LIFTING DEVICE

DEVICE NAME: VACUUM LIFTING DEVICE

ENGINEERING NOTE NUMBER: 58

DRAWING NUMBER: 9306-ME-302260

APPLICABLE STANDARD: ANSI/ASME B30.20-1985

RATED LOAD: 25 lb

TEST LOAD: 32 lb

TEST LOAD PERCENT: 128%

LAST LOAD TEST DATE: AUGUST/23/1993

COLOR: ALUMINUM

STRESS CALCULATIONS:

Done by: J. RAFAEL F. SILVA

Date: JULY, 20th, 1993

Reviewed by:

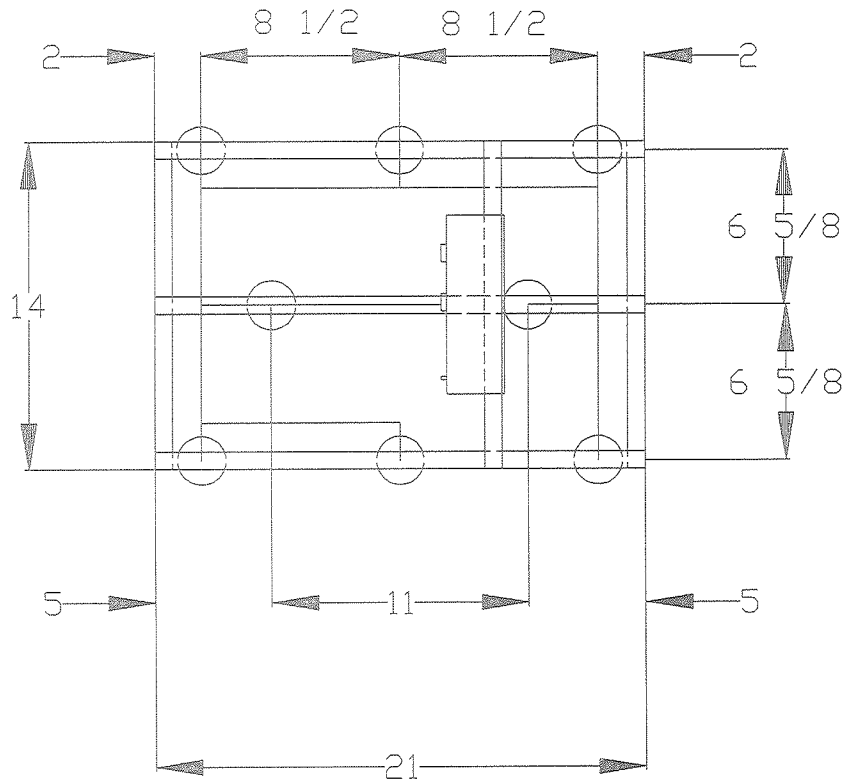
Date: 8/24/93

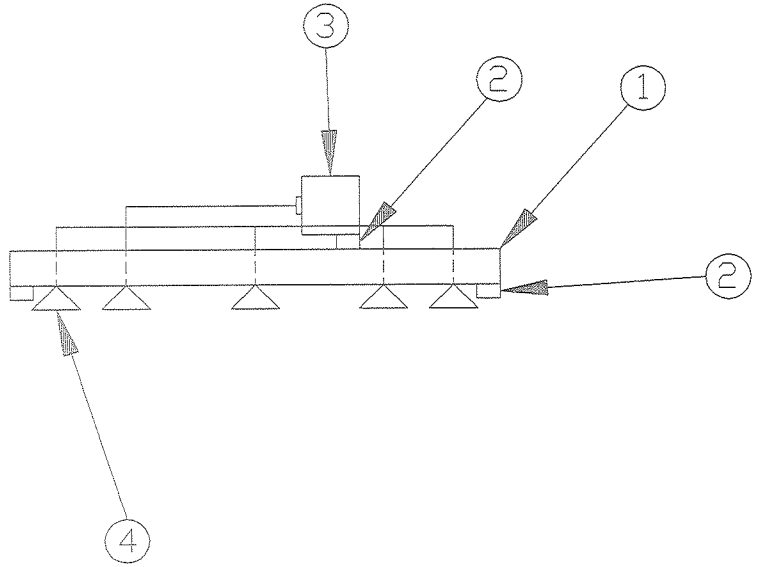
REMARKS:

IDENTIFICATION:

Engineering Note Number & Rated Load Must be Clearly Marked On a Conspicuous Surface.

1. GENERAL LAY. OUT





REV.		DRAWN	DATE
		APPD.	DATE

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
4		SUCTION CUPS PIAB F-50	8
3		PUMP PIAB M2500	1
2		6061-T6511 3/4" x 1" x 13 7/8"	3
1		6061-T6511 1 1/2" x 3/4" x 21"	3

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	RAFAEL SILVA	07/19/93
FRACTIONS	DECIMALS	ANGLES	DRAWN	RAFAEL SILVA	07/19/93
±1/64	±.005	±.25°	CHECKED		

1. BREAK ALL SHARP EDGES .25" MAX.
2. DO NOT SCALE DRAWING
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982
4. MAX. ALL SHOWN SURFACES 125 √

APPROVED

USED ON

MATERIAL:

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

VACUUM LIFTING DEVICE - 21"

SCALE	SOFTWARE	DRAWING NUMBER	REV.
1:2	AUTOCAD	9302-ME-302260	—

FILE: E302260.DWG

LIFTING DEVICE – 21"

THE VACUUM LIFTING DEVICE SPECIFIED AND DESIGNED ACCORDING TO THE FERMILAB RD ENGINEERING NOTE #42 HAS TO BE ADAPTED TO WORK IN ANOTHER JOB.

THE DEVICE IS NOT GOING TO BE REDESIGNED, ONLY ADAPTED AND CHECKED TO VERIFY THE SAFETY WHEN IN OPERATION.

SO, THIS ENGINEERING NOTE PRESENTS THE NEW DIMENSIONS, VERIFY THE SUITABILITY TO THE NEW APPLICATION AND STABLISH THE NEW LIMITATIONS TO BE OBSERVED.

<u>SUMMARY</u>

1. DRAWING ME-302260 (DWG) SHOWING THE GENERAL LAY-OUT OF THE ADAPTED FRAME
2. PLATES
3. VACUUM COMPONENTS
4. ALUMINUM FRAME: THE LONGITUDINAL BEAMS
5. OTHER COMPONENTS
6. <u>LIMITATIONS</u>
7. ANNEX 1 & 2

LIFTING DEVICE / PLATES

OBJECTIVE:

HANDLING OF LEAD PLATES

2) LEAD PLATES

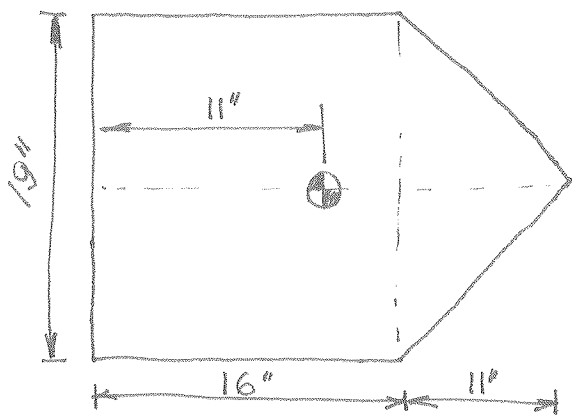
A) MATERIAL

- CHEMICAL LEAD (99.9% Pb, 0.1% IMPURITIES)

$\sigma_y = 800$ psi $E = 2.6 \times 10^6$ psi $d = 0.410$ lb/in^3

$\sigma_u = 2{,}300$ psi $\varepsilon = 40.5\%$

B) SIZES



THICKNESS: 2.8 mm
~7/64"

WEIGHT < 25 lb

THIS SIZES (DIMENSIONS) ARE APROXIMATED.

C) DEFORMATION

SMALL DEFORMATIONS ARE ALLOWED IN THE LEAD PLATES.

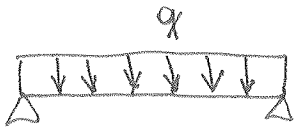
(IT IS NOT A CRITICAL ISSUE)

CALCULATION OF THE DISTANCE BETWEEN SUCTION CUPS:

1) RECTANGULAR SECTION

PLATE: $b \times l \times t$ $\qquad d = lb/in^3$

1) BETWEEN SUPPORTS:



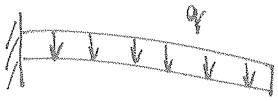
$$q = \frac{W}{l} = d.b.t$$

$$M_{MAX} = \frac{q l^2}{8} \Rightarrow M_{MAX} = \frac{(dtb) l^2}{8}$$

$$\sigma = \frac{Mc}{I}, \quad c = \frac{t}{2}, \quad I = \frac{bt^3}{12} \Rightarrow \sigma = \frac{3}{4}\frac{d l^2}{t}$$

$$\Rightarrow \boxed{l_S = \sqrt{\frac{4}{3}\frac{\sigma t}{d}}}$$

2) EDGE:



$$q = \frac{W}{l} = dbt$$

$$M_{MAX} = \frac{q l^2}{2} \Rightarrow M_{MAX} = \frac{(dbt) l^2}{2}$$

$$\sigma = \frac{Mc}{I}, \quad c = \frac{t}{2}, \quad I = \frac{bt^3}{12} \Rightarrow \sigma = 3\frac{d l^2}{t}$$

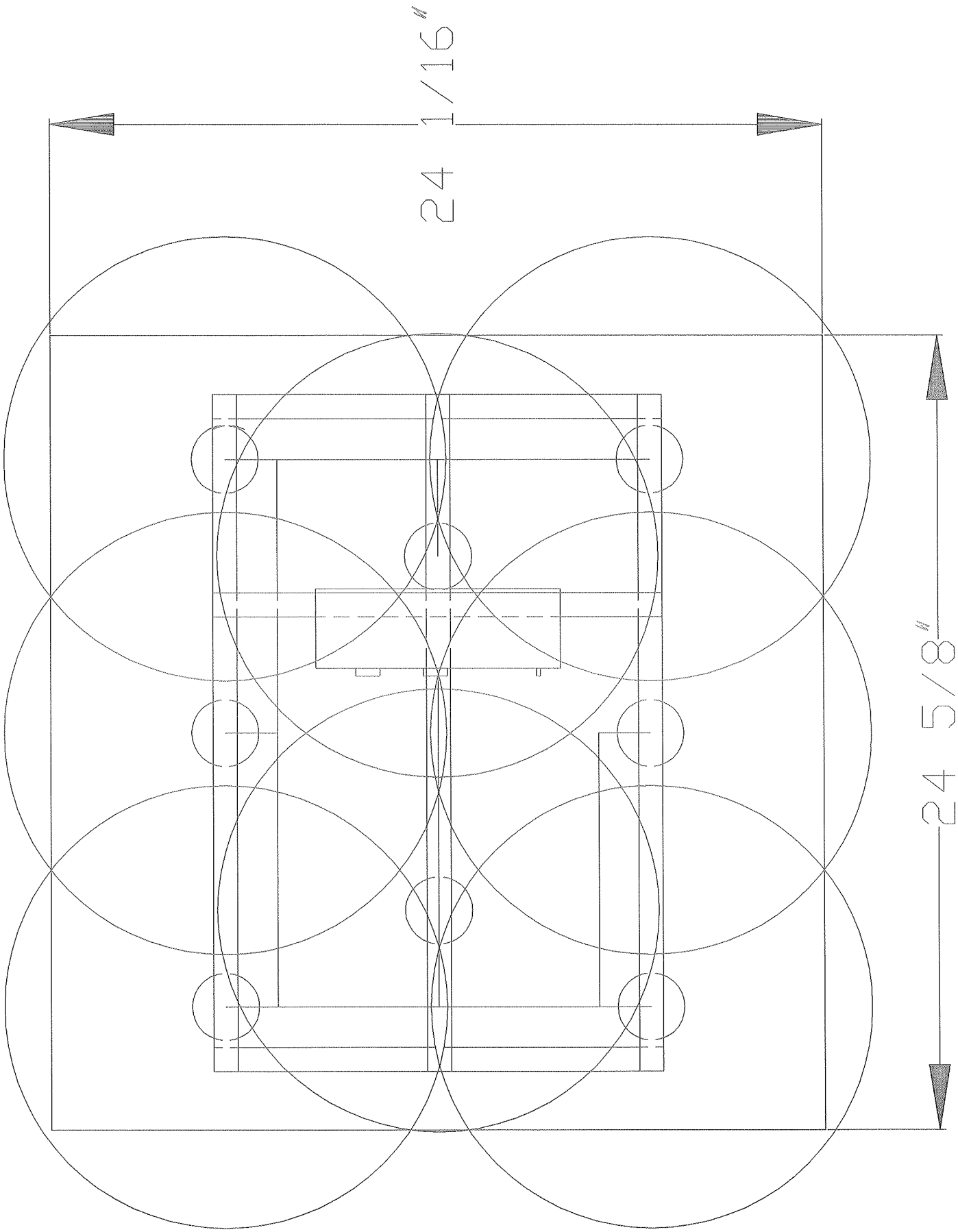
$$\Rightarrow \boxed{l_E = \sqrt{\frac{1}{3}\frac{\sigma t}{d}}} \qquad l_E = \frac{l_S}{2} \Rightarrow l_E < l_S$$

$\Rightarrow$ MAXIMUM DISTANCE: $\sqrt{\frac{1}{3}\frac{\sigma t}{d}}$ //

CONSIDERING A SF = 50% OVER THE BEGINNING OF PLASTIC DEFORMATION: $l = \sqrt{\frac{1}{3} \cdot \frac{800}{(1.5)} \cdot \frac{7/64}{0.41}} \Rightarrow$

$$l_{MAX} = 6.887'' \Rightarrow \boxed{l \leq 6\tfrac{7}{8}''} \Rightarrow \text{MAXIMUM CANTILEVER!}$$

MAXIMUM SIZE ("ENVELOPE") OF THE PLATE TO BE HANDLED (ALLOWABLE)



3. VACUUM COMPONENTS

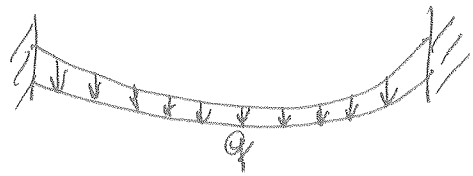
ALL THE VACUUM COMPONENTS WERE SPECIFIED TO WORK FOR THE ORIGINAL FRAME (WITH 20 CUPS (PADS) AND LARGER DIMENSIONS). PLEASE SEE ANNEX 1 FOR METHOD OF SELECTION.

CHECKING THE COMPONENTS

1) DEFORMATION OF THE HEAD PLATE DUE TO VACUUM PAD

AS THE THICKNESS IS SMALLER, IT NEEDS TO BE CHECKED.

CONSIDERING THE MODEL:



- SOLID CIRCULAR PLATE
- UNDER UNIFORM DISTRIBUTED PRESSURE OVER ALL AREA.
- FIXED EDGE RESTRAINT.

R&Y, 6º ed, 1989, CHP 10, Tb 24, CASE 10b, p. 429

THE HIGHEST VACUUM WOULD BE 29.6 in Hg ~ 14.5 psi

THE CALCULATION SHOWS THAT IT IS TO HIGH AS THE MAXIMUM RADIAL BENDING STRESS REACHES 982 psi > 800 psi!

SO SETING TO $q = 11.5$ psi ⇒ VACUUM = 23.46 in Hg

AND $\sigma_{MAX} = 778.4$ psi < 800 psi.

SO: MAX VACUUM <u>23 in Hg</u>

VARIABLE SHEET

St	Input	Name	Output	Unit	Comment
					Case 10 - Solid Circular plate with uniformly distributed pressure. p.429
	14.5	q		psi	Uniform pressure
	0	r0		in	Radius to start of pressure
					Table 24 - Roark & Young (6 ed) Formulas for flat circular plates of constant thickness
		case	'Case_10b		Reference number
		caution	'_		Caution Message
		caution	'_		
		caution	'_		
		matl#			Material Number (See Material Table)
		matl			Material name
		plot	'y		Generate plots? 'n=no (Default=yes)
	2.6E6	E		psi	Young's Modulus
	.45	nu			Poisson's ratio
	1.045	a		in	Outer Radius (PIAB F 50)
	.11	t		in	Plate Thickness (2.8mm)
		D	361.609	in-lb	Plate Constant
					AT RADIUS:
	0	r		in	Radius
		y	-.0007472	in	Deflection
		th	0	rad	Radial Slope Angle
		Mr	1.435	in-lb/in	Radial Bending Moment
		Mt	1.435	in-lb/in	Tangential Bending Moment
		Qr	0	lb/in	Shear Force
		sigma_r	711.565	psi	Radial Bending Stress
		sigma_t	711.565	psi	Tangential Bending Stress
					AT OUTER EDGE:
		ya	0	in	Deflection
		tha	0	rad	Radial Slope Angle
		Mra	-1.979	in-lb/in	Radial Bending Moment
		Qa	'No_data	lb/in	Shear Force
					AT CENTER:
		yc	-.0007472	in	Deflection
		Mc	1.435	in-lb/in	Radial Bending Moment

VARIABLE SHEET

St	Input	Name	Output	Unit	Comment
					Case 10 - Solid Circular plate with uniformly distributed pressure. p.429
	14.5	q		psi	Uniform pressure
	0	r0		in	Radius to start of pressure
					Table 24 - Roark & Young (6 ed) Formulas for flat circular plates of constant thickness
		case	'Case_10b		Reference number
		caution	'_		Caution Message
		caution	'_		
		caution	'_		
		matl#			Material Number (See Material Table)
		matl			Material name
		plot	'y		Generate plots? 'n=no (Default=yes)
	2.6E6	E		psi	Young's Modulus
	.45	nu			Poisson's ratio
	1.045	a		in	Outer Radius (PIAB F 50)
	.11	t		in	Plate Thickness (2.8mm)
		D	361.609	in-lb	Plate Constant
					AT RADIUS:
	1.045	r		in	Radius
		y	0	in	Deflection
		th	0	rad	Radial Slope Angle
		Mr	-1.979	in-lb/in	Radial Bending Moment
		Mt	-.891	in-lb/in	Tangential Bending Moment
		Qr	-7.576	lb/in	Shear Force
		sigma_r	-981.469	psi	Radial Bending Stress
		sigma_t	-441.661	psi	Tangential Bending Stress
					AT OUTER EDGE:
		ya	0	in	Deflection
		tha	0	rad	Radial Slope Angle
		Mra	-1.979	in-lb/in	Radial Bending Moment
		Qa	'No_data	lb/in	Shear Force
					AT CENTER:
		yc	-.0007472	in	Deflection
		Mc	1.435	in-lb/in	Radial Bending Moment

VARIABLE SHEET

St	Input	Name	Output	Unit	Comment
					Case 10 - Solid Circular plate with uniformly distributed pressure. p.429
	11.5	q		psi	Uniform pressure
	0	r0		in	Radius to start of pressure
					Table 24 - Roark & Young (6 ed) Formulas for flat circular plates of constant thickness
		case	'Case_10b		Reference number
		caution	'_		Caution Message
		caution	'_		
		caution	'_		
		matl#			Material Number (See Material Table)
		matl			Material name
		plot	'y		Generate plots? 'n=no (Default=yes)
	2.6E6	E		psi	Young's Modulus
	.45	nu			Poisson's ratio
	1.045	a		in	Outer Radius (PIAB F 50)
	.11	t		in	Plate Thickness (2.8mm)
		D	361.609	in-lb	Plate Constant
					AT RADIUS:
	1.045	r		in	Radius
		y	0	in	Deflection
		th	0	rad	Radial Slope Angle
		Mr	-1.57	in-lb/in	Radial Bending Moment
		Mt	-.706	in-lb/in	Tangential Bending Moment
		Qr	-6.009	lb/in	Shear Force
		sigma_r	-778.406	psi	Radial Bending Stress
		sigma_t	-350.283	psi	Tangential Bending Stress
					AT OUTER EDGE:
		ya	0	in	Deflection
		tha	0	rad	Radial Slope Angle
		Mra	-1.57	in-lb/in	Radial Bending Moment
		Qa	'No_data	lb/in	Shear Force
					AT CENTER:
		yc	-.0005926	in	Deflection
		Mc	1.138	in-lb/in	Radial Bending Moment

Table 24 - Case 10: Deflection

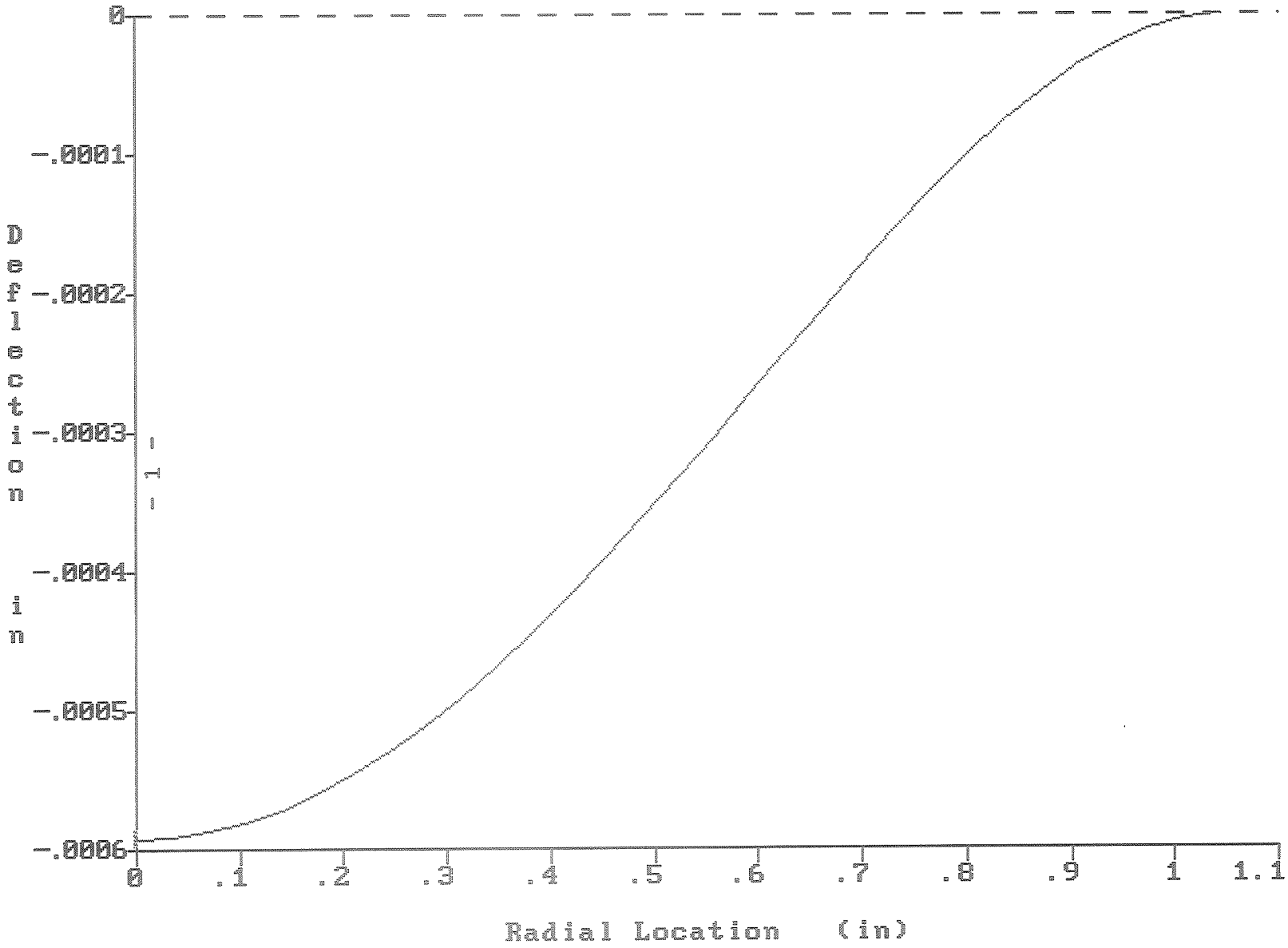


Table 24 - Case 10: Slope Angle

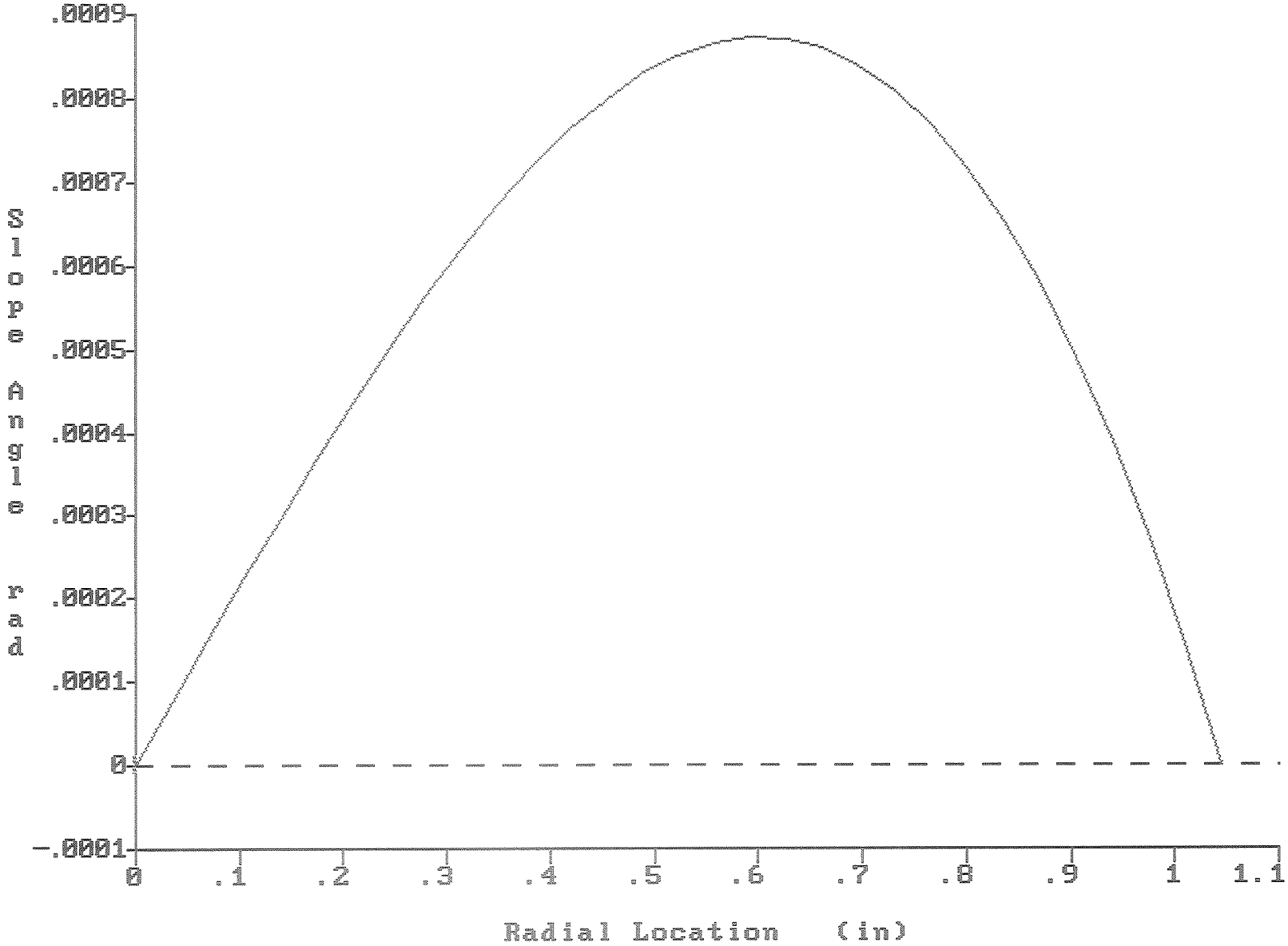


Table 24 - Case 10: Radial Bending Moment

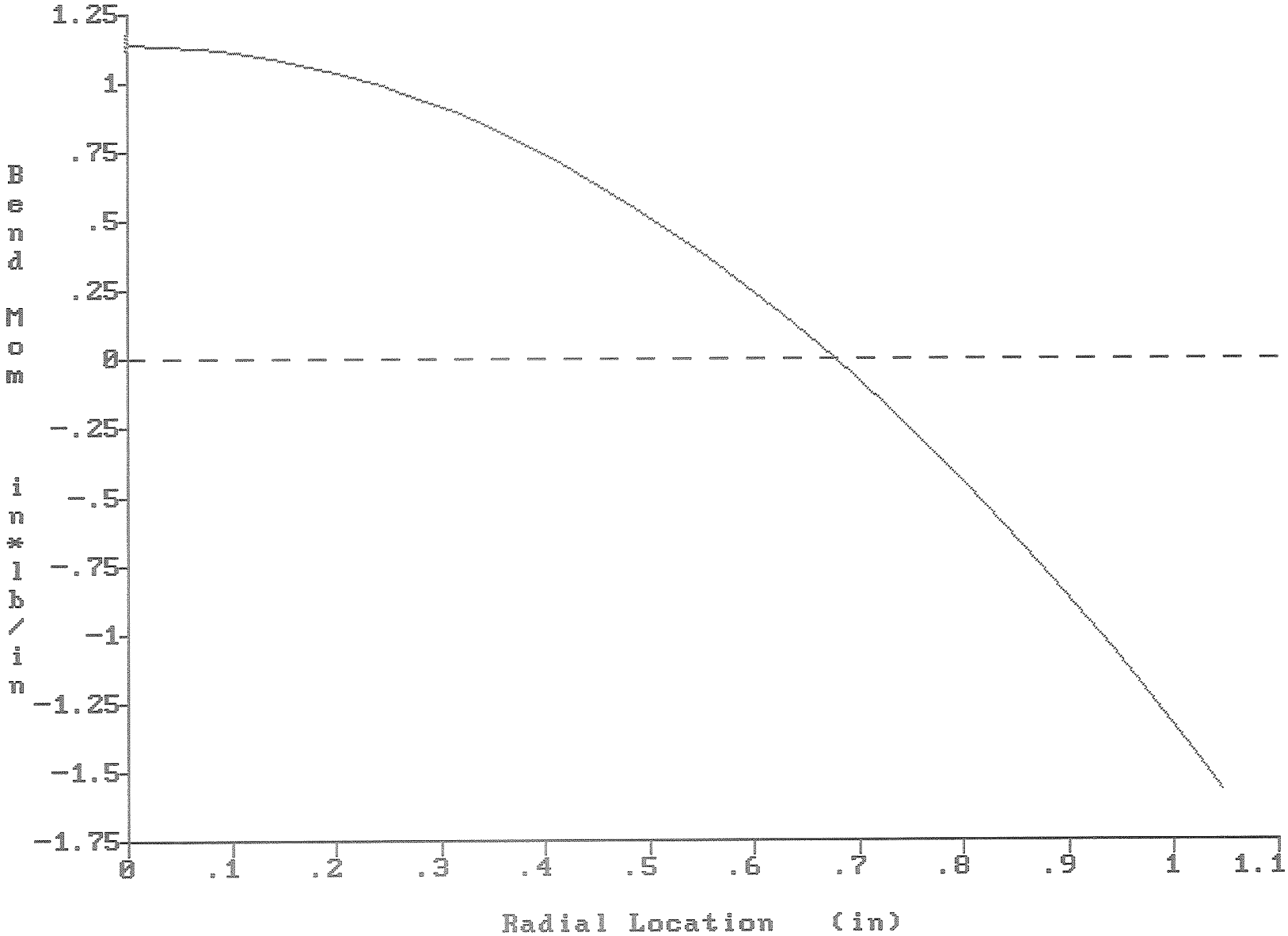


Table 24 - Case 10: Tangential Bending Moment

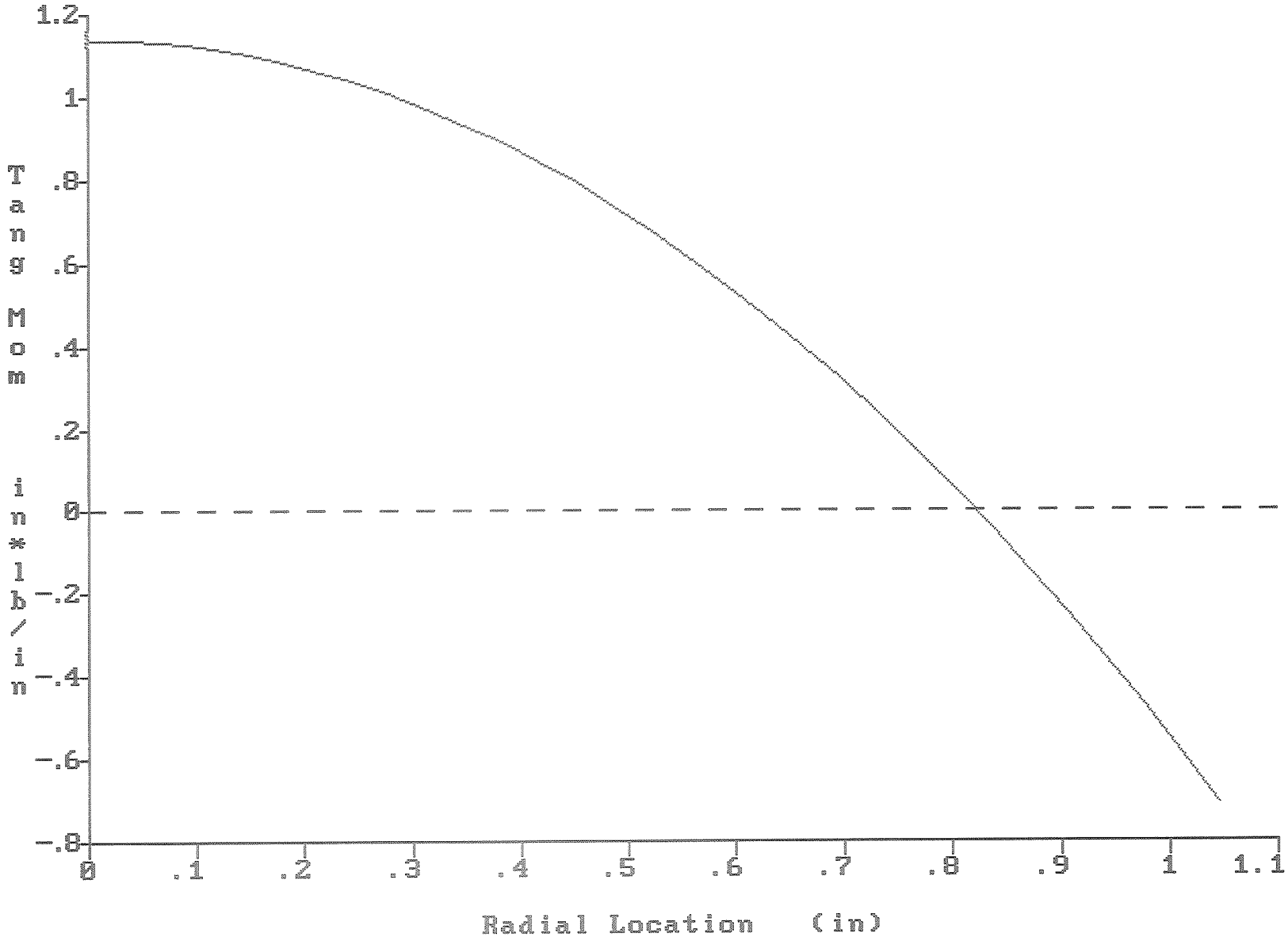


Table 24 - Case 10: Shear Force

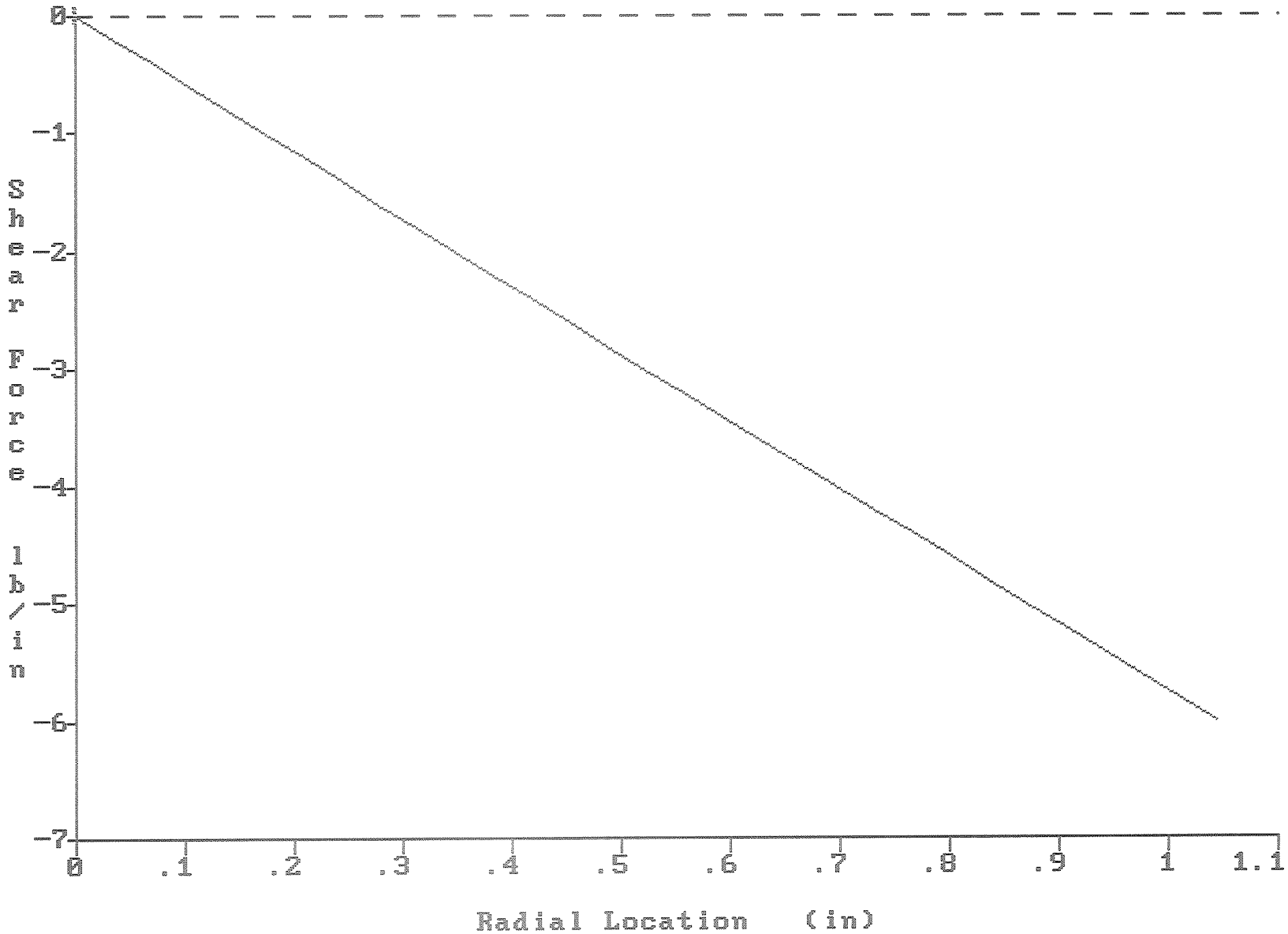


Table 24 - Case 10: Radial Bending Stress

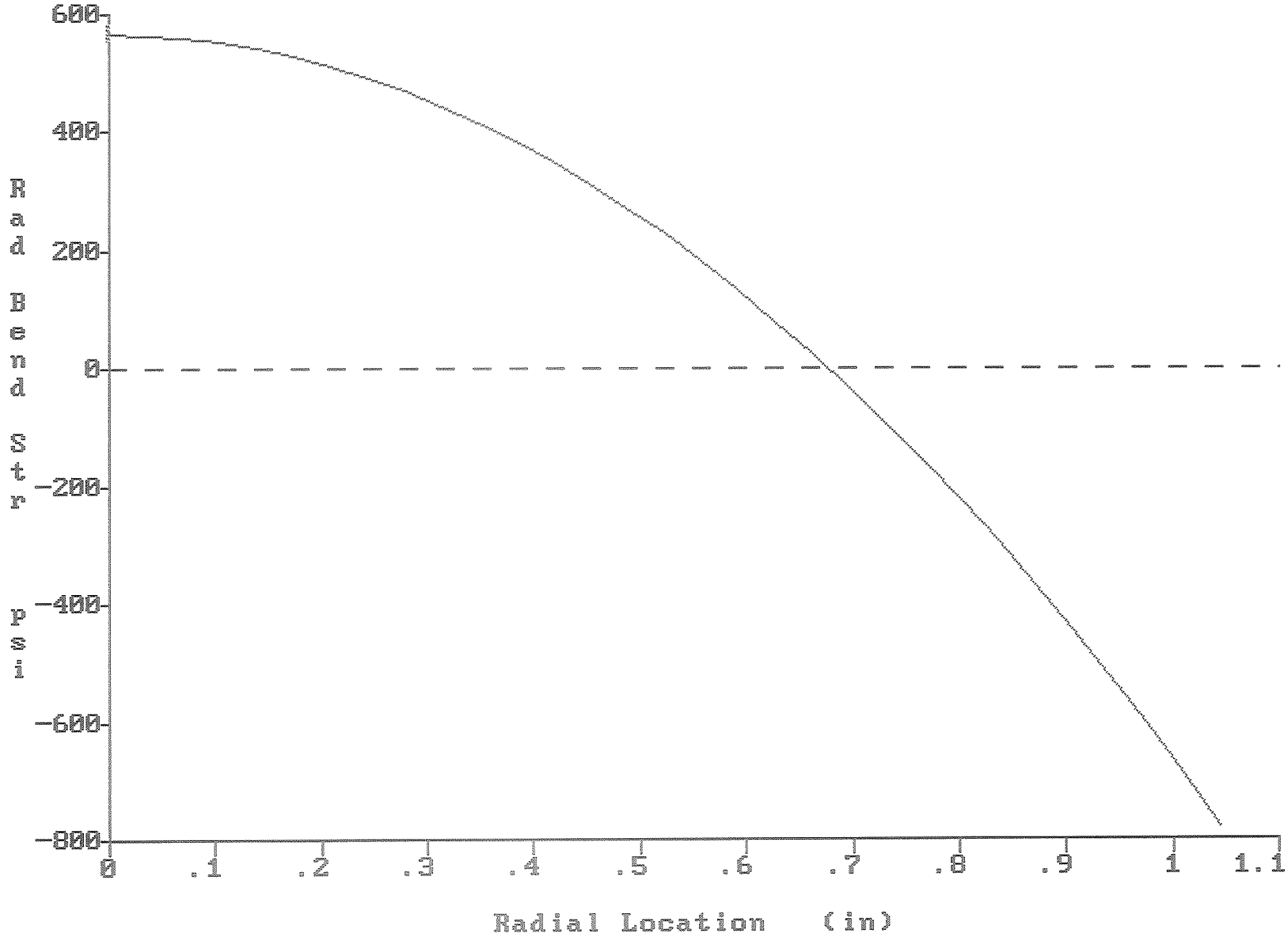
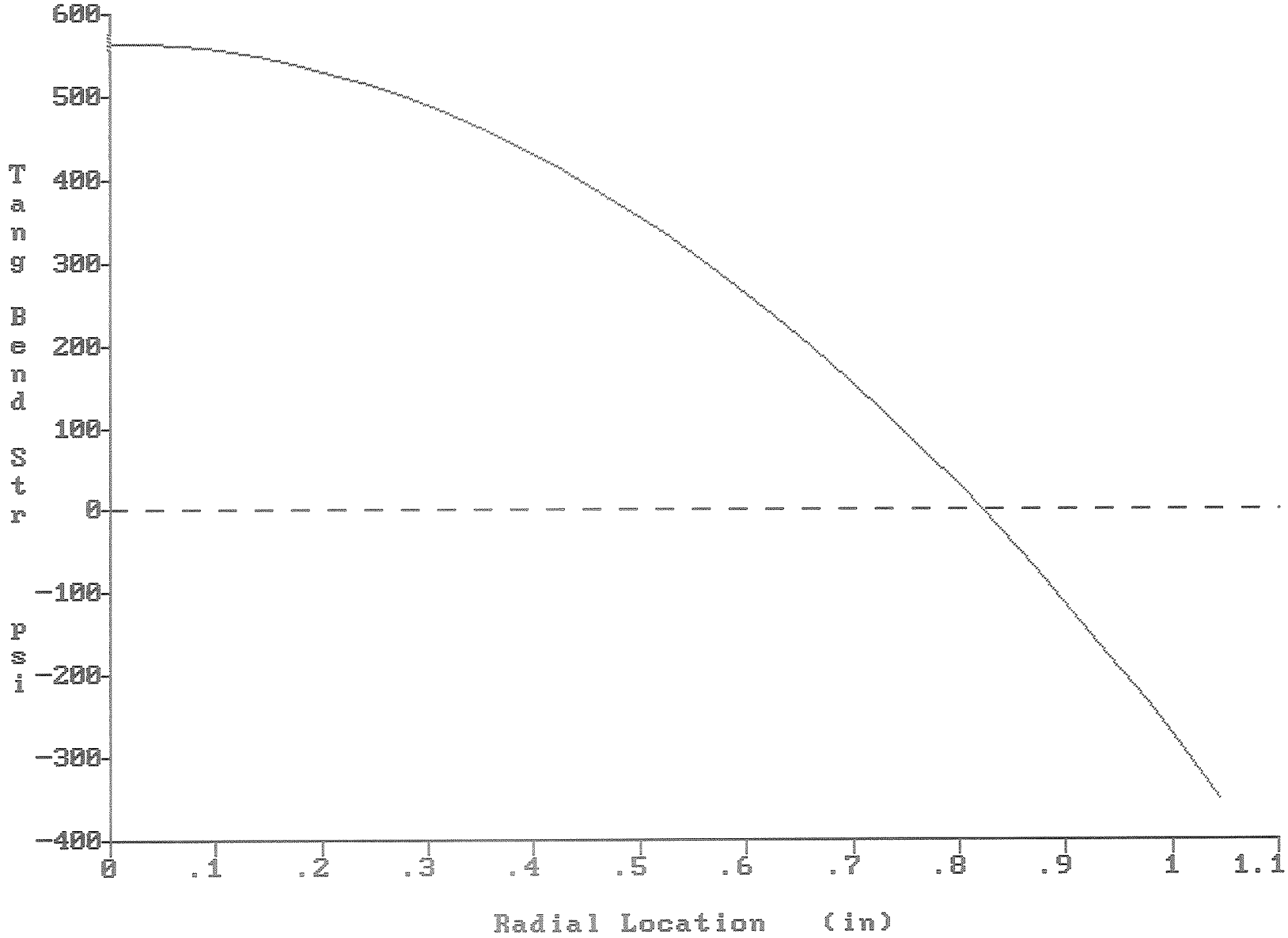


Table 24 - Case 10: Tangential Bending Stress



ACCORDING TO ANSI/ASME B30.20.1985 (p.25),
"BELOW-THE-HOOK LIFTING DEVICES",

$UPC = A \times (Hg/2)$
(ULTIMATE PAD CAPACITY)

$A = \frac{\pi (2.09)^2}{4} \Rightarrow A = 3.43 \text{ in}^2$

$Hg_{MAX} = 23 \Rightarrow UPC = (3.43)\left(\frac{23}{2}\right) \Rightarrow UPC = 39.4 \text{ lb/cup}_{(PAD)}$

FOR HORIZONTAL SURFACES, $SF_{ANSI} = 2.0 \Rightarrow$

$\text{LOAD/cup}_{(PAD)} = \frac{39.4}{2} \Rightarrow \boxed{\text{LOAD/cup}_{(PAD)} = 19.7 \text{ lb/cup}_{(PAD)}}$

ACCORDING TO THE MANUFACTURER, THE MAXIMUM LOAD/CUP SHOULD BE (p.33, LIFTING POWER, 18" Hg, FSO) $\Rightarrow$ 16.28 lb/cup. DIVIDED BY THE RECOMMENDED SF = 2.0 $\Rightarrow$ LOAD = 8.14 lb/cup

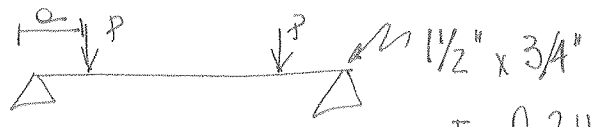
AS THE NUMBER OF CUPS = 8, $\Rightarrow$ LOAD (MAX) = 65.12 lb.

IF $W_{MAX} = 25$ lb $\Rightarrow SF_{EXTRA} = \frac{65.12}{25} \Rightarrow SF_{EXTRA} = 2.6$!

18 in Hg SHOULD BE TAKEN AGAIN AS THE DESIGNED MINIMUM PRESSURE (VACUUM).

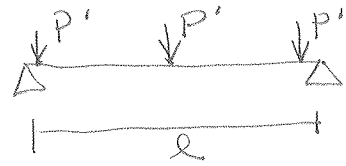
4. THE ALUMINUM FRAME

CENTRAL BEAM



$I = 0.211$

LATERAL BEAMS

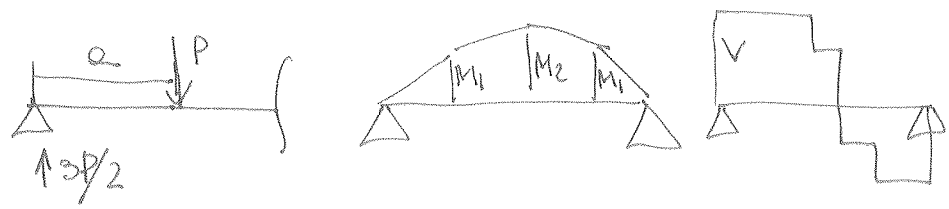


$S = 0.281$

IF $a > l/4 \Rightarrow$ CENTRAL BEAM COULD BE CRITICAL

BUT $a/l = 5/21 = 0.238 < 0.250 \Rightarrow$ LATERAL BEAMS ARE CRITICAL

MOMENT



$$M_{MAX} = \left(\frac{3P}{2}\right)\cdot\left(\frac{l}{2}\right) - P\left(\frac{l}{2} - a\right) = \frac{3Pl}{4} - P\left(\frac{l}{2} - a\right)$$

$$M_{MAX} = P\left(\frac{3l}{4} - \frac{l}{2} + a\right) = P\left(\frac{l}{4} + a\right)$$

$$M_{MAX} = P\left(\frac{21}{4} + 2\right) \Rightarrow M_{MAX} = (7.25).P$$

THE MAXIMUM THEORETICAL LOAD IS 21.12 lb/wp. (p.33, PIAB)

SO: $M_{MAX} = (7.25).(21.12) \Rightarrow M_{MAX} = \underline{153.12 \text{ lb-in}}$

$$\sigma_{MAX} = \frac{M}{S} = \frac{153.12}{0.281}$$

$$\Rightarrow \sigma_{MAX} = \underline{545 \text{ psi}}$$

ACCORDING TO AA - 30, p. 40, Tb. 3.3.27, spec. 14,

$$S_\ell = \frac{L_b S_c}{I\ y} = 146.$$

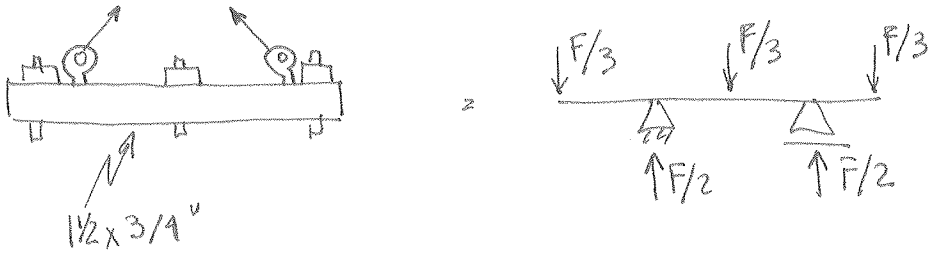
$$\frac{L_b \cdot S_c}{I y} = L_b \cdot \left(\frac{I/c}{I}\right) = \frac{L_b}{c} \quad ; \quad c = 3/4''$$

$$\text{So } L_b = 146 \times \left(\frac{4}{3}\right) \Rightarrow L_b = 195''$$

As $L_b = 195'' >> \text{MAX SPAN} = 21''$ $\Rightarrow$ $F = 21\ ksi$ (Tb. 3.3.27)

$$SF = \frac{\sigma_A}{\sigma_M} = \frac{21{,}000}{545} \Rightarrow \underline{SF = 38.5\,!}$$

FOR THE TRANSVERSAL BEAM



$J = 0.211\ in^4$
$S = 0.281\ in^3$

AS SHOWN IN THE FOLLOWING PAGES,

$M_{MAX} = 270$ lb·in. $\sigma_{MAX} = \frac{M_{MAX}}{S}$

$\sigma_{MAX} = \frac{270}{0.281} \Rightarrow \sigma_{MAX} = 961$ psi

AS SEEN BEFORE, $F = 21$ ksi (AA 30, p.40, TD. 3.3.27, SPEC 14)

So: $SF = \frac{21{,}000}{961} \Rightarrow \underline{SF = 21.8}$!

Module B-3: Multi-Span Beams Under Transverse Loading

* S P A N 1 *

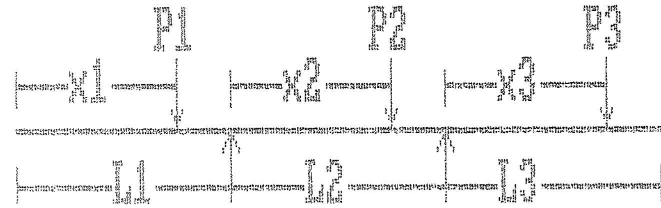
L1 = 2.0 x1 = 0
E1 = 9.5e6 I1 = .0352
P1 = 135

* S P A N 2 *

L2 = 9.875 x2 = 4.9375
E2 = 9.5e6 I2 = .0352
P2 = 135

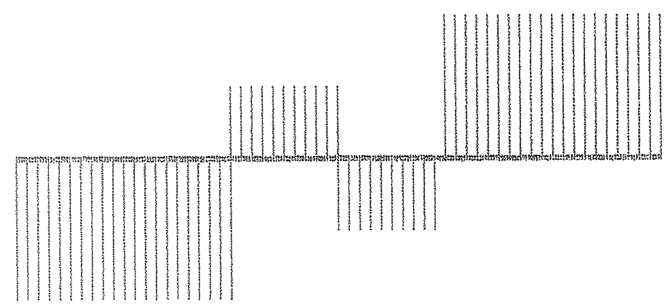
* S P A N 3 *

L3 = 2.0 x3 = 2.0
E3 = 9.5e6 I3 = .0352
P3 = 135



Reactions:
R1= 0.00E+00 R2= 2.02E+02 R3= 2.02E+02
R4= 0.00E+00

Shear Force:



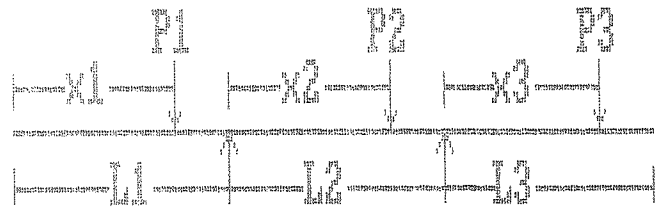
Vmax =-1.350000E+02 Span 1

ENTER F5 FOR MOMENT DIAGRAM OR
F7 FOR LOADING/BOUNDARY CONDITION MENU

F2PRINT F3DISP F5PREV F7MENU F8REDO F9SAVE F10TOP

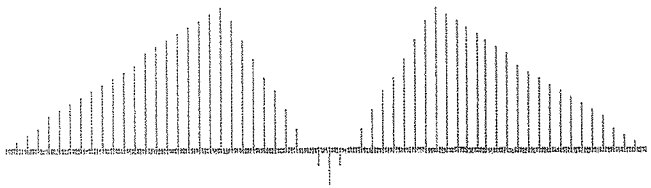
Module B-3: Multi-Span Beams Under Transverse Loading

```
                 * S P A N  1 *
L1 = 2.0                x1 = 0
E1 = 9.5e6              I1 = .0352
P1 = 135
                 * S P A N  2 *
L2 = 9.875              x2 = 4.9375
E2 = 9.5e6              I2 = .0352
P2 = 135
                 * S P A N  3 *
L3 = 2.0                x3 = 2.0
E3 = 9.5e6              I3 = .0352
P3 = 135
```



Reactions:
R1= 0.00E+00 R2= 2.02E+02 R3= 2.02E+02
R4= 0.00E+00

Bending Moment:



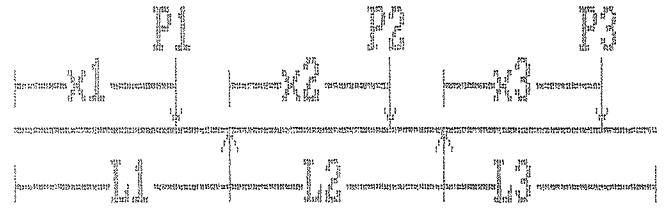
Mmax =-2.700000E+02 Span 2

ENTER F5 FOR DEFLECTION DIAGRAM, F6 FOR SHEAR DIAGRAM, OR
F7 FOR LOADING/BOUNDARY CONDITION MENU

F2PRINT F3DISP F5PREV F6NEXT F7MENU F8REDO F9SAVE F10TOP

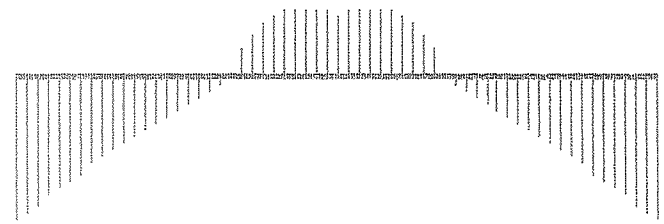
Module B-3: Multi-Span Beams Under Transverse Loading

```
                 * S P A N  1 *
L1 = 2.0              x1 = 0
E1 = 9.5e6            I1 = .0352
P1 = 135
                 * S P A N  2 *
L2 = 9.875            x2 = 4.9375
E2 = 9.5e6            I2 = .0352
P2 = 135
                 * S P A N  3 *
L3 = 2.0              x3 = 2.0
E3 = 9.5e6            I3 = .0352
P3 = 135
```



Reactions:
R1= 0.00E+00 R2= 2.02E+02 R3= 2.02E+02
R4= 0.00E+00

Deflection:



Ymax =-4.128809E-03 Span 3

ENTER F6 FOR MOMENT DIAGRAM OR
F7 FOR LOADING/BOUNDARY CONDITION MENU

F2PRINT F3DISP F6NEXT F7MENU F8REDO F9SAVE F10TOP

5. OTHER COMPONENTS :

THE TRANSVERSAL BEAM AND EYE BOLTS AND BOLTS DESIGN WERE DONE FOR THE MAVIER ORIGINAL FRAME. SEE ANNEX 2 FOR DETAILS.

6. RULES/LIMITATIONS

- DO NOT EXCEED 24 5/8" x 24 1/16" OF SIZE OF THE PLATES

- DO NOT WORK OUT OF THE RANGE BETWEEN 18 in Hg AND 22 in Hg

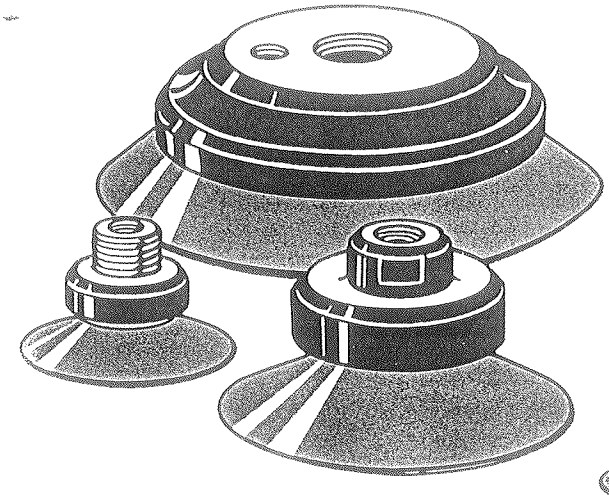
-

ANNEX I

VACUUM COMPONENTS SELECTION

— ORIGINAL DEVICE

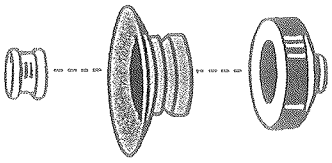
Model "F" Suction Cups



Material Properties

Material	Wear Resistance	Oil Resistance	Working Temperature	Weather & Ozone Resistance
* FDA Silicone 50 (Food Quality)	Good	Good	−95°F–+480°F	Excellent
Silicone 50	Good	Good	−95°F–+480°F	Excellent
* Terban 50	Outstanding	Outstanding	−55°F–+340°F	Outstanding
TWO 50	Excellent	Good	−40°F–+230°F	Excellent

* New materials available by special request



Fitting is a one-time investment . . .
Cup portion is easily detached when needed to be replaced.

Measurements and Article Numbers

Model	Outer Diameter in.	Height incl. Fitting in.	Height without Fitting in.	Suction Cup Complete Art. No.	Suction Cup without Fitting Art. No.	Connection Threads (NPS)	Connection Type	Complete Fitting Art. No.	Fitting Parts: Connection Plate Art. No.	Fitting Parts: Filter Art. No.	Fitting Parts: Locking Plug Alt. Locking Washer Art. No.
F 15	.650	.630	.453	31.50.014	31.50.125	10/32"	Male	31.07.030	—	—	—
F 20	.866	.421	.315	31.50.015	31.50.126	10/32"/1/8"	Female/Male	31.50.200	31.50.141	31.50.163	31.50.140
F 25	1.060	.461	.354	31.50.016	31.50.127	10/32"/1/8"	Female/Male	31.50.200	31.50.141	31.50.163	31.50.140
F 30	1.260	.500	.394	31.50.017	31.50.128	10/32"/1/8"	Female/Male	31.50.200	31.50.141	31.50.163	31.50.140
F 40	1.650	.846	.512	31.50.018	31.50.129	1/8"	Female	31.50.201	31.50.143	31.50.164	31.50.142
F 50	2.090	1.020	.689	31.50.019	31.50.130	1/8"	Female	31.50.202	31.50.145	31.50.165	31.50.144
F 75	3.030	.787	.512	31.50.020	31.50.131	1/8",10/32"	Female	31.50.203	31.50.147	31.50.166	31.50.146
F110	4.410	1.060	.787	31.50.021	31.50.132	1/2",1/8"	Female	31.50.204	31.50.149	31.50.167	31.50.148
F150	5.980	1.300	1.020	31.50.022	31.50.133	1/2",1/8"	Female	31.50.205	31.50.151	31.50.167	31.50.150

When ordering a silicone cup, an "S" should be added after the article number.
When ordering a FDA cup, an "ST" should be added after the article number.
When ordering a terban cup, a "T" should be added after the article number.

All suction cup measurements are at static position.

Lifting Power

Model	Lifting Power 6" Hg.	Lifting Power 18" Hg.	Lifting Power 27" Hg.	Dry sheet metal 6" Hg.	Dry sheet metal 18" Hg.	Dry sheet metal 27" Hg.	Lowest Limit for the Curvature of the Working Surface, R min.	Max. Movement of the Suction Cup at a Load of 27" Hg., Y max.
F 15	0.77	1.87	2.42	0.77	1.43	1.65	0.512 in.	0.039 in.
F 20	1.32	3.19	4.18	1.10	1.76	1.87	0.709 in.	0.059 in.
F 25	1.98	4.29	5.50	1.76	1.98	2.20	0.866 in.	0.059 in.
F 30	2.64	5.50	6.82	1.98	2.42	2.64	0.984 in.	0.079 in.
F 40	4.40	8.80	11.00	3.30	5.50	6.60	2.050 in.	0.098 in.
F 50	7.92	16.28	21.12	5.28	8.80	11.00	2.170 in.	0.118 in.
F 75	17.60	44.00	59.40	13.20	24.20	30.80	5.910 in.	0.118 in.
F110	30.80	92.40	123.20	30.80	55.00	66.00	9.840 in.	0.157 in.
F150	66.00	187.00	242.00	55.00	132.00	176.00	19.690 in.	0.236 in.

Vacuum = Hg., Lifting Power = lbf.
N.B. Max. measured values are given.

Always count with a safety factor of >2.

SELECTING THE SUCTION CUP PJAB F-50, WE HAVE

$\phi = 2.090$ in => ~~[illegible]~~ $\underline{1.045}$

$h = 0.689''$ ($1.020''$ with FITTING)

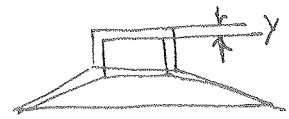
LIFTING POWER.

6 in Hg → 7.92 lb (132 lb/Hg in)

18 in Hg → 16.28 lb (0.90 lb/Hg in)

27 in Hg → 21.12 lb (0.78 lb/Hg in)

MAX MOV. OF CUP @ 27" Hg (y) => 0.118"



FROM R.X.7 WITH $a = 1.045$ AND $q = 15$ psi (29.6 in Hg)

=> $y = 0.0002929''$ AND $\sigma_R = 385.51$ psi.

ACCORDING TO "BELOW-THE-HOOK LIFTING DEVICES", ANSI / ASME B30.20 – 1985 (p.25):

UPC = A (Hg/2)

↳ ULTIMATE PAD CAPACITY

$A = \pi(2.09)^2/4$ => $A = 3.43$ in^2 (=> 1.7 lb/Hg in).

Hg = 27 => UPC = 46.3 lb.

FOR HORIZONTAL SURFACES WE HAVE SF = 2.0 =>

LOAD/CUP = $\frac{46.3}{2}$ => $\boxed{\text{LOAD/CUP}_{\text{ANSI}} = 23.1 \text{ lb}}$

AS 23.1 IS GREATER THAN 21.12 lb/CUP (MANUFACTURER) LETS CONSIDER THAT.
PJAB CATALOG ALSO RECOMEND FS > 2.0 =>

LOAD/CUP ≤ $\frac{21.12}{2}$ = 10.56 => LOAD/CUP OF $\underline{10 \text{ lb}}$

ASSUMING THAT => NUMBER OF CUPS = $\frac{73}{10}$ = 7.3 CUPS

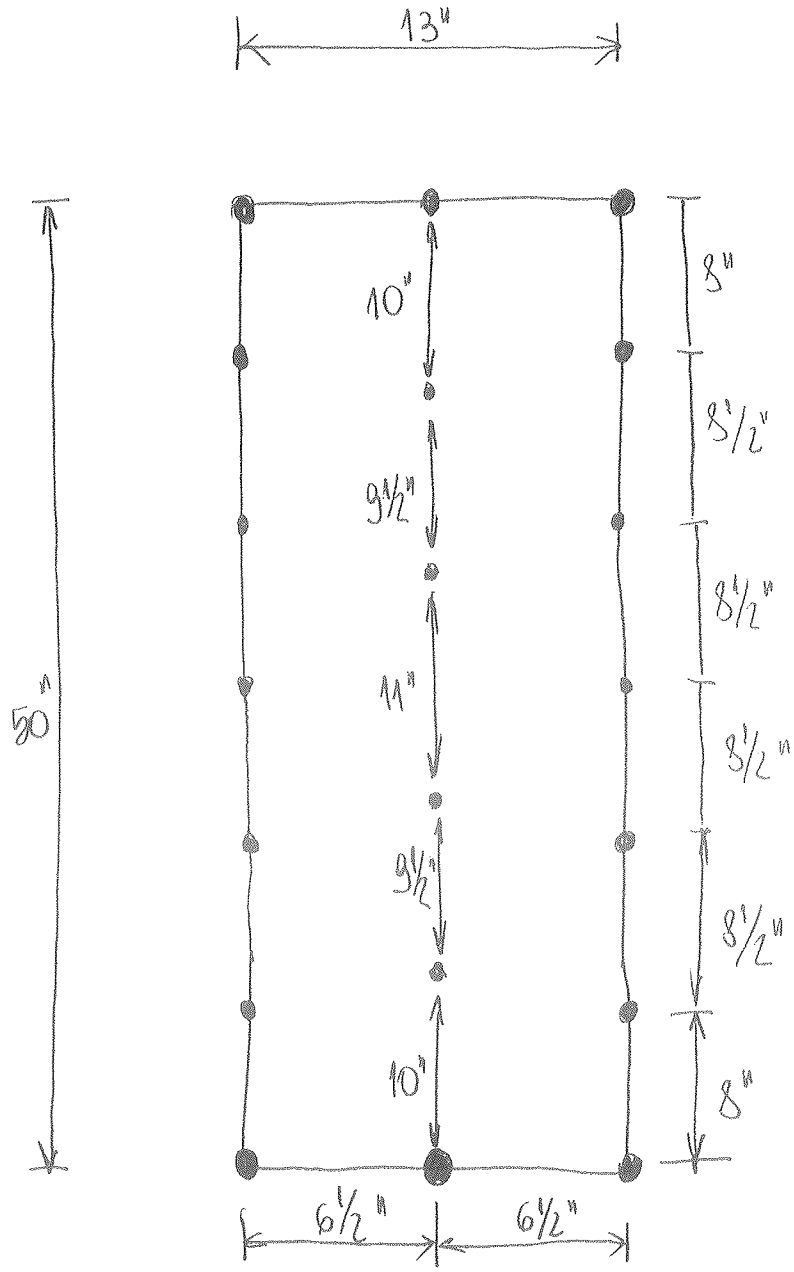
=> $\boxed{8 \text{ CUPS}}$

~~OBS~~: 18" Hg => 9 CUPS

6" Hg => 19 CUPS

LAY-OUT – CUPS

DUE TO NUMBERS FROM P. 1 AND 2, WE HAVE

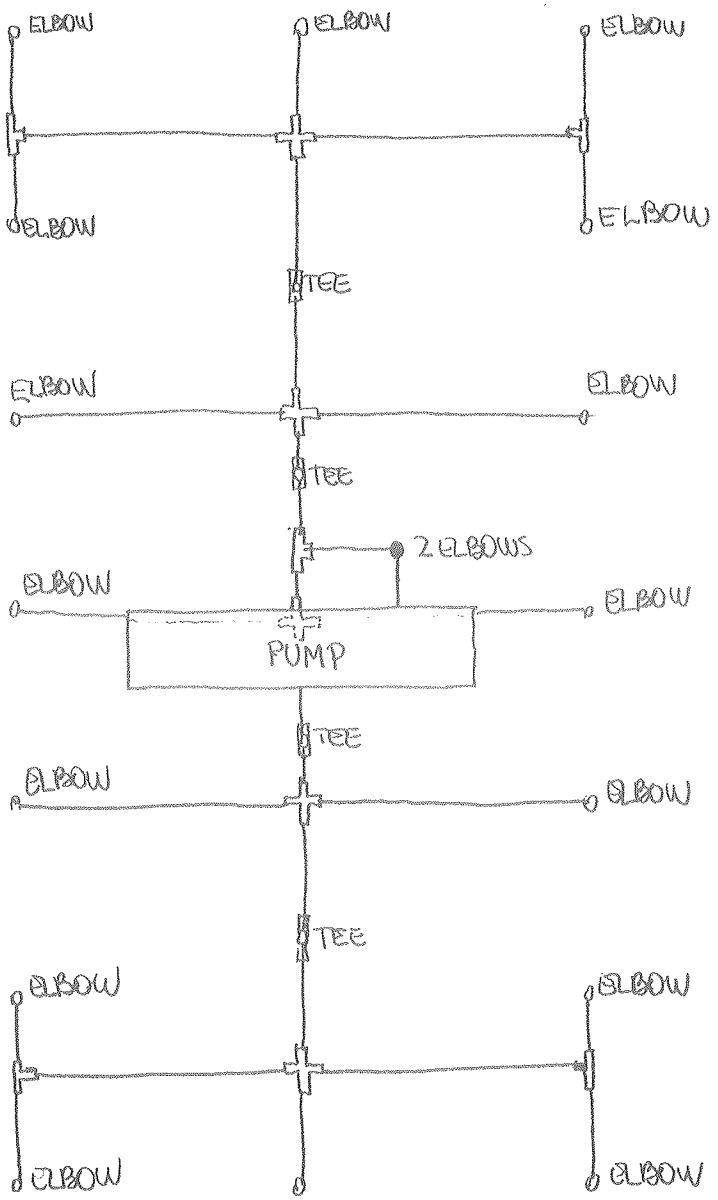


SO WE ARE GOING TO USE 20 CUPS.

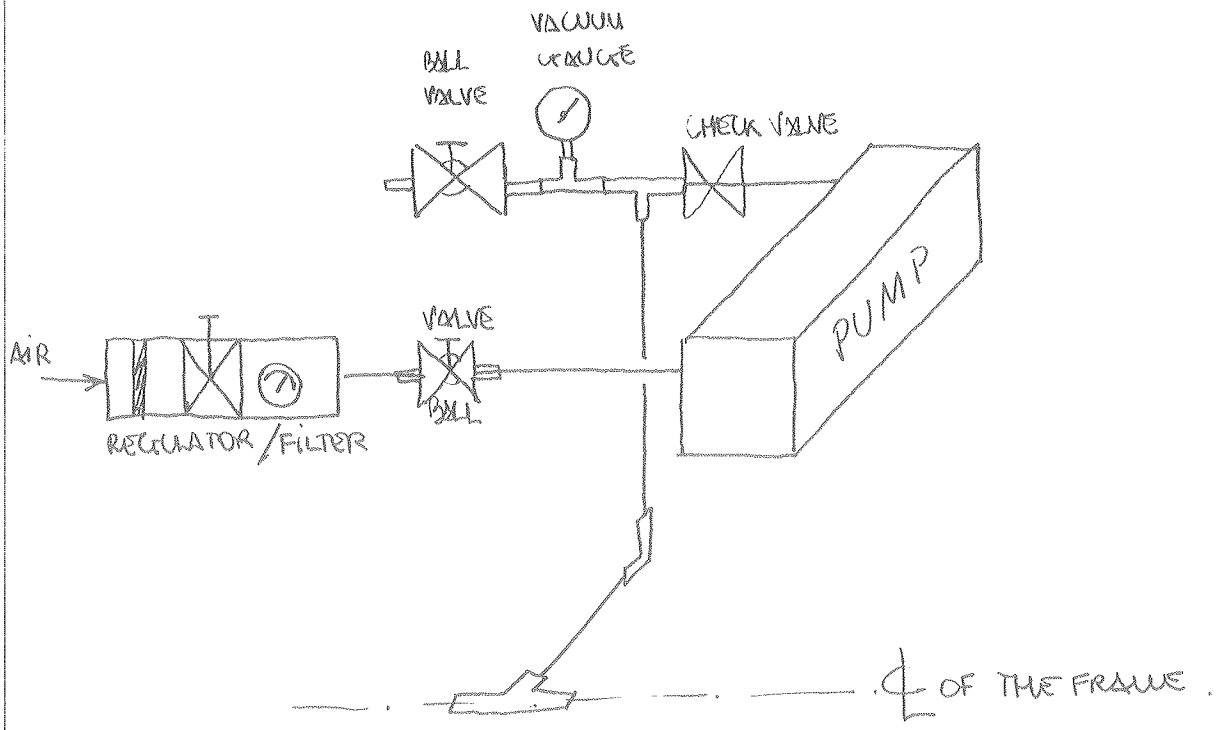
$\frac{73}{20} = 3.65\,lb/cup = 46\%$ OF THE LOAD AT 6 in Hg.

AT 18 in Hg WE HAVE $\frac{3.65}{16.28} = 0.224 \Rightarrow SF = 4.46$

LAY-OUT VACUUM LINES



LAY-OUT – PUMP


VACUUM GAUGE
BALL VALVE
CHECK VALVE
PUMP
VALVE
AIR
BALL
REGULATOR / FILTER
℄ OF THE FRAME

PUMP

VOLUME OF CUP(N) $\frac{1}{2}\left(\frac{\pi(2.09)^2}{4} \cdot (0.689)\right) = 1.18\ in^3$

20 CUPS => $20 \times 1.18 = 23.6\ in^3$

TUBBING : $\left(\frac{\pi(1/8)^2}{4}\right) \cdot 150 = 1.8\ in^3$

TOTAL : $25.4\ in^3$ =

CONSIDERING SF = 3.0 => $76.2\ in^3$ (DUE TO FITTINGS, LEAKS, ETC.) = 0.53 cuft

TAKING 18 in Hg AS DESIGN PRESSURE (SF = 4.46), GOING TO PIAB CATALOG P.7 AND LOOKING FOR A "D" PUMP MODEL WE HAVE (FOR 0.53 cuft)

18 in Hg
(L @ 87psi)
(M @ 58psi)
(H @ 72psi)

PUMP	TIME (s)
L63D	9.8
M63D	24.0
L125D	5.1
M125D	12.0
L190D	3.3
M190D	8.0
L250D	2.4
M250D	6.0
M375D	4.0

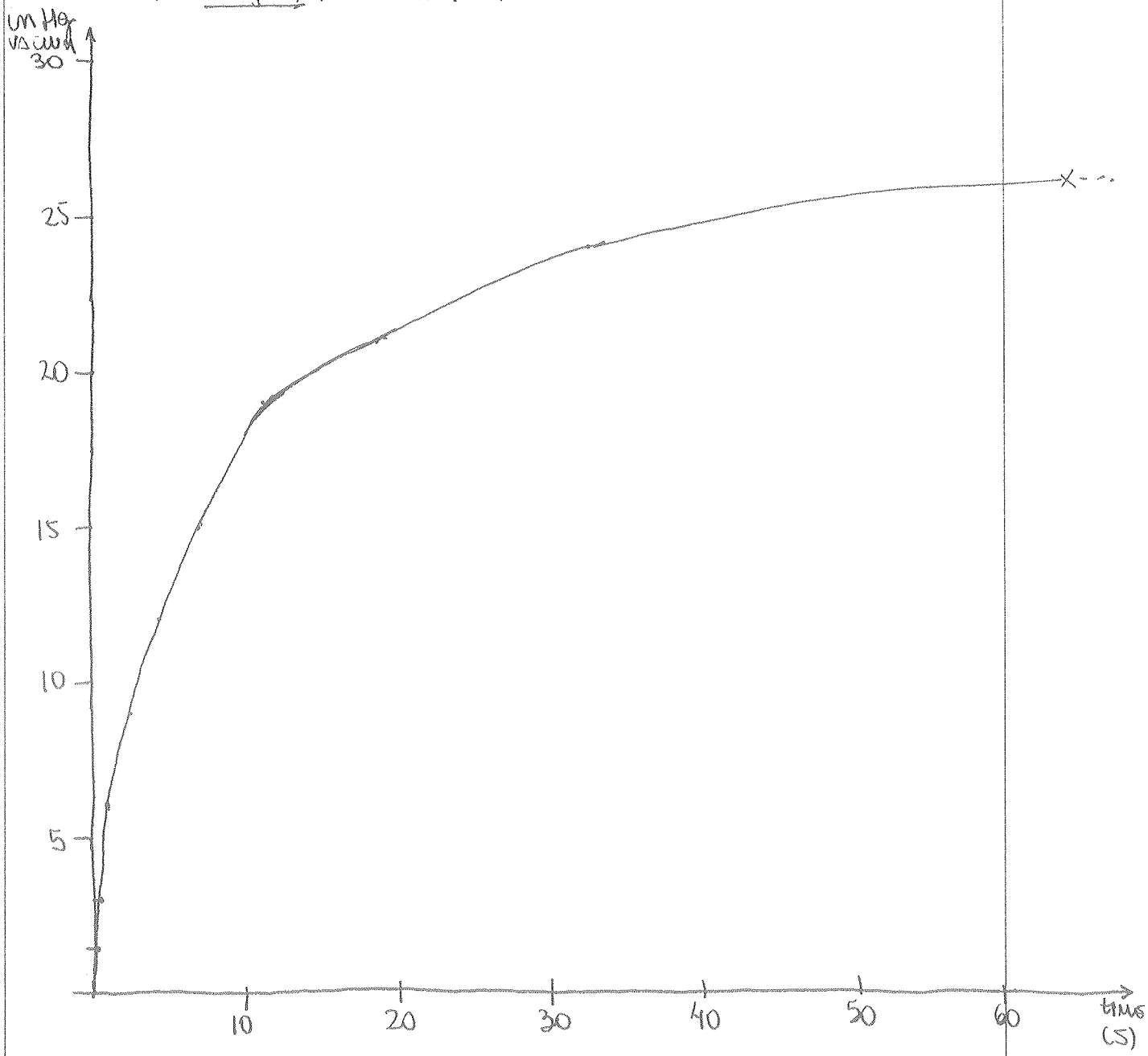
THE MANUFACTURER RECOMENDS (p.6) THE USE OF "M" SERIES FOR MATERIAL HANDLING WITH SUCTION CUPS. METAL.

PUMP	TIME (s) (18" Hg, 0.53 cuft)	AIR PRESSURE (N) (PSI)	WEIGHT (lb)	L (in)	W (in)	D (in)	AIR CONSUMPTION @ (*) AIR PRESSURE	MAX VACU @ (*) AIR PRE
L 125 D	5.1	87	1.54	7.6	2.5	1.7	6.2	21.9
L 190 D	3.3	87	1.98	7.6	2.5	2.5	9.3	21.9
L 250 D	2.4	87	1.98	7.6	2.5	2.5	12.4	21.9
M 250 D	6.0	58	1.98	7.6	2.5	2.5	8.8	27.0
M 375 D	4.0	58	2.64	7.6	2.5	3.3	13.2	27.0

M 250 D

M 250 D → 6.0 s → 18 in Hg
9.8 s → 21 in Hg
12.7 s → 24 in Hg
59.8 s → 27 in Hg.

FOR 1 cuft, ACCORDING PIAB:



SO, WILL BE RECOMENDED TO USE 24 in Hg OR MORE → 12.7 s! ⇒ MORE THAN 18.7 lb/cup ⇒ SF = 5.1.
(0.53 cuft)

Available in three different series . . .

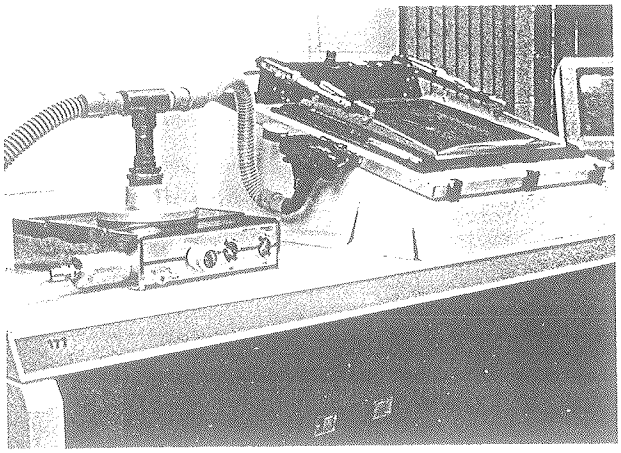
L-series: max. 18" Hg. at 58 psi, 22" Hg. at 87 psi

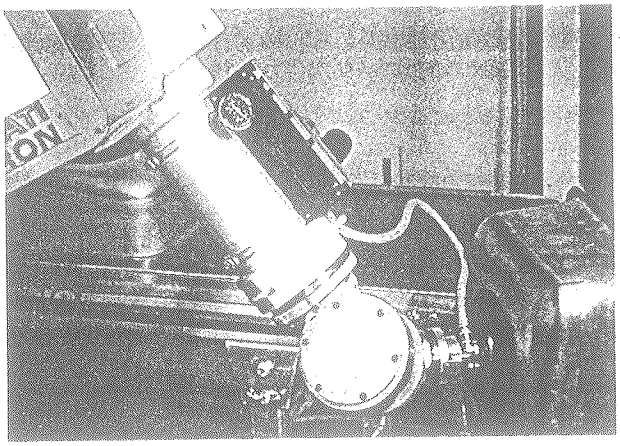
M-series: max. 27" Hg. at 58 psi **H-series:** max. 29.6" Hg. at 72 psi

TYPICAL APPLICATIONS

L-series: The low vacuum pump gives high air flow and is suitable for applications where the system cannot be tightly closed and where only moderate vacuum is required.

- Material handling with suction cups, e.g. packaging and printing industries
- Material handling with some orifices open to atmosphere
- Vacuum Holding, e.g. printed circuit boards
- Robotics with porous surfaces, e.g. corrugated boxes



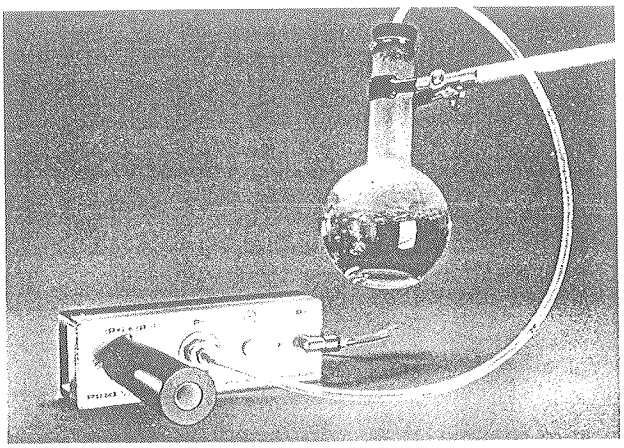


M-series: The medium vacuum pump is suitable for applications where little or no leakage occurs.

- Material handling with suction cups, e.g. glass, metal, plastics, wood, etc.
- Robotics with non-porous surfaces, e.g. automobile industry
- Vacuum Forming
- Vacuum holding and placing, e.g. vacuum frame tables
- Liquid filling by vacuum displacement

H-series: The high vacuum pump is designed for applications where high vacuums (up to 29.6" Hg.) are required.

- Pharmaceutical Industry
- Chemi-Technical Industry
- Laboratories
- Industrial Finishing



Aid to Selection

PIAB Vacuum Pumps are operated by compressed air and to choose the correct size and model consideration has to be given to:

1. The level of vacuum required.
2. The amount of free air the pump should continue to pull at that vacuum (if any).
3. The approximate volume of the space in which the vacuum is to be maintained.
4. The time available.
5. The compressed air consumption.
6. The distance the pump can be installed from the point of evacuation.

Induced free air (scfm) at inches Hg.

L-series @ 87 psi
M-series @ 58 psi
H-series @ 72 psi

inches Hg.

VACUUM PUMP	0	1.5	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	28.5
M16	1.00	0.77	0.52	0.35	0.24	0.14	0.10	0.07	0.03	0.01	—	—
M32	2.00	1.54	1.06	0.70	0.48	0.28	0.20	0.14	0.06	0.03	—	—
M60	4.00	3.08	2.12	1.40	0.98	0.56	0.40	0.28	0.12	0.06	—	—
L63D	11.30	8.80	6.40	3.90	2.50	1.80	1.30	0.88	0.53	—	—	—
M63D	7.00	4.58	3.17	1.87	0.88	0.67	0.45	0.33	0.22	0.10	—	—
L125D	22.60	17.60	12.80	7.80	5.00	3.60	2.60	1.76	1.06	—	—	—
M125D	14.00	9.16	6.34	3.74	1.76	1.34	0.90	0.66	0.44	0.20	—	—
H125	6.00	2.83	2.10	1.80	1.40	1.20	0.90	0.70	0.45	0.28	0.14	0.05
L190D	33.90	26.40	19.20	11.70	7.50	5.40	3.90	2.64	1.59	—	—	—
M190D	21.00	13.74	9.51	5.61	2.64	2.01	1.35	0.99	0.66	0.30	—	—
L250D	45.20	35.20	25.60	15.60	10.00	7.20	5.20	3.20	2.12	—	—	—
M250D	28.00	18.32	12.68	7.48	3.52	2.68	1.80	1.32	0.88	0.40	—	—
H250	12.00	5.66	4.20	3.60	2.80	2.40	1.80	1.40	0.90	0.56	0.28	0.10
M375D	42.00	27.48	19.02	11.22	5.28	4.02	2.70	1.98	1.32	0.60	—	—
H375	18.00	8.49	6.30	5.40	4.20	3.60	2.70	2.10	1.35	0.84	0.42	0.15
L250	61.88	35.30	24.70	15.60	9.90	7.05	5.30	3.55	2.10	—	—	—
M250	50.00	26.47	17.65	8.82	3.88	2.12	1.94	1.41	0.88	0.46	—	—
L500	123.75	70.60	49.40	31.10	19.80	14.10	10.60	7.10	4.20	—	—	—
M500	100.00	52.95	35.30	17.65	7.06	4.23	3.88	2.82	1.76	0.88	—	—
H500	24.00	11.31	8.40	7.20	5.60	4.80	3.60	2.80	1.80	1.10	0.56	0.21
L1000	247.50	141.00	102.00	63.50	38.80	28.20	21.20	14.10	8.50	—	—	—
M1000	200.00	105.90	70.60	35.30	14.12	8.46	7.76	5.64	3.52	1.76	—	—
H1000	50.00	22.62	16.80	14.40	11.20	9.60	7.20	5.60	3.60	2.20	1.10	0.42
L2000	495.00	282.00	205.00	124.00	77.70	56.50	42.40	28.20	16.90	—	—	—
M2000	400.00	211.80	141.20	70.60	28.24	16.94	15.52	11.20	7.06	3.53	—	—
H2000	95.00	45.24	33.60	28.80	22.40	19.20	14.40	11.20	7.20	4.40	2.20	0.84
L4000	990.00	565.00	406.00	247.00	159.00	113.00	84.70	56.50	33.90	—	—	—
M4000	800.00	423.60	282.40	141.20	56.48	33.84	31.04	22.59	14.12	7.06	—	—
H4000	190.00	90.48	62.00	57.00	44.80	38.40	28.80	22.40	14.40	8.80	4.40	1.70

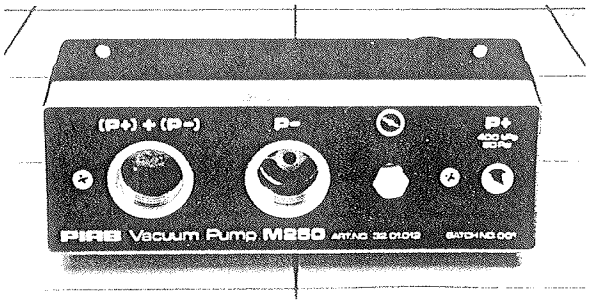
Time in seconds for evacuation of 1 cubic foot to desired vacuum

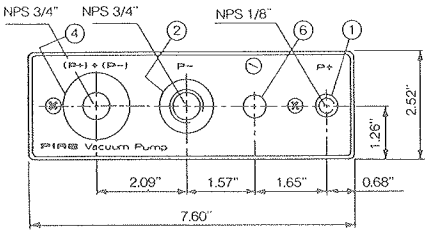
L-series @ 87 psi
M-series @ 58 psi
H-series @ 72 psi

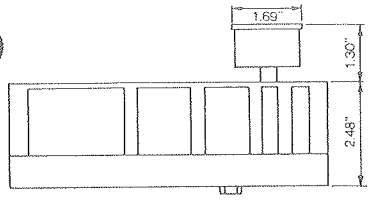
inches Hg.

VACUUM PUMP	1.5	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	28.5	29.6
M16	3.10	8.30	19.80	56.00	93.00	142.00	218.00	342.00	680.00	—	—	—
M32	1.60	4.20	9.90	28.30	47.00	71.00	110.00	170.00	340.00	—	—	—
M60	0.80	2.10	5.00	14.20	23.50	35.50	55.00	85.00	170.00	—	—	—
L63D	0.28	0.66	1.74	3.96	7.20	12.00	18.60	31.20	—	—	—	—
M63D	0.57	1.25	4.00	9.60	18.10	28.30	45.30	73.60	135.00	453.00	—	—
L125D	0.14	0.34	0.90	1.98	3.66	5.94	9.60	15.60	—	—	—	—
M125D	0.29	0.63	2.00	4.80	9.00	14.20	22.60	36.80	68.00	227.00	—	—
H125	—	2.80	5.70	8.50	14.60	20.00	28.00	43.00	71.00	128.00	198.00	450.00
L190D	0.09	0.22	0.58	1.32	2.40	4.00	6.20	10.40	—	—	—	—
M190D	0.19	0.42	1.30	3.20	6.00	9.40	15.10	24.50	45.00	151.00	—	—
L250D	0.07	0.17	0.46	0.96	1.86	3.12	4.56	7.80	—	—	—	—
M250D	0.14	0.30	1.00	2.40	4.50	7.00	11.30	18.50	32.50	113.30	—	—
H250	—	1.40	2.90	4.30	7.30	10.00	14.00	21.50	35.50	64.00	99.00	225.00
M375D	0.10	0.21	0.67	1.60	3.02	4.72	7.55	12.27	22.50	75.50	—	—
H375	—	0.90	1.90	2.80	4.90	6.70	9.30	14.30	23.70	42.70	66.00	150.00
L250	0.07	0.16	0.44	0.96	1.92	3.00	4.68	7.92	—	—	—	—
M250	0.10	0.22	0.74	2.00	4.20	6.80	10.80	18.20	34.00	112.00	—	—
L500	0.036	0.08	0.22	0.48	0.96	1.50	2.34	3.96	—	—	—	—
M500	0.048	0.11	0.37	1.00	2.10	3.40	5.40	9.10	17.00	56.00	—	—
H500	—	0.70	1.50	2.20	3.70	5.00	7.00	10.80	17.80	32.00	49.50	113.00
L1000	0.018	0.042	0.114	0.246	0.456	0.78	1.14	1.98	—	—	—	—
M1000	0.024	0.055	0.190	0.500	1.000	1.70	2.70	4.60	8.50	28.00	—	—
H1000	—	0.350	0.800	1.100	1.900	2.50	3.50	5.40	8.90	16.00	25.00	62.00
L2000	0.012	0.240	0.060	0.120	0.234	0.366	0.594	1.02	—	—	—	—
M2000	0.012	0.028	0.095	0.250	0.500	0.850	1.400	2.30	4.30	14.00	—	—
H2000	—	0.180	0.400	0.600	1.000	1.300	1.800	2.70	4.50	8.00	12.50	31.00
L4000	0.006	0.012	0.030	0.060	0.114	0.192	0.312	0.51	—	—	—	—
M4000	0.006	0.014	0.047	0.130	0.250	0.430	0.700	1.15	2.15	7.00	—	—
H4000	—	0.090	0.200	0.300	0.500	0.600	0.900	1.40	2.30	4.00	6.30	15.00

M250D Vacuum Pump



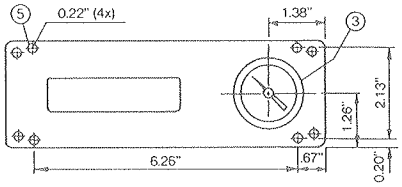




1. Compressed air connection
2. Vacuum connection
3. Vacuum gauge
4. Exhaust
5. Mounting holes
6. Additional vacuum Connection

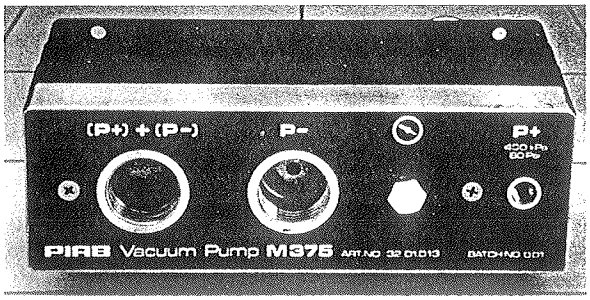
Air Consumption: 8.8 scfm at 58 psi
Optimum Feed Pressure: 58 psi
Max. Supply Pressure: 100 psi
Max. Vacuum: 27 in. Hg. at 58 psi
Working Temperature: -4°F to 176°F

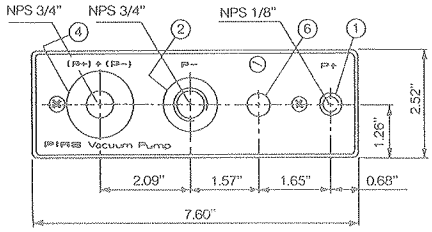
Weight: 1.98 lbs.
Material: anodized aluminum, brass, nitrile rubber
Sound Level: unloaded: 75 dB(A)
loaded up to 27 in. Hg.: 55 dB(A)
Article No: 32.01.012

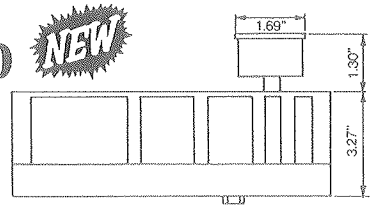


M375D Vacuum Pump

NEW



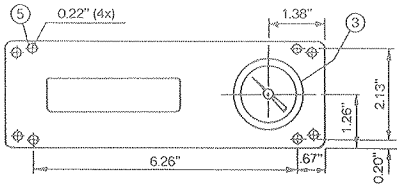




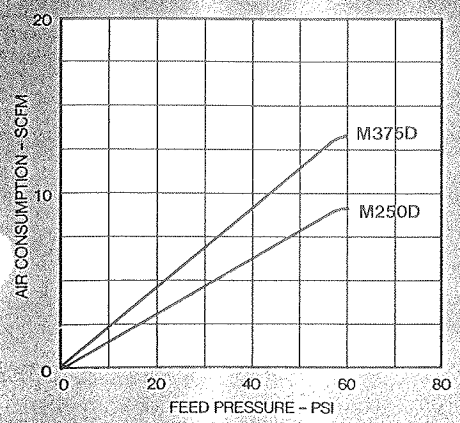
1. Compressed air connection
2. Vacuum connection
3. Vacuum gauge
4. Exhaust
5. Mounting holes
6. Additional vacuum Connection

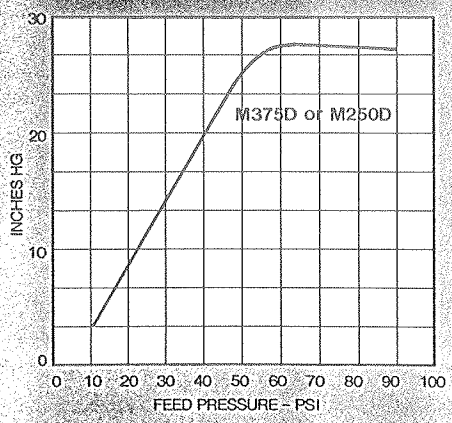
Air Consumption: 13.2 scfm at 58 psi
Optimum Feed Pressure: 58 psi
Max. Supply Pressure: 100 psi
Max. Vacuum: 27 in. Hg. at 58 psi
Working Temperature: -4°F to 176°F

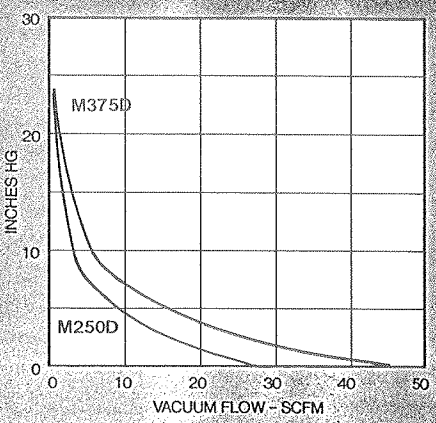
Weight: 2.64 lbs.
Material: anodized aluminum, brass, nitrile rubber
Sound Level: unloaded: 75 dB(A)
loaded up to 27 in. Hg.: 55 dB(A)
Article No: 32.01.013



Induced air at (in. Hg.) scfm (vacuum flow)	0	1.5	3	6	9	12	15	18	21	24	27	28.5	29.6
	FEED PRESSURE 58 psi												
M250D	28	18.32	12.68	7.48	3.52	2.68	1.8	1.32	0.88	.40	—	—	—
M375D	42	27.48	19.02	11.22	5.28	4.02	2.7	1.98	1.32	.60	—	—	—
Time in seconds for evacuation of a 1 cf volume to a desired vacuum (in. Hg.)													
M250D	—	.14	.30	1.00	2.4	4.50	7.00	11.30	18.50	32.5	113.3	—	—
M375D	—	.10	.21	.67	1.6	3.02	4.72	7.55	12.27	22.5	75.5	—	—







ANNEX 2

OTHER COMPONENTS

- TRANSVERSAL BEAM
- BOLTS
- EYE BOLTS

BOLTS :

WORST 100 lb/BOLT

18 - 8 - Stainless Steel Allen Socket head Screw.

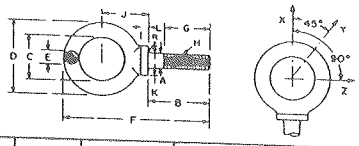
1/4" BOLT => Stress Area = 0.0364 in²

$\sigma = \frac{100}{0.0364} = 2,747.3$ psi => $\sigma_{ALLOWABLE}$ WITH SF=3 OF 8.2 ksi

EYE BOLTS :

5/16" => 45° => 200 lb EACH => 800 lb => SF ≥ 5

TABLE 1-27 Type 2 Shoulder-Pattern Eyebolt



Nominal Size		A Shank Dia	B Shank Length	C Eye ID	D Nominal Eye OD	E Eye Sect. Dia	F Overall Length	G Min. Length Full Thread	H Thread Size UNC-2A	J ℄ Eye To Shoulder	K Shoulder Dia	L Shoulder Height	R Radius Under Shoulder	W_x (1)Safe Working Load, lb, at 0°	W_y 45°	W_z 90°
1/4*	0.25	0.25 0.28	1.00 1.06	0.69 0.81	1.19	0.19 0.25	2.22 2.53	0.75	1/4–20 or .250–20	0.69 0.81	0.50 0.56	0.12 0.19	0.015 0.025	400	100	80
5/16*	0.31	0.31 0.34	1.12 1.19	0.81 0.94	1.44	0.25 0.31	2.66 2.97	0.81	5/16–18 or .3125–18	0.88 1.00	0.56 0.62	0.12 0.19	0.015 0.025	800	200	160
3/8*	0.38	0.38 0.41	1.25 1.38	0.94 1.06	1.69	0.31 0.38	3.09 3.47	0.88	3/8–16 or .375–16	1.06 1.19	0.62 0.69	0.12 0.19	0.015 0.025	1400	350	280
7/16	0.44	0.44 0.47	1.38 1.50	1.00 1.12	1.81	0.34 0.41	3.41 3.78	1.00	7/16–14 or .4375–14	1.19 1.31	0.75 0.81	0.19 0.25	0.015 0.025	2000	500	400
1/2*.	0.50	0.50 0.53	1.50 1.62	1.12 1.25	2.12	0.44 0.50	3.81 4.19	1.12	1/2–13 or .500 –13	1.31 1.44	0.88 0.94	0.19 0.25	0.015 0.025	2600	650	520
9/16	0.56	0.56 0.59	1.62 1.75	1.19 1.31	2.25	0.47 0.53	4.19 4.56	1.25	9/16–12 or .5625–12	1.50 1.62	0.94 1.00	0.22 0.28	0.020 0.045	3000	750	600
5/8*	0.62	0.62 0.66	1.75 1.88	1.31 1.44	2.56	0.56 0.62	4.56 4.94	1.38	5/8–11 or .625–11	1.59 1.72	1.00 1.06	0.25 0.31	0.020 0.045	4000	1000	800
3/4*	0.75	0.75 0.78	2.00 2.12	1.44 1.56	2.81	0.62 0.69	5.06 5.50	1.62	3/4–10 or .750–10	1.72 1.91	1.12 1.25	0.25 0.31	0.020 0.045	6000	1500	1200
7/8*	0.88	0.88 0.91	2.25 2.38	1.56 1.69	3.19	0.75 0.81	5.75 6.19	1.81	7/8–9 or .875–9	2.03 2.22	1.31 1.44	0.31 0.38	0.040 0.065	6600	1670	1330
1*	1.00	1.00 1.06	2.50 2.62	1.69 1.81	3.56	0.88 0.94	6.44 6.88	2.06	1–8 or 1.000–8	2.22 2.41	1.50 1.62	0.38 0.44	0.060 0.095	8000	2000	1600
1 1/8	1.12	1.12 1.19	2.75 2.88	1.94 2.06	4.06	1.00 1.06	7.31 7.75	2.31	1 1/8–7 or 1.125–7	2.59 2.78	1.69 1.81	0.44 0.50	0.060 0.095	10000	2500	2000
1 1/4*	1.25	1.25 1.34	3.00 3.12	2.12 2.25	4.44	1.09 1.16	8.00 8.44	2.50	1 1/4–7 or 1.250–7	2.84 3.03	1.88 2.00	0.50 0.56	0.060 0.095	15000	3750	3000
1 1/2*	1.50	1.50 1.59	3.50 3.62	2.44 2.56	5.19	1.31 1.38	9.22 9.72	3.00	1 1/2–6 or 1.500–6	3.19 3.44	2.12 2.25	.0.50 0.62	0.060 0.095	18000	4500	3600
1 3/4	1.75	1.75 1.84	3.75 3.88	2.75 3.00	6.00	1.50 1.62	10.50 11.12	3.19	1 3/4–5 or 1.750–5	3.88 4.12	2.50 2.62	0.50 0.62	0.060 0.095	22000	5500	4400
2*	2.00	2.00 2.09	4.00 4.12	3.06 3.44	6.88	1.75 1.88	11.53 12.22	3.38	2–4 1/2 or 2.000–4.50	4.25 4.50	2.88 3.00	0.62 0.75	0.060 0.095	26000	6500	5200

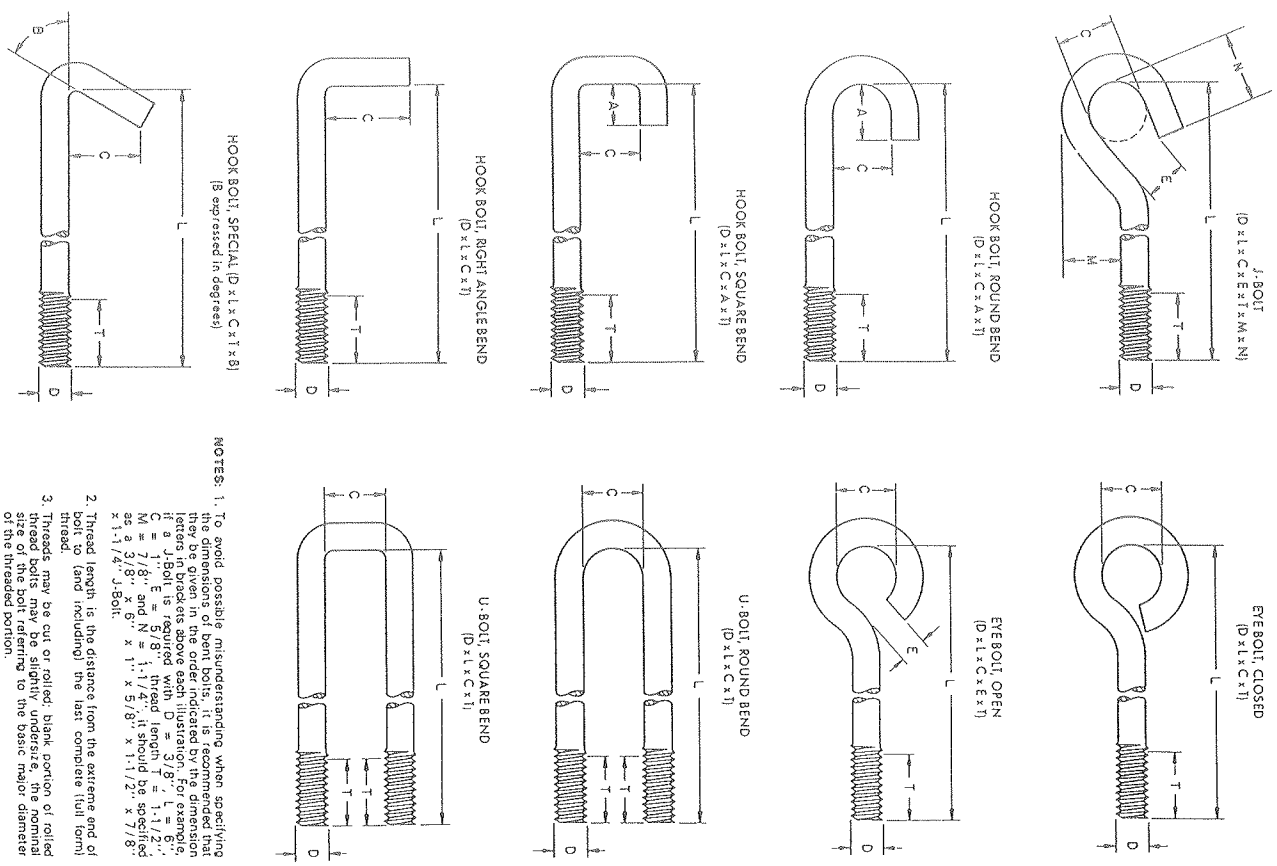
*Preferred.

(1) Applies if shoulder is properly seated. Otherwise safe working load of Type 1 applies. These safe working loads are based on the following percentages of minimum proof loads shown in ASTM A 489; 0° – 66.6 per cent, 45° – 16.7 per cent, 90° – 13.3 per cent.

All dimensions in inches.

SOURCE: ANSI B18.15-1969, as published by the American Society of Mechanical Engineers.

TABLE 1-28 Bent Bolts

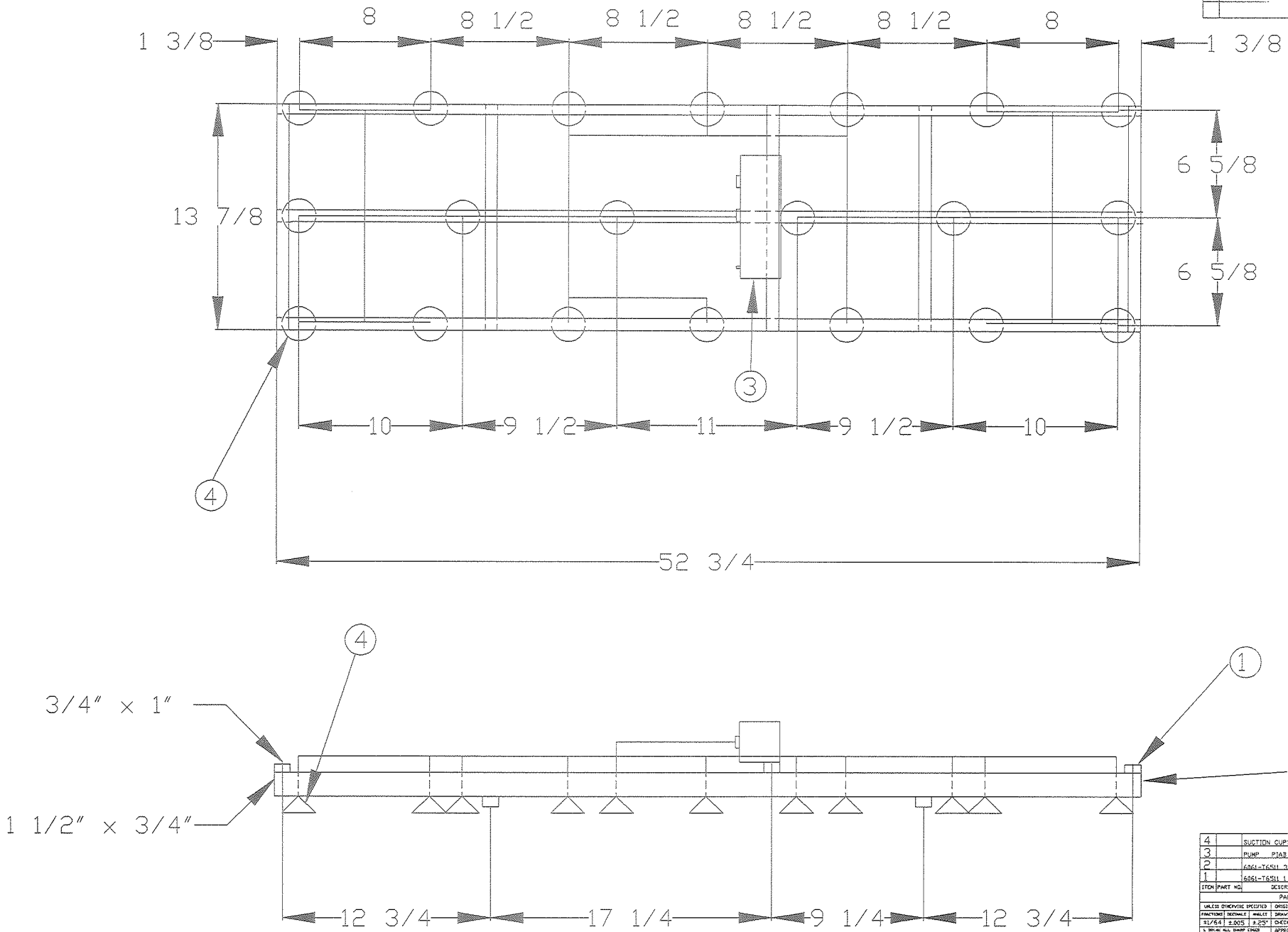


NOTES: 1. To avoid possible misunderstanding when specifying bent bolts, it is recommended that they be given in the order indicated by the dimension letters in brackets above each illustration. For example, if a J-Bolt is required with D = 3/8", L = 6", C = 1", E = 5/8", thread length T = 1-1/2", M = 7/8", and N = 1-1/4", it should be specified as a 3/8" x 6" x 1" x 5/8" x 1-1/2" x 7/8" x 1-1/4" J-Bolt.

2. Thread length is the distance from the extreme end of bolt to (and including) the last complete (full form) thread.

3. Threads may be cut or rolled; blank portion of rolled thread bolts may be slightly undersize, the nominal size of the bolt referring to the basic major diameter of the threaded portion.

SOURCE: Industrial Fasteners Institute.



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
4		SUCTION CUPS PIAB F-50	20
3		PUMP PIAB M2500	1
2		6061-T6511 3/4" x 1" x 13 7/8"	5
1		6061-T6511 1 1/2" x 3/4" x 52 3/4"	3

PARTS LIST

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	RS	6/9/92
FRACTIONS	DECIMALS	ANGLES	DRAWN	RS	6/9/92
±1/64	±.005	±.25°	CHECKED		
1. DEBURR ALL SHARP EDGES AT MAC.			APPROVED		
2. DO NOT SCALE DRAWING			USED ON		
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982					
4. SPAC ALL MACH. SURFACES 125			MATERIAL		

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

VACUUM LIFTING DEVICE

SCALE	SOFTWARE	DRAWING NUMBER	REV.
1:2	AUTOCAD	9302-ME-302229	A

FILE: