AEROSPACE INFORMATION REPORT

AIR1593™	REV. A

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Superseding AIR1593

(R) Clamp Loads and Bending Stresses in Aircraft Tubing Installations

RATIONALE

Scope has been revised. ARP994 added to Sections 2 and 3. Section 5 added. Figure 1 redrawn and re-identified as Tables 1, 2, and 3. Loop clamps in Figure 1 revised to show mounting position is above tube centerline. Wall thickness for titanium sizes Ø 1.250 and Ø 1.500 in Table 3 revised to coincide with AS5620 specifications resulting in new P values.

1. SCOPE

This SAE Aerospace Information Report (AIR) contains information relative to stresses and loads developed in tubes caused by tube deflections encountered in misaligned installations.

Users are advised that when calculating the stresses and loads of a tubing system, the yield strength of existing loop clamp material is significantly lower than the tubing materials specified herein and should be considered.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific examption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP994 Design of Tubing Installations for Aerospace Hydraulic Systems

3. APPLICABILITY

It is realized that actual service conditions will be more complex than the straining conditions assumed in this report. Accordingly, information presented herein is primarily intended for use as a guide to stress and load magnitudes for designers as reference only. Each application needs to be analyzed for individual stresses. For additional design considerations, refer to ARP994.

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4. DISCUSSION

Two bending modes are considered (see Figure 1). Case 1 illustrates a mode involving two or more consecutive misaligned clamps, or a tube misaligned with a boss or bulkhead fitting. In this case, the tubing has been offset to form a transition between two parallel but displaced axes. Case 2 illustrates a mode involving one clamp misaligned with others in the same run. The equations for load and stress describe the condition of 100% fixed beams, assuming rigid clamps as the worst case.

Solutions for stress and load for Case 1 have been calculated and are tabulated for selected tube materials and wall thicknesses for tube displacements from 1/16 to 1/2 inch in 1/16 inch increments with tube spans from 5 to 40 inches in 5 inch increments. For Case 2, values for stress are the same as for Case 1; load values are two times those specified in Case 1. Blank spaces in tables indicate calculated stresses were in excess of tubing yield strength. (For aluminum tube, yield strength (F_y) = 34000 psi; for corossion resistant steel, F_y = 120000 psi; for titanium, F_y = 105000 psi.)

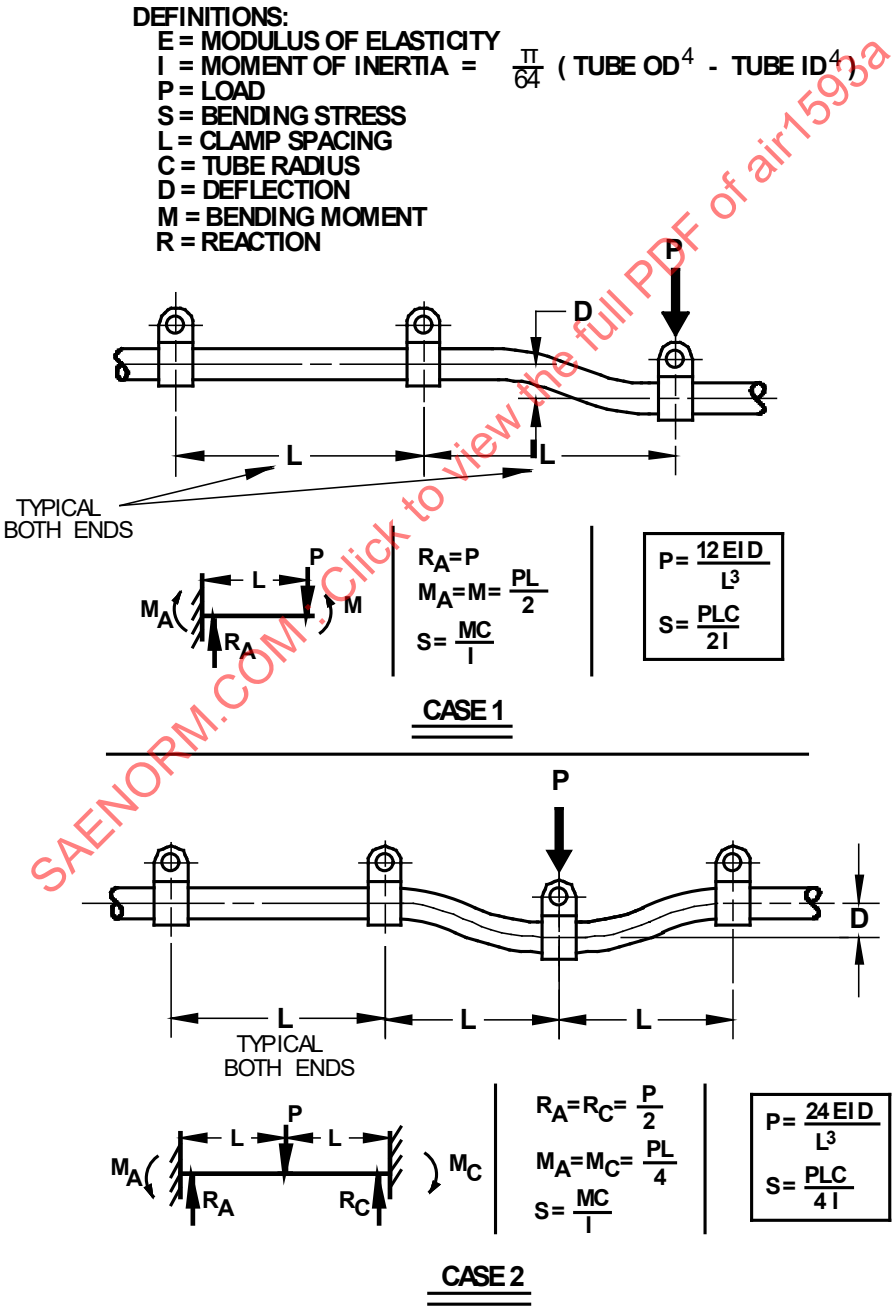

Figure 1

Table 1 - Tube material: aluminum alloy 6061-T6 per AMS-T-7081

TUBE MATERIAL: AL ALLOY 6061-T6 PER AMS-T-7081 $E = 9.9 \times 10^6$ INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.250 INCH DIA 0.020 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	18.56	4.64	2.06	1.16	0.74	0.52	0.38	0.29
	P	5.72	0.71	0.21	0.09	0.05	0.03	0.02	0.01
0.1250	S	-	9.28	4.13	2.32	1.49	1.03	0.76	0.58
	P		1.43	0.42	0.18	0.09	0.05	0.03	0.02
0.1875	S	-	13.92	6.19	3.48	2.23	1.55	1.14	0.87
	P		2.14	0.64	0.27	0.14	0.08	0.05	0.03
0.2500	S	-	18.56	8.25	4.64	2.97	2.06	1.52	1.16
	P		2.86	0.85	0.36	0.18	0.11	0.07	0.04
0.3125	S	-	23.20	10.31	5.80	3.71	2.58	1.89	1.45
	P		3.57	1.06	0.45	0.23	0.13	0.08	0.06
0.3750	S	-	27.84	12.38	6.96	4.46	3.09	2.27	1.74
	P		4.29	1.27	0.54	0.27	0.16	0.10	0.07
0.4375	S	-	32.48	14.44	8.12	5.20	3.61	2.65	2.03
	P		5.00	1.48	0.63	0.32	0.19	0.12	0.08
0.5000	S	-	-	16.50	9.28	5.94	4.13	3.03	2.32
	P			1.69	0.71	0.37	0.21	0.13	0.09
TUBE SIZE 0.312 INCH DIA 0.028 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	23.20	5.80	2.58	1.45	0.93	0.64	0.47	0.36
	P	15.19	1.90	0.56	0.24	0.12	0.07	0.04	0.03
0.1250	S	-	11.60	5.16	2.90	1.86	1.29	0.95	0.73
	P		3.80	1.12	0.47	0.24	0.14	0.09	0.06
0.1875	S	-	17.40	7.73	4.35	2.78	1.93	1.42	1.09
	P		5.69	1.69	0.71	0.36	0.21	0.13	0.09
0.2500	S	-	23.20	10.31	5.80	3.71	2.58	1.89	1.45
	P		7.59	2.25	0.95	0.49	0.28	0.18	0.12
0.3125	S	-	29.00	12.89	7.25	4.64	3.22	2.37	1.81
	P		9.49	2.81	1.19	0.61	0.35	0.22	0.15
0.3750	S	-	-	15.47	8.70	5.57	3.87	2.84	2.18
	P			3.37	1.42	0.73	0.42	0.27	0.18
0.4375	S	-	-	18.05	10.15	6.50	4.51	3.31	2.54
	P			3.94	1.66	0.85	0.49	0.31	0.21
0.5000	S	-	-	20.63	11.60	7.43	5.16	3.79	2.90
	P			4.50	1.90	0.97	0.56	0.35	0.24

Table 1A - Tube material: aluminum alloy 6061-T6 per AMS-T-7081

TUBE MATERIAL: AL ALLOY 6061-T6 PER AMS-T-7081 $E = 9.9 \times 10^6$ INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.375 INCH DIA 0.028 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	27.84	6.96	3.09	1.74	1.11	0.77	0.57	0.44
	P	27.47	3.43	1.02	0.43	0.22	0.13	0.08	0.05
0.1250	S	-	13.92	6.19	3.48	2.23	1.55	1.14	0.87
	P		6.87	2.03	0.86	0.44	0.25	0.16	0.11
0.1875	S	-	20.88	9.28	5.22	3.34	2.32	1.70	1.31
	P		10.30	3.05	1.29	0.66	0.38	0.24	0.16
0.2500	S	-	27.84	12.38	6.96	4.46	3.09	2.27	1.74
	P		13.73	4.07	1.72	0.88	0.51	0.32	0.21
0.3125	S	-	-	15.47	8.70	5.57	3.87	2.84	2.18
	P			5.09	2.15	1.10	0.64	0.40	0.27
0.3750	S	-	-	18.56	10.44	6.68	4.64	3.41	2.61
	P			6.10	2.58	1.32	0.76	0.48	0.32
0.4375	S	-	-	21.66	12.18	7.80	5.41	3.98	3.05
	P			7.12	3.00	1.54	0.89	0.56	0.38
0.5000	S	-	-	24.75	13.92	8.91	6.19	4.55	3.48
	P			8.14	3.43	1.76	1.02	0.64	0.43
TUBE SIZE 0.500 INCH DIA 0.028 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	9.28	4.13	2.32	1.49	1.03	0.76	0.58
	P		8.62	2.55	1.08	0.55	0.32	0.20	0.13
0.1250	S	-	18.56	8.25	4.64	2.97	2.06	1.52	1.16
	P		17.23	5.11	2.15	1.10	0.64	0.40	0.27
0.1875	S	-	27.84	12.38	6.96	4.46	3.09	2.27	1.74
	P		25.85	7.66	3.23	1.64	0.96	0.60	0.40
0.2500	S	-	-	16.50	9.28	5.94	4.13	3.03	2.32
	P			10.21	4.31	2.21	1.28	0.80	0.54
0.3125	S	-	-	20.63	11.60	7.43	5.16	3.79	2.90
	P			12.76	5.38	2.76	1.60	1.00	0.67
0.3750	S	-	-	24.75	13.92	8.91	6.19	4.55	3.48
	P			15.32	6.46	3.31	1.91	1.21	0.81
0.4375	S	-	-	28.88	16.24	10.40	7.22	5.30	4.06
	P			17.87	7.54	3.86	2.23	1.41	0.94
0.5000	S	-	-	33.00	18.56	11.88	8.25	6.06	4.64
	P			20.42	8.62	4.41	2.55	1.61	1.08

Table 1B - Tube material: aluminum alloy 6061-T6 per AMS-T-7081

TUBE MATERIAL: AL ALLOY 6061-T6 PER AMS-T-7081 $E = 9.9 \times 10^6$ INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.625 INCH DIA 0.035 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	11.60	5.16	2.90	1.86	1.29	0.95	0.73
	P		21.03	6.23	2.63	1.35	0.78	0.49	0.33
0.1250	S	-	23.20	10.31	5.80	3.71	2.58	1.89	1.45
	P		42.07	12.46	5.26	2.69	1.56	0.98	0.66
0.1875	S	-	-	15.47	8.70	5.57	3.87	2.84	2.18
	P			18.70	7.89	4.04	2.34	1.47	0.99
0.2500	S	-	-	20.63	11.60	7.43	5.16	3.79	2.90
	P			24.93	10.52	5.38	3.12	1.96	1.31
0.3125	S	-	-	25.78	14.50	9.28	6.45	4.74	3.63
	P			31.16	13.15	6.73	3.90	2.45	1.64
0.3750	S	-	-	30.94	17.40	11.14	7.73	5.68	4.35
	P			37.39	15.77	8.08	4.67	2.94	1.97
0.4375	S	-	-	-	20.30	12.99	9.02	6.63	5.08
	P				18.40	9.42	5.45	3.43	2.30
0.5000	S	-	-	-	23.20	14.85	10.31	7.58	5.80
	P				21.03	10.77	6.23	3.92	2.63
TUBE SIZE 0.750 INCH DIA 0.042 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	13.92	6.19	3.48	2.23	1.55	1.14	0.87
	P		43.61	12.92	5.45	2.79	1.62	1.02	0.68
0.1250	S	-	27.84	12.38	6.96	4.46	3.09	2.27	1.74
	P		87.23	25.85	10.90	5.58	3.23	2.03	1.36
0.1875	S	-	-	18.56	10.44	6.68	4.64	3.41	2.61
	P			38.77	16.36	8.37	4.85	3.05	2.04
0.2500	S	-	-	24.75	13.92	8.91	6.19	4.55	3.48
	P			51.69	21.81	11.17	6.46	4.07	2.73
0.3125	S	-	-	30.94	17.40	11.14	7.73	5.68	4.35
	P			64.61	27.26	13.96	8.08	5.09	3.41
0.3750	S	-	-	-	2.088	13.37	9.28	6.82	5.22
	P				32.71	16.75	9.69	6.10	4.09
0.4375	S	-	-	-	24.36	15.59	10.83	7.96	6.09
	P				38.16	19.54	11.31	7.12	4.77
0.5000	S	-	-	-	27.84	17.82	12.38	9.09	6.96
	P				43.61	22.33	12.92	8.14	5.45

Table 1C - Tube material: aluminum alloy 6061-T6 per AMS-T-7081

TUBE MATERIAL: AL ALLOY 6061-T6 PER AMS-T-7081 E = 9.9 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 1.000 INCH DIA 0.049 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	18.56	8.25	4.64	2.97	2.06	1.52	1.16
	P		123.21	36.51	15.40	7.89	4.56	2.87	1.93
0.1250	S	-	-	16.50	9.28	5.94	4.13	3.03	2.32
	P			73.01	30.80	15.77	9.13	5.75	3.85
0.1875	S	-	-	24.75	13.92	8.91	6.19	4.55	3.48
	P			109.52	46.20	23.66	13.69	8.62	5.78
0.2500	S	-	-	33.00	18.56	11.88	8.25	6.06	4.64
	P			146.03	61.60	31.54	18.25	11.49	7.70
0.3125	S	-	-	-	23.20	14.85	10.31	7.58	5.80
	P				77.01	39.43	22.82	14.37	9.63
0.3750	S	-	-	-	27.84	17.82	12.38	9.09	6.96
	P				92.41	47.31	27.38	17.24	11.55
0.4375	S	-	-	-	32.48	20.79	14.44	10.61	8.12
	P				107.81	55.20	31.94	20.12	13.48
0.5000	S	-	-	-	-	23.76	16.50	12.12	9.28
	P					63.08	36.51	22.99	15.40
TUBE SIZE 1.250 INCH DIA 0.065 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	23.20	10.31	5.80	3.71	2.58	1.89	1.45
	P		316.32	93.72	39.54	20.24	11.72	7.38	4.94
0.1250	S	-	-	20.63	11.60	7.43	5.16	3.79	2.90
	P			187.45	79.08	40.49	23.43	14.76	9.89
0.1875	S	-	-	30.94	17.40	11.14	7.73	5.68	4.35
	P			281.17	118.62	60.73	35.15	22.13	14.83
0.2500	S	-	-	-	23.20	14.85	10.31	7.58	5.80
	P				158.16	80.98	46.86	29.51	19.77
0.3125	S	-	-	-	29.00	18.56	12.89	9.47	7.25
	P				197.70	101.22	58.58	36.89	24.71
0.3750	S	-	-	-	-	22.28	15.47	11.36	8.70
	P					121.47	70.29	44.27	29.66
0.4375	S	-	-	-	-	25.99	18.05	13.26	10.15
	P					141.71	82.01	51.64	34.60
0.5000	S	-	-	-	-	29.70	20.63	15.15	11.60
	P					161.96	93.72	59.02	39.54

Table 1D - Tube material: aluminum alloy 6061-T6 per AMS-T-7081

TUBE MATERIAL: AL ALLOY 6061-T6 PER AMS-T-7081 E = 9.9 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 1.500 INCH DIA 0.083 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	27.84	12.38	6.96	4.46	3.09	2.27	1.74
	P		690.93	204.72	86.37	44.22	25.59	16.11	10.80
0.1250	S	-	-	24.75	13.92	8.91	6.19	4.55	3.48
	P			409.44	172.73	88.44	51.18	32.23	21.59
0.1875	S	-	-	-	20.88	13.37	9.28	6.82	5.22
	P				259.10	132.66	76.77	48.34	32.39
0.2500	S	-	-	-	27.84	17.82	12.38	9.09	6.96
	P				345.46	176.88	102.36	64.46	43.18
0.3125	S	-	-	-	-	22.28	15.47	11.36	8.70
	P					221.10	127.95	80.57	53.98
0.3750	S	-	-	-	-	26.73	18.56	13.64	10.44
	P					265.32	153.54	96.69	64.77
0.4375	S	-	-	-	-	31.19	21.66	15.91	12.18
	P					309.53	179.13	112.80	75.57
0.5000	S	-	-	-	-	-	24.75	18.18	13.92
	P						204.72	128.92	86.37

Table 2 - Tube material: CRES 21-6-9

TUBE MATERIAL: CRES 21-6-9 E = 28.5 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.250 INCH DIA 0.016 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	53.44	13.36	5.94	3.34	2.14	1.48	1.09	0.83
	P	13.83	1.73	0.51	0.22	0.11	0.06	0.04	0.03
0.1250	S	106.88	26.72	11.88	6.68	4.28	2.97	2.18	1.67
	P	27.66	3.46	1.02	0.43	0.22	0.13	0.08	0.05
0.1875	S	-	40.08	17.81	10.02	6.41	4.45	3.27	2.50
	P		5.19	1.54	0.65	0.33	0.19	0.12	0.08
0.2500	S	-	53.44	23.75	13.36	8.55	5.94	4.36	3.34
	P		6.92	2.05	0.86	0.44	0.26	0.16	0.11
0.3125	S	-	66.80	29.69	16.70	10.69	7.42	5.45	4.17
	P		8.64	2.56	1.08	0.55	0.32	0.20	0.14
0.3750	S	-	80.16	35.63	20.04	12.83	8.91	6.54	5.01
	P		10.37	3.07	1.30	0.66	0.38	0.24	0.16
0.4375	S	-	93.52	41.56	23.38	14.96	10.39	7.63	5.84
	P		12.10	3.59	1.51	0.77	0.45	0.28	0.19
0.5000	S	-	106.88	47.50	26.72	17.10	11.88	8.72	6.68
	P		13.83	4.10	1.73	0.89	0.51	0.32	0.22
TUBE SIZE 0.312 INCH DIA 0.019 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	66.80	16.70	7.42	4.17	2.67	1.86	1.36	1.04
	P	32.39	4.05	1.20	0.51	0.26	0.15	0.09	0.06
0.1250	S	-	33.40	14.84	8.35	5.34	3.71	2.73	2.09
	P		8.10	2.40	1.01	0.52	0.30	0.19	0.13
0.1875	S	-	50.10	22.27	12.52	8.02	5.57	4.09	3.13
	P		12.15	3.60	1.52	0.78	0.45	0.28	0.19
0.2500	S	-	66.80	29.69	16.70	10.69	7.42	5.45	4.17
	P		16.20	4.80	2.02	10.40	0.60	0.38	0.25
0.3125	S	-	83.50	37.11	20.87	13.36	9.28	6.82	5.22
	P		20.25	6.00	2.53	1.30	0.75	0.47	0.32
0.3750	S	-	100.20	44.53	25.05	16.03	11.13	8.18	6.26
	P		24.29	7.20	3.04	1.55	0.90	0.57	0.38
0.4375	S	-	116.89	51.95	29.22	18.70	12.99	9.54	7.31
	P		28.34	8.40	3.54	1.81	1.05	0.66	0.44
0.5000	S	-	-	59.38	33.40	21.38	14.84	10.91	8.35
	P			9.60	4.05	2.07	1.20	0.76	0.51

Table 2A - Tube material: CRES 21-6-9

TUBE MATERIAL: CRES 21-6-9 E = 28.5 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.375 INCH DIA 0.020 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	80.16	20.04	8.91	5.01	3.21	2.23	1.64	1.25
	P	60.28	7.53	2.23	0.94	0.48	0.28	0.18	0.12
0.1250	S	-	40.08	17.81	10.02	6.41	4.45	3.27	2.50
	P		15.07	4.46	1.88	0.96	0.56	0.35	0.24
0.1875	S	-	60.12	26.72	15.03	9.62	6.68	4.91	3.76
	P		22.60	6.70	2.83	1.45	0.84	0.53	0.35
0.2500	S	-	80.16	35.63	20.04	12.83	8.91	6.54	5.01
	P		30.14	8.93	3.77	1.93	1.12	0.70	0.47
0.3125	S	-	100.20	44.53	25.05	16.03	11.13	8.18	6.26
	P		37.67	11.16	4.71	2.41	1.40	0.88	0.59
0.3750	S	-	-	53.44	30.06	19.24	13.36	9.82	7.51
	P			13.39	5.65	2.89	1.67	1.05	0.71
0.4375	S	-	-	62.34	35.07	22.44	15.59	11.45	8.77
	P			15.63	6.59	3.38	1.95	1.23	0.82
0.5000	S	-	-	71.25	40.08	25.65	17.81	13.09	10.02
	P			17.86	7.53	3.86	2.23	1.41	0.94
TUBE SIZE 0.500 INCH DIA 0.026 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	106.88	26.72	11.88	6.68	4.28	2.97	2.18	1.67
	P	186.50	23.31	6.91	2.91	1.49	0.86	0.54	0.36
0.1250	S	-	53.44	23.75	13.36	8.55	5.94	4.36	3.34
	P		46.62	13.81	5.83	2.98	1.73	1.09	0.73
0.1875	S	-	80.16	35.63	20.04	12.83	8.91	6.54	5.01
	P		69.94	20.72	8.74	4.48	2.59	1.63	1.09
0.2500	S	-	106.88	47.50	26.72	17.10	11.88	8.72	6.68
	P		93.25	27.63	11.66	5.97	3.45	2.17	1.46
0.3125	S	-	-	59.38	33.40	21.38	14.84	10.91	8.35
	P			34.54	14.57	7.46	4.32	2.72	1.82
0.3750	S	-	-	71.25	40.08	25.65	17.81	13.09	10.02
	P			41.44	17.48	8.95	5.18	3.26	2.19
0.4375	S	-	-	83.13	46.76	29.93	20.78	15.27	11.69
	P			48.35	20.40	10.44	6.04	3.81	2.55
0.5000	S	-	-	95.00	53.44	34.20	23.75	17.45	13.36
	P			55.26	23.31	11.94	6.91	4.35	2.91

Table 2B - Tube material: CRES 21-6-9

TUBE MATERIAL: CRES 21-6-9 E = 28.5 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.625 INCH DIA 0.033 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	33.40	14.84	8.35	5.34	3.71	2.73	2.09
	P		57.65	17.08	7.21	3.69	2.14	1.34	0.90
0.1250	S	-	66.80	29.69	16.70	10.69	7.42	5.45	4.17
	P		115.30	34.16	14.41	7.38	4.27	2.69	1.80
0.1875	S	-	100.20	44.53	25.05	16.03	11.13	8.18	6.26
	P		172.95	51.24	21.62	11.07	6.41	4.03	2.70
0.2500	S	-	-	59.38	33.40	21.38	14.84	10.91	8.35
	P			68.32	28.82	14.76	8.54	5.38	3.60
0.3125	S	-	-	74.22	41.75	26.72	18.55	13.63	10.44
	P			85.41	36.03	18.45	10.68	6.72	4.50
0.3750	S	-	-	89.06	50.10	32.06	22.27	16.36	12.52
	P			102.49	43.24	22.14	12.81	8.07	5.40
0.4375	S	-	-	103.91	58.45	37.41	25.98	19.08	14.61
	P			119.57	50.44	25.83	14.95	9.41	6.31
0.5000	S	-	-	118.75	66.80	42.75	29.69	21.81	16.70
	P			136.65	57.65	29.52	17.08	10.76	7.21
TUBE SIZE 0.750 INCH DIA 0.039 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	40.08	17.81	10.02	6.41	4.45	3.27	2.50
	P		118.02	34.97	14.75	7.55	4.37	2.75	1.84
0.1250	S	-	80.16	35.63	20.04	12.83	8.91	6.54	5.01
	P		236.03	69.94	29.50	15.11	8.74	5.51	3.69
0.1875	S	-	-	53.44	30.06	19.24	13.36	9.82	7.51
	P			104.90	44.26	22.66	13.11	8.26	5.53
0.2500	S	-	-	71.25	40.08	25.65	17.81	13.09	10.02
	P			139.87	59.01	30.21	17.48	11.01	7.38
0.3125	S	-	-	89.06	50.10	32.06	22.27	16.36	12.52
	P			174.84	73.76	37.77	21.85	13.76	9.22
0.3750	S	-	-	106.88	60.12	38.48	26.72	19.63	15.03
	P			209.81	88.51	45.32	26.23	16.52	11.06
0.4375	S	-	-	-	70.14	44.89	31.17	22.90	17.53
	P				103.26	52.87	30.60	19.27	12.91
0.5000	S	-	-	-	80.16	51.30	35.63	26.17	20.04
	P				118.02	60.42	34.97	22.02	14.75

Table 2C - Tube material: CRES 21-6-9

TUBE MATERIAL: CRES 21-6-9 E = 28.5 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 1.000 INCH DIA 0.052 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	-	53.44	23.75	13.36	8.55	5.94	4.36	3.34
	P		372.99	110.52	46.62	23.87	13.81	8.70	5.83
0.1250	S	-	106.88	47.50	26.72	17.10	11.88	8.72	6.68
	P		745.98	221.03	93.25	47.74	27.63	17.40	11.66
0.1875	S	-	-	71.25	40.08	25.65	17.81	13.09	10.02
	P			331.55	139.87	71.61	41.44	26.10	17.48
0.2500	S	-	-	95.00	53.44	34.20	23.75	17.45	13.36
	P			442.06	186.50	95.49	55.26	34.80	23.31
0.3125	S	-	-	118.75	66.80	42.75	29.69	21.81	16.70
	P			552.58	233.12	119.36	69.07	43.50	29.14
0.3750	S	-	-	-	80.16	51.30	35.63	26.17	20.04
	P				279.74	143.23	82.89	52.20	34.97
0.4375	S	-	-	-	93.52	59.85	41.56	30.54	23.38
	P				326.37	167.10	96.70	60.90	40.80
0.5000	S	-	-	-	106.88	68.40	47.50	34.90	26.72
	P				372.99	190.97	110.52	69.60	46.62

Table 3 - Tube material: titanium 3AL-2.5V

TUBE MATERIAL: TITANIUM 3AL-2.5V E = 15.0 X 10^6 INDUCED BENDING STRESS "S" IN KSI APPLIED FORCE "P" IN POUNDS									
TUBE SIZE 0.250 INCH DIA 0.016 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	28.13	7.03	3.13	1.76	1.13	0.78	0.57	0.44
	P	7.28	0.91	0.27	0.11	0.06	0.03	0.02	0.01
0.1250	S	56.25	14.06	6.25	3.52	2.25	1.56	1.15	0.88
	P	14.56	1.82	0.54	0.23	0.12	0.07	0.04	0.03
0.1875	S	84.38	21.09	9.38	5.27	3.38	2.34	1.72	1.32
	P	21.84	2.73	0.81	0.34	0.17	0.10	0.06	0.04
0.2500	S	-	28.13	12.50	7.03	4.50	3.13	2.30	1.76
	P		3.64	1.08	0.45	0.23	0.13	0.08	0.06
0.3125	S	-	35.16	15.63	8.79	5.63	3.91	2.87	2.20
	P		4.55	1.35	0.57	0.29	0.17	0.11	0.07
0.3750	S	-	42.19	18.75	10.55	6.75	4.69	3.44	2.64
	P		5.46	1.62	0.68	0.35	0.20	0.13	0.09
0.4375	S	-	49.22	21.88	12.30	7.88	5.47	4.02	3.08
	P		6.37	1.89	0.80	0.41	0.24	0.15	0.10
0.5000	S	-	56.25	25.00	14.06	9.00	6.25	4.59	3.52
	P		7.28	2.16	0.91	0.47	0.27	0.17	0.11
TUBE SIZE 0.375 INCH DIA 0.019 INCH WALL		CLAMP SPAN "L" (INCHES)							
TUBE DEFLECTION		5	10	15	20	25	30	35	40
0.0625	S	42.19	10.55	4.69	2.64	1.69	1.17	0.86	0.66
	P	30.38	3.80	1.13	0.47	0.24	0.14	0.09	0.06
0.1250	S	84.38	21.09	9.38	5.27	3.38	2.34	1.72	1.32
	P	60.77	7.60	2.25	0.95	0.49	0.28	0.18	0.12
0.1875	S	-	31.64	14.06	7.91	5.06	3.52	2.58	1.98
	P		11.39	3.38	1.42	0.73	0.42	0.27	0.18
0.2500	S	-	42.19	18.75	10.55	6.75	4.69	3.44	2.64
	P		15.19	4.50	1.90	0.97	0.56	0.35	0.24
0.3125	S	-	57.23	23.44	13.18	8.44	5.86	4.30	3.30
	P		18.99	5.63	2.37	1.22	0.70	0.44	0.30
0.3750	S	-	63.28	28.13	15.82	10.13	7.03	5.17	3.96
	P		22.79	6.75	2.85	1.46	0.84	0.53	0.36
0.4375	S	-	73.83	32.81	18.46	11.81	8.20	6.03	4.61
	P		26.59	7.88	3.32	1.70	0.98	0.62	0.42
0.5000	S	-	84.38	37.50	21.09	13.50	9.38	6.89	5.27
	P		30.38	9.00	3.80	1.94	1.13	0.71	0.47