SECTION 6.0

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
PAGE 6.1 OF 26
DATE May 1969

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE

SUBJECT: STRUCTURE

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

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POST OFFICE BOX 2
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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE BUILT UP MEMBERS

SUBJECT: STRUCTURE

6.1 BUILT UP - MEMBERS

6.1.1 WIND INDUCED VIBRATIONS

WHEN WIND PASSES PERPENDICULAR TO THE TUBULAR MEMBERS OF THE BUILT UP COLUMN STRUCTURES, VORTEX SHEDDING CAUSES ALTERNATING FORCES WHICH ARE VERY REGULAR IN OCCURANCE. WHEN THE VORTEX FREQUENCY COINCIDES WITH THE NATURAL FREQUENCY OF ANY TUBULAR MEMBER VIBRATION AMPLITUDES BECOME LARGE AND CAN CAUSE FATIGUE FAILURE WITHIN A VERY SHORT TIME IF THE STRESS LEVEL IN THE MEMBER IS ABOVE THE ENDURANCE LIMIT OF THE MATERIAL, WHICH FOR STEEL IS AT APPROX. .5 $S_{ULTIMATE}$ (50% OF ULTIMATE STRENGTH)

IN ORDER TO ELIMINATE THE DANGER OF WIND INDUCED FATIGUE-FAILURE OF THE STRUCTURAL MEMBERS IT IS PROPOSED THAT THE LENGTH OF ANY MEMBER BE LIMITED TO A NUMBER SLIGHTLY BELOW THE LENGTH AT WHICH SELF EXCITED VIBRATIONS CAN OCCURE UNDER LAMINAR FLOW CONDITIONS.
THE DANGER OF FAILURE IS GREATLY REDUCED UNDER TURBULENT WIND CONDITIONS SINCE THE VORTICE SHEDDING IS THEN RANDOM IN NATURE AND THUS CAN SAFELY BE IGNORED.

THE FOLLOWING IS A DERIVATION OF MAXIMUM PERMISSIBLE LENGTH OF TUBULAR MEMBERS AS A FUNCTION OF OUTSIDE DIA. OR PIPE SIZE.

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE — BUILT UP MEMBERS

SUBJECT: STRUCTURE

WIND FORCE ACTING ON MEMBER : (P. UNIT LENGTH)

$$F_W = C_K \cdot .00256\, V^2 A \qquad (V^2 - \text{MPH},\ A - \text{FT}^2)$$

OR :

$$F_W = C_K \cdot \frac{.00256}{12} V^2 A$$

$$= \underline{C_K \; .000214\, V^2 D} \qquad (\text{LBS}/\text{FT}) \qquad 1.)$$

WHERE C_K = V. KARMAN LIFT COEFFICIENT
D = PIPE DIA. (IN)

THE V. KARMAN LIFT COEFFICIENT IS RELATIVELY CONSTANT AT .50 FOR REYNOLDS NO.S OF 100 TO 100,000 (LAMINAR FLOW) AND DECREASES RAPIDLY AS THE FLOW BECOMES TURBULENT.

IN THE LAMINAR FLOW REGION THE PERIOD OF VORTEX SHEDDING IS SIMPLY RELATED TO THE WIND VELOCITY AND THE DIAMETER OF THE MEMBER WITH

$$f_W = \frac{V_W}{D_0} N_S \qquad (\text{CPS})$$

WHERE N_S = STROUHAL NO. = .20 FOR THE REGION OF INTEREST.
V_W = WIND VELOCITY IN FT/SEC., D_0 IN FT.

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OPERATED BY ASSOCIATED UNIVERSITIES, INC., UNDER CONTRACT WITH THE NATIONAL SCIENCE FOUNDATION

PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE BUILT UP MEMBERS

SUBJECT: STRUCTURE

FOR V_W IN MPH AND $N_S = .20$

$$f_W = \frac{5280}{3600}\ .20\ \frac{12}{D_0}$$

$$= \underline{3.52\ \frac{V_W}{D_0}} \qquad 2.)$$

ALL TUBULAR MEMBERS IN THE BUILTUP COLUMNS ARE RIGIDLY WELDED AT THE ENDS TO THE MEMBERS TO WHICH THEY CONNECT, THUS COULD POSSIBLY BE CONSIDERED TO BE BETWEEN A CLAMPED - CLAMPED AND SIMPLY SUPPORTED BEAM.

FOR A HALF CLAMPED - CLAMPED BEAM THE FOLLOWING FORMULA DEFINES ITS LOWEST TRANSVERSE RESONANCE :

$$f_n = \frac{15.4}{2\pi}\sqrt{\frac{EI}{\mu_1 L^4}} = 2.45\sqrt{\frac{EI}{\mu_1 L^4}}$$

WHERE $\mu_1 = \frac{\rho A}{g} = \frac{\rho \pi D t}{386}$

FOR A THIN WALLED TUBE :

$$I = \pi r^3 t = \frac{\pi D_0^3 t}{8}$$

THUS : $f_n = 2.45\sqrt{\frac{E}{L^4}\ \frac{D^{\cancel{3}2}\cancel{\pi t}}{\rho\ 8} \times \frac{386}{\cancel{\pi D t}}}$

$$= 17.0\sqrt{\frac{E}{\rho}\ \frac{D_0^2}{L^4}}$$

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FOR STEEL $E = 30 \times 10^6$, $\rho = .283 \ ^{LBS}/_{IN^3}$

$$\frac{E}{\rho} = \frac{30 \times 10^6}{.283} = \underline{1.06 \times 10^8}$$

THEREFOR $F_n = 17.0 \times 1.03 \times 10^4 \frac{D_0}{L^2}$

$$= \underline{17.5 \times 10^4 \frac{D_0}{L^2}} \qquad 3)$$

REYNOLDS NO. $N_R = \frac{V_0 D_0}{\nu}$

$\nu = .0001566 \ ^{SEC}/_{FT^2}$ FOR STANDARD AIR

$N_R = 6400 \ V_0 D_0$

$$= 6400 \left(\frac{5280}{3600}\right) V_0 \frac{D}{12} = \underline{780 \ V_0 D_0} = 200{,}000 \qquad 4)$$

HENCE :

$$17.5 \times 10^4 \frac{D_0}{L^2} \cong 3.52 \frac{V_W}{D_0} = 3.52 \frac{200{,}000}{780 \ D_0^2}$$

$$L^2 = \frac{175{,}000 \quad 780}{200{,}000 \quad 3.52} D_0^3$$

$$L^2 = \underline{194 \ D^3}$$

$$L \leqq \underline{\underline{13.92 \ D^{\frac{3}{2}}}} \qquad 5)$$

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SUBJECT: STRUCTURE

TABLE OF PERMISSIBLE MAX. MEMBER LENGTHS:

PIPE SIZE (STD. PIPE)	O.D (IN)	$D^{1.5}$	L_{MAX} (IN)
$\frac{1}{8}$	.405	.257	3.5
$\frac{1}{4}$	.540	.397	5.5
$\frac{3}{8}$	.675	.554	7.5
$\frac{1}{2}$	.840	.770	10.5
$\frac{3}{4}$	1.050	1.076	15
1	1.315	1.507	21
$1\frac{1}{4}$	1.660	2.140	30
$1\frac{1}{2}$	1.900	2.620	36
2	2.375	3.660	51
$2\frac{1}{2}$	2.875	4.870	67
3.	3.500	6.520	90
$3\frac{1}{2}$	4.000	8.000	111
4	4.500	9.520	132
5	5.563	13.200	183
6	6.625	17.000	234
8	8.625	25.300	350
10	10.750	35.200	488
12	12.750	46.000	640

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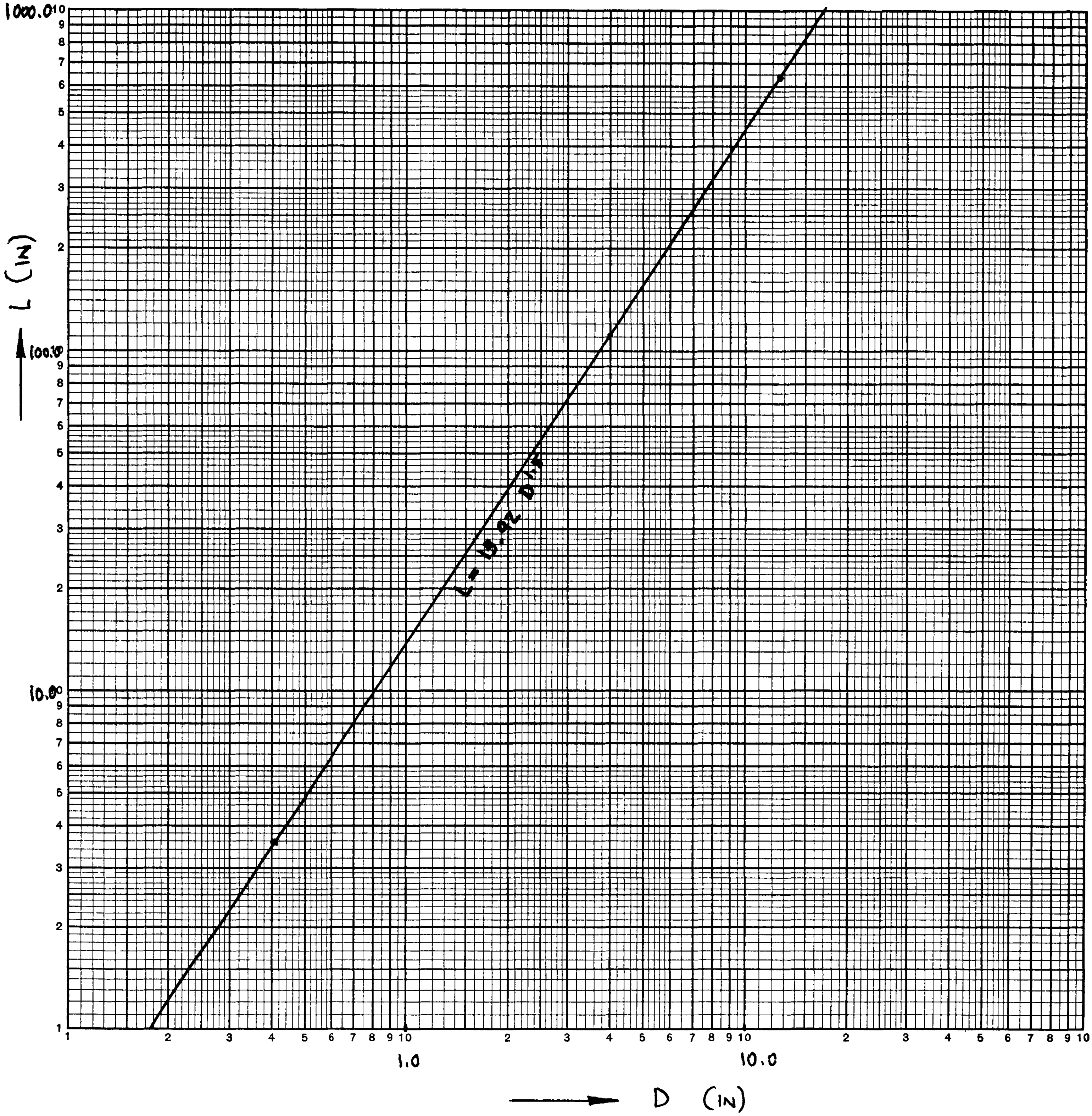
300 FT. DIA. HOMOLOGY TELESCOPE

RAP-79

BUILT UP MEMBERS



MAX. UNSUPPORTED MEMBER LENGTH V.S. OUTSIDE DIA.

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SUBJECT: STRUCTURE

6.1.2 EVALUATION OF V. HOERNER BUILT UP MEMBER TYPE "A"

THIS MEMBER REPRESENTS A TYPICAL STRUCTURAL MEMBER USED IN THE HOMOLOGY REFLECTOR CONCEPT AND HAS THE FOLLOWING PHYSICAL DIMENSIONS :

OVERALL LENGTH , L = 669.4 IN

ITEM	DESCRIPTION	MEMBER SIZE	O.D.	AREA (IN^2)
1	PYRAMID	$2\frac{1}{2}$" STD. PIPE	2.875	1.704
2	CHORDS	2" STD. PIPE	2.375	1.075
3	BATTENS	$\frac{1}{2}$" STD. PIPE	.840	.250
4	DIAGONALS	$\frac{1}{2}$" STD. PIPE	.840	.250
5	TRIANGLES	$\frac{1}{8}$" STD. PIPE	.405	.072

A LAYOUT WAS MADE OF THIS STRUCTURE AND THE MAXIMUM UNSUPPORTED MEMBER LENGTHS WERE SCALED FROM IT WHICH ARE AS FOLLOWS :

1	PYRAMID	:	56 IN
2	CHORDS	:	56 "
3	BATTENS	:	30 "
4	DIAGONALS	:	30 "
5	TRIANGLES	:	14 "

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COMPARING THIS TO THE TABLE OF PERMISSIBLE MEMBER LENGTHS WE FIND THAT ONLY THE PYRAMIDS ARE PROPERLY SIZED AND THAT ALL OTHER MEMBERS ARE TOO LONG FOR SAFE OPERATION UNDER WIND CONDITIONS.

IN ORDER TO GET PROPERLY SIZED MEMBERS WE MUST THEREFOR INCREASE THE O.D. OF THE TUBULAR MEMBERS; THIS REQUIRES THE USE OF STEEL TUBING INSTEAD OF STD. PIPE

ANOTHER CRITERIA IS THE MINIMUM PERMISSIBLE WALL THICKNESS OF THE TUBE WHICH FOR PRACTICAL REASONS MUST NEVER BE BELOW 3/32 IN., SINCE A THINNER WALL COULD NOT BE WELDED WITHOUT RUNNING THE RISK OF BURNING THROUGH THE TUBE WALLS (THE MINIMUM SIZE OF WELDING ELECTRODES IS 1/16 IN). FURTHERMORE, THE HANDLING OF THESE BUILT UP MEMBERS REQUIRES THAT A MINIMUM WALL THICKNESS BE MAINTAINED IN ORDER TO AVOID LOCAL DAMAGE DURING TRANSPORTATION OR ERECTION.

THUS FROM GRAPH (O.D REQ'D V.S L REQ'D) WE FIND THE FOLLOWING REQUIRED DIAMETERS:

CHORDS	:	APPROX. 2.6 IN	
BATTENS	:	" 1.7 "	WALL THICKNESS: .094 IN MIN.
DIAGONALS	:	" 1.7 "	
TRIANGLES	:	" 3/4" STD. PIPE	

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THE RELATIVE THIN WALL THICKNESS OF ONLY 3/32 IN SELECTED AS A MINIMUM REQUIRES THAT THE LOCAL BUCKLING CRITERIA BE CHECKED.

FOR COLD DRAWN OR MACHINED TUBES WILSON AND NEWMARK ON THE BASIS OF EXTENSIVE TESTS, SUGGEST A SAFE DESIGN FORMULA FOR STEEL COLUMNS :

$$S = 2 \times 10^6 \frac{t}{R_{AVG.}} \quad \text{(RE : ROARK PAGE 274)}$$

USING THIS FORMULA WE GET FOR VARIOUS TUBE OUTSIDE DIAMETERS :

TUBE DIA. D_0	$D_0^{1.5}$	$R_{AVG.}$	$\frac{t}{R}$	L_{MAX}	$\frac{L}{r}$	S_{MAX} (PSI)	$S_{C\,MAX}$ (PSI)
1.0	1.00	.453	.207	13.92	.32	41,300	17,500
1.25	1.39	.578	.163	19.3	.41	32,600	17,220
1.50	1.84	.703	.133	26.0	.50	26,600	16,840
1.75	2.32	.828	.113	32.1	.59	22,600	16,680
2.00	2.82	.953	.098	39.0	.67	19,600	16,360
2.25	3.37	1.078	.087	46.7	.76	17,400	16,120
2.50	3.95	1.203	.078	54.8	.85	15,600	15,860
2.75	4.56	1.328	.070	63.2	.94	14,000	15,610
3.00	5.18	1.453	.065	72.0	1.03	13,000	15,340
3.25	5.85	1.578	.059	81.4	1.12	11,800	15,070
3.50	6.52	1.703	.055	91.0	1.20	11,000	14,800

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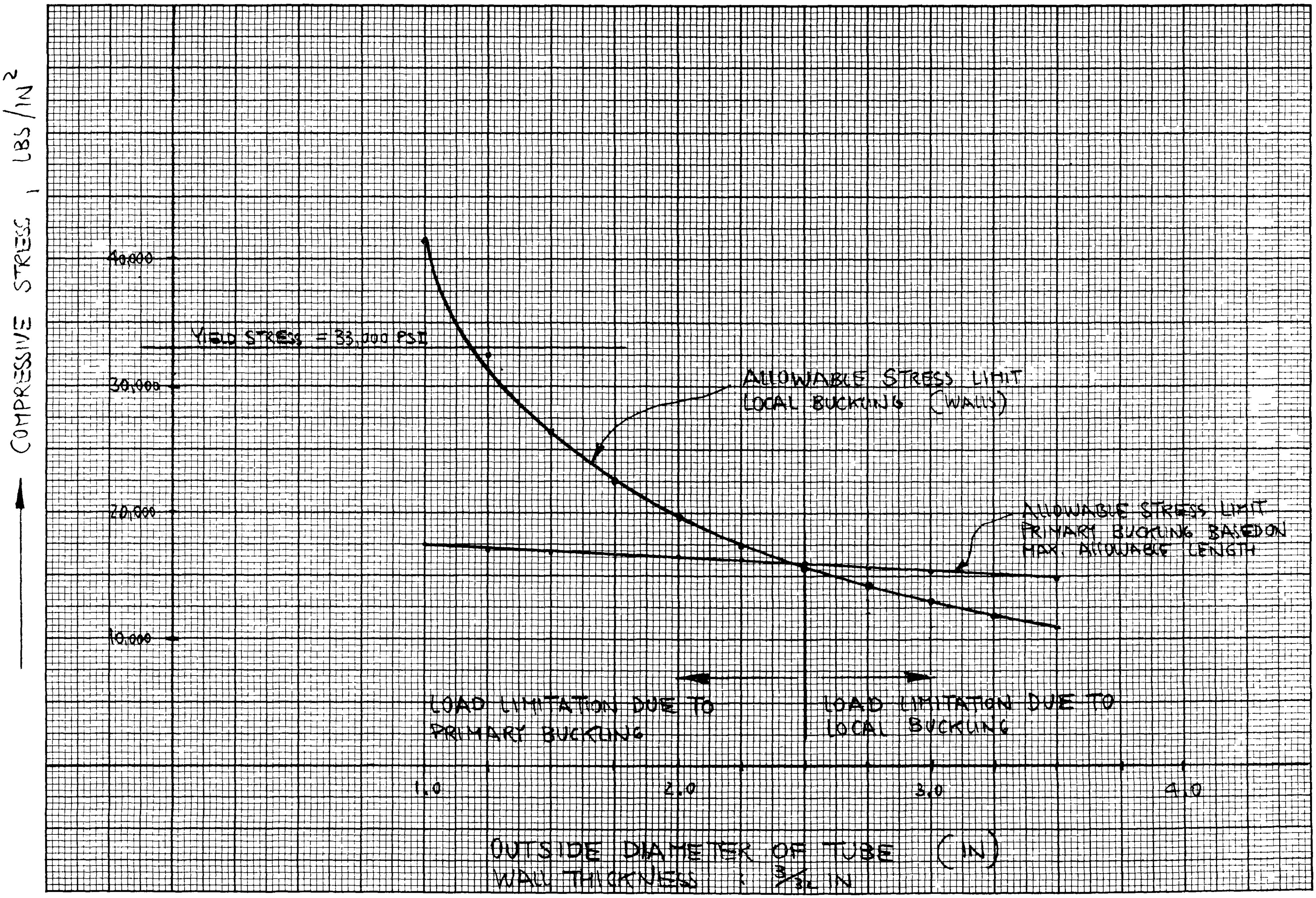
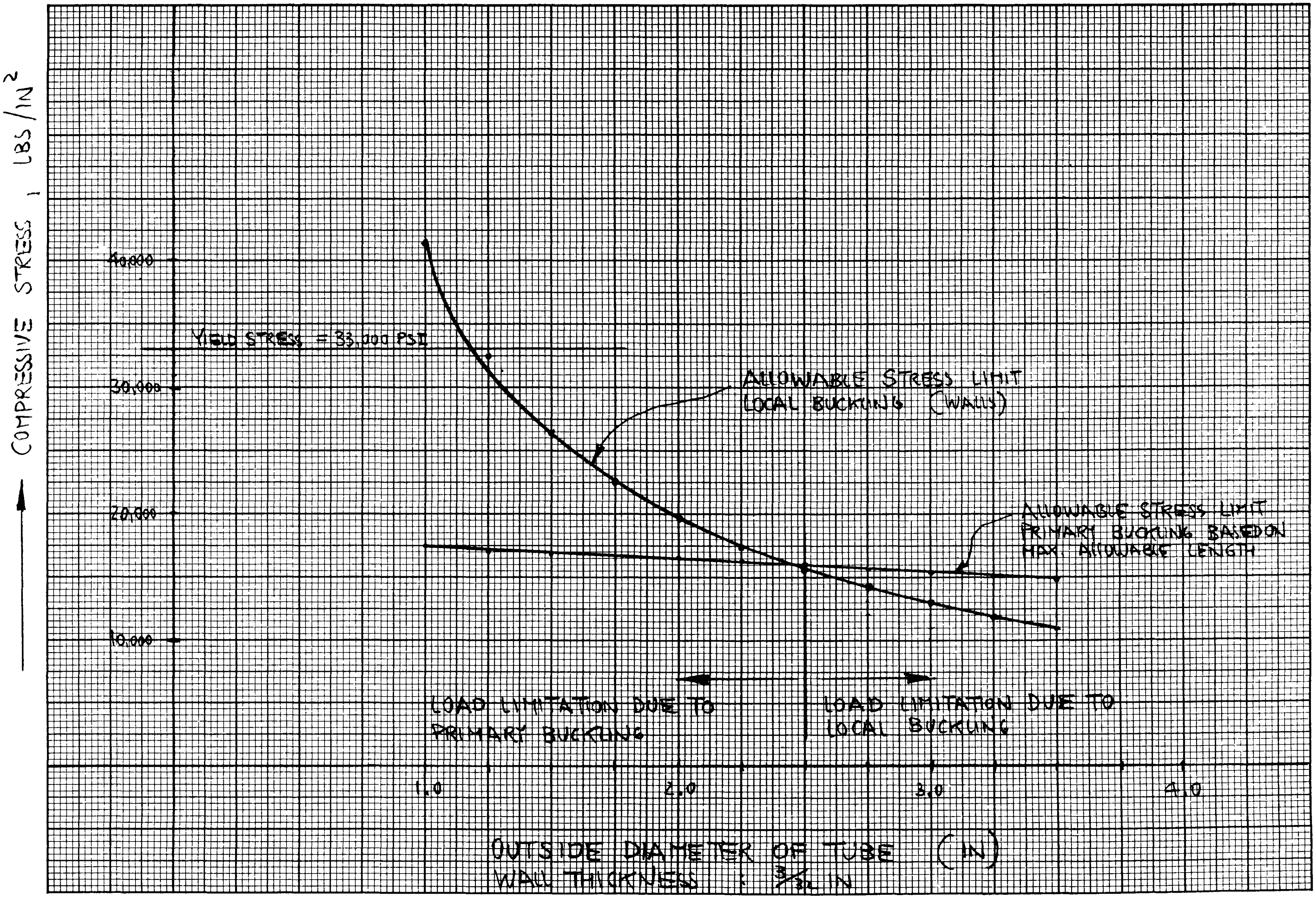

COMPRESSIVE STRESS, LBS/IN²
40,000
30,000
20,000
10,000
YIELD STRESS = 33,000 PSI
ALLOWABLE STRESS LIMIT
LOCAL BUCKLING (WALLS)
ALLOWABLE STRESS LIMIT
PRIMARY BUCKLING BASED ON
MAX. ALLOWABLE LENGTH
LOAD LIMITATION DUE TO
PRIMARY BUCKLING
LOAD LIMITATION DUE TO
LOCAL BUCKLING
1.0
2.0
3.0
4.0
OUTSIDE DIAMETER OF TUBE (IN)
WALL THICKNESS : 3/32 IN

300 FT. DIA. HOMOLOGY TELESCOPE



6.11 G= 26

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SUBJECT: STRUCTURE

THE REQUIRED MEMBER DIMENSIONS THUS ARE :

ITEM	DESCRIPTION	MEMBER SIZE	O.D	AREA (IN^2)	WEIGHT (LBS/FT)
1	PYRAMID	$2\frac{1}{2}$" STD. PIPE	2.875	1.704	5.79
2	CHORDS	$2\frac{5}{8}$" - .134 IN WALL	2.625	1.05	3.565
3	BATTENS	$1\frac{5}{8}$ - .095 "	1.625	.457	1.552
4	DIAGONALS	$1\frac{5}{8}$ - .095 "	1.625	.457	1.552
5	TRIANGLES	$\frac{3}{4}$" STD. PIPE	1.050	.333	1.130

WEIGHT COMPARISON :

FROM THE LAYOUT THE FOLLOWING WAS SCALED :

TOTAL LENGTH OF ALL PYRAMID MEMBERS : 28 FT
TOTAL LENGTH OF ALL CHORD MEMBERS : 140 "
TOTAL LENGTH OF ALL DIAGONAL & BATTENS : 369 "
TOTAL LENGTH OF ALL TRIANGLE MEMBERS 25 "

WEIGHT OF MEMBERS	ORIGINAL	REVISED
PYRAMIDS	28 × .5.79 = 162 #	28 × 5.79 = 162 #
CHORDS	140 × 3.65 = 511 #	140 × 3.565 = 499 #
DIAGONALS & BATTENS	369 × .85 = 314 #	369 × 1.552 = 573 #
TRIANGLES	25 × .24 = 6 #	25 × 1.130 = 28 #
	TOTAL 993 #	TOTAL 1262 #

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THIS REPRESENTS A WEIGHT INCREASE OF APPROXIMATELY

$$\frac{269}{993} 100 = \underline{27\ \%}$$

OVER THE WEIGHT ESTIMATED BY DR. V. HOERNER.

A LIST OF ALL MEMBERS CONTAINED V. HOERNER REPORT NO. 21 OF JAN. 10, 1969 SHOWS THAT THE MAJORITY OF THE MEMBERS FOR THE REFLECTOR ARE SHORTER THAN 669.4 IN AND IT IS HENCE CONCLUDED THAT THEY WOULD FOLLOW A SIMILAR PATTERN.

IT IS HOPED THAT THE FINAL DESIGN WILL PERMIT A SLIGHT REDUCTION OF THIS WEIGHT INCREASE AND THAT THE TOTAL GAIN CAN BE HELD TO LESS THAN 20%.

FOR THE PURPOSE OF DYNAMIC - AND COST ANALYSIS IT IS THUS ASSUMED THAT THE REFLECTOR WEIGHT WOULD BE:

$$W_{REFLECTOR} = \underline{1300\ \text{TONS}}$$

INSTEAD OF THE 1100 TONS CALCULATED BY DR. V. HOERNER.

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THE V. HOERNER CONCEPT FOR THE BUILT UP MEMBERS OF THE HOMOLOGY TELESCOPE IS BASED ON A CURVED CHORD MEMBER CONFIGURATION WHICH IS VERY DIFFICULT TO MAKE AND HENCE VERY COSTLY DUE TO THE INCREASED LABOR TIME REQUIRED FOR STRUCTURAL LAYOUT, FITTING AND WELDING.
FURTHERMORE THE LACING OF THE STRUCTURE IS IRREGULAR AND THEREFOR EACH DIAGONAL BLOCK HAS DIFFERENT CONTACT ANGLES WHICH COMPLICATES THE FABRICATION.

IT WOULD BE LESS COSTLY TO a) USE STRAIGHT SECTIONS AND b) TO USE A PARALLEL LACING ARRANGEMENT (SEE LAYOUT)

THE WEIGHT OF THE BUILT UP MEMBER PER THIS DESIGN WOULD THEN BE (BASED ON SCALING OF LAYOUT):

PYRAMIDS	:	28	×	5.79	=	162 #
CHORDS	:	141	×	3.565	=	503 #
DIAGONALS & BATTENS	:	393	×	1.552	=	610 #
TRIANGLES	:	33	×	1.130	=	37 #
						1312 #

V.S. 1262 # FOR THE CURVED BEAM OR ONLY 50 # INCREASE.
FURTHERMORE THE BENDING STIFFNESS IS IMPROVED WHICH MAY MAKE IT POSSIBLE TO REDUCE THE CHORD MEMBERS SLIGHTLY IN SIZE.

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SUBJECT: STRUCTURE

ANOTHER FEASIBLE SOLUTION TO THE WIND INDUCED VIBRATION PROBLEM WOULD BE TO PERMIT RESONANCE OF A MEMBER AT THE CRITICAL WIND VELOCITY AND TO SELECT A STRUCTURAL MATERIAL WITH A SUFFICIENTLY HIGH ENOUGH ENDURANCE LIMIT SO THAT THE MEMBER CAN SUSTAIN THE IMPOSED VIBRATIONS FOR AN INDEFINITE PERIOD.

THIS REFLECTOR WEIGHT WOULD THEN BE AS ORIGINALLY CALCULATED. THE COST OF THE REFLECTOR WOULD HOWEVER INCREASE BY ABOUT \$ .10 /LB (FROM \$ .40 TO \$ .50 /LB OR APPROX. 25 %) IF A CARBON STEEL WOULD BE USED.

IN ORDER TO DEMONSTRATE THE FEASIBILITY OF THIS APPROACH, THE FOLLOWING EXAMPLE IS ANALIZED:

MEMBER	:	DIAGONAL OR BATTEN	
L	:	30 IN	
D_0	:	.840 IN	$\frac{1}{2}$" STD. PIPE
A	:	.250 IN^2	
I	:	.017 IN^4	
W	:	.850 LBS/FT	

$$f_n = 2.45\sqrt{\frac{EI}{\mu L^4}} \quad ; \quad \mu = \frac{.850}{12 \times 386} = 1.84 \times 10^{-4} \ \frac{LBS\ SEC^2}{IN}$$

$$f_n = 2.45\sqrt{\frac{30\times10^6 \times .017\times10^4}{1.84 \times (30)^4}} \cong \underline{136\ CPS}$$

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THE CRITICAL WINDVELOCITY AT WHICH RESONANCE WILL OCCURE IS THEN :

$$V_{W_{CR}} = \frac{F_n}{3.52} D_o = \frac{136}{3.52} .840 \cong \underline{33 \text{ MPH}}$$

THE DISTURBING FORCE IS AT 38 MPH APPROX. :

$$F = .50 \times .00256 \, (33)^2 \left[\frac{30 \times .840}{144} \right] = \underline{.240 \text{ LBS}}$$

$$S_{B\,MAX} = \frac{M_{B\,MAX}}{Z} = \frac{P \frac{\ell}{8} (r)}{I} = \frac{(M) F \frac{\ell}{8} r}{I}$$

$$S_{B\,MAX} = (M) \frac{.240 \frac{30}{8} .420}{.017} = \underline{22.2 \; (M)}$$

WHERE M = MAGNIFICATION FACTOR

AT $S_{B\,MAX}$ = 15,000 PSI $M \cong \frac{\pi}{.48}^{*} = \underline{6.54}$

THUS $S_{B\,MAX} = 22.2 \times 654 = \underline{14,500 \text{ LBS/IN}^2}$

TO THIS SHOULD BE ADDED THE NORMAL TENSION OR COMPRESSION STRESS OCCURING IN THE MEMBER AND THE STRESS DUE TO THE AMPLITUDE MAGNIFICATION CAUSED BY THE AXIAL LOAD.

* SEE DERIVATION OF MAGNIFICATION FACTOR & DAMPING

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ESTIMATE OF DAMPING RATE (MEMBER ONLY)

THE RATIO OF DAMPING ENERGY TO STRAIN ENERGY IS :

$$\eta_s = \frac{D_0}{\pi \frac{(S_{MAX})^2}{E} V_0 \beta}$$

{RE : MECHANICAL DESIGN & SYSTEMS HDBOOK, BY ROTHBART, SECTION 34}

$D_0 = D_D V_0 \alpha$ = TOTAL DAMPING ENERGY DISSIPATED BY MEMBER (IN LBS/CYCLE)

S_{MAX} = MAX. INDUCED STRESS (LBS/IN^2)

V_0 = TOTAL EFFECTIVE VOLUME OF MEMBER CONTRIBUTING TO THE DISSIPATION OF DAMPING ENERGY AND SUBJECT TO A STRESS BETWEEN 0 - AND S_{MAX} (IN^3)

β = STRAIN ENERGY INTEGRAL

α = DAMPING ENERGY INTEGRAL

D_D = SPECIFIC DAMPING ENERGY AT THE MAXIMUM STRESS (IN LBS / IN^3 / CYCLE)

FOR .25% CARBON STEEL STRESSED AT 30.000 PSI :
$D \cong$ 1.35 IN LBS / IN^3 / CYCLE

FOR A CYLINDRICAL BEAM UNDER UNIFORM BENDING :
$\alpha = .21$ AND $\beta = .21$ AT $n = 2$

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THE SPECIFIC DAMPING ENERGY "D" IS CONSIDERED HEREIN TO BE THE DAMPING ENERGY AT THE "AVERAGE STRESS".

THE AVERAGE STRESS IS ASSUMED TO BE $\frac{2}{3}$ SMAX.

THUS :

$$\eta_s = \frac{D\,\cancel{V_0 K}}{\pi \frac{(S_{MAX})^2}{E} \cancel{V_0 K}} = \frac{D\,\frac{E}{\pi}}{(S_{MAX})^2}$$

$$\underline{\underline{\eta_s = 9.57 \times 10^6 \frac{D}{(S_{MAX})^2}}}$$

FOR SAE 1025 STEEL :

SMAX (LBS/IN^2)	D ($IN\,LBS/IN^3$)
8,000	.026
10,000	.050
15,000	.017
20,000	.400
30,000	1.350
40,000	10.000 * (2.8 FOR SAE 4130)

THESE FIGURES ARE PLOTTED ON THE FOLLOWING PAGE

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SUBJECT: STRUCTURE

THE SPECIFIC DAMPING ENERGY "D" IS CONSIDERED HEREIN TO BE THE DAMPING ENERGY AT THE "AVERAGE STRESS".

THE AVERAGE STRESS IS ASSUMED TO BE $\frac{2}{3}$ SMAX.

THUS :

$$\eta_s = \frac{D \cancel{V_0 K}}{\pi \frac{(S_{MAX})^2}{E} \cancel{V_0 K}} = \frac{D \frac{E}{\pi}}{(S_{MAX})^2}$$

$$\underline{\underline{\eta_s = 9.57 \times 10^6 \frac{D}{(S_{MAX})^2}}}$$

<u>FOR SAE 1025 STEEL</u> :

SMAX (LBS/IN²)	D (IN LBS/IN³)
8,000	.026
10,000	.050
15,000	.017
20,000	.400
30,000	1.350
40,000	10.000 * (2.8 FOR SAE 4130)

THESE FIGURES ARE PLOTTED ON THE FOLLOWING PAGE

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TELEPHONE ARBOVALE 456-2011

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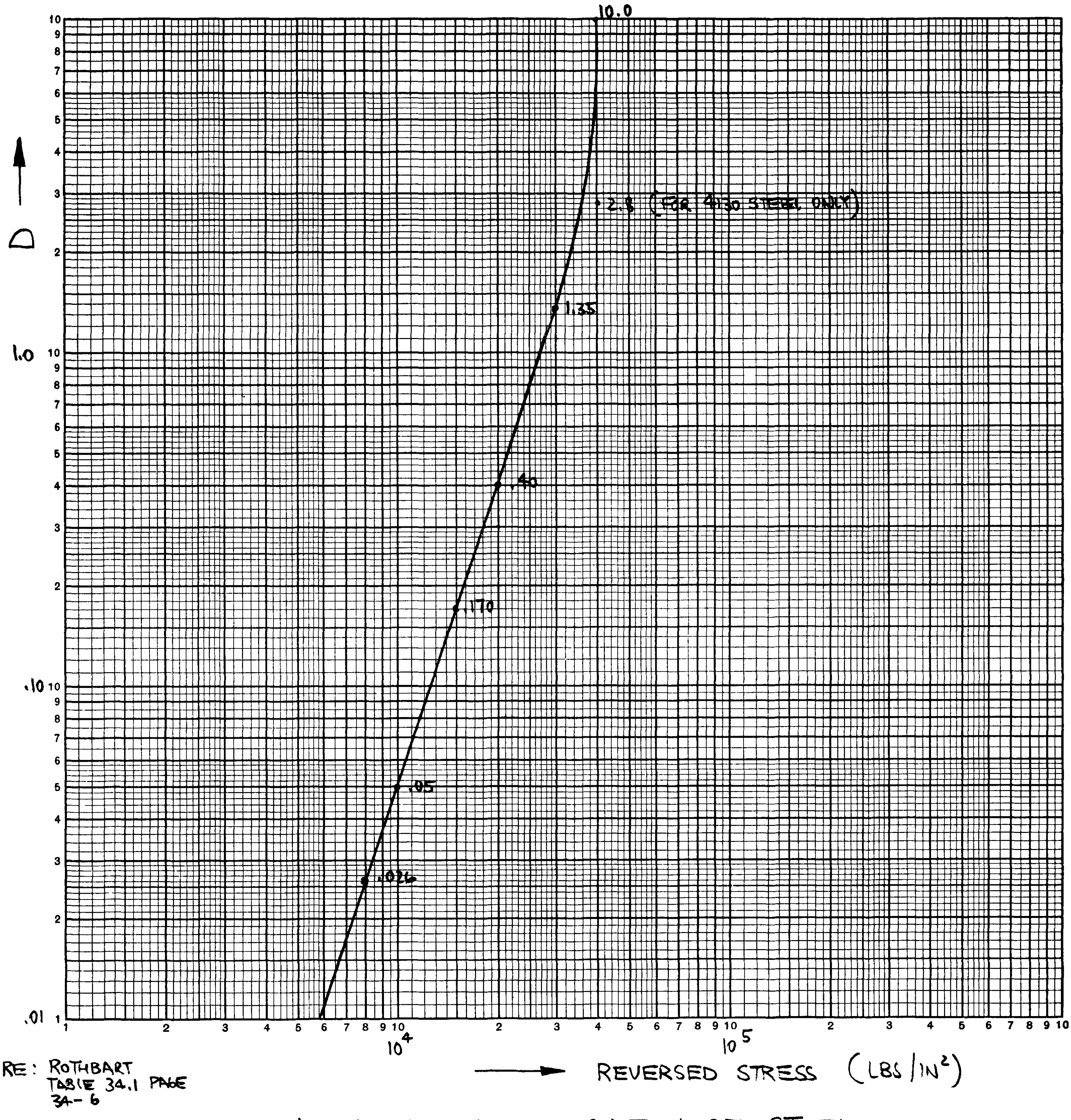

RE: ROTHBART
TABLE 34.1 PAGE
34-6

DAMPING CAPACITY OF SAE 1025 STEEL

D = ENERGY ABSORBED, IN LBS/IN³ OF STRESSED MATERIAL PER CYCLE

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S_{MAX} (LBS/IN^2)	$(S_{MAX})^2$ (10^6)	D (IN.LBS/CYCLE)	η (%)	$S_{AVERAGE}$ (CORRESPONDING) (LBS/IN^2)
8,000	64	.026	.39	12,000
10,000	100	.050	.48	15,000
15,000	225	.170	.72	22,500
20,000	400	.400	.96	30,000
30,000	900	1.35	1.44	45,000
40,000	1600	10.0 (2.8*)	6.0 (1.66*)	60,000

THE ENDURANCE LIMIT IS AT APPROX 10^7 CYCLES FOR STEEL AT APPROX. 50% OF ULTIMATE STRENGTH.

MATERIAL	TENSILE STRENGTH (PSI)	ENDURANCE STRENGTH (PSI)	AMPLITUDE DECAY (%)	RELATIVE MAGNIFICATION
1. * A-53 TYPE S, GR. "B" (STD. PIPE)	60,000	30,000	.96	327
2. ** A-106 GRADE "C" (HIGH TEMP. PIPE)	70,000	35,000	1.02	307
3. *** SAE 1040 (TUBING ONLY)	75,000	37,500	1.04	302

*(**) Y.P ≅ 35,000 LBS/IN^2
*** Y.P = 52,000 "

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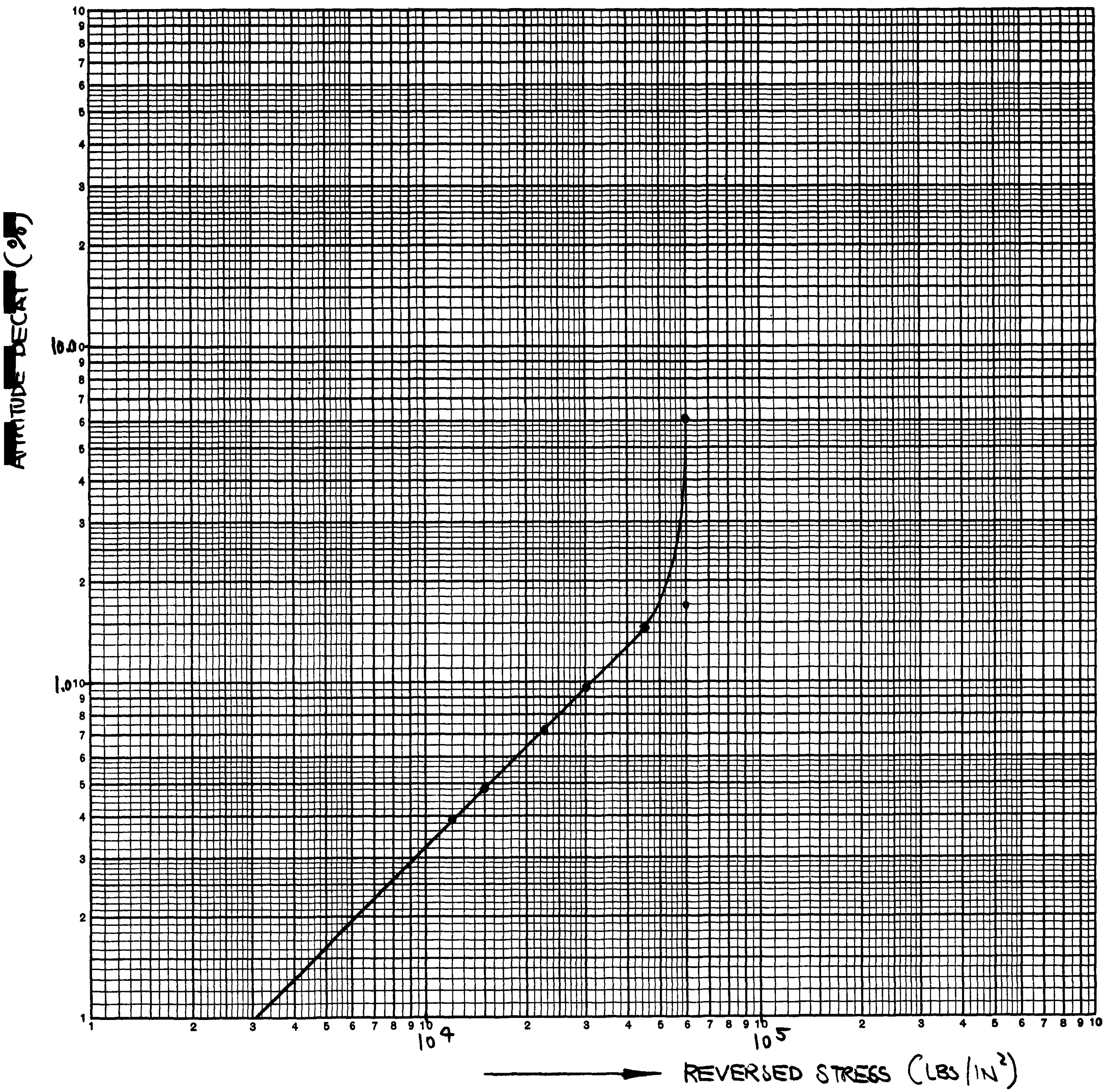
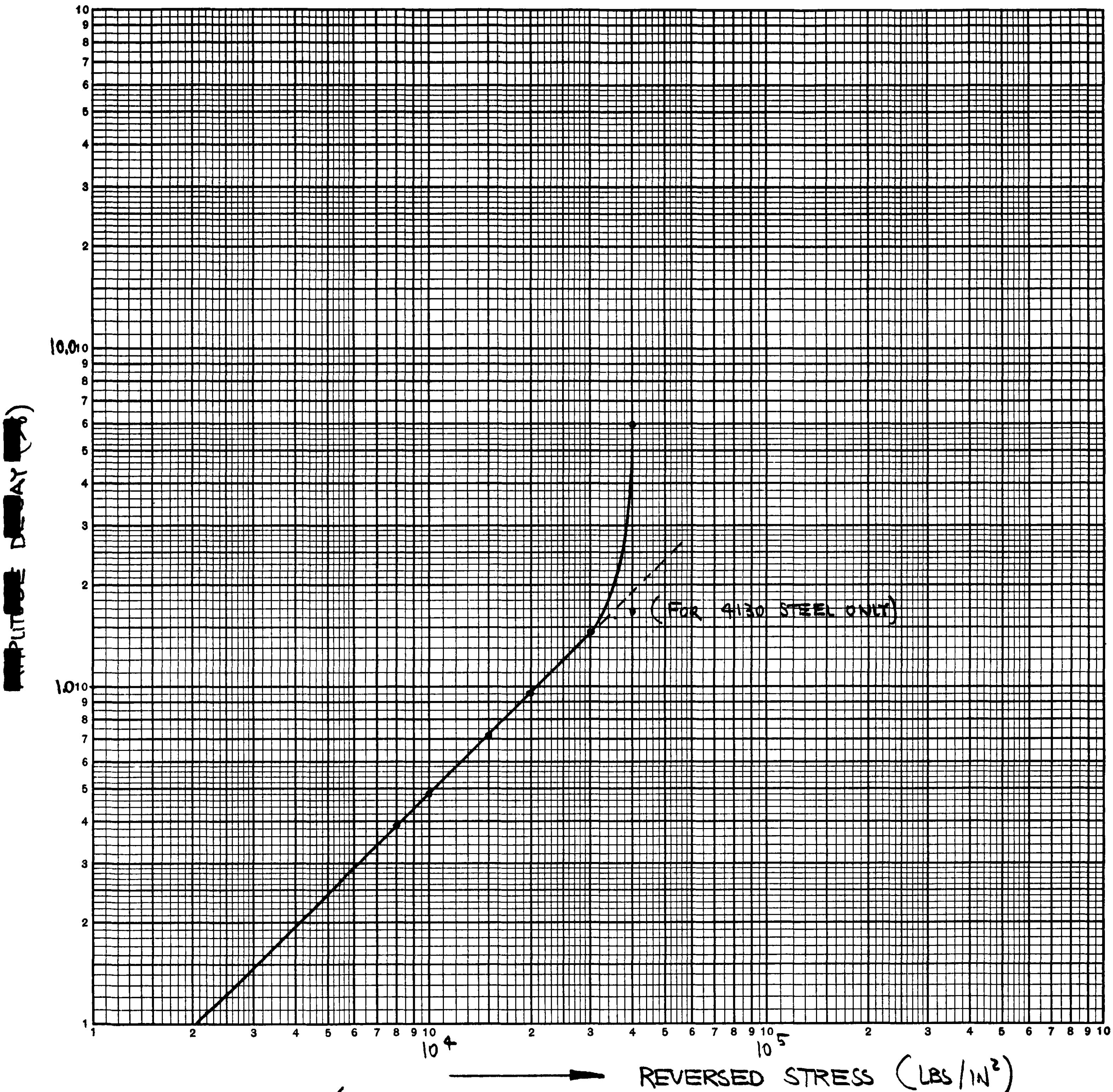


DAMPING ENERGY / STRAIN ENERGY AS FUNCTION OF MAXIMUM BENDING STRESS BASED ON AVERAGE STRESS IN MEMBER



DAMPING ENERGY/STRAIN ENERGY AS FUNCTION OF MAXIMUM STRESS FOR SAE-1025 STEEL

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6.1.3. END CONNECTIONS

THE HOMOLOGY PROGRAM ASSUMES FRICTIONLESS PINNED END-CONNECTIONS WHICH IN PRACTICE HOWEVER CANNOT BE OBTAINED. THERE ARE FOR INSTANCE SEVERAL JOINTS CONNECTING UP TO 13 MEMBERS AND FOR ALL PRACTICAL PURPOSE SUCH JOINTS SHOULD BE CONSIDERED RIGID.

THE ONLY END FLEXIBILITY ATTAINABLE IS THROUGH THE SELECTION OF THE END CONNECTION WHICH IN THIS CASE IS ASSUMED TO BE A SINGLE TUBULAR MEMBER OF $\frac{1}{12}$ TOTAL BUILT UP MEMBER LENGTH. (SEE DWGS. 109-D-017 FOR INSTANCE)

TO CONSIDER THE EFFECT OF JOINT-END CONNECTION STIFFNESS JOINT # 45 AND MEMBER # 45-57 IS STUDIED AS FOLLOWS:

LENGTH OF BUILT UP MEMBER, $L = 1531$ IN

CROSSECTION $A = 59.26 \text{ IN}^2$

$$\frac{\ell}{r} = \frac{L}{3.34\ A^{.667}} = \frac{1531}{3.34(59.26^{.667})} \cong \underline{30} \qquad (1^*$$

$$F_m = .358\ L\ A\sqrt{\left[1+(6.26/A)^{.667}\right]}$$

$$= .358(1531)(59.26)\sqrt{\left[1+\left(\frac{6.26}{59.26}\right)^{.667}\right]} \cong \underline{38{,}600 \text{ LBS}} \qquad (2$$

= MAX. NORMAL FORCE

* EQUATIONS # 1, 2 & 3 BY S.V. HOERNER

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$$P_m = A\,(S_A - S_g)\left(1 - \frac{S_g}{S_E}\right) \quad = \text{MAX. AXIAL LOAD} \qquad (3$$

$$S_g = 4{,}130\left(\frac{L}{1000}\right) \quad : \text{STRESS IN CHORDS FROM DEAD LOAD}$$

$$= 4{,}130 \times 1{,}531 \quad = \underline{6{,}320 \text{ PSI}}$$

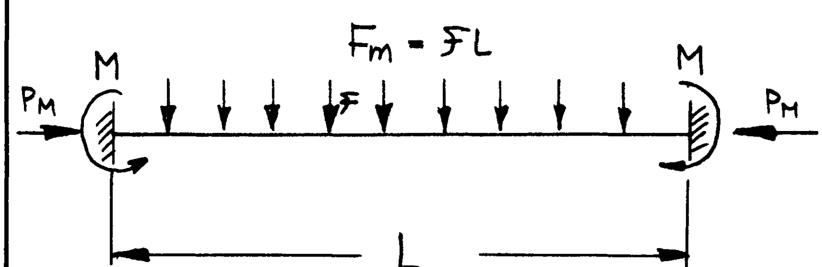
$$S_A = \underline{18{,}360 \text{ PSI}} \quad : \text{ALLOWABLE STRESS FOR } \frac{\ell}{r} = 30$$
$$YP = 33{,}000 \text{ PSI}$$

$$S_E = \underline{35{,}400 \text{ PSI}} \quad : \text{SAG CORRECTED EULER STRESS}$$

$$P_m = 59{,}26\,(18{,}360 - 6{,}320)\left(1 - \frac{6320}{35{,}400}\right)$$

$$= 59{,}26\,(12{,}040)(.82)$$

$$= \underline{600{,}000 \text{ LBS}}$$



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$$M = \frac{F_m}{L} \frac{EI}{P_m} \left(1 - \frac{\frac{1}{2}u}{tg\frac{1}{2}u}\right)$$

$$j = \sqrt{\frac{EI}{P_m}}$$

$$u = \frac{L}{j} = \frac{L}{\sqrt{\frac{EI}{P_m}}}$$

$$r = \sqrt{\frac{I}{A}} = \frac{L}{(\frac{\ell}{r})^2}$$

$$I = r^2 A = \frac{L^2}{(\frac{\ell}{r})^2} A$$

$$I = \frac{(1531)^2}{(30)^2} 59.26 = \underline{154{,}000 \text{ IN}^4}$$

$$j = \sqrt{\frac{30 \times 10^6 \times 154{,}\cancel{000}}{600{,}\cancel{000}}} = \underline{2{,}770}$$

$$j^2 = 2{,}770^2 = \underline{7.7 \times 10^6}$$

$$u = \frac{1531}{2{,}270} = \underline{.676} \quad ; \quad \frac{u}{2} = \underline{.338}$$

$$M = \frac{38{,}600}{1531} \times \frac{30 \times 10^6 \times 154{,}\cancel{000}}{600{,}\cancel{000}} \left(1 - \overset{.04}{\frac{.338}{.3522}}\right)$$

$$= 25.2 \times 7.7 \times 10^6 \times .04$$

$$= \underline{7{,}750{,}000 \text{ IN LBS}}$$

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PROJECT: 300 FT. DIA. HOMOLOGY TELESCOPE — BUILT UP MEMBERS

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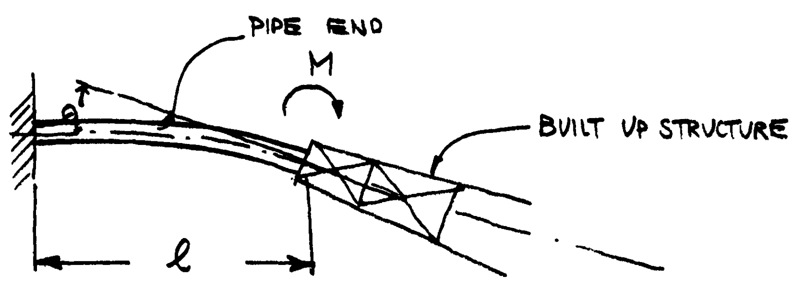
CONSIDERING A MAXIMUM ALLOWABLE COMBINED STRESS OF 33,000 PSI THE END MEMBER IS SIZED AT:

20" – 100 SCHEDULE PIPE : $Z = 332 \text{ IN}^3$ $I = 3{,}320 \text{ IN}^4$
$A = 75.3 \text{ IN}^2$

$$S_{B\,MAX} = \frac{7{,}750{,}000}{332} = \underline{23{,}400 \text{ PSI}}$$

$$S_{C\,MAX} = \frac{600{,}000}{75.3} \approx \underline{8{,}000 \text{ PSI}}$$

$$S_{COMB.\,MAX} = S_{B\,MAX} + S_{C\,MAX} = \underline{\underline{31{,}400 \text{ PSI}}}$$



$$\theta = -\frac{M\ell}{EI} \quad ; \quad K = \frac{M}{\theta} = \frac{EI}{\ell}$$

$$K_{JOINT} = \frac{30 \times 10^6 \times 3{,}320}{1531/12} = 780 \times 10^6 \text{ IN LBS/RAD}$$

$$= \underline{\underline{65 \times 10^6 \text{ FT LBS/RAD}}}$$

THIS IS A SIGNIFICANT NO. AND SHOULD BE CONSIDERED IN THE FINAL HOMOLOGY DESIGN.

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