SECTION 1.0

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

DATE June 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: LOADS AND MOMENTS

1.0 LOADS AND MOMENTS

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

PROJECT: 300 FT. DIA. HOMOLOGY RADIO TELESCOPE WIND LOADS

SUBJECT: LOADS & MOMENTS

1.1 WIND LOADS AND MOMENTS

THE APPLICABLE WIND VELOCITIES TO BE CONSIDERED FOR THE DETERMINATION OF LOADS AND MOMENTS WERE GIVEN BY DR. SEBASTIAN V. HOERNER AND BILL HORNE AS FOLLOWS:

CONDITION	REFLECTOR POSITION	WIND-VELOCITY (MPH)
1. TRACKING	ANY	18 MPH (AVERAGE)
2. DRIVE TO STOW	ANY	45 MPH
3. SURVIVAL	ZENITH POINTED	85 MPH *

FOR THE PURPOSE OF THIS INVESTIGATION IT IS ASSUMED THAT THE WIND VELOCITY PROFILES FOR CONDITIONS 1. AND 2. CAN BE CONSIDERED CONSTANT; THUS ESCALATION OF WIND VELOCITY AT DIFFERENT HEIGHTS IS TAKEN TO BE NEGLIGIBLE.

FOR CONSIDERATION OF THE MAXIMUM SURVIVAL WINDLOAD A VELOCITY GRADIENT AS A FUNCTION OF ELEVATION HEIGHT SHOULD BE CONSIDERED.
THE MOST RECENT ESTIMATE, BASED ON A 100 YEAR RECURRENCE PERIOD WAS MADE BY "AMMAN AND WHITNEY" IN 1962 FOR THE CONSIDERATION OF SURVIVAL LOADS ON THE 600 FT. DIA. "SUGAR-GROVE" INSTRUMENT.

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"AMMAN AND WHITNEY" RECOMMENDED AT THAT TIME THAT FOR THE SUGAR GROVE LOCATION THE FUNCTION OF THE DESIGN VELOCITY SHOULD BE TAKEN AS :

a) : $V_H = 88.6 \left(\frac{H}{30}\right)^{\frac{1}{7}}$ (MPH)

AND THE "FASTEST MILE" VELOCITY WITH :

b) : $V_H = 67.5 \left(\frac{H}{30}\right)^{\frac{1}{5}}$ (MPH)

FUNCTION "b" WAS BASED ON THE RECORDED "FASTEST MILE" OF 67.5 MPH AT A HIGHT OF 30 FT. THIS HIGHEST INSTANTANEOUS VELOCITY WAS RECORDED AT ELKINS AIRPORT DURING THE PERIOD FROM 1944 ÷ 1962.

THE FACTOR $\frac{1}{N} = \frac{1}{7}$ OR $\frac{1}{5}$ IS DETERMINED BY SITE CONDITIONS AND DECREASES WITH INCREASING GROUND ROUGHNESS.

OVER COASTAL WATER "n" IS ESTIMATED TO BE 10.5 AND OVER THE CENTER OF LARGE CITIES IS 1.6.

ASSUMING THAT THE SURFACE CONDITIONS FOR THE CONSIDERED SITE IS SLIGHTLY BETTER THAN SUGAR GROVE, A FACTOR OF $\frac{1}{N} = \frac{1}{5}$ IS USED. THUS AT A HIGHT OF APPROX. 170' ABOVE THE GROUND THE WIND VELOCITY IS THEN

$$V_{H=170} = 67.5 \left(\frac{170}{30}\right)^{\frac{1}{5}} \cong \underline{95 \text{ MPH}}$$

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THE REFLECTOR RIM IS AT AN ELEVATION OF APPROX. 256 FT. WHEN ZENITH POINTED DURING SURVEIVAL CONDITION, THUS THE WIND VELOCITY THERE IS:

$$V_{H=256} = 67.5 \left(\frac{256}{30}\right)^{\frac{1}{5}} \approx \underline{105 \text{ MPH}}$$

THEREFOR FOR THE PURPOSE OF THIS INVESTIGATION AN AVERAGE WIND VELOCITY OF 100 MPH WILL BE USED FOR THE DETERMINATION OF MAXIMUM LOADS AND MOMENTS.

AT NORMAL TEMPERATURE AND PRESSURE CONDITIONS ($t = 70°F$, $p = 29.92$ IN. Hg, $\gamma_{AIR} = .075$ #/FT³) THE AERODYNAMIC PRESSURES (STAGNATION PRESSURE) ARE: ($q = .0256\,V^2$)

$$q_{18} = .00256\,(18)^2 = \underline{.83 \text{ LBS/FT}^2}$$

$$q_{45} = .00256\,(45)^2 = \underline{5.18 \text{ LBS/FT}^2}$$

$$q_{100} = .00256\,(100^2) = \underline{25.6 \text{ LBS/FT}^2}$$

FROM WIND TUNNEL REPORT JPL-CP-3 (FIGURES 10, 11) THE APPLICABLE DRAG- AND MOMENT COEFFICIENTS ARE FOUND TO BE:

$C_{D\theta=0°} = +1.50$ $C_{m\theta=0°} = 0$

$C_{D\theta=130°} = +.58$ $C_{m\theta=130°} = .160$

$C_{D\theta=90°} = +.26$ * $C_{m\theta=90°} = .150$

} C_m FOR $F/D = .33$ ≈ C_m FOR $F/D = .42$

* MIT REPORT #1015

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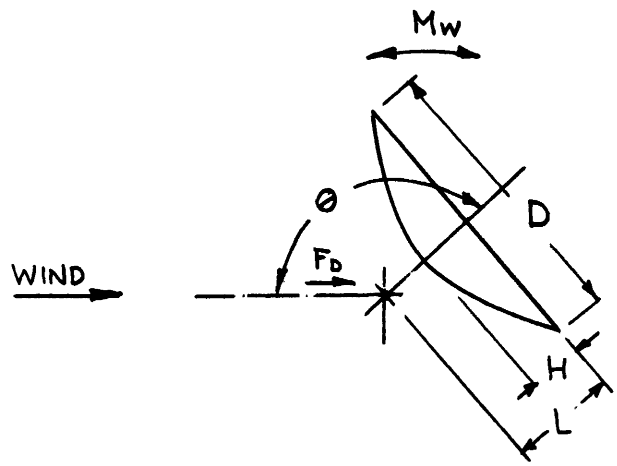
1.2 MOMENTS AND FORCES

a) ABOUT ELEVATION OR AZIMUTH AXES:

DRAG FORCE, $F_D = C_D\, q\, A$ (LBS)

MOMENT, $M_W = C_m\, q\, A\, D$ (FT-LBS)

A = PROJECTED REFLECTOR AREA ; D = REFLECTOR DIA.



LIFT NEGLECTED

D = 300 FT

L ≅ 86.4 FT

H ≅ 44 FT

$H/D = 44/300 = .147$ V.S. JPL DATA FOR $H/D = .150$ (OK)

TRACKING CONDITION (V = 18 MPH)

$M_{W0} =$ $= 0$ FT-LBS

$M_{W90} = .150\,(.83)\,\underbrace{\frac{300^2\pi}{4}}_{21.2\times10^6}(300)$ $= 2.63\times10^6$ FT-LBS

$M_{W130} = .160 \times 21.2\times10^6 \times .83$ $= 2.81\times10^6$ FT LBS

$F_{D0} = 1.50 \times .83 \underbrace{\left(\frac{300^2\pi}{4}\right)}_{7.07\times10^4}$ $= 88\times10^3$ LBS

$F_{D90} = .26 \times .83\,(7.07\times10^4)$ $= 15.3\times10^3$ LBS

$F_{D130} = .58 \times .83\,(7.07\times10^4)$ $= 34\times10^3$ LBS

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DRIVE TO STOW CONDITION (V = 45 MPH)

M_{W_0} = = 0

$M_{W_{90}}$ = .150 (5.18) 21.2×10^6 = 16.5×10^6 FT-LBS

$M_{W_{130}}$ = .160 (5.18) 21.2×10^6 = 17.5×10^6 FT-LBS

F_{D_0} = 1.50 (5.18) 7.07×10^4 = 550×10^3 LBS

$F_{D_{90}}$ = .26 (5.18) 7.07×10^4 = 96×10^3 LBS

$F_{D_{130}}$ = .58 (5.18) 7.07×10^4 = 212×10^3 LBS

SURVIVAL CONDITION (V = 100 MPH) $\theta = 90°$

$M_{W_{90}}$ = .150 (25.6) 21.2×10^6 = 81.5×10^6 FT-LBS

$F_{D_{90}}$ = .26 (25.6) 7.07×10^4 = 470×10^3 LBS

b) MAXIMUM MOMENTS AT BASE : (TO TOP OF RAILS)

DISTANCE FROM TOP OF RAIL TO ℄ ELEVATION AXIS : 166 FT. = h

$M_{BASE} = (F_D h) + M_W$

AT 18 MPH $(\theta=0)$: $M_{BASE\,MAX} = (88\times10^3)166 + 0 = 14.6\times10^6$ FT-LBS

AT 45 MPH $(\theta=0)$: $M_{BASE\,MAX} = (550\times10^3)166 + 0 = 91.2\times10^6$ FT-LBS

AT 100 MPH $(\theta=90)$: $M_{BASE\,MAX} = (470\times10^3)166 + 81.5\times10^6 \cong 160\times10^6$ FT-LBS

ADDING 20% TO THE ABOVE FIGURES TO INCLUDE THE DRAG ON THE TOWER STRUCTURE WE GET : (SEE NEXT PAGE)

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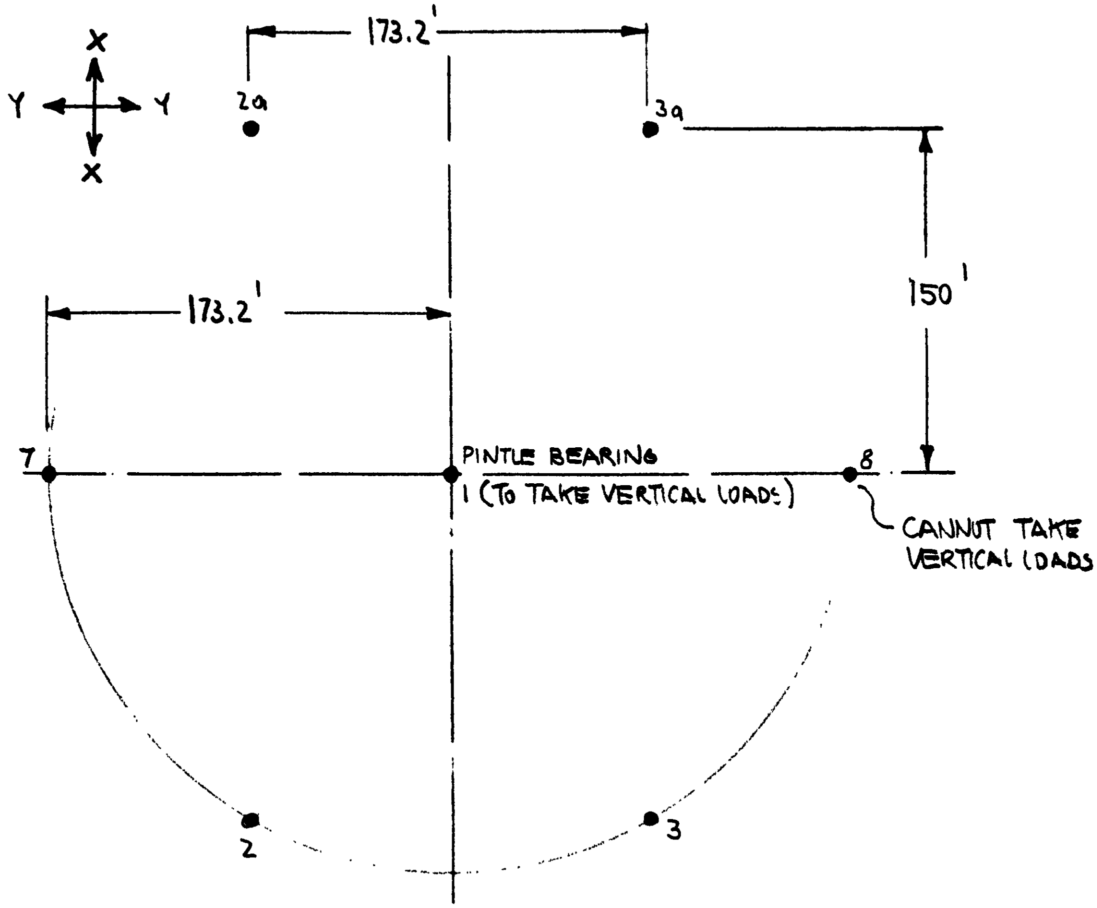
$M_{BASE\ MAX}$ @ 18 MPH $= 1.2 \times 14.6 \times 10^6 \cong \underline{17.5 \times 10^6 \text{ FT-LBS}}$

$M_{BASE\ MAX}$ @ 45 MPH $= 1.2 \times 91.2 \times 10^6 \cong \underline{110 \times 10^6 \text{ FT-LBS}}$

$M_{BASE\ MAX}$ @ 100 MPH $= 1.2 \times 160 \times 10^6 \cong \underline{192 \times 10^6 \text{ FT-LBS}}$

1.3. LOADS ON TRUCKS DUE TO WIND

1) VON HOERNER'S ARRANGEMENT :



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a) MOMENT IN X-X DIRECTION :

VERTICAL LOADS DUE TO WIND ON TRUCKS 2,3, 2a & 3a
(SHEARLOAD IS TAKEN BY PINTLE BEARING AT LOCATION -1-)

AT 18 MPH WIND VELOCITY ($\theta = 0$), $L_{TV} = \frac{17.5 \times 10^6}{2 \times 300} = \pm$ 29,200 LBS

AT 45 MPH WINDVELOCITY ($\theta = 0$), $L_{TV} = \frac{110 \times 10^6}{.6 \times 10^3} = \pm$ 184,000 LBS

AT 100 MPH WINDVELOCITY ($\theta = 90$), $L_{TV} = \frac{192 \times 10^6}{.6 \times 10^3} = \pm$ 320,000 LBS

b) MOMENT IN Y-Y DIRECTION :

FROM THE LAYOUT IT IS APPARENT THAT THE TOWER/MOUNT STRUCTURE IS TORSIONAL VERY FLEXIBLE ABOUT THE X-X AXIS. THUS THE HORIZONTAL SHEAR LOAD IS TRANSFERED VIA THE ELEVATION BEARINGS INTO THE TOWERS WHICH HAVE POINTS 2 & 3 AT THE CORNER LOCAT. IT IS THEREFOR REASONABLE TO ASSUME THAT ONLY THESE POINTS WILL REACT TO HORIZONTAL SHEARLOADS ACTING ON THE BEARINGS.

PINTLE BEARING -1- AND TRUCK -7- WILL REACT TO THE TANGENTIAL LOAD AT THE STOW LOCK ARRANGEMENT OR PITCH RADIUS OF THE ELEVATION GEAR DUE TO THE AERODYNAMIC MOMENT ACTING ON THE REFLECTOR.

IN THIS CASE THE PINTLE BEARING MUST BE DESIGNED FOR BOTH VERTICAL- AND SHEAR REACTIONS.

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THE VERTICAL REACTIONS AT POINTS 2, 3, 2a & 3a ARE THEN:

AT 18 MPH, $\theta = 0°$, $L_{TV} = \frac{17.5\times10^6}{2\times173.2} = \pm$ 50,300 LBS (MAX. VALUE)

AT 18 MPH, $\theta = 130°$, $L_{TV} = \frac{1.2}{346.4}\left[(34\times10^3\times166) + (2.81\times10^6 \frac{166}{90})\right] = \pm$ 37,500 LBS

AT 45 MPH, $\theta = 0°$, $L_{TV} = \frac{110\times10^6}{.346\times10^3} = \pm$ 318,000 LBS

AT 100 MPH, $\theta = 90°$, $L_{TV} = \frac{(470\times166)10^3\times1.2 + 1.2\times81.5\times10^6(\frac{166}{90})}{.346\times10^3} = \pm$ 760,000 LBS

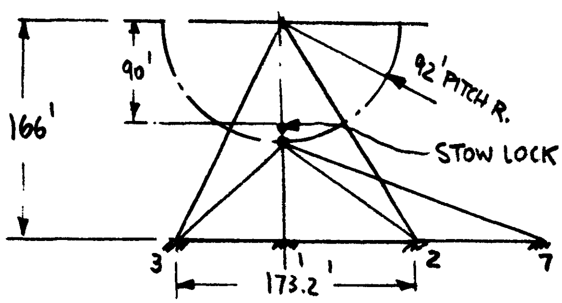
THE VERTICAL REACTIONS AT POINTS 1 & 7 ARE:

AT 18 MPH, $\theta = 130°$, $L_{TV} = \frac{1.2\times2.81\times10^6}{173.2}\left(\frac{74}{92}\right) = \pm$ 15,600 LBS

AT 45 MPH, $\theta = 130°$, $L_{TV} = \frac{1.2\times17.5\times10^6}{173.2}\left(\frac{74}{92}\right) = \pm$ 97,500 LBS

AT 100 MPH, $\theta = 90°$, $L_{TV} = \frac{1.2\times81.5\times10^6}{173.2}\left(\frac{76}{90}\right) = \pm$ 475,000 LBS

THUS THE MAXIMUM VERTICAL LOAD ON THE TRUCKS IS: ± 760,000 LBS
AND THE MAXIMUM VERTICAL LOAD ON THE PINTLE BG.: ± 475,000 LBS



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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE WEIGHTS

SUBJECT: LOADS & MOMENTS

1.4 WEIGHT SUMMARY (MOVING WEIGHTS)

ITEM	DESCRIPTION	NO. REQD	UNIT WEIGHT (TONS)	TOTAL WEIGHT (TONS)
1	REFLECTOR STRUCTURE	1	1150	1150
2	REFLECTOR SURFACE	1	100	100
3	FEED ASS'Y	1	2	2
4	ELEVATION GEAR	1	8	8
5	BACK UP STRUCTURE	1	20	20
	REFLECTOR ASSEMBLY	1		1280
6	TOWER STRUCTURE	1	610	610
7	CATWALKS & LADDERS	1	10	10
8	ELEVATION BEARINGS	2	20	40
9	ELEVATION DRIVE	1	46	46
10	PINTLE BEARING	1	4	4
	TOWER ASSEMBLY	1		720
11	TRUCK ASSEMBLIES	5	45	225
12	TRUCK ASSEMBLY	1	25	25
	TOTAL WEIGHT OF TELESCOPE			2,240 TONS

NOTE: FOR DESIGN OF TRACK USE 3000 TONS.

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1.5 STABILITY :

ASSUMING THAT THE PINTLE BEARING TAKES ABOUT $\frac{1}{3}$ OF THE DEADLOAD OF 2240 TONS SAY 740 TONS, THE MINIMUM DEADLOAD PER EACH OF THE FOUR MAIN TRUCKS IS :

$$L_T = \frac{(2240 - 740)}{4} = \underline{375 \text{ TONS}} = \underline{750{,}000 \text{ LBS}}$$

THIS COMPARES TO A MAXIMUM VERTICAL LOAD DUE TO WIND DURING SURVIVAL CONDITION OF $\pm$ 760,000 LBS WHICH INDICATES THAT THE SYSTEM IS NOT STABLE.

CONSIDERING NEXT THAT THE PINTLE BEARING TAKES ONLY $\frac{1}{4}$ OF THE DEADLOAD, THE MINIMUM DEADLOAD PER TRUCK IS :

$$L_T = \frac{(2240 - 560)}{4} = \underline{420 \text{ TONS}} = \underline{840{,}000 \text{ LBS}}$$

THIS WOULD LEAVE A SAFETY MARGIN OF $\frac{840 - 760}{840} \cong 10\%$ AGAINST OVERTURNING.

NO COUNTERWEIGHT WILL BE REQUIRED!

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1.6 SUMMARY, MAXIMUM LOADS :

PINTLE BEARING :

1. LATERAL:, AT 40 MPH WIND, θ=0°		:	550,000 LBS
2. VERTICAL:	a) DEADLOAD	:	1,120,000 LBS
	b) SNOW (20 #/FT²)	:	375,000 "
	c) STRAIN DUE TO RAIL WAVYNESS	:	178,000 "
	TOTAL	:	1,673,000 LBS
	SAY	:	1,700,000 LBS

TRUCKS :

1. LATERAL		:	0
2. VERTICAL :	a) DEAD LOAD	:	840,000 LBS
	b) SNOW (20 #/FT²)	:	282,000 "
	c) WIND LOAD	:	760,000 "
	TOTAL	:	1,882,000 LBS
	SAY	:	1,900,000 LBS

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