CHAPTER 4. METAL STRUCTURE, WELDING, AND BRAZING

SECTION 1. IDENTIFICATION OF METALS

4-1. GENERAL. Proper identification of the aircraft structural material is the first step in ensuring that the continuing airworthiness of the aircraft will not be degraded by making an improper repair using the wrong materials.

a. Ferrous (iron) alloy materials are generally classified according to carbon content. (See table 4-1.)

TABLE 4-1. Ferrous (iron) alloy materials.

MATERIALS	CARBON CONTENT
Wrought iron	Trace to 0.08%
Low carbon steel	0.08% to 0.30%
Medium carbon steel	0.30% to 0.60%
High carbon steel	0.60% to 2.2%
Cast iron	2.3% to 4.5%

b. The strength and ductility, or toughness of steel, is controlled by the kind and quantity of alloys used and also by cold-working or heat-treating processes used in manufacturing. In general, any process that increases the strength of a material will also decrease its ductility.

c. Normalizing is heating steel to approximately 150 °F to 225 °F above the steel's critical temperature range, followed by cooling to below that range in still air at ordinary temperature. Normalizing may be classified as a form of annealing. This process also removes stresses due to machining, forging, bending, and welding. After the metal has been held at this temperature for a sufficient time to be heated uniformly throughout, remove the metal from the furnace and cool in still air. Avoid prolonging the soaking of the metal at high temperatures, as this practice will cause the grain structure to enlarge. The length of time required for the soaking temperature depends on the mass of the metal being treated. The soaking time is roughly ¼ hour per inch of the diameter of thickness (Ref: Military Tech Order (T.O.) 1-1A-9).

4-2. IDENTIFICATION OF STEEL STOCK. The Society of Automotive Engineers (SAE) and the American Iron and Steel Institute (AISI) use a numerical index system to identify the composition of various steels. The numbers assigned in the combined listing of standard steels issued by these groups represent the type of steel and make it possible to readily identify the principal elements in the material.

a. The basic numbers for the four digit series of the carbon and alloy steel may be found in table 4-2. The first digit of the four number designation indicates the type to which the steel belongs. Thus, "1" indicates a carbon steel, "2" a nickel steel, "3" a nickel chromium steel, etc. In the case of simple alloy steels, the second digit indicates the approximate percentage of the predominant alloying element. The last two digits usually indicate the mean of the range of carbon content. Thus, the designation "1020" indicates a plain carbon steel lacking a principal alloying element and containing an average of 0.20 percent (0.18 to 0.23) carbon. The designation "2330" indicates a nickel steel of approximately 3 percent (3.25 to 3.75) nickel and an average of 0.30 percent, (0.28 to 0.33) carbon content. The designation "4130" indicates a chromium-molybdenum steel of approximately 1 percent (0.80 to 1.10) chromium, 0.20 percent (0.15 to 0.25) molybdenum, and 0.30 percent (0.28 to 0.33) carbon.

b. There are numerous steels with higher percentages of alloying elements that do not fit into this numbering system. These include a large group of stainless and heat resisting alloys in which chromium is an essential alloying element. Some of these alloys are identified by three digit AISI numbers and many others by designations assigned by the steel company that produces them. The few examples in table 4-3 will serve to illustrate the kinds of designations used and the general alloy content of these steels.

c. "1025" welded tubing as per Specification MIL-T-5066 and "1025" seamless tubing conforming to Specification MIL-T-5066A are interchangeable.

4-3. INTERCHANGEABILITY OF STEEL TUBING.

a. "4130" welded tubing conforming to Specification MIL-T-6731, and "4130" seam-less tubing conforming to Specification MIL-T-6736 are interchangeable.

b. NE-8630 welded tubing conforming to Specification MIL-T-6734, and NE-8630 seamless tubing conforming to Specification MIL-T-6732 are interchangeable.

4-4. IDENTIFICATION OF ALUMINUM. To provide a visual means for identifying the various grades of aluminum and aluminum alloys, such metals are usually marked with symbols such as a Government Specification Number, the temper or condition furnished, or the commercial code marking. Plate and sheet are usually marked with specification numbers or code markings in rows approximately 5 inches apart. Tubes, bars, rods, and extruded shapes are marked with specification numbers or code markings at intervals of 3 to 5 feet along the length of each piece.

The commercial code marking consists of a number which identifies the particular composition of the alloy. In addition, letter suffixes (see table 4-4) designate the basic temper designations and subdivisions of aluminum alloys.

TABLE 4-2. Numerical system for steel identification.

TYPES OF STEELS	NUMERALS AND DIGITS
Plain carbon steel	10XX
Carbon steel with additional sulfur for easy machining.	11XX
Carbon steel with about 1.75% manganese	13XX
.25% molybdenum.	40XX
1% chromium, .25% molybdenum	41XX
2% nickel, 1% chromium, .25% molybdenum	43XX
1.7% nickel, .2% molybdenum	46XX
3.5% nickel, .25% molybdenum	48XX
1% chromium steels	51XX
1% chromium, 1.00% carbon	51XXX
1.5% chromium steels	52XX
1.5% chromium, 1.00% carbon	52XXX
1% chromium steel with .15% vanadium	61XX
.5% chromium, .5% nickel, .20% molybdenum	86XX
.5% chromium, .5% nickel, .25% molybdenum	87XX
2% silicon steels, .85% manganese	92XX
3.25% nickel, 1.20% chromium, .12% molybdenum	93XX

TABLE 4-3. Examples of stainless and heat-resistant steels nominal composition (percent)

ALLOY DESIGNATION	CARBON	CHROMIUM	NICKEL	OTHER	GENERAL CLASS OF STEEL
302	0.15	18	9		Austenitic
310	0.25	25	20		Austenitic
321	0.08	18	11	Titanium	Austenitic
347	0.08	18	11	Columbium or Tantalum	Austenitic
410	0.15	12.5			Martensitic, Magnetic
430	0.12	17			Ferritic, Magnetic
446	0.20	25		Nitrogen	Ferritic, Magnetic
PH15-7 Mo	0.09	15	7	Molybdenum, Aluminum	Precipitation Hardening
17-4 PH	0.07	16.5	4	Copper, Columbium or Tantalum	Precipitation Hardening

TABLE 4-4. Basic temper designations and subdivisions from aluminum alloys.

NON HEAT-TREATABLE ALLOYS		HEAT-TREATABLE ALLOYS	
Temper Designation	**Definition**	**Temper Designation**	**Definition**
-0	Annealed recrystallized (wrought products only) applies to softest temper of wrought products.	-0	Annealed recrystallized (wrought products only) applies to softest temper of wrought products.
-H1	Strain-hardened only. Applies to products which are strain-hardened to obtain the desired strength without supplementary thermal treatment.	-T1	Cooled from an elevated temperature shaping process (such as extrusion or casting) and naturally aged to a substantially stable condition.
-H12	Strain-hardened one-quarter-hard temper.	-T2	Annealed (castings only).
-H14	Strain-hardened half-hard temper.	-T3	Solution heat-treated and cold-worked by the flattening or straightening operation.
-H16	Strain-hardened three-quarters-hard temper.	-T36	Solution heat-treated and cold-worked by reduction of 6 percent
-H18	Strain-hardened full-hard temper.	-T4	Solution heat-treated.
-H2	Strain-hardened and then partially annealed. Applies to products which are strain-hardened more than the desired final amount and then reduced in strength to the desired level by partial annealing.	-T42	Solution heat-treated by the user regardless of prior temper (applicable only to 2014 and 2024 alloys).
-H22	Strain-hardened and partially annealed to one-quarter-hard temper.	-T5	Artificially aged only (castings only).
-H24	Strain-hardened and partially annealed to half-hard temper.	-T6	Solution heat-treated and artificially aged.
-H26	Strain-hardened and partially annealed to three-quarters-hard temper.	-T62	Solution heat-treated and aged by user regardless of prior temper (applicable only to 2014 and 2024 alloys).
-H28	Strain-hardened and partially annealed to full-hard temper.	-T351, -T451, -T3510, -T3511, -T4510, -T4511.	Solution heat-treated and stress relieved by stretching to produce a permanent set of 1 to 3 percent, depending on the product.
-H3	Strain-hardened and then stabilized. Applies to products which are strain-hardened and then stabilized by a low temperature heating to slightly lower their strength and increase ductility.	-T651, -T851, -T6510, -T8510, -T6511, -T8511.	Solution heat-treated, stress relieved by stretching to produce a permanent set of 1 to 3 percent, and artificially aged.
-H32	Strain-hardened and then stabilized. Final temper is one-quarter hard.	-T652	Solution heat-treated, compressed to produce a permanent set and then artificially aged.
-H34	Strain-hardened and then stabilized. Final temper is one-half hard.	-T8	Solution heat-treated, cold-worked and then artificially aged.
-H36	Strain-hardened and then stabilized. Final temper is three-quarters hard.	-T/4	Solution heat-treated, cold-worked by the flattening or straightening operation, and then artificially aged.
-H38	Strain-hardened and then stabilized. Final temper is full-hard.	-T86	Solution heat-treated, cold-worked by reduction of 6 percent, and then artificially aged.
-H112	As fabricated; with specified mechanical property limits.	-T9	Solution heat-treated, artificially aged and then cold-worked.
-F	For wrought alloys; as fabricated. No mechanical properties limits. For cast alloys; as cast.	-T10	Cooled from an elevated temperature shaping process artificially aged and then cold-worked.
		-F	For wrought alloys; as fabricated. No mechanical properties limits. For cast alloys; as cast.

4-5. - 4-15. [RESERVED.]

SECTION 2. TESTING OF METALS

4-16. HARDNESS TESTING. If the material type is known, a hardness test is a simple way to verify that the part has been properly heat-treated. Hardness testers such as Rockwell, Brinell, and Vickers can be useful to check metals for loss of strength due to exposure to fire or abusive heating. Also, understrength bolts can be found and removed from the replacement part inventory by checking the hardness of the bolt across the hex flats. Although hardness tests are generally considered nondestructive, hardness testing does leave a small pit in the surface; therefore, hardness tests should not be used on sealing surfaces, fatigue critical parts, load bearing areas, etc., that will be returned to service. These hardness tests provide a convenient means for determining, within reasonable limits, the tensile strength of steel. It has several limitations in that it is not suitable for very soft or very hard steels. Hardness testing of aluminum alloys should be limited to distinguishing between annealed and heat-treated material of the same aluminum alloy. In hardness testing, the thickness and the edge distance of the specimen being tested are two factors that must be considered to avoid distortion of the metal. Several readings should be taken and the results averaged. In general, the higher the tensile strength, the greater its hardness. Common methods of hardness testing are outlined in the following paragraphs. These tests are suitable for determining the tensile properties resulting from the heat treatment of steel. Care should be taken to have case-hardened, corroded, pitted, decarburized, or otherwise nonuniform surfaces removed to a sufficient depth. Exercise caution not to cold-work, and consequently harden, the steel during removal of the surface.

4-17. ROCKWELL HARDNESS TEST. The Rockwell hardness test is the most common method for determining hardness of ferrous and many nonferrous metals. (See table 4-5.) It differs from Brinell hardness testing in that the hardness is determined by the depth of indentation made by a constant load impressing on an indenter. In this test, a standard minor load is applied to set a hardened steel ball or a diamond cone in the surface of the metal, followed by the application of a standard major load. The hardness is measured by depth of penetration. Rockwell superficial hardness tests are made using light minor and major loads and a more sensitive system for measuring depth of indentation. It is useful for thin sections, very small parts, etc. Calibration of Rockwell hardness testers is done in accordance with American Society of Testing Materials (ASTM E-18) specifications.

4-18. BRINELL HARDNESS TEST. In this test a standard constant load, usually 500 to 3,000 kg, is applied to a smooth flat metal surface by a hardened steel-ball type indenter, 10 mm in diameter. The 500-kg load is usually used for testing nonferrous metals such as copper and aluminum alloys, whereas the 3,000-kg load is most often used for testing harder metals such as steels and cast irons. The numerical value of Brinell Hardness (HB), is equal to the load, divided by the surface area of the resulting spherical impression.

$$HB = \frac{P}{(\pi \frac{D}{2}[D - \sqrt{(D^2 - d^2)}])}$$

Where P is the load, in kg; D is the diameter of the ball, in mm; and d is the diameter of the indentation, in mm.

a. General Precautions. To avoid misapplication of Brinell hardness testing, the fundamentals and limitations of the test procedure must be clearly understood. To avoid inaccuracies, the following rules should be followed.

(1) Do not make indentations on a curved surface having a radius of less than 1 inch.

(2) Do make the indentations with the correct spacing. Indentations should not be made too close to the edge of the work piece being tested.

(3) Apply the load steadily to avoid overloading caused by inertia of the weights.

(4) Apply the load so the direction of loading and the test surface are perpendicular to each other within 2 degrees.

(5) The thickness of the work piece being tested should be such that no bulge or mark showing the effect of the load appears on the side of the work piece opposite the indentation.

(6) The indentation diameter should be clearly outlined.

b. Limitations. The Brinell hardness test has three principal limitations.

(1) The work piece must be capable of accommodating the relatively large indentations.

(2) Due to the relatively large indentations, the work piece should not be used after testing.

(3) The limit of hardness, 15 HB with the 500-kg load to 627 HB with the 3,000-kg load, is generally considered the practical range.

c. Calibration. A Brinell Hardness Tester should be calibrated to meet ASTM standard E10 specifications.

4-19. VICKERS HARDNESS TEST. In this test, a small pyramidal diamond is pressed into the metal being tested. The Vickers Hardness number (HV) is the ratio of the load applied to the surface area of the indention. This is done with the following formula.

$$HV = P / 0.5393d^2$$

a. The indenter is made of diamond, and is in the form of a square-based pyramid having an angle of 136 degrees between faces. The facets are highly-polished, free from surface imperfections, and the point is sharp. The loads applied vary from 1 to 120 kg; the standard loads are 5, 10, 20, 30, 50, 100, and 120 kg. For most hardness testing, 50 kg is maximum.

b. A Vickers hardness tester should be calibrated to meet ASTM standard E10 specifications, acceptable for use over a loading range.

4-20. MICROHARDNESS TESTING. This is an indentation hardness test made with loads not exceeding 1 kg (1,000 g). Such hardness tests have been made with a load as light as 1 g, although the majority of microhardness tests are made with loads of 100 to 500 g. In general, the term is related to the size of the indentation rather than to the load applied.

a. Fields of Application. Microhardness testing is capable of providing information regarding the hardness characteristics of materials which cannot be obtained by hardness tests such as the Brinell or Rockwell, and are as follows.

(1) Measuring the hardness of precision work pieces that are too small to be measured by the more common hardness-testing methods.

(2) Measuring the hardness of product forms such as foil or wire that are too thin or too small in diameter to be measured by the more conventional methods.

(3) Monitoring of carburizing or nitriding operations, which is sometimes accomplished by hardness surveys taken on cross sections of test pieces that accompanied the work pieces through production operations.

(4) Measuring the hardness of individual microconstituents.

(5) Measuring the hardness close to edges, thus detecting undesirable surface conditions such as grinding burn and decarburization.

(6) Measuring the hardness of surface layers such as plating or bonded layers.

b. Indenters. Microhardness testing can be performed with either the Knoop or the Vickers indenter. The Knoop indenter is used mostly in the United States; the Vickers indenter is the more widely used in Europe.

(1) Knoop indentation testing is performed with a diamond, ground to pyramidal form, that produces a diamond-shaped indentation with an approximate ratio between long and short diagonals of 7 to 1. The indentation depth is about one-thirtieth of its length. Due to the shape of the indenter, indentations of accurately measurable length are obtained with light loads.

(2) The Knoop hardness number (HK) is the ratio of the load applied to the indenter to the unrecovered projected area of indentation. The formula for this follows.

$$HK = P / A = P / Cl^2$$

Where P is the applied load, in kg; A is the unrecovered projected area of indentation, in square mm; l is the measured length of the long diagonal, in mm; and C is 0.07028, a constant of the indenter relating projected area of the indentation to the square of the length of the long diagonal.

4-21. INDENTATIONS. The Vickers indenter penetrates about twice as far into the work piece as does the Knoop indenter. The diagonal of the Vickers indentation is about one-third of the total length of the Knoop indentation. The Vickers indenter is less sensitive to minute differences in surface conditions than is the Knoop indenter. However, the Vickers indentation, because of the shorter diagonal, is more sensitive to errors in measuring than is the Knoop indentation. (See figure 4-1.)

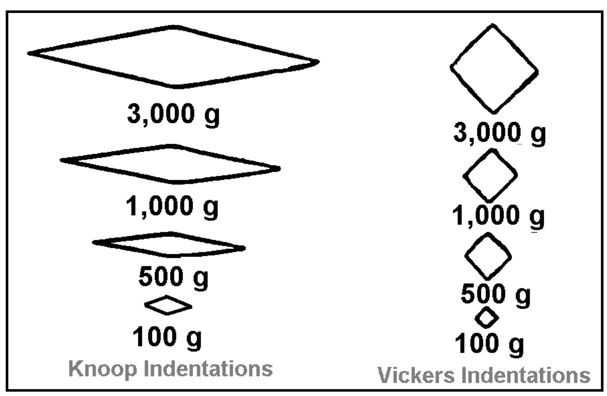


FIGURE 4-1. Comparison of indentation made by Knoop and Vickers indenters in the same work metal and at the same loads.

4-22. MAGNETIC TESTING. Magnetic testing consists of determining whether the specimen is attracted by a magnet. Usually, a metal attracted by a magnet is iron, steel, or an iron-base alloy containing nickel, cobalt, or chromium. However, there are exceptions to this rule since some nickel and cobalt alloys may be either magnetic or nonmagnetic. Never use this test as a final basis for identification. The strongly attracted metals could be pure iron, pure nickel, cobalt, or iron-nickel-cobalt alloys. The lightly attracted metals could be cold-worked stainless steel, or monel. The nonmagnetic metals could be aluminum, magnesium, silver, or copper-base alloy, or an annealed 300-type stainless steel.

4-23. ALUMINUM TESTING. Hardness tests are useful for testing aluminum alloy chiefly as a means of distinguishing between annealed, cold-worked, heat-treated, and heat-treated and aged material. It is of little value in indicating the strength or quality of heat treatment. Typical hardness values for aluminum alloys are shown in table 4-5.

a. Clad aluminum alloys have surface layers of pure aluminum or corrosion-resistant aluminum alloy bonded to the core material to inhibit corrosion. Presence of such a coating may be determined under a magnifying glass by examination of the edge surface which will show three distinct layers. In aluminum alloys, the properties of any specific alloy can be altered by work hardening (often called strain-hardening), heat treatment, or by a combination of these processes.

b. Test for distinguishing heat-treatable and nonheat-treatable aluminum alloys. If for any reason the identification mark of the alloy is not on the material, it is possible to distinguish between some heat-treatable alloys and some nonheat-treatable alloys by immersing a sample of the material in a 10 percent solution of caustic soda (sodium hydroxide). Those heat-treated alloys containing several percent of copper (2014, 2017, and 2024) will turn black due to the copper content. High-copper alloys when clad will not turn black on the surface, but the edges will turn black at the center of the sheet where the core is exposed. If the alloy does not turn black in the caustic soda solution it is not evidence that the alloy is nonheat-treatable, as various high-strength heat-treatable alloys are not based primarily on the use of copper as an alloying agent. These include among others 6053, 6061, and 7075 alloys. The composition and heat-treating ability of alloys which do not turn black in a caustic soda solution can be established only by chemical or spectro-analysis.

TABLE 4-5. Hardness values for aluminum alloys. (Reference MIL-H-6088G.)

Material Commercial Designation	Hardness Temper	Brinell number 500 kg. load 10 mm. ball
1100	0	23
	H18	44
3003	0	28
	H16	47
2014	0	45
	T6	135
2017	0	45
	T6	105
2024	0	47
	T4	120
2025	T6	110
6151	T6	100
5052	0	47
	H36	73
6061	0	30
	T4	65
	T6	95
7075	T6	135
7079	T6	135
195	T6	75
220	T4	75
C355	T6	80
A356	T6	70

4-24.—4-35. [RESERVED.]

SECTION 3. PRECAUTIONARY MEASURES

4-36. FLUTTER AND VIBRATION PRECAUTIONS. To prevent the occurrence of severe vibration or flutter of flight control surfaces during flight, precautions must be taken to stay within the design balance limitations when performing maintenance or repair.

a. Balance Changes. The importance of retaining the proper balance and rigidity of aircraft control surfaces cannot be overemphasized. The effect of repair or weight change on the balance and center of gravity is proportionately greater on lighter surfaces than on the older heavier designs. As a general rule, repair the control surface in such a manner that the weight distribution is not affected in any way, in order to preclude the occurrence of flutter of the control surface in flight. Under certain conditions, counter-balance weight is added forward of the hinge line to maintain balance. Add or remove balance weights only when necessary in accordance with the manufacturer's instructions. Flight testing must be accomplished to ensure flutter is not a problem. Failure to check and retain control surface balance within the original or maximum allowable value could result in a serious flight hazard.

b. Painting and Refinishing. Special emphasis is directed to the effect of too many extra coats of paint on balanced control surfaces. Mechanics must avoid adding additional coats of paint in excess of what the manufacturer originally applied. If available consult the aircraft manufacturer's instructions relative to finishing and balance of control surfaces.

c. Trapped Water or Ice. Instances of flutter have occurred from unbalanced conditions caused by the collection of water or ice within the surface. Therefore, ventilation and drainage provisions must be checked and retained when maintenance is being done.

d. Trim Tab Maintenance. Loose or vibrating trim tabs will increase wear of actuating mechanisms and hinge points which may develop into serious flutter conditions. When this happens, primary control surfaces are highly susceptible to wear, deformation, and fatigue failures because of the buffeting nature of the airflow over the tab mechanism. Trailing-edge play of the tab may increase, creating an unsafe flutter condition. Careful inspection of the tab and its mechanism should be conducted during overhaul and annual inspection periods. Compared to other flight control systems on the aircraft, only a minor amount of tab-mechanism wear can be tolerated.

(1) Free play and stiffness may best be measured by a simple static test where "upward" and "downward" (or "leftward" and "rightward") point forces are applied near the trailing edge of the tab at the span-wise attachment of the actuator (so as not to twist the tab). The control surface to which the trim tab is attached should be locked in place. Rotational deflection readings are then taken near the tab trailing edge using an appropriate measuring device, such as a dial gauge. Several deflection readings should be taken using loads first applied in one direction, then in the opposite. If the tab span does not exceed 35 percent of the span of the supporting control surface, the total free play at the tab trailing edge should not exceed 2 percent of the tab chord. If the tab span equals or exceeds 35 percent of the span of the supporting control surface, the total free play at the tab trailing edge should not exceed 1 percent of the distance from the tab hinge line to the trailing edge of the tab perpendicular to the tab hinge line. For example, a tab that has a chord of

4 inches and less than or equal to 35 percent of the control surface span would have a maximum permissible free play of 4 inches x 0.020 or 0.080 inches (total motion up and down) measured at the trailing edge. Correct any free play in excess of this amount.

(2) Care must also be exercised during repair or rework to prevent stress concentration points or areas that could increase the fatigue susceptibility of the trim tab system. Advisory Circular (AC) 23.629-1A, Means of Compliance with Section 23.629, "Flutter," contains additional information on this subject.

NOTE: If the pilot has experienced flutter, or thinks he/she has, then a complete inspection of the aircraft flight control system and all related components including rod ends, bearings, hinges, and bellcranks must be accomplished. Suspected parts should be replaced.

4-37. LOAD FACTORS FOR REPAIRS. In order to design an effective repair to a sheet metal aircraft, the stresses that act on the structure must be understood.

a. Six types of major stresses are known and should be considered when making repairs. These are tension, compression, bending, torsion, shear, and bearing

b. The design of an aircraft repair is complicated by the requirement that it be as light as possible. If weight were not critical, repairs could be made with a large margin of safety. But in actual practice, repairs must be strong enough to carry all of the loads with the required factor of safety, but they must not have too much extra strength. A joint that is too weak cannot be tolerated, but neither can one that is too strong because it can create stress risers that may cause cracks in other locations.

4-38. TRANSFER OF STRESSES WITHIN A STRUCTURE. An aircraft structure must be designed in such a way that it will accept all of the stresses imposed upon it by the flight and ground loads without any permanent deformation. Any repair made must accept the stresses, carry them across the repair, and then transfer them back into the original structure. These stresses are considered as flowing through the structure, so there must be a continuous path for them, with no abrupt changes in cross-sectional areas along the way. Abrupt changes in cross-sectional areas of aircraft structure that are subject to cycle loading/stresses will result in stress concentration that may induce fatigue cracking and eventual failure. A scratch or gouge in the surface of a highly-stressed piece of metal will cause a stress concentration at the point of damage.

a. Multirow Fastener Load Transfer. When multiple rows of rivets are used to secure a lap joint, the transfer of stresses is not equal in each row. The transfer of stress at each row of rivets may be thought of as transferring the maximum amount capable of being transferred without experiencing rivet shear failure.

b. Use Of Stacked Doublers. A stacked doubler is composed of two or more sheets of material that are used in lieu of a single, thicker sheet of material. Because the stress transferred at each row of rivets is dependent upon the maximum stress that can be transferred by the rivets in that row, the thickness of the sheet material at that row need only be thick enough to transfer the stress applied. Employing this principle can reduce the weight of a repair joint.

4-39.—4-49. [RESERVED.]

SECTION 4. METAL REPAIR PROCEDURES

4-50. GENERAL. The airframe of a fixed-wing aircraft is generally considered to consist of five principal units; the fuselage, wings, stabilizers, flight control surfaces, and landing gear.

a. Aircraft principal structural elements (PSE) and joints are designed to carry loads by distributing them as stresses. The elements and joints as originally fabricated are strong enough to resist these stresses, and must remain so after any repairs. Long, thin elements are called members. Some examples of members are the metal tubes that form engine mount and fuselage trusses and frames, beams used as wing spars, and longerons and stringers of metal-skinned fuselages and wings. Longerons and stringers are designed to carry principally axial loads, but are sometimes required to carry side loads and bending moments, as when they frame cutouts in metal-skinned structures. Truss members are designed to carry axial (tension and compression) loads applied to their ends only. Frame members are designed to carry side loads and bending moments in addition to axial loads. Beam members are designed to carry side loads and bending moments that are usually large compared to their axial loads. Beams that must resist large axial loads, particularly compression loads, in combination with side loads and bending moments are called beam-columns. Other structural elements such as metal skins, plates, shells, wing ribs, bulkheads, ring frames, intercostal members, gussets, and other reinforcements, and fittings are designed to resist complex stresses, sometimes in three dimensions.

b. Any repair made on an aircraft structure must allow all of the stresses to enter, sustain these stresses, and then allow them to return into the structure. The repair must be equal to the original structure, but not stronger or stiffer, which will cause stress concentrations or alter the resonant frequency of the structure.

c. All-metal aircraft are made of very thin sheet metal, and it is possible to restore the strength of the skin without restoring its rigidity. All repairs should be made using the same type and thickness of material that was used in the original structure. If the original skin had corrugations or flanges for rigidity, these must be preserved and strengthened. If a flange or corrugation is dented or cracked, the material loses much of its rigidity; and it must be repaired in such a way that will restore its rigidity, stiffness, and strength.

4-51. RIVETED (OR BOLTED) STEEL TRUSS-TYPE STRUCTURES. Repairs to riveted structures may be made employing the general principles outlined in the following paragraphs on aluminum alloy structures. Repair methods may also be found in text books on metal structures. Methods for repair of the major structural members must be specifically approved by the Federal Aviation Administration (FAA).

4-52. ALUMINUM ALLOY STRUCTURES. Extensive repairs to damaged stressed skin on monocoque-types of aluminum alloy structures must be made in accordance with FAA-approved manufacturer's instructions or other FAA-approved source.

a. Rivet Holes. Rivet holes are slightly larger than the diameter of the rivet. When driven, solid rivets expand to fill the hole. The strength of a riveted joint is based upon the expanded diameter of the rivet. Therefore, it is important that the proper drill size be used for each rivet diameter.

(1) The acceptable drill size for rivets may be found in Metallic Materials and Elements for Flight Vehicle Structure (MIL-HDBK-5).

(2) Avoid drilling oversized holes or otherwise decreasing the effective tensile areas of wing-spar capstrips, wing, fuselage, fin-longitudinal stringers, or highly-stressed tensile members. Make all repairs, or reinforcements, to such members in accordance with factory recommendations or with the specific approval of an FAA representative.

b. Disassembly Prior to Repairing. If the parts to be removed are essential to the rigidity of the complete structure, support the structure prior to disassembly in such a manner as to prevent distortion and permanent damage to the remainder of the structure. When rivets are removed, undercut rivet heads by drilling. Use a drill of the same size as the diameter of the rivet. Drilling must be exactly centered and to the base of the head only. After drilling, break off the head with a pin punch and carefully drive out the shank. On thin or unsupported metal skin, support the sheet metal on the inside with a bucking bar. Removal of rivet heads with a cold chisel and hammer is not recommended because skin damage and distorted rivet holes will probably result. Inspect rivet joints adjacent to damaged structure for partial failure by removing one or more rivets to see if holes are elongated or the rivets have started to shear.

c. Effective Tools. Care must also be taken whenever screws must be removed to avoid damage to adjoining structure. When properly used, impact wrenches can be effective tools for removal of screws; however, damage to adjoining structure may result from excessive vertical loads applied through the screw axis. Excessive loads are usually related to improperly adjusted impact tools or attempting to remove screws that have seized from corrosion. Remove seized screws by drilling and use of a screw extractor. Once the screw has been removed, check for structural cracks that may appear in the adjoining skin doubler, or in the nut or anchor plate.

4-53. SELECTION OF ALUMINUM FOR REPLACEMENT PARTS. All aluminum replacement sheet metal must be identical to the original or properly altered skin. If another alloy is being considered, refer to the information on the comparative strength properties of aluminum alloys contained in MIL-HDBK-5.

a. Temper. The choice of temper depends upon the severity of the subsequent forming operations. Parts having single curvature and straight bend lines with a large bend radius may be advantageously formed from heat-treated material; while a part, such as a fuselage frame, would have to be formed from a soft, annealed sheet, and heat-treated after forming. Make sure sheet metal parts which are to be left unpainted are made of clad (aluminum coated) material. Make sure all sheet material and finished parts are free from cracks, scratches, kinks, tool marks, corrosion pits, and other defects which may be factors in subsequent failure.

b. Use of Annealed Alloys for Structural Parts. The use of annealed aluminum alloys for structural repair of an aircraft is not recommended. An equivalent strength repair using annealed aluminum will weigh more than a repair using heat-treated aluminum alloy.

4-54. HEAT TREATMENT OF ALUMINUM ALLOY PARTS. All structural aluminum alloy parts are to be heat-treated in accordance with the heat-treatment instruction issued by the manufacturers of the part. In the case of a specified temper, the sequence of heat-treating operations set forth in

MIL-HDBK-5 and corresponding specifications. If the heat-treatment produces warping, straighten the parts immediately after quenching. Heat-treat riveted parts before riveting, to preclude warping and corrosion.

a. Quenching. Quench material from the solution heat-treating temperature as rapidly as possible after removal from the furnace. Quenching in cold water is preferred, although less drastic chilling (hot or boiling water, or airblast) is sometimes employed for bulk sections, such as forgings, to minimize quenching stresses.

b. Reheating at Temperatures Above Boiling Water. Reheating of 2017 and 2024 alloys above 212 °F tend to impair the original heat treatment. Therefore, reheating above 212 °F, including the baking of primers, is not acceptable without subsequent complete and correct heat treatment.

4-55. BENDING METAL. When describing a bend in aviation, the term "bend radii" is used to refer to the inside radius. Requirements for bending the metal to various shapes are frequently encountered. When a metal is bent, it is subjected to changes in its grain structure, causing an increase in its hardness.

a. The minimum radius is determined by the composition of the metal, its temper, and thickness. Table 4-6 shows the recommended radius for different types of aluminum. Note that the smaller the thickness of the material, the smaller the recommended minimum bend radius, and that as the material increases in hardness, the recommended bend radii increases.

b. When using layout techniques, the mechanic must be able to calculate exactly how much material will be required for the bend. It is easier to lay out the part on a flat sheet before the bending or shaping is performed. Before bending, smooth all rough edges, remove burrs, and drill relief holes at the ends of bend lines and at corners; to prevent cracks from starting. Bend lines should preferably be made to lie at an angle to the grain of the metal (preferably 90 degrees).

c. Bend radii (BR) in inches for a specific metal composition (alloy) and temper is determined from table 4-6. For example, the minimum bend radii for 0.016 thick 2024-T6 (alloy and temper) is found is found to be 2 to 4 times the material thickness or 0.032 to 0.064.

4-56. SETBACK.

a. Setback is a measurement used in sheet metal layout. It is the distance the jaws of a brake must be setback from the mold line to form a bend. For a 90 degree bend, the point is back from the mold line to a distance equal to the bend radius plus the metal thickness. The mold line is an extension of the flat side of a part beyond the radius. The mold line dimension of a part, is the dimension made to the intersection of mold lines, and is the dimension the part would have if its corners had no radius. (See figure 4-2.)

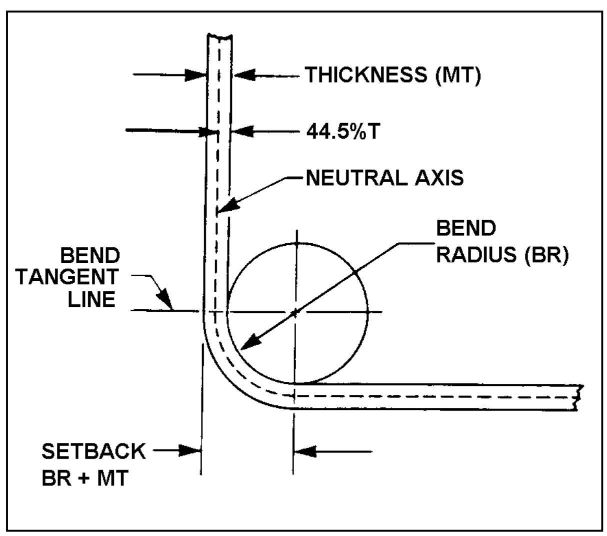


FIGURE 4-2. Setback for a 90-degree bend.

TABLE 4-6. Recommended radii for 90-degree bends in aluminum alloys.

Alloy and	Approximate sheet thickness (t) (inch)					
temper	**0.016**	**0.032**	**0.064**	**0.128**	**0.182**	**0.258**
2024-0[1]	0	0-1t	0-1t	0-1t	0-1t0-1t	0-1t
2024-T3[1, 2]	1½t-3t	2t-4t	3t-5t	4t-6t	4t-6t	5t-7t
2024-T6[1]	2t-4t	3t-5t	3t-5t	4t-6t	5t-7t	6t-10t
5052-0	0	0	0-1t	0-1t	0-1t	0-1t
5052-H32	0	0	½t-1t	½t-1½t	½t-1½t	½t-1½t
5052-H34	0	0	½t-1½t	1½t-2½t	1½t-2½t	2t-3t
5052-H36	0-1t	½t-1½t	1t-2t	1½t-3t	2t-4t	2t-4t
5052-H38	½t-1½t	1t-2t	1½t-3t	2t-4t	3t-5t	4t-6t
6061-0	0	0-1t	0-1t	0-1t	0-1t	0-1t
6061-T4	0-1t	0-1t	½t-1½t	1t-2t	1½t-3t	2½t-4t
6061-T6	0-1t	½t-1½t	1t-2t	1½t-3t	2t-4t	3t-4t
7075-0	0	0-1t	0-1t	½t-1½t	1t-2t	1½t-3t
7075-T6[1]	2t-4t	3t-5t	4t-6t	5t-7t	5t-7t	6t-10t

[1] Alclad sheet may be bent over slightly smaller radii than the corresponding tempers of uncoated alloy.
[2] Immediately after quenching, this alloy may be formed over appreciably smaller radii.

b. To determine setback for a bend of more or less than 90 degrees, a correction known as a K-factor must be applied to find the setback.

(1) Table 4-7 shows a chart of K-factors. To find the setback for any degree of bend, multiply the sum of the bend radius and metal thickness by the K-value for the angle through which the metal is bent.

(2) Figure 4-3 shows an example of a piece of 0.064 inch sheet metal bent through 45 degrees to form an open angle of 135 degrees. For 45 degrees, the K-factor is 0.41421. The setback, or the distance from the mold point to the bend tangent line, is:

Setback = K(BR + MT)
= 0.41421 (0.25 + 0.064)
= 0.130 inches

(3) If a closed angle of 45 degrees is formed, the metal must be bent through 135 degrees. The K-factor for 135 degrees is 2.4142, so the setback, or distance from the mold point to the bend tangent line, is 0.758 inch.

4-57. RIVETING.

a. The two major types of rivets used in aircraft are the common solid shank rivet, which must be driven using an air-driven rivet gun and bucking bar; and special (blind) rivets, which are installed with special installation tools. Design allowables for riveted assemblies are specified in MIL-HDBK-5.

(1) Solid shank rivets are used widely during assembly and repair work. They are identified by the material of which they are made, the head type, size of shank, and temper condition.

TABLE 4-7. K-chart for determining setback for bends other than 90 degrees.

Deg.	K	Deg.	K	Deg.	K	Deg.	K	Deg:	K
1	0.0087	37	0.3346	73	0.7399	109	1.401	145	3.171
2	0.0174	38	0.3443	74	0.7535	110	1,428	146	3.270
3	0.0261	39	0.3541	75	0.7673	111	1.455	147	3.375
4	0.0349	40	0.3639	76	0.7812	112	1.482	148	3.487
5	0.0436	41	0.3738	77	0.7954	113	1.510	149	3.605
6	0.0524	42	0.3838	78	0.8097	114	1.539	150	3.732
7	0.0611	43	0.3939	79	0.8243	115	1.569	151	3.866
8	0.0699	44	0.4040	80	0.8391	116	1.600	152	4.010
9	0.0787	45	0.4142	81	0.8540	117	1.631	153	4.165
10	0.0874	46	0.4244	82	0.8692	118	1.664	154	4.331
11	0.0963	47	0.4348	83	0.8847	119	1.697	155	4.510
12	0.1051	48	0.4452	84	0.9004	120	1.732	156	4.704
13	0.1139	49	0.4557	85	0.9163	121	1.767	157	4.915
14	0.1228	50	0.4663	86	0.9324	122	1.804	158	5.144
15	0.1316	51	0.4769	87	0.9489	123	1.841	159	5.399
16	0.1405	52	0.4877	88	0.9656	124	1.880	160	5.671
17	0.1494	53	0.4985	89	0.9827	125	1.921	161	5.975
18	0.1583	54	0.5095	90	1.000	126	1.962	162	6.313
19	0.1673	55	0.5205	91	1.017	127	2.005	163	6.691
20	0.1763	56	0.5317	92	1.035	128	2.050	164	7.115
21	0.1853	57	0.5429	93	1.053	129	2.096	165	7.595
22	0.1943	58	0.5543	94	1.072	130	2.144	166	8.144
23	0.2034	59	0.5657	95	1.091	131	2.194	167	8.776
24	0.2125	60	0.5773	96	1.110	132	2.246	168	9.514
25	0.2216	61	0.5890	97	1-130	133	2.299	169	10.38
26	0.2308	62	0.6008	98	1.150	134	2.355	170	11.43
27	0.2400	63	0.6128	99	1.170	135	2.414	171	12.70
28	0.2493	64	0.6248	100	1.191	136	2.475	172	14.30
29	0.2586	65	0.6370	101	1.213	137	2.538	173	16.35
30	0.2679	66	0.6494	102	1.234	138	2.605	174	19.08
31	0.2773	67	0.6618	103	1.257	139	2.674	175	22.90
32	0.2867	68	0.6745	104	1.279	140	2.747	176	26.63
33	0.2962	69	0.6872	105	1.303	141	2.823	177	38.18
34	0.3057	70	0.7002	106	1.327	142	2.904	178	57.29
35	0.3153	71	0.7132	107	1.351	143	2.988	179	114.59
36	0.3249	72	0.7265	108	1.376	144	3.077	180	Inf.

(2) The material used for the majority of solid shank rivets is aluminum alloy. The strength and temper conditions of aluminum alloy rivets are identified by digits and letters similar to those used to identify sheet stock. The 1100, 2017-T, 2024-T, 2117-T, and 5056 rivets are the six grades usually available. AN-type aircraft solid rivets can be identified by code markings on the rivet heads. A rivet made of 1100 material is designated as an "A" rivet, and has no head marking. The 2017-T alloy rivet is designated as a "D" rivet and has a raised teat on the head. Two dashes on a rivet head indicate a 2024-T alloy designated as a "DD" rivet. The 2117-T rivet is designated as an "AD" rivet, and has a dimple on the head. A "B" designation is given to a rivet of 5056 material and is marked with a raised cross on the rivet head. Each type of rivet is identified by a part number to allow the user to select the correct rivet. The numbers are in series and each series represents a particular type of head. (See figure 4-4 and table 4-8.)

(3) An example of identification marking of rivet follows.

MS 20470AD3-5	Complete part number
MS	Military standard number
20470	Universal head rivet
AD	2117-T aluminum alloy
3	3/32nds in diameter
5	5/16ths in length

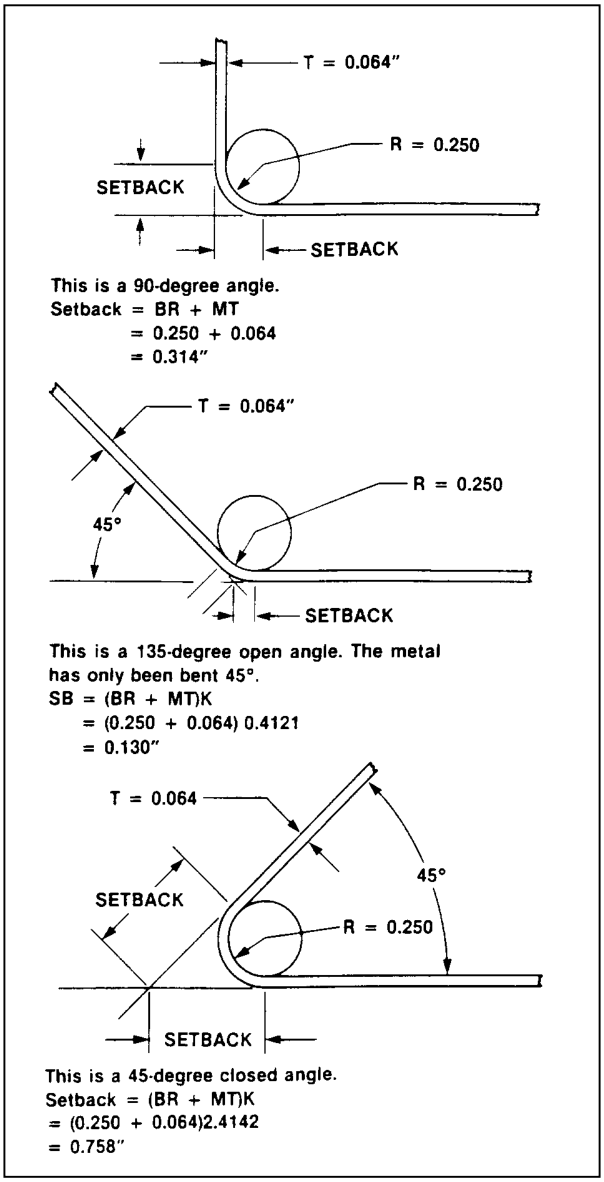


FIGURE 4-3. Methods of determining setback for bends other than 90 degree.

(4) Countersunk head rivets (MS20426 supersedes AN426 100-degree) are used where a smooth finish is desired. The 100-degree countersunk head has been adopted as the standard in the United States. The universal head rivet (AN470 superseded by MS20470) has been adopted as the standard for protruding-head rivets, and may be used as a replacement for the roundhead, flathead, and brazier head rivet. These rivets can also be purchased in half sizes by designating a "0.5" after the main length (i.e., MS20470 AD4-3.5).

RIVET IDENTIFICATION

The material can be identified by the head marking

Rivet	Material Code	Head Marking	Material
	A	PLAIN (Dyed)	1100
	AD	DIMPLED	2117
	D	RAISED DOT	2017T
	DD	TWO RAISED DASHES	2024
	B	RAISED CROSS (Dyed)	5056
	E	RAISED CIRCLE	7050
	M	TWO DOTS	Monel

PART NUMBER BREAKDOWN

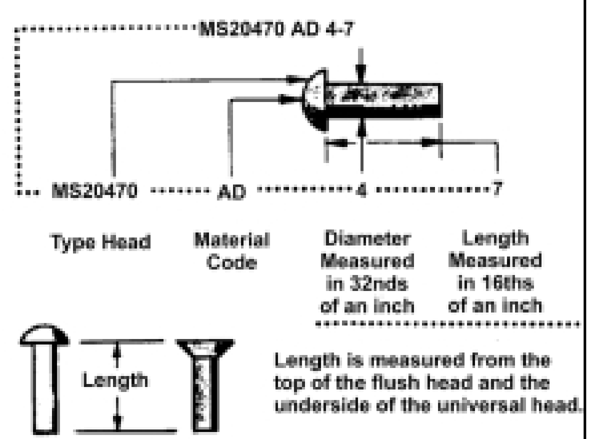


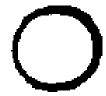
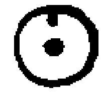
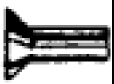
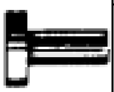
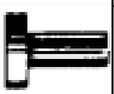
FIGURE 4-4. Rivet identification and part number breakdown.

b. Replace rivets with those of the same size and strength whenever possible. If the rivet hole becomes enlarged, deformed, or otherwise damaged; drill or ream the hole for the next larger size rivet. However, make sure that the edge distance and spacing is not less than minimums listed in the next paragraph. Rivets may not be replaced by a type having lower strength properties, unless the lower strength is adequately compensated by an increase in size or a greater number of rivets. It is acceptable to replace 2017 rivets of 3/16 inch diameter or less, and 2024 rivets of 5/32 inch diameter or less with 2117 rivets for general repairs, provided the replacement rivets are 1/32 inch greater in diameter than the rivets they replace.

TABLE 4-8. Aircraft rivet identification.

Material	1100	2117T	2017T	2017T-HD	2024T	5056T	7075-T73
Head Marking	Plain 	Dimpled 	Raised Dot 	Raised Dot 	Raised Double Dash 	Raised Cross 	Three Raised Dashes 
AN Material Code	A	AD	D	D	DD	B	
 **AN425 78▪ Counter-Sunk Head**	X	X	X	X	X		X
 **AN426 100▪ Counter-Sunk Head MS20426**	X	X	X	X	X	X	X
 **AN427 100▪ Counter-Sunk Head MS20427**							
 **AN430 Round Head MS20470**	X	X	X	X	X	X	X
 **AN435 Round Head MS20613 MS20615**							
 **AN 441 Flat Head**							
 **AN 442 Flat Head MS20470**	X	X	X	X	X	X	X
 **AN 455 Brazier Head MS20470**	X	X	X	X	X	X	X
 **AN 456 Brazier Head MS20470**	X	X	X	X	X	X	X
 **AN 470 Universal Head MS20470**	X	X	X	X	X	X	X
Heat Treat Before Using	No	No	Yes	No	Yes	No	No
Shear Strength psi	10000	30000	34000	38000	41000	27000	
Bearing Strength psi	25000	100000	113000	126000	136000	90000	

TABLE 4-8. Aircraft rivet identification. (continued)

	Material	Carbon Steel	Corrosion-Resistant Steel	Copper	Monel	Monel Nickel-Copper Alloy	Brass	Titanium
	Head Marking	Recessed Triangle 	Recessed Dash 	Plain 	Plain 	Recessed Double Dots 	Plain 	Recessed Large and Small Dot 
	AN Material Code		F	C	M	C		
	**AN425 78▪ Counter-Sunk Head**							
	**AN426 100▪ Counter-Sunk Head MS20426**							MS 20426
	**AN427 100▪ Counter-Sunk Head MS20427**	X	X	X	X			
	**AN430 Round Head MS20470**							
	**AN435 Round Head MS20613 MS20615**	X MS20613	X MS20613	X		X MS20615	X MS20615	
	**AN 441 Flat Head**	X		X	X			X
	**AN 442 Flat Head MS20470**							
	**AN 455 Brazier Head MS20470**							
	**AN 456 Brazier Head MS20470**							
	**AN 470 Universal Head MS20470**							
	Heat Treat Before Us-ing	No	No	No	No	No	No	No
	Shear Strength psi	35000	65000	23000	49000	49000		95000
	Bearing Strength psi	90000	90000					

c. Rivet edge distance is defined as the distance from the center of the rivet hole to the nearest edge of the sheet. Rivet spacing is the distance from the center of the rivet hole to the center of the adjacent rivet hole. Unless structural deficiencies are suspected, the rivet spacing and edge distance should duplicate those of the original aircraft structure. If structural deficiencies are suspected, the following may be used in determining minimum edge distance and rivet spacing.

(1) For single row rivets, the edge distance should not be less than 2 times the diameter of the rivet and spacing should not be less than 3 times the diameter of the rivet.

(2) For double row rivets, the edge distance and spacing should not be less than the minimums shown in figure 4-5.

(3) For triple or multiple row rivets, the edge distance and spacing should not be less than the minimums shown in figure 4-5.

d. The 2117 rivets may be driven in the condition received, but 2017 rivets above 3/16 inch in diameter and all 2024 rivets are to be kept packed in dry ice or refrigerated in the "quenched" condition until driven, or be reheat treated just prior to driving, as they would otherwise be too hard for satisfactory riveting. Dimensions for formed rivet heads are shown in figure 4-6(a), together with commonly found rivet imperfections.

e. When solid shank rivets are impractical to use, then special fasteners are used. Special fastening systems used for aircraft construction and repair are divided into two types, special and blind fasteners. Special fasteners are sometimes designed for a specific purpose in an aircraft structure. The name "special fasteners" refers to its job requirement and the tooling needed for installation. Use of special fasteners may require an FAA field approval.

f. Blind rivets are used under certain conditions when there is access to only one side of the structure. Typically, the locking characteristics of a blind rivet are not as good as a driven rivet. Therefore, blind rivets are usually not used when driven rivets can be installed.

Blind rivets shall not be used:

(1) in fluid-tight areas;

(2) on aircraft in air intake areas where rivet parts may be ingested by the engine, on aircraft control surfaces, hinges, hinge brackets, flight control actuating systems, wing attachment fittings, landing gear fittings, on floats or amphibian hulls below the water level, or other heavily-stressed locations on the aircraft;

CAUTION: For metal repairs to the airframe, the use of blind rivets must be specifically authorized by the airframe manufacturer or approved by a representative of the FAA.

(3) Self plugging friction-lock cherry rivets. This patented rivet may be installed when there is access to only one side of the structure. The blind head is formed by pulling the tapered stem into the hollow shank. This swells the shank and clamps the skins tightly together. When the shank is fully upset, the stem pulls in two. The stem does not fracture flush with the rivet head and must be trimmed and filed flush for the installation to be complete. Because of the friction-locking stem, these rivets are very sensitive to vibrations. Inspection is visual, with a loose rivet standing out in the standard "smoking rivet" pattern. Removal consists of punching out the friction-

locked stem and then treating it like any other rivet. (See figure 4-7.)

(4) Mechanical-lock rivets have a device on the puller or rivet head which locks the center stem into place when installed. Many friction-lock rivet center stems fall out due to vibrations; this in turn, greatly reduces its shear strength. The mechanical-lock rivet was developed to prevent that problem. Various manufacturers make mechanical-lock fasteners such as: Bulbed Cherrylock, CherryMax, Olympic-Loks, and Huck-Loks.

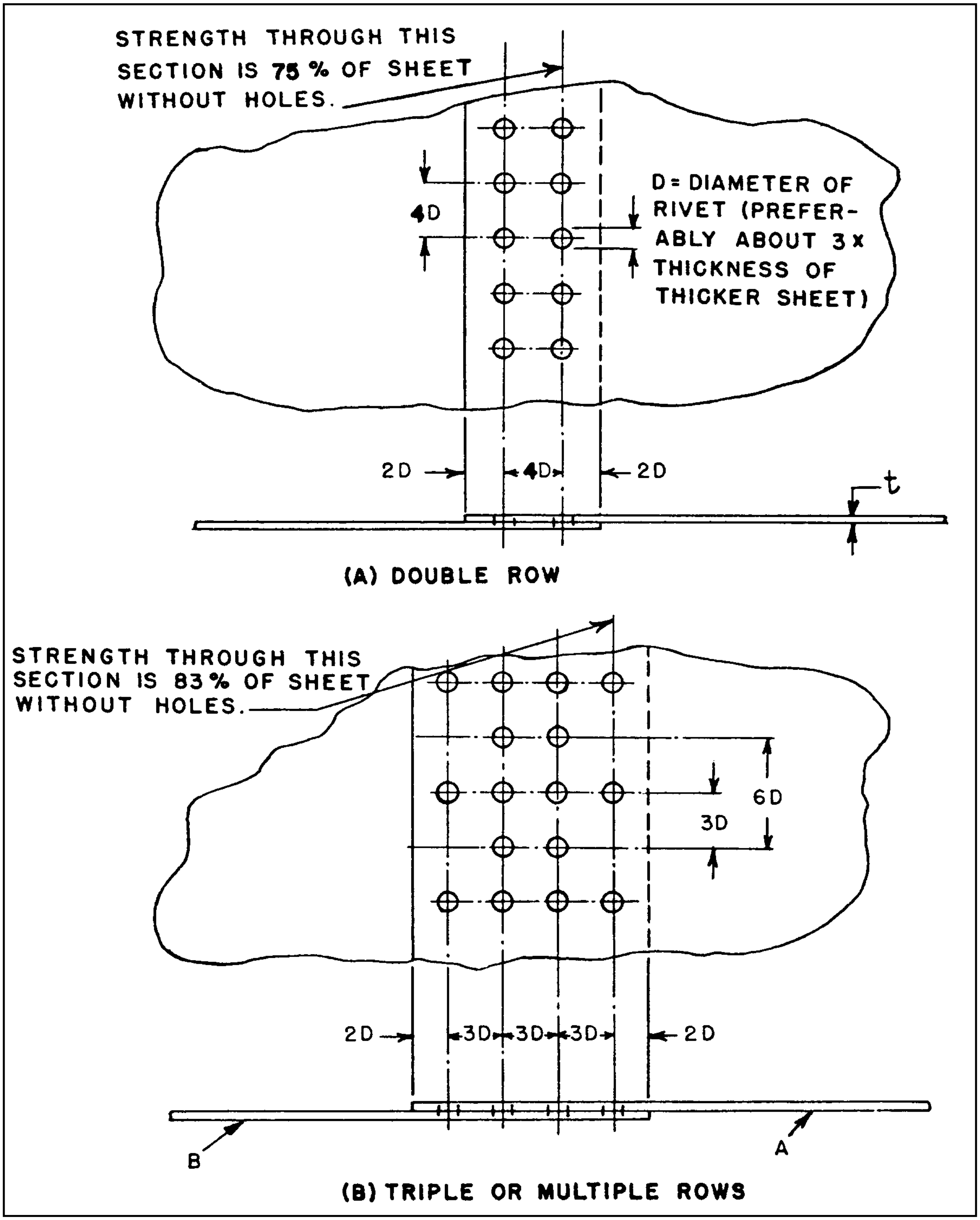


FIGURE 4-5. Rivet hole spacing and edge distance for single-lap sheet splices.

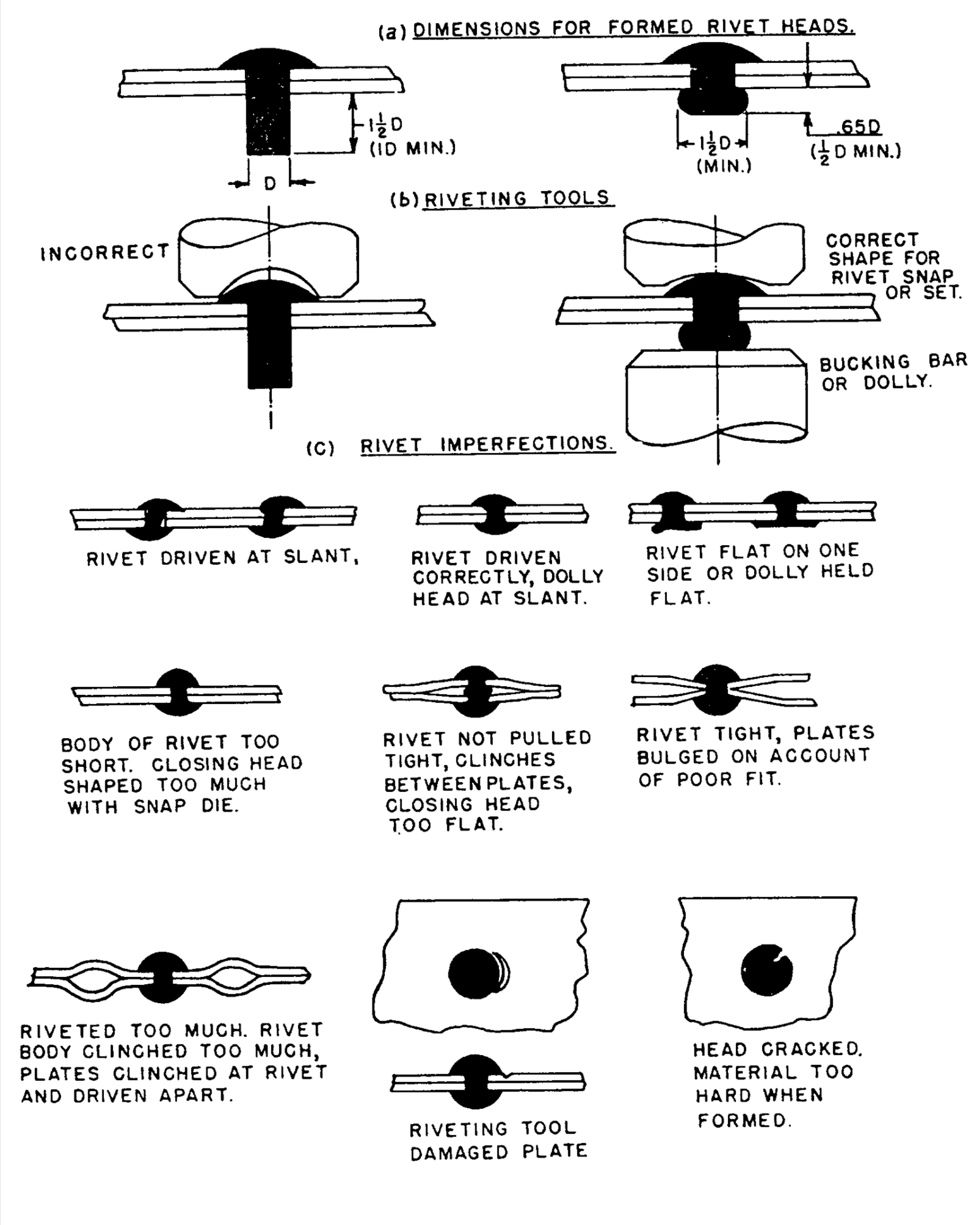


FIGURE 4-6. Riveting practice and rivet imperfections.

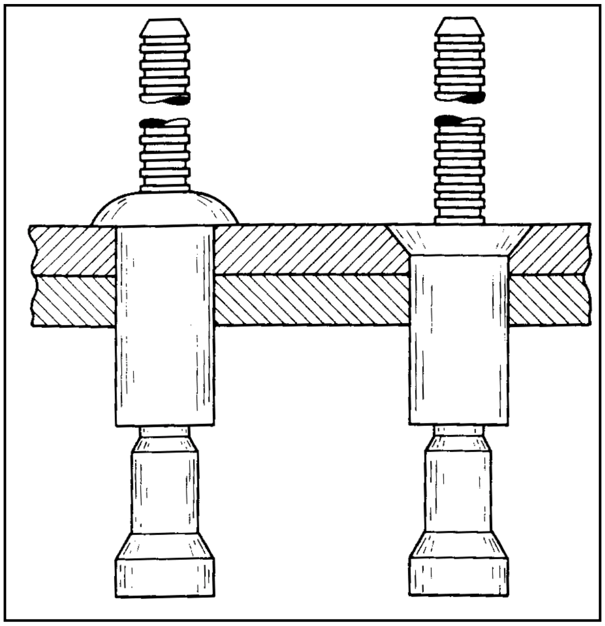


FIGURE 4-7. Self plugging friction-lock Cherry rivets.

(5) Bulbed Cherrylock Rivets. One of the earlier types of mechanical-lock rivets developed were Bulbed Cherrylock blind rivets. These blind rivets have as their main advantage the ability to replace a solid shank rivet size for size. (See figure 4-8.)

(a) A Bulbed Cherrylock consists of three parts; a rivet shell, a puller, and a lockring. The puller or stem has five features which are activated during installation; a header, shank expanding section, lockring indent, weak or stem fracture point, and a serrated pulling stem. Carried on the pulling stem, near the manufactured head, is the stem lockring. When the rivet is pulled the action of the moving stem clamps together the sheets of metal and swells the shank to fill the drilled hole. When the stem reaches its preset limit of travel, the upper stem breaks away (just above the lockring) as the lockring snaps into the recess on the locking stem. The rough end of the retained stem in the center on the manufactured head must never be filed smooth, because it will weaken the strength of the lockring and the center stem could fall out. (See figure 4-8.)

(b) The Bulbed Cherrylock rivets are available in two head styles: universal and 100° countersunk. Their lengths are measured in increments of 1/16 inch. It is important to select a rivet with a length related to the grip length of the metal being joined.

(c) The Bulbed Cherrylock rivet can be installed using a G35 cherry rivet hand puller or a pneumatic Bulbed Cherrylock pulling tool.

(6) The CherryMax (see figure 4-9) rivet uses one tool to install three standard rivet diameters and their oversize counterparts. This makes the use of CherryMax rivets very popular with many small general aviation repair shops. CherryMax rivets are available in four nominal diameters 1/8, 5/32, 3/16, and 1/4 inch and three oversized diameters. CherryMax rivets are manufactured with two head styles, universal and countersunk. The CherryMax rivets consists of five parts; bulbed blind header, hollow rivet shell, locking (foil) collar, driving anvil, and pulling stem. The blind bulbed header takes up the extended shank and forms the bucktail on a CherryMax rivet stem. Rivet sleeves are made from 5056 aluminum, monel, and INCO 600. The stems are made from alloy steel, CRES, and INCO X-750 stem. CherryMax rivets have an ultimate shear strength ranging from 50 KSI to 75 KSI.

(7) An Olympic-Lok (see figure 4-10) rivet is a light three-piece mechanically locked, spindle-type blind rivet. It carries its stem lock integral to the manufactured head. While installing, the lockring is pressed into a groove on the pulling stem just as the rivet completes drawing the metal together. After installation is completed, never file the stem of an Olympic-Lok rivet, because it will weaken the lockring attachment. The Olympic-Lok fastener is available in three head styles:

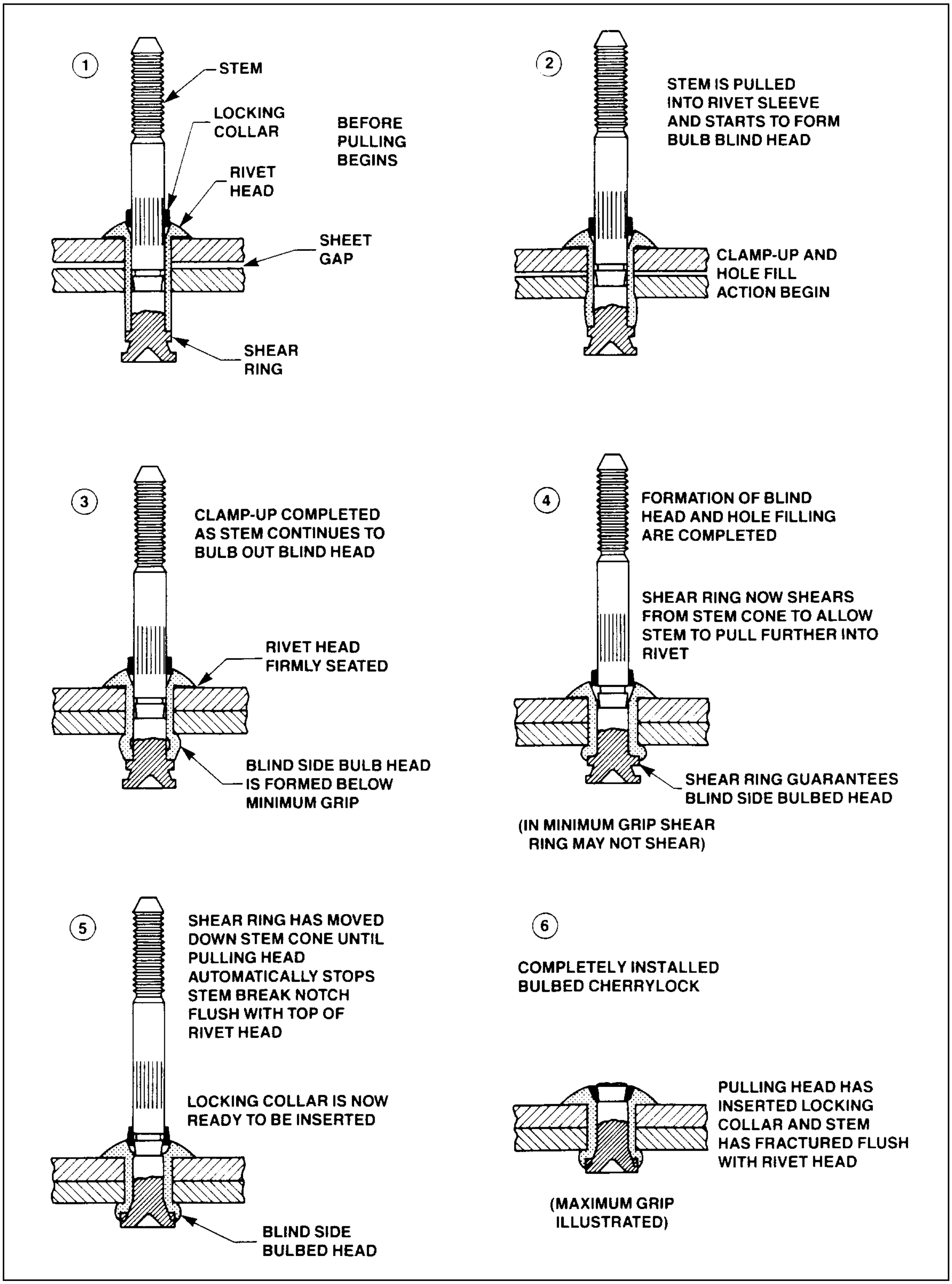


FIGURE 4-8. Mechanical-lock (Bulbed Cherrylock) Cherry rivet.

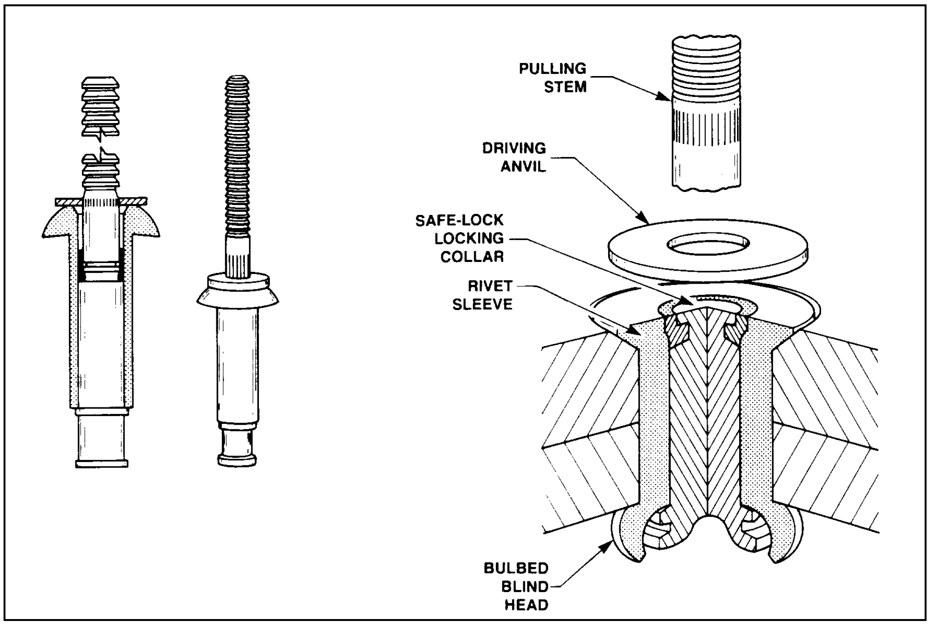


FIGURE 4-9. CherryMax rivet.

universal protruding, 100-degree flush countersink, and 100-degree flush shear; and three diameters 1/8, 5/32, and 3/16 inch. The three diameters are available in eight different alloy combinations of 2017-T4, A-286, 5056, and monel. Olympic-Lok lock spindles are made from the same material as the sleeves.

(8) Huck rivets (see figure 4-11) are available in two head styles, protruding and flush. They are available in four diameters 1/8, 5/32, 3/16, and 1/4 inch. Their diameters are measured in increments of 1/32 inch and lengths are measured in 1/16 inch increments. They are manufactured in three different combinations of alloys: 5056 aluminum sleeve with 2024 aluminum alloy pin, A-286 corrosion-resistant steel sleeve with an A-286 pin, and a monel 400 sleeve with an A-286 pin. The Huck fastener has the ability to tightly draw-up two or more sheets of metal together while being installed. After the take-up of the Huck fastener is completed, the lockring is squeezed into a groove on the pulling stem. The anvil or footer (of the installation tool) packs the ring into the groove of the pulling stem by bearing against the lockring.

(9) Common pull-type Pop rivets, produced for nonaircraft related applications, are not approved for use on certificated aircraft structures or components.

g. Design a new or revised rivet pattern for strength required in accordance with one of the following:

(1) The aircraft manufacturer's maintenance manuals.

(2) The techniques found in structural text books and using the mechanical properties found in MIL-HDBK-5.

(3) The specific instructions in paragraphs 4-58g through 4-58n. When following the instruction in paragraphs 4-58g through 4-58n, the general rule for the diameter of the rivets used to join aluminum sheets is to use a diameter approximately three times the thickness of the thicker sheet. Do not use rivets where they would be placed in tension, tending to pull the heads off; and backup a lap joint of thin sheets with a stiffener section.

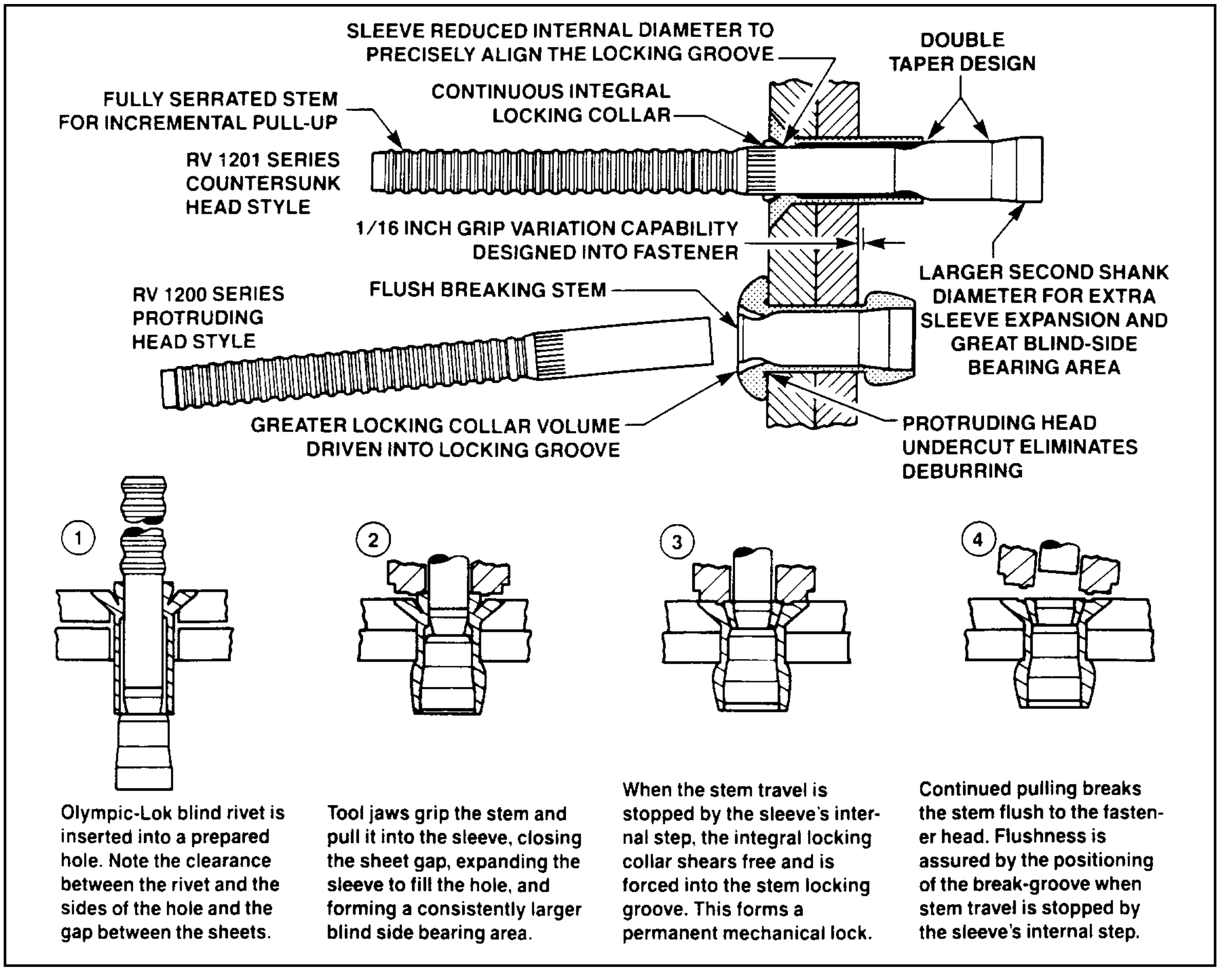


FIGURE 4-10. Olympic-Lok rivet.

4-58. REPAIR METHODS AND PRECAUTIONS FOR ALUMINUM STRUCTURE. Carefully examine all adjacent rivets outside of the repair area to ascertain that they have not been harmed by operations in adjacent areas. Drill rivet holes round, straight, and free from cracks. Deburr the hole with an oversize drill or deburring tool. The rivet-set used in driving the rivets must be cupped slightly flatter than the rivet head. (See figure 4-6.) Rivets are to be driven straight and tight, but not overdriven or driven while too hard, since the finished rivet must be free from cracks. Information on special methods of riveting, such as flush riveting, usually may be obtained from manufacturer's service manuals.

a. Splicing of Tubes. Round or streamline aluminum alloy tubular members may be repaired by splicing. (See figure 4-12.) Splices in struts that overlap fittings are not acceptable. When solid rivets go completely through hollow tubes, their diameter must be at least one-eighth of the outside diameter of the outer tube. Rivets which are loaded in shear should be hammered only enough to form a small head and no attempt made to form the standard roundhead. The amount of hammering required to form the standard roundhead often causes the rivet to buckle inside the tube. (Correct and incorrect examples of this type of rivet application are incorporated in figure 4-12.)

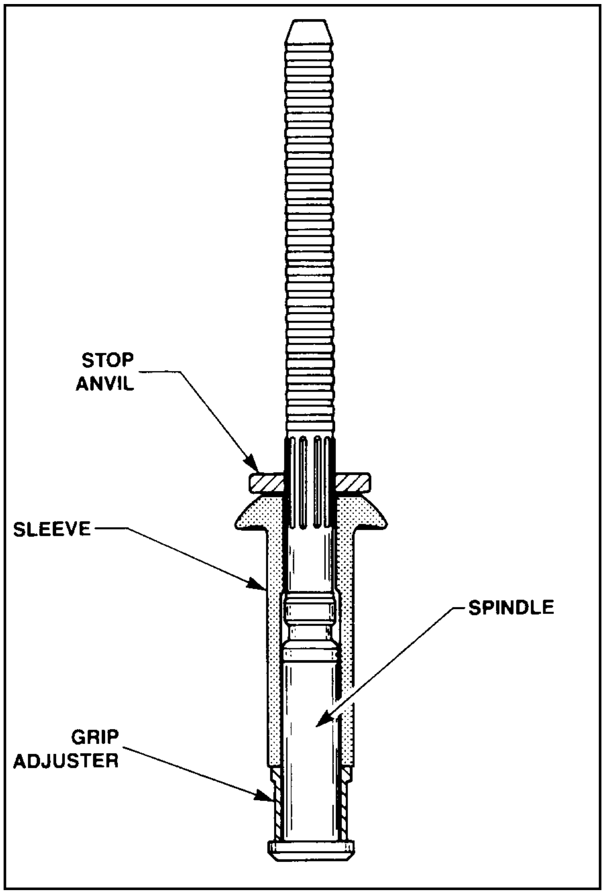


FIGURE 4-11. Huck rivet.

b. Repairs to Aluminum Alloy Members. Make repairs to aluminum alloy members with the same material or with suitable material of higher strength. The 7075 alloy has greater tensile strength than other commonly used aluminum alloys such as 2014 and 2024, but is subject to somewhat greater notch sensitivity. In order to take advantage of its strength characteristics, pay particular attention to design of parts to avoid notches, small radii, and large or rapid changes in cross-sectional areas. In fabrication, exercise caution to avoid processing and handling defects, such as machine marks, nicks, dents, burrs, scratches, and forming cracks. Cold straightening or forming of 7075-T6 can cause cracking; therefore, it may be advisable to limit this processing to minor cold straightening.

c. Wing and Tail Surface Ribs. Damaged aluminum alloy ribs either of the stamped sheet-metal type or the built-up type employing special sections, square or round tubing, may be repaired by the addition of suitable reinforcement. (Acceptable methods of repair are shown in figures 4-13 and 4-14.) These examples deal with types of ribs commonly found in small and medium size aircraft. Repair schemes developed by the aircraft manufacturer are acceptable, but any other methods of reinforcement are major repairs and require approved data.

d. Trailing and Leading Edges and Tip Strips. Repairs to wing, control surface trailing edges, leading edges, and tip strips should be made by properly executed and reinforced splices. Acceptable methods of trailing edge repairs are shown in figure 4-15.

e. Repair of Damaged Skin. In cases where metal skin is damaged extensively, repair by replacing an entire sheet panel from one structural member to the next. The repair seams are to lie along stiffening members, bulkheads, etc.; and each seam must be made exactly the same in regard to rivet size, splicing, and rivet pattern as the manufactured seams at the edges of the original sheet. If the two manufactured seams are different, the stronger one will be copied. (See figure 4-16 for typical acceptable methods of repairs.)

f. Patching of Small Holes. Small holes in skin panels which do not involve damage to the stiffening members may be patched by covering the hole with a patch plate in the manner shown in figure 4-16. Flush patches also may be installed in stressed-skin type construction. An acceptable and easy flush patch may be made by trimming out the damaged area and then installing a conventional patch on the underneath side or back of the sheet being repaired. A plug patch plate of the same size and skin thickness as the opening may then be inserted and riveted to the patch plate. Other types of flush patches similar to those used for patching plywood may be used. The rivet pattern used, however, must follow standard practice to maintain satisfactory strength in the sheet.

g. Splicing of Sheets. The method of copying the seams at the edges of a sheet may not always be satisfactory. For example, when the sheet has cutouts, or doubler plates at an edge seam, or when other members transmit loads into the sheet, the splice must be designed as illustrated in the following examples.

(1) Material: Clad 2024 sheet, 0.032 inch thickness. Width of sheet (i.e., length at splice) = "W" = 10 inches.

(2) Determine rivet size and pattern for a single-lap joint similar to figure 4-5.

(a) Use rivet diameter of approximately three times the sheet thickness, 3 x 0.032 = 0.096-inch. Use 1/8-inch 2117-T4 (AD) rivets (5/32-inch 2117-T4 (AD) would be satisfactory).

(b) Use the number of rivets required per inch of width "W" from table 4-10. (Number per inch 4.9 x .75 = 3.7 or the total number of rivets required = 10 x 3.7 or 37 rivets.) See notes in table.

(c) Lay out rivet pattern with spacing not less than shown in figure 4-5. Referring to figure 4-5(A), it seems that a double row pattern with the minimum spacing will give a total of 40 rivets. However, as only 37 rivets are required, two rows of 19 rivets each equally spaced over the10 inches will result in a satisfactory splice.

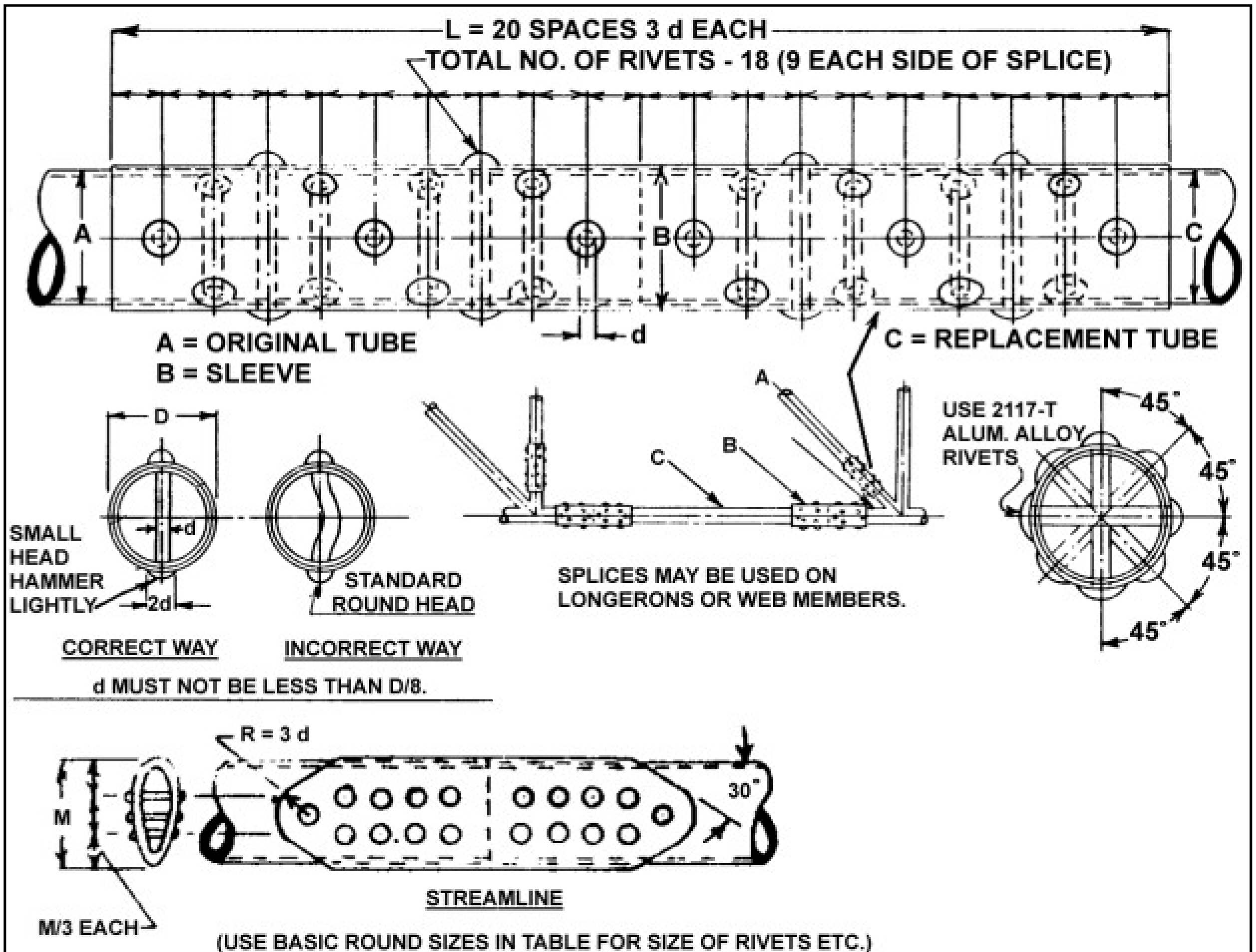
h. Straightening of Stringers or Intermediate Frames. Members which are slightly bent may be straightened cold and examined with a magnifying glass for cracks or tears to the material. Reinforce the straightened part to its original shape, depending upon the condition of the material and the magnitude of any remaining kinks or buckles. If any strain cracks are apparent, make complete reinforcement in sound metal beyond the damaged portion.

i. Local Heating. Do not apply local heating to facilitate bending, swaging, flattening, or expanding operations of heat-treated aluminum alloy members, as it is difficult to control the temperatures closely enough to prevent possible damage to the metal, and it may impair its corrosion resistance.

j. Splicing of Stringers and Flanges. It is recommended that all splices be made in accordance with the manufacturer's recommendations. If the manufacturer's recommendations are not available, the typical splices for various shapes of sections are shown in figures 4-17 through 4-19. Design splices to carry both tension and compression, and use the splice shown in figure 4-18 as an example illustrating the following principles.

(1) To avoid eccentric loading and consequent buckling in compression, place splicing or reinforcing parts as symmetrically as possible about the centerline of the member, and attach to as many elements as necessary to prevent bending in any direction.

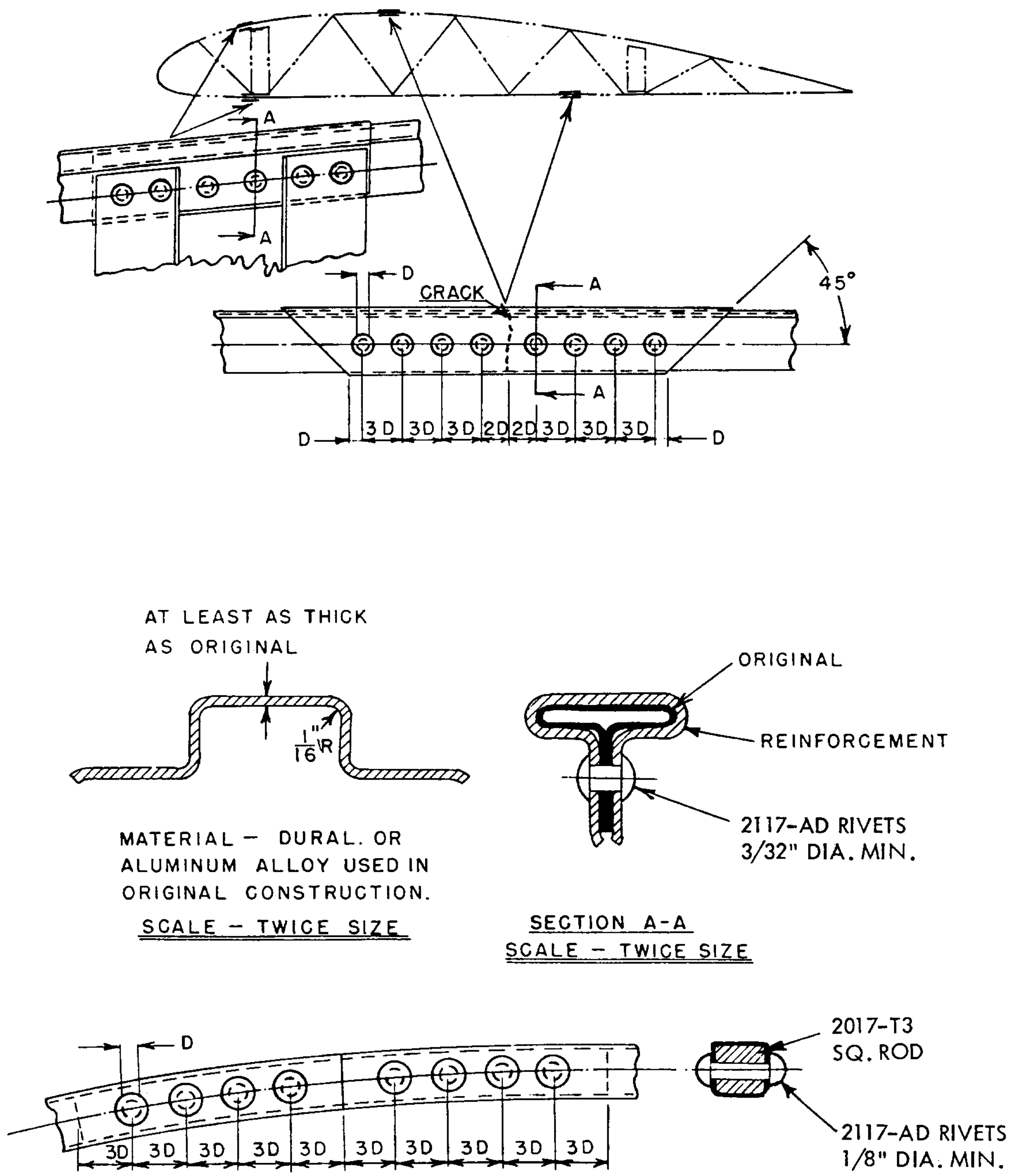
(2) To avoid reducing the strength in tension of the original bulb angle, the rivet holes at the ends of the splice are made small (no larger than the original skin attaching rivets), and the second row of holes (those through the bulbed leg) are staggered back from the ends. In general, arrange the rivets in the splice so that the design tensile load for the member and splice plate can be carried into the splice without failing the member at the outermost rivet holes.



A, C *	3/4	7/8	1	1-1/8	1-1/4	1-/3/8	1-1/2	1-/5/8	1-3/4	1-7/8
	.065	.065	.065	.065	.058	.058	.058	.058	.058	.058
B	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2	1-5/8	1-3/4	1-7/8	2
	ALL .058 THICK									
RIVET DIA.	5/32	5/32	3/16	3/16	3/16	3/16	1/4	1/4	1/4	1/4
L	9-3/8	9-3/8	11-1/4	11-1/4	11-1/4	11-1/4	15	15	15	15
* INCLUDES ALL THICKNESSES UP TO AND INCLUDING MAXIMUM SHOWN.										

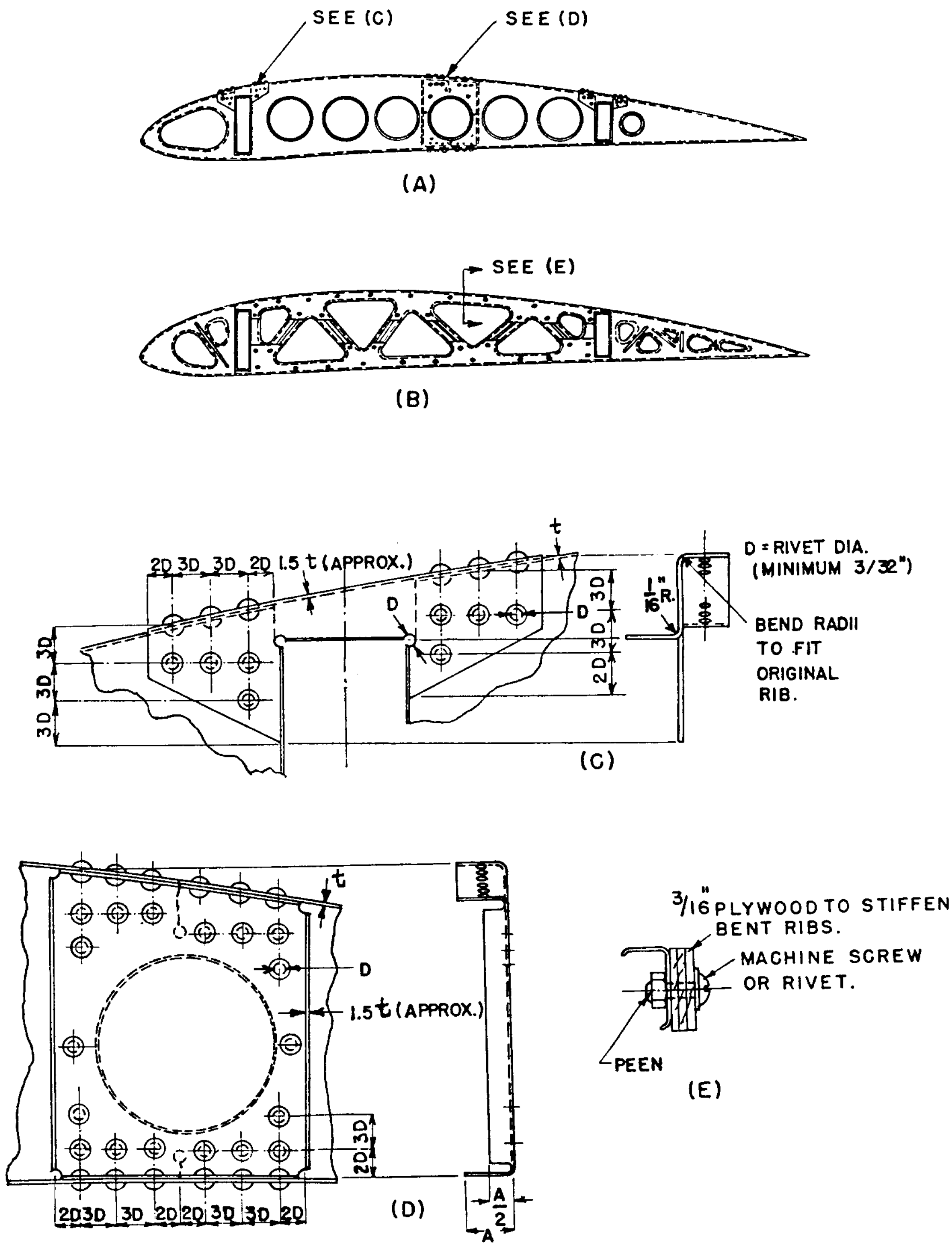
NOTE. USE SAME MATERIAL AS ORIGINAL FOR SLEEVE AND REPLACEMENT TUBE.

FIGURE 4-12. Typical repair method for tubular members of aluminum alloy.



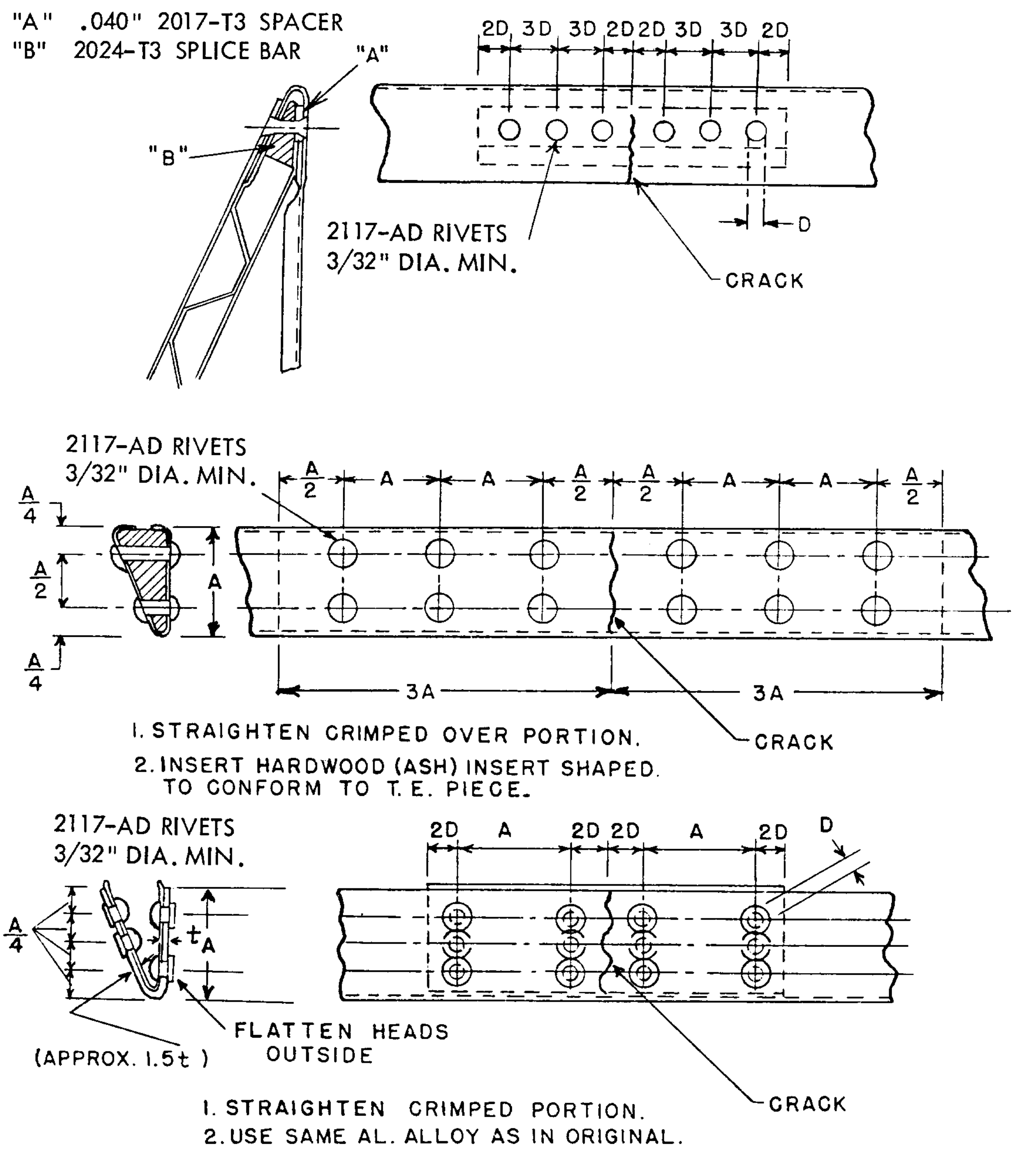
NOTE: FOR MINIMUM NUMBER OF RIVETS REQUIRED, SEE PARAGRAPH 4-58g AND SUBSEQUENT.

FIGURE 4-13. Typical repair for buckled or cracked metal wing rib capstrips.



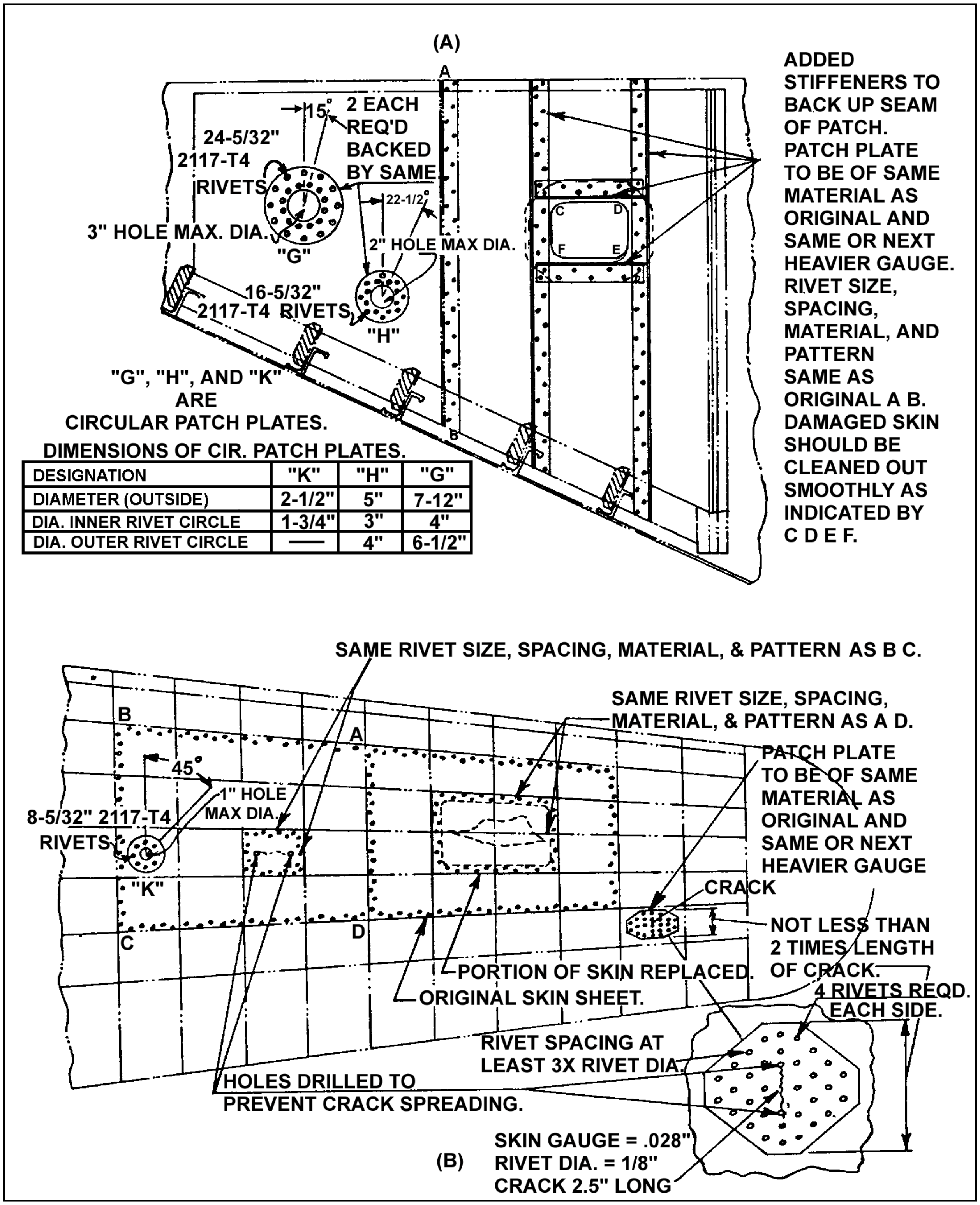
NOTE: FOR MINIMUM NUMBER OF RIVETS REQUIRED, SEE PARAGRAPH 4-58g AND SUBSEQUENT.

FIGURE 4-14. Typical metal rib repairs (usually found on small and medium-size aircraft).



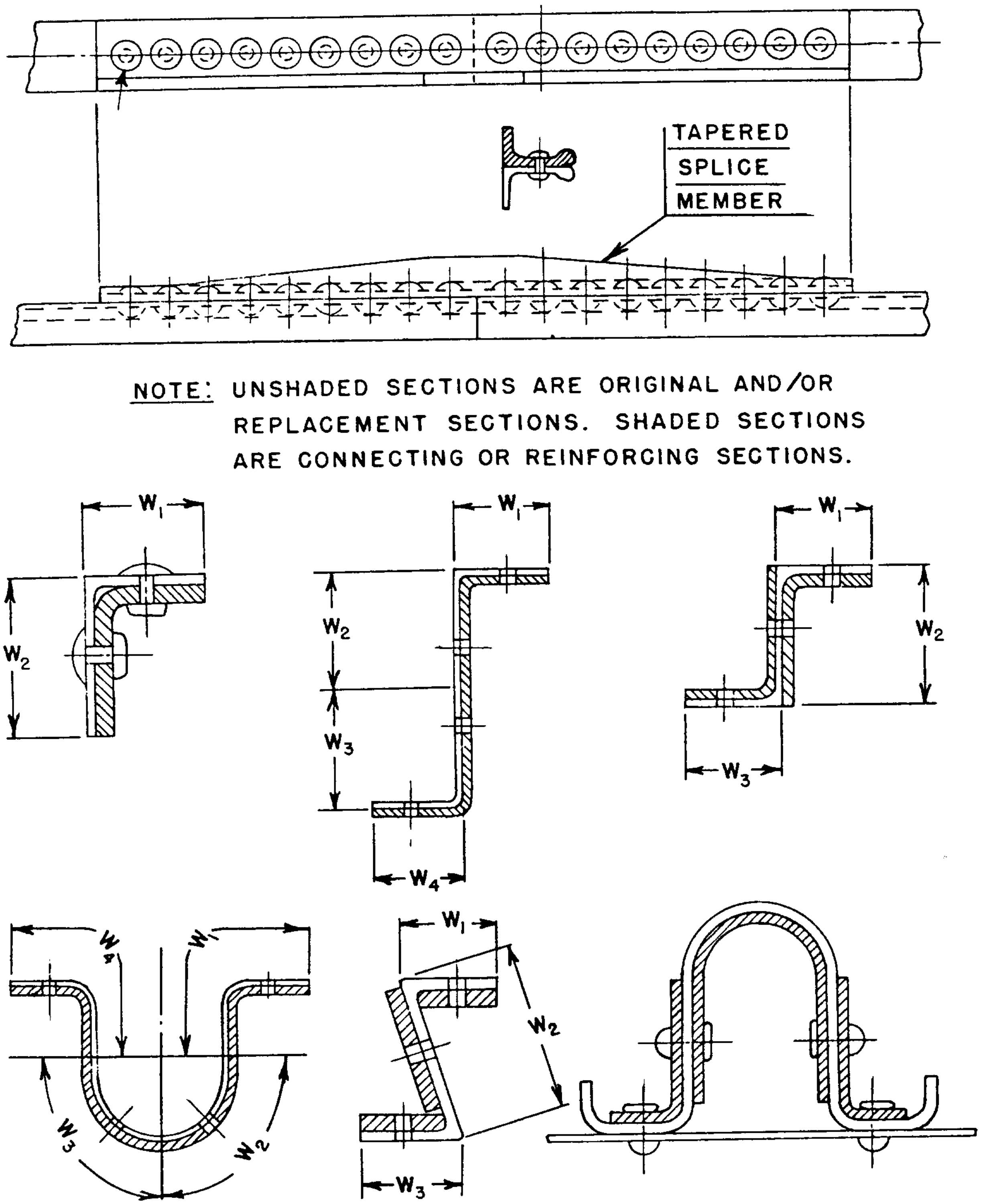
NOTE: FOR MINIMUM NUMBER OF RIVETS REQUIRED, SEE PARAGRAPH 4-58g AND SUBSEQUENT.

FIGURE 4-15. Typical repairs of trailing edges.



DESIGNATION	"K"	"H"	"G"
DIAMETER (OUTSIDE)	2-1/2"	5"	7-12"
DIA. INNER RIVET CIRCLE	1-3/4"	3"	4"
DIA. OUTER RIVET CIRCLE	—	4"	6-1/2"

FIGURE 4-16. Typical repairs of stressed sheet metal coverings. (Refer to tables 4-9, 4-10, and 4-11 to calculate number of rivets to be used.)



NOTE: FOR MINIMUM NUMBER OF RIVETS REQUIRED, SEE PARAGRAPH 4-58g AND SUBSEQUENT.

FIGURE 4-17. Typical stringer and flange splices.

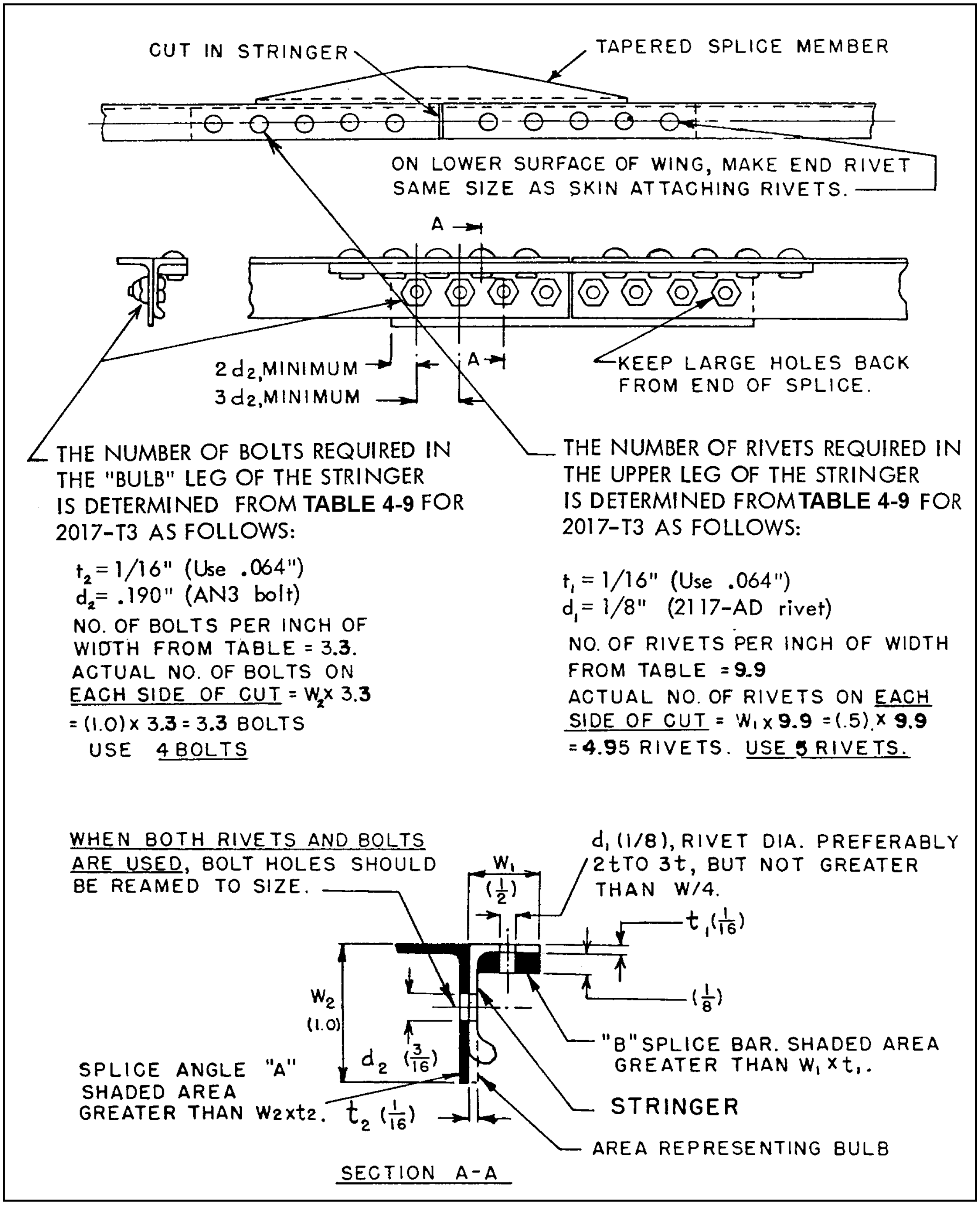
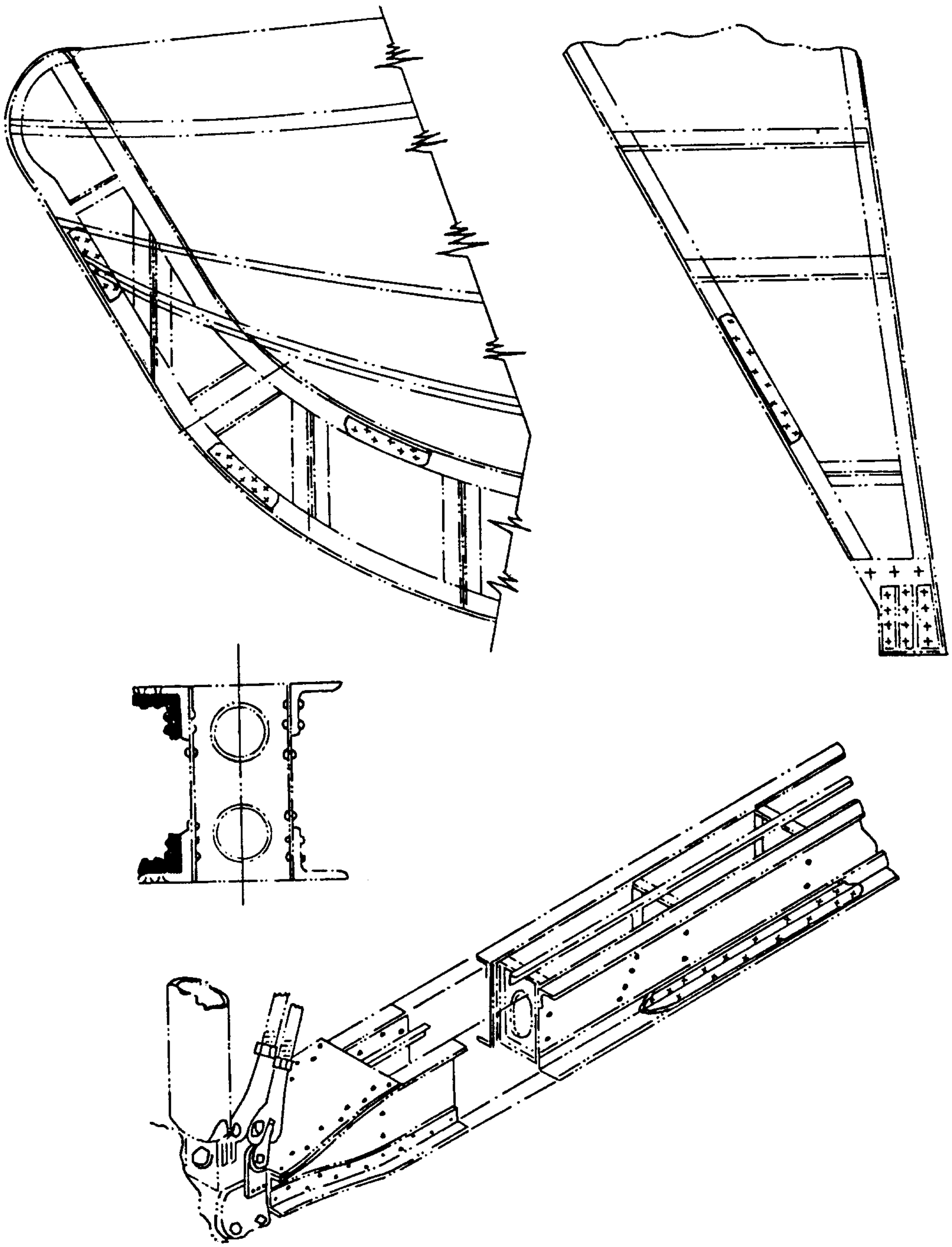


FIGURE 4-18. Example of stringer splice (material-2017 alloy).



NOTE: FOR MINIMUM NUMBER OF RIVETS REQUIRED, SEE PARAGRAPH 4-58g AND SUBSEQUENT.

NOTE: STRENGTH INVESTIGATION IS USUALLY REQUIRED FOR THIS TYPE OF REPAIR.

FIGURE 4-19. Application of typical flange splices and reinforcement.

(3) To avoid concentration of load on the end rivet and consequent tendency toward progressive rivet failure, the splice is tapered at the ends by tapering the backing angle and by making it shorter than the splice bar. (See figure 4-18.)

(4) The preceding principles are especially important in splicing stringers on the lower surface of stressed skin wings, where high-tension stresses may exist. When several adjacent stringers are spliced, stagger the splices if possible.

k. Size of Splicing Members. When the same material is used for the splicing members as for the original member, the cross-section area (i.e., the shaded areas in figure 4-17), of the splice material will be greater than the area of the section element which it splices. The area of a section element (e.g., each leg of an angle or channel) is equal to the width multiplied by the thickness. For example, the bar "B" in figure 4-18 is assumed to splice the upper leg of the stringer, and the angle "A" is assumed to splice the bulbed leg of the stringer. Since the splice bar "B" is not as wide as the adjacent leg, its thickness must be increased such that the area of bar "B" is at least equal to the area of the upper leg of the stringer.

l. The Diameter of Rivets in Stringers. The diameter of rivets in stringers might preferably be between two and three times the thickness "t" of the leg, but must not be more than 1/4th the width "W" of the leg. Thus, 1/8-inch rivets are chosen in the example, figure 4-18. If the splices were in the lower surface of a wing, the end rivets would be made the same size as the skin-attaching rivets, or 3/32 inch.

m. The Number of Rivets. The number of rivets required on each side of the cut in a stringer or flange may be determined from standard text books on aircraft structures, or may be found in tables 4-9 through 4-11.

(1) In determining the number of rivets required in the example, figure 4-18, for attaching the splice bar "B" to the upper leg, the thickness "t" of the element of area being spliced is 1/16 inch (use 0.064), the rivet size is 1/8 inch, and table 4-9 shows that 9.9 rivets are required per inch of width. Since the width "W" is 1/2 inch, the actual number of rivets required to attach the splice bar to the upper leg on each side of the cut is 9.9 (rivets per inch) x 0.5 (inch width) = 4.95 (use 5 rivets).

(2) For the bulbed leg of the stringer "t" = 1/16 inch (use 0.064); AN-3 bolts are chosen, and the number of bolts required per inch of width = 3.3. The width "W" for this leg, however, is 1 inch; and the actual number of bolts required on each side of the cut is 1 x 3.3 = 3.3 (use 4 bolts). When both rivets and bolts are used in the same splice, the bolt holes must be accurately reamed to size. It is preferable to use only one type of attachment, but in the above example, the dimensions of the legs of the bulb angle indicated rivets for the upper leg and bolts for the bulb leg.

n. Splicing of Intermediate Frames. The same principles used for stringer splicing may be applied to intermediate frames when the following point is considered. Conventional frames of channel or Z sections are relatively deep and thin compared to stringers, and usually fail by twisting or by buckling of the free flange. Reinforce the splice joint against this type of failure by using a splice plate heavier than the frame and by splicing the free flange of the frame with a flange of the splice plate. (See figure 4-20.) Since a frame is likely to be subjected to bending loads, make the length of splice plate "L" more than twice the width "W_2," and the rivets spread out to cover the plate.

TABLE 4-9. Number of rivets required for splices (single-lap joint) in bare 2014-T6, 2024-T3, 2024-T36, and 7075-T6 sheet, clad 2014-T6, 2024-T3, 2024-T36, and 7075-T6 sheet, 2024-T4, and 7075-T6 plate, bar, rod, tube, and extrusions, 2014-T6 extrusions.

Thickness "t" in inches	No. of 2117-T4 (AD) protruding head rivets required per inch of width "W" — Rivet size					No. of Bolts
	3/32	1/8	5/32	3/16	1/4	AN-3
.016	6.5	4.9	- -	- -	- -	- -
.020	6.9	4.9	3.9	- -	- -	- -
.025	8.6	4.9	3.9	- -	- -	- -
.032	11.1	6.2	3.9	3.3	- -	- -
.036	12.5	7.0	4.5	3.3	2.4	- -
.040	13.8	7.7	5.0	3.5	2.4	3.3
.051	- -	9.8	6.4	4.5	2.5	3.3
.064	- -	12.3	8.1	5.6	3.1	3.3
.081	- -	- -	10.2	7.1	3.9	3.3
.091	- -	- -	11.4	7.9	4.4	3.3
.102	- -	- -	12.8	8.9	4.9	3.4
.128	- -	- -	- -	11.2	6.2	3.2

NOTES:

a. For stringers in the upper surface of a wing, or in a fuselage, 80 percent of the number of rivets shown in the table may be used.

b. For intermediate frames, 60 percent of the number shown may be used.

c. For single lap sheet joints, 75 percent of the number shown may be used.

ENGINEERING NOTES:

a. The load per inch of width of material was calculated by assuming a strip 1 inch wide in tension.

b. Number of rivets required was calculated for 2117-T4 (AD) rivets, based on a rivet allowable shear stress equal to 40 percent of the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 160 percent of the sheet allowable tensile stress, using nominal bolt diameters for rivets.

c. Combinations of sheet thickness and rivet size above the underlined numbers are critical in (i.e., will fail by) bearing on the sheet; those below are critical in shearing of the rivets.

d. The number of AN-3 bolts required below the underlined number was calculated based on a sheet allowable tensile stress of 70,000 psi and a bolt allowable single shear load of 2,126 pounds.

TABLE 4-10. Number of rivets required for splices (single-lap joint) in 2017, 1017 ALCLAD, 2024-T3 ALCLAD sheet, plate, bar, rod, tube, and extrusions.

Thickness "t" in inches	No. of 2117-T4 (AD) protruding head rivets required per inch of width "W"					No. of Bolts
	Rivet size					
	3/32	1/8	5/32	3/16	1/4	AN-3
.016	6.5	4.9	- -	- -	- -	- -
.020	<u>6.5</u>	4.9	3.9	- -	- -	- -
.025	6.9	<u>4.9</u>	3.9	- -	- -	- -
.032	8.9	4.9	3.9	3.3	- -	- -
.036	10.0	5.6	<u>3.9</u>	3.3	2.4	- -
.040	11.1	6.2	4.0	<u>3.3</u>	2.4	- -
.051	- -	7.9	5.1	3.6	<u>2.4</u>	3.3
.064	- -	9.9	6.5	4.5	2.5	3.3
.081	- -	12.5	8.1	5.7	3.1	3.3
.091	- -	- -	9.1	6.3	3.5	3.3
.102	- -	- -	10.3	7.1	3.9	<u>3.3</u>
.128	- -	- -	12.9	8.9	4.9	3.3

NOTES:

a. For stringers in the upper surface of a wing, or in a fuselage, 80 percent of the number of rivets shown in the table may be used.

b. For intermediate frames, 60 percent of the number shown may be used.

c. For single lap sheet joints, 75 percent of the number shown may be used.

ENGINEERING NOTES:

a. The load per inch of width of material was calculated by assuming a strip 1 inch wide in tension.

b. Number of rivets required was calculated for 2117-T4 (AD) rivets, based on a rivet allowable shear stress equal to percent of the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 160 percent of the sheet allowable tensile stress, using nominal hole diameters for rivets.

c. Combinations of sheet thickness and rivet size above the underlined numbers are critical in (i.e., will fail by) bearing on the sheet; those below are critical in shearing of the rivets.

d. The number of AN-3 bolts required below the underlined number was calculated based on a sheet allowable tensile stress of 55,000 psi and a bolt allowable single shear load of 2,126 pounds.

TABLE 4-11. Number of rivets required for splices (single-lap joint) in 5052 (all hardnesses) sheet.

Thickness "t" in inches	No. of 2117-T4 (AD) protruding head rivets required per inch of width "W" — Rivet size					No. of Bolts
	3/32	1/8	5/32	3/16	1/4	AN-3
.016	6.3	4.7		- -	- -	- -
.020	6.3	4.7	3.8	- -	- -	- -
.025	6.3	4.7	3.8	- -	- -	- -
.032	<u>6.3</u>	4.7	3.8	3.2	- -	- -
.036	7.1	4.7	3.8	3.2	2.4	- -
.040	7.9	<u>4.7</u>	3.8	3.2	2.4	- -
.051	10.1	5.6	<u>3.8</u>	3.2	2.4	- -
.064	12.7	7.0	4.6	3.2	2.4	- -
.081	- -	8.9	5.8	4.0	<u>2.4</u>	3.2
.091	- -	10.0	6.5	4.5	2.5	3.2
.102	- -	11.2	7.3	5.1	2.8	3.2
.128	- -	- -	9.2	6.4	3.5	3.2

NOTES:

a. For stringers in the upper surface of a wing, or in a fuselage, 80 percent of the number of rivets shown in the table may be used.

b. For intermediate frames, 60 percent of the number shown may be used.

c. For single lap sheet joints, 75 percent of the number shown may be used.

ENGINEERING NOTES:

a. The load per inch of width of material was calculated by assuming a strip 1 inch wide in tension.

b. Number of rivets required was calculated for 2117-T4 (AD) rivets, based on a rivet allowable shear stress equal to 70 percent of the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 160 percent of the sheet allowable tensile stress, using nominal hole diameters for rivets.

c. Combinations of sheet thickness and rivet size above the underlined numbers are critical in (i.e., will fail by) bearing on the sheet, those below are critical in shearing of the rivets.

4-59. REPAIRING CRACKED MEMBERS. Acceptable methods of repairing various types of cracks in structural elements are shown in figures 4-21 through 4-24. The following general procedures apply in repairing such defects.

a. Drill small holes 3/32 inch (or 1/8 inch) at the extreme ends of the cracks to minimize the possibility of their spreading further.

b. Add reinforcement to carry the stresses across the damaged portion and to stiffen the joints. (See figures 4-14 through 4-17.) The condition causing cracks to develop at a particular point is stress concentration at that point in conjunction with repetition of stress, such as produced by vibration of the structure. The stress concentration may be due to the design or to defects such as nicks, scratches, tool marks, and initial stresses or cracks from forming or heat-treating operations. It should be noted, that an increase in sheet thickness alone is usually beneficial but does not necessarily remedy the conditions leading to cracking.

4-60. STEEL AND ALUMINUM FITTINGS.

a. Steel Fittings. Inspect for the following defects.

(1) Fittings are to be free from scratches, vise and nibbler marks, and sharp bends or edges. A careful examination of the fitting with a medium power (at least 10 power) magnifying glass is acceptable as an inspection.

(2) When repairing aircraft after an accident or in the course of a major overhaul, inspect all highly-stressed main fittings, as set forth in the manufacturer's instruction manual.

(3) Replace torn, kinked, or cracked fittings.

(4) Elongated or worn bolt holes in fittings, which were designed without bushings, are not to be reamed oversize. Replace such fittings, unless the method of repair is approved by the FAA. Do not fill holes with welding rod. Acceptable methods of repairing elongated or worn bolt holes in landing gear, stabilizer, interplane, or cabane-strut ends are shown in figure 4-25.

b. Aluminum and Aluminum Alloy Fittings.

(1) Replace damaged fittings with new parts that have the same material specifications.

(2) Repairs may be made in accordance with data furnished by the aircraft manufacturer, or data substantiating the method of repair may be submitted to the FAA for approval.

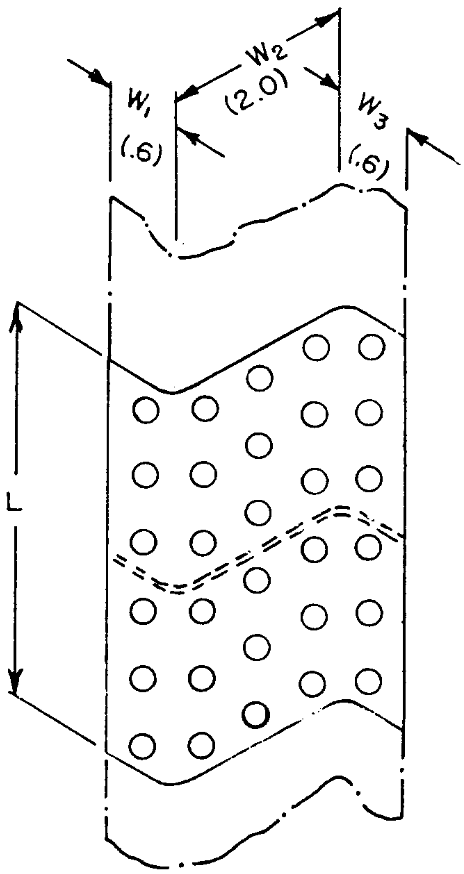
4-61. CASTINGS. Damaged castings are to be replaced and not repaired unless the method of repair is specifically approved by the aircraft manufacturer or substantiating data for the repair has been reviewed by the FAA for approval.

4-62. SELECTIVE PLATING IN AIRCRAFT MAINTENANCE. Selective plating is a method of depositing metal from an electrolyte to the selected area. The electrolyte is held in an absorbent material attached to an inert anode. Plating contact is made by brushing or swabbing the part (cathode) with the electrolyte-bearing anode.

a. Selective Plating Uses. This process can be utilized for any of the following reasons.

THE NUMBER OF RIVETS REQUIRED IN EACH LEG ON EACH SIDE OF THE CUT IS DETERMINED BY THE WIDTH "W," THE THICKNESS OF THE FRAME "t," AND THE RIVET DIAMETER "d" USING TABLE 4-10 IN A MANNER SIMILAR TO THAT FOR STRINGERS IN FIGURE 4-20.

NOTE b. IN TABLE 4-10 INDICATES THAT ONLY 60 PERCENT OF THE NUMBER OF RIVETS SO CALCULATED NEED BE USED IN SPLICES IN INTERMEDIATE.



EXAMPLE: (FOR 2017-T3 aluminum alloy frame)

FLANGE LEG

t = .040"
d = 1/8" 2117-T4 (AD)
W_1 & W_3 = .6 inch

NO. OF RIVETS PER INCH OF WIDTH FROM TABLE 4-10 = 6.2

No. of rivets required = W x 6.2 =
.6 x 6.2 = 3.72 or 4 rivets.
60 percent of 4 rivets = 2.4 rivets.
USE 3 RIVETS ON EACH SIDE OF THE CUT IN EACH FLANGE LEG.

WEB OF ZEE (OR CHANNEL)

t = .040"
d = 1/8" 2117-T4 (AD) rivet
W = 2.0 inches

NO. OF RIVETS PER INCH OF WIDTH FROM TABLE 4-10 = 6.2

No. of rivets required = W x 6.2 =
2.0 x 6.2 = 12.4 or 13 rivets.
60 percent of 13 rivets = 7.8 rivets.
USE 8 RIVETS ON EACH SIDE OF CUT IN THE WEB OF ZEE (OR CHANNEL).

"L" SHOULD BE MORE THAN TWICE W_2

Thickness of splice plate to be greater than that of the frame to be spliced.

FIGURE 4-20. Example of intermediate frame stringer splice (material 2017-T3 AL alloy).

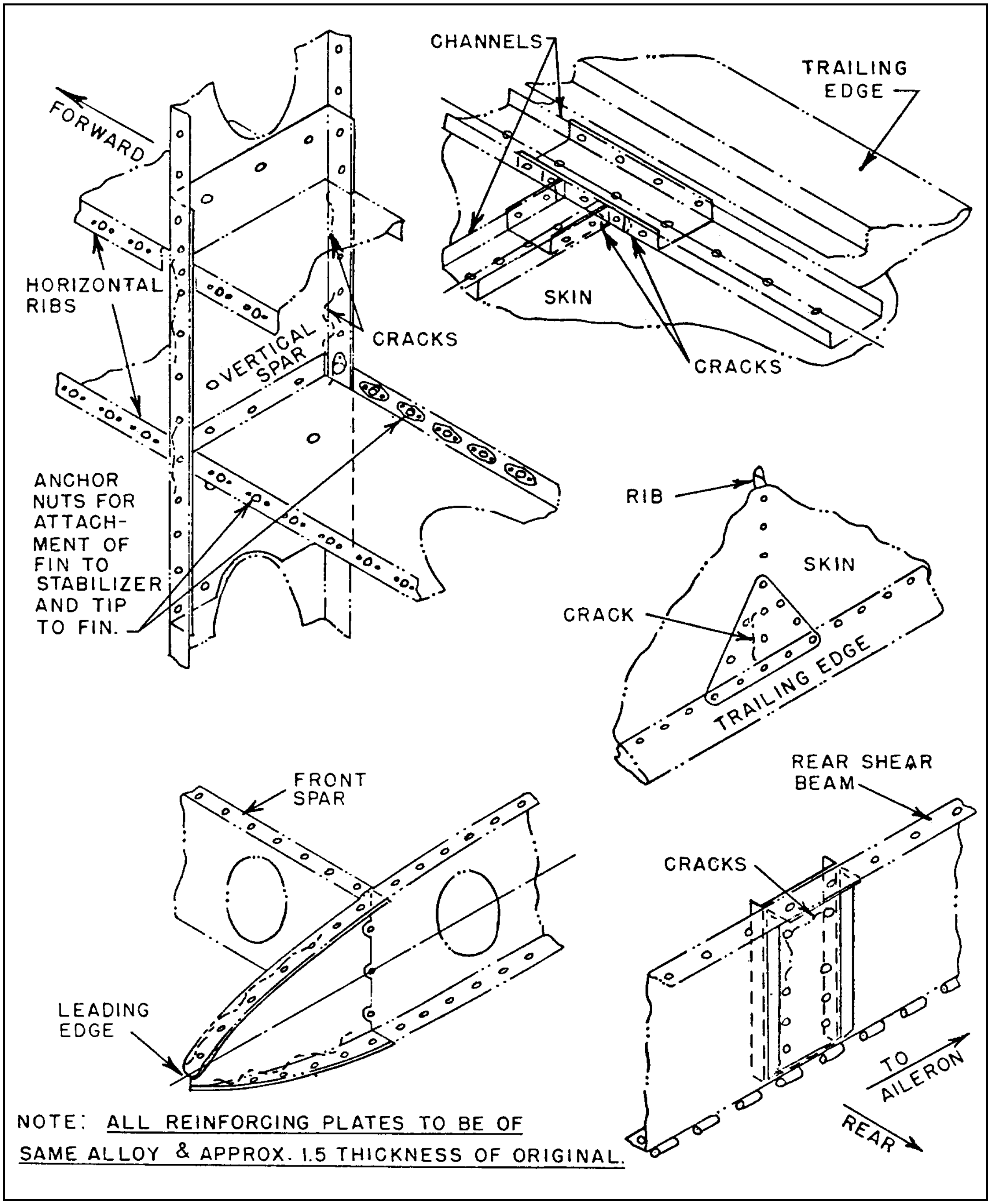


FIGURE 4-21. Typical methods of repairing cracked leading and trailing edges and rib intersections.

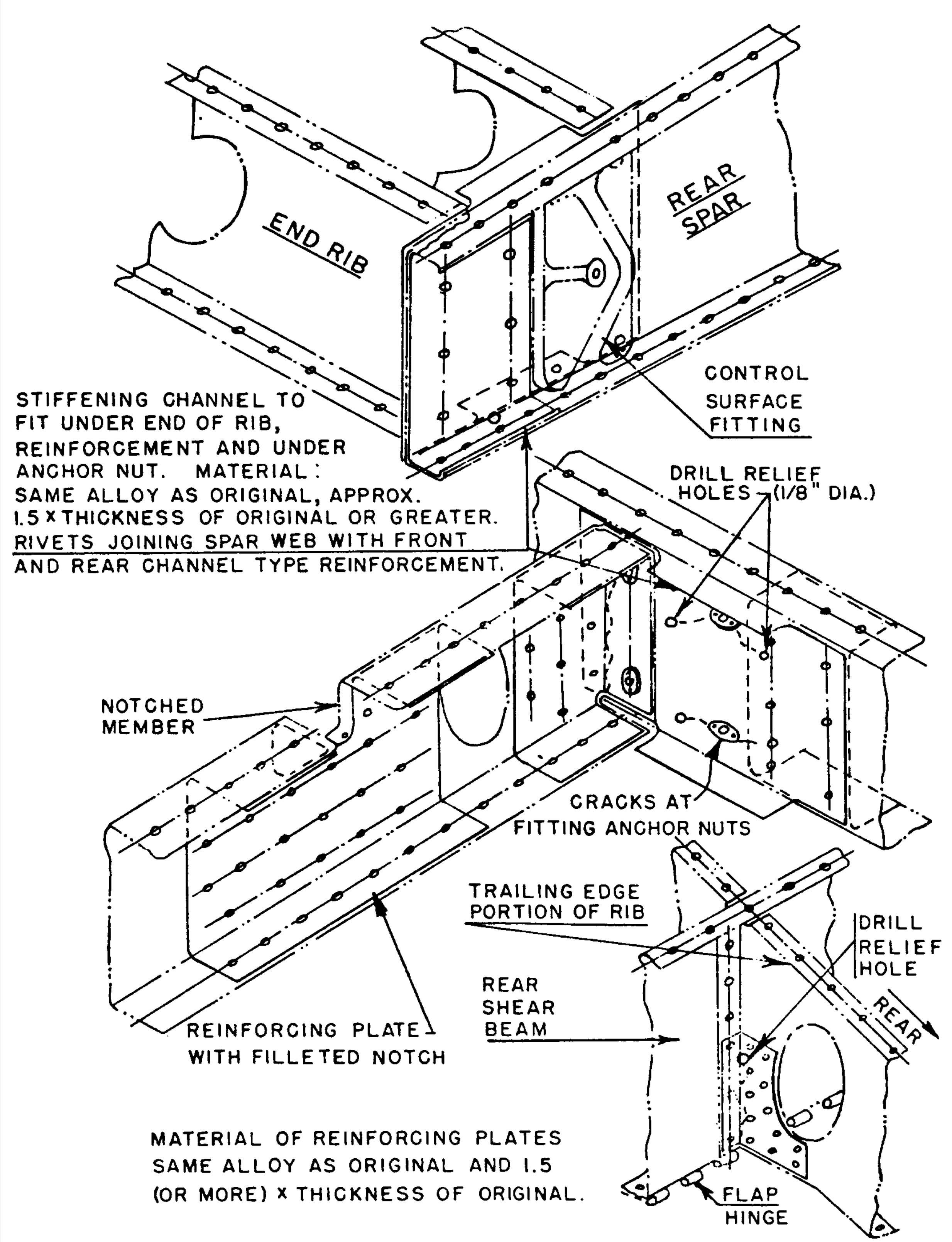


FIGURE 4-22. Typical methods of replacing cracked members at fittings.

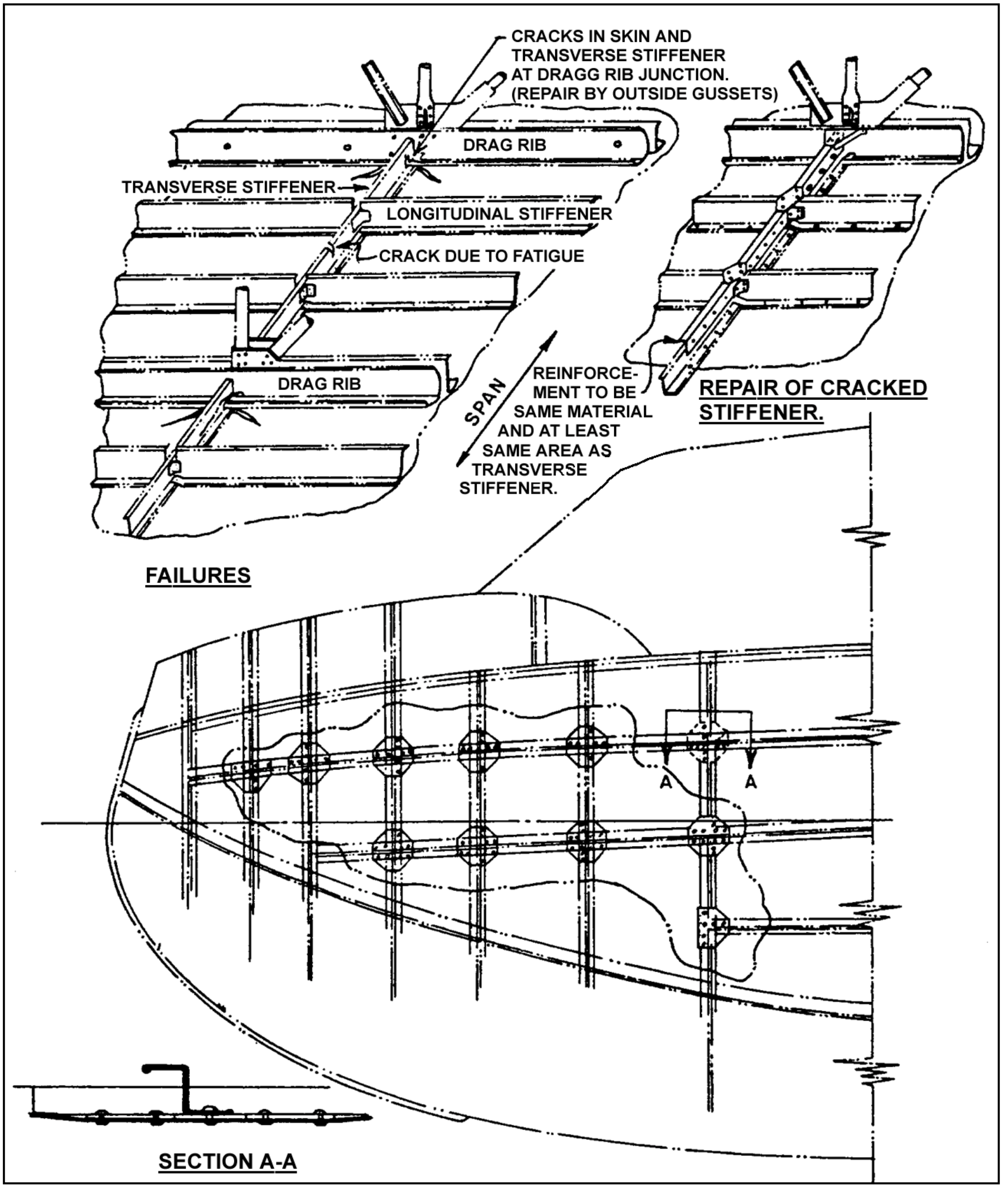


FIGURE 4-23. Typical methods of repairing cracked frame and stiffener combination.

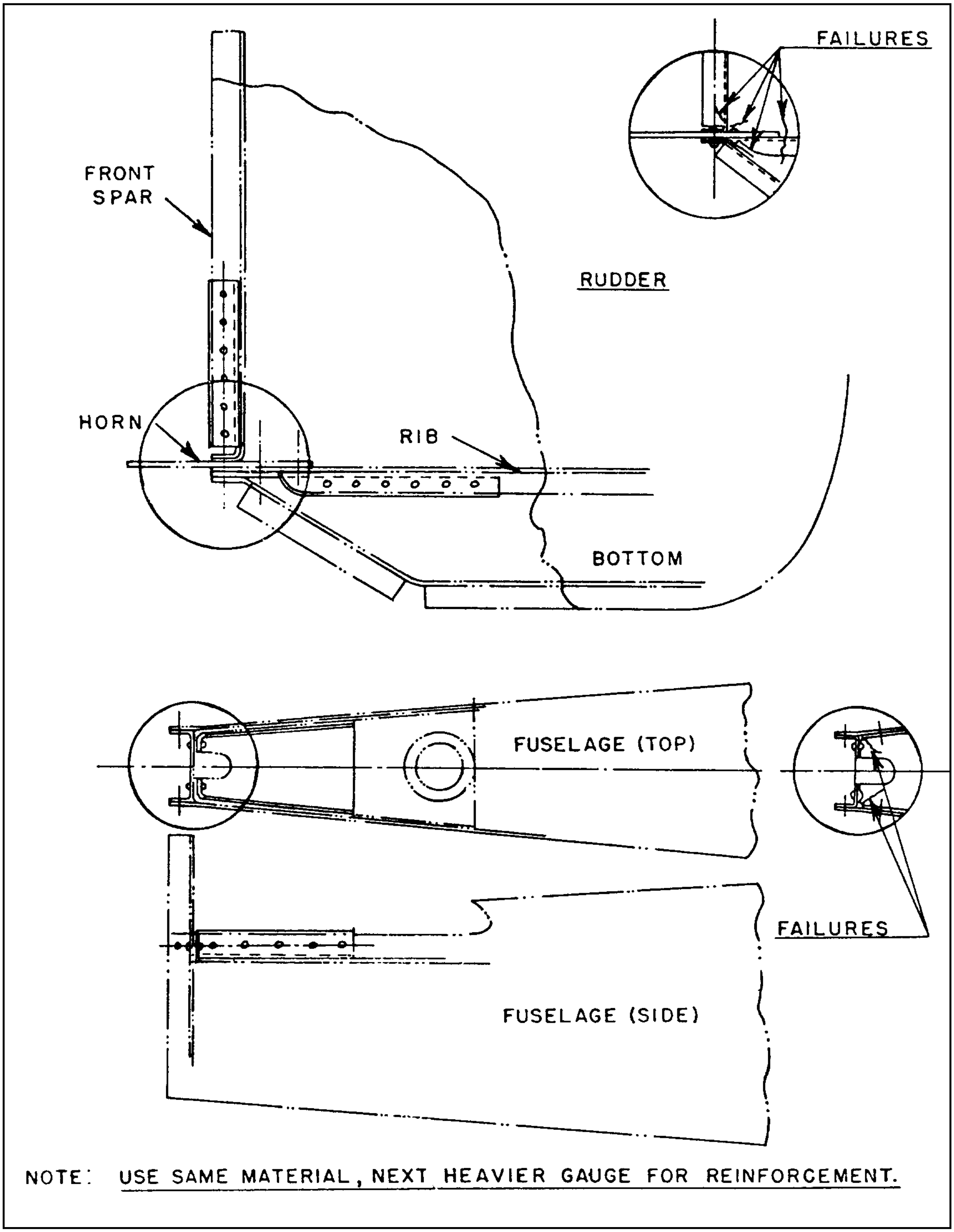


FIGURE 4-24. Typical repairs to rudder and to fuselage at tail post.

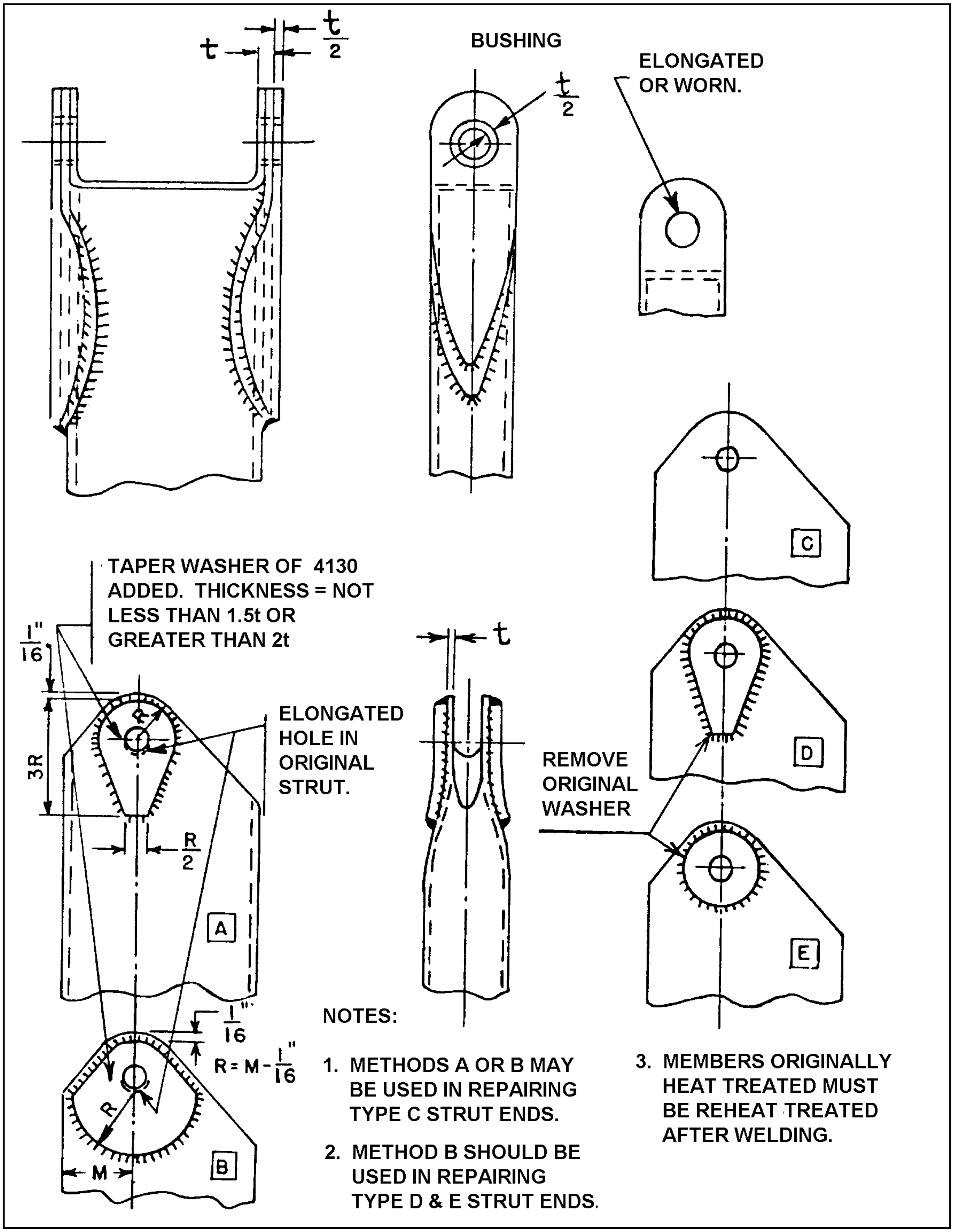


FIGURE 4-25. Typical methods of repairing elongated or worn bolt holes.

(1) To prevent or minimize disassembly, or reassembly.

(2) Resizing worn components (plate to size).

(3) Filling in damaged or corroded areas.

(4) To plate small areas of extremely large parts.

(5) To plate electrical contacts.

(6) To plate parts too large for existing baths.

(7) To supplement conventional plating.

(8) To plate components which become contaminated if immersed in a plating bath.

(9) To cadmium-plate ultrahigh strength steels without hydrogen embrittlement.

(10) On-site plating.

(11) Reverse current applications (e.g., stain removal, deburring, etching, and dynamic balancing).

b. Specifications. Selective plating (electrodepositions), when properly applied, will meet the following specifications and standards.

(1) QQ-C-320, Chromium Plating.

(2) QQ-N-290, Nickel Plating.

(3) QQ-P-416, Cadmium Plating.

(4) QQ-S-365, Silver Plating.

(5) QQ-Z-325, Zinc Plating.

(6) MIL-T-10727, Tin Plating.

(7) MIL-C-14550, Copper Plating.

(8) MIL-G-45204, Gold Plating.

c. General Requirements.

(1) Areas to be repaired by this process should be limited to small areas of large parts, particularly electrical or electronic parts.

(2) All solutions should be kept clean and free from contamination. Care should be taken to insure that the solutions are not contaminated by used anodes or other plating solutions. Brush-plating solutions are not designed to remove large amounts of scale, oil, or grease. Mechanical or chemical methods should be used to remove large amounts of scale or oxide. Use solvents to remove grease or oil.

(3) Brush-plating solutions are five to fifty times as concentrated as tank solutions. The current densities used range from 500 to 4,000 amps/feet^2. The voltages listed on the solution bottles have been precalculated to give proper current densities. Too high a current density burns the plating, while too low a current density produces stressed deposits and low efficiencies. Agitation is provided by anode/cathode motion. Too fast a motion results in low efficiencies and stressed deposits, and too slow a motion causes burning. A dry tool results in burnt plate, coarse grain structure, and unsound deposits. The tool cannot be too wet. Solution temperatures of 110 °F to 120 °F are reached during operation.

(4) Materials such as stainless steel, aluminum, chromium, and nickel (which have a passive surface) will require an activating operation to remove the passive surface. During the activating process, do not use solutions that have been previously used with reverse current (because of solution contamination).

d. Equipment. The power source should operate on either 110 or 220-volt alternating current (AC), 60 Hertz, single-phase input. It should have a capability to produce direct current (DC) having smooth characteristics with controlled ripple and be able to output a current of at least 25 amperes at 0 to 25 volts. Minimum instrumentation of the power source should include a voltmeter, ammeter, and ampere-hour meter.

(1) The ammeter should provide a full-scale reading equal to the maximum capacity of the power source, and with an accuracy of ±5 percent of the current being measured.

(2) The voltmeter should have sufficient capacity to provide a full-scale reading equal to the maximum capacity of the power source and an accuracy of ±1.0 volt.

(3) An ampere-hour meter should be readable to 0.001 ampere-hour and have an accuracy of ±0.01 ampere-hour.

(4) The stylus should be designed for rapid cooling and to hold anodes of various sizes and configurations. For safety, the anode holder should be insulated.

(5) The containers for holding and catching runoff solutions should be designed to the proper configuration and be inert to the specific solution.

(6) The mechanical cleaning equipment and materials should be designed and selected to prevent contamination of the parts to be cleaned.

e. Materials. The anodes should be of high-purity dense graphite or platinum-iridium alloys. Do not mix solutions from different suppliers. This could result in contamination.

f. Detail Requirements. On large parts, no area greater than approximately 10 percent of the total area of the part should be plated by this selective plating process. Small parts may be partially or completely plated. Special cases exceeding these limitations should be coordinated with the manufacturer of the plating equipment being used and their recommendations should be followed.

g. Anode Selection. As a general guide, the contact area of the anode should be approximately one-third the size of the area to be plated. When selecting the anode, the configuration of the part will dictate the shape of the anode.

h. Required Ampere-Hour Calculation. The selected plating solution has a factor which is equal to the ampere-hours required to deposit 0.0001 inch on 1 square inch of surface. Determine the thickness of plating desired on a certain area, and multiply the solution factor times the plating thickness times the area in square inches to determine the ampere-hours required. This factor may vary because of temperature, current density, etc.

i. Cleaning. Remove corrosion, scale, oxide, and unacceptable plating prior to processing. Use a suitable solvent or cleaner to remove grease or oil.

j. Plating on Aluminum and Aluminum Base Alloys.

(1) Electroclean the area using direct current until water does not break on the surface. This electroclean process should be accomplished at 10 to 15 volts, using the appropriate electroclean solution.

(2) Rinse the area in cold, clean tap water.

(3) Activate the area with reverse current, 7 to 10 volts, in conjunction with the proper activating solution until a uniform, gray-to-black surface is obtained.

(4) Rinse thoroughly in cold, clean tap water.

(5) Immediately electroplate to color while the area is still wet, using the appropriate nickel solution.

(6) Rinse thoroughly.

(7) Immediately continue plating with any other solution to desired thickness.

(8) Rinse and dry.

k. Plating on Copper and Copper Base Alloys.

(1) Electroclean the area using direct current until water does not break on the surface. The electroclean process should be accomplished at 8 to 12 volts using the appropriate electroclean solution.

(2) Rinse the area in cold, clean tap water.

(3) Immediately electroplate the area with any of the plating solutions, except silver. Silver requires an undercoat.

(4) Rinse and dry.

l. Plating on 300 and 400 Series Stainless Steels, Nickel Base Alloys, Chrome Base Alloys, High Nickel Ferrous Alloys, Cobalt Base Alloys, Nickel Plate, and Chrome Plate.

(1) Electroclean the area using direct current until water does not break on the surface. This electroclean process should be accomplished at 12 to 20 volts using the appropriate electrocleaning solution.

(2) Rinse the area in cold, clean tap water.

(3) Activate the surface using direct current for 1 to 2 minutes, using the activating solution, and accomplish at 6 to 20 volts.

(4) Do not rinse.

(5) Immediately nickel-flash the surface to a thickness of 0.00005 to 0.0001 inch, using the appropriate nickel solution.

(6) Rinse thoroughly.

(7) Immediately continue plating with any other solution to desired thickness.

(8) Rinse and dry.

m. Plating on Low-Carbon Steels (Heat Treated to 180,000 psi).

(1) Electroclean the area using direct current until water does not break on the surface. This electroclean process should be accomplished at 12 to 20 volts, using the appropriate electrocleaning solution.

(2) Rinse the area in cold, clean tap water.

(3) Reverse-current etch at 8 to 10 volts, using the appropriate activating solution, until a uniform gray surface is obtained.

(4) Rinse thoroughly.

(5) Immediately electroplate the part using any solutions, except copper or silver. Both of these require undercoats.

(6) Rinse and dry.

n. Plating on Cast Iron and High-Carbon Steels (Steels Heat Treated to 180,000 psi).

(1) Electroclean the area using direct current until water does not break on the surface. This electroclean process should be accomplished at 12 to 20 volts, using the appropriate electrocleaning solution.

(2) Rinse the area thoroughly in cold, clean tap water.

(3) Reverse-current etch at 8 to 10 volts, using the appropriate etching solution, until a uniform gray is obtained.

(4) Rinse thoroughly.

(5) Remove surface smut with 15 to 25 volts using the appropriate activating solution.

(6) Rinse thoroughly.

(7) Electroplate immediately, using any of the solutions, except copper or silver (both of these require undercoats).

(8) Rinse and dry.

o. Plating on Ultrahigh Strength Steels (Heat Treated Above 180,000 psi).

(1) Electroclean the area using reverse current until water does not break on the surface. This electroclean process should be accomplished at 8 to 12 volts using the appropriate electroclean solution.

(2) Rinse the area thoroughly in cold, clean tap water.

(3) Immediately electroplate the part, using either nickel, chromium, gold, or cadmium. Other metals require an undercoat of one of the above. Plate initially at the highest voltage recommended for the solution so as to develop an initial barrier layer. Then reduce to standard voltage.

(4) Rinse and dry.

(5) Bake the part for 4 hours at 375 °F ± 25 °F.

NOTE: Where the solution vendor provides substantiating data that hydrogen embrittlement will not result from plating with a particular solution, then a postbake is not required. This substantiating data can be in the form of aircraft industry manufacturer's process specifications, military specifications, or other suitable data.

NOTE: Acid etching should be avoided, if possible. Where etching is absolutely necessary, it should always be done with reverse current. Use alkaline solutions for initial deposits.

p. Dissimilar Metals and Changing Base. As a general rule, when plating two dissimilar metals, follow the plating procedure for the one with the most steps or activation. If activating steps have to be mixed, use reverse-current activation steps prior to direct-current activation steps.

q. Plating Solution Selection.

(1) Alkaline and neutral solutions are to be used on porous base metals, white metals, high-strength steel, and for improved coating ability. Acid solutions are to be used for rapid buildup and as a laminating structure material in conjunction with alkaline-type solutions.

(2) Chrome brush-plating solutions do not yield as hard a deposit as bath-plating solutions. The hardness is about 600 Brinell as compared to 1,000 Brinell for hard chrome deposited from a tank.

(3) Silver-immersion deposits will form with no current flowing on most base metals from the silver brush-plating solutions. Such deposits have poor adhesion to the base metal. Consequently, a flash of a more noble metal should be deposited prior to silver plating to develop a good bond.

(4) In general, brush plating gives less hydrogen embrittlement and a lower fatigue strength loss than does equivalent tank deposits. However, all brush-plated, ultrahigh strength steel parts (heat treated above 180,000 psi) should be baked, as mentioned, unless it is specifically known that embrittlement is not a factor.

r. Qualification Tests. All brush-plated surfaces should be tested for adhesion of the electrodeposit. Apply a 1-inch wide strip of Minnesota Mining and Manufacturing tape code 250, or an approved equal, with the adhesive side to the freshly plated surface. Apply the tape with heavy hand pressure and remove it with one quick motion perpendicular to the plated surface. Any plating adhering to the tape should be cause for rejection.

s. Personnel Training for Quality Control. Manufacturers of selective-plating equipment provide training in application techniques at their facilities. Personnel performing selective plating must have adequate knowledge of the methods, techniques, and practices involved. These personnel should be certified as qualified operators by the manufacturers of the products used.

4-63.—4-73. [RESERVED.]

SECTION 5. WELDING AND BRAZING

4-74. GENERAL. This section covers weld repairs to aircraft and component parts only. Observe the following procedures when using such equipment as gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), plasma arc welding, and oxyacetylene gas welding. When repairs of any of these flight-critical parts are required, it is extremely important to make the weld repairs equal to the original weld. Identifying the kind of metal to be welded, identifying the kind of welding process used in building the part originally, and determining the best way to make welded repairs are of utmost importance.

a. Welding is one of the three commonly used methods of joining metals without the use of fasteners. Welding is done by melting the edges of two pieces of metal to be joined and allowing the molten material to flow together so the two pieces will become one.

b. Brazing is similar to welding in that heat is used to join the material; but rather than melting, the metal is heated only enough to melt a brazing rod having a much lower melting point. When this brazing rod melts, it wets the surfaces to be joined, and when it cools and solidifies, it bonds the pieces together.

c. Soldering is similar to brazing except that brazing materials normally melt at temperatures above 425 °C (800 °F), while solders melt at temperatures considerably lower.

d. The next step in making airworthy weld repairs is to decide the best process to use, considering the available state-of-the-art welding equipment, and then deciding the correct weld-filler material to use. Before any weld repairs can be made, the metal parts to be welded must be cleaned properly, fitted and jigged properly, and all defective welds must be removed to prepare for an aircraft quality weld repair.

e. Finally, after the weld is completed, the weld must be inspected for defects. All these things are necessary in order to make an airworthy weld repair.

f. Aircraft welding Qualifications. Four groups of metals a person can be certified and qualified to use are:

(1) Group 1, 4130 Steel.
(2) Group 2, Stainless Steel.
(3) Group 3, Aluminum
(4) Group 4, Titanium.

g. For other group listing of metal the welder may qualify, refer to Mil-Std-1595A.

h. Most large business or agencies conduct their own certification tests, or they have an outside testing lab validate the certification tests.

4-75. EQUIPMENT SELECTION. Use the welding equipment manufacturer's information to determine if the equipment will satisfy the requirements for the type of welding operation being undertaken. Disregarding such detailed operating instructions may cause substandard welds. For example, when using GTAW equipment, a weld can be contaminated with tungsten if the proper size electrode is not used when welding with direct current reverse polarity. Another example, the depletion of the inert gas supply below the critical level causes a reduction in the gas flow and will increase the danger of atmospheric contamination.

(a) Electric welding equipment versatility requires careful selection of the type current and polarity to b used. Since the composition and thickness of metals are deciding factors, the selection may vary with each specific application. Metals having refractory surface oxide films (i.e., magnesium alloys and aluminum and its alloys), are generally welded with alternating current (AC), while direct current (DC) is used for carbon, low alloy, noncorrodible, and heat-resisting steels. General recommendations covering current and polarity are shown in table 4-12.

(b) Oxyacetylene gas equipment is suitable for welding most metals. It is not, however, the best method to use on such materials as stainless steel, magnesium, and aluminum alloys; because of base metal oxidization, distortion, and loss of ductility.

NOTE: If oxyacetylene is used for welding stainless steel or aluminum, all flux must be removed, as it may cause corrosion.

4-76. ACCURATELY IDENTIFY THE TYPE OF MATERIAL TO BE REPAIRED. If positive identification of the material is not possible, contact the aircraft manufacturer or subject the item to a metallurgical laboratory analysis. Before any welding is attempted, carefully consider the weldability of the alloy, since all alloys are not readily weldable. The following steels are readily weldable; plain carbon (of the 1000 series), nickel steel (of the Society of Automotive Engineers (SAE) 2300 series), chrome-nickel alloys (of the SAE 3100 series), chrome-molybdenum steels (of the SAE 4100 series), and low nickel-chrome-molybdenum steel (of the SAE 8600 series).

4-77. PREPARATION FOR WELDING.

a. Hold elements to be welded in a welding jig or fixture which is sufficiently rigid to prevent misalignment due to expansion and contraction of the heated material and which positively and accurately positions the pieces to be welded.

b. Clean parts to be welded with a wire brush or other suitable method prior to welding. Do not use a brush of dissimilar metal, such as brass or bronze on steel. The small deposit left by a brass or bronze brush will materially weaken the weld, and may cause cracking or subsequent failure of the weld. If the members are metallized, the surface metal may be removed by careful sandblasting followed by a light buffing with emery cloth.

4-78. INSPECTION OF A COMPLETED WELD. Visually inspect the completed weld for the following:

(a) The weld has a smooth seam and uniform thickness. Visual inspection shall be made of the completed weld to check for undercut and/or smooth blending of the weld contour into the base metal.

(b) The weld is tapered smoothly into the base metal.

(c) No oxide has formed on the base metal more than 1/2 inch from the weld.

(d) There are no signs of blowholes, porosity, or projecting globules. Many military specifications, as well as American Society of Testing Materials (ASTM) codes, specify acceptable limits of porosity and other types of defects that are acceptable.

(e) The base metal shows no signs of pitting, burning, cracking, or distortion.

(f) The depth of penetration insures fusion of base metal and filler rod.

(g) The welding scale is removed. The welding scale can be removed using a wire brush or by sandblasting. Remove any roll over, cold lab, or unfued weld metal. Check underside of welded joint for defects.

TABLE 4-12. Current and polarity selection for inert gas welding.

MATERIAL	ALTERNATING CURRENT With High-Frequency Stabilization	DIRECT CURRENT STRAIGHT Polarity
Magnesium up to 1/8 in. thick	1	N.R.
Magnesium above 3/16 in. thick	1	N.R.
Magnesium Castings	1	N.R.
Aluminum up to 3/32 in. thick	1	N.R.
Aluminum over 3/32 in. thick	1	N.R.
Aluminum Castings	1	N.R.
Stainless Steel		1
Low Carbon Steel, 0.015 to 0.030 in.		1
Low Carbon Steel, 0.030 to 0.125 in.	N.R.	1

1 Recommended N.R. Not Recommended

4-79. MICROFISSURES Cracks in parts and materials can vary from tiny microfissures, that are visible only with magnification, to those easily identified by unaided eyes. Microfissures are the worst type of defect for two reasons; they are often hard to detect, and they produce the worst form of notch effect/stress concentration. Once they form, they propagate with repeated applications of stress and lead to early failures. Every possible means should be used to detect the presence of cracks, and ensure their complete removal before welding operations proceed. (See figure 4-26.)

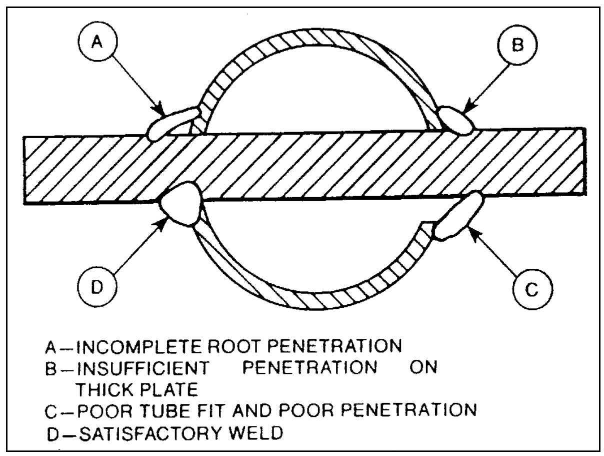


FIGURE 4-26. Common defects to avoid when fitting and welding aircraft certification cluster.

4-80. NONDESTRUCTIVE TESTING or evaluation is advisable in critical applications. Nondestructive testing methods such as; magnetic particle, liquid penetrant, radiography, ultrasonic, eddy current, and acoustic emission can be used; however, they require trained and qualified people to apply them.

4-81. PRACTICES TO GUARD AGAINST Do not file or grind welds in an effort to create a smooth appearance, as such treatment causes a loss of strength. Do not fill welds with solder, brazing metal, or any other filler. When it is necessary to weld a joint which was previously welded, remove all of the old weld material before rewelding. Avoid welding over a weld, because reheating may cause the material to lose its strength and become brittle. Never weld a joint which has been previously brazed.

4-82. TORCH SIZE (Oxyacetylene welding). When using oxyacetylene welding, the torch tip size depends upon the thickness of the material to be welded. Commonly used sizes, proven satisfactory by experience, are shown in table 4-13.

TABLE 4-13. Torch tip sizes.

Thickness of steel (in inches)	Diameter of hole in tip	Drill size
0.015 to 0.031	0.026	71
0.031 to 0.065	.031	68
0.065 to 0.125	.037	63
0.125 to 0.188	.042	58
0.188 to 0.250	.055	54
0.250 to 0.375	.067	51

4-83. WELDING RODS AND ELECTRODES Use welding rods and electrodes that are compatible with the materials to be welded. Welding rods and electrodes for various applications have special properties suitable for the application intended.

Lap welds are used in shear applications. The weld throat of the fillet weld is considered the plane 45 degrees to the surface plane of the sheet being welded and is equal to 0.707 times the thickness of the sheet stock. (See figure 4-27.)

P_{WS} = *0.707xtx1xFwsu*

where: P_{WS} = *the allowable tensile strength of the joint.*

t = *the thickness of the sheet stock (the throat of the weld joint.*

l = *the length of the weld joint.*

Fwsu = *the shear strength of the filled rod material.*

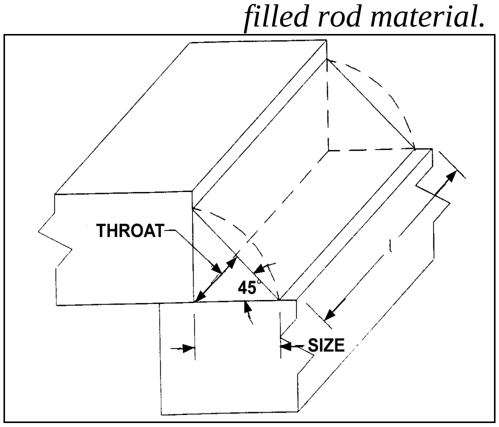


FIGURE 4-27. Lap Weld Strength Calculation

4-84. ROSETTE WELDS are generally employed to fuse an inner reinforcing tube (liner) with the outer member. Where a rosette weld is used, drill a hole, (in the outside tube only) of sufficient size to insure fusion of the inner tube. A hole diameter of approximately one-fourth the tube diameter of the outer tube serves adequately for this purpose. In cases of tight-fitting sleeves or inner liners, the rosettes may be omitted. Rosette weld edge distance is 1/2 the diameter of the tube, as measured from the edge of the rosette hole to the end of the inside and outside tube. Rosettes shall not be considered when determining the strength of a welded form. Drill an 1/8-inch hole in the lower tube in the center of the intended rosette weld so the heat does not burn away the outer tube. This small hole tends to bleed off the heat from the torch and keeps the size of the rosette small.

4-85. HEAT-TREATED MEMBERS Certain structural parts may be heat treated and, therefore, could require special handling. In general, the more responsive an alloy steel is to heat treatment, the less suitable it is for welding because of its tendency to become brittle and lose its ductility in the welded area. Weld the members which depend on heat treatment for their original physical properties by using a welding rod suitable for producing heat-treated values comparable to those of the original members. (See paragraph 4-74.) After welding, heat treat the affected members to the manufacturer's specifications.

4-86. TYPES OF WELDING.

a. Gas Welding. A fuel gas such as acetylene or hydrogen is mixed inside a welding torch with oxygen to produce a flame with a temperature of around 6,300 °F (3,482 °C).

This flame is used to melt the materials to be welded. A filler rod is melted into the puddle of molten metal to reinforce the weld. When highly-reactive metals such as aluminum are gas welded, they must be covered with flux to exclude oxygen from the molten metal and keep oxides from forming which would decrease the strength of the weld. (An illustration of a carburizing flame, a neutral flame, and an oxidizing flame is shown in figure 4-28.)

b. Shielded Metal Arc Welding (SMAW). This method is the most familiar and common type and is known in the trade as stick welding. A metal wire rod coated with a welding flux is clamped in an electrode holder connected to the power supply with a heavy electrical cable. The metal to be welded is also attached to the power supply. The electrical power is supplied to the work at a low voltage

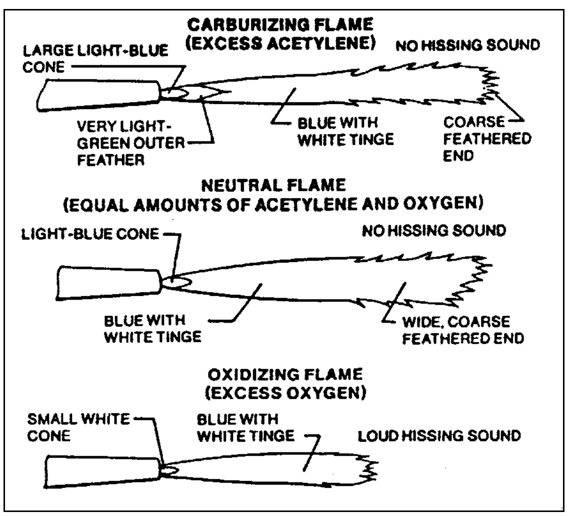


FIGURE 4-28. Basic gas-welding flames: Each has distinctive shape, color and sound. Neutral flame is the most used.

and high current and may be either AC or DC, depending upon the type of welding being done. An arc is struck between the rod and the work and produces heat in excess of 10,000 °F, which melts both the material and the rod. As the flux melts, it releases an inert gas which shields the molten puddle from oxygen in the air and prevents oxidation. The molten flux covers the weld and hardens to an airtight slag cover that protects the weld bead as it cools. This slag must be chipped off to examine the weld.

c. Gas Metal Arc Welding (GMAW). This method of welding was formerly called Metal Inert Gas (MIG) welding and is an improvement over stick welding because an uncoated wire electrode is fed into the torch and an inert gas such as argon, helium, or carbon dioxide flows out around the wire to protect the puddle from oxygen. The power supply connects between the torch and the work, and the arc produces the intense heat needed to melt the work and the electrode. Low-voltage high-current DC is used almost exclusively with GMAW welding. GMAW is used more for large-volume production work than for aircraft repair.

d. Gas Tungsten Arc Welding (GTAW). This is the form of electric arc welding that fills most of the needs in aircraft maintenance. It is more commonly known as Tungsten Inert Gas (TIG) welding and by the trade names of Heliarc or Heliweld. These trade names were derived from the fact that the inert gas originally used was helium.

(1) Rather than using a consumable electrode such as is used in both of the other two methods we have discussed, the electrode in TIG welding is a tungsten rod. (In earlier procedures using this form of welding, a carbon electrode was used, but it has been replaced almost exclusively with tungsten.)

(2) The 250+ amp arc between the electrode and the work melts the metal at 5,432 °F, and a filler rod is manually fed into the molten puddle. A stream of inert gas such as argon or helium flows out of the torch and envelopes the arc, thereby preventing the formation of oxides in the puddle.

(3) The versatility of TIG welding is increased by the power supply that is used. Direct current of either polarity or alternating current may be used. (See figures 4-29 and 4-30.)

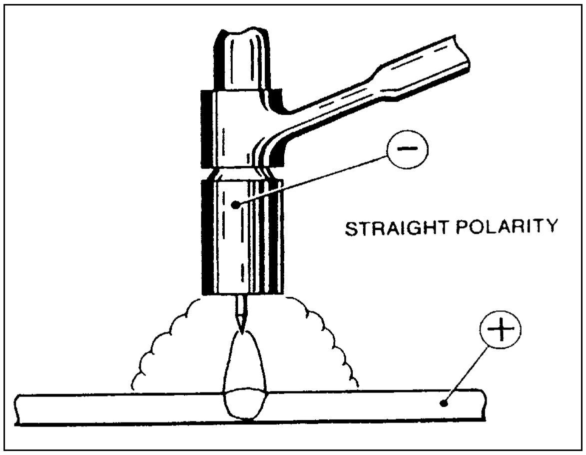


FIGURE 4-29. Set TIG welder to DC current, straight polarity for welding mild steel, stainless steel and titanium

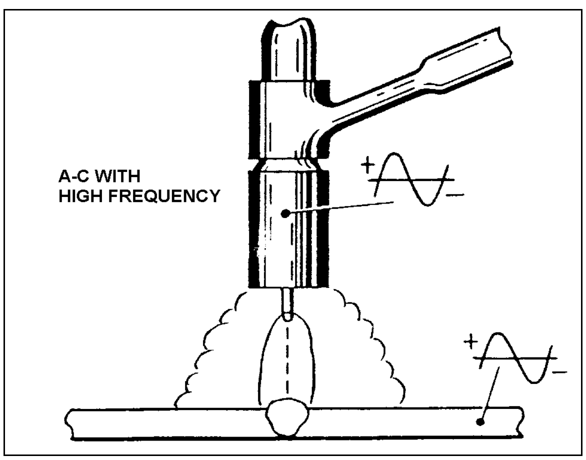


FIGURE 4-30. Set TIG to AC current for welding aluminum and magnesium.

4-87. ELECTRIC-RESISTANCE WELDING. Many thin sheet metal parts for aircraft, especially stainless steel parts, are joined by one of the forms of electric resistance welding, either spot welding or seam welding.

a. Spot Welding. Two copper electrodes are held in the jaws of the spot welding machine, and the material to be welded is clamped between them. Pressure is applied to hold the electrodes tightly together, and electrical current flows through the electrodes and the material. The resistance of the material being welded is so much higher than that of the copper electrodes that enough heat is generated to melt the metal. The pressure on the electrodes forces the molten spots in the two pieces of metal to unite, and this pressure is held after the current stops flowing long enough for the metal to solidify. Refer to MIL HDBK-5 for joint construction and strength data. The amount of current, pressure, and dwell time are all carefully controlled and matched to the type of material and the thickness to produce the correct spot welds. (See figure 4-31.)

b. Seam Welding. Rather than having to release the electrodes and move the material to form a series of overlapping spot welds, a seam-welding machine is used to manufacture fuel tanks and other components where a continuous weld is needed. Two copper wheels

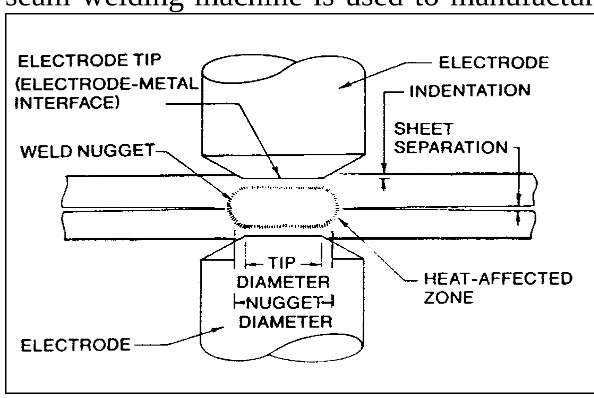


FIGURE 4-31. In spot welding, heat is produced by electrical resistance between copper electrodes. Pressure is simultaneously applied to electrode tips to force metal together to complete fusing process. Spot-weld-nugget size is directly related to tip size.

replace the bar-shaped electrodes. The metal to be welded is moved between them, and electric pulses create spots of molten metal that overlap to form the continuous seam.

4-88. BRAZING. Brazing refers to a group of metal-joining processes in which the bonding material is a nonferrous metal or alloy with a melting point higher than 425 C (800 F), but lower than that of the metals being joined. Brazing includes silver brazing (erroneously called silver soldering or hard soldering), copper brazing, and aluminum brazing.

NOTE: Never weld over a previously brazed joint.

a. Brazing requires less heat than welding and can be used to join metals that are damaged by high heat. However, because the strength of brazed joints is not as great as welded joints, brazing is not used for structural repairs on aircraft. In deciding whether brazing of a joint is justified, it should be remembered that a metal, which will be subjected to a sustained high temperature in use, should not be brazed.

b. A brazing flux is necessary to obtain a good union between the clean base metal and the filler metal. There are a number of readily available manufactured fluxes conforming to AWS and AMT specifications.

c. The base metal should be preheated slowly with a mild flame. When it reaches a dull-red heat (in the case of steel), the rod should be heated to a dark (or purple) color and dipped into the flux. Since enough flux adheres to the rod, it is not necessary to spread it over the surface of the metal.

d. A neutral flame is used in most brazing applications. However, a slightly oxidizing flame should be used when copper-zinc, copper-zinc-silicon, or copper-zinc-nickel-silicon filler alloys are used. When brazing aluminum and its alloys, a neutral flame is preferred, but if difficulties are encountered, a slightly reduced flame is preferred to an oxidizing flame.

e. The filler rod can now be brought near the tip of the torch, causing the molten bronze to flow over a small area of the seam. The base metal must be at the flowing temperature of the filler metal before it will flow into the joint. The brazing metal melts when applied to the steel and runs into the joint by capillary attraction. In braze welding, the rod should continue to be added, as the brazing progresses, with a rhythmic dipping action; so that the bead will be built to a uniform width and height. The job should be completed rapidly and with as few passes of the rod and torch as possible.

f. When the job is finished, the metal should be allowed to cool slowly. After cooling, remove the flux from the parts by immersing them for 30 minutes in a lye solution.

(1) Copper brazing of steel is normally done in a special furnace having a controlled atmosphere, and at a temperature so high that field repairs are seldom feasible. If copper brazing is attempted without a controlled atmosphere, the copper will probably not completely wet and fill the joint. Therefore, copper brazing in any conditions other than appropriately controlled conditions is not recommended.

(a) The allowable shear strength for copper brazing of steel alloys should be 15 thousand pounds per square inch (kpsi), for all conditions of heat treatment.

(b) The effect of the brazing process on the strength of the parent or base metal of steel alloys should be considered in the structural design. Where copper furnace brazing is employed, the calculated allowable strength of the base metal, which is subjected to the temperatures of the brazing process, should be in accordance with table 4-14.

TABLE 4-14. Calculated allowable strength of base metal.

Material	Allowable Strength
Heat-treated material (including normalized) used in "as-brazed" condition	Mechanical properties of normalized material
Heat-treated material (including normalized) reheat-treated during or after brazing	Mechanical properties corresponding to heat treatment performed

(2) Alloys commonly referred to as silver solders melt above 425 °C (800 °F), and when using them the process should be called silver brazing.

(a) The principal use of silver brazing in aircraft work is in the fabrication of high-pressure oxygen lines and other parts which must withstand vibration and high temperatures. Silver brazing is used extensively to join copper (and its alloys), nickel, silver, various combinations of these metals, and thin steel parts. Silver brazing produces joints of higher strength than those produced by other brazing processes.

(b) It is necessary to use flux in all silver-brazing operations, because of the necessity for having the base metal chemically clean, (without the slightest film of oxide to prevent the silver-brazing alloy from coming into intimate contact with the base metal).

(c) The joint must be physically and chemically clean, which means it must be free of all dirt, grease, oil, and paint. After removing the dirt, grease, and paint, any oxide should be removed by grinding or filing the piece until bright metal can be seen. During the soldering operation, the flux continues the process of keeping oxide away from the metal and aids the flow of solder.

(d) In figure 4-32, three types of joints for silver brazing are shown; flanged butt, lap, and edge joints. If a lap joint is used, the amount of lap should be determined according to the strength needed in the joint. For strength equal to that of the base metal in the heated zone, the amount of lap should be four to six times the metal thickness.

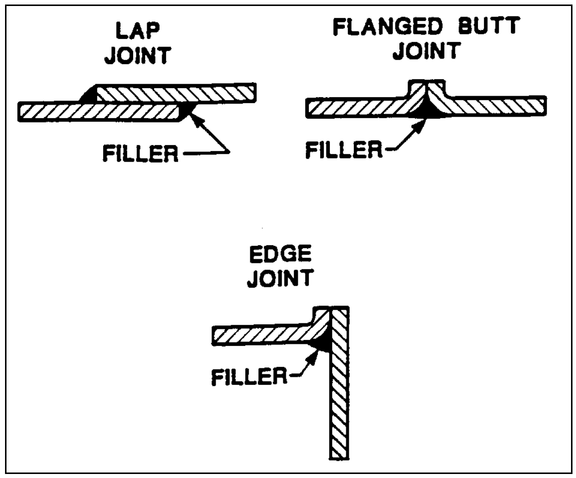


FIGURE 4-32. Silver brazing joints**.**

(e) The oxyacetylene flame for silver brazing should be neutral, but may have a slight excess of acetylene. It must be soft, not harsh. During both preheating and application of the solder, the tip of the inner cone of the flame should be held about 1/2 inch from the work. The flame should be kept moving so that the metal will not become overheated.

(f) When both parts of the base metal are at the right temperature (indicated by the flow of flux), brazing alloy can be applied to the surface of the under or inner part at the edge of the seam. It is necessary to simultaneously direct the flame over the seam, and keep moving it so that the base metal remains at an even temperature.

(3) The torch can be shut off simply by closing the acetylene off first and allowing the gas remaining in the torch tip to burn out. Then turn off the oxygen valve. If the torch is not to be used again for a long period, the pressure should be turned off at the cylinder. The hose lines should then be relieved of pressure by opening the torch needle valves and the working pressure regulator, one at a time, allowing the gas to escape. Again, it is a good practice to relieve the oxygen pressure and then the acetylene pressure. The hose should then be coiled or hung carefully to prevent damage or kinking.

(4) Soft soldering is used chiefly for copper, brass, and coated iron in combination with mechanical seams; that is, seams that are riveted, bolted, or folded. It is also used where a leak-proof joint is desired, and sometimes for fitting joints to promote rigidity and prevent corrosion. Soft soldering is generally performed only in very minor repair jobs. This process is used to join electrical connections because it forms a strong union with low electrical resistance.

(a) Soft solder gradually yields under a steadily applied load and should not be used unless the transmitted loads are very low. It should never be used as a means of joining structural members.

(b) A soldering iron is the tool used in soldering. Its purpose is to act as a source of heat for the soldering operation. The bit, or working face, is made from copper since this metal will readily absorb heat and transmit it to the work. Figure 4-33 shows a wedge-shaped bit.

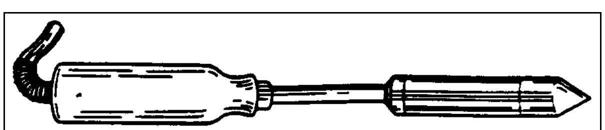


FIGURE 4-33. Electric soldering iron**.**

(c) To tin the soldering iron, it is first heated to a bright red, and then the point is cleaned (by filing) until it is smooth and bright. No dirt or pits should remain on its surface. After the soldering iron has been mechanically cleaned, it should be reheated sufficiently to melt solder and chemically cleaned by rubbing it firmly on a block of sal ammoniac (ammonium chloride). Rosin flux paste may also be used. Solder is then applied to the point and wiped with a clean cloth.

(d) A properly tinned copper iron has a thin unbroken film of solder over the entire surface of its point.

(e) Soft solders are chiefly alloys of tin and lead. The percentages of tin and lead vary considerably in various solder, with a corresponding change in their melting points, ranging from 145-311 °C (293-592 °F). Half-and-half (50/50) solder is a general purpose solder and is most frequently used. It contains equal proportions of tin and lead, and it melts at approximately 182 °C (360 °F).

(f) The application of the melted solder requires somewhat more care than is apparent. The parts to be soldered should be locked together or held mechanically or manually while tacking. To tack the seam, the hot copper iron is touched to a bar of solder, then the drops of solder adhering to the copper iron are used to tack the seam at a number of points. The film of solder between the surfaces of a joint must be kept thin to make the strongest joint.

(g) A hot, well-tinned soldering copper iron should be held so that its point lies flat on the metal (at the seam), while the back of the copper iron extends over the seam proper at a 45-degree angle, and a bar of solder is touched to the point. As the solder melts, the copper iron is drawn slowly along the seam. As much solder as necessary is added without raising the soldering copper iron from the job. The melted solder should run between the surfaces of the two sheets and cover the full width of the seam. Work should progress along the seam only as fast as the solder will flow into the joint.

4-89. AIRCRAFT PARTS NOT TO BE WELDED.

a. Brace Wires and Cables. Do not weld aircraft parts whose proper function depends upon strength properties developed by cold-working. Among parts in this classification are streamlined wire and cables.

b. Brazed and Soldered Parts. Do not weld brazed or soldered parts as the brazing mixture or solder will penetrate and weaken the hot steel.

c. Alloy Steel Parts. Do not weld alloy steel parts such as aircraft bolts, turnbuckle ends, etc., which have been heat treated to improve their mechanical properties.

d. Nos. 2024 and 7075 Aluminum. Do not weld these two aluminum alloys (that are often used in aircraft construction) because the heat from the welding process will cause severe cracking. The 2024 aluminum is most often used in wing skins, fuselage skins, and in most structured airframe parts. The 7075 aluminum is most often used in machined fittings such as wing-spar attachments, landing-gear attachments, and other structural parts.

4-90. WELDING ROD SELECTION. Most aircraft repair shops that are prepared to make weld repairs should have the basic selection of welding rods available. The best rods to stock, the metals they weld, and the AWS specification number are shown in table 4-15.

4-91. REPAIR OF TUBULAR MEMBERS.

a. Inspection. Prior to repairing tubular members, carefully examine the structure surrounding any visible damage to insure that no secondary damage remains undetected. Secondary damage may be produced in some structure, remote from the location of the primary damage, by the transmission of the damaging load along the tube. Damage of this nature usually occurs where the most abrupt change in direction of load travel is experienced. If this damage remains undetected, subsequent normal loads may cause failure of the part.

b. Location and Alignment of Welds. Unless otherwise noted, welded steel tubing may be spliced or repaired at any location along the length of the tube. To avoid distortion, pay particular attention to the proper fit and alignment.

c. Members Dented at a Cluster. Repair dents at a steel-tube cluster joint by welding a specially formed steel patch plate over the dented area and surrounding tubes. (See figure 4-34.) To prepare the patch plate, cut a section of steel sheet of the same material and thickness as the heaviest tube damaged. Trim the reinforcement plate so that the fingers extend over the tubes a minimum of 1.5 times the respective tube diameter. (See figure 4-34.) Remove all the existing finish on the damaged cluster-joint area to be covered by the reinforcement plate. The reinforcement plate may be formed before any welding is attempted, or it may be cut and tack-welded to one or more of the tubes in the cluster joint, then heated and formed around the joint to produce a smooth contour. Apply sufficient heat to the plate while forming so that there is generally a gap of no more than 1/16 inch from the contour of the joint to the plate. In this operation avoid unnecessary heating, and exercise care to prevent damage at the point of the angle formed by any two adjacent fingers of the plate. After the plate is formed and tack welded to the cluster joint, weld all the plate edges to the cluster joint.

TABLE 4-15. Chart showing Welding Filler Rod selection.

Welding Rod #	AMS Spec.	AWS Spec.	Welds these Metals
4130	AMS 6457	AWS A5.18	Mild Steel, 4130 steel
4140	AMS 6452	AWS A5.28	4140 Steel
4043	AMS 4190	AWS A5.10	Most weldable Aluminum
308L	AMS 5692	AWS A5.9	304 Stainless steel
316L	AMS 5692	AWS A5.9	316 Stainless steel
AZ61A	AMS 4350	AWS A5.19	AZ61A Magnesium
ERTi-5	AMS 4954	AWS A5-16	Titanium

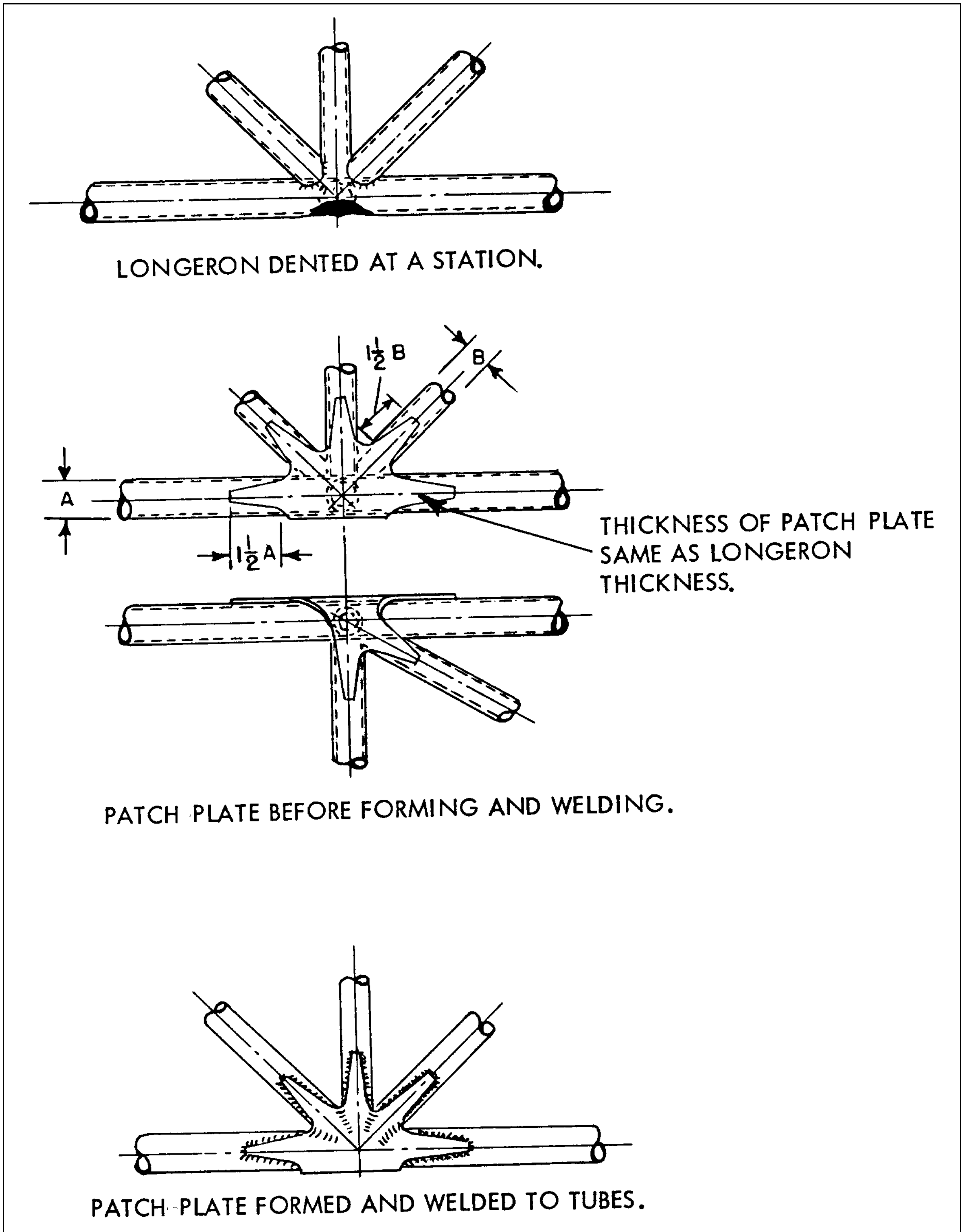


FIGURE 4-34. Finger patch repairs for members dented at a cluster.

d. Members Dented in a Bay. Repair dented, bent, cracked, or otherwise damaged tubular members by using a split-sleeve reinforcement. Carefully straighten the damaged member, and in the case of cracks, drill No. 40 (0.098) inch stop holes at the ends of the crack.

4-92. REPAIR BY WELDED SLEEVE. This repair is outlined in figure 4-35. Select a length of steel tube sleeve having an inside diameter approximately equal to the outside diameter of the damaged tube and of the same material, and at least the same wall thickness. Diagonally cut the sleeve reinforcement at a 30-degree angle on both ends so that the minimum distance of the sleeve from the edge of the crack or dent is not less than 1-1/2 times the diameter of the damaged tube. Cut through the entire length of the reinforcement sleeve, and separate the half-sections of the sleeve. Clamp the two sleeve sections to the proper positions on the affected areas of the original tube. Weld the reinforcement sleeve along the length of the two sides, and weld both ends of the sleeve to the damaged tube. (See figure 4-35.) The filling of dents or cracks with welding rod in lieu of reinforcing the member is not acceptable.

4-93. REPAIR BY BOLTED SLEEVE. Do not use bolted-sleeve repairs on welded steel-tube structure unless specifically authorized by the manufacturer or the FAA. The tube area removed by the bolt holes, in this type of repair, may prove critical.

4-94. WELDED-PATCH REPAIR. Dents or holes in tubing may be repaired by using a patch of the same material, one gauge thicker. (See figure 4-36.)

a. Dented Tubing.

(1) Dents are not deeper than 1/10 of tube diameter, do not involve more than 1/4 of the tube circumference, and are not longer than tube diameter.

(2) Dents are free from cracks, abrasions, and sharp corners.

(3) The dented tubing can be substantially reformed, without cracking, before application of the patch.

b. Punctured Tubing. Holes are not longer than tube diameter and involve not more than 1/4 of tube circumference.

4-95. SPLICING TUBING BY INNER-SLEEVE METHOD. If the damage to a structural tube is such that a partial replacement of the tube is necessary, the inner-sleeve splice is recommended; especially where a smooth tube surface is desired. (See figure 4-37.)

a. Make a diagonal cut when removing the damaged portion of the tube, and remove the burr from the edges of the cut by filing or similar means. Diagonally cut a replacement steel tube of the same material and diameter, and at least the same wall thickness, to match the length of the removed portion of the damaged tube. At each end of the replacement tube allow a 1/8-inch gap from the diagonal cuts to the stubs of the original tube. Select a length of steel tubing of the same material, and at least the same wall thickness, and of an outside diameter equal to the inside diameter of the damaged tube. Fit this inner-sleeve tube material snugly within the original tube, with a maximum diameter difference of 1/16 inch. From this inner-sleeve tube material cut two sections of tubing, each of such a length that the ends of the inner sleeve will be a minimum distance of 1-1/2-tube diameters from the nearest end of the diagonal cut.

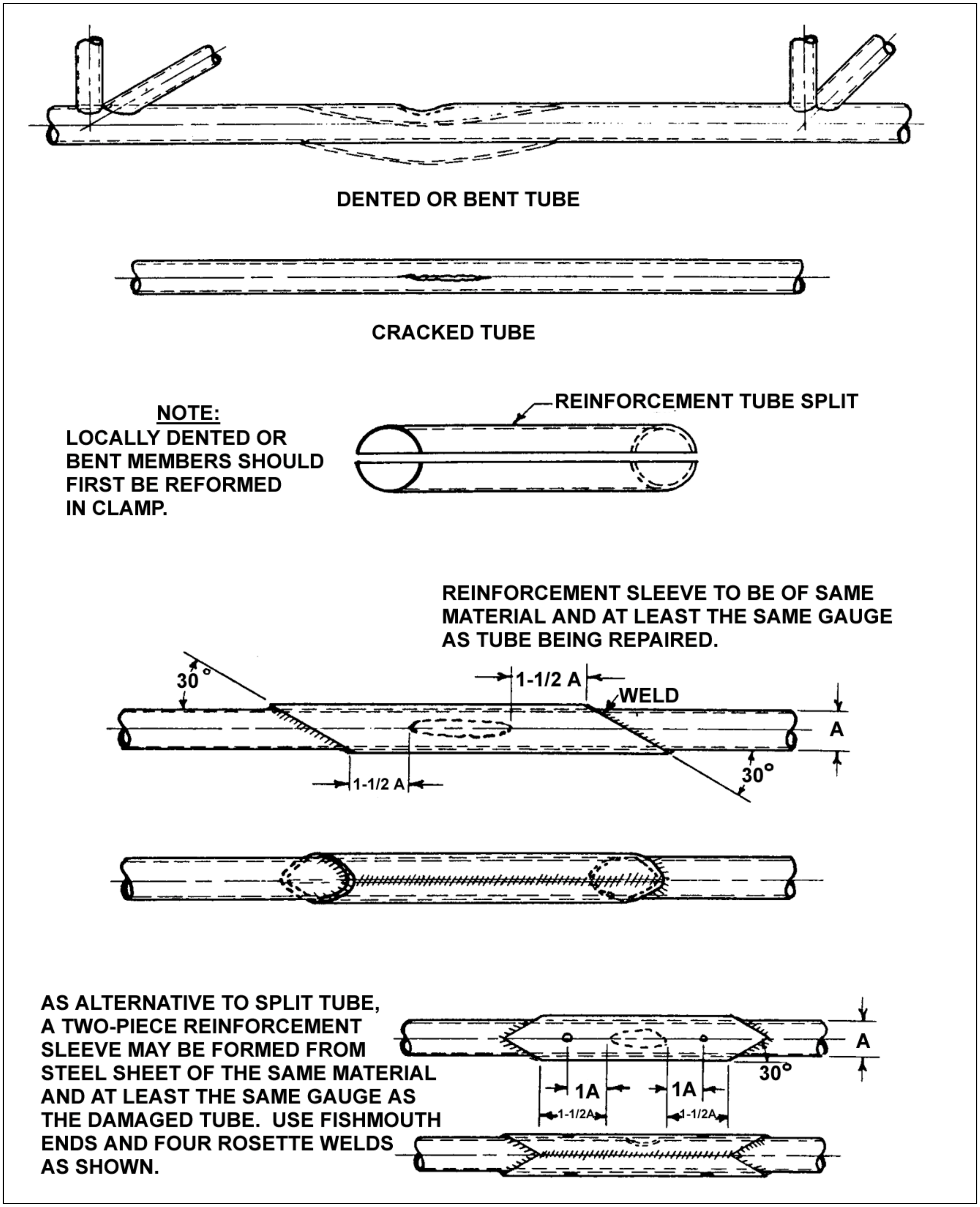


FIGURE 4-35. Members dented in a bay (repairs by welded sleeve).

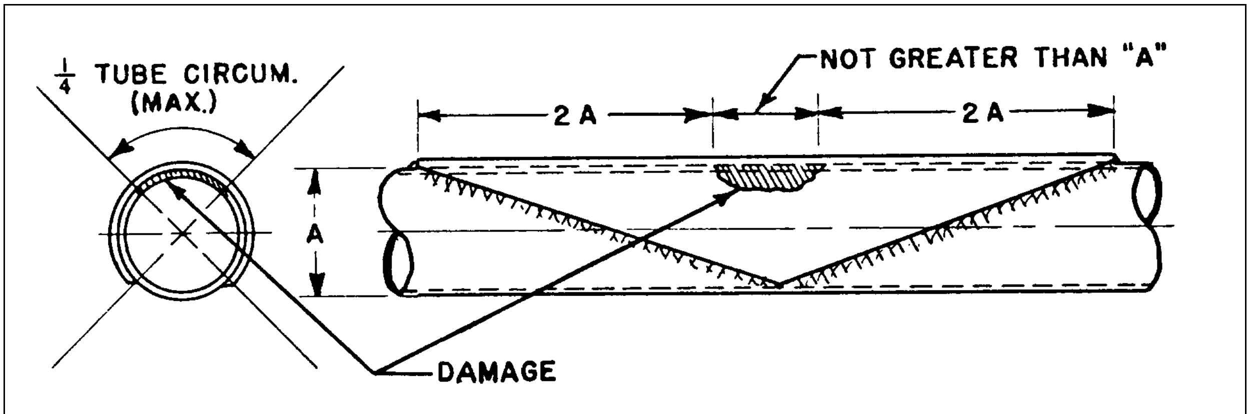


FIGURE 4-36. Welded patch repair.

b. If the inner sleeve fits very tightly in the replacement tube, chill the sleeve with dry ice or cold water. If this is insufficient, polish down the diameter of the sleeve with emery cloth. Tack the outer and inner replacement tubes using rosette welds. Weld the inner sleeve to the tube stubs through the 1/8-inch gap, forming a weld bead over the gap.

4-96. SPLICING TUBING BY OUTER-SLEEVE METHOD. If partial replacement of a tube is necessary, make the outer-sleeve splice using a replacement tube of the same diameter. Since the outer-sleeve splice requires the greatest amount of welding, it should be used only when the other splicing methods are not suitable. Information on the replacement by use of the outer-sleeve method is given in figure 4-38 and figure 4-39.

a. Remove the damaged section of a tube utilizing a 90-degree cut. Cut a replacement steel tube of the same material, diameter, and at least the same wall thickness to match the length of the removed portion of the damaged tube. This replacement tube must bear against the stubs of the original tube with a total tolerance not to exceed 1/32 inch. The outer-sleeve tube material selected must be of the same material and at least the same wall thickness as the original tube. The clearance between inside diameter of the sleeve and the outside diameter of the original tube may not exceed 1/16 inch.

b. From this outer-sleeve tube material, cut diagonally (or fishmouth) two sections of tubing, each of such length that the nearest end of the outer sleeve is a minimum distance of 1-1/2-tube diameters from the end of the cut on the original tube. Use a fishmouth sleeve wherever possible. Deburr the edges of the sleeves, replacement tube, and the original tube stubs.

c. Slip the two sleeves over the replacement tube, align the replacement tube with the original tube stubs, and slip the sleeves over the center of each joint. Adjust the sleeves to suit the area and provide maximum reinforcement.

d. Tack weld the two sleeves to the replacement tube in two places before welding. Apply a uniform weld around both ends of one of the reinforcement sleeves and allow the weld to cool; then, weld around both ends of the remaining reinforcement tube. Allow one sleeve weld to cool before welding the remaining tube to prevent undue warping.

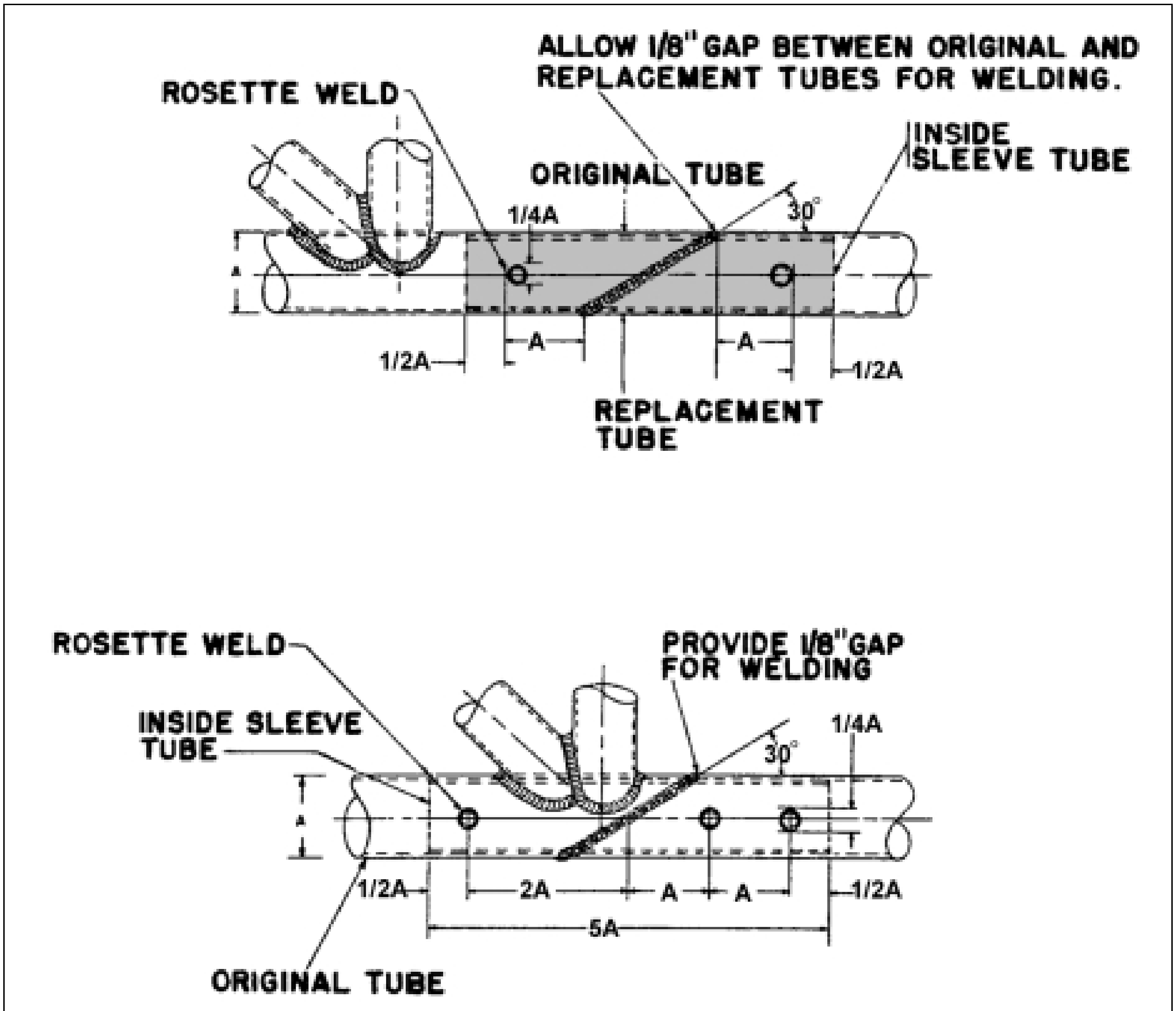
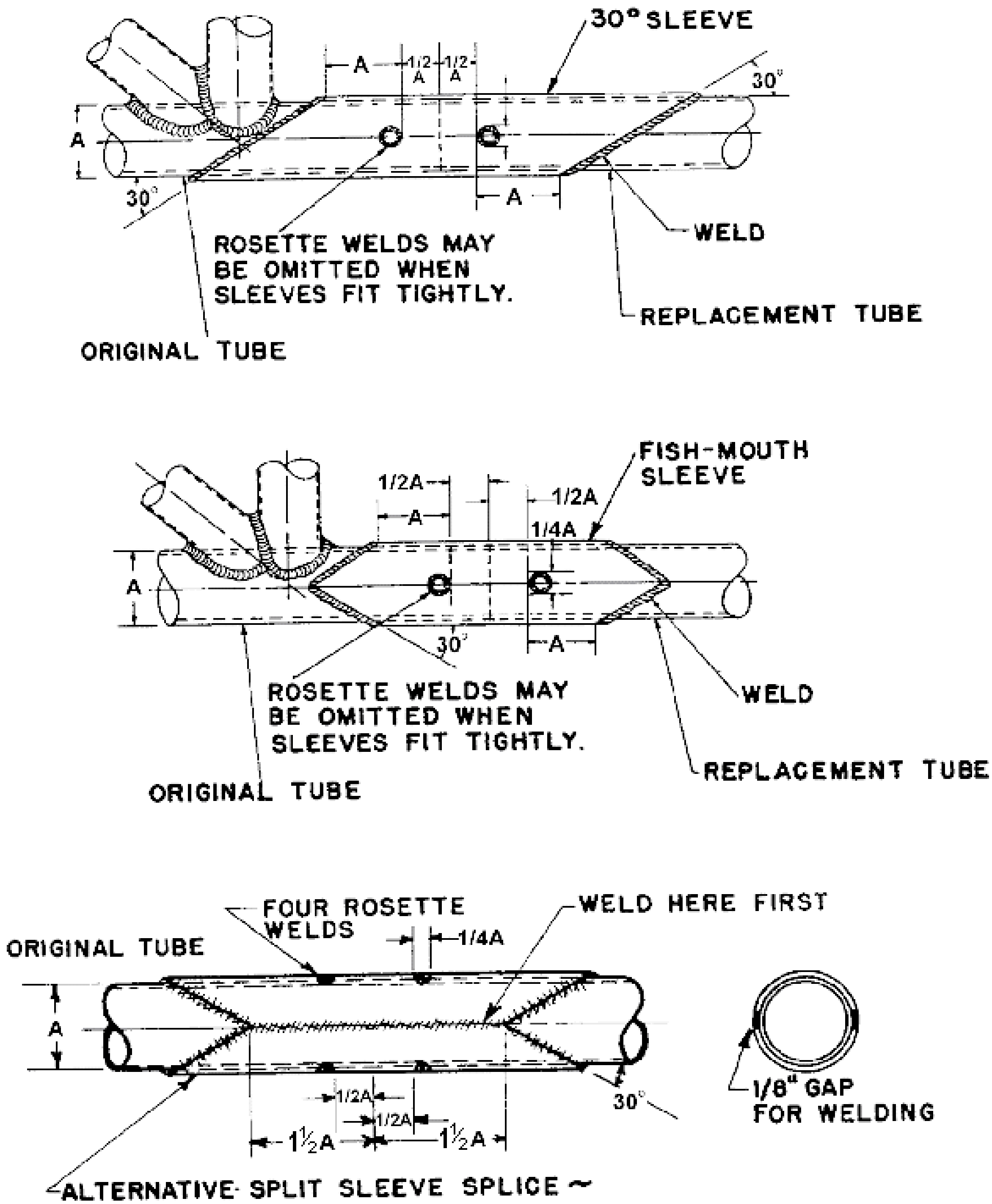


FIGURE 4-37. Splicing by inner-sleeve method.

4-97. SPLICING USING LARGER DIAMETER REPLACEMENT TUBES. The method of splicing structural tubes, as shown in figure 4-40, requires the least amount of cutting and welding. However, this splicing method cannot be used where the damaged tube is cut too near the adjacent cluster joints, or where bracket-mounting provisions make it necessary to maintain the same replacement tube diameter as the original. As an aid to installing the replacement tube, squarely cut the original damaged tube leaving a minimum short stub equal to 2-1/2-tube diameters on one end and a minimum long stub equal to 4-1/2-tube diameters on the other end. Select a length of steel tube of the same material and at least the same wall thickness, having an inside diameter approximately equal to the outside diameter of the damaged tube. Fit this replacement tube material snugly around the original tube with a maximum diameter difference of 1/16 inch. From this replacement tube material, cut a section of tubing diagonally (or fishmouth) of such a length that each end of the tube is a minimum distance of 1-1/2-tube diameters from the end of the cut on the original tube. Use a fishmouth cut replacement tube wherever possible. Deburr the edges of the replacement tube and original tube stubs. If a fishmouth cut is used, file out the sharp radius of the cut with a small round file.



IF OUTSIDE DIAMETER OF ORIGINAL TUBE IS LESS THAN 1 INCH, SPLIT SLEEVE MAY BE MADE FROM STEEL TUBE OR SHEET STEEL. USE SAME MATERIAL OF AT LEAST THE SAME GAUGE.

FIGURE 4-38. Splicing by outer-sleeve method (replacement by welded outside sleeve).

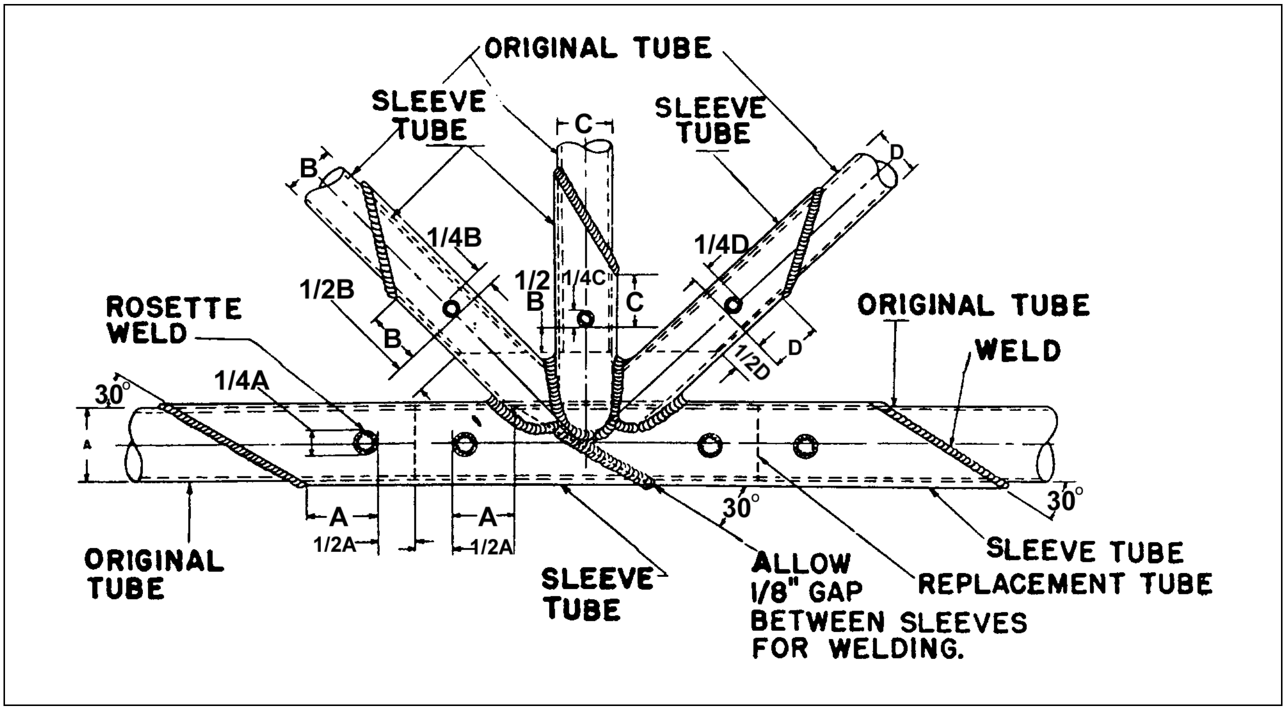


FIGURE 4-39. Tube replacement at a station by welded outer sleeves.

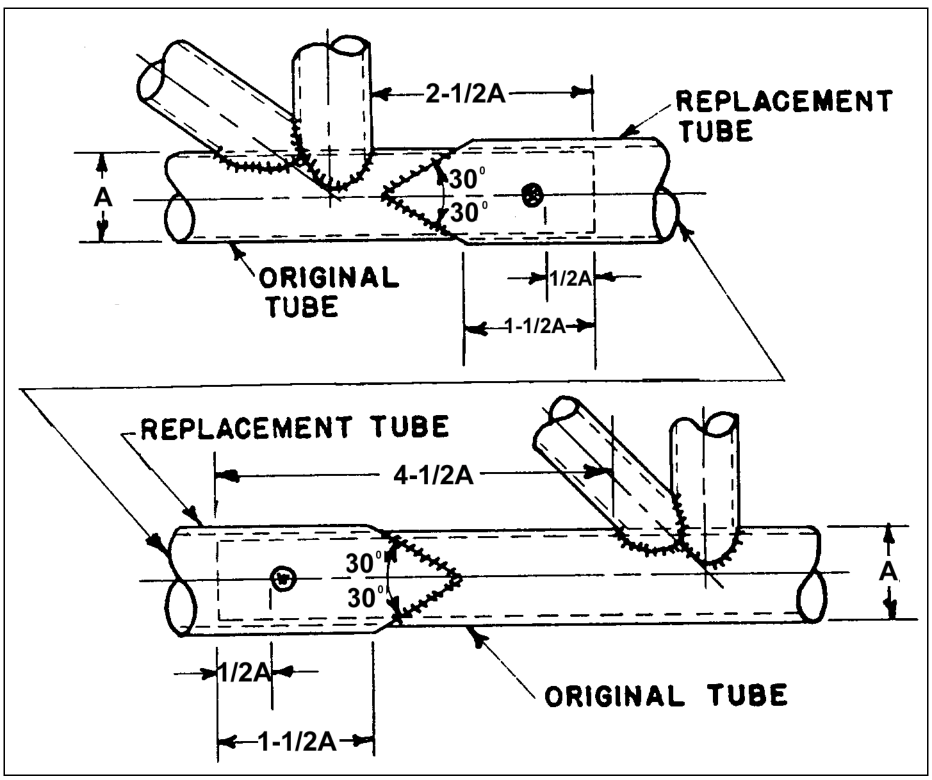


FIGURE 4-40. Splicing using larger diameter replacement tube.

Spring the long stub of the original tube from the normal position, slip the replacement tube over the long stub, and then back over the short stub. Center the replacement tube between the stubs of the original tube. Tack weld one end of the replacement tube in several places, then weld completely around the end. In order to prevent distortion, allow the weld to cool completely, then weld the remaining end of the replacement tube to the original tube.

4-98. REPAIRS AT BUILT-IN FUSELAGE FITTINGS. Make splices in accordance with the methods described in paragraphs 4-86 through 4-92. Repair built-in fuselage fittings in the manner shown in figure 4-41. The following paragraphs outline the different methods as shown in figure 4-41.

a. Tube of Larger Diameter Than Original. A tube (sleeve) of larger diameter than the original is used in the method shown in figure 4-41 (A). The forward splice is a 30-degree scarf splice. Cut the rear longeron (right) approximately 4 inches from the centerline of the joint and fit a 1 inch long spacer over the longeron, and edge weld this spacer and longeron. Make a tapered "V" cut approximately 2 inches long in the aft end of the outer sleeve, and swage the end of the outer sleeve to fit the longeron and weld.

b. Tube of Same Diameter as Original. In the method shown in figure 4-41 (B) the new section is the same size as the longeron forward (left) of the fitting. The rear end (right) of the tube is cut at 30 degrees and forms the outside sleeve of the scarf splice. A sleeve is centered over the forward joint as indicated.

c. Simple Sleeve. In figure 4-41 (C), it is assumed the longeron is the same size on each side of the fitting. It is repaired by a sleeve of larger diameter than the longeron.

d. Large Difference in Longeron Diameter Each Side of Fitting. Figure 4-41 (D) assumes that there is 1/4-inch difference in the diameter of the longeron on the two sides of the fitting. The section of longeron forward (left) of the fitting is cut at 30 degrees, and a section of tubing of the same size as the tube and of such length as to extend well to the rear (right) of the fitting is slipped through it. One end is cut at 30 degrees to fit the 30-degree scarf at left, and the other end fishmouthed. This makes it possible to insert a tube of proper diameter to form an inside sleeve for the tube on the left of the fitting and an outside sleeve for the tube on the right of the fitting.

4-99. ENGINE-MOUNT REPAIRS. All welding on an engine mount must be of the highest quality, since vibration tends to accentuate any minor defect. Engine-mount members should preferably be repaired by using a larger diameter replacement tube, telescoped over the stub of the original member, and using fishmouth and rosette welds. However, 30-degree scarf welds in place of the fishmouth welds will be considered acceptable for engine-mount repair work.

a. Repaired engine mounts must be checked for accurate alignment. When tubes are used to replace bent or damaged ones, the original alignment of the structure must be maintained. When drawings are not available, this can be done by measuring the distance between points of corresponding members that have not been distorted.

b. Grind out all cracked welds.

c. Use only high-grade metallurgically controlled (mc) welding rods for engine-mount repairs.

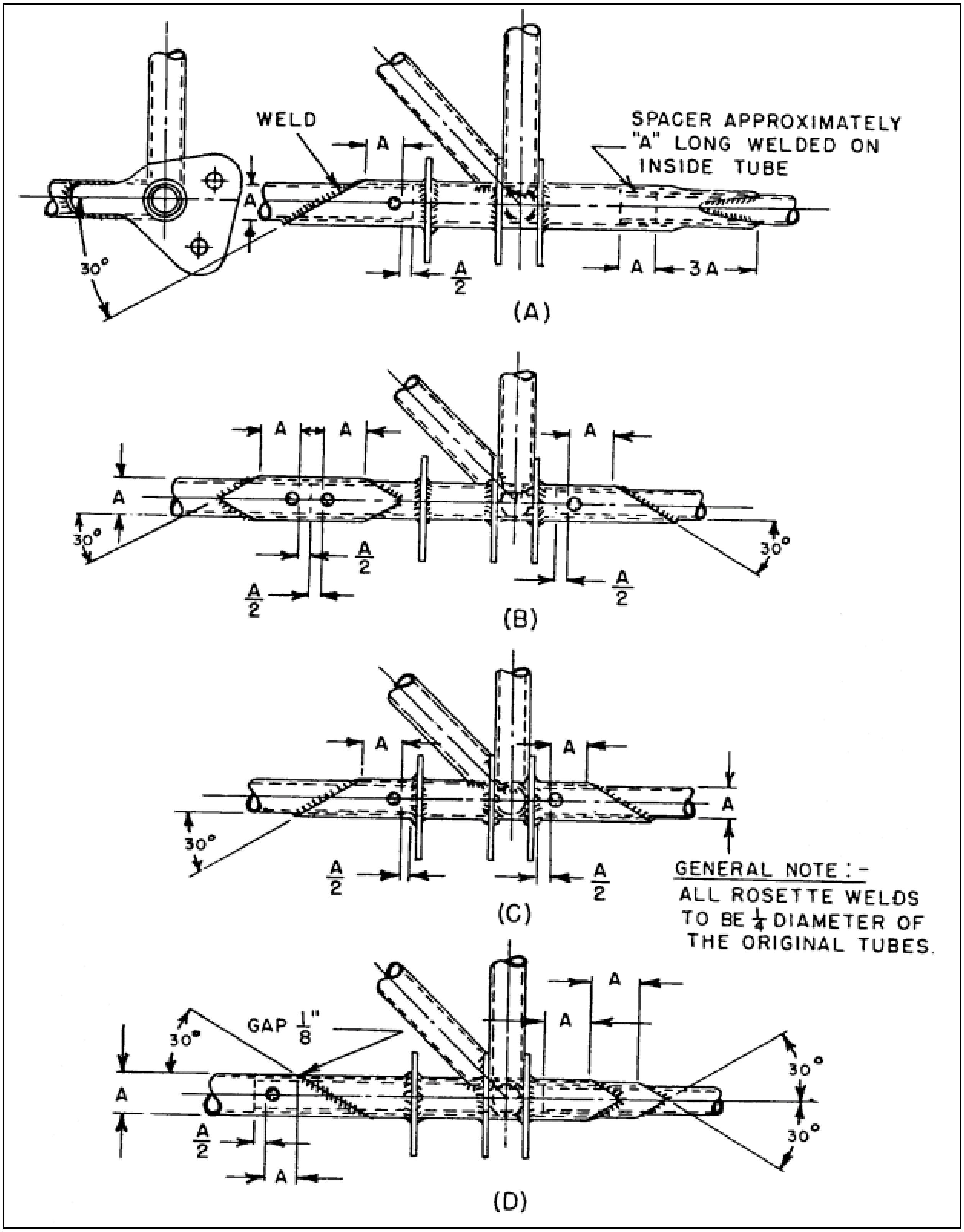


FIGURE 4-41. Repairs at built-in fuselage fittings.

d. If all members are out of alignment, reject the engine mount and replace with one supplied by the manufacturer or one which was built to conform to the manufacturer's drawings. The method of checking the alignment of the fuselage or nacelle points should be requested from the manufacturer.

e. Repair minor damage, such as a crack adjacent to an engine-attachment lug, by rewelding the ring and extending a gusset or a mounting lug past the damaged area. Engine-mount rings which are extensively damaged must not be repaired, unless the method of repair is specifically approved by the FAA, or the repair is accomplished in accordance with FAA-approved instructions.

f. If the manufacturer stress relieved the engine mount after welding it, the engine mount should be re-stress relieved after the weld repairs are made.

4-100. BUILT-UP TUBULAR WING OR TAIL-SPARS. Repair built-up tubular wing or tail-spars by using any of the applicable splices and methods of repair shown in figure 4-35 through figure 4-45, provided the spars are not heat treated. In the case of heat-treated spars, the entire spar assembly would have to be reheat treated to the manufacturer's specifications after completion of the repair. In general, this will be found less practicable than replacing the spar with one furnished by the manufacturer or holder of the PMA for the part.

4-101. WING-BRACE STRUTS AND TAIL-BRACE STRUTS. In general, it will be found advantageous to replace damaged wing-brace struts made either from rounded or streamlined tubing with new members purchased from the original manufacturer. However, there is no objection, from an airworthiness point of view, to repairing such members in a proper manner. An acceptable method of repair, if streamlined tubing is used, will be found in figure 4-43. Repair similar members made of round tubes using a standard splice, as shown in figure 4-35, figure 4-37, or figure 4-38.

a. Location of Splices. Steel-brace struts may be spliced at any point along the length of the strut provided the splice does not overlap part of an end fitting. The jury-strut attachment is not considered an end fitting; therefore, a splice may be made at this point. The repair procedure and workmanship minimize distortion due to welding and the necessity for subsequent straightening operations. Observe every repaired strut carefully during initial flights to ascertain that the vibration characteristics of the strut and attaching components are not adversely affected by the repair. A wide range of speed and engine-power combination must be covered during this check.

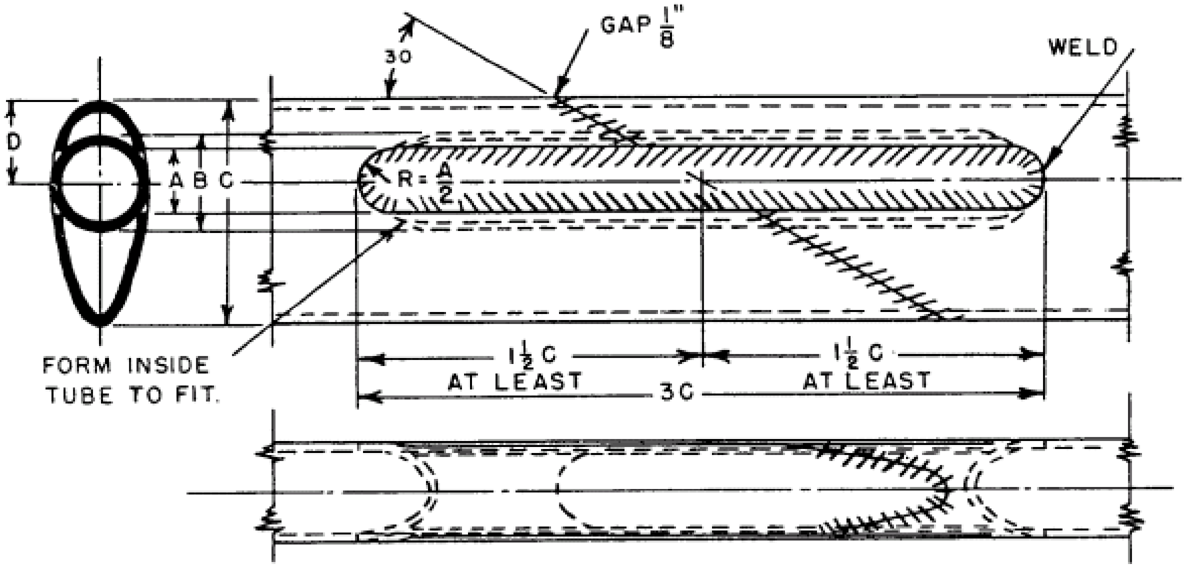
b. Fit and Alignment. When making repairs to wing and tail surface brace members, ensure to proper fit and alignment to avoid distortion.

4-102. LANDING GEAR REPAIR.

a. Round Tube Construction. Repair landing gears made of round tubing using standard repairs and splices as shown in figure 4-35 and figure 4-41.

b. Streamline Tube Construction. Repair landing gears made of streamlined tubing by either one of the methods shown in figure 4-42, figure 4-44, or figure 4-45.

c. Axle Assemblies. Representative types of repairable and nonrepairable landing gear axle assemblies are shown in figures 4-46 and 4-47. The types as shown in A, B, and C of this figure are formed from steel tubing and may be repaired by the applicable method



A- Slot Width (Original Tube).
B- Outside Diameter (Insert Tube).
C- Streamline Tube Length of Major Axis.

S.L. Size	A	B	C	D
1”	.375	.563	1.340	.496
1-¼	.375	.688	1.670	.619
1-½	.500	.875	2.005	.743
1-¾	.500	1.000`	2.339	.867
2	.500	1.125	2.670	.991
2-¼	.500	1.250	3.008	1.115
2-½	.500	1.375	3.342	1.239

ROUND INSERT TUBE (B) SHOULD BE AT LEAST OF SAME MATERIAL AND ONE GAUGE THICKER THAN ORIGINAL STREAMLINE TUBE (C).

FIGURE 4-42. Streamline tube splice using round tube (applicable to landing gear).

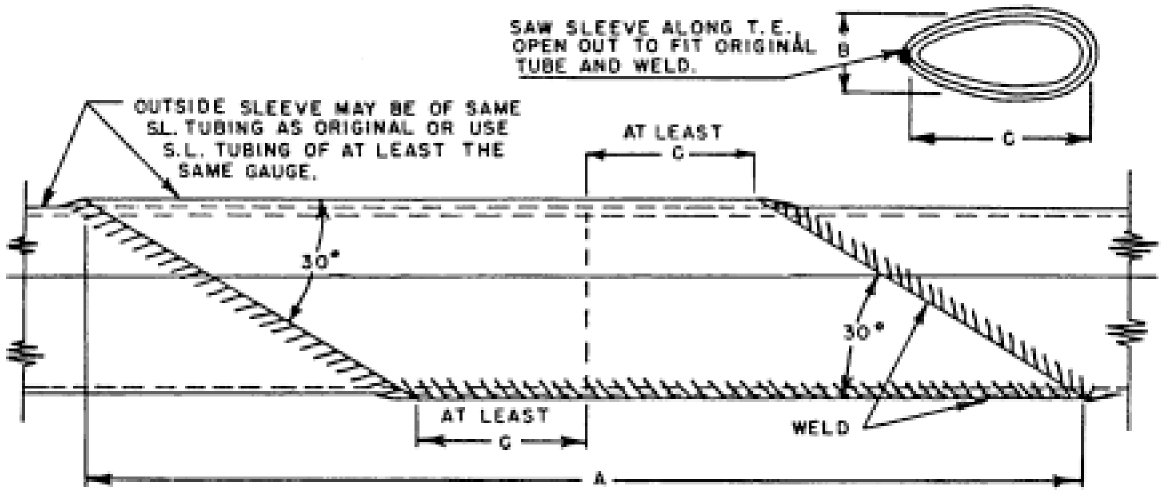
d. shown in figure 4-35 through figure 4-45. However, it will always be necessary to ascertain whether or not the members are heat treated. The axle assembly as shown in figure 4-47 is, in general, of a nonrepairable type for the following reasons.

(1) The axle stub is usually made from a highly heat-treated nickel alloy steel and carefully machined to close tolerances. These stubs are usually replaceable and must be replaced if damaged.

(2) The oleo portion of the structure is generally heat treated after welding, and is perfectly machined to ensure proper functioning of the shock absorber. These parts would be distorted by welding after machining.

4-103. REPAIRS TO WELDED ASSEMBLIES. These repairs may be made by the following methods.

a. A welded joint may be repaired by cutting out the welded joint and replacing it with one properly gusseted. Standard splicing procedures should be followed.



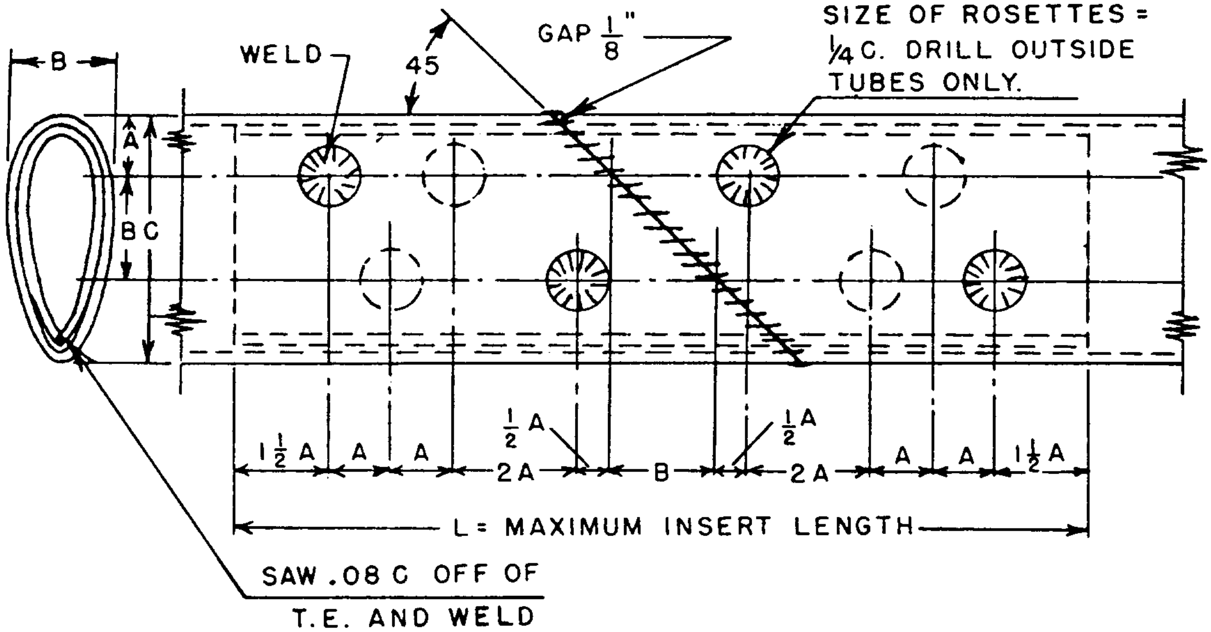
A- Minimum Length of Sleeve.
B- Streamline Tube Length of Minor Axis.
C- Streamline Tube Length of Major Axis.

S.L. Size	A	B	C
1”	7.324	.572	1.340
1-¼	9.128	.714	1.670
1-½	10.960	.858	2.005
1-¾	12.784	1.000	2.339
2	14.594	1.144	2.670
2-¼	16.442	1.286	3.008
2-½	18.268	1.430	3.342

FIGURE 4-43. Streamline tube splice using split sleeve (applicable to wing and tail surface brace struts and other members).

b. Replacing weld deposit by chipping out the metal deposited by the welding process and rewelding after properly reinforcing the joint by means of inserts or external gussets.

4-104. STAINLESS STEEL STRUCTURE. Repair structural components made from stainless steel, particularly the “18-8” variety (18 percent chromium, 8 percent nickel), joined by spot welding, in accordance with the instructions furnished by the manufacturer, DER, or FAA. Substitution of bolted or riveted connections for spot-welded joints are to be specifically approved by a DER or the FAA. Repair secondary structural and non-structural elements such as tip bows or leading and trailing edge tip strips of wing and control surfaces by soldering with a 50-50 lead-tin solder or a 60-40 lead-tin solder. For best results, use a flux of phosphoric acid (syrup). Since the purpose of flux is to attack the metal so that the soldering will be effective, remove excess flux by washing the joint. Due to the high-heat conductivity of the stainless steel, use a soldering iron large enough to do the work properly.



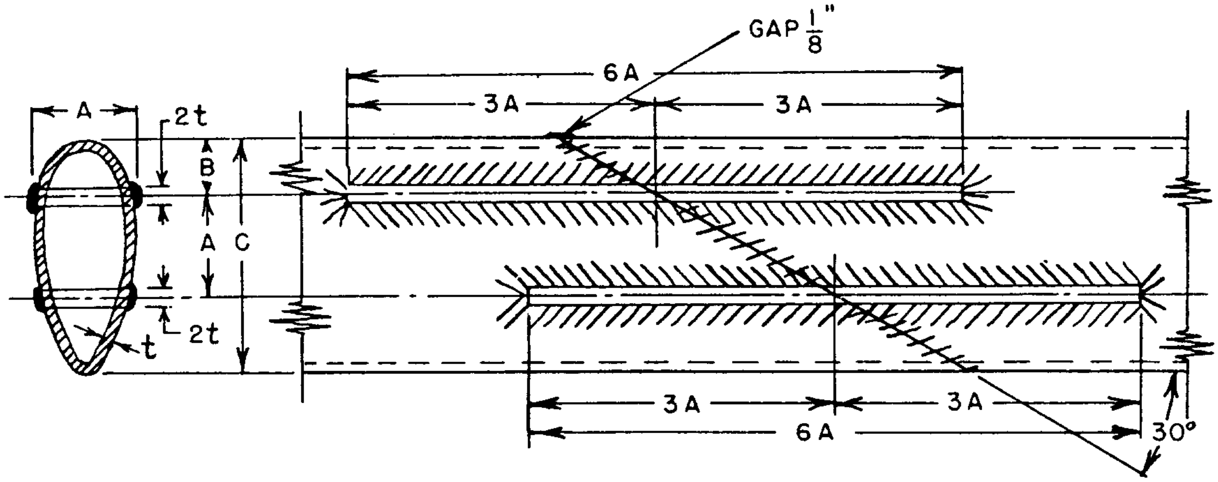
INSERT TUBE IS OF SAME STREAMLINE TUBING AS ORIGINAL.

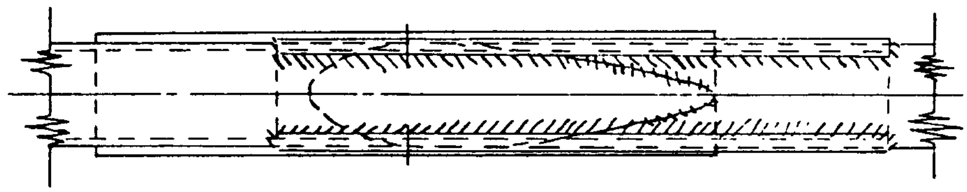
A- Is ²/₃ B.

B- Is Minor Axis Length of Original Streamline Tube.
C- Is Major Axis Length of Original Streamline Tube.

S.L. Size	A	B	C	L
1”	.382	.572	1.340	5.160
1-¼	.476	.714	1.670	6.430
1-½	.572	.858	2.005	7.720
1-¾	.667	1.000	2.339	9.000
2	.763	1.144	2.670	10.300
2-¼	.858	1.286	3.008	11.580
2-½	.954	1.430	3.342	12.880

FIGURE 4-44. Streamline tube splice using split insert (applicable to landing gear).





A- Streamline Tube Length of Minor Axis, Plate Widths.
B- Distance of First Plate From Leading Edge, 2/3 A.
C- Streamline Tube Length of Major Axis.

S.L. Size	A	B	C	6A
1”	.572	.382	1.340	3.430
1-¼	.714	.476	1.670	4.280
1-½	.858	.572	2.005	5.150
1-¾	1.000	.667	2.339	6.000
2	1.144	.762	2.670	6.860
2-¼	1.286	.858	3.008	7.720
2-½	1.430	.954	3.342	8.580

FIGURE 4-45. Streamline tube splice using plates (applicable to landing gear).

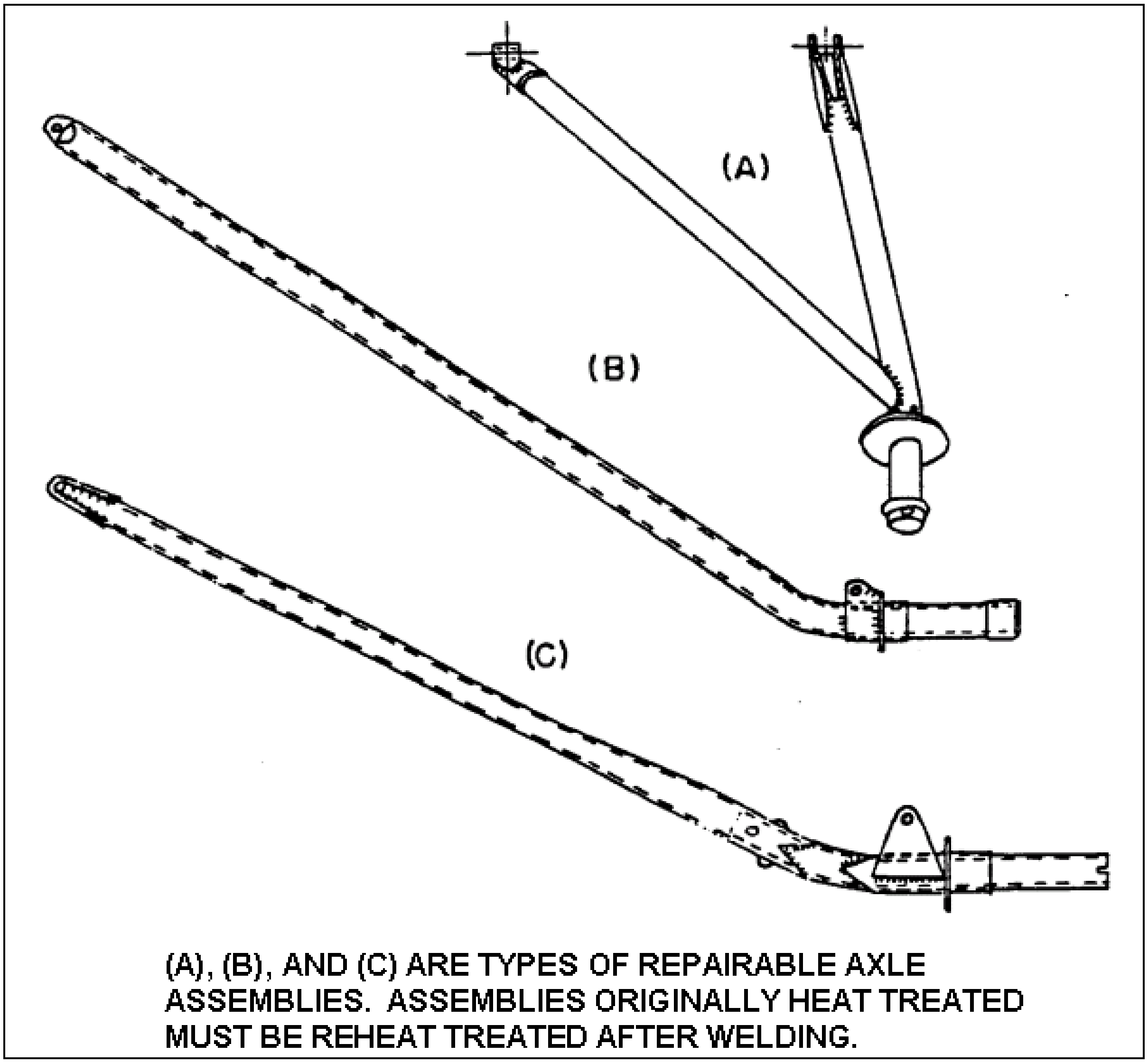


FIGURE 4-46. Representative types of repairable axle assemblies.

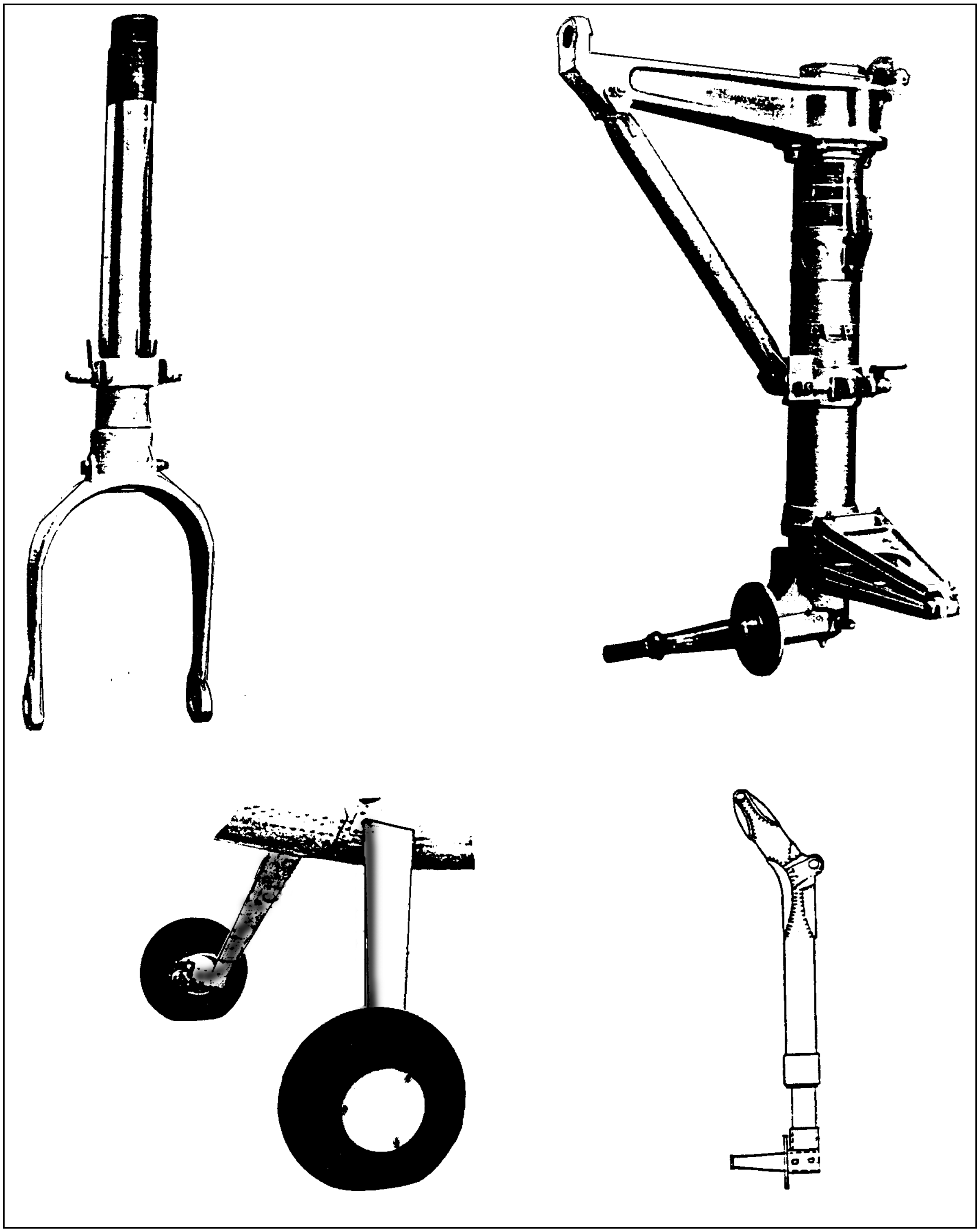


FIGURE 4-47. Landing gear assemblies that CANNOT be repaired by welding.

4-105.—4-110. [RESERVED.]

SECTION 6. WELDING AND BRAZING SAFETY

4-111. GENERAL. A number of inherent hazards exist in the use of oxy-fuel welding and cutting apparatus. It is necessary that proper safety and operating procedures are understood. A thorough understanding of the proper safety and operating procedures minimizes the hazards involved and adds to the pleasure and efficiency of your work.

4-112. FIRE AND EXPLOSION SAFETY. Fires occur in welding areas because flammables are left where they can be ignited by welding sparks or gas welding flames. Before welding, clear the welding area of all flammables such as rags, paper, wood, paint cans, solvent, and trash containers. Do not weld in areas where flammables are present.

a. Unless absolutely necessary, never weld any tank or radiator that has had a flammable in it, including gasoline, av-gas, motor oil, hydraulic fluid, or any other liquid that could ignite if the vapor and temperature reach a flashpoint. Explosions often occur when empty tanks are being welded or cut open with a torch.

b. If welding such tanks or radiator coolers is absolutely necessary, the tank must first be washed with a caustic-based, water-soluble liquid, rinsed with plenty of clear water, and then dried. Before welding, the tank or container should be thoroughly purged with argon, or other inert gas, while the welding is in process.

4-113. WELDING WORK AREA.

a. The work area must have a fireproof floor, concrete floors are recommend.

b. Use heat-resistant shields to protect nearby walls or unprotected flooring from sparks and hot metal.

c. Maintain an adequate suction ventilation system to prevent the concentration of oxygen/fuel gas, flammable gases, and/or toxic fumes. It is important to remember that oxygen will not burn. The presence of oxygen, however, serves to accelerate combustion, and causes materials to burn with great intensity.

CAUTION: Oil and grease in the presence of oxygen can ignite and burn violently.

d. A completely clean welding shop area with white walls, ceiling, and floor; and with plenty of light, is better for welding. The better the lighting conditions, the easier it is to see the weld puddle and make excellent aircraft-quality welds.

e. During oxy-fuel processes use work benches or tables with fireproof tops. Fire bricks commonly top these surfaces and support the work.

f. Chain or otherwise secure oxygen and fuel gas cylinders to a wall, bench, post, cylinder cart, etc. This will protect them from falling and hold them upright.

4-114. FIRE PROTECTION. Practice fire prevention techniques whenever oxy-fuel operations are in progress. Simple precautions prevent most fires, and minimize damage in the event a fire does occur. Always practice the following rules and safety procedures.

a. Inspect oxy-fuel apparatus for oil, grease, or damaged parts. DO NOT use the oxy-fuel apparatus if oil or grease is present or if damage is evident. Have the oxy-fuel apparatus cleaned and/or repaired by a qualified repair technician before it is used.

b. Never use oil or grease on or around any oxy-fuel apparatus. Even a trace of oil or grease can ignite and burn violently in the presence of oxygen.

c. Keep flames, heat, and sparks away from cylinders and boxes.

d. Flying sparks can travel as much as 35 feet. Move combustibles a safe distance away from areas where oxy-fuel operations are performed.

e. Use approved heat-resistant shields to protect nearby walls, floor, and ceiling.

f. Have a fire extinguisher of the proper class (ABC) and size in the work area. Inspect it regularly to ensure that it is in proper working order. Know how it is used.

g. Use oxy-fuel equipment only with the gases for which it is intended.

h. DO NOT open an acetylene cylinder valve more than approximately 1-1/2 turns and preferably no more than 3/4 of a turn. Keep the cylinder wrench, if one is required, on the cylinder valve so, if necessary, the cylinder may be turned off quickly.

i. On all gases except acetylene, open the cylinder valve completely to seal the cylinder back-seal packing.

j. Never test for gas leaks with a flame. Use an approved leak-detector solution.

k. When work is complete, inspect the area for possible fires or smoldering materials.

l. Special care should be taken when welding structural tubing that has been coated on the inside with linseed oil. Smoke and fire may be generated by the heat of the torch. Ensure that an observer with a fire extinguisher is close.

4-115. PROTECTIVE APPAREL.

a. Protect yourself from sparks, flying slag, and flame brilliance at all times.

(1) For gas welding and brazing, use number 3 or 4 green-shaded tempered lenses.

(2) When gas welding aluminum, use cobalt-blue tint lenses.

(3) When arc welding, including TIG, MIG, and plasma cutting; use number 9 to 12 green lenses and a full face-and-neck covering helmet.

(4) Electronically darkening lenses provide number 3 to 12 automatic darkening as soon as the arc is ignited.

b. Wear protective gloves, sleeves, aprons, and lace-up shoes to protect skin and clothing from sparks and slag.

CAUTION: Keep all clothing and protective apparel absolutely free of oil or grease.

4-116. FIRST-AID KITS. Always keep a special welder's first-aid kit where it is easily accessible. Burns are the most common welding accidents.

4-117.—4-128. [RESERVED.]