A&P TEST READY

VOLUME 2

THE STUDY GUIDE

AIRFRAME

Structures · Systems · Inspection



FAA Aviation Mechanic Written Test

Complete ACS knowledge coverage · Worked examples · Glossary & Index

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A&P Airframe: The Study Guide

Volume 2 — Complete Text for the FAA Aviation Mechanic Airframe Written Test

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How to Use This Book

This volume covers everything on the FAA Aviation Mechanic Airframe written test. It follows the knowledge elements of the Airman Certification Standards (FAA-S-ACS-1, Area II), and every one of the 199 Airframe elements is mapped to the section that teaches it. The map is in the Appendix at the back of the book, and each section also lists its ACS codes under the heading.

Chapters run from basic to advanced. The book opens with the structures you can see and touch (metal, controls, wood, fabric and composites), moves to the mechanical systems (landing gear, hydraulics, inspection, environmental systems), then to instruments, avionics, fuel and electrical systems, and closes with ice, fire, rotorcraft and water systems. Each chapter opens with learning objectives and its ACS code, and closes with a summary, review questions with answers, and a pointer to the matching practice topic in the A&P Test Ready Airframe kit.

- **Highlighted terms** are defined where they first appear and again in the Glossary.
- **Worked examples** are set in shaded boxes. Cover the solution and work them yourself first.
- **Rules** are the points examiners test most. **Exam traps** list the wrong answers the test is built to catch. **Key numbers** boxes collect the values worth memorizing.
- Nearly every concept has a figure. Diagrams are drawn to show real proportions and real component arrangements; photographs show what the hardware looks like on an aircraft.
- The **Definitions** page collects the formulas and regulatory definitions to memorize. The **Index** points to every section where a term is used.

This book is a study aid for the written test. Always follow the manufacturer's current instructions and FAA-approved data when working on an aircraft. Numbers quoted here are typical values for learning; the aircraft's own manual governs.

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Chapter 1. Metallic Structures

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CHAPTER OBJECTIVES

Learning objectives. After studying this chapter you should be able to:

1. Describe truss, monocoque and semimonocoque structures and name the parts that carry load in each.
2. Identify aluminum alloys and tempers and explain how heat treatment strengthens them.
3. Inspect sheet metal for defects and choose repair material, rivets and hardware.
4. Lay out a rivet pattern, calculate rivet length, and compute bend allowance and setback.
5. Remove and install solid and special rivets correctly and work safely around sheet metal.
6. Explain gas and inert-gas welding, shielding gases, gas storage, and steel tube weld repairs.

ACS reference: AM.II.A (Metallic Structures). **Kit practice topics:** SHEET, WELD.

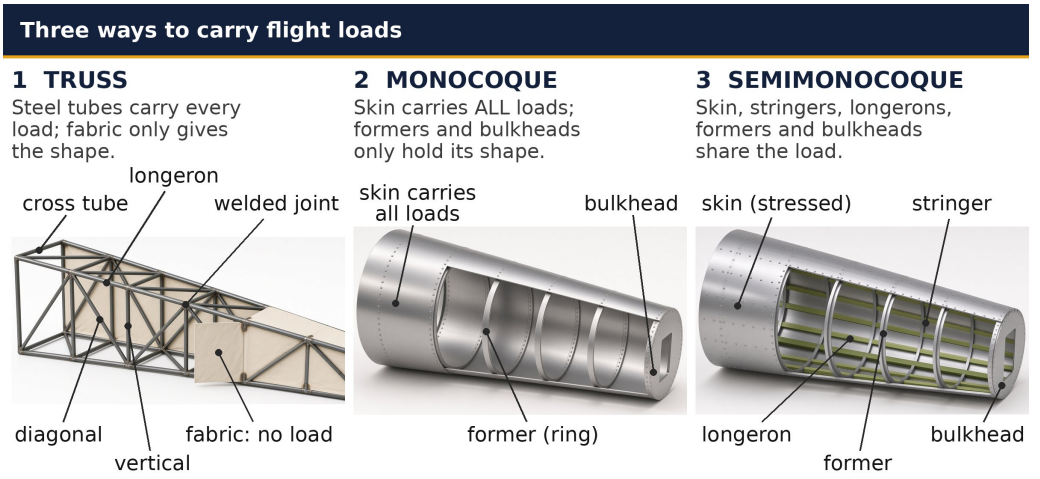
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Most aircraft you will work on are built from aluminum sheet held together with rivets. Sheet metal is the first hands-on skill most technicians learn, and it is the largest single block of questions on the Airframe test. This chapter starts with how a metal structure carries load, then covers the metals, the defects you look for, the repair layout and the fasteners, and finishes with welding.

1.1 How Metal Structures Carry Load

ACS AM.II.A.K17

Every structure must resist five stresses: **tension** (pulling apart), **compression** (squeezing), **shear** (sliding one layer over another), bending (a combination of tension on one side and compression on the other) and **torsion** (twisting). A rivet in a lap joint is mainly loaded in shear; a skin panel carries tension and shear; a stringer carries compression and bending.



Based on FAA-H-8083-31B, AMT Handbook–Airframe, Figs. 1-15 to 1-17. Illustration, not to scale.

Figure 1-1. The three basic ways to carry flight loads. A truss uses tubes; a monocoque shell uses only skin; a semimonocoque shell shares the load between skin, stringers and formers.

Truss structures

A **truss** is a framework of tubes or rods joined into triangles. A *Pratt truss* uses rigid diagonal members that can carry tension and compression; a *Warren truss* uses diagonals alone with no vertical members. Steel tube fuselages on many light airplanes are welded Warren trusses covered with fabric. The covering gives shape but carries no primary load.

Monocoque and semimonocoque

In a pure **monocoque** (“single shell”) structure, the skin carries all the loads, shaped by formers and bulkheads. It is light but cannot tolerate dents or cutouts. Nearly every metal airplane today is **semimonocoque**: the skin is reinforced by longitudinal **stringers** and **longerons** and by vertical formers and **bulkheads**. Damage to one member is shared with the others, so the structure is *damage tolerant*.

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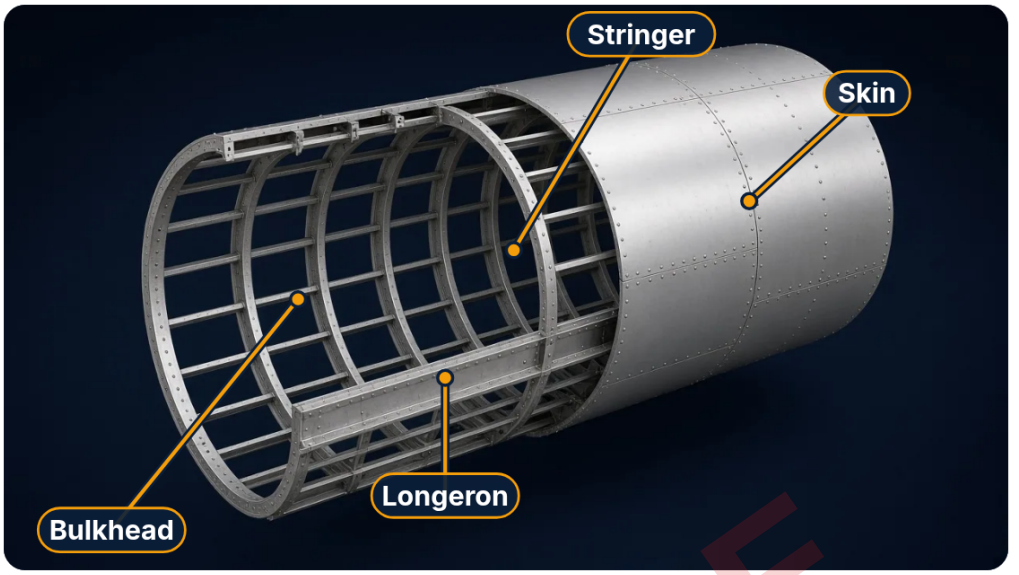


Figure 1-2. Semimonocoque fuselage construction. Skin, stringers, longerons, formers and bulkheads share the load, so damage to one part does not cause collapse.

Wings

A metal wing is built around one or more **spars**, the main spanwise beams that carry bending loads. **Ribs** give the airfoil its shape and transfer air loads from the skin to the spars. When the skin itself carries a large share of the load, the wing is said to have *stressed skin*. A *cantilever* wing has no external struts; a *semicantilever* wing uses struts. Wing fuel tanks may be separate tanks or *integral* (wet-wing) tanks, sealed sections of the wing structure itself (Chapter 10).

> **Rule.** Primary structure carries flight, ground or pressurization loads; its failure could endanger the aircraft. Secondary structure (fairings, wheel pants, fillets) does not. Repairs to primary structure are usually major repairs.

1.2 Aluminum Alloys, Tempers and Heat Treatment

ACS AM.II.A.K3, K6

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Pure aluminum is soft. Adding small amounts of other metals and heat treating them produces alloys as strong as mild steel at one-third the weight. The Aluminum Association uses a four-digit code. The first digit names the main alloying element.

Aluminum alloy designations (four-digit system)

Series	Main alloying element	Aircraft example
1xxx	99 % or purer aluminum	1100 rivets (A)
2xxx	Copper	2024 skins, 2117 rivets
3xxx	Manganese	3003 cowls, fairings
4xxx	Silicon	welding filler wire
5xxx	Magnesium	5052 fuel tanks, tubing
6xxx	Magnesium + silicon	6061 fittings, tube
7xxx	Zinc	7075 spars, fittings

Temper codes

-F as fabricated

-O annealed (soft)

-H strain hardened

-W solution treated, unstable

-T3 solution treated, cold worked, nat. aged

-T4 solution treated, natural aged

-T6 solution treated, artificially aged

Clad (Alclad) sheet has a thin layer of pure aluminum on each face for corrosion protection; do not sand through it.

Figure 1-3. The four-digit alloy code and the temper codes you must recognize. 2024 and 7075 are the main structural alloys.

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2024-T3 is the workhorse for fuselage and wing skins: strong, good fatigue resistance, but it corrodes easily, so it is usually supplied as **Alclad** sheet with a thin pure-aluminum coating on each face. **7075-T6** is stronger but less ductile and is used for spars, stringers and highly loaded fittings. **5052-H32** is not heat-treatable; it is used for fuel tanks and lines because it bends and welds well. **6061-T6** is used for fittings, tubing and welded parts.

Temper designations

The suffix after the dash is the **temper**. **-F** is as fabricated; **-O** is annealed (softest); **-H** is strain-hardened (for non-heat-treatable alloys such as 3003 and 5052); **-W** is solution-heat-treated but unstable; and **-T** codes describe heat-treated tempers. T3 is solution-treated, cold-worked and naturally aged; T4 is solution-treated and naturally aged; T6 is solution-treated and artificially aged.

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How heat treatment works

Solution heat treatment heats the alloy until the alloying elements dissolve evenly into the aluminum (about 910–930 °F for 2024), then quenches it rapidly in water so they are trapped in solution. Any delay in quenching lets them come back out at the grain boundaries, causing intergranular corrosion later. Over the following hours and days, the trapped elements form fine particles that strengthen the metal. This is **precipitation hardening**, or *aging*. If it happens at room temperature, it is natural aging; if the part is reheated to a moderate temperature (roughly 250–375 °F) to speed it up, it is artificial aging.

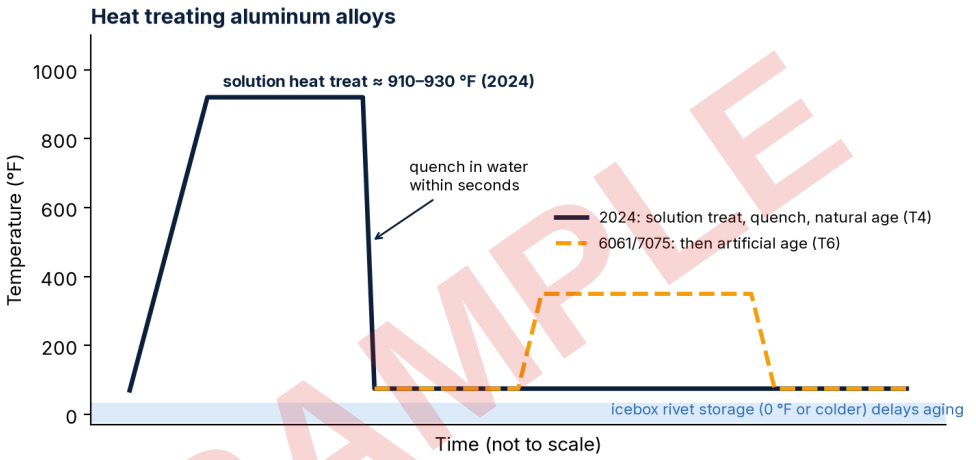


Figure 1-4. Heat-treatment sequence for aluminum. Solution treatment and a fast quench, then natural aging (T4) or artificial aging (T6). Refrigeration slows aging, which is why "icebox" rivets are kept cold.

Annealing does the opposite: it softens the metal by heating it and cooling it slowly, so it can be formed. Heating clad sheet too many times lets the core alloy diffuse into the pure cladding and destroys its corrosion protection, so clad material is reheat-treated only a limited number of times.

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WORKED EXAMPLE

Worked Example 1-1. Why are DD rivets kept in a freezer? 2024-T4 (DD) rivets are too hard to drive once they have aged. The shop solution-heat-treats them, quenches them, and stores them at 0 °F or colder, which stops natural aging. The mechanic must drive them shortly after removal from the freezer (the handbook allows roughly 15–20 minutes), before they harden. 2017-T (D) rivets are handled the same way. AD rivets (2117-T4) are driven as received, which is why they are the most common rivet in the field.

1.3 Inspecting Metal Structures and Classifying Damage

ACS AM.II.A.K1, K2

Inspection begins with a clean surface, good light, a flashlight held at a low angle and a magnifier. Look along rivet lines and around fittings, where stress concentrates. Common defects are:

- **Dent:** a smooth depression with no change in thickness, caused by impact.
- **Crease:** a sharp fold that has work-hardened the metal; treat it as a crack.
- **Scratch, nick or gouge:** removes metal and raises stress; gouges are deep, often with sharp edges.
- **Crack:** a separation in the metal, often starting at a fastener hole or a sharp corner.
- **Working rivet:** a loose rivet that moves under load. Look for a black ring of aluminum oxide “smoking” from around the head, often streaked aft by airflow.
- **Corrosion:** white powder on aluminum, red rust on steel, or bubbling paint (Chapter 6).
- **Distortion, buckling or elongated holes:** signs that a member has been overloaded.

Damage is classed by the structural repair manual (SRM) as **negligible** (no repair beyond cleanup, such as a smooth dent within limits), **repairable by patching**, **repairable by insertion** (cutting out the damaged section and splicing in new material), or **requiring replacement** of the part.

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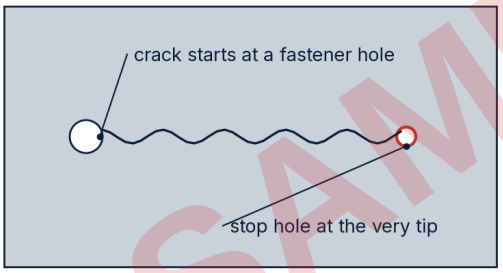
Testing methods

Where the eye can't see, use **nondestructive inspection** (NDI). **Dye penetrant** finds surface cracks in any nonporous material. **Eddy current** finds surface and near-surface cracks and corrosion in conductive metals, including around fastener holes, without removing paint. **Ultrasonic** inspection finds internal flaws and measures thickness. **Magnetic particle** inspection works only on ferromagnetic (iron-based) parts. Radiography (X-ray) shows internal structure. Coin tapping (Chapter 3) finds delaminations in bonded panels.

Stopping a crack

A crack grows because its sharp tip concentrates stress. Drilling a small hole at the tip replaces the sharp point with a round edge. This is **stop drilling**. It is a temporary measure or a step before a patch, not a repair by itself.

Stop-drilling a crack



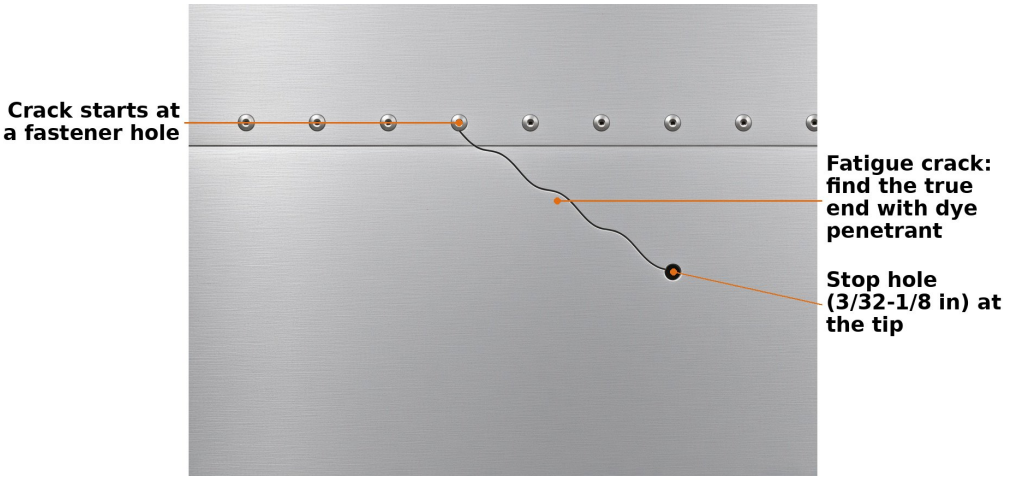
Procedure

1. Find the true end of the crack (dye penetrant, magnifier).
2. Drill a 3/32–1/8 in hole exactly at the tip.
3. Deburr; the round hole spreads the stress so the crack stops.
4. Patch over it if required.

Figure 1-5. Stop-drilling a crack. The hole must be at the true end of the crack; a hole short of the tip does nothing.

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Real-part view: a stop hole drilled at the true end of a fatigue crack.

EXAM TRAP

- A dent is not repaired just because it is ugly; check the SRM for negligible-damage limits first.
- A working rivet is replaced with the **next larger size** only if the enlarged hole still meets edge distance and spacing; otherwise use the same size after correcting the cause.
- Magnetic particle inspection cannot be used on aluminum, titanium or austenitic stainless steel.

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1.4 Selecting Repair Materials and Fasteners

ACS AM.II.A.K3, K5

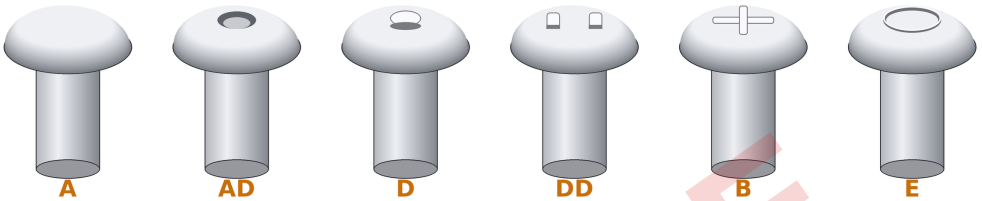
The basic rule of structural repair is to **restore the original strength without adding unnecessary weight or stiffness**. Use the same alloy and temper as the original, and a thickness equal to or one gauge thicker than the original. Do not substitute a stronger but more brittle alloy (7075 for 2024 in a skin, for example) without approved data, because a stiffer patch attracts load and can crack the surrounding skin.

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Solid rivets

Solid rivets are identified by head shape, alloy marking and size. The two head styles used most are **MS20470** universal head (protruding, replaces the older round, flat and brazier heads) and **MS20426** 100° countersunk head (flush). Diameter is given in thirty-seconds of an inch; length in sixteenths.

A Head markings (MS20470 universal head, shown about 4x size)

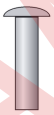


A	AD	D	DD	B	E
1100	2117-T4	2017-T	2024-T	5056	7050-T73
plain	dimple	raised dot	two raised dashes	raised cross	raised ring

B Actual size (print at 5.5 in wide)



US quarter



MS20470AD4-8
1/8 in dia, 1/2 in long

C Reading the part number

MS20470 AD 4 -8

MS20470 = universal head

AD = 2117-T4 alloy

4 = dia 4/32 = 1/8 in

-8 = length 8/16 = 1/2 in

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Figure 1-6. Rivet alloy identification by head marking. Learn the letter code; the test often gives a part number and asks for alloy, size or length.

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WORKED EXAMPLE

Worked Example 1-2. Decoding a part number. What is an MS20426AD5-8 rivet?

Solution. MS20426 = 100° countersunk head. AD = 2117-T4 aluminum. The dash numbers decode as:

$$\text{Diameter} = \frac{5}{32}\ \text{in}$$

$$\text{Length} = \frac{8}{16} = \frac{1}{2}\ \text{in}$$

For a countersunk rivet, length is measured overall, including the head; for a protruding head, it is measured from under the head.

Choosing the diameter. A common rule of thumb is that rivet diameter should be about three times the thickness of the thickest sheet being joined. Rivets smaller than $\frac{3}{32}$ in are not used in structure.

Choosing the length. The rivet must pass through the **grip** (total thickness of material) and leave enough shank, 1.5 times the diameter, to form a proper **shop head**. A correctly driven shop head is 1.5 D wide and 0.5 D high.

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Solid rivet sizing: length, grip and the shop head

AC 43.13-1B, Ch. 4

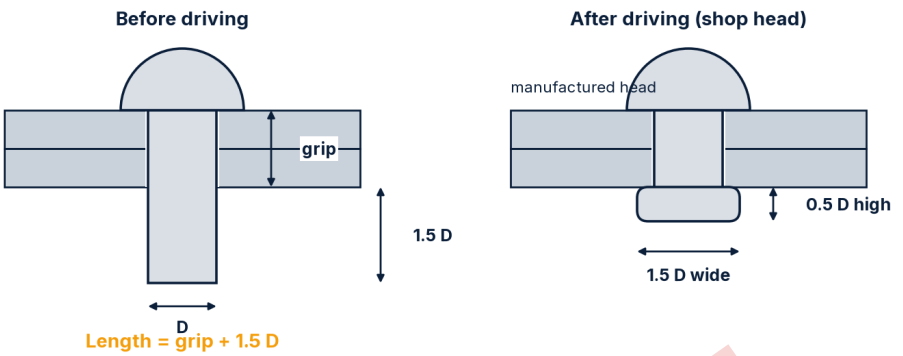
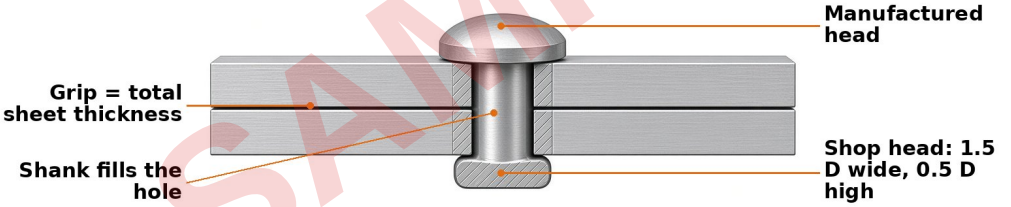


Figure 1-7. Rivet length and shop-head dimensions. Length = grip + 1.5 D. The driven head should be 1.5 D in diameter and 0.5 D high.



Real-part view: driven solid rivet in section.

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WORKED EXAMPLE

Worked Example 1-3. Rivet length. Two sheets of 0.040 in and 0.032 in are joined with $\frac{1}{8}$ in AD rivets. What length is needed?

Solution.

$$\begin{aligned} \text{Grip} &= 0.040 + 0.032 = 0.072 \text{ in} \\ \text{Allowance} &= 1.5 \times 0.125 = 0.1875 \text{ in} \\ \text{Length} &= 0.072 + 0.1875 = 0.2595 \text{ in} \end{aligned}$$

The next standard length is $\frac{4}{16}$ in (0.250) — too short — so use $\frac{\mathbf{5}}{\mathbf{16}}$ **in** (0.3125). Part number: MS20470AD4-5.

Special (blind) fasteners

Where only one side is accessible, use **blind rivets**. Friction-lock and mechanical-lock types (Cherry, CherryMAX, Olympic-Lok) are pulled with a special tool; the mechanically locked kinds retain the stem and can replace solid rivets of the same size where approved. Hi-Shear rivets and Hi-Lok bolts are high-strength pin fasteners with a collar, used in shear joints. Lockbolts combine bolt and rivet features for heavy structure. Rivnuts are blind threaded inserts for attaching fairings and deice boots. AN/MS/NAS bolts, nuts and washers are covered in the General volume; in structure, bolts must have the correct grip length so threads do not bear in the hole.

1.5 Rivet Layout, Forming and Drilling

ACS AM.II.A.K4, K7

Edge distance and spacing

Edge distance is measured from the center of a rivet hole to the edge of the sheet. The minimum is **2 D**; 2.5 D is preferred, and for countersunk rivets 2.5 D is the minimum. **Rivet pitch** is the distance between rivet centers in the same row; the minimum is **3 D** (AC 43.13-1B; 4 D for a two-row layout per FAA-H-8083-31B). The handbook gives an average pitch of 4 to 6 D, and in some instances up to

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about 10 D; on a repair, match the original spacing or follow the SRM. **Transverse pitch** (gauge) is the distance between rows, normally 75 % of the rivet pitch and not less than 2.5 D.

Rivet layout terms: lap joint, two staggered rows

Drawn to scale, D = 1/8 in: edge distance 2.5 D, pitch 4 D (typical 4–6 D per FAA-H-8083-31B), gauge 0.75 p

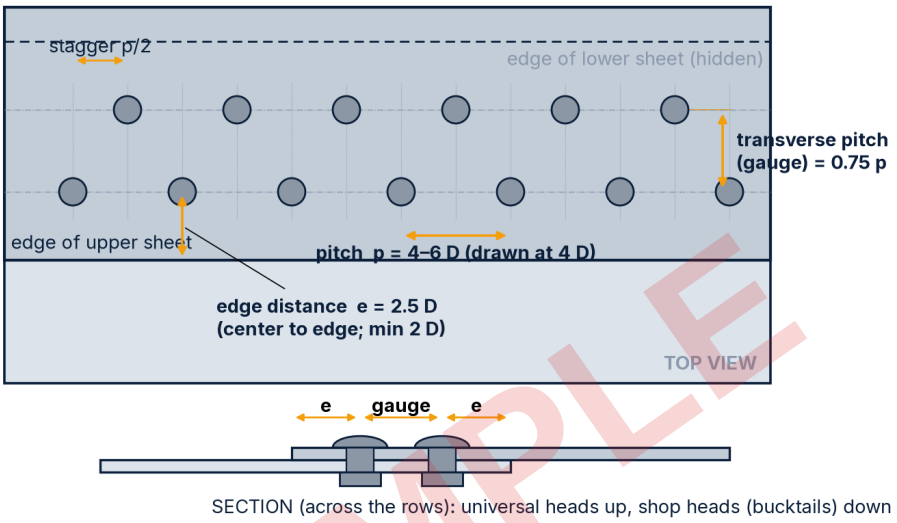


Figure 1-8. Rivet layout terms. Edge distance, pitch and transverse pitch, with rows staggered so that no single line through the sheet is weakened by every row.

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WORKED EXAMPLE

Worked Example 1-4. Layout for $\frac{1}{8}$ in rivets. Find minimum edge distance, minimum pitch and a typical transverse pitch for a 6 D pitch.

Solution. D = 0.125 in.

Edge distance	=	2 × 0.125 = 0.25 in
(preferred 2.5D)	=	2.5 × 0.125 = 0.3125 in
Minimum pitch	=	3 × 0.125 = 0.375 in
Pitch at 6D	=	6 × 0.125 = 0.75 in
Transverse pitch	=	0.75 × 0.75 = 0.5625 in

The transverse pitch exceeds 2.5 D (0.3125 in), so it is acceptable.

How many rivets?

A repair must carry the load the original skin carried. The handbook method compares the shear strength of the rivets with the tensile (or bearing) strength of the sheet. AC 43.13-1B gives tables of the number of rivets required per inch of damage for each sheet thickness and rivet size. When a repair patch is larger, the rivet count on each side of the damage must carry the full load across it.

Countersinking and dimpling

A flush rivet needs a cone-shaped seat. If the sheet is thicker than the rivet head, the hole is machine **countersunk** with a stop countersink. If the sheet is thinner, countersinking would leave a **knife edge**, so the sheet is **dimpled** instead, pressing the metal into a cone with dies. 7075-T6 and magnesium crack when cold-dimpled and must be hot-dimpled.

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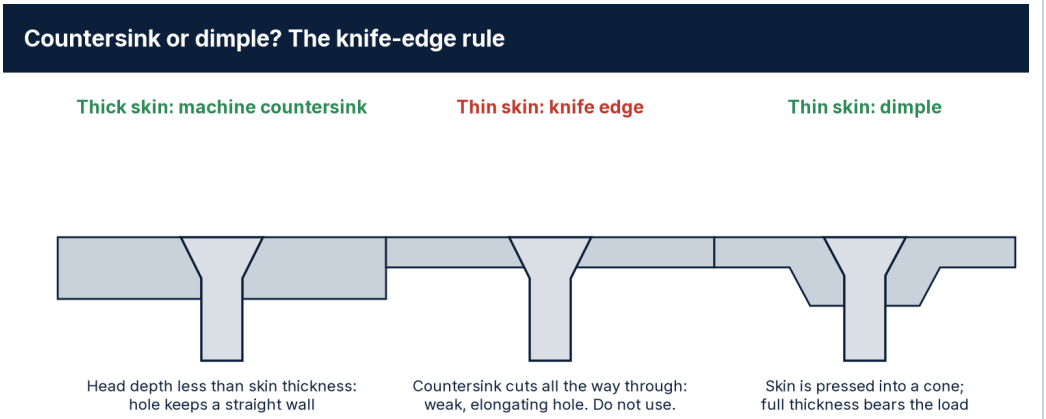


Figure 1-9. Countersink only when the head fits within the skin thickness; otherwise dimple.

Bending sheet metal

Metal is bent on a cornice brake or press brake around a radius. Too small a radius cracks the outside of the bend; each alloy and temper has a **minimum bend radius**. The flat layout must account for the metal used in the curve. **Bend allowance** (BA) is the length of the curved portion measured along the neutral axis; **setback** (SB) is the distance from the mold point to the bend tangent line.

$$BA = (0.01743\ R + 0.0078\ T) \times N$$

where R = inside radius, T = thickness, N = degrees of bend.

$$SB = K \times (R + T)$$

where K = 1 for a 90° bend (K comes from a table for other angles).

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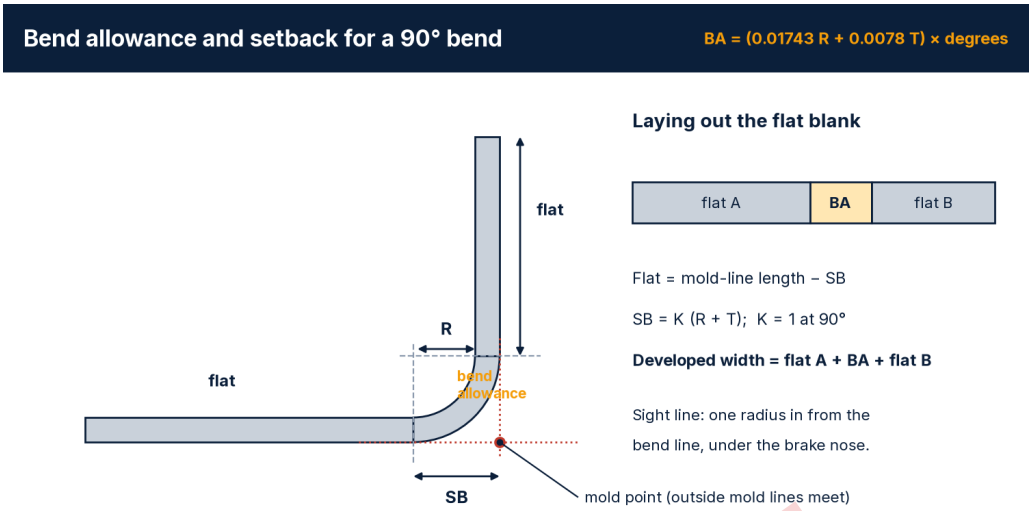


Figure 1-10. Bend allowance, setback and the mold point. The flat blank equals flat A + BA + flat B.

WORKED EXAMPLE

Worked Example 1-5. Developing a channel leg. A 90° bend is made in 0.040 in 2024-T3 with a 0.125 in inside radius. The outside dimensions of the angle are 1.00 in by 1.00 in. Find BA, SB and the total flat length.

Solution.

$$\begin{aligned} BA &= (0.01743 \times 0.125 + 0.0078 \times 0.040) \times 90 \\ &= (0.002179 + 0.000312) \times 90 \\ &= 0.224 \text{ in} \\ SB &= 1 \times (0.125 + 0.040) = 0.165 \text{ in} \\ \text{Each flat} &= 1.00 - 0.165 = 0.835 \text{ in} \\ \text{Total} &= 0.835 + 0.224 + 0.835 = 1.894 \text{ in} \end{aligned}$$

The flat-pattern length is **1.894 in**.

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The **sight line** is a mark one radius in from the bend tangent line; it is placed directly under the nose of the brake so the bend begins in the right place. Relief holes are drilled where two bends meet to prevent cracking at the corner.

Drilling

Use a No. 30 drill (0.1285 in) for $\frac{1}{8}$ in rivets and a No. 40 (0.098 in) for $\frac{3}{32}$ in rivets; $\frac{5}{32}$ in rivets use a No. 21. Drill slightly oversize so the rivet slips in but does not wobble. Pilot drill large holes, hold the drill perpendicular to the skin, deburr every hole and remove chips from between sheets. Hold sheets together with **Clecos** while drilling and riveting.

1.6 Installing and Removing Rivets

ACS AM.II.A.K8

Driving

Solid rivets are driven with a rivet gun and a **bucking bar**, or squeezed with a hand or pneumatic squeezer. The gun's set must match the head; the bucking bar's weight must suit the rivet size. Too light a bar or too long a burst leaves the shop head under-driven; too much work hardens the rivet and can crack the head. A properly driven rivet fills the hole completely, swells the shank, and has a shop head of the dimensions shown in Section 1.4. Clinched (tilted), cracked or flattened heads are drilled out.

Removing a rivet

Remove the *manufactured* head, never the shop head, so the hole is not enlarged:

1. File a flat on a protruding head and center-punch it.
2. Drill with a drill **one size smaller** than the rivet shank, only to the base of the head.
3. Snap the head off with a pin punch in the drilled hole, or pry it off.
4. Support the structure and drive the shank out with a pin punch.

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Rule. If the hole is enlarged, use the next larger rivet size, and check that edge distance and pitch still meet the minimums for the larger rivet.

1.7 Sheet Metal Safety

ACS AM.II.A.K9

Wear safety glasses for all drilling, riveting and grinding. Wear hearing protection near rivet guns. Never point a rivet gun at anyone or operate it without a set against material; a loose set can be fired like a bullet. Keep fingers clear of shears, brakes and squeezers. Deburr edges and wear gloves when handling sheet. Keep the work area clear of chips; aluminum dust and magnesium shavings are flammable, and magnesium fires must never be fought with water. Use respirators when sanding primers that contain chromates.

1.8 Welding Gases, Storage and Flame Welding

ACS AM.II.A.K10, K11, K12

The gases

Oxyacetylene welding burns acetylene with pure oxygen to produce a flame of about 6,300 °F. Acetylene is unstable at pressures above **15 psi**, so it is dissolved in acetone inside a cylinder filled with porous material. Never draw acetylene above 15 psi, and store and use acetylene cylinders upright so acetone does not reach the regulator. Oxygen is stored at about 2,200 psi; oil or grease near oxygen fittings can ignite spontaneously, so never lubricate oxygen equipment.

Storage and handling: cylinders are chained upright, caps on when not in use, away from heat and from each other (oxygen and fuel gases separated by distance or a fire wall). Open the oxygen valve fully; open the acetylene valve no more than about 1.5 turns so it can be shut quickly. Use a check valve and flashback arrestor at the torch.

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