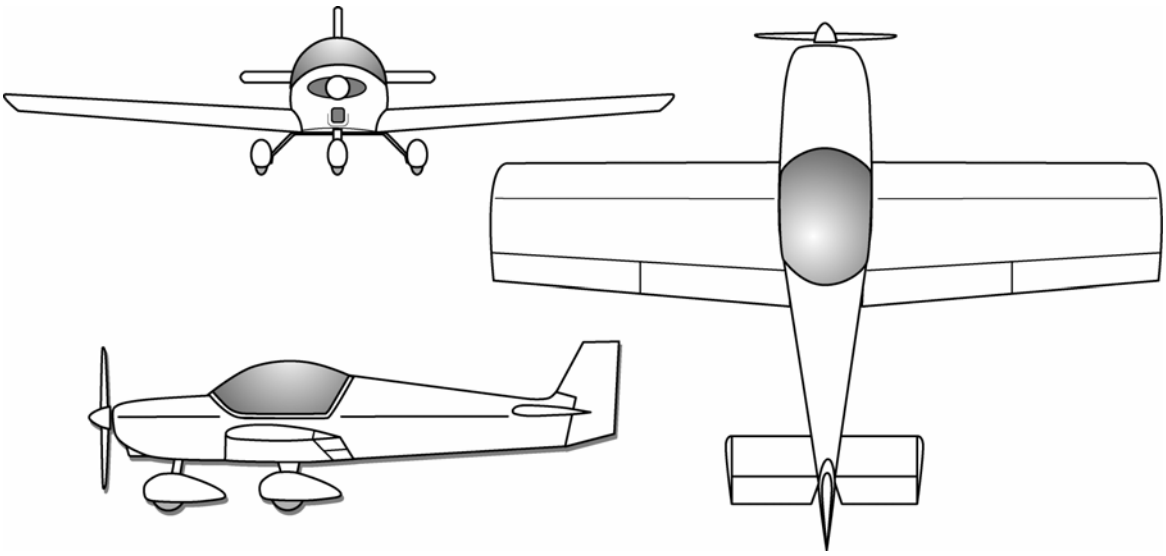
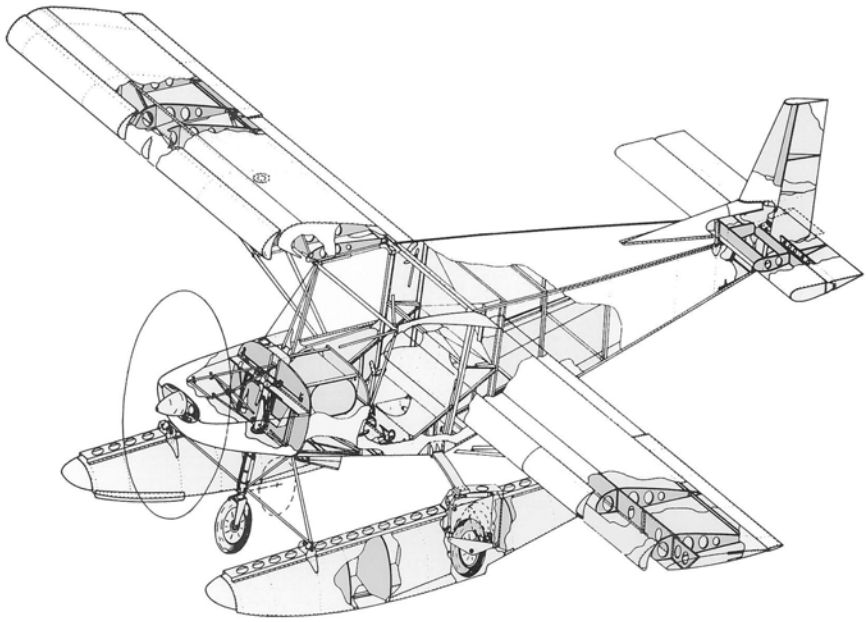
CONSTRUCTION STANDARDS

FOR ZENAIR LIGHT AIRPLANES





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PURPOSE OF THE CONSTRUCTION STANDARDS (CS)

CS #001

The purpose of the Construction Standards (CS) is to outline in a handy manual format the standards to be used for manufacturing (building), maintaining and/or repairing your Zenair light aircraft.

Whereas the drawings and photo assembly guides for a specific model show the parts, dimensions, assemblies, the specific tolerances where required, as well as the assembling procedures, the present Construction Standards (CS) supply the general specifications as per the index CS #000. The CS is the source for the recommended and acceptable raw material, suggested rivets and their correct installation. It also goes over the suitable type of bolts when threaded fasteners are specified in the drawing. The author hopes that the CS will allow the builder/manufacturer to acquire a better understanding of the process and to minimize the need for questions and requests for approval to fix mistakes and perform repairs.

The Construction Standards reflect the successful design philosophy of designer Chris Heintz, and applies to modern sheet metal construction for light aircraft. They are straight forward and efficient methods proven by their “in-service experience” on the designer’s airplanes since 1970.

NOTE: The FAA’s AC 43-13 “Acceptable Methods, Techniques, and Practices” may alternatively be used.

UPDATES, REVISION: Check for current drawing list on web site, www.zenithair.com/bldr/index.html.

PHOTO ASSEMBLY GUIDE: Some pictures of the different assemblies may not correspond with the drawings. The drawings always come first.

METRIC SYSTEM

All manufacturing dimensions on the designer's drawing are given in metric (millimeters), with the exception of standard North America raw material and hardware which are specified in inches (")

1" = 25.4mm
1kg=2.2lbs

NOTE: The drawings are not full scale on purpose. This will avoid the temptation you may have to measure the drawing, or check the parts against them. This could lead to inconsistencies as paper shrinks and expands with humidity and size variation occurs with printing.

Also: The number of rivets is given in digits (so is the pitch spacing between holes);
NEVER COUNT THE **+** MARKINGS ON THE DRAWINGS

VISUAL INSPECTION

Check for:

- Corrosion protection where applicable and on all steel parts.
- Do all rivets squeeze the matching parts tightly? No burrs in between?
- Proper edge distance?
- Are all items safety-tied as required? (Cotter pin, locking wire, etc ...).
- Are the bolts tight and of correct length?

ABBREVIATIONS

6061-T6 aluminum alloy - heat treatment
4130 steel alloy (N normalized, A annealed)

AD solid rivets (hard)
AN / MS aircraft hardware (army navy / military standard)
A3 Avex blind rivet 3/32" diameter aluminum rivet
A4 Avex blind rivet 1/8" diameter aluminum rivet
A5 Avex blind rivet 5/32" diameter aluminum rivet
AS5 Avex blind rivet 5/32" diameter stainless steel rivet (these rivets have domed head, use a flat nose piece on the riveter)

AWG American wire gauge

CH Chris Heintz
CL aircraft center line
CG center of gravity
dl developed length
DWG drawing

e edge distance
EXT extrusion
F.95 flanged lightening hole 95mm diameter
HL Hinge Line
H.T. horizontal tail
I/B Inboard

LE Leading Edge
L left (capital L, sitting in aircraft facing forwards)
l length (small l)

FRWD forward
MAC mean aerodynamic chord
mm millimeters
NPT national pipe thread
O/B outboard
OD outside diameter (tube)
Plc's places
P/N part number
QTY quantity

R right (sitting in aircraft facing forwards)
R1/4" or R1/8" or R3 bend radius
R12 edge distance radius (see CS#101)
REQ'D quantity required
S.L. nylon self locking nuts AN365
S.S. stainless steel
STOL short take off and landing
STN station

t material thickness in thousands of an inch
TD tail dragger
V voilure (wings) drawing 7-V-0
W/ with
XL Zodiac CH 601 XL
Yu coordinates to upper curvature
Yl coordinates to lower curvature

SYMBOLS

~ approximate
" inches t=.025"
Ø hole diameter, drill bit size Ø 3/16"
number, #30 drill bit
< less than
≤ less than or equal
> greater than
≥ greater than or equal
° degree, 90º
+/- tolerance
& and
x multiplication (times)

|a| absolute value of 'a'
- - - - hidden line

△ increment (change)

TERMINOLOGY

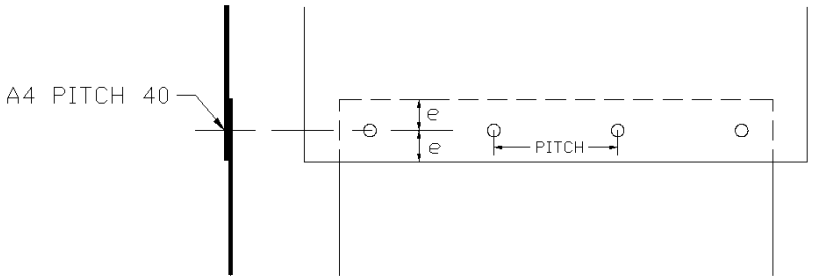
Fairlead: wear resistant plastic material (nylon) to guide control cables through airframe.
No rivet zone: indicates an area where holes will be drilled later through an overlapping part at a later time.
Pitch: maximum distance between rivets along a rivet line.
Web: flat surface between flanges (spar, ribs, and channels).

WORKING TOLERANCES:
Follow the dimensions indicated in the drawings as closely as possible. You are building a well designed light aircraft and not a jet airliner. Use common sense (for example it is easier to remake a spar which is 1/8" (3mm) too narrow than to start altering all the ribs and other parts which have to fit to the spar; besides the structural integrity, the flying characteristics and the performances may be adversely affected...)

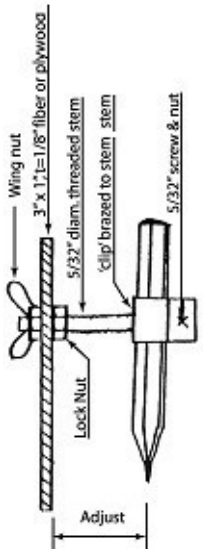
Try to achieve an accuracy of: 1/64" (.5mm) on spar and rib heights,
1/16" (1.5mm) on all other parts
1/8" (3mm) on the various assemblies and rivet spacing.

For drilled holes, the applicable tolerances are automatically provided when using the tools correctly. There are only a very few close tolerances to be respected. They are only common sense and shown on the drawings. Do not let yourself be discouraged with anyone else's differing opinion, or by reading too much...

SHEET METAL JOINTS: The skins overlap on top of each other. The drawings show the suggested position and rivet pitch of the sheet joints:



- Rivet lines: Use soft tip marker. NEVER USE A SCRIBE! Berol China marker (grease pencil), or Col-erase Pencil (color pencils) can also be used.
- Mark the rivet line on the rib flanges, use a marking gauge:
- Lay out the rivet pitch (spacing between holes) shown on the drawings. The drawings provide either the rivet pitch, or the number of rivets.



Marking gauge

After drilling, the parts are temporarily held in position with 'clecos'. Use the clecos as you drill an assembly together. When everything fits, disassemble, deburr the holes, apply corrosion protection, reassemble and rivet. When there is a choice, the original rivet head should be on the side of the thinnest part, or the outside of the aircraft.

Rivet Holes:

Standard edge distance for A4 and A5 = 10mm.

RIVET LINE: STRAIGHT LINE WITH OFFSET = e

END HOLE: FIRST AND LAST HOLE IN A RIVET LINE SET AT e FROM THE EDGES.

RIVET SPACING: FIRST LAYOUT THE RIVET LINE, SET THE END HOLES AT EACH END OF THE RIVET LINE, THEN DIVIDE THE INTERVAL FOR THE SPECIFIED PITCH.

CHECK: RIVETS IN THE INTERVAL ARE EVENLY SPACED.

PITCH = MAX DISTANCE BETWEEN RIVETS

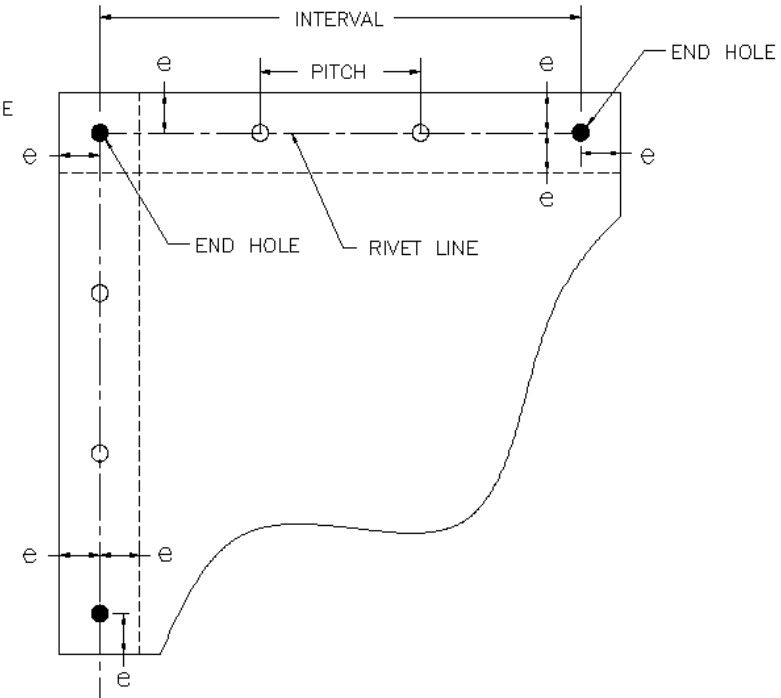
TOLERANCE +1.5mm

e = EDGE DISTANCE, MEASURED FROM CENTER OF HOLE TO EDGE OF SHEET

MINIMUM = 1.5d

d = HOLE DIAMETER

R = RADIUS



MINIMUM DISTANCE TO FLANGE = $R + \frac{d}{2}$

BENT RADIUS

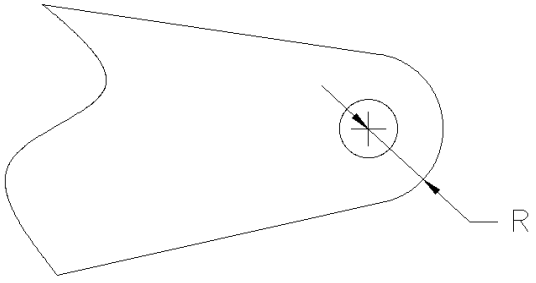
MINIMUM = $\frac{d}{2}$

EXTRUSION

Bolt Holes:

Minimum edge distance, Rmin, AN-3 through AN-8 bolts in 6061-T6 and 4130:

$R_{MIN} = 1.5 \times d$



R = Edge distance radius

HOLE DIAMETER

RIVETS HOLES

RIVET DIAMETER	3/32" (2.4mm)	1/8" (3.2mm)	5/32" (4mm)	3/16" (4.8mm)
NOMINAL DIAMETER (mm) NUMBER DRILLS	2.38 #40	3.18 #30	3.97 #20	4.76 #12
MAX. ACCETPABLE DIAM. IN $t < 1.0$mm	2.7mm	3.5mm	4.4mm	5.2mm
MAX. ACCETPABLE DIAM. IN $t \geq 1.0$mm	–	3.8mm	4.8mm	5.7mm

DRILLING: Compact electric drill (Approx. 2000 RPM) fitted with a rubber washer or rubber hose on drill bit shank (prevents damages to metal).

BOLT HOLES

Unless otherwise specified, bolt holes have the standard drill tolerance as follows:

BOLT AN	3	4	5	6	7	8
DIAMETER (mm)	4.76	6.35	7.94	9.53	11.11	12.7
DRILL SIZE (inches)	3/16	1/4	5/16	3/8	7/16	1/2
TOLERANCE (mm)	+.20 −.02		+.30 −.02			

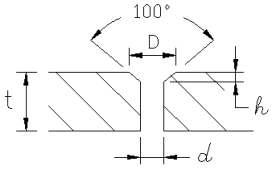
Only when reaming is specified on the drawings, the hole tolerance up to 20mm diameter (3/4") is +.04mm -.02mm

DIMPLING performed only up to and including t=1.0mm (0.040")

RIVET DIAMETER	3/32" (2.4mm)	1/8" (3.2mm)	5/32" (4mm)	3/16" (4.8mm)
MAX. ACCETPABLE DIAMETER AFTER DIMPLING:	0.110" (2.8mm)	0.146" (3.7mm)	0.185" (4.7mm)	0.217" (5.5mm)

MACHINE COUNTERSKING: For material thickness t ≥ 1.2mm (0.047") and extrusions (unless otherwise specified on the drawings).

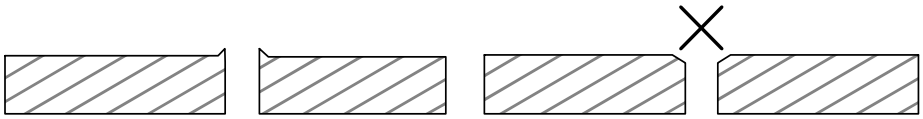
426 RIVETS	AD−3	AD−4	AD−5
$D=1.8\,d$	4.3mm	5.8mm	7.2mm
$h=0.4\,d$	0.96mm	1.28mm	1.6mm



$t \geq 1.2$mm

DE-BURRING: Using a drill bit to deburr thin material has tendency to countersink the hole, on the other hand, deburring with the flat side of a file can have a tendency to draw the edges of the hole: however, when using a numbered drill, the hole will be drilled oversize so it will not be necessary to force the rivets in the holes.

It is unusual for a drilled hole to leave fracture marks around the hole. The purpose of deburring is to assure contact between the parts: to remove burs that have accumulated between the parts.



EDGE FINISH

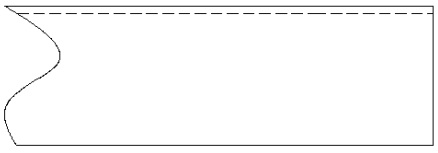
Sheet metal is cut with shear, snips, saw etc. As a general rule all primary structural tension members (i.e. structure subject to tensile stress in normal operation, wings spar caps, horizontal and vertical tail spar caps, fuselage longerons) shall not show the cutting mark: these are removed by lengthwise abrasion (body file, etc.)

Shear marks, (not saw marks) are acceptable on torsion and/or shear members and other secondary structural members.

On thicker sheets and plates shear marks are acceptable when a 100% visual inspection does not detect cracks (example: control horns, etc.)

Ends: Stringers, Stiffeners, Brackets and Angles:

The ends can be left:



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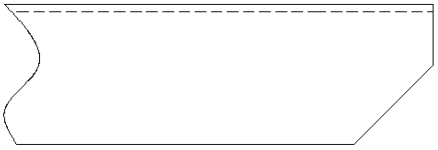

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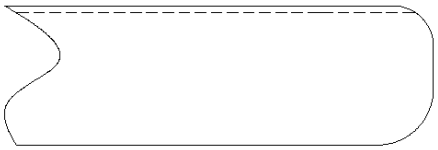
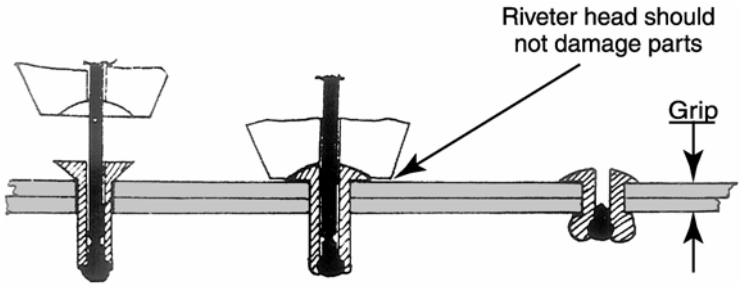


The blind rivets are set with a hand riveter or pneumatic riveter, machined with customized heads (nose piece) - it is easy, fast and quiet. They are used with access from one side only (no dolly or bucking bar is needed).
On the drawings; they are designated A4 and A5 and require minimum shear strength of 110 and 180 pounds respectively. The recommended rivets A4 and A5 (and supplied in the kit) are the Avdel "Avex" blind rivet. They have shear strength of 130 and 220 pounds respectively (stem removed). These aluminum rivets are corrosion resistant, they are multi-grip (you do not need many lengths for each diameter), and the stem is locked in (does not fall out).
The flush countersunk Avex rivet type A4 and A5 supplied in the kit need a specially machined head piece on the puller to get a low, protruding rounded head:



Zenair Denomination	Avdel Avex Ref.	Grip range
A4	1604-0412	0 to ¼" (0 to 6mm)
A5	1604-0514	0 to 5/16 (0 to 8mm)

To modify the riveter head: The objective is to bring the outer edge of the rivet down on the skin; the most effective is when the machined diameter of the nose piece is equal to the diameter of the rivet head. This will require two different size riveter heads, one for the A4 and another for the A5.

The machine depth is the distance from the sheet to the top of the rivet head; check the depth by pulling some rivets: if the nose piece marks and leaves a ring on the sheet then it is too deep; simply file the nose piece down. If there is a gap between the edge of the rivet head and the sheet then the nose piece is not deep enough.

Expect the standard (flat) riveter head (nose piece) to have been tempered by the manufacturer. Before it can be machined, de-temper (soften it) by heating it up with a blow torch until it glows. Let it cool off and proceed to machine the head. With aluminum rivets, it is not necessary to do any additional heat treatment to the nose piece.

CORROSION PROTECTION:

The CH aircraft have been designed to minimize corrosion as much as possible through the use of available materials (use of corrosion resistant 6061 alloy, no materials with large electro-potential difference in contact, etc.). If aircraft is based near the sea (salt or Na = sodium) or in a severely polluted industrial area (acid rain) the interior of the structure should all be primed with Zinc-Chromate primer or other equally effective primers after first degreasing the surface. This should obviously be done before riveting the various parts together.

When applying corrosion protection, the minimum application is to cover the rivet line where parts are riveted or bolted together (such as the overlap of the rib flange with the wing skins). Covering the complete part takes a little longer and adds additional weight; however, it will give a more uniform protection.

When to apply corrosion protection
In the kit, the parts are supplied in the bare state; they have not been treated with a corrosion inhibitor: during storage keep the parts in a dry environment at all times. First drill and cleco the parts as shown in the drawings, disassemble, and deburr. Apply the primer on the internal structure and let dry completely. The traditional method is to apply Zinc-Chromate primer on the individual parts.

Metal preparation for before priming
Gently scuff up the surface with a Scotch-bright general purpose hand pad 3M product P/N 7447+ (plastic pad similar to pad on back side of some sponges found around the kitchen!) do not use steel wool. De-grease the surface with a solvent on a clean rag, such as lacquer thinner. Apply the primer on both matting surfaces, let dry, then cleco the parts together for riveting. Only apply the primer on the inside surfaces, the primer may not be compatible with the top coat or paint!

Zinc-Chromate (Zn-Cr) primer
Read all safety labels: in some States Zinc-Chromate is prohibited. Zinc-Chromate primer is still readily available by mail order from most aircraft suppliers.

It comes in a concentrated paste much too heavy to brush on. You can either use the recommended solvent or simply use lacquer thinner as a reducer. With a spoon, scoop some out into another container, add solvent, and stir to dissolve the paste. Use a 2" bristle paint brush to apply the primer on the parts, if the solution looks too light, add in some more of the paste: all that is required is a thin coat of uniform color. Avoid a thick heavy coat that can also become brittle and flake off! A single application is applied to each part; let it dry completely before assembly.

Brushing the primer on the parts is one way to avoid breathing over-spray or vapors that may otherwise be associated with spraying!

OTHER NEWER APPROACHES / ALTERNATIVES

Cortec:
An alternative to Zinc-Chromate is Cortec VCI 373; this is a water based primer to treat the internal structure. This product lends itself to spraying with HVLP spray equipment.

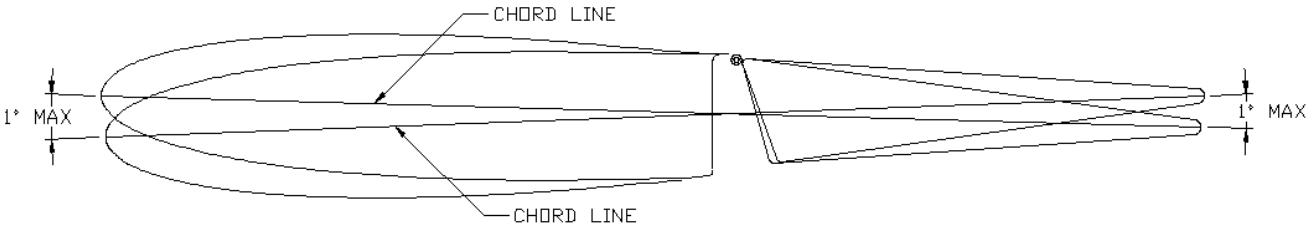
Corrosion X System: tel: 800-638-7361
An alternative to applying primers is Corrosion X System, this is sprayed after the sections are assembled to wait until the entire plane is built and spray corrosion resistant oil on the internal parts. The oil finds its way through all the seams and holes.

TWIST TOLERANCE:

CS #106

Elevator, Stabilizer: designed with zero twist

Max twist = 1 degree



	RECOMMENDED: MATERIAL/ SPECIFICATION	POSSIBLE ALTERNATIVE: MATERIAL / SPECIFICATION	**DO NOT USE**
ALUMINUM SHEETS	6061-T6 QQA 250/11	6061-T651 2024-T3 QQA250/4 2024-T352 2024-T4	6061-T4 7075 series 6063-T6
STEEL PLATE	4130 AISI 1025	4130N MIL-S 18729N (normalized) Low carbon steel Mild steel AISI 8630 MIL-S 18728	
BAR & RODS	6061-T6 QA 225/8	2024-T3 QQA 225/6 2024 –T4 2011-T3 QQA 225/3	
EXTRUSIONS	6061-T6 QQA 200/8	6061–T6511 2024-T3 2024-T4	6061-T4 6351-T4
DRAWN TUBE	4130N MIL-T 6736B (seamless S 6731 round tube)	AISI 8630 MIL-T 6732 MIL-T 6734A AISI 8735 to MIL-T 6733 AISI 4140, AISI 8740 etc. WW-T 700/6 MIL P-25995 pipes 5052-0 (fuel lines only)	6061-T4 6351-T4

Note: Specs. Updates, and/or equivalent specs are acceptable.

- Firewall: Any galvanized, low carbon steel is suitable.
  US std. gauge for sheet steel: gauge 26 = .46mm = .0187”
- Fiberglass Fairings use parts supplied by manufacturer.
  (Fairing: polyester + fiberglass)
- Windshield, Windows, and Canopy: acrylic and polycarbonate

ALUMINUM ALLOY / PROPERTIES

ALLOY & TEMPER	SPEC. SHEETS & PLATES	DIMENSIONS INCHES	DIMENSIONS mm	TOLERANCE ON THICKNESS (mm)	WEIGHT PER SHEET KG	WEIGHT PER SHEET LBS
6061–T6	QQA–250/11	.016"	.4	± .06	5	11
		.020"	.5		6.1	13.5
		.025"	.6		7.6	16.7
		.032"	.8		9.6	21
		.040"	1.0	± .075	12.6	27.5
		.063"	1.6	± .10	20	44
		.090"	2.3	± .11	27.4	60
		.125"=1/8"	3.2	± .12	40	88
		3/16"	4.8	± .16	60	132
		etc.				

STANDARD SHEET SIZE = 4 X 12 FEET = 1219 X 3660mm

UNIT WEIGHT (Kg/m^2) = DENSITY (Kg/dm^3) X THICKNESS (mm)

DENSITY = 2.7 Kg/dm^3 (6061)

WHERE APPLICABLE THE MANDATORY GRAIN DIRECTION IS SHOWN ON DRAWING: ◄——►

MECHANICAL PROPERTIES

TYPICAL MINIMUM "A" VALUE FROM MIL HDBK–5 (SHEETS AND EXTRUSIONS)

	ULTIMATE Ftu (kg/mm^2)	YIELD Fty (kg/mm^2)	ELONGATION e (%)	BEARING Fbru (kg/mm^2) e/D=2	BEARING Fbru (kg/mm^2) e/D=1.5
6061–T6	29.5	24.6	8	62	47
6351–T6 *	29.5	26.0	10	62	47

* See Alcan 51S (or CSA,HA5, GS11R)

NOTE: 1Ksi = 10^3 psi = 0.703 Kg/mm^2

- **Mild Steel Mechanical Properties**

Yield Strength Kg/mm²	Ultimate Tensile Strength Kg/mm²	Bearing strength Kg/mm²
25.3	38.6	63.3

Chromium-molybdenum (Chrom-moly) alloy:

- **Plate: ASI Alloy 4130N Mechanical Properties**

Yield Strength Kg/mm²	Ultimate Tensile Strength Kg/mm²	Elongation %	Bearing Strength Kg/mm²
53 min	67 min	12	98 min

- **Plate: 4130 annealed Mechanical Properties**

Yield Strength Kg/mm²	Ultimate Tensile Strength Kg/mm²	Elongation %
37 min	50 min	25

Steel parts: When “steel” is specified on the drawings, standard carbon alloy or mild steel, is suitable.

STEEL

BASE MATERIAL	ROD
Low alloy or carbon steel ("mild" steel) 4130N Chromium molybdenium steel 8630N and 8735 Nickel chromium, molybdenium steel	ER-80SD-2
18-8 stainless steel (exhaust) AISI 321 or equivalent	SS 347

- 4130N use normalized chrome-moly steel. After welding, let cool down in calm air (not a draft).

- Stainless steel (for exhaust manifold) AISI 321 (or equivalent 18-8 chom-nickel Weldable alloy, such as AMS 5510 etc., ASTM-A 167, etc, ASME-S 167, etc, Or MIL-E 1993, etc., or AISI 304, etc.)

ALUMINUM

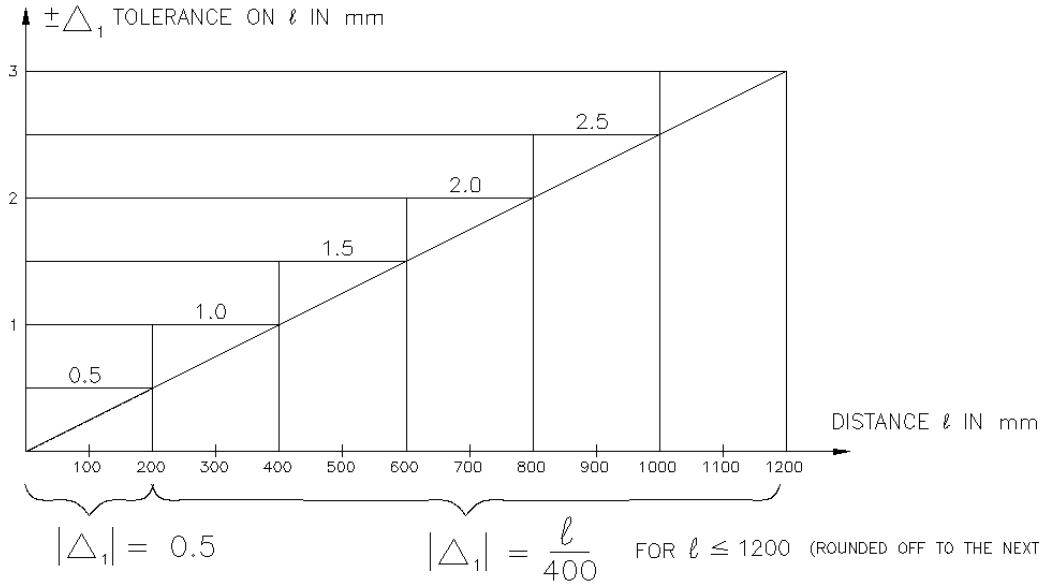
BASE MATERIAL	ROD
PURE ALUMINUM (1100 SERIES) MANGANESE ALLOY (3003 SERIES) MAGNESIUM + SILICON ALLOY (6000 SERIES) MAGNESIUM ALLOY (5000 SERIES)	SAME AS BASE OR 1100

WELDING: Unless you are a pro, have the welded parts welded professionally. Use electric or gas welding for 4130N and steel, TIG for the aluminum Fuel tanks.

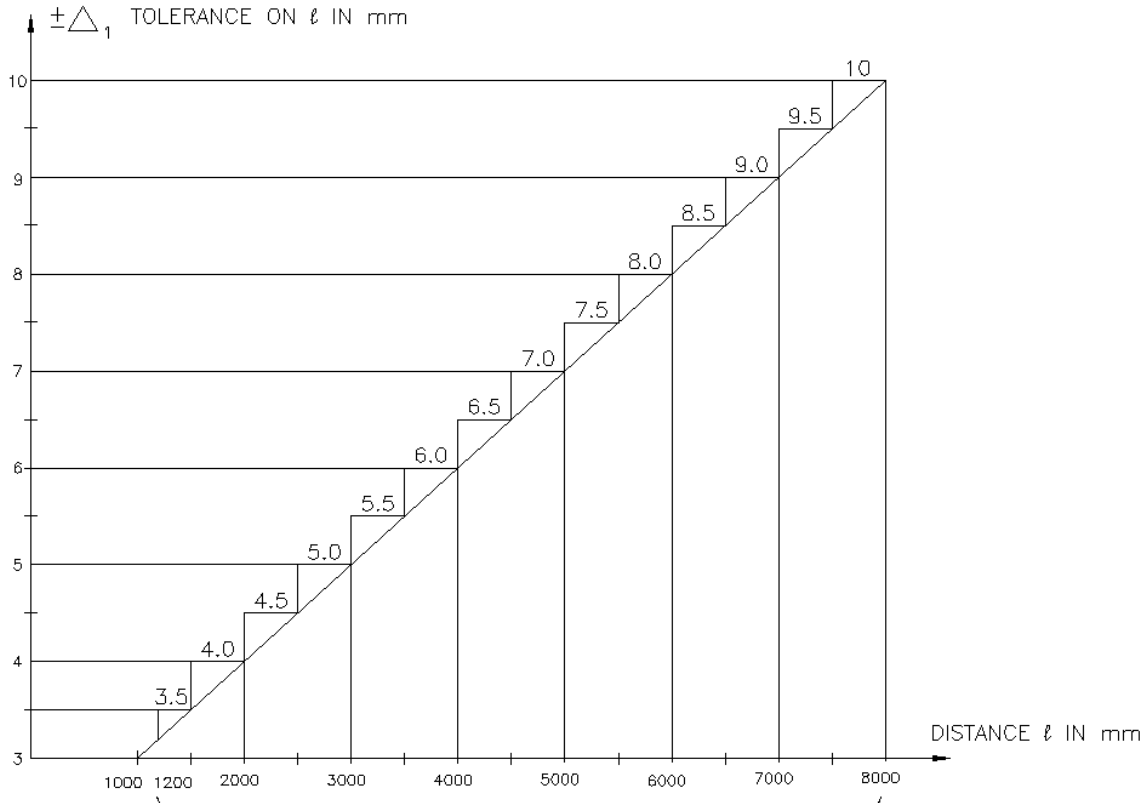
HEAT TREATMENT: Heat treatment is not a homebuilder's technique. Zenair aircraft have been designed so that no heat treatment is required by the builder.

The following system has been adopted in the absence of a general metric tolerance system, together with the specific tolerances of the CS and drawings where applicable.

Tolerance for length, for shearing or cutting sheets metal and extrusions:

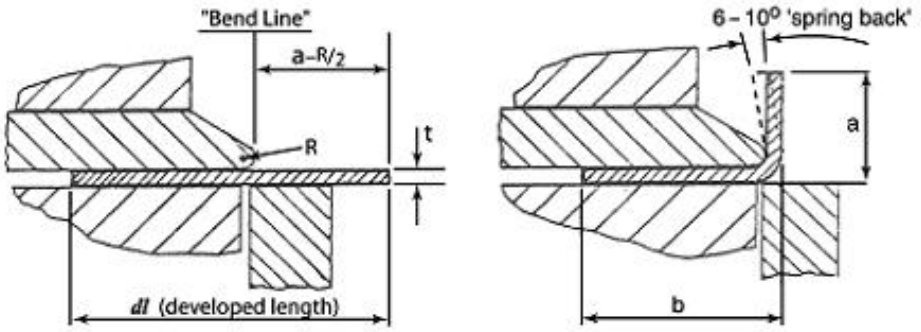


$|\triangle_1| = 0.5$ $|\triangle_1| = \frac{\ell}{400}$ FOR $\ell \leq 1200$ (ROUNDED OFF TO THE NEXT 0.5mm)

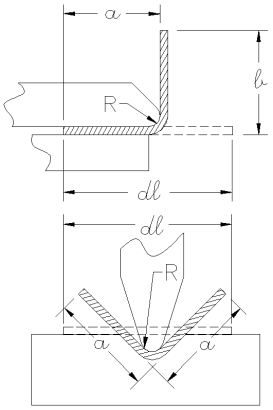


$|\triangle_1| = 2 + \frac{\ell}{1000}$ FOR $\ell > 1200$ (ROUNDED OFF TO THE NEXT 0.5mm)

Bending brake:



Press brake:



DEVELOPED WIDTH (LENGTH): $dl \approx a + b - (\frac{R}{2} + t)$

$dl \approx a + b - 2$ FOR R=3mm, $t \leq$ 1mm (0.040")

UNLESS OTHERWISE SPECIFIED ON THE DRAWINGS:

THE MINIMUM BEND RADIUS IS: $R_{min.} = 3 \times t$ FOR $t \leq$ 1mm (.040")

FOR ALL PRACTICAL PURPOSE: R = 3mm (1/8") FOR $t \leq$ 1mm (.040")

R = 6mm (1/4") FOR 1.6mm (0.063") $\leq t \leq$ 3.2mm (0.125")

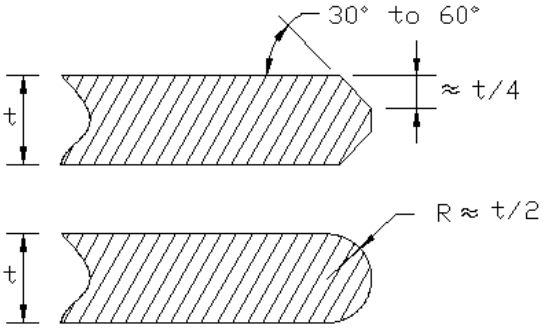
NOTE: FOR $t \geq$ 1.6mm (0.063"), THE EXTREMITIES ARE TO BE

CHAMFERED

or

ROUNDED

BEFORE BENDING



BENDING - ANGLES: GENERAL TOLERANCE

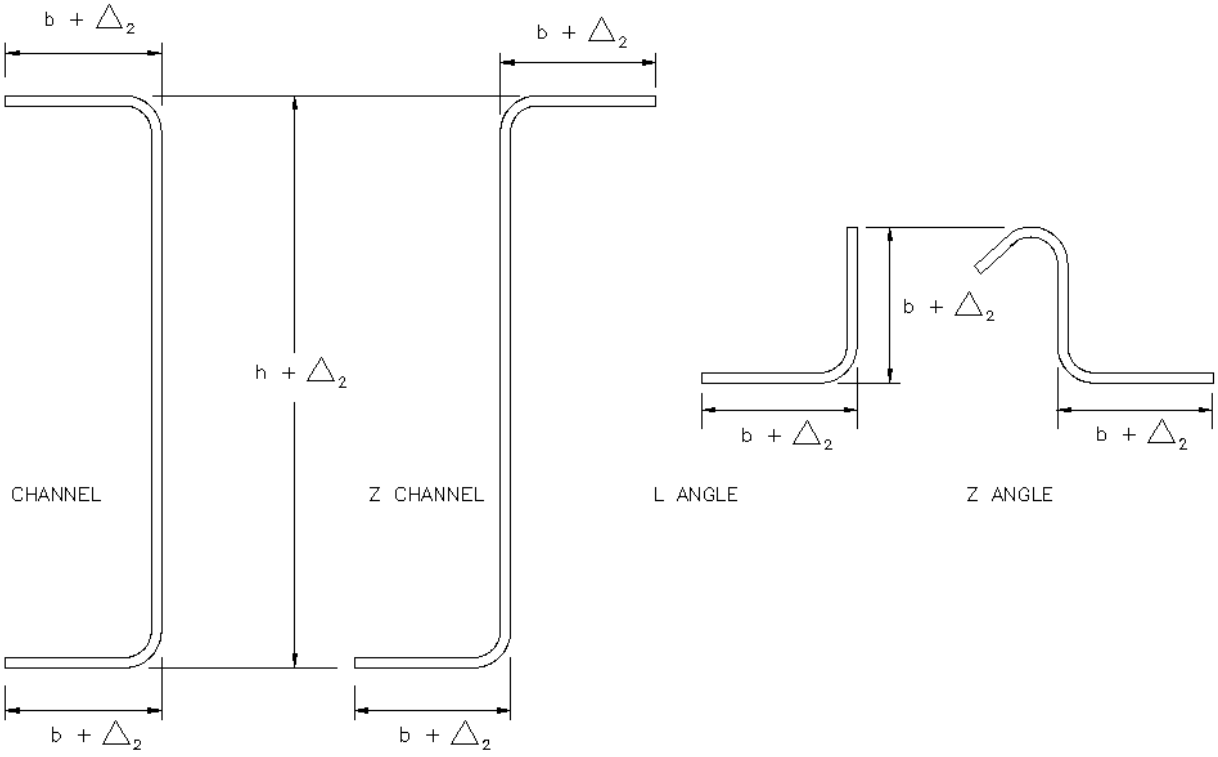
Note: 1.5mm (0.060”) is readily obtained in production and visually checked without precision measuring equipment.

Channel height & formed flange width:

$\triangle_2$ = MAX. ACCEPTABLE = $\pm$1.5mm

b = FLANGE WIDTH

h = HEIGHT



Built up assemblies:

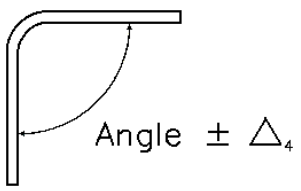
$$\triangle_3 \text{ MAX. ACCEPTABLE} = \pm \sum \left| \triangle_1 \right|$$

ABSOLUTE VALUE

SUMMATION OVER ALL PARTS

Angles:

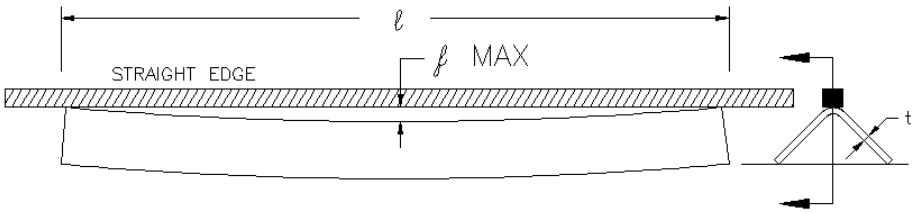
$\triangle_4 = \pm$ 1.7 DEGREES (3 DEGREE SLOPE)



BENT STRAIGHTNESS

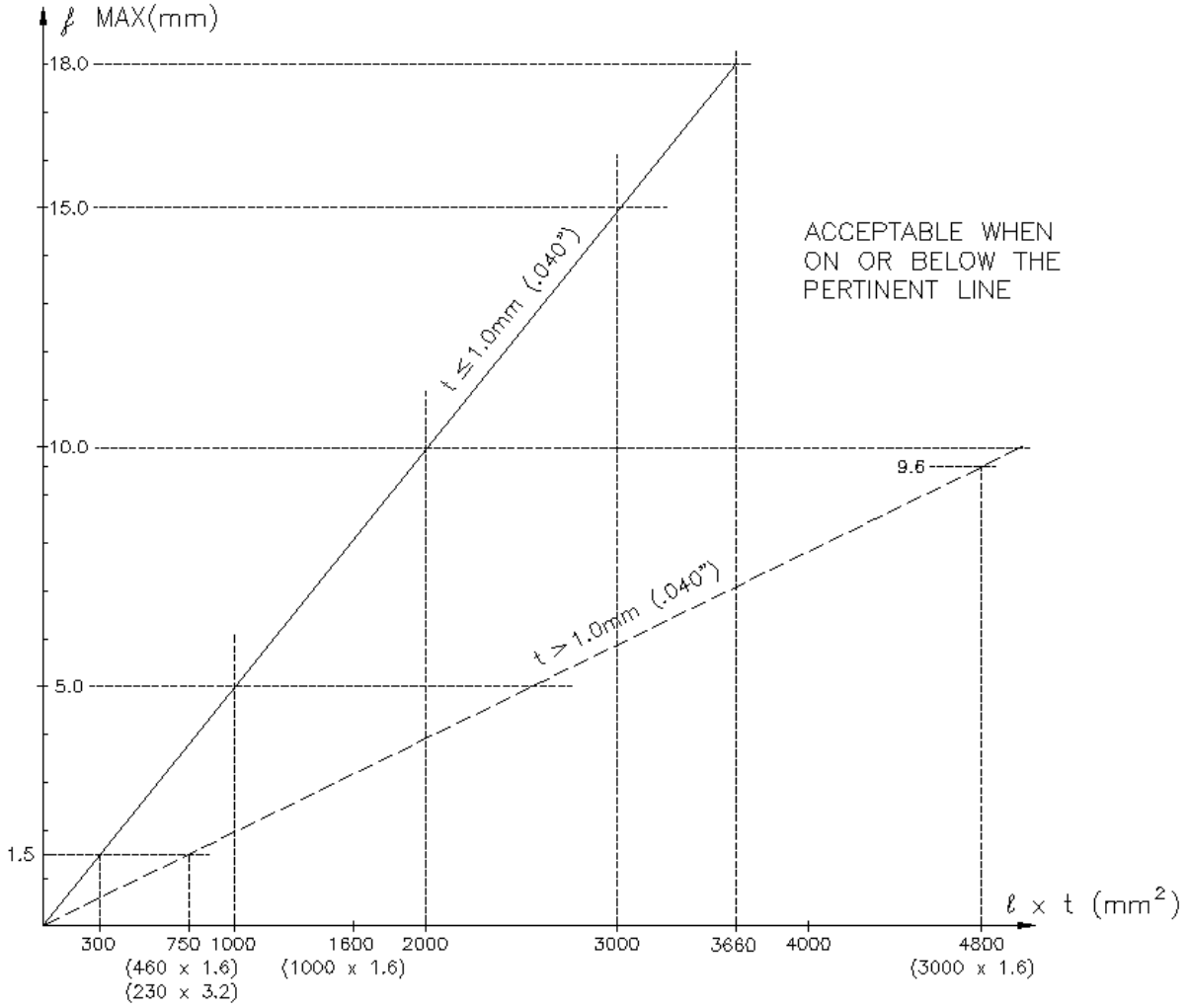
In addition to the tolerances given in CS #300, CS #301, and CS #302 the following tolerances apply:

– BEND STRAIGHTNESS

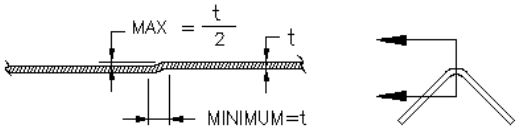


FOR $t \leq .040"$ $\quad f$ (MAX ACCEPTABLE) $= \frac{\ell}{200}$

FOR $t > .040"$ $\quad f$ (MAX ACCEPTABLE) $= \frac{\ell \times t}{500}$



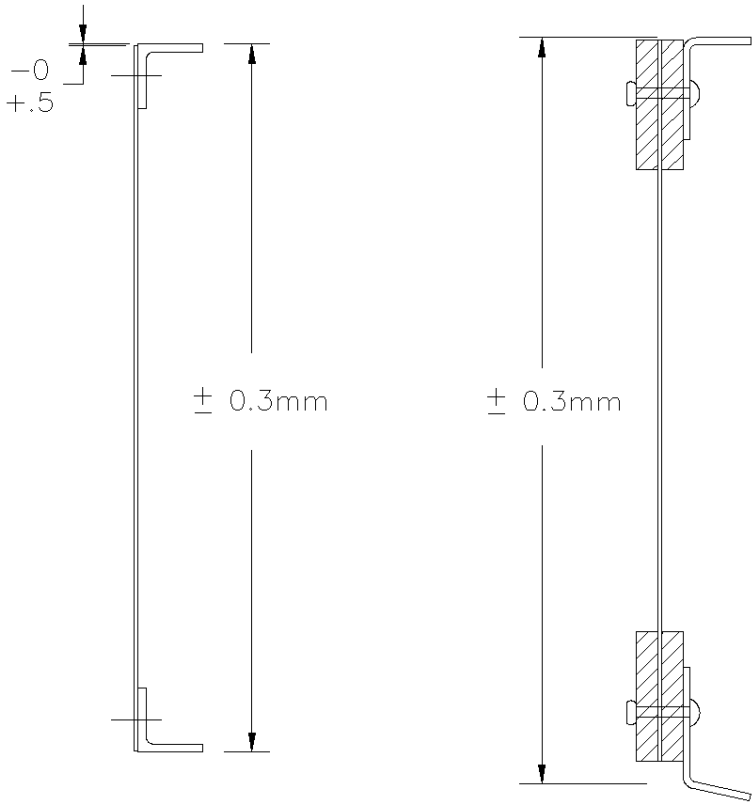
– LOCATION OF IMPERFECTIONS (DIE JOINTS, "DEEP" CRIMPS, ETC...) ABOVE GENERAL STRAIGHTNESS TOLERANCES APPLY, AS WELL AS FOLLOWING:



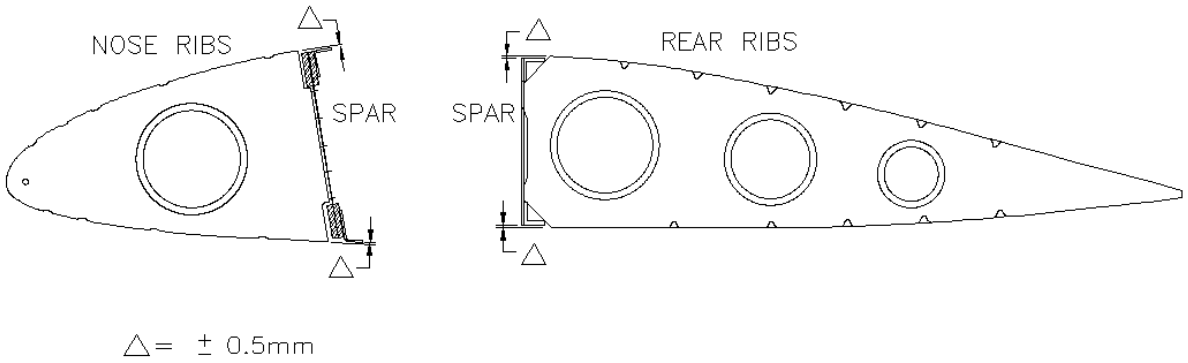
Close tolerance

Where required, dimensions marked in a box XX. X have a maximum acceptable tolerance of +/- 0.3mm

The built up wing spar has the following maximum acceptable tolerance:



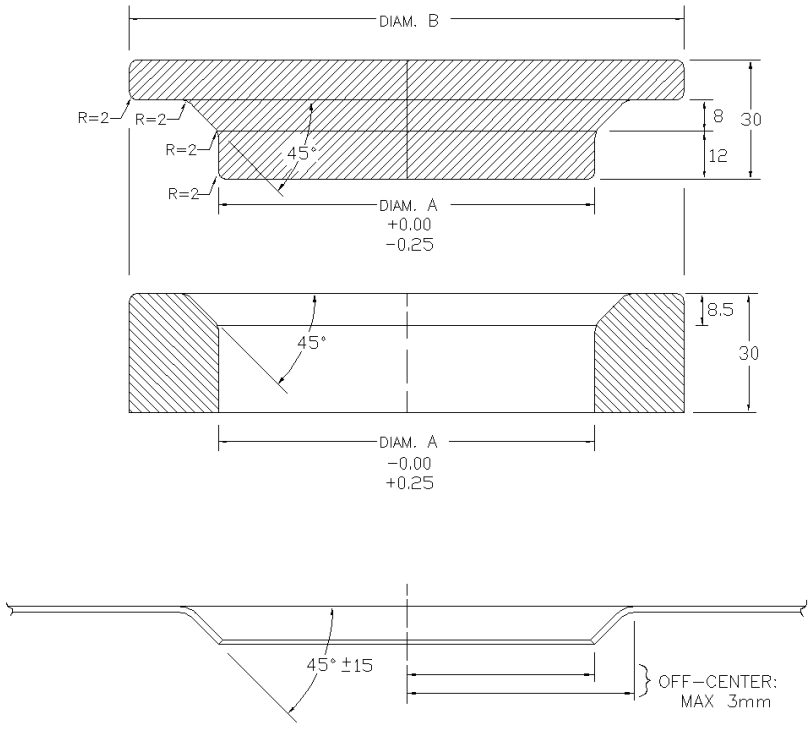
Rib height at the spar (to avoid waviness on wing and tail surfaces)

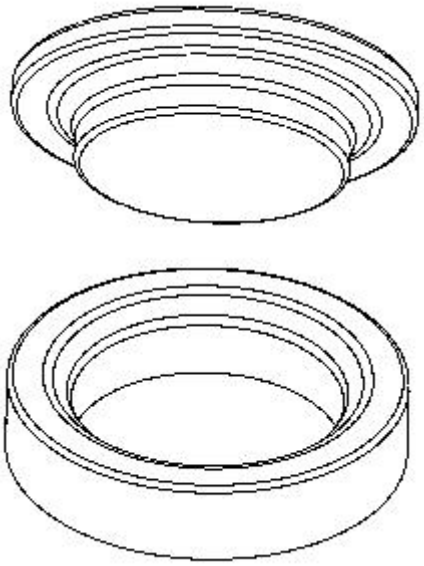


The holes F.51, F.65, etc. are cut out to the “flycut” diameter, then flanged with the following tools:

FLANGED HOLE	F.51	F.65	F.95	F.115
FLYCUT DIAMETER =	51.5mm	65.5mm	95.5mm	115.5mm
DIE DIAM. A =	51mm	65mm	95mm	115mm
DIE DIAM. B =	82mm	110mm	140mm	170mm

Carbon steel flanging die (male & female): finish with Emory cloth, R=2mm

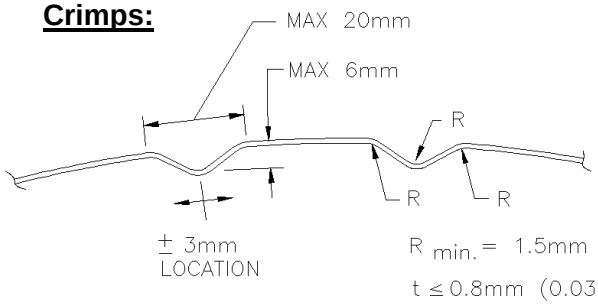


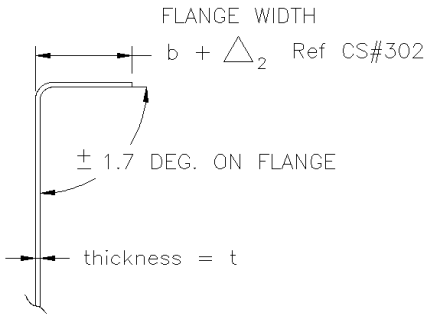


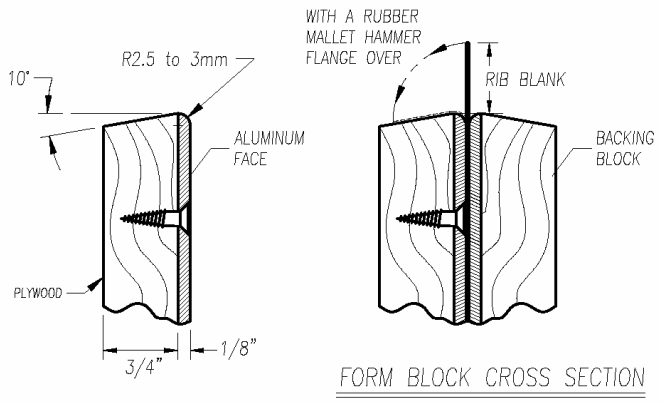
Above: Flanging dies.
Left: Flange hole in sheet.

Place the cut out sheet on the female die, insert the male die (self-centering) and use any press to create the flange (even a 3/4" bolt and two plates, or a heavy vise will do a good job on the relatively thin sheet metal used).

Crimps:

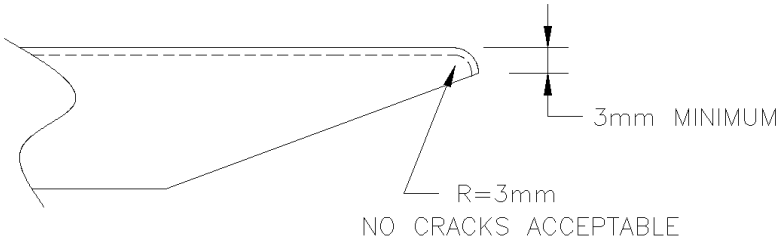




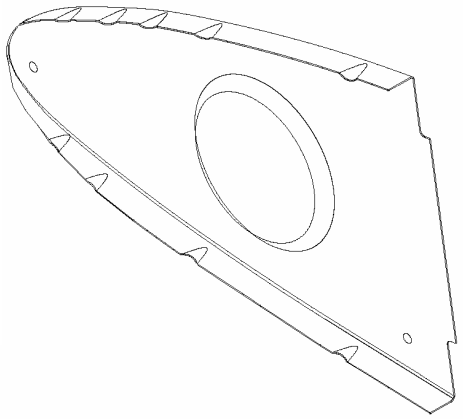


The drawings specify the forming blocks. Clamp the rib blank between the two corresponding blocks with ¼" bolts. The flange should protrude evenly. If there is more than 2 mm variation, start over again and be more careful. With the mallet, hammer the flange over.

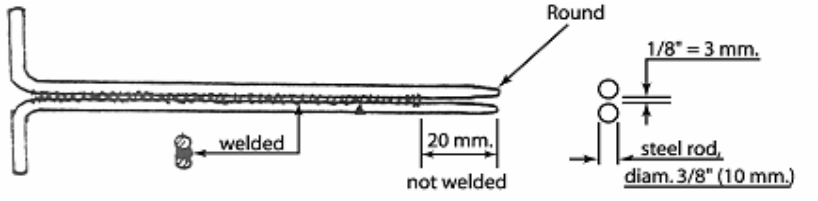
Leading Edge Flange:



At the leading edge of the rib, a small flange to position the profile LE radius and provide a stop to diagonal buckling.



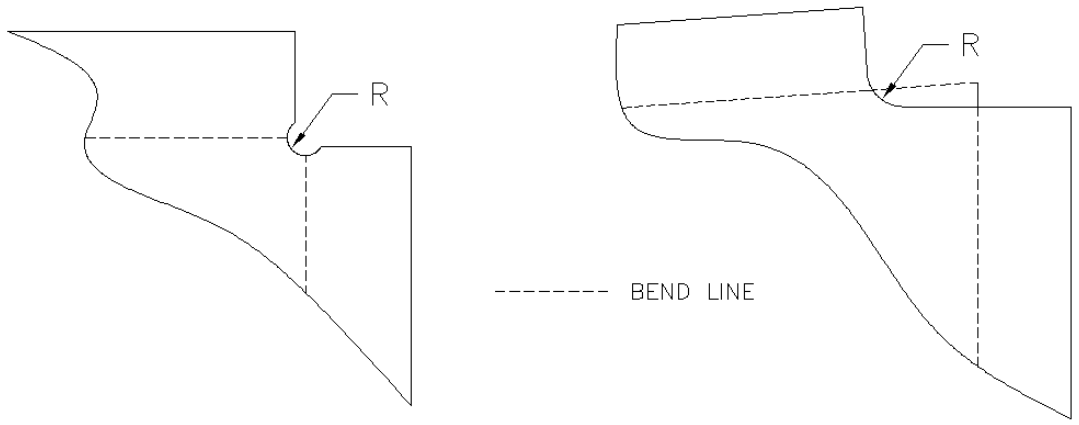
Crimping tool for "corrugating" the flanges:



Finishing the Ribs:
With a Bucking bar (rounded and filed edges) and plastic face hammer straighten out the flange nicely in-between the crimps. Add or remove to a crimp depth to flatten the rib web. Then add the lightening holes.

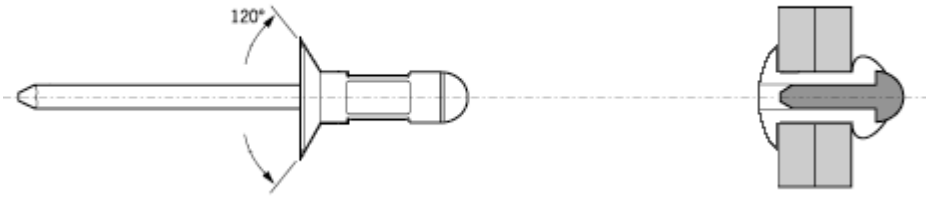
CORNER RELIEF CUTOUT

Cut outs to be bent require a corner relief hole or radius.



R_{min} = 3mm (diam 1/4") FOR $t \leq .040" = 1mm$

R_{max} = 6mm (diam 1/2") FOR $t > .040"$

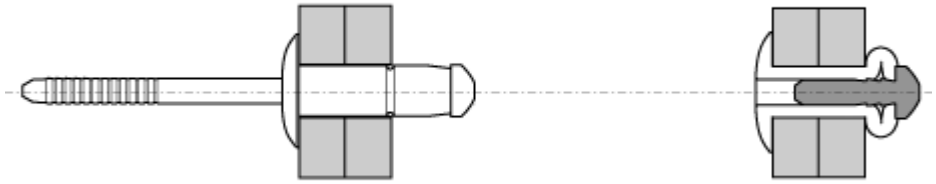


CODE	MAKE	BRAND	REFERENCE	DIAMETER	DRILL BIT	CODE
A4	AVDEL	AVEX	#1604-0412	3.2mm (1/8")	#30	A4
AF4	same		same			AF4
A5	same		#1604-0514	4mm (5/32")	#20	A5
AF5			same			AF5
A6	same		same	4.8mm (3/16")	3/16"	AF4

AF4 and AF5 are set with a flat nose piece on rivet puller (flush head, countersunk or dimple material at 100degrees, same as AN426 rivets).

A4 and A5 have a low-protruding round (domed) head formed with the special nose on the riveter tool, see CS #104.

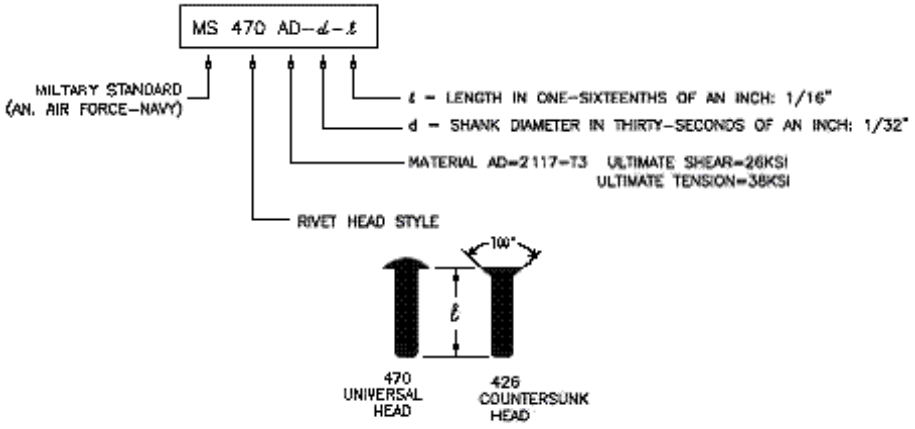
Note: The original head of the rivet is used on the outside of the aircraft, and/or the thinnest material side for material thickness t ≤ 1.0mm unless otherwise specified. For t > 1.0mm, it is left to the choice of builder.



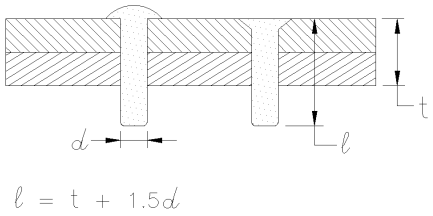
CODE	MAKE	BRAND	REFERENCE	DIAMETER	DRILL BIT
AS5	Avinox	AVEX	#0BE61–00512	4mm (5/32")	#20

SOLID SHANK 2117 (AD) RIVETS: Are set in the T3 (or T4) condition, with a rivet press, hand pneumatic riveter, etc. at the choice of the manufacturer.

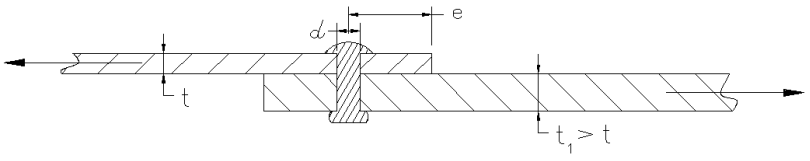
- The drill diameter and hole tolerance is given on CS #102
- The length of the rivet is chosen to meet the acceptable set rivet dimension on CS #403

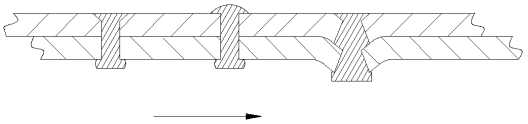


As a rule of thumb:



- All AD (and only AD) rivets have a small dimple in the center of the original head (its purpose is for identification, but is very handy to center the drill when drilling out is required!)





Increasing joint shear strength at constant diameter d constant thickness t (increase is small)

RIVET DIAMETER mm inches	2.4 3/32"	3.2 1/8"	4.0 5/32"	4.8 3/16"
NOMINAL SHEAR Kg	98	176	270	390
MINIMUM THICKNESS t(mm)	.8	1.0	1.2	–

Nominal single sheet strength

The minimum thickness t, is given for an ultimate bearing strength of 47 kg/mm² (67Ksi) for 6061-T6 with e/d=1.5.

It is the minimum thickness at which the nominal ultimate shear strength of the 2117-T3 rivets equals the tear-out strength of the sheet metal with an edge distance of 1.5 (=e/d)

(rivets 2117–T3: Ftu = 26.7 Kg/mm^2 (38 Ksi), Fsu = 19.6 Kg/mm^2 (28 Ksi)

For $t < t_{mini.}$ the ultimate load is smaller (tear–out)

For $t > t_{mini.}$ no improvement (rivet shears off)

For larger edge distance, and/or stronger material, $t_{mini.}$ increases

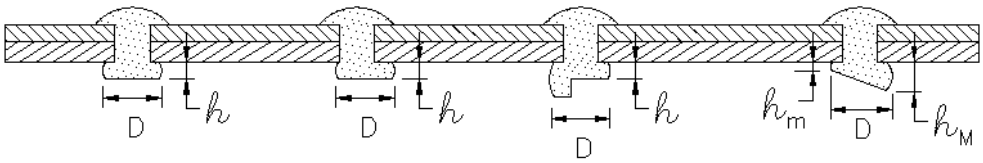
For countersunk rivets in dimpled sheet metal, the joint strength is slightly increased (larger bearing area).

For more design detail: refer to MIL HDBK–5

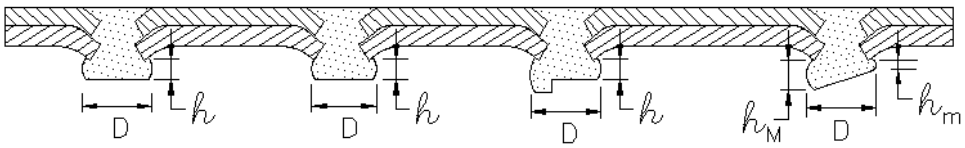
SOLID RIVET - SETTING DIMENSIONS

TOLERANCES

RIVET SIZE	NOMINAL D=1.5d	NOMINAL h=0.5d	MAX ACCEPT. D=1.7d	MAX ACCEPT. h=0.8d	MIN ACCEPT. D=1.25d	MIN ACCEPT. h=0.3d
AD−3	3.6mm	1.2mm	4.1mm	2.0mm	3.0mm	0.7mm
AD−4	4.8mm	1.6mm	5.4mm	2.6mm	4.0mm	0.95mm
AD−5	6.0mm	2.0mm	6.7mm	3.2mm	5.0mm	1.2mm
AD−6	7.1mm	2.4mm	8.1mm	3.8mm	6.0mm	1.4mm

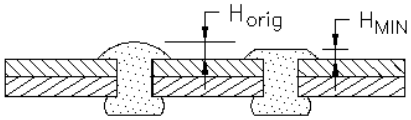


$$h = \frac{h_M + h_m}{2}$$

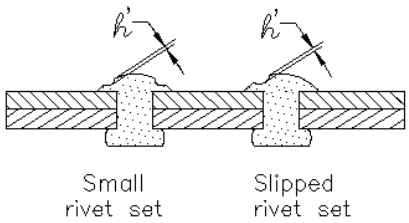


DAMAGED ORIGINAL RIVET HEAD

– FLATENED OR GROUND HEAD $H_{MIN} = 0.3d$



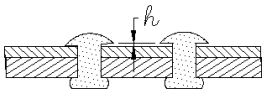
– MARKED HEADS are acceptable when only slightly marked $h' \leq 0.3\, H_{orig}$



RIVETS 470	AD−3	AD−4	AD−5	AD−6
H_{orig}	1.0mm	1.4mm	1.7mm	2.0mm
h'_{MINI}	0.3mm	1.6mm	0.6mm	0.7mm

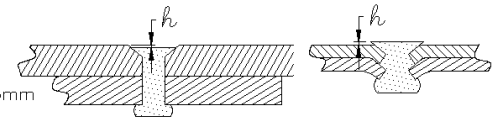
– GAP UNDER THE HEAD

acceptable when $h \leq 0.3$mm



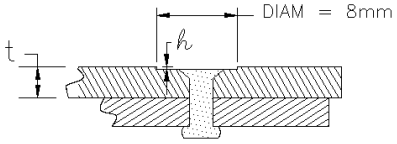
– UNFLUSHNESS OF THE RIVET

acceptable when $h_{MAX} \leq \pm 0.3$mm

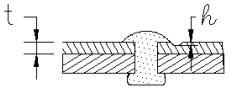


– UNDERGROUND FLUSH RIVETS

acceptable when $h \leq 0.1$mm X t
(common grinder diameter = 8mm)



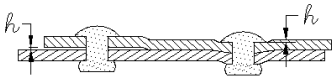
– MARKS ON STRUCTURE (setting die)



t	1.2mm	1.0mm	0.8mm	0.6mm	0.5, 0.4mm
h	0.25mm	0.20mm	0.15mm	0.12mm	0.10mm

– DISTORTED BY PRESSURE

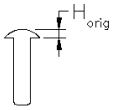
acceptable when $h \leq 0.2$mm



same for 426 rivets

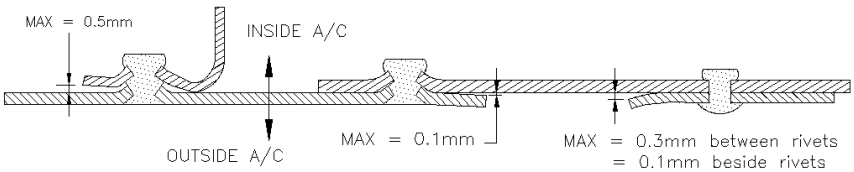
– DISTORTED

acceptable when $h \leq 0.3 H_{orig}$

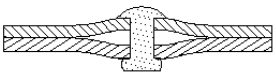


RIVET SIZE	AD–3	AD–4	AD–5	AD–6
H_{orig}	1.0mm	1.4mm	1.7mm	2.0mm
h_{MAX}	0.3mm	0.4mm	0.5mm	0.6mm

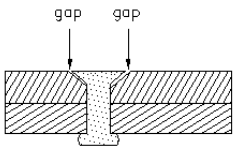
– SHEET METAL EDGE LIFTS UP:



UNACCEPTABLE IMPERFECTIONS



– Disjointed sheet metal is not acceptable when the bulging due to internal rivet growing, burs, chips, etc. is visibly obvious:

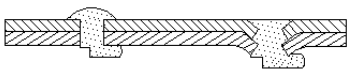


– Excentric or oversized machines countersking is not acceptable when the gap is visisble: use next larger size rivet.

– All the rivets which do not meet the tolerance specified in CS 403 and 404.

– CRACKED HEADS (orignal or formed) are not acceptable. When the heads crack systematically, supply new rivets.

– The following examples are inacceptable formed heads:



For corrective action: see CS#305

– shiming: see CS#311 page 3/4

The drawings specify the usual North American airframe bolts type AN or MS 3 through 20, which have a minimum tensile strength of 88 kg/mm² (125ksi) and a shear strength of 53kg/mm² (75 psi).

They may be replaced by any equivalent standard bolt (see CS#406)
To be consistent with the AN denomination the following applies:

BOLT Diameter	Thread per inch + quality	Tolerance on Diam	CASTLE NUT–shear AN320	LOCKNUT Nylon AN365	WASHER standard AN960	WASHER thickness t
3/16" 4.8mm	10–32 UNF–3A	+.000 −.012"	–3	–1032	–10	1.6mm 1/16"
1/4" 6.35mm	1/4–28 UNF–3A		–4	–428	–416	
5/16" 7.9mm	5/16–24 UNF–3A		–5	–524	–516	
3/8" 9.6mm	3/8–24 UNF–3A		–6	–624	–616	
7/16" 11.1mm	7/16–20 UNF–3A		–7	–720	–716	
1/2" 12.7mm	1/2–20 UNF–3A		–8	–820	–816	

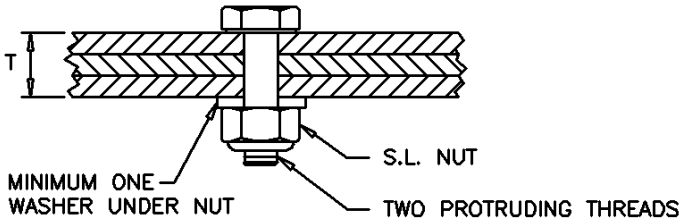
→ AN310 (Tension type castle nut)
→ AN315 (JAM NUT)

Following table is based on Ftu = 88kg/mm² (125 ksi)
Fsu = 53 kg/mm² (75ksi) Fsu = Ftu/1.66

BOLT Diameter	BOLT AN NUMBER	Ult. tensile (kg)	Ult. single shear (kg)
3/16" 4.8mm	3	1023	939
1/4" 6.35mm	4	1892	1669
5/16" 7.9mm	5	3044	2608
3/8" 9.6mm	6	4672	3756
7/16" 11.1mm	7	6282	5103
1/2" 12.7mm	8	8573	6668

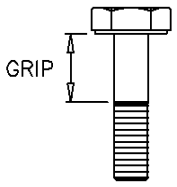
Note: The actual strength of the bolt joint is a function of the material characteristics (bearing, shear strength) and geometry (edge distance, e/d, thickness, t, etc) similar to the riveted joints.

- **Minimum: no washer under the head, one washer under the nut.**
- **Maximum: one washer under the head, three washers under the nut**
- **Minimum: Two threads protruding over the locknut.**

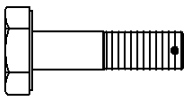


No threads in the parts to be joined.

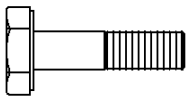
The bolt grip is the clean (unthreaded) length of the shank; it should not be shorter than the total thickness (T) of the parts to be assembled. AN BOLT LENGTH come by increments of 1/8" = .125" Washers AN960-X16 washers are 1/16" =.063" thick (2 washers = 1/8")



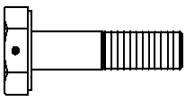
DASH NO.	AN3	AN4	AN5	AN6
3	.0625	N/A	N/A	N/A
4	.125	.0625	.0625	N/A
5	.25	.1875	.1875	.0625
6	.375	.3125	.3125	.1875
7	.5	.4375	.4375	.3125
10	.625	.5625	.5625	.4375
11	.75	.6875	.6875	.5625
12	.875	.8125	.8125	.5625
13	1	.9375	.9375	.8125
14	1.125	1.0625	1.0625	.9375
15	1.25	1.1875	1.1875	1.0625
16	1.375	1.3125	1.3125	1.1875



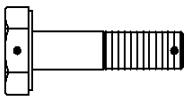
HOLES: DRILL SHANK
EXAMPLE: AN4–5



NO HOLES
AN4–5A



DRILLED HEAD
AN4H–5A



DRILLED HEAD & SHANK
AN4H–5

CASTLE NUT
AN310

SELF LOCKING NUT
AN365

FLAT WASHER
AN960

COTTER PIN
AN380

FINE THREAD SERIES

BOLT SIZE	STANDARD TYPE NUT MS20365, AN365	ALTERNATE VALUE AN310	SHEAR TYPE NUTE MS20364, AN316	ALTERNATE VALUE AN320
	inch pounds	inch pounds	inch pounds	inch pounds
AN3	20–25	20–28	12–15	12–19
AN4	50–70	50–75	30–40	30–48
AN5	100–140	100–150	60–85	60–106
AN6	160–190	160–260	95–110	95–170

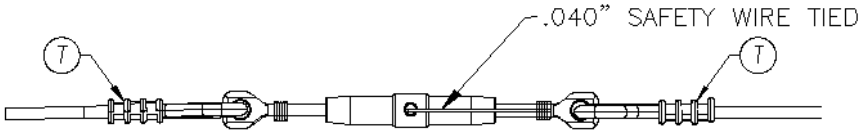
Drag torque: Run the nut down to near contact with the washer and check the friction drag torque required to turn the nut. Add the drag torque to the desired torque. This is referred to as the final torque which should register on the indicator or setting on the torque wrench.

These torque values are derived for oil-free cadmium-plated threads, and are recommended for all installation procedures. They are not to be used for checking tightness of installed parts during service.

When using AN310 and AN320 castellated nuts where alignment between bolt and cotter pin holes is not reached using normal torque values, use alternative torque values or replace nut.

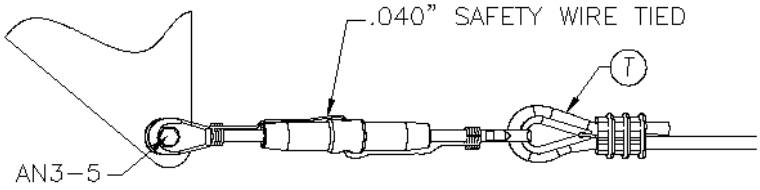
Ref. Table for AN 365 nuts on AN-3 to -8 bolts, dry (not oiled) threads – refer to Chapter 7 section 3 of AC43.13-1B

Nutpates: AN366, MS 21069



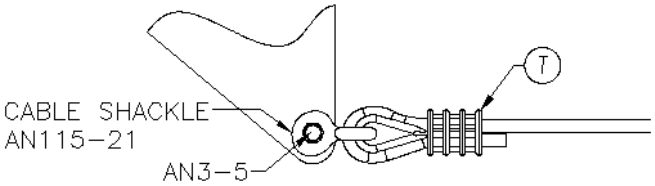
DETAIL E

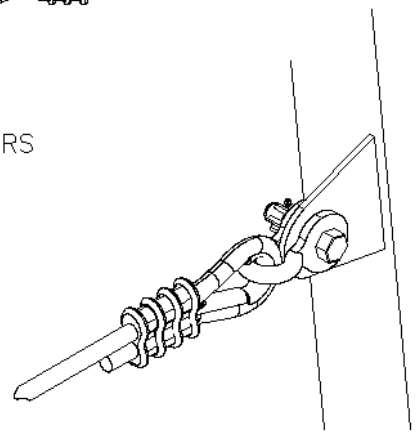
ASSEMBLY AN140
BARREL TURNBUCKLE AN155-22S
CABLE EYE END AN170-22RS
CABLE EYE LEFT AN170-22LS



DETAIL F

ASSEMBLY AN130
BARREL TURNBUCKLE AN155-22S, AN161-22RS
FORK LEFT AN170-22LS, CABLE EYE RIGHT AN161-22RS
AN3-5 BOLT WASHER AN960-10 CASTLE NUT
AN310-3 COTTER PIN AN380-2-2

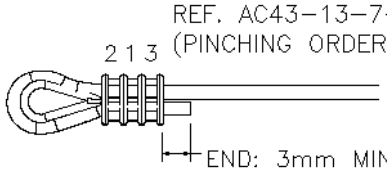




DETAIL (S)
CABLE SHACKLE TO
RUDDER PEDALS

DETAIL S

CABLE SHACKLE AN115-21 WITH AN3-5 BOLT WASHER AN960-10,
CASTLE NUT AN310-3 COTTER PIN AN380-2-2

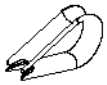


USE NICOPRESS
SWAGING TOOL

DETAIL T

1/8" CABLE THIMBLE, NICOPRESS SLEEVE

NICOPRESS: 18-3M (COPPER)
24-3M (ZINC PLATED COPPER)
S-11-004



1/8" CABLE THIMBLE
(AN100-4)
F-15-204

CABLE SHACKLES
AN115-21

CONTROL CABLE
1/8"X7X19 GALVANIZED, 2000 LBS
or STAINLESS TO MIL C5424 1760 LBS

Cables

Cables should be tensioned using a properly calibrated tension gauge. Read and follow the instructions provided by the tension gauge manufacturer to ensure the proper tension value has been achieved. See the aircraft drawings for specific cable tensions.

Control cables are prone to stretch over time therefore the cable tension should be checked on a regular basis. Check the cable tension after the first flight, at 25 hours, 50 hours, and during each annual inspection thereafter to prevent the control cables from becoming loose.

Push Rods

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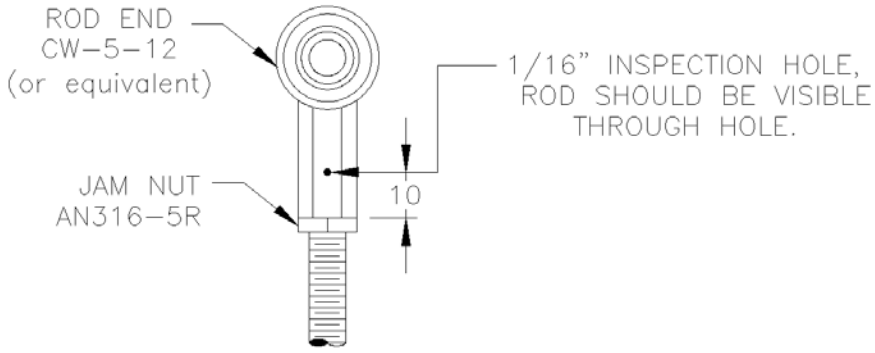
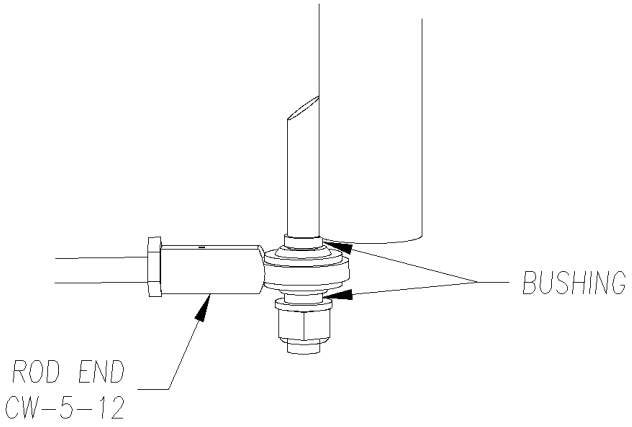
Rod Ends

Rod Ends CW-5-12 or equivalent should be used on the end of control rods. A witness hole should be drilled through the rod end at least 10mm from the bottom of the rod end and threads should be visible through the witness hole. A Jam Nut, AN316-5R, should be installed and tightened against the rod end to prevent the rod end from unintentionally turning on the threaded rod.



If necessary, bushings should be installed to prevent the rod end from binding against the attached part.



Piano Hinge

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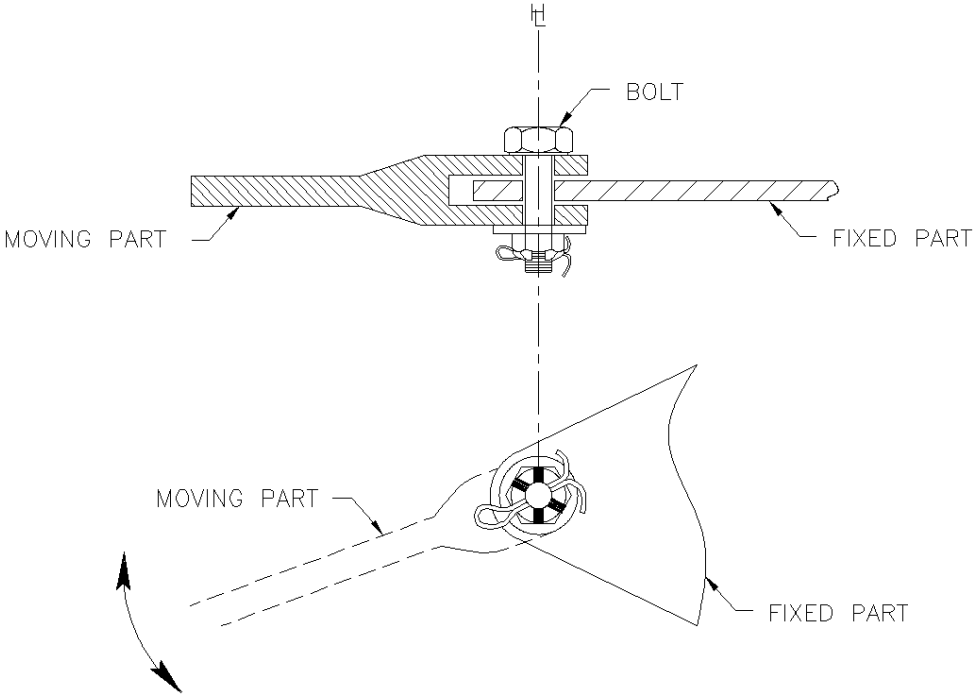
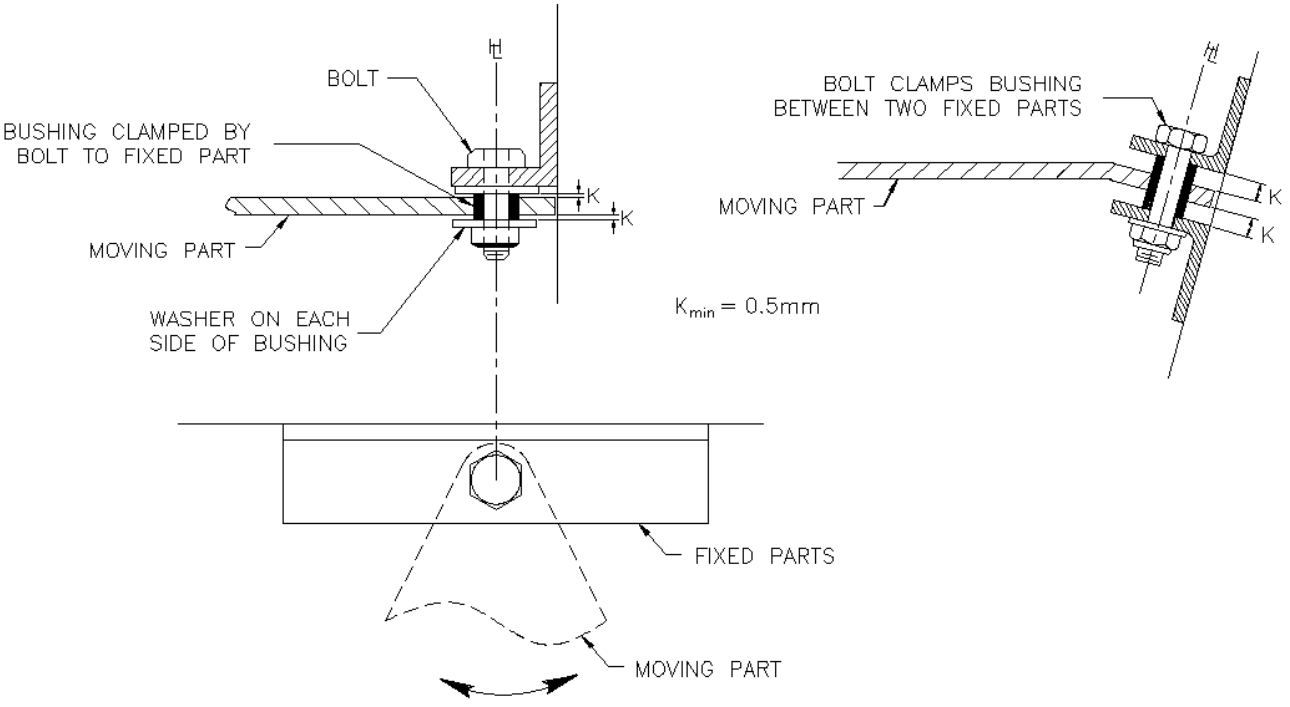
DEFINITION OF A BOLT SUBJECT TO ROTATION:

1) A bolt subject to rotation is defined as a bolt whose shank can rotate on its bearing surface during operation of the airplane:

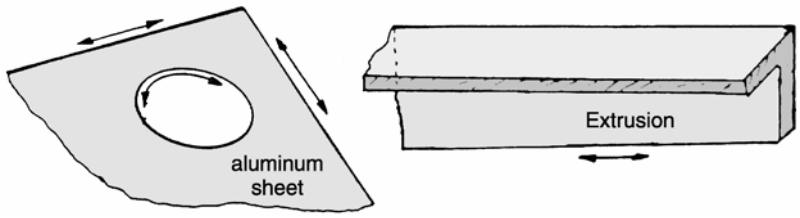


2) A bolt which clamps a bushing to a fixed parts is not a “bolt subject to rotation”
NOTE: That in this case the outside of the bushing, not the bolt, is the fixed bearing surface of the rotating part



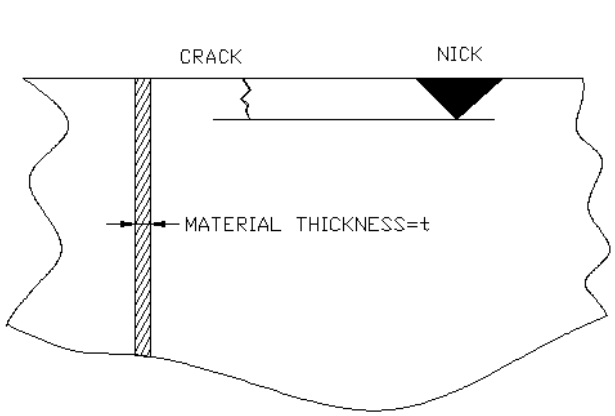
Scratches:
a) Spars and longerons: All transverse scratches and nicks must be removed by filing and sanding lengthwise.
b) All other parts: Unless deep, scratches will not reduce the fatigue-life of the structure

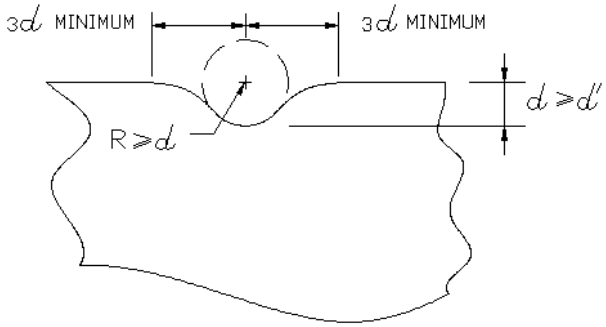
Especially IMPORTANT: Any scratch and/or nick must be removed from the spars and fuselage longerons by filing and sanding LENGTHWISE.



CRACKED PARTS: Replace every part which reveals cracks after manufacturing. Cracks may occur when bending with too small of a radius (R<3 x t), forgetting to sand the edges smooth, mishandling (tool or other marks…).

Cracks On all parts an acceptable way to remove a nick or a crack, is lengthwise filing and check to following tolerance:





NOTE: WHEN d' OR d IS LARGER THAN 3t, THE ABOVE CORRECTIVE ACTION IS INACCEPTABLE, AND THE PART MUST BE REPLACED.

Replacing rivets: Rivet replacing applies to solid and/or blind rivets

When the rivets are outside the specified tolerance and cannot be reset in a satisfactory way, they are drilled out, the hole tolerance may need checking, and new rivets are set.

DRILLING OUT RIVETS:

- Use the same size drill bit as the original hole (#30 for A4)
- Carefully drill off the rivet head (remove rivet head from drill bit).
- Turn the drill by hand (or apply short power bursts on the trigger) to push the remainder of the rivet out.
- For blind rivets, check that the drill bit does not made contact with the steel mandrel in the rivet, this could cause the drill bit to slide and elongate the hole.
- When the hole tolerance is unacceptable, the next larger size rivet is used.

Edge distance: With oversize rivets, the distance 'e' is the original value as specified on the drawings.

NOTE: Check the edge distance on the larger rivet is greater than 1.5 x rivet diameter.

Rivets replaced by bolts

When rivet(s) have to be replaced (or added) and it is questionable if the rivet(s) can be set correctly and/or easily, the rivet(s) may be replaced by bolt(s).

Use AN3 bolts

"Cherry" rivets may be used to replace the rivets specified on the drawings.

Adding rivets

When changing the rivet or going to the next size up is not practical or possible, the unacceptable rivet is left as is and one additional rivet is set in the same rivet line or pattern, at a distance of minimum 3d, measured from the center of the bad rivet to the center of the new hole, and a maximum ½ x pitch from the defective rivet.

– make sure the additional rivet has also acceptable edge distance.

If required (insufficient edge distance, thin sheet metal buckling, etc…) additional rivets may be drilled and set between the standard rivets as per drawings. Use the same diameter and type of rivets.

Note: Minimum edge distance = 1.5 x rivet diameter.

Minimum spacing between rivets = 3 x rivet diameter.

SKINS AND JOINTS

CS #604

It may be necessary on the skins (wings, control surfaces, and fuselage) to add joints for manufacturing and/or repair purposes.

The use of several smaller skins instead of one “large” skin as shown on the drawings is acceptable when:

- The skins are of the same thicknesses or thicker,
- They overlap a stiffener, rib, bulkhead, etc… with the correct edge distance for the fasteners,
- The largest rivet size and the smallest rivet pitch of the adjacent panel edges are used on the new joints (unless otherwise authorized by the designer).

When in doubt, use common sense: use the thickest skin, the largest rivet diameter and the smallest pitch!

INSPECTION PANELS (ACCESS HOLES)

Box cutout with L angles.
Rivet or use nutplates to secure cover.

SHIMMING

The maximum allowable shim thickness is equal to the fastener diameter.

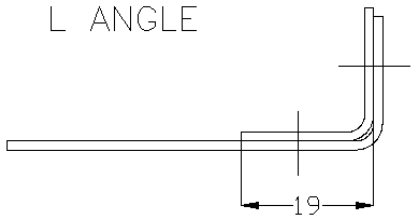
Example: Fastener is AN4 bolt: Max shim thickness = ¼”

When and where required, shims may be used to obtain a good fit and/or finish between parts which do not match perfectly.

DOUBLERS

ANGLE DOUBLER: When the original flange is too short, there are missed drilled holes in the flange (part was installed upside down); an angle doubler may be used when:

- the thickness of the doubler is equal to the thickness of the doubled part
- the rivet pitch specified in the drawings is maintained



This present edition of the Construction Standards (CS) is a second draft. We hope that it is a useful resource in building, maintaining and/or repairing your Zenair light aircraft.
We would like to hear your comments about this draft, and suggestions on how we can improve this manual in future editions.
Please use the space below for your comments and suggestions:

Thank you for your feedback.

Please return the completed form to:
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Email: info@zenithair.com