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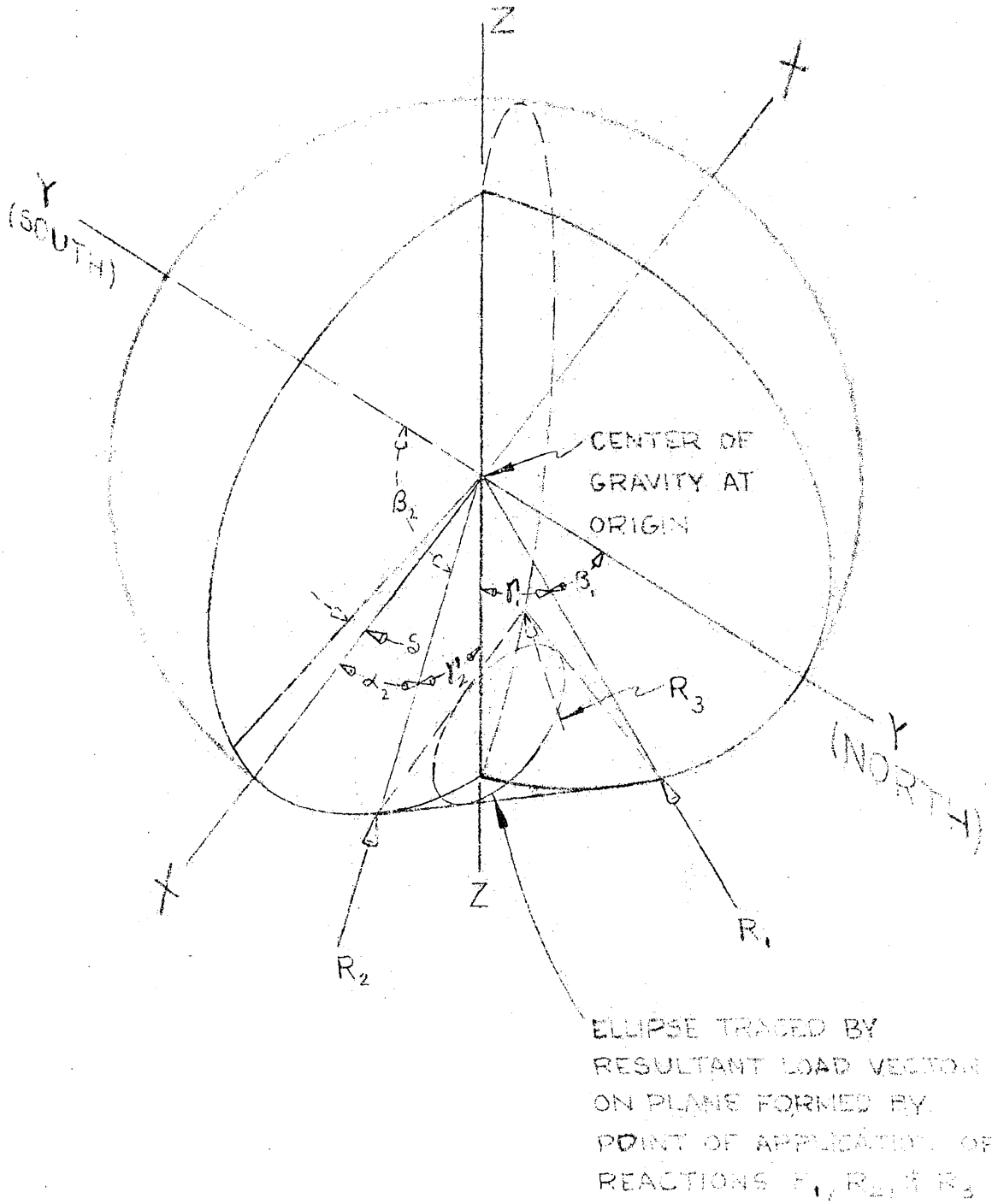
A.C. HERRICK		A-2062

TITLE

AUS - 140 FT. RADIO TELESCOPE

STABILITY OF SPHERE ON 3 SUPPORTS



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SCHEARER		A-2062

TITLE AUI - 140 FT. RADIO TELESCOPE

SPHERE ON THREE SUPPORTS

IT IS REQUIRED TO DETERMINE THE STABILITY AND REACTIVE LOADS OF A SPHERE SUPPORTED BY THREE SYMMETRIC ELEMENTS. THE SKETCH ON THE PREVIOUS PAGE SHOWS THE NOTATION AND THE GENERAL ARRANGEMENT TO BE USED.

TO MAINTAIN STABILITY THE ELLIPTICAL CONE TRACED BY THE RESULTANT LOAD VECTOR MUST BE ENCLOSED BY THE TRIANGULAR CONE FORMED BY THE REACTIVE LOADS. FOR THIS ANALYSIS THE BOUNDARIES OF THE TWO FIGURES OF THE ASSUMED TANGENT FOR LOADS EXPECTED IN A 120 M.P.H. WIND. MAGNITUDES OF THE LOADS HAVE BEEN TAKEN FROM THE CALCULATIONS OF NED L. ASHTON DATED MAY 2, 1952.

FOR EASE OF CONSTRUCTION THE TWO IDEAL FIGURES HAVE BEEN PROJECTED UPON A PLANE PARALLEL TO THE XY PLANE AND AT THE BOTTOM OF THE SPHERE.

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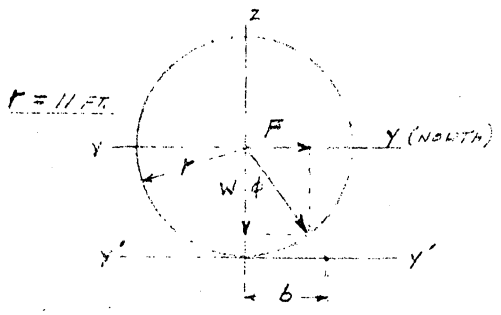
R. C. STEPANIAK		A-3042

TITLE

ACT - 140 FT. RADIO TELESCOPE

SPHERE ON 2 SUPPORTS



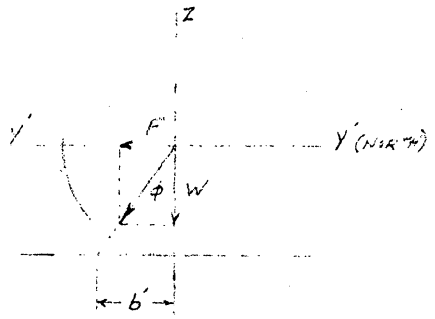
SOUTH WIND - 120 MPH

$F = 452{,}000$ LBS

$W = 4{,}563{,}000$ LBS

$\tan\phi = \frac{F}{W} =$

$b = r \tan\phi = 11\left(\frac{452{,}000}{4{,}563{,}000}\right) = 1.090$ FT.



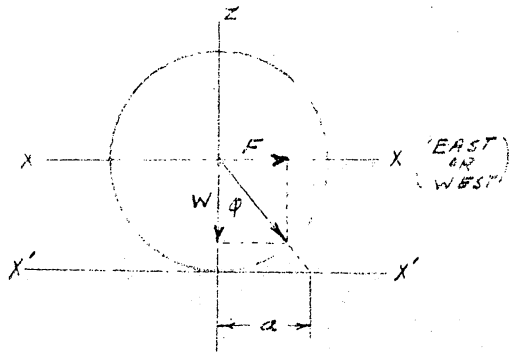
NORTH WIND - 120 MPH

$F = 452{,}000$ LBS.

$W = 3{,}397{,}000$ LBS.

$\tan\phi = \frac{F}{W}$

$b' = r \tan\phi = 11\left(\frac{452{,}000}{3{,}397{,}000}\right) = 1.464$ FT.



EAST OR WEST WIND - 120 MPH

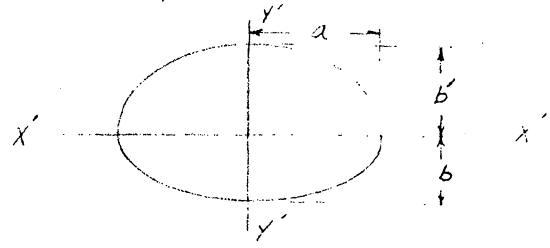
$F = 1{,}100{,}000$ LBS.

$W = 3{,}980{,}000$ LBS.

$\tan\phi = \frac{F}{W}$

$a = r \tan\phi = 11\left(\frac{1{,}100{,}000}{3{,}980{,}000}\right) = 3.040$ FT.

LOADING ELLIPSE ON X' Y'' PLANE.



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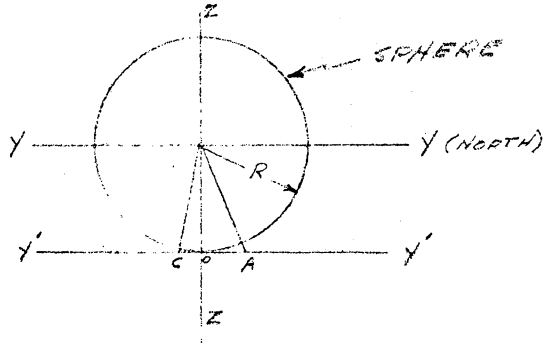
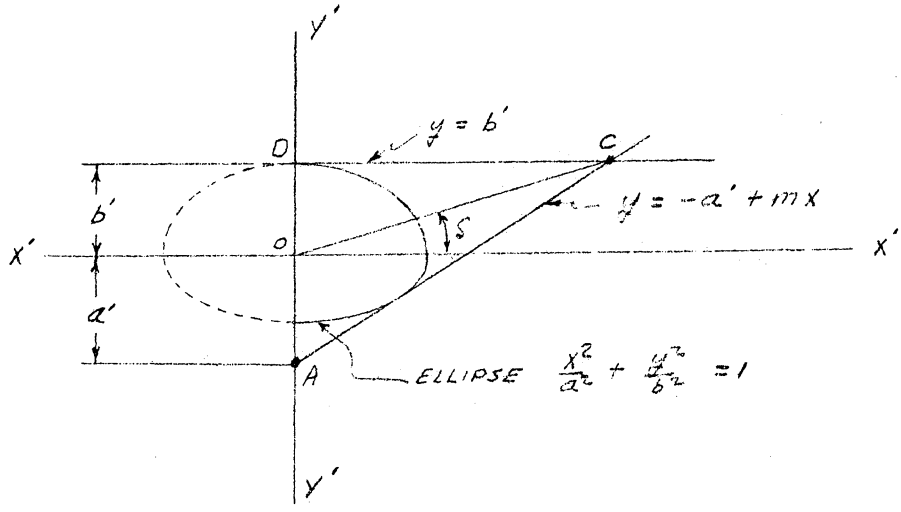
TITLE AUI - 140 FT RADIO TELESCOPE

STABILITY OF SPHERE ON 3 SUPPORTS

LOCATION OF X'Y' PLANE



ANALYTICAL SOLUTION FOR STABLE LOCATION OF SUPPORTS



POINT "A" IS LOCATED AS FAR FROM THE X' AXIS AS THE TELESCOPE DESIGN PERMITS. DC AND AC ARE MADE TANGENT TO THE ELLIPSE AND LOCATE POINT "C", THE POINT OF ACTION OF R_3 ON PLANE X'Y'

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STABILITY OF SPHERE ON 3 SUPPORTS (cont.)

LINE AC: $y = -a' + \frac{dy}{dx} x$ $\qquad m = \frac{dy}{dx}$ = slope

$$\frac{dy}{dx} = \frac{y + a'}{x}$$

ELLIPSE $\qquad \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

$$\frac{2x\,dx}{a^2} + \frac{2y\,dy}{b^2} = 0$$

$$\frac{2x\,dx}{a^2} = -\frac{2y\,dy}{b^2}$$

$$\frac{dy}{dx} = -\frac{2x b^2}{2y a^2}$$

$$\frac{dy}{dx} = -\frac{x b^2}{y a^2}$$

LINE AC AND ELLIPSE ARE TANGENT $\left(\frac{dy}{dx}_{ELLIPSE} = \frac{dy}{dx}_{LINE}\right)$

$$\frac{y + a'}{x} = -\frac{x b^2}{y a^2}$$

$$y^2 a^2 + y a^2 a' + x^2 b^2 = 0 \qquad \text{------- (1)}$$

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$\frac{x^2 b^2 + y^2 a^2}{a^2 b^2} = 1$$

$$x^2 b^2 + y^2 a^2 - a^2 b^2 = 0 \qquad \text{-------- (2)}$$

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TITLE: AJI - 140 FT RADIO TELESCOPE

STABILITY OF SPYDER ON 3 SUPPORTS (Cont.)

SOLVE EQUATIONS #1 & #2 SIMULTANEOUSLY

$$y^2 a^2 + y\alpha^2 a' + x^2 b^2 = 0 \quad \text{---- (1)}$$

$$-y^2 a^2 + \alpha^2 b^2 - x^2 b^2 = 0 \quad \text{---- (2)}$$

$$y a^2 a' + \alpha^2 b^2 = 0$$

$$y = -\frac{\alpha^2 b^2}{a^2 a'}$$

$$y = -\frac{b^2}{a'}$$

X IS DETERMINED BY SUBSTITUTION INTO EQ. FOR ELLIPSE

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$\frac{x^2}{a^2} = 1 - \frac{y^2}{b^2}$$

$$x^2 = a^2 - \frac{a^2}{b^2} y^2$$

$$x = +\sqrt{a^2 - \frac{a^2}{b^2} y^2}$$

POSITIVE ONLY FOR QUADRANT IN USE.

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TITLE: AUI - 140 FT. RADIO TELESCOPE

STABILITY OF SPHERE ON 3 SUPPORTS

SINCE R_1 IS ACTING 8.25° FORWARD OF Z AXIS, $a' = r \tan 8.25° = 11(\tan 8.25°) = 1.595$ FT.

THEN $a = 3.040$ FT.
$b = 1.090$ FT.
$a' = 1.595$ FT.

$$Y_B = -\frac{b^2}{a'} = -\frac{(1.090)^2}{1.595} = -0.745 \text{ FT.}$$

$$X_B = +\left[a^2 - \frac{a^2}{b^2} Y^2\right]^{1/2} = \left[(3.040)^2 - \left(\frac{3.040}{1.090}\right)^2 (0.745)^2\right]^{1/2}$$

$$X_B = \left[9.242 - \frac{9.242}{1.188}(0.555)\right]^{1/2} = [4.925]^{1/2}$$

$$X_B = 2.219 \text{ FT.}$$

$$\text{SLOPE} = \frac{dy}{dx} = \frac{Y_B + a'}{X_B} = \frac{-0.745 + 1.595}{2.219} = 0.338$$

EQ. OF LINE ABC

$$y = -a' + \frac{dy}{dx} x$$

$$y = -1.595 + 0.338 x$$

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TITLE

AUI - 140 FT. RADIO TELESCOPE

STABILITY OF SPHERE ON 3 SUPPORTS.

EQ. OF LINE "DC" IS $y = b'$ OR $y = 1.464$

SOLVING WITH LINE AC GIVES 'C' POINT

$$y_c = 1.464 \quad \& \quad y = -1.595 + 0.338X$$

$$1.464 = -1.595 + 0.338X$$

$$0.338X = 3.059$$

$$X_c = 9.050 \text{ FT.}$$

LENGTH OF "DC"

$$DC = \left[(DC)^2 + (b')^2 \right]^{1/2} = \left[(9.050)^2 + (1.464)^2 \right]$$

$$DC = \left[84.046 \right]^{\frac{1}{2}}$$

$$DC = 9.168 \text{ FT.}$$

$$\text{TAN } \delta = \frac{b'}{DC} = \frac{1.464}{9.050}$$

$$\text{TAN } \delta = 0.16176$$

$$\delta = 9^\circ 11'$$

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TITLE

AUI - 140 FT. RADIO TELESCOPE

STABILITY OF SPHERE ON 3 SUPPORTS.

REFERRING POINT 'C' TO SPHERE FROM X'Y' PLANE

$$\text{TAN } \gamma_3' = \frac{0.5}{r}$$

r = SPHERE RADIUS

r = 11 FT.

$$\text{TAN } \gamma_3' = \frac{9.168}{11.00}$$

$$\text{TAN } \gamma_3' = 0.8335$$

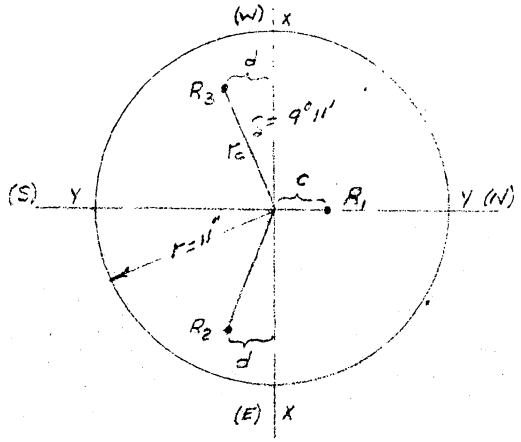
$$\gamma_3' = 39°-47'$$

RADIUS OF LOCATING CIRCLE ON SPHERE

$$r_c = r \sin \gamma_3'$$

$$r_c = 11(0.64033) = 7.044 \text{ FT.}$$

NOTATION FOR DETERMINING LOADS ON HYDROSTATIC PADS.



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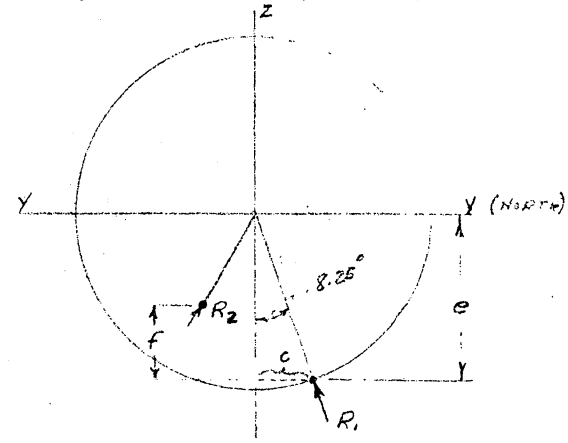

ELEVATION

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TITLE AUI - 140 FT. RADIO TELESCOPE

LOADS ON AZIMUTH TRUCK PADS.

$C = 11' \sin 8.25° = 1.578$ FT.

$d = \frac{1}{2} \sin 9°11' = 1.124$ FT.

$e = 11' \cos 8.25° = 10.886$ FT.

$F = 11'[\cos 8.25° - \cos 39°49']$ = 2.437 FT.

$\cos \beta_3 = \cos 39°49' = 0.76810$

$\cos \beta_2 = \cos 39°49' = 0.76810$

$\cos \gamma_1 = \cos 8°15' = 0.98965$

$\cos \beta_{2 \text{ or } 3} = \frac{d}{F} = 0.10218$

FOR NORTH OR SOUTH WIND CONDITIONS MOMENTS IN THE ZY PLANE MAY BE USED DUE TO SYMMETRICAL LOCATION OF R_2 & R_3.

ALSO DUE TO SYMMETRY $R_2 = R_3 = R_5$
(SUBSCRIPT FOR SIDE PAD.)

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TITLE

AVE - RADIO TELESCOPE - 140 FT.

LOADS ON HYDROSTATIC PADS.

NORTH WIND - 120 MPH.

F = 452,000 LBS.

W = 3,397,000 LBS.

Σ (MOMENTS ABOUT R_1) = 0

$$Wc + Fe - 2R_s(c+d)\cos\gamma_s - 2R_s f\cos\beta_s = 0$$

$$2R_s\left[(c+d)\cos\gamma_s + f\cos\beta_s\right] = Wc + Fe$$

$$R_s = \frac{Wc + Fe}{2\left[(c+d)(\cos\gamma_s) + f\cos\beta_s\right]}$$

$$R_s = \frac{(3,397,000)(1.578) + (452,000)(10.886)}{2\left[(2.702)(0.76810) + 2.437(0.10218)\right]} = \frac{10,280,000}{4.648}$$

R_s = 2,212,000 LBS.

LOAD ON EACH SIDE PAD.

$\Sigma F_z = 0$

$$2R_s\cos\gamma_s + R_1\cos\gamma_1 - W = 0$$

$$R_1 = \frac{W - 2R_s\cos\gamma_s}{\cos\gamma_1}$$

$$R_1 = \frac{3,397,000 - 2(2,212,000)(0.76810)}{0.98965}$$

$$R_1 = \frac{3,397,000 - 3,397,000}{0.98965}$$

R_1 = 0

LOAD ON FRONT PAD

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TITLE AUI - RADIO TELESCOPE - 140 FT.

LOADS ON HYDROSTATIC PADS.

SOUTH WIND - 120 MPH

$F = 452,000$ LBS.

$W = 4,563,000$ LBS.

$$\Sigma M_{R_1} = 0$$

$$Wc - Fe - 2R_S(c+d)\cos\gamma_S - 2R\cos\beta_S = 0$$

$$R_S = \frac{Wc - Fe}{2[(c+d)\cos\gamma_S + f\cos\beta_S]}$$

$$R_S = \frac{4,563,000(1.578) - 452,000(10.686)}{2[2.702(0.76810) + 2.437(0.10218)]}$$

$$R_S = \frac{2,280,000}{4.648}$$

$$R_S = 490,500 \text{ LBS.}$$

LOAD ON EACH SIDE PAD

$$\Sigma F_Z = 0$$

$$2R_S\cos\gamma_S + R_1\cos\gamma_1 - W = 0$$

$$R_1 = \frac{W - 2R_S\cos\gamma_S}{\cos\gamma_1} = \frac{4563,000 - 2(490,500)(0.76910)}{0.98965}$$

$$R_1 = \frac{3,809,000}{0.98965}$$

$$R_1 = 3,849,000 \text{ LBS.}$$

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TITLE AUL - 140 FT RADIO TELESCOPE

LOADS ON HYDROSTATIC PADS.

NO WIND CONDITION $F = 0$

$W = 3,980,000$ LBS.

$\Sigma M_{R_1} = 0$

$$W c - 2 R_S \cos \gamma_S (c+d) - 2 R_S (\cos \beta_S) f = 0$$

$$R_S = \frac{W c}{2\left[(c+d)(\cos \gamma_S) + f \cos \beta_S\right]}$$

$$R_S = \frac{(3,980,000)(1.575)}{4648}$$

$R_S = 1,351,000$ LBS.

LOAD ON EACH SIDE PAD

$\Sigma F_V = 0$

$$W - 2 R_S \cos \gamma_S - R_1 \cos \gamma_1 = 0$$

$$R_1 = \frac{W - 2 R_S \cos \gamma_S}{\cos \gamma_1}$$

$$R_1 = \frac{3,980,000 - 2(1,351,000)(0.76810)}{0.98965}$$

$R_1 = 1,905,000$ LBS.

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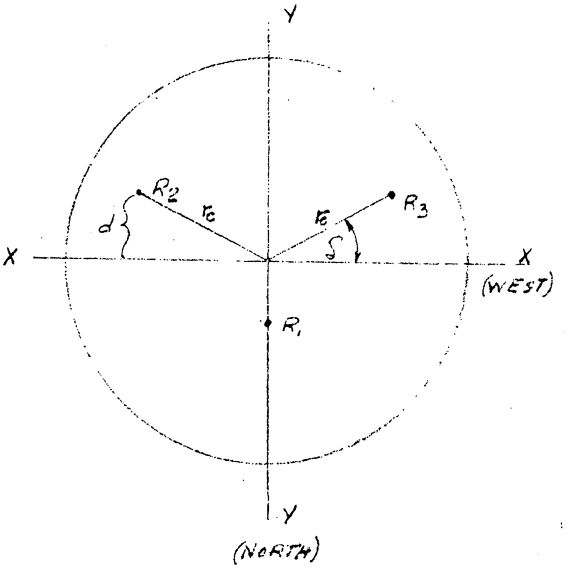
TITLE

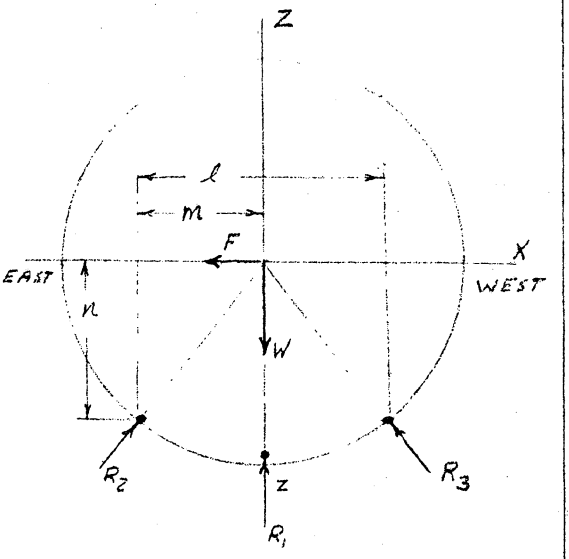
AUI - 140 FT. RADIO TELESCOPE

LOADS ON HYDROSTATIC PADS

THE LOADS ON THE PADS DUE TO EAST OR WEST WINDS CAN BE DETERMINED BY THE SUMMATION OF MOMENTS AND FORCES IN THE "ZX" PLANE.



PLAN



ELEVATION

$\ell = 2 r_c \cos\delta = 2(7.044 \cos 9°11') = 13.907$ FT.

$m = r_c \cos\delta = \frac{13.907}{2} = 6.954$ FT.

$n = r \cos\gamma_2 = 11' \cos 39°49' = 8.449$ FT.

$\cos\gamma_3 = \cos 39° 49' = 0.76810$

$\cos\gamma_2 = \cos 39° 49' = 0.76810$

$\cos\delta = \cos 8° 15' = 0.98965$

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AUI - 140 FT. RADIO TELESCOPE

LOADS ON HYDROSTATIC PADS.

$$\cos \alpha_1 = \cos 90^\circ = 0$$

$$\cos \alpha_2 = \frac{r_c \cos \delta}{r} = \frac{7.044}{11}(0.98718) = 0.63215$$

$$\cos \alpha_3 = \cos \alpha_2 = 0.63215$$

$$\cos \beta_1 = \sin 8^\circ 15' = 0.14349$$

$$\cos \beta_2 = \frac{d}{r} = \frac{1.124}{11} = 0.10218$$

$$\cos \beta_3 = \frac{d}{r} = 0.10218$$

WEST WIND - 120 MPH $\quad F = 1,100,000$

$W = 3,980,000$

$\Sigma M_2 = 0$ IN "XZ" PLANE

$$R_3 \ell \cos \gamma_3 + R_1 m \cos \gamma_1 + F n - W m = 0$$

$$R_3 \ell \cos \gamma_3 = W m - F n - R_1 m \cos \gamma_1$$

$$R_3 = \frac{W m - F n - R_1 m \cos \gamma_1}{\ell \cos \gamma_3}$$

$$R_3 = \frac{(3,980,000)(6.954) - (1,100,000)(8.249) - R_1(6.954)(0.99965)}{(13.907)(0.76810)}$$

$$R_3 = \frac{18,383,000 - 6.892 R_1}{10.682}$$

$$R_3 = 1,721,000 - 0.6443 R_1$$

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TITLE

AUI - 140 FT. RADIO TELESCOPE

LOADS ON HYDROSTATIC PADS

$\Sigma F_x = 0$

$$F + R_3 \cos\alpha_3 + R_1 \cos\alpha_1 - R_2 \cos\alpha_2 = 0$$

SUBSTITUTE FOR R_3 ($R_3 = 1{,}721{,}000 - 0.6443\, R_1$)

$$F + 1{,}721{,}000 \cos\alpha_3 - 0.6443 \cos\alpha_3 R_1 + R_1 \cos\alpha_1 - R_2 \cos\alpha_2 = 0$$

$$R_2 = \frac{F + 1{,}721{,}000 \cos\alpha_3 - 0.6443 \cos\alpha_3 R_1 + R_1 \cos\alpha_1}{\cos\alpha_2}$$

$$R_2 = \frac{1{,}100{,}000 + 1{,}721{,}000(0.63215) - 0.6443(0.63215) R_1}{0.63215}$$

$$R_2 = 3{,}461{,}000 - 0.6443\, R_1$$

$\Sigma F_y = 0$

$$R_1 \cos\beta_1 - R_2 \cos\beta_2 - R_3 \cos\beta_3 = 0$$

SUBSTITUTE FOR R_2 & R_3

$$R_1 \cos\beta_1 - (3{,}461{,}000 - 0.6443 R_1)\cos\beta_2 - (1{,}721{,}000 - 0.6443 R_1)\cos\beta_3 = 0$$

$$R_1 [\cos\beta_1 + 0.6443(\cos\beta_2 + \cos\beta_3)] = 3{,}461{,}000 \cos\beta_2 + 1{,}721{,}000 \cos\beta_3$$

$$R_1 = \frac{3{,}461{,}000 \cos\beta_2 + 1{,}721{,}000 \cos\beta_3}{\cos\beta_1 + 0.6443(\cos\beta_2 + \cos\beta_3)}$$

$$R_1 = \frac{3{,}461{,}000(0.10218) + 1{,}721{,}000(0.10218)}{0.14349 + 0.6443(0.10218 + 0.10218)}$$

$$R_1 = 1{,}924{,}000 \text{ LBS.}$$

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TITLE: AJI - 140 FT. RADIO TELESCOPE

LOADS ON HYDROSTATIC PADS.

WEST WIND (Cn.T.)

$R_2 = 3,461,000 - 0.6443\ R_1$ $\qquad R_1 = 1,924,000$ LBS.

$R_2 = 3,461,000 - 0.6443(1,924,000)$

$R_2 = 2,221,000$ LBS.

$R_3 = 1,721,000 - 0.6443(R_1)$

$R_3 = 1,721,000 - 0.6443(1,924,000)$

$R_3 = 481,000$ LBS.

EAST WIND

SINCE R_2 & R_3 ARE SYMMETRICAL ABOUT THE Z Y PLANE R_1 WILL BE THE SAME AND R_3 WILL EQUAL R_2 FOR THE WEST WIND.

$R_1 = 1,924,000$ LBS.

$R_2 = 481,000$ LBS.

$R_3 = 2,221,000$ LBS.

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AUI - 140 FT RADIO TELESCOPE

SUMMARY OF MAXIMUM LOADS. WIND: 120 MPH

$R_{1\,max}$ = 3,849,000 LBS. (SOUTH WIND)

$R_{2\,max}$ = 2,221,000 LBS. (WEST WIND)

$R_{3\,max}$ = 2,221,000 LBS. (EAST WIND)

NORMAL OPERATION AT NO WIND

R_1 = 1,905,000 LBS.

R_2 = 1,351,000 LBS.

R_3 = 1,351,000 LBS.

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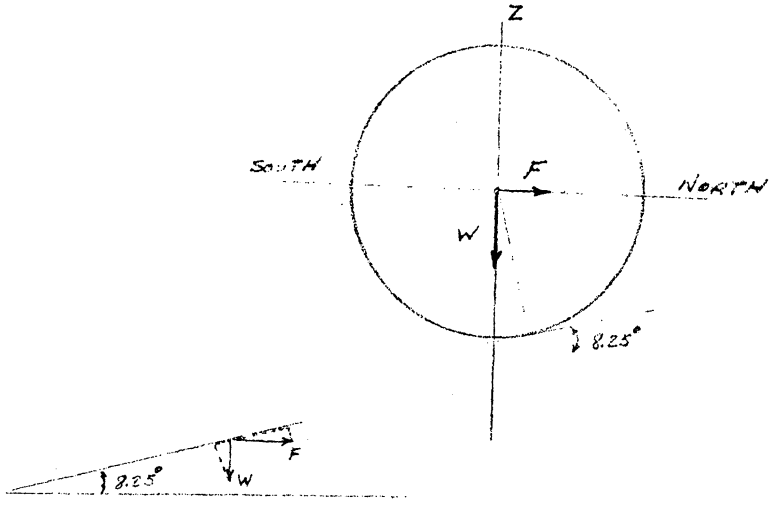
TITLE

AUI - 140 FT. RADIO TELESCOPE

IN ADDITION TO OVERTURNING ABOUT THE SUPPORTING PADS THERE IS A POSSIBILITY THAT THE HORIZONTAL WIND FORCE COULD PUSH THE MASS UP PLANE FORMED BY THE PADS SINCE THERE IS RELATIVELY NO FRICTION.

SLIDING OVER FORWARD PAD



F = 452,000 LBS.

W = 4,563,000 LBS.

FORCE UP PLANE = $F \cos 8.25^\circ = (452{,}000)(0.98965) = 447{,}000$ LBS.

FORCE DOWN PLANE = $W \sin 8.25^\circ = (4{,}563{,}000)(0.14349) = 654{,}700$ LBS.

SYSTEM IS STABLE SINCE RESTORING FORCE IS GREATEST