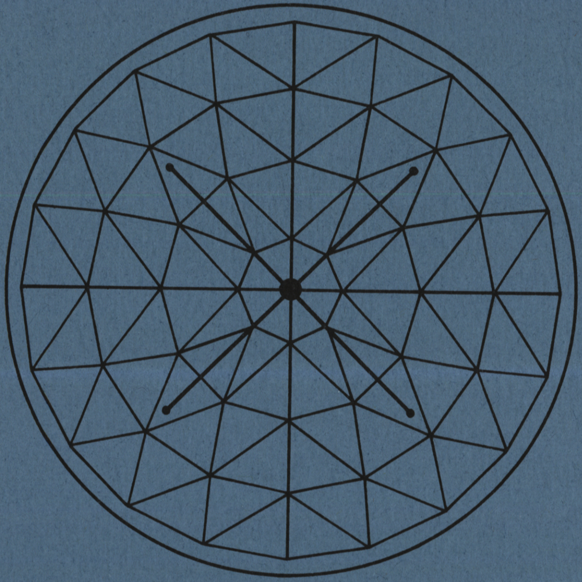

SECTION 3.0

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

3.0 AZIMUTH TURNTABLE

PREPARED BY O. R. Heine APPROVED BY ________ SUBMITTED BY S.D.L.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.2 OF 76
DATE 12-26-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

3.1. TRUCKS & RAILS

LOOKING AT THE STRUCTURAL CONCEPT OF THE HOMOLOGY TELESCOPE IT BECOMES EVIDENT THAT THE DEADLOAD CAN BE ASSUMED TO BE EVENLY DIVIDED AMONG THE 4 TRUCKS. THUS IN ADDITION TO THE MAX. LOAD DUE TO 100 MPH WIND THE TRUCK WHEELS OF EACH TRUCK MUST SUPPORT A DEADLOAD OF :

$$L_{TW} = \frac{1680}{4} = \underline{420 \text{ TONS}}$$

HENCE THE MAXIMUM TOTAL LOAD EACH TRUCK WHEEL-ARRANGEMENT MUST SUPPORT IS

$$L_{T\,MAX} = L_{TW} + L_{TV}$$

$$= 420 + 380$$

$$L_{T\,MAX} = \underline{800 \text{ TONS}} = 1{,}600{,}000 \text{ LBS}$$

THE MAXIMUM LOAD AT THE SUPPORT POINT IS 100 TONS LESS (WEIGHT OF TRUCK ASSEMBLY) OR

$$L_{MAX} = \underline{700 \text{ TONS}} = 1{,}400.000 \text{ LBS}$$

USE 1,560,000 LBS

PREPARED BY O.R.HEINE APPROVED BY ________ SUBMITTED BY S.D.L.

REPORT NO. H79-6
CONTRACT NO. RAP-79
PAGE 3.3 OF 76
DATE 12-26-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

AT A TOTAL NUMBER OF 32 WHEELS PER TRUCK ASSEMBLY (16 AXLES, 8 P. TRACK) THE MAXIMUM WHEEL LOAD IS THEN:

$$L_{W\,MAX} = \frac{1,760,000^{*}}{32} = \underline{55,000 \text{ LBS}}$$

A STANDARD 4-WHEEL TRUCK WITH 7"x 12" JOURNAL AXLES HAS A RATED CAPACITY OF 157,500 LBS OR ONLY 39,500 LBS PER WHEEL.

HOWEVER A STUDY OF THE SPECIFICATION FOR AXLES, BOLSTERS AND SIDEFRAMES INDICATES THAT THE ELASTIC LIMIT WOULD OCCURE AT APPROXIMATELY 276,000 LBS OR 69,000 LBS WHICH WOULD GIVE A SAFETY MARGIN OF

$$SM_{SURVIVAL} = \frac{69,000}{55,000} = \underline{1.25}$$

THE STANDARD 4-WHEEL TRUCK WILL HAVE 38 IN. DIA. TWO WEAR WROUGHT STEEL WHEELS WHICH ARE RIM TOUGHENED PER AAR SPEC. M-107-67 CLASS C. THE WHEEL BASE OF THE TRUCKS IS 72 IN (6 FT)

ASSUMING THAT EACH ADJACENT TRUCK CAN BE POSITIONED AT A CENTER DISTANCE OF 4', THE TOTAL CENTER DISTANCE BETWEEN FRONT- AND REAR WHEELS WOULD BE:

$$(3 \times 4') + (4 \times 6') = \underline{36 \text{ FT}}$$

* + 10 % SAFETY MARGIN

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.4 OF 76
DATE 12-26-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

IN ORDER TO HAVE CLEARANCE BETWEEN TO ADJACENT TRUCK ASSEMBLIES RUNNING ON THE DOUBLE RAILROAD TRACK-BED A CENTER TO CENTER DISTANCE BETWEEN THE TRACKS OF AT LEAST 9 FT. (108 IN) WILL BE REQUIRED

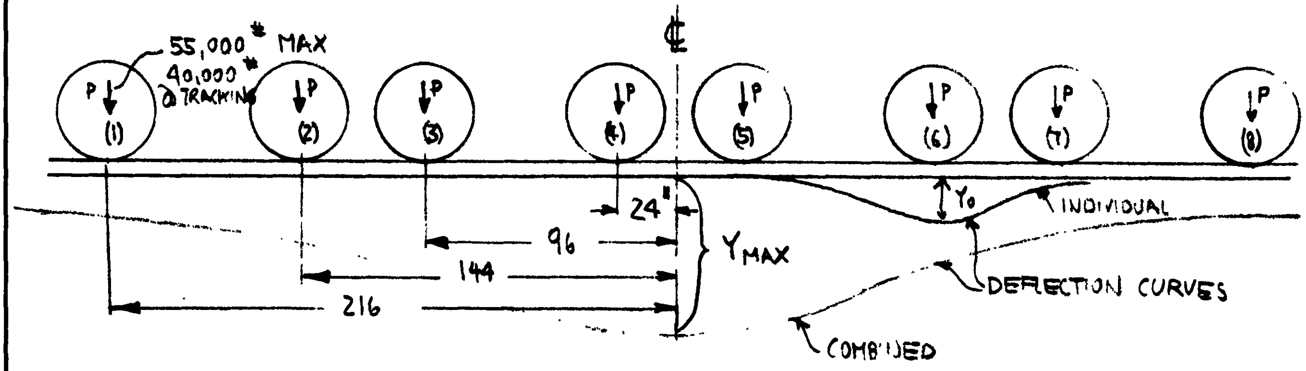
3.2 STIFFNESS OF RAIL ROAD TRACK :

ASSUME : RAIL = STD. 131 #

$I_{RAIL} = 88.6\ IN^4$

$E_{RAIL} = 30 \times 10^6\ \#/IN^2$

$K_{RAIL\ BED} = 2000\ \#/IN^2$ (MOD. OF SUBGRADE REACTION)



$$\beta = \sqrt[4]{\frac{K}{4EI}} = \sqrt[4]{\frac{2000}{4 \times 30 \times 10^6 \times 88.6}} = \underline{.0208\ IN^{-1}}$$

$$y_0 = \frac{\beta P}{2K} = \frac{.0208 \times 40,000}{2 \times 2000} = \underline{.208\ IN}$$

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REPORT NO. H79-8
CONTRACT NO. BAP-79
PAGE 35 OF 76
DATE 12-26-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS AND RAILS

SUBJECT: AZIMUTH TURNTABLE

FROM TABLE 7 IN "SEELY & SMITH" :

$\beta x_1 = .208 \times 216 = 4.5 \qquad A\beta x_1 = .0132$

$\beta x_2 = .208 \times 144 = 3.0 \qquad A\beta x_2 = .0422$

$\beta x_3 = .208 \times 96 = 2.06 \qquad A\beta x_3 = .0540$

$\beta x_4 = .208 \times 24 = .50 \qquad A\beta x_4 = .8231$

$$y_{MAX} = \frac{P\beta}{2K}\left(A\beta x_1 + A\beta x_2 + A\beta x_3 + A\beta x_4\right)2$$

$$= .208\left(.0132 + .0422 + .0540 + .8231\right)2$$

$$= .208\,(1.865) \cong \underline{.390\ \text{IN}}$$

$$Y_{AVERAGE} \cong \frac{Y_0 + Y_{MAX}}{2} = \frac{.208 + .390}{2} \cong \underline{.300\ \text{IN}}$$

$$K_{TRACK} = \frac{L_W\ (\text{OPERATION})}{Y_{AVERAGE}}$$

$$= \frac{40{,}000 \times 32}{.300}$$

$$K_{TRACK} = \underline{4.27 \times 10^6\ \text{LBS/IN}} \quad (\text{LINEAR SPRING CONSTANT})$$

THE TRUCK ASSEMBLY SHOULD BE MADE AT LEAST EQUALLY AS STIFF AS THE TRACKBED !

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.3 STRESSES IN RAIL AND WHEELS

3.3.1 BENDING STRESS IN RAIL

THE MAXIMUM BENDING MOMENT IN THE RAIL IS SEEN UNDER WHEEL # 5 (OUTER WHEEL).

$$M_{B\,MAX} = \frac{P_{MAX}}{4\beta} \sum C_{\beta x}$$

$$\frac{P_{MAX}}{4\beta} = \frac{55,000}{4 \times .208} = 660,000 = M_0$$

$\beta x_1 = .208\ (0) = 0$ — $C_{\beta x_1} = 1.0000$

$\beta x_2 = .208\ (72) = 1.5$ — $C_{\beta x_2} = -.2068$

$\beta x_3 = .208\ (120) = 2.5$ — $C_{\beta x_3} = -.1149$

$\beta x_4 = .208\ (192) = 4.0$ — $C_{\beta x_4} = +.0019$

$\beta x_5 = .208\ (240) = 5.0$ — $C_{\beta x_5} = +.0084$

$\beta x_6 = .208\ (312) = 6.5$ — $C_{\beta x_6} = +.0012$

$\beta x_7 = .208\ (360) = 7.5$ — $C_{\beta x_7} = -.0003$

$\beta x_8 = .208\ (432) = 9.0$ — $C_{\beta x_8} = -$

$\sum C_{\beta x} = .6895$

$$M_{B\,MAX} = .69\ M_0 = .69 \times 660,000 = \underline{455,000 \text{ IN LBS}}$$

$$\sigma_{B\,MAX} = \frac{M_{B\,MAX}}{I/c} = \frac{455,000}{88.6} \times 3.9 = \underline{20,000 \text{ PSI}}$$

- OK -

$C = 3.90$ IN FOR $131^{\#}$ RAIL

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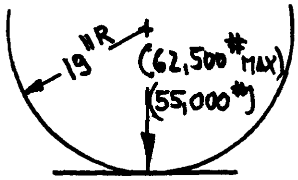
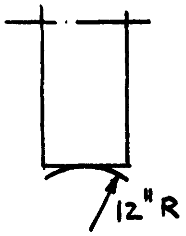
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.3.2. CONTACT STRESS IN WHEELS AND RAIL





$$\frac{B}{A} = \frac{19}{12} = \underline{1.58}$$

$$A+B = \frac{1}{2\times12} + \frac{1}{2\times19} = .0417 + .0263 = \underline{.0680} \quad IN^{-1}$$

$$\Delta = \frac{2(1-\mu^2)}{(A+B)E} = \frac{2(1-.25^2)}{.068\times30\times10^6} = \underline{9.2\times10^{-7} \ IN^3/LB}$$

$$b = C_b\sqrt[3]{P\Delta} \qquad C_b^* = .77 \ \text{FOR} \ \frac{B}{A} = 1.58$$

$$= .77\sqrt[3]{62{,}500\times9.2\times10^{-7}} = \underline{.298 \ IN}$$

$$\frac{b}{\Delta} = \frac{.298}{9.2\times10^{-7}} = \underline{324{,}000 \ LBS/IN^2}$$

$$\sigma_{MAX} = -C_\sigma^*\left(\frac{b}{\Delta}\right) = .73\times324{,}000 = \underline{236{,}000 \ PSI}$$

$$\tau_{MAX} = C_\tau^*\left(\frac{b}{\Delta}\right) = .24\times324{,}000 = \underline{78{,}000 \ PSI}$$

$$\tau_{G\,MAX} = C_G^*\left(\frac{b}{\Delta}\right) = .22\times324{,}000 = \underline{71{,}000 \ PSI}$$

* FROM FIG. 183 IN SEELY & SMITH "ADVANCED MECHANICS OF MATERIALS"

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.8 OF 76
DATE 12-27-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

THE BEFORE GOING CALCULATIONS INDICATE THAT THE MAXIMUM BENDING STRESS IN THE RAIL IS WITHIN THE ELASTIC LIMIT OF THE MATERIAL.

THE CONTACT STRESSES IN BOTH WHEELS AND RAIL ARE HOWEVER QUITE HIGH AND YIELDING (LOCAL PERMANENT CONTACT DEFORMATIONS) MUST BE EXPECTED.

IN ORDER TO MINIMIZE THE PERMANENT DEFORMATIONS IN THE RAIL SURFACES DUE TO SURVIVAL LOADS AND POSSIBLY EVEN DUE TO OPERATIONAL LOADS BOTH WHEELS AND RAILS SHOULD BE HEAT TREATED.

3.4 DESIGN OF TRUCKS

THE TRUCK DESIGN MUST PERMIT WHEEL LOAD EQUALIZATION SO THAT ALL 32 WHEEL CAN EQUALLY SHARE THE VERTICAL LOAD ON THE TRUCK.

THIS IS BEST ACHIEVED IN THIS CASE BY MEANS OF A ROCKER BEAM ARRANGEMENT

THE ROCKER BEAMS SHOULD BE DESIGNED TO SUPPORT THE MAXIMUM SURVEIVAL LOAD SAFELY AND FOR MINIMUM FLEXIBILITY.

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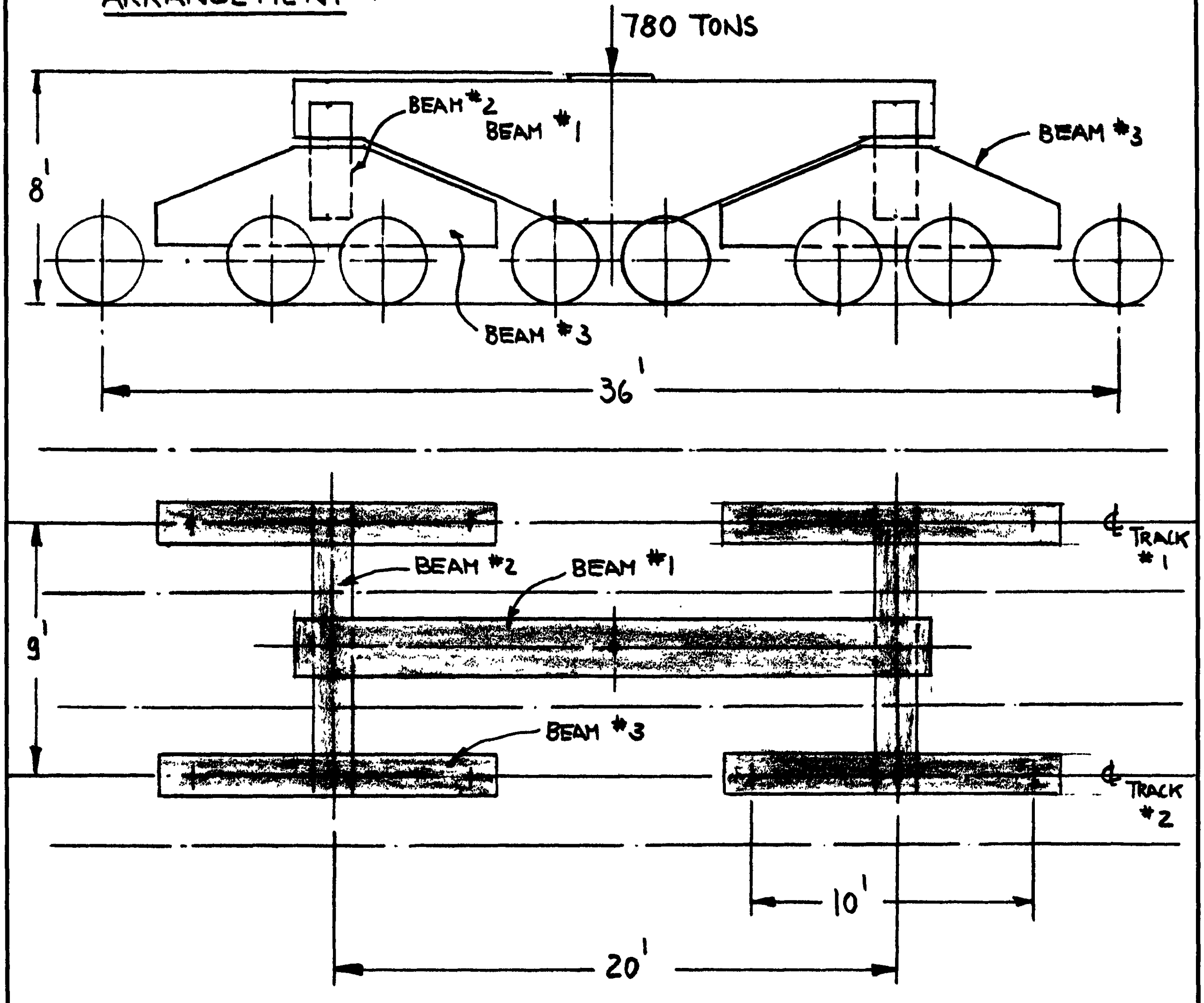
NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.9 OF 76
DATE 12-27-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE — TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

ARRANGEMENT :



NOTE : CURVATURE OF TRACK RADIUS NEGLECTED !

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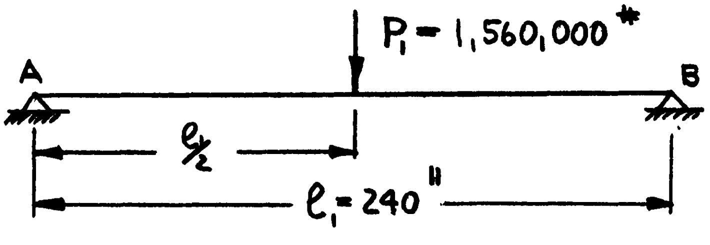
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.10 OF 76
DATE 12-27-68

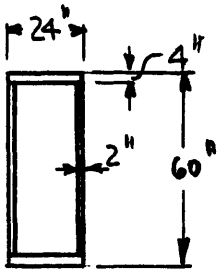
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

BEAM #1



BEAM TO HAVE EQUAL BENDING STRENGHT

CROSS SECTION @ ℄



$$I_{MAX} = (96 \times 1568) + 4(11,717)$$

$$= 150,000 + 47,000 = \underline{197,000 \text{ IN}^4}$$

$$Z_{MAX} = \frac{197,000}{30} = \underline{6,560 \text{ IN}^3}$$

$$A_{MAX} = (2 \times 96) + 2(104) = \underline{400 \text{ IN}^2}$$

$$M_{B\,MAX} = \frac{P\ell}{4} = \frac{1,560,000 \times 240}{4} = \underline{93.5 \times 10^6 \text{ "\#}}$$

$$S_{B\,MAX} = \frac{M_{B\,MAX}}{Z_{MAX}} = \frac{93.5 \times 10^6}{6.56 \times 10^3} = \underline{\underline{14,300 \text{ PSI}}}$$

(OK)

$$\Delta_{B\,MAX} \cong \frac{M\ell^2}{24EI} = \frac{93.5 \times \cancel{240}^2 \cancel{\times 10^6}\ 5.77 \times 10^4}{24 \times 30 \cancel{\times 10^6} \times 197 \cancel{\times 10^3}} = \underline{\underline{.038 \text{ IN}}}$$

SHEAR DEFLECTION, CONTACT DEF. ETC. SAY ~ $= \underline{.012 \text{ IN}}$

$$\Delta_{1\,TOTAL} = \underline{\underline{.050 \text{ IN}}}$$

$$K_1 = \frac{P_1}{\Delta_1} = \frac{1.56 \times 10^6}{.050} = \underline{\underline{31.6 \times 10^6 \text{ \#/IN}}}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

APPROX. WEIGHT OF BEAM #1 :

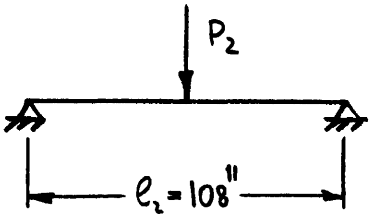
$$W_1 = (.75 \times 400 \times .283 \times 276)1.10 = \underline{26,000 \text{ LBS}}$$

WEIGHT OF SADDLE ESTD :

$$W_{S_1} = 24 \times 36 \times 4 \times .283 = \underline{1,000 \text{ LBS}}$$

$$\Sigma = \underline{\underline{27,000 \text{ LBS}}}$$

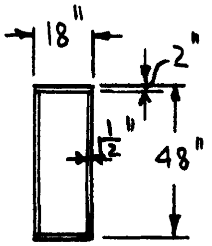
BEAM #2



$$P_2 = \left(\frac{P_1}{2}\right) + 13,500$$

$$P_2 = 780,000 + 13,500 = \underline{793,500}$$

CROSS SECTION @ ℄ : $I_{MAX} = (36 \times 1058) + (3 \times 7098)$



$$= 38,100 + 21,300 = \underline{59,400} \text{ IN}^4$$

$$Z_{MAX} = \frac{59,400}{24} = \underline{2,500 \text{ IN}^3}$$

$$A = (2 \times 36) + (3 \times 44) = \underline{204 \text{ IN}^2}$$

$$M_{BMAX} = \frac{P_2 \ell_2}{4} = \frac{793,500 \times 108}{4} = \underline{21.4 \times 10^6} \text{ ''\#}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

$$S_{BMAX} = \frac{M_{BMAX}}{Z_{MAX}} = \frac{21.4\times10^{6}}{2.50\times10^{3}} = \underline{\underline{8,600\ PSI}}$$

(OK)

$$\Delta_{BMAX} = \frac{M\ell^{2}}{24EI} = \frac{21.4\cancel{\times10^{6}}\times1.08^{2}\cancel{\times10^{4}}}{24\times30\cancel{\times10^{6}}\times5.94\cancel{\times10^{4}}} = \underline{.006\ IN}$$

ASSUME SHEAR DEFLECTION ETC. TO BE $= \underline{.004\ IN}$

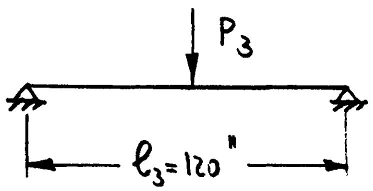
$\Delta_{2\,TOTAL} = \underline{\underline{.010\ IN}}$

$$K_2 = \frac{P_1}{\Delta_2} = \frac{1.56\times10^{6}}{.010} \cong \underline{\underline{156\times10^{6}\ \#/IN}}$$

APPROX. WEIGHT OF BEAM #2 :

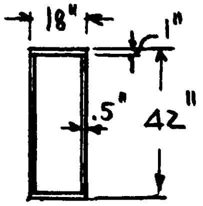
$$W_2 = (.75\times204\times.283\times126)\,1.10 = \underline{\underline{6,000\ LBS}}$$

BEAM # 3



$$P_3 = \left(\frac{P_2}{2}\right) + 3000 = \underline{400,000}\ \#$$

CROSS SECTION @ ℄ :



$$I_{MAX} = (18\times841) + 5300$$

$$= 15,100 + 5,300 = \underline{20,400\ IN^{4}}$$

$$Z_{MAX} = \frac{20,400}{21} = \underline{973\ IN^{3}}$$

$$A_{MAX} = 36 + 40 = \underline{76\ IN^{2}}$$

PREPARED BY O.R. HEINE APPROVED BY ______ SUBMITTED BY S.D.L.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.13 OF 76
DATE 12-27-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

$$M_{B MAX} = \frac{P_3 \ell_3}{4} = \frac{400{,}000 \times 120}{4} = \underline{12 \times 10^6 \text{ IN-LBS}}$$

$$S_{B MAX} = \frac{M_{B MAX}}{Z_{MAX}} = \frac{12 \times 10^6}{973} = \underline{12{,}300 \text{ PSI}}$$

(OK)

$$\Delta_{B\ MAX} = \frac{M_3 \ell^2}{24EI} = \frac{12 \times \cancel{10^6} \times 1.2^2 \times \cancel{10^4}}{24 \times 30 \times \cancel{10^6} \times 2.04 \times \cancel{10^4}} \cdot = \underline{.012 \text{ IN}}$$

ASSUME SHEAR DEFLECTION ETC. TO ADD = .003 IN

Δ_3 TOTAL = .015 IN

$$K_3 = \frac{P_1}{\Delta_3} = \frac{1.56 \times 10^6}{.015} = \underline{104 \times 10^6 \text{ \#/IN}}$$

APPROX. WEIGHT OF BEAM #3 :

$$W_3 = (.75 \times 138 \times 76 \times .283)\,1.10 \cong \underline{2{,}500 \text{ LBS}}$$

WEIGHT SUMMARY OF WALKING BEAMS :

BEAM #1 , 1 - REQ'D = 27,000 LBS
BEAM #2 , 2 - REQ'D @ 6,000# = 12,000 "
BEAM #3 , 4 - REQ'D @ 2,500# = 10,000 "
Σ = 49,000 LBS
SAY 50,000 LBS

= 25 TONS

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURN TABLE

3.5 SPRING CONSTANT OF TRUCK AND RAILS :

3.5.1 IN VERTICAL DIRECTION :

$K_{TRACK} = 4.27 \times 10^6$ LBS/IN

$K_1 = 31.60 \times 10^6$ LBS/IN

$K_2 = 156.00 \times 10^6$ LBS/IN

$K_3 = 104.00 \times 10^6$ LBS/IN

$K_{TRUCK\ BOLSTER} = \frac{212,000}{.075} \times 8 = 22.50 \times 10^6$ LBS/IN

$K_{SIDE\ FRAME} = \frac{167,000}{.062} \times 16 = 43.20 \times 10^6$ LBS/IN

$K_{AXLE,\ BEARINGS,\ WHEELS}$ ASSUME $= 50.00 \times 10^6$ LBS/IN

$$\text{THUS } K_{v_{TRUCK}} = \frac{10^6}{\frac{1}{4.27} + \frac{1}{31.6} + \frac{1}{156} + \frac{1}{104} + \frac{1}{22.5} + \frac{1}{43.2} + \frac{1}{50}}$$

$$= \frac{10^6}{.233 + .032 + .006 + .009 + .045 + .023 + .020}$$

$$= \frac{10^6}{.368}$$

$$K_{v_{TRUCK}} \cong \underline{2.7 \times 10^6 \text{ LBS/IN}} \quad (\text{USE } 1.8 \times 10^6)$$

THE ROTATIONAL SPRING CONSTANT OF THE AZIMUTH TURNTABLE CONSISTING OF 6 TRUCKS AND INCLUDING THE FLEXIBILITY OF THE CIRCULAR RAIL ROAD TRACKS IS THEN :

$$K_{TR\theta_v} = 2.7 \times 10^6 (173.2)(1078)\,3 = 1.50 \times 10^{12} \text{ FT-LBS/RAD}$$

$$\text{USE } K_{TR\theta_v} = \underline{1.0 \times 10^{12} \text{ FT-LBS/RAD}}^{*}$$

* TO INCLUDE FLEXIBILITY OF MOUNTING AREA.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.5.2 IN LATERAL DIRECTION :

$$K_{L\ BOLSTER} = \frac{212 \times 10^3 \times 8}{.055} = 30.8 \times 10^6\ ^{LBS}/_{IN}$$

$$K_2 : \quad I = (4 \times 281.3) + (96 \times 136)$$

$$= 1124 + 13,000$$

$$= \underline{14,124\ IN^4}$$

$$\Delta = \frac{P\ell^3}{6EI}, \quad K = \frac{6EI}{\ell^3}$$

$$K_{L2} = \frac{6 \times 14,124 \times 30 \times 10^6}{(108)^3}(2) = 4.0 \times 10^6\ ^{LBS}/_{IN}$$

$$K_{L\ TRUCK} = \frac{10^6}{\frac{1}{30.8} + \frac{1}{4.0}}$$

$$= \frac{10^6}{.0323 + .250} = \frac{10^6}{.282}$$

$$K_{L\ TRUCK} = \underline{3.55 \times 10^6\ ^{LBS}/_{IN}} \quad \text{USE} \quad \underline{3.0 \times 10^6\ ^{LBS}/_{IN}}$$

(TO ACCOUNT FOR OTHER FLEXIBILITIES)

FOR 4 UNITS $K_{L\ TRUCK} = \underline{\underline{12 \times 10^6\ ^{LBS}/_{IN}}}$

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.16 OF 76
DATE 12-30-68

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE — TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.6 WEIGHT ESTIMATE, TRUCK ASSEMBLY
(WITH STD. RAIL ROAD COMPONENTS)

ITEM DESCRIPTION	NO. REQD	UNIT WEIGHT (LBS)	TOTAL WEIGHT (LBS)
38" DIA. WHEELS	32	3,530	56,500
7"x12" JOURN. AXLES	16		
SIDE FRAMES	16	1,030	16,500
BOLSTERS	8	1,635	13,000
WALKING BEAM #1	1	27,000	27,000
WALKING BEAM #2	2	6,000	12,000
WALKING BEAM #3	4	2,500	10,000
MISCALL.*			15,000
GEAR TRAINS	4	2,500	10,000

TOTAL WEIGHT OF TRUCK ASSEMBLY : 160,000 LBS
80 TONS

5-REQ'D @ 80 TONS = 400 TONS TOTAL

STRUCTURAL WT. EXCLUSIVE GEAR TRAINS : 75 TONS

* INCLUDES WEIGHT OF BRAKES, AIR COMPRESSOR (FOR BRAKE RELEASE) BRACKETS ETC.

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.17 OF 76
DATE 1-22-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

3.7 ALTERNATE TRUCK DESIGN.

FOUNDATION TO BE CONCRETE SLAB AND TRACK TO CONSIST OF TWO 175 # CRANE RAILS @ 5 FT. CENTER TO CENTER. WHEELS TO BE STD. 36 IN. DIA. DOUBLE FLANGE CRANE-WHEELS HAVING A RATED LOAD CAPACITY OF 176,000 LBS EACH.

8 WHEELS ARE REQUIRED PER TRUCK @ 4 FT. CENTER DISTANCE.

MAXIMUM WHEEL LOAD IS ASSUMED TO BE 250,000 LBS.

3.8 STIFFNESS OF CONCRETE TRACK BED; (PRELIMINARY)

3.8.1 STRESS IN RAIL

RAIL PROPERTIES :

$I_{MAX} = 70.515 \text{ IN}^4$

$Z_{MIN} = 23.373 \text{ IN}^3$

BASEWIDTH = 6 IN

HEIGHT = 6 IN

$$\beta = \sqrt[4]{\frac{K}{4EI}} \quad ; \quad M_{B\,MAX} = \frac{P_{MAX}}{4\beta}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

K_0 FOR CONCRETE : 3.0×10^6 LBS/IN^3

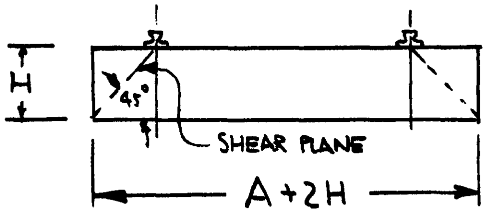
$$K = K_0 L = 3.0 \times 10^6 \times 6 = \underline{18 \times 10^6 \text{ LBS/IN}^2}$$

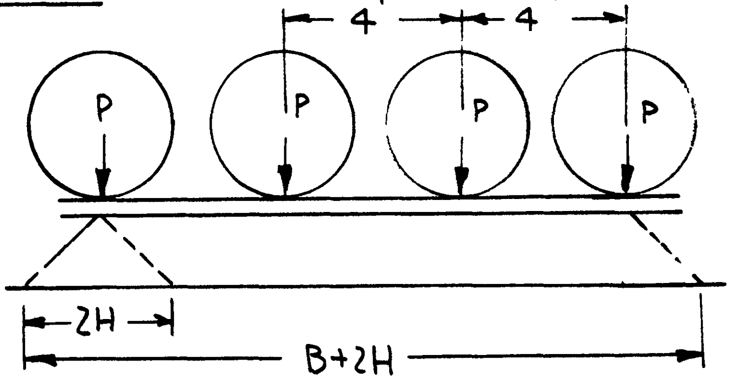
$$\beta = \sqrt[4]{\frac{18 \times 10^6}{4 \times 30 \times 10^6 \times 70.515}} = \sqrt[4]{.00213} = \underline{.215 \text{ IN}^{-1}}$$

$$M_{BMAX} \text{ IN RAIL} = \frac{250,000}{4 \times .215} = \underline{291,000 \text{ IN LBS}}$$

$$S_{BMAX} \text{ IN RAIL} = \frac{291,000}{23.373} = \underline{12,400 \text{ PSI}} \quad \text{(OK)}$$

3.8.2 SIZING OF CONCRETE SLAB :





ASSUME : H = 2 FT

THEN : A + 2H = 5 + 4 = $\underline{9 \text{ FT}}$

AND : B + 2H = 16 + 4 = $\underline{20 \text{ FT}}$

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.19 OF 76
DATE 1-22-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

EFFECTIVE PRESSURE AREA = 9×30 = $\underline{270 \text{ FT}^2}$
(AT STOW POSITION)

THEREFOR : BEARING PRESSURE, $q = \frac{8 \times 250{,}000}{270} = \underline{7{,}400 \text{ PSF}}$ (OK)

$$I_{SLAB} = \frac{108 \times 24^3}{12} = \underline{124{,}000 \text{ IN}^4}$$

K_0 FOR SOIL = 400 LBS/IN^3 (SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES, GROUP GM*)

$$K = K_0 l = 400 \times 108 = \underline{43{,}200 \text{ LBS/IN}^2}$$

$$\beta = \sqrt[4]{\frac{43{,}200}{4 \times 3.0 \times 10^6 \times 124{,}000}} = \sqrt[4]{2.90 \times 10^{-8}} = \underline{1.3 \times 10^{-2} \text{ IN}^{-1}}$$

$$M_{BMAX} = \frac{W_{MAX}}{4\beta^2}(B\beta_a + B\beta_b) = \frac{8350}{4 \times (.013)^2}(.42)$$

$W_{MAX} = \frac{2 \times 10^6}{240} = 8350 \text{ \#/IN}$

$$= \frac{8350}{.00068}(.42) = \underline{5.2 \times 10^6 \text{ INLBS}}$$

$\beta_a = \beta_b = .013 \times 120 = 1.56$
$B\beta_a = .21$

$$S_{BMAX} = \frac{5.2 \times 10^6}{1.24 \times 10^5 / 12} = \underline{\underline{500 \text{ PSI}}} \quad \text{(OK)}$$

V.S. MODULUS OF RUPTURE OF APPROX. 750 PSI
(ENDURANCE LIMIT ≈ 375 PSI)
REQUIRES SOME STEEL REINFORCEMENT !

* FROM BILL HORNE

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.20 OF 76
DATE 1-22-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

3.8.3 DEFLECTIONS : (PRELIMINARY)

a) RAIL : $Y_{0_R} = \frac{\beta P}{2K} = \frac{.215 \times 250{,}000}{2 \times 18 \times 10^6} = \underline{.0015 \text{ IN}}$

b) FOUNDATION & SOIL : $Y_{0_F} = \frac{W}{2K}(2 - A_{\beta a} - A_{\beta b})$

$A_{\beta a}$ FOR $a = 120$ IN : $\beta a = 120 \times .013 = 1.56$

$A_{\beta a} = D_{\beta b} = .217$

$$Y_{0_F} = \frac{8350}{2 \times 43{,}200} \overset{(1.566)}{(2 - .434)} = \underline{.1520 \text{ IN}}$$

$$Y_{TRACK} = .1520 + .0015 = \underline{\underline{.1535 \text{ IN}}}$$

SPRING CONSTANT : (PRELIMINARY)

$$K_{TRACK} = \frac{2 \times 10^6}{.1535} = \underline{\underline{13.0 \times 10^6 \text{ LBS/IN}}}$$

OR ASSUME SINGLE WHEEL PAIR LOAD OF 500,000 LBS OVER A 4 FT (48 IN WIDTH) + 2×6 IN

THEN $Y_{0F} = \frac{500{,}000/60}{2 \times 75{,}500} \times 1.753 = \underline{.0970 \text{ IN}}$ OK

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.21 OF 76
DATE 1-22-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAIL

SUBJECT: AZIMUTH TURNTABLE

3.84 CONTACT STRESS IN WHEEL AND RAIL :

$R_{WHEEL} = 18$ IN ; $R_{RAIL} = 18$ IN

$$\frac{B}{A} = \frac{18}{18} = \underline{1.0}$$

$$A + B = \frac{1}{2\times18} + \frac{1}{2\times18} = \underline{.0555 \text{ IN}^{-1}}$$

$$\Delta = \frac{2(1-\mu^2)}{(A+B)E} = \frac{2(1-.25^2)}{.0555\times30\times10^6} = \underline{11.2\times10^{-7} \text{ IN}^3/\text{LB}}$$

$$b = C_b\sqrt[3]{P\Delta} \; ; \; C_b = .90 \text{ FOR } \frac{B}{A} = 1.0$$

$$= .90\sqrt[3]{250{,}000\times11.2\times10^{-7}} = \underline{.588 \text{ IN}}$$

$$\frac{b}{\Delta} = \frac{.588}{11.2\times10^{-7}} = \underline{525{,}000 \text{ LBS}/\text{IN}^2}$$

$$\sigma_{MAX} = -C_\sigma\left(\frac{b}{\Delta}\right) = .64\times525{,}000 = \underline{\underline{340{,}000 \text{ PSI}}}$$

$$\tau_{MAX} = C_\tau\left(\frac{b}{\Delta}\right) = .22\times525{,}000 = \underline{\underline{115{,}000 \text{ PSI}}}$$

$$\tau_{6\,MAX} = C_{\tau_6}\left(\frac{b}{\Delta}\right) = .19\times525{,}000 = \underline{\underline{100{,}000 \text{ PSI}}}$$

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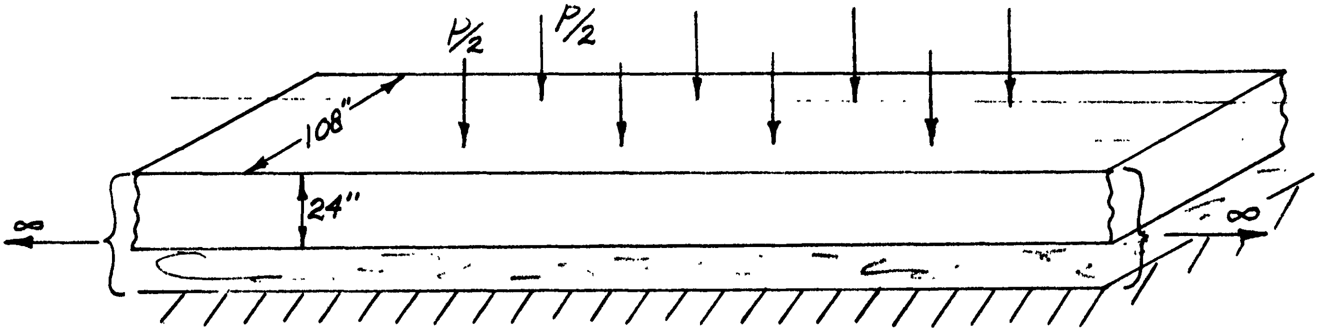
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE AZIMUTH TURNTABLE
SUBJECT: DESIGN IN CIRCUMFERENTIAL DIRECTION
REFERENCE: NRAO DRAWING NO. 109-D-012
FINAL FOUNDATION ANALYSIS

3.8.5 I. CONCRETE FOUNDATION IN THE CIRCUMFERENTIAL DIRECTION IS CONSIDERED TO BE AN INFINITE BEAM ON AN ELASTIC FOUNDATION.



LOADS, P/2 AT 4' CENTERS LONGITUDINALLY AND 5' CENTERS TRANSVERSLY; $P = 3.5 \times 10^5$ LBS.

ASSUME THESE CONCRETE PROPERTIES:

$$f_c' = 4000 \text{ PSI}$$

WORKING STRESS FOR CONCRETE:

$$f_c = 0.45 \times 4000$$

$$= 1800 \text{ PSI}$$

THE FOLLOWING REFERENCE MAKES A STATEMENT AS TO THE ENDURANCE LIMIT OF CONCRETE:

F.S. OPLE, JR. & C.L. HALSBOS; "PROBABLE FATIGUE LIFE OF PLAIN CONCRETE WITH STRESS GRADIENT"; ACI JOURNAL, TITLE NO. 63-2 VOL. 63; JAN '66; PG 59

CONCLUSION 7, PG 79 MAKES THE FOLLOWING STATEMENT: "THE CURRENT AASHO ALLOWABLE CONCRETE COMPRESSIVE STRESS OF 0.40 f_c IS A CONSERVATIVE ESTIMATE OF THE FATIGUE STRENGTH OF CONCRETE IN COMPRESSION.... A COMPRESSIVE STRESS OF 0.50 f_c' MAY BE ALLOWED AT THE TOP FIBRES

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REPORT NO. H79-6
CONTRACT NO. RAP-79
PAGE 3.23 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

WORKING STRESS FOR STEEL:

$$f_s = 20000 \text{ PSI}$$

THIS REFERENCE COMMENTS ON THE ENDURANCE LIMIT OF STEEL:

KENNETH T. BURTON & EIVIND HOGNESTAD; "FATIGUE TESTS OF REINFORCING BARS - TACK WELDING OF STIRRUPS" ACI JOURNAL, TITLE NO. 64-24; VOL. 64; MAY 1967, PG. 244

FIGURE 5 ON PG 249 CLEARLY SHOWS THAT THE ENDURANCE LIMIT IS ABOUT 20KSI.

MODULUS OF ELASTICITY:

$E_c = \omega^{1.5} 33 \sqrt{f_c''}$ ACI CODE SEC 1102(a)

FOR 4000 PSI CONCRETE, $E_c = 3.6 \times 10^6$ PSI

USE! WORKING STRESS DESIGN

SEE ACI BUILDING CODE TABLE 1002(a)
SECTION 1003

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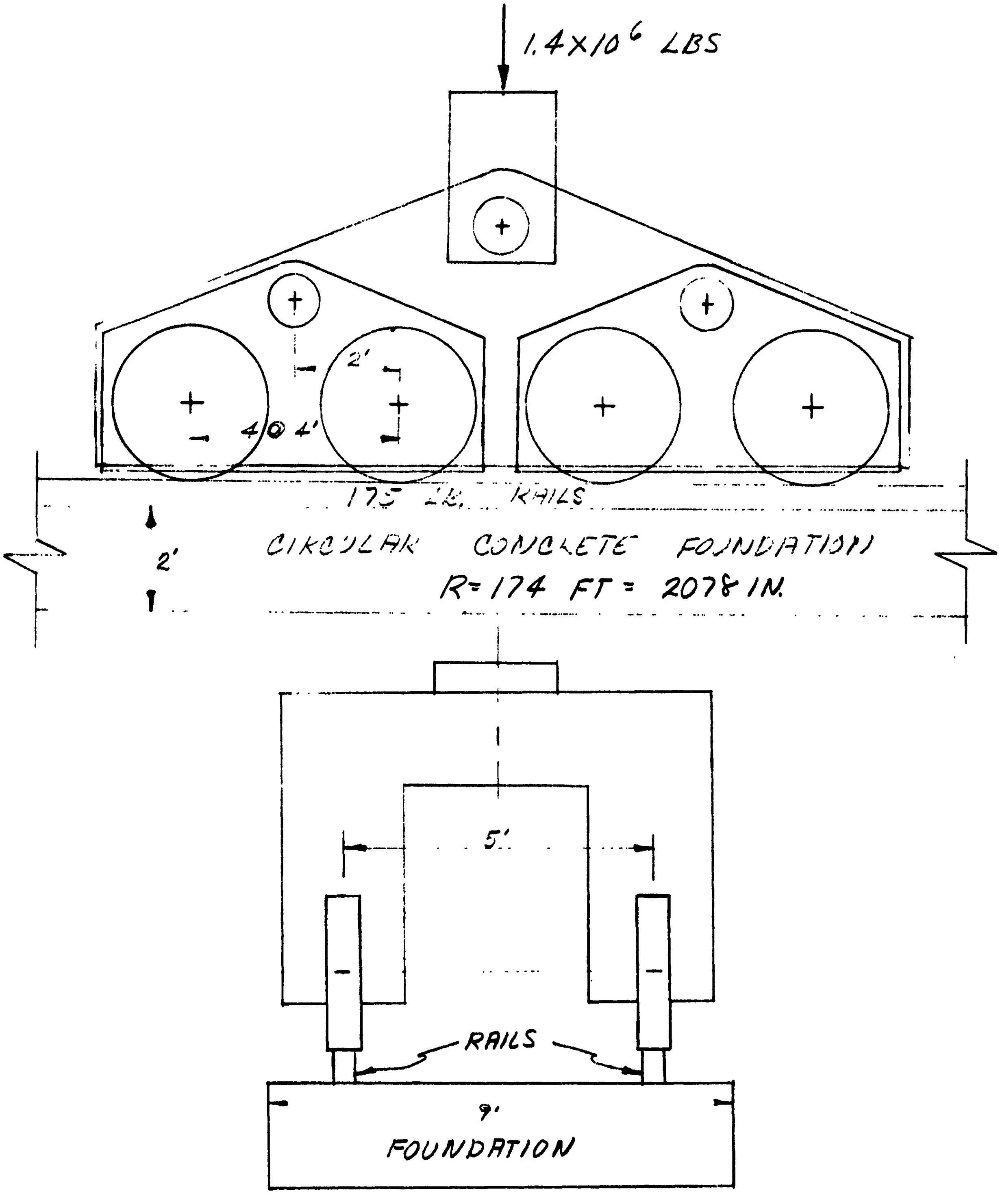
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.24 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE



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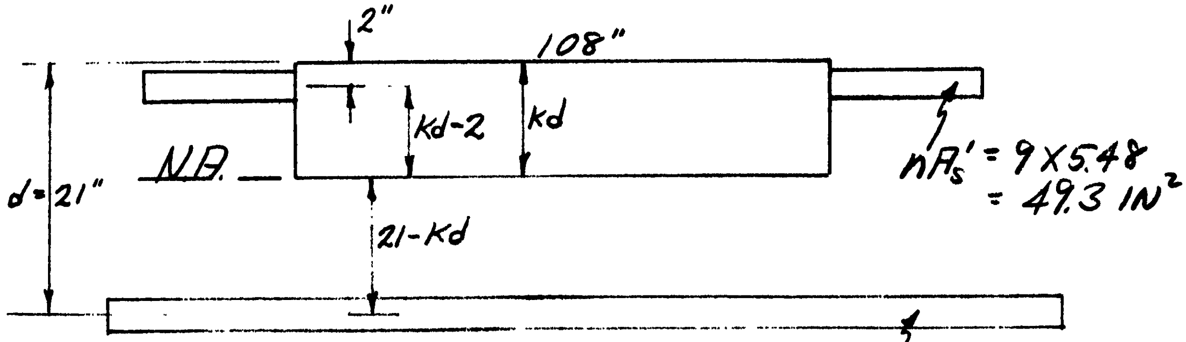
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.25 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

LONGITUDINAL TRANSFORMED SECTION

TRY: $A_s = 27.55 \text{ IN}^2$ $A_s' = 5.48 \text{ IN}^2$



AREA MOMENTS ABOUT N.A.:

$nA_s = 9 \times 27.55$
$= 247.5 \text{ IN}^2$

$$108\,kd\left(\frac{kd}{2}\right) + 49.3(kd-2) = 248(21-kd)$$

$$54(kd)^2 + 49.3\,kd - 98.6 = 5208 - 248\,kd$$

$$54(kd)^2 + 297\,kd = 5307$$

$$(kd)^2 + 5.50\,kd + \left(\frac{5.50}{2}\right)^2 = \overset{105.86\ \ 7.56}{\cancel{98.3 + \left(\frac{5.50}{2}\right)^2}}$$

$$(kd + 2.75)^2 = (10.29)^2$$

$$kd = 7.54 \text{ IN.} \quad ; \quad K = 0.359$$

MOMENT OF INERTIA OVER POSITIVE MOMENT LENGTH

$$I_1 = \frac{108\overset{429}{(7.54)^3}}{12} + (108 \times 7.54)\overset{14.28}{\cancel{\left(\frac{7.54}{2}\right)^2}} + 49.3\overset{30.75}{\cancel{(5.54)^2}} + 247.5\overset{181.}{\cancel{(13.46)^2}}$$

$$= 3860 + 11620 + 1514 + 44{,}800$$

$$= 61{,}790 \text{ IN}^4$$

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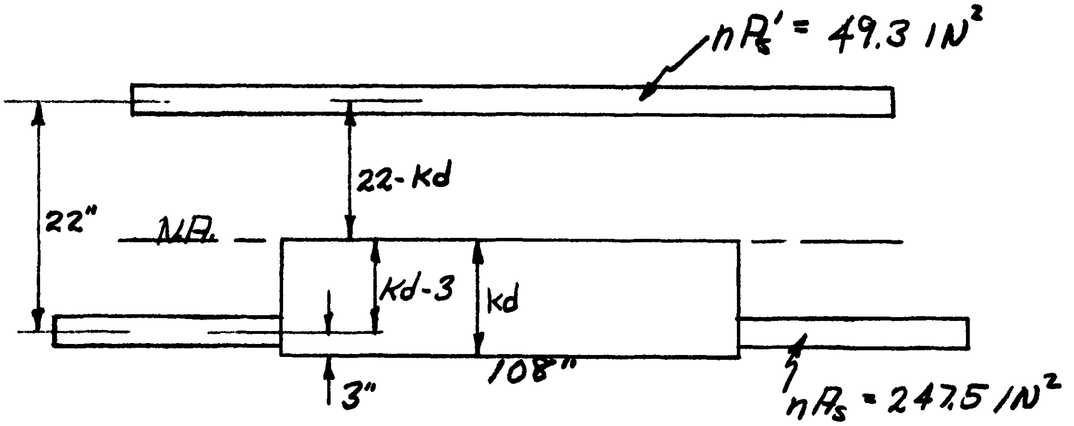
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

OVER THE PORTION OF THE BEAM WITH NEGATIVE MOMENT THERE WILL BE A DIFFERENT DEPTH FOR THE COMPRESSION BLOCK AND A DIFFERENT MOMENT OF INERTIA



AREA MOMENTS ABOUT NEUTRAL AXIS:

$$108Kd\left(\frac{Kd}{2}\right) + 247.5(Kd-3) = 49.3(22-Kd)$$

$$54(Kd)^2 + 247.5Kd - 744 = 1085 - 49.3Kd$$

$$54(Kd)^2 + 297Kd = 1829$$

$$(Kd)^2 + 5.50Kd + \left(\frac{5.50}{2}\right)^2 = \overset{41.43}{\cancel{33.87}} + \overset{7.56}{\cancel{\left(\frac{5.50}{2}\right)^2}}$$

$$(Kd + 2.75)^2 = (6.44)^2$$

$$Kd = 3.69\ IN.$$

MOMENT OF INERTIA:

$$I_2 = \frac{108\overset{50.3}{\cancel{(3.69)^3}}}{12} + (108 \times 3.69)\overset{3.40}{\cancel{\left(\frac{3.69}{2}\right)^2}} + 247.5\overset{0.477}{\cancel{(0.69)^2}} + 49.3\overset{335.5}{\cancel{(18.31)^2}}$$

$$= 452 + 1356 + 118 + 16570$$

$$= 18,496\ IN^4$$

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REPORT NO. H79-6
CONTRACT NO. RAP-79
PAGE 3.27 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

THE BEAM HAS TWO INERTIAS, ONE THREE TIMES THE OTHER. FOR THIS ITERATION THE EFFECTIVE MOMENT OF INERTIA WILL BE TAKEN AS THE AVERAGE.

$$I_{EFFECTIVE} = \frac{I_1 + I_2}{2}$$

$$= \frac{18496 + 61790}{2}$$

$$= 40,143 \ IN^4$$ ←

CAUTION: THE FINAL DESIGN SHOULD CONSIDER THE CHANGE IN INERTIA. THE ANALYTICAL PROCEDURE IS OUTLINED IN; HETENYI, M.; BEAMS ON ELASTIC FOUNDATION; UNIVERSITY OF MICHIGAN PRESS; 1946; Pg 97

COMPUTE THE CONSTANT, β, FROM THE EFFECTIVE INERTIA.

$$\beta = \sqrt{\frac{K}{4EI}}$$

WHERE:

$K = 400 \ LBS/IN^3 \times 108 \ IN.$
$= 43,200 \ LBS/IN. \ DEFL. /LINEAL \ IN.$
$E_c' = 3.64 \times 10^6 \ PSI$
$I = 4.014 \times 10^4 \ IN^4$

$$\beta = \sqrt[4]{\frac{4.32 \times 10^4}{4 \times 3.64 \times 10^6 \times 4.014 \times 10^4}}$$

$$= \sqrt[4]{7.41 \times 10^{-8}}$$

$$= 0.0165 \ IN^{-1}$$

$$\lambda = \frac{6.28}{0.0165}$$

$$= 381 \ IN = 31.7 \ FT,$$ ←

NOTE: TO ACCOUNT FOR LACK OF ISOTROPIC CURVATURE

$$E_c' = \frac{E_c}{1-\nu^2} = \frac{360 \times 10^6}{1-(0.1)^2}$$

$$= 3.64 \times 10^6$$

λ, THE WAVELENGTH OF THE ELASTIC CURVE, IS AN INDICATION OF THE LENGTH OF THE INFINITE BEAM TO BE CONSIDERED.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

COMPUTE MOMENTS BY A SEMI-GRAPHICAL PROCEDURE: SUPERIMPOSE THE FOUR LOADS TO OBTAIN THE MOMENT DIAGRAM IN THE VICINITY OF THE TRUCK. FOR A CONCENTRATED LOAD:

$$M = \frac{P}{4\beta} C(\beta x)$$

βx	x	$C(\beta x)$
0	0	1.000
0.5	30.3	0.242
1.0	60.6	-0.111
1.5	90.9	-0.207
2.0	121.2	-0.179
2.5	151.5	-0.115
3.0	182.0	-0.056
3.5	212.	-0.018
4.0	242.	+0.002
4.5	272	0.009
5.0	303	0.008

THE FUNCTIONS OF (βx) ARE TAKEN FROM THE HETENYI REFERENCE

THE SUPERPOSITION IS DONE GRAPHICALLY ON PG. 10. A MAXIMUM OCCURS AT $x_1 = 96''$. NUMERICALLY

$$M_{MAX}\Big/_{x_1=96} = \frac{P}{4\beta}\left[C(\beta x_1) + C(\beta x_2) + C(\beta x_3) + C(\beta x_4)\right]$$

WHERE: $x_1 = 96$, $x_2 = 48$, $x_3 = 0$, $x_4 = 48$

$$= \frac{P}{4\beta}\Big[C(\overset{1.587}{\cancel{0.0165 \times 96}}) + C(\overset{0.793}{\cancel{0.0165 \times 48}})$$

$$+ C(\overset{0}{\cancel{0.0165 \times 0}}) + C(\overset{0.793}{\cancel{0.0165 \times 48}})$$

$$= \frac{P}{4\beta}\Big[- 0.2079 - 0.0048 + 1.00 - 0.0048)$$

$$= \frac{P}{4\beta}(0.7825)$$

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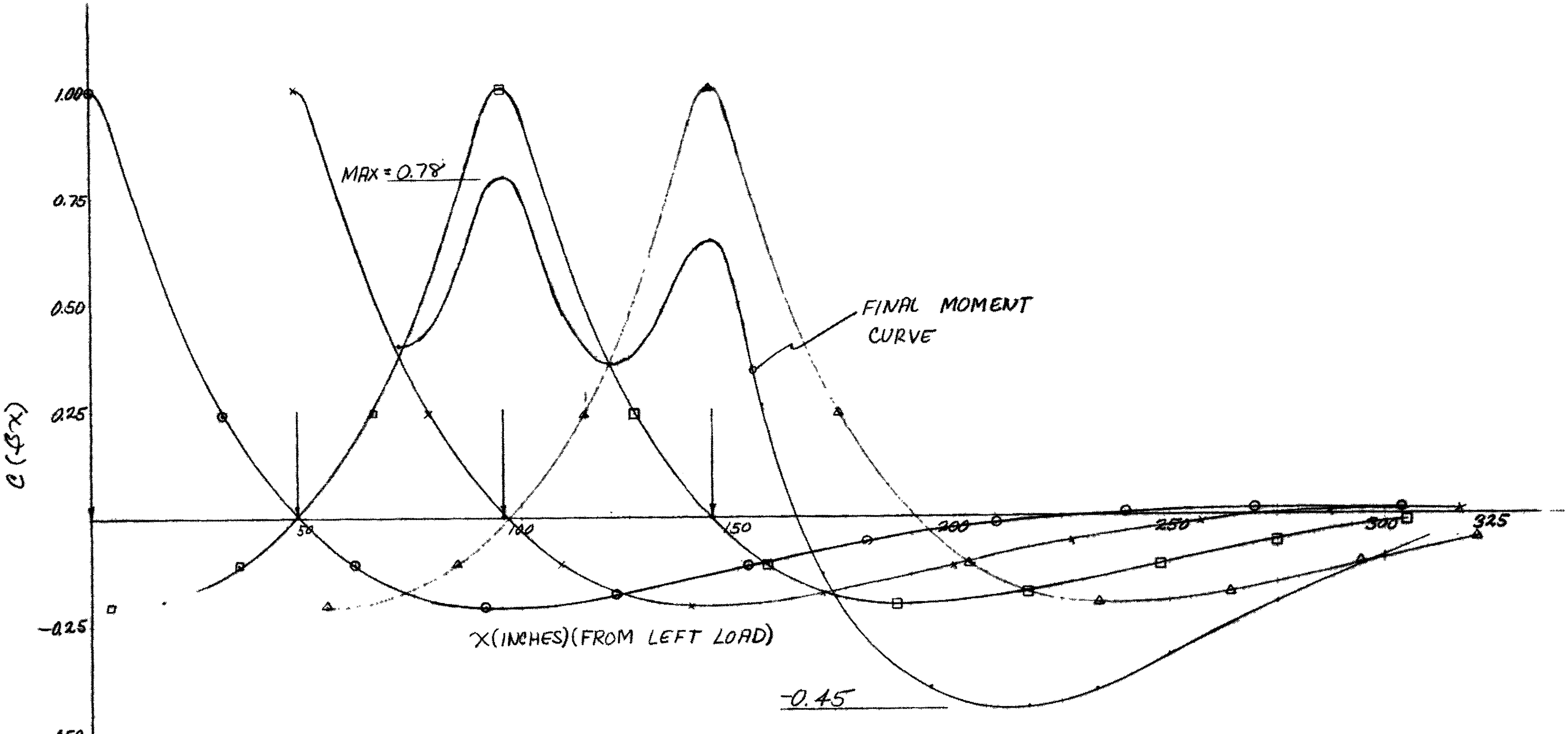

FIGURE 1 LONGITUDINAL INFINITE BEAM MOMENT DIAGRAM

W.B.

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

$$M_{MAX} = \frac{3.50\times10^{5}\times 0.7825}{4\times 0.0165}$$

$$= 4.15\times10^{6} \text{ IN-LBS}$$

A MAXIMUM NEGATIVE MOMENT OCCURS AT $x_1 = 212''$

$$M_{MIN}\Big|_{x_1=212} = \frac{P}{4\beta}\left[C(\beta x_1) + C(\beta x_2) + C(\beta x_3) + C(\beta x_4)\right]$$

WHERE: $x_1 = 212,\ x_2 = 164,\ x_3 = 116,\ x_4 = 68$

$$= \frac{P}{4\beta}\Big[C(\overset{3.50}{\cancel{0.0165\times212}}) + C(\overset{2.71}{\cancel{0.0165\times164}})$$

$$+ C(\overset{1.91}{\cancel{0.0165\times116}}) + C(\overset{1.12}{\cancel{0.0165\times68}})$$

$$= \frac{P}{4\beta}\Big[-0.0177 - 0.0883 - 0.1889 - 0.1516)$$

$$= \frac{-P}{4\beta}(-0.4465)$$

$$= -\frac{3.50\times10^{5}\times 0.4465}{4\times 0.0165}$$

$$M_{MIN} = -2.365\times10^{6} \text{ IN-LBS}$$

COMPUTE STRESSES IN POSITIVE AND NEGATIVE MOMENT PORTIONS

POSITIVE MOMENT LENGTH:

$$f_c = \frac{Mc}{I}$$

$M = 4.15\times10^{6}$ IN-LB
$c = 7.54$ IN
$I = 61,790$

$$f_c = \frac{4.15\times10^{6}\times 7.54}{6.179\times10^{4}}$$

$f_c = 506$ PSI < 1800 PSI OK

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.31 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

$$f_{cs} = \frac{4.15 \times 10^{6} \times 13.46}{6,179 \times 10^{4}} = 903$$

$$f_s = n f_{cs} = 9 \times 903$$

$$= 8,130 \text{ PSI} < 20,000 \text{ PSI O.K.}$$

NEGATIVE MOMENT LENGTH:

$$M = -2.365 \times 10^{6} \text{ IN-LBS}$$
$$I = 1.85 \times 10^{4} \text{ IN}^{4}$$

$$f_c = \frac{Mc}{I} = \frac{2.365 \times 3.69 \times 10^{6}}{1.85 \times 10^{4}}$$

$$= 472 \text{ PSI} < 1800 \text{ PSI OK}$$

$$f_{cs} = \frac{2.365 \times 18.31 \times 10^{6}}{1.85 \times 10^{4}} = 2340 \text{ PSI}$$

$$f_s = n f_{cs} = 9 \times 2340$$

$$= 21,050 \text{ PSI} > 20,000 \text{ PSI ALLOWABLE}$$

COMPUTE DEFLECTIONS BY A METHOD SIMILAR TO THAT USED FOR MOMENTS

βx	x	$A(\beta x)$
0	0	1.000
0.5	30.3	0.823
1.0	60.6	0.508
1.5	90.9	0.238
2.0	121.2	0.067
2.5	151.5	-0.017
3.0	182.0	-0.042
3.5	212	-0.039
4.0	242	-0.026
4.5	272	-0.013
5.0	303	-0.005

$$y = \frac{P\beta}{2k} A(\beta x)$$

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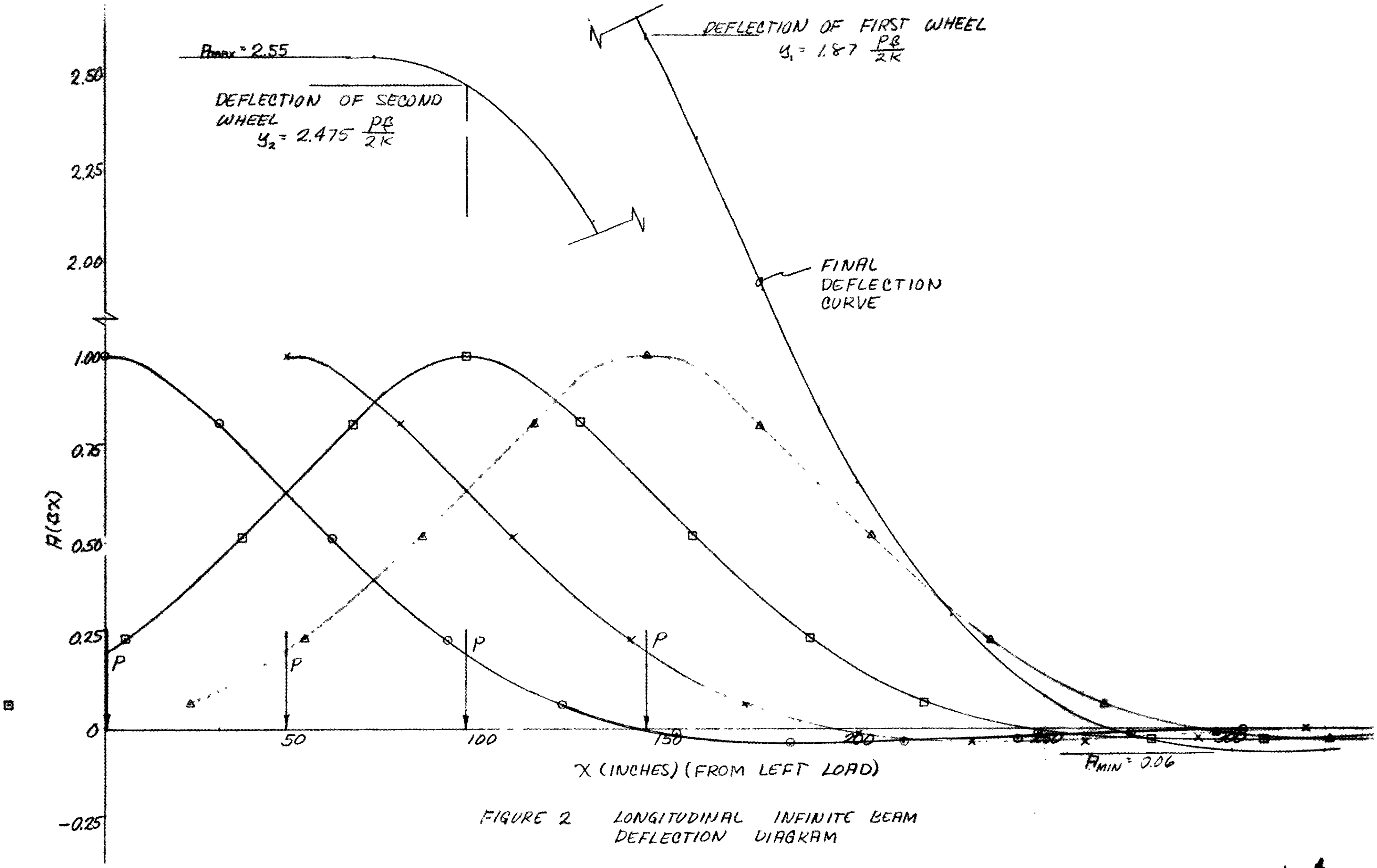

FIGURE 2 LONGITUDINAL INFINITE BEAM DEFLECTION DIAGRAM

W. B.

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

THE SEMIGRAPHICAL SOLUTION TO THE DEFLECTION CURVE IS GIVEN ON PG. 14. A MAXIMUM OCCURS AT $X_1 = 72$.

$$y_{MAX} = \frac{P\beta}{2K}\left[A(\beta X_1) + A(\beta X_2) + A(\beta X_3) + A(\beta X_4)\right]$$

WHERE: $X_1 = 72$, $X_2 = 24$, $X_3 = 24$, $X_4 = 72$

$$y_{MAX} = \frac{P\beta}{2K}\left[A(\overset{1.188}{0.0165 \times 72}) + A(\overset{0.396}{0.0165 \times 24}) + A(\overset{0.396}{0.0165 \times 24}) + A(\overset{1.188}{0.0165 \times 72})\right]$$

$$y_{MAX} = \frac{P\beta}{2K}\left[0.3966 + 0.8805 + 0.8805 + 0.3966\right)$$

$$= \frac{3.60 \times 10^{5} \times 1.65 \times 10^{-2}}{2 \times 4.32 \times 10^{4}}(2.554)$$

$$= 0.0668 \times 2.554$$

$$= 0.1705 \text{ IN.}$$

FROM THE GRAPHICAL SOLUTION THE DEFLECTION OF THE TOP PIVOT IS FOUND

DEFLECTION OF FIRST WHEEL

$$y_1 = 1.87 \frac{P\beta}{2K} = 1.87 \times 0.0668$$

$$= 0.125 \text{ IN}$$

DEFLECTION OF SECOND WHEEL

$$y_2 = 2.475 \frac{P\beta}{2K} = 2.475 \times 0.0668$$

$$= 0.1653 \text{ IN.}$$

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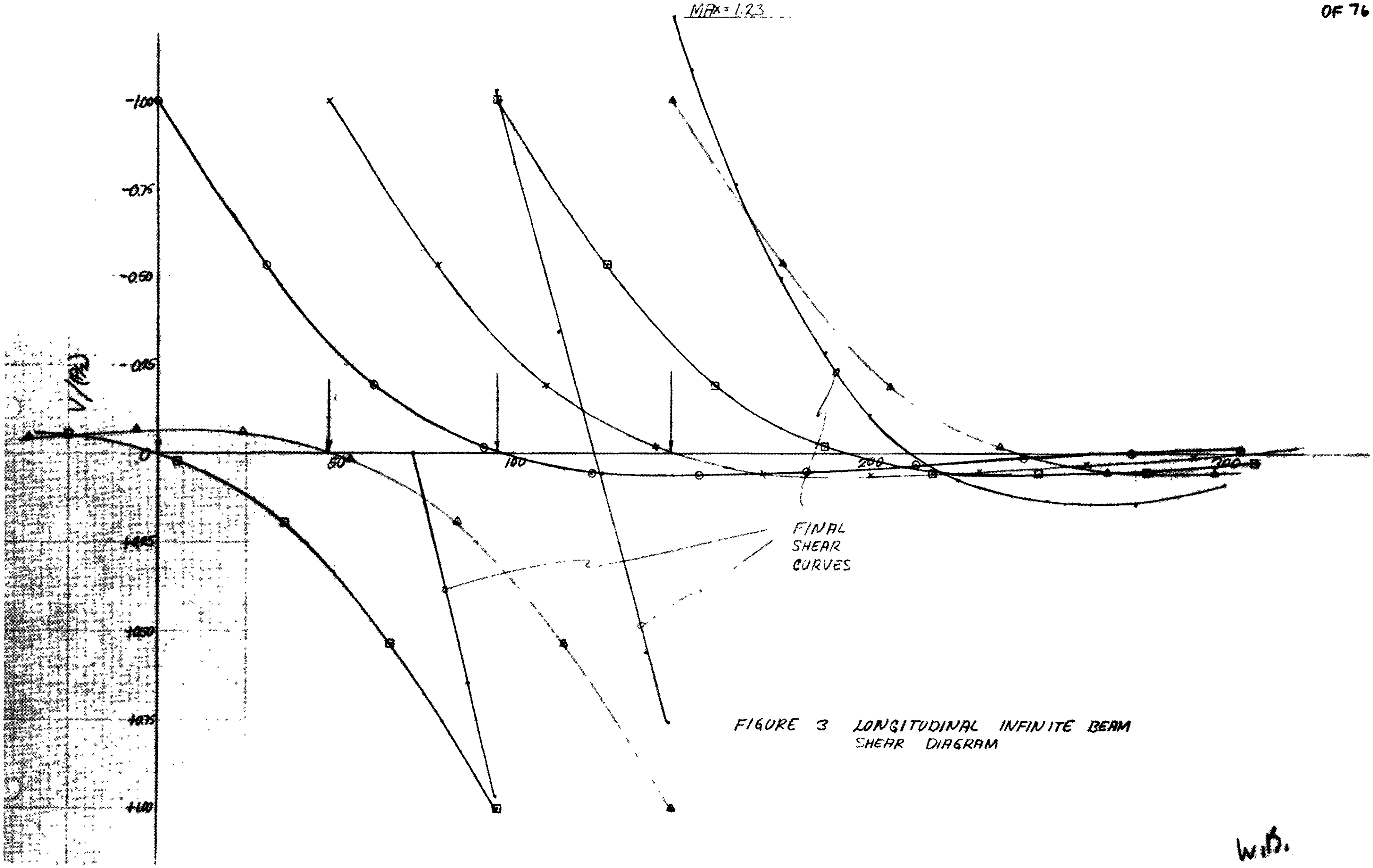


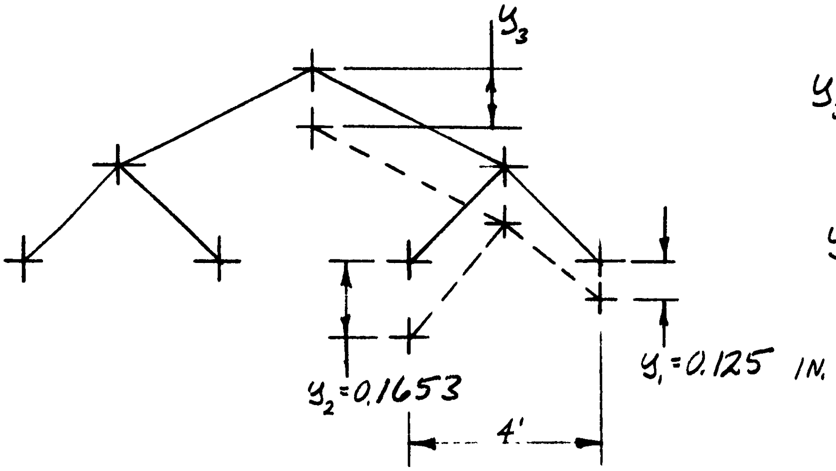
FIGURE 3 LONGITUDINAL INFINITE BEAM
SHEAR DIAGRAM

W.B.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-35 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE



$$y_3 = \frac{y_1 + y_2}{2}$$

$$= \frac{0.125 + 0.1653}{2}$$

$$y_3 = 0.145 \text{ IN.}$$

THE ALLOWABLE DEFLECTION IS:

$$y_{ALL.} = \frac{4P}{K_{ALL}}$$

WHERE THE ALLOWABLE STIFFNESS IS GIVEN AS:

$$K_{ALL} = 1.3 \times 10^7 \text{ LBS/IN.}$$

$$y_{ALL} = \frac{4 \times 3.50 \times 10^5}{1.3 \times 10^7}$$

$$= 0.1076 \text{ IN.} < y_3 = 0.145 \quad \text{N.G.}$$

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REPORT NO. H79-6
CONTRACT NO. RAP-79
PAGE 3-36 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

COMPUTE EFFECTIVE LENGTH OF RIGID BEAM REQUIRED TO OBTAIN SPECIFIED STIFFNESS

$$K_S L_{EFF} = K_{ALL}$$

$$L_{EFF} = \frac{K_{ALL}}{K_S} = \frac{1.3 \times 10^7 \text{ LBS/IN DEFL}}{4.32 \times 10^4 \text{ LBS/IN DEFL/LIN. IN}}$$

$$L_{EFF} = 301.5 \text{ LINEAL INCHES}$$

COMPARING L_{EFF} TO L OF DEFLECTION DIAGRAM (PG. 14), IN RANGE WHERE FOUNDATION REACTION IS "SIGNIFICANT", SAY AS AN EXAMPLE WHERE $\delta = \frac{1}{2} \delta_{MAX}$

$$x_1 = 170'' \quad \text{OR} \quad L = 196 \text{ IN.}$$

SINCE L REQUIRED FOR THE RIGID BEAM IS MUCH GREATER THAN $L = 196$ IN., IT IS DOUBTFUL THAT ANY REASONABLE SECTION WOULD PROVIDE THE STIFFNESS REQUIRED.

$$\text{THUS} \quad K_{AQ} = \frac{1.4 \times 10^6}{.145} - \underline{9.67 \times 10^6} \text{ LBS/IN}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

COMPARE DEAD WEIGHT DEFLECTION WITH MAXIMUM NEGATIVE DEFLECTION DUE TO LIVE LOAD

MAXIMUM NEGATIVE DEFLECTION:

$$A_{MIN} = 0.06 \quad AT \quad X_1 \approx 325 \text{ IN}$$

$$y_{MIN} = 0.06 \frac{P\beta}{2K}$$

$$= 0.06 (0.0668)$$

$$= 40.2 \times 10^{-4} \text{ IN.}$$

DEAD WEIGHT DEFLECTION:

$$y_{DW} = \frac{W}{K}$$

$$\text{WHERE} \quad W = \frac{150 \times 9 \times 2}{12}$$

$$= 225 \text{ LBS/LIN. IN.}$$

$$y_{DW} = \frac{225}{4.32 \times 10^{4}}$$

$$= 56.3 \times 10^{-4} \text{ IN} > 40.2 \times 10^{-4} \text{ IN} = y_{MIN}$$

THEREFORE THE FOUNDATION DOES NOT LIFT-OFF (OR REQUIRE TENSION TO BE DEVELOPED IN FOUNDATION.) THE BEAM ON AN ELASTIC FOUNDATION MODEL IS A GOOD ONE.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

COMPUTE THE SHEAR FOR THE LONGITUDINAL INFINITE BEAM. SUPERIMPOSE THE FOUR LOADS BY A SEMIGRAPHICAL PROCEDURE:

$$V = -\frac{P}{2} D(\beta x)$$

βx	x	$D(\beta x)$
0	0	1.00
0.5	30.3	0.5323
1.0	60.6	0.1987
1.5	90.9	0.0158
2.0	121.2	-0.0563
2.5	151.5	-0.0658
3.0	182.0	-0.0493
3.5	212	-0.0283
4.0	242	-0.0120
4.5	272	-0.0023
5.0	303	0.0019

THE SEMIGRAPHICAL SOLUTION IS GIVEN ON PG. 17. FROM THAT FIGURE A SHEAR MAXIMUM OCCURS AT $x_1 = 144$". NUMERICALLY:

$$x_1 = 144, \; x_2 = 96, \; x_3 = 48, \; x_4 = 0$$

$$V = -\frac{P}{2}\{D(0.0165 \times 144) + D(0.0165 \times 96) + D(0.0165 \times 48) + D(0.0165 \times 0)\}$$

$$= -\frac{P}{2}\{\overset{-0.0671}{D(2.375)} + \overset{-0.0023}{D(1.583)} + \overset{+0.3182}{D(0.792)} + \overset{+1.00}{D(0)}\}$$

$$\begin{array}{r} 0.3195 \\ \underline{0.3131} \\ .0064 \\ \underline{\times .2} \\ .00128 \end{array} \qquad \begin{array}{r} 0.3195 \\ \underline{-0.0013} \\ 3182 \end{array}$$

$$V = -\frac{3.5 \times 10^5}{2}\{1.249\} \quad \text{GRAPHICALLY } \{1.23\} \text{ O.K.}$$

$$V_{MAX} = 2.01 \times 10^5 \text{ LBS.}$$

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-31 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

THE NOMINAL SHEAR STRESS IS:

$v = \frac{V}{bd}$ ACI BUILDING CODE SEC 1201(a)

$v = \frac{0.201 \times 10^6}{108 \times 21}$

$= 88.7$ PSI

$v_{ALL} = 1.1\sqrt{f_c}$ ACI BUILDING CODE TABLE 1002(a)

$= 70$ PSI WITH NO VERTICAL REINFORCEMENT

$v_{ALL} = 5.0\sqrt{f_c'}$ WITH REINFORCEMENT

$= 316$ PSI > 88.7 PSI OK.

DETERMINE SPACING OF VERTICAL REINFORCEMENT

SPACING DETERMINED BY RESTRICTIONS IN SEC 1706 ACI CODE

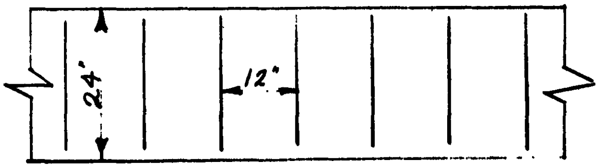
$S = \frac{d}{2} = \frac{24}{2} = 12$ IN.

LONGITUDINALLY

S = 12 INCHES, #2 U-STIRRUPS

TRANSVERSELY:

S = 12 INCHES OF #2 U-STIRRUPS
OR 4 SETS OF U-STIRRUPS



LONGITUDINAL

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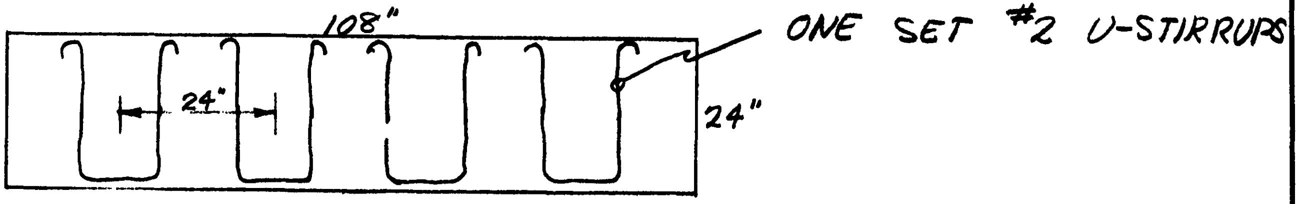
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-40 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE



TRANSVERSE

CHECK CRITERIA FOR AREA OF STEEL LONGITUDINALLY:

$$A_s \overset{?}{>} 0.0015 A_G$$

$$12 \times 8 \times 0.05 \overset{?}{>} 0.0015 \times 144 \times 12$$

$$4.80 IN > 2.59 IN^2 \quad \therefore \quad OK$$

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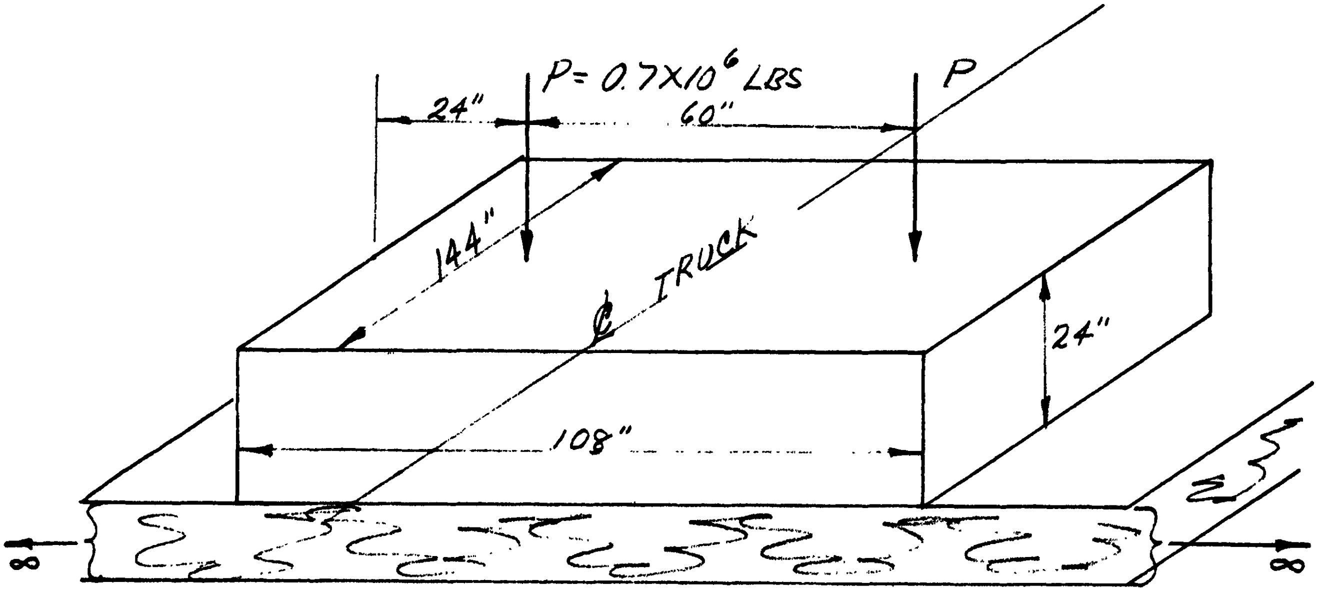
REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-41 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
AZIMUTH TURNTABLE
SUBJECT: DESIGN IN THE TRANSVERSE DIRECTION

II. THE FOUNDATION IN THE TRANSVERSE DIRECTION IS CONSIDERED TO BE A FINITE BEAM ON AN ELASTIC FOUNDATION



THE LOADS, P, ACT OVER THE 144" WIDTH. THIS IS THE SAME AS HAVING ONE-FOURTH THE LOAD ACTING ON A BEAM 48" WIDE.

$K' = 400 \text{ LBS/IN}^3$

$K = 144 \times 400$

$= 57{,}600$ LBS/IN. DEFL. / LINEAL IN.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

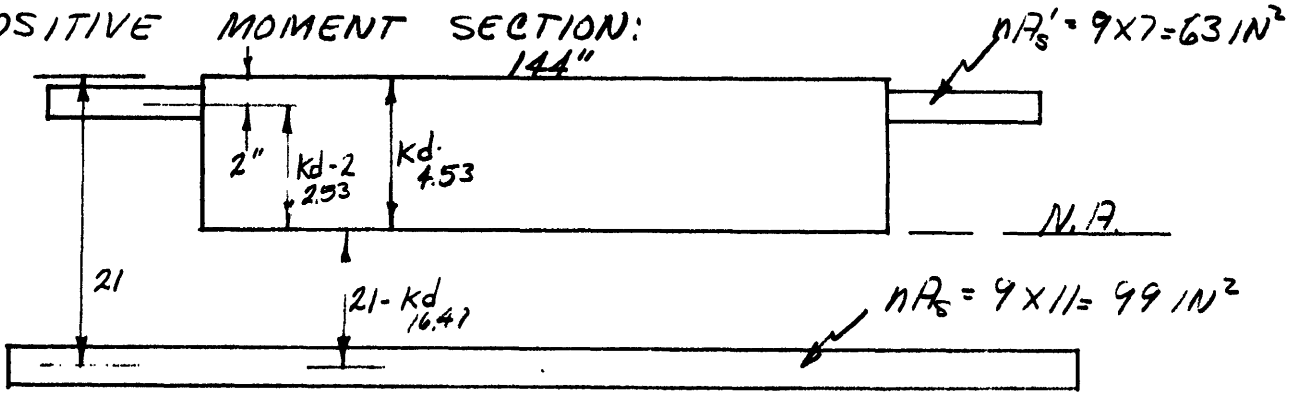
TRANSVERSE TRANSFORMED SECTION:

TRY: $A_s = 11.0 \text{ IN}^2$

$A_s' = 7.0 \text{ IN}^2$

DEPTH OF COMPRESSION BLOCK AND MOMENT OF INERTIA

POSITIVE MOMENT SECTION:



$$144kd\left(\frac{kd}{2}\right) + 63(kd-2) = 99(21-kd)$$

$$72(kd)^2 + 63kd - 126 = 2080 - 99kd$$

$$72(kd)^2 + 162kd = 2206$$

$$(kd)^2 + 2.25kd + \left(\frac{2.25}{2}\right)^2 = \cancel{\overset{31.92}{30.65} + \overset{1.265}{\left(\frac{2.25}{2}\right)^2}}$$

$$(kd + 1.125)^2 = (5.66)^2$$

$$kd = 4.53 \text{ INCHES}$$

$$I = \frac{144\overset{93.1}{(4.53)^3}}{12} + (144 \times 4.53)\overset{5.13}{\left(\frac{4.53}{2}\right)^2} + 63\overset{6.41}{(2.53)^2} + 99\overset{271.}{(16.47)^2}$$

$$= 1118 + 3350 + 404 + 26850$$

$$= 31{,}720 \text{ IN}^4$$

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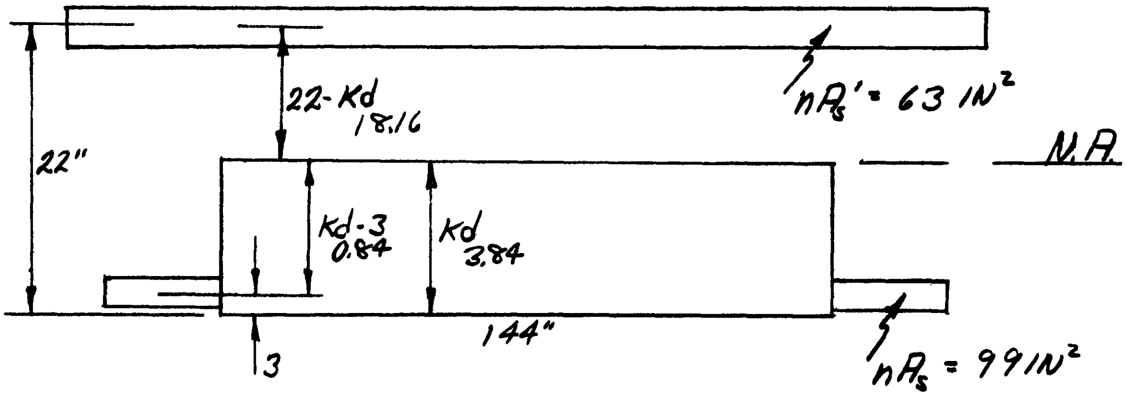
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

NEGATIVE MOMENT SECTION:



$$144Kd\left(\frac{Kd}{2}\right) + 99(Kd-3) = 63(22-Kd)$$

$$72(Kd)^2 + 99Kd - 297 = 1388 - 63Kd$$

$$72(Kd)^2 + 162\,Kd = 1685$$

$$(Kd)^2 + 2.25\,Kd + \left(\frac{2.25}{2}\right)^2 = \overset{24.67}{\cancel{23.4}} + \overset{\cancel{1.265}}{\cancel{\left(\frac{2.25}{2}\right)^2}}$$

$$(Kd + 1.13)^2 = (4.97)^2$$

$$Kd = 3.84 \text{ INCHES}$$

$$I = \frac{144\overset{56.6}{(3.84)^3}}{12} + (144 \times 3.84)\overset{3.685}{\left(\frac{3.84}{2}\right)^2} + 99\overset{0.705}{(0.84)^2} + 63\overset{329.5}{(18.16)^2}$$

$$= 679 + 2037 + 69 + 20{,}750$$

$$= 23{,}535\ IN^4$$

AGAIN, AS AN APPROXIMATION, AN EFFECTIVE MOMENT OF INERTIA IS USED. THE MORE EXACT ANALYSIS IS EXPLAINED IN THE HETÉNYI REFERENCE. THE STIFFNESS IS WEIGHTED TOWARD THE INERTIA OF THE POSITIVE MOMENT LENGTH SINCE POSITIVE MOMENT WILL EXIST ON 2/3 THE LENGTH OF THE BEAM.

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-44 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

$$I_{EFF} = 23{,}535 + \frac{2}{3}(31{,}720 - 23{,}535)$$

$$= 28{,}995 \ IN^4 \quad \longleftarrow$$

$$\beta = \sqrt[4]{\frac{K}{4EI}}$$

$$\beta = \sqrt[4]{\frac{5.76 \times 10^4}{4 \times 3.64 \times 10^6 \times 2.90 \times 10^4}}$$

$$= \sqrt[4]{13.62 \times 10^{-8}}$$

$$= 0.0192 \ IN^{-1} \quad \longleftarrow$$

$$\lambda = \frac{6.28}{0.0192}$$

$$= 327.5 \ IN. = 27.25 \ FT.$$

THE PROCEDURE FOR THE SOLUTION OF A FINITE BEAM ON AN ELASTIC FOUNDATION WITH TWO SYMETRICALLY PLACED LOADS IS FOUND IN TIMOSHENKO,S; STRENGTH OF MATERIALS, PART II; D. VAN NOSTRAND COMPANY, INC.; 1956; PG. 15-17

$$M' = \frac{P}{4\beta}\left\{C[\beta(l-c)] + C(\beta c)\right\}$$

$$V' = \frac{P}{2}\left\{D[\beta(l-c)] + D(\beta c)\right\}$$

$$M'' = \frac{Q_0}{4\beta}[1 + C(\beta l)] + \frac{M_0}{2}[1 + D(\beta l)]$$

$$V'' = -\frac{Q_0}{2}[1 - D(\beta l)] - \frac{M_0\beta}{2}[1 - A(\beta l)]$$

TO FACILITATE USE OF THE TABLES IN HETÉNYI THE NAMES OF VARIABLES ARE CHANGED IN TIMOSHENKO'S EQUATIONS:

$$A(\beta x) \equiv \phi(\beta x); \ B(\beta x) \equiv \zeta(\beta x); \ C(\beta x) \equiv \psi(\beta x); \ D(\beta x) \equiv \theta(\beta x)$$

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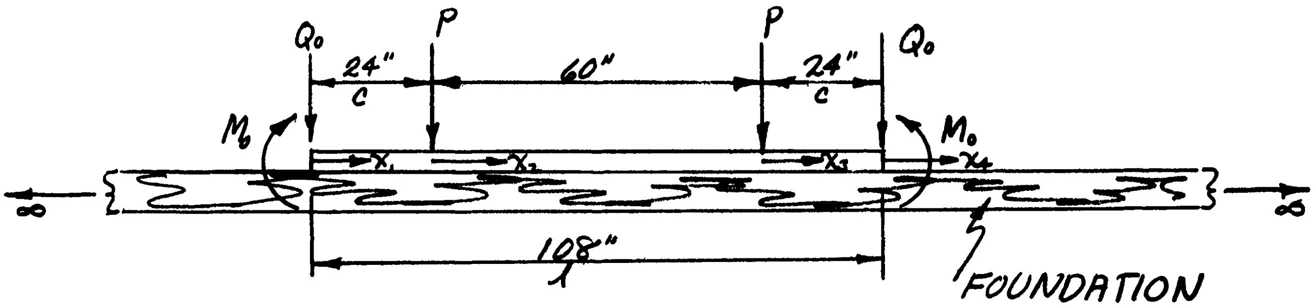
REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-45 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE



$$M' = \frac{P}{4\beta}\left\{C[\beta(l-c)] + C(\beta c)\right\}$$

$$= \frac{P}{4\beta}\left\{C[0.0192(108 \overset{84}{-} 24)] + C(0.0192 \times 24)\right\}$$

$$= \frac{P}{4\beta}\left\{C\overset{-0.2075}{(1.613)} + C\overset{0.2842}{(0.461)}\right\}$$

$$= \frac{0.7 \times 10^6 \times 0.0767}{4 \times 0.0192}$$

$$\begin{array}{r} 0.2853 \\ -\underline{0.2742} \\ .0111 \end{array} \qquad \begin{array}{r} 0.2853 \\ \underline{-0.0011} \\ 0.2842 \end{array} \qquad \begin{array}{r} 0.2842 \\ \underline{-0.2075} \\ 0.0767 \end{array}$$

$$M' = 0.7 \times 10^6 \text{ IN-LBS}$$

$$V' = \frac{P}{2}\left\{D[\beta(l-c)] + D(\beta c)\right\}$$

$$= \frac{P}{2}\left\{D[0.0192(108 \overset{84}{-} 24)] + D(0.0192 \times 24)\right\}$$

$$= \frac{P}{2}\left\{D\overset{-0.0084}{(1.613)} + D\overset{0.5649}{(0.461)}\right\}$$

$$= \frac{0.70 \times 10^6 \times 0.5565}{2}$$

$$V' = 0.1947 \times 10^6 \text{ LBS}$$

$$\begin{array}{r} -0.0097 \\ -\underline{(-0.0078)} \\ 0.0019 \\ \underline{.3} \\ .00057 \end{array} \qquad \begin{array}{r} -0.0078 \\ \underline{-0.0006} \\ -0.0084 \end{array} \qquad \begin{array}{r} 0.5657 \\ \underline{-0.5573} \\ 0.0084 \end{array} \qquad \begin{array}{r} 0.5657 \\ \underline{-0.0008} \\ .5649 \end{array} \qquad \begin{array}{r} 0.5649 \\ \underline{-0.0084} \\ +0.5565 \end{array}$$

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-46 OF 76
DATE MAY 7 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

$$M'' = \frac{Q_0}{4\beta}\left[1 + C(\beta l)\right] + \frac{M_0}{2}\left[1 + D(\beta l)\right]$$

$$= \frac{Q_0}{4\beta}\left[1 + C(0.0192 \times 108)\right] + \frac{M_0}{2}\left[1 + D(0.0192 \times 108)\right]$$

$$= \frac{Q_0}{4\beta}\left[1 + C\overset{-0.1706}{(2.075)}\right] + \frac{M_0}{2}\left[1 + D\overset{-0.0607}{(2.075)}\right]$$

$$= \frac{Q_0}{4 \times 0.0192}\left[+0.8294\right] + \frac{M_0}{2}\left[0.9393\right]$$

$$\begin{array}{rr} 1.0000 & 1.0000 \\ \underline{-0.1706} & \underline{-0.0607} \\ +0.8294 & +.9393 \end{array}$$

$$M'' = 10.8\, Q_0 + 0.469\, M_0$$

$$V'' = -\frac{Q_0}{2}\left[1 - D(\beta l)\right] - \frac{M_0\beta}{2}\left[1 - A(\beta l)\right]$$

$$= -\frac{Q_0}{2}\left[1 - D(0.0192 \times 108)\right] - \frac{M_0\beta}{2}\left[1 - A(0.0192 \times 108)\right]$$

$$= -\frac{Q_0}{2}\left[1 - D\overset{(-0.0607)}{(2.075)}\right] - \frac{M_0\beta}{2}\left[1 - A\overset{0.0493}{(2.075)}\right]$$

$$= -\frac{1.0607}{2}\, Q_0 - \frac{0.0192 \times 0.9507}{2}\, M_0$$

$$\begin{array}{rr} 0.0504 & \\ \underline{0.0482} & 0.0504 \\ 0.0022 & \underline{0.0011} \\ \underline{\times .5} & 0.0493 \\ .00110 & 1.0000 \\ & \underline{.0493} \\ & .9507 \end{array}$$

$$V'' = -0.5304\, Q_0 - 0.00912\, M_0$$

$$M' + M'' = 0$$

$$V' + V'' = 0$$

1) $0.7 \times 10^6 + 10.8\, Q_0 + 0.469\, M_0 = 0$

2) $0.1947 \times 10^6 - 0.5304\, Q_0 - 0.00912\, M_0 = 0$

FROM 2)

$$-0.530\, Q_0 = +0.00912\, M_0 - 0.1947 \times 10^6$$

$$Q_0 = \frac{+0.00912\, M_0 - 0.1947 \times 10^6}{-0.530}$$

$$Q_0 = -0.01778\, M_0 + 0.3675 \times 10^6$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

FROM 1):

$$0.7\times10^6 + 10.8(-0.01778 M_0 + 0.3675\times10^6) + 0.469 M_0 = 0$$

$$0.7\times10^6 - 0.192 M_0 + 3.97\times10^6 + 0.469 M_0 = 0$$

$$+0.277 M_0 + 4.67\times10^6 = 0$$

$$M_0 = -\frac{4.67\times10^6}{0.277}$$

$$M_0 = -16.87\times10^6 \text{ IN-LBS} \longleftarrow$$

$$Q_0 = -0.01776(-16.87\times10^6) + 0.3675\times10^6$$

$$= +0.2995\times10^6 + 0.3675\times10^6$$

$$Q_0 = 0.667\times10^6 \text{ LBS} \longleftarrow$$

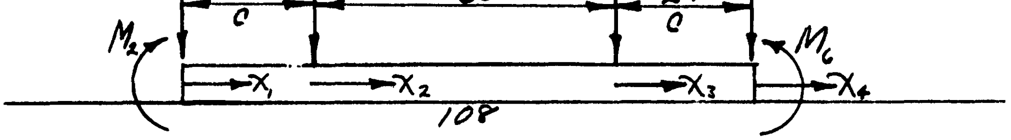
SUBSTITUTE INTO 1) AGAIN:

$$0.7\times10^6 + 10.8(0.667\times10^6) + 0.469(-16.87\times10^6) \overset{?}{=} 0$$

$$0.7\times10^6 + 7.20\times10^6 - 7.91\times10^6 \overset{?}{=} 0$$

$$7.90\times10^6 - 7.91\times10^6 \approx 0 \quad \text{CK.}$$

AS A FURTHER CHECK, THERE SHOULD BE ZERO MOMENT AT THE ENDS OF THE BEAM.



NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-48 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURN TABLE

COMPUTE BENDING MOMENTS

CONDITION THE MOMENT EQUATION SO THAT GRAPHICAL SUPERPOSITION IS SIMPLIFIED

$$M_x = \frac{0.667 \times 10^6}{4 \times 0.0192} C(\beta x_1) + \frac{0.7 \times 10^6}{4 \times 0.0192} C(\beta x_2) + \frac{0.7 \times 10^6}{4 \times 0.0192} C(\beta x_3)$$

$$+ \frac{0.667 \times 10^6}{4 \times 0.192} C(\beta x_4) + \frac{(-16.87 \times 10^6)}{2} D(\beta x_1)$$

$$+ \frac{(-16.87 \times 10^6)}{2} D(\beta x_4)$$

$$M_x = 8.68 \times 10^6 C(\beta x_1) + 9.12 \times 10^6 C(\beta x_2) + 9.12 \times 10^6 C(\beta x_3)$$

$$+ 8.68 \times 10^6 C(\beta x_4) - 8.44 \times 10^6 D(\beta x_1) - 8.44 \times 10^6 D(\beta x_4)$$

MULTIPLYING AND DIVIDING BY THE SMALLEST COEFFICIENT, 8.44×10^6;

$$M_x = \{ 1.03\, C(\beta x_1) + 1.082\, C(\beta x_2) + 1.082\, C(\beta x_3)$$

$$+ 1.03\, C(\beta x_4) - D(\beta x_1) - D(\beta x_4) \}\, 8.44 \times 10^6$$

THESE FUNCTIONS OF "C" AND "D" MAY BE EASILY TABULATED AND GRAPHED. THE RESULTANT SUPERPOSITION MUST BE MULTIPLIED BY 8.44×10^6.

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NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-41 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

βx	x	$C(\beta x)$	$M_{\alpha\alpha} = 1.03C(\beta x)$	$M_{\beta\beta} = 1.082C(\beta x)$
0	0	+1.0000	1.030	1.082
0.3	15.62	+0.4888	0.503	0.529
0.6	31.25	+0.1430	0.147	0.155
0.9	46.8	−0.0658	−0.068	−0.071
1.2	62.5	−0.1716	−0.177	−0.186
1.5	78.2	−0.2068	−0.213	−0.224
1.8	93.8	−0.1985	−0.204	−0.215
2.1	109.4	−0.1676	−0.173	−0.181
2.4	125.0	−0.1282	−0.132	−0.139

βx	x	$D(\beta x)$
0	0	1.000
0.3	15.62	0.708
0.6	31.25	0.453
0.9	46.8	0.253
1.2	62.5	0.109
1.5	78.2	0.016
1.8	93.8	−0.038
2.1	109.4	−0.062
2.4	125.0	−0.067

PREPARED BY B McM APPROVED BY W.B. SUBMITTED BY S.D.L.

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

$$M|_{x=0} = \frac{Q_1}{4\beta} C(\beta x_1) + \frac{P_3}{4\beta} C(\beta x_2) + \frac{P_4}{4\beta} C(\beta x_3) + \frac{Q_5}{4\beta} C(\beta x_4) + \frac{M_2}{2} D(\beta x_1) + \frac{M_6}{2} D(\beta x_4)$$

WHERE: $x_1 = 0$, $x_2 = 24$, $x_3 = 84$, $x_4 = 108$

NOTE: THE SIGN OF ABCISSAS ARE UNIMPORTANT SINCE $C(\beta x)$ AND $D(\beta x)$ ARE SYMETRIC AND ANTI-SYMETRIC, RESPECTIVELY, WITH RESPECT TO THE ORIGIN.

$Q_1 = Q_5 = 0.667 \times 10^6$ LBS

$M_2 = M_6 = -16.87 \times 10^6$ IN.-LBS

$P_3 = P_4 = 0.7 \times 10^6$ LBS.

$$M|_{x_1=0} = \frac{Q_1}{4\beta} C(0.0192 \times 0) + \frac{P_3}{4\beta} C(0.0192 \times 24) + \frac{P_4}{4\beta} C(0.0192 \times 84) + \frac{Q_5}{4\beta} C(0.0192 \times 108) + \frac{M_2}{2} D(0.0192 \times 0) + \frac{M_6}{2} D(0.0192 \times 108)$$

$$= \frac{Q_1}{4\beta} \overset{1.0000}{C(0)} + \frac{P_3}{4\beta} \overset{0.2842}{C(0.461)} + \frac{P_4}{4\beta} \overset{-0.2075}{C(1.612)} + \frac{Q_5}{4\beta} \overset{-0.1706}{C(2.075)} + \frac{M_2}{2} \overset{1.000}{D(0)} + \frac{M_6}{2} \overset{-0.0607}{D(2.075)}$$

0.2853
0.2742
0.0111
.1
0.0011
0.2853
−0.0011
+0.2842

$$M|_{x_1=0} = \frac{0.667 \times 10^6 \times 1.0}{4 \times 0.0192} + \frac{0.7 \times 10^6 \times 0.2842}{4 \times 0.0192} + \frac{0.7 \times 10^6 \times (-0.2075)}{4 \times 0.0192} + \frac{0.667 \times 10^6 \times (-0.1706)}{4 \times 0.0192} + \frac{(-16.87 \times 10^6) \times 1.000}{2.0} + \frac{(-16.87 \times 10^6) \times (-0.0607)}{2.0}$$

$$M|_{x_1=0} = 8.69 \times 10^6 + 2.593 \times 10^6 - 1.892 \times 10^6 - 1.482 \times 10^6 - 8.44 \times 10^6 + 0.512 \times 10^6$$

$$= 11.795 \times 10^6 - 11.814 \times 10^6 \approx 0$$

CK.

PREPARED BY B MCM APPROVED BY W B. SUBMITTED BY S.D.L.

REPORT NO. H-79-6
CONTRACT NO. RAP-74
PAGE 3-51 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

THE MOMENT DIAGRAM IS GIVEN ON PG. 30
NUMERICALLY THE MAXIMUM AND MINIMUM MOMENTS ARE

$$M_{MAX}\big|_{x=24''} = \{1.03\,C(\beta x_1) + 1.082\,C(\beta x_2) + 1.082\,C(\beta x_3) + 1.03\,C(\beta x_4) - D(\beta x_1) - D(\beta x_4)\}\,8.44\times10^6$$

WHERE: $x_1 = 24,\ x_2 = 0,\ x_3 = 84,\ x_4 = 108$

$$= \{1.03\,C(0.0192\times24) + 1.082\,C(0.0192\times0) + 1.082\,C(0.0192\times84) + 1.03\,C(0.0192\times108) - D(0.0192\times24) - D(0.0192\times108)\}\,8.44\times10^6$$

$$= \{1.03\,C\overset{0.2842}{(0.461)} + 1.082\,C\overset{1.000}{(0)} + 1.082\,C\overset{-0.2075}{(1.612)} + 1.03\,C\overset{-0.1706}{(2.075)} - D\overset{0.5649}{(0.461)} - D\overset{-0.0607}{(2.075)}\}\,8.44\times10^6$$

$$\begin{array}{r} 0.2853 \\ \underline{0.2742} \\ 0.0111 \\ \underline{\times\ .1} \\ 0.00111 \end{array} \qquad \begin{array}{r} 0.2853 \\ \underline{-0.0011} \\ 0.2842 \end{array} \qquad \begin{array}{r} 0.5657 \\ \underline{-0.5573} \\ 0.0084 \\ \underline{\times\ .1} \\ 0.00084 \end{array} \qquad \begin{array}{r} 0.5657 \\ \underline{-0.0008} \\ 0.5649 \end{array}$$

$$= \{0.2927 + 1.082 - 0.2245 - 0.1755 - 0.5649 + 0.0607\}\,8.44\times10^6$$

$$= \{0.4705\}\,8.44\times10^6$$ (GRAPHICALLY: $\{0.46\}$ CK)

$$M_{MAX}\big|_{x_1=24''} = 3.97\times10^6 \text{ IN-LBS.} \longleftarrow$$

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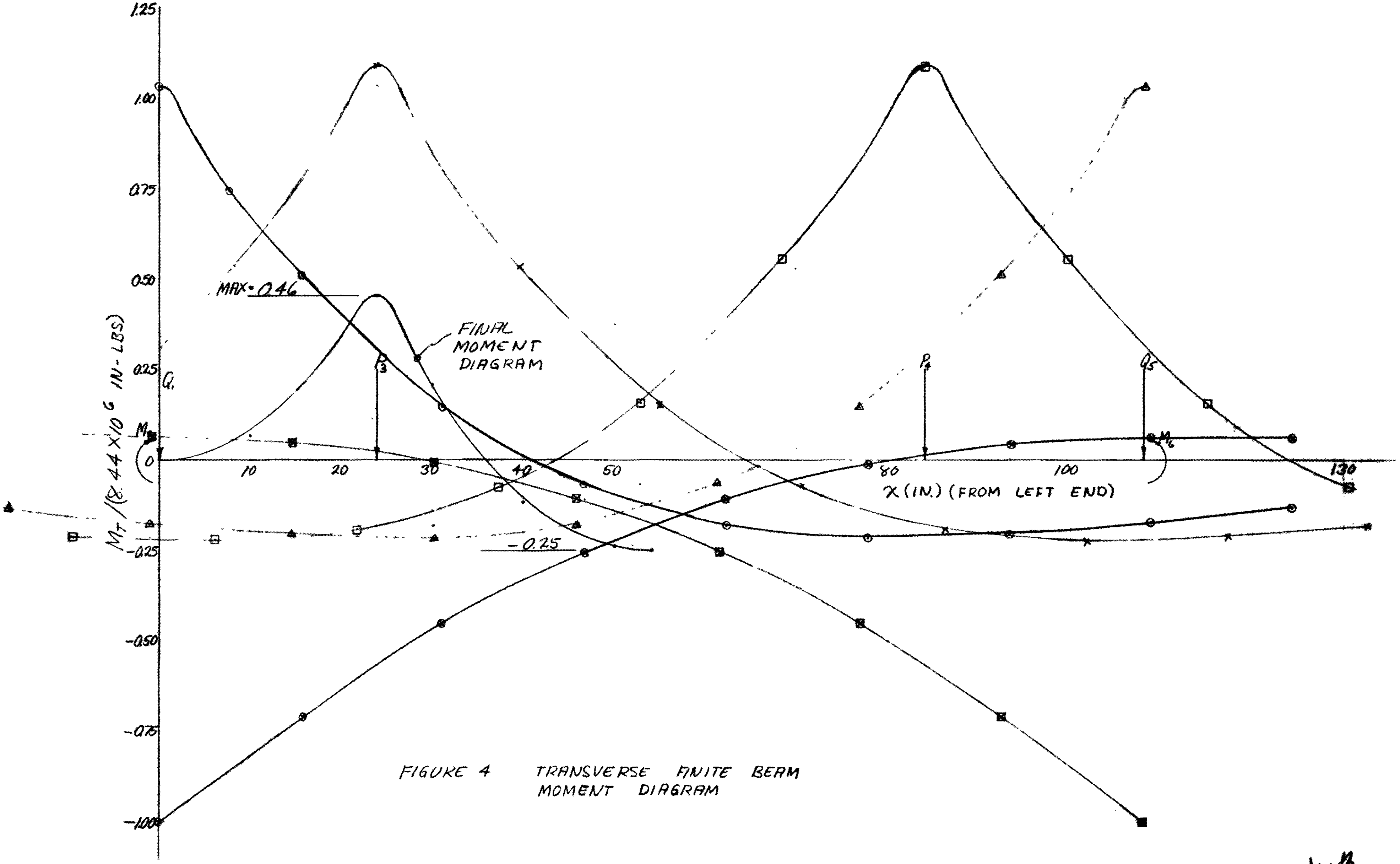

FIGURE 4 TRANSVERSE FINITE BEAM MOMENT DIAGRAM

WB.

NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-53 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

FOR MINIMUM MOMENT:

$$x_1 = 54'' \quad x_2 = 30'' \quad x_3 = 30'' \quad x_4 = 54''$$

$$M_{MIN}/_{x_1=54'} = \{1.03C(0.0192 \times 54) + 1.082C(0.0192 \times 30)$$
$$+ 1.082C(0.0192 \times 30) + 1.03C(0.0192 \times 54)$$
$$- D(0.0192 \times 54) - D(0.0192 \times 54)\} 8.44 \times 10^6$$

$$= \{1.03\overset{-0.1252}{C(1.038)} + 1.082\overset{+0.1653}{C(0.576)}$$
$$+ 1.082\overset{+0.1653}{C(0.576)} + 1.03\overset{-0.1252}{C(1.038)}$$
$$- \overset{0.1800}{D(1.038)} - \overset{0.1800}{D(1.038)}\} 8.44 \times 10^6$$

$$\begin{array}{rrrrrr} -0.1259 & -0.1223 & 0.1709 & 0.1709 & 0.1839 & 0.1839 \\ \underline{-(-0.1223)} & \underline{+(-0.0029)} & \underline{0.1615} & \underline{-0.0056} & \underline{0.1790} & \underline{-0.0039} \\ 0.0036 & -0.1252 & 0.0094 & 0.1653 & 0.0049 & 0.1800 \\ \underline{\times .8} & & \underline{\times .6} & & \underline{\times .8} & \\ 0.00288 & & .00564 & & .00392 & \end{array}$$

$$= \{-0.1291 + 0.1790 + 0.1790 - 0.1291 - 0.1800 - 0.1800\} 8.44 \times 10^6$$

$$= \{-0.2602\} \times 8.44 \times 10^6 \text{ (GRAPHICALLY: } \{-0.25\} \text{ CK)}$$

$$M_{MIN} = 2.20 \times 10^6 \text{ IN.-LBS.} \longleftarrow$$

<u>CALCULATE THE STRESSES</u> OCCURING IN THE REINFORCED BEAM AT THE MAXIMUM AND MINIMUM MOMENT SECTIONS

MAXIMUM POSITIVE MOMENT SECTION:

$$\sigma = \frac{My}{I} \qquad M = 3.97 \times 10^6 \text{ IN.-LBS}$$
$$I = 31,720 \text{ IN}$$

$$f_c = \frac{3.97 \times 10^6 \times 4.53}{3.172 \times 10^4}$$
$$= 577 \text{ PSI} < 1800 \text{ PSI ALL. OK.}$$

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-54 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

$f_{cs} = \frac{3.97 \times 10^6 \times 16.47}{3.17 \times 10^4}$ (STRESS IN CONCRETE ADJACENT TO STEEL)

$= 2060$ PSI

$f_s = n f_{cs} = 9 \times 2060$

$= 18,560$ PSI $< 20,000$ PSI ALL. OK.

MAXIMUM NEGATIVE MOMENT SECTION:

$\sigma = \frac{My}{I}$ $M = 2.20 \times 10^6$ IN-LBS
$I = 23,535$ IN^4

$f_c = \frac{2.20 \times 10^6 \times 3.84}{2.354 \times 10^4}$

$= 359$ PSI < 1800 PSI ALL. OK.

$f_{cs} = \frac{2.20 \times 10^6 \times 18.16}{2.354 \times 10^4}$

$= 1696$ PSI

$f_s = 9 \times f_{cs} = 9 \times 1696$

$= 15,280$ PSI $< 20,000$ PSI ALL. OK.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

COMPUTE THE DEFLECTIONS OF THE TRANSVERSE FINITE BEAM

THE EQUATION FOR DEFLECTION IS:

$$y = \frac{Q_1 \beta}{2K} A(\beta x) + \frac{P_3 \beta}{2K} A(\beta x_2) + \frac{P_4 \beta}{2K} A(\beta x_3) + \frac{Q_5 \beta}{2K} A(\beta x_4)$$
$$+ \frac{M_2 \beta^2}{K} B(\beta x_1) + \frac{M_6 \beta^2}{K} B(\beta x_4)$$

AGAIN THE EQUATION IS SIMPLIFIED:

$$y = \frac{0.667\times10^{6}\times1.92\times10^{-2}}{2\times5.76\times10^{4}} A(\beta x_1) + \frac{0.70\times10^{6}\times1.92\times10^{-2}}{2\times5.76\times10^{4}} A(\beta x_2)$$
$$+ \frac{0.70\times10^{6}\times1.92\times10^{-2}}{2\times5.76\times10^{4}} A(\beta x_3) + \frac{0.667\times10^{6}\times1.92\times10^{-2}}{2\times5.76\times10^{4}} A(\beta x_4)$$
$$+ \frac{(-16.87\times10^{9})\overset{3.685\times10^{-4}}{(1.92\times10^{-2})^2}}{5.76\times10^{4}} B(\beta x_1)$$
$$+ \frac{(-16.87\times10^{6})\overset{3.685\times10^{-4}}{(1.92\times10^{-2})^2}}{5.76\times10^{4}} B(\beta x_4)$$

$$y = 0.1112\, A(\beta x_1) + 0.1168\, A(\beta x_2) + 0.1168\, A(\beta x_3)$$
$$+ 0.1112\, A(\beta x_4) - 0.108\, B(\beta x_1) - 0.108\, B(\beta x_4)$$

$$y = \{1.03\, A(\beta x_1) + 1.08\, A(\beta x_2) + 1.08\, A(\beta x_3) + 1.03\, A(\beta x_4)$$
$$- B(\beta x_1) - B(\beta x_4)\}\, 0.108$$

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-56 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
SUBJECT: AZIMUTH TURNTABLE

βx	x	$A(\beta x)$	$y_{Q,Q_5} = 1.03 A(\beta x)$	$y_{RR} = 1.08 A(\beta x)$	$B(\beta x)$
0	0	1.0000	1.030	1.080	0
0.15	7.81	0.9796	1.010	1.058	0.1286
0.3	15.62	0.9267	0.956	1.000	0.2189
0.45	23.44	0.8515	0.877	0.919	0.2774
0.6	31.25	0.7628	0.786	0.824	0.3099
0.9	46.8	0.5712	0.589	0.617	0.3185
1.2	62.5	0.3898	0.401	0.421	0.2807
1.5	78.2	0.2384	0.246	0.258	0.2226
1.8	93.8	0.1234	0.127	0.133	0.1610
2.1	109.4	0.0438	0.045	0.047	0.1057
2.4	125.0	-0.0056	-0.006	-0.006	0.0613

THE SEMIGRAPHICAL SOLUTION IS GIVEN ON PG 35. FROM THAT CURVE, A HORIZONTAL TANGENT OCCURS AT $x = 54''$.

NUMERICALLY; $x_1 = 54$, $x_2 = 30$, $x_3 = 30$, $x_4 = 54$

$$y\big|_{x=54} = \{1.03\,A(0.0192 \times 54) + 1.08\,A(0.0192 \times 30)$$

$$+ 1.08\,A(0.0192 \times 30) + 1.03\,A(0.0192 \times 54)$$

$$- B(0.0192 \times 54) - B(0.0192 \times 54)\}\,0.108$$

$$= \{1.03\,A\overset{0.4851}{(1.038)} + 1.08\,A\overset{0.7776}{(0.576)} + 1.08\,A\overset{0.7776}{(0.576)}$$

$$+ 1.03\,A\overset{0.4851}{(1.038)} - B\overset{-0.3051}{(1.038)} - B\overset{-0.3051}{(1.038)}\}\,0.108$$

PREPARED BY B McM APPROVED BY W.B. SUBMITTED BY S.D.L.

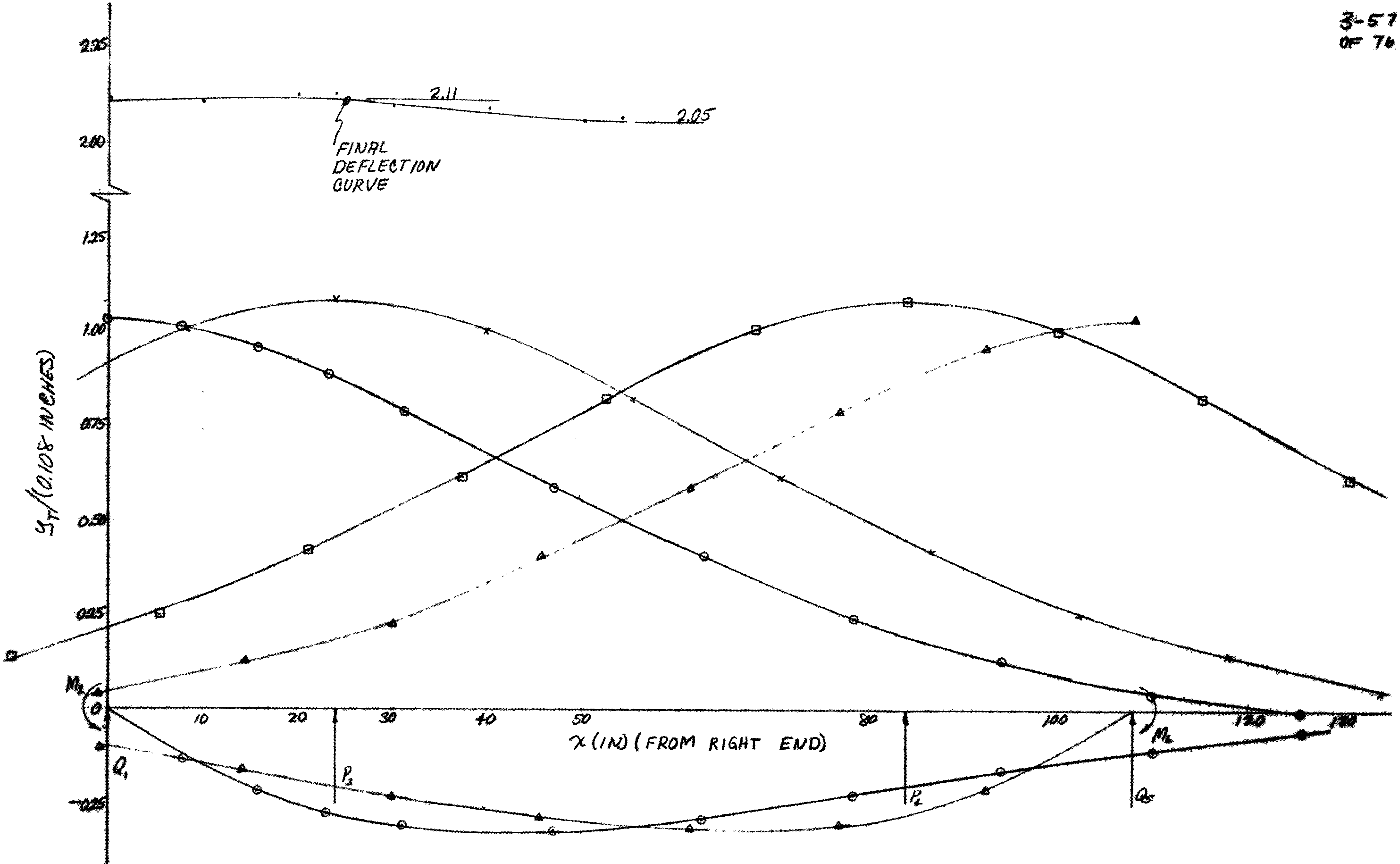

FIGURE 5 TRANSVERSE FINITE BEAM DEFLECTION DIAGRAM

W.B.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-58 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABIE

$$
\begin{array}{r}0.4899\\ \underline{0.4839}\\ .0060\\ \underline{.8}\\ .00480\end{array}
\quad
\begin{array}{r}0.4899\\ \underline{-\ .0048}\\ 0.4851\end{array}
\quad
\begin{array}{r}0.7813\\ \underline{-0.7752}\\ 0.0061\\ \underline{.6}\\ .00366\end{array}
\quad
\begin{array}{r}0.7813\\ \underline{.0037}\\ .7776\end{array}
\quad
\begin{array}{r}0.3061\\ \underline{0.3049}\\ 0.0012\\ \underline{.8}\\ .00096\end{array}
\quad
\begin{array}{r}0.3061\\ \underline{.0010}\\ 0.3051\end{array}
$$

$$y = \{0.500 + 0.840 + 0.840 + 0.500 - 0.3051 - 0.3051\}\ 0.108$$

$$= \{2.07\}\ 0.108 \qquad \text{GRAPHICALLY } \{2.05\} \quad \text{CK}$$

$$= 0.2235 \text{ IN}$$

ANOTHER HORIZONTAL TANGENT OCCURS AT $x_1 = 24$ IN.

$$x_1 = 24,\ x_2 = 0,\ x_3 = 60,\ x_4 = 84$$

$$y = \{1.03\,A(0.0192 \times 24) + 1.08\,A(0.0192 \times 0) + 1.08\,A(0.0192 \times 60)$$

$$+ 1.03\,A(0.0192 \times 84) - B(0.0192 \times 24) - B(0.0192 \times 84\}\ 0.108$$

$$= \{1.03\,A\overset{0.8453}{(0.461)} + 1.08\,A\overset{1.000}{(0)} + 1.08\,A\overset{0.4172}{(1.152)} + 1.03\,A\overset{0.1911}{(1.612)}$$

$$- B\overset{0.2806}{(0.461)} - B\overset{0.1993}{(1.612)}\}\ 0.108$$

$$
\begin{array}{r}0.8459\\ \underline{0.8403}\\ 0.0056\\ \underline{.1}\\ .00056\end{array}
\quad
\begin{array}{r}0.8459\\ \underline{.0006}\\ 0.8453\end{array}
\quad
\begin{array}{r}0.4183\\ \underline{0.4126}\\ 0.0057\\ \underline{.2}\\ .00114\end{array}
\quad
\begin{array}{r}0.4183\\ \underline{.0011}\\ 0.4172\end{array}
\quad
\begin{array}{r}0.1919\\ \underline{0.1879}\\ 0.0040\\ \underline{.2}\\ .00080\end{array}
\quad
\begin{array}{r}0.1919\\ \underline{.0008}\\ 0.1911\end{array}
$$

$$
\begin{array}{r}0.2832\\ \underline{0.2803}\\ .0029\\ \underline{.1}\\ .00029\end{array}
\quad
\begin{array}{r}0.2803\\ \underline{.0003}\\ .2806\end{array}
\quad
\begin{array}{r}0.1997\\ \underline{0.1976}\\ 0.0021\\ \underline{.2}\\ .00042\end{array}
\quad
\begin{array}{r}0.1997\\ \underline{-0.0004}\\ 0.1993\end{array}
$$

$$y = \{0.871 + 1.08 + 0.451 + 0.197 - 0.2806 - 0.1993\}\ 0.108$$

$$= \{2.12\}\ 0.108 = 0.229 \text{ IN.} \qquad \text{GRAPHICALLY } \{2.11\} \quad \text{CK.}$$

PREPARED BY B McM APPROVED BY WB. SUBMITTED BY S.D.L.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-57 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

ASSUME THAT THE DEFLECTION GIVEN IN THE LONGITUDINAL ANALYSIS ACCOUNTS FOR ALL VERTICAL DEFLECTION AND THAT ONLY VARIATION IN THE DEFLECTION CURVE IS OF IMPORTANCE IN THE TRANSVERSE ANALYSIS. (A COMPLETE ANALYSIS WOULD REQUIRE THE CONSIDERATION OF THE FOUNDATION AS A PLATE WITH SHARP CHANGES IN MOMENTS OF INERTIA)

$$\text{THEN, } \Delta y = 0.229 - 0.2235$$

$$= 0.006 \text{ IN.}$$

AN APPROXIMATION WOULD BE THAT ONE-HALF OF THIS DEFLECTION BE ADDED TO THE DEFLECTIONS IN THE LONGITUDINAL DIRECTIONS.

$$y_{TOT.} = y_3 + \frac{\Delta y}{2}$$

$$= 0.145 + 0.003$$

$$= 0.148$$

COMPUTE THE SHEAR

AS A LAST INVESTIGATION, THE SHEAR IN THE TRANSVERSE FINITE BEAM IS DETERMINED

THE SHEAR EQUATION IS:

$$V = -\frac{Q_1}{2} D(\beta x_1) - \frac{P_3}{2} D(\beta x_2) - \frac{P_4}{2} D(\beta x_3) - \frac{Q_5}{2} D(\beta x_4)$$
$$- \frac{M_2 \beta}{2} A(\beta x_1) - \frac{M_6 \beta}{2} A(\beta x_4)$$

SIMPLIFYING THIS EQUATION.

$$V = -\frac{0.667 \times 10^6}{2} D(\beta x_1) - \frac{0.70 \times 10^6}{2} D(\beta x_2) - \frac{0.70 \times 10^6}{2} D(\beta x_3)$$
$$- \frac{0.667 \times 10^6}{2} D(\beta x_4) - \frac{(-16.87 \times 10^6)(1.92 \times 10^{-2})}{2} A(\beta x_1)$$
$$- \frac{(-16.87 \times 10^6)(1.92 \times 10^{-2})}{2} A(\beta x_4)$$

PREPARED BY B McM APPROVED BY W.H. SUBMITTED BY S.D.L.

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

$$-V = 0.333\times10^6 D(\beta x_1) + 0.35\times10^6 D(\beta x_2) + 0.35\times10^6 D(\beta x_3) + 0.333\times10^6 D(\beta x_4) - 0.1618\times10^6 A(\beta x_1) - 0.1618\times10^6 A(\beta x_4)$$

$$-V = \{2.06\, D(\beta x_1) + 2.165\, D(\beta x_2) + 2.165\, D(\beta x_3) + 2.06\, D(\beta x_4) - A(\beta x_1) - A(\beta x_4)\}\, 0.1618\times10^6$$

βx	x	$D(\beta x)$	$V_{R_1R_5}=2.06\,D(\beta x)$	$V_{R_3R_4}=2.165\,D(\beta x)$	$A(\beta x)$
0	0	1.00	2.06	2.165	1.00
0.15	7.81	0.8510	1.753	1.843	0.9796
0.30	15.62	0.7078	1.458	1.532	0.9267
0.45	23.44	0.5742	1.183	1.243	0.8515
0.6	31.25	0.4529	0.932	0.980	0.7628
0.9	46.8	0.2527	0.521	0.548	0.5712
1.2	62.5	0.1091	0.225	0.236	0.3898
1.5	78.2	0.0158	0.033	0.034	0.2384
1.8	93.8	-0.0376	-0.077	-0.081	0.1234
2.1	109.4	-0.0619	-0.128	-0.134	0.0438
2.4	125.0	-0.0669	-0.138	-0.145	-0.0056

THE SEMI-GRAPHICAL SOLUTION FOR SHEAR OCCURS ON PG. 39 FROM THAT CURVE THE MAXIMUM SHEAR OCCURS AT $X_1 = 24''$

CALCULATE P_3 FROM CURVE: $P_3 = \{2.4 + 1.95\}\, 0.1618\times10^6$
$= 0.703\times10^6$ LBS CK.

PREPARED BY B McM APPROVED BY W.H. SUBMITTED BY S.D.L.

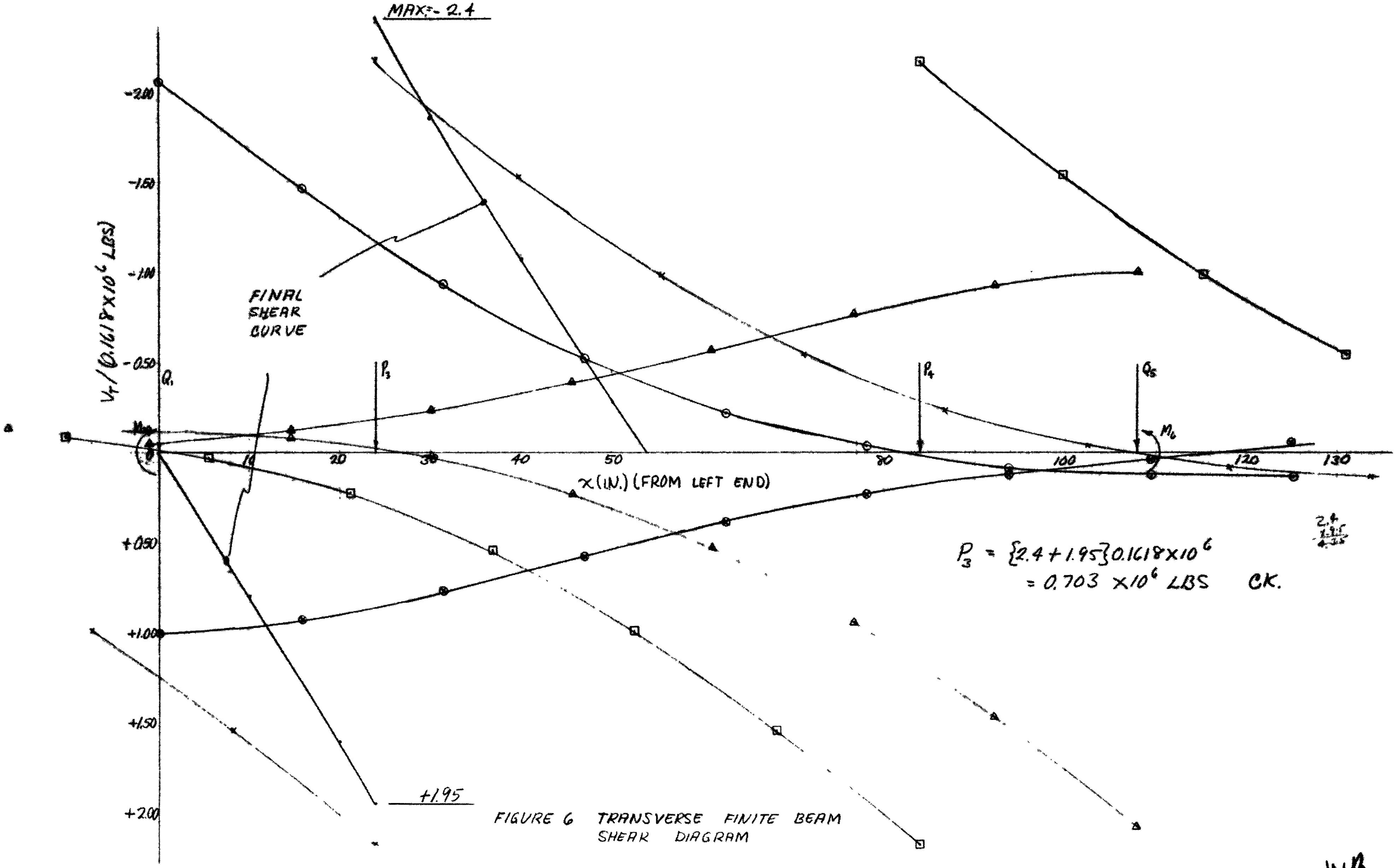

FIGURE 6 TRANSVERSE FINITE BEAM SHEAR DIAGRAM

$$P_3 = \{2.4 + 1.95\} 0.1618 \times 10^6$$
$$= 0.703 \times 10^6 \text{ LBS} \quad \text{CK.}$$

2.4
1.95
4.35

W.B.

REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3-62 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

NUMERICALLY: $x_1 = 24''$, $x_2 = 0$, $x_3 = 60''$, $x_4 = 84''$

$$-V = \{2.06\,D(0.0192\times24) + 2.165\,D(0.0192\times0) + 2.165\,D(0.0192\times60)$$
$$+ 2.06\,D(0.0192\times84) - A(0.0192\times24) - A(0.0192\times84)\}\,0.1618\times10^6$$
$$= \{2.06\,D(\overset{0.5649}{0.461}) + 2.165\,D(\overset{1.00}{0}) - 2.165\,D(\overset{0.1285}{1.152})$$
$$-2.06\,D(\overset{-0.0082}{1.612}) - A(\overset{0.8453}{0.461}) + A(\overset{0.1911}{1.612})\}\,0.1618\times10^6$$

$$\begin{array}{r}0.5657\\ \underline{0.5573}\\ .0084\\ \underline{\times .1}\\ .00084\end{array}\qquad
\begin{array}{r}0.5657\\ \underline{.0008}\\ .5649\end{array}\qquad
\begin{array}{r}0.1293\\ \underline{0.1252}\\ 0.0041\\ \underline{.2}\\ .00082\end{array}\qquad
\begin{array}{r}0.1293\\ \underline{-.0008}\\ .1285\end{array}\qquad
\begin{array}{r}-0.0097\\ \underline{-0.0078}\\ .0019\\ \underline{.2}\\ .00038\end{array}\qquad
\begin{array}{r}-0.0078\\ \underline{-.0004}\\ -.0082\end{array}$$

$$\begin{array}{r}0.1919\\ \underline{0.1879}\\ .0040\\ \underline{.2}\\ .00080\end{array}\qquad
\begin{array}{r}0.1919\\ \underline{.0008}\\ .1911\end{array}\qquad
\begin{array}{r}0.8459\\ \underline{0.8403}\\ 0.0056\\ \underline{.1}\\ .00056\end{array}\qquad
\begin{array}{r}0.8459\\ \underline{.0006}\\ .8453\end{array}$$

$$-V = \{1.162 + 2.165 - 0.2785 + 0.0169 - 0.8453 + 0.1911\}\,0.1618\times10^6$$

$$= \{2.41\}\,0.1618\times10^6$$ GRAPHICALLY: $\{2.40\}$ CK.

$V = -0.390\times10^6$ LBS

THE NOMINAL SHEAR STRESS IS:

$v = V/bd$ ACI BUILDING CODE, SEC 1201(a)

$$v = \frac{0.390\times10^6}{.21\times.144\times10^5} = 129 \text{ PSI}$$

$v_{AL} = 5\sqrt{f_c'}$ (WITH VERTICAL STIRRUPS) (ACI BUILDING CODE, TABLE 1002(a))

$= 316$ PSI (4000 PSI CONCRETE)

> 129 PSI $= v$. O.K.

PREPARED BY B McM APPROVED BY W.K. SUBMITTED BY S.D.L.

REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3-63 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: AZIMUTH TURNTABLE

COMPARE EXISTING STEEL AREA TO MINIMUM ALLOWED BY TEMPERATURE STEEL REQUIREMENTS

SEE ACI CODE SEC 807

$A_S > 0.0020\ A_G$

LONGITUDINALLY:

$A_G = bh = 108 \times 24$

$= 2590\ IN^2$

$A_S \overset{?}{>} 0.0020 \times 2590 = 5.18\ IN^2 < 7\ IN^2 \therefore OK$

TRANSVERSELY:

$A_G = bh = 144 \times 24$

$= 3450\ IN^2$

$A_S \overset{?}{>} 0.0020 \times 3450 = 6.90\ IN^2 < 7\ IN^2 \therefore OK.$

PREPARED BY B McM APPROVED BY W.B. SUBMITTED BY S.D.L.

REPORT NO. H79-6
CONTRACT NO. RAP-79
PAGE 3.64 OF 76
DATE MAY 7, 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE
AZIMUTH TURNTABLE
SUBJECT: CONCRETE FOUNDATION FOR 300' HOMOLOGY TELESCOPE

3.8.6 SUMMARY OF FINAL ANALYSIS

SECTION USED:

CROSS-SECTION DIMENSIONS OF CONCRETE

LONGITUDINAL: WIDTH = 108 IN.
DEPTH = 24 IN.

TRANSVERSE: WIDTH = 144 IN.
DEPTH = 24 IN.

TOTAL REINFORCING STEEL AREA:

LONGITUDINAL: TOP = 5.48 IN^2
BOTTOM = 27.55 IN^2

TRANSVERSE:
(EFFECTIVE WIDTH TAKEN AS 144 IN.) TOP = 7.00 IN^2/144 IN.
BOTTOM = 11.00 IN^2/144 IN.

VERTICAL = (NOT SPECIFIED)

RESULTS:

	COMPUTED		ALLOWABLE
MAXIMUM CONCRETE STRESS:			
COMPRESSION =	577 PSI	OK	1800 PSI
SHEAR =	129 PSI	OK	316 PSI **
MAXIMUM STEEL STRESS:	21,050 PSI *	OK	20,000 PSI
FOUNDATION STIFFNESS: (AT TRUCK MAIN PIVOT)	9.67×10^6 LBS/IN	OK	

WEIGHT OF STEEL REQ'D : $33 \times 12 \times .283 = 112$ #/FT
$+ 18 \times \frac{108}{12} \times .283 = 46$ #/FT
158 "

TOTAL $= 158 \times \frac{1090}{2000} = 86$ TONS
USE 90 TONS

* SLIGHTLY TOO HIGH!

** WITH VERTICAL REINFORCEMENT

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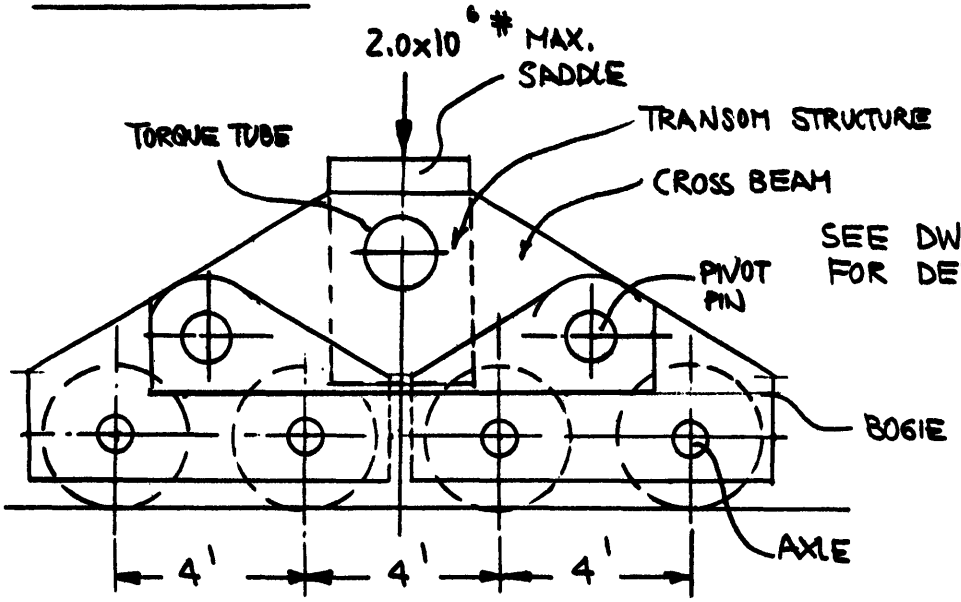
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAIL
SUBJECT: AZIMUTH TURNTABLE

3.9 DESIGN OF TRUCKS

THE TRUCK DESIGN MUST PERMIT WHEEL LOAD EQUALIZATION SO THAT ALL 8 WHEELS CAN SHARE THE MAXIMUM VERTICAL LOAD OF 2×10^6 LBS.
THIS IS BEST ATTAINED BY HINGING INDIVIDUAL BOGIES.

ARRANGEMENT :



SEE DWG # 109-D-012 FOR DETAILS

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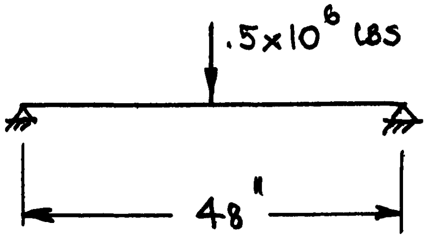
REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.66 OF 76
DATE 1-22-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURN TABLE

BOGIE :



$$M_{B\,MAX} = \frac{P\ell}{4} = \frac{.5\times10^{6}\times48}{4} = \underline{6.0\times10^{6}\text{ IN LBS}}$$

$$Z = \frac{bh^{2}}{6} \quad ; \quad b = 2t = 2\text{ IN } (1\text{ IN PLATE})$$
$$h = 51\text{ IN}$$

$$Z_{MAX} = \frac{2\times51^{2}}{6} = \underline{870\text{ IN}^{3}}$$

$$\frac{M_{B\,MAX}}{Z_{MAX}} = \frac{6\times10^{6}}{.87\times10^{3}} = 6{,}900\text{ PSI}$$

$$S_{C\,MAX} = 1.513 \times 6{,}900 = 10{,}400\text{ PSI (OK)}$$
$$S_{t\,MAX} = 6.140 \times 6{,}900 = 42{,}500 \text{ '' } *$$
$$S_{S\,MAX} = 2.39\ \frac{.5\times10^{6}}{2\times51} = 11{,}700 \text{ '' (OK)}$$

* NEEDS TO BE LOCALLY REINFORCED (TOP PLATE),
SEE DRAWING 109-D-012

STRUCTURE TO HAVE EQUAL BENDING STRENGTH!

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 347 OF 76
DATE 1-23-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

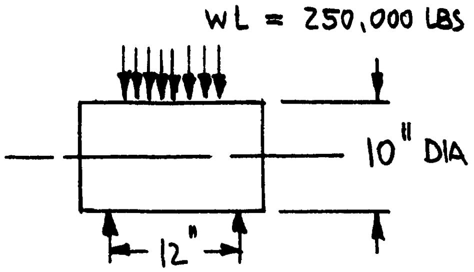
$$\Delta_{B\,MAX} \cong \frac{M\ell^2}{24EI} \qquad I = \frac{2 \times 51^3}{12} = \underline{22{,}100 \text{ IN}^4}$$

$$\Delta_{B\,MAX} \cong \frac{\cancel{6}.\times \cancel{10^6} \times (48)^2}{\underset{4}{\cancel{24}} \times 30 \times \cancel{10^6} \times 22.1 \times \cancel{10^3}} \overset{2.3\times\cancel{10^3}}{} = \underline{.0010 \text{ IN}}$$

$$\Delta_{S_{MAX}} \cong .5\frac{M}{AG} = .5\frac{6 \times \cancel{10^6}}{102 \times 11.5 \times \cancel{10^6}} \cong \underline{.0025 \text{ IN}}$$

$$\text{TOTAL DEFLECTION} = \Delta_{B_{MAX}} + \Delta_{S_{MAX}} \cong \underline{\underline{.0035 \text{ IN}}}$$

AXLE



$$M_{B\,MAX} = \frac{250{,}000 \times 12}{8} = \underline{375{,}000 \text{ IN LBS}}$$

$$Z = \frac{\pi d^3}{32} = \frac{\pi\, 10^3}{32} = \underline{98 \text{ IN}^3}$$

$$S_{B\,NOM} = \frac{375{,}000}{98} = \underline{3830 \text{ PSI}}$$

$$\left.\begin{array}{llll} S_C & = .6 \times 3{,}830 & = -2300 & \text{PSI} \\ S_T & = 2.73 \times 3{,}830 & = +10{,}500 & '' \\ S_S & = 2.43\,\frac{250{,}000}{10^2\cancel{\pi/4}} & = 7{,}800 & \text{PSI} \end{array}\right\} \text{OK}$$

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NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
GREEN BANK, WEST VIRGINIA 24944
TELEPHONE ARBOVALE 456-2011

REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.68 OF 76
DATE 1-23-69

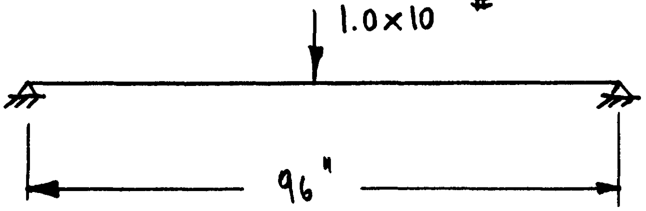
PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

$$\Delta_{B\,MAX} = \frac{5}{384}\,\frac{W\,L^3}{E\,I} \qquad I = \frac{\pi d^4}{64} = \underline{490 \text{ IN}^4}$$

$$\Delta_{B\,MAX} = \frac{5}{384}\cdot\frac{.250\times\cancel{10^6}\times\overset{1730\;\;1}{(12)^3}}{30\times\cancel{10^6}\times 440} = \underline{\text{NEGLIGIBLE}} \;!$$

CROSS BEAM



$h = 50$ IN
$b = 2t = 5$ IN ($2\frac{1}{2}$ IN. PLTS)

$$M_{B\,MAX} = \frac{P\ell}{4} = \frac{1.0\times10^6\times96}{4} = \underline{24\times10^6 \text{ IN LBS}}$$

$$Z_{MAX} = \frac{5\times50^2}{6} = \underline{2080 \text{ IN}^3}$$

$$I_{MAX} = \frac{5\times50^3}{12} = \underline{52{,}200 \text{ IN}^4}$$

$$A_{MAX} = 5\times50 = \underline{250 \text{ IN}^2}$$

$$\frac{M_{B\,MAX}}{Z_{MAX}} = \frac{24\times10^6}{2.08\times10^3} = 11{,}500 \text{ PSI}$$

S_{C} MAX. $= 2.53 \times 11{,}500 = 29{,}200$ PSI *
S_{t} MAX. $= .962 \times 11{,}500 = 11{,}100$ PSI (OK)
S_{S} MAX. $= 1.7 \times \frac{1.0\times10^6}{250} = 6{,}800$ PSI (OK)

* REQUIRES LOCAL REINFORCEMENT
BEAM TO HAVE EQUAL BENDING STRENGTH !

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TELEPHONE ARBOVALE 456-2011

REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.69 OF 76
DATE 1-23-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

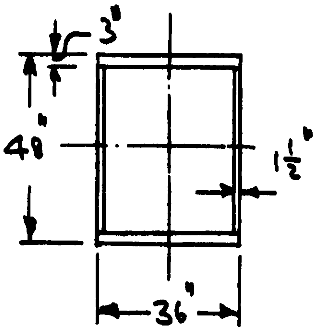
SUBJECT: AZIMUTH TURNTABLE

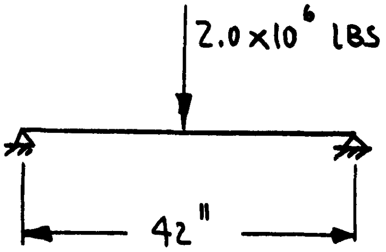
$$\Delta_{B\,MAX} = \frac{M\ell^2}{24EI} = \frac{\cancel{24}\cancel{\times 10^6} \times \overset{92\cancel{\times 10^4}}{(96)^2}}{\cancel{24} \times 30 \times \cancel{10^6} \times 52.2 \cancel{\times 10^4}} \cong \underline{.006\text{ IN}}$$

$$\Delta_{S\,MAX} = .5\frac{M}{AG} = .5\frac{24 \cancel{\times 10^6}}{250 \times 11.5 \cancel{\times 10^6}} \cong \underline{.004\text{ IN}}$$

$$\Delta_{total} \cong \underline{\underline{.010\text{ IN}}}$$

TRANSOM :





$$A = (6 \times 36) + (3 \times 42) = 216 + 126 = \underline{342\text{ IN}^2}$$

$$I = (108 \times 1013) + (3 \times 6174) = 109{,}000 + 18{,}500 = \underline{127{,}500\text{ IN}^4}$$

$$Z = \frac{127{,}500}{24} = \underline{5{,}320\text{ IN}^3}$$

$$M_{B\,MAX} = \frac{2.0 \times 10^6 \times 42}{4} = \underline{21 \times 10^6\text{ IN LBS}}$$

$$\frac{M_{B\,MAX}}{Z} = \frac{21 \times 10^6}{5.32 \times 10^3} \cong \underline{4000\text{ PSI}}$$

$$\left.\begin{aligned} S_{t\,MAX} &= 1.513 \times 4000 \cong 6000\text{ PSI} \\ S_{C\,MAX} &= 6.14 \times 4000 = 24{,}500\text{ "} \\ S_{S\,MAX} &= 2.39 \times \frac{2.0 \times 10^6}{342} = 13{,}500\text{ "} \end{aligned}\right\}\text{ OK}$$

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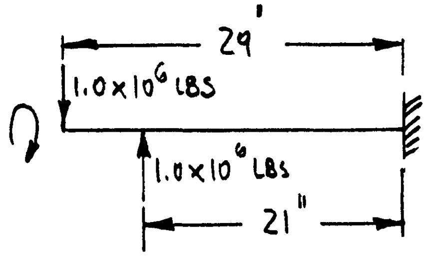
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.70 OF 76
DATE 1-23-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

$$\Delta_{B\,MAX} = \frac{M\ell^2}{48EI} = \frac{21\cancel{\times10^6}\times\overset{1.76\cancel{\times10^3}}{(42)^2}}{48\times30\cancel{\times10^6}\times127.5\cancel{\times10^3}} = \text{NEGLIBIBLE}$$

$$\Delta_{S\,MAX} = .25\,\frac{M}{AG} = \frac{.25\times21\cancel{\times10^6}}{342\times11.5\cancel{\times10^6}} \cong \underline{\underline{.0015\text{ IN}}}$$

TORQUE TUBE



L = 38"

O.D = 18 IN
I.D = 10 IN

$$M_{B\,MAX} = 1.0\times10^6\times8 = \underline{8.0\times10^6\text{ IN LBS}}$$

$$A = \left(\frac{18^2\pi}{4}\right)-\left(\frac{10^2\pi}{4}\right) = 254-79 = \underline{175\text{ IN}^2}$$

$$I = \frac{\pi}{64}\left(D^4-d^4\right) = \frac{\pi}{64}\overset{95,000}{\left(18^4-10^4\right)} = \underline{4,680\text{ IN}^4}$$

$$Z = \frac{I}{9} = \frac{4680}{9} = \underline{520\text{ IN}^3}$$

$$S_{B\,MAX} = \frac{8.0\times10^6}{.52\times10^3} = \underline{\underline{15,400\text{ PSI}}}\quad\text{OK}$$

$$\Delta_{B\,MAX} = \frac{8.0\cancel{\times10^6}\times8}{30\cancel{\times10^6}\times4.68\times10^3}\;18.5 \cong \underline{\underline{.0085\text{ IN}}}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.10 SPRING CONSTANT OF TRUCK AND RAILS

3.10.1 IN VERTICAL DIRECTION :

Δ BOGIE = .0035 IN
Δ AXLE = ÷
Δ CROSS BEAM = .0100 IN
Δ PIN = .0010 IN (ASSUMED)
Δ TRANSOM = .0150 IN
Δ TORQUE TUBE = .0085 IN

$$\Delta_{TRUCK} = \Sigma_{\Delta} = .0380 \text{ IN} \quad \text{AT } 2.0 \times 10^{6} \text{ LBS LOAD}$$

$$K_{\underset{V}{TRUCK}} = \frac{2.0 \times 10^{6}}{.0380} \cong \underline{52 \times 10^{6} \text{ LBS/IN}}$$

$$K_{V\,TRACK} \cong \underline{10 \times 10^{6} \text{ LBS/IN}}$$

$$K_{V_{COMB}} = \frac{10^{6}}{\frac{1}{52} + \frac{1}{10}} = \underline{8.4 \times 10^{6} \text{ LBS/IN}}$$

USE $\underline{\underline{10 \times 10^{6} \text{ LBS/IN}}}$ (MAKE TRUCKSTRUCTURE SOMEWHAT STIFFER)

THE ROTATIONAL SPRING CONSTANT OF THE AZIMUTH TURN TABLE INCLDG. THE FLEXIBILITY OF THE TRACKBED IS THEN (FOR 6 TRUCKS) :

$$K_{TR\,\theta_V} = 10 \times 10^{6} (173.2)(1078)\,3 = \underline{\underline{5.4 \times 10^{12}}} \text{ FT-LBS/RAD}$$

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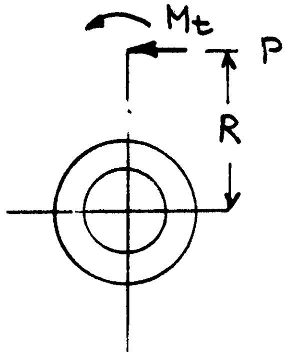
REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.72 OF 76
DATE 1-23-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

3.10.2 IN LATERAL DIRECTION :

$$M_t = \frac{4}{2}\,\frac{M_{tG}}{R_W} \times R = 2\,\frac{13,000}{1.5} \times 36 = \underline{624,000 \text{ IN LBS}}$$



M_{tG} = GEAR BOX OUTPUT TORQUE (FT-LBS)
R_W = WHEEL RADIUS (FT)
R = RADIUS OF APPLICATION OF FORCE (IN)

$$I_p = \frac{\pi}{32}\left(18^4 - 10^4\right) = \underline{9,360 \text{ IN}^4}$$

$$Z_P = \frac{I_p}{R} = \frac{9,360}{9} = \underline{1040 \text{ IN}^3}$$

$$S_T = \frac{624,000}{1040} \approx \underline{600 \text{ PSI}} \quad (\text{INSIGNIFICANT})$$

$$\theta = \frac{M_t\,\ell}{G\,I_p} = \frac{\overset{.624}{\cancel{624,000}} \times 38}{11.5 \cancel{\times 10^6} \times 9.36 \times 10^3} = \underline{.00022 \text{ RAD}}$$

$$\Delta = .00022 \times 36 \cong \underline{.008 \text{ IN}}$$

$$k_{TL} = \frac{P}{\Delta} = \frac{624,000/18}{.008} = \underline{4.35 \times 10^6 \text{ LBS/IN}}$$

USE $\underline{\underline{4.0 \times 10^6 \text{ LBS/IN}}}$ PER TRUCK

3.10.3 COMBINED LATERAL SPRING CONSTANT (GEAR TRAINS INCL'D)

$$K_{TL} = 4 \times 4.0 \times 10^6 \times (173.2)^2\,12 = \underline{5.75 \times 10^{12} \text{ FT-LBS/RAD.}}$$

$$K_{GT} = 4.8 \times 10^{12} \text{ \#/RAD}$$

$$K_{CL} = \underline{\underline{2.6 \times 10^{12}}} \text{ FT LBS/RAD}$$

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.73 OF 76
DATE 1-23-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.11 WEIGHT ESTIMATE, TRUCK ASSEMBLY (TRUCK W. CRANE WHEELS)
(TAKE OFF FROM DRAWING)

	ITEM DESCRIPTION	NO. REQ'D	UNIT WEIGHT (LBS)	TOTAL WEIGHT (LBS)
1)	36" DIA. CRANE WHEELS	8	1720	14,000
2)	AXLES	4	400	1,600
3)	DRIVE AXLES	4	750	3,000
4)	BOGIES	4	3500	14,000
5)	CROSS BEAMS	2	9000	18,000
6)	TRANSOM STRUCTURE	1	7500	7,500
7)	TORQUE TUBE	1	4000	4,000
8)	SADDLE	1	3500	3,500
9)	PIVOT PINS	2	600	1,200
10)	GEAR TRAINS	4	2500	10,000
11)	BRAKES & MISCALL.			10,000

TOTAL WEIGHT OF TRUCK ASSEMBLY : 86,800 LBS
SAY 90,000 LBS
= 45 TONS

STRUCTURAL WEIGHT EXCLUSIVE
GEAR TRAINS : 40 TONS

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.74 OF 76
DATE 1-27-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE — TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

3.12 COST ESTIMATE - AZIMUTH TURNTABLE

3.12.1 TURNTABLE WITH RAILROAD TRACKBED

A) DOUBLE RAIL ROAD TRACK ON GRAVEL BALLAST : $ 100,000.-
(346.4 FT. DIA ONLY)
(ESTD $ 100,000.- FOR 346.4 DIA TRACK BY V. HOERNER, RE: REPORT OF DEC. 5, 1967 PAGE 8, ITEM 3)

B) TRUCK ASSEMBLIES (5 REQ'D) EXCLDG. DRIVES :

	1. 16 - 38" DIA WHEEL PAIRS, AXLE & BEARINGS @ 1000.-		16,000.-
*	2. 16 - STD. SIDE FRAMES @ 600.-	5' BASE 125 TO CAPACITY	9,600.-
	3. 8 - STD. BOLSTERS @ 400.-		3,200.-
	4. 64,000 LBS OF FABRICATED STRUCTURE @ .40		25,600.-
	5. 135 TO. CONCRETE & STEEL COUNTER WEIGHTS @ 75.-		10,000.-
	7. 2 - BRAKE SETS @ 750.-		1,500.-
	8. COMPRESSOR, VALVES ETC.		1,500.-
	9. LABOR (ASSEMBLY)		7,000.-
	UNIT COST		: $ 75,000.-

COST FOR 5-UNITS @ 75,000.-	: $ 375,000.-
COST OF TRACK	$ 100,000.-
TOTAL COST OF AZIMUTH TURNTABLE WITH STD. RAIL ROAD COMPONENTS	: $ 475,000.-
TOTAL WEIGHT OF EACH TRUCK ASSY LESS COUNTERW.	: 80 TONS

* RE: QUOTATION BY AMERICAN STEEL FOUNDRIES.

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REPORT NO. H 79-8
CONTRACT NO. RAP-79
PAGE 3.75 OF 76
DATE 1-27-69

PROJECT: 300 FT DIA. HOMOLOGY TELESCOPE — TRUCKS & RAILS

SUBJECT: AZIMUTH TURNTABLE

3.12.2. TURNTABLE WITH CRANE RAILS AND CONCRETE FOUNDATION :

A) FOUNDATION AND RAIL, (346.4 FT. DIA.) :

1. 63.5 TONS - 175* CRANE RAIL (39' LENGTH) @ 260.- :	$ 16,500.-
* 2. 1450 SETS CLIPS & FILLERS @ .75/SET	1,100.-
3. 2900 STUDS & NUTS, PLACED @ 2.-/UNIT	5,800.-
4. 1004 YD^3 CONCRETE - PLACED - @ 50.-/YD^3	50,200.-
5. 90 TO. REINFORCING STEEL @ 400.-/TON	36,000.-
6. 6200 FT^2 FORMS @ 1.0/FT^2	6,200.-
7. 1004 YD^3 - EXCAVATION @ 10.-/YD^3	~10,000.-
8. 15,000 LBS TIEDOWN PLATES @ .20/UNIT	3,000.-
9. 56 WELD JOINTS @ 50.-/JOINT	~3,000.-
TOTAL COST OF OUTER TRACK	131,800.-
SAY	$ 135,000.-

* BASED ON QUOTATIONS BY BETHLEHEM STEEL
RAIL HEAT TREATED AND BENT TO EXACT CURVATURE
ENDS PREPARED FOR WELDING.

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REPORT NO. H79-8
CONTRACT NO. RAP-79
PAGE 3.76 OF 76
DATE 1-27-69

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE TRUCKS & RAILS
SUBJECT: AZIMUTH TURNTABLE

B) <u>TRUCK ASSEMBLIES</u> (W. CRANE WHEELS) EXCLDG. DRIVES:

*	1.	8 - 36" DIA WHEELS @ 1720 LBS @ $ 860.-	SAY	$ 7,000.-
*	2.	4 - AXLES @ 400 LBS @ $ 200.- } INCLDG. BEARINGS	SAY	1,000.-
*	3.	4 - AXLES @ 750 LBS @ $ 375.- }		1,500.-
	4.	68,000 LBS OF FABRICATED STRUCTURE @ .60	SAY	41,000.-
	5.	BRAKES & MISCALL.	SAY	2,000.-
	6.	COMPRESSOR, VALVES ETC.		1,500.-
	7.	LABOR (ASSEMBLY)		6,000.-
		UNIT COST		: $ 60,000.-

COST FOR 5-UNITS @ $ 60,000.- : $ 300,000.-
COST OF CONCRETE TRACK BED : $ 135,000.-
TOTAL COST OF AZIMUTH TURNTABLE WITH CRANE COMPONENTS : $ 435,000.-

TOTAL WEIGHT OF EACH TRUCK ASS'Y 45 TONS**

* VERBAL QUOTATION BY BETHLEHEM STEEL CORP. ** NO. C.WT. REQ'D.

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