CHAPTER 5

ALUMINUM ALLOY

5.0 GENERAL PROPERTIES

5.00 The general strength properties and related characteristics of various aluminum alloys are listed in the tables at the end of this chapter. Particular attention should be paid to the detailed notes at the bottom of each table and to the general explanatory notes in Chapter 3. These tables will be revised and amplified from time to time as found necessary and to include new materials of construction.

5.1 COLUMNS

5.10 Column Formulas

5.100 Primary Failure. The general formulas for primary instability are given in Sec. 1.27. For convenience, these formulas are repeated in Table 5-1 in simplified form applicable to round aluminum alloy tubes. These formulas can also be used for columns having cross sections other than those of round tubes when local instability is not critical.

5.101 Local Failure. Table 5-1 also contains notes and references concerning the local instability of round tubes. The local failure stresses for columns having cross sections of other shapes are given in the allowable stress curves at the end of this chapter.

5.11 Column Stress Curves. Curves of the allowable column stresses for various cross sectional shapes are given in Figs. 5-1 to 5-4. The allowable stress is plotted against the effective slenderness ratio which is defined by the formula:

$$L'/\rho = L/\rho\sqrt{c} \qquad (5:1)$$

The geometrical properties of circular corrugations are given in Fig. 5-5 in order to facilitate their use in conjunction with Figs. 5-3 and 5-4.

5.2 BEAMS

5.20 General. See Sec. 1.21, Eq. 1:3, and Sec. 1.414 for general information on beams.

5.21 Simple Beams. Beams of solid, tubular, or similar cross sections can be assumed to fail through exceeding an allowable modulus of rupture in bending (F_b). For solid sections it can usually be safely assumed that F_b equals the ultimate tensile stress.

5.210 Round tubes. For round tubes the value of F_b will depend on the D/t ratio as well as the ultimate tensile stress. The bending modulus of rupture of 17ST round tubes is given in Fig. 5-6. It should be noted that these values apply only when the tubes are restrained against local buckling at the loading points. (These curves were obtained from National Bureau of Standards test data).

5.211 Thin-Walled Cylinders. Information on the failure of thin-walled cylinders in bending is given in Secs. 1.631 and 1.641.

TABLE 5-1 COLUMN FORMULAS FOR ROUND ALUMINUM ALLOY TUBING

(REVISED OCT '40)

Material	F_{ty}-psi	F_{co}-psi	Short Columns: Column Formula (a)	Short Columns: Basic Eq.	Critical L'/ρ (b)	Long Columns (a)	Local Failure
Aluminum Alloy - General		(F_{cy}) times $\left(1 + \frac{F_{cy}}{200,000}\right)$	Eq. 1:26	1:26	$1.732 \times \pi\sqrt{E/F_{co}}$	$\frac{\pi^2 E}{(L'/\rho)^2}$	Note (c)
17ST	30,000	34,500	34,500-245 L'/ρ	1:26	94	$101.6 \times 10^6/(L'/\rho)^2$	Fig. 5-1
17ST	40,000	42,500	42,500-334.5 L'/ρ	1:26	84.6	$101.6 \times 10^6/(L'/\rho)^2$	Fig. 5-1
24ST	40,000 42,000	50,000	50,000-427 L'/ρ	1:26	78	$101.6 \times 10^6/(L'/\rho)^2$	Fig. 5-1
24SRT	58,000	70,000	70,000-707 L'/ρ	1:26	66	$101.6 \times 10^6/(L'/\rho)^2$	Fig. 5-1

Note (a). $L'/\rho = L/\rho\sqrt{c}$; L'/ρ shall not exceed 150 without specific authority from the procuring or licensing agency.
Note (b). Critical L'/ρ is that above which the columns are "long" and below which they are "short".
Note (c). Must be determined by test unless conservatively assumed.

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5.212 Unconventional Cross-Sections. Sections other than solid or tubular should be tested to determine the allowable bending stress.

5.22 Built-up Beams. Built-up beams will usually fail due to local failures of the component parts. In aluminum alloy construction the strength of fittings and joints is an important feature.

5.23 Thin-web beams. The allowable stresses for thin-web beams will depend on the nature of the failure and are determined from the allowable stresses of the web in tension and of the flanges or stiffeners in compression. See Ref. 15 for general stress analysis methods.

5.3 TORSION

5.30 General. The torsional failure of aluminum-alloy tubes may be due to plastic failure of the metal, elastic instability of the walls, or to an intermediate condition. Pure shear failure will not usually occur within the range of wall thicknesses commonly used for aircraft tubing.

5.31 Allowable Torsional Shear Stresses. In the range of low values of D/t no theoretical formula is directly applicable. The result of tests have been used to determine the empirical curves of Fig. 5-7.

For high values of D/t the equations given in Sec. 1.632 can be used provided that the allowable stress so determined does not exceed the proportional limit in shear.

5.4 COMBINED LOADINGS

5.40 Round Tubes in Bending and Compression. The general theory of failure under combined loadings is given in Sec. 1.424. In the case of combined bending and compression it is necessary to consider the effects of secondary bending, that is, bending produced by the axial load acting in conjunction with the lateral deflection of the column. In general, Eq. 1:37, Sec. 1.424 can be used in the following forms for safe values:

$$\frac{f_b'}{F_b} + \frac{f_c}{F_c} = 1.0 \text{ - - - - - - - - - - - - - - - - - } (5:2)$$

where f_b' = maximum bending stress including effects of secondary bending.

F_b = bending modulus of rupture.

f_c = axial compressive stress.

F_c = allowable column stress.

5.41 Tubes in Bending and Torsion. Equations 1:37 Sec. 1.424 can be used in the following forms for safe values:

Round tubes: $R_b^2 + R_s^2 = 1.0$ - - - - - - - - - - -(5:3)

Streamline tubes: $R_b + R_s = 1.0$ - - - - - - - - - - -(5:4)

Higher values can be used if substantiated by adequate test data.

5.42 Tubes in Bending, Compression and Torsion. The bending stresses should include the effects of secondary bending due to compression. The following empirical equation will serve as a working basis, pending a more thorough investigation of the subject:

$$R_c + R_b' + R_s^2 = 1.0 \text{ - - - - - - - - - - - - - - - - } (5:5)$$

In addition to using the above equation, the maximum normal compressive stress should also be determined. The later should not exceed the yield stress of the material.

5.5 JOINTS, FITTINGS AND PARTS

5.50 Bolted and Riveted Joints.

5.500 Shear. The allowable shear stresses and loads for rivets, bolts and pins are given in Table 5-12.

5.501 Bearing. The basic values of the allowable bearing stresses for various aluminum alloys will be found in the tables at the end of this chapter. These stresses are applicable only when the D/t ratio (diameter of rivet over thickness of sheet) is less than 5.5. When this ratio is equal to or greater than 5.5, the allowable bearing strengths must be substantiated by tests covering both yield and ultimate of the joint. The allowable bearing stresses for aluminum alloy rivets may be taken equal to that of the sheet, provided that the rivet material is not weaker than A17ST and provided that the allowable bearing stress for the sheet is not greater than 90,000 psi.

The allowable bearing strength of aluminum alloy sheet is given in Table 5-12. These values are to be used only for the design of the connecting elements of rigid joints when there is no possibility of relative movement between the parts joined without deformation of these parts. For other types of joints the allowable bearing stresses are to be reduced by dividing by the factors of safety (designated as "bearing factors") specified in Table 4-2.

The allowable bearing stresses given herein for 17S and 24S sheet, and for aluminum alloy forgings are based on a stress at which the deformation of the hole amounts to 4 percent of its original diameter.

5.502 Hollow-end rivets. If hollow-end rivets with solid cross-sections for a portion of the length (AN 450) are used, the strength of these rivets may be taken equal to the strength of solid rivets of the same material, provided that the bottom of the cavity is at least 25 percent of the rivet diameter from the plane of shear, as measured toward the hollow end, and further provided that they are used in locations where they will not be subjected to appreciable tensile stresses.

5.51 Welded Joints. Since torch welding generally is not considered acceptable as a method of joining major structural parts made of aluminum alloy, no values for allowable stresses for such joints will be given.

5.52 Tension Lugs. The strength of tension lugs can be computed by the formulas given in Sec. 4.53.

TABLE 5 - 2
MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY - 17S

			CONDITION		① 17ST SHEET AND PLATE	② 17ST ALCLAD SHEET	③ 17SRT SHEET	④ 17SRT ALCLAD SHEET
SPECIFICATION				ARMY	QQ-A-353	57-152-2A	QQ-A-353	
				NAVY	47A3	47A6	47A3	
				FEDERAL	QQ-A-353		QQ-A-353	
				SAE	26		26	
TENSION	1	F_{tu}	Ultimate Stress,	psi	55 000	50 000	55 000	50 000
	2	F_{ty}	Yield Stress,	psi	32 000	27 000	42 000	37 000
	3	F_{tp}	Proportional Limit,	psi	25 000	20 000		
	4	E	Modulus of Elasticity,	psi	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000
	5		Elongation in 2 in., %		See Fig. 1	See Fig. 1	See Fig. 1	See Fig. 1
COMPRESSION	6	F_{cu}	Ultimate (block) Stress,	psi	55 000	50 000	55 000	50 000
	7	F_{cy}	Yield Stress,	psi	32 000	28 000	42 000	37 000
	8	F_{cp}	Proportional Limit,	psi	25 000	20 000		
	9	F_{co}	Column Yield Stress,	psi				
	10	E_c	Modulus of Elasticity,	psi	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000
SHEAR	11	F_{su}	Ultimate Stress,	psi	33 000	30 000	33 000	30 000
	12	F_{st}	Torsional Modulus of Rupture,	psi	50 000			
	13	F_{sp}	Proportional Limit (torsion),	psi	15 000			
	14	G	Modulus of Rigidity (torsion),	psi	3 800 000		3 800 000	
BEARING	15	F_{br}	Ultimate Stress,	psi	75 000	68 000	75 000	68 000
	16		Rockwell Number					
	17		Brinell Number[3]		96		100	
FATIGUE	18	F_{be}	Bending Endurance Limit, (500,000,000 cycles of completely reversed stress)	psi	15 000			
	19	F_{se}	Torsional Endurance Limit, (20,000,000 cycles of completely reversed stress)	psi				
	20	w	Specific Weight,		0.101 lb/cu in.	174 lb/cu ft.		
	21		Nominal Chemical Composition		4% Cu, 0.5% Mg, 0.5% Mn.	(Alclad materials have surface coating of aluminum)		

22 REMARKS

1. See notes in Chapter 3.
2. Effective modulus may be assumed to be 10 000 000 psi. for purpose of analysis.
3. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.)

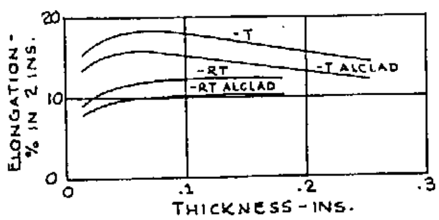


FIG. 1

TABLE 5 - 3

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY-17S

			CONDITION	① 17ST TUBING (BEFORE STRETCHING)[2]	② 17ST TUBING (STRETCHED)[2]	③ 17ST EXTRUDED SHAPES	④
SPECIFICATION			ARMY	57-187-2	57-187-2	QQ-A-351	
			NAVY	44T21 44T22	44T21 44T22	46A4	
			FEDERAL	WW-T-786	WW-T-786	QQ-A-351	
			SAE	26	26	26	
TENSION	1	F_{tu}	Ultimate Stress, psi	55 000	55 000	50 000	
	2	F_{ty}	Yield Stress, psi	30 000	40 000	30 000	
	3	F_{tp}	Proportional Limit, psi	20 000			
	4	E	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	
	5		Elongation in 2 in., %			12	
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	55 000	55 000	50 000	
	7	F_{cy}	Yield Stress, psi	30 000	36 000	30 000	
	8	F_{cp}	Proportional Limit, psi	20 000			
	9	F_{co}	Column Yield Stress, psi	34 500	42 500		
	10	E_c	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	
SHEAR	11	F_{su}	Ultimate Stress, psi	27 000	33 000	30 000	
	12	F_{st}	Torsional Modulus of Rupture, psi	50 000	50 000		
	13	F_{sp}	Proportional Limit (torsion), psi	15 000	15 000		
	14	G	Modulus of Rigidity (torsion), psi	3 800 000	3 800 000	3 800 000	
BEARING	15	F_{br}	Ultimate Stress, psi	75 000	75 000	75 000	
	16		Rockwell Number				
	17		Brinell Number [3]	96	96	87	
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500,000,000 cycles of completely reversed stress)	12 000	15 000	15 000	
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight, 0.101 lb/cu in. 174 lb/cu ft.				
	21		Nominal Chemical Composition 4% Cu, 0.5% Mg, 0.5% Mn.				

22 REMARKS

1. See notes in Chapter 3.
2. Tubing "as received" is stretched. If properly reheat-treated it will develop the properties given in Column 1.
3. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of diameter of ball (in mm.)

TABLE 5 - 4
MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY -17S

				①	②	③	④
CONDITION				17ST BAR (UP TO .750" THICK)	17ST BAR (.751" TO 3.000" THICK)		
SPECIFICATION			ARMY	QQ-A-351	QQ-A-351		
			NAVY	46A4	46A4		
			FEDERAL	QQ-A-351	QQ-A-351		
			SAE	26	26		
TENSION	1	F_{tu}	Ultimate Stress, psi	53 000	50 000		
	2	F_{ty}	Yield Stress, psi	30 000	28 000		
	3	F_{tp}	Proportional Limit, psi		20 000		
	4	E	Modulus of Elasticity, psi	10 300 000	10 300 000		
	5		Elongation in 2 in., %	16	16		
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	53 000	50 000		
	7	F_{cy}	Yield Stress, psi	30 000	28 000		
	8	F_{cp}	Proportional Limit, psi		20 000		
	9	F_{co}	Column Yield Stress, psi				
	10	E_c	Modulus of Elasticity, psi	10 300 000	10 300 000		
SHEAR	11	F_{su}	Ultimate Stress, psi	32 000	30 000		
	12	F_{st}	Torsional Modulus of Rupture, psi	50 000	50 000		
	13	F_{sp}	Proportional Limit (torsion), psi	15 000	15 000		
	14	G	Modulus of Rigidity (torsion), psi	3 800 000	3 800 000		
BEARING	15	F_{br}	Ultimate Stress, psi	75 000	75 000		
	16		Rockwell Number				
	17		Brinell Number [2]	92	87		
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500,000,000 cycles of completely reversed stress)	15 000	15 000		
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)	8 000	8 000		
	20	w	Specific Weight,	0.101 lb/cu in.	174 lb/cu ft.		
	21		Nominal Chemical Composition	4% Cu, 0.5% Mg, 0.5% Mn.			
	22	REMARKS	1. See notes in Chapter 3. 2. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.)				

TABLE 5 - 5

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY-24S

			CONDITION	① 24ST SHEET	② 24ST ALCLAD SHEET	③ 24SRT SHEET	④ 24SRT ALCLAD SHEET
SPECIFICATION			ARMY	57-152-6	11067	57-152-6	11067
			NAVY	47A10	47A8	47A10	47A8
			FEDERAL				
			SAE	24		24	
TENSION	1	F_{tu}	Ultimate Stress, psi	62 000	56 000	65 000	58 000
	2	F_{ty}	Yield Stress, psi	40 000	37 000	50 000	46 000
	3	F_{tp}	Proportional Limit, psi	32 000	27 000		
	4	E	Modulus of Elasticity, psi	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000
	5		Elongation in 2 in., %	See Fig. 1	See Fig. 1	See Fig. 1	See Fig. 1
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	62 000	56 000	65 000	58 000
	7	F_{cy}	Yield Stress, psi	40 000	37 000	50 000	46 000
	8	F_{cp}	Proportional Limit, psi				
	9	F_{co}	Column Yield Stress, psi				
	10	E_c	Modulus of Elasticity, psi	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000	10 300 000	Pri: 10 300 000[2] Sec: 9 300 000
SHEAR	11	F_{su}	Ultimate Stress, psi	37 000	34 000	39 000	35 000
	12	F_{st}	Torsional Modulus of Rupture, psi				
	13	F_{sp}	Proportional Limit (torsion), psi				
	14	G	Modulus of Rigidity (torsion), psi	3 800 000		3 800 000	
BEARING	15	F_{br}	Ultimate Stress, psi	90 000	82 000	93 000	83 000
	16		Rockwell Number				
	17		Brinell Number[3]	100		110	
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500 000,000 cycles of completely reversed stress)	14 000			
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight,	.100 lb/cu in.	173 lb/cu ft.		
	21		Nominal Chemical Composition	4.2% Cu, 1.5% Mg, 0.6% Mn.	(Alclad materials have surface coating of aluminum)		

22 REMARKS

1. See notes in Chapter 3
2. Effective modulus may be assumed to be 10 000 000 psi. for purposes of analysis.
3. 500 Kg. load on 100 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.)

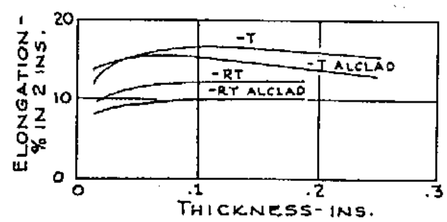


FIG. 1

TABLE 5 - 6 (REVISED OCT '44)

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY-24S

			CONDITION		① 24ST TUBING (BEFORE STRETCHING)[2]	② 24ST TUBING (AFTER STRETCHING)[2]	③ 24ST EXTRUDED SHAPES	④ 24ST BAR (UP TO 3" THICK)
SPECIFICATION				ARMY	10235 57-187-2	10235 57-187-2	QQ-A-354	QQ-A-354
				NAVY	ROUND 44T28 STR-LINE 44T31	ROUND 44T28 STR-LINE 44T31	46A9	46A9
				FEDERAL			QQ-A-354	QQ-A-354
				SAE	24	24	24	24
TENSION	1	F_{tu}	Ultimate Stress,	psi	62 000	62 000	58 000	62 000
	2	F_{ty}	Yield Stress,	psi	40 000	42 000	42 000 (4)	40 000
	3	F_{tp}	Proportional Limit,	psi	35 000			
	4	E	Modulus of Elasticity,	psi	10 300 000	10 300 000	10 300 000	10 300 000
	5		Elongation in 2 in., %				12	14
COMPRESSION	6	F_{cu}	Ultimate (block) Stress,	psi	62 000	62 000	57 000	62 000
	7	F_{cy}	Yield Stress,	psi	40 000		38 000	40 000
	8	F_{cp}	Proportional Limit,	psi				
	9	F_{co}	Column Yield Stress,	psi	50 000	50 000		
	10	E_c	Modulus of Elasticity,	psi	10 300 000	10 300 000	10 300 000	10 300 000
SHEAR	11	F_{su}	Ultimate Stress,	psi	37 000	37 000	34 000	37 000
	12	F_{st}	Torsional Modulus of Rupture,	psi				45 000
	13	F_{sp}	Proportional Limit (torsion),	psi				
	14	G	Modulus of Rigidity (torsion),	psi	3 800 000	3 800 000	3 800 000	3 800 000
BEARING	15	F_{br}	Ultimate Stress,	psi	90 000	90 000	83 000	90 000
	16		Rockwell Number					
	17		Brinell Number [3]		100	100	96	100
FATIGUE	18	F_{be}	Bending Endurance Limit, (500,000,000 cycles of completely reversed stress)	psi	14 000	14 000	14 000	14 000
	19	F_{se}	Torsional Endurance Limit, (20,000,000 cycles of completely reversed stress)	psi				
	20	w	Specific Weight,		0.100 lb/cu in.	173 lb/cu ft.		
	21		Nominal Chemical Composition		4.2% Cu, 1.5% Mg, 0.5% Mn.			

22 REMARKS

1. See notes in Chapter 3.
2. Tubing "as received" is stretched. If properly reheat-treated it will develop the properties given in Column 1.
3. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.)
4. 24ST extruded shapes "as received" are stretched. If properly reheat-treated they will develop a normal tensile yield stress of 38,000 psi.

TABLE 5 - 7 (ADDED OCT '40)

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY - 24S

				(1)	(2)	(3)	(4)
CONDITION				24SRT TUBING			
SPECIFICATION			ARMY	10235			
			NAVY				
			FEDERAL				
			SAE				
TENSION	1	F_{tu}	Ultimate Stress, psi	70 000			
	2	F_{ty}	Yield Stress, psi	58 000			
	3	F_{tp}	Proportional Limit, psi	44 000			
	4	E	Modulus of Elasticity, psi	10 300 000			
	5		Elongation in 2 in., %	10			
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	70 000			
	7	F_{cy}	Yield Stress, psi	54 800			
	8	F_{cp}	Proportional Limit, psi				
	9	F_{co}	Column Yield Stress, psi	70 000			
	10	E_c	Modulus of Elasticity, psi	10 300 000			
SHEAR	11	F_{su}	Ultimate Stress, psi				
	12	F_{st}	Torsional Modulus of Rupture, psi	47 500			
	13	F_{sp}	Proportional Limit (torsion), psi				
	14	G	Modulus of Rigidity (torsion), psi	3 800 000			
BEARING	15	F_{br}	Ultimate Stress, psi				
	16		Rockwell Number				
	17		Brinell Number	130			
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (300,000,000 cycles of completely reversed stress)				
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight,	lb/cu in.	lb/cu ft.		
	21		Nominal Chemical Composition				
	22	REMARKS	1. See notes in Chapter 3.				

TABLE 5 - 8

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY-52S

CONDITION				① 52S-1/4H (Sheet)	② 52S-1/2H (Sheet)	③ 52S-3/4H (Sheet)	④ 52S-H (Sheet)
SPECIFICATION			ARMY	QQ-A-318	QQ-A-318	QQ-A-318	QQ-A-318
			NAVY	47A11	47A11	47A11	47A11
			FEDERAL	QQ-A-318	QQ-A-318	QQ-A-318	QQ-A-318
			SAE				
TENSION	1	F_{tu}	Ultimate Stress, psi	31 000	34 000	37 000	39 000
	2	F_{ty}	Yield Stress, psi	21 000	24 000	29 000	33 000
	3	F_{tp}	Proportional Limit, psi				
	4	E	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	10 300 000
	5		Elongation in 2 in., %	See Fig. 1	See Fig. 1	See Fig. 1	See Fig. 1
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	31 000	34 000	37 000	39 000
	7	F_{cy}	Yield Stress, psi	21 000	24 000	29 000	33 000
	8	F_{cp}	Proportional Limit, psi				
	9	F_{co}	Column Yield Stress, psi				
	10	E_c	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	10 300 000
SHEAR	11	F_{su}	Ultimate Stress, psi	18 000	20 000	22 000	23 000
	12	F_{st}	Torsional Modulus of Rupture, psi				
	13	F_{sp}	Proportional Limit (torsion), psi				
	14	G	Modulus of Rigidity (torsion), psi	3 800 000	3 800 000	3 800 000	3 800 000
BEARING	15	F_{br}	Ultimate Stress, psi	56 000	61 000	66 000	70 000
	16		Rockwell Number				
	17		Brinell Number [2]	54	59	64	68
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500,000,000 cycles of completely reversed stress)	18 000	19 000	20 000	20 500
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight,	.098 lb/cu in.	167 lb/cu ft.		
	21		Nominal Chemical Composition	2.5% Mg, 0.25% Cr.			
	22		REMARKS				

REMARKS

1. See notes in Chapter 3.
2. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of the ball (in mm.).

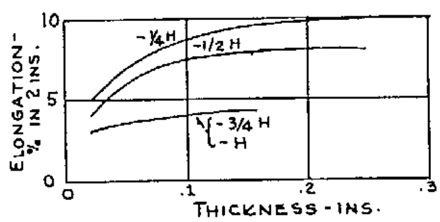


FIG. 1

TABLE 5 - 9 (REVISED OCT '46)
MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY RIVETS

				(1)	(2)	(3)	(4)
CONDITION				A17ST	17ST	24ST	53ST
SPECIFICATION			ARMY	25526 Type AD	25526 Type D	25526 Type DD	
			NAVY	43R5	43R5	43R5	43R5
			FEDERAL				
			SAE		26		
TENSION	1	F_{tu}	Ultimate Stress, psi	38 000	55 000	62 000	
	2	F_{ty}	Yield Stress, psi				
	3	F_{tp}	Proportional Limit, psi				
	4	E	Modulus of Elasticity, psi				
	5		Elongation in 2 in., %				
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi				
	7	F_{cy}	Yield Stress, psi				
	8	F_{cp}	Proportional Limit, psi				
	9	F_{co}	Column Yield Stress, psi				
	10	E_c	Modulus of Elasticity, psi				
SHEAR	11	F_{su}	Ultimate Stress, psi	25 000	30 000	35 000	22 000
	12	F_{st}	Torsional Modulus of Rupture, psi				
	13	F_{sp}	Proportional Limit (torsion), psi				
	14	G	Modulus of Rigidity (torsion), psi				
BEARING	15	F_{br}	Ultimate Stress, psi				
	16		Rockwell Number				
	17		Brinell Number				
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500,000,000 cycles of completely reversed stress)				
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight,	lb/cu in.	lb/cu ft.		
	21		Nominal Chemical Composition				

22 REMARKS

1. See notes in Chapter 3.
2. F_{su}= 25,000 psi is specification value. 27,000 psi may be used for design purposes, in conjunction with the nominal area of the rivet.

TABLE 5 - 10
MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY SAND CASTINGS[3]

				①	②	③	④
CONDITION				195-T4	195-T6	220-T4	
SPECIFICATION			ARMY	57-72-5	57-72-5	11309	
			NAVY	46A1	46A1	M-186	
			FEDERAL				
			SAE	38	38	324	
TENSION	1	F_{tu}	Ultimate Stress, psi	29 000	32 000	42 000	
	2	F_{ty}	Yield Stress, psi	13 000	18 000	22 000	
	3	F_{tp}	Proportional Limit, psi				
	4	E	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	
	5		Elongation in 2 in., %	6	3	12	
COMPRESSION	6	F_{cu}	Ultimate (block) Stress, psi	54 000	62 000	70 000	
	7	F_{cy}	Yield Stress, psi	14 000	22 000	23 000	
	8	F_{cp}	Proportional Limit, psi				
	9	F_{co}	Column Yield Stress, psi				
	10	E_c	Modulus of Elasticity, psi	10 300 000	10 300 000	10 300 000	
SHEAR	11	F_{su}	Ultimate Stress, psi	23 000	29 000	31 000	
	12	F_{st}	Torsional Modulus of Rupture, psi		22 000		
	13	F_{sp}	Proportional Limit (torsion), psi				
	14	G	Modulus of Rigidity (torsion), psi	3 800 000	3 800 000	3 800 000	
BEARING	15	F_{br}	Ultimate Stress, psi	40 000	46 000	68 000	
	16		Rockwell Number				
	17		Brinell Number[2]				
FATIGUE	18	F_{be}	Bending Endurance Limit, psi (500,000,000 cycles of completely reversed stress)	6 000	8 000	7 000	
	19	F_{se}	Torsional Endurance Limit, psi (20,000,000 cycles of completely reversed stress)				
	20	w	Specific Weight, lbs/cu.in.	.100	.100	.093	
	21		Nominal Chemical Composition	4% Cu.	4% Cu.	10% Mg.	

22 REMARKS

1. See notes in Chapter 3.
2. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.).
3. The above values are minimum values obtained from cast test bars. Due to the differences between the actual casting and the test bar, these values should be reduced by 50 percent when used for determining allowable stresses.

TABLE 5 - 11 (REVISED OCT 40)

MECHANICAL PROPERTIES OF MATERIALS

ALUMINUM ALLOY FORGINGS

			CONDITION		(1) 14ST (Up to 4" dia. or thickness)	(2) 17ST (Up to 4" dia. or thickness)	(3) 25ST (Up to 4" dia. or thickness)	(4) A51-ST (Up to 4" dia. or thickness)
SPECIFICATION				ARMY	57-153 Grade 5	57-153 Grade 1	57-153 Grade 2	57-153 Grade 3
				NAVY	M-277	46A7a	46A7a	
				FEDERAL	QQ-A-367	QQ-A-367	QQ-A-367	
				SAE		26	27	
TENSION	1	F_{tu}	Ultimate Stress,	psi	65 000	55 000	55 000	43 000
	2	F_{ty}	Yield Stress,	psi	50 000	30 000	30 000	34 000
	3	F_{tp}	Proportional Limit,	psi				
	4	E	Modulus of Elasticity,	psi	10 300 000	10 300 000	10 300 000	10 300 000
	5		Elongation in 2 in., %		10	16	16	12
COMPRESSION	6	F_{cu}	Ultimate (block) Stress,	psi	65 000	55 000	55 000	43 000
	7	F_{cy}	Yield Stress,	psi	50 000	30 000	30 000	34 000
	8	F_{cp}	Proportional Limit,	psi				
	9	F_{co}	Column Yield Stress,	psi				
	10	E_c	Modulus of Elasticity,	psi	10 300 000	10 300 000	10 300 000	10 300 000
SHEAR	11	F_{su}	Ultimate Stress,	psi	39 000	33 000	33 000	
	12	F_{st}	Torsional Modulus of Rupture,	psi				
	13	F_{sp}	Proportional Limit (torsion),	psi				
	14	G	Modulus of Rigidity (torsion),	psi	3 800 000	3 800 000	3 800 000	3 800 000
BEARING	15	F_{br}	Ultimate Stress,	psi	93 000	75 000	75 000	70 000
	16		Rockwell Number					
	17		Brinell Number 2		130	90	90	90
FATIGUE	18	F_{be}	Bending Endurance Limit, (500,000,000 cycles of completely reversed stress)	psi	12 000	12 000	12 000	
	19	F_{se}	Torsional Endurance Limit, (20,000,000 cycles of completely reversed stress)	psi				
	20	w	Specific Weight, lbs/cu. in.		.101	.101	.101	.097
	21		Nominal Chemical Composition		4%Cu, 0.8% Si, 0.75% Mn, 0.35% Mg	4% Cu, 0.5% Mg, 0.5% Mn.	4.5% Cu, 0.8% Si, 0.8% Mn.	1.0% Si, 0.60% Mg, 0.25% Cr.

22 REMARKS

1. See notes in Chapter 3.
2. 500 Kg. load on 10 mm. ball or load (in Kg.) equal to 5 times the square of the diameter of ball (in mm.)

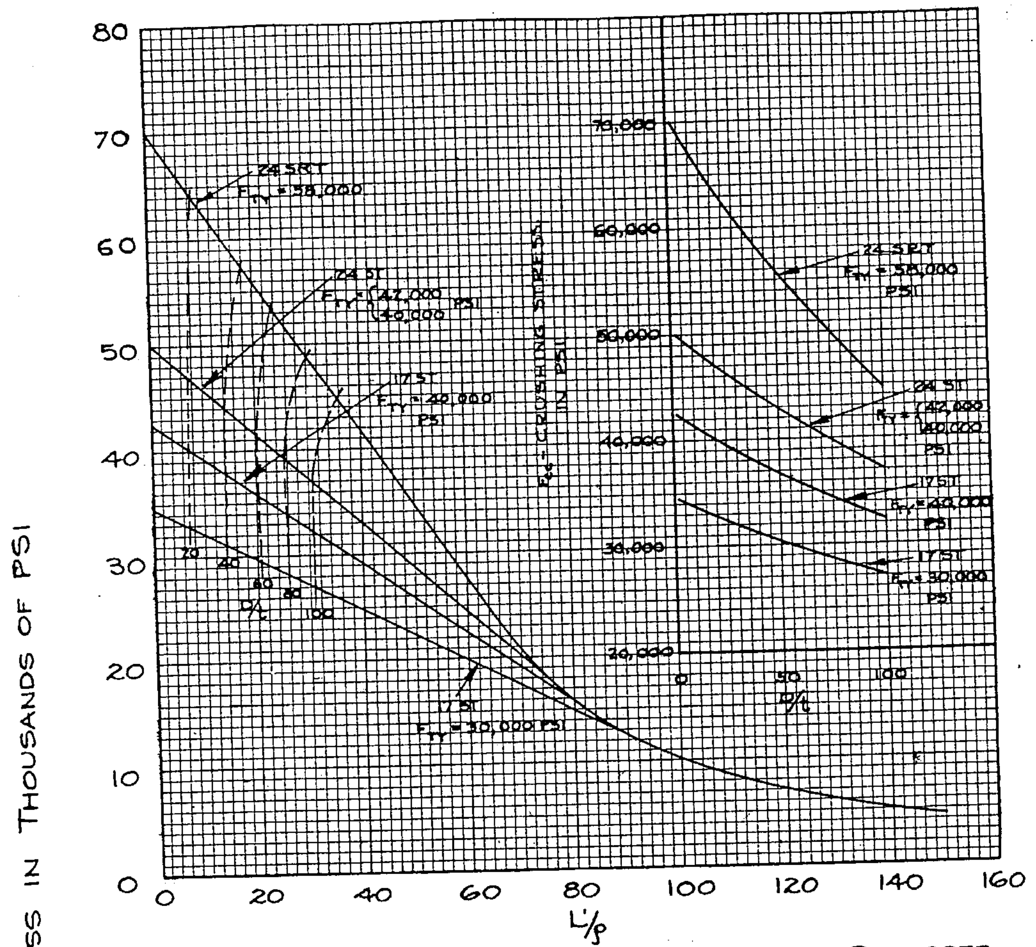


FIG. 5-1. ALLOWABLE COLUMN AND CRUSHING STRESSES FOR ALUMINUM ALLOY ROUND TUBING (REVISED OCT '40)

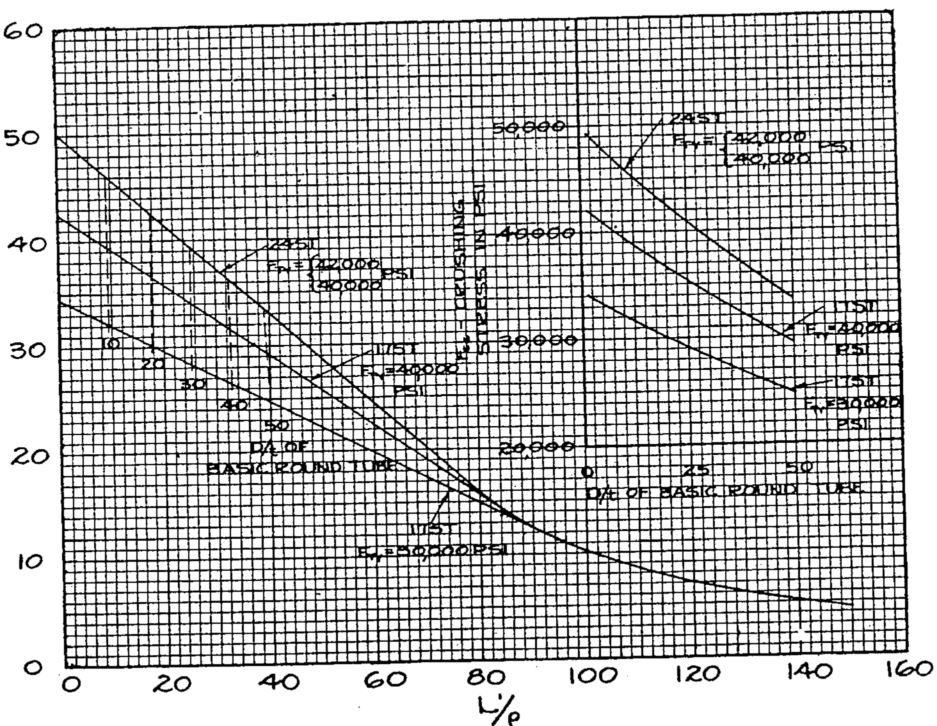


FIG. 5-2. ALLOWABLE COLUMN AND CRUSHING STRESSES FOR ALUMINUM ALLOY STREAMLINE TUBING

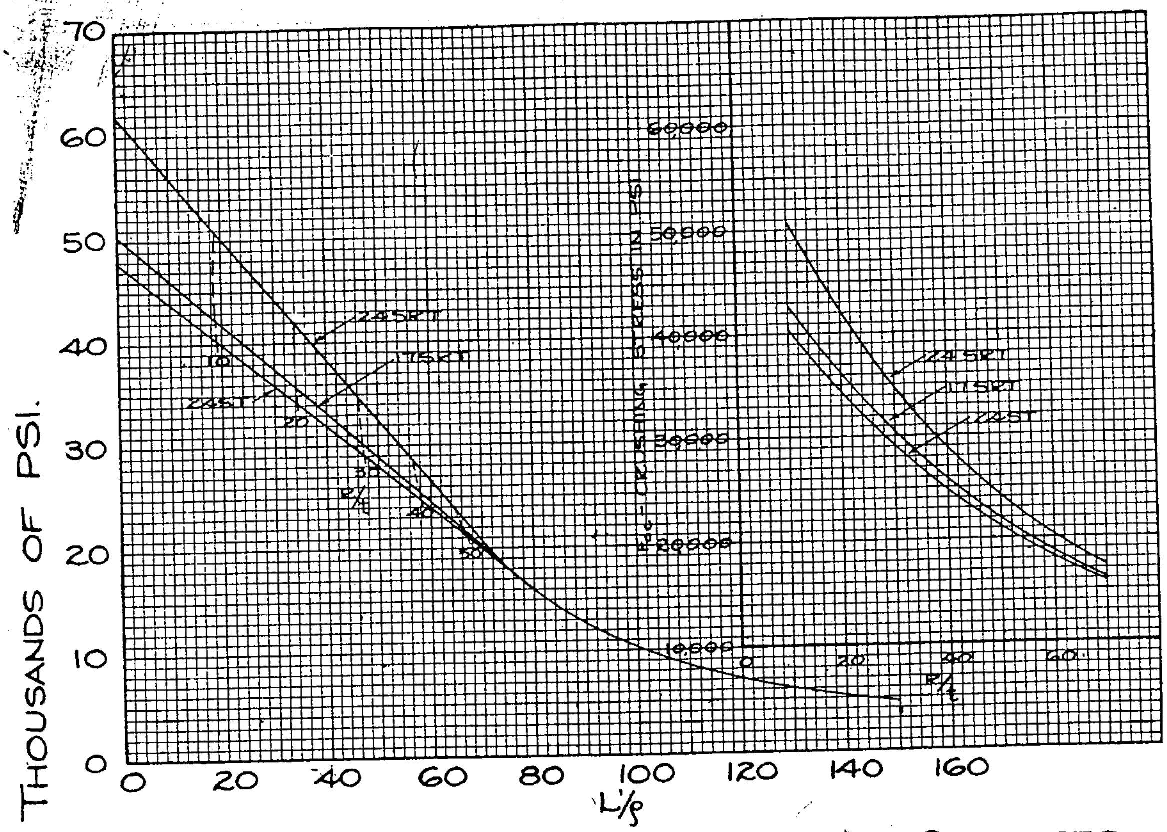


FIG. 5-3. ALLOWABLE COLUMN AND CRUSHING STRESSES CORRUGATED ALUMINUM ALLOY SHEET (CIRCULAR CORRUGATIONS)

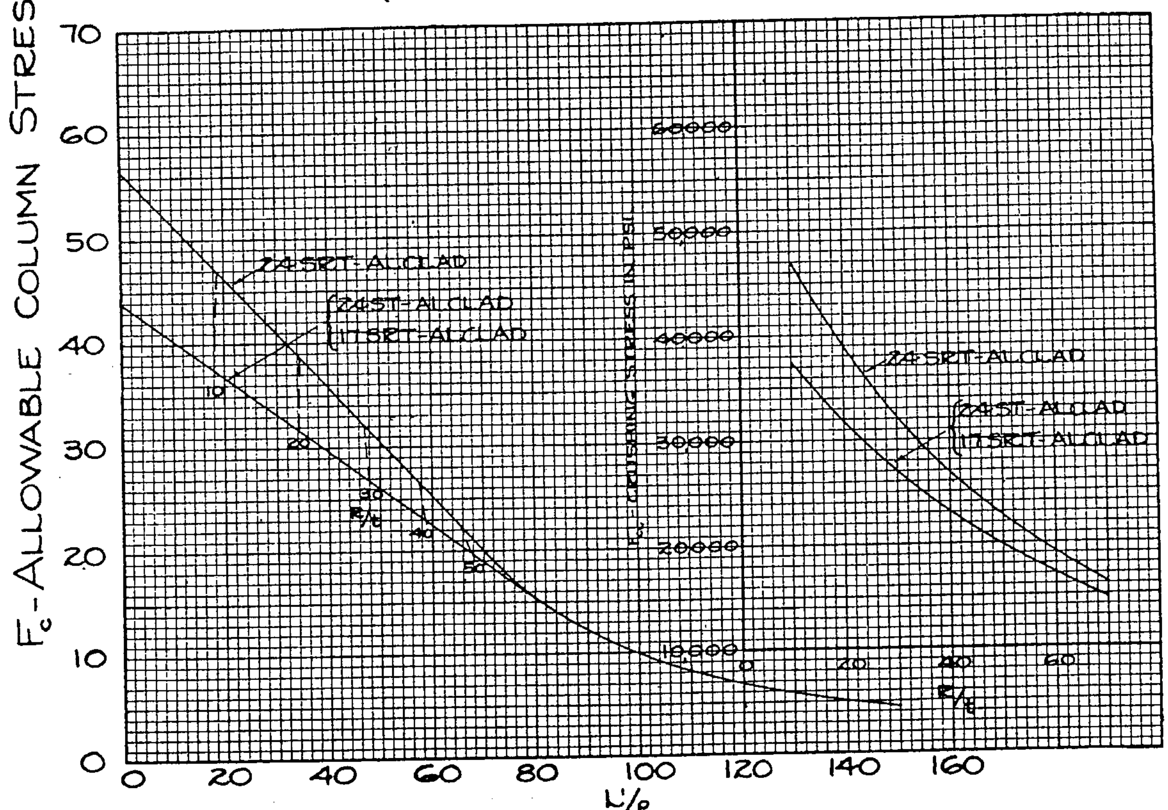


FIG. 5-4 ALLOWABLE COLUMN AND CRUSHING STRESSES CORRUGATED ALUMINUM ALLOY SHEET (ALUMINUM COVERED) (CIRCULAR CORRUGATIONS)

The geometrical properties of the standard corrugations are:

$I = 0.158\, t\, D^2$

$\rho = 0.359\, D$

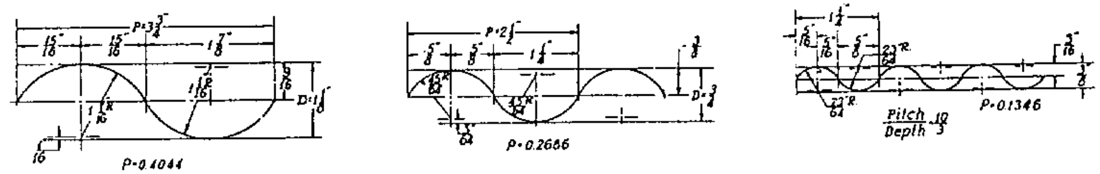
$W_e = 1.228\, W$

$R = 0.282\, P$

where

I = moment of inertia in.⁴ per inch width.
ρ = radius of gyration.
D = depth of corrugation.
P = pitch of corrugation.
W = width of corrugated sheet.
W_e = width of equivalent flat sheet.
R = radius of curvature of corrugation.
t = thickness of sheet.

The section properties of other circular corrugations, in terms of their pitch to depth ratio, are shown below.



Radius of gyration = 0.719 × $\frac{D}{2}$
Curvilinear length of one corrugation = 1.228 × pitch
$\frac{R}{P}$ = .282

STANDARD CORRUGATIONS

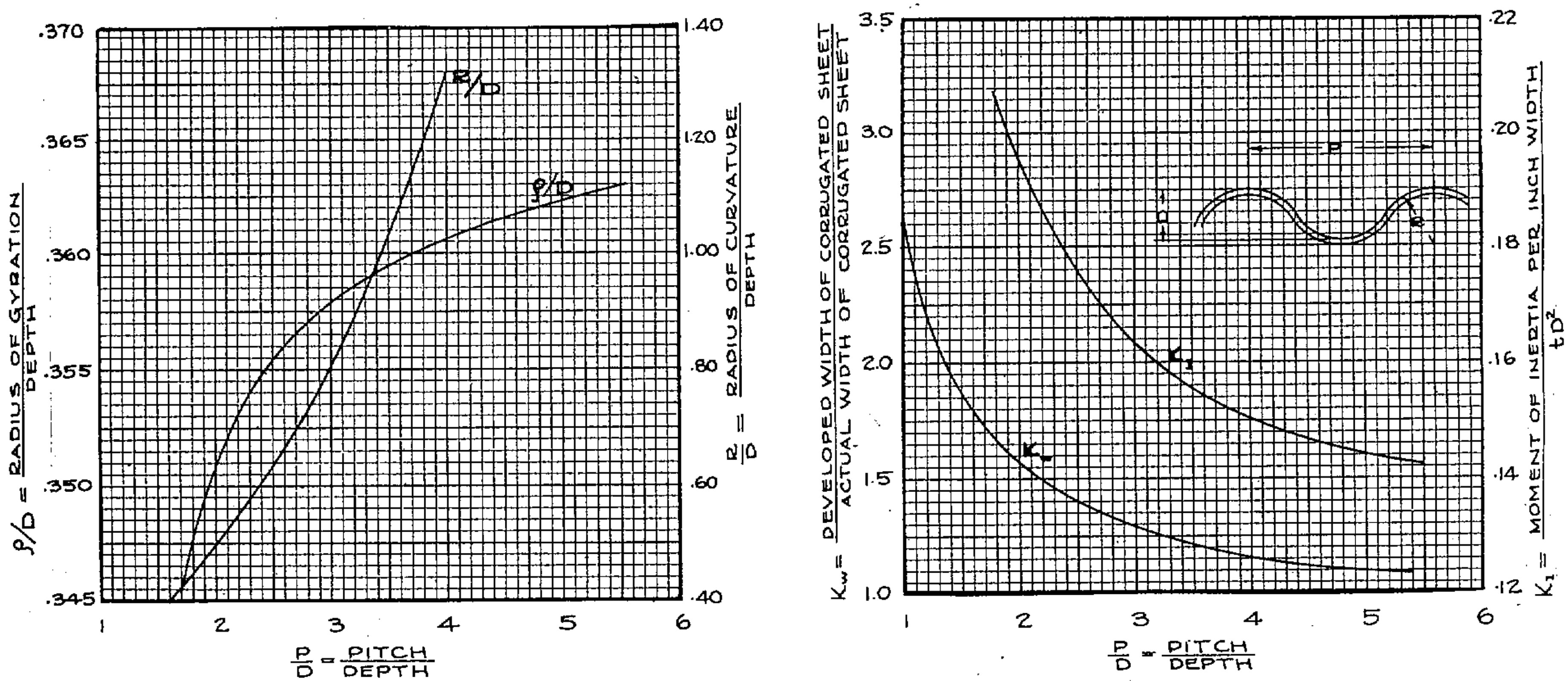


FIG. 5-5. GEOMETRICAL PROPERTIES OF CIRCULAR CORRUGATIONS

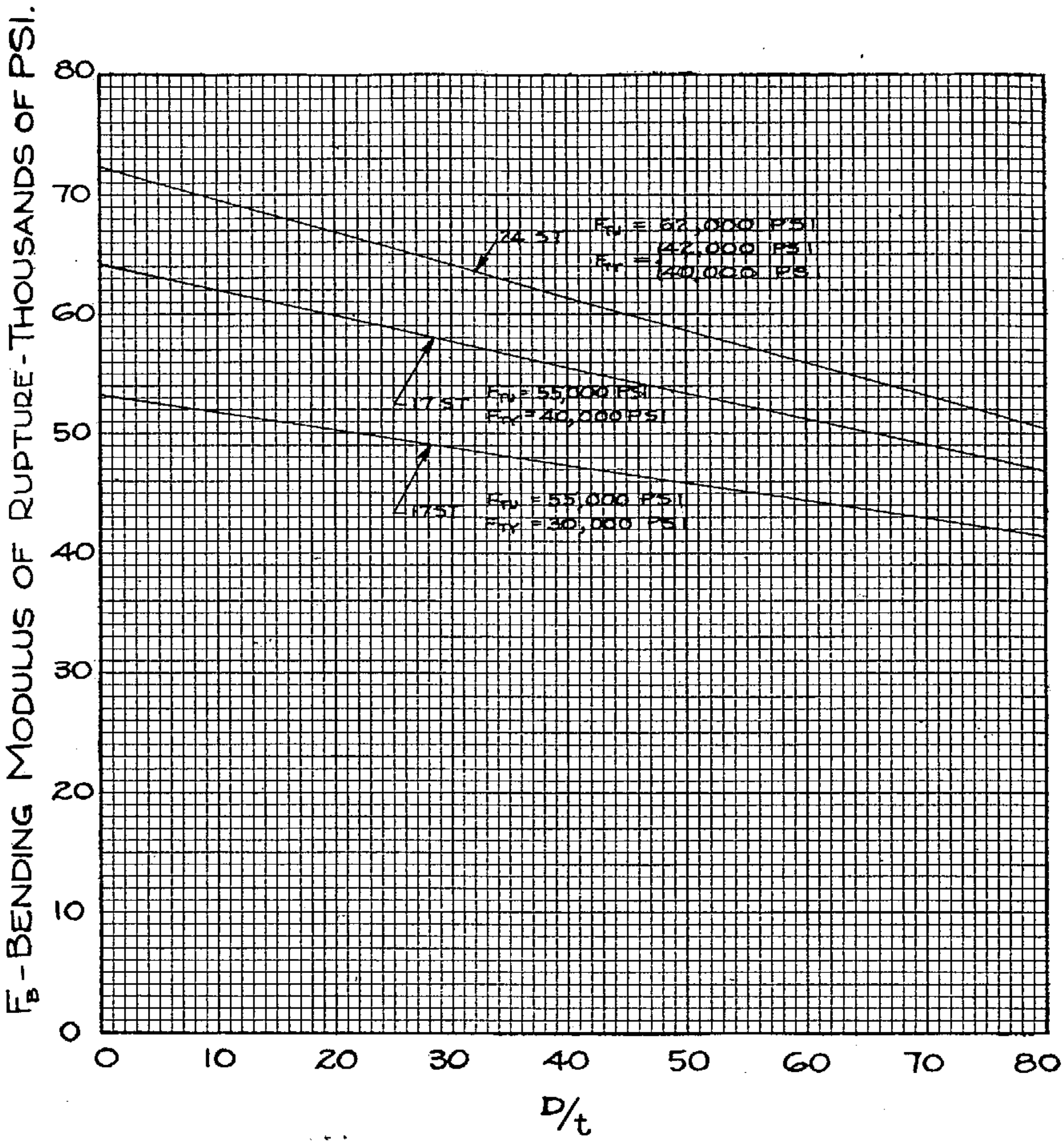


FIG. 5-6. BENDING MODULUS OF RUPTURE
ALUMINUM ALLOY ROUND TUBING RESTRAINED
AGAINST LOCAL BUCKLING AT LOADING POINTS

(REVISED OCT '40)

270850 O—40——9

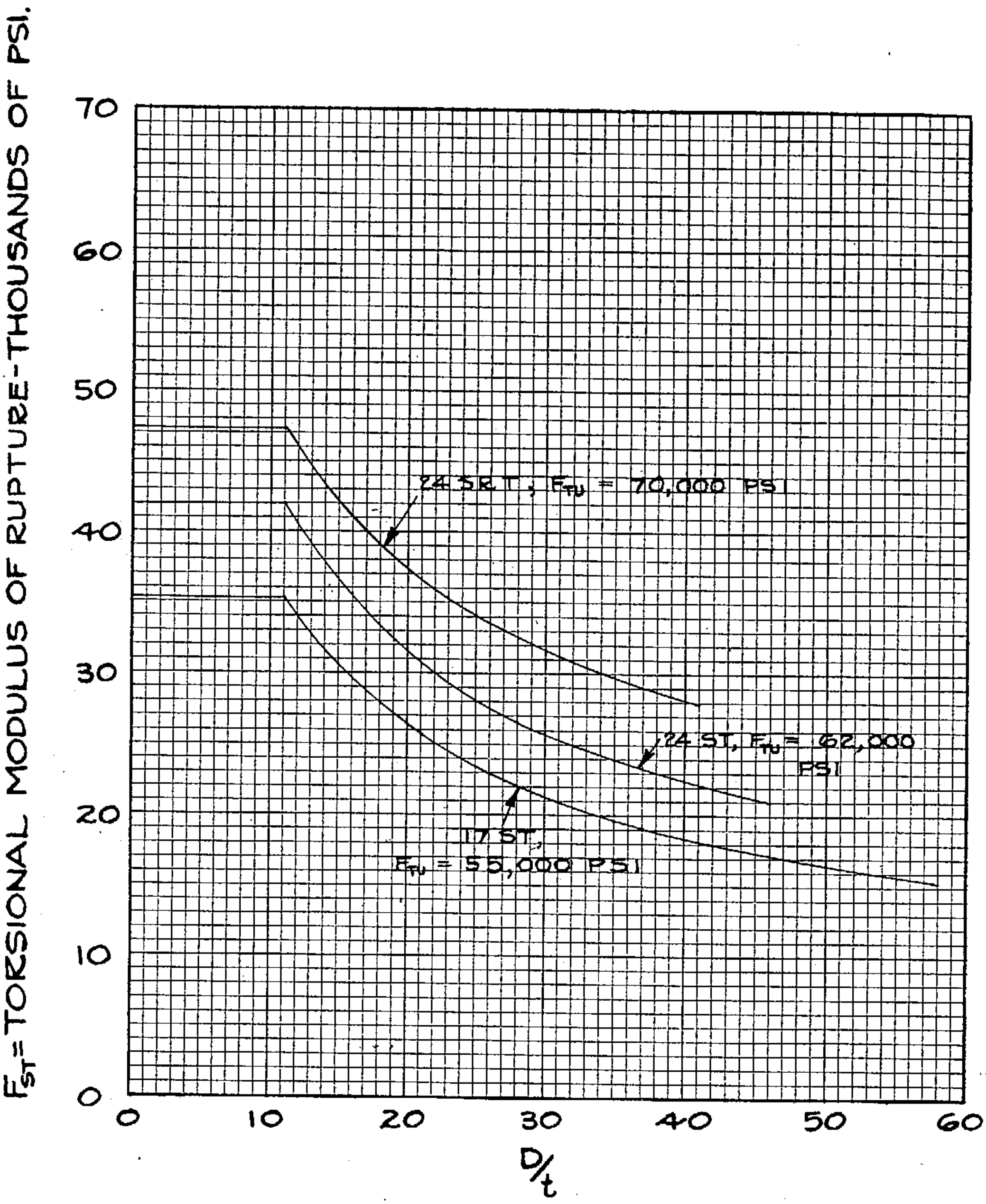


FIG. 5-7. TORSIONAL MODULUS OF RUPTURE OF ALUMINUM ALLOY ROUND TUBING

(REVISED OCT '40)

TABLE 5-12 (REVISED OCT '40)

SHEAR AND BEARING STRENGTHS OF ALUMINUM ALLOY RIVETS AND SHEET

ALLOWABLE SINGLE SHEAR STRENGTH OF ALUMINUM ALLOY RIVETS (LB.)

Dia. of Rivet or Pin, in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
A17ST & 56SH (F_{su}=27,000psi)	83	186	331	518	745	1325	2071	2984
17ST (F_{su}=30,000psi)	92	206	368	574	828	1472	2300	3313
24ST (F_{su}=35,000psi)	107	241	429	670	966	1718	2684	3865

ALLOWABLE BEARING* STRENGTH OF 17ST ALUMINUM ALLOY SHEET (LB.) (F_{br}=75,000psi)

SHEET THICKNESS \ Dia. of Rivet or Pin, In.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
.014	65							
.016	75							
.018	84	126						
.020	93	140						
.025	117	176	234					
.032	150	224	300	375				
.036	168	253	337	421	506			
.040	187	281	375	468	562			
.045	210	316	422	527	632			
.051	239	358	478	597	717	956		
.064	300	449	600	749	900	1200	1500	
.072	337	506	675	843	1012	1350	1687	2025
.081	379	569	759	949	1139	1518	1898	2278
.091	426	639	853	1066	1279	1706	2132	2559
.102	478	716	956	1195	1434	1912	2390	2868
.128	600	899	1200	1499	1800	2400	3000	3600
5/32	732	1097	1464	1829	2196	2928	3661	4393
3/16	878	1317	1757	2196	2636	3515	4394	5473
1/4	1171	1756	2343	2928	3515	4687	5859	7031

ALLOWABLE BEARING* STRENGTH OF 17ST ALCLAD ALUMINUM ALLOY SHEET (LB.) (F_{br}=68,000psi)

SHEET THICKNESS \ Dia. of Rivet or Pin, in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
.014	59							
.016	68							
.018	76	114						
.020	85	127						
.025	106	159	212					
.032	136	203	272	339				
.036	153	229	306	382	459			
.040	170	254	340	424	510			
.045	191	286	382	478	573			
.051	216	325	433	541	650	867		
.064	272	407	544	679	816	1088	1360	
.072	306	458	612	764	918	1224	1530	1836
.081	344	516	688	860	1032	1377	1721	2065
.091	386	579	773	966	1160	1547	1933	2320
.102	433	650	867	1083	1300	1734	2167	2601
.128	544	815	1088	1359	1632	2176	2720	3268
5/32	663	995	1327	1659	1991	2655	3319	3983
3/16	796	1194	1593	1991	2390	3187	3984	4781
1/4	1062	1593	2126	2655	3187	4250	5312	6376

ALLOWABLE SINGLE SHEAR STRENGTH OF ALUMINUM ALLOY RIVETS (LB.)

Dia. of Rivet or Pin, in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
A17ST & 56SH (F_{su}=27,000psi)	83	186	331	518	745	1325	2071	2984
17ST (F_{su}=30,000psi)	92	206	368	573	828	1472	2300	3313
24ST (F_{su}=35,000psi)	107	241	429	670	966	1718	2684	3865

ALLOWABLE BEARING* STRENGTH OF 24ST ALUMINUM ALLOY SHEET (LB.) (F_{br}=90,000psi)

SHEET THICKNESS \ Dia. of Rivet or Pin, in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
.014	78							
.016	90							
.018	101	151						
.020	112	168						
.025	140	210	281					
.032	180	269	360	449				
.036	202	303	405	506	607			
.040	225	337	450	562	675			
.045	253	379	506	632	759			
.051	286	430	573	716	860	1147		
.064	360	539	720	899	1080	1440	1800	
.072	405	607	810	1012	1215	1620	2025	2430
.081	456	683	910	1138	1366	1822	2278	2733
.091	511	767	1023	1279	1535	2047	2559	3071
.102	573	860	1147	1434	1721	2295	2868	3442
.128	720	1079	1440	1799	2160	2880	3600	4320
5/32	878	1317	1757	2195	2635	3514	4393	5271
3/16	1054	1581	2109	2636	3164	4218	5273	6328
1/4	1406	2108	2812	3514	4218	5625	7031	8437

ALLOWABLE BEARING* STRENGTH OF 24ST ALCLAD ALUMINUM ALLOY SHEET (LB.) (F_{br}=82,000psi)

SHEET THICKNESS \ Dia. of Rivet or Pin in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
.014	71							
.016	82							
.018	92	138						
.020	102	153						
.025	128	192	256					
.032	164	245	328	409				
.036	184	276	369	461	553			
.040	205	307	410	512	615			
.045	230	345	461	576	691			
.051	261	391	522	653	784	1045		
.064	328	491	656	819	984	1312	1640	
.072	369	553	738	922	1107	1476	1845	2214
.081	415	622	830	1037	1245	1660	2075	2490
.091	466	699	932	1165	1399	1865	2331	2798
.102	522	783	1045	1306	1568	2091	2613	3136
.128	656	983	1312	1639	1968	2624	3280	3936
5/32	800	1200	1601	2000	2401	3202	4002	4803
3/16	960	1440	1921	2401	2882	3843	4804	5765
1/4	1281	1920	2562	3202	3843	5125	6406	7687

* For D/t values > 5.5 the allowable bearing strengths must be substantiated by tests covering both yield and ultimate of the joint.