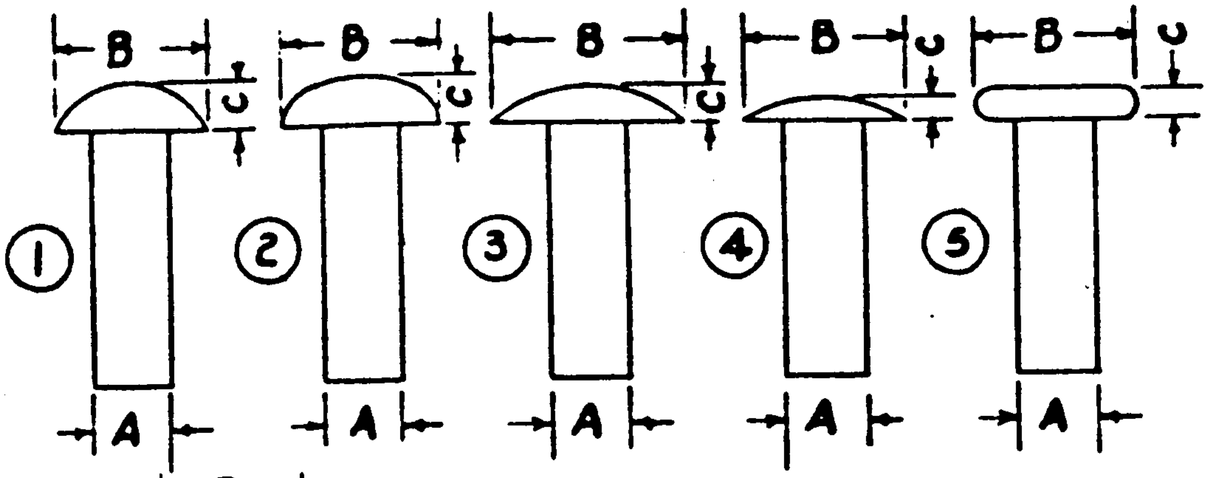


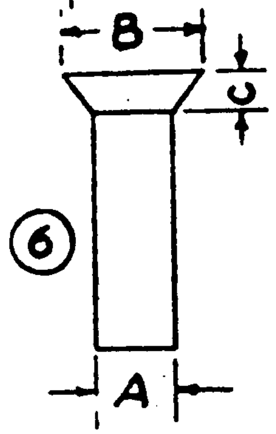
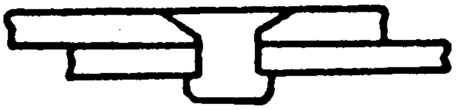


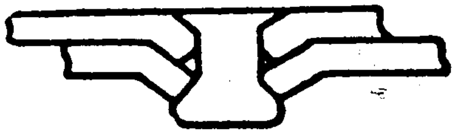
Fig. D1.25

No.	Rivet Types	B	C
1	Round Head	2A	.75A
2	Mushroom Head	2A	.625A
3	Brazier	2.5A	.50A
4	Modified Brazier	2A	.25 to .33A
5	Flat Head	2A	.4A
6	Ctsk. Head	1.81A	.5A



Machine Countersunk Type

Fig. a



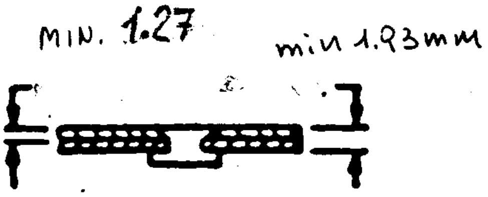
Press Countersunk - Double Dimpled Type.

Fig. b

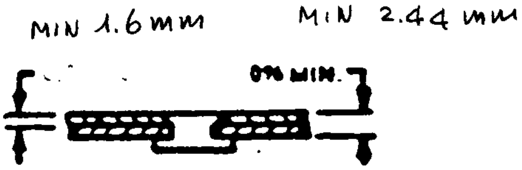
Combined Press and Machine Countersunk; or Dimpled Machine Countersunk Type.

Fig. c

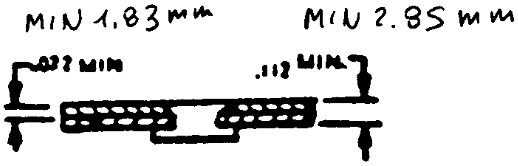
Approx. Sheet Limitations For Machine Countersunk Rivets (AN-426)



1/8 Dia. Rivet.

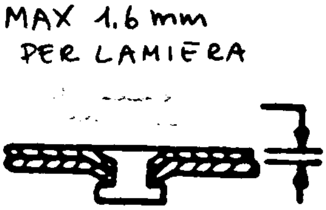


5/32 Dia. Rivet

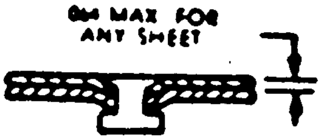


3/16 Dia. Rivet.

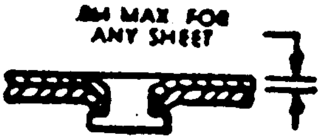
Approx. Limitations For Press Countersunk or Double Dimpled Rivets (AN-426)



1/8 Dia. Rivet.

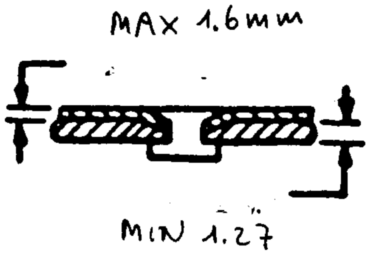


5/32 Dia. Rivet

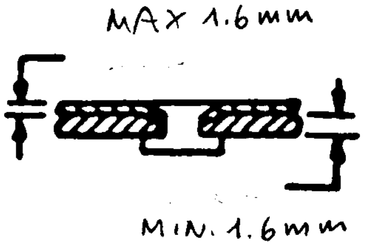


3/16 Dia. Rivet

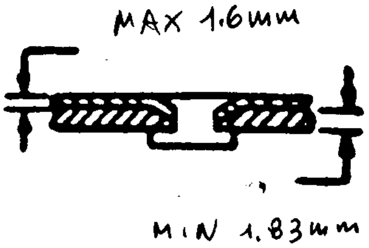
Approx. Limitations For Press-Machine Countersunk Rivets (AN-426)



1/8 Dia. Rivet



5/32 Dia. Rivet



3/16 Dia. Rivet

Table A

<table>
<tr><th colspan="5">PROTRUDING HEAD RIVET
NORMAL MINIMUM SPACING</th></tr>
<tr><td>Rivet Diameter</td><td>1/8</td><td>5/32</td><td>3/16</td><td>1/4</td></tr>
<tr><td>Normal Minimum Spacing</td><td>1/2</td><td>9/16</td><td>11/16</td><td>7/8</td></tr>
</table>

Table B

<table>
<tr><th colspan="5">NORMAL MINIMUM SPACING
PRESS AND MACHINE COUNTERSUNK FLUSH RIVETS</th></tr>
<tr><td>Rivet Diameter</td><td>1/8</td><td>5/32</td><td>3/16</td><td>1/4</td></tr>
<tr><td>Normal Minimum Spacing</td><td>11/16</td><td>27/32</td><td>1-1/32</td><td>1-1/4</td></tr>
</table>

Table D1.5 Shear Strengths of Protruding and Flush-Head Aluminum-Alloy Rivets

Diameter of rivet, in.	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
Shear strength, lb:								
5056, $F_{su}=28$ ksi	99	203	363	556	802	1,450	2,290	3,280
2117-T3, $F_{su}=30$ ksi	106	217	388	596	862	1,550	2,460	3,510
2017-T31[a], $F_{su}=34$ ksi	120	247	442	675	977	1,760	2,790	3,970
2017-T3, $F_{su}=38$ ksi	135	275	494	755	1,090	1,970	3,110	4,450
2024-T31[a], $F_{su}=41$ ksi	145	296	531	815	1,180	2,120	3,360	4,800

Single-shear rivet strength factors

Sheet thickness, in.:	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.016	0.964							
0.018	.984							
0.020	.996							
0.025	1.000	0.972						
0.032		1.000	0.964					
0.036			.980					
0.040			.996	0.964				
0.045			1.000	.980				
0.050				.996	0.972			
0.063				1.000	1.000	0.964		
0.071						.980	0.964	
0.080						.996	.974	
0.090						1.000	.984	
0.100							.996	0.972
0.125							1.000	1.000
0.160								
0.190								
0.250								

Double-shear rivet strength factors

Sheet thickness, in.:	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.016	0.688							
0.018	.753							
0.020	.792							
0.025	.870	0.714						
0.032	.935	.818	0.688					
0.036	.974	.857	.740					
0.040	.987	.896	.792	0.688				
0.045	1.000	.922	.831	.740				
0.050		.961	.870	.792	0.714			
0.063		1.000	.935	.883	.818	0.688		
0.071			.974	.919	.857	.740		
0.080			1.000	.948	.896	.792	0.688	
0.090				.974	.922	.831	.753	
0.100				1.000	.961	.870	.792	0.714
0.125					1.000	.935	.883	.818
0.160						.987	.935	.883
0.190						1.000	.974	.935
0.250							1.000	1.000

NOTE: Values of shear strength should be multiplied by the factors given herein whenever the D/t ratio is large enough to require such a correction.

Shear values are based on areas corresponding to the nominal hole diameters specified in table 8.1.1.1.1(*d*), note *e*.

Shear stresses in table 8.1.1.1.1(*d*) corresponding to 90 percent probability data are used wherever available.

Sheet thickness is that of the thinnest sheet in single-shear joints and the middle sheet in double-shear joints.

[a] The -T31 designation refers to rivets that have been heat-treated and then maintained in the heat-treated condition until driving.

2.8 RIVETS

2.8.2 STRENGTHS

TABLE 2.8.2.1(a) BJ RIVETS IN CLAD 2024-T3 AL. AL. SHEET

JOINT STRENGTHS (LB.)

RIVET DIAMETER	1/8				5/32				3/16			
	SINGLE SHEAR		DOUBLE SHEAR		SINGLE SHEAR		DOUBLE SHEAR		SINGLE SHEAR		DOUBLE SHEAR	
SHEET GAUGE[1]	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD
0.025	357	234	366	234								
0.032	374	300	469	300	551	372	580	372				
0.040	386	375	586	375	575	464	725	464	804	558	871	558
0.050	388		675	469	593	580	906	580	836	697	1089	697
0.063			727	599	596		1039	741	862		1393	890
0.071			750	675			1084	835			1469	1003
0.080			770	761			1122	941			1536	1131
0.090			776				1155	1059			1593	1272
0.100							1182	1177			1640	1413
0.125											1724	
RIVET SHEAR STRENGTHS	388		776		596		1192		862		1724	

TABLE 2.8.2.1(b) BJ RIVETS IN CLAD 2024-T42 AL. AL. SHEET

JOINT STRENGTHS (LB.)

RIVET DIAMETER	1/8				5/32				3/16			
	SINGLE SHEAR		DOUBLE SHEAR		SINGLE SHEAR		DOUBLE SHEAR		SINGLE SHEAR		DOUBLE SHEAR	
SHEET GAUGE[1]	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD	ULT.	YIELD
0.025	346	173	346	173								
0.032	374	222	440	222	549	275	549	275				
0.040	386	278	555	278	575	343	687	343	804	413	825	413
0.050	388	347	675	347	593	429	859	429	836	516	1030	516
0.063			727	470	596	581	1039	581	862	698	1370	698
0.071			750	529			1084	655	862	786	1469	786
0.080			770	596			1122	738			1536	886
0.090			776				1155	830			1593	997
0.100							1182	922			1640	1108
0.125											1724	1385
RIVET SHEAR STRENGTH	388		776		596		1192		862		1724	

1. Sheet gauge is that of the thinner sheet in single shear applications and the middle sheet in double shear applications.

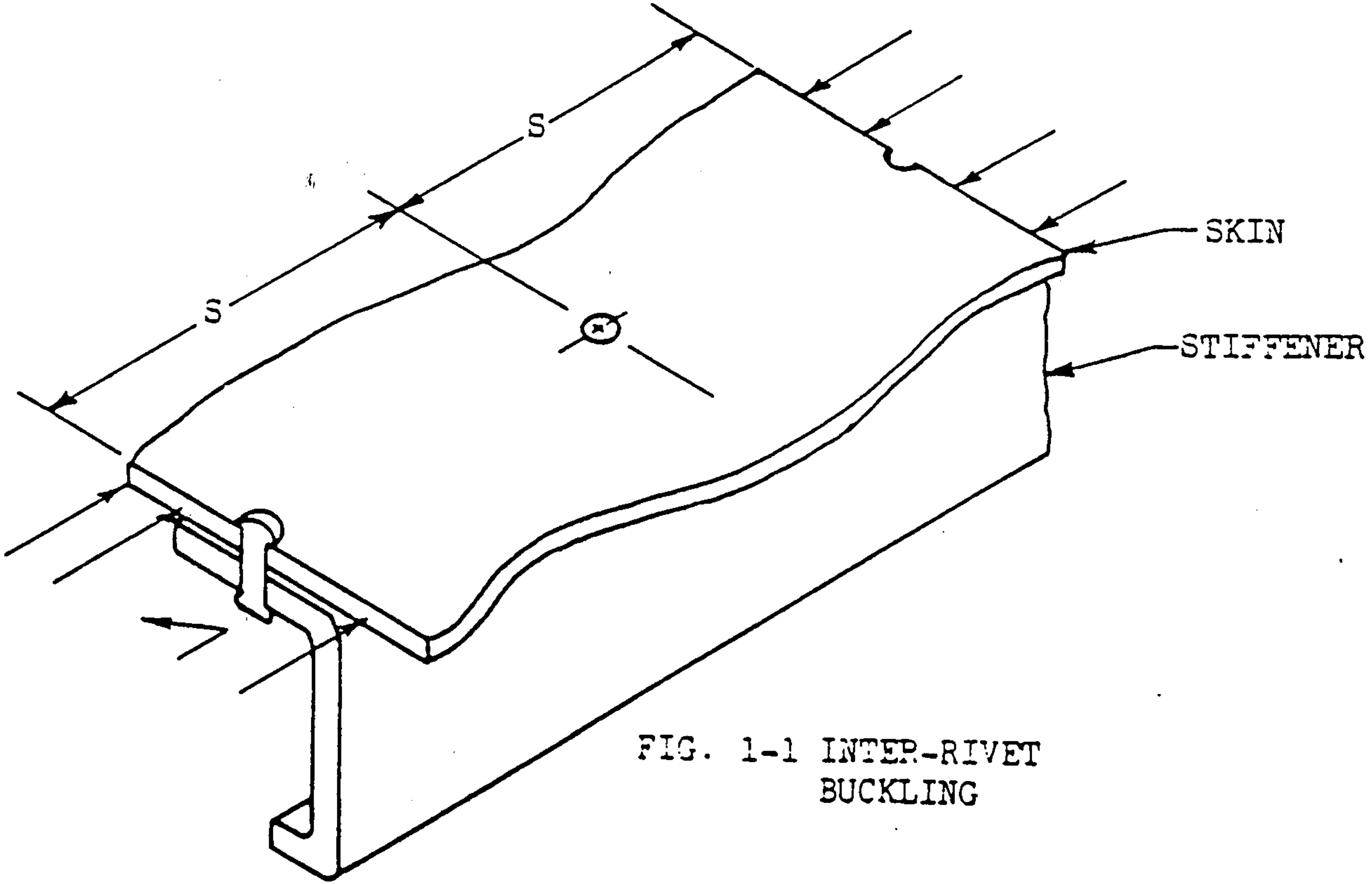


FIG. 1-1 INTER-RIVET BUCKLING

8.1 INTER-RIVET BUCKLING

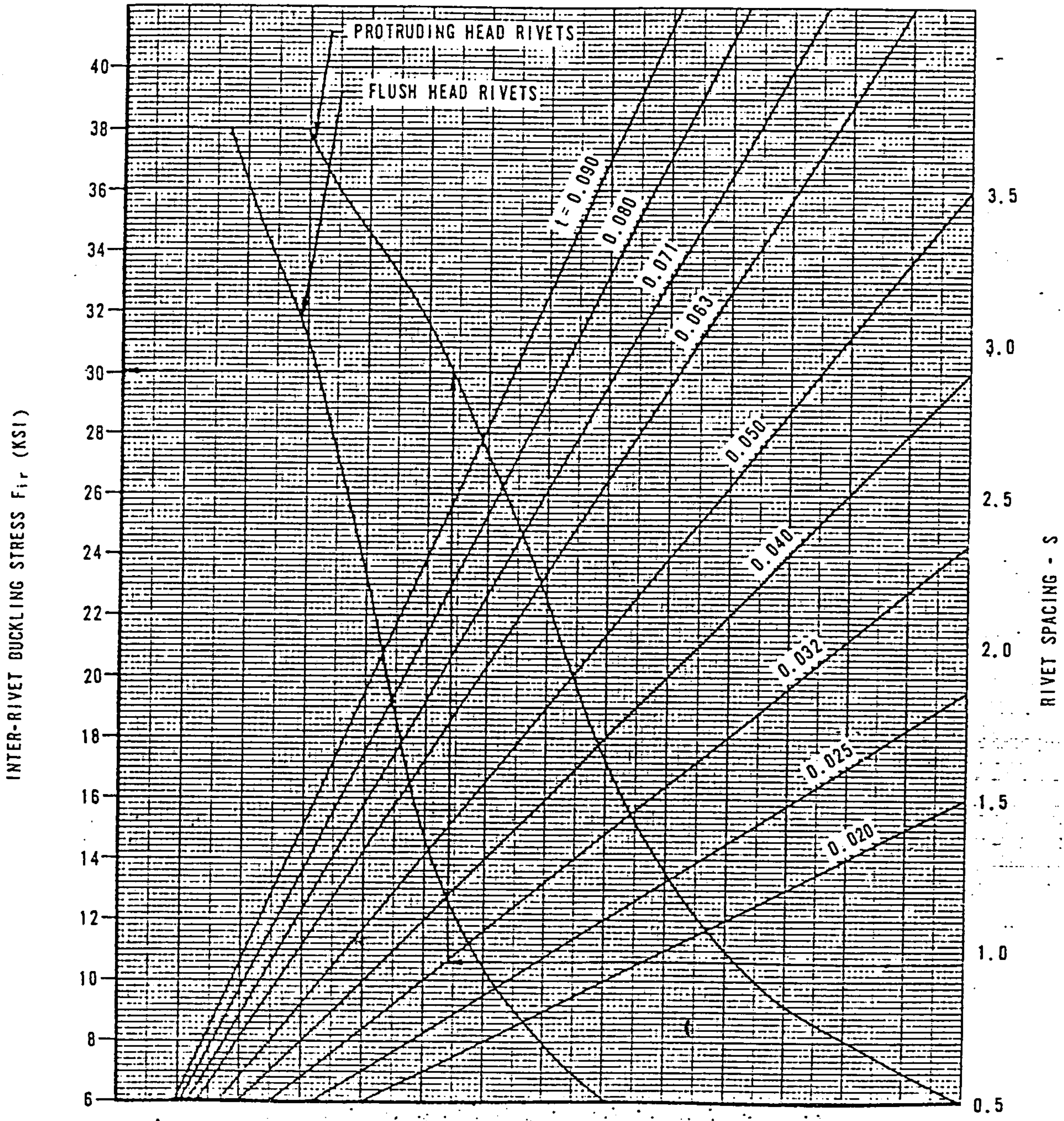


FIG. 8.1.1.2 2024-T3 CLAD SHEET

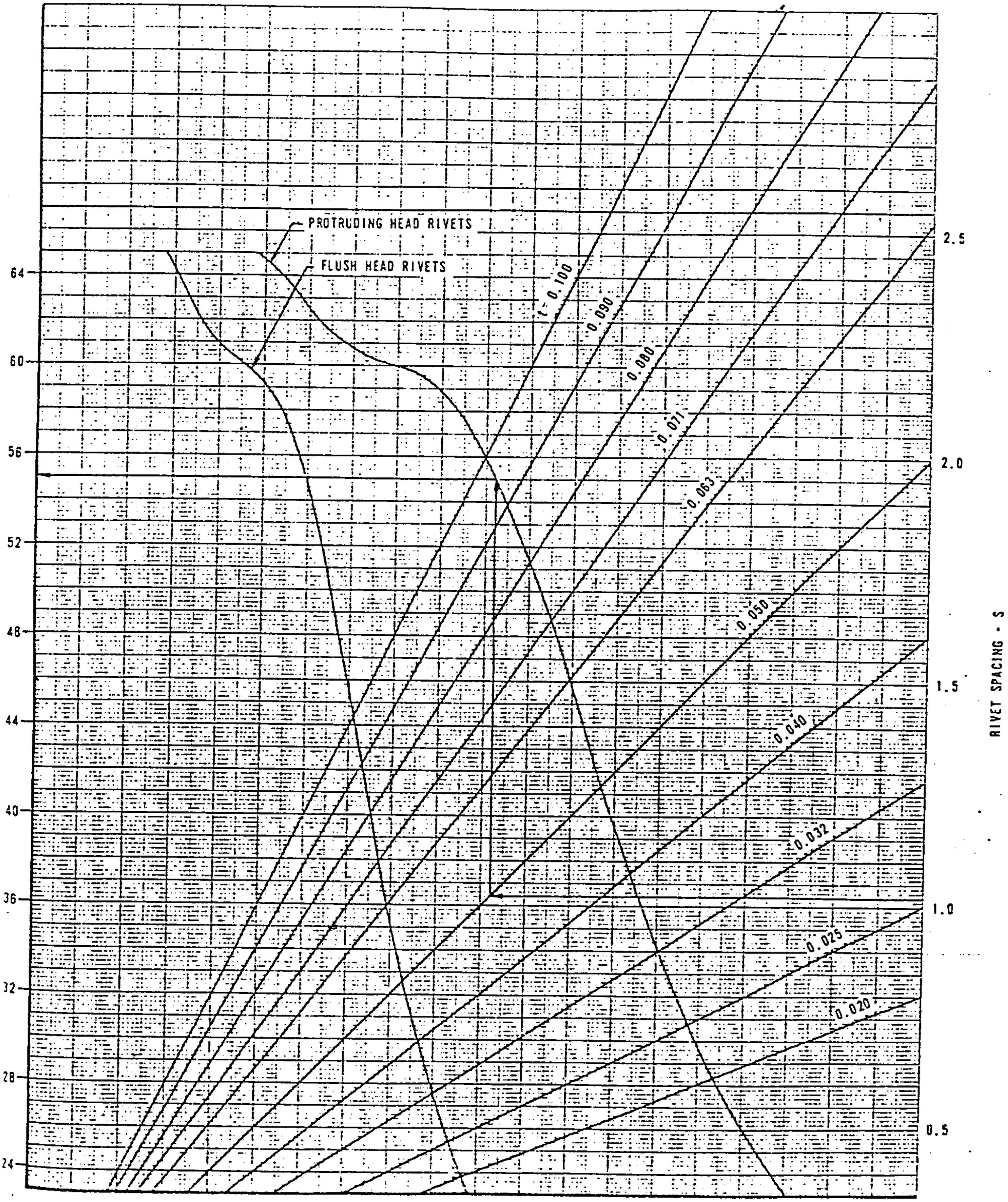


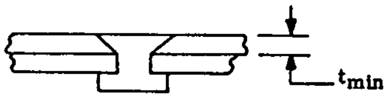
FIG. 8.1.1.3 7075-T6 CLAD SHEET

Table A
PROTRUDING HEAD RIVETS (AN470, AN442)
ULTIMATE TENSILE STRENGTH

Use this table for 24ST Alclad sheet and harder

Sheet Gauge	Allowable Rivet Load, Lbs. Per Rivet 3/32	1/8	5/32	3/16	1/4	5/16	3/8
.016	89						
.020	120	142					
.025	159	197	223				
.032	214	269	311	354			
.040	277	353	420	474	568		
.051	277	471	561	649	799	929	
.064		495	736	854	1077	1262	
.072		495	758	981	1245	1482	1669
.081			758	1094	1440	1721	1952
.091				1094	1651	1982	2265
.102					1882	2274	2622
.125					1982	2890	3353
.156					1982	3130	4336
.188						3130	4470
.250							4470

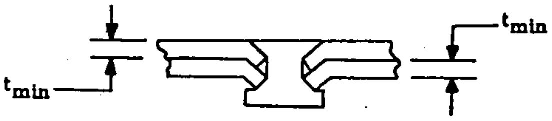
Table B
100° FLUSH HEAD RIVET (AN426) MACHINE COUNTERSUNK JOINT ULTIMATE TENSILE STRENGTH



Use this table for 24ST Alclad sheet and harder

Sheet Gauge	Allowable Rivet Load, Lbs. Per Rivet 3/32	1/8	5/32	3/16	1/4	5/16	3/8
.040	191						
.051	249	319					
.064	249	438	501				
.072		446	592	653			
.081		446	683	773			
.091			683	912			
.102				985	1275		
.125				985	1698	1941	
.156					1783	2660	2950
.188					1783	2817	3827
.250						2817	4023
t_{min}	.040	.051	.064	.072	.102	.125	.156

Table C
100° FLUSH HEAD RIVET (AN426) DOUBLE DIMPLE
ULTIMATE TENSILE STRENGTH



Use this table for 24ST Alclad sheet and harder

Sheet Gauge	Allowable Rivet Load, Lbs. Per Rivet 3/32	1/8	5/32	3/16	1/4
.020	103				
.025	137	168			
.032	185	233	271		
.040	241	305	362	409	
.051		408	485	562	694
.064		446	635	737	931
.072				850	1077
.081				970	1242
t_{min}	.020	.025	.032	.040	.051

D1.5 Aircraft Bolts.

The aircraft bolt is used primarily to transfer relatively large shear or tension loads from one structural member to another. Fig. D1.1 shows three standard aircraft bolts in common use. There are other types but they will not be presented in this limited chapter on connections.

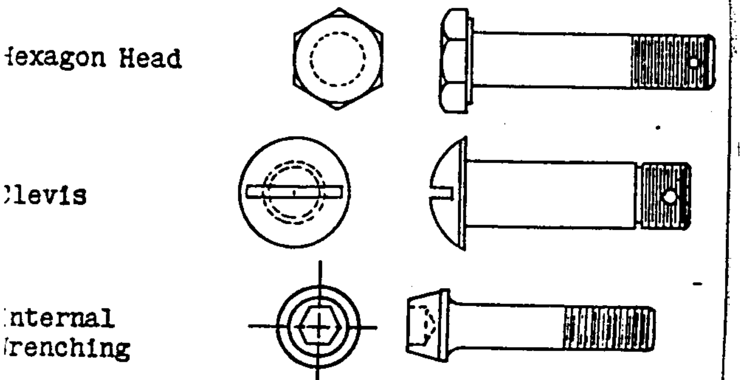


Fig. D1.1

Table D1.1

Ultimate Shear, Tensile & Bending Strengths of AN Steel Bolts (F_{tu} = 125,000, F_{su} = 75,000, F_b = 180,000)

Size of pin or bolt	Area of solid section, in.^2	Moment of inertia of solid, in.^4	Ultimate single shear strength at full diameter, lb.	Ultimate tensile strength (in thread), lb.	Ultimate Bending Moment in. lbs.
0.190	.02835	.0000640	2,126	2,210	121
1/4	.04908	.0001918	3,680	4,080	276
5/16	.07669	.0004682	5,750	6,500	539
3/8	.1105	.0009710	8,280	10,100	932
7/16	.1503	.001797	11,250	13,600	1,480
1/2	.1963	.003069	14,700	18,500	2,210
9/16	.2485	.004914	18,700	23,600	3,140
5/8	.3068	.007492	23,000	30,100	4,320
3/4	.4418	.01553	33,150	44,000	7,450
7/8	.6013	.02878	45,050	60,000	11,850
1	.7854	.04908	58,900	80,700	17,670

Table D1.2

Ultimate Shear and Tensile Strengths of Steel Internal Wrenching Bolts (F_{tu} = 160,000)

Size Dia.	Ult. Tensile Strength lbs.	Double Shear Strength lbs.	Size Dia.	Ult. Tensile Strength lbs.	Double Shear Strength lbs.
1/4	6,190	9,300	5/8	43,600	58,300
5/16	9,820	14,600	3/4	63,200	83,900
3/8	15,200	21,000	7/8	86,100	114,200
7/16	20,600	28,600	1.0	114,000	149,200
1/2	27,400	37,300	1-1/8	144,000	188,900
9/16	34,800	47,200	1-1/4	180,000	233,200

Table D1.2a

Ultimate Shear, Tensile and Bending Strengths of 2024 Aluminum Alloy Bolts

Dia.	SHEAR F_{su}-35,000	TENSION F_{tu}-62,000	BENDING F_b-72,000
3/16	992	1,059	46
1/4	1,717	1,975	110
5/16	2,684	3,189	216
3/8	3,868	4,937	373
7/16	5,261	6,663	592
1/2	6,871	9.104	884
9/16	8,697	11,563	1,260
5/8	10,738	14,719	1,730
3/4	15,463	21,573	2,980
7/8	21,046	29,520	4,740
1.0	27,489	39,759	7,070

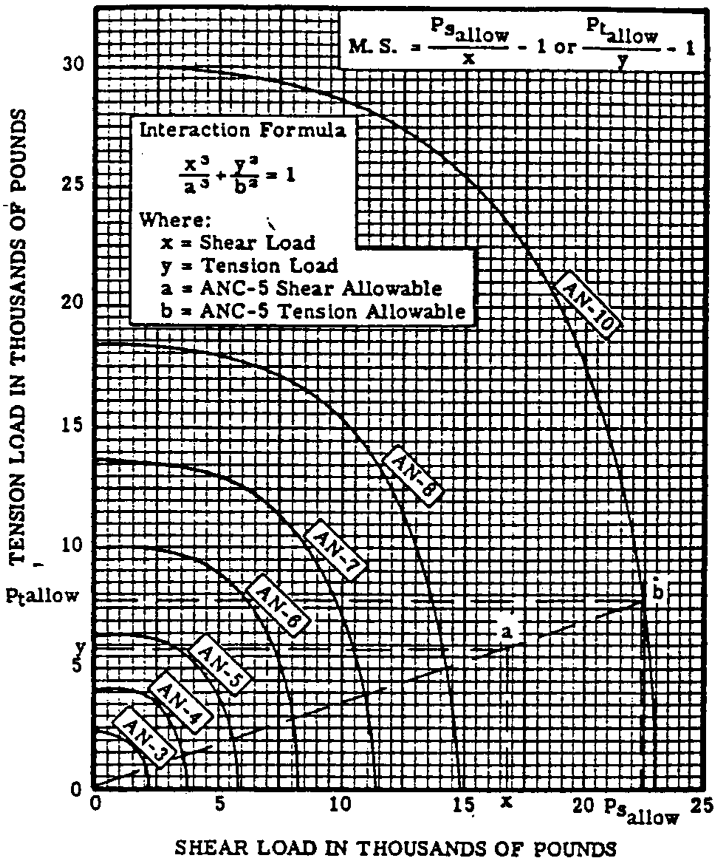


Fig. D1.4 Combined Shear and Tension on AN Steel Bolts (F_{tu} = 125,000, F_{su} = 75,000)

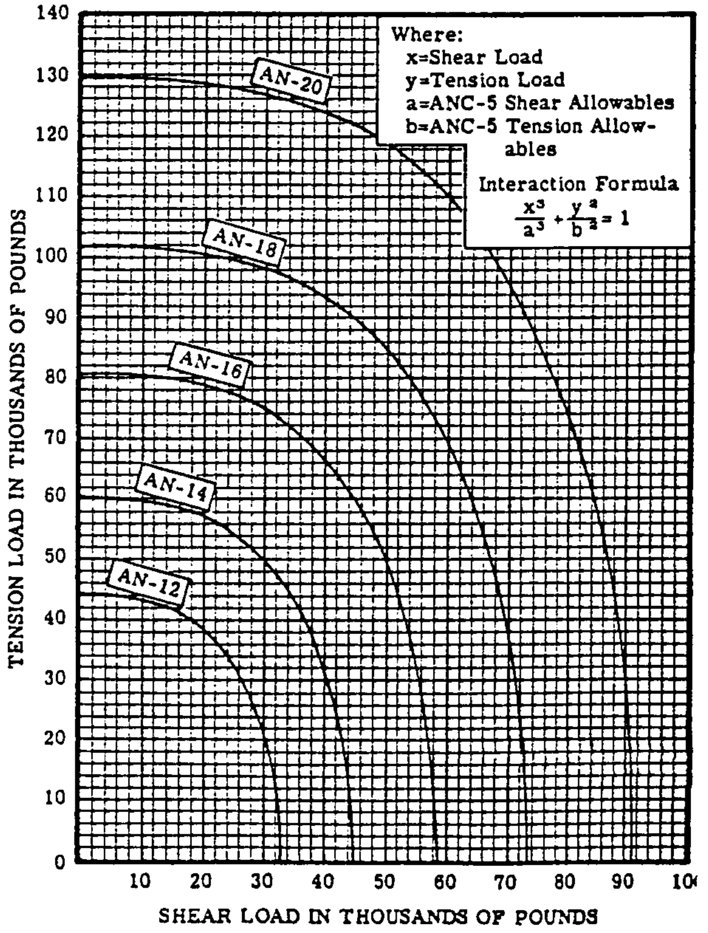


Fig. D1.5 Combined Shear and Tension on AN Steel Bolts

SECTION 7
FITTINGS

.1 SINGLE PIN JOINTS

.1.1 LUG ANALYSIS

o: maximum efficiency lugs should be designed so that :e ultimate allowable tension load is equal to the ulti– :ate allowable shear bearing load.

igure 7.1.1–1 defines a range of recommended geome– :es for steel, aluminum and titanium lugs.

igure 7.1.1–2 is used to analyze symmetrical lugs. The aterials corresponding to the numbered curves are iden– ied in Figure 7.1.1–3.

or obliquely loaded lugs, design factor k_θ is plotted in Figure 1.1-4 as a function of load angle. For design and material commendations see DM81B, Sections 14.33, 30.31, and 510.

Allowable load on lug.

Tension Critical:

$$P_t = K_t k_\theta F_{tu} Dt$$

where:

F_{tu} = material allowable ultimate tension stress in the axial, x, direction

k_θ = oblique tension loading factor, see Figure 7.1.1-4

K_t = tension strength factor, from Figure 7.1.1-2 using the calculated value of W/D

D = lug hole diameter, see Figure 7.1.1-1

t = lug thickness, see Figure 7.1.1-1

Shear–bearing Critical:

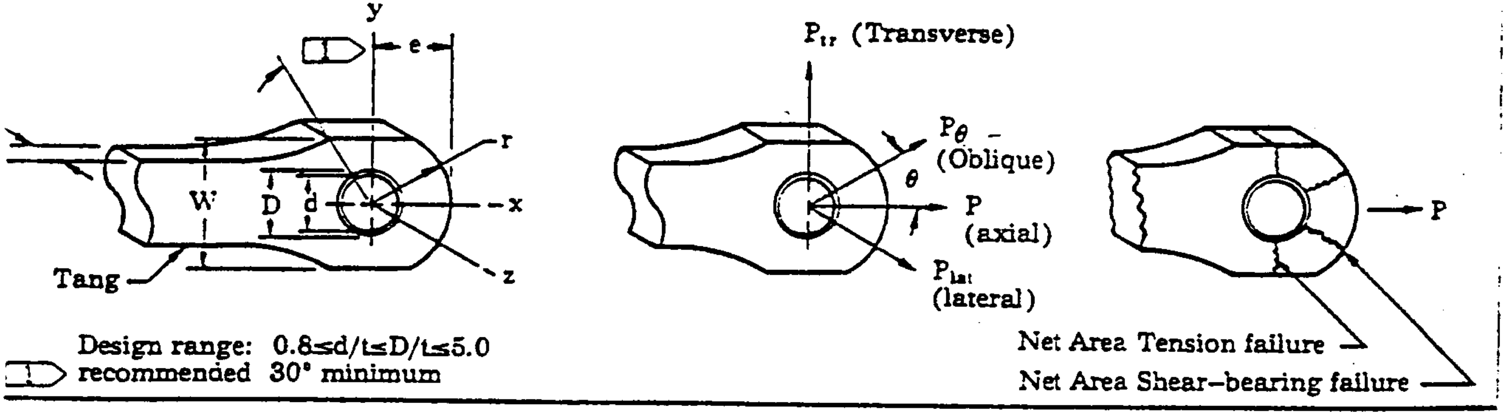
$$P_{sb} = K_{sb} k_\theta F_{tu_{min}} Dt$$

where:

$F_{tu_{min}}$ = minimum F_{tu} in the x or y direction

K_{sb} = shear–bearing strength factor, from Figure 7.1.1–2 corresponding to the value of e/D

LUG GEOMETRY AND LOAD ORIENTATION



SHAPES AND EQUIVALENTS

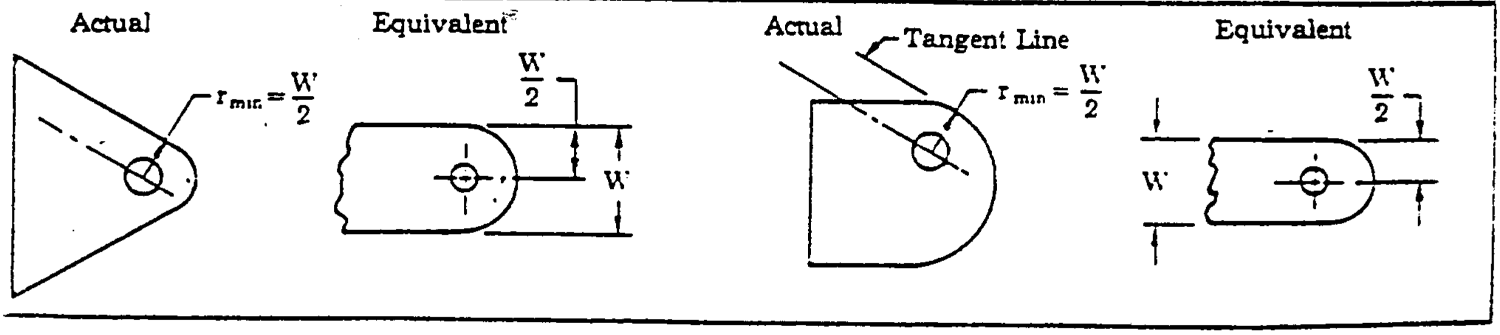
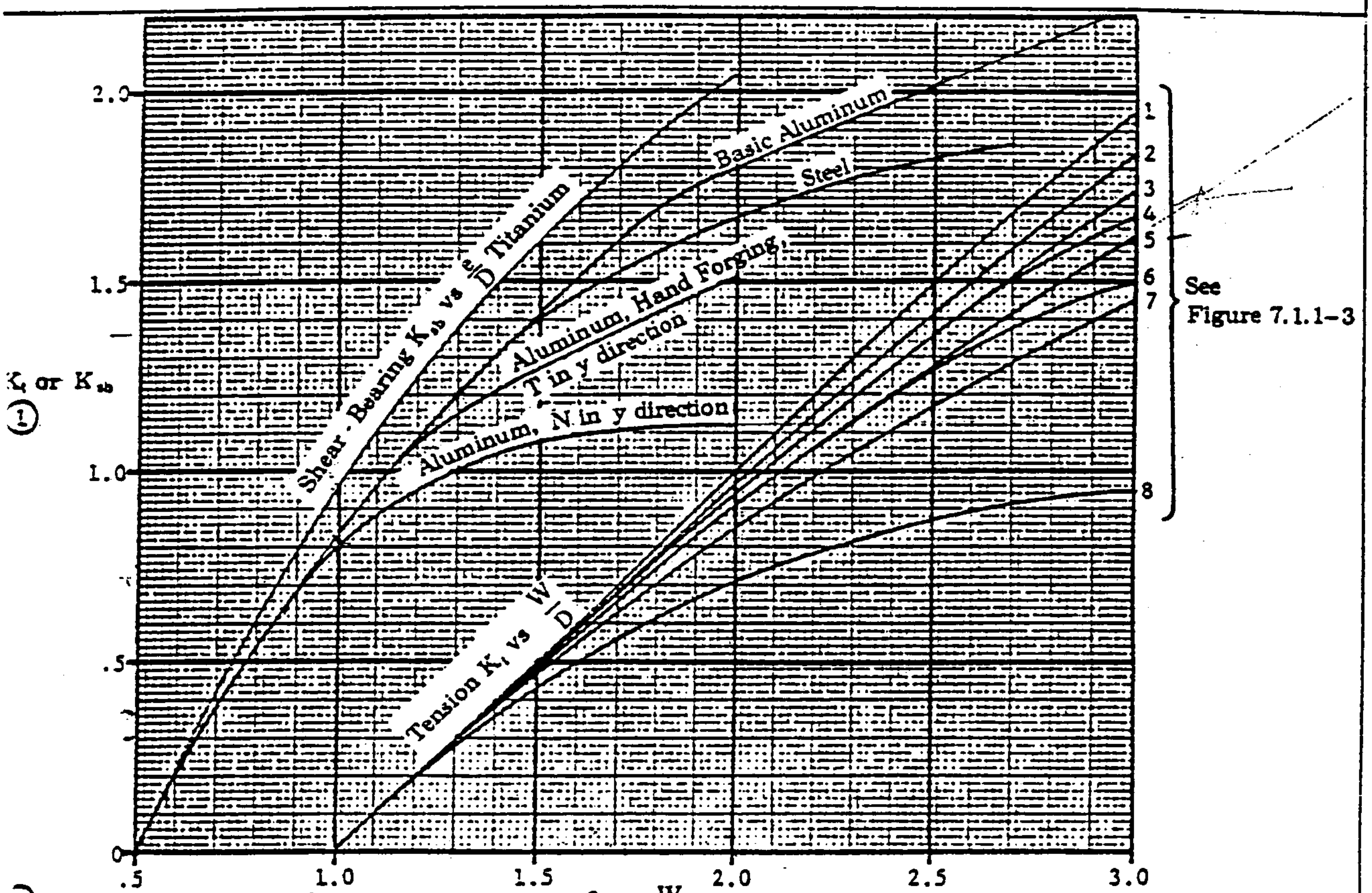


Figure 7.1.1–1

STRENGTH FACTORS – SYMMETRICAL LUG



① This K_t to be used only with equation of Section 7.1.1.

Figure 7.1.1–2

LUG MATERIALS

Tension Curve No. on Figure 7.1.1-2	Material ③	Grain In x Direction ①	Stock Size
1	Ti-6Al-4V	- - -	- - -
2	4130 Steel $F_{tu} \leqq 200$	L, T	- - -
	4340 Steel $F_{tu} \leqq 200$	L, T	- - -
	7075-T73 Plate	L, T	$\leqq 1.0$
	7075-T73 Bar and Extrusion	L	- - -
	7075-T73 Extrusion	T, N	- - -
	2014-T6 Hand Forged Billet	L	- - -
	2014-T6 Hand Forged Billet	T	$\leqq 36$ in^2
	7075-T73 Hand Forged Billet	L	$\leqq 36$ in^2
	2014-T6 Die Forging	L, T	- - -
	7075-T73 Die Forging	L, T	- - -
3	2024-T62 Plate	L, T	- - -
	2024-T3511 Extrusion	L, T, N	- - -
	2024-T42 Extrusion	L, T, N	- - -
	4340M Steel $F_{tu} = 270$	L, T	- - -
4	18-8 Stainless Steel Full Hard	- - -	- - -
5	2024-T42 Plate	L, T	- - -
	2024-T351 Plate	L, T	- - -
	7075-T73 Plate	L, T	>1.0 in.
	2024-T4 Bar	L, T	- - -
	7075-T73 Hand Forged Billet	L T	>36 in^2 ≤ 16 in^2
6	18-8 Stainless Steel, Annealed ④	- - -	- - -
7	2014-T6 Hand Forged Billet	T	>36 in^2
	7075-T73 Hand Forged Billet	T	>16 in^2
	356-T6 Aluminum Casting	- - -	- - -
8	Aluminum Plate	N	- - -
	Bar	N	- - -
	Hand Forged Billet	N	- - -
	Die Forging ②	N	- - -
	7075-T73 Bar	T	- - -

① L = Longitudinal grain direction
T = Long Transverse grain direction
N = Short Transverse grain direction

② For Die Forging N Direction Exists Only at Parting Plane

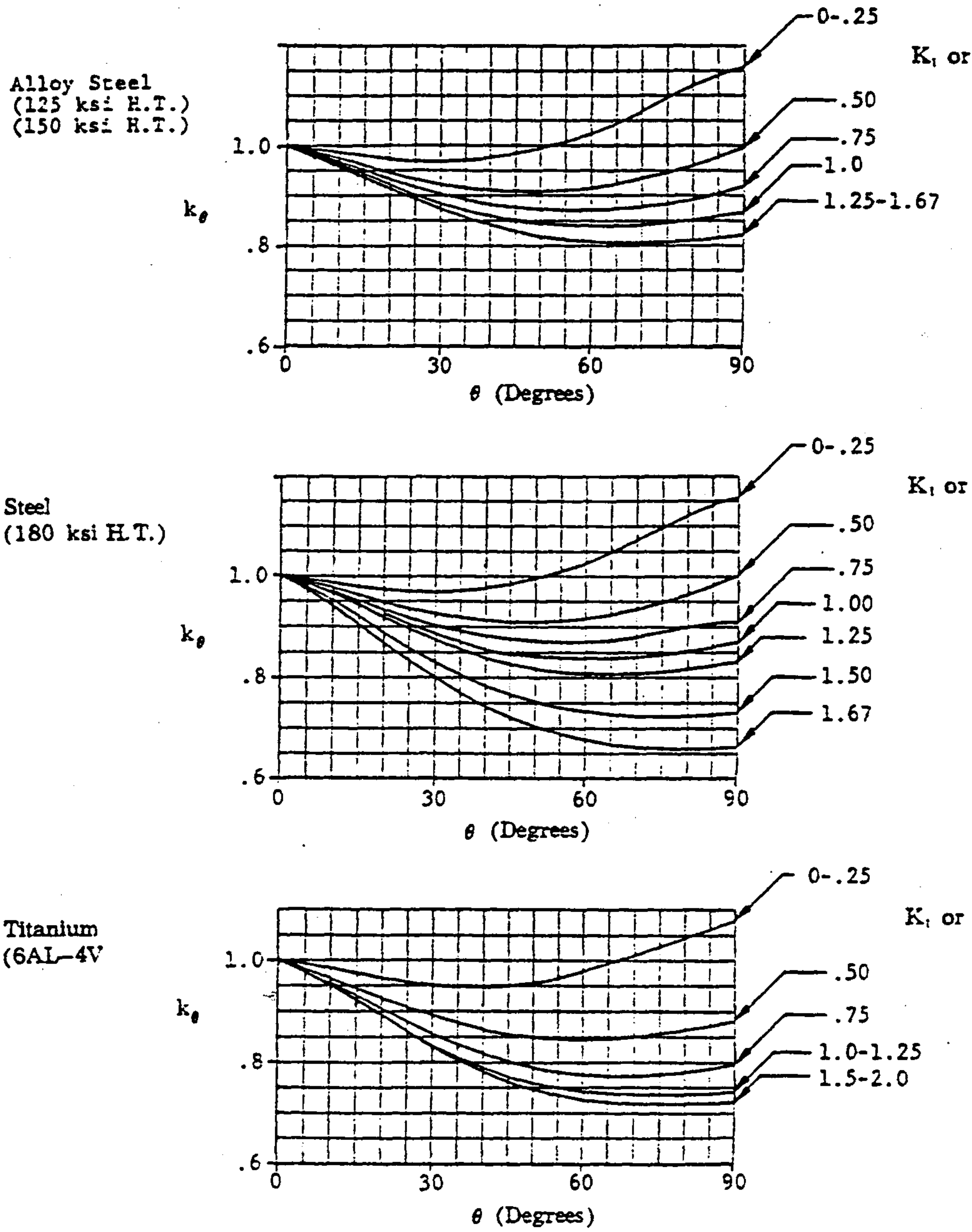
③ See DM813, Section 14.33 and 30.31

④ Yield is less than 2/3 ultimate, and could be critical value.

Figure 7.1.1–3

7.1.1 LUG ANALYSIS (Continued)

k_θ vs LOAD ANGLE ①

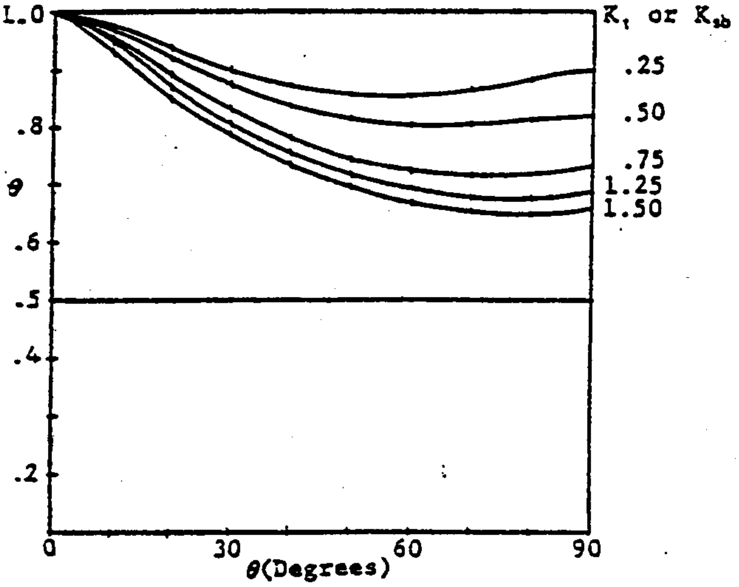


① These curves based on a balanced design ($K_t \approx K_{sb}$)

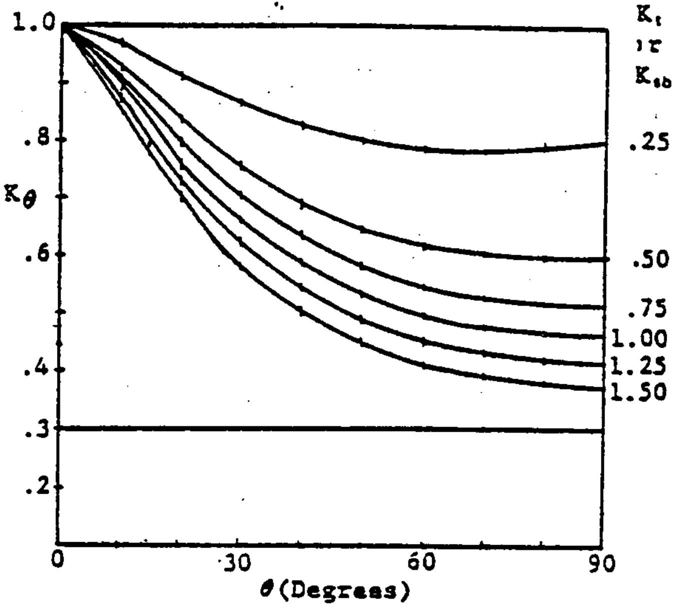
Figure 7.1.1–4

k_θ vs LOAD ANGLE ①

2024-T42 Plate
2024-T351 Plate

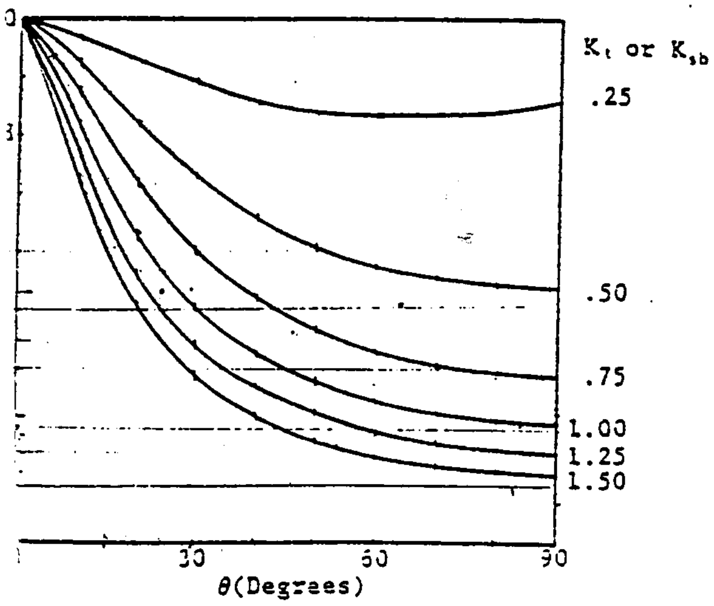


2024-T4 Bar
7075-T73 Plate
≦1.0 in.
356-T6 Al. Casting

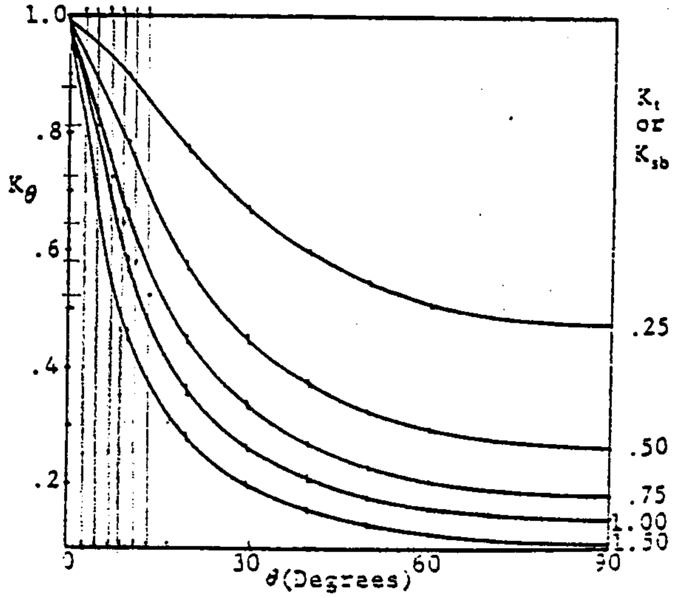


2024-T62 Plate
7075-T73 Plate
All Thicknesses
2024-T42 Extrusion
2024-T3511 Extrusion
7075-T73 Bar and
Extrusion

7075-T73 Hand Forg.
≦ 16 In²
7075-T73 Die Forg.
2014-T6 Die and Hand
Forging ≦ 36 In²
4340M Steel,
260-280 ksi H.T.



2014-T6 Hand
Forging > 36 In²
7075-T73 Hand
Forging >16 In²
Al. Alloy with Long.
Grain In "Y"
Direction

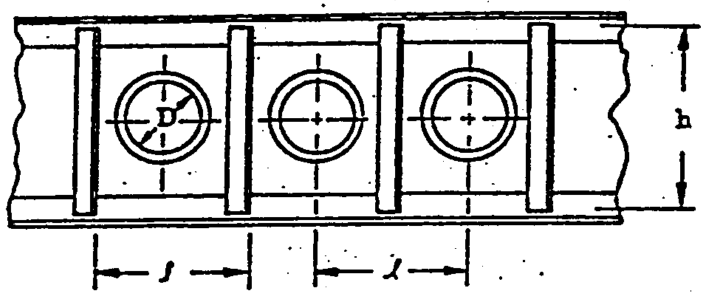


ese curves based on a
lanced design ($K_t \approx K_{sb}$)

Figure 7.1.1—4a

9.3.2.1 FLANGED HOLES IN INTERMEDIATE DIAGONAL TENSION WEBS

Flanged holes in intermediate diagonal tension webs should be restricted to lightly loaded areas not subject a sonic environment with the following limitations and modifications to the analysis proceudre shown in Section 8.1.1



1. $D < \frac{h}{2}$

   $D < \frac{2l}{3}$

2. Hole center location is within a distance of $\frac{h}{8}$ from beam horizontal centerline.

3. Stiffening ratio $\frac{A}{lt} > .25$ as defined in Section 8.1.1

4. Web shear stress is based on net area using the expression.

   $$f_s = \frac{V}{(h-D)t}$$

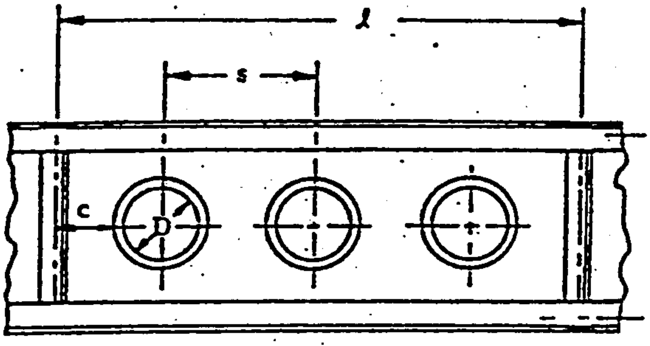
   The allowable web shear stress F obtained from Figures 8.1.1.1-1a, -1b or -1c is multiplied by a reduction factor of .75.

   $$\text{M.S.} = \frac{.75\,F_s}{f_s} - 1$$

Attachment requirements are shown in Section 8.1.1.5

9.3.2.2 FLANGED HOLES IN SHEAR RESIST. WEBS

Flanged holes may be used in shear resistant webs in : not subject to a sonic environment and of low stress inte with the following limitations:



1. $.20 < \frac{D}{h} < .50$

2. $1.50 < \frac{s}{D}$

3. $.15 < \frac{c}{h}$

The analysis procedure for shear resistant webs outline Section 8.2 is modified as follows:

Web shear stress is calculated from the expression

$$f_s = \frac{V}{ht}$$

Allowable gross area web shear stress is given by:

$$F_s = K_1 F_0$$

F_0 and K_1 are obtained from Figure 9.3.2.2-1.

$$\text{M.S.} = \frac{F_s}{f_s} - 1$$

9.3.2.2 FLANGED HOLES IN SHEAR RESISTANT WEBS (Continued)

To cover the case of large or closely spaced holes the following net shear stresses should be checked. These values should not exceed F_{su}.

$$f_{s_1} = f_s\left(\frac{s}{s-D}\right)$$, for one hole assume $s = l$

$$f_{s_2} = f_s\left(\frac{h}{h-D}\right)$$

ULTIMATE ALLOWABLE GROSS AREA SHEAR STRESS FOR ALUMINUM ALLOY SHEAR RESISTANT BEAMS WITH FLANGED HOLES.

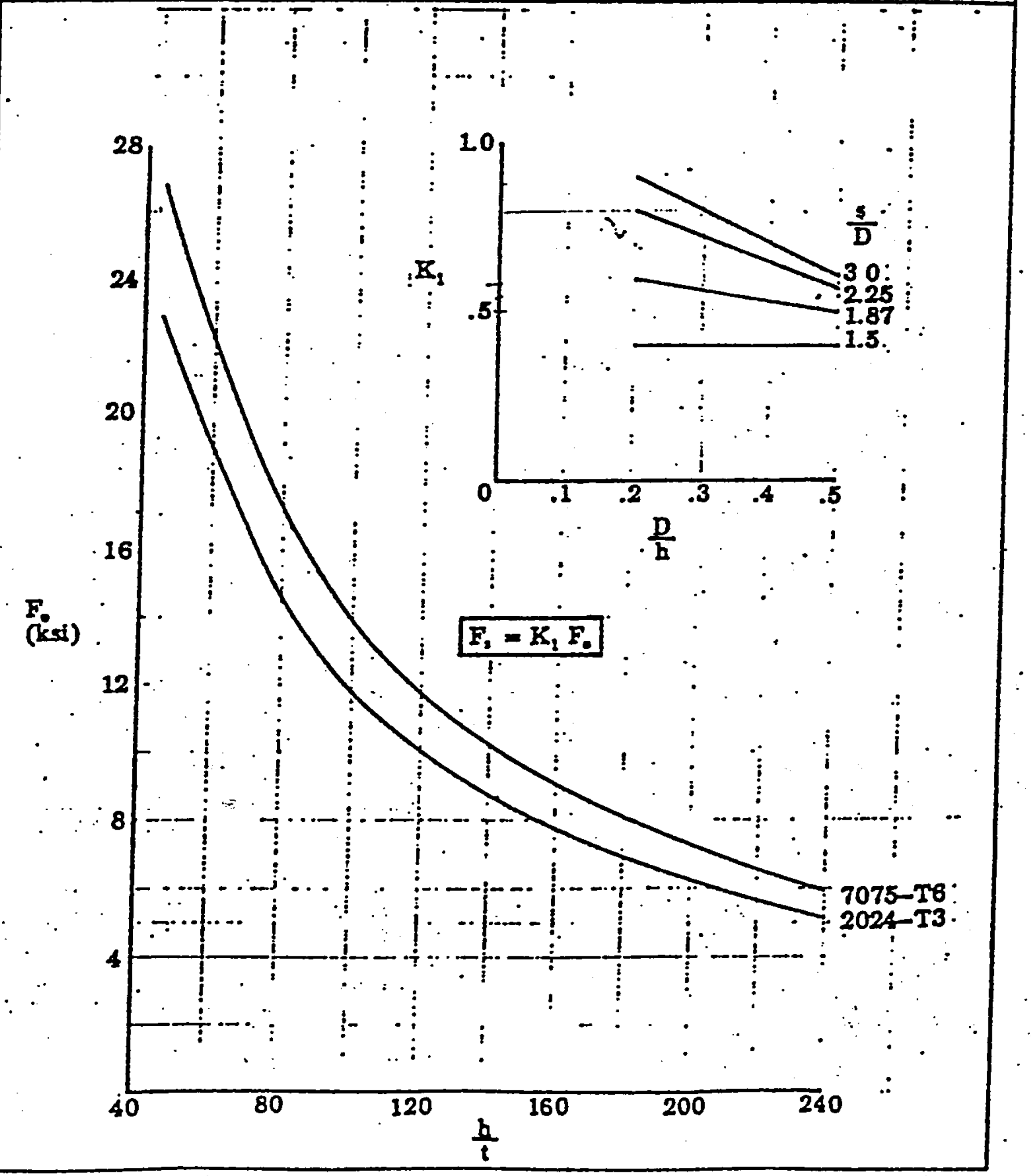
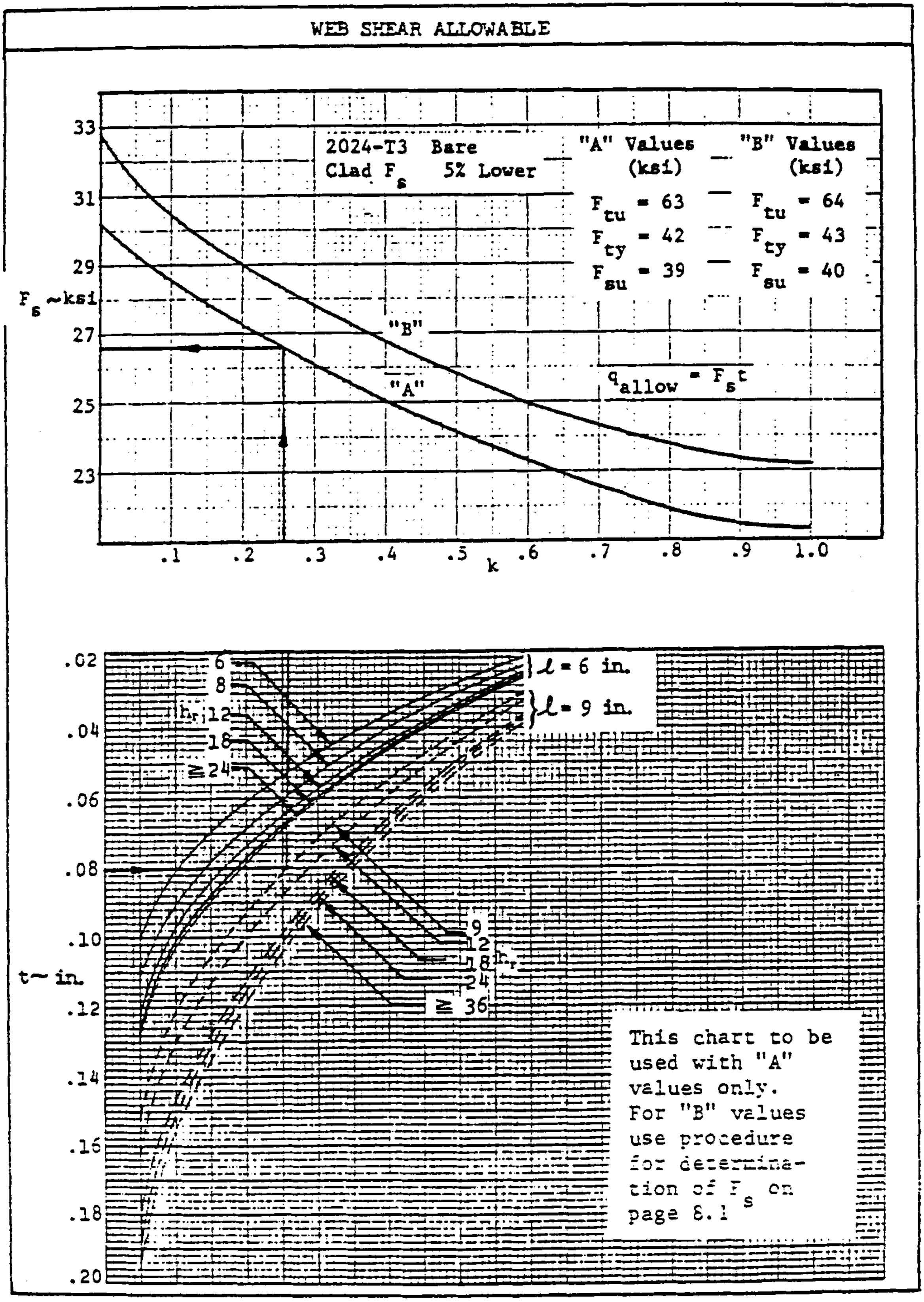


FIGURE 9.3.2.2-1

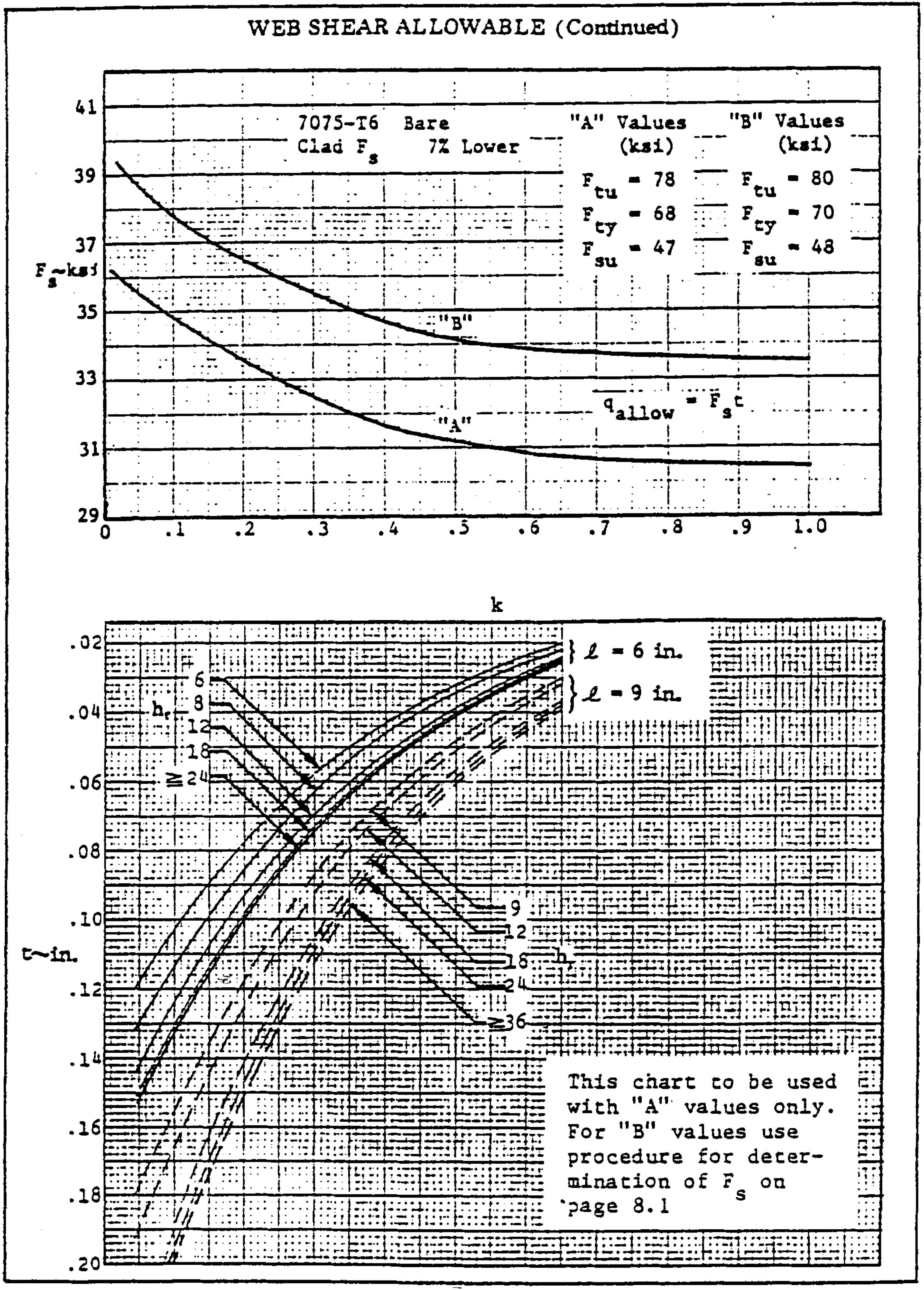
8.1.1.1 STIFFENER SPACING AND WEB THICKNESS
(Continued)



This chart to be used with "A" values only. For "B" values use procedure for determination of F_s on page 8.1

FIGURE 8.1.1.1-1a

8.1.1.1 STIFFENER SPACING AND WEB THICKNESS
(Continued)



This chart to be used with "A" values only. For "B" values use procedure for determination of F_s on page 8.1

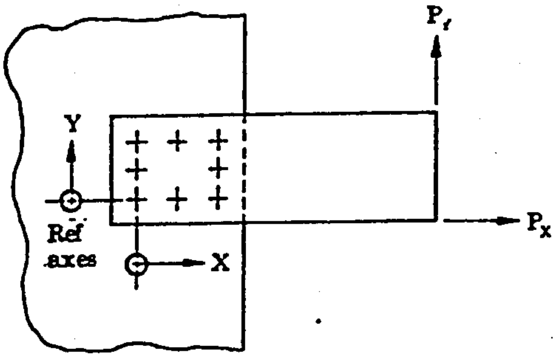
FIGURE 8.1.1.1-1b

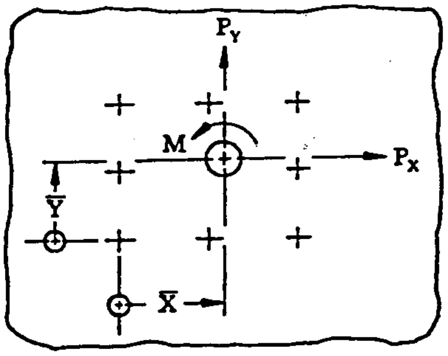
23.5 ECCENTRIC LOAD ON FASTENER GROUPS

Joints which have a misalignment between the load vector and the centroid of the fastener pattern will have additional loads induced on some of the fasteners. The analysis procedures shown in this section describe the methods used to balance an eccentric load on a fastener pattern.

23.5.1 ECCENTRIC SHEAR LOADS

Fastener patterns with loads in the plane of the joint will have shear loads on the fasteners. When the applied load is eccentric to the pattern centroid the individual fasteners will have vectorially combined loads. The analysis shown here will allow the analyst to find the final resultant load on any fastener in the pattern.





n fasteners of various diameters D

Take tabular solution:

Fast. No.	X	Y	D²	D²X	D²Y	D²X²	D²Y²
1							
2							
...							
n							
Summations			ΣD²	ΣD²X	ΣD²Y	ΣD²X²	ΣD²Y²

$$\bar{X} = \frac{\Sigma D^2 X}{\Sigma D^2}; \quad \bar{Y} = \frac{\Sigma D^2 Y}{\Sigma D^2}$$

Compute moment about group centroid ($\bar{X}$, $\bar{Y}$)

$$I = \Sigma D^2 X^2 + \Sigma D^2 Y^2 - \bar{X}\,\Sigma D^2 X - \bar{Y}\,\Sigma D^2 Y$$

The Load transfer at any fastener:

$$P_i = D_i^2 \left\{ \left[\frac{P_Y}{\Sigma D^2} + \frac{M(X_i - \bar{X})}{I}\right]^2 + \left[\frac{P_X}{\Sigma D^2} - \frac{M(Y_i - \bar{Y})}{I}\right]^2 \right\}^{\frac{1}{2}}$$

Note: For bearing critical (Limit Load) Analysis. Replace D^2 with D in the solution above

The fastener group should be compact particularly when joining a flexible member to a stiff member. Consider the elongated joint in the sketch below. The analyst tends to react the moment with the extreme fasteners and distribute axial loads equally among all three: this is unconservative, because the middle fastener prevents the required beam deformation (dashed line) and axial loads tend to transfer at end fasteners.