Y = \frac{k^2(.023614)}{k^3(.000018)}\left[(680,000)(.131326) - (297,000)(.002021)\right]$$

$$\Delta Y = \frac{1327}{k}\left[89,302 - 597\right] = \frac{115,958,347}{k} \leftarrow$$

$$D \cdot \Delta Z = k^2\left[(.023614)(.005858)(-287{,}600) - (.023614)(-.002021)(680{,}000)\right]$$

$$\Delta Z = \frac{-k^2(.023614)}{k^3(.000018)}\left[(.005858)(-287{,}600) + (.002021)(680{,}000)\right]$$

$$\Delta Z = \frac{1307}{k}\left[-1685 + 1374\right] = \frac{-4{,}065{,}000}{k} \leftarrow$$

$$\Delta F = k\left(\Delta X\, l + \Delta Y\, m + \Delta Z\, n\right)$$

$$\Delta F_A = \frac{k}{77.40}\left[0 + \frac{115{,}958{,}347}{k}(-0.26964) + \left(\frac{-4{,}065{,}000}{k}\right)(-0.80227)\right]$$

$$\Delta F_A = \frac{1}{77.40}\left[-31{,}267{,}000 + 3{,}261{,}220\right]$$

$$\Delta F_A = -361{,}832\,\# \leftarrow$$

$$\Delta F_B = -361{,}832\,\# \leftarrow$$

$$\Delta F_C = \frac{k}{41.04}\left[\frac{115{,}958{,}347}{k}(-0.13602) + \left(\frac{-4{,}065{,}000}{k}\right)(-0.97064)\right]$$

$$\Delta F_C = \frac{1}{41.04}\left[-15{,}772{,}650 + 3{,}945{,}650\right]$$

$$\Delta F_C = -288{,}182\,\# \leftarrow$$

$$\Delta F_D = -288{,}182\,\# \leftarrow$$

$$\Delta F_E = \frac{k}{90.72}\left[\frac{115{,}958{,}347}{k}(0.06851) + \left(\frac{-4{,}065{,}000}{k}\right)(-0.7544)\right]$$

$$\Delta F_E = \frac{1}{90.72}\left[7{,}944{,}300 + 3{,}065{,}580\right]$$

$$\Delta F_E = 121{,}361\,\# \leftarrow$$

$$\Delta F_F = 121{,}361\,\# \leftarrow$$

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South Wind - Cont. —

$$\Delta F_G = \frac{k}{50.76}\left[\frac{115,958,347}{k}(0.19939) + \left(\frac{-4,065,000}{k}\right)(-.91909)\right]$$

$$\Delta F_G = \frac{1}{50.76}\left[23,120,330 + 3,724,100\right]$$

$\Delta F_G = 523,098^{\#}$ ←

$\Delta F_H = 523,098^{\#}$ ←

$$\Delta F_I = \frac{k}{41.04}\left[\frac{115,958,347}{k}(0.24035) + \left(\frac{-4,065,000}{k}\right)(-0.97068)\right]$$

$$\Delta F_I = \frac{1}{41.04}\left[27,870,590 + 3,945,810\right]$$

$\Delta F_I = 775,253^{\#}$ ←

West Wind:

$\Delta Y = 0$ ←

$\Delta Z = 0$ ←

$$D \cdot \Delta X = k^2\left[(-1,100,000)(-.005858)(.131326) - (-1,100,000)(-.002021)^2\right]$$

$$\Delta X = \frac{k^2 (1,100,000)}{k^2 (.000018)}\left[-.000769 + .000004\right]$$

$$\Delta X = -\frac{46,582,500}{k}$$ ←

$\Delta F = K(\Delta x\ 2)$

$$\Delta F_A = \frac{k}{77.40}\left[\left(\frac{-46,582,500}{k}\right)(-0.53270)\right]$$

$\Delta F_A = 320,601^{\#}$ ←

$\Delta F_B = -320,601^{\#}$ ←

WEST WIND - CONT. -

$$\Delta F_C = \frac{k}{41.04}\left[\frac{-46,582,500}{k}\left(-0.19562\right)\right]$$

$\Delta F_C = 225,444^{\#}$ ←

$\Delta F_D = -225,444^{\#}$ ←

$$\Delta F_E = \frac{k}{50.72}\left[\frac{-46,582,500}{k}\left(-0.65314\right)\right]$$

$\Delta F_E = 335,371^{\#}$ ←

$\Delta F_F = -335,371^{\#}$ ←

$$\Delta F_G = \frac{k}{50.76}\left[\frac{-46,582,500}{k}\left(-0.35470\right)\right]$$

$\Delta F_G = 325,508^{\#}$ ←

$\Delta F_H = -325,508^{\#}$ ←

$$\Delta F_I = \frac{k}{41.04}\left[\frac{-46,582,500}{k}\left(0\right)\right]$$

$\Delta F_I = 0$ ←

Summary of change in Forces

PADS	# ΔF DUE TO FOUR WINDS			
	SOUTH	NORTH	WEST	EAST
A	-361,832	361,832	320,601	-320,601
B	-361,832	361,832	-320,601	320,601
C	-288,182	288,182	225,444	-225,444
D	-288,182	288,182	-225,444	225,444
E	121,361	-121,361	335,371	-335,371
F	121,361	-121,361	-335,371	335,371
G	529,098#	-529,098	325,508	-325,508
H	529,098#	-529,098	-325,508	325,508
I	775,253	-775,253	0	0