REFERENCE

TAD-494.6

AC NO: 43.13–1A CHG 2

DATE: 12/22/76

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: ACCEPTABLE METHODS, TECHNIQUES, AND PRACTICES—AIRCRAFT INSPECTION AND REPAIR

1. PURPOSE. This change transmits revised material for Advisory Circular 43.13–1A.

2. PRINCIPAL CHANGES. Chapter 16, Section 1, paragraph 867, has been revised to clarify recommended adjustments concerning aircraft instruments. The revision also deletes subparagraphs a and b of paragraphs 867 to discourage indiscriminate adjustments of altimeters and vertical speed indicators without the use of appropriate test equipment or standards.

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303 and 304	1972	303 and 304	12/22/76

R. P. Skully
Director, Flight Standards Service

Initiated by: AFS–804

Chapter 16. INSTRUMENTS

Section 1. MAINTENANCE OF INSTRUMENTS

864. GENERAL. The complexity of modern instruments, integrated flight systems, auto-pilots, air data computers, and inertial guidance systems necessitates complex maintenance procedures, sophisticated test equipment and qualified personnel. The safety of aircraft operated in the National Airspace System is dependent in a large degree upon the satisfactory performance of airborne instrument systems. It is, therefore, important that maintenance be accomplished using the best techniques and practices to assure optimum performance.

The term "system" as used in this chapter means those units of power source, sensors, transmitters, indicator, and controllers which together perform a function of display, interpretation, or control of the functions of an aircraft, its systems or the environment in which it operates.

865. DEFINITION. The definition of an instrument is contained in Part 1 of the Federal Aviation Regulations.

866. MAINTENANCE OF INSTRUMENTS. Repairs and overhaul of aircraft instruments should be made only by an FAA approved facility having proper test equipment, adequate manufacturer's maintenance manuals and service bulletins, and qualified personnel. Details concerning the repair and overhaul of various instruments differ considerably. Test, repair, and adjust instruments and instrument systems in accordance with the manufacturer's maintenance instructions, manuals, and applicable Federal Aviation Regulations. Consult the airframe manufacturer for specific maintenance instructions involving instruments that are installed or supplied by them.

* **867. TEST/ADJUSTMENT OF INSTRUMENTS.** Certain instruments, such as altimeters and vertical speed (rate of climb) indicators, are equipped with simple adjusting means. The barometric correlation adjustment should not be adjusted in the field; changing this adjustment may nullify the correspondence between the basic test equipment calibration standards and the altimeter. Additionally, correspondence between the encoding altimeter and its encoding digitizer or the associated blind encoder may be nullified. These adjustments should be accomplished by qualified personnel, using proper test equipment and adequate reference to the manufacturer's maintenance manuals. *

868. REPLACEMENT OF COMPONENTS. Replace damaged or defective instruments with identical serviceable components or components equivalent to the original in electrical and mechanical characteristics, operating tolerances, and the ability to function in the physical environmental conditions encounterd in the operation of the aircraft. Be sure all shipping plugs and gyro caging devices that may have been installed for shipping purposes are removed before installing an instrument. Check new installations carefully prior to applying electrical power or connecting test equipment to avoid damaging sensitive mechanisms. Test the new instrument after installation for proper functioning (where applicable).

869-879. RESERVED.

REFERENCE

CHANGE

AC NO: 43.13-1A CHG 1

DATE: 5/12/75

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
OST-FOB-10A, TAD-494.7
800 INDEPENDENCE AVE S.W.
WASH., D.C. 20590

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: ACCEPTABLE METHODS, TECHNIQUES, AND PRACTICES—AIRCRAFT INSPECTION AND REPAIR

1. PURPOSE.

This change transmits new and revised material for Advisory Circular 43.13-1A.

2. PRINCIPAL CHANGES.

a. Corrections have been made to paragraph 313 and Figure 10.1.

b. Chapter 2, Section 3, has been revised to add Selective Plating in aircraft maintenance. Chapter 4, Section 6 has been revised to add handling and care of aircraft recovered from water immersion.

c. A new Section 5, Cabin Interior Materials—Fire Protection Qualities, has been added to Chapter 7.

d. New information on tire slippage and maintenance has been added to Section 1 of Chapter 8.

3. HOW TO GET THIS PUBLICATION.

Copies of this change to AC 43.13-1A may be obtained by ordering from:

Superintendent of Documents
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For up-to-date information on how to order, and the price of this publication, check with the closest FAA office or obtain the latest copy of Advisory Circular 00-2, Advisory Circular Checklist and Status of the Federal Aviation Regulations. This checklist may be obtained without charge by requesting from:

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Washington, D.C. 20590

Initiated by: AFS-830

R. P. SKULLY, Director
Flight Standards Service

Initiated by:

PAGE CONTROL CHART

Remove Pages	Dated
i thru iv	1972
73 and 74	1972
127 and 128	1972
139 and 140	1972
149 and 150	1972
165 and 166	1972

Insert Pages	Dated
i	1972
ii thru iv	1975
73 thru 73-3	1975
74	1972
127	1972
128 thru 128-3	1975
139	1972
140 thru 140-1	1975
149	1972
150	1975
165	1975
166	1972

TABLE OF CONTENTS

Chapter 1. AIRCRAFT WOOD STRUCTURES

Section 1. MATERIALS AND PRACTICES

Section 2. FINISHING WOOD STRUCTURES

Chapter 2. AIRCRAFT METAL STRUCTURES

Section 1. REFERENCES AND PRECAUTIONARY MEASURES

Section 2. WELDING

TABLE OF CONTENTS—Continued

TABLE OF CONTENTS—Continued

TABLE OF CONTENTS—Continued

Chapter 7. IDENTIFICATION, TESTING, AND INSPECTION OF MATERIALS

TABLE OF CONTENTS—Continued

Paragraph *Page*

Section 3. MISCELLANEOUS EQUIPMENT

all highly stressed main fittings, as set forth in Chapter 7, and if necessary, take corrosion prevention measures as recommended in Chapter 6.

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

(4) Elongated or worn boltholes in fittings which were designed without bushings are not to be reamed oversize. Replace such fittings, unless the method of repair is approved by a representative of the FAA. Do not fill holes with welding rod. Acceptable methods of repairing elongated or worn boltholes in landing gear, stabilizer, interplane, or cabane-strut ends only, not originally equipped with pin plates, are shown in fiigure 2.36. (Also see figure 2.11 on longeron repair at fitting.)

b. *Aluminum and Aluminum Alloy Fittings.*

(1) Replace damaged fittings with new parts, having 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 review.

103. 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.

* **104. 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:

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

(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 ultra high strength steels without hydrogen embrittlement.

(10) On-site plating.

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

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

QQ-C-320	Chromium Plating
QQ-N-290	Nickel Plating
QQ-P-416	Plating, Cadmium
QQ-S-365	Silver Plating
QQ-Z-325	Zinc Plating
MIL-T-10727	Tin Plating
MIL-C-14550	Copper Plating
MIL-G-45204	Gold Plating

c. *General Requirements.*

(1) Areas to be repaired by this process should be limited to reasonably small areas of large parts, although it may be desirable to plate small parts, particularly electrical or electronic parts, in their entirety.

(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; 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° 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 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 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 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 his 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 one 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 forward (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 forward (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 forward (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 forward (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 forward (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 acid or silver. Both 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 forward (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 these require undercoats).

(8) Rinse and dry.

o. *Plating on Ultra High 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°±25° F.

NOTE 1: Where the solution vendor provides substantiating data that hydrogen embbrittlement will not result from plating with a particular solution, then a post bake is not required. This substantiating data can be in the form of aircraft industry manufacturers' process specifications, military specifications, or other suitable data.

NOTE 2: 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 forward (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 or 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, ultra high strength steel parts (heat treated above 180,000 psi) should be baked as mentioned in paragraph 104.o.(5), unless it is specifically known that embrittlement is not a factor.

r. ***Qualification Tests.*** All brush plated surfaces shall 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 shall 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 products of those training programs and certified as qualified operators by the manufacturers of the products used, as well as by local quality control departments. *

105.-114. RESERVED.

Section 4. REPAIR OF LAMINATE STRUCTURES

115. GENERAL. There is a wide variation in the composition and structural application of laminates, and it is essential that these factors be given major consideration when any restoration activities are undertaken. To a similar extent, there also exist many types of laminate structure repairs that may or may not be suitable for a given condition. For this reason, it is important that the aircraft or component manufacturer's repair data be reviewed when determining what specific type of repair is permissible and appropriate for the damage at hand.

The materials used in the repair of laminate structures must preserve the strength, weight, aerodynamic characteristics, or electrical properties of the original part or assembly. This can best be accomplished by replacing damaged material with material of identical chemical composition or a substitute approved by the manufacturer.

In order to eliminate dangerous stress concentrations, avoid abrupt changes in cross-sectional areas. Whenever possible, for scarf joints and facings, make small patches round or oval-shaped, and round the corners of large repairs. Smooth and properly contour aerodynamic surfaces.

It is recommended that test specimens be prepared at the same time that the actual repair is accomplished. These can then be subjected to a destructive test to establish the quality of the adhesive bond in the repaired part. To make this determination valid, the specimens must be assembled with the same adhesive batch mixture and subjected to curing pressure, temperature, and time identical with those in the actual repair.

a. Fiberglass Laminate Repairs. The following repairs are applicable to fiberglass laminate used for fairings, covers, cowlings, honeycomb panel facings, etc. Prior to undertaking the repair, clean the repair area thoroughly with a castile soap and warm water. Remove any paint by wet or dry sanding methods. Seed blasting may be used but caution must be exercised to not abrade the surfaces excessively.

Superficial scars, scratches, surface abrasion, or rain erosion can generally be repaired by applying one or more coats of a suitable resin, catalyzed to cure at room temperature, to the abraded surface. The number of coats required will depend upon the type of resin and severity of the damage.

Damage not exceeding the first layer or ply of fiberglass laminate can be repaired by filling with a putty consisting of a compatible room-temperature-setting resin and clean short glass fibers. Before the resin sets, apply a sheet of cellophane over the repair area and work out any bubbles and excess resin. After the resin has cured, sand off any excess and prepare the area for refinishing.

Damage deep enough to seriously affect the strength of the laminate (usually more than the first ply or layer of fabric) may be repaired as illustrated in figure 2.37. Coat the

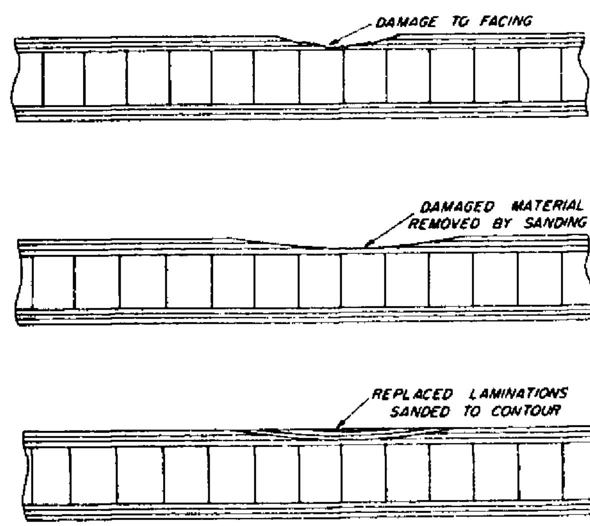

FIGURE 2.37.—Typical laminate (facing) repair.

in any cleaning process to avoid unnecessary breaking of the protective film, particularly at the edges of the aluminum sheet. Chromic acid and other inhibitive treatments tend to restore the oxide film.

d. *More severe cleaning is necessary* with intergranular corrosion (attack along grain boundaries). The mechanical removal of all corrosion products and visible delaminated metal layers must be accomplished in order to determine the extent of the destruction and to evaluate the remaining structural strength of the component. Inspection with a 5- to 10-power magnifying glass or the use of dye penetrant will assist in determining if all unsound metal and corrosion products have been removed. Grinding to blend or fair out the edges of damaged areas can best be accomplished by using aluminum oxide-impregnated rubber-base wheels. Chemically inhibit the exposed surfaces and restore chemical surface films or paint in the same manner as for other aluminum surfaces.

e. *Magnesium is the most chemically active* of the metals used in aircraft construction and is therefore the most difficult to protect. The prompt and complete correction of the coating failure is imperative if serious structural damage is to be avoided. Treat the corroded area with 10 percent chromic acid solution to which has been added approximately 20 drops of battery electrolyte per gallon, in the same manner as for aluminum alloys.

251. CORROSION PROOFING OF LANDPLANES AND SEAPLANES. In the repair or alteration of aircraft, use corrosion proofing materials the same as, or equivalent to, that originally applied unless the repair or alteration would result in increased susceptibility to corrosion, in which case, employ additional corrosion protection measures.

252. CORROSION PROOFING OF LANDPLANES CONVERTED TO SEAPLANES. A special problem is encountered in the conversion of landplanes to seaplanes. In general, landplanes do not receive corrosion proofing to the same extent as do seaplanes manufactured as such. Corrosion-proofing standards for landplanes converted to seaplanes are divided into two classes: (1) Necessary minimum precautions; and (2) Recommended precautions. Regardless of such precautions, it is imperative that the exterior surfaces of seaplanes be washed with clear fresh water immediately following extended water operation, or at least once a day when operated in salty or brackish water. Wash interior surfaces of seaplanes exposed to spray, taking care to prevent damage to electrical circuits or other items subject to injury.

a. *Necessary Minimum Precautions.* The following procedures are considered the minimum to safeguard the airworthiness of the converted aircraft and are not in themselves intended to maintain airworthiness for an indefinite period.

(1) Unless already protected, treat exposed fittings or fittings which can be reached through inspection openings with two coats of zinc chromate primer, paralketone, nonwater-soluble heavy grease, or comparable materials. This applies to items such as wing-root fittings, wing-strut fittings, control-surface hinges, horns, mating edges of fittings, and attach bolts, etc.

(2) Coat nonstainless control cables with grease or paralketone or other comparable protective coating, if not replaced with corrosion-resistant cables.

(3) Inspect all accessible sections of aircraft structure. Clean structural parts showing corrosion and refinish if corrosion attack is superficial. If a part is severely corroded, replace with an adequately corrosion-proofed part.

b. *Recommended Precautions.* The recommended precautions are those which are suggested as a means of maintaining such aircraft in condition for safe operation over extended periods of time.

(1) Provide additional inspection openings to assist in detecting corrosion. Experience has shown openings to allow inspection of lower and rearward portion of the fuselage to be particularly desirable.

(2) Incorporate additional provisions for free drainage and ventilation of all interiors to

prevent collection of moisture (scoop-type drain grommets).

(3) Protect the interior of structural steel tubing. This may be done by air and watertight sealing or by flushing with hot linseed oil and plugging the openings. Inspect tubing for missing sealing screws, presence of entrapped water, local corrosion around sealing screws, welded clusters, and bolted fittings which may be indicative of entrapped moisture.

(4) Slit the fabric of fabric-covered aircraft longitudinally on the bottom of the fuselage and tail structure for access to these sections. Coat the lower structural members with zinc chromate primer (two coats); follow by a coat of dope-proof paint or wrap with cellophane tape and rejoin the fabric. This precaution is advisable within a few months after start of operation as a seaplane.

(5) Spray the interior of metal-covered wings and fuselages with an adherent corrosion inhibitor.

(6) Place bags of potassium or sodium dichromate in the bottom of floats and boat hulls to inhibit corrosion.

(7) Prevent the entry of water by sealing, as completely as possible, all openings in wings, fuselage, control-surface members, openings for control cables, tail-wheel wells, etc.

253. CLEANERS, POLISHES, BRIGHTENERS. It is important that aircraft be kept thoroughly clean of deposits containing contaminating substances such as oil, grease, dirt, and other foreign materials.

a. Materials. Avoid damage to aircraft by not using harmful cleaning, polishing, brightening, or paint-removing materials. Use only those compounds which conform to existing government or established industry specifications or products that have been specifically recommended by the aircraft manufacturer as being satisfactory for the intended application. Observe the product manufacturer's recommendations concerning use of his agent.

b. Chemical Cleaners. Chemical cleaners must be used with great care in cleaning assembled aircraft. The danger of entrapping corrosive materials in faying surfaces and crevices counteracts any advantages in their speed and effectiveness. Use materials which are relatively neutral and easy to remove.

c. Removal of Spilled Battery Acid. In order to neutralize spilled battery acid, use sodium bicarbonate (baking soda), or sodium borate (borax) 20 percent by weight dissolved in water. After neutralization, remove alkali salt completely with copious quantities of water to prevent corrosion. An application of acidproof paint to the structure surrounding the battery may be an effective control for this type of corrosion.

* **254. HANDLING AND CARE OF AIRCRAFT RECOVERED FROM WATER IMMERSION.** Aircraft which were recovered from partial or total immersion in water, including flash floods, have been allowed to air dry, in certain instances, with no safety precautions other than a cursory inspection of the aircraft exterior. The lack of an adequate cleanup of water-immersed areas may subsequently adversely affect the safety of the aircraft. That is, water immersion increases the probability of corrosive attack, the removal of lubrication, the deterioration of aircraft materials, and/or degradation of electrical and avionic equipment.

Sea water, because of salt content, is more corrosive than surface fresh water. However, fresh water may contain varying amounts of salt and, as drying occurs, the salt concentration is increased and corrosive attack accelerated.

The most important factor following recovery of an aircraft from sea or fresh water immersion is prompt action. Components of the aircraft which have been water immersed, such as the powerplant, accessories, airframe sections, actuating mechanisms, screws, bearings, working surfaces, fuel and oil systems, wiring, radio, and radar should be disassembled, to the extent considered necessary, so that the contaminants can be completely removed.

a. Initial Fresh Water/Detergent Wash. As soon as possible after the aircraft is recovered from water immersion, thoroughly wash contaminated internal and external areas of the aircraft using a water/detergent solution as follows:

(1) Mix liquid detergent (MIL-D-16791, Type I) and isopropyl alcohol (TT-I-735) in * *ratio of eight parts detergent to 20 parts of alcohol. Add the detergent/alcohol mixture to 72 parts of tap water and mix thoroughly. For use, add one part of the foregoing concentrate to nine parts of tap water (warm water if available) and mix thoroughly.

(2) If the above specified detergent/alcohol materials are not available, use water emulsion cleaning compound (MIL-C-43613). Add one part compound to nine parts water. If the MIL cleaning compound is not available, use any available mild household detergent solution with fresh tap water.

b. *Safety Precautions.* The following safety precautions should be observed:

(1) Electrically ground the aircraft. Attach the ground lead to the aircraft at a point which is outside the area that could contain explosive vapors.

(2) If the landing gear of land planes is used as a supporting mechanism, install a spreader bar, jury strut, landing gear downlocks or other suitable devices to insure that the gear will not collapse. If the landing gear is not serviceable, insure that the aircraft is solidly supported to prevent hazardous movement.

(3) Disconnect and remove wet- and/or dry-cell batteries and isolate aircraft from all sources of electricity or other spark-producing devices. Spark-producing static electricity is generated at compressed air hose outlets, so this method should not be used for ventilating or purging fuel vapors.

(4) Remove all fuel, oil, and hydraulic fluid.

(5) Flush all fuel and oil cells with clean fresh water.

(6) Deflate tires, especially on magnesium wheels. Depressurize landing gear struts, pneumatic systems, and hydraulic accumulators.

c. *Reciprocating Engines and Propellers.* The propeller should be removed from the engine and the engine from the aircraft. The exterior of the engine and propeller should be washed with steam, or hot or cold fresh water.

The major accessories, engine parts, etc., should be removed and all surfaces flushed with fresh water, preferably hot. If facilities are available, the removed parts, size permitting, should be immersed in hot water or hot oil, 180° F., for a short period of time. Soft water is preferred and should be changed frequently. All parts must be completely dried by air blast or other means. If no heat drying facility is available, wipe the cleaned parts with suitable drying cloths.

Constant speed propeller mechanism should be disassembled, as required, to permit complete decontamination. Clean parts with steam or hot or cold fresh water. Dry the cleaned parts in an oven, but if a heat drying facility is not available, wipe the cleaned parts with suitable drying cloths.

d. *Gas Turbine, Turboprop and Turboshaft Engines.* The engine exhaust shield, insulation blankets, separate exhaust collectors, compressor housing, pinion cowl and/or upper pinion housing should be removed. The engine accessories, outer housing exhaust shields, and other exposed parts should be steam cleaned. The steam-cleaned parts should be dried in an oven at approximately 200° F., or with hot air from a portable engine heater, or with clean wiping cloths.

Immerse remainder of engine in 10-20 percent water solution of sodium dichromate, or hot, fresh water and apply sufficient agitation to provide complete flushing.

If immersion cannot be accomplished, flood the lower section of the compressor housing and thoroughly flush rotor blades with sodium dichromate solution or warm fresh water. Seal off combustion chamber openings and alternately fill and drain the combustion chamber with fresh water. Dry clean parts in an oven, or use dry air from a portable engine heater or wipe with suitable drying cloths.

e. *Airframe.* The salvageable components of the fuselage, wings, empennage, seaplane and amphibian hulls and floats, and movable surfaces should be processed as follows:

(1) The fabric from fabric-covered surfaces should be removed and replaced.

(2) The aircraft interior and exterior should be cleaned using steam under pressure with steam-cleaning compound. The steam should be directed into all seams and crevices where corrosive water may have penetrated. Avoid steam * *cleaning electrical equipment, such as terminal boards and relays.

(3) Areas that have been steam cleaned should be rinsed immediately with either hot or cold fresh water.

(4) Touch up all scratches and scars on painted surfaces using zinc chromate primer or preservative.

(5) Undrained hollow spaces or fluid entrapment areas should be provided temporary draining facilities by drilling out rivets at lowest point. Install new rivets after drainage.

(6) All leather, fabric upholstery, and insulation should be removed and replaced. Plastic or rubber foam which cannot be cleaned of all corrosive water should be replaced.

(7) All drain plugs or drive screws in tubular structures should be removed and the structure blown out with compressed air. If corrosive water has reached the tubular interiors, carefully flush with hot, fresh water and blow out water with compressed air. Roll the structure as necessary to remove water from pockets. Fill the tubes with hot linseed oil at approximately 180° F. Drain oil and replace drain plugs or drive screws.

(8) Clean sealed wood, metalite, and other nonmetallic areas, excluding acrylic plastics, with warm water. Wood, metalite, and other porous materials exposed to water immersion should be replaced, unless surfaces are adequately sealed to prevent penetration by corrosive water. Virtually all solvents and phenolic type cleaning agents are detrimental to acrylics and will either soften the plastic or cause crazing.

f. *Helicopter Rotor Dynamic Components.*

(1) All evidence of corrosive water should be removed from the exterior of transmissions and gear boxes by flushing with clean hot or cold fresh water.

(2) Where it is possible that corrosive water has reached the interior of the transmission or gear boxes, remove plugs and/or covers and drain completely. Flush interior of part with hot or cold fresh water. Drain residual water, replace plugs and/or covers, and reapply proper lubricant.

g. *Helicopter Blades.* Except for blades with wooden or other nonmetallic constructions, treat helicopter blades the same as propellers for reciprocating engines. Clean nonmetallic blades by hand, using warm water. Dry with wiping cloths or a warm air blast. When cleaning helicopter rotor blades, insure that nonsealed hollow members, such as the spars and blade pockets, are cleaned and dried.

h. *Fuel and Oil Systems.* Contaminated fuel and oil systems should be processed as follows:

(1) Flush oil system, including lines, using water-displacing preservative.

(2) Open fuel systems. Purge cells and fuel lines. Check effectiveness of the purging with combustible gas indicator. Remove bladder and self-sealing type fuel cells and all cavity liners or pads.

(3) Use clean, fresh water to wash fuel cells. After drying, spray interior walls with oil.

(4) Chemically treat bare metal surfaces of cleaned aluminum tanks with 10–20 percent water solution of sodium dichromate.

(5) Flush fuel lines with hot water (150° F. maximum). Dry, using clean, dry, compressed air.

i. *Landing Gear.* Process salvageable components of the landing gear, wheels, and brakes as follows:

(1) Remove tires and wheels.

(2) Steam clean wheels, rinse in fresh water, and dry.

(3) Remove wheel bearings and clean, using dry cleaning solvent.

(4) Immerse bearings in methyl alcohol and dry the cleaned bearings in air blast. Do not permit bearings to rotate during air blast drying. Reapply proper lubricant.

(5) Remove brakes, steam clean, and rinse with fresh water and dry.

j. *Electrical Equipment.*

(1) Wet cell batteries. The risk involved in using wet cell batteries that have been immersed in sea water may outweigh any economic advantage and should be replaced.

(2) Because of possible flight hazards and later defects caused by progressive corrosive attack, all electrical wiring immersed in corrosive water should be replaced. If wiring is*

* merely splashed or sprayed with corrosive water, flush thoroughly with clean, fresh water and dry, using compressed air. Following compressed air drying, coat with water dispensing preservative (MIL-C-81309, Grade A).

k. ***Miscellaneous Equipment.*** The following equipment should be thoroughly washed to remove dirt, salt, and other contaminants. Dry with air blast or other means, and, if required, reapply proper lubricant:

(1) Wiring and fuselage hydraulic units.

(2) Electric landing gears.

(3) Actuators.

(4) Cables.

(5) Accumulators.

(6) Hydraulic reservoirs.

(7) Flight control.

(8) Torque tubes and bell cranks.

(9) Heating units, ducts, etc. *

255.-264. RESERVED.

essary to remove anodic films from parts to be inspected, since the dye readily penetrates such films. Special procedures for removing the excess dye should be followed.

b. *Application of Penetrant.* The penetrant is applied by brushing, spraying, or by dipping and allowed to stand for a minimum of 2 minutes. Dwell time may be extended up to 15 minutes, depending upon the temperature of part and fineness of the defect or when the surface being inspected is ground. Parts being inspected should be dry and heated to at least 70° F., but not over 130° F. Very small indications require increased penetration periods.

c. *Removal of Dye Penetrant.* Surplus penetrant is usually removed by application of a special cleaner or remover, or by washing with plain water and the part allowed to dry. Water rinse may also be used in conjunction with the remover, subject to the manufacturer's recommendations.

d. *Application of Developer.* A light and even coat of developer is applied by spraying, brushing, or dipping. When dipping, avoid excess accumulation. Penetrant which has penetrated into cracks or other openings in the surface of the material will be drawn out by the developer resulting in a bright red indication. Some idea of the size of the defect may be obtained after experience by watching the size and rate of growth of the indication.

301. ULTRASONIC FLAW DETECTION. Ultrasonic flaw detection equipment has made it possible to locate defects in all types of materials without damaging the material being inspected. Very small cracks, checks, and voids, too small to be seen by X-ray, are located by means of ultrasonic inspection. An ultrasonic test instrument requires access to only one surface of the material to be inspected, and can be used with either straight line or angle beam testing techniques. The instrument electronically generates ultrasonic vibrations and sends them in a pulsed beam through the part to be tested. Any discontinuity within the part, or the opposite end, will reflect the vibration back to the instrument, which measures the elapsed time between the initial pulse and the return of all reflections and indicates such time lapse on a cathode ray indicator or paper recorder. Ultrasonic inspection requires a skilled operator who is familiar with the equipment being used as well as the inspection method to be used for the many different parts being tested.

302.–312. RESERVED.

Section 4. IDENTIFICATION OF FABRICS AND PLASTICS

313. IDENTIFICATION OF FABRIC. Cotton fabric is often used as covering for wing, fuselage, and control surfaces of aircraft. Acceptable grades of fabric for use on civil aircraft are listed in Chapter 3. In general, the fabric can be readily identified by a continuous marking to show the manufacturer's name or trademark and specification number. This marking may be found stamped along the selvage edge. The specification number for grade "A" fabric is AMS-3806, and for the intermediate grade AMS-3804. The corresponding FAA Technical Standard Order * Numbers for these materials are TSO-C15 and TSO-C14, respectively. Increasing interest in * the use of linen and certain synthetic fabrics in lieu of cotton has been noted. Identity of such materials should always be verified by the user.

314. IDENTIFICATION OF PLASTICS. Plastics cover a broad field of organic synthetic resins and may be divided into two main classifications—thermoplastic and thermosetting plastics.

a. Thermoplastics. Thermoplastics may be softened by heat and can be dissolved in various organic solvents. Two kinds of transparent thermoplastic materials are commonly employed in windows, canopies, etc. These materials are known as acrylic plastics and cellulose acetate plastics. These two plastics may be distinguished by the absence of color, the greater transparency, and the greater stiffness of the acrylic as compared to the slight yellow tint, lower transparency, and greater flexibility of cellulose acetate.

b. Thermosetting Plastics. Thermosetting plastics do not soften appreciably under heat but may char and blister at temperatures of 204° to 260° C. (400° to 500° F.). Most of the molded products of synthetic resin composition, such as phenolic, urea-formaldehyde, and melamine-formaldehyde resins, belong to the thermosetting group.

315.-320. RESERVED.

* Section 5. CABIN INTERIOR MATERIALS, FIRE PROTECTION QUALITIES

321. REQUIREMENTS FOR FIRE PROTECTION. The cleaning, repairing, and/or replacement of cabin interior materials necessitates continuing compliance with the fire protection requirements of the FARs. A recent field survey on this matter revealed a wide variance in the procedures used for maintaining cabin interior materials with respect to the fire protection qualities of these materials.

a. Interior Materials. The methods, techniques, practices, and materials used in the cleaning, repair, and replacement of cabin materials must meet the requirements of Section 43.13 of the FARs.

b. Fire Protection. The requirements relative to fire protection qualities of cabin interior materials are specified in:

(1) Section 121.312, for aircraft operated under Parts 121, 123, and 135.

(2) Section 127.91, for helicopters used in passenger service under Part 127.

c. Source of Information. If information regarding the original or properly altered fire protection qualities of certain cabin interior materials is not available, requests for this information should be made to the aircraft manufacturers or the local FAA regional office, specifying the model aircraft, the aircraft manufacturer, the date the aircraft was manufactured or the serial number, and the FAR Part under which the aircraft is operated (i.e., Part 91, Part 121, etc.). *

322.-325. RESERVED.

cycles. The dynamometer landings will consist of 50 Test A, load-speed-time cycles and 50 Test B, energy cycles.

(a) Test A, Load-speed-time.

1. Speed cycle. Land the tire against a dynamometer flywheel rotating at a peripheral speed of S_1 m.p.h. Immediately thereafter, decrease the flywheel speed at an average deceleration rate of D ft./sec./sec. until a value of S_2 is attained. No specific rate of deceleration is required after the flywheel's peripheral speed reaches a value of S_2. Decrease the speed of the flywheel in the above manner until a roll distance of RD feet has been covered, at which time the tire is unlanded.

2. Load cycle. After landing, increase the load from zero to L_1 pounds within T_1 seconds. Linearly increase the load with time to a value of L_2 pounds within T_2 seconds after landing, or at the moment of unlanding, whichever occurs first. If it is necessary to continue the roll after T_2 seconds to complete the required roll distance (RD), maintain the load at L_2 pounds.

3. Symbol definitions. Determine the numerical values, which are used for the following symbols, from the applicable airplane load-speed-time data:

S_1 = Initial dynamometer test speed.
S_2 = Speed at which the average deceleration between S_1 and S_2 does not exceed the specified values.
D = Constant rate of deceleration between S_1 and S_2 speeds.
RD = Roll distance in feet.
L_1 = Initial tire load.
L_2 = Maximum rated static load of the tire.
T_1 = Time for applying L_1 load. A T_1 tolerance of ±1 second is acceptable.

$$T_2 = \frac{S_1 - \sqrt{S_1^2 - 2D\ (RD)}}{D}$$

T_2 is the elapsed time for applying the L_2 load. A T_2 tolerance of +10% is acceptable. When T_2 is calculated by the aforementioned formula, S_2 may be ignored and D is assumed constant throughout roll distance (RD).

4. Test load adjustment. If the test load curve results in loads at a given speed being less than those dictated by the applicable aircraft data, eliminate the condition by making adjustments in T_2, L_1, and/or T_1

(b) Test B, Energy.

1. Kinetic energy. Calculate and adjust the kinetic energy of the flywheel for the rated maximum static load of the tire. In the event that the correct number of flywheel plates cannot be used to obtain the calculated kinetic energy value or proper flywheel width, select a greater number of plates and adjust the dynamometer speed to achieve the required kinetic energy.

2. Kinetic energy computation. Compute kinetic energy as follows:

$KE = CWV^2$

Where

KE = Kinetic energy, ft.-lb.
C = 0.011
W = tire load, pounds
V = 120 m.p.h.

3. Speed cycle. Land the test tire at 90 m.p.h. and unland at 0 m.p.h. Decrease the landing speed as necessary to assure that 56% of the calculated kinetic energy is absorbed by the tire.

4. Load cycle. Upon landing, and during the entire roll test, force the tire against the flywheel at its rated static load.

(c) Taxi Test.

1. Test parameters. Conduct a minimum of three dynamometer taxi tests under the following conditions:

Speed = 35 m.p.h.
Tire Load = Maximum static rating
Roll Distance = 35,000 feet.

2. Tire temperature. Heat the test tire to a temperature of not less than 120° F. at the start of each of the three taxi test cycles. Rolling the tire on the dynamometer is acceptable in obtaining this minimum tire temperature. Make no adjustments in the tire inflation pressure to compensate for increases due to temperature rise.

(9) Alternate Dynamometer Tests.

(a) Variable Loading. An alternate dynamometer test which more realistically simulates actual airplane performance on the runway may be used in lieu of the deceleration load-speed-time schedule. An acceleration load-speed-time schedule, wherein the dynamometer flywheel is accelerated to the applicable conditions, is acceptable.

(b) Alternate Procedure for Reinforced-tread Tires. Qualification of a high-speed tire with a given ply rating and reinforced tread will automatically qualify a lesser ply rating reinforced tread tire of the same size and skid depth, provided:

1. The test conditions S_1, RD, S_2, T_1, and T_2 are no less severe than those which are applicable to the lesser ply rating tire.

2. The ratio of the test loads, L_1 to L_2 is not less than that applicable to the lesser ply rating tire. Make any necessary adjustment in this ratio by increasing L_1.

(10) Optional Dynamometer Equipment. Dynamic tests may be conducted on any dynamometer test equipment which will provide the load, speed, time, and roll distance parameters of the tire.

c. Tubes. Punctured tubes may be repaired by the use of cemented or vulcanized patches.

(1) The procedure for making such repairs is substantially identical to that used in connection with repair of automobile tires:

***(a)* Keep the size of the patch to a minimum and avoid use of an excessive number of patches,** particularly in one area, as the weight of the material may contribute to excessive wheel vibration due to the tube being out-of-balance.

***(b)* The use of vulcanized patches is recommended** because they are considered more reliable.

***(c)* Reinstalled tires should be inflated, deflated, and again inflated** to insure that the inner-tube is not pinched. A pinched tube will chafe against the walls of the carcass and a thin spot will result in the rubber. In time, the tube wall will leak at this point. The pinching generally is due to the sticking of the tube to the carcass wall during the first inflation and the failure of the carcass to properly seat against the flange.

***(d)* The tube is then confined** to a smaller space and wrinkling (pinching) of the tube results. Complete deflation followed by inflation allows the tube to properly accommodate itself to the carcass which should now seat itself tightly against the flanges.

*__333. TIRE SLIPPAGE.__ To reduce the possibility of tire and tube failure due to slippage, and to provide a means of detecting tire slippage, tires should be marked and indexed with the wheel rim. Marking should be accomplished by painting a mark 1 inch in width and 2 inches in length across the tire sidewall and wheel rim. The paint used should be of a permanent type and contrasting color, such as white, red, or orange. Preflight inspection should include a check of slippage marks for alignment. If the slippage mark is not in alignment, the aircraft should not be operated until a detailed inspection is made, the reason determined, and if necessary the condition corrected.

334. TIRE MAINTENANCE. A program of tire maintenance can minimize tire failures and increase tire service life. Overinflation wears the center of the tread excessively, and reduces a tire's resistance to bruising, strains the tires beads, reduces traction and skid resistance. Underinflation increases deflection and may cause breakdown of the tire sidewalls. The manufacturer's recommendations should be followed to obtain maximum tire service life.

345.–349. RESERVED. *

Chapter 10. HYDRAULIC AND PNEUMATIC SYSTEMS

Section 1. HYDRAULIC SYSTEMS

392. GENERAL. Maintain, service, and adjust airplane hydraulic systems in accordance with manufacturers' maintenance manuals and pertinent component maintenance manuals. Certain general principles of maintenance and repair which apply are outlined below.

393. HYDRAULIC LINES AND FITTINGS. Carefully inspect all lines and fittings at regular intervals to insure airworthiness. Investigate any evidence of fluid loss or leaks. Check metal lines for leaks, loose anchorages, scratches, kinks, or other damage. Inspect fittings and connections for leakage, looseness, cracks, burrs, or other damage. Replace or repair defective elements.

a. Replacement of Metal Lines. When inspection shows a line to be damaged or defective, replace the entire line or if the damaged section is localized, a repair section may be inserted. In replacing lines, always use tubing of the same size and material as the original line. Use the old tubing as a template in bending the new line, unless it is too greatly damaged, in which case a template can be made from soft iron wire. Soft aluminum tubing (1100, 3003, or 5052) under ¼-inch outside diameter may be bent by hand. For all other tubing use an acceptable hand or power tube bending tool. Bend tubing carefully to avoid excessive flattening, kinking, or wrinkling. Minimum bend radii values are shown in figure 10.1. A small amount of flattening in bends is acceptable but do not exceed an amount such that the small diameter of the flattened portion is less than 75 percent of the original outside diameter. When installing the replacement tubing, line it up correctly with the mating part so that it is not forced into line by means of the coupling nuts.

b. Tube Connections. Many tubing connections are made using flared tube ends, and standard connection fittings: AN–818 nut and AN–819 sleeve.

Tube O.D. (inches)	Wrench torque range for tightening tube nuts (inch pounds)		Minimum bend radii measured at inside of bend. Dimension in inches. *	*
	Alum. alloy 1100–H14, 5052–O	Steel	Alum. alloy 1100–H14, 5052–O	Steel
⅛		30–70	⅜	
3/16	40–65	50–90	7/16	21/32
¼	60–80	70–120	9/16	⅞
5/16	75–125	90–150	¾	1⅛
⅜	150–250	155–250	15/16	1 5/16
½	200–350	300–400	1¼	1¾
⅝	300–500	430–575	1½	2 3/16
¾	500–700	550–750	1¾	2⅝
1	600–900		3	3½
1¼	600–900		3¾	4⅜
1½			5	5¼
1¾			7	6⅛
2			8	7

FIGURE 10.1.—Tube data.

In forming flares, cut the tube ends square, file smooth, remove all burrs and sharp edges, and thoroughly clean. The tubing is then flared using the correct 37° aviation flare forming tool for the size of tubing and type of fitting. A double flare is used on soft aluminum tubing ⅜-inch outside diameter and under, and a single flare on all other tubing. In making the connections, use hydraulic fluid as a lubricant and then tighten. Overtightening will damage the tube or fitting, which may cause a failure; undertightening may cause leakage which could result in a system failure.

CAUTION

Mistaken use of 45° automotive flare forming tools will result in improper tubing flare shape and angle causing misfit, stress and strain, and probable system failure.

c. Repair of Metal Tube Lines. Minor dents and scratches in tubing may be repaired. Scratches or nicks no deeper than 10 percent of the wall thickness in aluminum alloy tubing, that are not in the heel of a bend, may be repaired by burnishing with hand tools. Replace lines with severe die marks, seams, or splits in the tube. Any crack or deformity in a flare is also unacceptable and cause for rejection. A dent less than 20 percent of the tube diameter is not objectionable unless it is in the heel of a bend. Dents may be removed by drawing a bullet of proper size through the tube by means of a length of cable. A severely damaged line should be replaced; however, it may be repaired by cutting out the damaged section and inserting a tube section of the same size and material. Flare both ends of the undamaged and replacement tube sections and make the connection by using standard unions, sleeves, and tube nuts. If the damaged portion is short enough, omit the insert tube and repair by using one union and two sets of connection fittings.

d. Replacement of Flexible Lines. When replacement of a flexible line is necessary, use the same type, size, and length of hose as the line to be replaced. If the replacement of a hose with swaged-end-type fittings is necessary, obtain a new hose assembly of the correct size and composition. Certain synthetic oils require a specially compounded synthetic rubber hose which is compatible. Refer to the aircraft manufacturer's service information for correct part number for replacement hose. If the fittings on each end are of the collet type or sleeve type, a replacement may be fabricated as shown in figure 10.2. Typical aircraft hose specifications and their uses are shown in figure 10.3. Install hose assemblies without twisting. (See figure 10.4.) Never stretch a hose tight between two fittings as this will result in overstressing and eventual failure. The length of hose should be sufficient to provide about 5 percent to 8 percent slack. Avoid tight bends in flex lines as they may result in failure. Never exceed the minimum bend radii as indicated in figure 10.5.

Teflon hose is used in many aircraft systems because of its superior qualities for certain applications. Teflon is compounded from tetrafluoroethylene resin which is unaffected by fluids normally used in aircraft. It has an operating range of −65° F. to 450° F. For these reasons, Teflon is used in hydraulic and engine lubricating systems where temperatures and pressures preclude the use of rubber hose. Although Teflon hose has excellent performance qualities, it also has peculiar characteristics that require extra care in handling. It tends to assume a permanent set when exposed to high pressure or temperature. Do not attempt to straighten a hose that has been in service. Any excessive bending or twisting will cause kinking or weakening of the tubing wall. Replace any hose that shows signs of leakage, abrasion, or kinking. Any hose suspected of kinking may be checked with a steel ball of proper size. Figure 10.6 shows hose and ball sizes. The ball will not pass through if the hose is distorted beyond limits.

If the hose fittings are of the reusable type, a replacement hose may be fabricated as described in figure 10.2. When a hose assembly is removed the ends should be tied as shown in figure 10.7, so that its preformed shape will be maintained. Refer to figure 10.8 for minimum bend radii of Teflon hose.

All flexible hose installations should be supported at least every 24 inches. Closer supports are preferred. They should be carefully routed and securely clamped to avoid abrasion, kinking, or excessive flexing. Excessive flexing may cause weakening of the hose or loosening at the fittings.

e. O-Ring Seals. A thorough understanding of O-ring seal applications is necessary to determine when replacement must be made. The simplest application is where the O-ring merely serves as a gasket when it is compressed within a recessed area by applying pressure with a packing nut or screw cap. Leakage is not normally acceptable in this type of installation. In other installations the O-ring seals depend primarily upon their resiliency to accomplish their sealing action. When moving parts are involved, minor seepage may be normal and acceptable. A moist surface found on moving parts of hydraulic units is an indication the seal is being properly lubricated. In pneumatic systems, seal lubrication is provided by the installation of a grease-impreg-

☆ U.S. GOVERNMENT PRINTING OFFICE: 1975-631-513/928 3-1

CHANGE

AC NO: 43.13-1A CHG 1

DATE: 5/12/75

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: ACCEPTABLE METHODS, TECHNIQUES, AND PRACTICES—AIRCRAFT INSPECTION AND REPAIR

1. PURPOSE.

This change transmits new and revised material for Advisory Circular 43.13-1A.

2. PRINCIPAL CHANGES.

a. Corrections have been made to paragraph 313 and Figure 10.1.

b. Chapter 2, Section 3, has been revised to add Selective Plating in aircraft maintenance. Chapter 4, Section 6 has been revised to add handling and care of aircraft recovered from water immersion.

c. A new Section 5, Cabin Interior Materials—Fire Protection Qualities, has been added to Chapter 7.

d. New information on tire slippage and maintenance has been added to Section 1 of Chapter 8.

3. HOW TO GET THIS PUBLICATION.

Copies of this change to AC 43.13-1A may be obtained by ordering from:

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For up-to-date information on how to order, and the price of this publication, check with the closest FAA office or obtain the latest copy of Advisory Circular 00-2, Advisory Circular Checklist and Status of the Federal Aviation Regulations. This checklist may be obtained without charge by requesting from:

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Initiated by: AFS-830

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i thru iv	1972	i	1972
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73 and 74	1972	73 thru 73-3	1975
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127 and 128	1972	127	1972
		128 thru 128-3	1975
139 and 140	1972	139	1972
		140 thru 140-1	1975
149 and 150	1972	149	1972
		150	1975
165 and 166	1972	165	1975
		166	1972

TABLE OF CONTENTS

Chapter 1. AIRCRAFT WOOD STRUCTURES

Section 1. MATERIALS AND PRACTICES

Section 2. FINISHING WOOD STRUCTURES

Chapter 2. AIRCRAFT METAL STRUCTURES

Section 1. REFERENCES AND PRECAUTIONARY MEASURES

Section 2. WELDING

TABLE OF CONTENTS—Continued

TABLE OF CONTENTS—Continued

TABLE OF CONTENTS—Continued

Chapter 7. IDENTIFICATION, TESTING, AND INSPECTION OF MATERIALS

Paragraph *Page*

Section 1. IDENTIFICATION OF METALS

Section 2. TESTING OF METALS

Section 3. NONDESTRUCTIVE TESTING

Section 4. IDENTIFICATION OF FABRICS AND PLASTICS

* Section 5. CABIN INTERIOR MATERIALS, FIRE PROTECTION QUALITIES

Chapter 8. AIRCRAFT EQUIPMENT

Section 1. LANDING GEAR EQUIPMENT

Section 2. LIFE PRESERVERS AND LIFERAFTS

TABLE OF CONTENTS—Continued

Paragraph *Page*

Section 3. MISCELLANEOUS EQUIPMENT

TABLE OF CONTENTS—Continued

Chapter 9. WINDSHIELDS, ENCLOSURES, AND EXITS

Section 1. PLASTIC WINDSHIELDS AND ENCLOSURES

Chapter 10. HYDRAULIC AND PNEUMATIC SYSTEMS

Section 1. HYDRAULIC SYSTEMS

Chapter 11. ELECTRICAL SYSTEMS

Section 1. CARE OF ELECTRICAL SYSTEMS

Section 2. EQUIPMENT INSTALLATION

Section 3. ELECTRIC WIRE

TABLE OF CONTENTS—Continued

Section 4. WIRE MARKING

Section 5. CONNECTORS

Section 6. CONDUITS

Section 7. ROUTING, TYING, LACING, AND CLAMPING

Section 8. STORAGE BATTERIES

Chapter 12. PROPELLERS, ROTORS, AND ASSOCIATED EQUIPMENT

Section 1. INSPECTION OF PROPELLERS

TABLE OF CONTENTS—Continued

Section 2. REPAIR OF WOOD AND COMPOSITION PROPELLERS

Section 3. REPAIR OF METAL PROPELLERS

Section 4. OVERHAUL OF PROPELLERS

Section 5. ASSEMBLY OF PROPELLER TO ENGINE

Section 6. PRECAUTIONS

Section 7. MAINTENANCE OF ROTOR BLADES

Chapter 13. WEIGHT AND BALANCE

TABLE OF CONTENTS—Continued

Chapter 14. ENGINES AND FUEL SYSTEMS

Section 1. ENGINES

Section 2. FUEL SYSTEMS

Section 3. EXHAUST SYSTEMS

Chapter 15. RADIO AND ELECTRONIC SYSTEMS

Section 1. MAINTENANCE OF RADIO AND ELECTRONIC SYSTEMS

TABLE OF CONTENTS—Continued

TABLE OF CONTENTS—Continued

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS—Continued

LIST OF ILLUSTRATIONS—Continued

LIST OF ILLUSTRATIONS—Continued

LIST OF ILLUSTRATIONS—Continued

Chapter 1. AIRCRAFT WOOD STRUCTURES

Section 1. MATERIALS AND PRACTICES

1. MATERIALS. Three forms of wood are commonly used in aircraft: solid wood, plywood, and laminated wood. Although several kinds of modified wood are sometimes used for special purposes, these three forms constitute the bulk of all wood aircraft construction materials.

a. Quality of Wood. All wood and plywood used in the repair of aircraft structures should be of aircraft quality. Figure 1.2 lists the permissible variations in characteristics and properties of aircraft wood.

b. Species Substitution. The species used to repair a part should be the same as that of the original whenever possible; however, permissible substitutes are given in figure 1.2.

c. Effects of Shrinkage. When the moisture content of wood is lowered, its dimensions decrease. The dimensional change is greatest in a tangential direction (across the fibers and parallel to the growth rings), somewhat less in a radial direction (across the fibers and perpendicular to the growth rings), and is negligible in a longitudinal direction (parallel to the fibers). These dimensional changes can have several detrimental effects upon a wood structure, such as loosening of fittings and wire bracing and checking or splitting of wood members.

A few suggestions for minimizing these shrinkage effects are:

(1) Use bushings that are slightly short so that when the wood member shrinks the bushings do not protrude and the fittings may be tightened firmly against the member.

(2) Gradually drop off plywood face plates either by feathering or by shaping as shown in figure 1.1.

2. REPLACEMENT OF DRAINHOLES AND SKIN STIFFENERS. Whenever repairs are made that require replacing a portion that includes drainholes, skin stiffeners, or any other items, the repaired portion must be provided with similar drainholes, skin stiffeners, or items of the same dimensions in the same location. Reinforcing, under skin repairs, that interferes with the flow of water from some source, such as inspection holes, is to be provided with drainholes at the lowest points.

3. CONTROL SURFACE FLUTTER PRECAUTIONS. When repairing control surfaces, especially on high-performance airplanes, care must be exer-

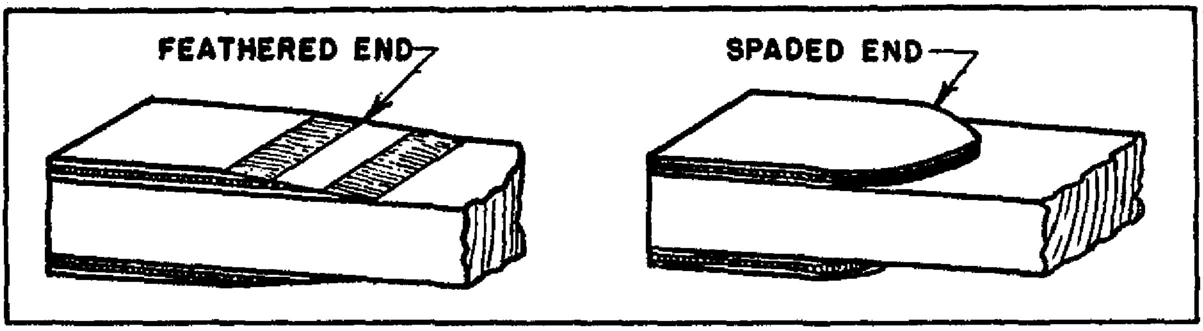


Figure 1.1.—Tapering of face plates.

FIGURE 1.2.—Selection and properties of aircraft wood.

Species of wood	Strength properties as compared to spruce	Maximum permissible grain deviation (slope of grain)	Remarks
1	2	3	4
Spruce (Picea) Sitka (P. Sitchensis) Red (P. Rubra) White (P. Glauca).	100%	1:15	Excellent for all uses. Considered as standard for this table.
Douglas Fir (Pseudotsuga Taxifolia).	Exceeds spruce ------	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Difficult to work with hand tools. Some tendency to split and splinter during fabrication and considerable more care in manufacture is necessary. Large solid pieces should be avoided due to inspection difficulties. Gluing satisfactory.
Noble Fir (Abies Nobilies) ------	Slightly exceeds spruce except 8 percent deficient in shear.	1:15	Satisfactory characteristics with respect to workability, warping, and splitting. May be used as direct substitute for spruce in same sizes providing shear does not become critical. Hardness somewhat less than spruce. Gluing satisfactory.
Western Hemlock (Tsuga Heterophylla).	Slightly exceeds spruce	1:15	Less uniform in texture than spruce. May be used as direct substitute for spruce. Upland growth superior to lowland growth. Gluing satisfactory.
Pine, Northern White (Pinus Strobus).	Properties between 85 percent and 96 percent those of spruce.	1:15	Excellent working qualities and uniform in properties but somewhat low in hardness and shock-resisting capacity. Cannot be used as substitute for spruce without increase in sizes to compensate for lesser strength. Gluing satisfactory.
White Cedar, Port Oxford (Charaecyparis Lawsoniana).	Exceeds spruce ------	1:15	May be used as substitute for spruce in same sizes or in slightly reduced sizes providing reductions are substantiated. Easy to work with hand tools. Gluing difficult but satisfactory joints can be obtained if suitable precautions are taken.
Poplar, Yellow (Liriodendrow Tulipifera).	Slightly less than spruce except in compression (crushing) and shear.	1:15	Excellent working qualities. Should not be used as a direct substitute for spruce without carefully accounting for slightly reduced strength properties. Somewhat low in shock-resisting capacity. Gluing satisfactory.

(See notes following table.)

Notes for figure 1.2.

1. *Defects Permitted.*

a. *Cross grain.* Spiral grain, diagonal grain, or a combination of the two is acceptable providing the grain does not diverge from the longitudinal axis of the material more than specified in column 3. A check of all four faces of the board is necessary to determine the amount of divergence. The direction of free-flowing ink will frequently assist in determining grain direction.

b. *Wavy, curly, and interlocked grain.* Acceptable, if local irregularities do not exceed limitations specified for spiral and diagonal grain.

c. *Hard knots.* Sound hard knots up to ⅜-inch in maximum diameter are acceptable providing: (1) they are not in projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of flanges of box beams (except in lowly stressed portions); (2) they do not cause grain divergence at the edges of the board or in the flanges of a beam more than specified in column 3; and (3) they are in the center third of the beam and are not closer than 20 inches to another knot or other defect (pertains to ⅜-inch knots—smaller knots may be proportionately closer). Knots greater than ¼-inch must be used with caution.

d. *Pin knot clusters.* Small clusters are acceptable providing they produce only a small effect on grain direction.

e. *Pitch pockets.* Acceptable, in center portion of a beam providing they are at least 14 inches apart when they lie in the same growth ring and do not exceed 1½ inch length by ⅛-inch width by ⅛-inch depth and providing they are not along the projecting portions of I-beams, along the edges of rectangular or beveled unrouted beams, or along the edges of the flanges of box beams.

f. *Mineral streaks.* Acceptable, providing careful inspection fails to reveal any decay.

2. *Defects Not Permitted.*

a. *Cross grain.* Not acceptable, unless within limitations noted in 1a.

b. *Wavy, curly, and interlocked grain.* Not acceptable, unless within limitations noted in 1b.

c. *Hard knots.* Not acceptable, unless within limitations noted in 1c.

d. *Pin knot clusters.* Not acceptable, if they produce large effect on grain direction.

e. *Spike knots.* These are knots running completely through the depth of a beam perpendicular to the annual rings and appear most frequently in quartersawed lumber. Reject wood containing this defect.

f. *Pitch pockets.* Not acceptable, unless within limitations noted in 1e.

g. *Mineral streaks.* Not acceptable, if accompanied by decay (see 1f).

h. *Checks, shakes, and splits.* Checks are longitudinal cracks extending, in general, across the annual rings. Shakes are longitudinal cracks usually between two annual rings. Splits are longitudinal cracks induced by artificially induced stress. Reject wood containing these defects.

i. *Compression wood.* This defect is very detrimental to strength and is difficult to recognize readily. It is characterized by high specific gravity; has the appearance of an excessive growth of summer wood; and in most species shows but little contrast in color between spring wood and summer wood. In doubtful cases reject the material, or subject samples to a toughness machine test to establish the quality of the wood. Reject all material containing compression wood.

j. *Compression failures.* This defect is caused from the wood being overstressed in compression due to natural forces during the growth of the tree, felling trees on rough or irregular ground, or rough handling of logs or lumber. Compression failures are characterized by a buckling of the fibers that appear as streaks on the surface of the piece substantially at right angles to the grain, and vary from pronounced failures to very fine hairlines that require close inspection to detect. Reject wood containing obvious failures. In doubtful cases reject the wood, or make a further inspection in the form of microscopic examination or toughness test, the latter means being the more reliable.

k. *Decay.* Examine all stains and discolorations carefully to determine whether or not they are harmless, or in a stage of preliminary or advanced decay. All pieces must be free from rot, dote, red heart, purple heart, and all other forms of decay.

cised that the repairs do not involve the addition of weight aft of the hinge line. Such a procedure may adversely disturb the dynamic and static balance of the surface to a degree which would induce flutter. As a general rule, it will be necessary to repair control surfaces in such a manner that the structure is identical to the original so that the weight distribution and resulting mass balance are not affected in any way.

4. GLUING PRECAUTIONS. Satisfactory glue joints in aircraft will develop the full strength of wood under all conditions of stress. To produce this result, the gluing operation must be carefully controlled so as to obtain a continuous, thin, uniform film of solid glue in the joint with adequate adhesion to both surfaces of the wood. Some of the more important conditions involve:

a. Properly prepared wood surfaces.

b. Glue of good quality, properly prepared.

c. Good gluing technique.

5. PREPARATION OF WOOD SURFACES FOR GLUING. It is recommended that no more than 8 hours be permitted to elapse between final surfacing and gluing. The gluing surfaces should be machined smooth and true with planers, jointers, or special miter saws. Planer marks, chipped or loosened grain, and other surface irregularities will not be permitted. Sandpaper must never be used to smooth softwood surfaces that are to be glued. Sawed surfaces must approach well-planed surfaces in uniformity, smoothness, and freedom from crushed fibers.

a. *Tooth-planing,* or other means of roughening smooth well-planed surfaces of normal wood before gluing is not recommended. Such treatment of well-planed wood surfaces may result in local irregularities and objectionable rounding of edges. While sanding of planed surfaces is not recommended for softwoods, sanding is a valuable aid in improving the gluing characteristics of some hard plywood surfaces, wood that has been compressed through exposure to high pressure and temperatures, resin-impregnated wood (impreg and compreg), and laminated paper plastic (papreg).

b. *Wood surfaces for gluing* should be free from oil, wax, varnish, shellac, lacquer, enamel, dope, sealers, paint, dust, dirt, oil, glue, crayon marks, and other extraneous materials.

c. *Wetting tests* are useful as a means of detecting the presence of wax. Drops of water placed on the surface of wax-coated wood do not spread or wet the wood. At present, preliminary gluing tests appear to be the only positive means of actually determining the gluing characteristics of plywood surfaces.

6. GLUES. Glues used in aircraft repair fall into two general groups: casein glues and resin glues. Any glue that meets the performance requirements of applicable United States military specifications or has previously been accepted by the FAA is satisfactory for use in certificated civil aircraft. In all cases, glues are to be used strictly in accordance with the glue manufacturer's recommendations.

a. *Casein Glues.* Casein glues have been widely used in wood aircraft repair work. The forms, characteristics, and properties of water-resistant casein glues have remained substantially the same for many years, except for the addition of preservatives. Casein glues for use in aircraft should contain suitable preservatives such as the chlorinated phenols and their sodium salts to increase their resistance to organic deterioration under high-humidity exposures. Most casein glues are sold in powder form ready to be mixed with water at ordinary room temperatures.

b. *Synthetic Resin Glues.* Synthetic resin glues for wood are outstanding in that they retain their strength and durability under moist conditions and after exposure to water. The best known and most commonly used synthetic resin glues are the phenol-formaldehyde, resorcinol-formaldehyde, and urea-formaldehyde types. The resorcinol-formaldehyde type glue is recommended for wood aircraft applications. Materials, such as walnut-shell flour, are often added by the glue manufacturer to the resin glues to give better working characteristics and joint-forming properties. The suitable curing temperatures for both urea-formaldehyde and resorcinol glues are from 70° F. up. At the 70° F. minimum temperature it may take as long as 1 week for the glueline in a spar splice to cure to full strength. Thinner pieces of wood and/or higher curing temperatures shorten curing time considerably. The strength of a joint cannot be depended upon if assembled and cured at temperatures below 70° F.

7. MIXING OF RESIN GLUES. Liquid resin glues may come ready for use or in a form which requires only the addition of a hardener. In all cases, the mixing, glue consistency, assembly time, etc., should comply with the glue manufacturers' recommendations and instructions. Cold-setting synthetic-resin glue, when prepared for use, is limited in working life, and care should be taken to discard the glue and clean the equipment before the end of the working life period. In very warm weather it may be found advisable to keep the gluepot in a bath of cool water, approximately 70° F., to prolong the working life of the mixture.

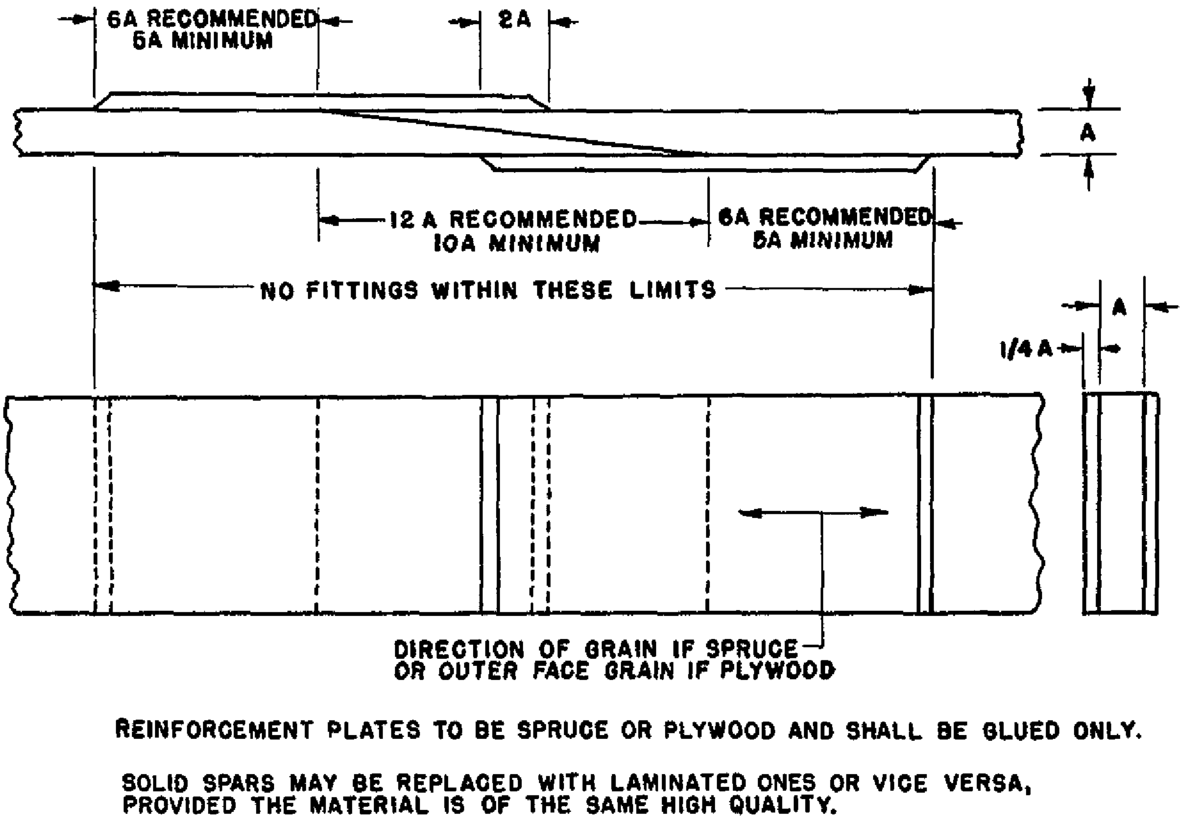


FIGURE 1.4.—Method of splicing solid or laminated rectangular spars.

but not necessarily, at a bolthole or cutout and spread in each direction until, in most cases, they extend a short distance beyond the ends of the plates where the resistance to spar shrinkage disappears. Other factors which have been found conducive to the formation of cracks, due to spar shrinkage in the region of plywood plates, are poor protective finishes, large cutouts, and metal fittings which utilize two lines of large diameter bolts.

The presence of cracks does not necessarily mean that the spar must be discarded. If the crack is not too long or too close to either edge and can be reinforced properly, it will probably be more economical and satisfactory to effect a repair than to install a new spar or section. However, a generally acceptable procedure suitable for all airplane models cannot be described here. It is recommended the manufacturer or the Federal Aviation Administration be contacted for specific instructions before making repairs not in accordance with the manufacturer's approved instructions or the recommendations of this advisory circular, because of the possibility of strength deficiencies.

16. ELONGATED HOLES IN SPARS. In cases of elongated boltholes in a spar or cracks in the vicinity of boltholes, splice in a new section of spar, or replace the spar entirely, unless the method of repair is specifically approved by a representative of the FAA. In many cases, it has been found advantageous to laminate the new section of the spar (using aircraft plywood for the outer faces), particularly if the spar roots are being replaced.

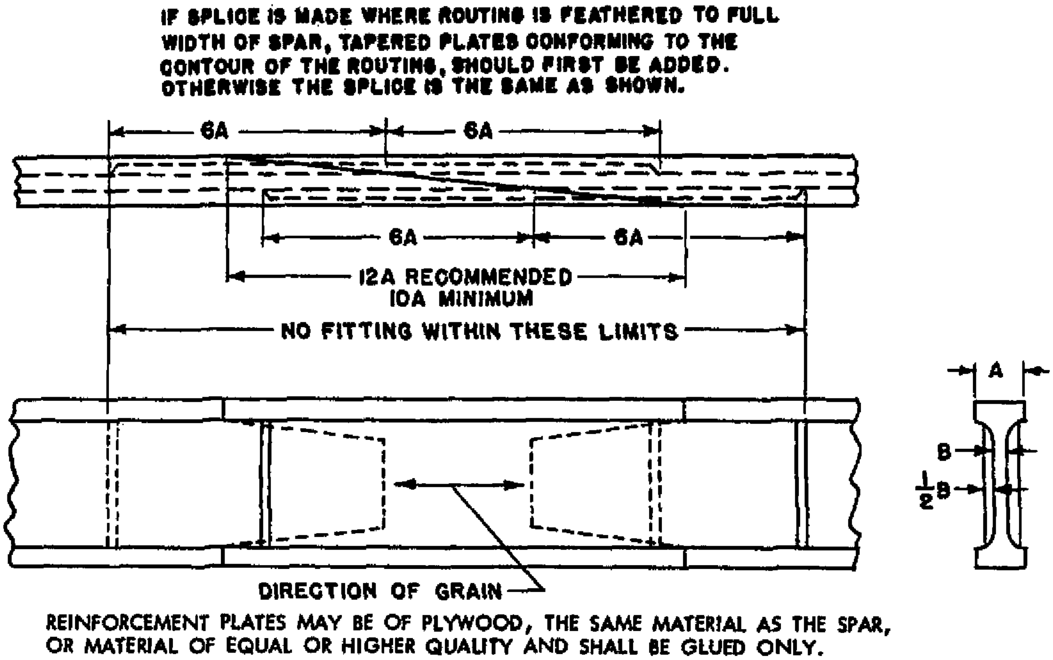


FIGURE 1.5.—Method of splicing solid "I" spars.

17. RIB REPAIRS. Make replacement ribs from a manufacturer's approved drawing, or from a drawing made by the repair agency, and certified by the manufacturer as correct. The original rib may be used as a pattern in making the new rib if it is not too seriously damaged to permit comparison. Wood ribs should not be attached to wood spars by nails driven through the rib capstrips, as this weakens the rib materially. The attachment should be by means of glue with cement-coated, barbed, or spiraled nails driven through the vertical rib members on each side of the spar. The drawing or pattern should be retained by the repair agency for use by the FAA inspector when making his inspection. (Acceptable methods of repairing damaged ribs are shown in figure 1.10.)

a. Compression Ribs. Acceptable methods of repairing damaged compression ribs are shown in figure 1.11. (A) illustrates the repair of a compression rib of the "I" section type; i.e., wide, shallow capstrips, a center plywood web with a rectangular compression member on each side of the web. The rib is assumed to be cracked through capstrips, web member, and compression member. Cut the compression member as shown in (D), remove and replace the shortest section, adding the reinforcement blocks as also shown in figure 1.11(D). Cut and replace the aft portion of the capstrips and reinforce as shown in figure 1.10 except that the reinforcement blocks are split in the vertical direction to straddle the center web. The plywood sideplates, as indicated in figure 1.11(A), are glued on. These plates are added to reinforce the damaged web. (B) illustrates a compression rib of the type that is basically a standard rib with rectangular compression members added to one side and plywood web to the other side. The method used in this repair is essentially the same as in (A) except that the plywood reinforcement plate shown in solid black in section B-B is continued the full distance between spars. (C) illustrates a compression rib of the "I" type with a rectangular vertical member each side of the web. Th

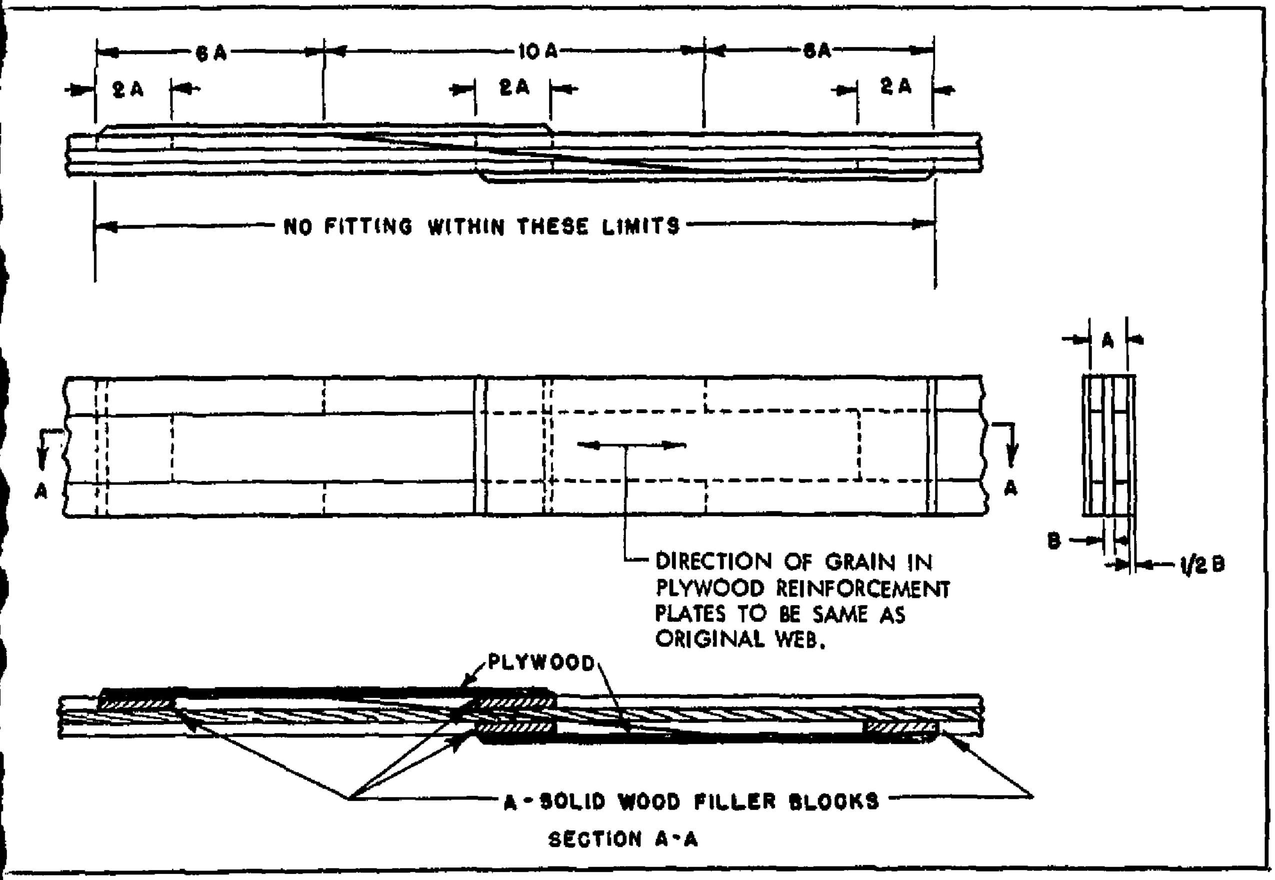


FIGURE 1.6.—Repairs to built-up "I" spar.

method of repair is essentially the same as in (A) except the plywood reinforcement plates on each side shown in solid black in section C–C are continued, as in (C), the full distance between spars.

18. PLYWOOD SKIN REPAIR. Make extensive repairs to damaged stressed skin plywood structures in accordance with specific recommendations from the manufacturer. It is recommended that repairs be made by replacing the entire panel from one structural member to the next, if damage is very extensive. When damaged plywood skin is repaired, carefully inspect the adjacent internal structure for possible hidden damage. Repair any defective frame members prior to making skin repairs.

a. Types of Patches. Four types of patches—the surface or overlay patch, the splayed patch, the plug patch, and the scarf patch—are acceptable for repairing plywood skins. Surface patches should not be used on skins over 1/8 inch thick. Splayed patches should not be used on skins over 1/10 inch thick. There are no skin thickness limitations for the use of scarf patches and plug patches.

b. Determination of Single or Double Curvature. Much of the outside surface of plywood aircraft is curved. On such areas, plywood used for repairs to the skin must be similarly curved. Curved skins are either of single curvature or of double (compound) curvature. A simple test to determine which type of curvature exists may be made by laying a sheet of heavy paper on the surface in question. If the sheet can be made to fit the surface without wrinkling, the surface is either flat or has single curvature. If, however, the sheet cannot be made to fit the surface without wrinkling, the surface is of double curvature.

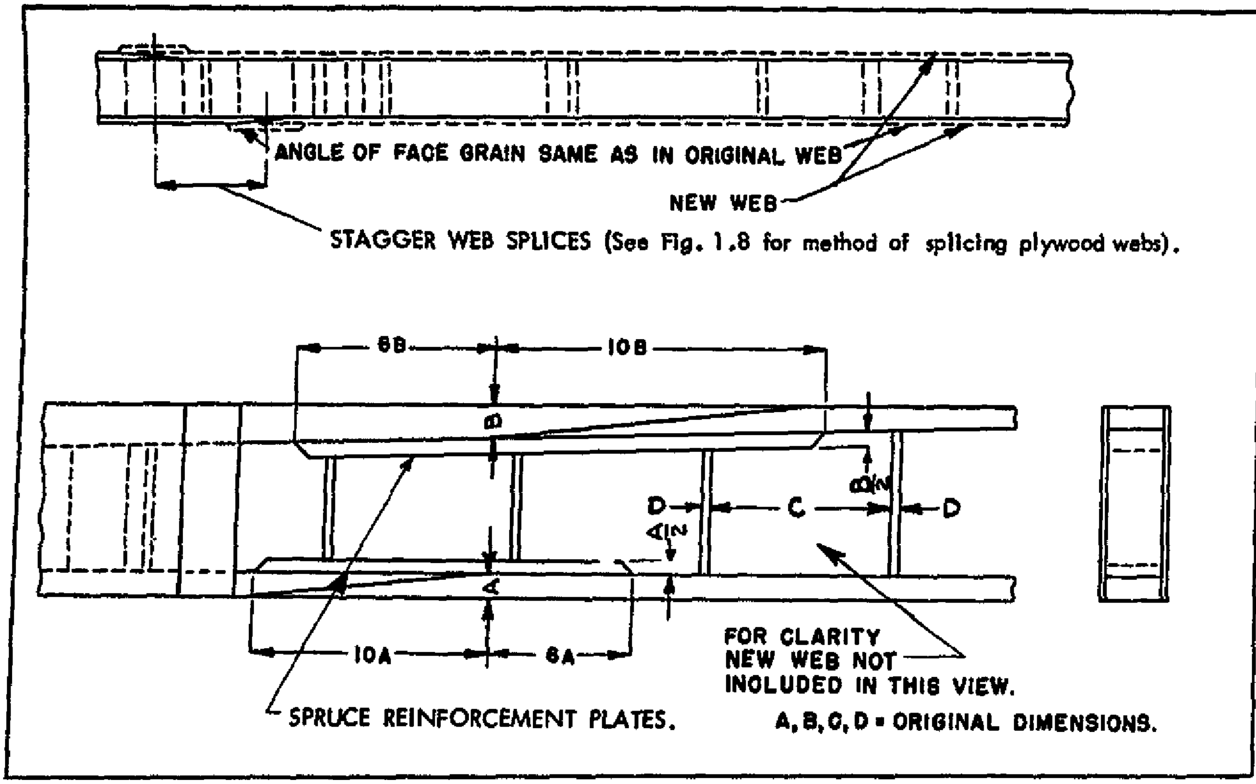


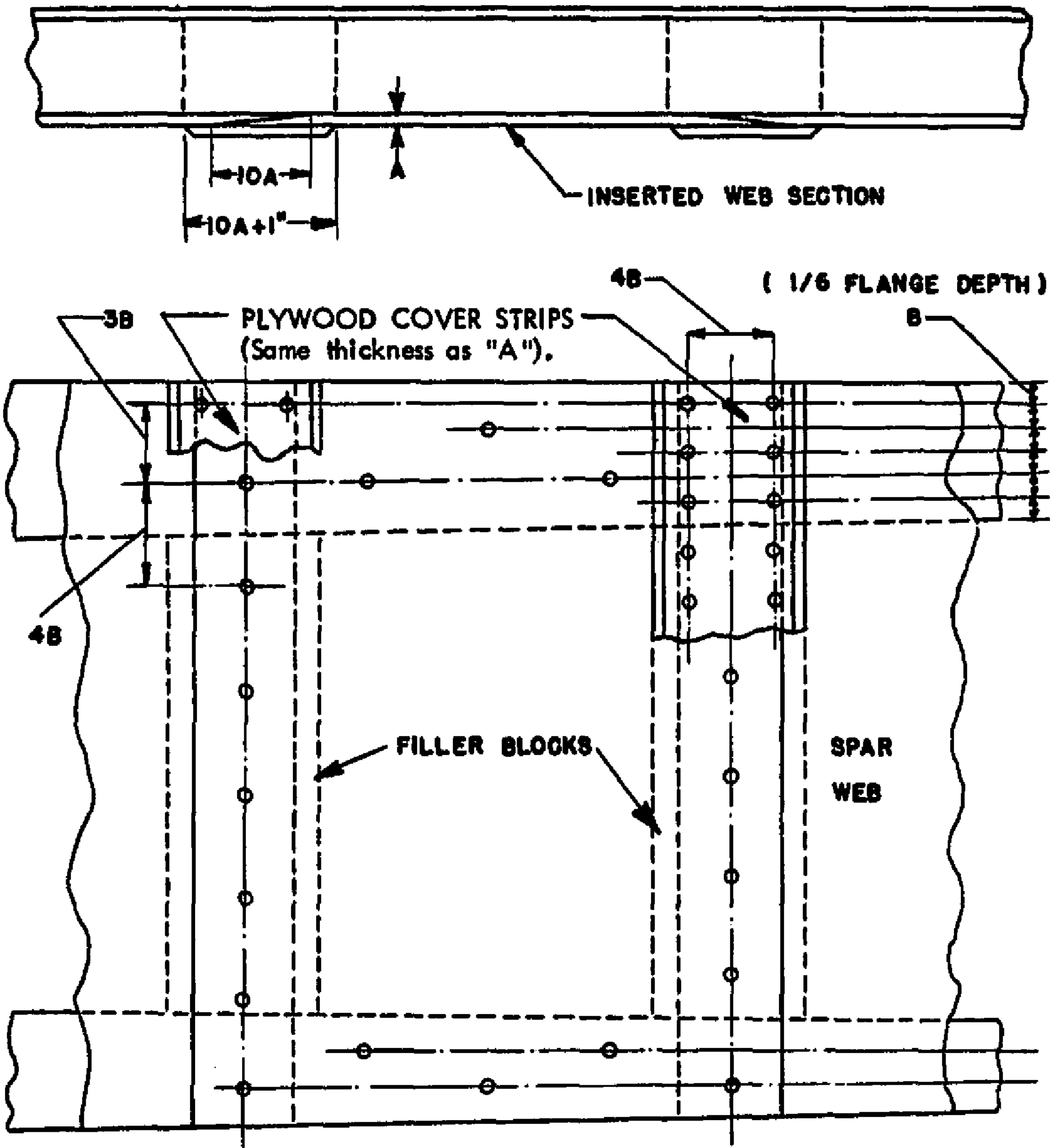
FIGURE 1.7.—Method of splicing box-spar flanges (plate method).

19. REPAIRS TO SINGLE CURVATURE PLYWOOD SKIN. Repairs to skins of single curvature may usually be formed from flat plywood, either by bending it dry or after soaking it in hot water. The degree of curvature to which a piece of plywood can be bent will depend upon the direction of the grain and the thickness. Figure 1.12 is presented as a guide in determining which process of bending should be used for the curvature being considered. Plywood, after softening, may be bent on a cold ventilated form, or it may be bent over the leading edge near the part being patched if space permits. In either method it should be allowed to dry completely on the form. When bending plywood over a leading edge, drying may be hastened by laying a piece of coarse burlap over the leading edge before using it as a bending form.

A fan to circulate the air over the bent piece will speed the drying. In bending pieces of small radii, or to speed up the bending of a large number of parts of the same curvature, it may be necessary to use a heated bending form. The surface temperature of this form may be as high as 149° C. (300° F.), if necessary, without danger of damage to the plywood. The plywood should be left on the form, however, only long enough to dry to room conditions.

20. REPAIRS TO DOUBLE CURVATURE PLYWOOD SKIN. The molded plywood necessary for a repair to a damaged plywood skin of double curvature cannot be made from flat plywood unless the area to be repaired is very small, or is of exceedingly slight double curvature; therefore, molded plywood of the proper curvature must be on hand before the repair can be made. If molded plywood of the proper curvature is available, the repair may be made following the recommended procedures.

21. SPLAYED PATCH. Small holes with largest dimensions not over 15 times the skin thickness in skins not more than 1/10 inch in thickness



1. AFTER INSERTED WEB HAS BEEN GLUED AND NAILED IN PLACE, GLUE AND NAIL COVER STRIP OVER ENTIRE LENGTH OF SPLICE JOINTS.

2. SECTIONAL SHAPE OF FILLER BLOCKS MUST CONFORM EXACTLY TO TAPER OF SPAR. THEY MUST NOT BE TOO TIGHTLY FITTED OR WEDGING ACTION WILL LOOSEN EXISTING GLUE JOINTS OF WEBS TO FLANGES. IF TOO LOOSELY FITTED, CRUSHING OF WEB WILL OCCUR WHEN CLAMPING.

3. DIRECTION OF FACE GRAIN OF NEW PLYWOOD WEB AND COVER STRIPS TO BE SAME AS ORIGINAL WEB.

FIGURE 1.8.—Method of splicing box-spar webs.

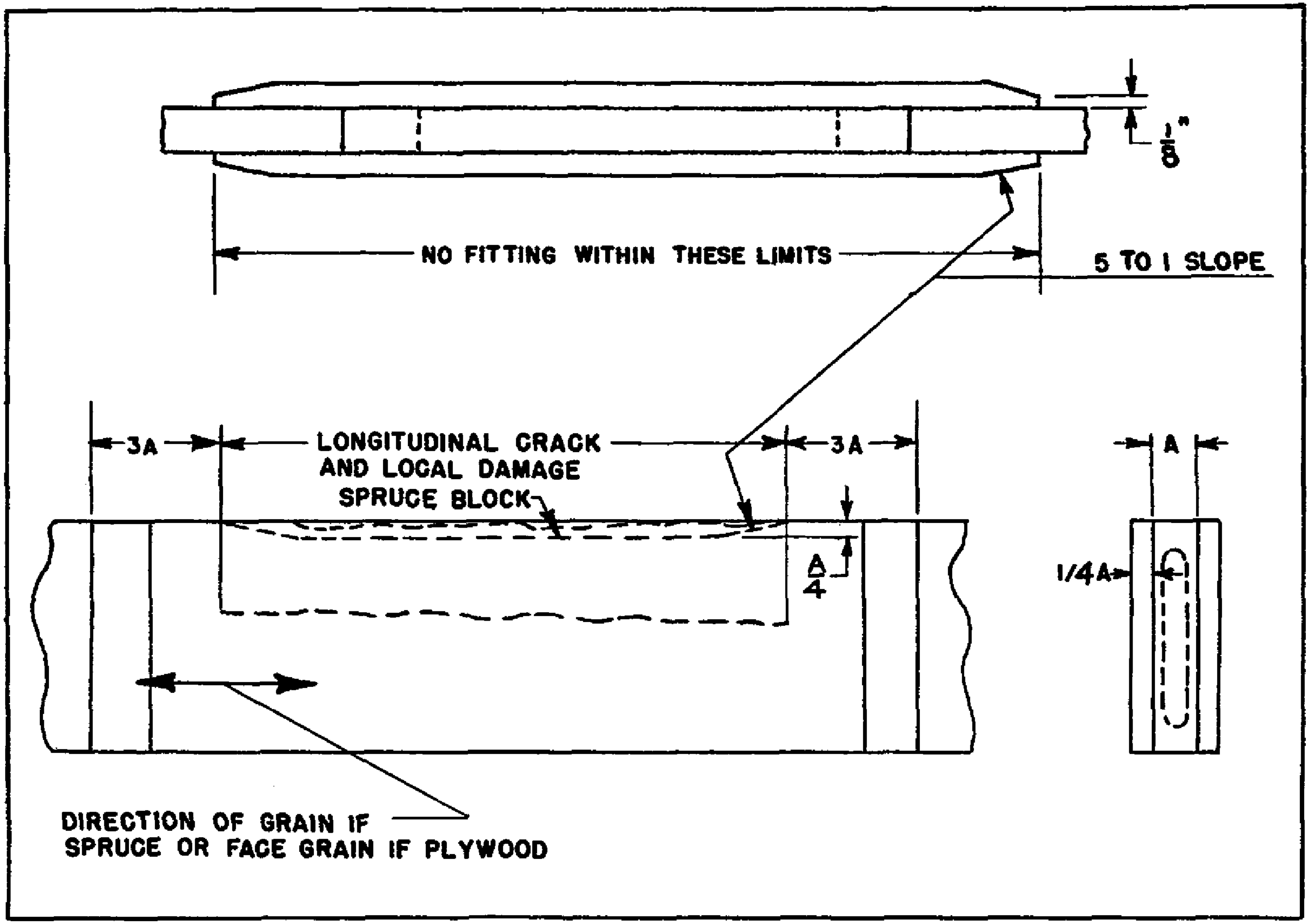


FIGURE 1.9.—Method of reinforcing a longitudinal crack and/or local damage in a solid or internally routed spar.

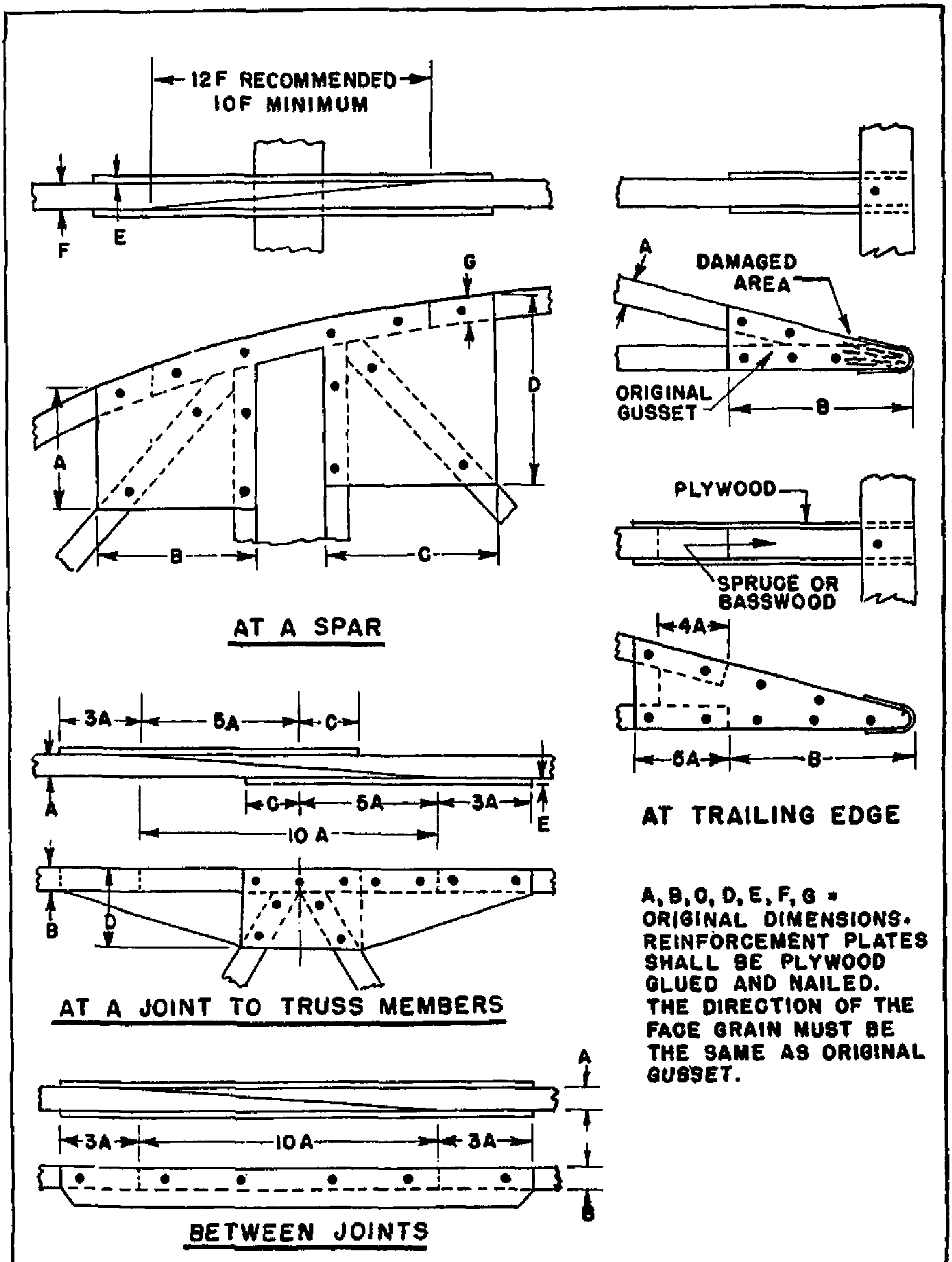


FIGURE 1.10.—Repair of wood ribs.

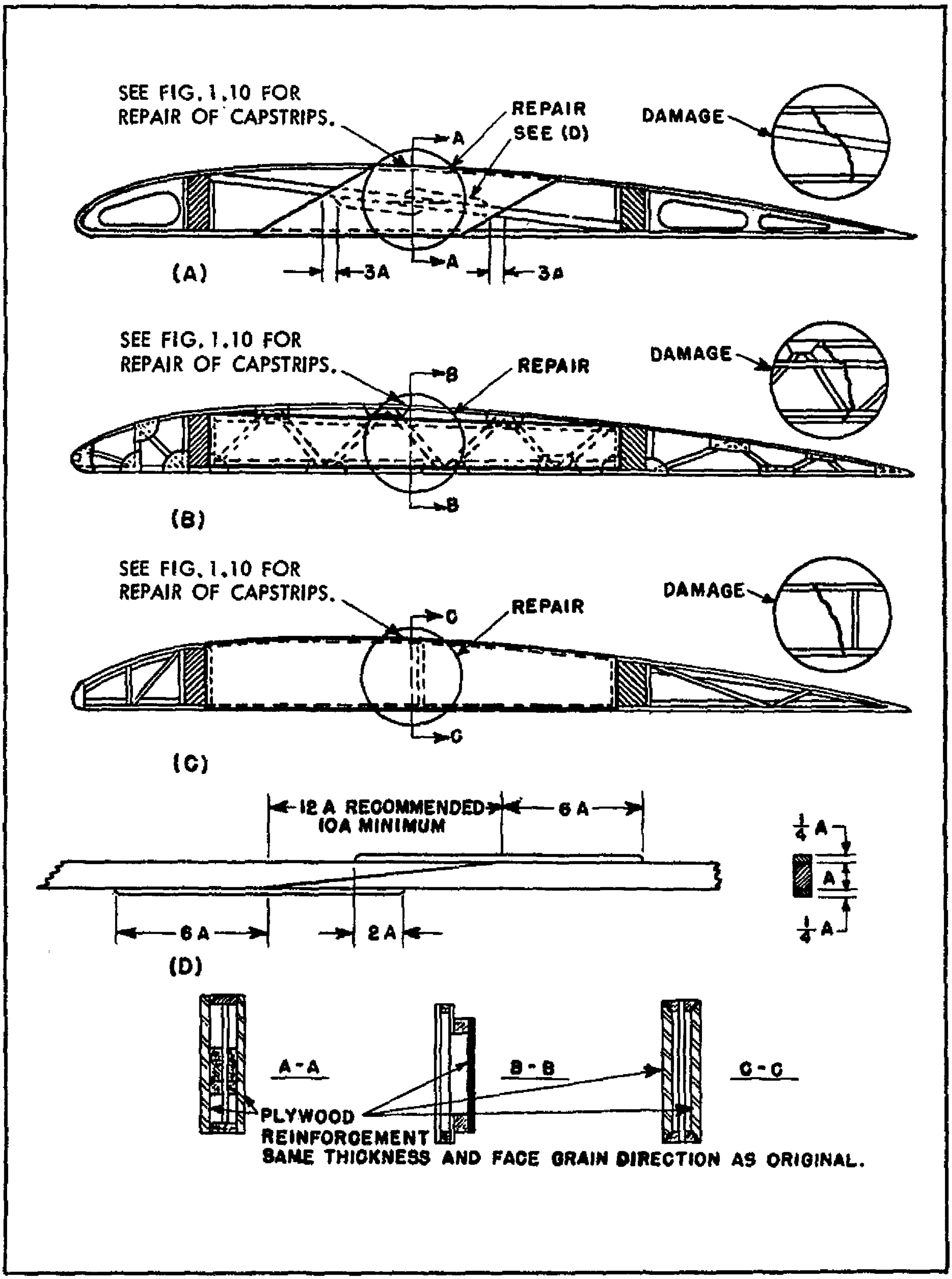
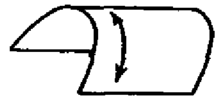
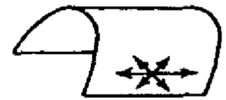
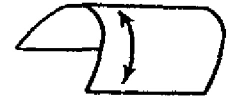


FIGURE 1.11.—Typical wing compression rib repairs.

Plywood thickness		10 Percent moisture content, bent on cold mandrels		Thoroughly soaked in hot water and bent on cold mandrels	
		At 90° to face grain 	At 0° or 45° to face grain 	At 90° to face grain 	At 0° or 45° to face grain 
(1)	(2)	(3)	(4)	(5)	(6)
Inch	No. plies	Inches	Inches	Inches	Inches
0.035	3	2.0	1.1	0.5	0.1
.070	3	5.2	3.2	1.5	.4
.100	3	8.6	5.2	2.6	.8
.125	3	12	7.1	3.8	1.2
.155	3	16	10	5.3	1.8
.185	3	20	13	7.1	2.6
.160	5	17	11	6	2
.190	5	21	14	7	3
.225	5	27	17	10	4
.250	5	31	20	12	5
.315	5	43	28	16	7
.375	5	54	36	21	10

Columns (1) and (3) may also be used for determining the maximum thickness of single laminations for curved members.

FIGURE 1.12.—Minimum recommended bend radii for aircraft plywood.

may be repaired by using a circular splayed patch as illustrated in figure 1.13. The term "splayed" is used to denote that the edges of the patch are tapered, but the slope is steeper than is allowed in scarfing operations. The steps shown in figure 1.13 should be taken in making a splayed patch.

a. *Lay out the patch* according to figure 1.13. Tack a small piece of plywood over the hole for a center point, and draw two circles, the inner one to be the size of the hole, and the outer one marking the limits of the taper. The difference between the radii is 5T (5 times the thickness of the skin). If one leg of the dividers has been sharpened to a chisel edge, the dividers may be used to cut the inner circle completely through.

b. *Taper the hole* evenly to the outer mark with a chisel, knife, or rasp.

c. *Prepare a circular tapered patch* to fit the prepared hole and glue the patch into place with face-grain direction matching that of the original surface.

d. *Use waxed paper* between the patch and a plywood pressure plate cut to the exact size of the patch. This prevents extruded glue from binding patch and plate together. Center the plate carefully over the patch.

e. *Apply pressure.* As there is no reinforcement behind this patch, care must be used so that pressure is not great enough to crack the skin. On horizontal surfaces, weights or sandbags will be sufficient. On patches too far in for the use of standard hand clamps, jaws of greater length may be improvised.

f. *Fill, sand,* and refinish the patch.

22. **SURFACE PATCH.** Plywood skins that are damaged between or along framing members may be repaired by surface or overlay patches as shown in figure 1.14. Trim the damaged skin to a rectangular or triangular shape and round the corners. The radius of rounded corners should be at least 5 times the skin thickness. Cover surface patches with fabric before finishing. Fabric should overlap the original skin at least 2 inches. Surface patches located

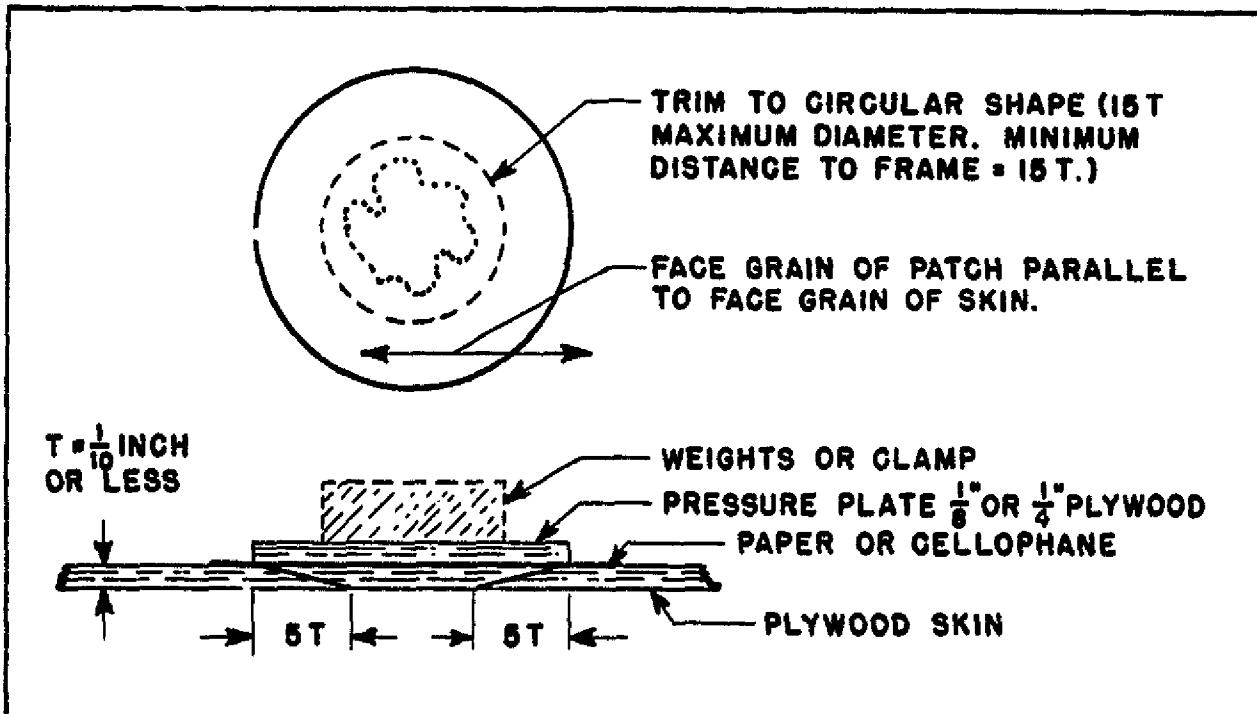


FIGURE 1.13.—Splayed patch.

entirely aft of the 10 percent chordline, or which wrap around the leading edge and terminate aft of the 10 percent chordline are permissible. Bevel forward edges of patches located entirely aft of the 10 percent chordline to 4 times the skin thickness. Surface patches may have as much as a 50-inch perimeter and may cover as much as 1 frame (or rib) space. The face-grain direction must be the same as the original skin.

23. SCARF PATCH. A properly prepared and inserted scarf patch is the best repair for damaged plywood skins and is preferred for most skin repairs. Figure 1.15 shows the details and dimensions to be used when installing typical scarf skin patches when the back of the skin is accessible. Follow figure 1.16 when the back of the skin is not accessible. The scarf slope of 1 in 12 shown in both figures is the steepest slope permitted for all species of plywood. If the radius of curvature of the skin at all points on the trimmed opening is greater than 100 times the skin thickness, a scarf patch may be installed.

Scarf cuts in plywood may be made by hand plane, spoke shave, scraper, or accurate sandpaper block. Rasped surfaces, except at the corners of scarf patches and sawed surfaces, are not recommended as they are likely to be rough or inaccurate.

Nail-strip gluing is often the only method available for gluing scarf joints in plywood when used in repair work; therefore, it is essential that all scarf joints in plywood be backed with plywood or solid wood to provide adequate nailholding capacity. The face grain direction of the plywood patch should be the same as that of the original skin.

a. Scarf Patches (Back of Skin Accessible). When the back of a damaged plywood skin is accessible (such as a fuselage skin), it should be repaired with scarf patches following the details shown in figure 1.15. Whenever possible, the edge of the patch should be supported as shown in section C–C. When the damage follows or extends to a framing member, the scarf may be supported as shown in section B–B.

Damages that do not exceed 25 times the skin thickness in diameter after being trimmed to a circular shape, and if the trimmed opening is not nearer than 15 times the skin thickness to a framing member, may be repaired as shown in figure 1.15, section D–D. The backing block is carefully shaped from solid wood and fitted to the inside surface of the skin, and is temporarily held in place with nails. A hole, the exact size of the inside circle of the scarf patch, is made in the block, and is centered over the trimmed area of damage. The block is removed, after the glue on the patch has set, and leaves a flush surface to the repaired skin.

b. Steps in Making Scarf Patch (Back of Skin Not Accessible).

(1) After removing damaged sections, install backing strips, as shown in figure 1.16, along all edges that are not fully backed by a rib or a spar. To prevent warping of the skin, backing strips should be made of a soft-textured plywood, such as yellow poplar or spruce rather than solid wood. All junctions between backing strips and ribs or spars should have the end of the backing strip supported by a saddle gusset of plywood.

(2) If needed, nail and glue the new gusset plate to rib. It may be necessary to remove and replace the old gusset plate by a new saddle gusset; or, it may be necessary to nail a saddle gusset over the original.

(3) Attach nailing strips to hold backing strips in place while the glue sets. Use bucking bar where necessary to provide support for nailing. Unlike the smaller patches made in a continuous process, work on the airplane must wait while the glue, holding the backing strips, sets. After setting, complete finishing in usual manner.

24. PLUG PATCHES. Two types of plug patches, oval and round, may be used on plywood skins provided the damage can be covered by the patches whose dimensions are given in figures 1.17 and 1.18. As the plug patch is strictly a skin repair, it should be used only for damage that does not involve the supporting structure under the skin. Oval patches must be prepared

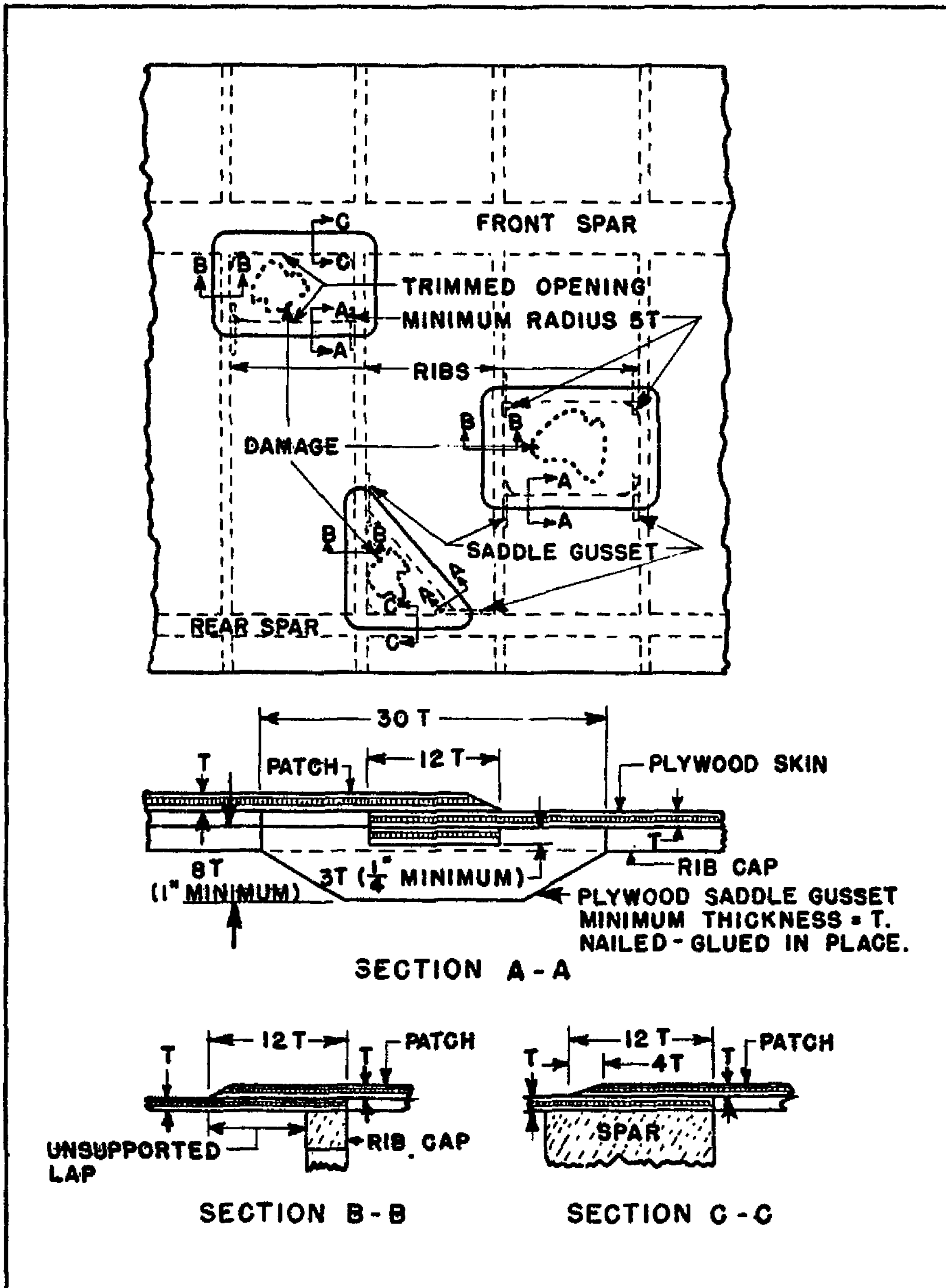


FIGURE 1.14.—Surface patches.

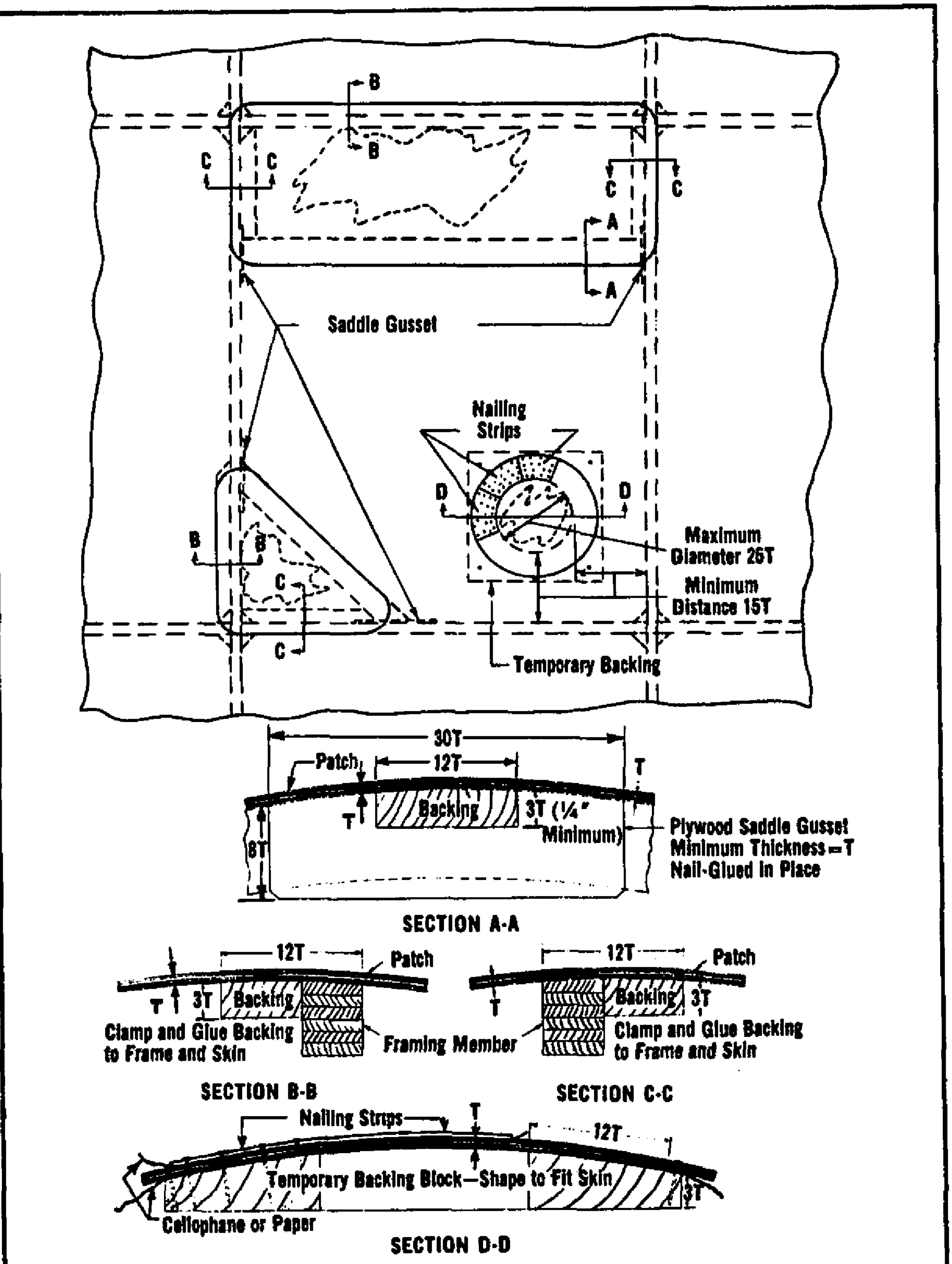


FIGURE 1.15.—Scarf patches—back of skin accessible.

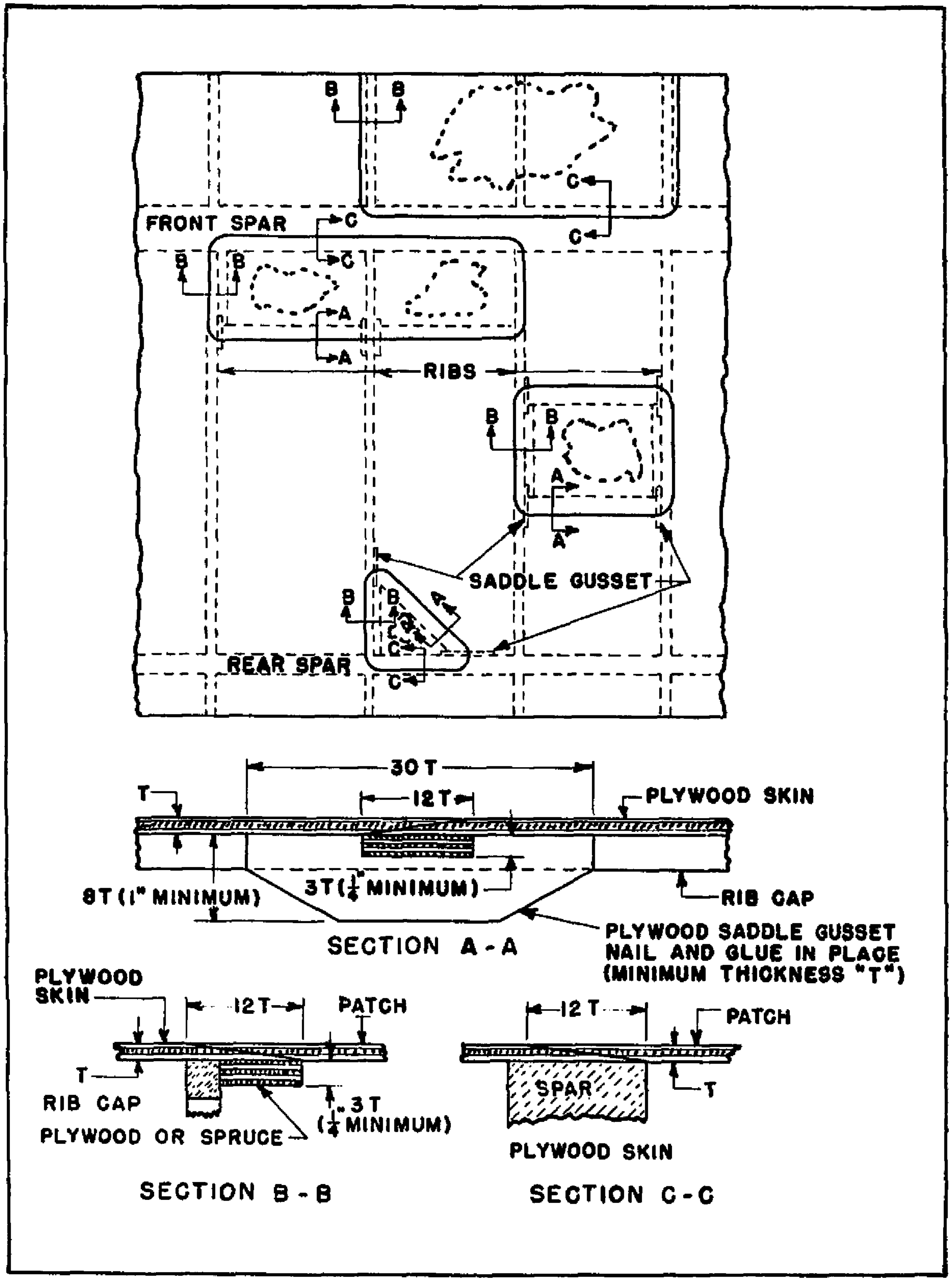
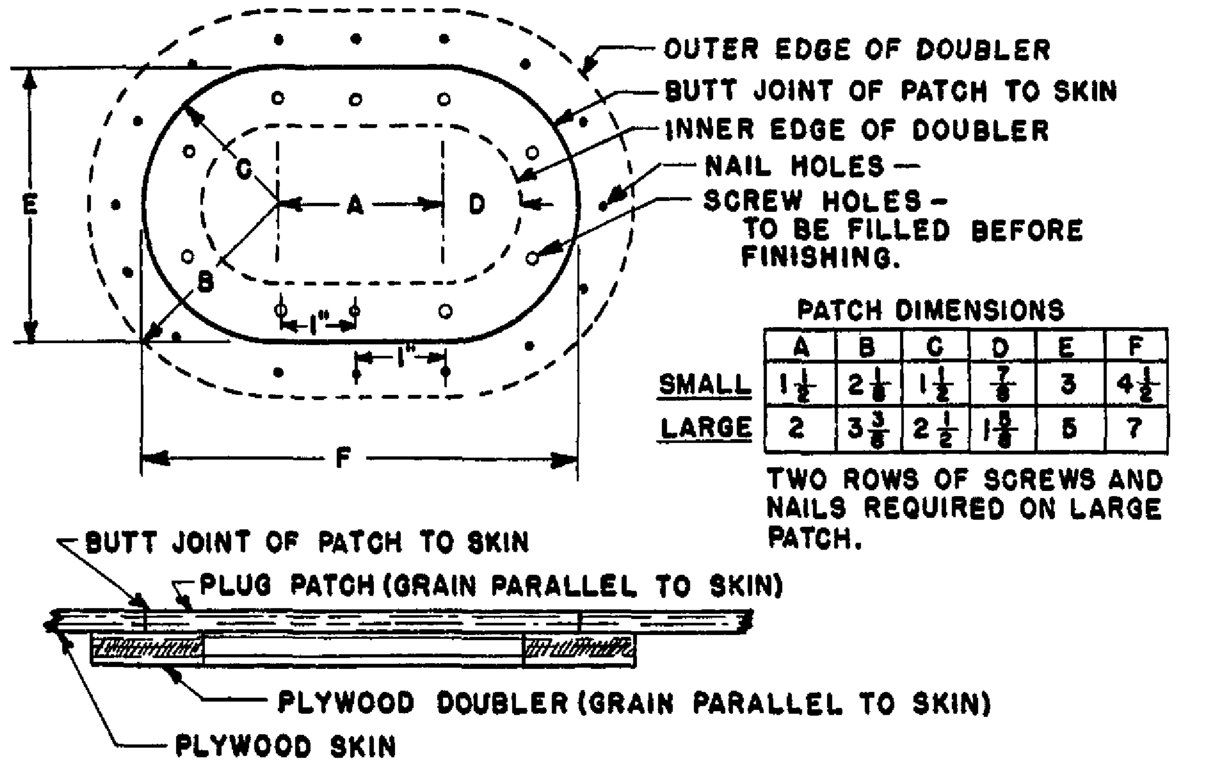


FIGURE 1.16.—Scarf patches—back of skin not accessible.



PATCH DIMENSIONS

	A	B	C	D	E	F
SMALL	1 1/2	2 1/8	1 1/2	7/8	3	4 1/2
LARGE	2	3 3/8	2 1/2	1 5/8	5	7

FIGURE 1.17.—Oval plug patch assembly.

with the face grain carefully oriented to the same direction as the original skin. Orientation of the face grain direction of the round plug patch to that of the skin surface is no problem, as the round patch may be rotated until grain directions match.

a. Steps in Making Oval Plug Patch.

(1) Explore the area about the hole to be sure it lies at least the width of the oval doubler from a rib or a spar. Refer to figure 1.17 for repair details.

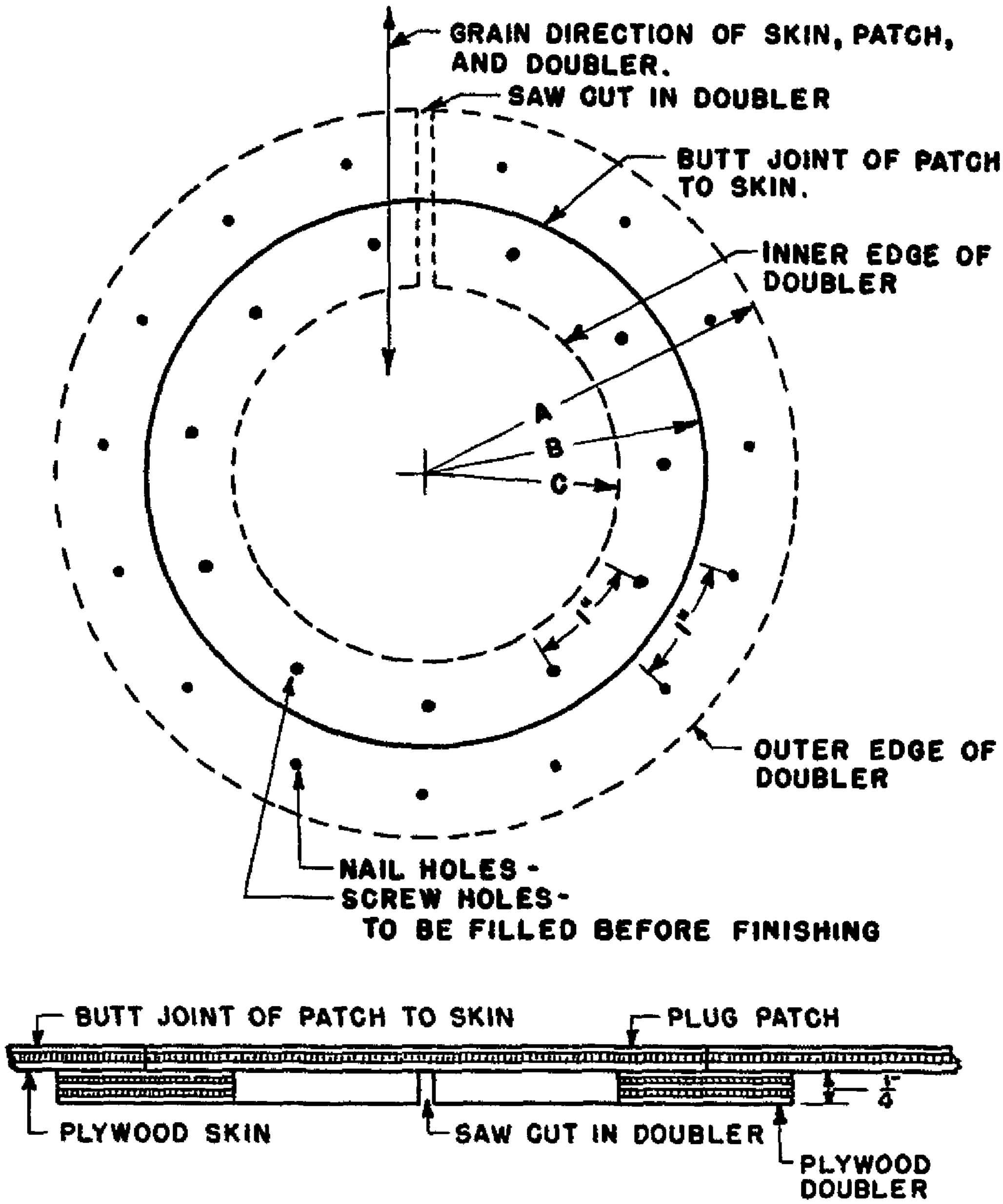
(2) Lay a previously prepared oval plug patch over the damage and trace the patch. Saw to the line and trim the hole edges with a knife and sandpaper.

(3) Mark the exact size of the patch on one surface of the oval doubler and apply glue to the area outside the line. The oval doubler should be made of some soft-textured plywood, such as yellow poplar or spruce. Insert doubler through the hole and bring it, glue side up, to the underside of the skin with its pencil outline of the patch matching the edges of the hole. If the curvature of the surface to be repaired is greater than a rise of 1/8 inch in 6 inches, the doubler should be preformed by hot water or steam bending to the approximate curvature.

(4) Apply nailing strips outlining the hole to apply glue pressure between doubler and skin. Use bucking bar to provide support for nailing. When two rows of nails are used, stagger nail spacing.

(5) Apply glue to remaining surface and to an equivalent surface on the patch.

(6) Lay the patch in position over the doubler, and screw the pressure plate to the patch assembly using a small nail to line up the holes



DIMENSIONS

	A	B	C
SMALL CIRCULAR PLUG PATCH	2 3/8	2	1 3/8
LARGE CIRCULAR PLUG PATCH	3 7/8	3	2 1/8

(TWO ROWS OF SCREWS AND NAILS REQUIRED FOR LARGE PATCH.)

FIGURE 1.18.—Round plug patch assembly.

that have been previously made with patch and plate matching. No. 4 roundhead screws are used. Lead holes in the plywood doubler are not necessary. Waxed paper or cellophane between the plate and patch prevents glue from sealing the plate to the patch. No clamps or further pressure need be applied as the nailing strips and screws exert ample pressure. Hot sandbags, however, may be laid over the patch to speed the setting of the glue. Finish in the usual manner.

b. ***Round Plug Patch.*** The steps in making a round plug patch shown in figure 1.18 are identical with those for making the oval patch except the insertion of the doubler. In using the round patch, where access if from only one side, the round doubler cannot be inserted unless it has been split.

25. FABRIC PATCH. Small holes not exceeding 1 inch in diameter, after being trimmed to a smooth outline, may be repaired by doping a fabric patch on the outside of the plywood skin. The edges of the trimmed hole should first be sealed and the fabric patch should overlap the plywood skin by at least 1 inch. Holes nearer than 1 inch to any frame member, or in the leading edge or frontal area of the fuselage, should not be repaired with fabric patches.

26.-36. RESERVED.

Section 2. FINISHING WOOD STRUCTURES

37. GENERAL. Any repair to spars, ribs, skin surfaces, or other structural parts of the airframe involves finishing as the final step of the job. The time and effort spent during the preparatory phase of the refinishing process will be reflected in the appearance of the finished surface. Adherence to the instructions issued by the finish manufacturer is necessary to obtain the appearance desired and protective characteristics for the product used.

38. PRECAUTIONS TO BE OBSERVED. When making repairs, avoid excessive contamination of surfaces with glue squeezeout at joints and on all surfaces. Excess glue should always be removed before applying finish. Because paints and glues are incompatible, even a slight amount of glue underneath the finish may cause premature deterioration.

a. *Soiling substances,* such as oil and grease, should be removed as completely as possible. Naphtha may be used to sponge off oil and grease. Markings that are made by grease pencils or lumber crayons containing wax are harmful and should be removed, but marks made by ordinary soft graphite pencils and nonblotting stamp pad inks may be safely finished over. All dust, dirt, and other solid particles should be cleaned off.

b. *Sawdust, shavings,* and chips must be removed from enclosed spaces before they are sealed off by replacement of skin. A vacuum cleaner is useful for such cleaning.

c. *Since no satisfactory gluable sealer* has yet been developed, it is necessary to avoid applying sealer over the areas where glue will be applied. Mark off areas to receive glue, allowing an additional 1/4 inch on each side of the glue area to provide for misalinement when mating the parts. It is preferable to leave some unsealed areas rather than risk weakening the glue joint by accidental overlap of the seale into the glued areas.

d. *Finish is likely to crack* when applied ove flush-driven nails and screws. To avoid this, a strip of tape may be applied over the heads after application of sealer and before the final finish is applied.

e. *Fill all holes* left from nail-strip gluing or countersunk nails and screws with a wood filler before finishing the surface. It may be necessary to cover with a patching putty th slight depressions left after applying filler, if a completely smooth surface is desired; but, as rule, patching putty may be dispensed wit safety.

f. *Treat surfaces* which are likely to come contact with fabric during the doping proces with a dope-proof paint, cellophane tape, etc to protect them against the action of the so vents in the dope.

39. FINISHING OF INTERIOR SURFACES. Finis repaired ribs, spars, interior of plywood ski and other internal members, including areas c contact between metal and wood, by applyi at least two coats of spar varnish. Prot built-up box spars and similar closed stru tures on the interior by at least one heavy co of spar varnish or lionoil. Where better protection is required, as on the surfaces of wheel wells and the bottoms of hulls below the floo boards, an additional coat of aluminized sea consisting of 12 to 16 ounces of alumi paste per gallon of sealer may be applied.

40. FINISHING OF EXTERIOR SURFACES. Exter surfaces should first be sealed with at least t coats of sealer or spar varnish. The surfa finish should then be completed by the applic tion of enamel, aluminized varnish, or oth special finish as required to duplicate the orig nal finish. If dope or lacquer is used to complete the finish, the sealer coats should be dope-proof. Spar varnish or sealer conforming to Specification MIL-V-6894 is satisfactory.

41. FINISHING OF END GRAIN SURFACES. End grain surfaces, such as edges of plywood skins and holes in spars and other primary structural members, require careful protection. Sand these surfaces smooth. Apply two coats of a highly pigmented sealer, or one coat of wood filler, and one coat of clear sealer to end grain interior surfaces and cut holes. Exterior end grain surfaces (except those covered with doped fabric) require an additional (third) coat of clear sealer. A final coat of aluminized varnish may be applied to end grain surfaces. If the surfaces are to be finished with dope or lacquer, a dope-proof sealer similar to Specification MIL-V-6894 should be used.

Exposed end grain includes such surfaces as those around ventholes, inspection holes, fittings, and exposed scarfed or tapered surfaces such as those of tapered blocking.

42. FINISHING WITH FABRIC OR TAPE. To refinish with fabric or tape, it is first necessary to insure that paint has been removed from an area greater than that to be covered by the fabric.

a. ***Apply two brush coats*** of a dope-proof sealer similar to Specification MIL-V-6894, allowing the first coat to dry 2 hours and the second coat at least 6 hours. Follow with one coat of clear dope, and allow it to dry 45 minutes. Apply a second coat of clear dope and lay into the wet film a piece of pinked-edge airplane cloth. All air bubbles should be worked out by brushing to insure maximum adherence. Allow this to dry 45 minutes. Apply one brush coat to insure proper penetration, and at least one spray coat of clear dope, allowing each to dry 45 minutes. The dried spray coat may be sanded with fine sandpaper to obtain a smoother finish. Complete the refinishing of the surface by application of lacquer, enamel, or aluminized varnish as required to match the adjacent area.

b. ***The size of the fabric patch*** should be such as to extend at least 1/2 inch on each side of any crack or group of cracks, at least 1 inch on each side of a scarfed joint glue line, and at least 2 inches beyond any edge of a skin patch to insure proper adhesion.

43.-53. RESERVED.

Chapter 2. AIRCRAFT METAL STRUCTURES

Section 1. REFERENCES AND PRECAUTIONARY MEASURES

I. REFERENCES. The following chapters of this C should be referred to when accomplishing repairs to aircraft metal structures:

a. Identification and Inspection of Materials. Identification and inspection of materials should be conducted in accordance with Chapter 7.

b. Corrosion Protection. Corrosion protection treatment, cleaners, and paint removing should be accomplished in accordance with Chapter 6.

c. Aircraft Hardware. Acceptable means of ttachment are listed in Chapter 5.

5. FLUTTER AND VIBRATION PRECAUTIONS. To revent the occurrence of severe vibration or utter of flight control surfaces during flight, recautions must be taken to stay within the esign balance limitations when performing aintenance or repair.

a. Balance Changes. The importance of retain- the proper balance and rigidity of aircraft ntrol surfaces cannot be underestimated. As general rule, repair the control surface in h a manner that the structure is identical to original so that the weight distribution is t affected in any way. In order to preclude he occurrence of flutter of the control surface n flight, a degree of static and/or dynamic balnce is established for each model of aircraft. der certain conditions, counter-balance ght is added forward of the hinge line to ntain balance. Remove or add balance ght only when necessary in accordance h the manufacturer's instructions, or obtain A approval. Flight testing may be required. ilure to check and retain control surface bale within the original or maximum allowa- value could result in a serious flight hazl.

b. Materials and Construction Techniques. The development of new materials and techniques has made possible the use of control surfaces of less mass weight for a given area than some aircraft of older design. The effect of repair or weight change on the balance and center of gravity is proportionately greater on lighter surfaces than on the older designs. Since control surfaces on some models are balanced for flutter-free operation up to maximum speed for which the aircraft was originally designed, special attention, therefore, must be given to such surfaces relative to the effects of structural repairs and rework on their balance condition.

c. Painting and Refinishing. Special emphasis is directed to the effect indiscriminate application of extra coats of dope or paint has on the balance of control surfaces. Proper maintenance of control surface balance may require removal of dope or paint, down to the base coat, prior to application of finish coats. Consult the aircraft manufacturer's instructions relative to finishing and balance of control surfaces.

d. 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. Certain construction designs do not provide for ventilation and may collect moisture through condensation which will affect balance. In the event this condition is found, refer to the manufacturer's instructions for moisture removal.

e. Trim Tab Maintenance. In addition to unbalanced control surface, loose or vibrating trim tabs will increase wear of actuating mechanisms and hinge points which may develop serious flutter conditions. Most trim tabs are not balanced separately from the control surface. Minimum tab flutter is maintained through rigid actuating mechanisms. Trim tabs and their actuating mechanism are constructed as lightly as possible to keep the weight aft of the hinge line of the control surface as low as possible. Actuating mechanisms are highly susceptible to wear, deformation, and fatigue failures because of the buffeting nature of airflow over the tab mechanism. Trailing-edge play of the tab may increase, through wear of the mechanism, to an unsafe condition. Careful inspection of the tab and its mechanism should be conducted during overhaul and inspection periods. Compared to other systems on the aircraft, only a minor amount of tab-mechanism wear can be tolerated. In the absence of a specified limit for tab trailing edge movement in the manufacturer's manual, it is acceptable to use a limit of 2 1/2% of the chord, measured at the trailing edge of the tab. For example, a tab that has a chord of 4" would have a maximum permissible free play of 4" x .025 or 0.100 inches (total motion up and down) measured at the trailing edge. Correct any free play in excess of this amount. Care must also be exercised during repair or rework to prevent stress concentration points or areas which could increase the fatigue susceptibility of the trim tab system.

56. BRAZING. Brazing may be used for repa to primary aircraft structures only if brazi was originally approved for the particular a plication. Brazing is not suitable for repair welds in steel structures due to lower streng values of the brazed joint as compared welded joints. Brazing may be used in the r pair of secondary structures.

Due to the large number of brazing allo used, it is difficult to be certain that the mat rial selected for repairing a brazed joint w result in a joint having the same streng characteristics as the original. In cases whe it is necessary to apply copper alloy brazi material, more than once on a steel surfac and particularly if temperatures over 2,000° are reached, there is a possibility that brazi metal may penetrate between the grains in th steel to an extent that may cause crackin Copper brazing of steel is normally accom plished in a special furnace having a controlle atmosphere, and at a temperature so high th field repairs are seldom feasible. If coppe brazing is attempted without a controlled a mosphere, the copper will probably not com pletely flow and fill the joint. Therefore, co per brazing in any other than appropriatel controlled conditions is not recommended.

57.-67. RESERVED.

Section 2. WELDING

68. **GENERAL.** This section covers weld repairs to aircraft and component parts thereof with the exception of welding on powerplants and propellers which is provided in chapters 12 and 14 respectively. Observe the following when using such equipment as tungsten inert gas (TIG), metal inert gas (MIG), plasma arc, shield carbon arc, and oxygen-acetylene gas.

a. ***Equipment Selection.*** Use the welding equipment manufacturers' information to determine if the equipment will satsify the requirements for the type of welding operation being undertaken. Disregarding such detailed operating instructions may cause substandard welds. For example, when using TIG 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.

(1) **Electric welding equipment** versatility requires careful selection of the type current and polarity to be 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 A.C., while D.C. is used for carbon, low alloy, noncorrodible, and heat-resisting steels, copper, etc. General recommendations covering current and polarity are shown in figure 2.1.

(2) **Oxygen-acetylene gas equipment** is suitable for welding most metals. It is not, how-

FIGURE 2.1.—Current and polarity selection for inert gas welding.

	ALTERNATING CURRENT*	DIRECT CURRENT	
MATERIAL	With High-Frequency Stabilization	STRAIGHT Polarity	REVERSE Polarity
Magnesium up to 1/8 in. thick	1	N.R.	2
Magnesium above 3/16 in. thick	1	N.R.	N.R.
Magnesium Castings	1	N.R.	2
Aluminum up to 3/32 in. thick	1	N.R.	2
Aluminum over 3/32 in. thick	1	N.R.	N.R.
Aluminum Castings	1	N.R.	N.R.
Stainless Steel	2 *	1	N.R.
Brass Alloys	2 *	1	N.R.
Silicon Copper	N.R.	1	N.R.
Silver	2	1	N.R.
Silver Cladding	1	N.R.	N.R.
Hard-facing	1	1	N.R.
Cast Iron	2 *	1	N.R.
Low Carbon Steel, 0.015 to 0.030 in.	2**	1	N.R.
Low Carbon Steel, 0.030 to 0.125 in.	N.R.	1	N.R.
High Carbon Steel, 0.015 to 0.030 in.	2 *	1	N.R.
High Carbon Steel, 0.030 in. and up	2 *	1	N.R.

1. Recommended 2. Acceptable N.R. Not Recommended

*Where A.C. is recommended as second choice, use approximately 25% higher current than is recommended for DCSP.

**Do not use A.C. on tightly jigged part.

ever, the best method to use on such materials as stainless steels, magnesium, and aluminum alloys because of base metal oxidization, distortion, and loss of ductility.

NOTE: When oxyacetylene is used, all flux must be removed, as it may cause corrosion.

b. ***Accurately Identify the Type of Material to be Repaired.*** Reference to chapter 7 may provide this information. If positive identification 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 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.

c. ***Preparation for Welding.*** Hold elements to be welded in a welding jig or fixture which is sufficiently rigid to prevent misalinement due to expansion and contraction of the heated material and which positively and accurately position the pieces to be welded.

d. ***Cleaning Prior to Welding.*** Clean parts to be welded with a wire brush or other suitable methods. When cleaning with a wire brush, do not use a brush of dissimilar metal; for example, 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. In case members were metallized, the surface metal may be removed by careful sandblasting followed by a light buffing with emery cloth.

e. ***Condition of Complete Weld.*** Make sure that:

(1) The finished weld has a smooth seam and is uniform in thickness;

(2) The weld metal is tapered smoothly into the base metal;

(3) No oxide has formed on the base metal at a distance of more than 1/2 inch from the weld;

(4) The weld shows no signs of blowholes porosity, or projecting globules;

(5) The base metal shows no signs of pitting, burning, cracking, or distortion;

(6) The depth of penetration insures fusion of base metal and filler rod; and

(7) Welding scale is removed by wire brushing or sandblasting.

f. ***Practices to Guard Against.*** Do not file welds in an effort to make a smooth-appearing job, 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 reweld a joint which was previously welded, remove all 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.

g. ***Torch Size (Oxyacetylene Welding).*** The size of the torch tip depends upon the thickness of the material to be welded. Commonly used sizes proved satisfactory by experience are:

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

h. ***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. Figure 2.3 shows the allowable strength for the weld metal. Figure 2.2 lists specifications for corresponding metals, and the applicable specification will identify the use of A.C. or D.C., straight or reverse polarity.

i. ***Rosette Welds.*** Rosette welds are generally employed to fuse an inner reinforcing tube (liner) with the outer member. Where a rosette weld is used, drill the hole, in the outside tube only, of a sufficient size to insure fusion of

FIGURE 2.2.—Specifications guide for welding metals.

Material To Be Welded	Electric Welding	Tungsten Inert Gas (TIG)	Metal Inert Gas (MIG)	Shield Carbon—ARC	Oxygen Acetylene
Medium & High Tensile Steel. Stress Relieved	MIL–E–22200/1 MIL–9018	MIL–E–23765/1B Class MIL–E–705–2	MIL–E–23765/1B Class MIL–E–705–4	NONE	MIL–R–908A Class 1
High Carbon Steel	MIL–E–7018 MIL–E–22200	MIL–E–23765/1B Class MIL–E–705–2	MIL–E–23765/1B Class MIL–E–705–6	MIL–R–CUS1–A	MIL–R–908A Class 1
Low and Medium Carbon Steel	MIL–E–15599–C [1]	MIL–E–23765/1B Class MIL–E–705–2	MIL–E–23765/1B Class MIL–E–705–6	MIL–R–CUS1–A	MIL–R–5632 Class 1
Aluminum and Aluminum Alloy	MIL–E–15997A	QQR–566 MIL–E–16053–K [2]	QQR–566 MIL–E–16053–K [2]	QQR–566 [2]	QQR–566 [2]
Stainless Alloys	MIL–E–6844 M–L–E–22200 [3]	MIL–R–5031B [3]	MIL–R–5031B [3]	MIL–R–5031B [3]	MIL–R–5031B [3]
Copper and Nickel Alloys	NONE	QQR–571A [4]	MIL–E–21659 [4]	QQR–571A [4]	QQR–571A [4]
Magnesium Alloys	NONE	MIL–R–6944 Specify Alloy	MIL–W–18326 Specify Alloy	NONE	MIL–R–6944 Specify Alloy
Hard Surface Filler	MIL–E–19141 (Refer to A.W.S A5.13 or ASTM–A399)	MIL–E–19141 (Refer to A.W.S A5.13 or ASTM–A399)	MIL–E–19141 (Refer to A.W.S. A5.13 or ASTM–A399)	MIL–E–19141 (Refer to A.W.S. A5.13 or ASTM–A399)	MIL–19141 (Refer to A.W.S. A5.13 or ASTM–A399)

[1] Specify MIL Type 6010, 6011, 6012, 6013, 6020, 6024, 6027—Same as A.W.S. Number for type.

[2] Specify Aluminum Alloy by Aluminum Assoc. Number e.g.: Type 1100, 5083, etc.

[3] Specify Alloy by A.I.S.I. Number e.g.: 304, 316, 342, etc.

[4] Specify type per A.W.S. A5.6–66 or ASTM B–225–66.

A.W.S. American Welding Society
ASTM American Society for Testing Materials
A.I.S.I. American Iron and Steel Institute (SAE).

FIGURE 2.3.—Strengths of welded joints.

Material	Heat treatment subsequent to welding	Welding rod or electrode	Ultimate stress in shear × 1000	Ultimate tensile stress × 1000
Carbon and Alloy steels	None	MIL–R–5632, Class I MIL–E–15599, Classes E–6010 & E–6013	32 32	51 51
Alloy steels	None	MIL–R–5632, Class 2	43	72
Alloy steels	Stress relieved	MIL–E–6843, Class 10013 MIL–E–18038, Class E–10015 & E–10016	50	85
Alloy steels	Stress relieved	MIL–E–18038, Class E–12015 & E–12016	60	100

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.

j. *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, using a welding rod suitable for producing heat-treated values comparable to those of the original members (see paragraph 68h). After welding, reheat-treat such members to the manufacturer's specifications.

69. STEEL PARTS NOT TO BE WELDED.

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

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

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.

70. REPAIR OF TUBULAR MEMBERS.

a. *Inspection.* Prior to repairing tubular members, carefully examine the structure surrounding any visible damage to insure that n secondary damage remains undetected. Secondary damage may be produced in some structu remote from the location of the primary dam age by the transmission of the damaging loa along the tube. Damage of this nature usuall occurs where the most abrupt change in dire tion of load travel is experienced. If this dam age remains undetected, subsequent norma loads may cause failure of the part.

b. *Location and Alinement of Welds.* Unle otherwise noted, welded steel tubing may spliced or repaired at any joint along the leng of the tube. Pay particular attention to th proper fit and alinement to avoid distortion.

c. *Members Dented at a Cluster.* Repair de at a steel-tube cluster-joint by welding a sp cially formed steel patch plate over the dente area and surrounding tubes, as shown in figure 2.4. To prepare the patch plate, cut a section of steel sheet of the same material and thickne as the heaviest tube damaged. Trim the re forcement plate so that the fingers extend o the tubes a minimum of 1.5 times the resp tive tube diameter as shown in the figu Remove all the existing finish on the damag cluster-joint area to be covered by the reinfor ment plate. The reinforcement plate may formed before any welding is attempted, or may be cut and tack-welded to one or more the tubes in the cluster-joint, then heated a

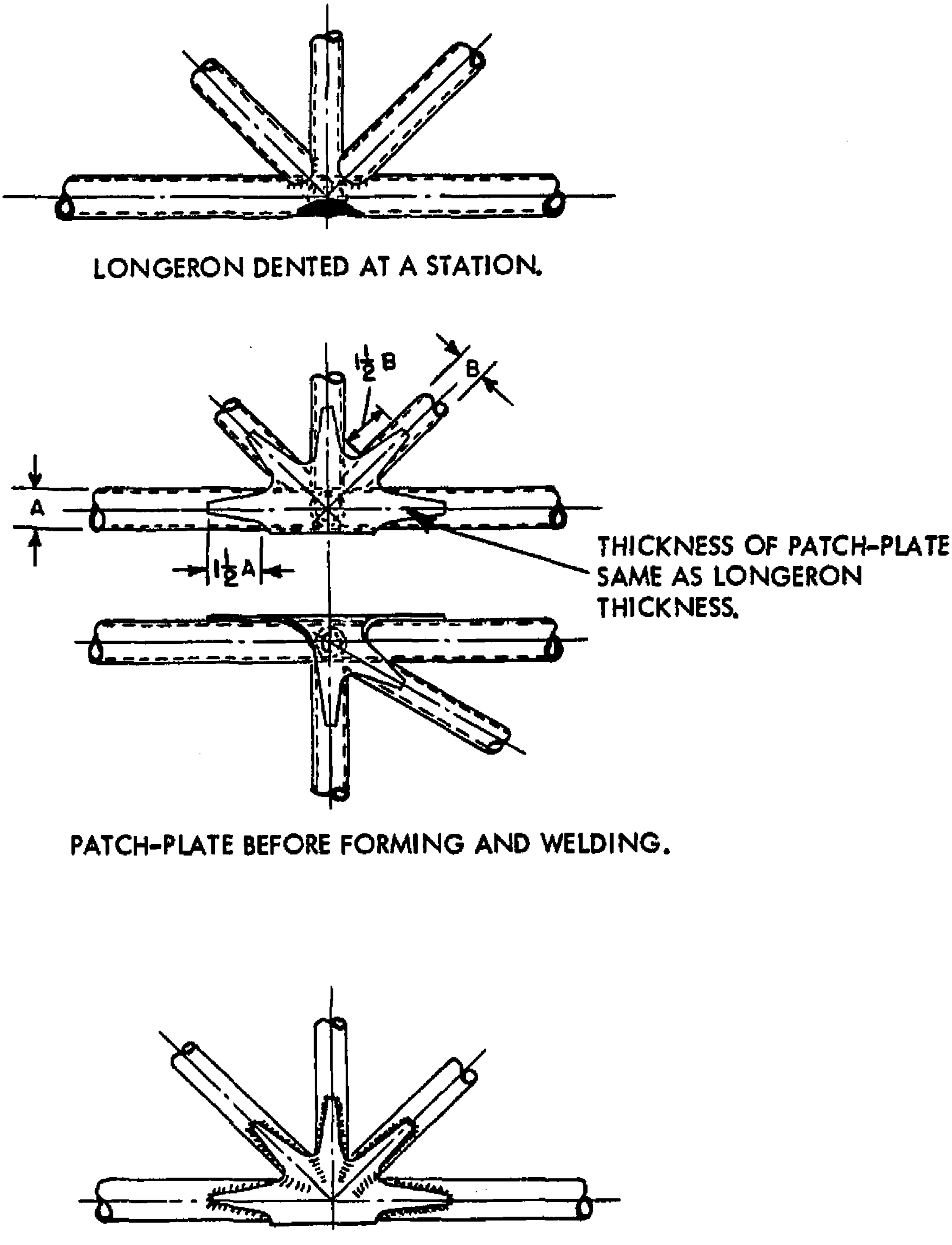


FIGURE 2.4.—Members dented at a cluster.

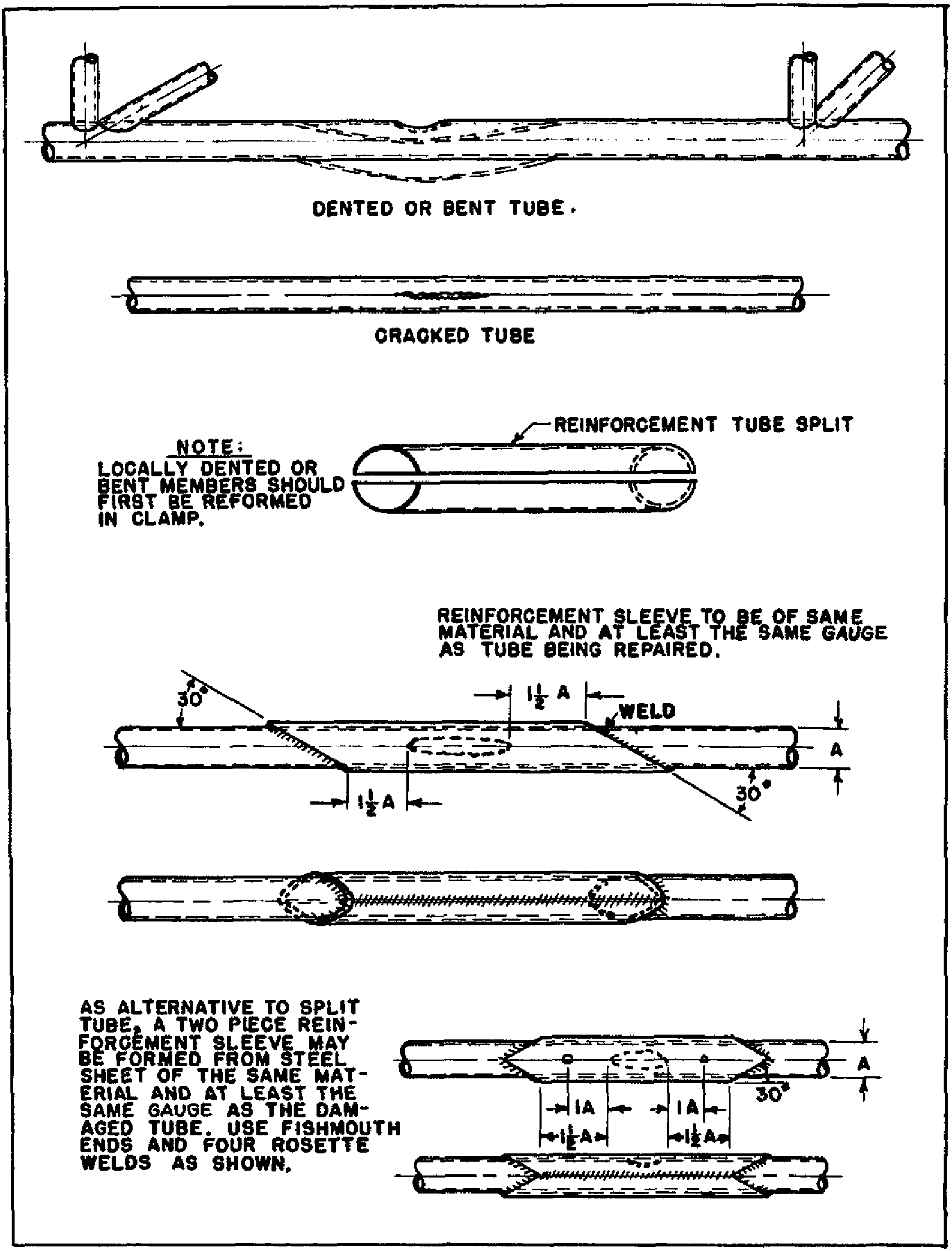


FIGURE 2.5.—Members dented in a bay—repairs by welded sleeve.

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.

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) stop-holes at the ends of the crack.

71. REPAIR BY WELDED SLEEVE. This repair is outlined in figure 2.5. 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° 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 as shown in the figure. The filling of dents or cracks with welding rod in lieu of reinforcing the member is not acceptable.

72. 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 boltholes in this types of repair may prove critical.

73. WELDED-PATCH REPAIR. Dents or holes in tubing may be repaired by a welded patch of the same material and one gauge thicker, as shown in figure 2.6 provided:

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.

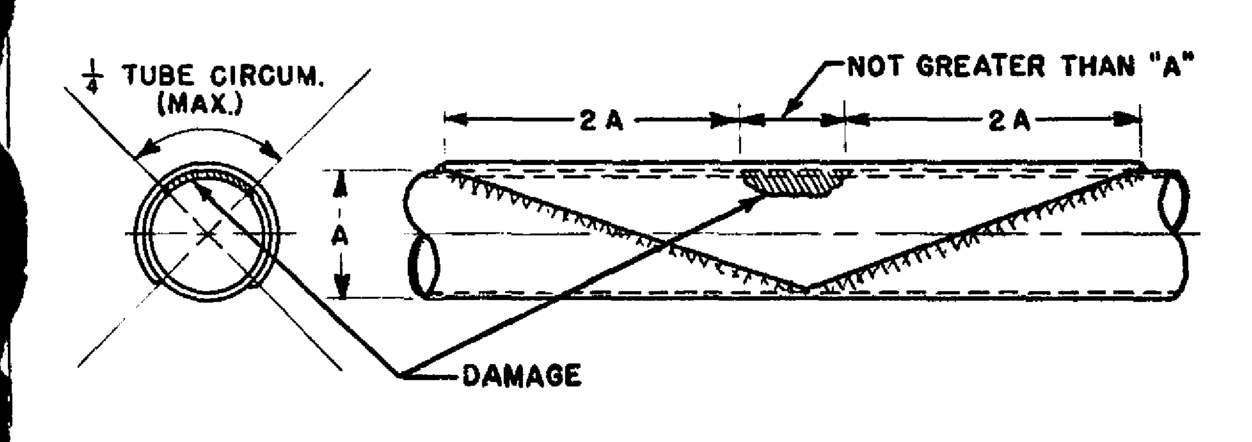


FIGURE 2.6.—Welded patch repair.

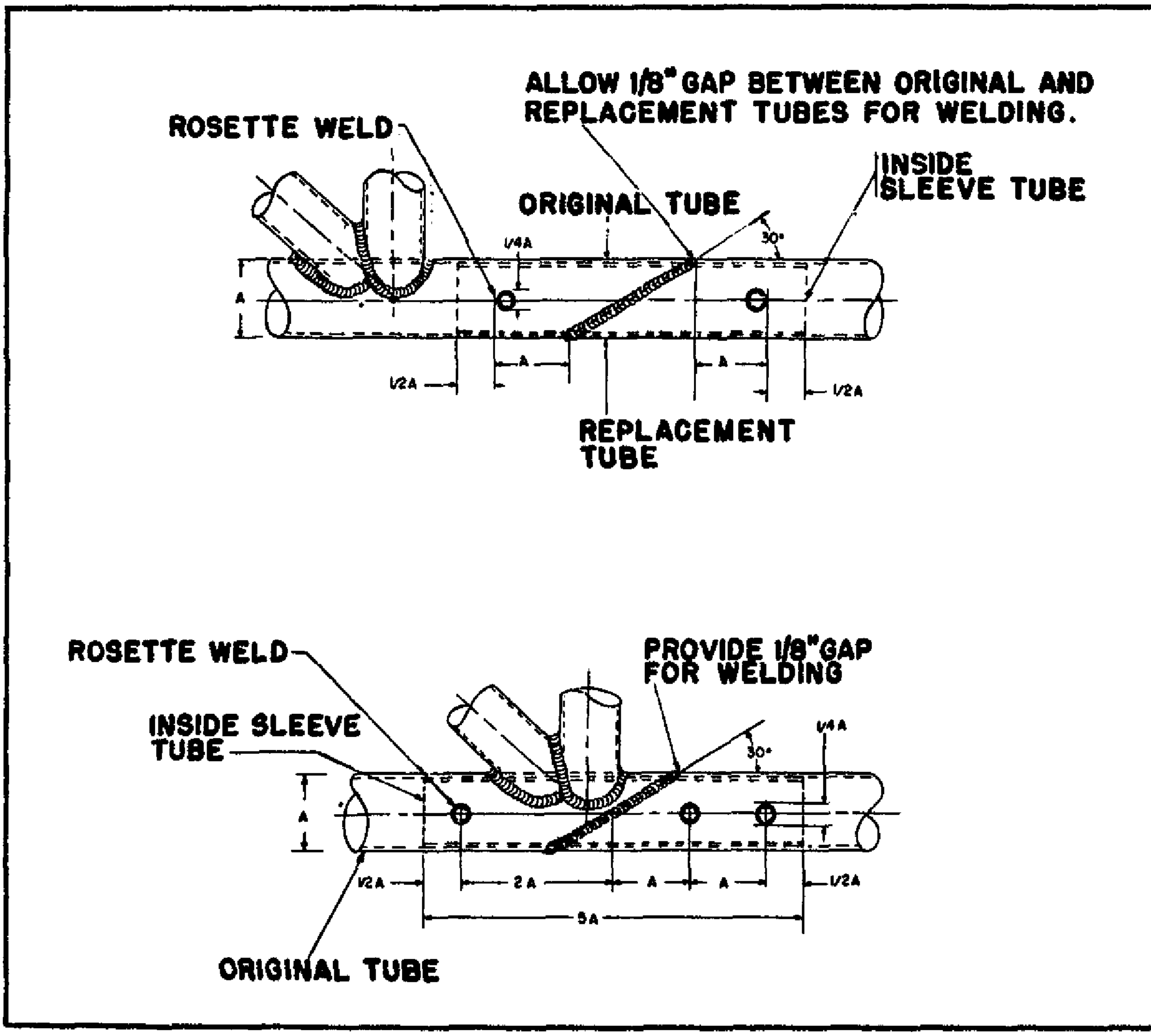


FIGURE 2.7.—Splicing by inner sleeve method.

74. 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 shown in figure 2.7 is recommended, especially where a smooth tube surface is desired. 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 innersleeve tube material snugly within the original tube, with a maximum diameter difference of 1/16 inch. From this inner-sleeve tube material cut 2 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.

If the inner sleeve fits very tightly in the replacement tube, chill the sleeve with dry ice or

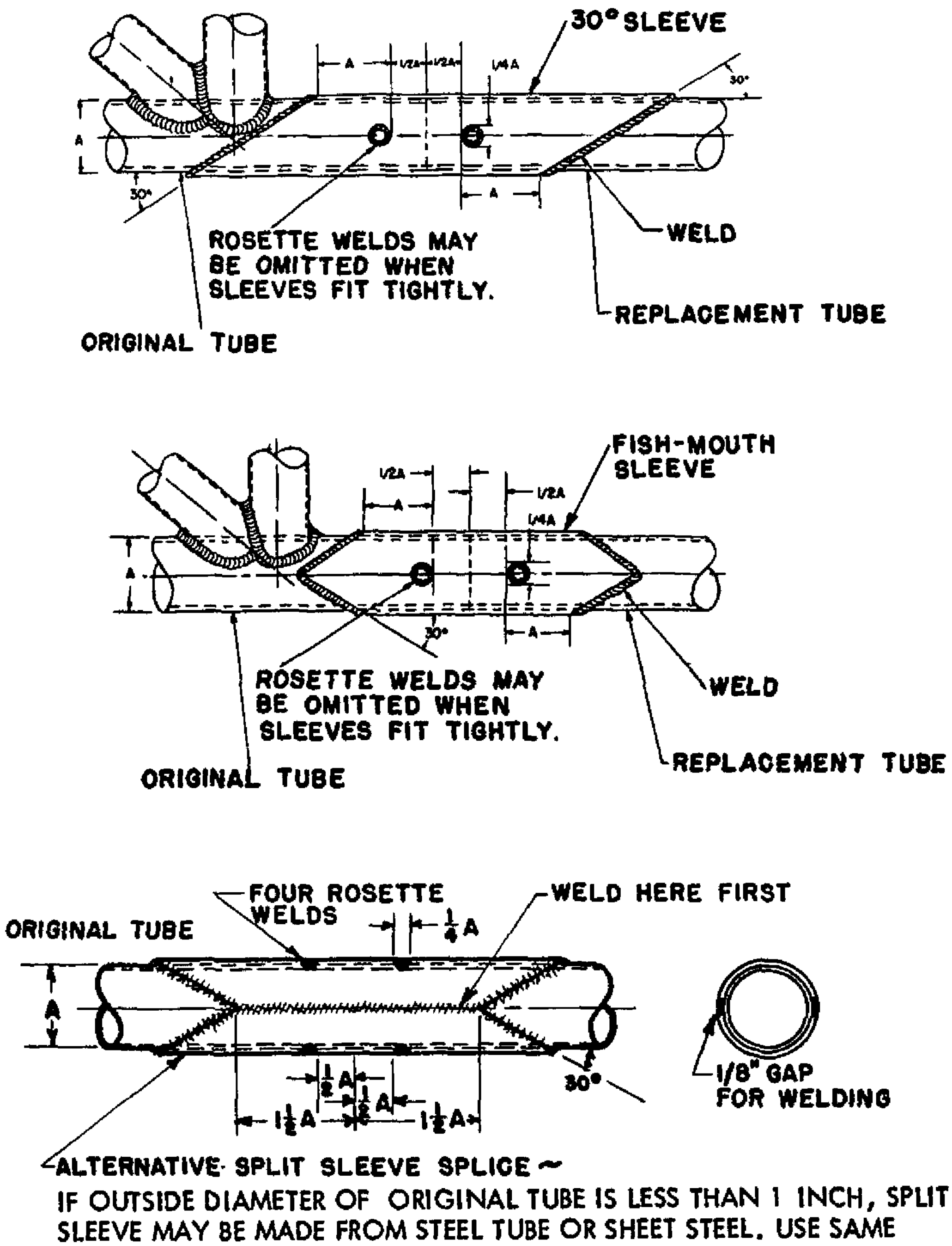


FIGURE 2.8.—Splicing by outer sleeve method—replacement by welded outside sleeve.

in cold water. If this is insufficient, polish down the diameter of the sleeve with emery cloth. Weld the inner sleeve to the tube stubs through the 1/8-inch gap, forming a weld bead over the gap.

75. 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 welded outside sleeve method is given in figures 2.8 and 2.9.

Remove the damaged section of a tube utilizing a 90° 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 mat rial selected must be of the same material an at least the same wall thickness as the origin tube. The clearance between inside diameter c the sleeve and the outside diameter of the orig inal tube may not exceed 1/16 inch. From thi outer sleeve tube material, cut diagonally (o fishmouth) 2 sections of tubing, each of suc length that the nearest end of the outer sleev is a minimum distance of 1 1/2-tube diameter from the end of the cut on the original tub Use a fishmouth sleeve wherever possible. Re move the burr from the edges of the sleeves replacement tube, and the original tube stubs Slip the two sleeves over the replacement tube aline the replacement tube with the origina tube stubs, and slip the sleeves out over th center of each joint. Adjust the sleeves to sui the area and to provide maximum reinforce ment. Tackweld the two sleeves to the replace ment tube in two places before welding. Apply a uniform weld around both ends of one of the reinforcement sleeves and allow the weld t cool; then, weld around both ends of the r

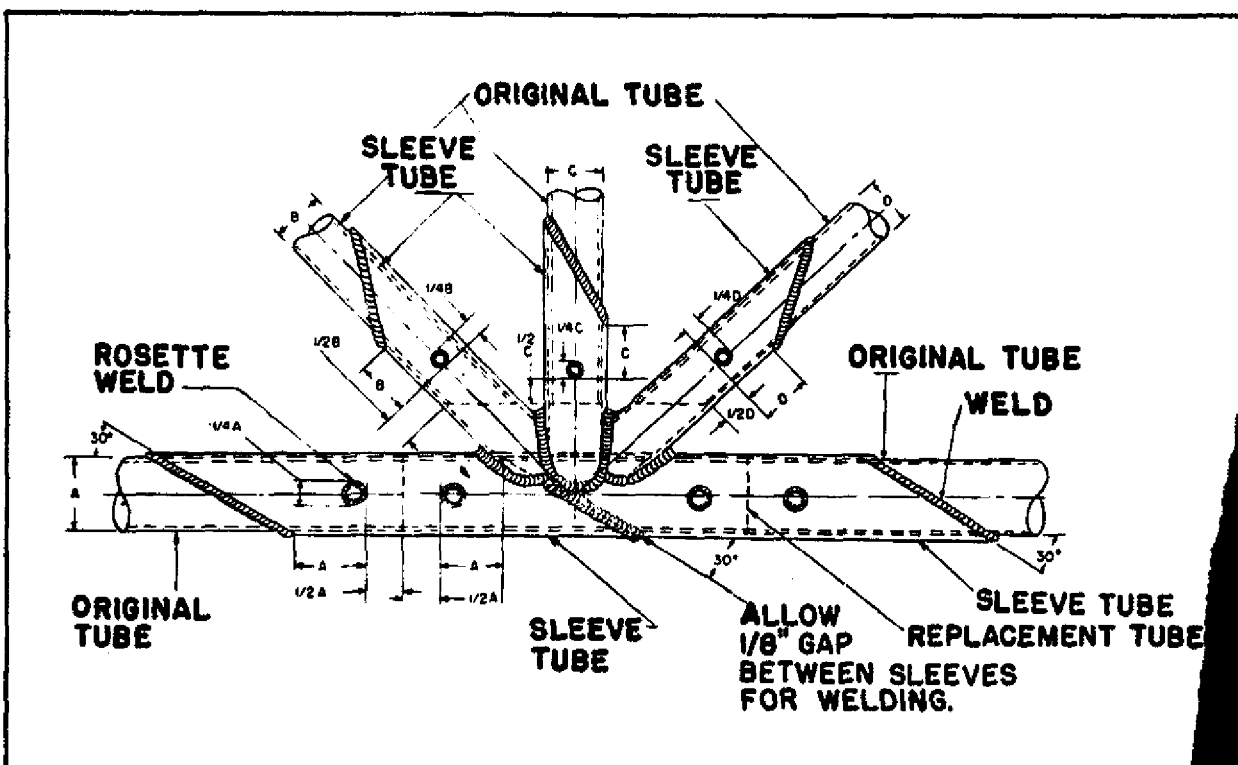


FIGURE 2.9.—Tube replacement at a station by welded outer sleeves.

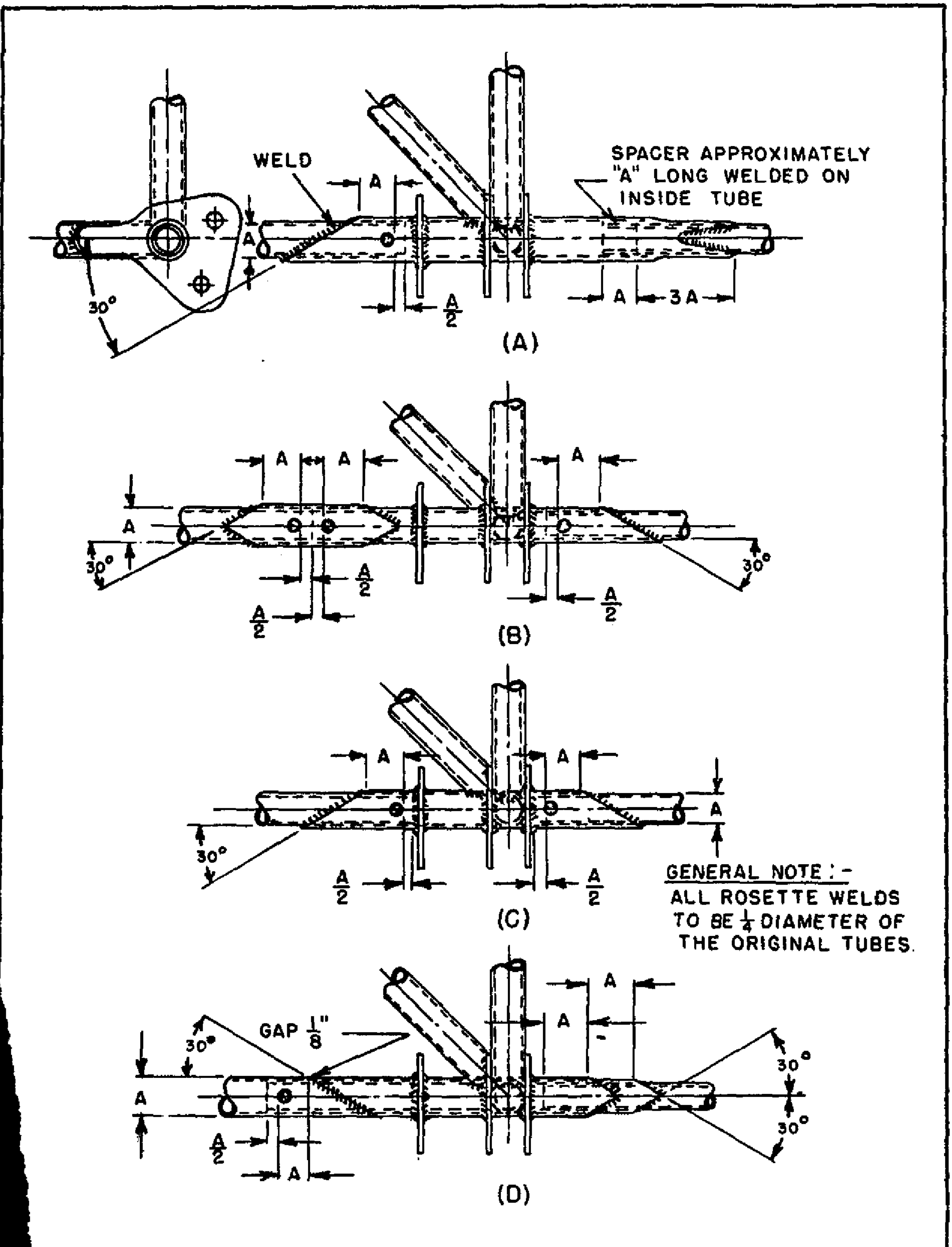
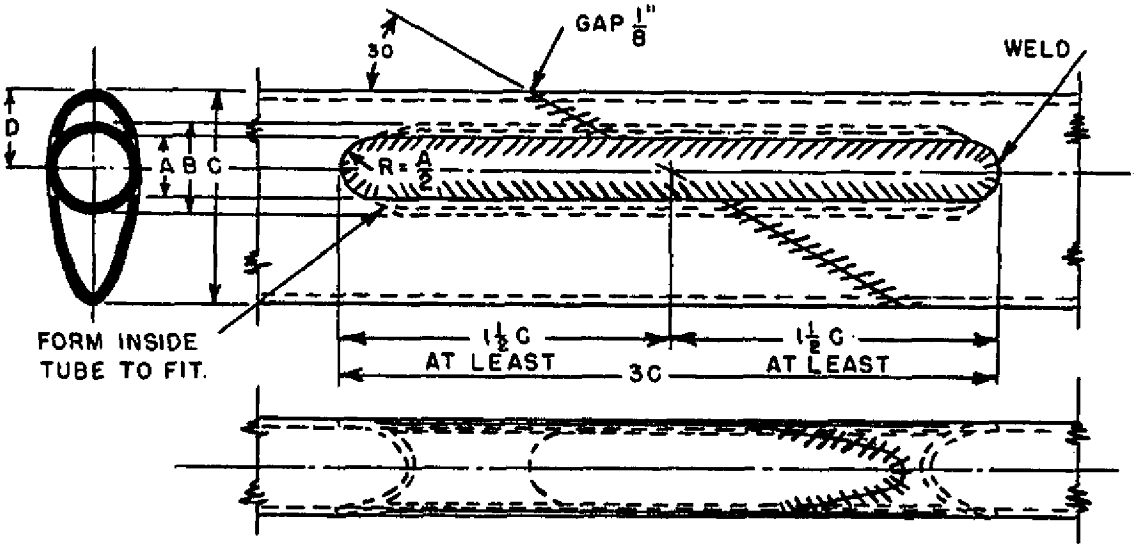


FIGURE 2.11.—Repairs at built-in fuselage fittings.

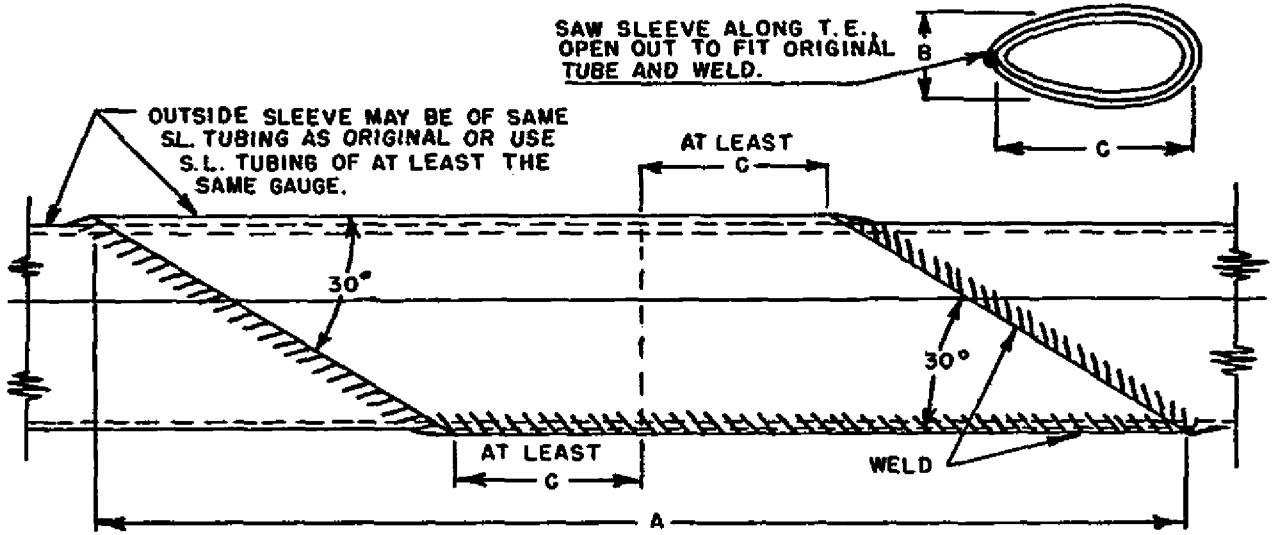


A - SLOT WIDTH (ORIGINAL TUBE)
B - OUTSIDE DIAMETER (INSERT TUBE)
C - STREAMLINE TUBE LENGTH OF MAJOR AXIS

S.L. SIZE	A	B	C	D
1"	3/8"	9/16"	1.340"	.496"
1-1/4	3/8	11/16	1.670	.619
1-1/2	1/2	7/8	2.005	.743
1-3/4	1/2	1	2.339	.867
2	1/2	1-1/8	2.670	.991
2-1/4	1/2	1-1/4	3.008	1.115
2-1/2	1/2	1-3/8	3.342	1.239

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

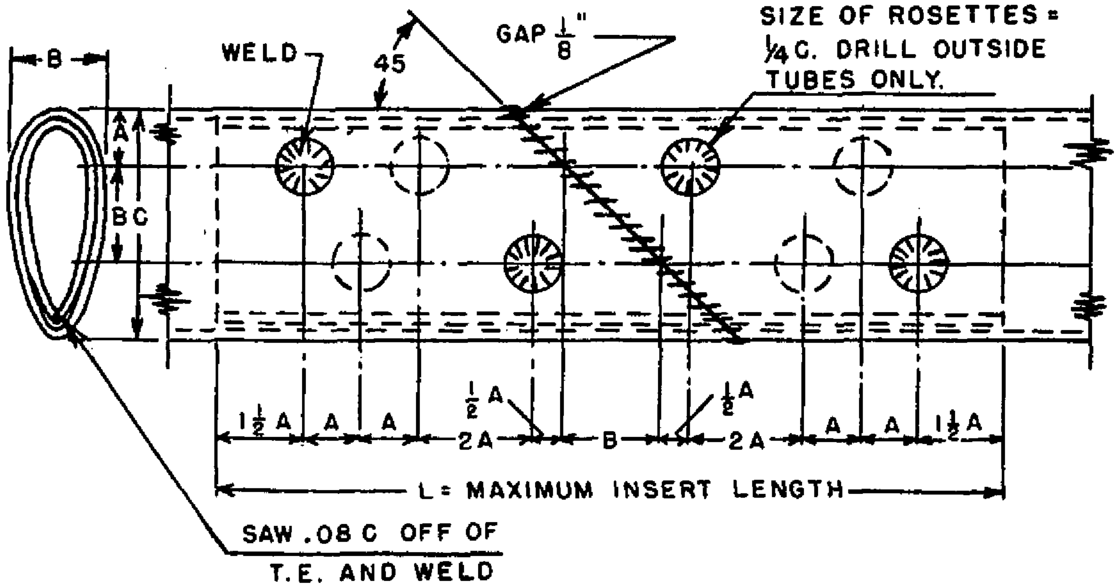
FIGURE 2.12.—Streamline tube splice using round tube (applicable to landing gears).



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"
1-1/4	9.128	.714	1.670
1-1/2	10.960	.858	2.005
1-3/4	12.784	1.000	2.339
2	14.594	1.144	2.670
2-1/4	16.442	1.286	3.008
2-1/2	18.268	1.430	3.342

FIGURE 2.13.—Streamline tube splice using split sleeve (applicable to wing and tail surface brace struts and other members).



INSERT TUBE IS OF SAME STREAMLINE TUBING AS ORIGINAL.

A IS $\frac{2}{3}$ 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	5.16
1 1/4	.476	.714	1.670	6.43
1 1/2	.572	.858	2.005	7.72
1 3/4	.667	1.000	2.339	9.00
2	.763	1.144	2.670	10.30
2 1/4	.858	1.286	3.008	11.58
2 1/2	.954	1.430	3.342	12.88

FIGURE 2.14.—Streamline tube splice using split insert (applicable to landing gears).

c. Axle Assemblies. Representative types of repairable and nonrepairable landing gear axle assemblies are shown in figure 2.16. 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 shown in figures 2.5 thru 2.15 in this Advisory Circular. However, it will always be necessary to ascertain whether or not the members are heat treated.

The axle assembly as shown in figure 2.16(D) 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 should be replaced if damaged.

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

. BUILT-UP TUBULAR WING OR TAIL SURFACE ARS. Repair built-up tubular wing or tail surce spars by using any of the applicable lices and methods of repair shown in figures 5 through 2.15 provided the spars are not eat-treated. In the case of heat-treated spars, e entire spar assembly would have to be reat-treated to the manufacturer's specificans after completion of the repair. In genal, this will be found less practicable than placing the spar with one furnished by the anufacturer.

WING AND TAIL BRACE STRUTS. In general, 'ill be found advantageous to replace dam- wing-brace struts made either from ded or streamlined tubing with new mem- purchased from the original manufac-. However, there is no objection from an rthiness point of view to repairing such ers in a proper manner. An acceptable d, in case streamlined tubing is used, will nd in figure 2.13. Repair similar mem- iade of round tubes using a standard as shown in figures 2.5, 2.7, or 2.8.

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 should be such as to 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.

(1) Fit and Alignment. When making repairs to wing and tail surface brace members, pay particular attention to proper fit and alinement to avoid distortion.

82. REPAIRS TO WELDED PARTS. Repairs to welded assemblies may be made by:

a. Replacing welded joints—cutting out the welded joint and replacing it with one properly gusseted, or

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

83. 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. Substitution of bolted or riveted connections for spot-welded joints are to be specifically approved by an authorized representative of the FAA.

a. Secondary Structural and Nonstructural Elements. Repair such elements 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 alloy of these metals. 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. Repair leaky spot-welded seams in boat hulls, fuel tanks, etc., in similar manner.

84.–94. RESERVED.

Section 3. METAL REPAIR PROCEDURES

95. RIVETED OR BOLTED STEEL TRUSS-TYPE STRUCTURES. Repairs to riveted or bolted steel truss-type structures should be made, employing the general principles outlined in the following paragraphs on aluminum alloy structures. Methods for repair of vital members should be specifically approved by a representative of the Federal Aviation Administration.

96. ALUMINUM ALLOY STRUCTURES. Extensive repairs to damaged stressed skin on monocoque types of aluminum alloy structures should preferably be made in accordance with specific recommendations of the manufacturer of the aircraft. In many cases, repair parts, joints, or reinforcements can be designed, and proof of ıdequate strength shown, without the calcula-ion of the design loads and stresses, by prop-rly considering the material and dimensions f the original parts and the riveted attach-ıents. Examples illustrating the principles of his method as applied to typical repairs are ;iven in this handbook, or may be found in extbooks on metal structures. An important oint to bear in mind in making repairs on ıonocoque structures is that a repaired part ıust be as strong as the original with respect o all types of loads and general rigidity.

a. Use of Annealed Alloys for Structural Parts. he use of annealed 2017 or 2024 for any ructural repair of an aircraft is not consid-ed satisfactory because of its poor corrosion-isting properties.

. Hygroscopic Materials Improperly Moisture-fed. The use of hygroscopic materials im-erly moisture-proofed, such as impreg-d fabrics, or leather, and the like, to effect r-tight joints and seams is not an accepta-actice.

rilling Oversized Holes. Avoid drilling zed holes or otherwise decreasing the effective tensile areas of wing-spar capstrips, wing, fuselage, or fin longitudinal stringers, or other highly stressed tensile members. Make all repairs or reinforcements to such members in accordance with factory recommendations or with the specific approval or a representative of the Federal Aviation Administration.

d. Disassembly Prior to Repairing. If the parts to be removed are essential to the rigidity of the complete structure, support the remaining structure prior to disassembly in such a manner as to prevent distortion and permanent damage to the remainder of the structure. When rivets are to be removed, weaken the rivet head by drilling. Use a drill of the same size as the rivet. Drilling must be exact center and to the base of the head only. After drilling, break off the head with a pin punch and carefully drive out the shank. Removal of rivet heads with a cold chisel and hammer is not recommended because skin damage and distorted rivet holes will probably result. Care must also be taken whenever screws must be removed for disassembly or removal of stress plates, access plates, fillets, etc., 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 being 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 screw by drilling and use of a screw extractor. Structural cracks may appear in the doubler or tang that runs parallel to the line of anchor or plate nuts installed for securing access doors or plates. Inspect rivet joints adjacent to damaged structure for partial failure (slippage) by removing one or more rivets to see if holes are elongated or the rivets have started to shear.

97. SELECTION OF ALUMINUM FOR REPLACEMENT PARTS. In selecting the alloy, it is usually satisfactory to use 2024 in place of 2017 since the former is stronger. Hence, it will not be permissible to replace 2024 by 2017 unless the deficiency in strength of the latter material is compensated by an increase in material thickness, or the structural strength is substantiated by tests or analysis. Information on the comparative strength properties of these alloys, as well as 2014, 6061, 7075, etc., is contained in MIL–HDBK–5, *Metallic Materials and Elements for Flight Vehicle Structure.* 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 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.

a. ***Forming Sheet Metal Parts.*** Bend lines should preferably be made to lie at an angle to the grain of the metal (preferably 90°). 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. For material in the heat-treated condition, the bend radius should be large. (See figure 2.17 for recommended bend radii.)

FIGURE 2.17.—Recommended radii for 90° bends in aluminum alloys.

Alloy and temper	Approximate sheet thickness (t) (inch)					
	0.016	0.032	0.064	0.128	0.182	0.258
2024–0 [1]	0	0–1t	0–1t	0–1t	0–1t	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 slight smaller radii than the corresponding tempers of uncoated alloy.
[2] Immediately after quenching, this alloy may be formed over appreciably smaller radii.

98. HEAT TREATMENT OF ALUMINUM ALLOY PARTS. All structural aluminum alloy parts are to be heat-treated in accordance with the heat-treatment instructions issued by the manufacturers of the materials. If the heat-treatment produces warping, straighten the parts immediately after quenching. Heat-treat riveted parts before riveting, to preclude warping and corrosion. When riveted assemblies are heated in a salt bath, the salt cannot be entirely washed out of the crevices, thus causing cor sion.

a. ***Quenching in Hot Water or Air.*** Quench terial from the solution heat-treating temp ture as rapidly as possible, with a mini delay after removal from the furnace. Qu ing in cold water is preferred, although drastic chilling (hot or boiling water blast) is sometimes employed for bulk tions, such as forgings, to minimize quenching stresses.

b. ***Transferring Too Slowly From Heat-Treatment Medium to Quench Tank.*** Transfer of 2017 alloys from the heat-treatment medium to the quenchtank should be accomplished as quickly as possible. An elapsed time of 10 to 15 seconds will, in many cases, result in noticeably impaired corrosion resistance.

c. ***Reheating at Temperatures Above Boiling Water.*** Reheating of 2017 and 2024 alloys at temperatures above that of boiling water after heat treatment, and the baking of primers at temperatures above that of boiling water, will not be considered acceptable without subsequent complete and correct heat treatment, as such practice tends to impair the original heat treatment.

99. RIVETING.

a. ***Identification of Rivet Material.*** Identification of rivet material is contained in Chapter 5.

b. ***Replacement of Aluminum Alloy Rivets.*** All rotruding head rivets (roundhead, flathead, nd brazier head) may be replaced by rivets of he same type or by AN-470 Universal head ivets. Use flushhead rivets to replace flushead rivets.

c. ***Replacement Rivet Size and Strength.*** Relace rivets with those of the same size and trength whenever possible. If the rivet hole ecomes enlarged, deformed, or otherwise damged, drill or ream the hole for the next large ize rivet; however, make sure that the edge stance and spacings are not less than miniums listed in the next paragraph. Rivets may be replaced by a type having lower ngth properties, unless the lower strength dequately compensated by an increase in or a greater number of rivets.

Replacement Rivet-Edge Distances and ngs for Sheet Joints. Rivet-edge distance is d as the distance from the center of the hole to the nearest edge of the sheet. spacing is the distance from the center rivet hole to the center of the adjacent rivet hole. The following prescribes the minimum edge distance and spacing:

(1) **Single row**—edge distance not less than 2 times the diameter of the rivet and spacing not less than 3 times the diameter of the rivet.

(2) **Double row**—edge distance and spacing not less than the minimums shown in figure 2.18.

(3) **Triple or multiple rows**—edge distance and spacing not less than the minimums shown in figure 2.18.

e. ***Use of 2117-T3 Aluminum Alloy Replacement Rivets.*** It is acceptable to replace 2017-T3 rivets of 3/16-inch diameter or less, and 2024-T4 rivets of 5/32-inch diameter or less with 2117-T3 rivets for general repairs, provided the replacement rivets are 1/32 inch greater in diameter than the rivets they replace and the edge distances and spacing are not less than the minimums listed in the preceding paragraph.

f. ***Driving of Rivets.*** 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 either 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 flat rivet heads are shown in figure 2.19, together with commonly found rivet imperfections.

g. ***Blind-Type and Hollow Rivets.*** Do not substitute hollow rivets for solid rivets in load-carrying members without specific approval of the application by a representative of the Federal Aviation Administration.

Blind rivets may be used in blind locations in accordance with the conditions listed in Chapter 5, provided the edge distances and spacings are not less than the minimum listed in paragraph 99d.

h. ***New and Revised Rivet Patterns.*** Design a new or revised rivet pattern for the strength required in accordance with the specific instructions in paragraphs 100e and 100j.

A general rule for the diameter of rivets used to join dural sheets is to use a diameter ap-

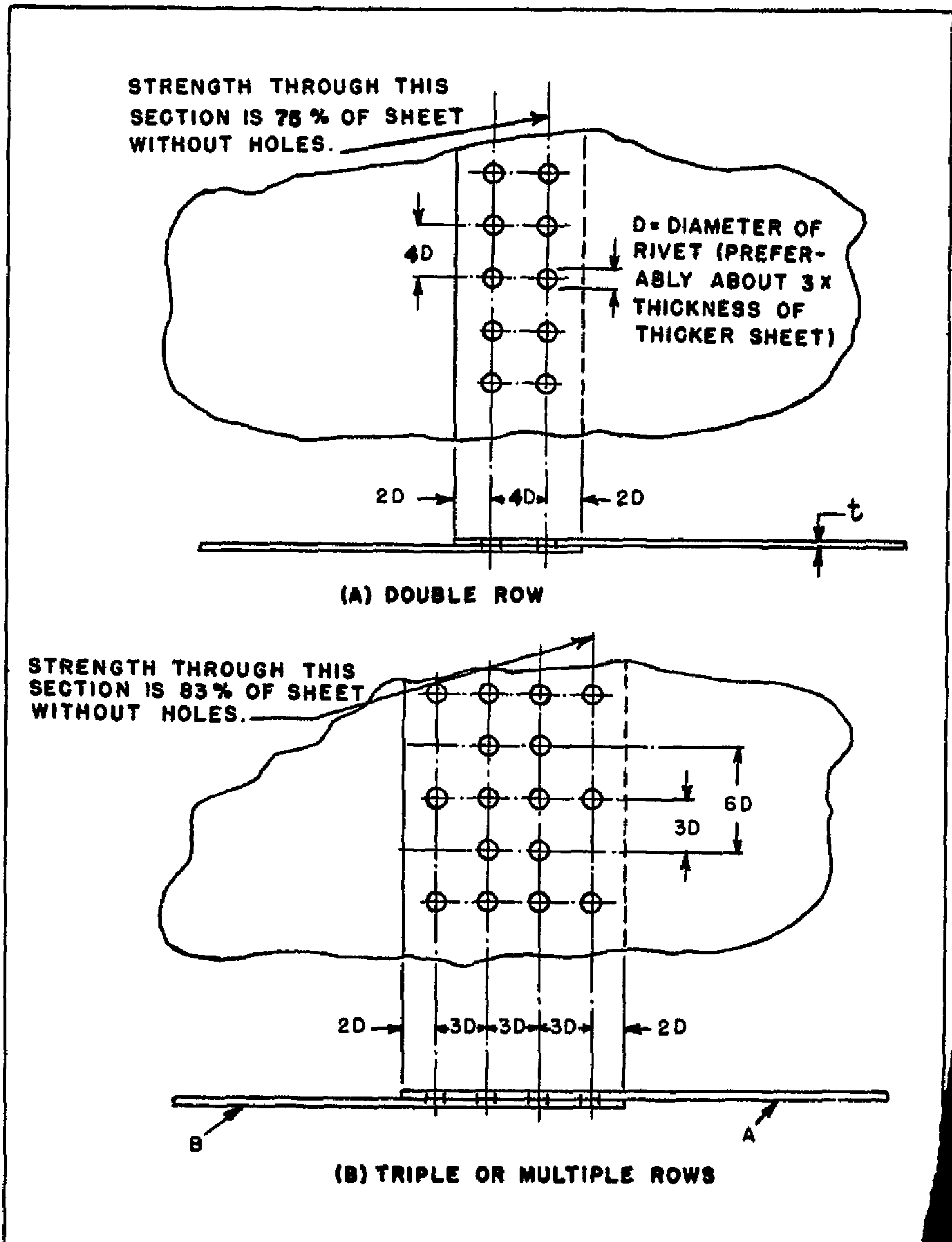


FIGURE 2.18.—Rivet hole spacing and edge distance for single-lap sheet splices.

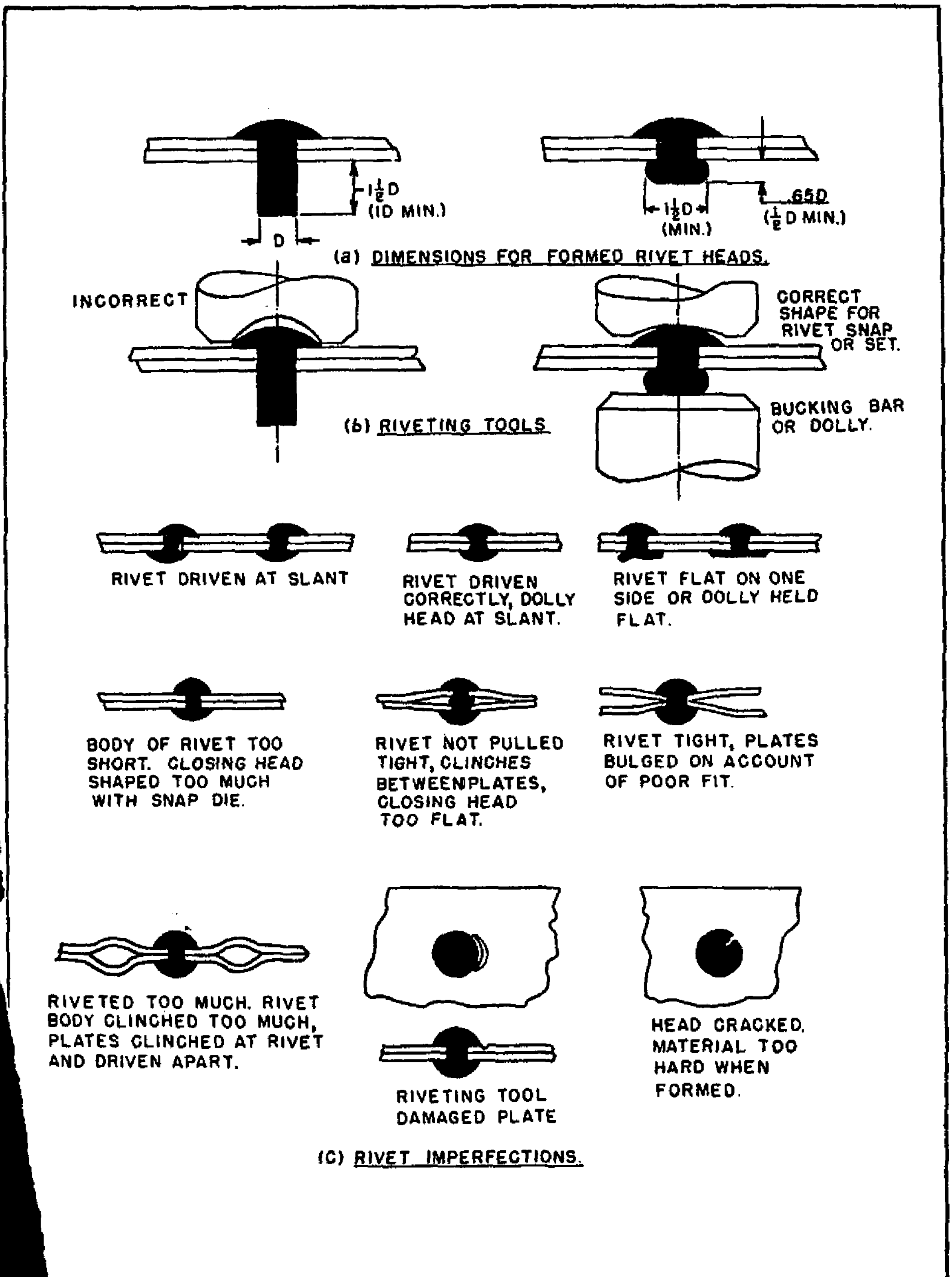


FIGURE 2.19.—Riveting practice and rivet imperfections.

proximately 8 times the thickness of the thicker sheet. Do not use rivets where they would be placed in tension tending to pull the heads off. Back up a lap joint of thin sheets by a stiffening section.

100. REPAIR METHODS AND PRECAUTIONS FOR ALUMINUM STRUCTURE. Carefully examine all adjacent rivets after the repair or alteration is finished to ascertain that they have not been harmed by operations in adjacent areas.

Drill rivet holes round, straight, and free from cracks. The rivet-set used in driving the rivets must be cupped slightly flatter than the rivethead as shown in figure 2.19. 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 tubular members may be repaired by splicing as shown in figure 2.20. 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. Satisfactory rivetheads may be produced in such installations by spinning, if the proper equipment is available. (Correct and incorrect examples of this type of rivet applications are incorporated in figure 2.20.)

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 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; hence, 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 sheetmetal 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 2.21 and 2.22.) These examples deal with types of ribs commonly found in small and medium aircraft. Repair schemes developed by the aircraft manufacturer are acceptable, and any other methods of reinforcement will be specifically approved by a representative of the FAA.

(1) Trailing and Leading Edges and Tip Strips Repairs to wing and control surface trailin and leading edges and tip strips should b made by properly executed and reinforce splices. Acceptable methods of trailing edge r pairs are shown in figure 2.23.

d. Repair of Damaged Skin. In case metal ski is damaged extensively, make repairs replacin an entire sheet panel from one structural mem ber to the next. The repair seams are to along stiffening members, bulkheads, etc., a each seam must be made exactly the same i regard to rivet size, splicing, and rivet patter as the manufactured seams at the edges of th original sheet. If the two manufactured sea are different, the stronger one will be copi (See figure 2.24 for typical acceptable meth of repairs.)

(1) Patching of Small Holes. Small hole skin panels which do not involve damage to stiffening members may be patched by c ing the hole with a patch plate in the ma shown in figure 2.24.

Flush patches also may be install stressed skin-type construction. An acce and easy flush patch may be made by tri *maining reinforcement tube.* Allow one sleeve weld to cool before welding the remaining tube to prevent undue warping.

76. SPLICING USING LARGER DIAMETER REPLACEMENT TUBES. The method of splicing structural tubes, as shown in figure 2.10, 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 in 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 about 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. Remove the burr from 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. Spring the long stub of the original tube from the normal position, slip the replacement tube over the long stub, then back over the short stub. Center the replacement tube between the stubs of the original tube. In several places tack-weld one end of the replacement tube, 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.

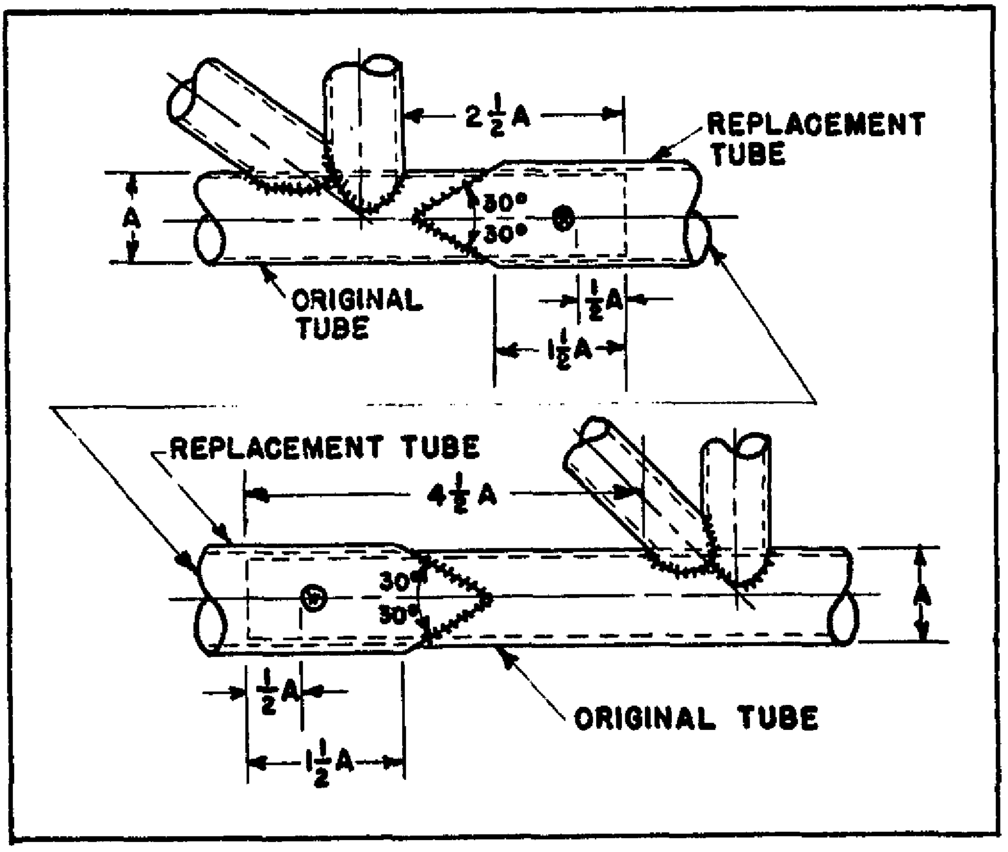


FIGURE 2.10.—Splicing using larger diameter replacement tube.

77. REPAIRS AT BUILT-IN FUSELAGE FITTINGS. Make splices in accordance with the methods described in paragraphs 70 through 75. Repair built-in fuselage fittings in the manner shown in figure 2.11. The following paragraphs outline the different methods as shown in the figure:

a. *Tube of Larger Diameter Than Original.* A tube (sleeve) of larger diameter than original is used in the method shown in figure 2.11(A). This necessitates reaming the fitting holes (at longeron) to a large diameter. The forward splice is to be a 30° scarf splice. Cut the rear longeron (right) approximately 4 inches from the centerline of the joint and a spacer 1 inch long fitted over the longeron. 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 2.11(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° and forms the outside sleeve of the scarf splice. A sleeve is centered over the forward joint as indicated.

c. *Simple Sleeve.* It is assumed the longeron is the same size on each side of the fitting in this case, figure 2.11(C), and it is repaired by a simple sleeve of larger diameter than the longeron.

d. *Large Difference in Longeron Diameter Each Side of Fitting.* Figure 2.11(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°, 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° to fit the 30° scarf at left and the other end fishmouthed as shown. This makes it possible to insert a tube of such diameter as 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.

78. ENGINE MOUNT REPAIRS. All welding on a engine mount should be of the highest qualit since vibration tends to accentuate any minc defect. Engine-mount members should prefera bly be repaired by using a larger diameter re placement tube telescoped over the stub of th original member and using fishmouth and ro sette welds. However, 30° scarf welds in plac of the fishmouth welds will be considered ac ceptable for engine-mount repair work.

a. *Check of Alignment.* Repaired engin mounts must be checked for accurate align ment. When tubes are used to replace bent o damaged ones, the original alignment of th structure must be maintained. This can b done by measuring the distance betwee points of corresponding members that have no been distorted, and by reference to the manu facturer's drawings.

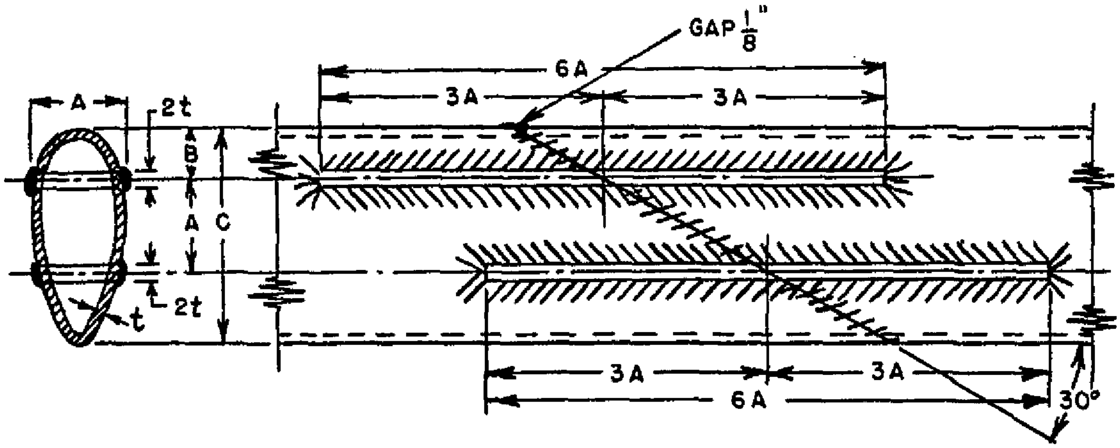
b. *Cause for Rejection.* If all members are out of alinement, reject the engine mount and re place by one supplied by the manufacturer o one which was built to conform to the man facturer's drawings. The method of checki the alignment of the fuselage or nacelle poi should be requested from the manufacturer.

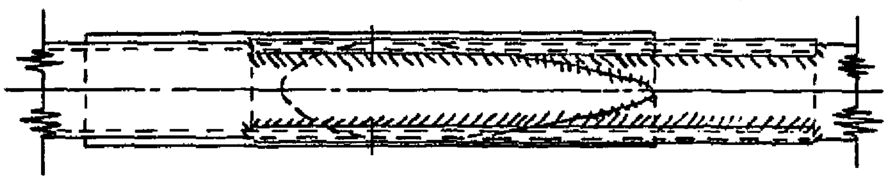
c. *Engine Mount Ring Damage.* Repair min damage, such as a crack adjacent to an engi attachment lug, by rewelding the ring and e tending a gusset or a mounting lug past t damaged area. Engine mount rings which a extensively damaged must not be repaired, u less the method of repair is specifically a proved by an authorized representative of t FAA, or the repair is accomplished in acco ance with FAA approved instructions f nished by the aircraft manufacturer.

79. LANDING GEAR REPAIR.

a. *Round Tube Construction.* Repair la gears made of round tubing using standa pairs and splices as shown in figures 2. 2.11.

b. *Streamline Tube Construction.* Repai ing gears made of streamlined tubing by one of the methods shown in figures 2. 2.15.





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	3.43
1-1/4	.714	.476	1.670	4.28
1-1/2	.858	.572	2.005	5.15
1-3/4	1.000	.667	2.339	6.00
2	1.144	.762	2.670	6.86
2-1/4	1.286	.858	3.008	7.72
2-1/2	1.430	.954	3.342	8.58

FIGURE 2.15.—Streamline tube splice using plates (applicable to landing gears).

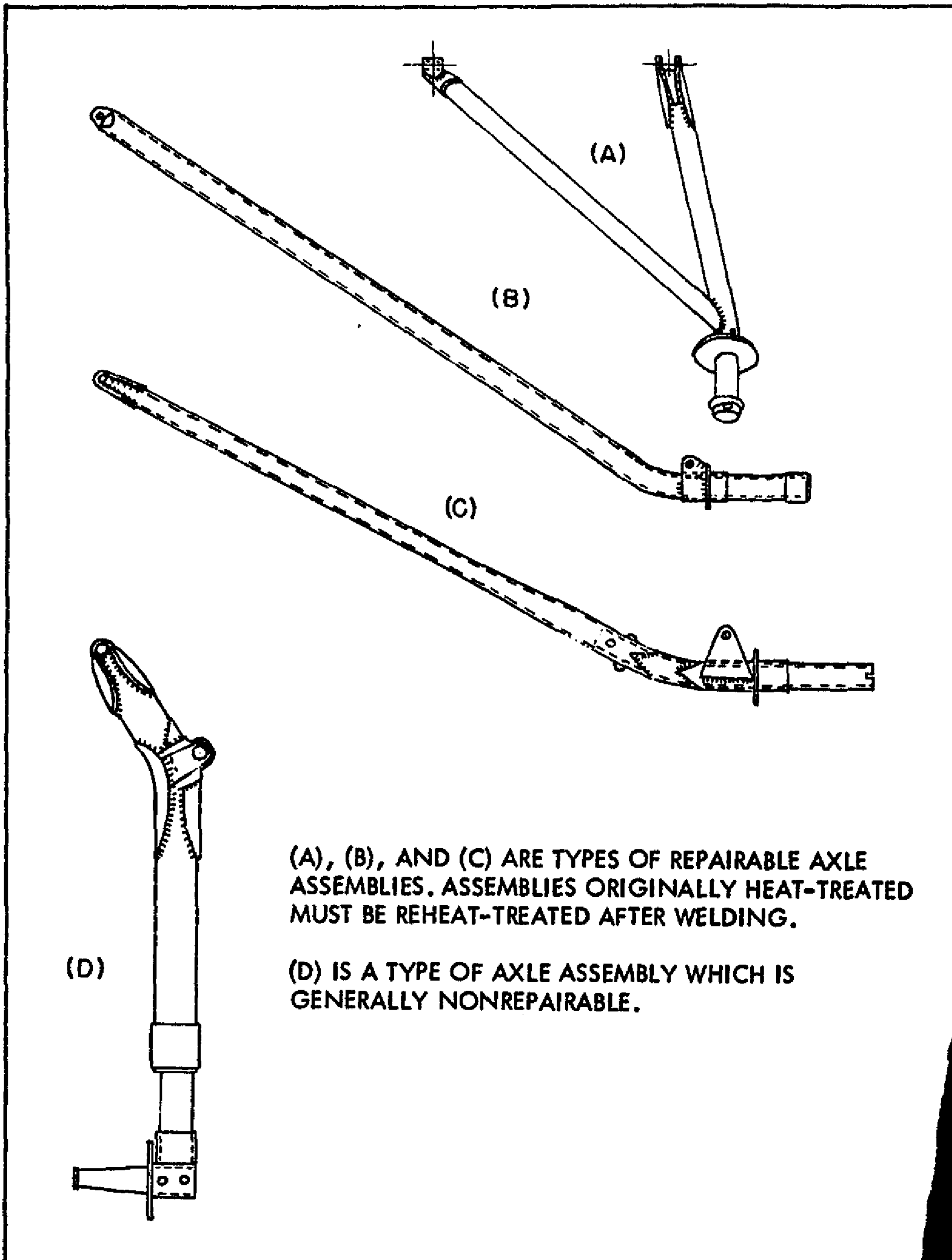
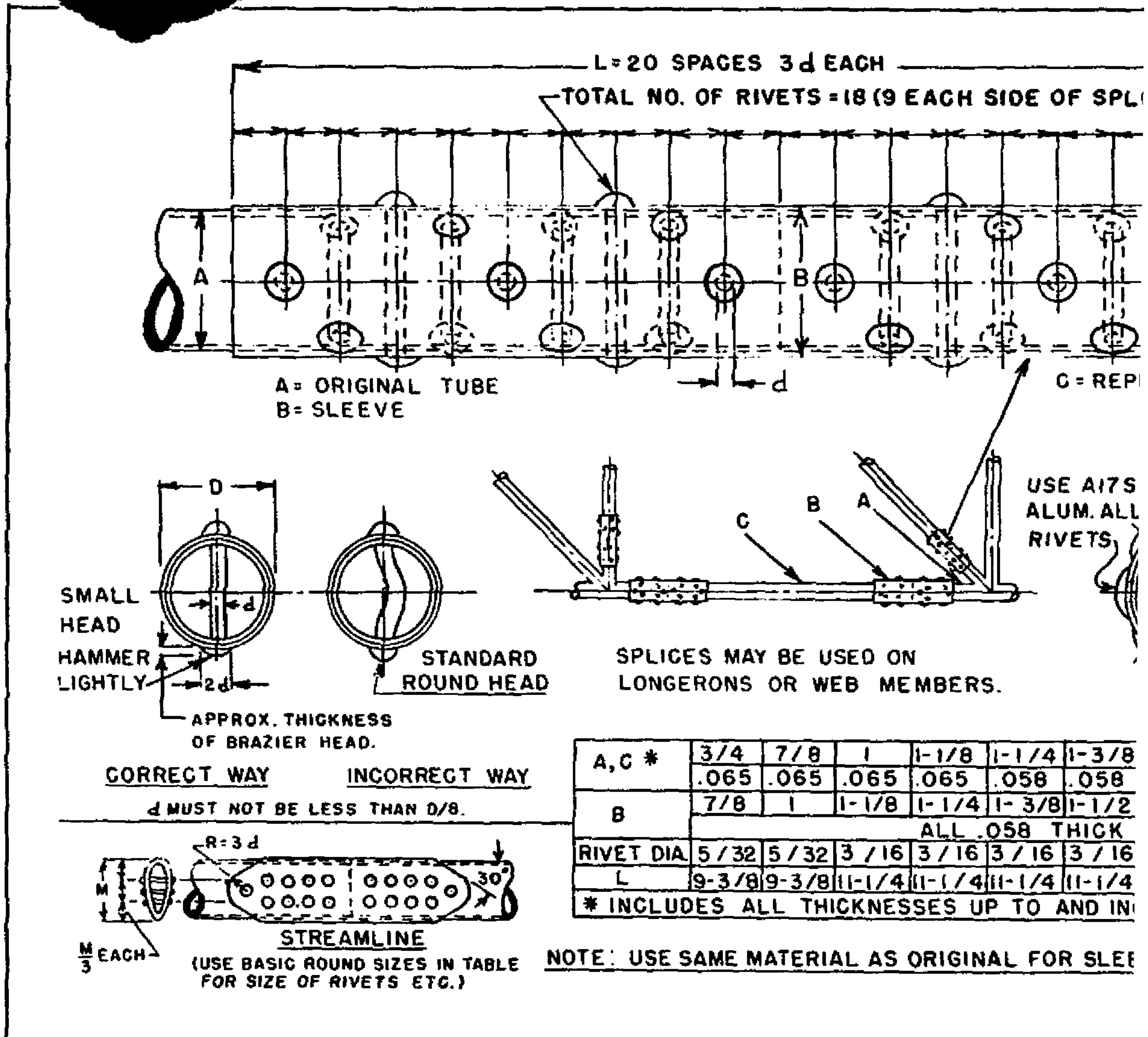


FIGURE 2.16.—Representative types of repairable and nonrepairable axle assemblies.



A, C *	3/4	7/8	1	1-1/8	1-1/4	1-3/8
	.065	.065	.065	.065	.058	.058
B	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2
	ALL .058 THICK					
RIVET DIA	5/32	5/32	3/16	3/16	3/16	3/16
L	9-3/8	9-3/8	11-1/4	11-1/4	11-1/4	11-1/4

* INCLUDES ALL THICKNESSES UP TO AND IN

Figure 2.20.—Typical repair method for tubular members of aluminum allo

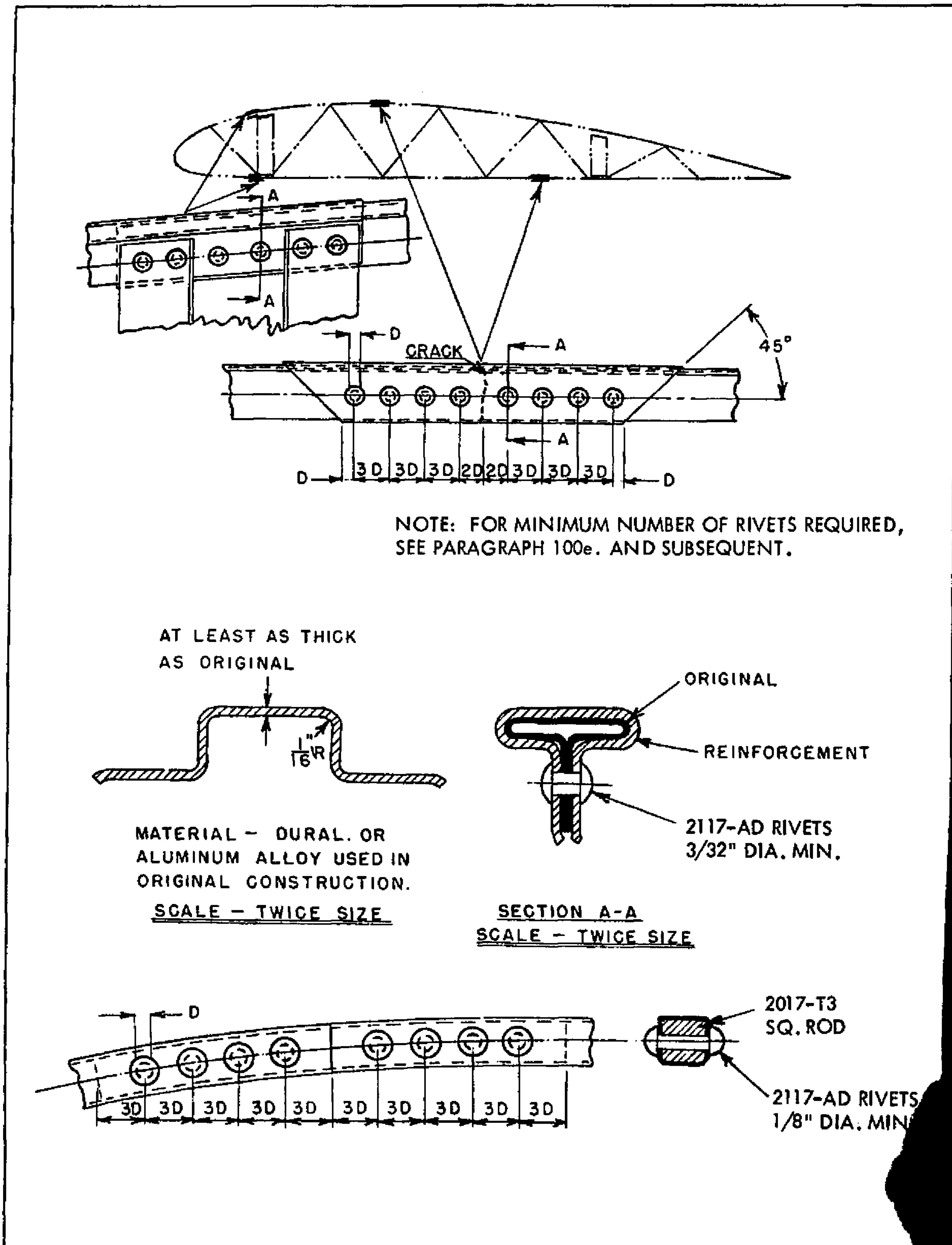


FIGURE 2.21.—Typical repair for buckled or cracked formed metal wing rib capstrips.

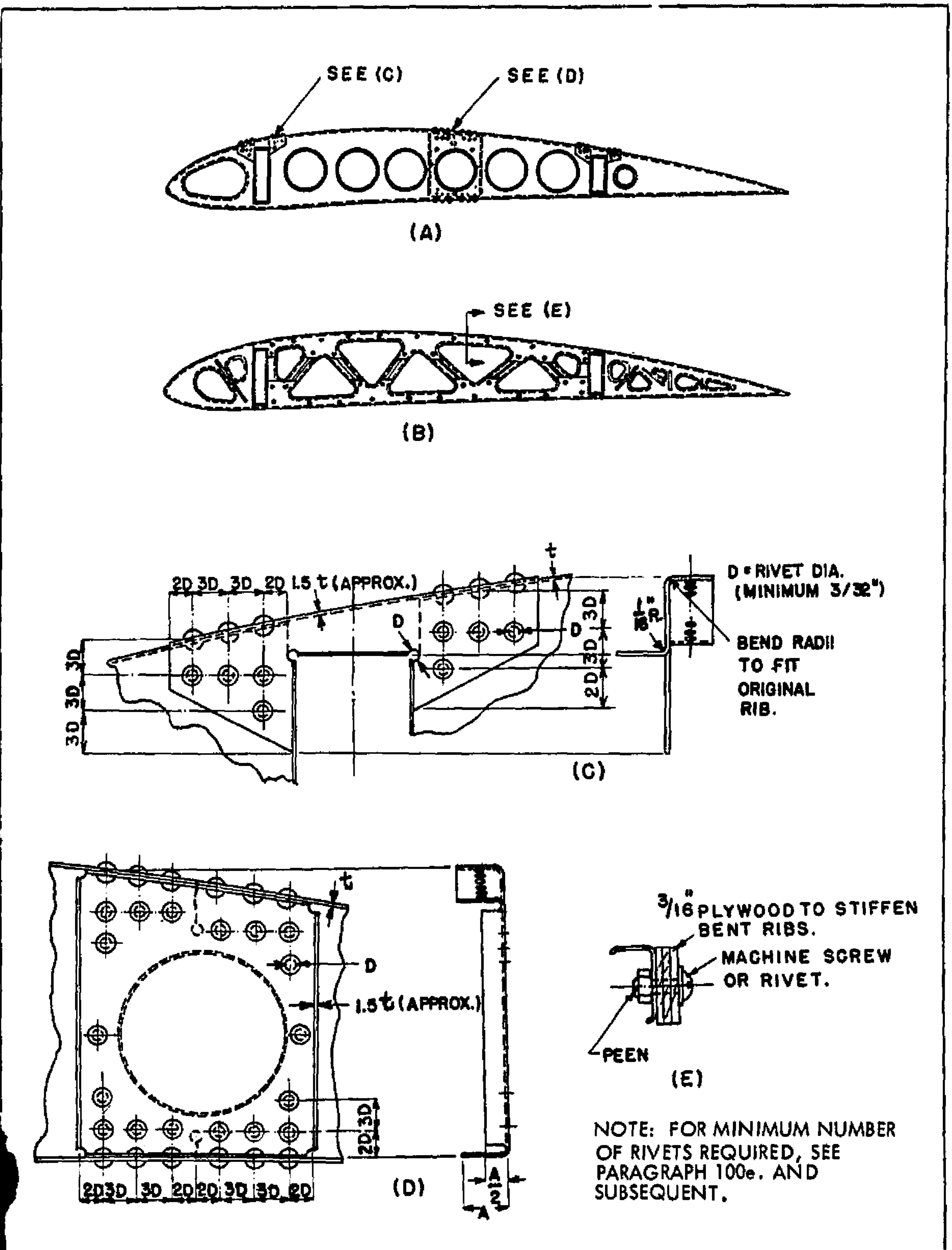


FIGURE 2.22.—Typical metal rib repairs (usually found on small and medium-size aircraft).

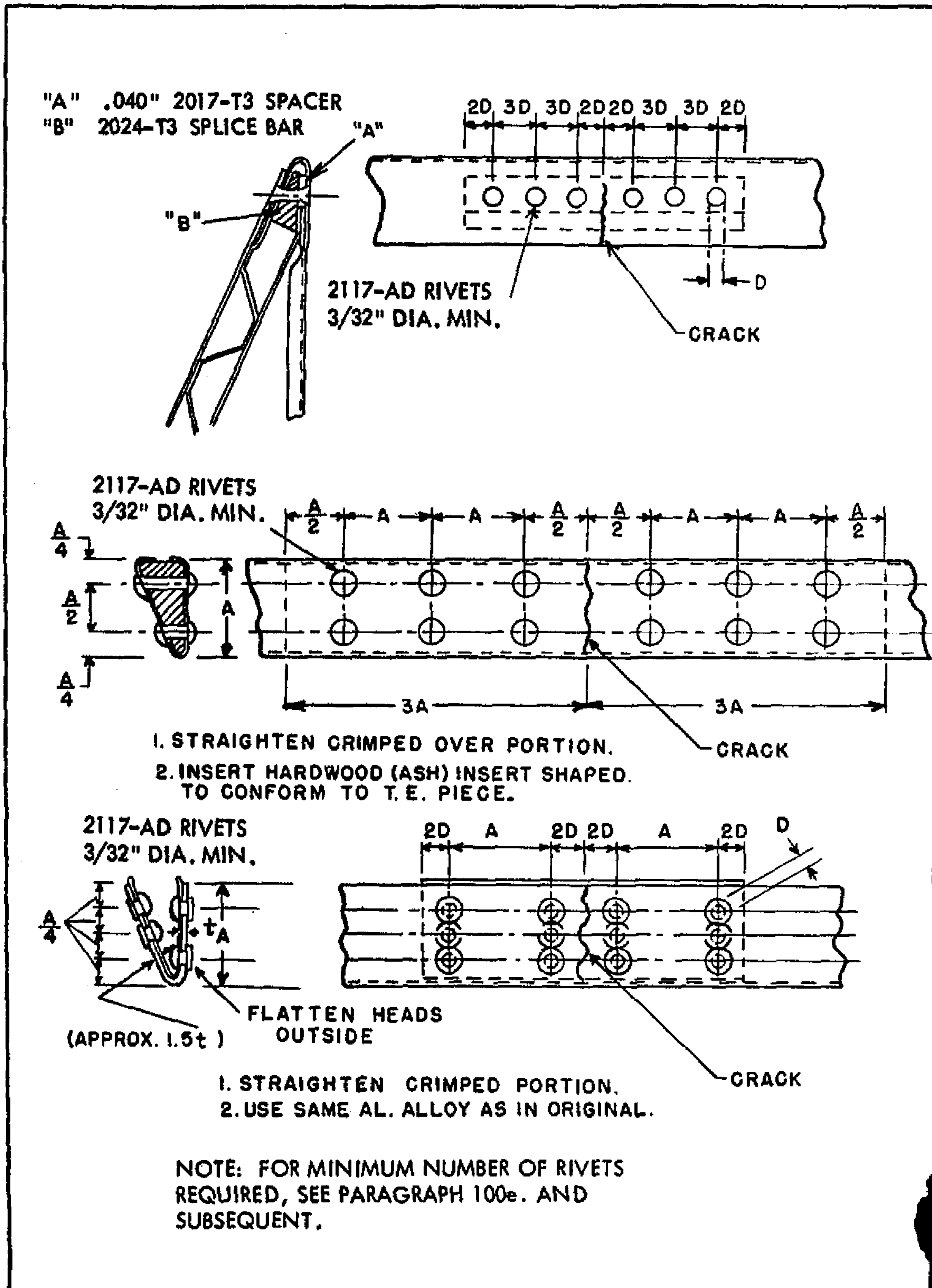
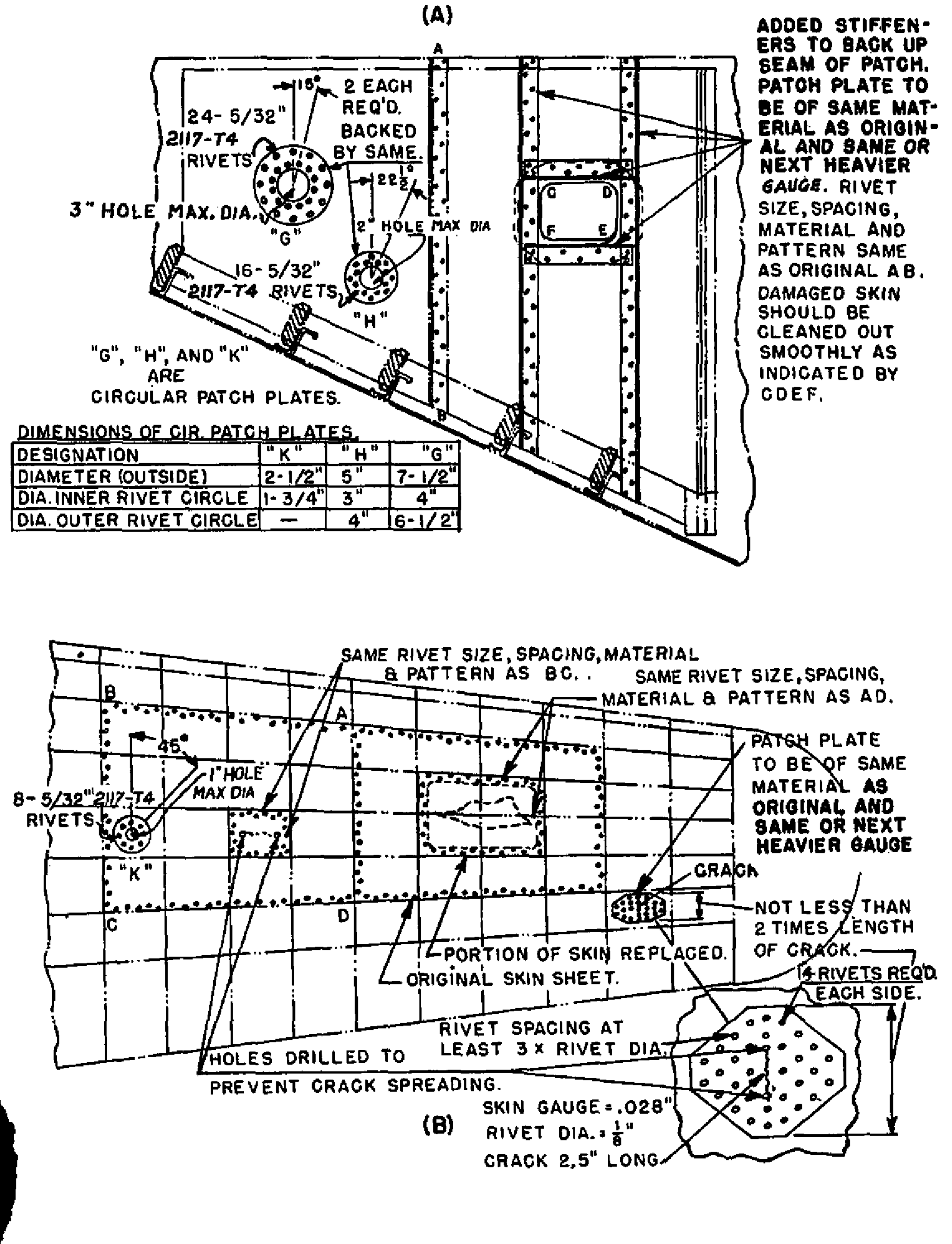


FIGURE 2.28.—Typical repairs of trailing edges.



DIMENSIONS OF CIR. PATCH PLATES.

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

FIGURE 2.24—Typical repairs of stressed sheet metal covering.

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 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 (ref. Chapter 1). The riveting pattern used, however, must follow standard practice to maintain satisfactory strength in the sheet.

In general, patches in metal skin are not restricted as to size or shape; however, those of rectangular, circular, square, oval, and rectangular with round ends usually are more desirable because of appearance and ease of installation.

e. *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 2.18.

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

(b) Use the number of rivets required per inch of width "W" from figure 2.29. (Number per inch 4.9 × .75 = 3.7 or the total number of rivets required = 10 × 3.7 or 37 rivets.)

(c) Lay out rivet pattern with spacing not less than shown in figure 2.18. Referring to figure 2.18(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 the 10 inches will result in a satisfactory splice.

f. *Straightening of Stringers or Intermediate Frames.* Members which are slightly bent may be straightened cold and examined with a magnifying glass for injury to the material. Rein force the straightened parts to an extent, de pending upon the condition of the material an the magnitude of any remaining kinks or buc kles. If any strain cracks are apparent, mak complete reinforcement in sound metal beyon the damaged portion.

(1) *Local Heating.* Do not apply local heat ing to facilitate bending, swaging, flattening or expanding operations of heat-treated alumi num alloy members, as it is difficult to contro the temperatures closely enough to preven possible damage to the metal, and it may im pair its corrosion resistance.

g. *Splicing of Stringers and Flanges.* Make splices in accordance with the manufacturer's recommendations, which are usually contained in a repair manual.

Typical splices for various shapes of sections are shown in figures 2.25 and 2.26. Design splices to carry both tension and compression, and use the splice shown in figure 2.26 as an ex ample illustrating the following principles:

(1) *Statement of Principles:*

(a) To avoid eccentric loading and conse quent buckling in compression, place splicin or reinforcing parts as symmetrically as pos ble about the centerline of the member, and a tach to as many elements as necessary to pr vent bending in any direction;

(b) To avoid reducing the strength tension of the original bulb angle the riv holes at the ends of the splice are made sma (no larger than the original skin attaching riv ets), and the second row of holes (thos through the bulbed leg) are staggered b from the ends. In general arrange the rivet the splice so that the design tensile load for member and spliceplate can be carried int splice without failing the member at the most rivet holes;

(c) To avoid concentration of loa end rivet and consequent tendency tow gressive rivet failure, the splice is ta the ends, in this case, by tapering the angle and by making it shorter than th bar (ref. figure 2.26); and

(d) The preceding principles are

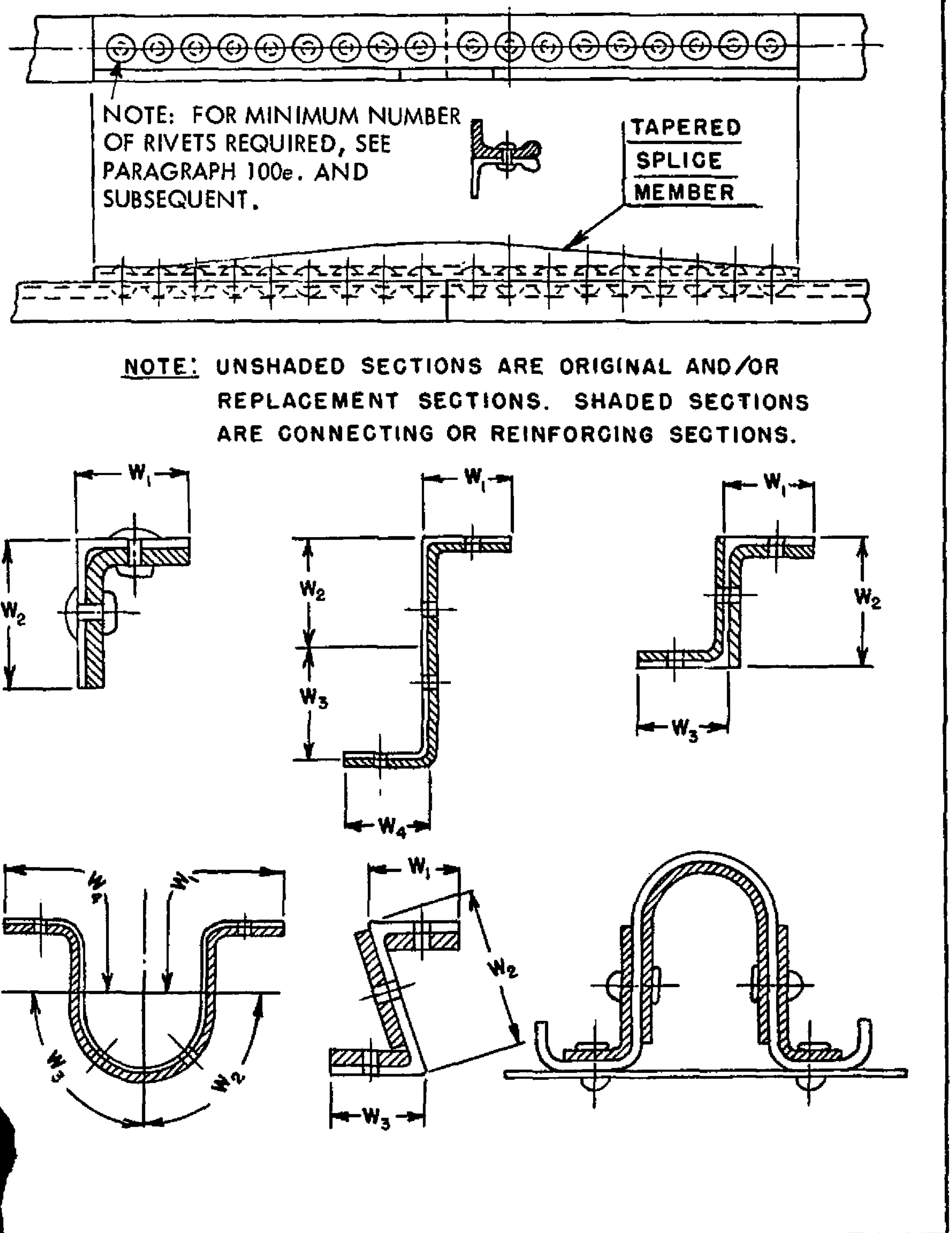


FIGURE 2.25.—Typical stringer and flange splices.

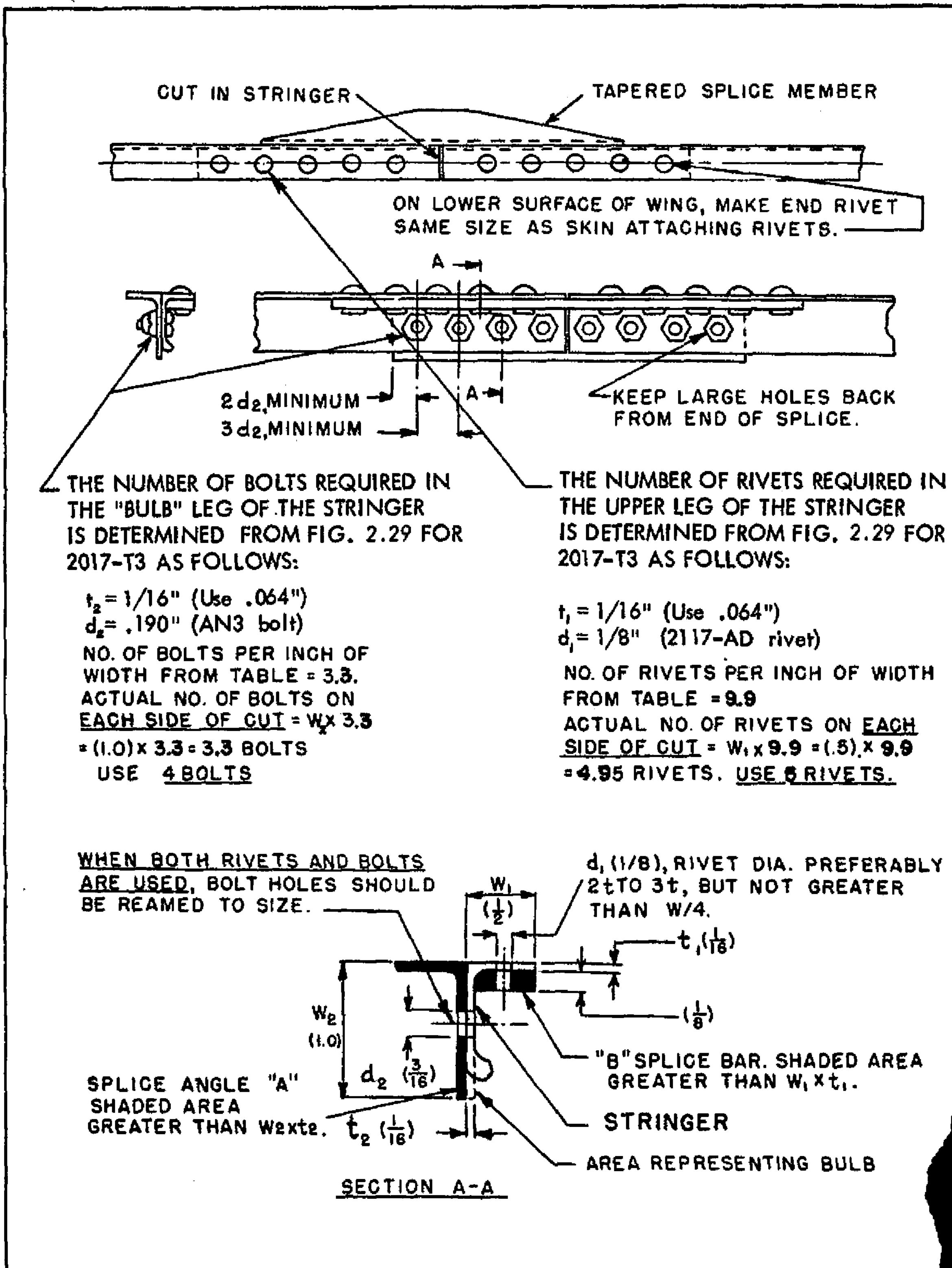


Figure 2.26.—Example of stringer splice (material—2017 alloy).

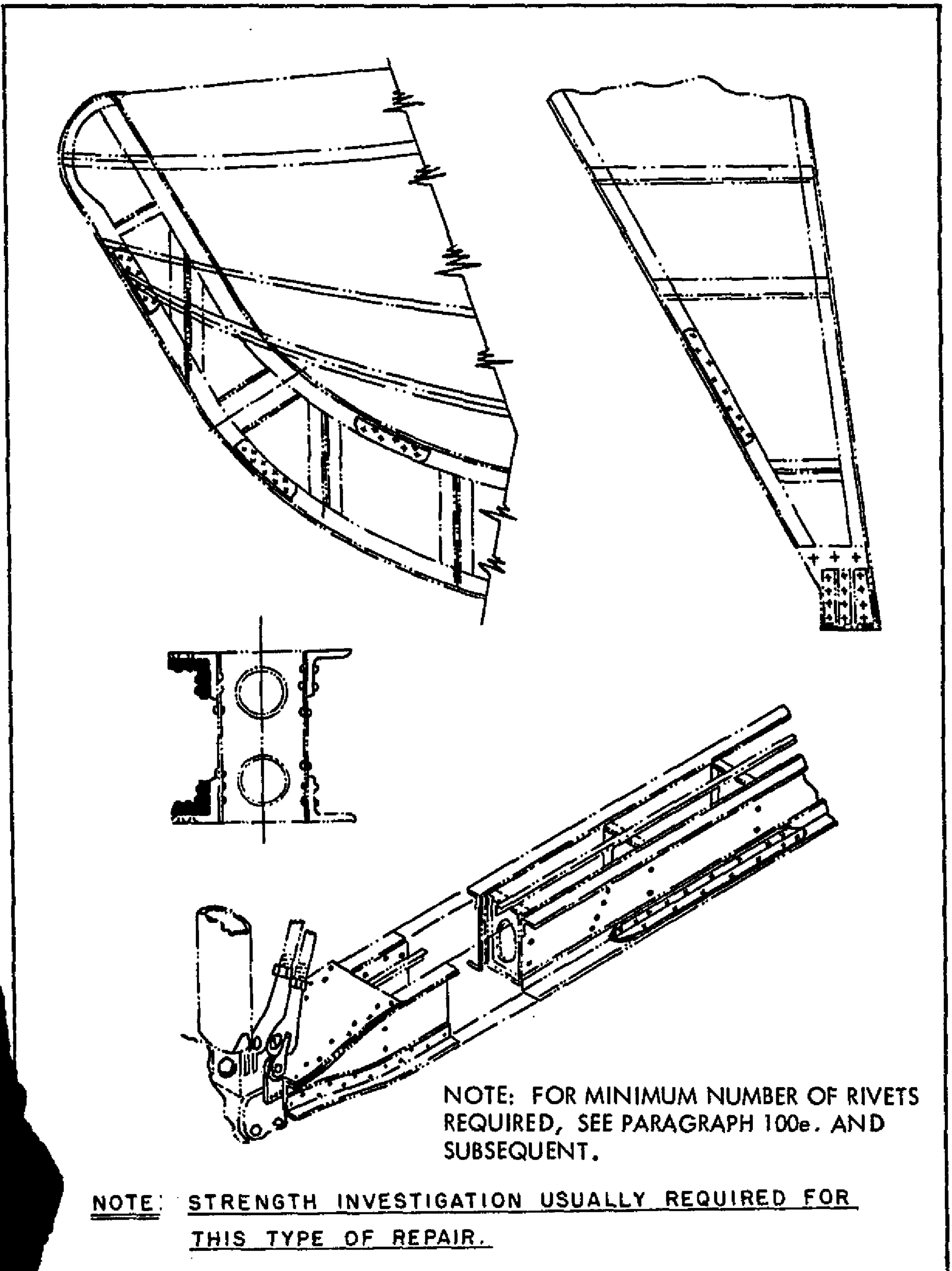


FIGURE 2.27.—Application of typical flange splices and reinforcement.

cially 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.

h. *Size of Splicing Members.* When the same material is used for the splicing members as for the original member, the next cross-section area (i.e., the shaded areas in figure 2.25) of the splicing member 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 2.26 is assumed to splice the upper leg of the stringer, and the angle "A" to splice the bulbed leg of the stringer. Since the splice bar "B" is not as wide as the adjac leg, and since the rivet diameter is also su tracted from the width, the bar is made tw as thick in order to obtain sufficient net area.

i. *The Diameter of Rivets in Stringers.* The ameter of rivets in stringers might preferal be between 2 and 3 times the thickness "t" the leg, but must not be more than 1/4 t width "W" of the leg. Thus, 1/8-inch rivets a chosen in the example, figure 2.26. If t splices were in the lower surface of a wing, t end rivets would be made the same size as t skin-attaching rivets or 3/32 inch.

j. *The Number of Rivets.* The number of rive required on each side of the cut in a stringer flange may be determined from standard tex

FIGURE 2.28.—Number of rivets required for splices (single-lap joint) in bare 2014–T6, 2024–T3, 2024–T36, a 7075–T6 sheet, clad 2014–T6, 2024–T3, 2024–T36, and 7075–T6 sheet, 2024–T4, and 7075–T6 plate, bar, rod, tub and extrusions, 2014–T6 extrusions.

Thickness "t" in inches	No. of 2117–AD protruding head rivets required per inch of width "W"					No. of bolts
	3/32	1/8	5/32	3/16	1/4	AN–3
0.016	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 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: *The above table was computed as follows:*

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

2. Number of rivets required was calculated for 2117–AD rivets, based on a rivet allowable shear stres 40 percent of the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 160 percent o allowable tensile stress, using nominal hole diameters for rivets.

3. Combinations of sheet thickness and rivet size above the heavy line are critical in (i. e., will fail by) the sheet; those below are critical in shearing of the rivets.

4. The number of AN–3 bolts required below the heavy line was calculated based on a sheet allowable tens of 70,000 p.s.i. and a bolt allowable single shear load of 2,126 pounds.

ıks on aircraft structures, or may be found figures 2.28, 2.29, and 2.30. In determining ɔ number of rivets required in the example, ure 2.26, for attaching the splice bar "B" to e upper leg, the thickness "t" of the element area being spliced is 1/16 inch (use 0.064), e rivet size is 1/8 inch, and figure 2.29 shows at 9.9 rivets are required per inch of width. nce the width "W" is 1/2 inch, the actual ımber of rivets required to attach the splice-ır to the upper leg on each side of the cut is 9 (rivets per inch) × 0.5 (inch width) = 95 (use 5 rivets).

ɔr the bulbed leg of the stringer "t" = 1/16 ch (use 0.064); AN-3 bolts are chosen and ıe number of bolts required per inch of width 3.3. The width "W" for this leg, however, is inch and the actual number of bolts required ı each side of the cut is 1 × 3.3 = 3.3 (use 4 ɔlts). When both rivets and bolts are used in the same splice, the boltholes 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.

(1) Splicing of Intermediate Frames. The same principles used for stringer-splicing may be applied to intermediate frames, when the following point is considered:

(a) Conventional frames of channel or Z section 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 spliceplate, as illustrated in figure 2.31. Since a frame is likely to be subjected to bending loads, make the length of spliceplate

ɪGURE 2.29.—Number of rivets required for splices (single-lap joint) in 2017, 2017 ALCLAD, 2024–T36 and 2024–T36 ALCLAD sheet, plate, bar, rod, tube, and extrusions.

·kness "t" in inches	No. of 2117—AD protruding head rivets required per inch of width "W"					No. of bolts
	3/32	1/8	5/32	3/16	1/4	AN-3
	6.5	4.9				
	6.5	4.9	3.9			
	6.9	4.9	3.9			
	8.9	4.9	3.9	3.3		
	10.0	5.6	3.9	3.3	2.4	
	11.1	6.2	4.0	3.3	2.4	
		7.9	5.1	3.6	2.4	3.3
		9.9	6.5	4.5	2.5	3.3
		12.5	8.1	5.7	3.1	3.3
			9.1	6.3	3.5	3.3
			10.3	7.1	3.9	3.3
			12.9	8.9	4.9	3.3

ɔr stringers in the upper surface of a wing, or in a fuselage, 80 percent of the number of rivets shown in the be used.
ʳ intermediate frames, 60 percent of the number shown may be used.
ʾingle lap sheet joints, 75 percent of the number shown may be used.

NOTES: *The above table was computed as follows:*

ıd per inch of width of material was calculated by assuming a strip one inch wide in tension.
er of rivets required was calculated for 2117-AD rivets, based on a rivet allowable shear stress equal to the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 160 percent of the sheet nsile stress, using nominal hole diameters for rivets.
ıbinations of sheet thickness and rivet size above the heavy line are critical in (i.e., will fail by) bearing on those below are critical in shearing of the rivets.
ɔ number of AN-3 bolts required below the heavy line was calculated based on a sheet allowable tensile stress .s.i. and a bolt allowable single shear load of 2,126 pounds.

"L" more than twice the width "W_2" and the rivets spread out to cover the plate.

101. REPAIRING CRACKED MEMBERS. Acceptable methods of repairing various types of cracks in structural elements are shown in figures 2.32 to 2.35. 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 (as shown in figures 2.32 to 2.35).

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 d sign or to defects such as nicks, scratches, to marks, and initial stresses or cracks fro forming or heat-treating operations. It shou be noted, that an increase in sheet thickne alone is usually beneficial, but does not nece sarily remedy the conditions leading to crac ing.

102. STEEL AND ALUMINUM FITTINGS.

a. ***Steel Fittings—Inspection for Defects.***

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

(2) When repairing aircraft after an accide or in the course of a major overhaul, inspe

FIGURE 2.30.—Number of rivets required for splices (single-lap joint) in 5052 (all hardnesses) sheet.

Thickness "t" in inches	No. of 2117—AD protruding head rivets required per inch of width "W"					No. of bolt
	3/32	1/8	5/32	3/16	1/4	AN-3
0.016	6.3	4.7		--------	--------	--------
.020	6.3	4.7	3.8	--------	--------	--------
.025	6.3	4.7	3.8	--------	--------	--------
.032	6.3	4.7	3.8	3.2	--------	--------
.036	7.1	4.7	3.8	3.2	2.4	--------
.040	7.9	4.7	3.8	3.2	2.4	--------
.051	10.1	5.6	3.8	3.2	2.4	--------
.064	12.7	7.0	4.6	3.2	2.4	--------
.081	--------	8.9	5.8	4.0	2.4	3.2
.091	--------	10.0	6.5	4.5	2.5	3.
.102	--------	11.2	7.3	5.1	2.8	3.
.128	--------	--------	9.2	6.4	3.5	3.

NOTES:

a. For stringers in the upper surface of a wing, or in a fuselage, 80 percent of the number of rivets sho 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: *The above table was computed as follows:*

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

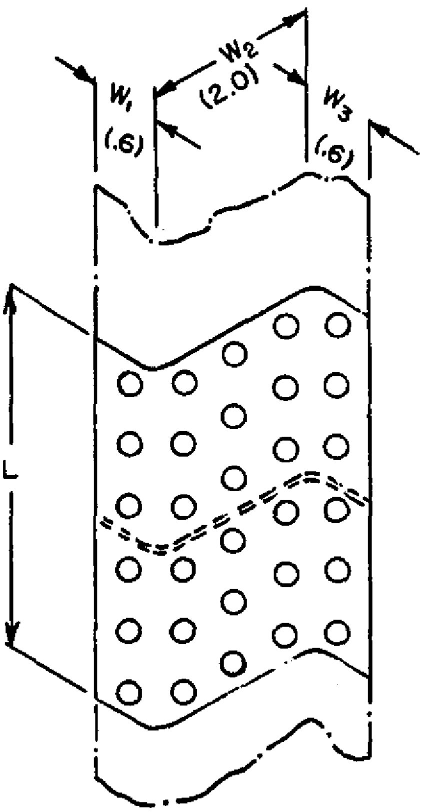
2. Number of rivets required was calculated for 2117-AD rivets, based on a rivet allowable shear stre 70 percent of the sheet allowable tensile stress, and a sheet allowable bearing stress equal to 165 percent of allowable tensile stress, using nominal hole diameters for rivets.

3. Combinations of sheet thickness and rivet size above the heavy line are critical in (i.e., will fail by) be the sheet; those below are critical in shearing of the rivets.

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 FIG. 2.29 IN A MANNER SIMILAR TO THAT FOR STRINGERS IN FIG. 2.26.

NOTE b. IN FIG. 2.29 INDICATES THAT ONLY 60% OF THE NUMBER OF RIVETS SO CALCULATED NEED BE USED IN SPLICES IN INTERMEDIATE FRAMES

EXAMPLE (For 2017-T3 aluminum alloy frame)



FLANGE LEG

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

NO. OF RIVETS PER INCH OF WIDTH FROM FIG. 2.29 = 6.2

No. of rivets required = W x 6.2 =
.6 x 6.2 = 3.72 or 4 rivets.
60% 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-AD rivet
W = 2.0 inches

NO. OF RIVETS PER INCH OF WIDTH FROM FIG. 2.29 = 6.2

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

SHOULD BE MORE THAN TWICE W_2
hickness of splice plate to be greater than that of the frame to be spliced.

FIGURE 2.31.—Example of splice of intermediate frame (material 2017 AL alloy).

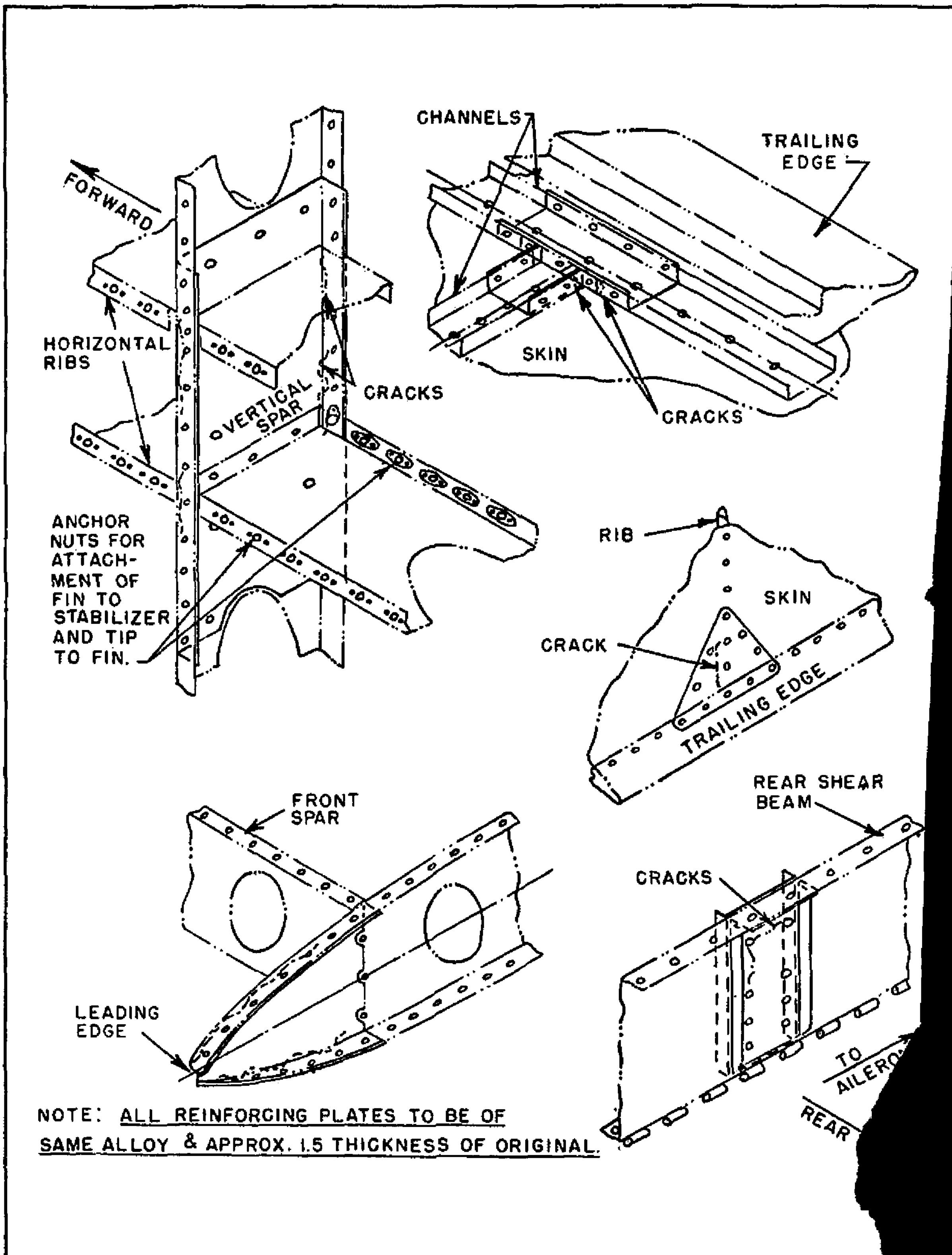


FIGURE 2.32.—Typical methods of repairing cracked leading and trailing edges and rib intersections.

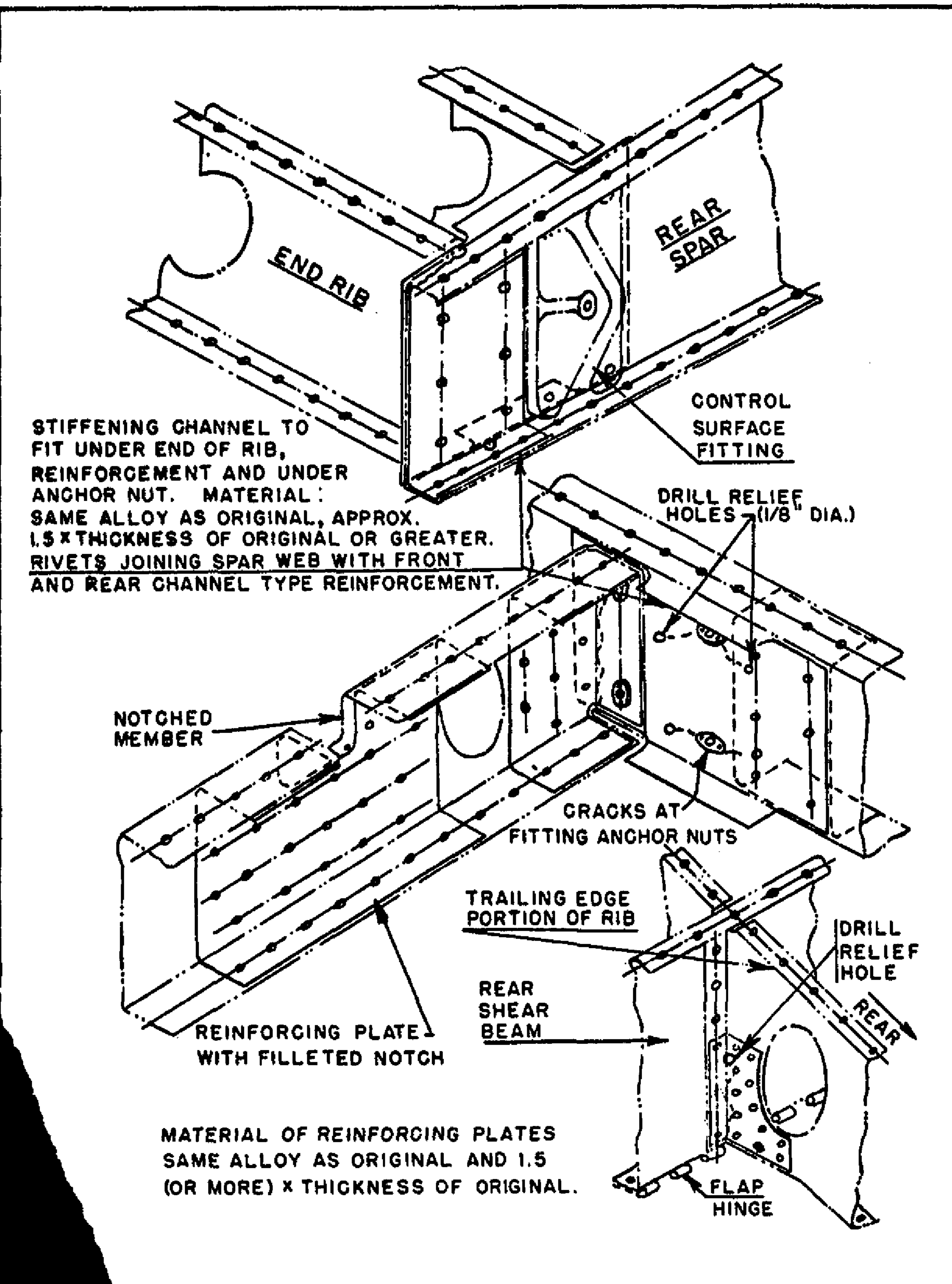


FIGURE 2.38.—Typical methods of replacing cracked members at fittings.

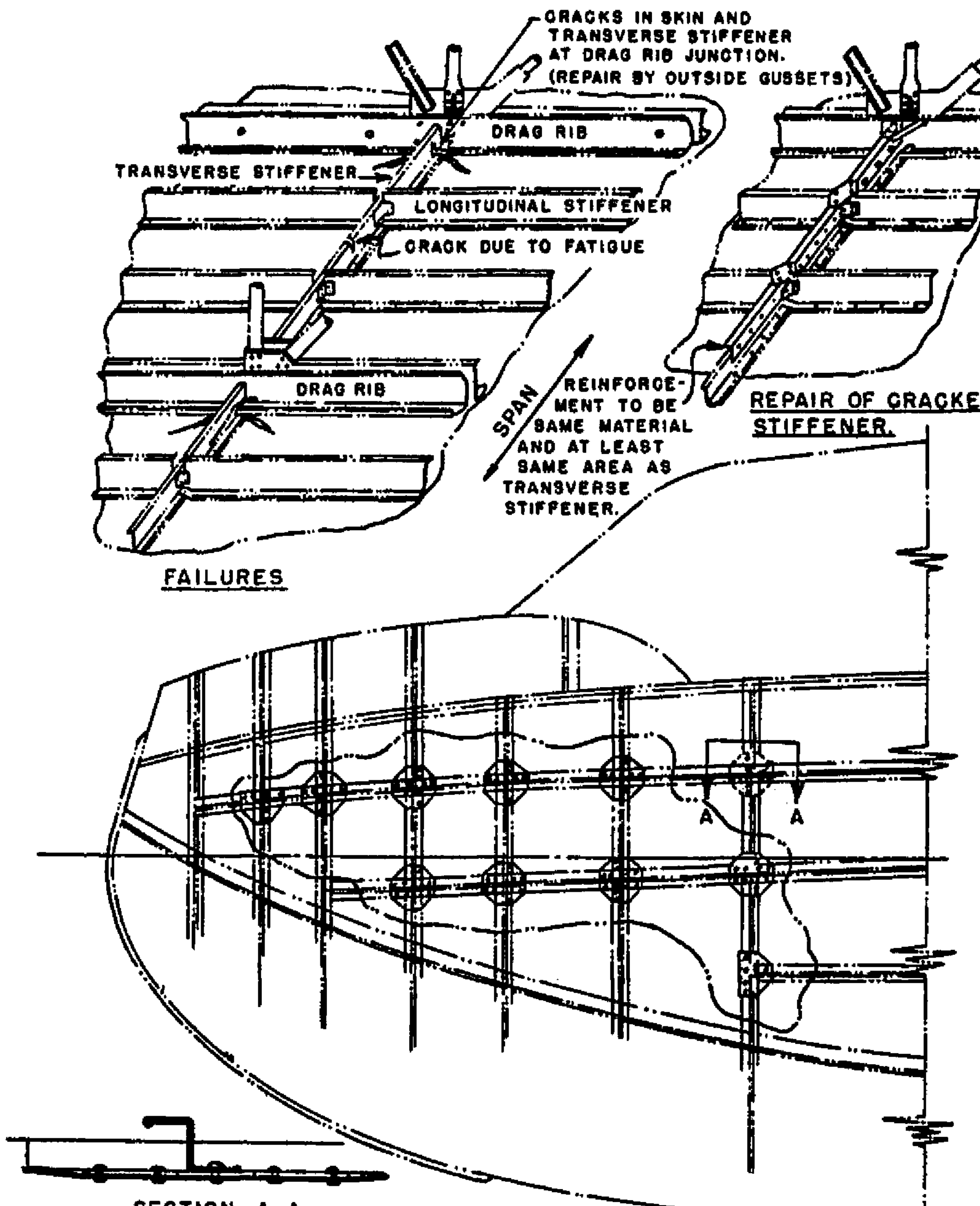
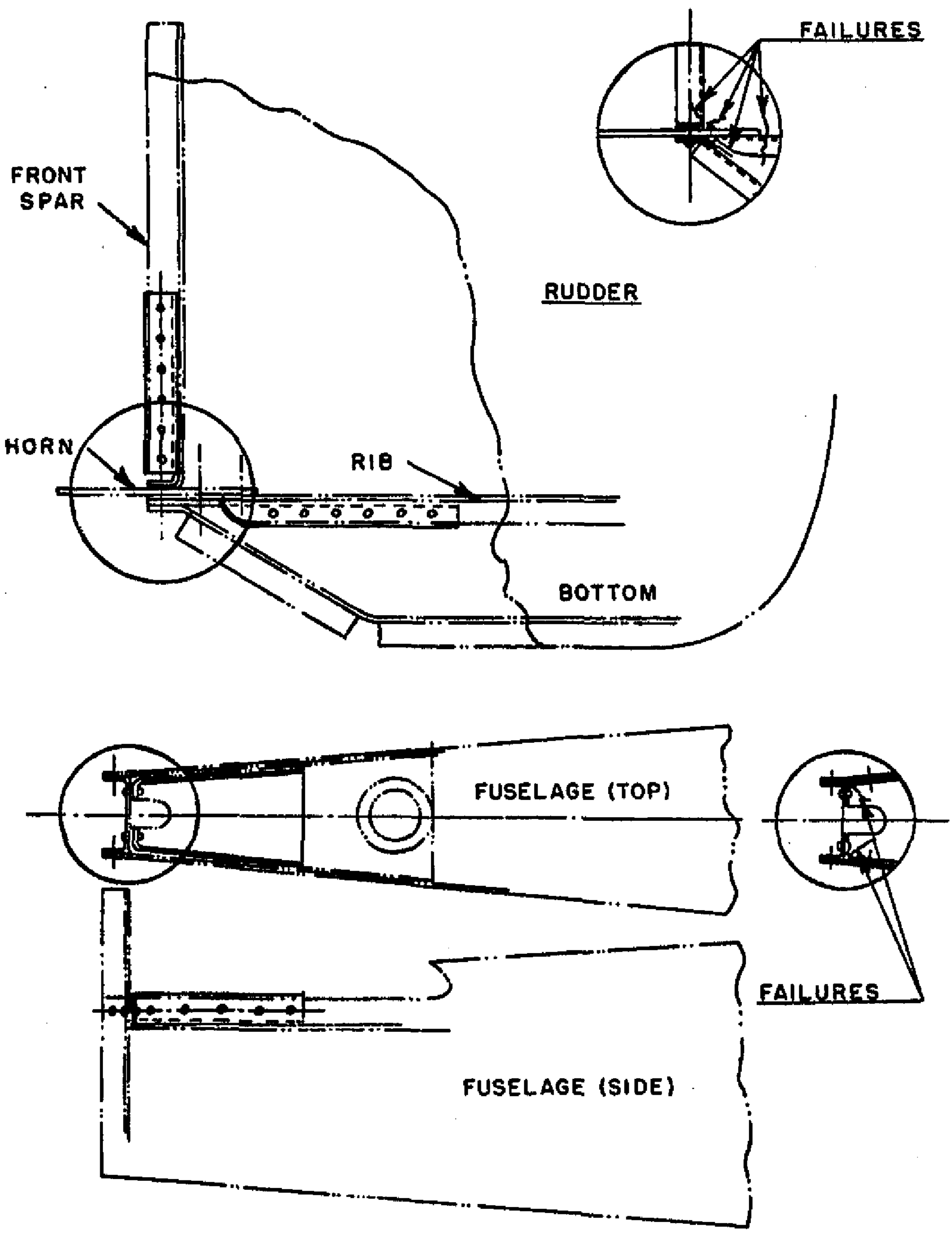


FIGURE 2.34.—Typical methods of repairing cracked frame and stiffener combinat



TE: USE SAME MATERIAL, NEXT HEAVIER GAUGE FOR REINFORCEMENT.

FIGURE 2.35.—Typical repairs to rudder and to fuselage at tail post.

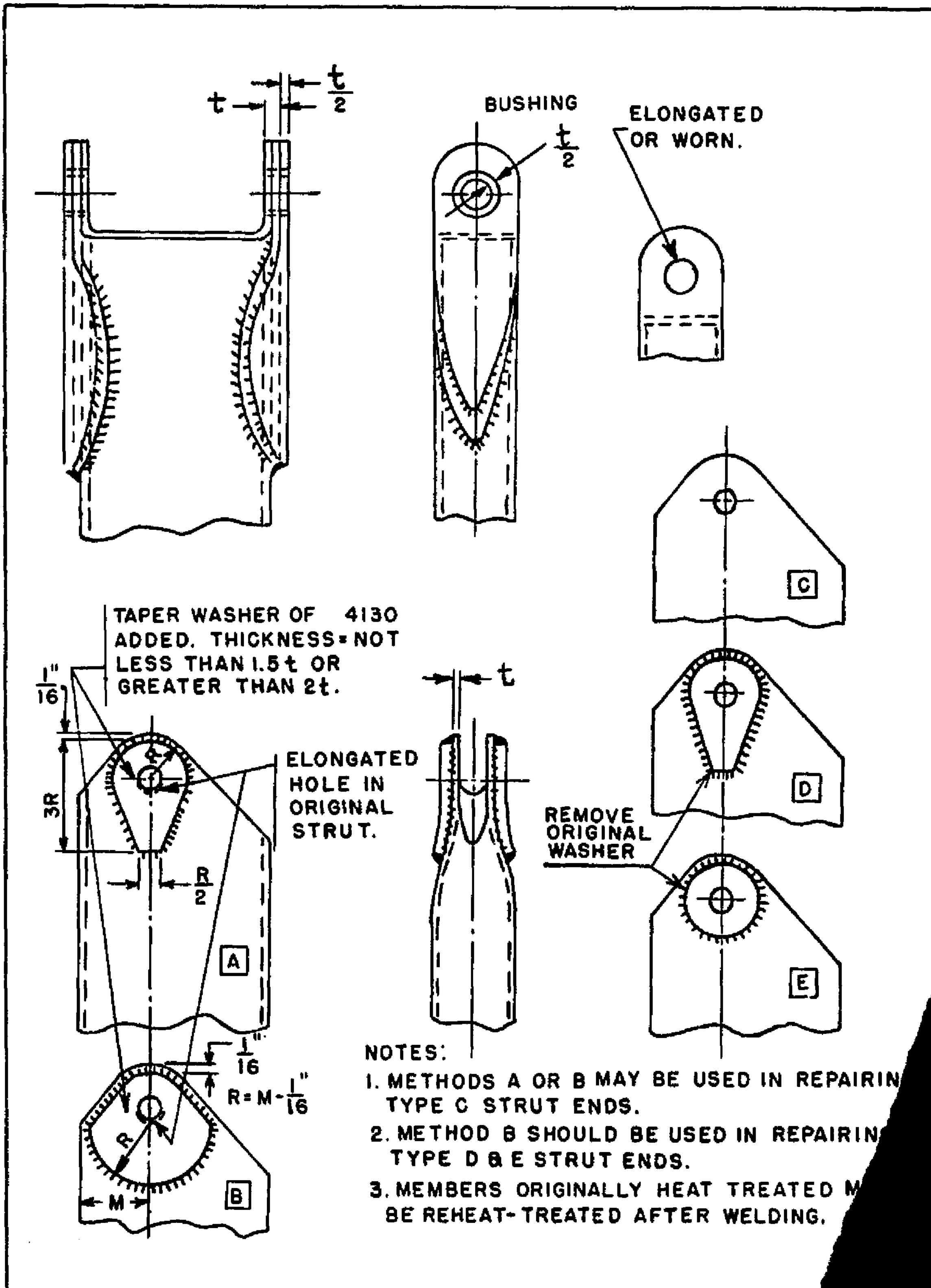


FIGURE 2.36.—Typical methods of repairing elongated or worn boltholes.

highly stressed main fittings, as set forth in apter 7, and if necessary, take corrosion vention measures as recommended in Chap- 6.

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

(4) Elongated or worn boltholes in fittings ich were designed without bushings are not be reamed oversize. Replace such fittings, ess the method of repair is approved by a resentative of the FAA. Do not fill holes h welding rod. Acceptable methods of re- ring elongated or worn boltholes in landing r, stabilizer, interplane, or cabane-strut ends y, not originally equipped with pin plates, are wn in fiigure 2.36. (Also see figure 2.11 on geron repair at fitting.)

. Aluminum and Aluminum Alloy Fittings.

(1) Replace damaged fittings with new parts, ing the same material specifications.

(2) Repairs may be made in accordance with a furnished by the aircraft manufacturer or a substantiating the method of repair may be mitted to the FAA for review.

. CASTINGS. Damaged castings are to be re- ced and not repaired unless the method of air is specifically approved by the aircraft nufacturer or substantiating data for the re- r has been reviewed by the FAA.

. SELECTIVE PLATING IN AIRCRAFT MAINTE- NCE. Selective plating is a method of deposit- metal from an electrolyte to the selected a. The electrolyte is held in an absorbent terial attached to an inert anode. Plating tact is made by brushing or swabbing the t (cathode) with the electrolyte-bearing de.

Selective Plating Uses. This process can be l for any of the following reasons:

o prevent or minimize disassembly, re- r masking costs.

izing worn components (plate to size).

ing in damaged or corroded areas.

plate small areas of extremely large

plate electrical contacts.

plate parts too large for existing

(7) To supplement conventional plating.

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

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

(10) On-site plating.

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

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

QQ-C-320	Chromium Plating
QQ-N-290	Nickel Plating
QQ-P-416	Plating, Cadmium
QQ-S-365	Silver Plating
QQ-Z-325	Zinc Plating
MIL-T-10727	Tin Plating
MIL-C-14550	Copper Plating
MIL-G-45204	Gold Plating

c. General Requirements.

(1) Areas to be repaired by this process should be limited to reasonably small areas of large parts, although it may be desirable to plate small parts, particularly electrical or electronic parts, in their entirety.

(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; 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° 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 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 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 process. Small parts may be partially or completely plated. Special cases exceeding these limitations should be coordinated with the ma facturer of the plating equipment being used his recommendations should be followed.

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

h. *Required Ampere-Hour Calculation.* selected plating solution has a factor which equal to the ampere-hours required to dep 0.0001 inch on one square inch of surface. termine the thickness of plating desired or certain area and multiply the solution fac times the plating thickness times the area square inches to determine the ampere-hours quired. This factor may vary because of te perature, current density, etc.

i. *Cleaning.* Remove corrosion, scale, oxi and unacceptable plating prior to processi Use a suitable solvent or cleaner to remove gre or oil.

j. *Plating on Aluminum and Aluminum B Alloys.*

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

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

(3) Activate the area with reverse curre 7 to 10 volts, in conjunction with the pro activating solution until a uniform gray to bla surface is obtained.

(4) Rinse thoroughly in cold, clean tap wat

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

(6) Rinse thoroughly.

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

(8) Rinse and dry.

k. *Plating on Copper and Copper*

(1) Electroclean the area usin (direct) current until water does no the surface. The electroclean process accomplished at 8 to 12 volts using t priate electroclean solution.

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

(3) Immediately electroplate the area with .y of the plating solutions except silver. Silver quires an undercoat.

(4) Rinse and dry.

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

(1) Electroclean the area using forward lirect) current until water does not break on e surface. This electroclean process should be complished at 12 to 20 volts using the appro'iate electrocleaning solution.

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

(3) Activate the surface using forward lirect) current for 1 to 2 minutes using the tivating solution and accomplish at 6 to 20 ›lts.

(4) Do not rinse.

(5) Immediately nickel flash the surface to thickness of 0.00005 to 0.0001 inch using the ›propriate nickel solution.

(6) Rinse thoroughly.

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

(8) Rinse and dry.

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

(1) Electroclean the area using forward lirect) current until water does not break on .e surface. This electroclean process should be complished at 12 to 20 volts using the appro:iate electrocleaning solution.

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

(3) Reverse current etch at 8 to 10 volts, g the appropriate activating solution, until form gray surface is obtained.

Rinse thoroughly.

mediately electroplate the part using ns except copper acid or silver. Both re undercoats.

se and dry.

g on Cast Iron and High-Carbon Steels at Treated to 180,000 psi).

lectroclean the area using forward 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 these require undercoats).

(8) Rinse and dry.

o. *Plating on Ultra High 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°±25° F.

NOTE 1: Where the solution vendor provides substantiating data that hydrogen embbrittlement will not result from plating with a particular solution, then a post bake is not required. This substantiating data can be in the form of aircraft industry manufacturers' process specifications, military specifications, or other suitable data.

NOTE 2: 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 forward (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 or 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, ultra high strength steel parts (heat treated above 180,000 psi) should be baked as mentioned in paragr 104.o.(5), unless it is specifically known t embrittlement is not a factor.

r. ***Qualification Tests.*** All brush plated s faces shall be tested for adhesion of the elec deposit. Apply a 1-inch wide strip of Minnes Mining and Manufacturing tape code 250, or approved equal, with the adhesive side to freshly plated surface. Apply the tape w heavy hand pressure and remove it with quick motion perpendicular to the plated s face. Any plating adhering to the tape shall cause for rejection.

s. ***Personnel Training for Quality Cont*** Manufacturers of selective plating equipm provide training in application techniques their facilities. Personnel performing select plating must have adequate knowledge of methods, techniques, and practices involv These personnel should be products of th training programs and certified as qualified erators by the manufacturers of the produ used, as well as by local quality control depa ments.

105.-114. RESERVED.

Section 4. REPAIR OF LAMINATE STRUCTURES

115. GENERAL. There is a wide variation in the composition and structural application of laminates, and it is essential that these factors be given major consideration when any restoration activities are undertaken. To a similar extent, there also exist many types of laminate structure repairs that may or may not be suitable for a given condition. For this reason, it is important that the aircraft or component manufacturer's repair data be reviewed when determining what specific type of repair is permissible and appropriate for the damage at hand.

The materials used in the repair of laminate structures must preserve the strength, weight, aerodynamic characteristics, or electrical properties of the original part or assembly. This can best be accomplished by replacing damaged material with material of identical chemical composition or a substitute approved by the manufacturer.

In order to eliminate dangerous stress concentrations, avoid abrupt changes in cross-sectional areas. Whenever possible, for scarf joints and facings, make small patches round or oval-shaped, and round the corners of large repairs. Smooth and properly contour aerodynamic surfaces.

It is recommended that test specimens be prepared at the same time that the actual repair is accomplished. These can then be subjected to a destructive test to establish the quality of the adhesive bond in the repaired part. To make this determination valid, the specimens must be assembled with the same adhesive batch mixture and subjected to curing pressure, temperature, and time identical with those in the actual repair.

a. *Fiberglass Laminate Repairs.* The following repairs are applicable to fiberglass laminate used for fairings, covers, cowlings, honeycomb panel facings, etc. Prior to undertaking the repair, clean the repair area thoroughly with castile soap and warm water. Remove a paint by wet or dry sanding methods. Se blasting may be used but caution must be ex cised to not abrade the surfaces excessively.

Superficial scars, scratches, surface ab sion, or rain erosion can generally be repair by applying one or more coats of a suital resin, catalyzed to cure at room temperatu to the abraded surface. The number of co required will depend upon the type of re and severity of the damage.

Damage not exceeding the first layer or of fiberglass laminate can be repaired by fil with a putty consisting of a compatible ro temperature-setting resin and clean short gl fibers. Before the resin sets, apply a sheet cellophane over the repair area and work c any bubbles and excess resin. After the res has cured, sand off any excess and prepare t area for refinishing.

Damage deep enough to seriously affect t strength of the laminate (usually more th the first ply or layer of fabric) may be r paired as illustrated in figure 2.37. Coat t

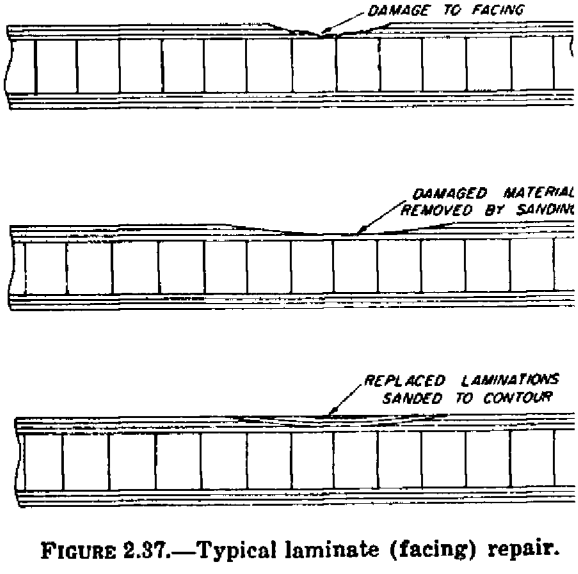


FIGURE 2.37.—Typical laminate (facing) repair.

l area with room-temperature-setting and apply contoured pieces of glass fab- aked in resin. Apply a cellophane sheet he repair and work out any bubbles and resin. After the resin has cured, scrape excess resin and sand the surface of the to the original contour.

nage that extends completely through ıcing and into the core requires the re- nent of the damaged core and facing. A d for accomplishing this type of repair is in figure 2.38. An alternate method for ing the facing is shown in figure 2.39. ımaged portion is carefully trimmed out rcular or oval shape and the core mate- moved completely to the opposite facing. se caution so as not to damage the oppo- cing or to start delamination between ngs and the core around the damage.

CAUTION

ıding fiberglass laminates gives off a fine dust ıt may cause skin and/or respiratory irritation less suitable skin and respiration protection is ed.

replacement core stock of the same ma- and density as the original (or an accept- ubstitute) and cut it to fit snugly in the ned hole. When all pieces of replacement laminations are cut and soaked in resin, all surfaces of the hole and the scarfed with resin. Then coat all surfaces of the replacement with resin and insert it into ole. After all of the pieces of resin-im- ıated glass-fabric facing are in place, the entire area with a piece of cellophane carefully work down the layers of fabric move any air bubbles and excess resin. y light pressure by means of sand bags or ıuum blanket. When the resin has cured, the repair to match the original contour efinish the surface.

mage that is completely through a lami- sandwich structure may be repaired as il- ated in either figure 2.39 or 2.40. The ed joint method, figure 2.40, is normally on small punctures up to 3 or 4 inches in mum dimension and in facings which are of thin fabric that is difficult to peel. The ed joint, figure 2.39, is most often used on

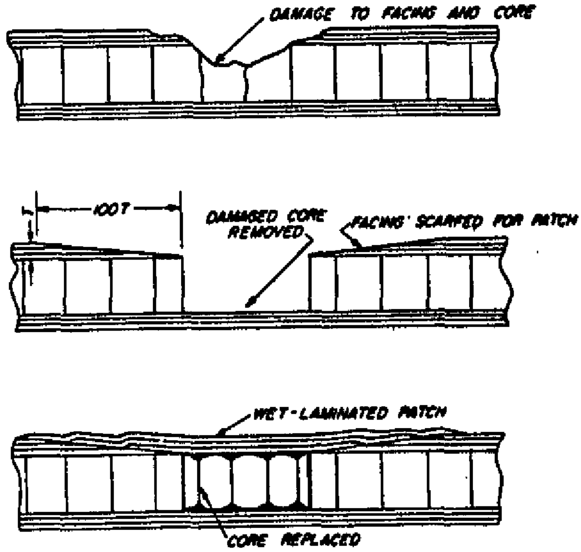


FIGURE 2.38.—Typical core and facing repair.

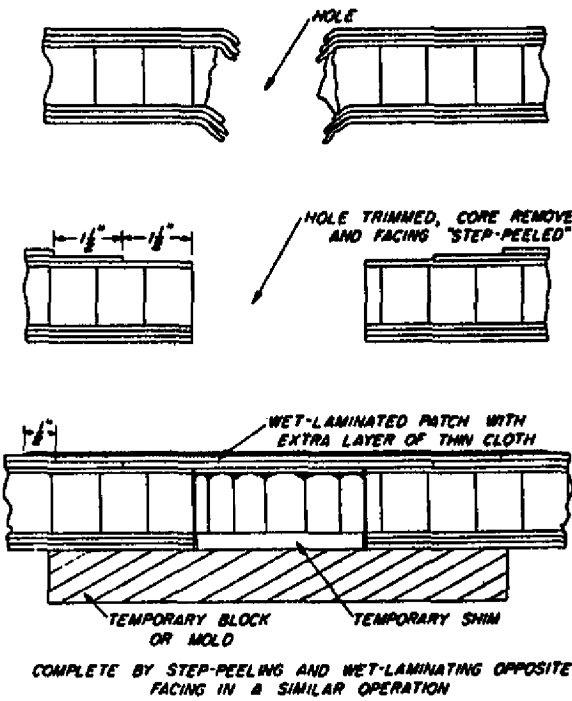


FIGURE 2.39.—Typical stepped joint repair.

larger repairs to facings composed of thick fabrics.

When access for repair is possible from only one side, blind repair procedures are employed.

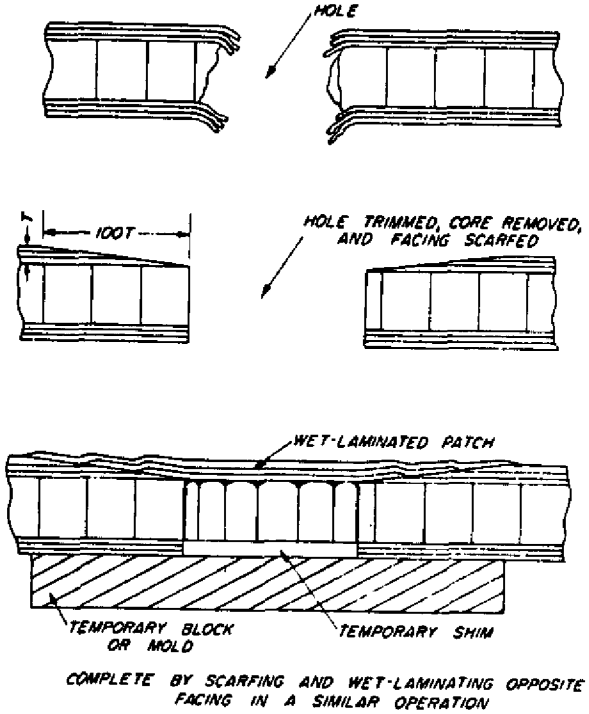


FIGURE 2.40.—Typical scarfed joint repair.

Repairs of this type have been made by u glass-fiber-reinforced plastic backing pla proximately 0.060-inch thick. The b plate can be fabricated from layers of fabric and room-temperature-curing re sandwiching the resin-impregnated laye tween two sheets of cellophane. Work t cess resin out and allow the plate to cur flat surface or a cellophane-covered surf the proper curvature near the damaged or at the same location on a comparable u aged part. The technique for bondin backing plate in place is similar to tha trated in figure 2.41 for metal-faced la repairs. After the backing plate is bon place with resin, complete the repair as in figure 2.38.

b. ***Metal-Faced Laminate Repairs.*** Re laminate with magnesium, titanium, o less steel facings require procedures w specially devised and not included in lowing methods of repair. Aluminum such as 7075–T6, 2024–T3, and 2014–T

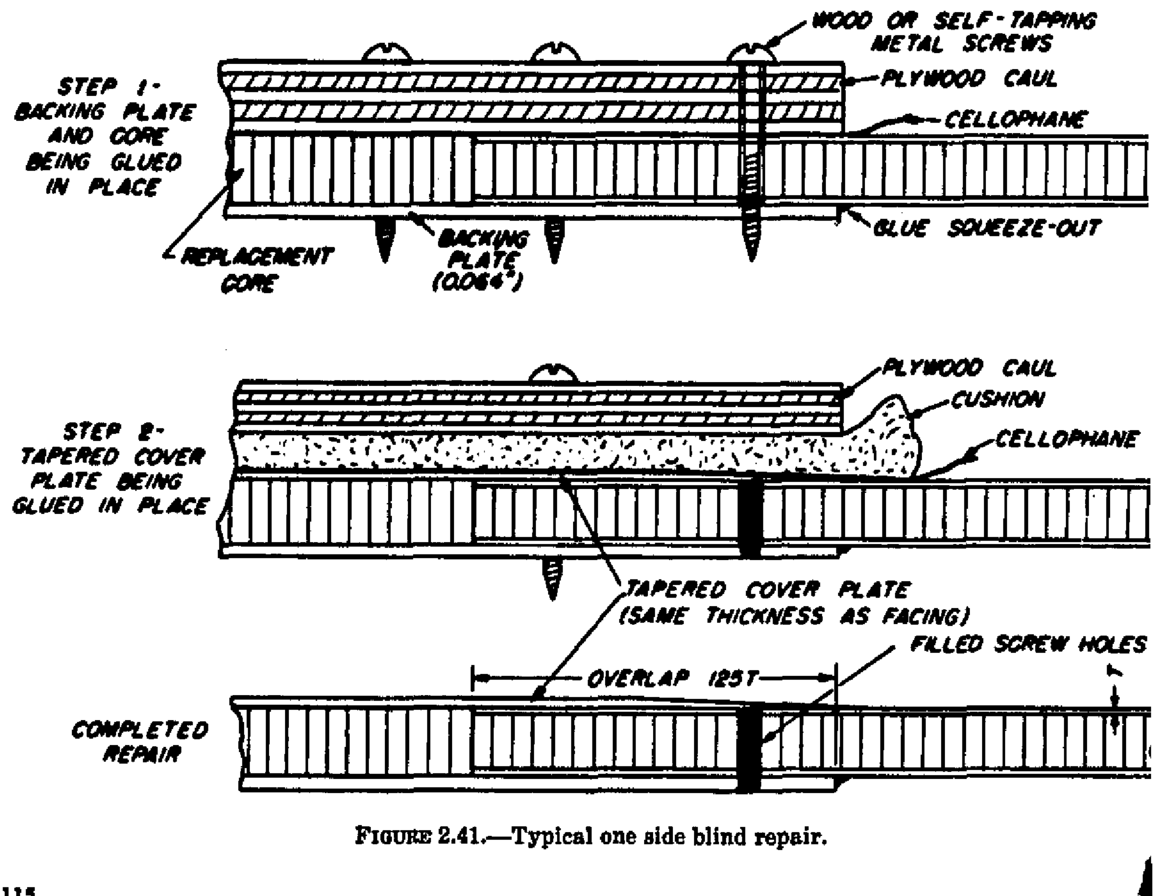


FIGURE 2.41.—Typical one side blind repair.

ıonly used for the repair of facings for ıated structural parts having aluminum gs. For maximum corrosion resistance, nly clad aluminum for repairs to clad alum alloy facings.

ıts, scratches, or fractures, not exceeding ourth inch in largest dimension, in alumifacings may be repaired with a suitable such as viscous epoxy resin. Thoroughly the repair area with fine sandpaper and ıe before applying the filler. After the has partially cured, remove any excess with a sharp scraper or chisel. When tely cured, sand to original contour. If ımage included a fracture, reclean the round the filled hole and apply a surface as shown in figure 2.42, by means of resin and a similar curing cycle.

tures or punctures in one facing and damage to the core of an aluminumıminate may be repaired by several difmethods. The technique used will deupon the size of the damage and the ıgth, aerodynamic, and sonic fatigue rence requirements of the area involved. If repair requires aerodynamic smoothness, facing surrounding the repair core cavity

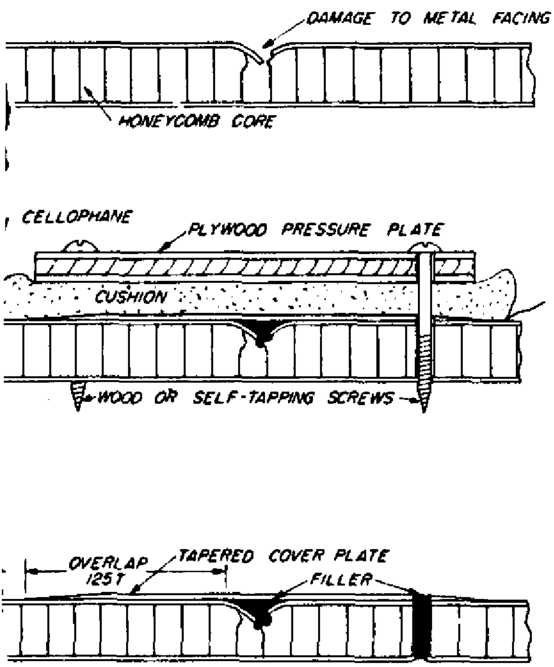


FIGURE 2.42.—Typical metal facing patch.

may have to be step cut to one-half its thickness. This can be done by using a router with an end mill bit and a template.

Damage that extends completely through the core and both facings may be repaired using the same general techniques as those used for repairing fiberglass laminates when both facings are accessible (see figures 2.39 and 2.40). When the inner facing is not accessible, a procedure such as that shown in figure 2.41 may be used. The outer surface patch could then be installed in a manner similar to the repair shown in figure 2.42.

After locating the extent of the total damaged area by tapping or other nondestructive test methods, remove the damaged facing and that portion of the core material which is also affected. The depth to which the core must be removed will depend upon the type of core material and method of repair. If the replacement core material is the same as the original, fabricate it to shape keeping the same core ribbon or grain direction. When a substitution is permissible, wood or glass-fabric honeycomb cores are sometimes used in the repair of aluminum honeycomb cores as they are generally easier to shape. Typical types of core replacements are shown in figure 2.43. Resin fills can be used to replace the core and facing where smaller core damage exists. Phenolic microballoons, low-density insulating materials and/or other ingredients, are added to lower the density and give greater flexibility, thus lowering stress concentrations in the repair area.

For the repair of larger holes in which it is inconvenient to use a face patch because of aerodynamic smoothness requirements in that area, both the core and facing are sometimes replaced with glass-fiber fabric discs and resin. Undercut the core, as shown in figure 2.44, in order to obtain a better bonding of the fill with the facing. Fill the core cavity with accurately shaped resin-saturated glass cloth discs, and press each ply down to remove any air bubbles. Special care should be taken that the final plies fit well against the underside of the top facing. When the core cavity is filled, close the cutout in the facing with resin-impregnated glass-fiber fabric discs that have been precut to size.

There are five general types of facing

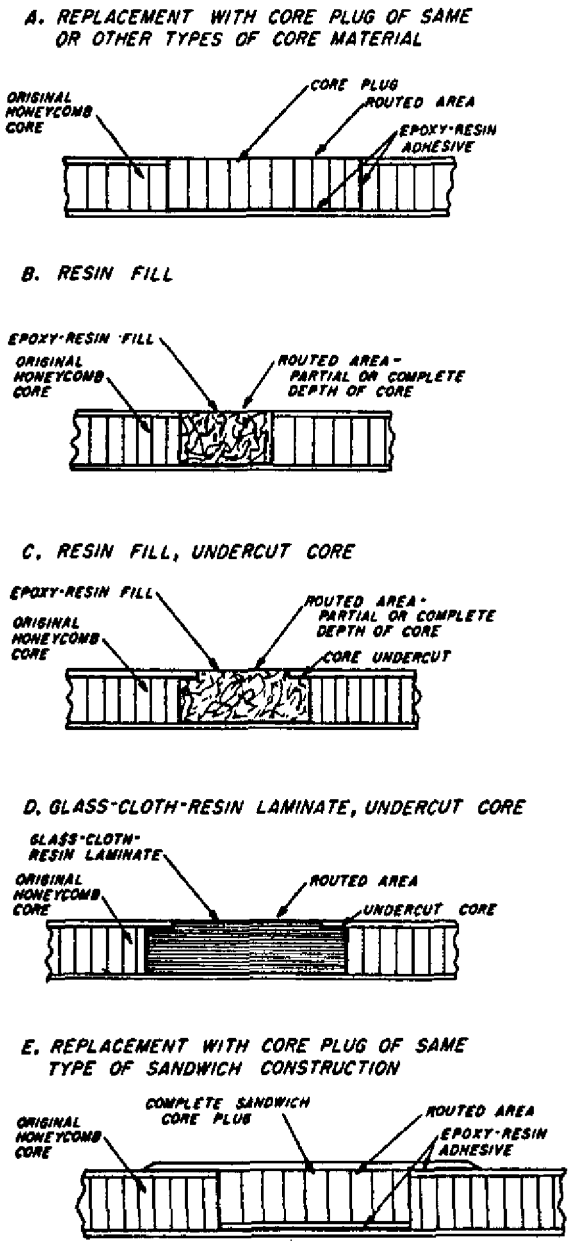


FIGURE 2.43.—Typical types of core replacement.

patches used after replacement of the co been completed and they are described b Each of these patches meet certain servi quirements that must be considered bef decision can be reached as to which is a priate for a specific application.

(1) A Small, Flush Plug-type. A plug c same material and thickness as the faci bonded in place after the core has bee placed. This type of patch gives aerody smoothness but does not replace any o strength initially lost in the damaged facin

(2) An Overlap Type Metal Facing Patc overlap surface patch is bonded in plac the facing and replaced core. With this t patch, and good bonding techniques, p cally full strength of the facing is reg Overlaps of less than 125 times the thi of the facing can be used in repairs wh skins are not highly stressed.

(3) A Step-type Facing Patch. The ste facing patch retains aerodynamic smoot but has only a maximum of 50 percent c original facing tensile strength.

(4) A Scarf-type Facing Patch. This is a bination of the overlap and the ste which results in the same aerody smoothness as the step-type but gr strength efficiency.

(5) An Overlap Type Resin-glass Facing An overlap patch of glass-fiber fabric resin has fair aerodynamic smoothness a easy to fabricate with a minimum of e ment. It fits easily in transition curvature results in a lower facing strength tha original skin.

c. ***Finishing.*** The type of finish coating a to a laminate repair will normally be

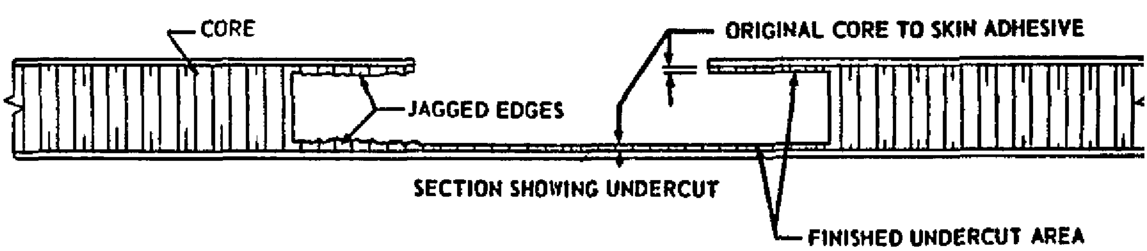


FIGURE 2.44.—Typical undercut core material cavity.

d by the facing material and the applica-
of the part or assembly. Rain erosion of
ic parts, the need for electrical or dielec-
›roperties and/or the necessity for anticor-
n coatings must be considered when the
:e of finish is made. Plastic-faced parts
as radomes are finished primarily for rain
on while aluminum- or other metal-faced
ıates are finished for corrosion protection.
coatings to perform their function properly, it is essential that they be applied to surfaces that are clean, free of voids, and exceedingly smooth.

The edges of all parts not protected by a bonding of aluminum or glass-fabric laminate must be sealed to reduce the rate of moisture absorption. The wood-bonded edges of plywood, mahogany, spruce, or balsa may be given two coats of aluminized spar varnish.

116.-126. RESERVED.

Chapter 3. FABRIC COVERING

Section 1. PRACTICES AND PRECAUTIONS

TEXTILE MATERIALS. All fabric, surface reinforcing tape, machine thread, lacing etc., used for re-covering or repairing an aft structure must be high-grade aircraft e material of at least as good quality and alent strength as those described in sub-raphs a through g.

Aircraft Fabric. Acceptable fabrics such as and linen for covering wings, control es, and fuselages are listed in figure 3.1. s conforming to the Aeronautical Mate-pecifications incorporate a continuous ng showing the specification number to it identification of the fabric in the field.

Re-covering Aircraft. Re-cover or repair air- with fabric of at least as good quality equivalent strength as that originally used he aircraft. However, in re-covering air- which were originally covered with low gth or so-called "glider cloth," it is con-ed more desirable to use Grade A or "in-ediate" fabric conforming to AMS 3806 or , as amended, respectively. Certain syn-c and fiberglass fabrics have been devel- that are acceptable alternates to AMS or AMS 3804 fabric, providing the Sup-ental Type Certificate (STC) installation uctions furnished with the material are wed. Specification MIL–C–9084, MIL–Y–C, and MIL–G–1140 materials in the un-ed condition have equivalent strength char-istics to TSO–C15 material specifications.

Reinforcing Tape. Acceptable reinforcing is listed in figure 3.2. Use reinforcing tape imilar quality as the fabric and at least half the strength of that conforming to fication MIL–T–5661.

Surface Tape. Use surface tape (also finish-ape) having approximately the same prop-s as the fabric used. See figure 3.2.

e. *Lacing Cord.* Use lacing cord having a strength of at least 80 pounds double or 40 pounds single strand. See figure 3.2.

f. *Machine Thread.* Use machine thread having a strength of at least 5 pounds single strand (figure 3.2).

g. *Hand-Sewing Thread.* Use hand-sewing thread having a strength of at least 14 pounds single strand (figure 3.2).

128. COVERING PRACTICES. The method of fabric attachment should be identical, as far as strength and reliability are concerned, to the method used by the manufacturer of the airplane to be re-covered or repaired. Fabric may be applied so that either the warp or fill-threads are parallel to the line of flight. Either the envelope method or blanket method of covering is acceptable.

a. *Flutter Precautions.* When re-covering or repairing control surfaces, especially on high performance airplanes, make sure that dynamic and static balances are not adversely affected. Weight distribution and mass balance must be considered to preclude the possibility of induced flutter.

129. PREPARATION OF THE STRUCTURE FOR COVERING. One of the most important items in covering aircraft is proper preparation of the structure. Dopeproofing, covering edges which are likely to wear the fabric, preparation of plywood surfaces, and similar operations, if properly done, will do much toward insuring an attractive and long-lasting job.

a. *Dopeproofing.* Treat all parts of the structure which come in contact with doped fabric with a protective coating such as aluminum foil, dopeproof paint or cellulose tape. Clad aluminum and stainless steel parts need not be dopeproofed.

b. *Chafe Points*. Cover all points of the structure, such as sharp edges, boltheads, etc., which are likely to chafe or wear the covering with doped-on fabric strips or cover with an adhesive tape. After the cover has been installed, reinforce the chafe points of the fabric by doping on fabric patches. Where a stronger reinforcement is required, apply a cotton duck or leather patch sewed to a fabric patch and then dope in place. Reinforce all portions of the fabric pierced by wires, bolts, or other projections.

c. *Inter-Rib Bracing*. Conventional wing ribs, which do not have permanent inter-rib bracing should be bound in position by means of cotton tape running parallel to the beams. Apply the tape diagonally between the top and bottom capstrips of each successive rib approximately halfway between the front and rear beams. Apply the tape continuously from the butt rib to the tip rib with one turn of tape around each intermediate rib capstrip.

d. *Preparation of Plywood Surfaces for Covering*. Prior to covering plywood surfaces with fabric, prepare the surface by cleaning and applying sealer and dope.

(1) **Cleaning**. Sand all surface areas which have been smeared with glue in order to expose a clean wood surface. Remove loose deposits such as woodchips and sawdust. Remove oil or grease spots by carefully washing with naphtha.

(2) **Application of Sealer and Dope**. Apply one brush coat or two dip coats (wiped) of a dopeproof sealer such as that conforming to Specification MIL–V–6894 thinned to 30 percent nonvolatile content and allow to dry 2 to 4 hours. Finally, before covering, apply two brush coats of clear dope allowing the first coat of dope to dry approximately 45 minutes before applying the second coat.

130. FABRIC SEAMS. Seams parallel to the line of flight are preferable; however, spanwise seams are acceptable.

a. *Sewed Seams*.

(1) Machine-sewn seams (parts D, E, and F of figure 3.3) should be of the folded fell or French fell types. Where selvage edges or pinked edges are joined, a plain lap se satisfactory.

(2) Begin hand sewing or tacking point where machine sewing or uncut fal again reached. Lock hand sewing at int of 6 inches, and finish the seam with stitch and a knot (figure 3.4). At the where the hand sewing or permanent t is necessary, cut the fabric so that it c doubled under before sewing or permanent ing is performed (figure 3.3 (C)). After sewing has been completed, remove the t rary tacks. In hand sewing, use a minim four stitches per inch.

(3) Cover a sewed spanwise seam metal- or wood-covered leading edge pinked-edge surface tape at least 4 wide.

(4) Cover a sewed spanwise seam trailing edge with pinked-edge surface t least 3 inches wide. For aircraft with exceed speeds in excess of 200 m.p.h notches at least 1 inch in depth and 1 i width in both edges of the surface tape used to cover spanwise seams on trailing especially the trailing edges of control sur Space notches at intervals not exceedi inches. On tape less than 3 inches wid notches should be 1/3 the tape width. I event that the surface tape begins to se because of poor adhesion or other cause tape will tear at a notched section, thus venting progressive loosening of the length of the tape which could seriously the controlling of the aircraft.

(5) Cover a double-stiched lap joint pinked-edge surface tape at least 4 i wide.

(6) Make sewed spanwise seams o upper or lower surface in a manner tha amount of protuberance is minimum. Cove seam with pinked-edge tape at least 3 i wide.

(7) Sewed seams parallel to the lir flight (chordwise) may be located over however, place the seam on the rib so tha lacing will not penetrate through the seam.

Materials	Specification	Minimum tensile strength new (undoped)	Minimum tearing strength new (undoped)	Minimum tensile strength deteriorated (undoped)	Thread count per inch	Use and remarks
lane cloth ercerized otton Grade "A").	Society Automotive Engineers AMS 3806 (TSO-C15 references this spec.).	80 pounds per inch warp and fill.	5 pounds warp and fill.	56 pounds per inch.	80 minimum, 84 maximum warp and fill.	For use on all aircraft. Required on aircraft with wing loadings greater than 9 p.s.f. Required on aircraft with placarded never-exceed speed greater than 160 m.p.h.
"	MIL–C–5646	"	"	"	"	Alternate to AMS 3806.
lane cloth ellulose itrate pre-oped.	MIL–C–5643	"	"	"	"	Alternate to MIL–C–5646 or AMS 3806 (undoped). Finish with cellulose nitrate dope.
lane cloth ellulose cetate utyrate, redoped.	MIL–C–5642.	"	"	"	"	Alternate to MIL–C–5646 or AMS 3806 (undoped). Finish with cellulose acetate butyrate dope.
lane cloth ercerized ton.	Society Automotive Engineers AMS 3804 (TSO-C14 references this spec.).	65 pounds per inch warp and fill.	4 pounds warp and fill.	46 pounds per inch.	80 minimum, 94 maximum warp and fill.	For use on aircraft with wing loadings of 9 p.s.f. or less, provided never-exceed speed is 160 m.p.h. or less.
lane cloth ercerized tton.	Society Automotive Engineers AMS 3802.	50 pounds per inch warp and fill.	3 pounds warp and fill.	35 pounds per inch.	110 maximum warp and fill.	For use on gliders with wing loading of 8 p.s.f. or less, provided the placarded never-exceed speed is 135 m.p.h. or less.
bric .	A. A. F. No. 16128. AMS 3802.	55 pounds per inch warp and fill.	4 pounds warp and fill.	39 pounds per inch.	80 minimum warp and fill.	Alternate to AMS 3802–A.
----	British 7F1 ----	----	----	----	----	This material meets the minimum strength requirements of TSO–C15.

FIGURE 3.1.—Textile fabric used in aircraft covering.

Materials	Specification	Yarn size	Minimum tensile strength	Yards per pound	Use and remarks
Reinforcing tape, cotton.	MIL-T-5661		150 pounds per one-half-inch width.		Used as reinforcing tape on and under rib lacing Strength of other widths a in proportion.
Lacing cord, prewaxed braided cotton.	MIL-C-5649		80 pounds double.	310 minimum.	Lacing fabric to structure less already waxed, mu lightly waxed before usi
Lacing cord, special cotton.	U.S. Army No. 6-27.	20/3/3/3	85 pounds double.		"
Lacing cord, braided cotton.	MIL-C-5648		80 pounds single.	170 minimum.	"
Lacing cord thread; linen and linen-hemp.	MIL-T-6779	9 ply 11 ply	59 pounds single. 70 pounds single.	620 minimum. 510 minimum.	"
Lacing cord thread; high-tenacity cotton.	MIL-T-5660	Ticket No. 10.	62 pounds single.	480 minimum.	"
Machine thread cotton.	Federal V-T-276b.	20/4 ply	5 pounds single.	5,000 normal.	Use for all machine sewing
Hand sewing thread cotton.	V-T-276b. Type III B.	8/4 ply	14 pounds single.	1,650 normal.	Use for all hand sewing. Use waxed thread.
Surface tape cotton (made from AN-C-121).	MIL-T-5083		80 lbs/in.		Use over seams, leading trailing edges, outer edge ribs, pinked, scalloped or st edges.
Surface tape cotton.	Same as fabric used.		Same as fabric used.		Alternate to MIL-T-5083.

FIGURE 3.2.—Miscellaneous textile materials.

b. ***Doped Seams.***

(1) For a lapped and doped spanwise seam on a metal- or wood-covered leading edge, lap the fabric at least 4 inches and cover with pinked-edge surface tape at least 4 inches wide.

(2) For a lapped and doped spanwise seam at the trailing edge, lap the fabric at least 4 inches and cover with pinked-edge sur at least 3 inches wide.

131. COVERING METHODS.

a. ***The Envelope Method.*** The envel of covering is accomplished by sewi widths of fabric cut to specified and machine sewn to form an envel

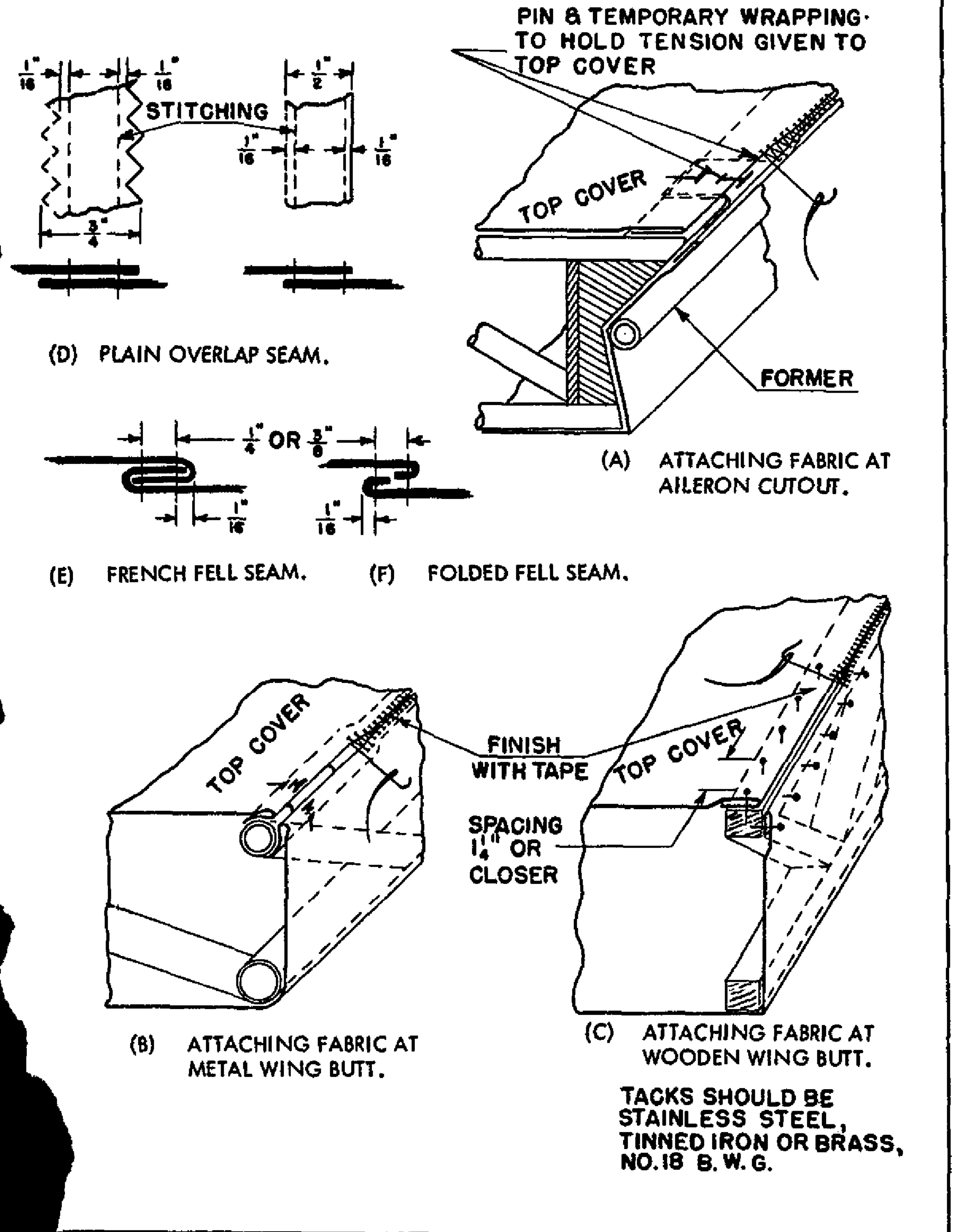


FIGURE 3.3.—Typical methods of attaching fabric.

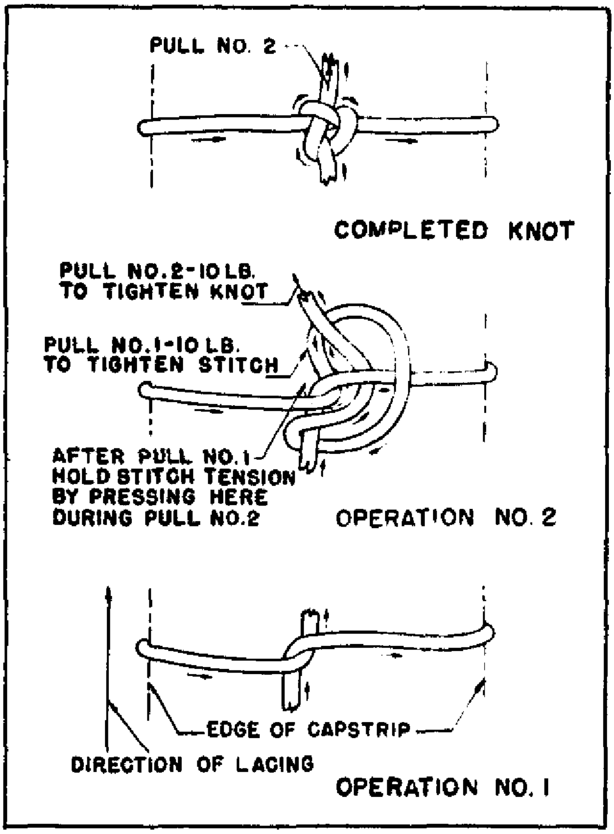


FIGURE 3.4.—Standard knot for rib lacing and terminating a sewed seam (modified seine knot).

can be drawn over the frame. The trailing and outer edges of the covering should be machine sewn unless the component is not favorably shaped for sewing, in which case, the fabric should be joined by hand sewing.

b. *The Blanket Method.* The blanket method of covering is accomplished by sewing together widths of fabric of sufficient lengths to form a blanket over the surfaces of the frame. Join the trailing and outer edges of the covering by a plain overthrow or baseball stitch. For airplanes with placard never-exceed speed of 150 miles per hour or less, the blanket may be lapped at least 1 inch and doped to the frame or the blanket, lapped at least 4 inches at the nose of metal- or wood-covered leading edges, doped, and finished with pinked-edge surface tape at least 4 inches wide. When fabricating both the envelope and blanket coverings, cut the fabric in lengths sufficient to pass completely around the frame, starting at the t ing edge and returning to the trailing edge.

132. REINFORCING TAPE. Place reinforcing of at least the width of the capstrips unde lacing. In the case of wings with plywoo metal leading edge covering, the reinfor tape need be brought only to the front sp the upper and lower surfaces.

a. *Use of Antitear Strips.* On aircraft never-exceed speed in excess of 250 mile hour, antitear strips are recommended the reinforcing tape on the upper surf wings, and the bottom surface of that p the wing in the slipstream. Where the anti strip is used on both the top and bottom faces, pass it continuously up to and aro the leading edges and back to the trailing e Where the strip is used only on the top face, carry it up to and around the lead edge and back on the lower surface as far as the front beam. For this purpose the stream should be considered as being equ the propeller diameter plus one extra rib s on each side.

Cut antitear strips from the same materia used for covering and wide enough to ext beyond the reinforcing tape on each side to engage the lacing cord. Attach the st applying dope to that part of the fabric covered by the strip, and apply dope f over the strip.

133. LACING.

a. Securely fasten both surfaces of f covering on wings and control surfaces t ribs by lacing cord or any other metho nally approved for the aircraft. Care sh taken to insure that all sharp edges a which the lacing cord may bear are pr by tape in order to prevent abrasio cord. Join separate lengths of lacing the splice knot shown in figure 3.5. the common square knot for this ercise the utmost care to assure sion and security of all stitches. or starting stitch use a double l trated in figure 3.6. Make all stitches using a single loop tied o standard knot for rib lacing (mo shown in figure 3.4). The spacing between starting stitch and the next stitch should ne-half the normal stitch spacing. Final lo- on of the knot depends upon the original tion selected by the manufacturer. If such rmation is not available, consider position- the knot where it will have the least effect he aerodynamics of the airfoil. The seine t admits a possibility of improper tighten- resulting in a false (slip) form with tly reduced efficiency and must not be used titch tie-offs. Lock the tie-off knot for the stitch by an additional half-hitch. Where ning ends, as at the rear beam and at the ling edge, space the last two stitches at half normal spacing. Under no circum- nces pull tie-off knots back through the lac- holes.

. ***The double-loop lacing*** illustrated in figure represents a method for obtaining higher ngths than possible with the standard sin- lacing. When using the double-loop lacing, the tie-off knot shown in figure 3.8.

. ***Fuselage Lacing.*** Fabric lacing is also neces- y in the case of deep fuselages, and on fuse- es where former strips and ribs shape the ric to a curvature. In the latter case, lace fabric at intervals to the formers. Attach- of the fabric to fuselages must be so ac- plished as to be at least the equivalent in ngth and reliability to that used by the ufacturer of the airplane.

. STITCH SPACING. The stitch spacing should not exceed the spacing approved on the origi- nal aircraft. In case the spacing cannot be as- certained due to destruction of the covering, acceptable rib-stitch spacing is specified in figure 3.9. Place the lacing holes as near to the capstrip as possible in order to minimize the tendency of the cord to tear the fabric. Lightly wax all lacing cords with beeswax for protec- tion. In case waxed-braided cord is used, this procedure is unnecessary. (See figure 3.2 for acceptable lacing cords.)

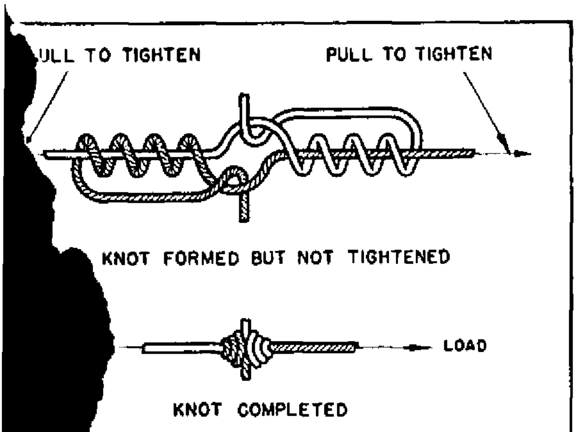


FIGURE 3.5.—Splice knot.

135. SURFACE TAPE (FINISHING TAPE). Cover all lacing with tape of at least the quality and width used on the original airplane. This tape should not be applied until the first coat of dope has dried. Replace all inspection openings in the covering, and reinforce the fabric around them and along leading edges with tape. Wear or friction, induced by moving parts or fittings, can be repaired by sewing a leather patch on a fabric patch and doping in place. Pinked surface tape is sometimes ap- plied over the trailing edges of control surfaces and airfoils. For sure application, the tape must be at least 3 inches in width, and if the aircraft never-exceed speed is greater than 200 miles per hour, notch the tape at intervals not exceeding 18 inches. If separation of the tape from the trailing edge begins, it will tear at a notched section and thereby prevent loosening of the entire strip which could seriously affect the controllability of the aircraft.

136. SPECIAL FASTENERS. When repairs are made to fabric surfaces attached by special mechani- cal methods, duplicate the original type of fas- tener. When self-tapping screws are used for the attachment of fabric to the rib structure, observe the following procedure:

a. ***Redrill the holes*** where necessary due to wear, distortion, etc., and in such cases, use a screw one size larger as a replacement.

b. ***Extend the length of the screw*** beyond the rib capstrip at least two threads of the grip (threaded part).

c. ***Install a thin washer,*** preferably celluloid, under the heads of screws and dope pinked- edge tape over each screw head.

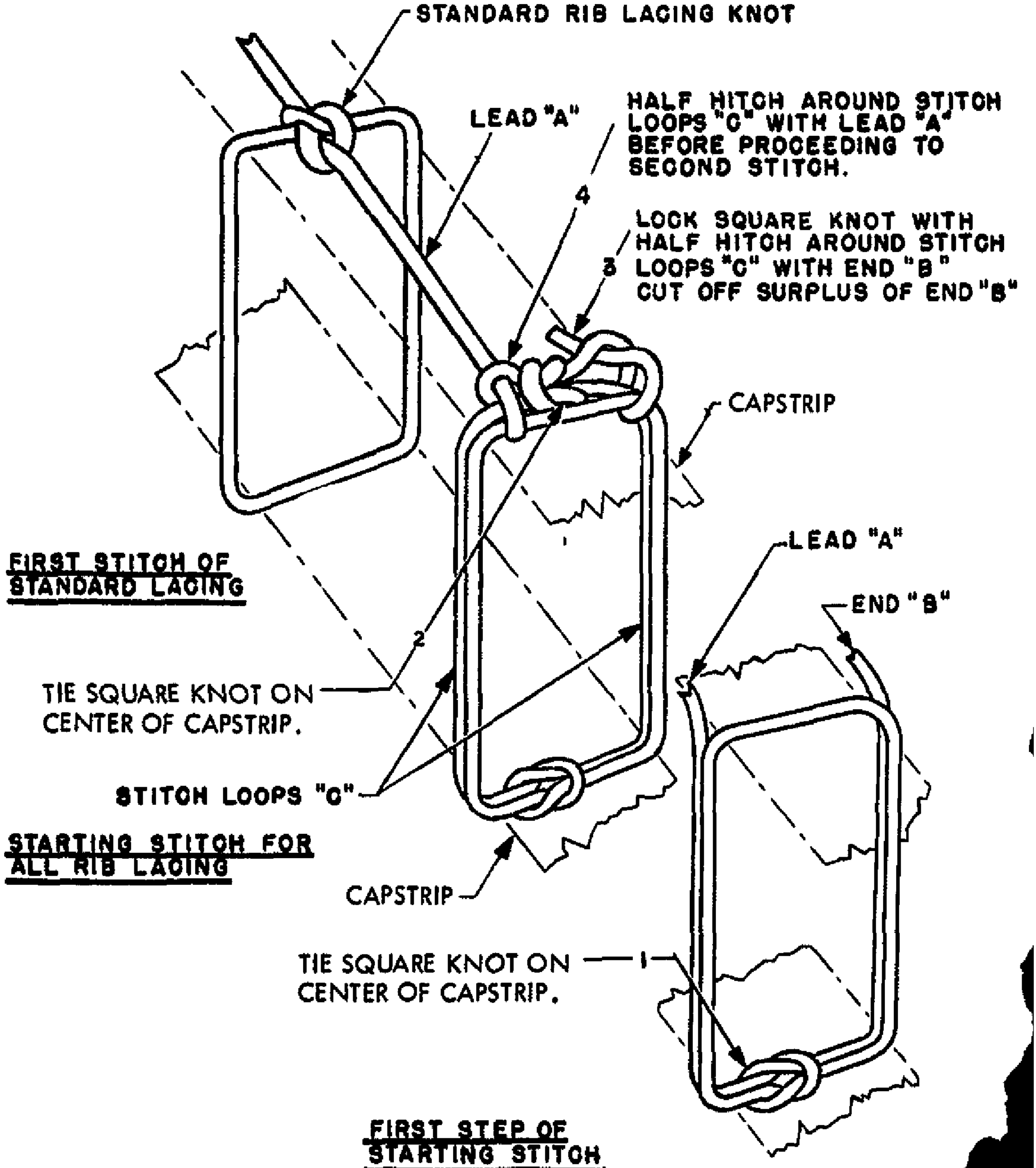


FIGURE 8.6.—Starting stitch for rib stitching.

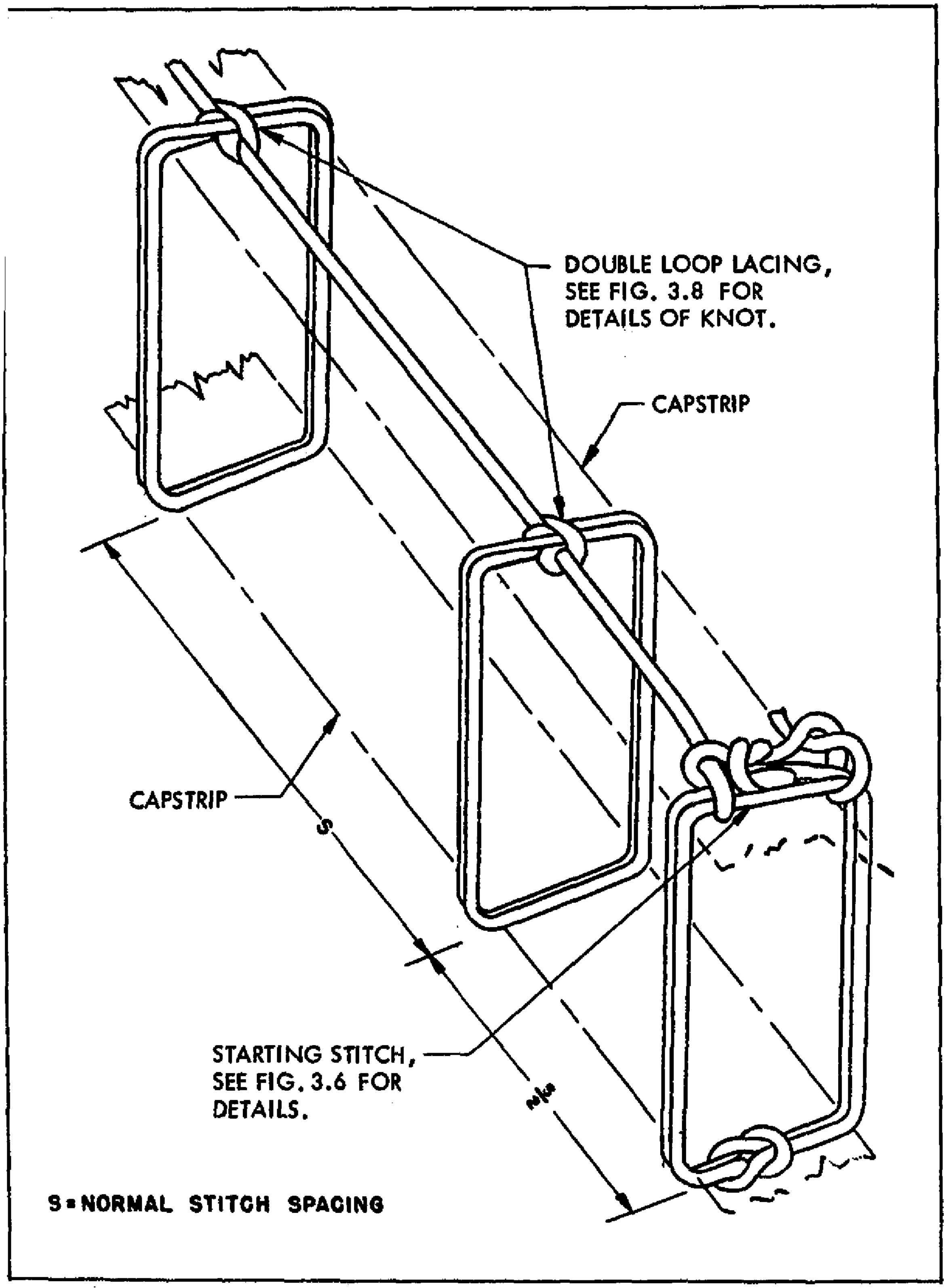


FIGURE 3.7.—Standard double loop lacing.

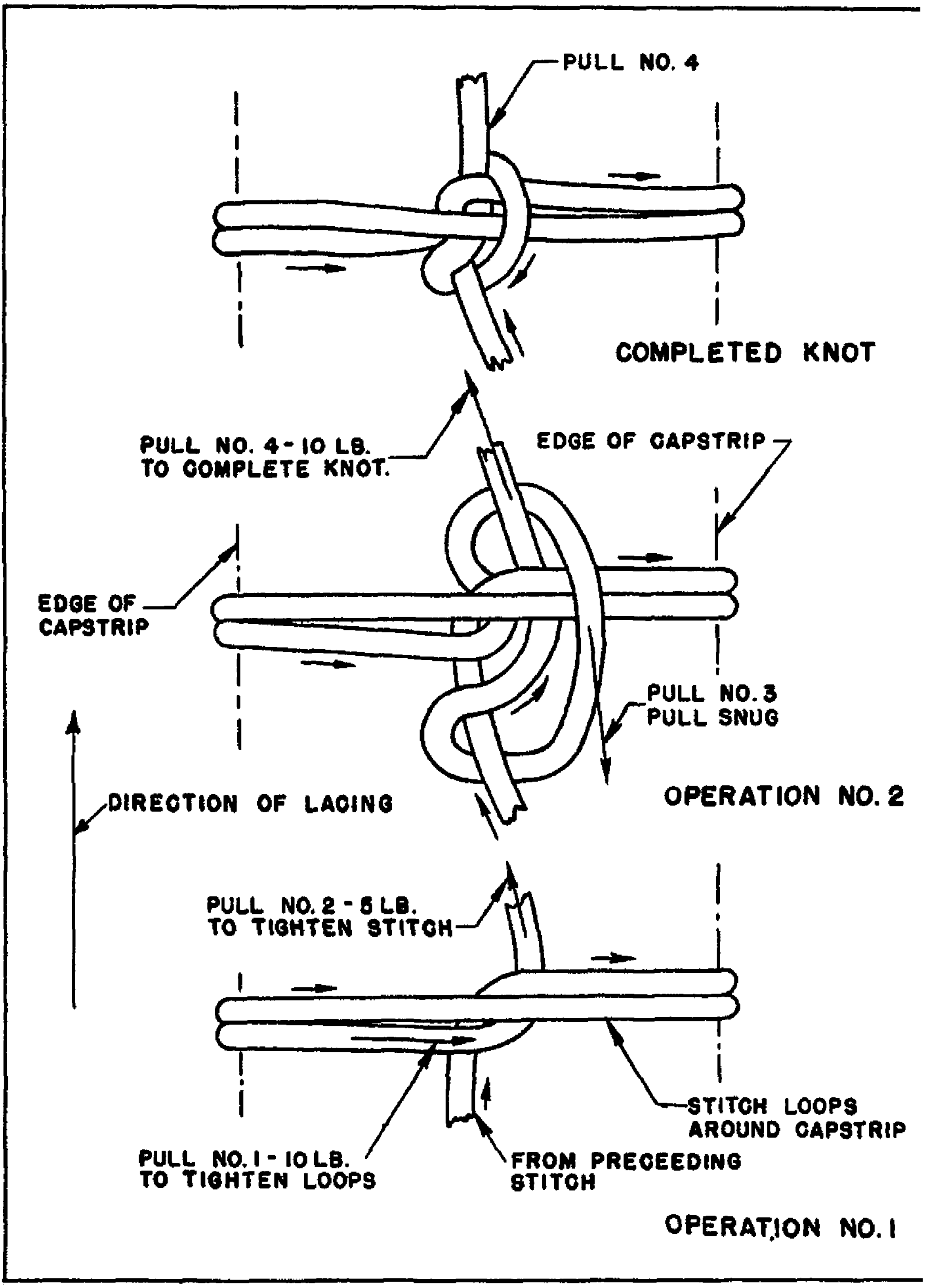


FIGURE 8.8.—Standard knot for double loop lacing.

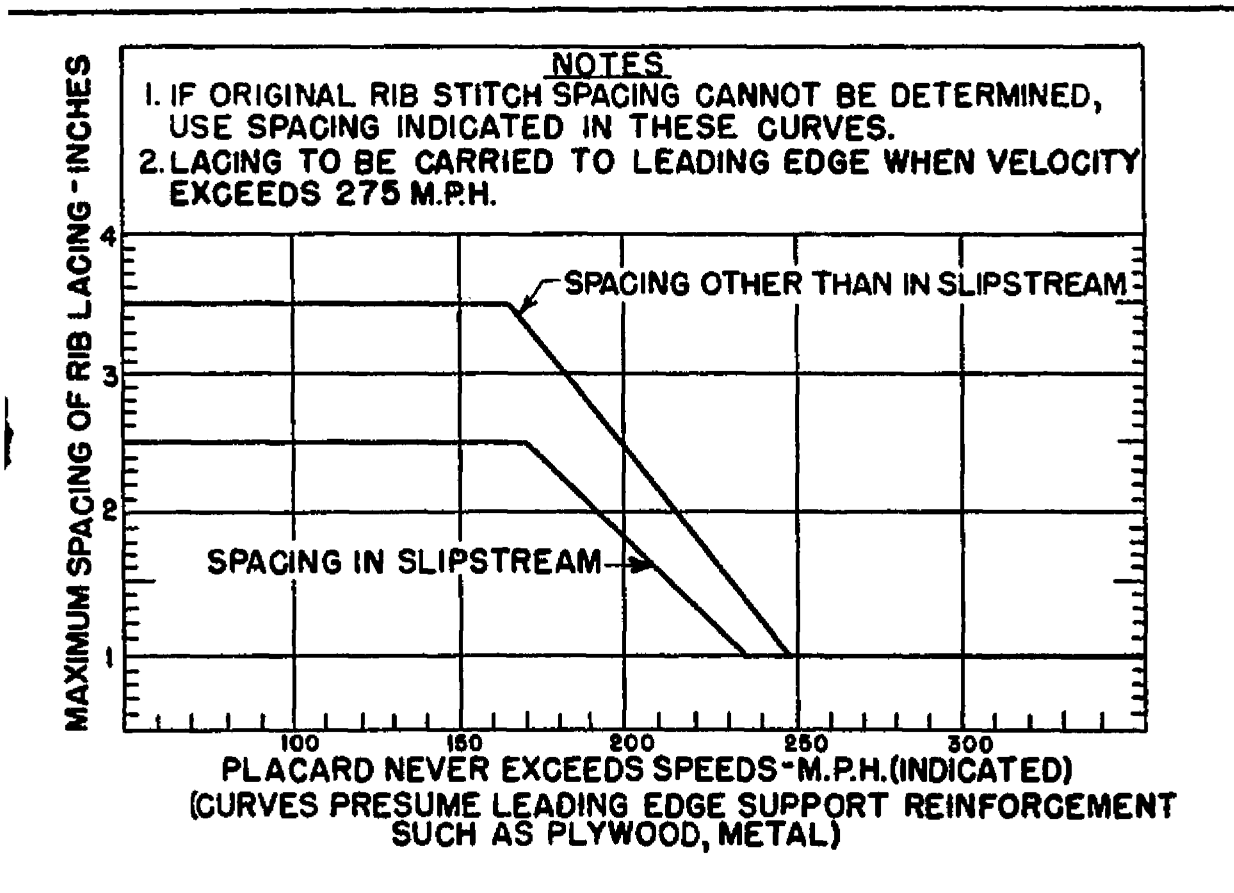


FIGURE 8.9.—Fabric attachment spacing.

37.–147. RESERVED.

Section 2. DOPING

148. APPLICATION OF AIRCRAFT DOPE, EPOXY, AND RESINS. Determine that dope and fabric materials are compatible by consulting the product manufacturer's instructions before applying finish to aircraft surfaces. Compatibility of products may also be determined by wetting samples of the fabric with the impregnating materials and thorough examination of the material after it has dried. The following military specifications, or later revisions thereof, apply to aircraft dope, epoxy, and polyester resins:

MIL-D-5549A-1	Clear dope, cellulose-acetate butyrate.
MIL-D-7850	Fungicidal dope, first coat, cellulose-acetate, butyrate.
MIL-D-5550A-1	Pigmented dope, cellulose-acetate, butyrate.
MIL-D-5551A-2	Pigmented dope, gloss, cellulose-acetate butyrate.
MIL-D-5553A-2	Clear dope, nitrate.
MIL-D-5552A-1	Clear dope, gloss, cellulose nitrate.
MIL-D-5554A-1	Gloss dope, cellulose nitrate.
MIL-D-5555-1	Pigmented dope, cellulose nitrate.
MIL-R-9300A	Resin, epoxy, low pressure laminating.
MIL-R-25042A	Resin, polyester, low pressure laminating.
MIL-R-7575B	Resin, polyester, low pressure laminating.

a. *Thinning.* Finishing materials are generally supplied at a consistency ready for brush application. For spraying operations, practically all aircraft dope, epoxy, or resin requires thinning. Thinning instructions are usually listed on the container label. Avoid use of thinning agents other than those specified by the product manufacturer. To do so may result in adverse chemical action. The amount of thinner to be used will depend on the material, atmospheric conditions, spraying equipment, the spraying technique of the operator, and the type of thinning agent employed. Thinning influences the drying time and the tautening properties of the finish, and it is necessary that it be done properly. Since local atmosphe conditions affect the doping process, determ the amount of thinner necessary at the ti the finishing material is to be applied by fi using it on experimental panels.

149. BLUSHING AND USE OF BLUSH-RETARDI THINNER. Blushing of dopes is very comm when doping is accomplished under humid c ditions. The condition is caused by the ra evaporation of thinners and solvents, wh lowers the temperature on the surface, causi condensation of moisture and producing white appearance known as "blush." Blushi tendencies are also increased, if strong c rents of air flow over the surface when app ing dope or immediately thereafter.

A blushed finish has very little protective tautening value. When the relative humidity such that only a small amount of blushing encountered, the condition may be eliminat by thinning the dope with a blush-retardi thinner and slightly increasing the room te perature. If it is not possible to correct hum ity conditions in the dope room, suspend dopi operations until more favorable atmosphe conditions prevail. The use of large amounts blush-retarding thinner is not advisable cause of the undesirable drying properties companying the use of this material.

150. NUMBER OF COATS. Apply as many coats dope as are necessary to result in a taut a well-filled finish job. A guide for finishing fa ric-covered aircraft follows:

a. Two coats of clear dope, brushed on a sanded after the second coat.

b. One coat of clear dope, either brushed sprayed, and sanded.

c. Two coats of aluminum pigmented dop sanded after each coat.

Section 3. REPAIRS TO FABRIC COVERING

55. **GENERAL.** Make repairs to fabric-covered ırfaces in a manner that will return the origiıl strength and tautness to the fabric. Sewed ɛpairs and unsewed (doped-on patches or pans) may be made. Do not dope fabric or tape ıto a surface which contains aluminum or :her color coats. Whenever it is necessary to dd fabric reinforcement, remove the old dope ither by softening and scraping or by sanding own to the point where the base coat or clear oat is exposed. Use clear dope in doping the ıbric to the surface. After reinforcement is ıade, normal finishing procedures may be folowed.

66. **REPAIR OF TEARS IN FABRIC.** Repair tears s shown in figure 3.10 by sewing the torn edges together using a baseball stitch and doping a piece of pinked-edge fabric over the tear. If the tear is a straight rip, the sewing is started at one end so that, as the seam is made, the edges will be drawn tightly together throughout its entire length. If the openings are cut in wings to inspect the internal structure, start the sewing at the corner or point so that the edges of the cover will be held in place while the seams are being made. The sewing is done with a curved needle and well-waxed thread. Clean the surface to be covered by the patch by rubbing the surface with a rag dipped in dope, wiping dry with a clean rag, or by scraping the surface with a putty knife after it has been softened with fresh dope. Dope solvent or acetone may be used for the same pur-

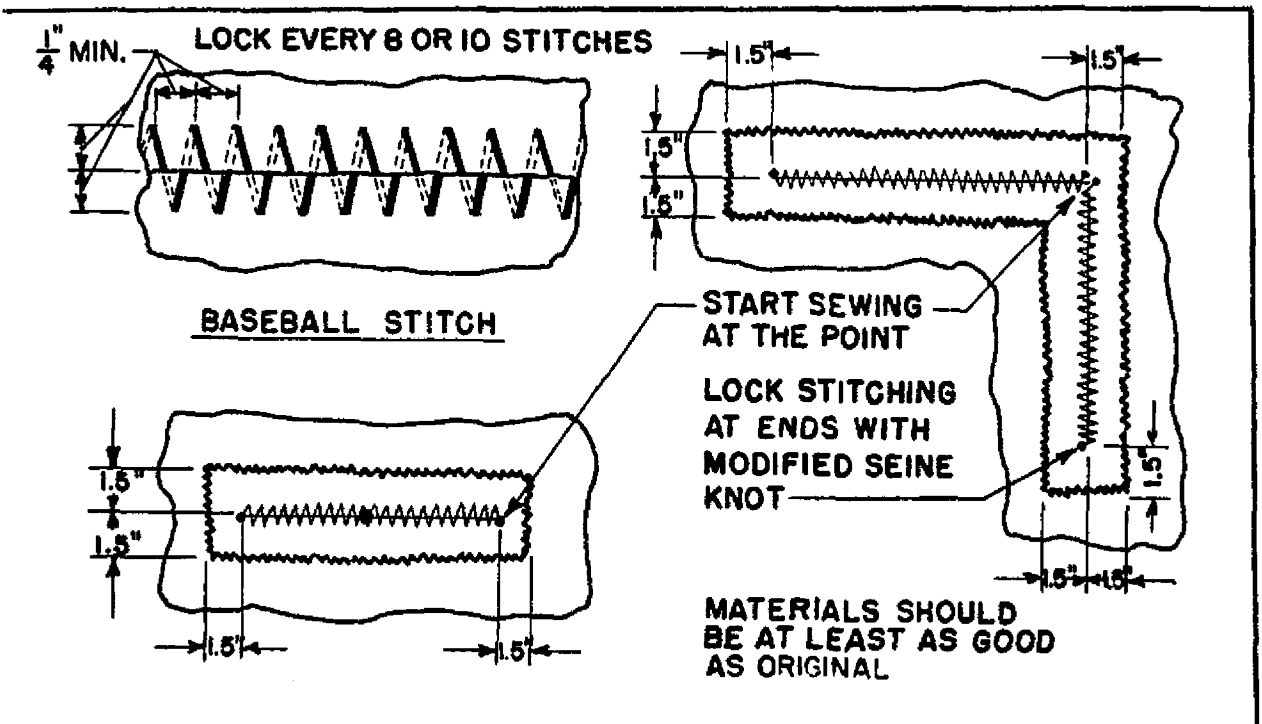


FIGURE 3.10.—Repair of tears in fabric.

pose, but care should be taken that it does not drop through on the inside of the opposite surface, causing the dope to blister. Cut a patch of sufficient size from airplane cloth to cover the tear and extend at least 1 1/2 inches beyond the tear in all directions. The edges of the patch should either be pinked similar to surface tape or frayed out about 1/4 inch on all edges.

167. SEWED PATCH REPAIR. When the damage is such that it will not permit sewing the edges together, a sewed-in repair patch may be used if the damage is not longer than 16 inches in any one direction (see figure 3.10). Cut out the damaged section, making a round or oval-shaped opening trimmed to a smooth contour. Clean the area of the old fabric to be doped as indicated in paragraph 166. Turn the edges of the patch 1/2 inch and sew to the edges of the opening. Before sewing, fasten the patch at several points with a few temporary stitches to facilitate sewing the seams. After the sewing is completed, clean the area of the old fabric to be doped as indicated for small repairs and then dope the patch in the regular manner. Apply surface tape over the seam with the second coat of dope. If the opening extends over or closer than 1 inch to a rib or other laced member, extend the patch 3 inches beyond the member. After sewing has been completed, rib lace the patch to the rib over a new section of reinforcing tape, using the method explained in paragraph 133. Do not remove the old rib lacing and reinforcing tape.

168. UNSEWED (DOPED-ON) REPAIRS. Unsewed (doped-on) repairs may be made on all aircraft fabric-covered surfaces provided the never-exceed speed is not greater than 150 miles per hour. A doped patch repair may be used if the damage does not exceed 16 inches in any direction. Cut out the damaged section making a round or oval shaped opening, trimmed to a smooth contour. Clean the edges of the opening which are to be covered by the patch with a grease solvent. Sand or wash off the dope from the area around the patch with dope thinner. Support the fabric from underneath while sanding.

For holes up to 8 inches in size, make fabric patch of sufficient size to provide a of at least 2 inches around the hole. On h over 8 inches in size, make the overlap of fabric around the hole at least 1/4 the hole ameter with a maximum limit of lap o inches. If the hole extends over a rib or clc than the required overlap to a rib or ot laced member, extend the patch at leas inches beyond the rib. In this case, after edges of the patch have been doped in pl and the dope has dried, lace the patch to rib over a new section of reinforcing tape the usual manner. Do not remove the old lacing and reinforcing tape. All patches sho have pinked edges or, if smooth, should be ished with pinked-edge surface tape.

169. REPAIR BY A DOPED-IN PANEL. When damage exceeds 16 inches in any directi make the repair by doping in a new panel. T type of repair may be extended to cover b the upper and lower surfaces and to cover s eral rib bays if necessary. Lace the panel to the ribs covered, and dope or sew as in t blanket method.

a. *Remove the surface tape* from the ribs a jacent to the damaged area and from the tr ing and leading edges of the section being paired. Leave the old reinforcing tape a lacing in place. Next, cut the fabric along a li approximately 1 inch from the ribs on t sides nearest the injury and continue the cu to completely remove the damaged section. not remove the old fabric from the leading a trailing edges, unless both upper and low surfaces are being re-covered.

b. *Cut a patch* to run around the trailing ed 1 inch and to extend from the trailing edge to and around the leading edge and back a proximately to the front beam. Extend t patch approximately 3 inches beyond the ri adjacent to the damage.

As an alternative attachment on metal- wood-covered leading edges, the patch may lapped over the old fabric at least 4 inches the nose of the leading edge, doped, and fi ished with at least 4 inches of pinked-edge su face tape.

c. ***Clean the area of the old fabric*** that is to be ›vered by the patch and apply a generous coat ' dope to this area. Put the new panel in ace, pull as taut as possible, and apply a coat f dope to that portion of the panel which over-ıps the old fabric. After this coat has dried, pply a second coat of dope to the overlapped rea and let dry.

d. ***Place reinforcing tape over the ribs*** under moderate tension and lace down in the approved manner.

e. ***Give the panel a coat of clear dope*** and allow to dry. Install surface tape with the second coat of dope over the reinforcing tape and over the edges of the panel. Finish the dope scheme, using the regular doping procedure.

170.-180. RESERVED.

Section 4. FABRIC TESTING

181. TESTING OF FABRIC COVERING. Field test instruments that are commonly used to test the tensile strength of aircraft fabric covering give only approximate indications of the fabric condition. Since the accuracy of field test instruments is affected by climatic and environmental conditions, a laboratory test is recommended when aircraft fabric covering is found to be marginal by field test methods. Laboratory test procedures are set forth in Federal Specification CCC-T-191B, methods 5122, 5132, 5134, or 5136; American Society of Testing Materials (ASTM) Method D39-61 or D39-49, and others. In all cases, test fabric specimens in the undoped condition. Use acetone, dope thinner, or other appropriate thinning agents for the removal of finishing materials.

a. *Strength Criteria for Aircraft Fabric.*

(1) Present minimum strength values for new aircraft fabric covering are contained in figure 3.1.

(2) The maximum permissible deterioration for used aircraft fabric based on a large number of tests in 30 percent. Fabric which h less than 70 percent of the original requir tensile strength would not be considered a: worthy. Figure 3.1 contains the minimum te sile strength values for deteriorated fabric tested in the undoped condition.

(3) Grade A fabric may be used whe only intermediate fabric is required. Wh testing for deteriorated condition, 46 poun (70 percent of original requirements for inte mediate fabric) is considered airworthy.

(4) Failures may occur in fiberglass cove ing where rib stitching has worn through tl reinforcing tape and covering material witho being detected through visual inspection. Su failures can be located by using a suitable su tion cup and lifting the fabric in the r stitched area. If the fabric pulls away from tl ribs, new stitching will need to be appli using additional reinforcing tape and doublin the number of stitches throughout the affect area. Five particular attention to the area within the propeller slipstream area.

182.-192. RESERVED.

Chapter 4. CONTROL CABLES AND TERMINALS

Section 1. INSPECTION AND REPAIR

93. GENERAL. Aircraft control cables are genrally fabricated from carbon steel or corroion-resistant steel wire and may consist of eiher flexible or nonflexible type construction.

Contents of this section may be used for conrol cable installations pertaining to both prinary and secondary system applications.

a. Cable Definitions. Construction features of 'arious cables are shown in figure 4.1. The folowing terms define components used in air:raft control cables.

(1) Wire—Each individual cylindrical steel :od or thread.

(2) *Strand*—Each group of wires helically wisted or laid.

(3) Core Strand—The central strand about which the remaining strands of the cable are helically laid.

(4) Cable—A group of strands helically wisted or laid about a central core.

(5) Preformed Cable—Cable in which the wires and strands are shaped prior to fabrication of the cable.

(6) Diameter—The diameter of cable is the diameter of the circumscribed circle.

(7) Lay or Twist—The helical form taken by the wires and strands in a cable. A cable is said to have a right-hand lay if the wires and strands twist in the same direction as the thread on a right-hand screw.

(8) Pitch—The distance in which a strand or wire makes one complete revolution about the axis of the cable or strand respectively.

194. CABLE SPECIFICATIONS. Cable size and strength data are given in figure 4.2. These values are acceptable for repair and modification of civil aircraft.

a. Cable Proof Loads. Cable terminals and

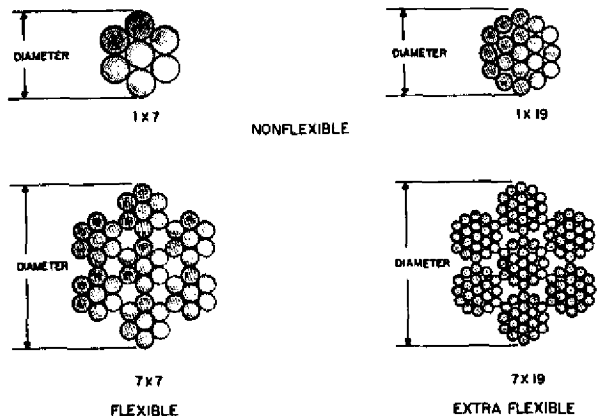


FIGURE 4.1.—*Cable cross section.*

splices should be tested for proper strength prior to installation. Gradually apply a test load equal to 60 percent of the cable breaking strengths given in figure 4.2 for a period of 3 minutes. Place a suitable guard over the cable during the test to prevent injury to personnel in the event of cable failure.

195. REPLACEMENT OF CABLES. Replace control cables when they become worn, distorted, corroded, or otherwise injured. If spare cables are not available, prepare exact duplicates of the damaged cable. Use materials of the same size and quality as the original. Standard swaged cable terminals develop the full cable strength and may be substituted for the original terminals wherever practical. However, if facilities and supplies are limited and immediate corrective action is necessary, repairs may be made by using cable bushings, eye splices, and the proper combination of turnbuckles in place of the original installation. (See figure 4.6c.)

a. Location of Splices. Locate splices so that no portion of the splice comes closer than two

Diameter (inch)	1X7 and 1X19				7X7, 7X19, and 6X19 (IWRC)			
	Nonflexible, carbon		Corrosion resisting		Flexible, carbon		Flexible, corrosion resisting	
	MIL-W-6940		MIL-C-5693		MIL-W-1511		MIL-C-5424	
	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds	Weight, pounds per 100 feet	Breaking strength, pounds
1/32	0. 25	185	0. 25	150				
3/64	. 55	375	. 55	375				
1/16	. 85	500	. 85	500	0. 75	480	0. 75	480
5/64	1. 40	800	1. 40	800				
3/32	2. 00	1, 200	2. 00	1, 200	1. 60	920	1. 60	920
7/64	2. 70	1, 600	2. 70	1, 600				
1/8	3. 50	2, 100	3. 50	2, 100	2. 90	2, 000	2. 90	1, 760
5/32	5. 50	3, 300	5. 50	3, 300	4. 50	2, 800	4. 50	2, 400
3/16	7. 70	4, 700	7. 70	4, 700	6. 50	4, 200	6. 50	3, 700
7/32	10. 20	6, 300	10. 20	6, 300	8. 60	5, 600	8. 60	5, 000
1/4	13. 50	8, 200	13. 50	8, 200	11. 00	7, 000	11. 00	6, 400
9/32					13. 90	8, 000	13. 90	7, 800
5/16	21. 00	12, 500	21. 00	12, 500	17. 30	9, 800	17. 30	9, 000
11/32					20. 70	12, 500		
3/8					24. 30	14, 400	24. 30	12, 000
7/16					35. 60	17, 600	35. 60	16, 300
1/2					45. 80	22, 800	45. 80	22, 800

*The strength values listed were obtained from straight tension tests and do not include the effects of wrapped ends.

FIGURE 4.2.—Strength of steel cable.

inches to any fair-lead or pulley. Locate connections at points where jamming cannot occur during any portion of the travel of either the loaded cable or the slack cable in the deflected position.

b. ***Cutting and Heating.*** Cut cables to length by mechanical means. The use of a torch in any manner is not permitted. Do not subject wires and cables to excessive temperature. Soldering bonding braid to control cable will not be considered satisfactory.

c. ***Ball-and-Socket Type Terminals.*** Do not use ball-and-socket type terminals or other types for general replacement that do not positively prevent cable untwisting, except where they were utilized on the original installation by the aircraft manufacturer.

d. ***Substitution of Cable.*** Substitution of cable for hard or streamlined wires will not be acceptable unless specifically approved by a representative of the Federal Aviation Administration.

196. MECHANICALLY FABRICATED CABLE ASSEMBLIES.

a. ***Swage Type Terminals.*** Swage type terminals, manufactured in accordance with Air Force-Navy Aeronautical Standard Specifications, are suitable for use in civil aircraft up to and including maximum cable loads. When swaging tools are used, it is important that all the manufacturers' instructions, including "go and no-go" dimensions, be followed in detail to avoid defective and inferior swaging. Observance of all instructions should result in a terminal developing the full rated strength of the cable. Critical dimensions, both before and after swaging, are shown in figure 4.8.

(1) Terminals. When swaging terminals onto cable ends, observe the following procedure:

(a) Cut the cable to the proper length, allowing for growth during swaging. Apply a preservative compound to the cable ends before insertion into the terminal barrel.

NOTE: Never solder cable ends to prevent fraying

Cable size (inches)	Wire strands	Before swaging				After swaging	
		Outside diameter	Bore diameter	Bore length	Swaging length	Minimum breaking strength (pounds)	Shank diameter*
1/16	7×7	0.160	0.078	1.042	0.969	480	0.138
3/32	7×7	.218	.109	1.261	1.188	920	.190
1/8	7×19	.250	.141	1.511	1.438	2,000	.219
5/32	7×19	.297	.172	1.761	1.688	2,800	.250
3/16	7×19	.359	.203	2.011	1.938	4,200	.313
7/32	7×19	.427	.234	2.261	2.188	5,600	.375
1/4	7×19	.494	.265	2.511	2.438	7,000	.438
9/32	7×19	.563	.297	2.761	2.688	8,000	.500
5/16	7×19	.635	.328	3.011	2.938	9,800	.563
3/8	7×19	.703	.390	3.510	3.438	14,400	.625

*Use gages in kit for checking diameters.

FIGURE 4.3.—Straight-shank terminal dimensions (AN-666, 667, 668, and 669).

since the presence of the solder will greatly increase the tendency of the cable to pull out of the terminal.

(b) Insert the cable into the terminal approximately one inch, and bend toward the terminal; straighten the cable back to normal position and then push the cable end entirely into the terminal barrel. The bending action puts a kink or bend in the cable end and provides enough friction to hold the terminal in place until the swaging operation can be performed. Bending also tends to separate the strands inside the barrel, thereby reducing the strain on them.

NOTE: If the terminal is drilled completely through, push the cable into the terminal until it reaches the approximate position shown in figure 4.4. If the hole is not drilled through, insert the cable until the end rests against the bottom of the hole.

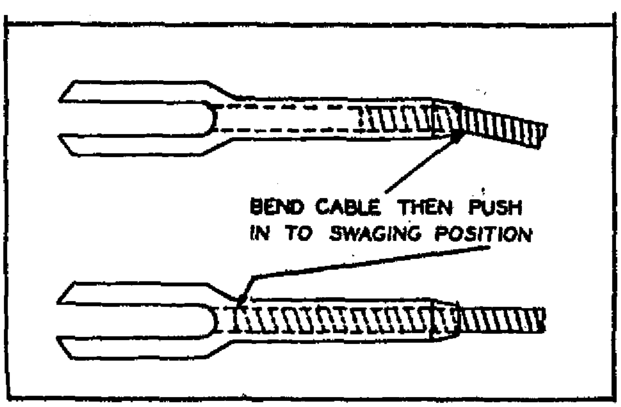


FIGURE 4.4.—Insertion of cable into terminal.

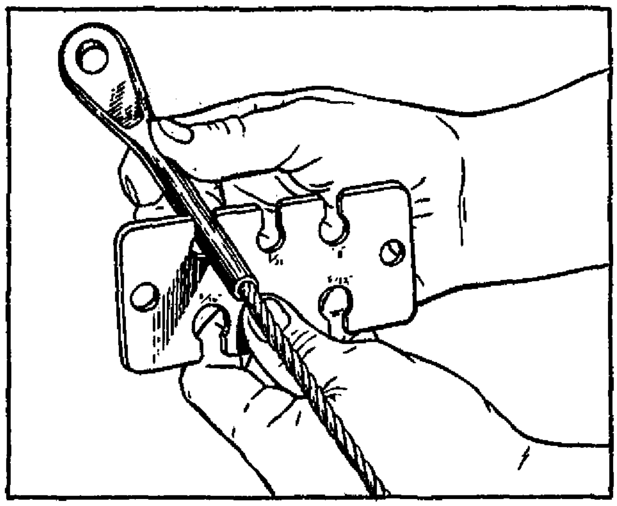


FIGURE 4.5.—Gauging terminal shank after swaging.

(c) Accomplish the swaging operation in accordance with the instructions furnished by the manufacturer of the swaging equipment.

(d) Inspect the terminal after swaging to determine that it is free from die marks and splits, and is not out-of-round. Check for cable slippage in the terminal and for cut or broken wire strands.

(e) Using a "go no-go" gauge or a mi-

crometer, check the terminal barrel diameter as shown in figure 4.5.

(f) Test the cable by proof-loading it to 60 percent of its rated breaking strength.

(2) Splicing. Completely severed cables, or those badly damaged in a localized area, may be repaired by the use of an eye terminal bolted to a clevis terminal. (See figure 4.6a.) However, this type of splice can only be used in free lengths of cable which do not pass over pulleys or through fair-leads.

(3) Swaged Ball Terminals. On some aircraft cables, swaged ball terminals are used for attaching cables to quadrants and special connections where space is limited. Single shank terminals are generally used at the cable ends, and double shank fittings may be used at either the end or in the center of the cable. Dies are supplied with the swaging machines for attaching these terminals to cables in the following manner:

(a) The steel balls and shanks have a hole through the center, and are slipped over the cable and positioned in the desired location.

(b) Perform the swaging operation in accordance with the instructions furnished by the manufacturer of the swaging equipment.

(c) Check the swaged fitting with a "go no-go" gauge to see that the fitting is properly

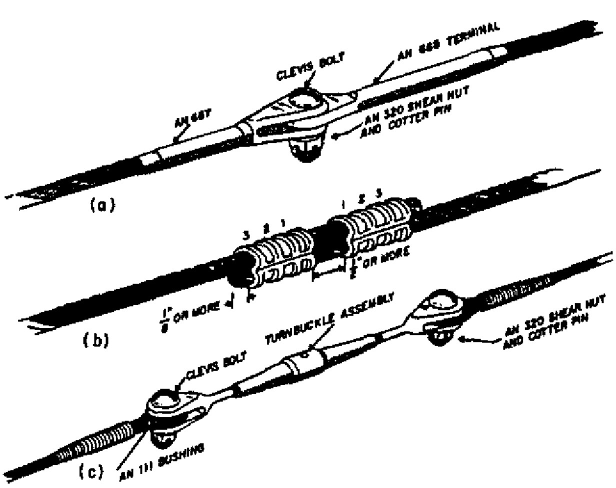


FIGURE 4.6.—Typical cable splices.

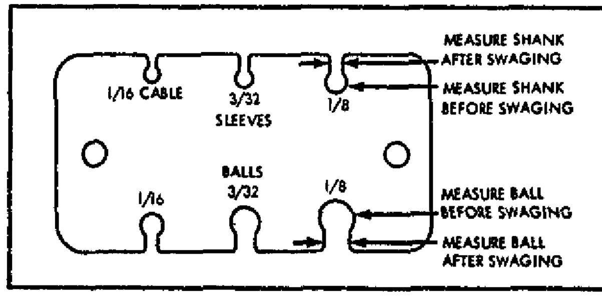


FIGURE 4.7.—Typical terminal gauge.

compressed. (See figure 4.7.) Also inspect the physical condition of the finished terminal.

(4) Cable Slippage in Terminal. Ensure that the cable is properly inserted in the terminal after the swaging operation is completed. Instances have been noted wherein only 1/4 inch of the cable was swaged in the terminal. Observance of the following precautions should minimize this possibility:

(a) Measure the length of the termin end of the fitting to determine the prop length of cable to be inserted into the barrel o the fitting.

(b) Lay off this length at the end of the cable and mark with masking tape. Since the tape will not slip, it will provide a positive marking during the swaging process.

(c) After swaging, check the tape marker to make certain that the cable did not slip during the swaging operation.

(d) Remove the tape and, using red paint, paint the junction of the swaged fitting and cable.

(e) At all subsequent service inspections of the swaged fittings, check for a gap in the painted section to see if cable slippage has occurred.

b. *Nicopress Process.* A patented process using copper sleeves may be used up to the full rated strength of the cable when the cable is looped around a thimble. This process may also be used in place of the five-tuck splice on cables up to and including 3/8-inch diameter. The use of sleeves that are fabricated of materials other than copper will require engineering approval of the specific application by a representative of the Federal Aviation Administration.

Cable size	Copper oval sleeve stock No.		Manual tool No.	Sleeve length before compression (approx.) (inches)	Sleeve length after compression (approx.) (inches)	Number of presses	Tested strength (pounds)
	Plain	Plated*					
14	18-11-B4	28-11-B4	51-B4-887	3/8	7/16	1	340
16	18-1-C	28-1-C	51-C-887	3/8	7/16	1	550
12	18-2-G	28-2-G	51-G-887	7/16	1/2	1	1, 180
8	18-3-M	28-3-M	51-M-850	9/16	3/4	3	2, 300
32	18-4-P	28-4-P	51-P-850	5/8	7/8	3	3, 050
16	18-6-X	28-6-X	51-X-850	1	1 1/4	4	4, 350
32	18-8-F2	28-8-F2	51-F2-850	7/8	1 1/16	4	5, 790
4	18-10-F6	28-10-F6	3-F6-950	1 1/8	1 1/2	3	7, 180
16	18-13-G9	28-13-G9	3-G9-950	1 1/4	1 5/8	3	11, 130
			No. 635 Hydraulic tool dies				
	18-23-H5	28-23-H5	Oval H5	1 1/2	1 7/8	1	16, 800
6	18-24-J8	28-24-J8	Oval J8	1 3/4	2 1/8	2	19, 700
	18-25-K8	28-25-K8	Oval K8	1 7/8	2 1/2	2	25, 200
6	18-27-M1	28-27-M1	Oval M1	2	2 5/8	3	31, 025
	18-28-N5	28-28-N5	Oval N5	2 3/8	3 1/8	3	39, 200

*Required on stainless cable.

FIGURE 4.8.—Copper oval sleeve data.

Before undertaking a nicopress splice, determine the proper tool and sleeve for the cable to be used. Refer to figures 4.8 and 4.10 for details on sleeves, tools, and the number of presses required for the various sizes of aircraft cable. The tool must be in good working condition and properly adjusted to assure a satisfactory splice.

To compress a sleeve, have it well centered in the tool groove with the major axis of the sleeve at right angles to the tool. If the sleeve appears to be out of line after the press is started, open the tool, re-center the sleeve, and complete the press.

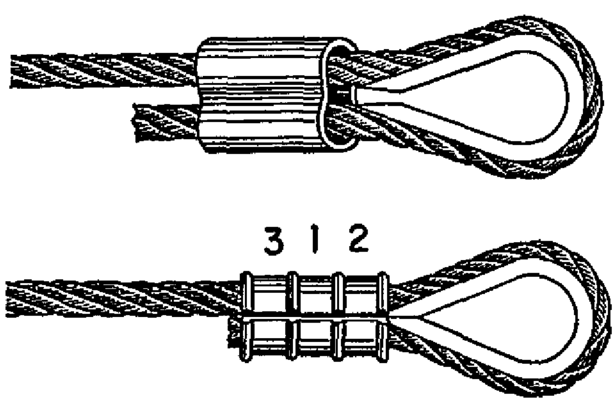


FIGURE 4.9.—Typical thimble-eye splice.

(1) Thimble-Eye Splice. Initially position the cable so that the end will extend slightly beyond the sleeve, as the sleeve will elongate somewhat when it is compressed. If the cable end is inside the sleeve, the splice may not hold the full strength of the cable. It is desirable that the oval sleeve be placed in close proximity to the thimble points, so that when compressed the sleeve will contact the thimble as shown in figure 4.9. The sharp ends of the thimble may be cut off before being used; however, make certain the thimble is firmly secured in the cable loop after the splice has been completed. When using a sleeve requiring three compressions, make the center compression first, the compression next to the thimble second, and the one farthest from the thimble last.

(2) Lap Splice. Lap or running splices may also be made with copper oval sleeves. When making such splices, it is usually necessary to use two sleeves to develop the full strength of the cable. The sleeves should be positioned as shown in figure 4.6b, and the compressions made in the order shown. As in the case of eye splices, it is desirable to have the cable ends extend beyond the sleeves sufficiently to allow for the increased length of the compressed sleeves.

(3) Stop Sleeves. Stop sleeves may be used for special cable end and intermediate fittings and they are installed in the same manner as Nicopress oval sleeves.

NOTE: All stop sleeves are plain copper—certain sizes are colored for identification.

(4) Terminal Gauge. To make a satisfactory copper sleeve installation, it is important that the amount of sleeve pressure be kept uniform. The completed sleeves should be checked periodically with the proper gauge. Hold the gauge so that it contacts the major axis of the sleeve. The compressed portion at the center of the sleeve should enter the gauge opening with very little clearance, as shown in figure 4.11. If it does not, the tool must be adjusted accordingly.

(5) Other Applications. The preceding information regarding copper oval sleeves and stop sleeves is based on tests made with flexible aircraft cable. The sleeves may also be used on

Cable size (inch)	Sleeve No.	Tool No.	Sleeve length (inch)	Sleeve O.D. (inch)	Tested strength (pounds
3/64	871-12-B4	51-B4-887	7/32	11/64	280
1/16	871-1-C	51-C-887	7/32	13/64	525
3/32	871-17-J (Yellow)	51-MJ	5/16	21/64	600
1/8	871-18-J (Red)	51-MJ	5/16	21/64	800
5/32	871-19-M	51-MJ	5/16	27/64	1, 200
3/16	871-20-M (Black)	51-MJ	5/16	27/64	1, 600
7/32	871-22-M	51-MJ	5/8	7/16	2, 300
1/4	871-23-F6	3-F6-950	11/16	21/32	3, 500
5/16	871-26-F6	3-F6-950	11/16	21/32	3, 800

NOTE: All stop sleeves are plain copper—certain sizes are colored for identification.

FIGURE 4.10.—Copper stop sleeve data.

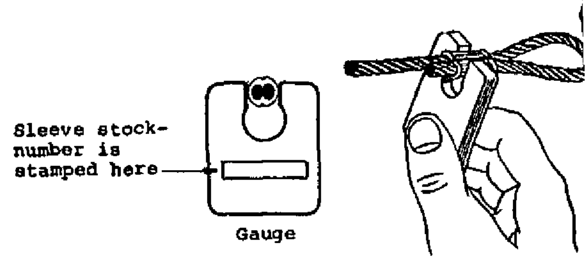


FIGURE 4.11.—Typical terminal gauge.

wire ropes of other constructon if each specific type of cable is proof tested initially. Because of variation in rope strengths, grades, construction, and actual diameters, the test is necessary to insure proper selection of materials the correct pressing procedure, and an adequate margin of safety for the intended use.

197. HAND FABRICATED CABLE ASSEMBLIES.

a. *Woven Splice Terminal.* The 5-tuck woven splice may be utilized on 7×7 flexible and 7×19 extra-flexible cables of 3/32 inch diameter or greater; however, this type of terminal will only develop 75 percent of the cable strength. It should not be used to replace high efficiency terminals unless it is definitely determined the design load for the cable is not greater than 75 percent of the cable minimum breaking strength.

In some cases it will be necessary to splice one end of the cable on assembly. For this reason, investigate the original installation for pulleys and fair-leads that might restrict the passage of the splice. The procedure for the fabrication of a woven splice is as follows. (Refer to figure 4.12 for the designation of numbers and letters referred to in this sequence of operations.)

(1) Secure the cables around a bushing or thimble, by means of a splicing clamp in a vise, with the free end to the left of the standing wire and away from the operator. If a thimble is used as the end fitting, turn to point outward approximately 45°.

(2) Select the free strand (1) nearest the standing length at the end of the fitting, and free this strand from the rest of the free ends. Next, insert a marlinspike under the first three

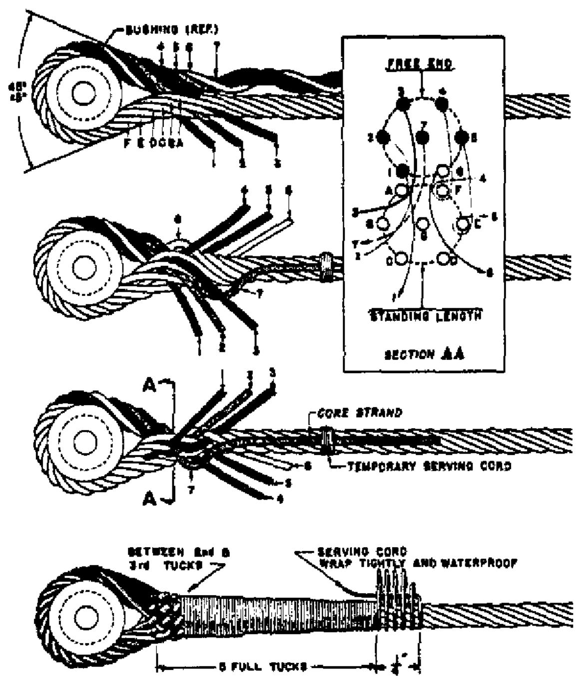


FIGURE 4.12.—Preparation of a woven cable splice.

strands (A, B, and C) of the standing length nearest the separated strand of the free end and separate them momentarily by twisting the marlinspike. Insert the free strand (1) under the three separated strands, through the opening created by the marlinspike. Pull the free end taut by means of pliers.

(3) Unlay a second strand (2), located to the left of the first strand tucked, and insert this second strand under the first two standing strands (A, B). Loosen the third free length (3), located to the left of the first two, and insert it under the first standing strand (A) of the original three (section AA).

(4) Remove the center or core strand (7) from the free end and insert it under the same standing strands (A, B). Temporarily secure the core strand to the body of the standing cable. Loosen the last free strand (6) located just to the right of the first (1) and tuck it under the last two strands (E, F) of the standing cable. Tuck the free strand (5) around standing strand (E). Tuck the free end (4) around the sixth standing strand (F) (see figure 4.12 section AA). Pull all strands snug toward the end fitting with the pliers. This completes the first tuck.

(5) Begin with the first free strand (1) and work in a counterclockwise direction, tucking free strands under every other strand. After the completion of every tuck, pull the strands tight with pliers toward the end fitting. After the completion of the third complete tuck, cut in half the number of wires in each free strand. Make another complete tuck with the wires remaining. At the completion of the fourth tuck, again halve the number of wires in the free strands and make one final tuck with the wires remaining. Cut off all protruding strands and pound the splice with a wooden or rawhide mallet to relieve the strands in the wires.

(6) Serve the splice with waxed linen cord. Start 1/4 inch from the end of the splice and carry the wrapping over the loose end of the cord and along the tapered splice to a point between the second and third tucks. Insert the end of the cord back through the last five wrappings and pull snug. Cut off the end, and if a thimble is used as an end fitting, bend down the points. Apply two coats of waterproofing to the cord, allowing two hours between coats. Carefully inspect the cable strands and splices for local failure. Weakness in a woven splice is made evident by a separation of the strand of serving cord.

b. ***Wrap-Soldered Terminal.*** The wrap-soldered splice terminal shown in figure 4.13 may be utilized on flexible cables less than 3/32 inch in diameter and on nonflexible single strand (19 wire) cable. This type of terminal will develop only 90 percent of the cable strength and should not be used to replace high efficiency terminals, unless it is definitely known that the design load for the cable is not greater than 90 percent of the cable minimum breaking strength. The method of making the wrapped and soldered splice is as follows.

(1) Use serving or wrapping wire made of commercial soft-annealed steel wire or commercial soft iron wire, thoroughly and smoothly tinned or galvanized.

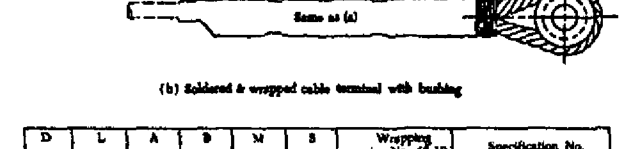
(2) Use half tin and half lead solder conforming to Federal Specification QQ–S–571.

The melting point of this solder varies from 320° to 390° F., and the tensile strength is approximately 5,700 pounds per square inch.

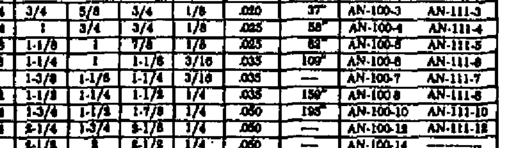
(3) Use solder flux consisting of stearic acid (there should be no mineral acid present) and resin, with a composition of 25 to 50 percent resin. A warming gluepot to keep the flux in fluid state is desirable.

(4) Before the cable is cut, solder the wires to prevent slipping. The preferred process is to tin and solder the cable thoroughly two to three inches by placing in a solder trough, finishing smooth with a soldering tool. The cable may be cut diagonally to conform to the required taper finish.

(5) After being soldered and cut, the cable is securely bent around the proper size thimble, and clamped so that the cables lie close and flat and the taper end for finish lies on the outside. If it is necessary to trim the taper at this point in the process, it is preferable that it be done by nipping. Grinding is permissible, provided a steel guard at least 3 inches long and 1/32 inch thick is placed between the taper end and the main cable during the operation; and that the heat generated from t grinding does not melt the solder and loos the wires.



(a) Soldered & wrapped cable terminal with thimble



(b) Soldered & wrapped cable terminal with bushing

D	L	A	B	M	S	Wrapping wire No. 46-19		Specification No.	
		Plus or minus 1/32"				Dia. inch	Approx. length	Thimble (A)	Bushing (B)
3/32	2-1/4	3/4	5/8	3/4	1/8	.020	37"	AN-100-3	AN-111-3
1/8	2-3/4	1	3/4	3/4	1/8	.025	58"	AN-100-4	AN-111-4
5/32	3-3/8	1-1/8	1	7/8	1/8	.025	82"	AN-100-5	AN-111-5
3/16	3-5/8	1-1/4	1	1-1/8	3/16	.035	109"	AN-100-6	AN-111-6
7/32	4	1-3/8	1-1/8	1-1/4	3/16	.035	—	AN-100-7	AN-111-7
1/4	4-1/2	1-1/2	1-1/4	1-1/2	1/4	.035	159"	AN-100-8	AN-111-8
5/16	5-1/4	1-3/4	1-1/2	1-7/8	1/4	.050	195"	AN-100-10	AN-111-10
3/8	6-1/4	2-1/4	1-3/4	2-1/8	1/4	.050	—	AN-100-12	AN-111-12
7/16	7	2-1/2	2	2-1/2	1/4	.050	—	AN-100-14	———
1/2	8	2-3/4	2-1/4	2-7/8	3/8	.050	—	AN-100-16	———

FIGURE 4.13.—Preparation of a wrapped soldered terminal.

(6) Serving may be done by hand or m chine, but in either case each serving convo tion must touch the adjoining one and pulled tightly against the cable, with spa for permitting a free flow of solder and insp tion. (See figure 4.13a.)

(7) Prevent drawing of the temper of a cable resulting from excessive temperature duration of applied heat. Use a soldering fl consisting of stearic acid and resin. The use, a flux, of sal-ammoniac or any other compou having a corrosive effect is not acceptable.

(8) Soldering is accomplished by immersi the terminal alternately in the flux and in t solder bath, repeating the operation until tho ough tinning and filling with solder under t serving wire and thimble is obtained. The ter perature of the solder bath and place whe terminal is withdrawn should not be abo 450° F. A soldering iron may be used in t final operation to give a secure and good-a pearing terminal. Assure that the solder com pletely fills the space under the serving wi and thimble. A slightly hollowed cast-irc block to support the splice during solderin may help in securing the best results. The us of abrasive wheels or files for removing exce solder is not recommended.

(9) As an alternative process for makin terminals for nonflexible cable, the oxyacety lene cutting method and the presolderin method (soldering before wrapping) are ac ceptable, but only under the following condi tions:

(a) that the process of cutting securel welds all wires together;

(b) that the annealing of the cable doe not extend more than one cable diameter fron the end,

(c) that no filing is done either before o after soldering;

(d) that for protection during the opera tion of grinding the tapered end of the cable, a steel guard at least three inches in length and 1/32 inch thick should be placed between the taper and the main cable;

(e) that heat from grinding does not draw the temper of the cable.

(10) Do not use wrap-soldered splice terminals ahead of the firewall, or in other fire zones, or in other locations where they might be subjected to high temperature.

198. CABLE SYSTEM INSPECTION. Aircraft cable systems are subject to a variety of environmental conditions and forms of deterioration that ultimately may be easy to recognize as wire/strand breakage or the not-so-readily visible types of wear, corrosion, and/or distortion. The following data will aid in detecting the presence of these conditions:

a. *Cable Damage.* Critical areas for wire breakage are those sections of the cable which pass through fairleads and around pulleys. Examine cables for broken wires by passing a cloth along the length of the cable. This will clean the cable for a visual inspection, and detect broken wires if the cloth snags on the cable. When snags are found, closely examine the cable to determine the full extent of the damage.

The absence of snags is not positive evidence that broken wires do not exist. Figure 4.14a shows a cable with broken wires that were not detected by wiping, but were found during a visual inspection. The damage became readily apparent (figure 4.14b) when the cable was removed and bent using the technique depicted in figure 4.14c.

NOTE: Tests by various aeronautical agencies have indicated that a few broken wires spread over the length of a cable will not result in a critical loss of strength. Obtain specific information regarding acceptable wire breakage limits from the manufacturer of the aircraft involved.

(1) External Wear Patterns. Wear will normally extend along the cable equal to the distance the cable moves at that location and may occur on one side of the cable only or on its entire circumference. Replace flexible and nonflexible cables when the individual wires in each strand appear to blend together (outer

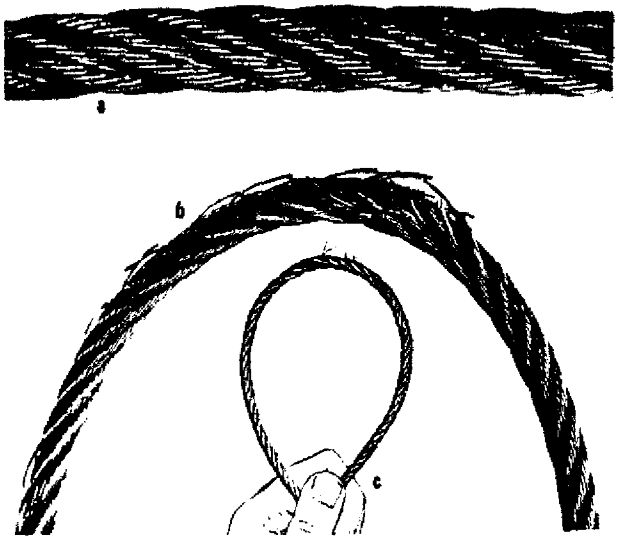


FIGURE 4.14.—Cable inspection technique.

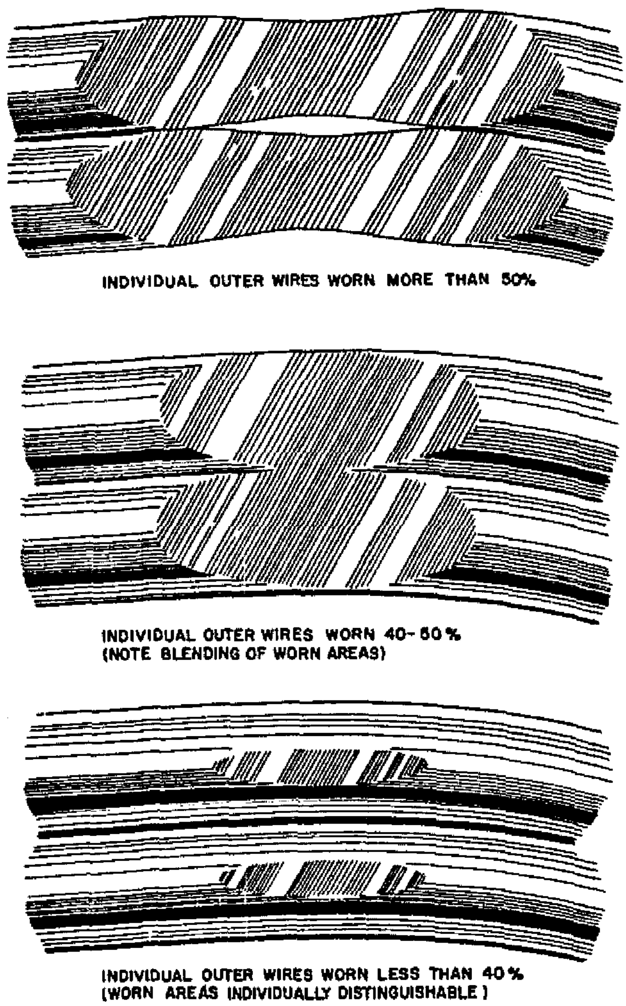


FIGURE 4.15.—Cable wear patterns.

FIGURE 4.16.—Worn cable (replacement necessary).

wires worn 40–50 percent) as depicted in figure 4.15. Actual instances of cable wear beyond the recommended replacement point are shown in figures 4.16 and 4.17.

(2) Internal Cable Wear. As wear is taking place on the exterior surface of a cable, the same condition is taking place internally, particularly in the sections of the cable which pass over pulleys and quadrants. This condition (shown in figure 4.18) is not easily detected unless the strands of the cable are separated. Wear of this type is a result of the relative motion between inner wire surfaces. Under certain conditions the rate of this type wear can be greater than that occurring on the surface.

(3) Corrosion. Carefully examine any cable

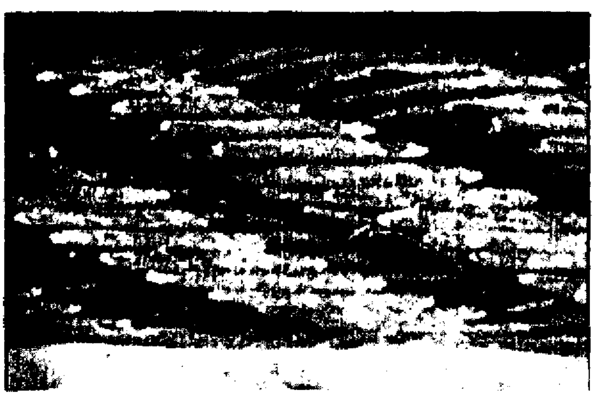


FIGURE 4.17.—Worn cable (replacement recommended).

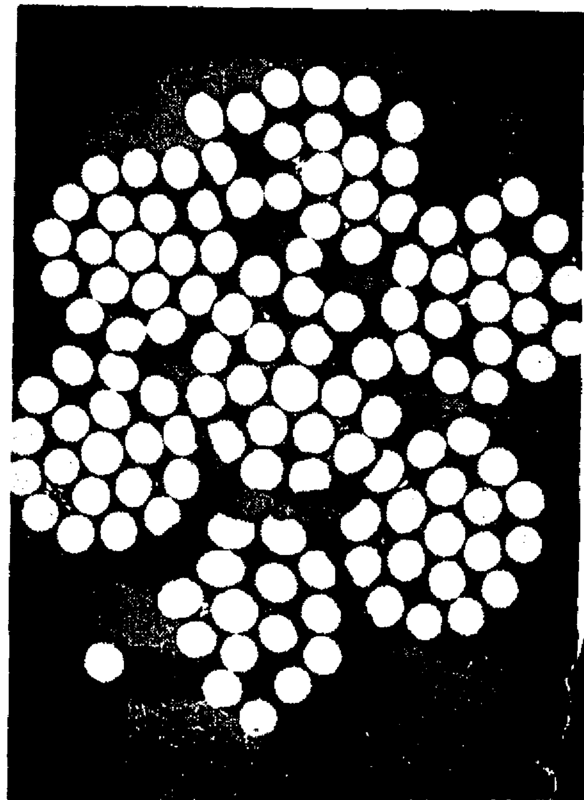


FIGURE 4.18.—Internal cable wear.

for corrosion that has a broken wire in a section not in contact with wear producing airframe components such as pulleys, fairleads, etc. It may be necessary to remove and bend the cable to properly inspect it for internal strand corrosion as this condition is usually not evident on the outer surface of the cable. Replace cable segments if internal strand rust or corrosion is found.

Areas especially conducive to cable corrosion are battery compartments, lavatories, wheel wells, etc., where concentrations of corrosive fumes, vapors, and liquids can accumulate.

NOTE: Check all exposed sections of cable for corrosion after a cleaning and/or metal-brightening operation has been accomplished in that area.

An example of cable corrosion, attributable to battery acid, is shown in figure 4.19.

b. *Wire Splices.* Standard manufacturing splices have been mistaken for defects in the cable because individual wire end splices were

FIGURE 4.19.—Corrosion.

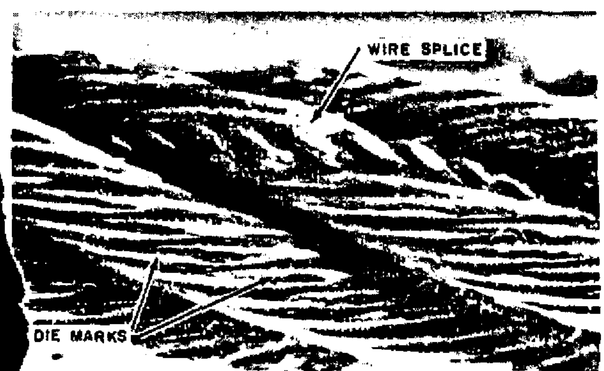


FIGURE 4.20.—Manufacturer's wire splice.

visible after assembly of a finished cable length. In some instances, the process of twisting outer strands around the core strand may also slightly flatten individual outer wires, particularly in the area of a wire splice. This flattening is the result of die sizing the cable and does not affect the strength of the cable. These conditions, as shown in figure 4.20, are normal and are not a cause for cable rejection.

c. ***Cable Maintenance.*** Frequent inspections and preservation measures such as rust prevention treatments for bare cable areas will help to extend cable service life. Where cables pass through fairleads, pressure seals, or over pulleys, remove accumulated heavy coatings of corrosion prevention compound. Provide corrosion protection for these cable sections by lubricating with a light coat of graphite grease or general purpose, low-temperature oil.

CAUTION

Avoid the use of vapor degreasing, steam cleaning, methylethylketone (MEK) or other solvents to remove corrosion-preventative compounds, as these methods will also remove the cable internal lubricant.

d. ***Routing.*** Examine cable runs for incorrect routing, fraying, twisting, or wear at fairleads, pulleys, anti-abrasion strips, and guards. Look for interference with adjacent structure, equipment, wiring, plumbing, and other controls. Inspect cable systems for binding, full travel, and security of attaching hardware. Check for slack in the cable system by attempting to move the control column and/or pedals while the gust locks are installed on the control surfaces. With the gust locks removed, actuate the controls and check for friction or hard movement. These are indications that excessive cable tension exists.

NOTE: If the control movement is stiff after maintenance operations are performed on control surfaces, check for parallel cables twisted around each other or cables connected in reverse.

e. ***Cable Fittings.*** Check swaged treminal reference marks for an indication of cable slippage within the fitting. Inspect the fitting assembly for distortion and/or broken strands at the terminal. Assure that all bearings and swivel fittings (bolted or pinned) pivot freely to prevent binding and subsequent failure. Check turnbuckles for proper thread exposure and broken or missing safety wires/clips.

f. ***Pulleys.*** Inspect pulleys for roughness, sharp edges, and presence of foreign material embedded in the grooves. Examine pulley bearings to assure proper lubrication, smooth rotation, freedom from flat spots, dirt, and paint spray. Periodically rotate pulleys, which turn through a small arc, to provide a new bearing surface for the cable. Maintain pulley alignment to prevent the cable from riding on the flanges and chafing against guards, covers, or adjacent structure. Check all pulley brackets and guards for damage, alignment, and security.

(1) **Pulley Wear Patterns.** Various cable system malfunctions may be detected by analyzing pulley conditions. These include such discrepan-

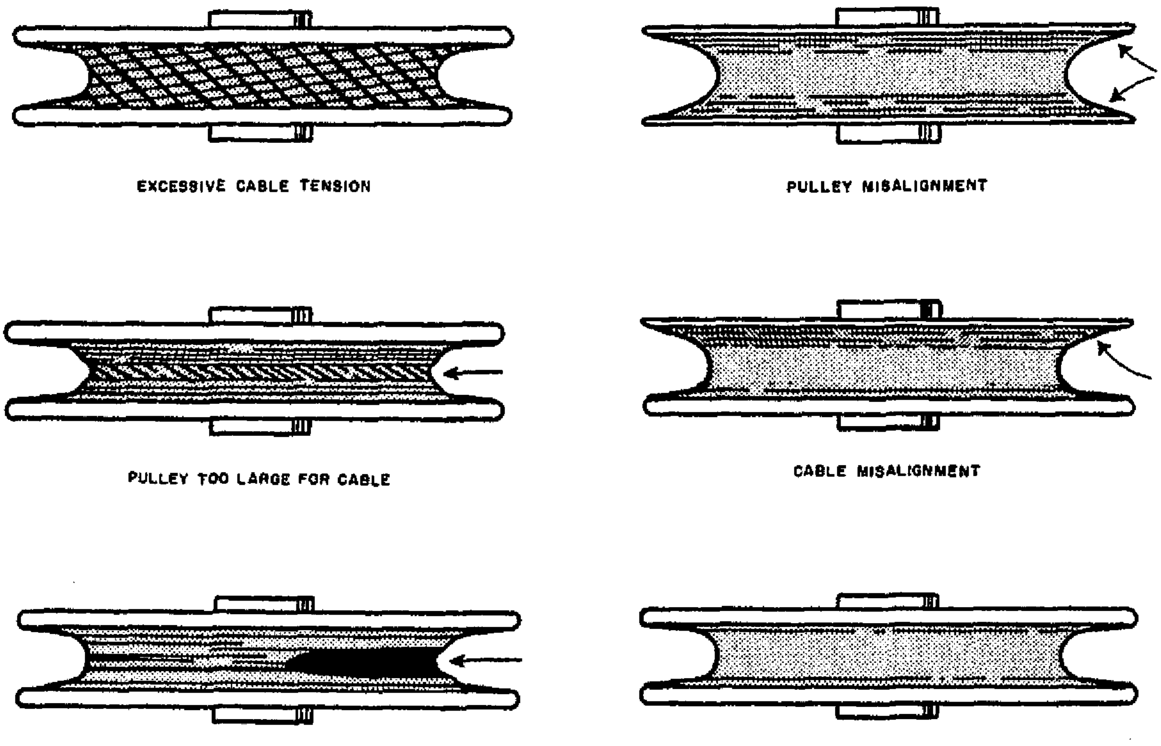


FIGURE 4.21.—Pulley wear patterns.

cies as too much tension, misalignment, pulley bearing problems, and size mismatches between cables and pulleys. Examples of these conditions are shown in figure 4.21.

g. ***Fairleads, Guides, Anti-Abrasion Strips.*** Inspect fairleads for wear, breakage, alignment, cleanness, and security. Examine cable routing at fairleads to assure that deflection angles are no greater than 3° maximum. Determine that all guides and anti-abrasion strips are secure and in good condition.

h. ***Pressure Seals and Seal Guards.*** Examine pressure seals for wear and/or material deterioration. Determine that the seal guards are positioned to prevent jamming of a pulley if a pressure seal fails and pieces slide along the cable.

199. CABLE TENSION ADJUSTMENT. Carefully adjust control cable tension in accordance with the airframe manufacturer's recommendations. On large aircraft, take the temperature of the immediate area into consideration when using a tensiometer. For long cable sections, use the average of two or three temperature readings to obtain accurate tension values. If necessary, compensate for extreme surface temperature variations that may be encountered if the aircraft is operated primarily in unusual geographic or climatic conditions such as arctic, arid, or tropic locations.

Use rigging pins and gust locks as necessary to assure satsifactory results. At the completion of rigging operations, check turnbuckle adjustment and safetying in accordance with Section 2 of this chapter.

200. CORROSION AND RUST PREVENTION. To insure a satisfactory service life for aircraft control cables, use a cable lubricant to reduce internal friction and prevent corrosion. Loose rust and surface corrosion may be removed with a stainless steel brush, being careful not to damage the cable. Care should be taken to remove all residue from the cable strands prior to rust prevention treatment. If the cable is made from tinned steel, coat the cable with rust preventive oil and wipe off any excess. It should be noted that corrosion-resistant steel cable does not require this treatment for rust prevention.

201.–211. RESERVED.

Section 2. SAFETY METHODS FOR TURNBUCKLES

212. GENERAL. Safety all turnbuckles with safety wire using either the double or single wrap method, or with any appropriately approved special safetying device complying with the requirements of FAA Technical Standard Order TSO–C21. The swaged and unswaged turnbuckle assemblies are covered by AN Standard Drawings. For safety wire sizes and materials, refer to figure 4.22. Do not reuse safety wire. Adjust the turnbuckle to the correct cable tension so that no more than three threads are exposed on either side of the turnbuckle barrel. Do not lubricate turnbuckles.

213. DOUBLE WRAP METHOD. Of the methods using safety wire for safetying turnbuckles, the method described here is preferred, although either of the other methods described is satisfactory. The method of double wrap safetying is shown in figure 4.23(A). Use two separate lengths of the proper wire (see figure 4.22). Run one end of the wire through the hole in the barrel of the turnbuckle and bend the end of the wire towards opposite ends of the turnbuckle. Then pass the second length of the wire into the hole in the barrel and bend the ends along the barrel on the side opposite the first. Spiral the two wires in opposite directions around the barrel to cross each other twice between the center hole and the ends. Then pass the wires at the end of the turnbuckle in opposite directions through the holes in the turnbuckle eyes or between the jaws of the turnbuckle fork, as applicable, laying one wire along the barrel and wrapping the other at least four times around the shank of the turnbuckle and binding the laid wires in place be fore cutting the wrapped wire off. Wrap th remaining length of safety wire at least fo turns around the shank and cut it off. Repe the procedure at the opposite end of the turi buckle.

Cable size	Type of wrap	Diameter of safety wire	Material (annealed condition)
1/16	Single	0.040	Copper, brass.[1]
3/32	Single	0.040	Copper, brass.[1]
1/8	Single	0.040	Stainless steel, Monel and "K" Monel.
1/8	Double	0.040	Copper, brass.[1]
1/8	Single	0.057 min.	Copper, brass.[1]
5/32 and greater.	Double	0.040	Stainless steel, Monel and "K" Monel.[1]
5/32 and greater.	Single	0.057 min.	Stainless steel, Monel or "K" Monel.[1]
5/32 and greater.	Double	0.051 [2]	Copper, brass.

[1] Galvanized or tinned steel, or soft iron wires are also acceptable.
[2] The safety wire holes in 5/32-inch diameter and larger turnbuckle terminals for swaging may be drilled sufficiently to accommodate the double 0.051-inch diameter copper or brass wires when used.

FIGURE 4.22—Turnbuckle safetying guide.

When a swaged terminal is being safetied, pass the ends of both wires, if possible, through the hole provided in the terminal for this purpose and wrap both ends around the shank as described above. When the hole in the terminal is not large enough to accommodate the ends of both wires, the hole may be enlarged in accordance with note 2 of figure 4.22 and the safetying completed as described above. If the hole is not large enough to allow passage of both wires, pass the wire through the hole and loop it over the free end of the other wire, and then wrap both ends around the shank as described.

a. Another satisfactory double wrap method is similar to the above, except that the spiraling of the wires is omitted as shown in figure 4.23(B).

b. The wrapping procedures described and shown on MS 33591 may be used in lieu of the safetying method shown herein.

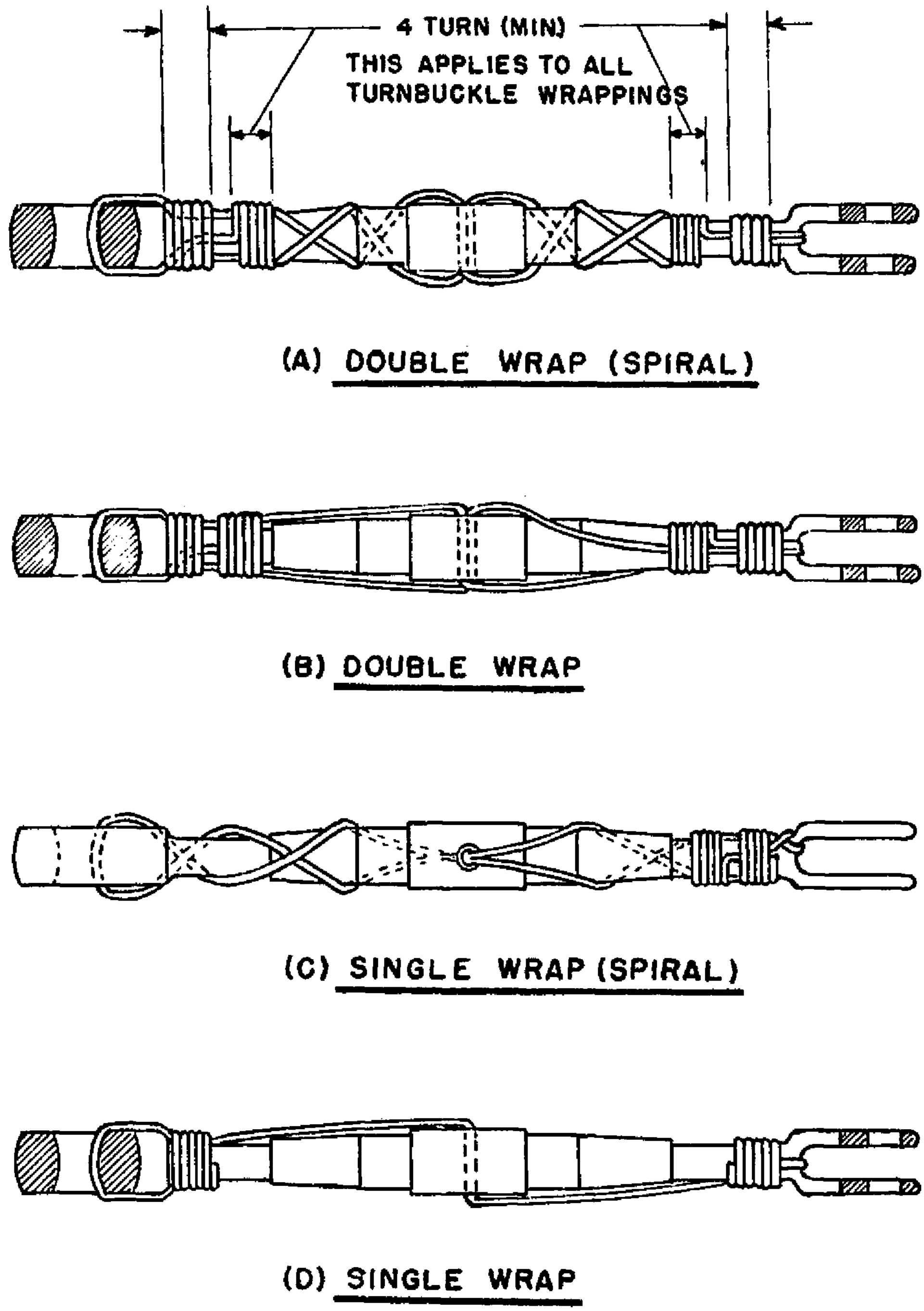


FIGURE 4.23.—Safetying turnbuckles.

214. SINGLE WRAP METHOD. The single wrap methods described in the following paragraphs and as illustrated in figures 4.23 (C) and (D) are acceptable but are not the equal of the double wrap methods.

a. Pass a single length of wire through the cable eye or fork, or through the hole in the swaged terminal at either end of the turnbuckle assembly. Spiral each of the wire ends in opposite directions around the first half of the turnbuckle barrel so as to cross each other twice. Thread both wire ends through the hole in the middle of the barrel so that the third crossing of the wire ends is in the hole. Again, spiral the two wire ends in opposite directions around the remaining half of the turnbuckle, crossing them twice. Then, pass one wire end through the cable eye or fork or through the hole in the swaged terminals, in the manner described above, wrap both wire ends around the shank for at least four turns each, cutting off excess wire. This method is shown in figure 4.23(C).

b. Pass one length of wire through the center hole of the turnbuckle and bend the wire ends toward opposite ends of the turnbuckle. Then pass each wire end through the cable eye or fork, or through the hole in the swaged terminal and wrap each wire end around the shank for at least four turns, cutting off excess wire. This method is shown in figure 4.23(D). After safetying, no more than three threads of the turnbuckle threaded terminal should be exposed.

215. SPECIAL LOCKING DEVICES. Several turnbuckle locking devices are available for securing turnbuckle barrels. Persons intending to use a special device must assure the turnbuckle assembly has been designed to accommodate such device. A typical unit is shown in figure 4.24. When special locking devices are not readily available, the use of safety wire is acceptable.

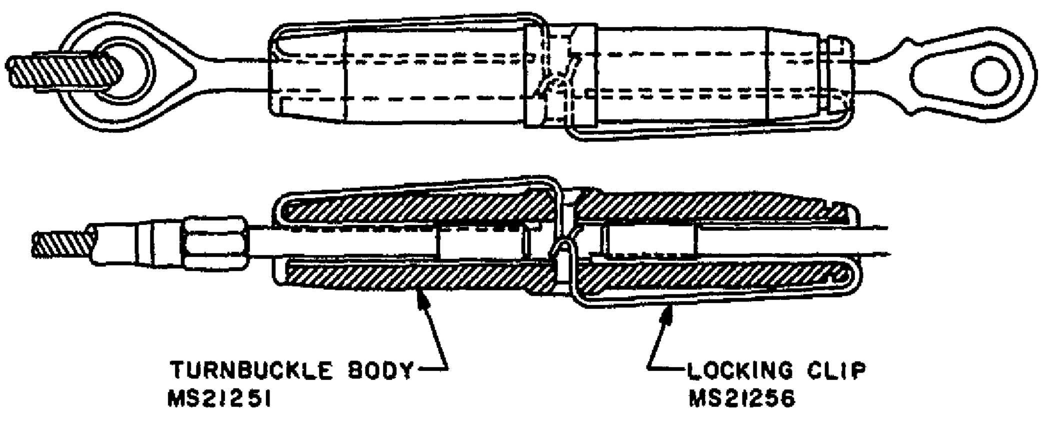


FIGURE 4.24.—Clip type locking device.

216.–226. RESERVED.

Chapter 5. AIRCRAFT HARDWARE

Section 1. IDENTIFICATION AND USE OF AIRCRAFT HARDWARE

27. **BOLTS.** Most bolts used in aircraft strucures are either general purpose AN bolts, or IAS (National Aircraft Standard) internal rrenching or close-tolerance bolts. In certain ases, aircraft manufacturers make up special olts for a particular application and it is necesary to use them or their equivalent in relacement.

a. ***Identification.*** AN-type aircraft bolts can be dentified by the code markings on the boltleads. The markings generally denote the bolt nanufacturer, the material of which the bolt is nade, and whether the bolt is a standard ANype or a special purpose bolt. AN standard teel bolts are marked with either a raised lash or asterisk, corrosion-resistant steel is inlicated by a single raised dash, and AN alumiium alloy bolts are marked with two raised lashes. The strength and dimensional details of AN bolts are specified on the Army/Navy Aeronautical Standard Drawings.

Special purpose bolts include the hightrength and low-strength types, close-tolerance ypes; such bolts are normally inspected y magnetic, fluorescent or equivalent inspecion methods. Typical markings include 'SPEC" (usually highly heat treated), an ircraft manufacturer's part number stamped n the head, or plain heads (low strength). Close-tolerance National Aircraft Standards (NAS) bolts are marked with either a raised r recessed triangle. The material markings for NAS bolts are the same as for AN bolts, xcept that they may be either raised or reessed. Bolts inspected magnetically (Magnalux) or by fluorescent means (Zyglo) are idenified by means of colored lacquer, or a head narking of a distinctive type. Figure 5.1 shows he typical coding used on aircraft boltheads.

b. ***Grip Length.*** In general, bolt-grip lengths should equal the material thickness. However, bolts of slightly greater grip length may be used provided washers are placed under the nut or the bolthead. In the case of plate nuts, add shims under the plate. For proper washers, refer to paragraph 231.

c. ***Locking or Safetying of Bolts.*** Lock or safety all bolts and/or nuts, except self-locking nuts. Do not reuse cotter pins and safety wire.

d. ***Bolt Fit.*** Many boltholes, particularly those in primary connecting elements, have close tolerances. Generally, it is permissible to use the first lettered drill size larger than the normal bolt diameter, except where the AN hexagon bolts are used in light-drive fit (reamed) applications and where NAS close-tolerance bolts or AN clevis bolts are used. Boltholes are to be normal to the surface involved to provide full bearing surface for the bolthead and nut, and not be oversized or elongated. In case of oversized or elongated holes in critical members, obtain advice from an FAA inspector or engineer, or the aircraft manufacturer before drilling or reaming the hole to take the next larger bolt, as usually, items such as edge distance, clearance, etc., must be considered.

e. ***Torques.*** The importance of correct applicacation can not be overemphasized. Undertorque can result in unnecessary wear of nuts and bolts as well as the parts they are holding together. When insufficient pressures are applied, uneven loads will be transmitted throughout the assembly which may result in excessive wear or premature failure due to fatigue. Overtorque can be equally damaging because of failure of a bolt or nut from overstressing the threaded areas. There are a few simple, but very important, procedures that should be followed to assure that correct torque is applied:

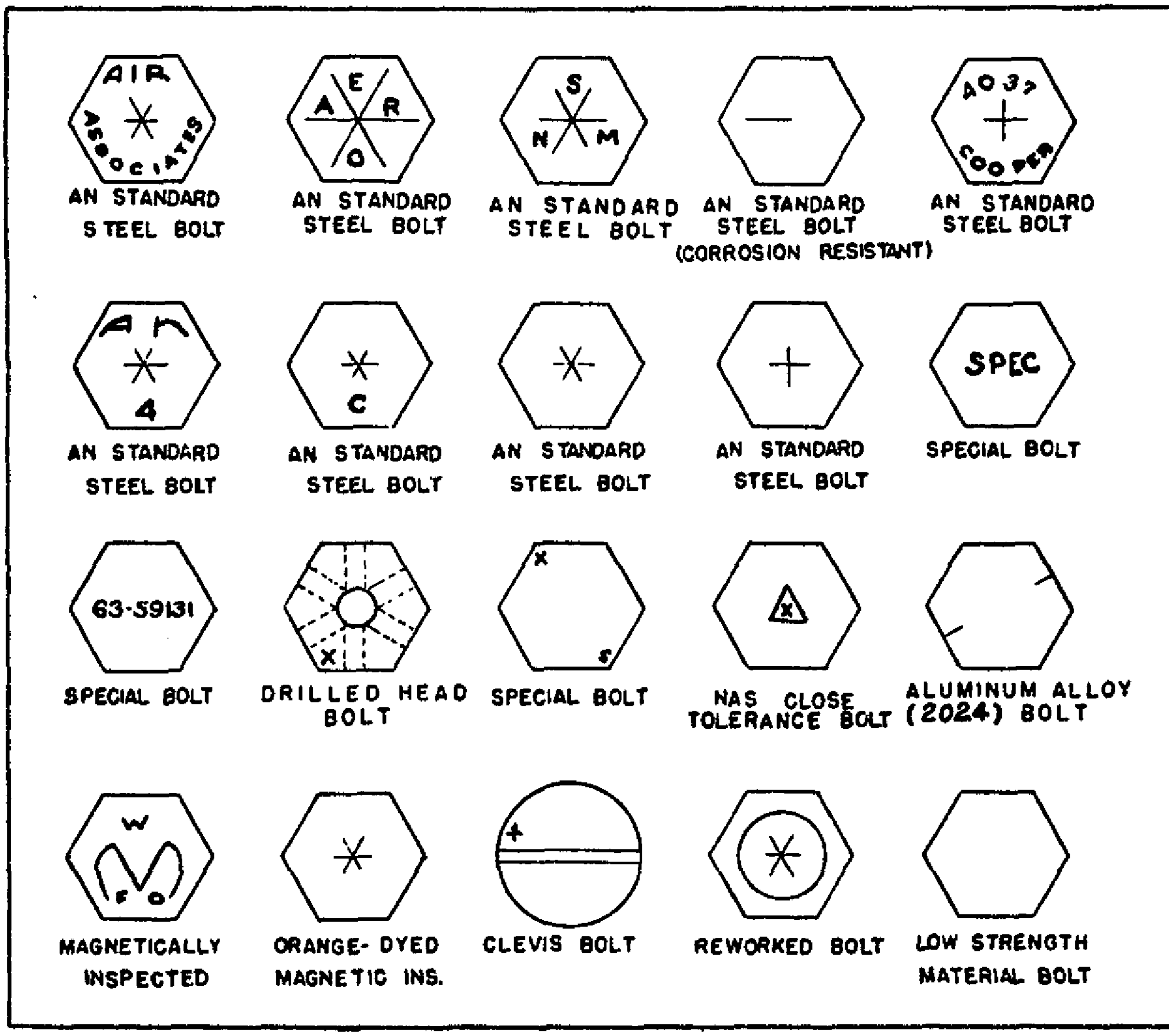


FIGURE 5.1.—Bolt identification.

(1) Calibrate the torque wrench periodically to assure accuracy; and re-check frequently.

(2) Be sure that bolt and nut threads are clean and dry (unless otherwise specified by the manufacturer).

(3) Run nut down to near contact with the washer or bearing surface and check "friction drag torque" required to turn the nut.

(4) Add the friction drag torque to the desired torque recommended by the manufacturer, or obtain desired torque as shown in figure 5.2. This is referred to as final torque which should register on the indicator or the setting for a snapover type wrench.

(5) Apply a smooth even pull when applying torque pressure. If chattering or a jerking motion occurs during final torque, back off and re-torque.

(6) When installing a castle nut, start alignment with the cotter pin hole at minimum recommended torque, plus friction drag torque, and do not exceed maximum plus friction drag. If the hole and nut castellation do not align, change washers and try again. Exceeding the maximum recommended torque is not recommended.

(7) If torque is applied to capscrews or ›ltheads, apply recommended torque plus fric-on drag torque as determined in step (8).

(8) If special adapters are used which 'ill change the effective length of the torque 'rench, the final torque indication or wrench ›tting must be adjusted accordingly. Deter-ıine the torque wrench indication or setting rith adapter installed as shown in figure 5.8. 'igure 5.2 is a composite chart of recom-ıended torque to be used when specific ›rque is not recommended by the manufac-urer. The chart includes standard nut and bolt ombinations currently used in aviation main-enance.

f. Hex-Head Bolts (AN-3 through AN-20). The ex-head aircraft bolt is an all-purpose struc-ural bolt used for general applications involv-ıg tension or shear loads. Alloy steel bolts maller than No. 10-32 and aluminum alloy ›olts smaller than 1/4-inch diameter are not to ›e used in primary structure. Do not use alu-ninum alloy bolts and nuts where they will be epeatedly removed for purposes of mainte-ance and inspection. Aluminum alloy nuts nay be used with cadmiumplated steel bolts oaded in shear on land airplanes, but are not o be used on seaplanes due to the possibility of lissimilar metals corrosion.

g. Close-Tolerance Bolts (AN-173 through AN-86 (Hex-Head), NAS-80 through NAS-86 (100° 'ountersunk)). Close-tolerance bolts are used in ıigh-performance aircraft in applications vhere the bolted joint is subject to severe load 'eversals and vibration. The standard AN ıex-head bolts may be used for the same appli-:ations provided a light-drive fit is accom-›lished.

h. Internal Wrenching Bolts (MS-20004 through MS-20024 or NAS-495). These bolts are suitable 'or use both in tension and shear applications. n steel parts, countersink the bolthole to seat he large radius of the shank at the head or, as n aluminum alloys, use a special heat-treated washer (NAS-143C) that fits the head to ›rovide adequate bearing area. A special heat-reated plain washer (NAS-143) is used under he nut. Use special high-strength nuts on these bolts. (Refer to paragraph 230c(7).) Replace all internal wrenching bolts by another internal wrenching bolt. Standard AN hex-head bolts and washers cannot be substituted for them, as they do not have the required strength.

i. Drilled-Head Bolts (AN-73). The AN drilled-head bolt is similar to the standard hex-bolt, but has a deeper head which is drilled to receive wire for safetying. The AN-3 and the AN-73 series of bolts are interchangeable for all practical purposes from the standpoint of tension and shear strengths.

228. SCREWS. In general, screws differ from bolts by the following characteristics: Usually lower material strength, a looser thread fit (No. 2), head shapes formed to engage a screwdriver, and the shank threaded along its entire length without a clearly defined grip. However, several types of structural screws are available that differ from the standard structural bolts only in the type of head.

The material is equivalent and a definite grip is provided. The AN-525 washerhead screws, the AN 509-100° countersunk structural screws, and the NAS-204 through NAS-235 are such parts. The material markings are the same as those used on AN standard bolts.

a. Structural Screws (NAS-204 through NAS-235, AN-509 and AN-525). This type of screw, when made of alloy steel such as SAE-4130, NE-8630, or equivalent, and heat-treated from 125,000 p.s.i., may be used for structural assembly in shear applications similar to structural bolts.

b. Self-Tapping Screws. The AN-504 and AN-506 screws are used for attaching minor removable parts such as nameplates and the like. AN-530 and AN-531 are used in blind applications for the temporary attachment of sheet metal for riveting and the permanent assembly of nonstructural assemblies. AN-535 is a plain head self-tapping screw used in the attachment of nameplates or in sealing drainholes in corrosion-proofing tubular structures, and is not intended to be removed after installation. Never use self-tapping screws to replace standard

BOLTS Steel Tension		BOLTS Steel Tension		BOLTS Aluminum	
AN 3 thru AN 20 AN 42 thru AN 49 AN 73 thru AN 81 AN 173 thru AN 186 MS 20033 thru MS 20046 MS 20073 MS 20074 AN 509 NK9 MS 24694 AN 525 NK525 MS 27039		MS 20004 thru MS 20024 NAS 144 thru NAS 158 NAS 333 thru NAS 340 NAS 583 thru NAS 590 NAS 624 thru NAS 644 NAS 1303 thru NAS 1320 NAS 172 NAS 174 NAS 517	Steel shear bolt NAS 464	AN 3DD thru AN 20DD AN 173DD thru AN 186DD AN 509DD AN 525D MS 27039D MS 24694DD	
NUTS		NUTS		NUTS	
Steel Tension	Steel Shear	Steel Tension	Steel Shear	Aluminum Tension	Aluminum Shear
AN 310 AN 315 AN 363 AN 365 NAS 1021 MS 17825 MS 21045 MS 20365 MS 20500 NAS 679	AN 320 AN 364 NAS 1022 MS 17826 MS 20364	AN 310 AN 315 AN 363 AN 365 MS 17825 MS 20365 MS 21045 NAS 1021 NAS 679 NAS 1291	AN 320 AN 364 NAS 1022 MS 17826 MS 20364	AN 365D AN 310D NAS 1021D	AN 320D AN 364D NAS 1022D

FINE THREAD SERIES

Nut-bolt size	Torque Limits in.-lbs.		Torque Limits in.-lbs.		Torque Limits in.-lbs.		Torque Limits in.-lbs.		Torque Limits in.-lbs.		Torque Limits in.-lbs.	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
8 -36	12	15	7	9	--------	--------	--------	--------	5	10	3	6
10 -32	20	25	12	15	25	30	15	20	10	15	5	10
1/4-28	50	70	30	40	80	100	50	60	30	45	15	30
5/16-24	100	140	60	85	120	145	70	90	40	65	25	40
3/8 -24	160	190	95	110	200	250	120	150	75	110	45	70
7/16-20	450	500	270	300	520	630	300	400	180	280	110	170
1/2 -20	480	690	290	410	770	950	450	550	280	410	160	260
9/16-18	800	1,000	480	600	1,100	1,300	650	800	380	580	230	360
5/8 -18	1,100	1,300	660	780	1,250	1,550	750	950	550	670	270	420
3/4 -16	2,300	2,500	1,300	1,500	2,650	3,200	1,600	1,900	950	1,250	560	880
7/8 -14	2,500	3,000	1,500	1,800	3,550	4,350	2,100	2,600	1,250	1,900	750	1,200
1 -14	3,700	4,500	2,200	3,300	4,500	5,500	2,700	3,300	1,600	2,400	950	1,500
1 1/8 -12	5,000	7,000	3,000	4,200	6,000	7,300	3,600	4,400	2,100	3,200	1,250	2,000
1 1/4 -12	9,000	11,000	5,400	6,600	11,000	13,400	6,600	8,000	3,900	5,600	2,300	3,650

COARSE THREAD SERIES

Nut-bolt size	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
8 -32	12	15	7	9	--------	--------	--------	--------	--------	--------	--------	--------
10 -24	20	25	12	15	--------	--------	--------	--------	--------	--------	--------	--------
1/4 -20	40	50	25	30	--------	--------	--------	--------	--------	--------	--------	--------
5/16-18	80	90	48	55	--------	--------	--------	--------	--------	--------	--------	--------
3/8 -16	160	185	95	110	--------	--------	--------	--------	--------	--------	--------	--------
7/16-14	235	255	140	155	--------	--------	--------	--------	--------	--------	--------	--------
1/2 -13	400	480	240	290	--------	--------	--------	--------	--------	--------	--------	--------
9/16-12	500	700	300	420	--------	--------	--------	--------	--------	--------	--------	--------
5/8 -11	700	900	420	540	--------	--------	--------	--------	--------	--------	--------	--------
3/4 -10	1,150	1,600	700	950	--------	--------	--------	--------	--------	--------	--------	--------
7/8 - 9	2,200	3,000	1,300	1,800	--------	--------	--------	--------	--------	--------	--------	--------
1 - 8	3,700	5,000	2,200	3,000	--------	--------	--------	--------	--------	--------	--------	--------
1 1/8 - 8	5,500	6,500	3,300	4,000	--------	--------	--------	--------	--------	--------	--------	--------
1 1/4 - 8	6,500	8,000	4,000	5,000	--------	--------	--------	--------	--------	--------	--------	--------

FIGURE 5.2.—Recommended torque values for nut-bolt combinations—(without lubrication).

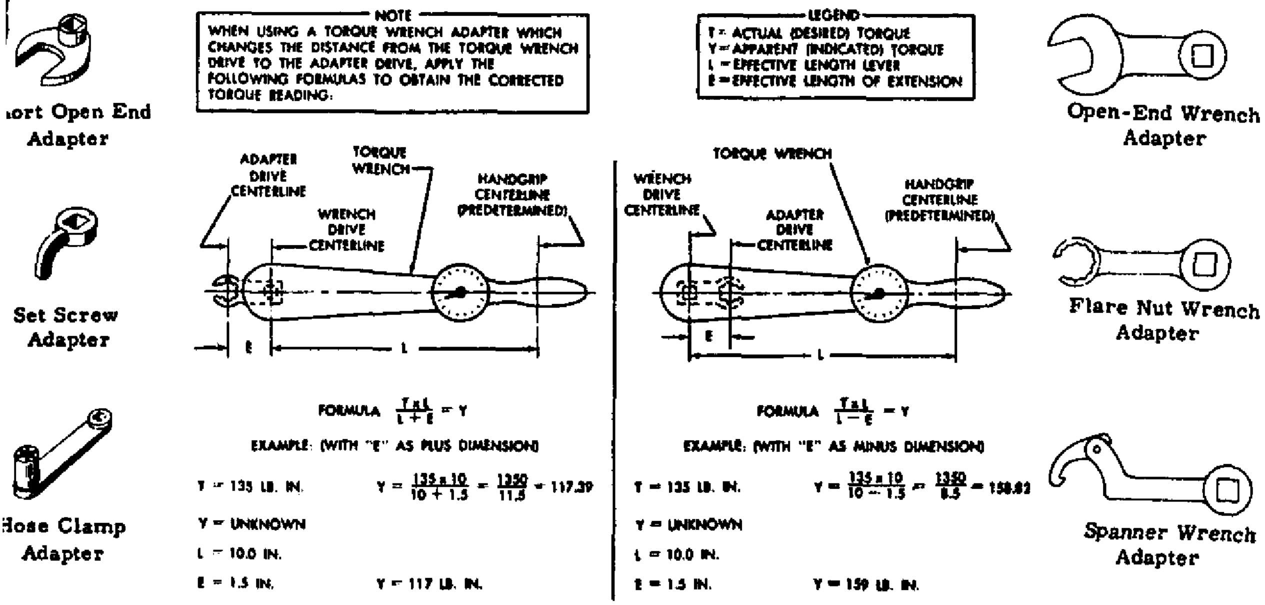


FIGURE 5.3.—Torque wrench with various adapters.

crews, nuts, bolts, or rivets in the original tructure.

'29. TAPER PINS (AN–385 AND AN–386). Plain ınd threaded taper pins are used in joints which carry shear loads and where absence of)lay is essential. The plain taper pin is drilled ınd usually safetied with wire. The threaded aper pin is used with a taper-pin washer (AN–975) and shear nut (safetied with cotter)in) or self-locking nut.

a. ***The Flathead Pin* (MS–20392).** Commonly alled a clevis pin, the flathead pin is used in onjunction with tie rod terminals and in sec-)ndary controls which are not subject to con-inuous operation. The pin is customarily in-talled with the head up so that if the cotter)in fails or works out, the pin will remain in)lace.

b. ***The AN–380 Cotter Pin.*** This is used for afetying bolts, screws, nuts, other pins, and in various applications where such safetying is ıecessary. Use AN–381 cotter pins in locations where nonmagnetic material is required or in ocations where resistance to corrosion is de-ired.

230. NUTS.

a. ***Self-Locking Nuts.*** Self-locking nuts are acceptable for use on certificated aircraft subject to the restrictions on the pertinent manufacturer's recommended practice sheets. Self-locking nuts are used on aircraft to provide tight connections which will not shake loose under severe vibration. Two types of self-locking nuts are currently in use, the all-metal type and the fiber or nylon lock type. Do not use self-locking nuts at joints which subject either the nut or bolt to rotation. They may be used with antifriction bearings and control pulleys, provided the inner race of the bearing is clamped to the supporting structure by the nut and bolt. Attach nuts to the structure in a positive manner to eliminate rotation or misalignment when tightening the bolts or screws.

(1) All-metal locknuts are constructed with either the threads in the locking insert out-of-phase with the load-carrying section, or with a saw-cut insert with a pinched-in thread in the locking section. The locking action of the all-metal nut depends upon the resiliency of the metal when the locking section and load-carrying section are engaged by screw threads.

(2) Fiber or nylon locknuts are constructed with an unthreaded fiber-locking insert held securely in place. The fiber or nylon has a smaller diameter than the nut, and when a bolt or screw is entered, it taps into the insert, producing a locking action. After the nut has been tightened, make sure the rounded or chamfered end bolts, studs, or screws extend at least the full round or chamfer through the nut. Flat end bolts, studs, or screws should extend at least 1/32 inch through the nut. When fiber-type self-locking nuts are reused, check the fiber carefully to make sure it has not lost its locking friction or become brittle. Do not reuse locknuts if they can be run up finger-tight. Bolts 5/16-inch diameter and over with cotter pinholes may be used with self-locking nuts but only if free from burrs around the holes. Bolts with damaged threads and rough ends are not acceptable. Do not tap the fiber-locking insert.

(3) Self-locking nut bases are made in a number of forms and materials for riveting and welding to aircraft structure or parts. Certain applications require the installation of self-locking nuts in channels, an arrangement which permits the attachment of many nuts with only a few rivets. These channels are track-like bases with regularly spaced nuts which are either removable or nonremovable. The removable type carries a floating nut, which can be snapped in or out of the channel, thus making possible the ready removal of damaged nuts. Nuts such as the clinch-type and spline-type which depend on friction for their anchorage are not acceptable for use in aircraft structures.

(4) Self-locking nuts may be used on aircraft engines and accessories when their use is specified by the engine manufacturer in his bulletins or manuals.

b. *Aircraft Castle Nut (AN–310).* The castle nut is used with drilled-shank AN hex-head bolts, clevis bolts, eye bolts, drilled-head bolts or studs, and is designed to accommodate a cotter pin or lockwire as a means of safetying.

c. *Miscellaneous Aircraft Nuts.*

(1) The plain nut (AN–315 and AN–335) has limited use on aircraft structures and requires an auxiliary locking device such as checknut or lockwasher.

(2) Light hex-nuts (AN–340 and AN–345) are used in miscellaneous applications an must be locked by an auxiliary device.

(3) The checknut (AN–316) is used as locking device for plain nuts, screws, threade rod ends, and other devices.

(4) The castellated shear nut (AN–320) i designed for use with clevis bolts and threade taper pins, which are normally subjected t shearing stress only.

(5) Wing nuts (AN–350) are intended fo use on hose clamps and battery connections etc., where the desired tightness is ordinaril obtained by the use of the fingers or han tools.

(6) Sheet spring nuts, such as speed nuts are used with standard and sheet metal self tapping screws in nonstructural locations They find various uses in supporting lin clamps, conduit clamps, electrical equipment access doors, and the like, and are available i several types.

(7) Two commercial types of high-strengt internal or external wrenching nuts are availa ble, the internal and external wrenching elastic stop nut and the Unbrako internal and externa wrenching nut. Both are of the self-lockin type, are heat-treated, and are capable of carry ing the high-strength bolt-tension load.

231. WASHERS. The types of washers used i aircraft structure are: plain washers, lock washers, and special washers.

a. *Plain washers (AN–960 and AN–970)* ar widely used under hex nuts to provide smoothbearing surface, to act as a shim and t adjust holes in bolts. Use plain washers unde lockwashers to prevent damage to surfaces Cadmiumplated steel washers are recom mended for use under boltheads or nuts on alu minum alloy or magnesium structures wher corrosion, if it occurs, will then be between th washer and the steel. The AN–970 stee washer provides a greater bearing area than th plain type, and is used in wooden structure under both boltheads and nuts to prevent loca crushing of the surface.

b. ***Lock washers (AN–935 and AN–936)*** may be ed with machine screws or bolts whenever e self-locking or castellated type of nut is t applicable. They are not to be used as fas- nings to primary or secondary structures, or here subject to frequent removal or corrosive nditions.

c. ***Ball-socket and seat-washers (AN–950 and N–955)*** are used in special applications where e bolt is installed at an angle to the surface, when perfect alinement with the surface is quired at all times. These washers are used gether.

d. ***Taper-pin washers (AN–975)*** are used with e threaded taper pin.

e. ***NAS–143 washers*** are used with NAS in- rnal wrenching bolts and internal wrenching uts. Type "C" is countersunk to seat the bolt- ead shank radius and a plain-type washer is sed under the nut. Both of these washers are eat treated from 125,000 to 145,000 p.s.i.

32. TYPES OF RIVETS.

a. ***Standard solid-shank rivets*** and the univer- al head rivets (AN–470) are used in aircraft onstruction in both interior and exterior loca- ions.

b. ***Roundhead rivets (AN–430)*** are used in the nterior of aircraft except where clearance is equired for adjacent members.

c. ***Flathead rivets (AN–442)*** are used in the in- erior of the aircraft where interference of ad- acent members does not permit the use of oundhead rivets.

d. ***Brazierhead rivets (AN–455 and AN–456)*** re used on the exterior surfaces of aircraft where flush riveting is not essential.

e. ***All protruding head rivets*** may be replaced y MS–20470 (supersedes AN–470) rivets. This has been adopted as the standard for pro- truding head rivets in this country.

f. ***Countersunk head rivets MS-20426*** (super- sedes AN–426 100°) are used on the exterior surfaces of aircraft to provide a smooth aero- dynamic surface, and in other applications where a smooth finish is desired. The 100° countersunk head has been adopted as the standard in this country.

233. MATERIAL APPLICATIONS.

a. ***2117–T3 is the most commonly*** used rivet material utilized in aluminum alloy structures. Its main advantage lies in the fact that it may be used in the condition received without fur- ther treatment.

b. ***The 2017–T3, 2017–T31, and 2024–T4*** rivets are used in aluminum alloy structures where strength higher than that of the 2117–T3 rivet is needed. See Handbook MIL–HDBK–5 for differences between the two types of 17ST riv- ets specified here.

c. ***The 1100 rivets of pure aluminum*** are used for riveting nonstructural parts fabricated from the softer aluminum alloys, such as 1100, 3003, and 5052.

d. ***When riveting magnesium alloy structures,*** 5056 rivets are used exclusively due to their corrosion-resistant qualities in combination with the magnesium alloys.

e. ***Mild steel rivets*** are used primarily in rivet- ing steel parts. Do not use galvanized rivets on steel parts subjected to high heat.

f. ***Corrosion-resistant steel rivets*** are used pri- marily in riveting corrosion-resistant steel parts such as firewalls, exhaust stack bracket attachments, and similar structures.

g. ***Monel rivets*** are used in special cases for riveting high-nickel steel alloys and nickel al- loys. They may be used interchangeably with stainless steel rivets as they are more easily driven. However, it is preferable to use stain- less steel rivets in stainless steel parts.

h. ***Copper rivets*** are used for riveting copper alloys, leather, and other nonmetallic mate- rials. This rivet has only limited usage in air- craft.

i. ***Hi-shear rivets*** are sometimes used in con- nections where the shearing loads are the pri- mary design consideration. Its use is restricted to such connections. It should be noted that hi- shear rivet patterns are not to be used for the installation of control surface hinges and hinge brackets. Do not paint the rivets prior to assembly, even where dissimilar metals are being joined. However, it is advisable to touch up each end of the driven rivet with zinc chromate primer to allow the later application of the general airplane finish.

j. *Blind rivets* in the MS–20600 through MS–20603 series rivets and the mechanically-locked stem NAS 1398, 1399, 1738, and 1739 rivets may be substituted for solid rivets in accordance with the blind rivet manufacturer's recommendations. They should not be used where the looseness or failure of a few rivets will impair the airworthiness of the aircraft. Design allowables for blind rivets are specified in MIL–HDBK–5, "Metallic Materials and Elements for Flight Vehicle Structures." Specific structural applications are outlined in MS–33522. Nonstructural applications for such blind rivets MS–20604 and MS–20605 are contained in MS 33557.

234. FASTENERS (COWL AND FAIRING). A num ber of patented fasteners are in use on aircraf A variety of these fasteners are commer cially available and the manufacturer's recom mendations concerning the proper use of thes types of fasteners should always be considere in other than replacement application.

235. UNCONVENTIONAL ATTACHMENTS. Do no use unconventional or new attachment device in the primary structure unless approved by representative of the Federal Aviation Admin istration.

236.–246. RESERVED.

Chapter 6. CORROSION PROTECTION

I7. **TYPES OF CORROSION.** Almost all metals ıed in aircraft are subject to corrosion. The :tack may take place over an entire metal sur-ıce, or it may be penetrating in nature, form-ıg deep pits. It may follow grain boundaries ı its attack on metallic surfaces or it may pen-:rate a surface at random. It may be accen-ıated by stresses from external loads or exist-ıg in the metallic structure from lack of ɔmogeneity or improper heat treatment. It is romoted by contact of the metals with ma-:rials that absorb water, such as wood, sponge ıbber, felt, dirt, surface film, etc. Corrosion is ɘferred to as the following types:

a. ***Direct Surface Attack.*** The most common ʏpe of general surface corrosion results from irect reaction of metal surface with oxygen in ıe air. Unless properly protected, steel will ıst and aluminum and magnesium will form ɔrrosion products. The attack may be acceler-ted by salt spray or salt-bearing air, by in-ustrial gases, or by the aircraft engine ex-aust gases.

b. ***Dissimilar Metals Corrosion.*** When two dis-imilar metals are in contact and are connected y an electrolyte (continuous liquid or gas ath—salt spray, exhaust gas, condensate) ac-ɘlerated corrosion of one of the metals may ccur. The most easily oxidized surface be-omes the anode and corrodes. The less active ıember of the couple becomes the cathode of he galvanic cell. The degree of attack depends n the relative activity of the two surfaces; the reater the difference in activity, the more se-ere the attack. The materials listed in Group I re quite active and corrode easily. They re-uire maximum protection. Group IV materials re the least active and therefore require mini-ıum protection. Except as noted below, when-ver metals from two different groups are in ontact with each other, special protection is equired to assure that dissimilar metal corro-sion does not occur. Although aluminum alloys and tin are in different groups than magne-sium, tin and the 5000 and 6000 series alumi-num alloys may each be used in contact with magnesium without such protection. Tin may also be used with all aluminum alloys without special protection.

(1) **Group I.** Magnesium and its alloys.

(2) **Group II.** All aluminum alloys, cadmium, zinc.

(a) ***Subgroup A.*** 1100, 3003, 5052, 6061, 220, 355, 356. All clad alloys.

(b) ***Subgroup B.*** 2014, 2017, 2024, 7075, 195. Under severe corrosive conditions, the sub-groups should be considered as dissimilar met-als insofar as corrosion protection is concerned. This is particularly true when a large area of an alloy of Subgroup B is in contact with a small area of Subgroup A. Severe corrosion of the alloy from Subgroup A may be expected.

(3) **Group III.** Iron, lead, and tin and their alloys (except stainless steels).

(4) **Group IV.** Stainless steels, titanium, chromium, nickel, and copper and their alloys, graphite (including dry film lubricants con-taining graphite).

c. ***Pitting.*** While pitting may occur in any metal, it is particularly characteristic of pas-sive materials such as the alloys of aluminum, nickel, and chromium. It is usually a localized breakdown of protection and may be due to a lack of homogeneity in the alloy surface, either from mechanical working or faulty heat treat-ment. It may also be due to an inclusion or rough spot in the metal surface or from local-ized contamination that breaks down the sur-face protection. Pitting takes place at random with no selective attack along grain bounda-ries. Isolated areas become anodic to the rest of the surface. Corrosion products formed ac-centuate the anodic characteristics in the pit area, and deep penetrating attack develops rather than a general surface attack.

d. ***Intergranular Corrosion.*** Selective attack along the grain boundaries of metal alloys is referred to as intergranular corrosion. It results from lack of uniformity in the alloy structure. It is particularly characteristic of precipitation hardened alloys of aluminum and some stainless steels. Aluminum alloys 2024 and 7075 which contain appreciable amounts of copper and zinc respectively are highly vulnerable to this type of attack if not quenched rapidly during heat treatment or given other special treatment such as the T73 temper condition for the 7075 alloys. Aluminum extrusions and forgings in general may contain nonuniform areas, which in turn may result in galvanic attack along the grain boundaries. This type of corrosion is difficult to detect in its original stage although ultrasonic and eddy current inspection methods are being used. When attack is well advanced, the metal may blister or delaminate. This is referred to as "exfoliation."

e. ***Stress Corrosion.*** This results from the combined effect of static tensile stresses applied to a surface over a period of time under corrosive conditions. In general, cracking susceptibility increases with stress, particularly at stresses approaching the yield point, and with increasing temperature, exposure time, and concentration of corrosive ingredients in the surrounding environment. Aluminum alloy bellcranks employing pressed-in taper pins, landing gear shock struts with pipe thread-type grease fittings, clevis joints, and shrink fits are examples of parts which are susceptible to stress corrosion cracking.

f. ***Corrosion Fatigue.*** Corrosion fatigue is a type of stress corrosion resulting from cyclic stresses on a metal in corrosive surroundings. Corrosion may start at the bottom of a shallow pit in the stressed area. Once attack begins, the continuous flexing prevents the repair of protective surface coating or oxide films and additional corrosion takes place in the area of stress. It is difficult to detect this type of attack in advance except as cracking develops.

g. ***Fretting.*** Fretting corrosion is a lim type of attack that develops when relative tion of small amplitude takes place betw close fitting components. The rubbing con destroys any protective film that may be p ent on the metallic surface and addition removes small particles of virgin metal fi the surface. These particles act as an abra and prevent the formation of any protec oxide film and exposes fresh active metal to atmosphere. If the contact areas are small sharp, deep grooves resembling brinnell ma ings or pressure indentations may be worn the rubbing surface. As a result, this type corrosion has also been called false brinnell when developed on bearing surfaces.

248. CORROSION PROTECTION MEASURES I BASIC MATERIALS. In the repair or alteratior aircraft, apply corrosion proofing of the sa type or equivalent to that originally appl unless the repair or alteration would result increased susceptibility to corrosion, in wh case use additional corrosion protection me ures. Aluminum and magnesium alloys n be protected by a variety of surface tre ments. Most aluminum alloy structural surfa have been electrically anodized in chromic-s furic acid tanks before fabrication. Magnesi sheet has received cold nitric-chromic a treatment; magnesium castings have usu received hot tank processing in fluoride dich mate mixtures. Steel surfaces may have b oxidized or plated during manufacture.

a. ***Anodizing and Related Processes.*** In a dizing, aluminum alloys are placed in an el trolytic bath causing a thin film of alumin oxide to form on the surface of the aluminu This is resistant to corrosion and affords a g paint base. Other processes which do not p vide as good a corrosive protection as anodiz are, however, good paint bases. These p cesses are:

(1) Alkaline cleaning followed by chro acid dip.

(2) Alcoholic phosphoric acid cleaner.

(3) Alkaline dichromate treatment.

b. ***Plating.*** Steels are commonly plated w other metals to prevent corrosion. Plating mplished by placing the article in an elec-ytic bath and metal from the plating solu-ı is deposited on it. Various metals used in ting vary in the corrosion protection they ırd steel. For instance, cadmium and zinc rode before the steel; hence, slight breaks cracks through the plating of these metals l not result in rusting of the exposed steel, ce the surface metal is corroded and pro-ts the steel. Chromium does not protect steel this method, as steel will corrode before the omium and thus depends on the tightness of plating for its protection. The process of tplate bake treatment to relieve hydrogen brittlement is a necessary part of replating cedures for high-strength steel parts. gh-strength nuts and bolts are highly sus-tible to failure from hydrogen embrittle-nt, at the many stress risers and notches in ir design, through normal usage of sus-ned and dynamic stresses. Because of the po-tial failures of embrittled parts, careful trol over the heat treatment, grinding, pre-te cleaning, plating, and postplate baking of gh-strength parts is necessary.

c. ***Sherardizing.*** Steel parts may be sherard-d by heating them in an atmosphere of zinc wder; however, this is not considered to be effective against corrosion as zinc or cad-um plating.

d. ***Phosphate Rust-Proofing.*** This process is mmercially known as Parkerizing, Bonderiz-g, Granodizing, etc. The coating placed on e part is used to protect steel parts after chining and before painting.

e. ***Chrome-Pickle Treatment.*** Magnesium parts ich have been immersed or brushed with a lution of nitric acid and sodium dichromate ll be protected for temporary storage. The ating also will serve as a bond for subse-ent organic finishes. Sealed chrome-pickle eatment is used on magnesium parts for long rm protection. Diluted chromic acid is a uch-up treatment. It is less critical to apply d can be applied over previously applied thin romate films.

f. ***Dichromate Treatment.*** The dichromate treat-ent consists of boiling magnesium parts in a solution of sodium dichromate. This treatment provides good paint base and protective quali-ties on all standard wrought magnesium alloys except the magnesium-thorium alloys HK 31A, HM 21A, and HM 31A. No coating forms on these alloys. Acid pickling of the magnesium surface prior to application of the dichromate treatment is required if maximum corrosion re-sistance of the finish is expected.

g. ***Stannate Immersion Treatment.*** This treat-ment deposits a layer of tin. It is a protective paint base for magnesium alloy parts which contain inserts and fasteners of a dissimilar metal such as brass, copper, or steel. This treatment cannot be used with parts containing aluminum inserts or fasteners because the high alkalinity of the bath attacks the aluminum.

h. ***Galvanic Anodizing Treatment.*** This is an electrolytic process used to provide a paint base and corrosion preventive film on magne-sium alloys containing manganese.

i. ***Cladding.*** Aluminum alloys which are sus-ceptible to corrosion are frequently clad with pure aluminum. Slight pits, scratches, or other defects through the cladding material will not result in corrosion of the core, since the pure aluminum on the edges of the defect will be preferentially corroded, protecting the core.

j. ***Metal Spraying.*** Metal is melted and sprayed on the surface to be protected. The surface must be properly prepared and thor-oughly cleaned to prevent peeling of the sprayed coat.

k. ***Shot-Peening.*** Shot-peening and other treat-ments by which the surface can be placed in compression are effective in preventing stress corrosion.

l. ***Organic Coatings.*** Zinc chromate primer, enamels, chlorinated rubber compounds, etc., are organic coatings commonly used to protect metals.

m. ***Dopeproofing.*** When doped fabrics are applied over an organic finished metal struc-ture, the dope will have a tendency to loosen the finish on the metal. For this reason, or-ganic coatings on the metal are usually covered with a dopeproof paint, with metal foil, or with cellulose tape to prevent the dope from striking through.

n. Tube Interiors. Protect the interiors of structural steel and aluminum tubing against corrosion. A small amount of water entrapped in a tube can corrode entirely through the tube thickness in a short period of time. Coat the tube interior by flushing with hot linseed oil, paralketone, or other corrosion inhibitor.

The flushing liquid is usually introduced through small holes drilled in the tubing. Allow the flushing liquid to drain and plug the holes with a screw or by other means to prevent entry of moisture. Air and watertight sealing of the tubing will also give adequate protection against corrosion if the tubing is internally dry before being sealed.

249. CONSTRUCTION OF CORROSION RESISTANT STRUCTURE. During fabrication, the use of such practices as listed below will reduce the sources of corrosion initiation.

a. Use combinations of metals which are as close together as possible in the galvanic series —do not use small aluminum clips on large stainless steel webs; use stainless steel fasteners in stainless steel assemblies.

b. Insulate dissimilar metals but do not use materials which absorb moisture or conduct it in "wick" fashion.

c. Paint cut edges.

d. Seal edges of faying surfaces on butt joints.

e. Provide adequate drainholes.

250. CORROSION REMOVAL. When corrosion is detected, remove it as quickly as possible and protect the surface from further corrosion. In those cases where the corrosion has progressed extensively, the strength of the part may be in jeopardy and the part may need to be replaced.

a. For steel parts, except for highly stressed steel or stainless steel surfaces, the use of abrasive papers, buffers, hand wire brushing, and steel wool are acceptable cleanup procedures. However, it should be recognized that it is practically impossible to remove all c sion products from the bottom of small and crevices. As a result, a part once rusty ally corrodes again, more easily than it di first time. Removing corrosion products highly stressed steel parts requires ca handling.

b. For aluminum parts, treatment include mechanical removal of as much of the c sion products as practicable, the inhibitic residual material by chemical means, foll by the restoration of permanent surface ings. Do not use steel wool, emery cloth, (except stainless steel) wire brushes, or se abrasive materials because particles of steel wool or emery cloth will become em ded in the soft material and cause corro Hand polishing corroded areas with house abrasives or with metal polish available u Specification MIL-P-6888 is acceptable fo on clad aluminum but must not be used or odized aluminum since it is severe enoug actually remove the protective anodized If the surface is particularly difficult clean. Type II material under Specifica MIL-C-5410 mixed 50-50 percent with sol or mineral spirits may be used. Treat any perficial corrosion with a 10 percent solutic sodium dichromate to which one percen chromium trioxide has been added or material available under Specification M C-5541. Allow these solutions to remain the corroded area for 5 to 20 minutes then wipe the surface dry. A more se cleaning procedure consists of using a 10 cent solution of chromic acid to which has added approximately 20 drops of battery trolyte per gallon. Thorough brushing wi stiff fiber brush should loosen or remove existing corrosion and assure complete p tration of the inhibitor into crevices and Allow the chromic acid to remain in place at least 5 minutes, then remove the exces flushing with water or wiping with a cloth. Apply a protective coating the same that the corrosion treatment is accomplis

c. When an anodized surface coating is d aged, it can only be partially restored by che cal surface treatment. Therefore, exercise ɪaning process to avoid unnecessary ɪf the protective film, particularly at of the aluminum sheet. Chromic acid inhibitive treatments tend to restore ilm.

severe cleaning is necessary with in- ɪr corrosion (attack along grain s). The mechanical removal of all products and visible delaminated ɪrs must be accomplished in order to the extent of the destruction and to he remaining structural strength of ɔnent. Inspection with a 5- to 10- gnifying glass or the use of dye pene- assist in determining if all unsound l corrosion products have been re- ɪinding to blend or fair out the edges ɪd areas can best be accomplished by ɪminum oxide-impregnated rubber- els. Chemically inhibit the exposed ɪnd restore chemical surface films or he same manner as for other alumi- ɪces.

ɪesium is the most chemically active of ɪ used in aircraft construction and is the most difficult to protect. The ɪd complete correction of the coating imperative if serious structural dam- be avoided. Treat the corroded area ercent chromic acid solution to which added approximately 20 drops of bat- rolyte per gallon, in the same man- aluminum alloys.

ɪOSION PROOFING OF LANDPLANES ɪLANES. In the repair or alteration of use corrosion proofing materials the or equivalent to, that originally ap- ɪss the repair or alteration would re- creased susceptibility to corrosion, in e, employ additional corrosion protec- ures.

ɪOSION PROOFING OF LANDPLANES ɪD TO SEAPLANES. A special problem tered in the conversion of landplanes ɪes. In general, landplanes do not re- ɪosion proofing to the same extent as ɪnes manufactured as such. Corrosion-proofing standards for landplanes converted to seaplanes are divided into two classes: (1) Necessary minimum precautions; and (2) Recommended precautions. Regardless of such precautions, it is imperative that the exterior surfaces of seaplanes be washed with clear fresh water immediately following extended water operation, or at least once a day when operated in salty or brackish water. Wash interior surfaces of seaplanes exposed to spray, taking care to prevent damage to electrical circuits or other items subject to injury.

a. *Necessary Minimum Precautions.* The following procedures are considered the minimum to safeguard the airworthiness of the converted aircraft and are not in themselves intended to maintain airworthiness for an indefinite period.

(1) Unless already protected, treat exposed fittings or fittings which can be reached through inspection openings with two coats of zinc chromate primer, paralketone, nonwater-soluble heavy grease, or comparable materials. This applies to items such as wing-root fittings, wing-strut fittings, control-surface hinges, horns, mating edges of fittings, and attach bolts, etc.

(2) Coat nonstainless control cables with grease or paralketone or other comparable protective coating, if not replaced with corrosion-resistant cables.

(3) Inspect all accessible sections of aircraft structure. Clean structural parts showing corrosion and refinish if corrosion attack is superficial. If a part is severely corroded, replace with an adequately corrosion-proofed part.

b. *Recommended Precautions.* The recommended precautions are those which are suggested as a means of maintaining such aircraft in condition for safe operation over extended periods of time.

(1) Provide additional inspection openings to assist in detecting corrosion. Experience has shown openings to allow inspection of lower and rearward portion of the fuselage to be particularly desirable.

(2) Incorporate additional provisions for free drainage and ventilation of all interiors to

prevent collection of moisture (scoop-type drain grommets).

(3) Protect the interior of structural steel tubing. This may be done by air and watertight sealing or by flushing with hot linseed oil and plugging the openings. Inspect tubing for missing sealing screws, presence of entrapped water, local corrosion around sealing screws, welded clusters, and bolted fittings which may be indicative of entrapped moisture.

(4) Slit the fabric of fabric-covered aircraft longitudinally on the bottom of the fuselage and tail structure for access to these sections. Coat the lower structural members with zinc chromate primer (two coats); follow by a coat of dope-proof paint or wrap with cellophane tape and rejoin the fabric. This precaution is advisable within a few months after start of operation as a seaplane.

(5) Spray the interior of metal-covered wings and fuselages with an adherent corrosion inhibitor.

(6) Place bags of potassium or sodium dichromate in the bottom of floats and boat hulls to inhibit corrosion.

(7) Prevent the entry of water by sealing, as completely as possible, all openings in wings, fuselage, control-surface members, openings for control cables, tail-wheel wells, etc.

253. CLEANERS, POLISHES, BRIGHTENERS. It is important that aircraft be kept thoroughly clean of deposits containing contaminating substances such as oil, grease, dirt, and other foreign materials.

a. Materials. Avoid damage to aircraft by not using harmful cleaning, polishing, brightening, or paint-removing materials. Use only those compounds which conform to existing government or established industry specifications or products that have been specifically recommended by the aircraft manufacturer as being satisfactory for the intended application. Observe the product manufacturer's recommendations concerning use of his agent.

b. Chemical Cleaners. Chemical cleaners must be used with great care in cleaning assembled aircraft. The danger of entrapping corrosive materials in faying surfaces and crevices counteracts any advantages in their speec fectiveness. Use materials which are neutral and easy to remove.

c. Removal of Spilled Battery Acid. to neutralize spilled battery acid, us bicarbonate (baking soda), or sodiu (borax) 20 percent by weight dissolved After neutralization, remove alkali : pletely with copious quantities of wat vent corrosion. An application of paint to the structure surrounding th may be an effective control for this ty rosion.

*** 254. HANDLING AND CARE OF AIRCRAF ERED FROM WATER IMMERSION.** Aircr were recovered from partial or total i in water, including flash floods, have lowed to air dry, in certain instances safety precautions other than a cursor tion of the aircraft exterior. The la adequate cleanup of water-immersed a subsequently adversely affect the safet aircraft. That is, water immersion inc probability of corrosive attack, the re lubrication, the deterioration of airc terials, and/or degradation of electi avionic equipment.

Sea water, because of salt content, corrosive than surface fresh water. fresh water may contain varying amoun and, as drying occurs, the salt concen increased and corrosive attack accelerat

The most important factor following of an aircraft from sea or fresh water i is prompt action. Components of the which have been water immersed, suc powerplant, accessories, airframe section ing mechanisms, screws, bearings, worl faces, fuel and oil systems, wiring, ra radar should be disassembled, to the ex sidered necessary, so that the contamir be completely removed.

a. Initial Fresh Water/Detergent Wa soon as possible after the aircraft is r from water immersion, thoroughly w taminated internal and external areas o craft using a water/detergent solution as

(1) Mix liquid detergent (MIL- Type I) and isopropyl alcohol (TT-I ight parts detergent to 20 parts of .dd the detergent/alcohol mixture to tap water and mix thoroughly. For ne part of the foregoing concentrate ts of tap water (warm water if avail-nix thoroughly.

the above specified detergent/alcohol .re *not* available, use water emulsion ompound (MIL-C-43613). Add one und to nine parts water. If the MIL ompound is not available, use any ild household detergent solution with ater.

Precautions. The following safety should be observed:

ctrically ground the aircraft. Attach lead to the aircraft at a point which he area that could contain explosive

the landing gear of land planes is supporting mechanism, install a r, jury strut, landing gear downlocks itable devices to insure that the gear ollapse. *If the landing gear is not* insure that the aircraft is solidly to prevent hazardous movement.

connect and remove wet- and/or dry-s and isolate aircraft from all sources ty or other spark-producing devices. ucing static electricity is generated at air hose outlets, so this method should d for ventilating or purging fuel

nove all fuel, oil, and hydraulic fluid. sh all fuel and oil cells with clean .

late tires, especially on magnesium epressurize landing gear struts, pneu-ms, and hydraulic accumulators.

ocating Engines and Propellers. The ould be removed from the engine and from the aircraft. The exterior of the l propeller should be washed with ot or cold fresh water.

r accessories, engine parts, etc., should l and all surfaces flushed with fresh erably hot. If facilities are available, d parts, size permitting, should be immersed in hot water or hot oil, 180° F., for a short period of time. Soft water is preferred and should be changed frequently. All parts must be completely dried by air blast or other means. If no heat drying facility is available, wipe the cleaned parts with suitable drying cloths.

Constant speed propeller mechanism should be disassembled, as required, to permit complete de-contamination. Clean parts with steam or hot or cold fresh water. Dry the cleaned parts in an oven, but if a heat drying facility is not available, wipe the cleaned parts with suitable drying cloths.

d. Gas Turbine, Turboprop and Turboshaft Engines. The engine exhaust shield, insulation blankets, separate exhaust collectors, compressor housing, pinion cowl and/or upper pinion housing should be removed. The engine accessories, outer housing exhaust shields, and other exposed parts should be steam cleaned. The steam-cleaned parts should be dried in an oven at approximately 200° F., or with hot air from a portable engine heater, or with clean wiping cloths.

Immerse remainder of engine in 10-20 percent water solution of sodium dichromate, or hot, fresh water and apply sufficient agitation to provide complete flushing.

If immersion cannot be accomplished, flood the lower section of the compressor housing and thoroughly flush rotor blades with sodium dichromate solution or warm fresh water. Seal off combustion chamber openings and alternately fill and drain the combustion chamber with fresh water. Dry clean parts in an oven, or use dry air from a portable engine heater or wipe with suitable drying cloths.

e. Airframe. The salvageable components of the fuselage, wings, empennage, seaplane and amphibian hulls and floats, and movable surfaces should be processed as follows:

(1) The fabric from fabric-covered surfaces should be removed and replaced.

(2) The aircraft interior and exterior should be cleaned using steam under pressure with steam-cleaning compound. The steam should be directed into all seams and crevices where corrosive water may have penetrated. Avoid steam *

* cleaning electrical equipment, such as terminal boards and relays.

(3) Areas that have been steam cleaned should be rinsed immediately with either hot or cold fresh water.

(4) Touch up all scratches and scars on painted surfaces using zinc chromate primer or preservative.

(5) Undrained hollow spaces or fluid entrapment areas should be provided temporary draining facilities by drilling out rivets at lowest point. Install new rivets after drainage.

(6) All leather, fabric upholstery, and insulation should be removed and replaced. Plastic or rubber foam which cannot be cleaned of all corrosive water should be replaced.

(7) All drain plugs or drive screws in tubular structures should be removed and the structure blown out with compressed air. If corrosive water has reached the tubular interiors, carefully flush with hot, fresh water and blow out water with compressed air. Roll the structure as necessary to remove water from pockets. Fill the tubes with hot linseed oil at approximately 180° F. Drain oil and replace drain plugs or drive screws.

(8) Clean sealed wood, metalite, and other nonmetallic areas, excluding acrylic plastics, with warm water. Wood, metalite, and other porous materials exposed to water immersion should be replaced, unless surfaces are adequately sealed to prevent penetration by corrosive water. Virtually all solvents and phenolic type cleaning agents are detrimental to acrylics and will either soften the plastic or cause crazing.

f. *Helicopter Rotor Dynamic Components.*

(1) All evidence of corrosive water should be removed from the exterior of transmissions and gear boxes by flushing with clean hot or cold fresh water.

(2) Where it is possible that corrosive water has reached the interior of the transmission or gear boxes, remove plugs and/or covers and drain completely. Flush interior of part with hot or cold fresh water. Drain residual water, replace plugs and/or covers, and reapply proper lubricant.

g. *Helicopter Blades.* Except for blades with wooden or other nonmetallic constructions, treat helicopter blades the same as propelle ciprocating engines. Clean nonmetal by hand, using warm water. Dry wi cloths or a warm air blast. When clea copter rotor blades, insure that nonseal members, such as the spars and blad are cleaned and dried.

h. *Fuel and Oil Systems.* Contamir and oil systems should be processed as :

(1) Flush oil system, including li water-displacing preservative.

(2) Open fuel systems. Purge cell lines. Check effectiveness of the pur combustible gas indicator. Remove bl self-sealing type fuel cells and all ca or pads.

(3) Use clean, fresh water to wash After drying, spray interior walls wit

(4) Chemically treat bare metal s cleaned aluminum tanks with 10–2 water solution of sodium dichromate.

(5) Flush fuel lines with hot wate maximum). Dry, using clean, dry, c air.

i. *Landing Gear.* Process salvageab nents of the landing gear, wheels, and follows:

(1) Remove tires and wheels.

(2) Steam clean wheels, rinse in fr and dry.

(3) Remove wheel bearings and cl dry cleaning solvent.

(4) Immerse bearings in methyl al dry the cleaned bearings in air blast. permit bearings to rotate during air bla Reapply proper lubricant.

(5) Remove brakes, steam clean, with fresh water and dry.

j. *Electrical Equipment.*

(1) Wet cell batteries. The risk in using wet cell batteries that have been in sea water may outweigh any eco vantage and should be replaced.

(2) Because of possible flight ha later defects caused by progressive co tack, all electrical wiring immersed sive water should be replaced. If

ashed or sprayed with corrosive water, ughly with clean, fresh water and dry, pressed air. Following compressed air at with water dispensing preservative 1309, Grade A).

llaneous Equipment. The following should be thoroughly washed to re- salt, and other contaminants. Dry last or other means, and, if required, oper lubricant:

ring and fuselage hydraulic units.

(2) Electric landing gears.

(3) Actuators.

(4) Cables.

(5) Accumulators.

(6) Hydraulic reservoirs.

(7) Flight control.

(8) Torque tubes and bell cranks.

(9) Heating units, ducts, etc. *

255.-264. RESERVED.

Chapter 7. IDENTIFICATION, TESTING, AND INSPECTION OF MATERIALS

Section 1. IDENTIFICATION OF METALS

IDENTIFICATION OF STEEL STOCK. The So-
y of Automotive Engineers (SAE) and the
erican Iron and Steel Institute (A.I.S.I.)
a numerical index system to identify the
position of various steels. The numbers as-
ed in the combined listing of standard
ls issued by these groups represent the
of steel and make it possible to readily
tify the principal elements in the material.
he first digit of the four number designa-
indicates the type to which the steel be-
s. Thus "1" indicates a carbon steel, "2" a
el steel, "3" a nickel chromium steel, etc.
he case of simple alloy steels, the second
t indicates the approximate percentage of
predominant alloying element. The last two
ts usually indicate the mean of the range of
on content. Thus the symbol "1020" indi-
s a plain carbon steel lacking a principal
ying element and containing an average of
percent (0.18 to 0.23) carbon. The symbol
30" indicates a nickel steel of approxi-
ely 3 percent (3.25 to 3.75) nickel and an
rage of 0.30 percent, (0.28 to 0.33) carbon
ent. The symbol "4130" indicates a chro-
m-molybdenum steel of approximately 1
ent (0.80 to 1.10) chromium, 0.20 percent
5 to 0.25) molybdenum, and 0.30 percent
8 to 0.33) carbon. The basic numbers for
four digit series of the carbon and alloy
ls may be found in figure 7.1.

Type of steels	Numerals and digits
Carbon Steels	1xxx
Plain Carbon Steels	10xx
Free Cutting Steels	11xx
Manganese Steels (Manganese 1.60 to 1.90%)	13xx
Nickel Steels	2xxx
3.50% nickel	23xx
5.00% nickel	25xx
Nickel Chromium Steels	3xxx
0.70% nickel, 0.07% chromium	30xx
1.25% nickel, 0.60% chromium	31xx
1.75% nickel, 1.00% chromium	32xx
3.50% nickel, 1.50% chromium	33xx
Corrosion and heat resisting	30xxx
Molybdenum Steels	40xx
Chromium Molybdenum Steels	41xx
Nickel Chromium Molybdenum Steels	43xx
Nickel Molybdenum Steels	
1.75% nickel, 0.25% molybdenum	46xx
3.50% nickel, 1.50% chromium	48xx
Chromium Steels	5xxx
Low chromium	51xx
Medium chromium	52xxx
Corrosion and heat resisting	51xxx
Chromium Vanadium Steels	6xxx
1.00% chromium	61xx
National Emergency Steels	8xxx
Silicon Manganese Steels	9xxx
2.00% silicon	92xx

FIGURE 7.1.—Numerical system for steel identification.

INTERCHANGEABILITY OF STEEL TUBING.

"1025" welded tubing as per Specification
–T–5066 and "1025" seamless tubing con-
ning to Specification MIL–T–5066A are in-
hangeable.

"4130" welded tubing as per Specification
–T–6731, and "4130" seamless tubing conforming to Specification MIL–T–6736 are interchangeable.

c. *NE–8630 welded tubing* conforming to Specification MIL–T–6734, and NE–8630 seamless tubing conforming to Specification MIL–T–6732 are interchangeable.

267. 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 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 s are marked with specification numbers or markings at intervals of 3 to 5 feet alon length of each piece. The commercial marking consists of a number which iden the particular composition of the alloy. Ir dition, letter suffixes designate the follov

Nonheat-treatable Alloys		Heat-treatable Alloys	
Temper designation	Definition	Temper designation	Definition
-O	Annealed recrystallized (wrought products only) applies to softest temper of wrought products.	-O	Annealed recrystallized (wr products only) applies to s temper of wrought products.
-H12	Strain-hardened one-quarter-hard temper.	-T2	Annealed (castings only).
-H14	Strain-hardened half-hard temper.	-T3	Solution heat-treated and worked by the flattening straightening operation.
-H16	Strain-hardened three-quarters-hard temper.	-T36	Solution heat-treated and worked by reduction of 6 pe
-H18	Strain-hardened full-hard temper.	-T4	Solution heat-treated.
-H22	Strain-hardened and partially annealed to one-quarter-hard temper.	-T42	Solution heat-treated by the regardless of prior temper plicable only to 2014 and alloys).
-H24	Strain-hardened and partially annealed to half-hard temper.		
-H26	Strain-hardened and partially annealed to three-quarters-hard temper.	-T5	Artificially aged only (cas only).
		-T6	Solution heat-treated and artifi aged.
-H28	Strain-hardened and partially annealed to full-hard temper.	-T62	Solution heat-treated and age user regardless of prior te (applicable only to 2014 and alloys).
-H32	Strain-hardened and then stabilized. Final temper is one-quarter hard.		
-H34	Strain-hardened and then stabilized. Final temper is one-half hard.	-T351, -T451, -T3510, -T3511, -T4510, -T4511.	Solution heat-treated and stres lieved by stretching to produ permanent set of 1 to 3 per depending on the product.
-H36	Strain-hardened and then stabilized. Final temper is three-quarters hard.	-T651, -T851, -T6510, -T8510, -T6511, -T8511.	Solution heat-treated, stress reli by stretching to produce a p anent set of 1 to 3 percent, artificially aged.
-H38	Strain-hardened and then stabilized. Final temper is full-hard.		
-H112	As fabricated; with specified mechanical property limits.	-T652	Solution heat-treated, compress produce a permanent set and artificially aged.
-F	For wrought alloys; as fabricated. No mechanical properties limits. For cast alloys; as cast.		
		-T81	Solution heat-treated, cold-wo by the flattening or straighte operation, and then artific aged.
		-T86	Solution heat-treated, cold-wo by reduction of 6 percent, and artificially aged.
		-F	For wrought alloys; as fabric No mechanical properties li For cast alloys; as cast.

FIGURE 7.2.—Basic temper designations and subdivisions for aluminum alloys.

. ***Clad aluminum alloys*** have surface layers of e aluminum or corrosion-resistant alumi- n alloy bonded to the core material to in- it corrosion. Presence of such a coating may determined under a magnifying glass by ex- nination of the edge surface which will show ree distinct layers.

b. ***Test for Distinguishing Heat-Treatable and nheat-Treatable Aluminum Alloys.*** If for any ason the identification mark of the alloy is t on the material, it is possible to distinguish tween some heat-treatable alloys and some nheat-treatable alloys by immersing a sam- e of the material in a 10 percent solution of ustic soda (sodium hydroxide). Those heat- eated 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 not heat-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-treatability of alloys which do not turn black in a caustic soda solution can be established only by chemical or spectro-analysis.

268.-278. RESERVED.

Section 2. TESTING OF METALS

279. HARDNESS TESTING. Hardness testing provides 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. In hardness testing, the thickness of the specimen being tested and the edge distance should be such that distortion of the metal due to these factors is eliminated. Several readings should be taken and the results averaged. In general, the higher the tensile strength, the greater is 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. Also, exercise caution not to cold-work and consequently harden the steel during removal of the surface. The relationship between tensile strength and hardness is indicated in figure 7.3.

280. BRINELL HARDNESS TEST. In this test a standard load is applied to a smooth surface of metal through a hardened steel ball, one centimeter in diameter. The numerical value of Brinell hardness is equal to the load divided by the surface area of the resulting spherical impression.

281. ROCKWELL HARDNESS TEST. In this test, a standard minor load is applied to seat 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 thinner sections, very small parts, etc.

282. VICKERS HARDNESS TEST. In this test small pyramidal diamond is pressed into metal. The hardness number is the ratio of load to the surface area of indentation.

283. TESTING ALUMINUM. Hardness tests useful for testing aluminum alloy chiefly a means of distinguishing between anneal cold-worked, heat-treated, and heat-trea and aged material. It is of little value in in cating the strength or quality of heat tre ment. Typical hardness values for alumin alloys are shown in figure 7.4.

FIGURE 7.4.—Hardness values for aluminum alloy

Material commercial designation	Hardness temper	Brinell numb 500 kg. loa 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

284.–294. RESERVED.

Rockwell C-scale hardness number[a]	Diamond pyramid hardness number (Vickers)	Brinell hardness number 10-mm. ball, 3000-kg. load			Rockwell hardness number[a]			Rockwell, superficial hardness number, superficial brale penetrator			Shore sclero-scope hardness number	Tensile strength[a] (approximate) in 1000 p. s. i.	Rockwell C-scale hardness number[a]
		Standard ball	Hultgren ball	Tungsten-carbide ball	A-scale, 60-kg. load, brale penetrator	B-scale, 100-kg. load, 1/16-in. diam. ball	D-scale, 100-kg. load, brale penetrator	15-N scale, 15-kg. load	30-N scale, 30-kg. load	45-N scale, 45-kg. load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
68	940				85.6		76.9	93.2	84.4	75.4	97		68
67	900				85.0		76.1	92.9	83.6	74.2	95		67
66	865				84.5		75.4	92.5	82.8	73.3	92		66
65	832			739	83.9		74.5	92.2	81.9	72.0	91		65
64	800			722	83.4		73.8	91.8	81.1	71.0	88		64
63	772			705	82.8		73.0	91.4	80.1	69.9	87		63
62	746			688	82.3		72.2	91.1	79.3	68.8	85		62
61	720			670	81.8		71.5	90.7	78.4	67.7	83		61
60	697		613	654	81.2		70.7	90.2	77.5	66.6	81		60
59	674		599	634	80.7		69.9	89.8	76.6	65.5	80	326	59
58	653		587	615	80.1		69.2	89.3	75.7	64.3	78	315	58
57	633		575	595	79.6		68.5	88.9	74.8	63.2	76	305	57
56	613		561	577	79.0		67.7	88.3	73.9	62.0	75	295	56
55	595		546	560	78.5		66.9	87.9	73.0	60.9	74	287	55
54	577		534	543	78.0		66.1	87.4	72.0	59.8	72	278	54
53	560		519	525	77.4		65.4	86.9	71.2	58.6	71	269	53
52	544	500	508	512	76.8		64.6	86.4	70.2	57.4	69	262	52
51	528	487	494	496	76.3		63.8	85.9	69.4	56.1	68	253	51
50	513	475	481	481	75.9		63.1	85.5	68.5	55.0	67	245	50
49	498	464	469	469	75.2		62.1	85.0	67.6	53.8	66	239	49
48	484	451	455	455	74.7		61.4	84.5	66.7	52.5	64	232	48
47	471	442	443	443	74.1		60.8	83.9	65.8	51.4	63	225	47
46	458	432	432	432	73.6		60.0	83.5	64.8	50.3	62	219	46

See footnotes at end of table.

FIGURE 7.3.—Rockwell C scale steel hardness numbers comparison table—continued.

Rockwell C-scale hardness number[a]	Diamond pyramid hardness number (Vickers)	Brinell hardness number 10-mm. ball, 3000-kg. load			Rockwell hardness number[a]			Rockwell, superficial hardness number, superficial brale penetrator			Shore sclero-scope hardness number	Tensile strength[b] (approxi-mate) in 1000 p. s. i.	Rockwell C-scale hardness number[a]
		Stand-ard ball	Hult-gren ball	Tung-sten-carbide ball	A-scale, 60-kg. load, brale penetra-tor	B-scale, 100-kg. load, 1/16-in. diam. ball	D-scale, 100-kg. load, brale penetra-tor	15-N scale, 15-kg. load	30-N scale, 30-kg. load	45-N scale, 45-kg. load			
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11	Col. 12	Col. 13	Col. 14
45	446	421	421	421	73.1	------	59.2	83.0	64.0	49.0	60	212	45
44	434	409	409	409	72.5	------	58.5	82.5	63.1	47.8	58	206	44
43	423	400	400	400	72.0	------	57.7	82.0	62.2	46.7	57	201	43
42	412	390	390	390	71.5	------	56.9	81.5	61.3	45.5	56	196	42
41	402	381	381	381	70.9	------	56.2	80.9	60.4	44.3	55	191	41
40	392	371	371	371	70.4	------	55.4	80.4	59.5	43.1	54	186	40
39	382	362	362	362	69.9	------	54.6	79.9	58.6	41.9	52	181	39
38	372	353	353	353	69.4	------	53.8	79.4	57.7	40.8	51	176	38
37	363	344	344	344	68.9	------	53.1	78.8	56.8	39.6	50	172	37
36	354	336	336	336	68.4	(109.0)	52.3	78.3	55.9	38.4	49	168	36
35	345	327	327	327	67.9	(108.5)	51.5	77.7	55.0	37.2	48	168	35
34	336	319	319	319	67.4	(108.0)	50.8	77.2	54.2	36.1	47	159	34
33	327	311	311	311	66.8	(107.5)	50.0	76.6	53.3	34.9	46	154	33
32	318	301	301	301	66.3	(107.0)	49.2	76.1	52.1	33.7	44	150	32
31	310	294	294	294	65.8	(106.0)	48.4	75.6	51.3	32.5	43	146	31
30	302	286	286	286	65.3	(105.5)	47.7	75.0	50.4	31.3	42	142	30
29	294	279	279	279	64.7	(104.5)	47.0	74.5	49.5	30.1	41	138	29
28	286	271	271	271	64.3	(104.0)	46.1	73.9	48.6	28.9	41	134	28
27	279	264	264	264	63.8	(103.0)	45.2	73.3	47.7	27.8	40	131	27
26	272	258	258	258	63.3	(102.5)	44.6	72.8	46.8	26.7	38	127	26
25	266	253	253	253	62.8	(101.5)	43.8	72.2	45.9	25.5	38	124	25
24	260	247	247	247	62.4	(101.0)	43.1	71.6	45.0	24.3	37	121	24
23	254	243	243	243	62.0	100.0	42.1	71.0	44.0	23.1	36	118	23
22	248	237	237	237	61.5	99.0	41.6	70.5	43.2	22.0	35	115	22
21	243	231	231	231	61.0	98.5	40.9	69.9	42.3	20.7	35	113	21

FIGURE 7.5.—Rockwell C scale steel hardness numbers ...

20	238	226	226	226	60.5	97.8	40.1	69.4	41.5	19.6	34	110	20
(18)	230	219	219	219		96.7					33	106	(18)
(16)	222	212	212	212		95.5					32	102	(16)
(14)	213	203	203	203		93.9					31	98	(14)
(12)	204	194	194	194		92.3					29	94	(12)
(10)	196	187	187	187		90.7					28	90	(10)
(8)	188	179	179	179		89.5					27	87	(8)
(6)	180	171	171	171		87.1					26	84	(6)
(4)	173	165	165	165		85.5					25	80	(4)
(2)	166	158	158	158		83.5					24	77	(2)
(0)	160	152	152	152		81.7					24	75	(0)

[1] The values in this table shown in bold-face type correspond to the values shown in the corresponding joint SAE-ASM-ASTM Committee on Hardness Conversions as printed in ASTM E48, table 2.
[2] Values in ( ) are beyond normal range and are given for information only.
[3] It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. Above the level of Rockwell C48, deviation increases with increasing hardness and the table shall not be used above Rc 48 except in the absence of other data specifically approved by the procuring agency.

Section 3. NONDESTRUCTIVE TESTING

295. GENERAL. The field of NDT (nondestructive testing) and inspection is too varied to be covered in detail in this handbook. This section provides a brief description of the various methods that are available for use in aircraft maintenance. The effectiveness of any particular method of NDT inspection depends upon the skill, experience and training of the persons applying the process. Each process is limited in its usefulness as an inspection tool through its adaptability to the particular component to be inspected. Consult the aircraft or product manufacturer for specific instructions regarding NDT inspection of their product.

296. INSPECTION BY MAGNIFYING GLASS AFTER WELDING. Careful examination of all joints with a medium-power magnifying glass (at least 10-power), after first removing all scale, is considered an acceptable method of inspection for repaired structures. The practice of filling steel tubular structures with hot linseed or petroleum base oils, under pressure, in order to coat the inside surface and inhibit corrosion, assists in the detection of weld cracks, as the hot oil will seep through cracks invisible to the eye. This practice, though not justifiable in all cases, is suggested where a very large portion of the structure has been rewelded.

297. MAGNETIC PARTICLE INSPECTION. Magnetic particle inspection of Magnaflux (a patented trade name used by the Magnaflux Corp.) can be used only on magnetic materials; i.e., iron and steel. Most stainless or high chromium nickel and manganese alloy steels, being nonmagnetic, cannot be inspected by this method. The method consists essentially of detection of discontinuities (cracks, voids, defects, pits, subsurface holes, etc.) by means of accumulation of magnetic particles on the discontinuities when the part has been magnetized. The magnetic particles are applied either dry as a powder or suspended in light oil. F complete magnetic inspection, both circu and longitudinal, magnetization should be e ployed.

CAUTION

Improper operation of Magnaflux equipment be cause of faulty equipment or by untrained persons can jeopardize the airworthiness of parts bein inspected. Minute electrical arc burns caused durin inspection by improper operation of Magnaflu equipment, can result in eventual failure of th part.

a. *Circular magnetization* is produced by tra mitting an electric current directly throu the article being tested, or through a cent conductor placed through the part, in whi case defects parallel to the flow of current m be detected. As an example, circular magne zation of a round steel bar would be produc by placing the ends of the steel bar betwe the heads of the magnetic inspection machi and passing a current through the bars. Ma netic particles applied either during or aft passage of the current, or after passage of t current in magnetically retentive steels, wou disclose discontinuities parallel to the axis the bar.

b. *Longitudinal magnetization* is induced in part by placing the part in a strong magne field, such as the center of a coil. Thus, longit dinal magnetization of a round steel bar wou be produced by placing the ends of the bar b tween the heads of a magnetic-inspecti machine and placing the D.C. solenoid arou the bar. After application of the magne particles, either during or subsequent to ma netization, discontinuities perpendicular to t axis of the bar would be disclosed.

c. *Red, black, and sometimes gray particles* a used in the wet or dry methods. In the case wet inspection, a fluorescent magnetic partic may also be used. This process is commercial known as Magnaglo. Articles inspected usi atter medium are illuminated by so-called k light, and the magnetic particles glow by 'escence causing any defects or indications e easily visible. The wet inspection proce- e provides better control and standardiza- ı of the concentration of magnetic particles, ier application to complex shapes, and indi- ions that are easier to interpret. This is due the difficulty of obtaining efficient distribu- ı of the dry powder during magnetization. e dry procedure is particularly suitable for ecting subsurface defects, such as, when pecting heavy welds, forgings, castings, etc. e wet continuous process is recommended most aircraft work.

l. ***The presence of accumulations of magnetic ticles*** in magnetic inspection does not neces- ily mean that a defect exists. Changes in tion of the part, particularly where the ange in section is very sharp, and also holes illed through a part, will frequently cause lications. Surface defects are most easily de- ted, however, since a crack will cause a arp line of magnetic particles to appear. bsurface defects are less easily detected, ice only a general collection of magnetic rticles will be observed.

e. ***After magnetic inspection*** carefully demag- tize and clean the parts. Examine for possi- e evidence of electrical arc burns that may ve occurred during inspection. All metal rticles must be removed and the serviceable rts coated with a suitable preservative.

f. ***Portable type magnetic particle inspection uipment*** such as Sonoflux has been developed r use in the detection of surface or slightly bsurface discontinuities in ferromagnetic rcraft materials and parts. This type equip- ent usually gives better results when the wet spension type of indicator, such as that con- rming to Specification MIL-I-6868, is used ith the powder supplied by the equipment anufacturer. As in other inspection methods, llow the manufacturers' recommendations ncerning use of the procedure.

98. X-RAY OR RADIOGRAPHIC INSPECTION. -ray may be used on either magnetic or non- agnetic materials for detecting subsurface voids such as open cracks, blowholes, etc. When a photographic film or plate is used to record the X-ray (in a similar manner to exposing a photographic film), the process is known as radiography. When the X-rays are projected through the part onto a fluorescent screen, the process is known as fluoroscopy. The technique used for radiography should be capable of indicating the presence of defects having a dimension parallel to the X-ray beam of 3 percent of the thickness of the part being radiographed for magnesium alloys, and 2 percent for all other metals and alloys. Inspection using a fluoroscopic screen is much less sensitive. Consequently, the radiographic method is usually used for inspection and the fluoroscopic method is used for culling.

a. ***Radiographic inspection*** is extensively used in the aircraft industry for the inspection of all types of castings including sand castings, permanent-mold castings, die castings, etc. X-ray is particularly useful for this application, since it is capable of disclosing defects which exist below the surface, and also since the open types of defects which may occur in castings (shrinks, blowholes, dross inclusions, etc.) are readily disclosed by proper use of X-rays. In the inspection of forged or wrought metals, on the other hand, X-ray inspection is not used so extensively. This is due to the fact that the process of forging or working may cause defects which originally existed in the metal to become tightwalled cracks. Such defects are somewhat difficult to disclose by X-rays. If doubt exists as to the suitability of the X-ray examination, consult a laboratory familiar with the X-ray examination of aircraft parts.

b. ***In radiography,*** values of peak kilovoltage, radiographic density range and penetrometer characteristics are often selected that produce less than optimum radiological data. This selection of high kilovoltage is made in order to reduce the exposure time. The use of too high a kilovoltage reduces the resolvable detail recorded on the radiographic film. As the kilovoltage is increased, X-rays of shorter wave length and greater penetrating power are produced. This presents a sound argument for increased kilovoltages but does not take into account the effects of scatter both within the sample and the radiographic film, which in reality, reduces the resolvability of details recorded on the X-rays.

c. ***If for some reason a short exposure time is required,*** a faster film is normally used with a higher kilovoltage; however, this has the effect of increasing the granularity and reducing the resolution on the radiographic material.

d. ***The use of low voltages*** results in improved radiographic signal-to-noise ratio and improved resolution. The recommended kilovoltages are shown in figure 7.5.

FIGURE 7.5.—Maximum recommended X-ray kilovolts.

Material	*Atomic No.*	*Max. KV*
Beryllium	4	25
Carbon	6	40
Magnesium	12	50
Alumium	18	75
Titanium	22	120
Steel	22–26	150
Steel	26–28	200
Silver	47	300
Lead	82	1–2 (megavolts)

299. FLUORESCENT PENETRANT. In this method of inspection (Zyglo), the article, which may be of metal, plastic material, etc., is first carefully cleaned to permit the fluorescent material to penetrate cracks and defects. It should be noted that cleaning of aluminum may necessitate stripping of any anodizing, since the anodized film, if formed after the defect, could prevent penetration of the fluorescent material and an anodized film tends to hold penetrants which may obscure defect indications. After the article is cleaned, it is either sprayed, painted, or immersed in a bath of fluorescent penetrant. The penetrant is a light oil which has the property of fluorescing or emitting visible light when excited by invisible radiation in the near ultra-violet range (so-called black light). It is important that the penetrant be given sufficient time to penetrate cracks and defects, and for fatigue cracks a minimum of 30 minutes is stipulated by MIL–I–6866. Heat may also be applied to facilitate entry of the penetrant. After the penetrant has had sufficient time to enter any defects, the excess on the surface of the article is washed o water spray. This washing should be ch by inspection with black light, by which r any penetrant left on the surface may t tected. After washing, a developer is us bring out the indication. This developer m in a liquid form or may be a light powde absorbs the penetrant as it oozes from c and defects in the part. The development also be aided by application of heat to the After the indications have been develope part is inspected under black light. Any ices into which the fluorescent material has etrated will show as luminous areas.

Indications which appear are us checked by close inspection with a magni glass, by etching with a suitable acid or ca solution, or it may be necessary to cross-se the part, a procedure which, of course stroys its usefulness. Usually a skilled ope can determine whether an indication act shows a defect or whether it is a false in tion. Also, the internal extent of the defec sometimes be estimated with fair accura should be noted that this process of inspe like all others, has its limitations. If the orescent material for any reason is not at penetrate into a defect, such a defect cann detected.

300. DYE PENETRANTS. Several dye pene type inspection kits are now available w will reveal the presence of surface crack defects and subsurface flaws which exter the surface of the part being inspected. T penetrant type inspection methods are co ered acceptable, provided the part being spected has been thoroughly cleaned, all a are readily accessible for viewing, and manufacturer's recommendations as to me of application are closely followed.

a. ***Cleaning.*** An inspection is initiated by cleaning the surface to be inspected of loose scale, oil, and grease. Precleaning usually be accomplished by vapor degrea or with volatile cleaners. Use a volatile cle as it will evaporate from the defects be applying the penetrant dye. Sand blastin not desirable as a cleaning method, since face indications may be obscured. It is not ary to remove anodic films from parts to be spected, since the dye readily penetrates such ms. Special procedures for removing the excess dye should be followed.

b. *Application of Penetrant.* The penetrant is pplied by brushing, spraying, or by dipping d allowed to stand for a minimum of 2 min-es. Dwell time may be extended up to 15 min-es, depending upon the temperature of part d fineness of the defect or when the surface ing inspected is ground. Parts being in-ected should be dry and heated to at least ° F., but not over 130° F. Very small indica-ons require increased penetration periods.

c. *Removal of Dye Penetrant.* Surplus pene-nt is usually removed by application of a ecial cleaner or remover, or by washing with in water and the part allowed to dry. Water e may also be used in conjunction with the over, subject to the manufacturer's recom-dations.

Application of Developer. A light and even of developer is applied by spraying, brush-r dipping. When dipping, avoid excess ac-lation. Penetrant which has penetrated cracks or other openings in the surface of naterial will be drawn out by the devel-resulting in a bright red indication. Some idea of the size of the defect may be obtained after experience by watching the size and rate of growth of the indication.

301. ULTRASONIC FLAW DETECTION. Ultrasonic flaw detection equipment has made it possible to locate defects in all types of materials without damaging the material being inspected. Very small cracks, checks, and voids, too small to be seen by X-ray, are located by means of ultrasonic inspection. An ultrasonic test instrument requires access to only one surface of the material to be inspected, and can be used with either straight line or angle beam testing techniques. The instrument electronically generates ultrasonic vibrations and sends them in a pulsed beam through the part to be tested. Any discontinuity within the part, or the opposite end, will reflect the vibration back to the instrument, which measures the elapsed time between the initial pulse and the return of all reflections and indicates such time lapse on a cathode ray indicator or paper recorder. Ultrasonic inspection requires a skilled operator who is familiar with the equipment being used as well as the inspection method to be used for the many different parts being tested.

302.–312. RESERVED.

Section 4. IDENTIFICATION OF FABRICS AND PLASTICS

313. IDENTIFICATION OF FABRIC. Cotton fabric is often used as covering for wing, fuselage, and control surfaces of aircraft. Acceptable grades of fabric for use on civil aircraft are listed in Chapter 3. In general, the fabric can be readily identified by a continuous marking to show the manufacturer's name or trademark and specification number. This marking may be found stamped along the selvage edge. The specification number for grade "A" fabric is AMS–3806, and for the intermediate grade AMS–3804. The corresponding FAA Technical Standard Order ✱Numbers for these materials are TSO–C15 and TSO–C14, respectively. Increasing interest in✱ the use of linen and certain synthetic fabrics in lieu of cotton has been noted. Identity of such materials should always be verified by the user.

314. IDENTIFICATION OF PLASTICS. Plastics cover a broad field of organic synthetic resins and may be divided into two main classifications—thermoplastic and thermosetting plastics.

a. Thermoplastics. Thermoplastics may softened by heat and can be dissolved in vario organic solvents. Two kinds of transpare thermoplastic materials are commonly employ in windows, canopies, etc. These materials a known as acrylic plastics and cellulose aceta plastics. These two plastics may be distinguish by the absence of color, the greater transparen and the greater stiffness of the acrylic as co pared to the slight yellow tint, lower transpa ency, and greater flexibility of cellulose aceta

b. Thermosetting Plastics. Thermosetting pl tics do not soften appreciably under heat may char and blister at temperatures of 204 260° C. (400° to 500° F.). Most of the mo products of synthetic resin composition, suc phenolic, urea-formaldehyde, and melan formaldehyde resins, belong to the thermose group.

315.–320. RESERVED.

Section 5. CABIN INTERIOR MATERIALS, FIRE PROTECTION QUALITIES

21. REQUIREMENTS FOR FIRE PROTECTION. The leaning, repairing, and/or replacement of cabin nterior materials necessitates continuing compli- nce with the fire protection requirements of the 'ARs. A recent field survey on this matter re- ealed a wide variance in the procedures used or maintaining cabin interior materials with spect to the fire protection qualities of these aterials.

a. Interior Materials. The methods, techniques, actices, and materials used in the cleaning, re- ir, and replacement of cabin materials must et the requirements of Section 43.13 of the Rs.

. Fire Protection. The requirements relative ire protection qualities of cabin interior ma- ls are specified in:

(1) Section 121.312, for aircraft operated under Parts 121, 123, and 135.

(2) Section 127.91, for helicopters used in passenger service under Part 127.

c. Source of Information. If information regarding the original or properly altered fire protection qualities of certain cabin interior materials is not available, requests for this information should be made to the aircraft manufacturers or the local FAA regional office, specifying the model aircraft, the aircraft manufacturer, the date the aircraft was manufactured or the serial number, and the FAR Part under which the aircraft is operated (i.e., Part 91, Part 121, etc.). *

322.-325. RESERVED.

Chapter 8. AIRCRAFT EQUIPMENT

Section 1. LANDING GEAR EQUIPMENT

326. GENERAL. Many factors affect the scope and frequency of landing gear system inspection and maintenance. The possibility of system malfunction increases with severe operating conditions, such as pilot training and agricultural operations. Cracks are the foremost area of concern, followed closely by worn, sheared, bent, or broken bolts, and elongated boltholes. Although these defects occur during normal aircraft usage, adverse operating conditions accelerate the problem.

Improper adjustment or lubrication can also cause malfunctioning, especially in landing gear retraction mechanisms. Excessive lubrication or the wrong type of lubricant can often be as bad or worse than none at all. With regard to lubrication, closely follow the manufacturer's service and maintenance instructions.

CAUTION

Inspect grease fittings after applying high pressure lubricant to determine that the spring-loaded ball has reseated. Failure of the ball to reseat is an indication of an internal failure of the fitting which can result in serious damage to the part being lubricated.

327. INSPECTION. Inspect the aircraft landing gear and all associated hardware closely for cracks, cleanliness, lubrication, leaks, deformation, excessive wear, and security of attachments. Before removing any accumulated dirt, closely observe the area being inspected while the wingtips are gently rocked up and down. Excessive motion between normally close fitting components may indicate wear, cracks, or improper adjustment. If a crack exists, it will generally be indicated by dirt or metallic particles which tend to outline the fault. Seepage of rust inhibiting oils, used to coat internal surfaces of steel tubes, also assists in the early detection of cracks. In addition, a sooty, oily residue around bolts, rivets, and pins is a good indication of looseness or wear.

Thoroughly clean and re-inspect the landing gear to determine the extent of any damage or wear. Some components may require removal and complete disassembly for detailed inspection. Others may require a specific check using an inspection process such as dye penetrant, magnetic particle, radiographic, ultrasonic, or eddy current (see Chapter 7). The frequency, degree of thoroughness, and selection of inspection methods are dependent upon the age, use, and general condition of the aircraft.

Inspect the aircraft structure surrounding any visible damage to insure that no secondary damage remains undetected. Forces can be transmitted along the affected member to remote areas where subsequent normal loads can cause failure at a later date.

a. Types of Malfunctions.

(1) Cracks. Prime locations for cracks on any landing gear are bolts, boltholes, pins, rivets, and welds. The following are typical locations where cracks may develop:

(a) Bolts. Most susceptible areas are at the radius between the head and the shank, and in the location where the threads join the shank, as shown in figure 8.1.

(b) Boltholes and Pinholes. Cracks primarily occur at the edge of boltholes or pinholes on

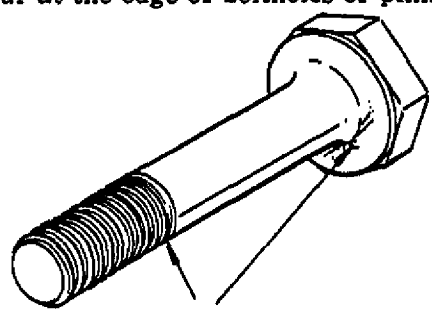


FIGURE 8.1.—Typical bolt cracks.

the surface and down inside the bore. (See figures 8.2 and 8.3.)

(c) ***Riveted Joints or Seams.*** The usual types of failure in this area are deformation of the rivet heads and skin cracks originating at the rivet holes.

(d) **Rod Ends.** Cracks and subsequent failures usually begin at the thread end near the bearing and adjacent to or under the jam nut. (See figure 8.4.)

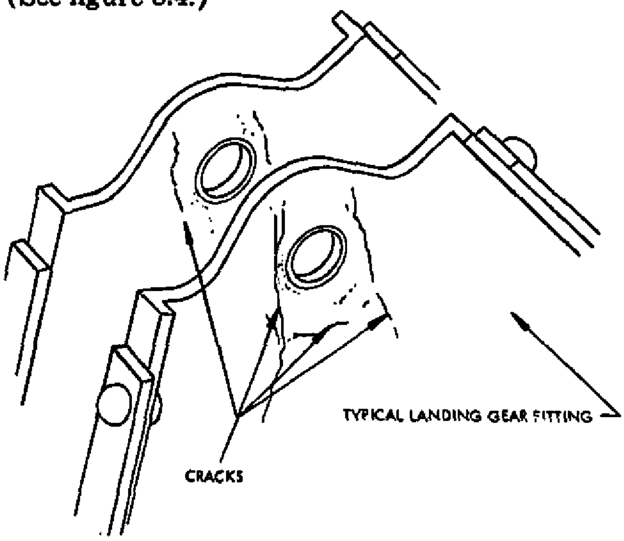


FIGURE 8.2.—Typical cracks near boltholes.

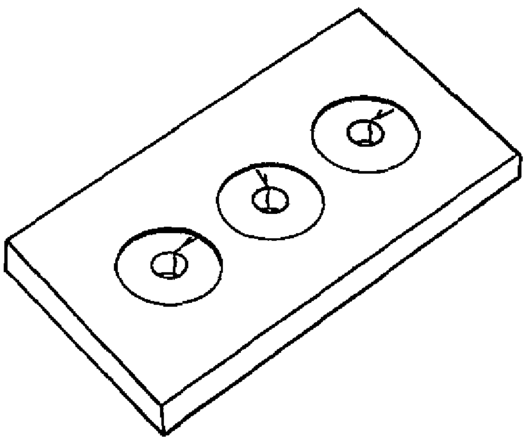


FIGURE 8.3.—Typical bolthole cracks.

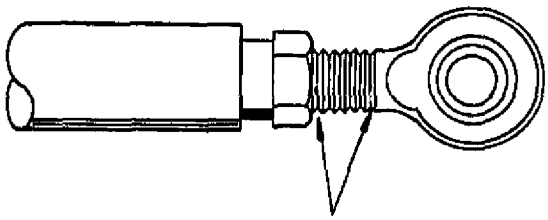


FIGURE 8.4.—Typical rod-end cracks.

(e) ***Welds.*** Cracks develop primarily along the edge of the weld adjacent to the base metal and along the centerline of the bead.

(2) **Elongated holes** are especially prevalent in taper-pin holes and boltholes or at the riveted joints of torque tubes and push-pull rods. (See figure 8.5.)

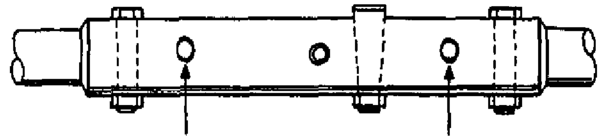


FIGURE 8.5.—Typical torque tube bolthole elongation.

(3) **Deformation** is common in rods and tubes and usually is noticable as stretched, bulged, or bent sections. As deformations of this type are difficult to see, the hands should be passed along the tube to feel for evidence of this discrepancy. Deformation of sheet metal web sections, at landing-gear component attachment points, usually can be seen when the area is highlighted with oblique lighting.

b. ***Landing Gear Components.*** The following items are susceptible to service difficulties and should be given attention.

(1) **Shock Absorbers.** Inspect the entire shock-strut for evidence of leaks, cracks, and possible bottoming of the piston, as this condition causes overloading of landing gear components and contributes to fatigue cracks. Check all bolts, boltholes, pins, and bushings for condition, lubrication and proper torque values. Grease fitting holes (pressure type) are especially vulnerable to cracks and cross-threading damage. Check all safety wire and other locking devices, especially at the main packing gland nuts.

When assembling shock-struts, use the correct type and number of "O"-rings, chevron seals, and backup rings. Use only the correct filler valve core assembly, and follow the manufacturer's instructions when servicing with fluid and air. Either too much or too little air or oil will affect aircraft handling characteristics during taxi, takeoff, and landing, and can cause structural overloads.

Shock cords and rubber discs deteriorate with age and exposure. When this type of shock absorber is used, inspect for general condition, i.e., cleanliness, stretching, fraying, and broken strands. These components must be kept free of petroleum products as they accelerate deterioration of the rubber.

(2) Nose Gear Assembly. Attention should be given to the steering mechanism and should include items such as: torque-links (scissors), torque-tubes, control rods and rod-end bearings, shimmy dampers, cables, and turning stops. In addition, check all nose landing gear components, including mud scrapers and slush deflectors, for damage from natural elements.

(a) Towing of some aircraft with the rudder locks installed may cause damage to the nose steering linkage and rudder control system. Exceeding the steering or towing stops should be followed by a close inspection of the entire nose steering assembly. A broken steering stop will allow turning beyond the design limit, transmitting excessive loads to structures and to the rudder control system. It is recommended that the nose steering arc limits be indicated on the steering collar or fuselage.

(b) Inspect shimmy dampers for leakage around the piston shaft and at fluid line connections, and for abnormal wear or looseness around the pivot points. Also check for proper rigging, "bottoming" of the piston in the cylinder, and the condition of the external stops on the steering collar.

(3) Tailwheels. Disassembly, cleaning, and rerigging of tailwheels are periodically necessary. Inspect for loose or broken bolts, broken springs, lack of lubrication, and general condition. Check steerable tailwheels for proper steering action, steering-horn wear, clearances, and for security and condition of steering springs and cables.

(4) Gear Doors. Inspect gear doors frequently for cracks, deformation, proper rigging, and general condition. Gear door hinges are especially susceptible to progressive cracking, which can ultimately result in complete failure, allowing the door to move and cause possible jamming of the gear. This condition could also result in the loss of the door in flight. In addition, check for proper safetying of the hinge pins and for distorted, sheared, loose, or cracked hinge rivets. Inspect the wheelwells for improper location or routing of components and related tubing or wiring which could interfere with the travel of the gear door actuating mechanisms.

(5) Floats. In order to maintain floats in an airworthy condition, frequent inspections should be made because of the rapidity with which corrosion takes place on aluminum alloy metal parts, particularly when the aircraft is operated in salt water. Examine metal floats and all metal parts on wooden or fiberglas floats for corrosion and take corrective action in accordance with the procedures described in Chapter 6. Repair damage to metal floats in the general manner outlined in Chapter 2 pertaining to aluminum and aluminum alloy structures. In the case of wooden floats, make repairs in accordance with general procedure outlined in Chapter 1. Repair fiberglass floats in accordance with the manufacturer's instructions or other acceptable practices.

(6) Skis and Ski Installation. It is advisable to examine ski installations frequently to keep them maintained in airworthy condition. If shock cord is used to keep the ski runner in proper trim, periodically examine to assure that the cord has enough elasticity to keep the runner in its required attitude and the cord is not becoming loose or badly frayed. Replace old or weak shock cords. When other means of restraint are provided, examine for excessive wear and binding, and replace or repair when such conditions are found. Examine the points of cable attachment, both on the ski and the airplane structure, for bent lugs due to excessive loads having been imposed while taxiing over rugged terrain or by trying to break loose frozen skis. If skis which permit attachment to the wheels and tires are used, maintain proper tire pressure as underinflated tires may push off the wheels if appreciable side loads are developed in landing or taxiing.

(a) Repair of Ski Runners. Fractured wooden ski runners usually require replacement. If a split at the rear end of the runner does not exceed 10 percent of the ski length, it may be repaired by attaching one or more wooden crosspieces across the top of the runner using glue and bolts. Bent or torn metal runners may be straightened if minor bending has taken place and minor tears may be repaired in accordance with procedures recommended in Chapter 2 relative to repair of metal structures.

(b) Ski Pedestals.

1. Tubular pedestals. Damaged pedestals made of steel tubing may be repaired by using standard tube splices as shown in Chapter 2, figures 2.5 and 2.15.

2. Cast pedestals. Consult an FAA representative on the repair of cast pedestals.

3. Sheet metal pedestals. Repair damaged pedestals made of aluminum alloy sheet in the general manner outlined in Chapter 2.

(7) Wheels. Inspect wheels at periodic intervals for cracks, corrosion, dents, distortion, and faulty bearings in accordance with the manufacturer's service information. In split-type wheels, recondition boltholes which have become elongated due to some play in the through-bolt, by the use of inserts or other suitable means. Pay particular attention to the condition of the through-bolts and nuts. Carefully inspect wheels used with tubeless tires for damage to the wheel flange and for proper sealing of the valve. The sealing ring used between the wheel halves should be free of damage and deformation. In bolting wheel halves together, tighten the nuts to the proper torque value. Periodically accomplish an inspection to assure the nuts are tight and there is no movement between the two halves of the wheel. Any movement between the wheel halves normally causes elongation of the boltholes. If the wear is too great to be corrected, as stated above, it may necessitate scrapping of the wheel. Maintain grease retaining felts in the wheel assembly in a soft, absorbent condition. If any have become hardened, wash them with a petroleum-base cleaning agent; if this fails to soften them, they should be replaced.

(a) Corrosion of Wheels. Thoroughly clean wheels if corroded and then examine for soundness. Smooth and repaint bare corroded spots with a protective coating such as zinc chromate primer and aluminum lacquer, or some other equally effective coating to prevent further corrosion. Replace wheels having severe corrosion which might affect their strength.

(b) Dented or Distorted Wheels. Replace wheels which wobble excessively due to deformation resulting from a severe side-load impact. In questionable cases, consult the local representative of the FAA concerning the airworthiness of the wheels. Dents of a minor nature do not affect the serviceability of a wheel.

(c) Wheel Bearings. Periodically inspect wheel bearings for condition. Replace damaged or excessively worn parts. Pack bearings with a high-melting-point grease prior to their installation. Avoid preloading the wheel bearing when installing on aircraft by tightening the axle nut just enough to prevent wheel drag or sideplay.

(8) Brakes. Maintain the clearance between the moving and stationary parts of a brake in accordance with the manufacturer's instructions. Disassemble and inspect the brake periodically and examine the parts for wear, cracks, warpage, corrosion, elongated holes, etc. If any of these or other faults are indicated, repair, recondition, or replace the affected parts in accordance with the manufacturer's recommendations. Surface cracks on the friction surfaces of the brake drums occur frequently due to high surface temperatures. These surface cracks may be disregarded as seriously affecting the airworthiness until they become cracks of approximately 1 inch in length.

(a) Hydraulic Brakes. For proper maintenance, periodically inspect the entire hydraulic system from the reservoir to the brakes. Maintain the fluid at the recommended level with proper brake fluid. When air is present in the brake system, bleed in accordance with the manufacturer's instructions. Replace flexible hydraulic hose which has deteriorated due to long periods of service and replace hydraulic piston seals when there is evidence of leakage. Service antiskid units according to the manufacturer's instructions.

(b) Mechanical Brakes. Keep the working parts of mechanically operated brakes free from dirt and foreign matter so the brakes can work freely at all times. Slack in the linkage system must be kept to a minimum.

(9) **Micro-Switches.** Inspect micro-switches for security of attachment, cleanliness, general condition, and proper operation. Check associated wiring for chafing, proper routing, and to determine that protective covers are installed on wiring terminals, if required. Check the condition of the rubber dust boots which protect the micro-switch plungers from dirt and corrosion.

328. CLEANING AND LUBRICATING. It is recommended that only easily removable neutral solutions be used when cleaning landing gear components. Any advantage, such as speed or effectiveness, gained by using cleaners containing corrosive materials, can be quickly counteracted if these materials become trapped in close-fitting surfaces and crevices. Wear points, such as landing gear up-and-down latches, jack-screws, door hinges, pulleys, cables, bellcranks, and all pressure-type grease fittings should be relubricated after every cleaning operation. To obtain proper lubrication of the main support bushings, it may be necessary to jack the aircraft.

NOTE: Anytime the aircraft is on jacks, check the landing gear main support bushings for wear. Consult the aircraft manufacturer's overhaul manual for specific wear tolerances.

During winter operation, excess grease may congeal and cause increased loads on gear retraction system electric motors and hydraulic pumps. This condition can lead to component malfunctions; therefore, it is recommended that cleanliness be stressed during and after lubrication.

329. EMERGENCY SYSTEMS. Exercise emergency landing gear systems periodically to insure proper operation and to prevent inactivity, dirt, and corrosion from rendering the system inoperative when needed. Most emergency systems employ either mechanical, pressure-bottle or free-fall extension capabilities. Check for proper safetying of triggering mechanisms, and for the presence of required placards and necessary accessories such as cranks, levers, handles, etc.

330. SPECIAL INSPECTIONS. Any time an aircraft has experienced a hard or overweight landing, it is recommended that a special structural inspection, which includes the landing gear, be performed. Typical areas which require special attention are landing gear support trusses for cracked welds, sheared bolts and rivets, and buckled structures; wheels and tires for cracks and cuts; and upper and lower wing surfaces for wrinkles, deformation, and loose or sheared rivets. If any damage is found, a detailed inspection is recommended.

331. RETRACTION TESTS. Periodically, perform a complete operational check of the landing gear retraction system. Inspect the normal extension and retraction system, the emergency extension system, and the indicating and emergency warning system. Determine that the actuating cylinders, linkage, slide tubes, sprockets, chain or drive gears, gear doors, and the up-and-down locks are in good condition and properly adjusted and lubricated. In addition an electrical continuity check of micro-switches and associated wiring is recommended. Only qualified personnel should attempt adjustments to the gear position and warning system micro-switches and then only by closely following the manufacturer's recommendations.

332. TIRES. It is essential that tires be inspected frequently for cuts, worn spots, bulges on the sidewalls, foreign bodies in the treads, and tread condition. Defective tires may be repaired or retreaded in accordance with the following paragraphs. The term, "retread," for the purpose of this advisory circular, refers to the several means of restoring a used tire, whether by applying a new tread alone or tread and sidewall material in varying amounts. It refers as well to the process of extending new sidewall material to cover the bead area of the tire. Aircraft tires are identified by type and rating (figure 8.6).

Type	MFG under FAR 37.167 (TSO C62)	Design and rating
I	No	Smooth contour.[1]
II	No	High pressure.[1]
III	Yes	Low pressure.[2]
IV	No	Extra low pressure.[1]
V	No	N/A.
VI	No	Low profile.[1]
VII	Yes	Extra high pressure "low speed".[2]
VII	Yes	Extra high pressure "high speed."[3]
VIII	Yes	Extra high pressure—Low profile "low speed."[2]
VIII	Yes	Extra high pressure—low profile "high speed."[3]

[1] Inactive for new design.
[2] Low speed for ground speeds below 160 m.p.h.
[3] High speed for ground speeds above 160 m.p.h.

FIGURE 8.6.—Aircraft tire types and ratings.

Tires rated for groundspeeds in excess of 160 m.p.h. have the type and rating embossed on the sidewall.

a. Repair and Retreading of Low-Speed Tires. The following procedures are applicable to other than Type VII and Type VIII high-speed aircraft tires.

(1) Tires having injuries of the following types may be repaired:

(a) ***Bead injuries*** where only the chafe resistant material is damaged or loose, or where minor injuries do not penetrate into more than 25 percent of the tire plies, up to a maximum of three damaged plies.

(b) ***Injuries in tread or sidewalls*** may be repaired by the spot repair method. This includes cuts in the tread area that are smaller than 1/2 inch in length and do not penetrate more than the following number of plies into the cord body.

Ply rating:	*Maximum cut depth*
Less than 8	None.
8 through 16	2 plies.
More than 16	4 plies.

(2) Nonrepairable Tires. If any of the following conditions exist, repair of the tire is not recommended:

(a) Evidence of flex breaks.

(b) Bead injuries that exceed the limits outlined in paragraph (1) (a) or affect the seal of the bead on tubeless-type tires.

(c) Evidence of separation between plies or around bead wire.

(d) Injuries requiring reinforcement. This includes injuries larger than those outlined under paragraph (1) (b) and all injuries requiring sectional repair.

(e) Kinked or broken beads.

(f) Weathering or radial cracks extending into the cord body.

(g) Evidence of blisters or heat damage.

(h) Cracked, deteriorated, or damaged inner liners of tubeless tires.

(3) Spot Repairs. Use repair methods conforming to the best aviation industry practices. Skive injuries require spot repairs at an approximate 45° angle to remove damaged rubber and cords.

Buff away exposed cord (refer to paragraph (1) (b) for cord damage limits) leaving only the ends at the skive line and the rubber between the cord plies exposed. Clean the area thoroughly before applying the vulcanizing cement. As soon as the cement is completely dry, cover the skived area of the carcass with repair cushion gum. Fill the cavity in the carcass with repair cushion gum and roll to remove air. The tread cavity can then be filled with tread repair gum well-rolled, to provide a solid repair.

(4) Bead or Chafe Repairs. Use repair methods conforming to the best aviation industry practices. Trim the frayed fabric ends. Turn back the loose area, buff and clean the surface, and immediately cement. Secure the fabric back in position. Vulcanize repairs larger than 2 inches.

(5) Retreadable Tires. Tires which are sound or which can be repaired as listed above may be retreaded as set forth in Specification MIL-R-7726.

(6) Marking of Retreaded Tires. Permanently mark each retreaded tire. Whenever it is necessary to replace the area containing the original marking, such markings must be replaced. In addition, each retreaded tire will:

(a) Display the letter "R" followed by a

number "1", "2", etc., to signify the sequential number of retreads applied thereon.

(b) Display the speed category increase if the tire is qualified for the increased speed in accordance with the requirements specified in FAR 37.167 (Technical Standard Order TSO-C62).

(c) Display the month and year of retread application.

(d) Display the name of the person retreading the tire.

(7) **Balance.** Each repaired or retreaded tire should not exceed the static unbalance limits as set forth in *Technical Standard Order* TSO-C62.

(8) **Tire Installation.** Install the tire on the wheel in such a manner that the tire-bead chafing area will not be torn or the tube pinched during the mounting process. When mounting tubeless tires, use procedures that assure a positive seal between the tire-bead and the wheel-rim area.

(9) **Clearance.** For retractable landing gears, *maintain sufficient* clearance between the tire and the surrounding structure during the retraction process. Carefully check clearances following installation of wheel assemblies equipped with retreaded tires because of the growth factor which may have increased the tire diameter and cross section.

b. ***Retreading Types VII and VIII High-Speed Tires.*** The following paragraphs describe ways of substantiating the acceptability of methods, techniques, and practices to be used in retreading of high-speed tires. Other methods may be used.

(1) **Number of Retreads.** The wide variation in tire operating environments which may affect total carcass life and serviceability makes it inadvisable to prescribe arbitrarily the maximum number of times a high-speed tire should be retreaded. This aspect, therefore, is controlled by thorough inspection of the carcass before retreading.

(2) **Condition of Tire to be Retreaded.** Retread only those tire carcasses found serviceable by thorough inspection. During inspection, use equipment, techniques, and procedures which are recommended by the tire manufacturer or that are equivalent to those in general use by FAA certificated repair agencies rated for retreading of high-speed aircraft tires. Determine the acceptability of damaged tires for retreading in accordance with established industry practices.

(3) **Retreading Criteria.**

(a) ***Processes, Methods, Techniques, Practices, and Equipment.*** The suitability of specific retread manufacturer's injury limitations, retreading processes, and equipment used is determined either by satisfactory service experience or substantiating tests.

(b) ***Materials.*** The acceptability of materials used in a retreading process may be determined by following the tire manufacturer's recommendations, or the materials may be substantiated by analysis and tests, such as dynamometer testing, or through satisfactory service experience.

(c) ***Unbalance.*** The moment of static unbalance in ounce-inches shall be no greater than the following moment values:

1. Tire diameters up to and including 28 inches: Moment $= .01D^2 + .38D$.

2. Tire diameters greater than 28 inches: Moment $= .034D^2 - .304D$.

D = Tire diameter (actual).

(d) ***Balance Marker.*** To indicate the lightweight point of the tire, remove old balance marker, and durably affix a new relocated balance marker, consisting of a single red dot of appropriate size to the sidewall of the tire immediately above the bead.

(e) ***Burst Pressure.*** Retreaded tires shall be capable of withstanding without failure, a burst pressure of at least 3 times the rated inflation pressure.

(f) ***Temperature.*** The airworthiness of retreaded tires shall not be adversely affected as a result of their being subjected to extreme ambient temperatures expected to be encountered during normal airplane operation.

(g) ***Tread Design.*** Substantiate decreases or increases in the number of tread ribs and grooves and changes in skid depth by dynamometer tests that are applicable to the tire groundspeed range.

(h) Underskid Thickness. The thickness of the rubber between the carcass and the bottom of the tread pattern (underskid) is not normally less than 80% of the mold skid depth. Requalify by dynamometer test, tire underskid/tread thickness which is greater than that previously qualified.

(i) Venting. Substantiate changes in venting pattern by dynamometer test.

(4) Marking and Identification. Do not obliterate the original manufacturer's marking and identifying data, unless it is necessary for proper retreading or repair. Permanently emboss the tire sidewall with retread information. If necessary, replace original identifying markings and include the following retread identification:

(a) Name of identifying letters of the retreading company.

(b) The letter "R" followed by a numeral "1", "2", etc., to signify first, second, etc., time the tire has been retreaded.

(c) Plant location of the retread manufacturer.

(d) Month and year of retread in numerical figures.

(e) If the dynamometer retread qualification speed is less than the previous (original) tire qualification speed, remove the previous speed marking and indicate the new (lower) rated speed. Identify tires that have been retreaded for use only on aircraft of a specific make/model and type design.

(5) Quality Control. The retreader's quality control system will be expected to maintain a satisfactory level of workmanship throughout the retreaded process including assurance that each retreaded tire is vented to prevent tread breakdown or separation.

(6) Records of Work Performed. Include at least the following information in the retreader's work record for each tire processed:

(a) Tire size.

(b) Ply rating.

(c) Speed rating.

(d) Serial number.

(e) Retread number.

(f) Type of tread applied.

(g) Month and year applied.

(7) Dynamometer tests. An acceptable means of determining that the methods, techniques, and practices utilized in the retread process will produce a tire that meets the requirements of FAR 43.13 is by subjecting a representative tire to the following dynamometer tests:

(a) General. Load-speed-time data compiled by the airplane manufacturer is the basis for establishing representative dynamometer tests. To determine tire performance, simulate the most critical combination of takeoff weight, speed, and airplane center-of-gravity position. Also, consider increased speeds resulting from elevated airport operations and high ambient temperatures.

(b) Selection of Tires for Qualification Testing. Retread only tires that are worn at least 80% from actual aircraft useage or which have undergone simulated equivalent operation during dynamometer testing. The sample retreaded tire must be properly identified and bear the qualifying retreaders markings.

(c) Test Inflation Pressure. Inflate the sample tire to the pressure necessary to obtain the same deflection on the flywheel (under the rated static load) as the flat-plate deflection the tire would have at its rated static load and inflation.

(d) Test Speeds. The applicable dynamometer test speeds corresponding to the maximum operational groundspeeds are as follows:

Maximum operational ground speed of aircraft (m.p.h.)		Dynamometer test speed (m.p.h.)
Over	*Not over*	
160	180	180
180	200	200
200	225	225
225	250	250

(e) Test Landing Interval. Schedule minimum time between landings to assure carcass peak temperatures of not less than 160° F. or contained air peak temperatures of not less than 140° F. for each run. Measure the carcass temperatures within 1 inch of the rim flange and also in the shoulder or crown area. Record any unavoidable deviations in the substantiating test data.

(8) Dynamometer Test Procedures. The high-speed retreaded tire shall withstand 100 dynamometer landings and at least three taxi-test cycles. The dynamometer landings will consist of 50 Test A, load-speed-time cycles and 50 Test B, energy cycles.

(a) Test A, Load-speed-time.

1. Speed cycle. Land the tire against a dynamometer flywheel rotating at a peripheral speed of S_1 m.p.h. Immediately thereafter, decrease the flywheel speed at an average deceleration rate of D ft./sec./sec. until a value of S_2 is attained. No specific rate of deceleration is required after the flywheel's peripheral speed reaches a value of S_2. Decrease the speed of the flywheel in the above manner until a roll distance of RD feet has been covered, at which time the tire is unlanded.

2. Load cycle. After landing, increase the load from zero to L_1 pounds within T_1 seconds. Linearly increase the load with time to a value of L_2 pounds within T_2 seconds after landing, or at the moment of unlanding, whichever occurs first. If it is necessary to continue the roll after T_2 seconds to complete the required roll distance (RD), maintain the load at L_2 pounds.

3. Symbol definitions. Determine the numerical values, which are used for the following symbols, from the applicable airplane load-speed-time data:

S_1 = Initial dynamometer test speed.

S_2 = Speed at which the average deceleration between S_1 and S_2 does not exceed the specified values.

D = Constant rate of deceleration between S_1 and S_2 speeds.

RD = Roll distance in feet.

L_1 = Initial tire load.

L_2 = Maximum rated static load of the tire.

T_1 = Time for applying L_1 load. A T_1 tolerance of ±1 second is acceptable.

$$T_2 = \frac{S_1 - \sqrt{S_1^2 - 2D\ (RD)}}{D}$$

T_2 is the elapsed time for applying the L_2 load. A T_2 tolerance of +10% is acceptable. When T_2 is calculated by the aforementioned formula, S_2 may be ignored and D is assumed constant throughout roll distance (RD).

4. Test load adjustment. If the test load curve results in loads at a given speed being less than those dictated by the applicable aircraft data, eliminate the condition by making adjustments in T_2, L_1, and/or T_1

(b) Test B, Energy.

1. Kinetic energy. Calculate and adjust the kinetic energy of the flywheel for the rated maximum static load of the tire. In the event that the correct number of flywheel plates cannot be used to obtain the calculated kinetic energy value or proper flywheel width, select a greater number of plates and adjust the dynamometer speed to achieve the required kinetic energy.

2. Kinetic energy computation. Compute kinetic energy as follows:

$$KE = CWV^2$$

Where

KE = Kinetic energy, ft.-lb.

C = 0.011

W = tire load, pounds

V = 120 m.p.h.

3. Speed cycle. Land the test tire at 90 m.p.h. and unland at 0 m.p.h. Decrease the landing speed as necessary to assure that 56% of the calculated kinetic energy is absorbed by the tire.

4. Load cycle. Upon landing, and during the entire roll test, force the tire against the flywheel at its rated static load.

(c) Taxi Test.

1. Test parameters. Conduct a minimum of three dynamometer taxi tests under the following conditions:

Speed = 35 m.p.h.

Tire Load = Maximum static rating

Roll Distance = 35,000 feet.

2. Tire temperature. Heat the test tire to a temperature of not less than 120° F. at the start of each of the three taxi test cycles. Rolling the tire on the dynamometer is acceptable in obtaining this minimum tire temperature. Make no adjustments in the tire inflation pressure to compensate for increases due to temperature rise.

(9) Alternate Dynamometer Tests.

(a) Variable Loading. An alternate dynamometer test which more realistically simulates

actual airplane performance on the runway may be used in lieu of the deceleration load-speed-time schedule. An acceleration load-speed-time schedule, wherein the dynamometer flywheel is accelerated to the applicable conditions, is acceptable.

(b) Alternate Procedure for Reinforced-tread Tires. Qualification of a high-speed tire with a given ply rating and reinforced tread will automatically qualify a lesser ply rating reinforced tread tire of the same size and skid depth, provided:

1. The test conditions S_1, RD, S_2, T_1, and T_2 are no less severe than those which are applicable to the lesser ply rating tire.

2. The ratio of the test loads, L_1 to L_2 is not less than that applicable to the lesser ply rating tire. Make any necessary adjustment in this ratio by increasing L_1.

(10) Optional Dynamometer Equipment. Dynamic tests may be conducted on any dynamometer test equipment which will provide the load, speed, time, and roll distance parameters of the tire.

c. Tubes. Punctured tubes may be repaired by the use of cemented or vulcanized patches.

(1) The procedure for making such repairs is substantially identical to that used in connection with repair of automobile tires:

(a) Keep the size of the patch to a minimum and avoid use of an excessive number of patches, particularly in one area, as the weight of the material may contribute to excessive wheel vibration due to the tube being out-of-balance.

(b) The use of vulcanized patches is recommended because they are considered more reliable.

(c) Reinstalled tires should be inflated, deflated, and again inflated to insure that the inner-tube is not pinched. A pinched tube will chafe against the walls of the carcass and a thin spot will result in the rubber. In time, the tube wall will leak at this point. The pinching generally is due to the sticking of the tube to the carcass wall during the first inflation and the failure of the carcass to properly seat against the flange.

(d) The tube is then confined to a smaller space and wrinkling (pinching) of the tube results. Complete deflation followed by inflation allows the tube to properly accommodate itself to the carcass which should now seat itself tightly against the flanges.

* **333. TIRE SLIPPAGE.** To reduce the possibility of tire and tube failure due to slippage, and to provide a means of detecting tire slippage, tires should be marked and indexed with the wheel rim. Marking should be accomplished by painting a mark 1 inch in width and 2 inches in length across the tire sidewall and wheel rim. The paint used should be of a permanent type and contrasting color, such as white, red, or orange. Preflight inspection should include a check of slippage marks for alignment. If the slippage mark is not in alignment, the aircraft should not be operated until a detailed inspection is made, the reason determined, and if necessary the condition corrected.

334. TIRE MAINTENANCE. A program of tire maintenance can minimize tire failures and increase tire service life. Overinflation wears the center of the tread excessively, and reduces a tire's resistance to bruising, strains the tires beads, reduces traction and skid resistance. Underinflation increases deflection and may cause breakdown of the tire sidewalls. The manufacturer's recommendations should be followed to obtain maximum tire service life.

345.–349. RESERVED. *

Section 2. LIFE PRESERVERS AND LIFERAFTS

344. GENERAL. Inflatable life preservers and liferafts are subject to general deterioration due to aging. Experience has indicated that such equipment may be in need of replacement at the end of 5 years due to porosity of the rubber-coated material. Wear of such equipment is accelerated when stowed on board aircraft because of vibration which causes chaffing of the rubberized fabric. This ultimately results in localized leakage. Leakage is also likely to occur where the fabric is folded because sharp corners are formed. When these corners are in contact with the carrying cases, or with adjacent parts of the rubberized fabric, they tend to wear through due to vibration.

345. INSPECTION PROCEDURE FOR LIFE PRESERVERS. Life preservers should be inspected at 8-month intervals for cuts, tears, or other damage to the rubberized material. Check the mouth valves and tubing for leakage, corrosion, and deterioration. Remove the carbon dioxide cylinder and check the discharge mechanism by operating the lever to ascertain that the pin operates freely. Check the gaskets and valve cores of the cylinder container and the pull cord for deterioration. If no defects are found, inflate the preserver with air to a 2-pound pressure and allow to stand for 12 hours. If the preserver still has adequate rigidity at the end of that time, deflate and fit with CO_2 cylinders having weights not less than that indicated on them by the manufacturer. All cylinders made in accordance with joint Army/Navy Specification MIL-C-00601D are so stamped and have a minimum permissible weight stamped on them. The use of such CO_2 cylinders is recommended. These cylinders have the 5/32-inch end disc sealed by an electric welding process, which is intended to provide a superior seal compared to the older type, which have a similar disc surrounded by a thin rubber seal. Inasmuch as the rubber is subject to deterioration, its ability to maintain pressure will possibly be affected. Leaky electrically welded seals will probably be discovered upon final inspection at the manufacturer's plant. If such a cylinder is up to weight at the end of 3 months in all probability it will remain so until used; whereas, the old type with the rubber seal is apt to lose its pressure with age. Having fitted the preserver with an adequately charged cylinder, mark the preserver to indicate the date of inspection and pack into its container. It is recommended that the aforementioned procedure be repeated every 12-month period, utilizing the CO_2 cartridge for inflation. Carbon dioxide permeates the rubberized fabric at a faster rate than air and will indicate if the porosity of the material is excessive.

346. REPAIR OF LIFE PRESERVERS. Leaks may be disclosed by immersion in soapy water. Repair leaks by the use of patches in accordance with the recommendations of the manufacturer. Clean corroded metal parts and replace missing or weakened lanyards. Life preserves which do not retain sufficient rigidity after the 12-hour period, because of general deterioration and porosity of the fabric, are beyond economical repair and should be replaced.

347. INSPECTION PROCEDURE FOR LIFERAFTS. Liferafts should be inspected at 3-month intervals for cuts, tears, or other damage to the rubberized material. If the raft is found to be in good condition, remove the CO_2 bottle(s) and inflate the raft with air to a pressure of 2 pounds. The air should be introduced at the fitting normally connected to the CO_2 bottle(s). After at least 1 hour to allow for the air within the raft to adjust itself to the ambient temperature, check pressure and adjust, if necessary, to 2 pounds and allow the raft to stand for 24 hours. If, after 24 hours, the pressure is less than 1 pound, examine the raft for leakage by using soapy water. In order to eliminate pressure variations due to temperature differences at the time the initial and final reading are taken, test the raft in a room where the temperature is fairly constant. If the pressure drop is satisfactory, the raft should be considered as being in an airworthy condition and returned to service after being fitted with correctly charged CO_2 bottles as determined by weighing them. Rafts more than 5 years old are likely to be unairworthy due to deterioration. It is suggested that the rafts be marked to indicate the date of inspection and that soapstone be used when folding them preparatory to insertion into the carrying case. Take care to see that all of the raft's required equipment is on board and properly stowed. If the raft lanyard, used to prevent the raft from floating away from the airplane, is in need of replacement, use a lanyard not less than 20 feet long and having a breaking strength of about 75 pounds. It is recommended that the aforementioned procedure be repeated every 18-month period utilizing the CO_2 bottle(s) for inflation. If a single bottle is used for inflating both compartments, it should be noted whether the inflation is proceeding equally to both compartments. Occasionally the formation of "carbon-dioxide snow" may occur in one passage of the distribution manifold and divert a larger volume of gas to one compartment, which may burst if the mattress valve is not open to relieve the pressure. If the pressure is satisfactory, return the raft to service in accordance with the procedure outlined.

348. REPAIR OF LIFERAFTS. When leaks due to tears, abrasion, or punctures are found, make repairs in accordance with the recommendations of the manufacturer. Recement partially torn away supporting patches on the tube to restore the raft to its airworthy condition. Replace mildewed or weak lanyards, particularly those by which the CO_2 bottle is operated. This applies also to the line used to attach the raft to the airplane. Check all metal parts for corrosion, and clean or repair if found to be defective. If leaky mattress valves have been found, they must be replaced.

349.-359. RESERVED.

Section 3. MISCELLANEOUS EQUIPMENT

360. PARACHUTES. With reasonable care, parachutes normally last at least 5 years. They should not be carelessly tossed about, left in airplanes so that they may become wet, or left in open places where they may be tampered with. They should not be placed where they may fall on oily floors or be subject to acid fumes from adjacent battery chargers. When repacking is scheduled, a careful inspection of the parachute should be made by a qualified parachute technician (rigger). If repairs or replacements of parts are necessary to maintain the airworthiness of the parachute assembly, such work must be done by the original parachute manufacturer or by a qualified parachute rigger, certificated in accordance with Part 65 of the Federal Aviation Regulations, or by an appropriately rated parachute loft certificated in accordance with Part 149 of the FAR.

361. SAFETY BELTS. The Civil Air Regulations require that when safety belts are to be replaced in aircraft manufactured after July 1, 1951, such belts must conform to standards established by the Federal Aviation Administration. These standards are contained in Technical Standard Order TSO-C22. Safety belts eligible for installation in aircraft may be identified by the marking TSO-C22 on the belt or by a military designation number since military belts comply with the strength requirements of the TSO. Airworthy type-certificated safety belts currently in aircraft may be removed for cleaning and reinstalled. However, when a type-certificated safety belt is found unairworthy, replacement with a TSO-C22 or a new military belt is preferred.

a. *The webbing of safety belts,* even when mildew-proofed, is subject to deterioration due to constant use, cleaning, and the effects of aging. The clamping action of the serrations of the commonly used buckle also causes a reduction in strength of the webbing and fraying occurs after long periods of usage. Fraying of belts is an indication of wear, and such belts are likely to be unairworthy because they can no longer hold the minimum required tensile load. Difference of opinion as to the airworthiness of a belt can be settled by testing a questionable belt to demonstrate that it will support the required load. Airworthy one-person type-certificated belts should be able to withstand a tensile load of 525 pounds, and TSO belts withstand the rated tensile load indicated on the belt label. Most one-person TSO belts are rated for 1,500 pounds. For two-person belts, double the loads. Since type-certificated belts will not afford the crash protection provided by a TSO or military belt, such type-certificated belts are not to be repaired nor should their buckles or end fittings be reused on safety belts. If replacement of webbing or hardware of TSO or military belt is attempted, use parts of identical design and material. Make the stitch pattern identical to the original and the number of stitches per inch equal to the number used in the original belt. There is no objection to having a greater total length of stitching, provided one line of stitches is not placed over another line. Space lines of stitching at least 3/16-inch apart. Keep a record, preferably in the logbook, stating the extent to which the belt was repaired and the date. Retain the original identification marking on the belt, conforming either to that required by TSO-C22 to a deviation from this marking, or to the military designation. Operators of a fleet of airplanes should follow the above suggestions, but keeping a record of renovations in a logbook is impractical, since the belts are never associated with any one particular aircraft for any length of time. Therefore, in addition to retaining the original identification label and attaching it to the renovated belt, use some additional simple marking to indicate that the belt has been renovated and show the date of renovation. The use of letter "R" followed by the date would be acceptable. This marking could be in the form of an indelible ink stamping or cloth label stitched to the webbing.

362. FLARES. Parachute flares are made of materials which are subject to decomposition upon aging. Humidity affects the small igniting charge and also the materials of the candle (illuminant). Hence, the percentage of misfires in old flares is likely to be quite high. To assure unfailing performance of flares, periodically inspect the flare installation. Inspect the entire system, starting at the release mechanism in the cockpit and ending at the flare. Only a qualified person should attempt such inspection, since inadvertent discharge of such pyrotechnics may cause serious damage. Past experience has indicated that it is advisable to return all electrically or pistol-operated flares to the manufacturer for reconditioning within a maximum period of 3 years, and that for mechanically operated flares, a maximum period of 4 years is recommended.

363. OXYGEN SYSTEMS.

a. *General.* The following instructions are to serve as a guide for the inspection and maintenance of aircraft oxygen systems. The information is applicable to both portable and permanently installed equipment.

(1) Aircraft Gaseous Oxygen Systems. The oxygen in gaseous systems is supplied from one or more high- or low-pressure oxygen cylinders. Since the oxygen is compressed within the cylinder, the amount of pressure indicated on the system gauge bears a direct relationship to the amount of oxygen contained in the cylinder. The pressure-indicating line connection is normally located between the cylinder and a pressure-reducing valve.

NOTE: Some of the gaseous oxygen systems do not use pressure-reducing valves. The high pressure is reduced to a useable pressure by a regulator. This regulator is located between the high- and low-pressure system.

(2) Aircraft Liquid Oxygen Systems. Thus far it has not been a practice to use liquid oxygen in civil aircraft due to its complexity. This however, may change at any time as technological advances are made.

(3) Portable Oxygen Systems. The three basic types of portable oxygen systems are: demand, pressure demand, and continuous flow. The component parts of these systems are identical to those of a permanent installation with the exception that some parts are miniaturized as necessary. This is done in order that they may be contained in a case or strapped around a person's shoulder. It is for this portability reason that it is essential special attention be given to assuring that any storage or security provision for portable oxygen equipment in the aircraft is adequate, in good condition, and accessible to the user.

NOTE: Check portable equipment including its security provisions frequently, as it is more susceptible to personnel abuse than a permanently installed system.

b. *Inspection.* Hands, clothing, and tools must be free of oil, grease, and dirt when working with oxygen equipment. Traces of these organic materials near compressed oxygen may result in spontaneous combustion, explosions, and/or fire.

(1) Oxygen Tanks and Cylinders. Inspect the entire exterior surface of the cylinder for indication of abuse, dents, bulges, and strap chafing.

(a) Examine the neck of cylinder for cracks, distortion, or damaged threads.

(b) Check the cylinder to determine if the markings are legible.

(c) Check date of last hydrostatic test. If the periodic retest date is past, do not return the cylinder to service until the test has been accomplished.

NOTE: This test period is established by the Department of Transportation in the Code of Federal Regulations, Title 49, Chapter I, Paragraph 173.34.

(d) Inspect the cylinder mounting bracket, bracket hold-down bolts and cylinder holding straps for cracks and deformation, cleanliness, and security of attachment.

(e) In the immediate area where the cylinder is stored or secured, check for evi-

dence of any types of interference, chafing, deformation, or deterioration.

(2) Lines and Fittings.

(a) Inspect oxygen lines for chafing, corrosion, flat spots and irregularities, i.e., sharp bends, kinks, and inadequate security.

(b) Check fittings for corrosion around the threaded area where lines are joined together. Pressurize the system and check for leaks. (Ref. c(2) (b) 4.)

CAUTION

In pressurizing the system, actuate the valve slowly to avoid surging which could rupture the line.

(3) Regulators, Valves, and Gauges.

(a) Examine all parts for cracks, nicks, damaged threads or other apparent damage.

(b) Actuate regulator controls and valve to check for ease of operation.

(c) Determine if the gauge is functioning properly by observing the pressure build-up and the return to zero when the system oxygen is bled off.

(4) Masks and Hoses.

(a) Check the oxygen mask for fabric cracks and rough face seals. If the mask is a fullface model, inspect glass or plastic for cleanness and state of repair.

(b) When appropriate, with due regard to hygienic considerations, the sealing qualities of an oxygen mask may be tested by placing thumb over connection at end of mask tube and inhaling very lightly. Remove thumb from disconnect after each continuous inhalation. If there is no leakage, mask will adhere tightly to face during inhalation and definite resistance to inhalation will be noticeable.

(c) Flex the mask hose gently over its entirety and check for evidence of deterioration or dirt.

(d) Examine the mask and hose storage compartment of cleanliness and general condition.

(e) If the mask and hose storage compartment is provided with a cover or release mechanism, check its operation.

c. Maintenance.

(1) Oxygen Tanks, Cylinders, and Hold Down Brackets.

(a) Remove from service any cylinders that show signs of abuse, dents, bulges, cracks, distortion, damaged threads, or defects which might render the cylinder unsafe. Typical examples of oxygen cylinder damage are shown in figure 8.7.

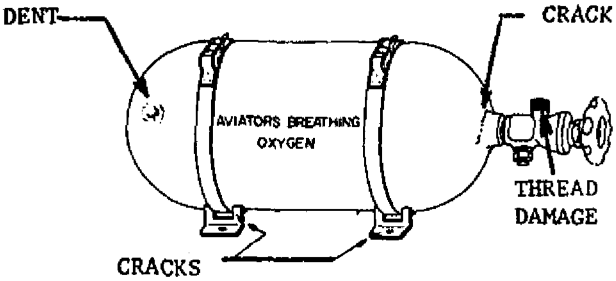


FIGURE 8.7.—Oxygen cylinder damage.

(b) When replacing an oxygen cylinder, be certain that the replacement cylinder is of the same size and weight as the one removed.

NOTE: Cylinders having greater weight or size will require strengthened cylinder mounting brackets, and a reevaluation to determine that the larger or heavier cylinder will not interfere with adjacent systems, components, or structural members, and that the strength of attaching structure is adequate.

(c) Replace or repair any cylinder mounting brackets that show sign of wear. Visible cracks may be welded in accordance with Chapter 2, Section 2 of this Advisory Circular. Replace cylinder straps or clamps that show wear or abuse. For typical mounting bracket crack and failure, see figure 8.8.

(2) Lines and Fittings.

(a) Replace any oxygen line that is chafed, rusted, corroded, dented, cracked, or kinked.

(b) Clean oxygen system fittings showing signs of rusting or corrosion in the threaded area. To accomplish this, use a cleaner recommended by manufacturers of oxygen equipment. Replace lines and fittings that cannot be cleaned.

1. The high-pressure lines which are located between the oxygen bottle, outside oxygen service filler, and the regulator are normally fabricated from stainless steel or thick-wall, seamless copper alloy tubing. The fittings on high-pressure lines are normally silver soldered.

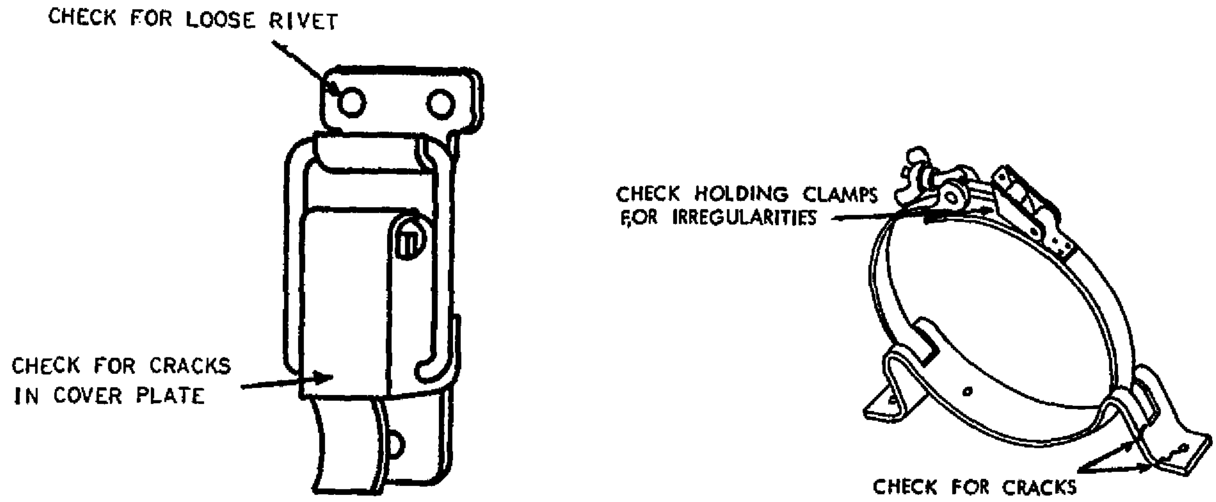


FIGURE 8.8.—Cylinder brackets and clamps.

NOTE: Use silver alloys free of cadmium when silver soldering. The use of silver solder which contains cadmium will emit a poisonous gas when heated to a molten state. This gas is extremely hazardous to health if inhaled.

2. The low-pressure lines extend from the pressure regulator to each passenger and crew oxygen outlet. These lines are fabricated from seamless aluminum alloy, copper, or flexible hose. Normally, flare- or flange-type connections are used. (Ref. Chapter 10, Section 1, para. 398b of this Advisory Circular.)

CAUTION

Do not allow oil, grease, flammable solvent, or other combustibles such as lint or dust to come in contact with threads or any parts that will be exposed to pressurized oxygen.

3. It is advisable to purge the oxygen system any time work has been accomplished on any of the lines and fittings. Use dry nitrogen or dry air for purging the system. All open lines should be capped immediately after purging.

4. When oxygen is being lost from a system through leakage, a sequence of steps may be necessary to locate the opening. Leakage may often be detected by listening for the distinct hissing sound of escaping gas. If this check proves negative, it will be necessary to soap-test all lines and connections with a castile soap and water solution or specially compounded leak-test material. Make the solution thick enough to adhere to the contours of the fittings. At the completion of the leakage test, remove all traces of the soap and water.

CAUTION

Do not attempt to tighten any connections while the system is charged.

(3) *Regulators, Valves, and Gauges.* Line maintenance of oxygen regulators, valves, and gauges does not include major repair. These components are precision made and their repair usually requires the attention of a repair station or the manufacturer. Care must be taken when reinstalling these components to ascertain if the threaded area is free of nicks, burrs, and contaminants that would prevent the connections from sealing properly.

CAUTION

Do not use petroleum lubricants on these components.

(4) *Masks and Hoses.*

(a) Troubleshooting. If a mask assembly is defective (leaks, does not allow breathing, or contains a defective microphone), it is advisable to return the mask assembly to the manufacturer or a repair station.

(b) Maintenance Practice and Cleaning.

1. Clean and disinfect mask assemblies after use, as appropriate.

NOTE: Use care to avoid damaging microphone assembly while cleaning and sterilizing.

2. Wash mask with a mild soap solution and rinse it with clear water.

3. To sterilize, swab the mask thoroughly with a gauze or sponge soaked in a water merthiolate solution. This solution should contain 1/5 teaspoon of merthiolate per 1 quart of water. Wipe the mask with a clean cloth and air dry.

4. Replace the hose if it shows evidence of deterioration.

5. Hoses may be cleaned in the same manner as the mask.

6. Observe that each mask breathing tube end is free of nicks, and that the tube end will slip into the cabin oxygen receptacle with ease and not leak.

d. Functional Testing After Repair. Following repair, and before inspection plates, cover plates, or upholstering are replaced, test the entire system.

(1) Open cylinder valve slowly and observe the pressure gauge on a high-pressure system. A pressure of approximately 1,800 p.s.i. (at 70° F.) should be indicated on the gauge. (Cylinder pressure will vary considerably with radical temperature changes.)

(a) Check system by installing one of the mask hose fittings (minus the mask) in each of the cabin wall outlets to determine whether there is a flow. If a demand mask is used, check by breathing through the mask (if appropriate, clean mask according to Par. c(4)(b)) to see whether there is a flow of oxygen.

(b) Check the complete system for leaks in accordance with the procedure outlined in c(2) (b) 4.

(c) If leaks are found, close the cylinder valve; open an outlet to reduce the pressure in the system to zero.

(2) A pressure drop check of the system may be made as follows:

(a) Open the cylinder valve and pressurize the system. Observe the pressure gauge (a pressure of approximately 1,800 p.s.i. at 70° F. should be indicated). For the light weight ICC 3HT 1850 cylinders, pressurize the system to approximately 1,850 p.s.i. at 70° F.

(b) Close the cylinder valve and wait approximately 5 minutes for temperatures to stabilize.

(c) Record the pressure gauge reading and temperature and after 1 hour, record the pressure gauge reading and temperature again.

(d) A maximum pressure drop of 100 p.s.i. is permissible.

NOTE: Conduct the above tests in an area where changes of temperature will be less than 10° F. In the event that a change in temperature greater than approximately 10° F. occurs during the 1-hour period, suitable corrections would be required, or reconduct the test under conditions of unvarying temperatures.

e. Service Requirements—Oxygen Cylinders. Standard weight cylinders must be hydrostatic tested at the end of each 5-year period. This is a Department of Transportation requirement. These cylinders carry an ICC or DOT 3AA 1800 classification and are suitable for the use intended. The lightweight cylinders must be hydrostatic tested every 3 years, and must be retired from service after 15 years or 4,380 pressurizations, whichever occurs first. These cylinders carry an ICC or DOT 3HT 1850 classification.

CAUTION

Use only aviation breathing oxygen when having the oxygen bottle charged. MIL-O-27210C specifies that the moisture content of aviation breathing oxygen must not exceed 0.005 milligrams of water vapor per liter of gas at a temperature of 70° F. and a pressure of 760 millimeters of mercury.

(1) Charging High-pressure Oxygen Cylinders. The following are recommended procedures for charging high-pressure oxygen cylinders from a manifold system, either permanently installed or trailer mounted. *Never attempt to charge a low-pressure cylinder directly from a high-pressure manifold system or cylinder.*

(a) *Inspection.* Do not attempt to charge oxygen cylinders if any of the following discrepancies exist:

1. Contaminated fittings on the manifold, cylinder, or outside filler valve. If in doubt, wipe with stabilized trichloroethylene; however, *do not permit solvent to enter any internal parts.* Let air dry.

2. Cylinder out of hydrostatic test date. DOT regulations require ICC or DOT 3AA designation cylinders to be hydrostatic tested to 5/3 their working pressure, every 5 years. Cylinders bearing designation ICC or

DOT 3HT must be hydrostatic tested to 5/3 their working pressure every 3 years, and retired from service 15 years or 4,380 filling cycles after date of manufacture, whichever occurs first.

3. Cylinder is completely empty. Do not charge, as the cylinder must be removed, inspected, and cleaned.

(b) Charging.

1. Connect cylinder valve outlet or outside filler valve to manifold.

2. Slowly open valve of cylinder to be charged and observe pressure on gauge of manifold system.

3. Slowly open valve of cylinder on manifold system having the lowest pressure and allow pressure to equalize.

4. Close cylinder valve on manifold system and slowly open valve of cylinder having next highest pressure. Continue this procedure until the cylinder has been charged in accordance with e(1) (d), Table of Filling Pressures.

(c) Top-off.

After the cylinder has been filled in accordance with the filling table (shown under e(1) (d)):

1. Close all valves on manifold system.

2. Close valve on filled cylinder and remove the cylinder from the manifold.

3. Using leak detector, test for leakage around cylinder valve threaded connections. (If leakage is present, discharge oxygen and return cylinder to facility for repair.)

4. Let cylinder stabilize for period of at least 1 hour, and then recheck pressure.

5. Make any necessary adjustments in pressure.

(d) Table of Filling Pressures.

Initial Temp (°F.)	*Filling Pressure (p.s.i.)*
0	1,650
10	1,700
20	1,725
30	1,775
40	1,825
50	1,875
60	1,925
70	1,975
80	2,000
90	2,050
100	2,100
110	2,150
120	2,200
130	2,250

Initial Temperature—Refers to ambient temperature in filling room.

Filling Pressure—Refers to the pressure to which aircraft cylinders should be filled. This table gives approximations only, and assumes a rise in temperature of approximately 25° F. due to heat of compression. This table also assumes the aircraft cylinders will be filled as quickly as possible and that they will only be cooled by ambient air; no water bath or other means of cooling being used.

Example: If ambient temperature is 70° F., fill aircraft cylinders to approximately 1,975 p.s.i.—as close to this pressure as the gauge may be read. Upon cooling, cylinders should have approximately 1,850 p.s.i. pressure.

(2) Charging of Low-Pressure Oxygen Systems and Portables. For recharging a low-pressure aircraft oxygen system, or portable cylinders, it is essential that the oxygen trailer or cart have a pressure-reducing regulator. Military types E–2 or C–1 reducing regulators are satisfactory. These types of regulators reduce the large cylinder pressure from 2,000 p.s.i. to a line pressure of 450 p.s.i.g. (A welding pressure reducing regulator is not satisfactory.)

CAUTION

When refilling the low-pressure system or portable cylinders, open the oxygen filler tank valve slowly to allow the system or portable cylinders to be filled at a slow rate. After the refilling operation is completed, check for leaks with a leak detector. If a leak is detected, paragraph c(2)(b) 4 should be referred to for corrective action.

364.–374. RESERVED.

Chapter 9. WINDSHIELDS, ENCLOSURES, AND EXITS

Section 1. PLASTIC WINDSHIELDS AND ENCLOSURES

375. GENERAL. These repairs are applicable to plastic windshields, enclosures, and windows *in nonpressurized airplanes.* For pressurized airplanes replace or repair plastic elements in accordance with the manufacturer's recommendation.

a. *Types of Plastics.* Two types of plastics are commonly used in transparent enclosures of aircraft. These materials are known as acrylic plastics and polyester plastics.

376. REPLACEMENT PANELS. Use material equivalent to that originally used by the manufacturer of the aircraft for replacement panels. There are many types of transparent plastics on the market. Their properties vary greatly, particularly in regard to expansion characteristics, brittleness under low temperatures, resistance to discoloration when exposed to sunlight, surface checking, etc. Information on these properties is in MIL-HDBK-17, *Plastics for Flight Vehicles, Part II—Transparent Glazing Materials,* available from the Government Printing Office. These properties have been considered by aircraft manufacturers in selecting materials to be used in their designs and the use of substitutes having different characteristics may result in subsequent difficulties.

377. INSTALLATION PROCEDURES. When installing a replacement panel, use the same mounting method employed by the manufacturer of the airplane. While the actual installation will vary from one type of aircraft to another, consider the following major principles when installing any replacement panel:

a. ***Never force a plastic panel*** out of shape to make it fit a frame. If a replacement panel does not fit easily into the mounting, obtain a new replacement or heat the whole panel and reform. When possible, cut and fit a new panel at ordinary room temperature.

b. ***In clamping or bolting plastic panels*** into their mountings, do not place the plastic under excessive compressive stress. It is easy to develop more than 1,000 pounds per square inch on the plastic by overtorquing a nut and bolt. Tighten each nut to a firm fit, then back off one full turn.

c. ***In bolt installations,*** use spacers, collars, shoulders, or stopnuts to prevent tightening the bolt excessively. Whenever such devices are used by the airplane manufacturer, retain them in the replacement installation. It is important that the original number of bolts, complete with washers, spacers, etc., be used. When rivets are used, provide adequate spacers or other satisfactory means to prevent excessive tightening of the frame to the plastic.

d. ***Mount plastic panels*** between rubbed, cork, or other gasket material to make the installation waterproof, to reduce vibration, and to help to distribute compressive stresses on the plastic.

e. ***Plastics expand and contract*** considerably more than the metal channels in which they are mounted. Mount windshield panels to a sufficient depth in the channel to prevent it from falling out when the panel contracts at low temperatures or deforms under load. When the manufacturer's original design permits, mount panels to a minimum depth of 1 1/8 inch and with a clearance of 1/8 inch between the plastic and the bottom of the channel.

f. ***In installations involving bolts or rivets,*** make the holes through the plastic oversize 1/8 inch diameter and center so that the plastic will not

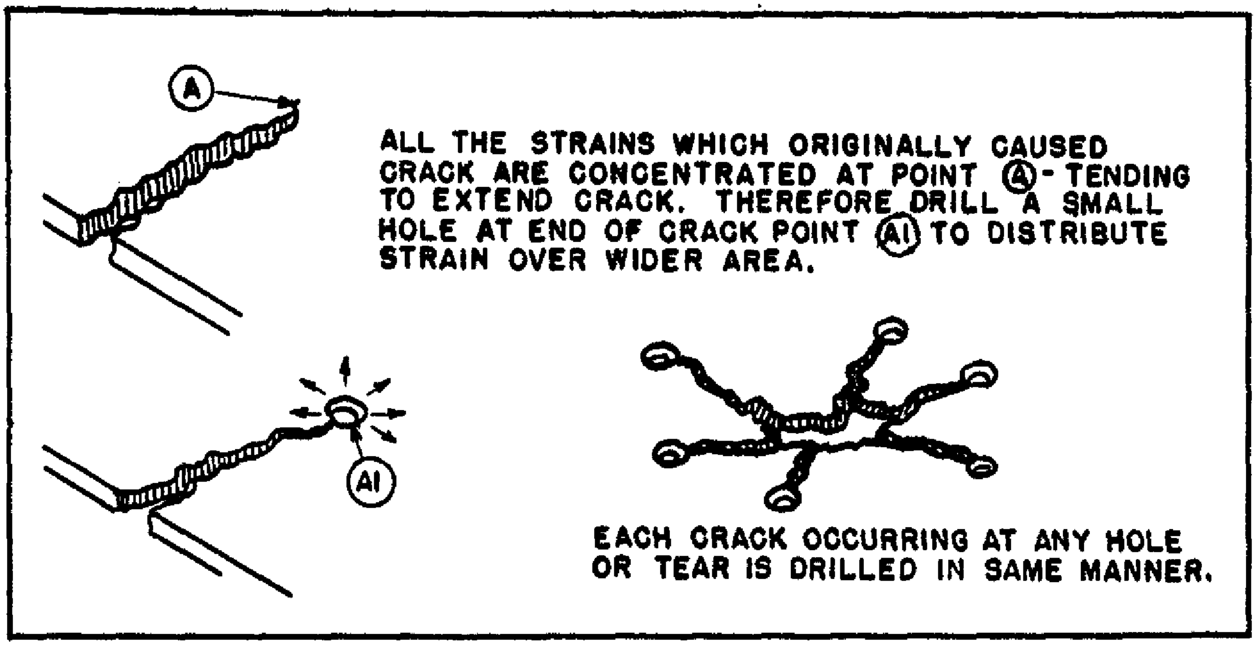


FIGURE 9.1.—Stop-drilling cracks.

bind or crack at the edge of the holes. The use of slotted holes is also recommended.

378. REPAIR OF PLASTICS. Replace extensively damaged transparent plastic rather than repair whenever possible since even a carefully patched part is not the equal of a new section either optically or structurally. At the first sign of crack development, drill a small hole at the extreme ends of the cracks as shown in figure 9.1. This serves to localize the cracks and to prevent further splitting by distributing the strain over a large area. If the cracks are small, stopping them with drilled holes will usually suffice until replacement or more permanent repair can be made. The following repairs are permissible; however, they are not to be located in the pilot's line of vision during landing or normal flight.

a. Surface Patch. If a surface patch is to be installed, trim away the damaged area and round all corners. Cut a piece of plastic of sufficient size to cover the damaged area and extend at least 3/4 inch on each side of the crack or hole. Bevel the edges as shown in figure 9.2. If the section to be repaired is curved, shape the patch to the same contour by heating it in an oil bath at a temperature of 248° to 302° F., or it may be heated on a hotplate until soft.

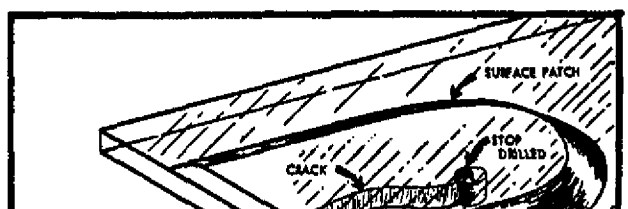


FIGURE 9.2.—Surface patches.

Boiling water should not be used for heating. Coat the patch evenly with plastic solvent adhesive and place immediately over the hole. Maintain a uniform pressure of from 5 to 10 pounds per square inch on the patch for a minimum of 3 hours. Allow the patch to dry 24 to 36 hours before sanding or polishing is attempted.

b. ***Plug Patch.*** In using inserted patches to repair holes in plastic structures, trim the holes to a perfect circle or oval and bevel the edges slightly. Make the patch slightly thicker than the material being repaired and similarly bevel the edges. Install patches in accordance with figure 9.3. Heat the plug until soft and press into the hole without cement and allow to cool to make a perfect fit. Remove the plug, coat the edges with adhesive, and then reinsert in the hole. Maintain a firm light pressure until the cement has set, then sand or file the edges level with the surface; buff and polish.

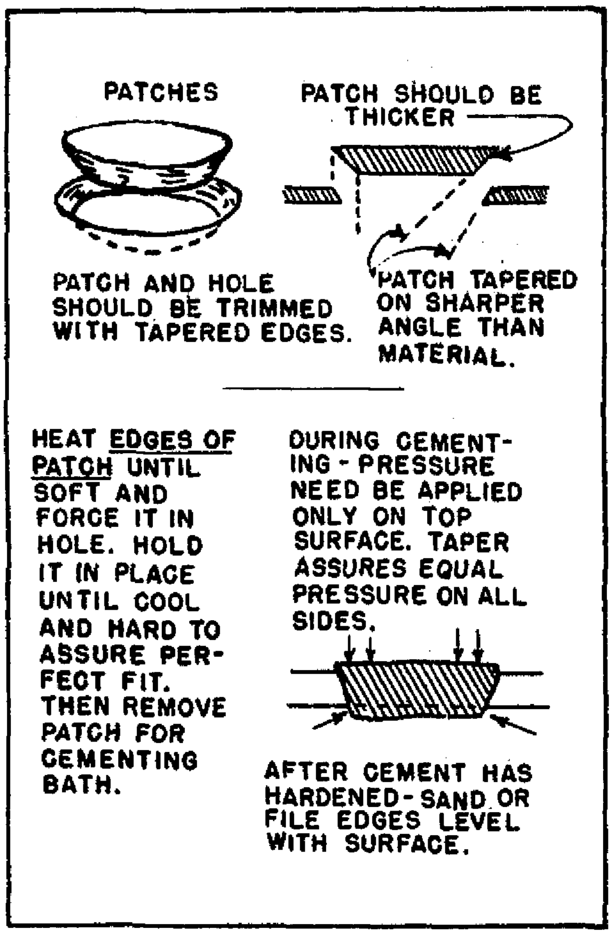


FIGURE 9.3.—Plug patch repair.

379. CLEANING AND POLISHING TRANSPARENT PLASTIC. Plastics have many advantages over glass for aircraft use, but they lack the surface hardness of glass, and care must be exercised while servicing the aircraft to avoid scratching or otherwise damaging the surface.

a. ***Cleaning.*** Clean the plastic by washing with plenty of water and mild soap, using a clean, soft, grit-free cloth, sponge, or bare hands. Do not use gasoline, alcohol, benzene, acetone, carbon tetracholoride, fire extinguisher or deicing fluids, lacquer thinners, or window cleaning sprays because they will soften the plastic and cause crazing.

b. ***Plastics should not be rubbed*** with a dry cloth since this is likely to cause scratches, and also build up an electrostatic charge which attracts dust particles to the surface. If after removing dirt and grease no great amount of scratching is visible, finish the plastic with a good grade of commercial wax. Apply the wax in a thin even coat and bring to a high polish by rubbing lightly with a soft cloth.

c. ***Polishing.*** Do not attempt hand polishing or buffing until the surface is clean. A soft, open-type cotton or flannel buffing wheel is suggested. Minor scratches may be removed by vigorously rubbing the affected area by hand, using a soft clean cloth dampened with a mixture of turpentine and chalk, or by applying automobile cleanser with a damp cloth. Remove the cleaner and polish with a soft, dry cloth. Acrylic and cellulose acetate plastics are thermoplastic. Friction created by buffing or polishing too long in one spot can generate sufficient heat to soften the surface. This will produce visual distortion and is to be guarded against.

380. EMERGENCY EXITS. The following material is intended as a guide for the inspection and maintenance of aircraft emergency exit provisions. Schedule inspections to coincide with all 100-hour/annual, progressive inspections or the maintenance procedures that have been approved by the Administrator. Before beginning inspection or maintenance activities of any type, consult the appropriate manufacturer's service manual for information specifying the type of exit release mechanism used.

a. Inspection. Examine the emergency exits and all associated hardware closely for deformation, excessive wear, security of attachment, lubrication, and cleanness.

(1) Doors.

(a) Inspect the door structure and skin for wrinkles, cracks, alignment with the fuselage, deep scratches, dents, loose rivets, corrosion, or any other indication of structural irregularity.

(b) Examine rubber seals for cuts, tears, excessive wear, proper contact with the entire door frame, and general deterioration.

(c) Inspect bearings, hinges, hinge fairings, latches, springs, pins, rods, handles, and related parts for wear and general condition.

(d) Examine the door jamb, frame, and supporting structure for cracks, loose fasteners, condition of stops, and corrosion or damage.

(e) Check the door for ease of operation and freedom of movement through its full range of travel.

(f) If a door warning light is provided, test it for proper operation and adjustment.

(g) Check the door locking mechanism for positive fit and at least the minimum lock pin engagement as specified in the applicable aircraft manual.

(2) Passenger Escape Hatches.

(a) Remove the escape hatch. Check for ease of removal and correct functioning of the release mechanism through all angles of pull likely to be encountered during emergency conditions.

CAUTION

If applicable, position one man outside the aircraft to catch the hatch, thereby preventing it from falling and damaging the wing and/or hatch.

(b) Examine the escape hatch structure for cracks, dents, deep scratches, alignment, loose rivets and/or bolts, corrosion, or any other indication of structural irregularity.

(c) Inspect the rubber seals for excessive wear, deterioration, cuts, tears, and proper contact with the fuselage.

(d) Check the operating mechanisms for wear, cracks, and general condition; springs for proper tension, alignment, and security.

(e) If applicable, inspect external release mechanisms for wear, cracks, and proper operation. Check for presence and legibility of external placards and exit location markings.

(f) Examine the escape hatch opening jamb, frame, stops, and skin for cracks and other evidence of damage or failure.

(g) If an emergency escape rope is provided, check it for accessibility, attachment, freedom of operation, rot, broken strands, and general condition. Inspect the storage container or tube for sharp edges or moisture.

(3) Crew Compartment Sliding Windows.

(a) Inspect the window frame for cracks, dents, questionable scratches, loose rivets, corrosion, or any other indication of structural irregularity.

(b) Examine the extrusion seal for wear, general deterioration, and proper contact with the fuselage canopy.

(c) Check the window teleflex mechanism for loose bearings, wear, corrosion, and proper operation.

(d) Inspect the windows for cracks, scratches, nicks, crazing, fogging or moisture between panes, delaminations, hot spots or discoloration.

NOTE: Fogging or delaminations of windows other than windshields are generally not cause for replacement unless visibility is impaired. It is suggested the manufacturer be consulted on any question concerning windows installed in pressurized aircraft.

b. *Maintenance.*

(1) Lubrication. Lubricate all moving parts of the exit latching mechanisms. The following practices will generally apply when specific procedures are not available.

(a) Piano hinges and operating mechanism pivot points—oil lightly and wipe off excess. Use only oil that is compatible with the type of seal used on that specific aircraft. Do not allow the oil to contact fabrics or finished surfaces.

(b) Latch bolts and sliding surfaces—

apply a light film from a graphite stick or latch lubricant (door ease).

(2) Seal Replacement. Information pertaining to special handling procedures for seals, gaskets, lubricants (dry or liquid), age limitations (shelf life), and types of adhesives may be found in the manufacturer's maintenance and overhaul manuals. Check the thickness of the seal or gasket for uniformity to prevent warping of the component, i.e., hatch or door. Exercise care when using adhesives to cement seals to the hatch frame or exit door as spillage or excessive amounts could cause the exit to bind.

NOTE: Replace seals and gaskets with materials recommended by the manufacturer. Many times these materials have been changed due to service experience, therefore a check of manufacturers' service information should be made to ascertain that any replacement parts, materials, etc., are those currently recommended.

(3) Hatch/Window Replacement. Check replacement hatches or windows for proper size and fit to preclude opening problems. Improper loading of the aircraft or an accident may cause binding of the hatch/window if inadequate clearance exists.

(4) Emergency Exit Service Difficulties. Emergency exits that fail to open unless extreme force is exerted are usually caused by one of the following:

(a) Paint or primers on the mating surfaces of the exit which are not allowed to dry completely. As a result, the surfaces will stick to each other.

(b) Latches that bind or fail to work unless pulled straight out.

(c) Failure to lubricate mating or rubbing surfaces.

(d) Failure to operate exits after final assembly. The exits may perform satisfactorily before the airplane is painted, but the finishing process results in the application of solvents, cleaners, primers, and paint finishes that may tend to make the exit inoperable. Check the exit for ease of release after painting and finishing of an aircraft.

c. *Operational Considerations.*

(1) *Placards.* Check to assure that all required placards and markings are installed (FAR 23.1557 (d) or 25.811). Make certain that curtains, drapes, clothes racks, etc. do not cover the placard or the exit operating handle.

When the normal exit identification signs are obstructed by compartmentation, galleys or other similar furnishings, use signs which contain the word "EXIT" and appropriate arrows to direct the attention of occupants to the exit locations.

(2) Precautions. Following any cabin interior modifications or configuration changes, check the accessability and operation of emergency exits by actual operation of the exit.

(a) Certain types of escape hatches have release handles which will not reinstall the lock pins into their locked position. If this type of release handle is pulled to any degree, either intentionally or inadvertently, it is necessary to ascertain that the locking pins are in position and safetied.

(b) Safety wire used to secure aircraft egress provisions should be of the type recommended by the manufacturer. Do not use stainless steel or other types of stiff wire. Acceptable substitutes would be either .011" copper or .020" aluminum soft safety wire.

(c) Some aircraft have inflatable door seals which assure a positive sealing capability during pressurization. Check these systems for proper operation in accordance with the manufacturer's maintenance instructions.

(d) Ascertain that seatbacks, tables, cabinets and other furnishings cannot interfere with the accessibility and opening of any exit either from inside or outside of the aircraft.

(3) Power Assist Devices. Some aircraft are presently equipped with powered systems to assist in door opening. It is imperative that the manufacturers' service instructions and manuals be reviewed before any maintenance is performed on such systems. These devices are usually hydraulically powered and, during an emergency condition, utilize a high-pressure bottle system as an alternate source (pneumatic or CO_2). Future designs will quite possibly involve various combinations of hydraulic, electrical, or pneumatic units. Strict attention to all servicing procedures will be essential to assure proper functioning of the power-assist device when needed in an emergency.

381.–391. RESERVED.

Chapter 10. HYDRAULIC AND PNEUMATIC SYSTEMS

Section 1. HYDRAULIC SYSTEMS

392. GENERAL. Maintain, service, and adjust airplane hydraulic systems in accordance with manufacturers' maintenance manuals and pertinent component maintenance manuals. Certain general principles of maintenance and repair which apply are outlined below.

393. HYDRAULIC LINES AND FITTINGS. Carefully inspect all lines and fittings at regular intervals to insure airworthiness. Investigate any evidence of fluid loss or leaks. Check metal lines for leaks, loose anchorages, scratches, kinks, or other damage. Inspect fittings and connections for leakage, looseness, cracks, burrs, or other damage. Replace or repair defective elements.

a. Replacement of Metal Lines. When inspection shows a line to be damaged or defective, replace the entire line or if the damaged section is localized, a repair section may be inserted. In replacing lines, always use tubing of the same size and material as the original line. Use the old tubing as a template in bending the new line, unless it is too greatly damaged, in which case a template can be made from soft iron wire. Soft aluminum tubing (1100, 3003, or 5052) under ¼-inch outside diameter may be bent by hand. For all other tubing use an acceptable hand or power tube bending tool. Bend tubing carefully to avoid excessive flattening, kinking, or wrinkling. Minimum bend radii values are shown in figure 10.1. A small amount of flattening in bends is acceptable but do not exceed an amount such that the small diameter of the flattened portion is less than 75 percent of the original outside diameter. When installing the replacement tubing, line it up correctly with the mating part so that it is not forced into line by means of the coupling nuts.

b. Tube Connections. Many tubing connections are made using flared tube ends, and standard connection fittings: AN-818 nut and AN-819 sleeve.

Tube O.D. (inches)	Wrench torque range for tightening tube nuts (inch pounds)		* Minimum bend radii measured at inside of bend. Dimension in inches. *	
	Alum. alloy 1100-H14, 5052-O	Steel	Alum. alloy 1100-H14, 5052-O	Steel
⅛		30-70	⅜	
3/16	40-65	50-90	7/16	21/32
¼	60-80	70-120	9/16	⅞
5/16	75-125	90-150	¾	1⅛
⅜	150-250	155-250	15/16	1 5/16
½	200-350	300-400	1¼	1¾
⅝	300-500	430-575	1½	2 3/16
¾	500-700	550-750	1¾	2⅝
1	600-900		3	3½
1¼	600-900		3¾	4⅜
1½			5	5¼
1¾			7	6⅛
2			8	7

FIGURE 10.1.—Tube data.

In forming flares, cut the tube ends square, file smooth, remove all burrs and sharp edges, and thoroughly clean. The tubing is then flared using the correct 37° aviation flare forming tool for the size of tubing and type of fitting. A double flare is used on soft aluminum tubing ⅜-inch outside diameter and under, and a single flare on all other tubing. In making the connections, use hydraulic fluid as a lubricant and then tighten. Overtightening will damage the tube or fitting, which may cause a failure; under-tightening may cause leakage which could result in a system failure.

CAUTION

Mistaken use of 45° automotive flare forming tools will result in improper tubing flare shape and angle causing misfit, stress and strain, and probable system failure.

*c. **Repair of Metal Tube Lines.*** Minor dents and scratches in tubing may be repaired. Scratches or nicks no deeper than 10 percent of the wall thickness in aluminum alloy tubing, that are not in the heel of a bend, may be repaired by burnishing with hand tools. Replace lines with severe die marks, seams, or splits in the tube. Any crack or deformity in a flare is also unacceptable and cause for rejection. A dent less than 20 percent of the tube diameter is not objectionable unless it is in the heel of a bend. Dents may be removed by drawing a bullet of proper size through the tube by means of a length of cable. A severely damaged line should be replaced; however, it may be repaired by cutting out the damaged section and inserting a tube section of the same size and material. Flare both ends of the undamaged and replacement tube sections and make the connection by using standard unions, sleeves, and tube nuts. If the damaged portion is short enough, omit the insert tube and repair by using one union and two sets of connection fittings.

*d. **Replacement of Flexible Lines.*** When replacement of a flexible line is necessary, use the same type, size, and length of hose as the line to be replaced. If the replacement of a hose with swaged-end-type fittings is necessary, obtain a new hose assembly of the correct size and composition. Certain synthetic oils require a specially compounded synthetic rubber hose which is compatible. Refer to the aircraft manufacturer's service information for correct part number for replacement hose. If the fittings on each end are of the collet type or sleeve type, a replacement may be fabricated as shown in figure 10.2. Typical aircraft hose specifications and their uses are shown in figure 10.3. Install hose assemblies without twisting. (See figure 10.4.) Never stretch a hose tight between two fittings as this will result in overstressing and eventual failure. The length of hose should be sufficient to provide about 5 percent to 8 percent slack. Avoid tight bends in flex lines as they may result in failure. Never exceed the minimum bend radii as indicated in figure 10.5.

Teflon hose is used in many aircraft systems because of its superior qualities for certain applications. Teflon is compounded from tetrafluoroethylene resin which is unaffected by fluids normally used in aircraft. It has an operating range of −65° F. to 450° F. For these reasons, Teflon is used in hydraulic and engine lubricating systems where temperatures and pressures preclude the use of rubber hose. Although Teflon hose has excellent performance qualities, it also has peculiar characteristics that require extra care in handling. It tends to assume a permanent set when exposed to high pressure or temperature. Do not attempt to straighten a hose that has been in service. Any excessive bending or twisting will cause kinking or weakening of the tubing wall. Replace any hose that shows signs of leakage, abrasion, or kinking. Any hose suspected of kinking may be checked with a steel ball of proper size. Figure 10.6 shows hose and ball sizes. The ball will not pass through if the hose is distorted beyond limits.

If the hose fittings are of the reusable type, a replacement hose may be fabricated as described in figure 10.2. When a hose assembly is removed the ends should be tied as shown in figure 10.7, so that its preformed shape will be maintained. Refer to figure 10.8 for minimum bend radii of Teflon hose.

All flexible hose installations should be supported at least every 24 inches. Closer supports are preferred. They should be carefully routed and securely clamped to avoid abrasion, kinking, or excessive flexing. Excessive flexing may cause weakening of the hose or loosening at the fittings.

*e. **O-Ring Seals.*** A thorough understanding of O-ring seal applications is necessary to determine when replacement must be made. The simplest application is where the O-ring merely serves as a gasket when it is compressed within a recessed area by applying pressure with a packing nut or screw cap. Leakage is not normally acceptable in this type of installation. In other installations the O-ring seals depend primarily upon their resiliency to accomplish their sealing action. When moving parts are involved, minor seepage may be normal and acceptable. A moist surface found on moving parts of hydraulic units is an indication the seal is being properly lubricated. In pneumatic systems, seal lubrication is provided by the installation of a grease-impreg-

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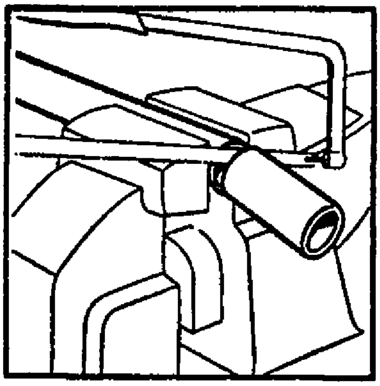
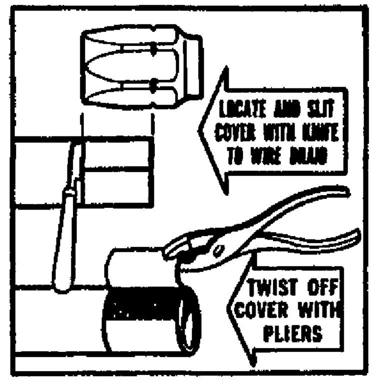
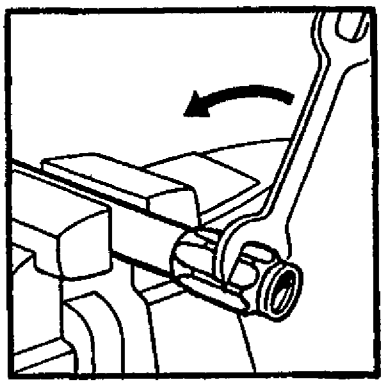


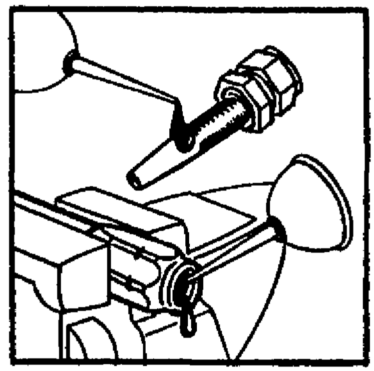
1. Place hose in vise and cut to desired length using fine tooth hacksaw or cut off wheel.



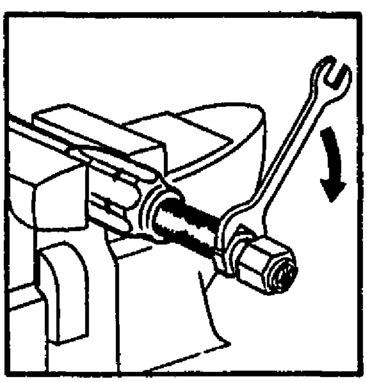
2. Locate length of hose to be cut off and slit cover with knife to wire braid. After slitting cover, twist off with pair of pliers. (see note below)



3. Place hose in vise and screw socket on hose counterclockwise.



4. *Lubricate inside of hose and nipple threads liberally.



5. Screw nipple into socket using wrench on hex of nipple and leave .005 inches to .031 inches clearance between nipple hex and socket.

NOTE:
Hose assemblies fabricated per MIL-H-8790 must have exposed wire braid coated with a special sealant.

NOTE:
Step 2 applies to high pressure hose only.

*CAUTION:
Do not use any petroleum product with hose designed for synthetic fluids "SKYDROL". For a lubricant during assembly use a vegetable soap liquid.

DISASSEMBLE IN REVERSE ORDER

FIGURE 10.2.—Hose assembly instructions.

SINGLE WIRE BRAID FABRIC COVERED

MIL. PART NO.	TUBE SIZE O.D.	HOSE SIZE I.D.	HOSE SIZE O.D.	RECOMM. OPER. PRESS.	MIN. BURST PRESS.	MAX. PROOF PRESS.	MIN. BEND RADIUS
MIL-H-8794- 3-L	3/16	1/8	.45	3,000	12,000	6,000	3.00
MIL-H-8794- 4-L	1/4	3/16	.52	3,000	12,000	6,000	3.00
MIL-H-8794- 5-L	5/16	1/4	.58	3,000	10,000	5,000	3.38
MIL-H-8794- 6-L	3/8	5/16	.67	2,000	9,000	4,500	4.00
MIL-H-8794- 8-L	1/2	13/32	.77	2,000	8,000	4,000	4.63
MIL-H-8794-10-L	5/8	1/2	.92	1,750	7,000	3,500	5.50
MIL-H-8794-12-L	3/4	5/8	1.08	1,500	6,000	3,000	6.50
MIL-H-8794-16-L	1	7/8	1.23	800	3,200	1,600	7.38
MIL-H-8794-20-L	1 1/4	1 1/8	1.50	600	2,500	1,250	9.00
MIL-H-8794-24-L	1 1/2	1 3/8	1.75	500	2,000	1,000	11.00
MIL-H-8794-32-L	2	1 13/16	2.22	350	1,400	700	13.25
MIL-H-8794-40-L	2 1/2	2 3/8	2.88	200	1,000	300	24.00
MIL-H-8794-48-L	3	3	3.56	200	800	300	33.00

Construction: Seamless synthetic rubber inner tube reinforced with one fiber braid, one braid of high tensile steel wire and covered with an oil resistant rubber impregnated fiber braid.

Identification: Hose is identified by specification number, size number, quarter year and year, hose manufacturer's identification.

Uses:
Hose is approved for use in aircraft hydraulic, pneumatic, coolant, fuel and oil systems.

Operating Temperatures:

Sizes -3 thru -12: Minus 65°F. to plus 250°F.

Sizes -16 thru -48: Minus 40°F. to plus 275°F.

NOTE: Maximum temperatures and pressures should not be used simultaneously.

MULTIPLE WIRE BRAID RUBBER COVERED

MIL PART NO.	TUBE SIZE O.D.	HOSE SIZE I.D.	HOSE SIZE O.D.	RECOMM. OPER. PRESS.	MIN. BURST PRESS.	MIN. PROOF PRESS.	MIN. BEND RADIUS
MIL-H-8788- 4-L	1/4	7/32	.63	3,000	16,000	8,000	3.00
MIL-H-8788- 5-L	5/16	9/32	.70	3,000	14,000	7,000	3.38
MIL-H-8788- 6-L	3/8	11/32	.77	3,000	14,000	7,000	5.00
MIL-H-8788- 8-L	1/2	7/16	.86	3,000	14,000	7,000	5.75
MIL-H-8788-10-L	5/8	9/16	1.03	3,000	12,000	6,000	6.50
MIL-H-8788-12-L	3/4	11/16	1.22	3,000	12,000	6,000	7.75
MIL-H-8788-16-L	1	7/8	1.50	3,000	10,000	5,000	9.63

Hose Construction: Seamless synthetic rubber inner tube reinforced with one fabric braid, two or more steel wire braids, and covered with a synthetic rubber cover (for gas applications request perforated cover).

Identification: Hose is identified by specification number, size number, quarter year and year, hose manufacturer's identification.

Uses: High pressure hydraulic, pneumatic, coolant, fuel and oil.

Operating Temperatures: Minus 65°F. to plus 200°F.

FIGURE 10.3.—Aircraft hose specifications.

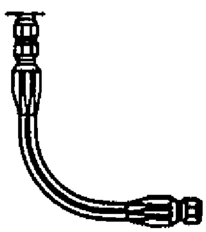
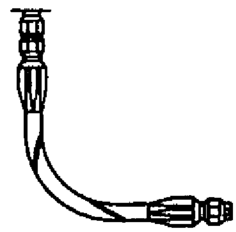
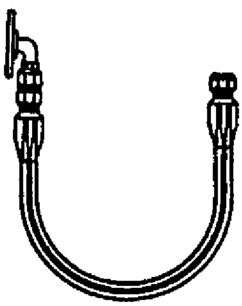
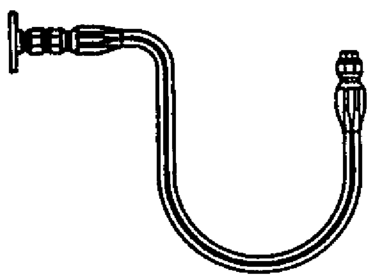
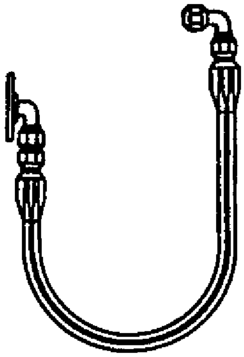
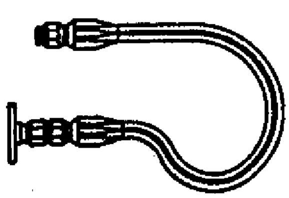
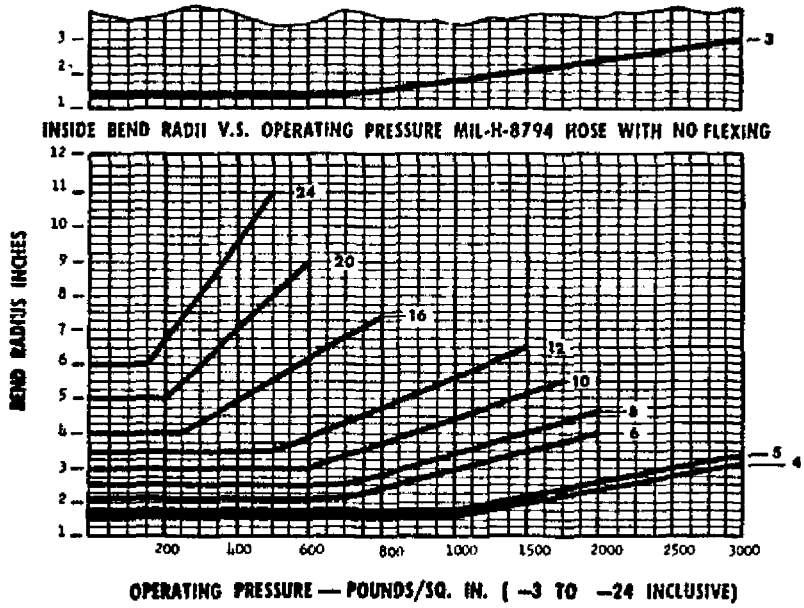
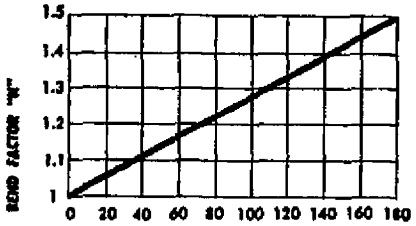
RIGHT WAY	WRONG WAY	
		Do not bend or twist the hose as illustrated.
		Allow enough slack in the hose line to provide for changes in length when pressure is applied. The hose will change in length from +2% to −4%.
		Metal end fittings cannot be considered as part of the flexible portion of the assembly.
		The use of elbows and adapters will assure easier installation and in many installations will remove the strain from the hose line and greatly increase service life.
		At all times keep the minimum bend radii of the hose as large as possible to avoid tube collapsing.

FIGURE 10.4.—Proper hose installations.



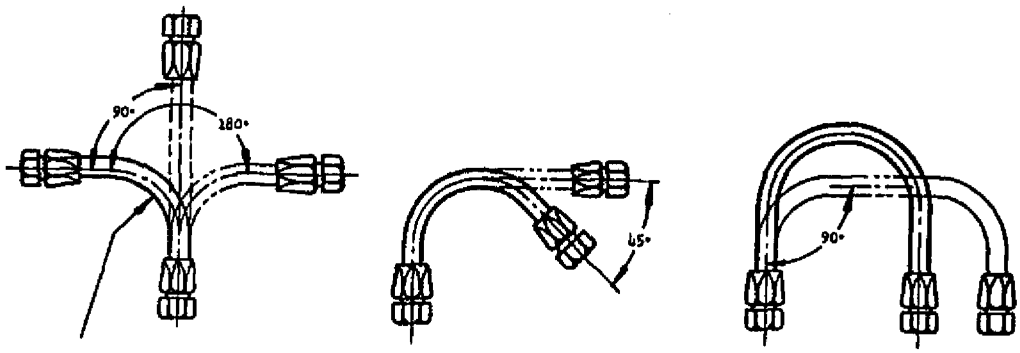
MINIMUM BEND RADII FOR −32, −40, AND −48 AT ALL PRESSURES ARE AS FOLLOWS: —32 13.25" —40 24" —48 33"



MIL-H-8788 HOSE WITH NO FLEXING	
DASH NO.	BEND RADII
4	3.000
5	3.375
6	5.000
8	5.750
10	6.500
12	7.750
16	9.625

MINIMUM BEND RADIUS OF HOSE UNDER FLEXING CONDITIONS = "N" × NO FLEXING BEND RADIUS OF EITHER MIL-H-8794 OR MIL-H-8788 HOSE.

EXAMPLE: FOR MIL-H-8794 HOSE −12 SIZE AT 1500 PSI AND HAVING A FLEXING RANGE OF 60° MINIMUM BEND RADIUS = 1.16 × 6.5 = 7½ INCHES (MEASURED AT INSIDE OF BEND).



MINIMUM BEND RADII MEASURED AT INSIDE OF BEND
DIMENSIONS IN INCHES.

FIGURE 10.5.—Minimum bend radii.

nated felt wiper ring. When systems are static, seepage past the seals is not normally acceptable.

(1) Inspection. During inspection, consider the following to determine whether seal replacement is necessary:

(a) How much fluid or air is permitted to seep past the seals? In some installations minor seepage is normal. Refer to manufacturers' maintenance information.

HOSE SIZE	BALL SIZE
-4	5/64
-5	9/64
-6	13/64
-8	9/32
-10	3/8
-12	1/2
-16	47/64
-20	61/64

FIGURE 10.6.—Ball diameters for testing hose restrictions or kinking.

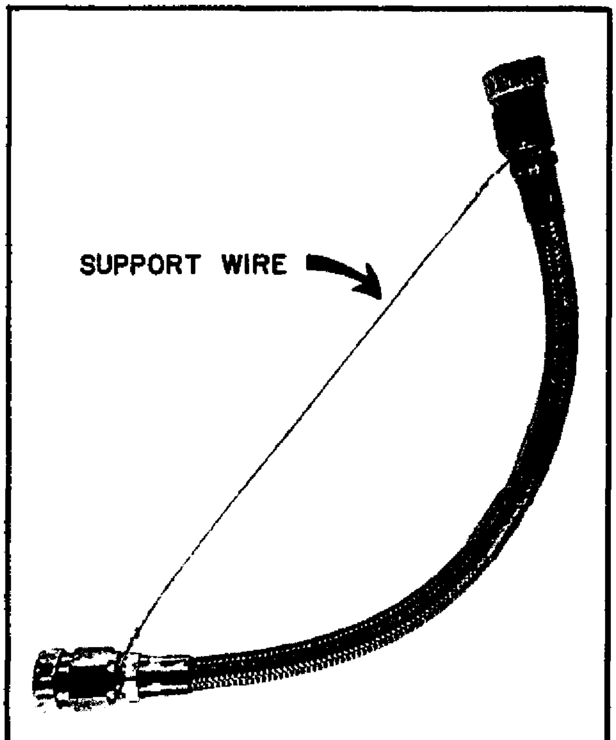


FIGURE 10.7.—Suggested handling of preformed hose.

(b) What effect does the leak have on the operation of the system? Know the system.

(c) Does the leak of fluid or air create a hazard or affect surrounding installations? A check of the system fluid and a knowledge of previous fluid replenishment is helpful.

(d) Will the system function safely until the next inspection?

(2) Do's and Don'ts That Apply to O-ring Seal Maintenance.

(a) Correct all leaks from static seal installations.

(b) Don't retighten packing gland nuts; retightening will, in most cases, increase rather than decrease the leak.

(c) Never reuse O-ring seals because they tend to swell from exposure to fluids, and become set from being under pressure. They may have minor cuts or abrasions that are not readily discernible by visual inspection.

(d) Avoid using tools that might damage the seal or the sealing surfaces.

(e) Do not depend upon color-coding. Coding may vary with manufacturer.

(f) Be sure that part number is correct.

(g) Retain replacement seals in their package until ready to use. This provides proper identification and protects the seal from damage and contamination.

(h) Assure that the sealing surfaces are clean and free of nicks or scratches before installing seal.

(i) Protect the seal from any sharp surfaces that it must pass over during installation. Use an installation bullet or cover the sharp surfaces with tape.

(j) Lubricate the seal so it will slide into place smoothly.

(k) Be sure the seal has not twisted during installation.

(l) Allow sufficient time for the seal to cold-flow to its original size before continuing with the installation.

(3) Storage of Replacement Seals.

(a) Store O-ring seals where temperatures do not exceed 120° F.

(b) Keep seals packaged to avoid exposure to ambient air and light, particularly sunlight.

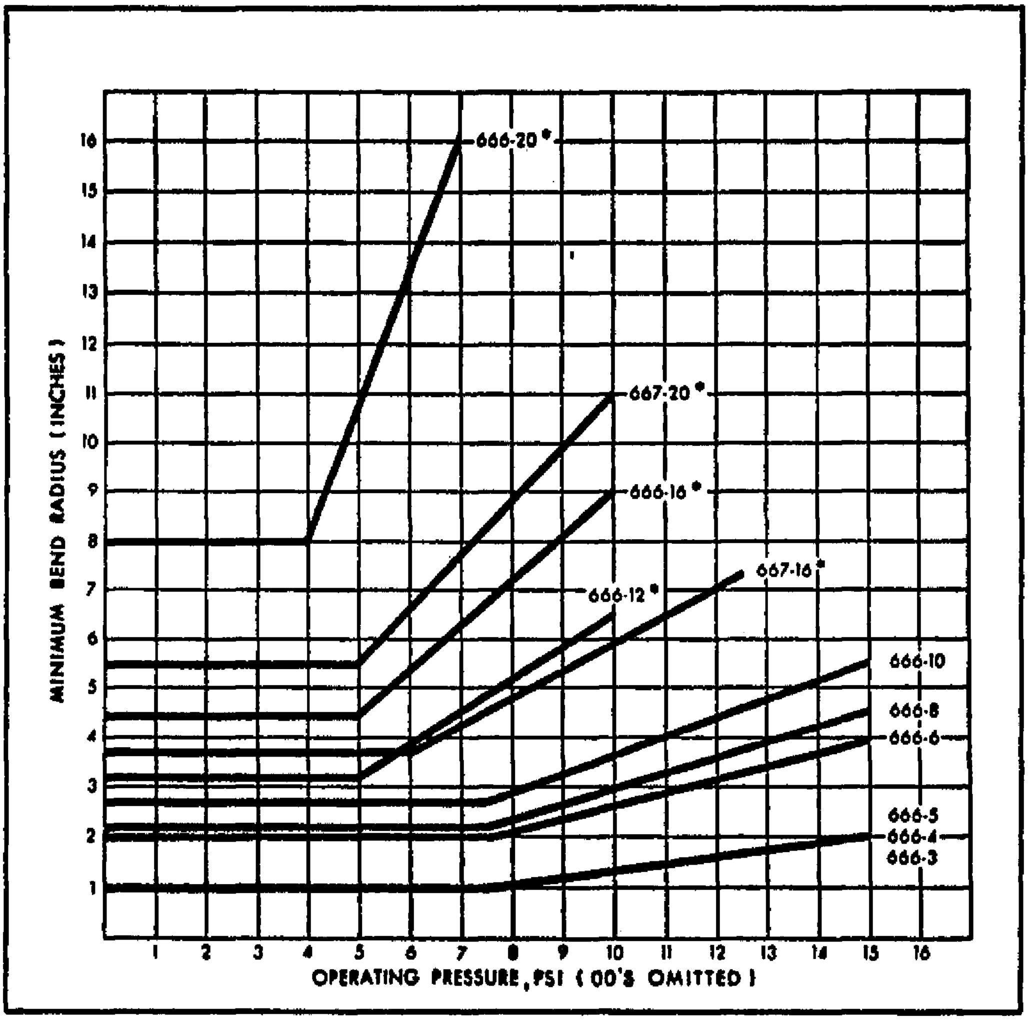


FIGURE 10.8.—Minimum bend radii—Teflon hose.

(c) Avoid storing O-ring seals on pegs or hooks, as in hardware stores. This practice leads to loss of identification, loss of cure dates, impairs cleanliness, and tends to cause the seals to become distorted and lose their resiliency from exposure to light and ambient air.

394. HYDRAULIC COMPONENTS. Hydraulic components such as pumps, actuating cylinders, selector valves, relief valves, etc., should be repaired or adjusted following the airplane and component manufacturer's instructions. Inspect hydraulic filter elements at frequent intervals and replace as necessary.

395.–405 RESERVED.

Chapter 11. ELECTRICAL SYSTEMS

Section 1. CARE OF ELECTRICAL SYSTEMS

406. GENERAL. The satisfactory performance of an aircraft is becoming more dependent upon the continued reliability of the electrical system. Reliability of the system is usually proportional to the amount of maintenance received and the knowledge of men who perform such maintenance. It is, therefore, important that maintenance be accomplished using the best techniques and practices to minimize the possibility of failure. This handbook is not intended to supersede or replace any government specification or specific manufacturer's instruction regarding electrical system maintenance.

The term "electrical system" as used in this circular means those parts of the aircraft which generate, distribute, and utilize electrical energy, including their support and attachments.

407. INSPECTION AND OPERATION CHECKS. Frequently, inspect equipment, electrical assemblies, and wiring installations for damage, general condition, and proper functioning to assure the continued satisfactory operation of the electrical system. Adjust, repair, overhaul, and test electrical equipment and systems in accordance with the recommendations and procedures set forth in aircraft and/or component maintenance instructions. Replace components of the electrical system that are damaged or defective with identical items or with equipment equivalent to the original in operating characteristics, mechanical strength, and the ability to withstand the environmental conditions encountered in the operation of the aircraft. *A suggested list of items to look for and* checks to be performed are:

a. Damaged or overheated equipment, connections, wiring, and installation.

b. Excessive resistance at high current carrying connections as determined by millivolt drop test.

c. Misalinement of electrically driven equipment.

d. Poor electrical bonding.

e. Dirty equipment and connections.

f. Improper support of wiring and conduit.

g. Loose connections, terminals, and ferrules.

h. Continuity of fuses.

i. Condition of electric lamps.

j. Insufficient clearance or poor insulation of exposed terminals.

k. Broken or missing safety wire, cotter pins, etc.

l. Operational check of electrically operated equipment such as motors, inverters, generators, batteries, lights, etc.

m. Voltage check of electrical system with portable precision voltmeter.

n. Miscellaneous irregularities such as poorly soldered or loose swaged terminals, loose quick disconnects, broken wire bundle lacing, broken or inadequate clamps, and insufficient clearance between exposed current-carrying parts and ground.

408. CLEANING AND PRESERVATION. Frequent cleaning of electrical equipment to remove dust, dirt, and grime is recommended. Fine emery cloth may be used to clean terminals and mating surfaces if they are corroded or dirty. Crocus cloth or very fine sandpaper may be used to polish commutators or slip rings. Do not use emery cloth on commutators since particles from the cloth may cause shorting and burning.

409. ADJUSTMENT. Accomplish adjustments to items of equipment such as regulators, generators, contactors, control devices, inverters, and relays outside the airplane on a test stand or test bench where all necessary instruments and test equipment are at hand. Follow the adjustment procedures outlined by the equipment manufacturer.

410. INSULATION OF ELECTRICAL EQUIPMENT. In some cases, a unit of electrical equipment is connected into a heavy current circuit, perhaps as a control device or relay. Such equipment is normally insulated from the mounting structure, since grounding the frame of the equipment may result in a serious ground fault in the event of equipment internal failure. If a ground connection for a control coil must be provided, use a separate small gauge wire.

411. BUS BAR MAINTENANCE. Periodically check bus bars used in aircraft electrical systems for general condition and cleanliness. Grease, oxide, or dirt on any electrical junction may cause the connectors to overheat and eventually fail. Clean bus bars by wiping with a clean soft cloth saturated with stoddard solvent and drying with a clean soft cloth.

412. JUNCTION BOXES.

a. *Junction Box Construction.* Fabricate replacement junction boxes using the same material as the original or from a fire-resistant, nonabsorbent material, such as aluminum alloy or an acceptable plastic material. Where fireproofing is necessary, a stainless steel junction box is recommended. Rigid construction will prevent "oil-canning" of the box sides, which could result in internal short circuits. In all cases, provide drainholes in the lowest portion of the box.

b. *Internal Arrangement.* The junction box arrangement should permit easy access to all installed items of equipment, terminals, and wires. Where marginal clearances are unavoidable, insert an insulating material between current-carrying parts and any grounded surface. It is not good practice to mount equipment on the covers or doors of junction boxes, since inspection for internal clearance is impossible when the door or cover is in the closed position.

c. *Junction Box Installation.* Securely mount junction boxes to the aircraft structure in such a manner that the contents are readily accessible for inspection. When possible, face the open side downward or at an angle so that loose metallic objects, such as washers or nuts, will tend to fall out of the junction box rather than wedge between terminals.

d. *Junction Box Wiring.* Junction box layouts must take into consideration the necessity for adequate wiring space and possible future additions. Lace or clamp electric wire bundles inside the box in a manner that terminals are not hidden, relay armatures are not fouled, and motion relative to any equipment is prevented. Protect cable at entrance openings against chafing using grommets or other suitable means.

413.-423. RESERVED.

Section 2. EQUIPMENT INSTALLATION

424. ELECTRICAL LOAD LIMITS. When installing additional equipment which consumes electrical power in an aircraft, determine that the total electrical load can be safely controlled or managed within the rated limits of the affected components of the aircraft's electrical power-supply system. Also determine that storage batteries forming a part of the affected system will be properly charged during flight.

a. *Wires, Wire Bundles, and Circuit Protective Devices.* Before any aircraft electrical load is increased, check the associated wires, wire bundles, and circuit protective devices (fuses or circuit breakers) to determine that the new total electrical load (previous maximum load plus added load) does not exceed the rated limits of the existing wires, wire bundles, or protective devices. Where necessary, add or replace with units having the correct rating.

425. GENERATORS. Compare the generator or alternator output ratings and limits prescribed by the manufacturer with the electrical loads which can be imposed on the affected generator or alternator by installed equipment. When the comparison shows that the probable total connected electrical load can exceed the output load limits of the generator(s) or alternator(s), reduce the load so that an overload cannot occur or provide means whereby the pilot or flight crew can readily and safely manage the electrical load so that it can be held within the prescribed limits. When a storage battery is part of the electrical power system, assure that the battery is continuously charged in flight, except when short intermittent loads are connected such as operation of radio transmitter, a landing gear motor, or other similar devices which may place short-time demand loads on the battery.

426. ACCEPTABLE MEANS OF CONTROLLING OR MONITORING THE ELECTRICAL LOAD.

a. The use of placards is recommended to inform the pilot and/or crewmembers the combination(s) of loads that may be connected to the power source.

b. Installations where the ammeter is in the battery lead, and the regulator system limits the maximum current that the generator or alternator can deliver, a voltmeter can be installed on the system bus. As long as the ammeter never reads "discharge" (except for short intermittent loads such as operating the gear and flaps) and the voltmeter remains at "system voltage," the generator or alternator will not be overloaded.

c. In installations where the ammeter is in the generator or alternator lead, and the regulator system does not limit the maximum current that the generator or alternator can deliver, the ammeter can be redlined at 100 percent of the generator or alternator rating. If the ammeter reading is never allowed to exceed the red line, except for short intermittent loads, the generator or alternator will not be overloaded.

d. Where the use of placards or monitoring devices is not practical or desired, and where assurance is needed that the battery in a typical small aircraft generator/battery power source will be charged in flight, the total continuous connected electrical load may be held to approximately 80 percent of the total rated generator output capacity. (When more than one generator is used in parallel, the total rated output is the combined output of the installed generators.)

e. When two or more generators are operated in parallel and the total connected system load can exceed the rated output of one generator, provide means for quickly coping with the sudden overloads which can be caused by generator or engine failure. Employ a quick load reduction system or procedure whereby the total load can be reduced to a quantity which is within the rated capacity of the remaining operable generator or generators.

f. Consider the total electrical load of devices that a pilot or flight crewmember would normally be expected to use as the probable continuous load. The use of placards or other load-monitoring devices or methods notwithstanding, the probable continuous load must not exceed the output capacity of the generator(s).

427. INVERTERS, ALTERNATORS, AND SIMILAR AIRCRAFT ELECTRICAL POWER SOURCES.

a. Connect the electrical load to inverters, alternators, and similar aircraft electrical power sources so that it cannot exceed the rated limits of the power source, unless effective monitoring means are provided whereby the pilot or flight crewmember can keep the load within the prescribed limits. Assure load circuit protective devices are time coordinated to trip prior to the inverter protective device or prior to electrical collapse of the inverter due to overload or fault in the load circuit. With the exception of the battery-charging provisions in the preceding paragraph, the same basic consideration with respect to load limits, inverters, alternators, and similar devices is applicable.

428. DETERMINATION OF ELECTRICAL LOAD.

a. The connected load of an aircraft electrical system may be determined by any one or a combination of several acceptable methods, techniques, or practices. However, regardless of the methods, techniques, or practice involved, any person who has need to know the status of a particular aircraft's electrical system should have available, current, and accurate data concerning the capacity of the installed electrical power source(s) and the load(s) imposed by installed electrical power consuming devices. Such data should provide a true picture of the status of the electrical system. Do not install new or additional electrical devices in an aircraft, nor change the capacity of any power source until the status of the electrical system in the aircraft has been determined accurately and found not to adversely affect the integrity of the electrical system.

429. CIRCUIT PROTECTION DEVICES.

a. *General.* Protect the wire with circuit breakers or fuses located as close as possible to the electrical power-source bus. Normally, the manufacturer of the electrical equipment specifies the fuse or breaker to be used when installing the respective equipment.

b. *Matching Protector to Wire.* The circuit breaker or fuse should open the circuit before the wire emits smoke. To accomplish this, the time-current characteristic of the protective device must fall below that of the associated wire. In order to obtain maximum utilization of the connected equipment, match the circuit protector characteristics.

c. *Circuit Protector Chart.* Figure 11.1 may be used as a guide for the selection of circuit breaker and fuse rating to protect copper conductor wire. This chart was prepared for the conditions specified by the notes which accompany the chart. If actual conditions deviate materially from those stated, ratings above or below the values recommended may be justified. For example, a wire run individually in the open air may possibly be protected by the circuit breaker of the next higher rating to that shown on the chart. In general, the chart is conservative for all ordinary aircraft electrical installations.

d. *Circuit Breaker Type.*

(1) All resettable type circuit breakers should open the circuit irrespective of the position of the operating control when an overload or circuit fault exists. Such circuit breakers are referred to as "trip free."

(2) Do not use automatic reset circuit breakers (which automatically reset themselves periodically) as circuit protective devices.

430. SWITCHES.

a. *General.* In all circuits where a switch

Section 3. ELECTRIC WIRE

442. GENERAL. Aircraft service imposes severe environmental conditions on electric wire. To assure satisfactory service, inspect the wire at regular intervals for abrasions, defective insulation, condition of terminal posts, and buildup of corrosion under or around swaged terminals. When replacing copper wire with aluminum wire, increase the gauge of the wire two sizes.

a. ***Voltage Drop in Wires.*** The voltage drop in the main power wires from the generation source or the battery to the bus should not exceed 2 percent of the regulated voltage, when the generator is carrying rated current or the battery is being discharged at the 5-minute rate. The following tabulation shows the maximum acceptable voltage drop in the load circuits between the bus and the utilization equipment.

Nominal system voltage	Allowable voltage drop continuous operation	Intermittent operation
14	0.5	1
28	1	2
115	4	8
200	7	14

b. ***Resistance.*** The resistance of the current return path through the aircraft structure is always considered negligible. However, this is based on the assumption that adequate bonding of the structure or a special electric current return path has been provided which is capable of carrying the required electric current with a negligible voltage drop. A resistance measurement of .005 ohms from ground point of the generator or battery to ground terminal of any electrical device may be considered satisfactory. Another satisfactory method of determining circuit resistance is to check the voltage drop across the circuit. If the voltage drop does not exceed the limit established by the aircraft or product manufacturer, the resistance value for the circuit may be considered satisfactory. When utilizing the voltage drop method of checking a circuit, maintain the input voltage at a constant value. Figures 11.3 and 11.4 show formulas that may be used to determine resistance in electrical wires.

FIGURE 11.3.—Examples determining voltage drop from electric wire chart (fig. 11.7).

Voltage drop	Enter chart (feet)	Amperes	Wire size from chart	Check
1	100	20	No. 6	VD=[2](.000436) (100)(20)=.872
0.5	$\frac{100}{0.5}=200$	20	No. 4	VD=[2](.000274) (100)(20)=.548
4	$\frac{100}{4}=25$	20	No. 12	VD=[2](.00188) (100)(20)=3.76
7	$\frac{100}{7}=14$	20	No. 14[1]	VD=[2](.00299) (100)(20)=5.98

[1] It should be noted that the No. 14 wire should not be used if any portion of its 100-foot length is to be confined in conduit, large bundles, or locations of high ambient temperature, as the intersection of the wire size and current lines fall below curve 1.

[2] Resistance values from figure 11.5.

FIGURE 11.4.—Examples determining voltage drop from electric wire chart (fig. 11.7).

Voltage drop	Wire size	Amperes	Max. length (ft.) from chart at voltage drop indicated	Check
1	No. 10	20	45	VD=[1](.0011) (20)(45)=.990
0.5	......	--	(45)(.5)= 22.5	VD=[1](.0011) (20)(22.5)=.495
4	......	--	(45) (4)= 180	VD=[1](.0011) (20)(180)=3.96
7	......	--	(45) (7)= 315	VD=[1](0011) (20)(315)=6.93

[1] Resistance values from figure 11.5.

FIGURE 11.5.—Copper electric wire current carrying capacity.

Wire size—Specification MIL-W-5086	Single wire in free air—maximum amperes	Wire in conduit or bundled—maximum amperes	Maximum resistance—ohms/1,000 feet (20° C.)	Nominal conductor area—circular mils	Finished wire weight—pounds per 1,000 feet
AN-20	11	7.5	10.25	1,119	5.6
AN-18	16	10	6.44	1,779	8.4
AN-16	22	13	4.76	2,409	10.8
AN-14	32	17	2.99	3,830	17.1
AN-12	41	23	1.88	6,088	25.0
AN-10	55	33	1.10	10,443	42.7
AN-8	73	46	.70	16,864	69.2
AN-6	101	60	.436	26,813	102.7
AN-4	135	80	.274	42,613	162.5
AN-2	181	100	.179	66,832	247.6
AN-1	211	125	.146	81,807	
AN-0	245	150	.114	104,118	382
AN-00	283	175	.090	133,665	482
AN-000	328	200	.072	167,332	620
AN-0000	380	225	.057	211,954	770

FIGURE 11.6.—Aluminum electric wire current carrying capacity.

Wire size—Specification MIL-W-7072	Single wire in free air—maximum amperes	Wire in conduit or bundled—maximum amperes	Maximum resistance—ohms/1,000 feet (20° C.)	Nominal conductor area—circular mils	Finished wire weight—pounds per 1,000 feet
AL-6	83	50	0.641	28,280	
AL-4	108	66	.427	42,420	
AL-2	152	90	.268	67,872	
AL-0	202	123	.169	107,464	166
AL-00	235	145	.133	138,168	204
AL-000	266	162	.109	168,872	250
AL-0000	303	190	.085	214,928	303

NOTE: *Aluminum wire.*—From figures 11.5 and 11.6 it will be noted that the conductor resistance of aluminum wire and that of copper wire two numbers higher are similar. Accordingly, the electric wire chart, figure 11.5 can be used when it is desired to substitute aluminum wire and the proper size can be selected by remembering to reduce the copper wire size by two numbers and by referring to figure 11.6. The use of aluminum wire sizes smaller than No. 6 is not recommended.

443. AIRCRAFT ELECTRICAL WIRE. Use aircraft-quality wire. Correct wire selection is dependent upon knowledge of current requirements, operating temperatures, and environmental conditions involved in the particular installation.

a. Conductors. Copper conductors are coated to prevent oxidation and to facilitate soldering. Tinned copper or aluminum wire is generally used in installations where operating temperatures do not exceed 221° F. (105° C.). Silver-coated copper wire is used where temperatures do not exceed 392° F. (200° C.). Nickel-coated copper wire is used for temperatures up to 500° F. (260° C.). Nickel-coated wire is more difficult to solder than tinned or silver-coated wire, but with proper techniques, satisfactory connections can be made.

b. Insulation. Polyvinylchloride (PVC) is a common insulation. It has good insulating properties and is self-extinguishing after the flame source is removed. Normal operating temperatures are limited to 221° F. (105° C.). Silicone rubber is rated at 392° F. (200° C.), is highly flexible, and self-extinguishing except in vertical runs. TFE Fluorocarbon (polytetrafluoroethylene) is widely used as high-temperature insulation. It will not burn, but will vaporize when exposed to flame. It is resistant to most fluids. FEP Fluorocarbon (fluorinated ethylene propolene) is rated at 392° F. (200° C.) but will melt at higher temperatures. Other properties of FEP are similar to TFE.

c. *Thermal and Abrasion Resistant Materials.* Glass braid has good thermal and abrasion qualities but moisture absorption is high. Asbestos and other minerals provide high temperature and flame resistance, but are highly absorbent. Moisture absorption is reduced by use of silicone rubber, TFE, or other saturants. Nylon is widely used in low-temperature wires for abrasion and fluid resistance. Polyimide, a new material has excellent thermal and abrasion resistant characteristics.

d. *Wire Selection.* When selecting wire, refer to figure 11.7a, for structural and environmental characteristics. Wire normally used for chassis wiring, in enclosed areas, or in compact wire harnesses protected by molded or braided coverings usually has low abrasion resistance. Wire used to interconnect units, or in long, open runs in the airframe, is designed to withstand normal aircraft environment without sleeving, jacketing, or other protection. Care must be taken in making all installations because no wire insulation or jacketing will withstand continuous scuffing or abrasion.

444. INSTRUCTIONS FOR USE OF ELECTRIC WIRE CHART. The chart is based on copper conductor wire meeting Specification MIL-W-5086. Curves 1, 2, and 3 are plotted to show the maximum ampere rating for the specified wire in size and under specified conditions shown.

a. In order to select the correct size of electric wire for equipment, two major requirements must be met:

(1) The size must be sufficient to prevent an excessive voltage drop while carrying the required current over the required distance.

(2) The size must be sufficient to prevent overheating of the wire while carrying the required current.

b. To simplify these determinations an electric wire chart (figure 11.7) may be used. In order to use this chart properly for the selection of wire we must know:

(1) the length in feet of the actual wire "run" from the bus to the equipment;

(2) the number of amperes of current it must carry;

(3) the amount of voltage drop permitted (see tabulation, paragraph 442a); and

(4) whether the current carried will be intermittent (maximum 2 minutes) or continuous, and if continuous, whether it is a single wire in free air, in a conduit, or in a bundle.

c. Assume that we wish to install a 50-foot length of wire from the bus to the equipment in a 28-volt system. By referring to the "allowable voltage drop table" (paragraph 442a), we find that we are permitted a 1-volt drop for continuous operation. Now referring to the "electrical wire chart" (figure 11.7), we find along the left side values numbered 5 to 200 showing the number of feet a wire may be run while carrying a given current, with a 1-volt loss or drop. Place a pointer on the horizontal line shown opposite the number 50.

d. Assuming that the current required by the equipment is 20 amperes, place another pointer at the top of the table on the diagonal line numbered 20 amperes. Now follow this diagonal line downward until it intersects the horizontal line number 50. From this point, drop straight downward to the bottom of the chart and we find that a wire size between a No. 8 and a No. 10 is required to prevent a greater drop than 1 volt. Since we are between these two numbers, select the larger size, No. 8. This is the smallest size which should be used to meet requirement a(1).

e. For requirement a(2): (1) Disregard the length of the wire, the numbers along the left side of the chart, and the horizontal lines for this determination; (2) Assume that the wire is to be a single wire in free air carrying continuous current; (3) Place a pointer at the top

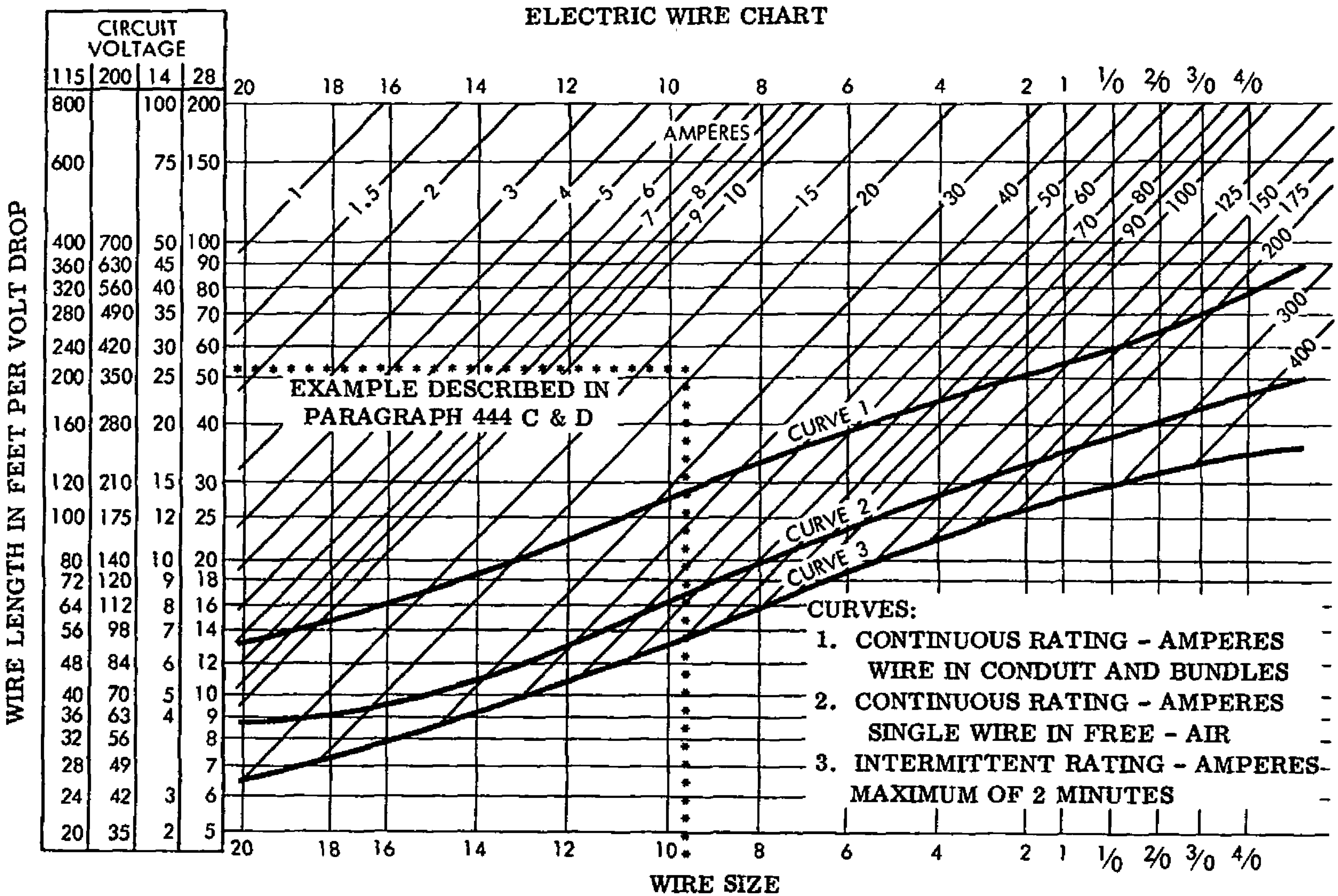


Figure 11.7

Figure 11.7.—Electric wire chart.

FIGURE 11.7A—Wire used in aircraft installations.

Standard	Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MS-25190 Type I	Mil-W-5086	Tinned copper	PVC, nylon	600 V.	105° C. 221° F.	Interconnection, low temperature gen. purpose, max. ambient temp. 60° C.
Type II	Mil-W-5086	Tinned copper	PVC, glass braid, nylon	600 V.	105° C.	Same as Type I with greater overload protection less moisture resistance.
Type III	Mil-W-5086	Tinned copper	PVC, glass braid, PVC, nylon	600 V.	105° C.	Same as Type II. Less common.
Type IV	Mil-W-5086	Tinned copper	PVC, nylon	3,000 V.	105° C.	Similar to Type I with higher voltage rating.
MS-25191	Mil-W-7072	Aluminum	PVC, glass braid, nylon braid	600 V.	105° C.	Light weight, use 2 sizes larger when replacing copper. Corrosive. 60° C. ambient.
MS-25471	Mil-W-8777	Silver-coated copper	Silicone rubber, glass braid, polyester braid	600 V.	200° C.	High temp. interconnection. Self-extinguishing. To 155° C. ambient.
MS-27110	Mil-W-8777	Silver-coated copper	Silicone rubber, glass braid, FEP fluorocarbon	600 V.	200° C. 392° F.	Same as MS-25417 but has smooth surface. To 155° C. ambient.
None	Mil-W-7139 Class 1	Silver-coated copper	TFE fluorocarbon and glass	600 V.	200° C. 392° F.	High temp. interconnection. Self-extinguishing. To 155° C. ambient.
None	Mil-W-7139 Class 2	Nickel-coated copper	TFE fluorocarbon and glass	600 V.	260° C. 500° F.	Same as Class 1. To 215° C. ambient.
MS-17331	Mil-W-22759	Silver-coated copper	Reinforced TFE asbestos	600 V.	200° C.	Abrasion resistant, resist thermal overload.
MS-17332	Mil-W-22759	Nickel-coated copper	Reinforced TFE asbestos	600 V.	260° C.	Same as MS-17331.
MS-17410	Mil-W-22759	Silver-coated copper	TFE, glass, FEP	600 V.	200° C.	Similar to Mil-W-7139 but with smooth surface.
MS-17411	Mil-W-22759	Silver-coated copper	Mineral reinforced TFE	1,000 V.	200° C.	Abrasion resistant, smooth surface can be used to replace Mil-W-7139.
MS-17412	Mil-W-22759	Nickel-coated copper	Mineral reinforced TFE	1,000 V.	260° C.	Same as MS-17411 may be used to replace Mil-W-7139, Class 2.

FIGURE 11.7A—Wire used in aircraft installations—continued.

Standard	Specification	Conductor	Insulation	Voltage rate	Conductor temp. rating	Remarks
MS-18000	Mil-W-22759	Silver-coated copper	Mineral reinforced TFE	600 V.	200° C.	Similar to MS-17411 and MS-17412 with thinner wall and less abrasion resistant.
MS-18001	Mil-W-22759	Nickel-coated copper	Mineral reinforced TFE	600 V.	260° C.	Same as MS-1800.
MS-18032	Mil-W-22759	Silver-coated copper	Fused laminated TFE	600 V.	200° C.	Hook-up similar to MS-21985 and MS-21986 with thinner wall and less abrasion resistance.
MS-18033	Mil-W-22759	Nickel-coated copper	Fused laminated TFE	600 V.	260° C.	Same as MS-18032. Laminated wall is uniform in cross section.
MS-18104	Mil-W-22759	Silver-coated copper	Extruded TFE polyimide coated	600 V.	200° C.	Similar to MS-18113 and MS-18114 but thinner wall and higher abrasion resistance.
MS-18105	Mil-W-22759	Nickel-coated copper	Extruded TFE polyimide coated	600 V.	260° C.	Same as MS-18104.
MS-18113	Mil-W-22759	Silver-coated copper	Extruded TFE	1,000 V.	200° C.	Similar to MS-21985 and MS-21986 but higher voltage rate.
MS-18114	Mil-W-22759	Nickel-coated copper	Extruded TFE	1,000 V.	260° C.	Same as MS-18113.
MS-21985	Mil-W-22759	Silver-coated copper	Extruded TFE	600 V.	200° C.	Hook-up.
MS-21986	Mil-W-22759	Nickel-coated copper	Extruded TFE	600 V.	260° C.	Hook-up.
MS-27125	Mil-W-25038	Nickel-clad copper (27% nickel)	Asbestos, glass, TFE	600 V.	260° C.	Fire resistant. Moisture, abrasion and fluid resistant where ambient temp. below 550° C.
None	Mil-W-16878 Type EE	Silver or nickel-coated copper	Extruded TFE	1,000 V.	200° C. or 260° C.	Hook-up—similar to MS-18113 and MS-18114.
M81044/1A	Mil-W-81044A (AS)	Silver-plated copper	Crosslinked extruded polyalkene	600 V.	−65 to +135	Aerospace electric systems (General purpose aircraft wiring) normal weight
M81044/2A	"	Tin-coated copper	"	"	"	
M81044/3A	"	Silver-plated copper	"	"	"	Aerospace electric systems (General electronic wiring)

M81044/4A	"	Tin-plated copper	"	"	"	Internal wiring of meters, panels, and electrical and electronic equipment.
M81044/5	"	Silver-plated copper	Crosslinked extruded polyalkene	"	−65 to +150	Aerospace electric systems (General purpose aircraft wiring) normal weight
M81044/6	"	Tin-coated copper	"	"	"	
M81044/7	"	Silver-plated high strength copper alloy	"			
M81044/8	"	Silver-plated copper	"	"	"	Aerospace electric systems (General purpose aircraft wiring) medium weight
M81044/9	"	Tin-coated copper	"	"	"	
M81044/10	"	Silver-plated high strength copper alloy	"	"	"	
M81044/11	"	Silver-plated copper	"	"	"	Aerospace electric systems (General electronic wiring) Internal wiring of meters, panels, and electrical and electronic equipment.
M81044/12	"	Tin-coated copper	"	"	"	
M81044/13	"	Silver-plated high strength copper alloy	"	"	"	
M81381/1	Mil-W-81381 (AS)	Silver-coated copper	Polyimide/FEP film	600 V.	−65 to +200	Aerospace electric systems (General electronic wiring) Internal wiring of meters, panels, and electrical and electronic equipment.
M81381/2		Nickel-coated copper				
M81381/3		Silver-coated copper				Aerospace electric systems (General purpose aircraft wiring) medium weight
M81381/4		Nickel-coated copper				

of the table on the diagonal line which is numbered 20 amperes; (4) Follow this line until the pointer intersects the diagonal line marked "curve 2;" and (5) Drop pointer straight downward to the bottom of the chart and we are between the number 16 and 18. As the results are again between sizes, select the larger No. 16 wire. This is the smallest size wire acceptable for carrying 20-ampere current in a single wire in free air without overheating.

f. Compare the wire sizes selected. Use a cable no smaller than No. 8 in order to satisfy requirement (a) and no smaller than a No. 16 in order to satisfy requirement (b). Since we must meet both requirements, select the larger No. 8.

g. In this particular instance, the voltage-drop requirement was more critical because it required a larger size than the heat-dissipation requirement. This is usually true when a relatively light current is carried over a relatively long distance. However, when a short wire and/or a heavy current is required, the heat-dissipation capabilities of the wire may become the critical factor and may dictate the size of the wire to be used.

h. The tabulation referenced in paragraph 442a shows several values of voltage drop which is allowable for various systems and conditions when selecting wire for use from the bus to the equipment. Additionally, the voltage drop permissible in wires from the generator to the bus and from the battery to the bus will vary with the regulated voltage of the system i.e., nominal 14 V., 28 V., 115 V., etc.

445. SPLICES IN ELECTRIC WIRE. Splicing of electric wire should be kept to a minimum and avoided entirely in locations subject to extreme vibrations. Splicing of individual wires in a group or bundle may be spliced provided the completed splice is located so it can be periodically inspected. Stagger splices (see figure 11.8) so the bundle does not become excessively enlarged. Many types of aircraft splice connectors are available for use when splicing individual wires. Use of the self-insulated splice connector is preferred; however, a noninsulated splice connector may be used provided the splice is covered with plastic sleeving which is secured at both ends. Solder splices may be used; however, they are particularly brittle and not recommended.

446. OPEN WIRING. Electric wiring is often installed in aircraft without special enclosing means. This practice is known as open wiring and offers the advantages of ease of maintenance and reduced weight.

a. *Wire Bundles.* To simplify maintenance and to minimize the damage that may result from a single fault, limit the number of wires in the run. Shielded wire, ignition wire, and wires which are not protected by a circuit breaker or fuse usually are routed separately. Avoid bending radii less than 10 times the outer diameter of the bundle to prevent excessive stresses on the wire insulation.

b. *Insulating Tubing.* Soft insulating tubing (spaghetti) cannot be considered as mechanical protection against external abrasion of wire, since at best it provides only a delaying action. Use conduit or ducting when mechanical protection is needed.

c. *Clamping of Wire Bundles.* Use clamps lined with nonmetallic material to support the wire bundle along the run. Tying may be used between clamps, but should not be considered as a substitute for adequate clamping. Adhetherefore are not acceptable as a clamping means.

d. Separation from Flammable Fluid Lines. An arcing fault between an electric wire and a metallic flammable fluid line may puncture the line and result in a serious fire. Consequently, make every effort to avoid this hazard by physical separation of the wire from lines or equipment containing oil, fuel, hydraulic fluid, or alcohol. When separation is impractical, locate the electric wire above the flammable fluid line and securely clamp to the structure. In no case, should a wire be supported by a flammable fluid line.

447. HEAT PRECAUTIONS. Separate wires from high temperature equipment, such as resistors, exhaust stacks, heating ducts, etc., to prevent insulation breakdown. Insulate wires that must run through hot areas with a high temperature insulation material such as asbestos, fiberglas, or teflon. Avoid high temperature areas when using cables having soft plastic insulation such as polyethylene because these materials are subject to deterioration and deformation at elevated temperatures. Many coaxial cables have this type of insulation.

448. PROTECTION AGAINST CHAFING. Protect wire and wire groups against chafing or abrasion as damaged insulation may result in short circuits, malfunctions, or inoperative equipment. Support wire bundles using MS-21919 cable clamps as indicated in figure 11.9. When clamped in position, if there is less than 1/4-inch clearance between a bulkhead cutout and the wire bundle, install a suitable grommet as indicated in figure 11.10. The grommet may be cut at 45° angle to facilitate installation provided it is cemented in place and the slot is lo-

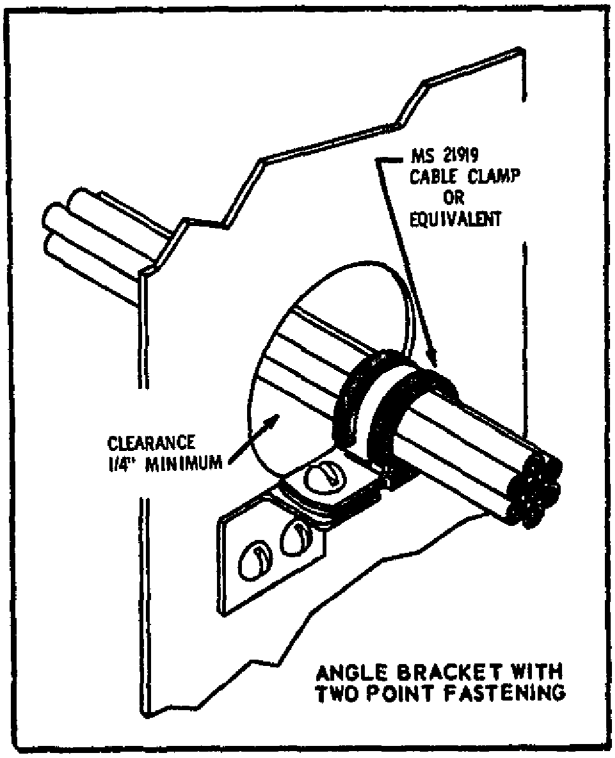
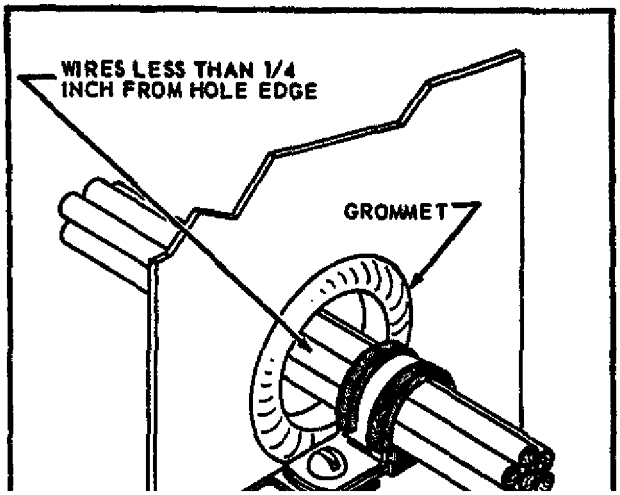


FIGURE 11.9—Cable clamp at bulkhead hole.



however, the following basic principles should be practiced:

a. Make sure all cutting tools used for stripping are sharp.

b. When using special wire stripping tools, adjust the tool to avoid nicking, cutting, or otherwise damaging the strands.

c. Damage to wires should not exceed the limits specified in figure 11.11.

FIGURE 11.11.—Allowable nicked or broken strands.

Wire size	*Nicked or broken strands*
Copper	
AN #22—#12	None
#10	2
#8 —#4	14
#2 —#0	12
Aluminum	
All Sizes	None

NOTE: Longitudinal scratches in copper wire are not considered cause for rejection or rework.

450. TERMINALS. Terminals are attached to the ends of electric wires to facilitate connection of the wires to terminal strips or items of equipment. The tensile strength of the wire to terminal joint should be at least equivalent to the tensile strength of the wire itself, and its resistance negligible relative to the normal resistance of the wire. Terminals specifically designed for use with the standard sizes of aircraft wire are available through normal supply channels. Haphazard choice of commercial terminals may lead to overheated joints, vibration failures, and corrosion difficulties.

a. Solder Terminals. For most applications, soldered terminals have been replaced by solderless terminals. The solder process has disadvantages that have been ... solder and become more susceptible to breakage due to vibration.

(5) The wire insulation may be charred during the soldering process.

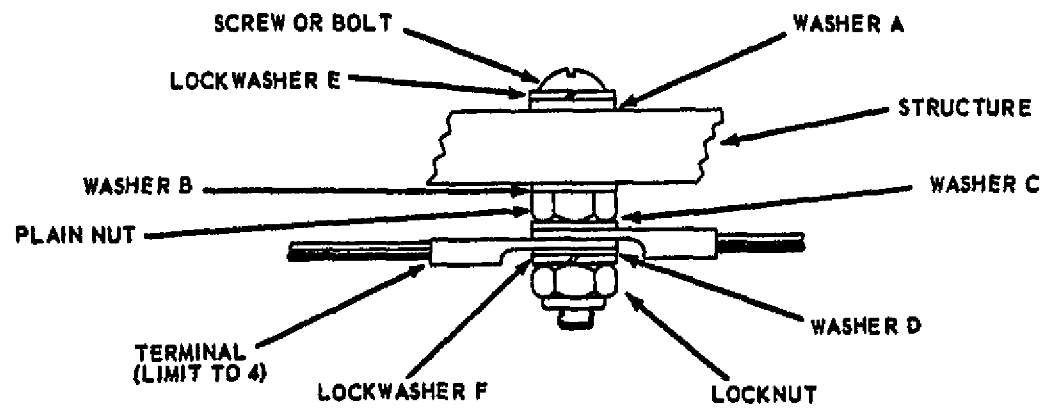
b. Solderless Terminals. The terminal manufacturer will normally provide a special crimping or swaging tool for joining the solderless terminal to the electric wire. Aluminum wire presents special difficulty in that each individual strand is insulated by an oxide coating. This oxide coating must be broken down in the crimping process and some method employed to prevent its reforming. In all cases, follow the terminal manufacturer's instructions when installing solderless terminals.

451. ATTACHMENT OF TERMINALS TO STUDS. Electrical equipment malfunction has frequently been traced to poor terminal connections at terminal boards. Loose, dirty, or corroded contact surfaces will produce localized heating which may ignite nearby combustible materials or overheat adjacent wire insulation to the smoking point.

452. BONDING JUMPER INSTALLATIONS. Make bonding jumpers as short as practicable, and install in such manner that the resistance of each connection does not exceed .003 ohm. The jumper must not interfere with the operation of movable aircraft elements, such as surface controls, nor should normal movement of these elements result in damage to the bonding jumper.

a. Bonding Connections. To assure a low-resistance connection, remove nonconducting finishes; such as paint and anodizing films, from the attachment surface to be contacted by the bonding terminal. Do not ground electric wiring directly to magnesium parts.

Figure 11.12.—Stud bonding or grounding to flat surface.



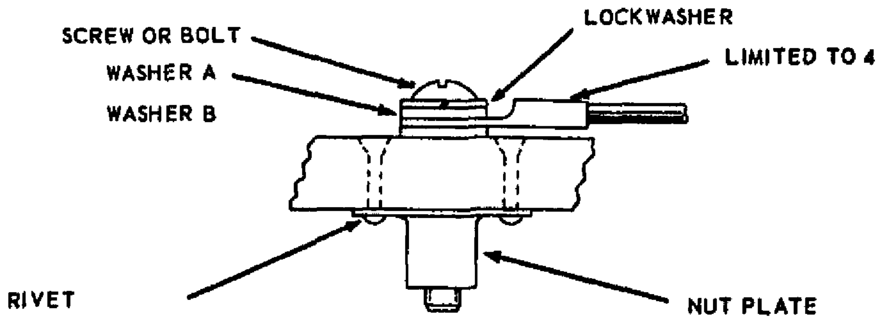
Aluminum Terminal and Jumper

Structure	*Screw or Bolt and Lock nut*	*Plain nut*	*Washer A*	*Washer B*	*Washer C & D*	*Lock washer E*	*Lock washer F*
Aluminum Alloys	Cad. Plated Steel	Cad. Plated Steel	Aluminum Alloy	Aluminum Alloy	Cad. Plated Steel or Aluminum	Cad. Plated Steel	Cad. Plated Steel
Magnesium Alloys	Cad. Plated Steel	Cad. Plated Steel	Magnesium Alloy	Magnesium Alloy	Cad. Plated Steel or Aluminum	Cad. Plated Steel	Cad. Plated Steel
Steel, Cadmium Plated	Cad. Plated Steel	Cad. Plated Steel	None	None	Cad. Plated Steel or Aluminum	Cad. Plated Steel	Cad. Plated Steel
Steel, Corrosion Resisting	Corrosion Resisting Steel	Cad. Plated Steel	None	None	Cad. Plated Steel or Aluminum	Cor. Resist Steel	Cad. Plated Steel

Tinned Copper Terminal and Jumper

Aluminum Alloys	Cad. Plated Steel	Cad. Plated	Aluminum Alloy	Aluminum Alloy	Cad. Plated	Cad. Plated	Cad. Plated

FIGURE 11.13.—Plate nut bonding or grounding to flat surface.



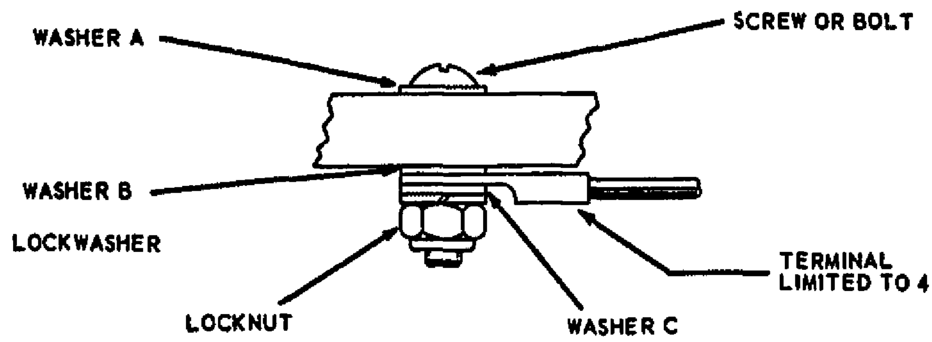
Aluminum Terminal and Jumper

Structure	*Screw or Bolt and Nut plate*	*Rivet*	*Lockwasher*	*Washer A*	*Washer B*
Aluminum Alloys	Cad. Plated Steel	Aluminum Alloy	Cadmium Plated Steel	Cad. plated steel or aluminum	None
Magnesium Alloys	Cad. Plated Steel	Aluminum Alloy	Cadmium Plated Steel	Cad. plated steel or aluminum	None or Magnesium alloy
Steel, Cadmium plated	Cad. Plated Steel	Cor. Resist. Steel	Cadmium Plated Steel	Cad. plated steel or aluminum	None
Steel, Corrosion Resisting	Corrosion Resist. Steel or Cad. Plated Steel	Cor. Resist. Steel	Cadmium Plated Steel	Cad. plated steel or aluminum	Cadmium plated steel

Tinned Copper Terminal and Jumper

Aluminum Alloys	Cad. Plated Steel	Aluminum Alloy	Cadmium Plated Steel	Cad. plated steel	Aluminum Alloy

FIGURE 11.14.—Bolt and nut bonding or grounding to flat surface.



Aluminum Terminal and Jumper

Structure	*Screw or Bolt and Nut plate*	*Lockwasher*	*Washer A*	*Washer B*	*Washer C*
Aluminum Alloy	Cad. Plated Steel	Cad. Plated Steel	Cad. plated steel or aluminum	None	Cad. plated steel or aluminum
Magnesium Alloy	Cad. Plated Steel	Cad. Plated Steel	Magnesium Alloy	None or Magnesium Alloy	Cad. plated steel or aluminum
Steel, Cadmium plated	Cad. Plated Steel	Cad. Plated Steel	Cad. Plated Steel	Cadmium plated steel	Cad. plated steel or aluminum
Steel, Corrosion Resisting	Corrosion Resist. Steel or Cad. plated steel	Cad. Plated Steel	Corrosion Resisting Steel	Cadmium plated steel	Cad. plated steel or aluminum

Tinned Copper Terminal and Jumper

Aluminum Alloy	Cad. Plated Steel	Cad. Plated Steel	Cad. plated steel	Aluminum alloy	Cad. plated steel

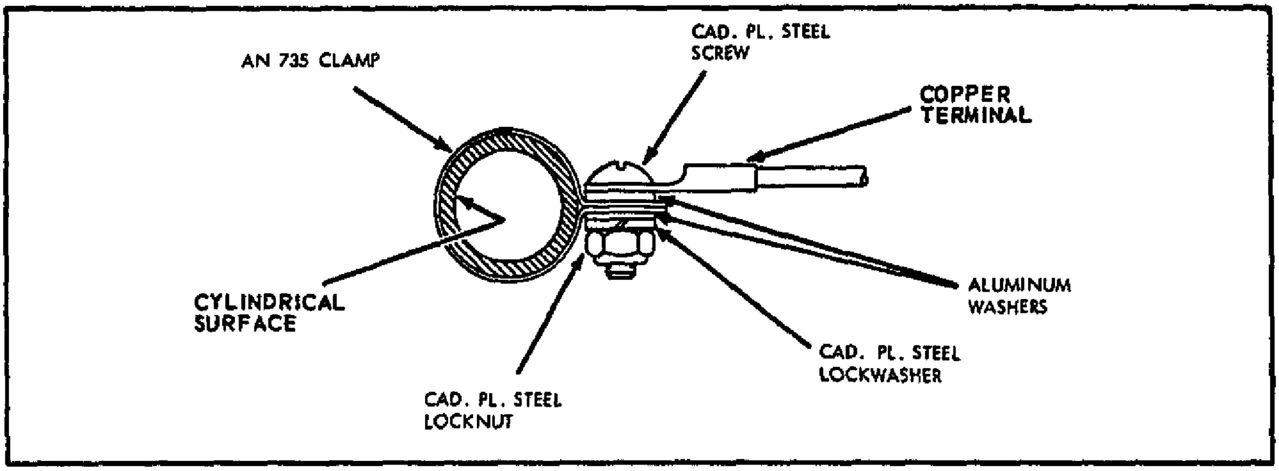


Figure 11.15—Copper jumper connecter to tubular structure.

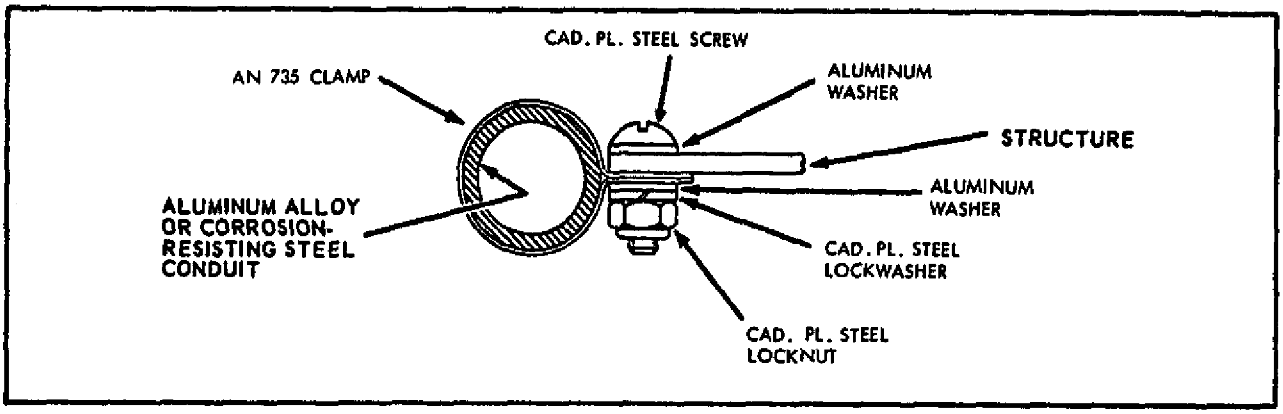
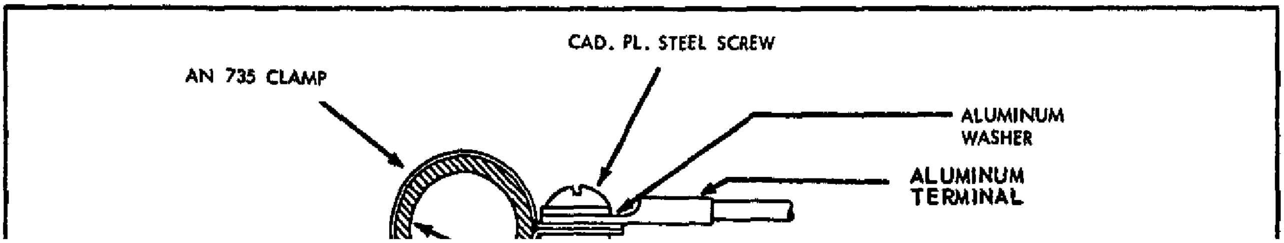


Figure 11.16.—Bonding conduit to structure.



avoided, the choice of jumper and hardware should be such that corrosion is minimized, and the part likely to corrode would be the jumper or associated hardware. Figures 11.12 through 11.17 show the proper hardware combinations for making a bond connection. At locations where finishes are removed, apply a protective finish to the completed connection to prevent subsequent corrosion.

c. ***Bonding Jumper Attachment.*** Avoid the use of solder to attach bonding jumpers. Bond tubular members by means of clamps to which the jumper is attached. Proper choice of clamp material will minimize the probability of corrosion.

d. ***Ground Return Connection.*** When bonding jumpers carry substantial ground return current, determine that the current rating of the jumper is adequate, and that a negligible voltage drop is produced.

453.–463. RESERVED.

Section 4. WIRE MARKING

464. WIRE IDENTIFICATION. To facilitate installation and maintenance, original wire-marking identification is to be retained. The wire identification marking should consist of a combination of letters and numbers which identify the wire, the circuit it belongs to, its gauge size, and any other information to relate the wire to a wiring diagram. The preferred method is to stamp the identification marking directly on the wire. Place identification markings at each end of the wire and at 12- to 15-inch intervals along the length of the wire. Wires less than 3 inches long need not be stamped. Wire lengths 3 to 7 inches should be stamped at the center. If the outer covering or wire insulation will not stamp easily, insulating tubing may be stamped with the identification mark and installed on the wire. Identification sleeves are normally used for identifying the following types of wire or cable:

a. Unjacketed shielded wire.

b. Thermocouple wire.

c. Multiconductor cable.

d. High temperature wire with insulation difficult to mark (such as asbestos, teflon, and fiberglas).

(1) Thermocouple wire identification is normally accomplished by means of identification sleeves. As the thermocouple wire is usually of the duplex type (two insulated wires within the same casing), each wire at the termination point bears the full name of the conductor

465. SLEEVE SELECTION FOR IDENTIFICATION.

a. Flexible vinyl sleeving, either clear or opaque, is satisfactory for general use.

b. For sleeving exposed to high temperatures (over 400° F.), use materials such as silicone rubber or silicone fiberglas.

c. Use nylon sleeving in areas where resistance to solvent and synthetic hydraulic fluids is necessary. The size of identification sleeving for the various sizes of wire are shown in figure 11.18.

FIGURE 11.18.—Sizes of identification sleeving.

Wire Size		Sleeving Size	
MIL-W-5086 AN	MIL-W-7072 AL	No.	Nominal I.D. (inches)
#24		12	.085
#22		11	.095
#20		10	.106
#18		9	.118
#16		8	.118
#14		7	.148
#12		6	.166
#10		4	.208
#8	#8	2	.263
#6	#6	0	.330
#4	#4	3/8 inch	.375
#2	#2	1/2 inch	.500
#1	#1	1/2 inch	.500
#0	#0	5/8 inch	.625
#00	#00	5/8 inch	.625
#000	#000	3/4 inch	.750
#0000	#0000	3/4 inch	.750

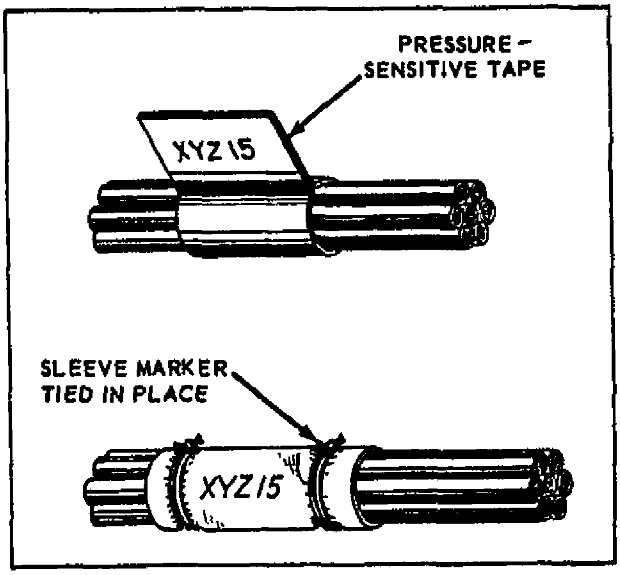


FIGURE 11.19.—Identification of wire bundles and harnesses.

467.–477. RESERVED.

Section 5. CONNECTORS

478. GENERAL PURPOSE CONNECTORS. Connectors (plugs and receptacles) are used to facilitate maintenance when frequent disconnection is required. Since the wires are soldered to the connector inserts, the joints should be individually installed and the wire bundle firmly supported to avoid damage by vibration. Connectors have been particularly vulnerable to corrosion in the past, due to condensation within the shell. Special connectors with waterproof features have been developed and may be used to replace nonwaterproof type plugs in areas where moisture causes a connector problem. Use a replacement connector of the same basic type and design as the connector it replaces. Connectors that are susceptible to corrosion difficulties may be treated with a chemically inert waterproof jelly. When replacing connector assemblies, use the socket-type insert on that half which is live or "hot" after the connector is disconnected to prevent unintentional grounding.

479. TYPES OF CONNECTORS. Connectors are identified by AN numbers and are divided into types and classes with manufacturer's variations in each type and class. The manufacturer's variations are differences in appearance and in the method of meeting the specification; however, they do not preclude mating plugs and receptacles of different manufacturers. There are six basic types of AN connectors used in aircraft which are further broken down into five classes as indicated in figures it is important that the soldered connectors are readily accessible. The back shell is held together by a threaded ring or by screws.

Class C—A pressurized connector with inserts that are not removable. Looks like a Class A connector but the inside sealing arrangement is sometimes different and is used on walls of bulkheads of pressurized equipment.

Class D—Moisture and vibration resisting connector which has a sealing grommet in the back shell. Wires are threaded through tight fitting holes in the grommet, thereby sealing against moisture.

Class K—A fireproof connector used in areas where it is vital that the electric current is not interrupted, even though connector may be exposed to continuous open flame. Wires are crimped to the pin or socket contacts and the shells are made of steel. This class of connectors is normally longer than the other classes of connectors.

480. AN CONNECTOR IDENTIFICATION. Code letters and numbers are marked on the coupling ring or shell to identify the connector. This code provides all the information necessary to obtain the correct replacement for a defective or damaged part. To facilitate ready identification the code found on a typical connector (as shown in figure 11.22) is explained as follows:

a. The letters AN indicate the connector was made to a government standard

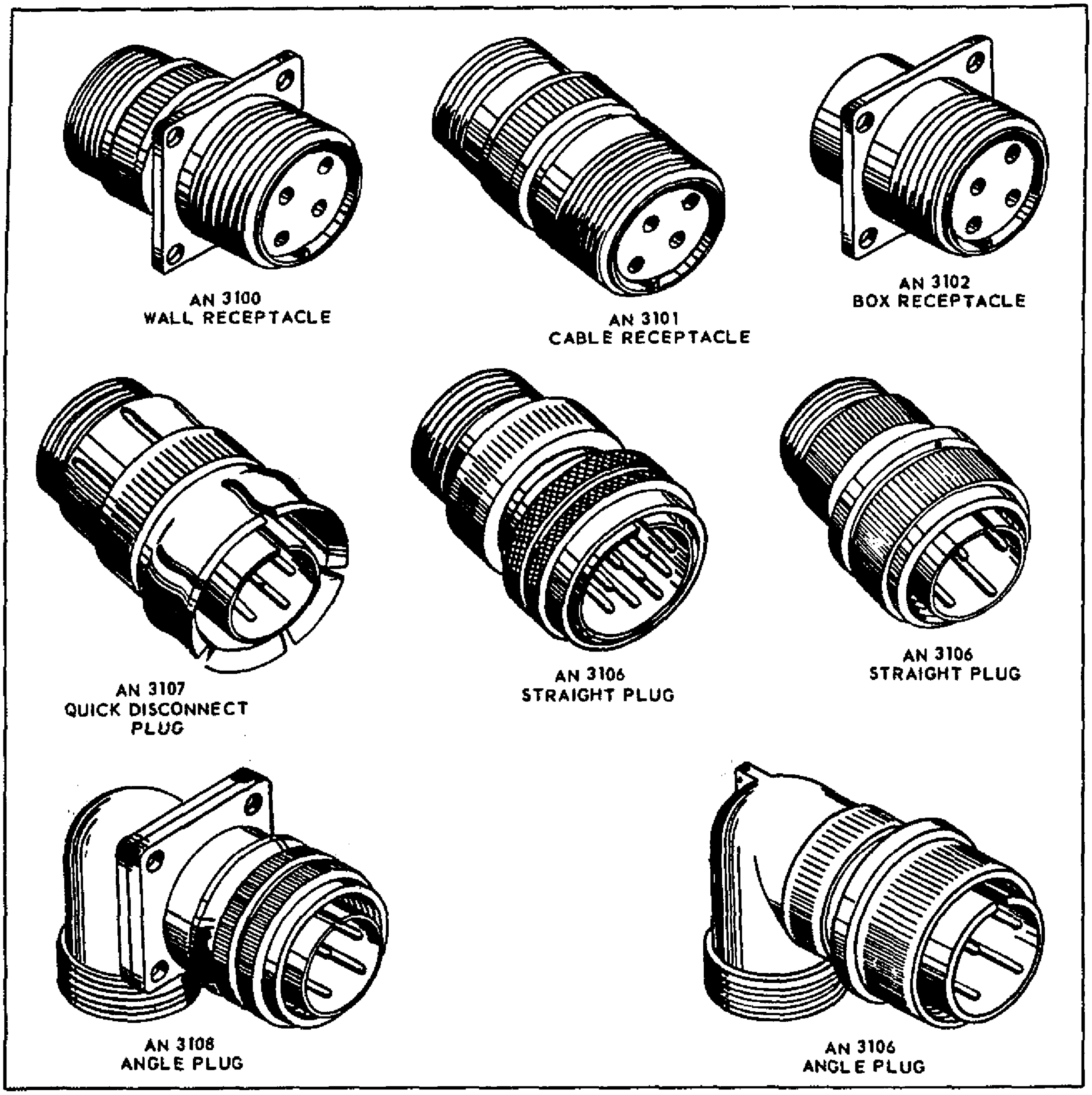


FIGURE 11.20.—AN connectors.

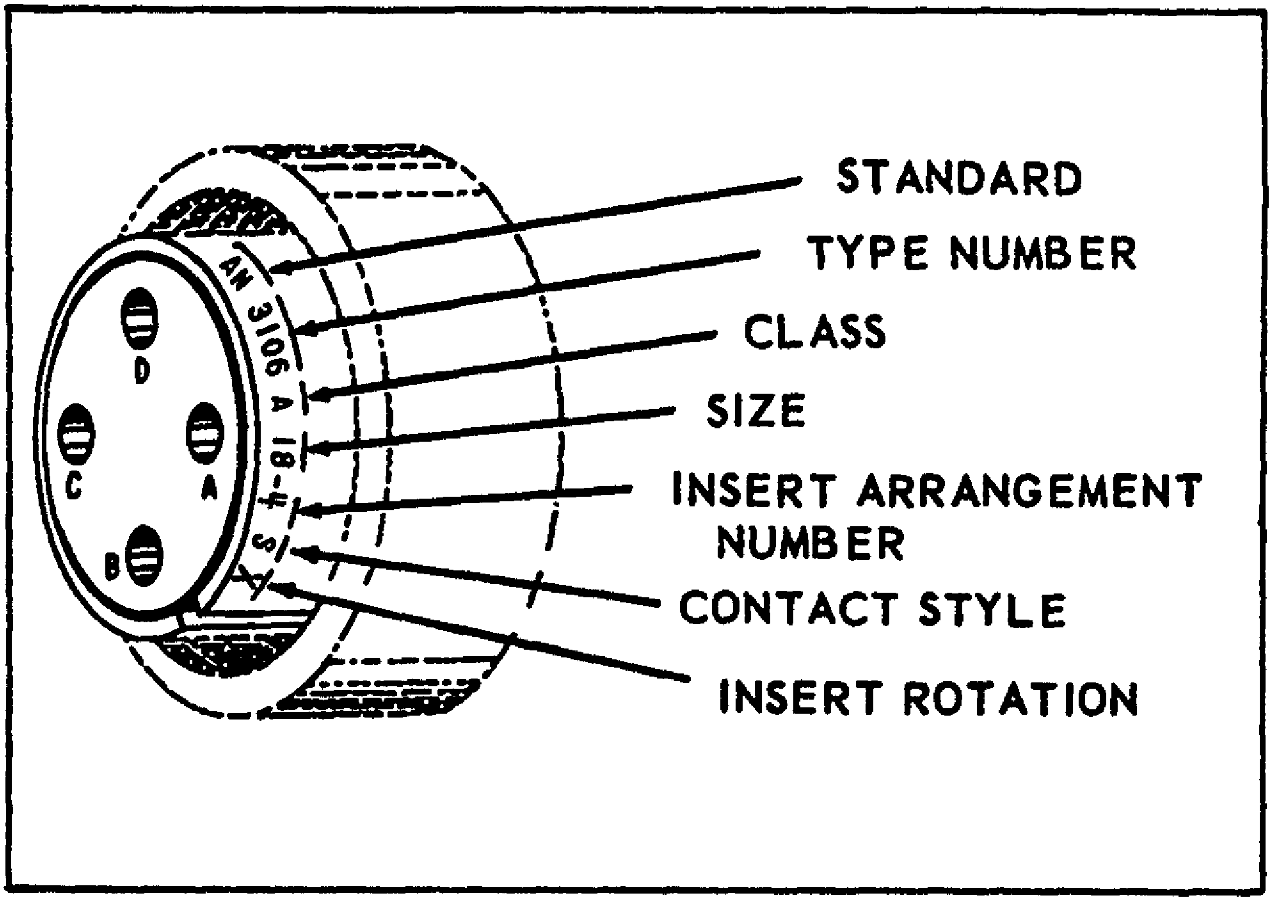


FIGURE 11.22.—AN connector marking.

e. Number 4 indicates a certain arrangement of contacts; however, this number does not indicate the number of contacts. Manufacturers of connectors provide charts giving diagrams of the various contact arrangements.

f. Letter(s) indicates contact style. This letter may be either a (P) or (S) which indicates whether the contacts are pins or sockets.

g. A letter may or may not follow the contact ture connector, rectangular shell connector, connectors with short body shells or of split shell construction used in applications where potting is required.

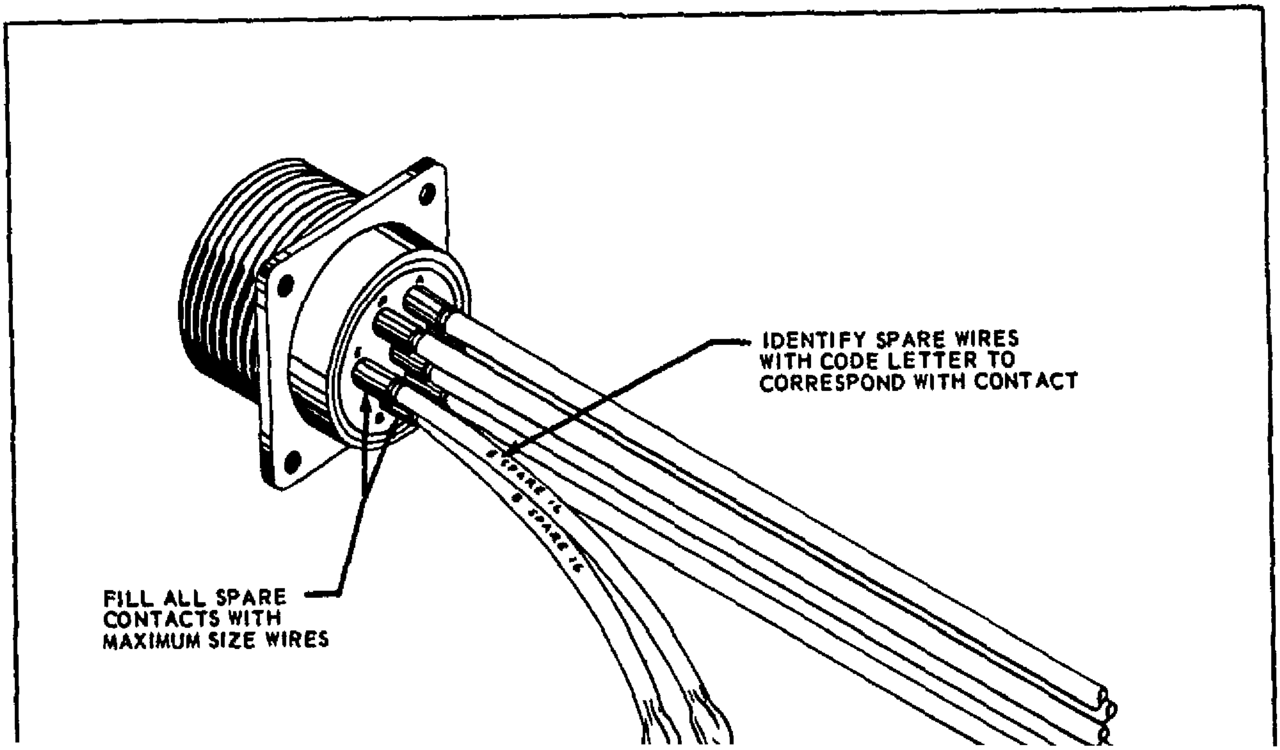
482. POTTING COMPOUNDS. Potting compounds meeting Specification MIL-S-8516 are prepared in ready-to-use tube-type dispensers, or in the unmixed state consisting of the base compound and accelerator packed in paired to the base compound and includes the time expended during the mixing and application processes. Mixed compounds that are not to be used immediately must be cooled and thawed quickly to avoid wasting the short working life. Chilled compounds should be thawed by blowing compressed air over the outside of the container. Normally the compound will be ready for use in 5 to 10 minutes.

CAUTION

Do not use heat or blow compressed air into the container when restoring to working temperature.

483. POTTING CONNECTORS. Connectors that have been potted primarily offer protection against concentration of moisture in the connectors. A secondary benefit of potting is the reduced possibility of breakage between the contact and wire due to vibration.

Solder wires to all contacts of the connector *prior to the application of the potting compound*. Wires that are not to be used should be long enough to permit splicing at a later date. Identify the wires not used as shown in figure 11.23 and cap the cut ends with potting compound prior to securing to the wire bundle. After the soldering operation, scrape off the resin and wash the connector with clean stoddard solvent, brushing vigorously. Rinse the areas to be potted with methylene chloride and complete the potting operation within 2 hours after this cleaning. Allow the potting com-



pound to cure for 24 hours at a room temperature of 70° to 75° F. or carefully place in a drying oven at 100° F. for 3 to 4 hours.

484. THROUGH BOLTS. Through bolts are sometimes used to make feeder connections through bulkheads, fuselage skin, or firewalls. Mount through bolts in such a manner that they are mechanically secure and independent of the terminal nuts. Provide sufficient cross section to insure adequate conductivity against overheating and enough contact area to minimize voltage drop. Mechanically secure such bolts independent of the terminal mounting nuts, taking particular care to avoid dissimilar metals among the terminal hardware. During inspection, pay particular attention to the condition of the insulator plate or spacer and the insulating boot that covers the completed terminal assembly.

485. TERMINAL STRIPS. Wires are usually joined at terminal strips. Use a terminal strip fitted with barriers to prevent the terminals on adjacent studs from contacting each other. Studs must be anchored against rotation. When more than four terminals are to be connected together, use two or more adjacent studs and mount a small metal bus across the studs. In all cases, the current is to be carried by the terminal contact surfaces and not by the stud itself. Replace defective studs with studs of the same size and material as terminal strip studs of the smaller sizes may shear due to overtightening the nut. Assure that the replacement stud is securely mounted in the terminal strip and that the terminal securing nut is tight. Mount terminal strips in such a manner that loose metallic objects cannot fall across the terminals or studs. It is good practice to provide at least one spare stud for future circuit expansion, or in case a stud is broken.

486.–496. RESERVED.

Section 6. CONDUITS

497. GENERAL. Conduit is available in metallic and nonmetallic materials and in both rigid and flexible form. Primarily, its purpose is for mechanical protection of the wire within, although some radio interference shielding may be provided.

498. SIZE OF CONDUIT. When selecting conduit size for a specific wire bundle application, it is common practice to allow for ease in maintenance and possible future circuit expansion by specifying the conduit inner diameter about 25 percent larger than the maximum diameter of the wire bundle. The nominal diameter of rigid metallic conduit is the O.D. Therefore, to obtain the I.D., subtract twice the tube wall thickness.

499. CONDUIT FITTINGS. From the abrasion standpoint, conduit is vulnerable at its ends. Affix suitable fittings to conduit ends in such manner that a smooth surface comes in contact with wire within. When fittings are not used, flare the end of the conduit to prevent wire insulation damage. Support the conduit using clamps along the conduit run.

500. CONDUIT INSTALLATION. Many of the past troubles with conduit can be avoided by proper attention to the following details:

a. Do not locate conduit where passengers or maintenance personnel might use it as a handhold or footstep.

b. Provide drainholes at the lowest point in a conduit run. Drilling burrs should be carefully removed.

c. Support conduit to prevent chafing against structure and to avoid stressing its end fittings.

501. RIGID CONDUIT. Repair conduit sections that have been damaged to preclude injury to the wires or wire bundle which may consume as much as 80 percent of the tube area. Minimum acceptable tube bend radii for rigid conduit is shown in figure 11.24. Kinked or wrinkled bends in rigid conduits are not considered acceptable. Tubing bends that have been flattened into an ellipse and the minor diameter is less than 75 percent of the nominal tubing diameter is not considered satisfactory because the tube area will have been reduced at least 10 percent. Carefully deburr tubing that has been formed and cut to final length to prevent wire insulation damage. When installing replacement tube sections with fittings at both ends, exercise care to eliminate mechanical strain.

502. FLEXIBLE CONDUIT. Flexible aluminum conduit conforming to Specification MIL-C-6136 is available in two types; Type I, Bare Flexible Conduit, and Type II, Rubber Covered Flexible Conduit. Flexible brass conduit conforming to Specification MIL-C-7931 is available and normally used instead of flexible aluminum where necessary to minimize radio interference. Flexible conduit may be used where it is impractical to use rigid conduit such as areas that have

Nominal tube O.D.	*Minimum bend radii (inches)*
1/8	3/8
3/16	7/16
1/4	9/16
3/8	15/16
1/2	1 1/4
5/8	1 1/2
3/4	1 3/4
1	3
1 1/4	3 3/4
1 1/2	5
1 3/4	7
2	8

FIGURE 11.24.—Bend radii for rigid conduit.

motion between conduit ends or where complex bends are necessary. The use of transparent adhesive tape is recommended when cutting flexible tubing with a hacksaw to minimize fraying of the braid. Center the tape over the cut reference mark and saw through the tape. After cutting the flexible conduit, remove the transparent tape, trim the frayed ends of the braid, remove burrs from inside the conduit, and install coupling nut and ferrule. Minimum acceptable bending radii for flexible conduit is shown in figure 11.25.

FIGURE 11.25.—Minimum bending radii for flexible aluminum or brass conduit.

Nominal I.D. of conduit (inches)	*Minimum bending radius inside (inches)*
3/16	2¼
¼	2¾
⅜	3¾
½	3¾
⅝	3¾
¾	4¼
1	5¾
1¼	8
1½	8¼
1¾	9
2	9¾
2½	10

503.-513. RESERVED.

Section 7. ROUTING, TYING, LACING, AND CLAMPING

514. GENERAL. Route and support aircraft wiring and conduits to prevent relative movement within the aircraft and provide protection against chafing between wires or other objects. Provide extra protection where wires or wire bundles may be subjected to rough handling. Soft insulation tubing is not regarded as satisfactory mechanical protection against abrasion or considered a substitute for proper clamping or tying. Secure all wiring so it is electrically and mechanically sound and neat in appearance.

515. WIRE BEND RADII. A wire bundle consists of a quantity of wires fastened or secured together—all traveling in the same direction. Wire bundles may consist of two or more groups of wires. It is often advantageous to have a number of wire groups individually tied within the wire bundle for ease of identity at a later date, as shown in figure 11.26. To improve the appearance and to minimize the possibility of insulation abrasion, comb wire groups and bundles so the wires lie parallel to each other. A combing tool similar to that shown in figure 11.27 may be made from any suitable insulating material, taking care to assure all edges are rounded to protect the wire insulation. Bends in wire groups or bundles should not be less than 10 times the outside diameter of the wire group or bundle. However, a bend 3 times the diameter is acceptable to facilitate connections to terminal strips, provided the wire group or bundle is supported at each end of the bend.

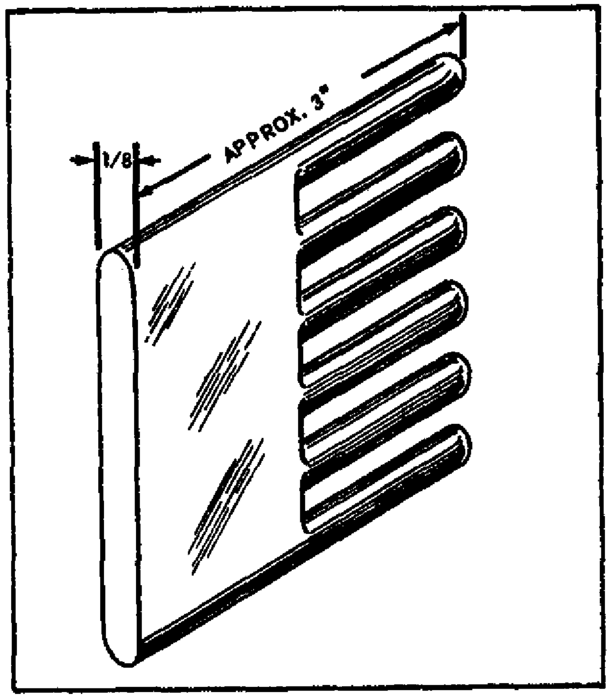


FIGURE 11.27.—Comb for straightening wires in bundles.

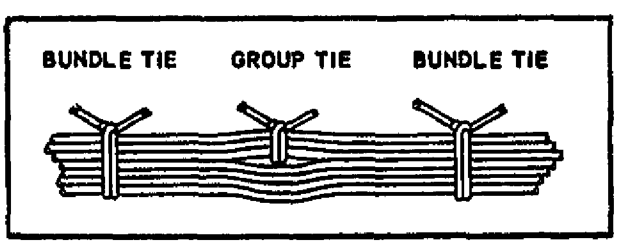


FIGURE 11.26.—Group and bundle ties.

516. SLACK. Normally, wire groups or bundles should not exceed 1/2 inch deflection between support points, as shown in figure 11.28. This measurement may be exceeded provided there is no possibility of the wire group or bundle touching a surface which may cause abrasion.

a. Provide sufficient slack at each end to:

(1) Permit replacement of terminals;

(2) Prevent mechanical strain on wires;

(3) Permit shifting of equipment for maintenance purposes.

517. ROUTING WIRES. In the process of accomplishing an aircraft repair, it is often neces-

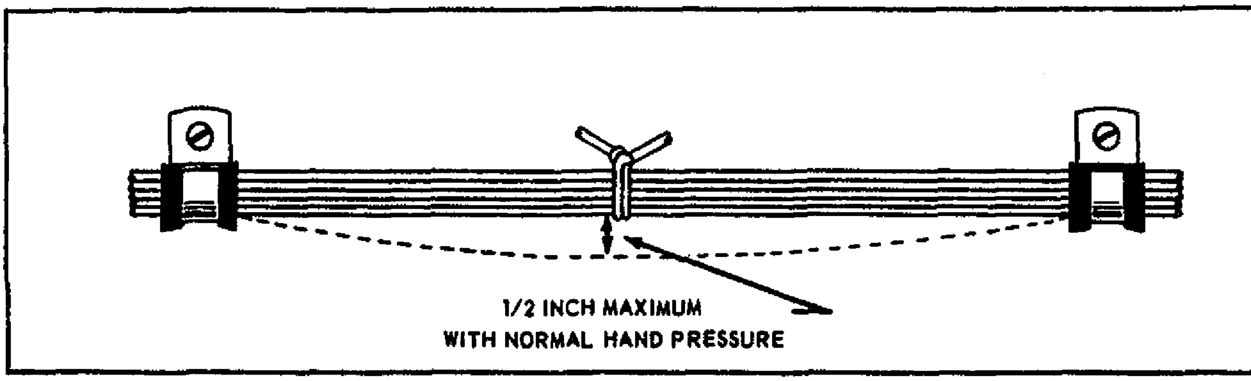


FIGURE 11.28.—Slack between supports.

sary or desirable to reroute a group or bundle of wire. When it is necessary to deviate from the routing used by the manufacturer, consider the following:

a. *Chafing.* Protect wires or wire groups against chafing or abrasion where contact with other wires or sharp surfaces would damage the insulation. When a wire bundle passes through a hole in a bulkhead, support as shown in figure 11.9. Insert a grommet if a wire passes within 1/4 inch of the hole edge, as shown in figure 11.10.

b. *Protection Against Battery Acids, Solvents, and Fluids.* It is not advisable to route wires below a battery or closer than 6 inches from the bilge of the fuselage. Protect wires that will be exposed to damage from fluids by an outer sleeving of plastic tubing, as shown in figure 11.29. Extend the plastic tubing well beyond the area of exposure and provide a 1/8-inch drainhole at the lowest point. Assure the wire insulation is not damaged when cutting the hole in the plastic. Frequently inspect wires exposed to battery acid or fluids and replace when the insulation jacket shows signs of discoloration or saturation by fluids.

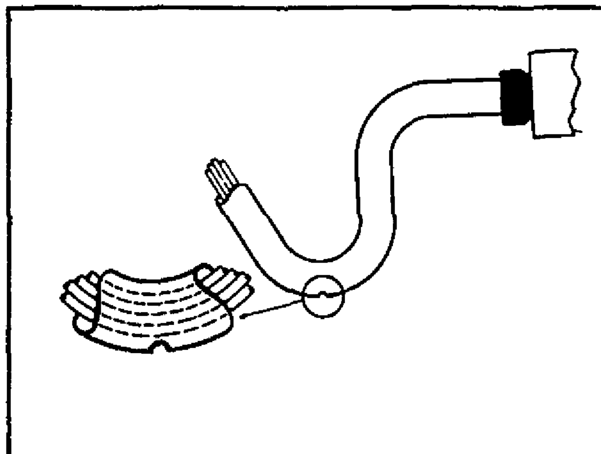


FIGURE 11.29.—Drainage hole in low point of tubing.

c. *Protection in Wheel Wells and Landing Gear Areas.* Wires located on landing gear and in the wheel well area can be exposed to many hazardous conditions if not suitably protected. Encase all wiring attached to a landing gear or located in the wheel well areas in conduit or protect by sleeves of flexible tubing and secure to prevent relative movement. Where wire bundles pass flex points, there should be no strain on attachments or excessive slack when parts are fully extended or retracted. Inspect the wiring and protective tubing frequently and replace at the first sign of wear.

d. *Protection Against Personnel and Cargo.* Install wiring so the structure affords protection against its use as a handhold and damage from cargo. Where the structure does not afford adequate protection, use conduit or provide a suitable mechanical guard.

e. *Protection Against High Temperature.* Wire insulation deteriorates rapidly when subjected to high temperatures. Insulate wires that must be run through hot areas with a material such as asbestos, fiberglass or equivalent high temperature-resistant product. Wherever possible, keep wires separated from high-temperature equipment; and when replacing wires, do not use low-temperature insulated wires to replace high-temperature insulated wires.

f. *Wiring Precautions*. Maintain a minimum clearance of 3 inches from any control cable. When this clearance cannot be maintained, install a mechanical guard. When wiring is run parallel to combustible fluid or oxygen lines, maintain as much separation as possible. Locate wires above or on a level with the fluid lines and, wherever possible, maintain a minimum separation of 6 inches. Where the separation is 1/2 inch to 2 inches, install clamps as shown in figure 11.30 to maintain separation. These clamps are not to be used as a means of supporting the wire bundle. Install additional clamps to support the wire bundle and fasten the clamps to the same structure used to support the fluid line to prevent relative motion. Maintain a minimum separation of at least 1/2 inch between plumbing lines and any wire.

518. CLAMPING. Support wires and wire bundles using clamps meeting Specification MS-21919. Exercise care to assure the wire is not pinched when installing clamps to support electrical wiring as shown in figures 11.31 through 11.34. Whenever practical, rest the back of the clamp against a structural member. Install clamps in such manner that the electrical wires do not come in contact with other parts of the aircraft when subjected to vibration. Leave sufficient slack between the last clamp and the electrical equipment to prevent strain at the terminal and to minimize adverse effects on shockmounted equipment. Where wires or wire bundles pass through bulkheads or other structural members, provide a grommet or suitable clamp to prevent abrasion.

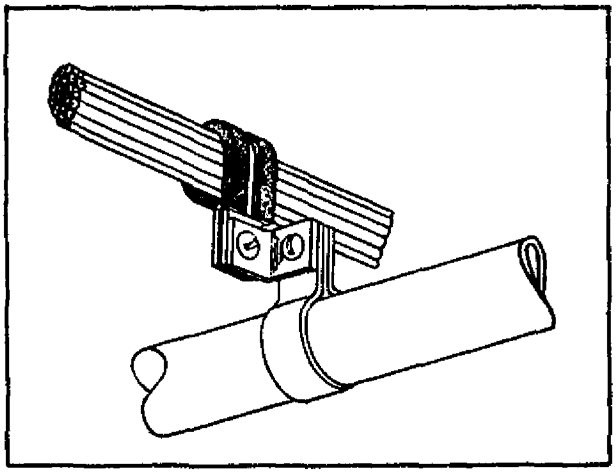


FIGURE 11.30.—Separation of wires from plumbing lines.

519. TIES AND LACING. Ties, lacing, and straps are used to secure wire groups or bundles, to provide ease of maintenance, inspection, and installation. Cord meeting Specification MIL-C-5649 and twine meeting Specification JAM-T-713 are suitable for lacing or tying wires. In lieu of applying ties, straps meeting Specification MS-17821 or MS-17822 may be used in areas where the temperature does not exceed 120° C. or where the wiring can be damaged by operating units if the strap fails.

a. *Lacing*. Lace wire groups or bundles inside junction boxes or other enclosures. Single cord-lacing method shown in figure 11.35 may be used for wire groups or bundles 1 inch in diameter or less. The recommended knot for starting the single cord-lacing method is a clove hitch secured by a double-looped overhand knot as shown in step "a" of figure 11.35. Use the double cord-lacing method on wire bundles 1 inch in diameter or larger as shown in figure 11.36. When using the double cord-lacing method, employ a bowline on a bight as the starting knot. Reference step "a" of figure 11.36.

b. *Tying*. Use wire group or bundle ties where the supports for the wire are more than 12 inches apart. A tie consists of a clove hitch around the wire group or bundle secured by a square knot as shown in figure 11.37.

520.-530. RESERVED.

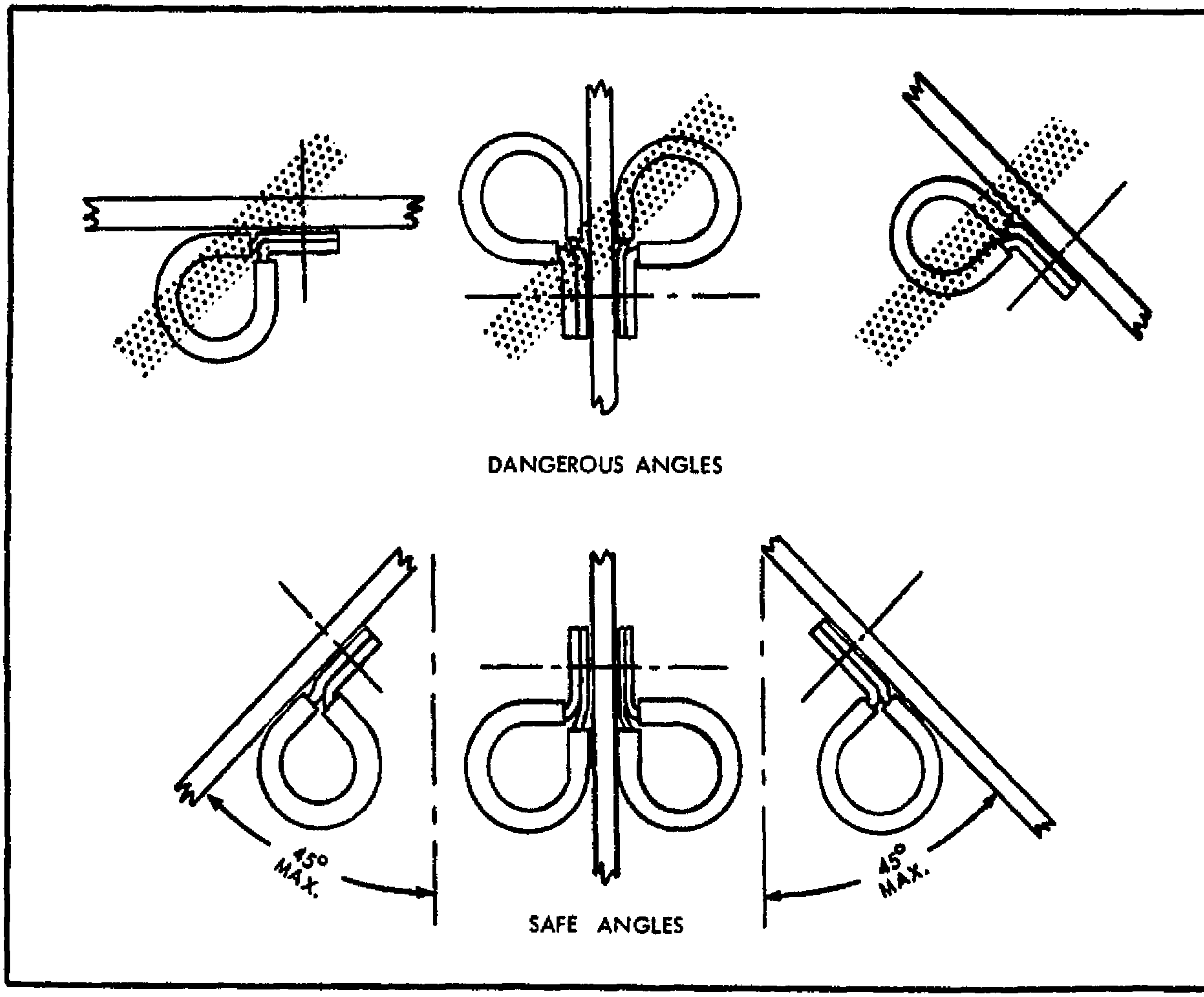


FIGURE 11.81.—Safe angle for cable clamps.

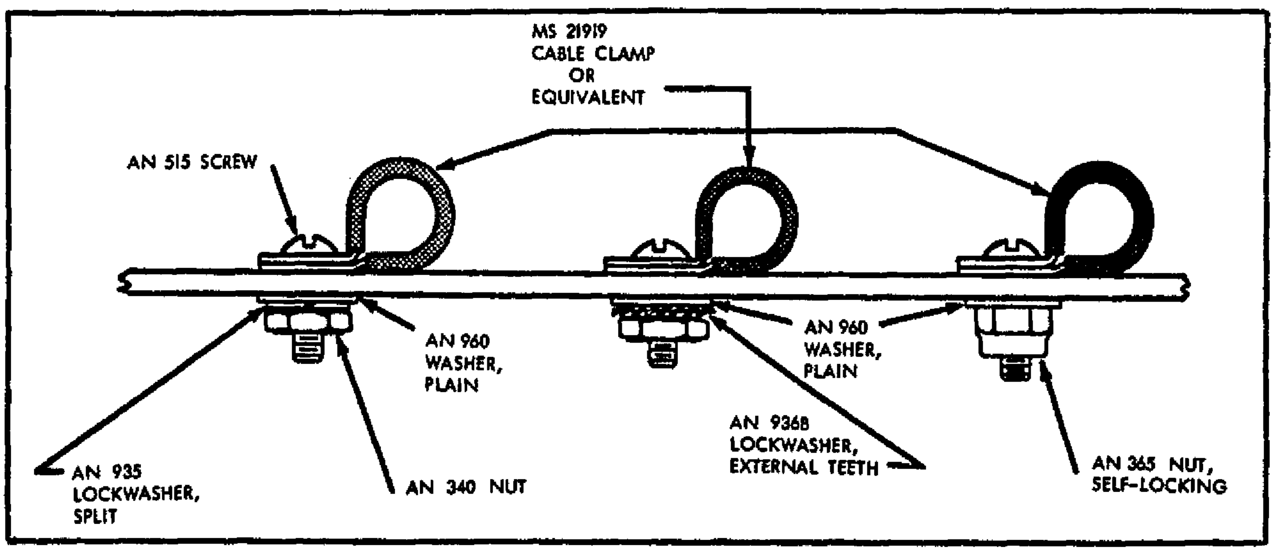


FIGURE 11.82.—Typical mounting hardware for MS-2919 cable clamps.

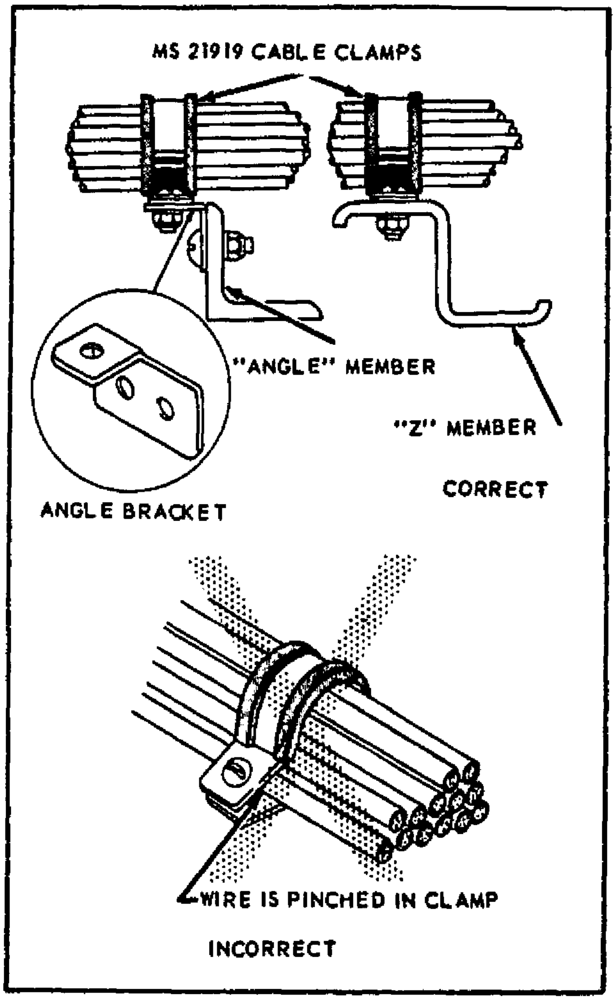


FIGURE 11.83.—Installing cable clamp to structure.

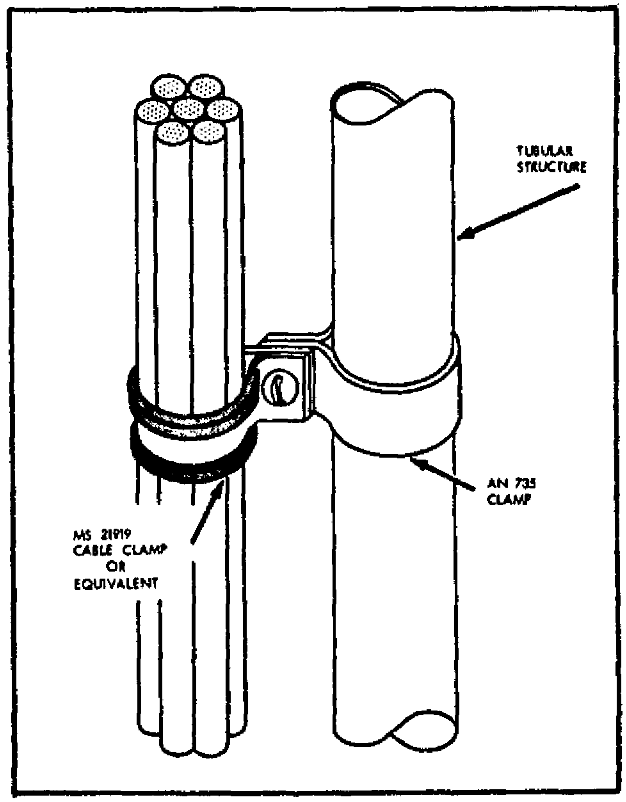


FIGURE 11.84.—Installing cable clamps to tubular structure.

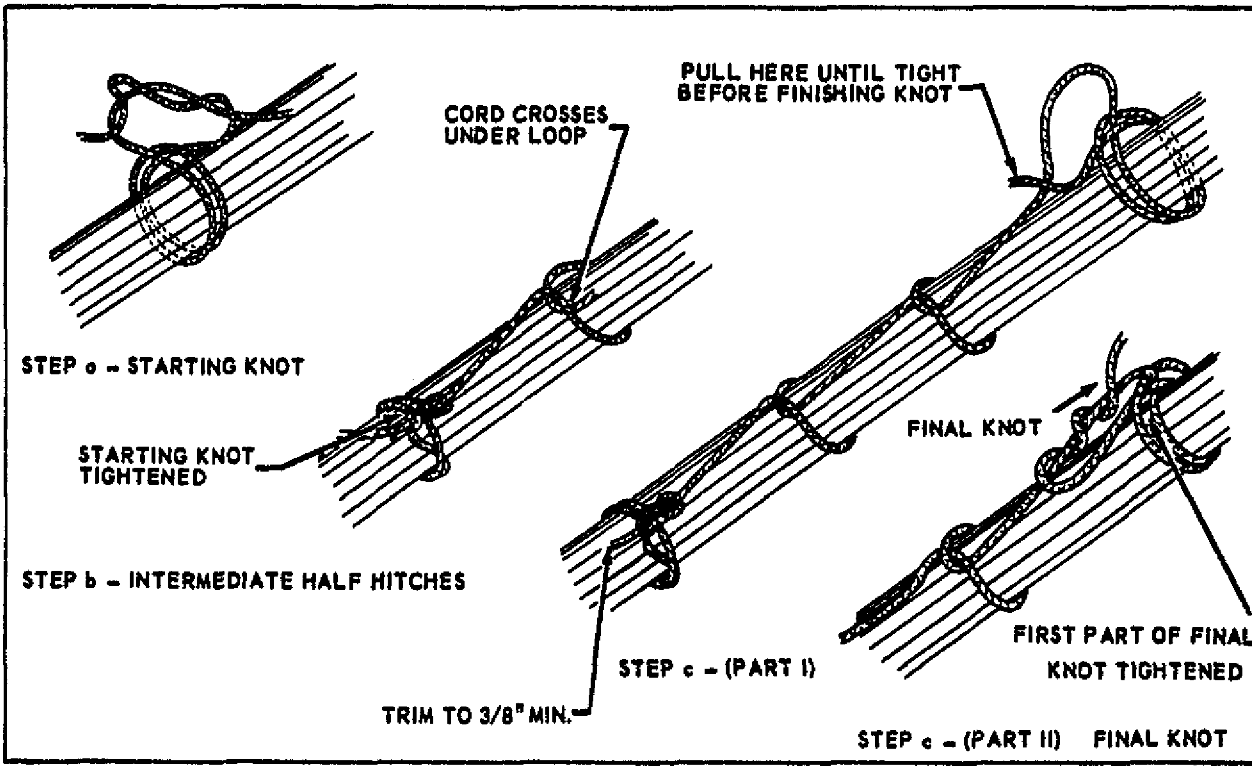


FIGURE 11.35.—Single cord lacing.

Section 8. STORAGE BATTERIES

531. GENERAL. Lead-acid and nickel-cadmium batteries are the two most common types used in aircraft. These batteries possess different characteristics and, therefore, should be maintained in accordance with the manufacturer's recommendations. Storage batteries are usually identified by the material used for the plates.

532. BATTERY OVERHEAT FAILURE. Operation of storage batteries beyond their ambient temperature or charging voltage limits will result in excessive cell temperatures leading to electrolyte boiling, rapid deterioration of the cell, and finally battery failure. The relationship between maximum charging voltage and the number of cells in the battery is also significant, since this will determine (for a given ambient temperature and state of charge) the rate at which energy is absorbed as heat within the battery. For lead-acid batteries, the voltage per cell should not exceed 2.35 volts. In the case of nickel-cadmium batteries, the charging voltage limit varies with design and construction with values of 1.4 and 1.5 volts per cell found satisfactory. In all cases, follow the recommendations of the battery manufacturer as to the proper charging voltage limits.

533. BATTERY FREEZING. Lead-acid batteries exposed to cold temperatures are subject to plate damage due to freezing of the electrolyte. The freezing point of electrolyte for various specific gravity levels is shown in figure 11.38. To prevent freeze damage, maintain the specific gravity at a reasonably high level, bearing in mind that lead-acid batteries are subject to a constant discharge due to the internal chemical action. Nickel-cadmium battery electrolyte is not as susceptible to freezing because no appreciable chemical change takes place between the charged and discharged state. However, the electrolyte will freeze at approximately minus 75° F.

FIGURE 11.38.—Lead-acid battery electrolyte freezing points.

Specific gravity	*Freeze point*	
	C.	*F.*
1.300	−70	−95
1.275	−62	−80
1.250	−52	−62
1.225	−37	−35
1.200	−26	−16
1.175	−20	− 4
1.150	−15	+ 5
1.125	−10	+13
1.100	− 8	+19

534. TEMPERATURE CORRECTION. U.S. manufactured lead-acid batteries are considered fully charged when the specific gravity reading is between 1.275 and 1.300. A 1/3 discharged battery reads about 1.240 and a 2/3 discharged battery will show a specific gravity reading of about 1.200 when tested by a hydrometer. However, to determine precise specific gravity readings, a temperature correction should be applied to the hydrometer indication as shown in figure 11.39. As an example, the hydrometer reading is 1.260; the temperature of the electrolyte is 40° F. or 16 points below the norm established for battery electrolyte. Therefore, the corrected specific gravity reading of the electrolyte is 1.244. Take care to assure the electrolyte is returned to the cell from which it was extracted. When a specific gravity difference of 0.050 or more eixsts between cells of a battery, the battery is approaching the end of its useful life and replacement should be considered. Electrolyte level may be adjusted by the addition of distilled water.

535. CHECKING LEAD-ACID BATTERIES. Use a hydrometer to determine the specific gravity of the battery electrolyte. The specific gravity is the weight of the electrolyte as compared to the weight of pure water.

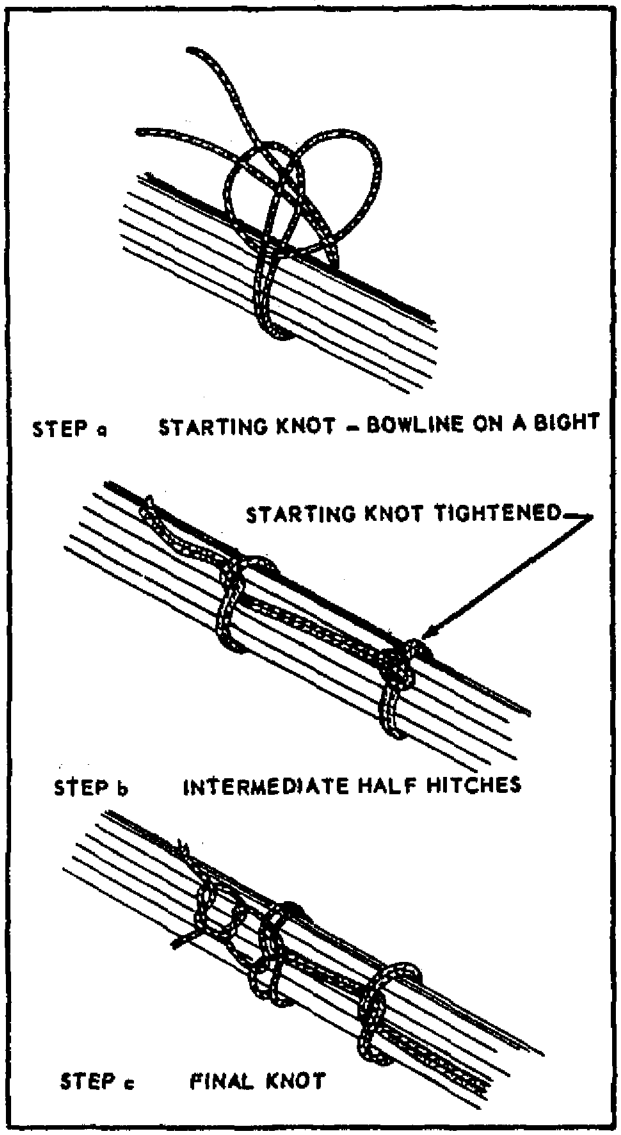


FIGURE 11.36.—Double cord lacing.

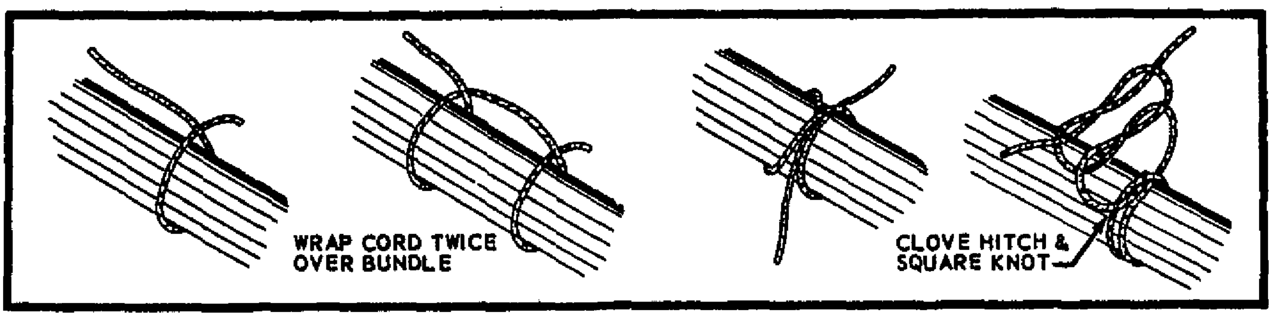


FIGURE 11.37.—Making ties.

FIGURE 11.39.—Sulfuric acid temperature correction.

Electrolyte temperature		Points to be subtracted or added to specific gravity readings
°C.	°F.	
60	140	+24
55	130	+20
49	120	+16
43	110	+12
38	100	+ 8
33	90	+ 4
27	80	0
23	70	− 4
15	60	− 8
10	50	−12
5	40	−16
− 2	30	−20
− 7	20	−24
−13	10	−28
−18	0	−32
−23	−10	−36
−28	−20	−40
−35	−30	−44

536. CHECKING NICKEL-CADMIUM BATTERIES. The state of charge of a nickel-cadmium battery cannot be determined by measuring the specific gravity of the electrolyte with a hydrometer as the electrolyte specific gravity does not change with the state of charge. The only accurate way to determine the state of charge of a nickel-cadmium battery is by a measured discharge. After the battery has been fully charged and allowed to stand for at least 2 hours, the fluid level may be adjusted, if necessary, using distilled or demineralized water. Because the fluid level varies with the state of charge, water should never be added while the battery is installed in the aircraft. Overfilling the battery will result in electrolyte spewage during charging. This will cause corrosive effects on the cell links, self discharge of the battery, dilution of the electrolyte density, and possible blockage of the cell vents and eventual cell rupture.

CAUTION

Servicing equipment used for lead-acid batteries is not to be used for servicing nickel-cadmium batteries as acid is detrimental to the proper functioning of a nickel-cadmium battery.

537. ELECTROLYTE CORROSION. Electrolyte spillage or leakage may result in serious corrosion of the nearby structure or control elements as both sulfuric acid and potassium hydroxide are actively corrosive. Electrolyte may be spilled during ground servicing, leaked when cell case rupture occurs, or sprayed from cell vents due to excessive charging rates. If the battery is not case enclosed, properly treat structural parts near the battery which may be affected by acid fumes. Treat all case and drain surfaces which have been affected by electrolyte with a solution of sodium bicarbonate (for acid electrolyte) or boric acid, vinegar, or a 3 percent solution of acetic acid for potassium hydroxide electrolyte.

CAUTION

Serious burns will result if the electrolyte comes in contact with any part of the body. Use rubber gloves, rubber apron, and protective goggles when handling electrolyte. If sulphuric acid is splashed on the body neutralize with a solution of baking soda and water, and shower or flush the affected area with water. For the eyes, use an eye fountain and flush with an abundance of water.

If potassium hydroxide contacts the skin, neutralize with 3 percent acetic acid, vinegar, or lemon juice, and wash with water.

For the eyes, wash with a weak solution of boric acid or a weak solution of vinegar and flush with water.

538. NOXIOUS FUMES. When charging rates are excessive, the electrolyte may boil to the extent that fumes containing droplets of the electrolyte are emitted through the cell vents. These fumes from lead-acid batteries may become noxious to the crewmembers and passengers; therefore, thoroughly check the venting system. Nickel-cadmium batteries will emit gas near the end of the charging process and during overcharge. The battery vent system in the aircraft should have sufficient air flow to prevent this explosive mixture from accumulating. It is often advantageous to install a jar in the battery vent discharge system serviced with an agent to neutralize the corrosive effect of battery vapors.

539. INSTALLATION PRACTICES.

a. Clean the external surface of the battery prior to installation in the aircraft.

b. When replacing lead-acid batteries with nickel-cadmium batteries, neutralize the battery box or compartment and thoroughly flush with clear water and dry. Acid residue can be detrimental to the proper functioning of a nickel-cadmium battery.

c. Check the condition of the vent system.

d. When installing batteries in an aircraft, exercise care to prevent inadvertent shorting of the battery terminals. Serious damage to the aircraft structure can be sustained by the resultant high discharge of electrical energy. This condition may normally be avoided by insulating the terminal posts during the installation process.

e. Assure the battery holddown devices are secure but not so tight as to exert excessive pressure which may cause the battery to buckle causing internal shorting of the battery.

f. If a quick disconnect type of battery connector which prohibits crossing the battery lead is not employed, assure that the aircraft wiring is connected to the proper battery terminal. Reverse polarity in an electrical system can seriously damage a battery. Assure battery cable connections are tight to prevent arcing or a high resistance connection.

540.-552. RESERVED.

Chapter 12. PROPELLERS, ROTORS, AND ASSOCIATED EQUIPMENT

Section 1. INSPECTION OF PROPELLERS

553. WOOD OR COMPOSITION PROPELLERS AND BLADES. Due to the nature of the wood itself, it is necessary that wood propellers and blades be inspected frequently to assure continued airworthiness. Inspect for such defects as cracks, bruises, scars, warpage, evidence of glue failure and separated laminations, sections broken off, and defects in the finish. Composition blades must be handled with the same consideration as wood blades.

a. *The fixed-pitch propellers* are normally removed from the engine at engine overhaul periods. Whenever the propeller is removed, visually inspect the rear surface for any indication of cracks. When any indications are found, disassemble the metal hub from the propeller. Inspect the bolts for wear and cracks at the head and threads and, if cracked or worn, replace with new AN bolts. Inspect for elongated boltholes, enlarged hub bore, and check for cracks inside of bore or anywhere on the propeller. Repair propellers found with any of these defects. If no defects are found, the propeller may be reinstalled on the engine. Prior to installation, touch up with varnish all places where the finish is worn thin, scratched, or nicked. Track and balance the propeller, and coat the hub bore and boltholes with some moisture preventive such as asphalt varnish. In case the hub flange is integral with the crankshaft of the engine, final track the propeller after it is installed on the engine. In all cases where a separate metal hub is used, accomplish final balance and track with the hub installed in the propeller.

b. *On new fixed-pitch propeller* installations, inspect bolts for tightness after first flight and after the first 25 hours of flying. Thereafter, inspect and check the bolts for tightness at least every 50 hours. No definite time interval can be specified, since bolt tightness is affected by changes in the wood caused by the moisture content in the air where the airplane is flown and stored. During wet weather, some moisture is apt to enter the propeller wood through the drilled holes in the hub. The wood swells, but since expansion is limited by the bolts extending between the two flanges, some of the wood fibers become crushed. Later, when the propeller dries out during dry weather or due to heat from the engine, a certain amount of propeller hub shrinkage takes place, and the wood no longer completely fills the space between the two hub flanges. Accordingly, the hub bolts become loose.

c. *In-flight tip failures* may be avoided by frequent inspections of the metal cap and leading edge strip, and the surrounding areas. Inspect for such defects as looseness or slipping, separation of soldered joints, loose screws, loose rivets, breaks, cracks, eroded sections, and corrosion. Inspect for separation between metal leading edge and cap, which would indicate the cap is moving outward in the direction of centrifugal force. This condition is often accompanied by discoloration and loose rivets. Inspect tip for cracks by grasping with hand and slightly twisting about the longitudinal blade centerline and by slightly bending the tip backward and forward. If leading edge and cap have separated, carefully inspect for cracks at this point. Cracks usually start at the leading edge of the blade. A fine line appearing in the fabric or plastic may indicate a crack in the wood.

d. *Examine the wood close to the metal sleeve* of wood blades for cracks extending outward on the blade. These cracks sometimes occur at the threaded ends of the lag screws, and may be an indication of internal cracking of the wood. Check tightness of the lag screws, which attach the metal sleeve to the wood blade, in accordance with the manufacturer's instructions. Inspect and protect the shank areas of composition blades next to the metal sleeve in the same manner as for wood blades.

554. METAL PROPELLERS AND BLADES. Metal propellers and blades are generally susceptible to fatigue failure resulting from concentration of stresses at the bottoms of sharp nicks, cuts, and scratches. It is especially necessary, therefore, to frequently and carefully inspect them for such injuries. Propeller manufacturers have published service bulletins and instructions which prescribe the manner in which these inspections are to be accomplished.

555. LUBRICATION. Inspect controllable pitch propellers frequently to determine that all parts are lubricated properly. It is especially recommended that all lubrication be accomplished at the periods and in the manner specified by the propeller manufacturer.

556.-566. RESERVED.

Section 2. REPAIR OF WOOD AND COMPOSITION PROPELLERS

567. GENERAL. Repair propellers in accordance with the best accepted practices and the latest techniques. Manufacturer's recommendations should in all cases be followed. It is necessary to mark the name of the manufacturer and model designation on the repaired propeller in the event original markings were removed during the repair or refinishing operations.

568. REPAIR OF WOOD PROPELLERS. Carefully examine wood propellers and blades requiring repair to be sure that they can be restored to their original airworthy condition. Refer doubtful cases to the manufacturer. Carefully evaluate propellers damaged to the following extent prior to attempting a repair:

A crack or deep cut across the grain of the wood.

Split blades.

Separated laminations, except the outside laminations of fixed-pitch propellers.

More screw or rivet holes, including holes filled with dowels, than used to attach the metal leading edge strip and tip.

An appreciable warp.

An appreciable portion of wood missing.

A crack, cut, or damage to the metal shank or sleeve of blades.

Broken lag screws which attach the metal sleeve to the blade.

Oversize shaft hole in fixed-pitch propellers.

Cracks between the shaft hole and boltholes.

Cracked internal laminations.

Excessively elongated boltholes.

a. *Fill small cracks* parallel to the grain with glue, thoroughly worked into all portions of the cracks, dried, and then sanded smooth and flush with the surface of the propeller. This also applies to small cuts. Dents or scars which have rough surfaces, or shapes that will hold a filler and will not induce failure, may be filled with a mixture of glue and clean fine sawdust thoroughly worked and packed into the defect, dried, and then sanded smooth and flush with the surface of the propeller. It is very important that all loose or foreign matter be removed from the place to be filled so that a good bond of the glue to the wood is obtained.

b. *Blade Inlays.* Inlays shown in figure 12.1 may be used. Make inlays of the same wood as the propeller blade; i.e., inlay a yellow birch propeller with yellow birch, not with white birch, and as near the same specific gravity as possible. Make repair joints to conform with figure 12.1 for taper of 10:1 from deepest point to feather edge or end of inlay. Measurements are taken along a straight line parallel to the grain or general slope of the surface on thrust and camber face. This rule applies also to the edge repairs. Extend grain of inlays in the same direction as the grain of the propeller laminations. Make inlays using a fishmouth, scarf, or butt joint. The permanency of the joint is in the order named, the fishmouth being preferable. Dovetail-type inlays should not be used. Do not exceed 1 large, 2 medium, or 4 small widely separated inlays per blade. Do not overlap a trailing and a leading edge inlay more than 25 percent, as shown in figure 12.1A. Propeller blades of a thickness ratio of .12 or more may be repaired, provided the cross-grained cut does not exceed 20 percent of the chord in length and the depth of cuts does not exceed 1/8 the blade thickness at the deepest point of damage. Blades with airfoil sections less than .12 thickness ratio may be repaired if the maximum depth of damage does not exceed 1/20 of the blade section thickness at the deepest point of damage. To determine the thickness ratio for a propeller blade, divide the maximum thickness of the airfoil section by the blade chord at the 3/4 radius station.

Example 1.

Given	6″ Chord
	.72 Maximum thickness of airfoil section
Computation	.72 ÷ 6 = .12 thickness ratio

Example shows the blade thickness ratio to be .12; therefore, an inlay ⅛ of blade thickness at the point of damage may be inserted.

Example 2.

Given	4″ Chord
	.36″ Maximum thickness of airfoil section
Computation	.36 ÷ 4 = .09 thickness ratio

Example shows blade thickness ratio to be less than .12; therefore, an inlay 1/20 the blade thickness at the point of damage may be inserted.

c. ***Hub Inlays.*** Inlays in the sides of hubs of fixed-pitched propellers which would exceed in depth a value greater than 5 percent of the difference between the hub and bore diameters are not acceptable. In the portion of the blade where it fairs into the hub, allowable depths for inlays are dependent upon the general proportions. Where the width and thickness are both very large in proportion to the hub and blade, maximum inlay depths of 7 1/2 percent of the section thickness at the inlay are permissible. Where the width and thickness are excessively small, maximum inlay depths of 2 1/2 percent of the section thickness at the center of the inlay are permissible; for propellers over 50 horsepower, cuts 2 1/2 percent deep may be filled with glue and sawdust, while for propellers under 50 horsepower, cuts 5 percent deep may be filled with glue and sawdust.

d. ***Blade Profiling.*** Narrow slivers up to 1/8 inch wide broken from the trailing edge at the wider portions of the blade may be repaired by sandpapering a new trailing edge, removing the least material possible, and fairing in a new trailing edge of smooth contour. Narrow both blades by the same amount. Near the hub or tip, use an inlay which does not exceed, at its greatest depth, 5 percent of the chord.

e. ***Propeller Tip Repairs.*** In order to replace the wood worn away at the end of the metal tipping, remove enough of the metal to make the minimum repair taper 10:1 each way from the deepest point. Due to the convex leading edge of the average propeller, this taper usually works out 8:1. Repairs under the metal tipping must not exceed 7 1/2 percent of the chord for butt or scarf joints, and 10 percent for fishmouth joints, with 3/4 inch maximum depth for any repair. Methods of repairing or replacing propeller blade metal caps or leading edge strips are contained in paragraph 569.

The scarfing of wood tips onto a propeller blade to replace a damaged tip is not considered an acceptable repair. The success of this type of repair is fully dependent upon the strength and quality of the glue joint. Since it is difficult to apply pressure evenly over the glue area, and since no satisfactory means are available for testing the strength of such joints, it is quite possible for defective glue joints to exist and remain undected until failure occurs.

f. ***Lamination Repairs.*** Whenever the glue joint of an outside lamination of fixed-pitch propellers is open, repair the propeller by removing the loose lamination and gluing on a new lamination of kiln dried wood of the same kind as the original lamination. It is not usually economical to attempt to repair separations between other laminations. Repair outside laminations, which have been crushed at the hub due to excessive drawing up of hub bolts, by planing and sanding one hub face smooth, removing a lamination on the other hub face and replacing it with a new lamination, thus building the hub thickness up to the original thickness. It is permissible to replace both outer laminations if necessary and feasible.

g. ***Repair of Elongated Boltholes.*** It is permissible to repair elongated boltholes by the insertion of a steel bushing around each bolt, as illustrated in figure 12.7. Machine the inside diameter of the bushing to fit the bolt snugly, and the outside diameter approximately 1/4 inch larger than the bolt size. Make the bushing approximately 1/2 inch long. Drill the face of the hub with a hole concentric with the bolt-

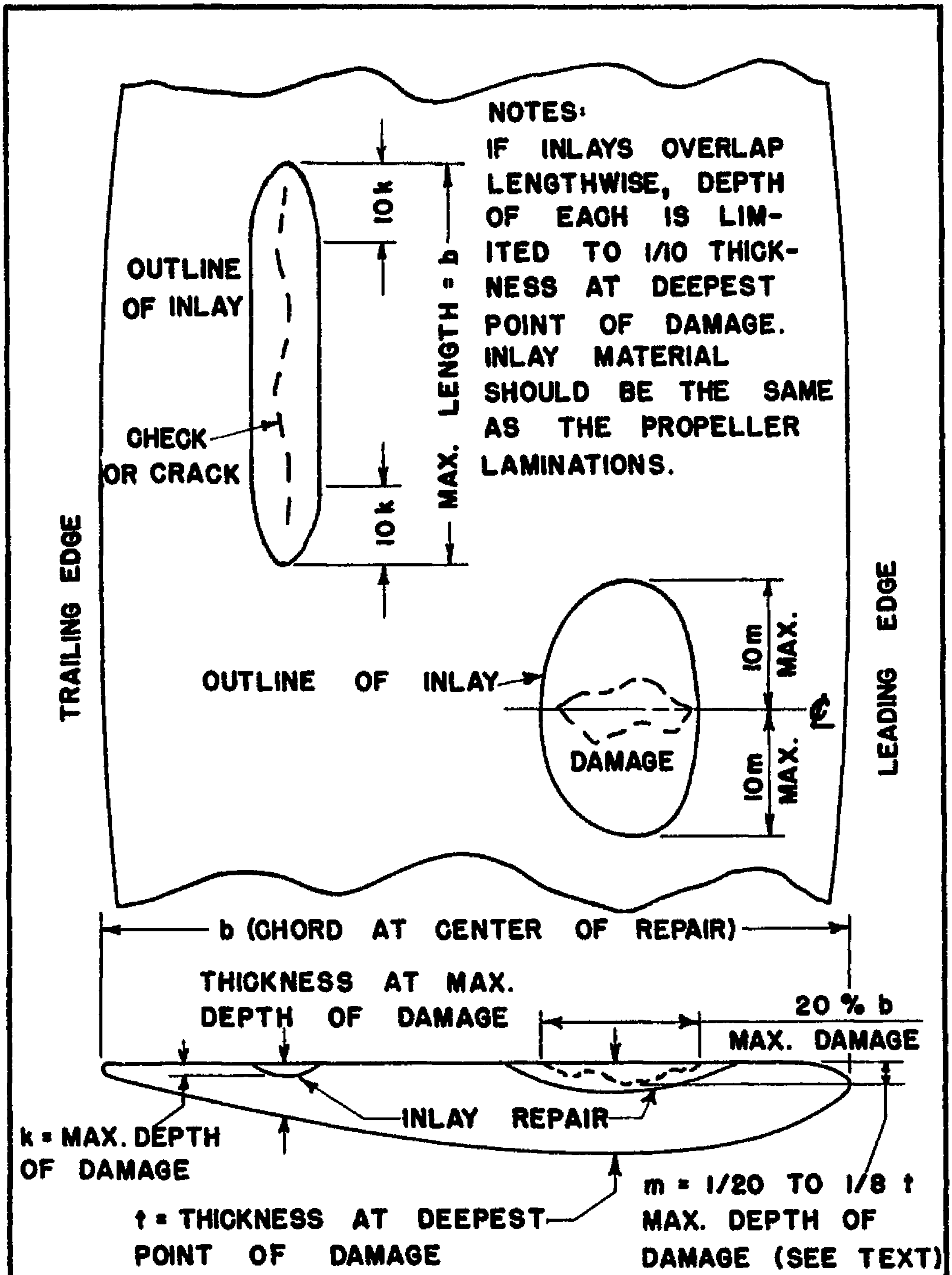


FIGURE 12.1.—Propeller repair by addition of small inlay. (See continuation.)

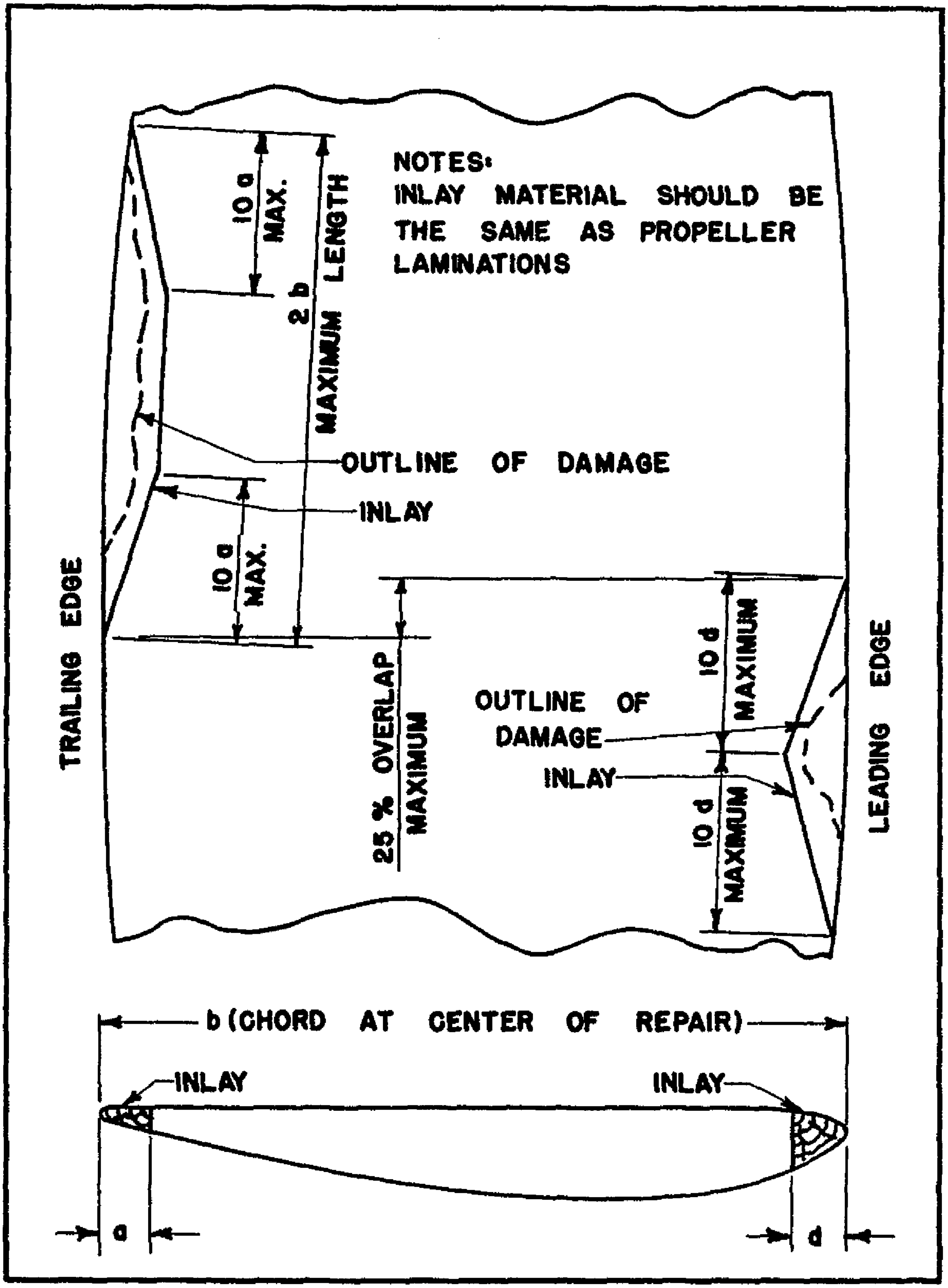


FIGURE 12.1A.—Propeller repair by addition of small inlay—continued.

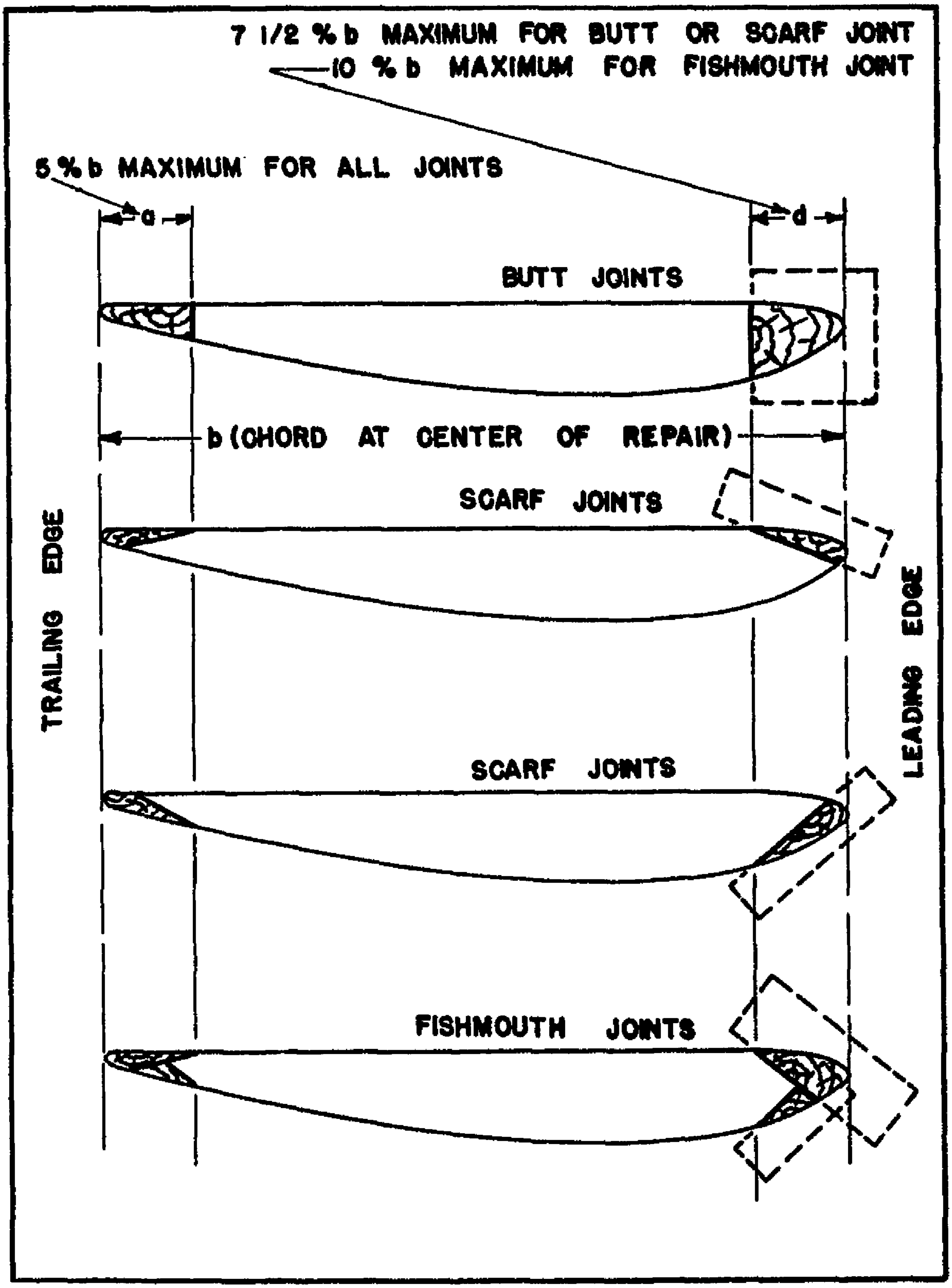


FIGURE 12.1B—Propeller repair by addition of small inlay—continued.

hole and only to a sufficient depth to accommodate the bushing so that it does not protrude above the surface of the wood hub. Do not drive the bushing into the hub. Fit the bushing into the hole in the hub with a clearance not exceeding .005 inch after moistureproofing. Protect the bushing hole from moisture by two coats of aluminum paint, varnish, glue, or other moisture-resistant coating.

h. *Repair of Plastic Covered Propellers and Blades.* Repair small cracks, dents, scratches, and cuts in the plastic of plastic-covered wood propellers and blades by using special repair cement supplied by the manufacturer. Instructions accompany the cements. Polishes and cleaners are available for preserving the gloss finish of varnished or plastic-covered propellers and blades.

569. REPAIR OF COMPOSITION BLADE. Repair composition blades in accordance with the manufacturer's instructions. For repairs to the metal cap and leading edge strip, the methods and procedures discussed in the following paragraphs may be followed:

a. *Replace fabric used to strengthen* the tips of wood blades when it becomes loose or worn through. Launder the fabric (mercerized cotton airplane cloth) to remove all sizing. Cut a piece of fabric to approximate size required to cover both faces of outer portion of blade. Recover the same portion that the original fabric covered. Apply glue to the wood where the fabric is to be put, using a rather thick solution of the glue. Use resorcinol glue when the temperature of the workroom can be kept above 21° C. (70° F.). Put the fabric on glued surface, starting at the leading edge of the thrust face, and work toward the trailing edge. Fold the fabric around the trailing edge over the camber face and toward the leading edge. Make a joint on the leading edge where it will be covered by the metal tipping. As the fabric is put on, smooth it out over the wood to prevent air bubbles or uneven gluing. Fabric must be perfectly flat on the blade. Trim excess fabric off with small scissors. Under no circumstances cut or score fabric with a knife. Allow the glue under the fabric to dry about 6 hours, then brush two coats of nitrate dope on the fabric, allowing one-half hour for drying time. Then sand the fabric lightly and brush a coat of pigment dope over it. Lightly sand the uncovered portion of the wood and apply two coats of a good grade of moisture-resistant varnish, allowing 12 to 16 hours drying time between coats.

b. *Metal Tip Replacement.* Replace tipping when it cannot be properly repaired. Cracks in the narrow necks of metal between pairs of lobes of the tipping are to be expected and are not defects. All other cracks are defects that require repair or elimination by new tipping. If the propeller does not require fabric, apply two coats of varnish to the wood to be covered by the metal tipping. If new fabric has been applied, puncture it with a pointed tool at each screw and rivet hole. Apply varnish, white lead, aluminum paint, etc., to all holes, allowing the wood to absorb as much as it can. With a soft lead pencil, draw guide centerlines on the propeller extending about 4 inches from the centers of old screw and rivet holes. This procedure is followed to insure use of the original screw and rivet holes in the propeller. New holes are not to be drilled. A number of wood propeller tip failures have occurred which have been attributed to the practice of drilling new rivet and/or screw holes in the wood tips when replacing the metal tipping. To avoid continued occurrence of these failures, it is strongly recommended that the manufacturer's procedure be closely adhered to, and any procedure which involves drilling new holes in the wood tip and plugging old holes with dowels is to be discontinued immediately.

(1) Obtain new tips and leading-edge strips, cut to size and formed to the approximate shape of the leading edge of the propeller. These pieces are usually supplied without holes so that the holes can be drilled in them to line up with the old screw and rivet holes in the propeller as stated below. If such material cut to shape is not available, the old tipping can be hammered flat and used as a pattern to lay off a new tip. For this purpose, use a piece of sheet metal of the same material and thickness as the old tip, and remove the burr from the cut edges of this piece.

(2) Lay the cutout flat metal strip over the leading edge, and proceed to bend this metal down over the leading edge of the propeller, being careful that the metal extends an equal width on thrust and camber faces. This can be done by following the impressions of the old tipping lines. Numerous waves will occur in the metal, but these will be eliminated as the work progresses. Obtain several pieces of strong rubber tape, 4 feet long, 1/2 inch wide, and 1/16 inch thick. While forming the metal, hold it in place on the propeller by wrapping the rubber tape around the blade. Start at the tip and work inboard, being careful not to cover the pencil lines placed on the propeller which show the location of the rivet holes. While metal is held in place, tap the leading edge with a rawhide or rubber mallet, using moderate force to make sure the metal is seated against the wood along the nose of the leading edge. Smooth the metal by hammering it with the mallet, backing up the opposite side of the blade with a laminated hardwood bucking block having an iron weight built in the center and a piece of leather fastened to the end on which the propeller bears. The block should measure about 2 by 4 inches. Start at the end of the blade and work toward the hub, moving bucking block so that it is always under the section being hammered. Continue to do this until the metal is well shaped to the profile of the propeller. Check to see that the metal has not moved from its original position. If this happens, remove the rubber tape, reset the metal, and rewrap the rubber tape, thus forming the metal to the leading edge.

(3) With a centerpunch and a hammer, proceed to locate the old screw and rivet holes, using the pencil marks on the blade as a guide. Punch the metal approximately 1/4 inch from the edge. After all holes have been located, remove the metal from the propeller. Drill screw and rivet holes in the metal with a 1/8-inch drill. File off burrs on the inside of the metal. Run the drill through the original rivet holes in the propeller in order to clean them. Cut or saw slots in the metal at the original positions. (Refer to old tipping metal for location of the slots.) Place the metal leading edges on the blades they were formed to fit, and hold them in place with rubber tape. With a centerpunch as large as or slightly larger than the diameter of the screw and rivet heads, proceed to punch metal into the original countersunk holes in the wood so that the screw and rivet heads may be entered to the correct depth (not more than 1/32 inch below the surface of the metal). Use screws and rivets of the appropriate material. Use screws one size larger than were originally in the propeller, and rivets of the solid flat countersunk-head type. Insert screws and rivets in their respective holes, and install rivets with their heads on the thrust face of the propeller. After rivets are tapped in place, cut off the excess length of the rivet, leaving 1/8 inch for heading. End cutters built up with solder to accurately measure this distance are very useful. When an assistant backs up the rivets with a steel bar 18 inches long and pointed to fit the rivet head, hammer the rivets either by hand or with a pneumatic hammer. Screws may be driven either by hand or with an electric screwdriver.

(4) Cut the metal of the cap tip on the camber face of the propeller to the shape of the propeller tip. Bevel the edge by hand-filing and trim off flat side of metal cap so that it extends about 3/16 inch all around the tip of the propeller. Form a hardwood block to the shape of the propeller tip thrust face. Put metal tipping in place and clamp this block to the underside of the tip with a C-clamp; turn this 3/16 inch of metal up and over the camber face of the tip. Tighten and complete the lap joint. Mount the propeller blade solidly, with the thrust face up, on a stand supporting the blade at several points along its radius. With a hammer and a flat-faced tool, proceed to smooth the metal, starting at the nose of the leading edge and working toward the edge of the metal until all wrinkles and high spots are removed. At the edge, use a caulking tool and, in the same manner, press the metal edge tightly against the wood. Turn the propeller over and repeat this operation on the camber face. Make sure that the thin tip is supported at all times when hammering. Apply solder over rivet and screwheads and over the metal seam of the tip of the propeller. Use 50-50 solder in wire form. Use muriatic acid as flux when soldering

brass. Use stainless steel soldering flux when soldering stainless steel tipping. File excess solder off and check the propeller balance while doing so. Polish the metal with a fine emery cloth or an abrasive drum driven by a flexible shaft. Vent the tipping by drilling three holes, No. 60 drill (.040), 3/16 inch deep in the tip end. Drill ventholes parallel to the longitudinal axis of the blade.

570. REFINISHING. After repairing a blade, it is usually necessary to refinish it. In some cases it may be necessary to completely remove the old finish. Apply the finish, where necessary, in accordance wih the recommendations of the propeller manufacturer, or with a material which has satisfactory adhesion and high moisture-resistant properties. Refinishing of plastic-covered blades requires special techniques. Some manufacturers make this information available through service bulletins. Refinish or repaint wood blades carefully so that the balance of the entire propeller is not disturbed. Coating one blade heavier than the other will produce unbalance and cause a noticeable vibration during flight.

571. PROPELLER BALANCING. It is always necessary to check the balance of the propeller after any repairs or refinishing. Accomplish final balance on a rigid knife-edge balancing stand or on a suspension-type balancer in a room free from air currents. There must not be any persistent tendency to rotate from any position on the balance stand, or to tilt on the suspension balancer. Horizontal unbalance may be corrected by the the application of finish or solder to the light blade. The light blade may be coated with a high grade of primer allowing for a finishing coat. After allowing each coat to dry 48 hours, recheck the balance. Then, as may be necessary, either the required amount of finish must be removed by carefully sandpapering or applying an additional finishing coat. Recheck the balance and sandpaper or apply additional finish as may be required to effect final balancing. Correct vertical unbalance in fixed-pitch propellers by applying putty to the light side of the wood hub at a point on the circumference approximately 90° from the longitudinal centerline of the blades. Weigh the putty and prepare a brass plate weighing slightly more than the putty. The thickness of the plate should be from 1/16 inch to 1/8 inch, depending on the final area, and be of sufficient size to accommodate the required number of flathead attaching screws. The plate may be made to fit on the hub face or to fit the shape of the light side of the wood hub, and drilled and countersunk for the required number of screws. Attach the plate and tighten all of the screws. After the plate is finally attached to the propeller, secure the screws to the plate by soldering the screwheads and recheck the propeller balance. All edges of the plate may be beveled to reduce its weight as necessary. The drilling of holes in the propeller and the insertion of lead or other material to assist in balancing will not be permitted.

572.–582. RESERVED.

Section 3. REPAIR OF METAL PROPELLERS

583. GENERAL. Reject damaged blades with model numbers which are on the manufacturer's list of blades that cannot be repaired. Follow manufacturer's recommendations in all cases, and make repairs in accordance with latest techniques and best industry practices.

584. STEEL BLADES. Due to the critical effects of surface injuries and their repair on the fatigue life of steel blades, all repairs must be made in accordance with the manufacturer's instructions.

585. ALUMINUM PROPELLER REPAIRS. Aluminum-alloy propellers and blades with dents, cuts, scars, scratches, nicks, leading-edge pitting, etc., may be repaired, provided the removal or treatment does not materially affect the strength, weight, or performance of the blade. Remove these damages or otherwise treat as explained below unless contrary to manufacturer's instructions or recommendations. More than one injury is not sufficient cause alone for rejection of a blade. A reasonable number of repairs per blade may be made and not necessarily result in a dangerous condition, unless their location with respect to each other is such to form a continuous line of repairs that would materially weaken the blade. Suitable sandpaper or fine-cut files may be used for removing the necessary amount of metal. In each case, the area involved will be smoothly finished with No. 00 sandpaper or crocus cloth, and each blade from which any appreciable amount of metal has been removed will be properly balanced before it is used. Etch suspected cracks and all repairs as discussed in paragraph 605. To avoid removal of an excessive amount of metal, local etching should be accomplished at intervals during the process of removing suspected cracks. Upon completion of the repair, carefully inspect the entire blade by etching or anodizing. Remove all effects of the etching process with fine emery paper. Blades identified by the manufacturer as being cold-worked (shot-blasted or cold-rolled) may require peening after repair. Accomplish repair and peening operations on this type of blade in accordance with the manufacturer's instructions. However, it is not permissible in any case to peen down the edges of any injury wherein the operation will lap metal over the injury.

a. *Round out nicks, scars, cuts,* etc., occurring on the leading edge of aluminum alloy blades as shown in figure 12.2 (view B). Blades that have the leading edges pitted from normal wear in service may be reworked by removing sufficient material to eliminate the pitting. In this case, remove the metal by starting well back from the edge, as shown in figure 12.3, and working forward over the edge in such a way that the contour will remain substantially the same, avoiding abrupt changes in contour or blunt edges. Trailing edges of blades may be treated in substantially the same manner. On the thrust and camber face of blades, remove the metal around any dents, cuts, scars, scratches, nicks, longitudinal surface cracks, and pits to form shallow saucer-shaped depressions as shown in figure 12.2 (view C). Exercise care to remove the deepest point of the injury and also remove any raised metal around the edges of the injury as shown in figure 12.2 (view A). For repaired blades, the permissible reduction in width and thickness for minimum original dimensions, allowed by the blade drawing and blade manufacturing specifications are shown in figure 12.4 for locations on the blade from the shank to 90 percent of the blade radius. Beyond the 90 percent blade radius point, the blade width and thickness may be modified as required.

b. *Shortening Blades.* When the removal or treatment of defects on the tip necessitates shortening a blade, shorten each blade used

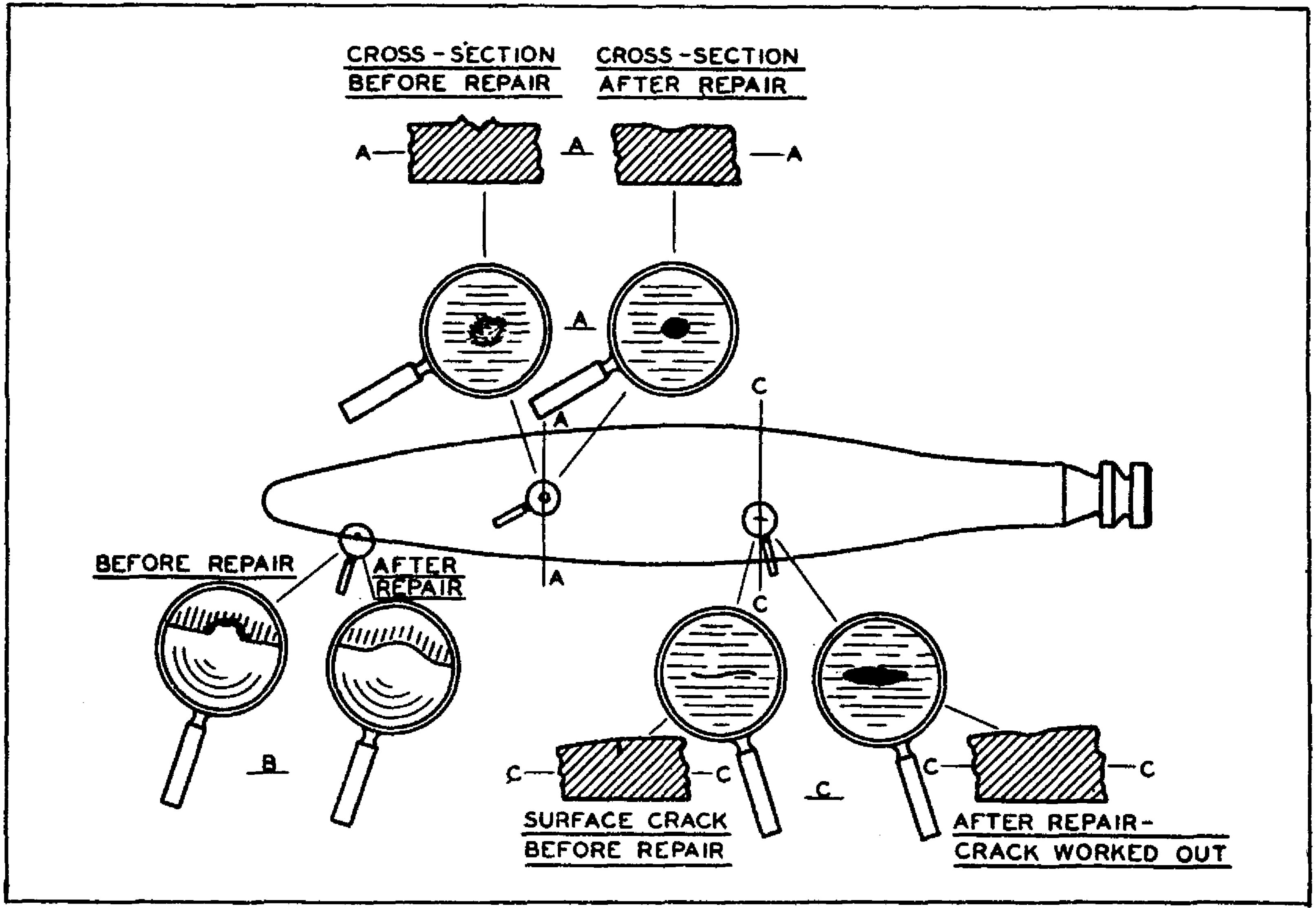


Figure 12.2.—Method of repairing surface cracks, nicks, etc., on aluminum alloy propellers.

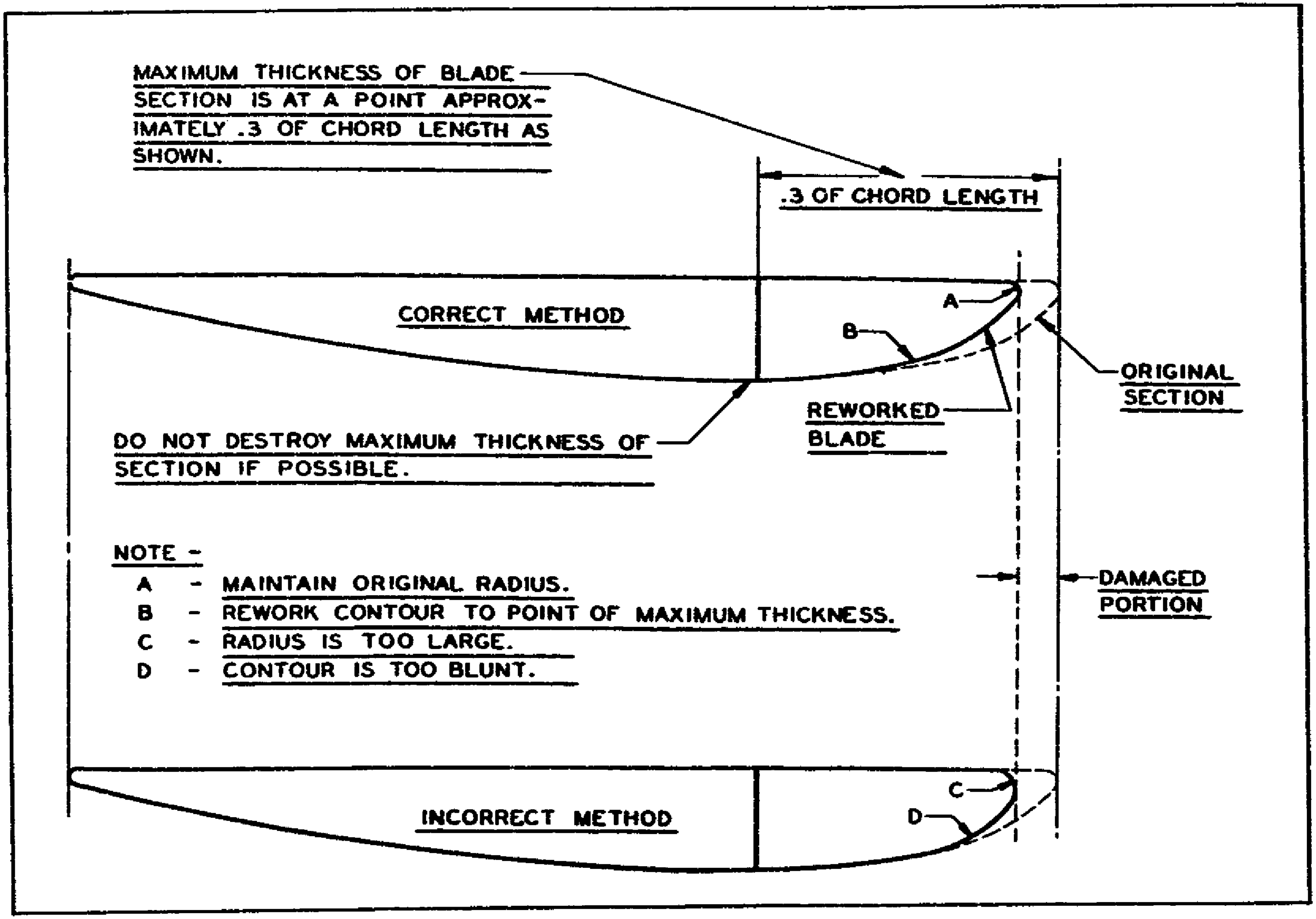


FIGURE 12.3.—Correct and incorrect method of reworking leading edge of aluminum alloy propellers.

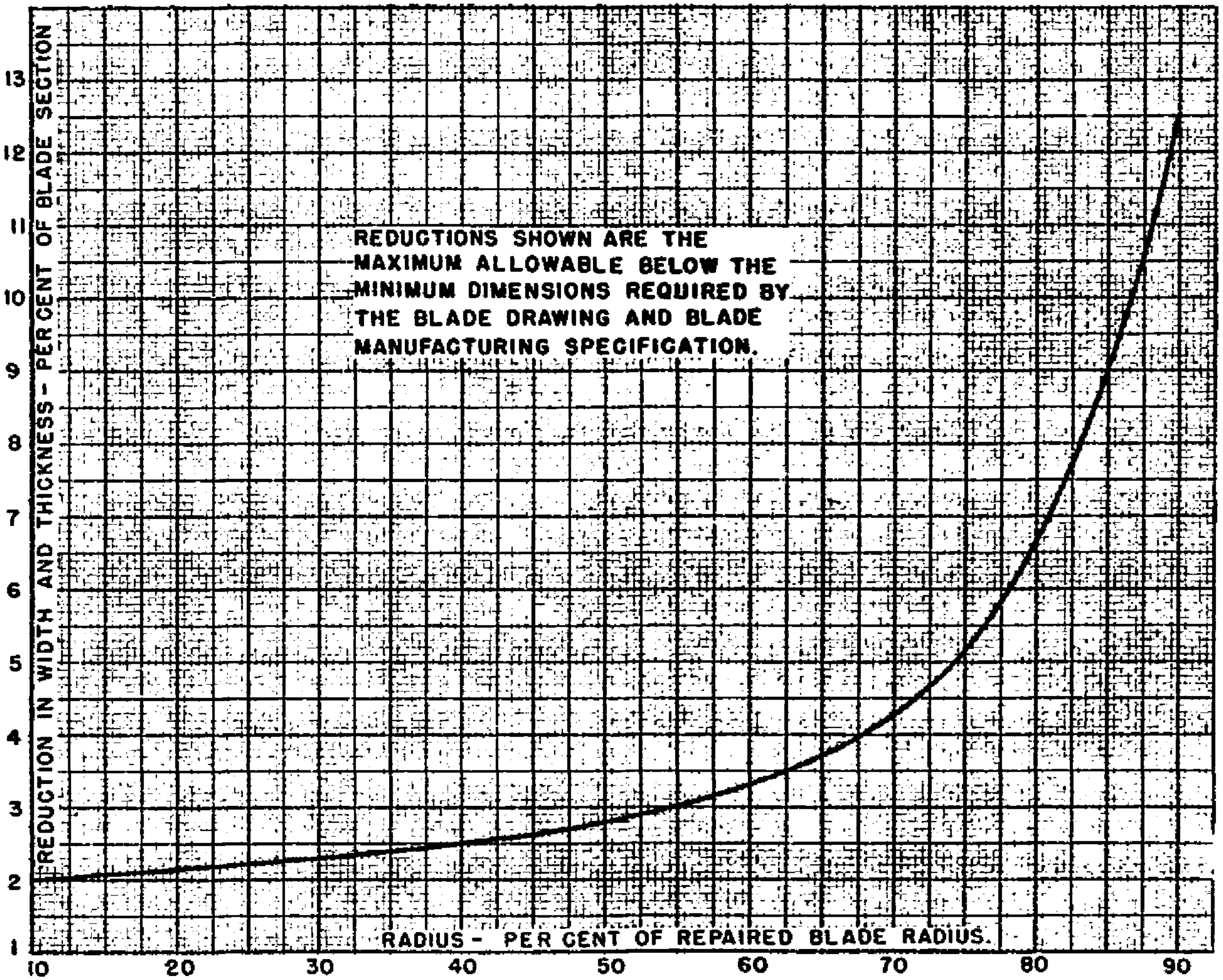


FIGURE 12.4.—Repair limits to blade section width and thickness for aluminum alloy propellers.

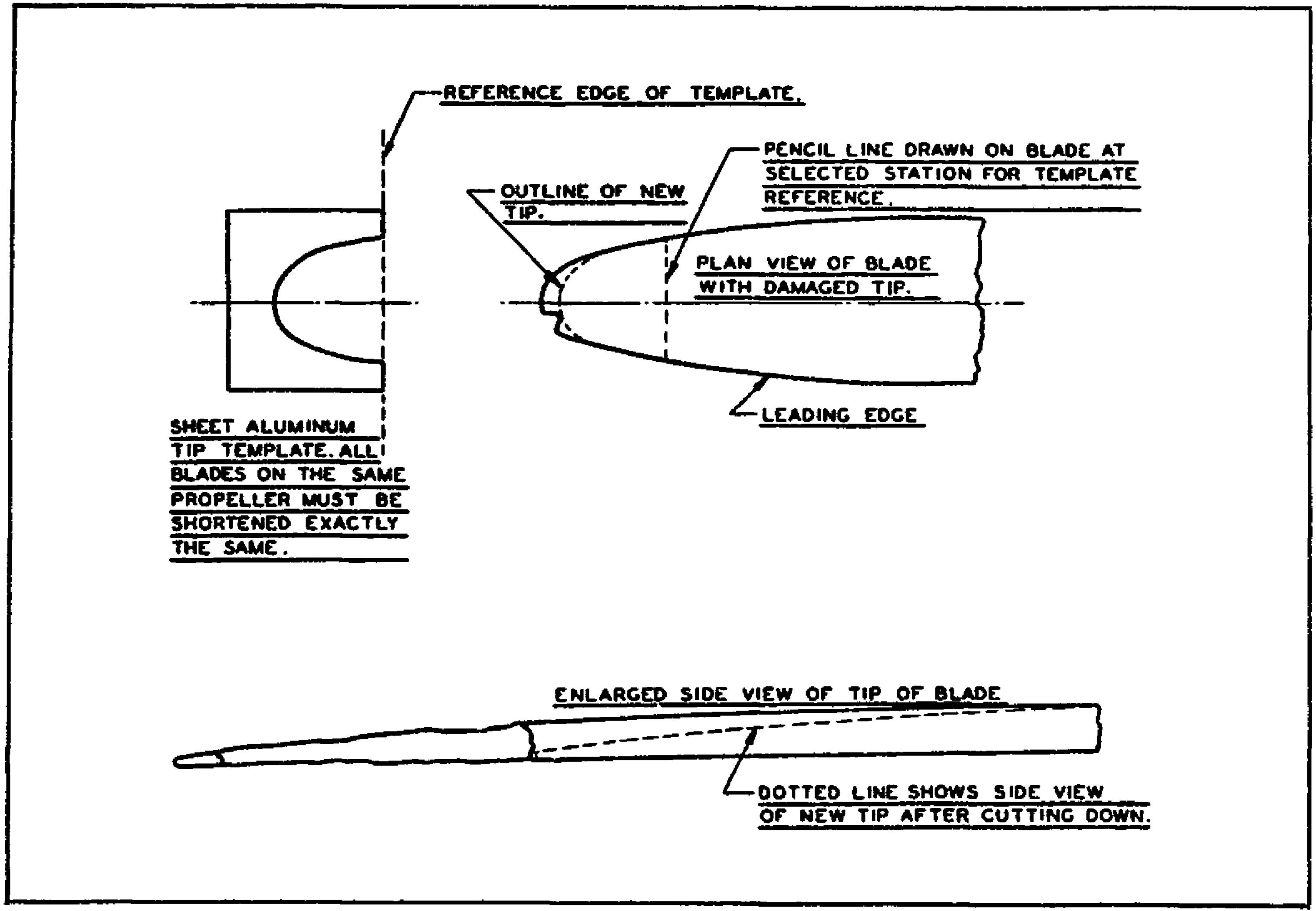


FIGURE 12.5.—Method of repairing damaged tip of aluminum alloy propellers.

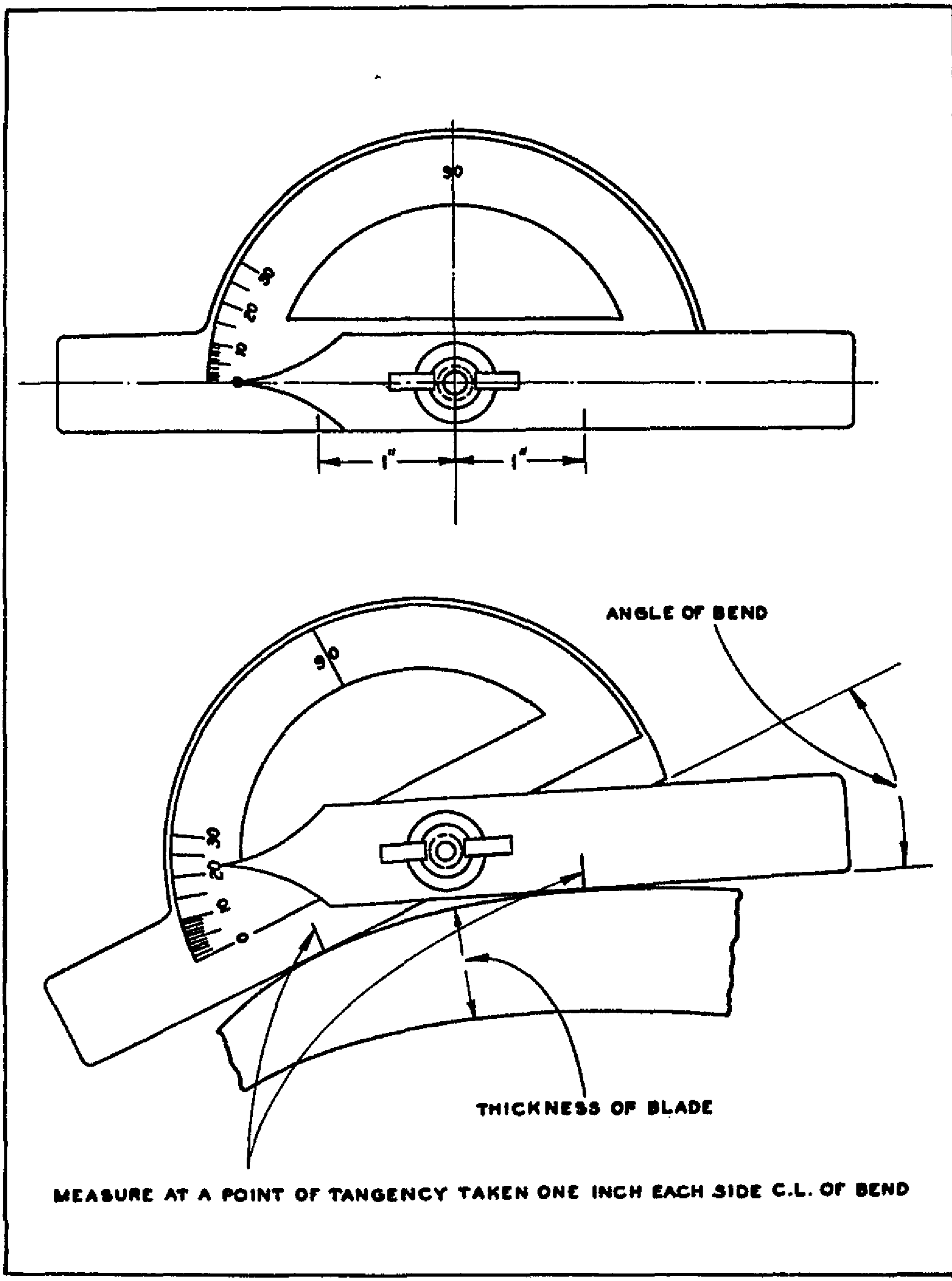


FIGURE 12.6.—Protractor and method of measuring angle of bend in aluminum alloy propellers.

with it and keep such sets of blades together (see figure 12.5 for acceptable methods). Mark the shortened blades to correspond with the manufacturer's system of model designation to indicate propeller diameter. In making the repair, it is not permissible to reduce the propeller diameter below the minimum diameter limit shown on the pertinent airplane specification.

c. *Straightening Propeller Blades.* Repair bent blades in accordance with the manufacturer's instructions. Carefully check the extent of a bend in face alinement by means of a protractor similar to the one illustrated in figure 12.6. Only bends not exceeding 20° at 0.15-inch blade thickness to 0 degrees at 1.1-inch blade thickness may be cold straightened. Straighten blades with bends exceeding these values only upon recommendation of the manufacturer, and only at facilities having proper heat-treatment equipment. In all cases, inspect the blades (as discussed in paragraph 605) for cracks and other injuries both before and after straightening.

586. REPAIR TOLERANCES. The following tolerances are those listed in the blade manufacturing specification for aluminum alloy blades and govern the width and thickness of new blades. These tolerances are to be used with the pertinent blade drawing to determine the minimum original blade dimensions to which the reduction of figure 12.4 may be applied. When repairs reduce the width or thickness of the blade below these limits, reject the blade. The face alignment or track of the propeller should fall within the limits recommended by the manufacturer for new propellers.

Basic diameter less than 10 feet 6 inches:
- Blade width—from shank to 24-inch station .... ± 3/64
  - from 24-inch station to tip .... ± 1/32
- Blade thickness .... ±0.025

Basic diameter 10 feet 6 inches to less than 14 feet 0 inches:
- Blade width—from shank to 24-inch station .... ± 1/16
  - from 30-inch station to tip .... ± 1/32
- Blade thickness—from shank to 24-inch station ...... ±0.030
  - from 30-inch station to tip ...... ±0.025

Basic diameter 14 feet 0 inches and over:
- Blade width—from shank to 30-inch station .... ± 3/32
  - from 36-inch station to tip .... ± 1/16
- Blade thickness—from shank to 30-inch station ...... ±0.040
  - from 36-inch station to tip ...... ±0.035

a. No repairs are permitted to the shanks (roots or hub ends) of aluminum alloy adjustable pitch blades. The shanks must be within manufacturer's tolerances.

587. PROPELLER BALANCE. Upon completion of repairs, check horizontal and vertical balance and correct any unbalance as recommended by the manufacturer. A coaxial hole is drilled in the butt end of certain aluminum alloy detachable blades for the application of lead to obtain static horizontal balance. The size of this hole must not be increased by the repair agency.

To effect vertical balance, follow the manufacturer's specific instructions. The outside of an eccentric hole must not be closer than 1/4 inch to the nearest external blade surface. As an alternate to drilling the two holes mentioned above, the manufacturer may have drilled a single eccentric hole having a diameter and depth conforming to the eccentric hole dimensions given in the table for application of lead. The outer edge of the hole must not be closer than 1 inch to the nearest external blade surface. Finish the ends of all balancing holes with a full sized drill having a spherical end to eliminate sharp corners. Remove the sharp edges of all holes by a 1/32-inch chamfer. The following table is included for inspection information only:

Size and depth of balancing holes.

Shank size	Max. concentric hole diameter (inch)	Max. concentric hole depth (inches)	Max. eccentric hole depth (5/8-inch max. dia.) (inches)
00	7/16	2½	2¼
0–V2	19/32	3⅜	3
½	⅝	3⅝	3½
1	¾	4¼	4
1½	13/16	4⅞	4½
2	⅞	5½	5
3	31/32	6⅛	6

588. STEEL HUBS AND HUB PARTS. Repairs to steel hubs and parts must be accomplished only in accordance with the manufacturer's recommendations. Welding and remachining is permissible only when covered by manufacturer's service bulletins.

589. PROPELLER HUB AND FLANGE REPAIR. When the propeller boltholes in a hub or crankshaft flange for fixed-pitch propellers become damaged or oversized, it is permissible to make repairs by methods (A) or (B) in figure 12.7, or by use of aircraft standard bolts 1/16 inch larger than the original bolts. Make the repairs in accordance with the recommendations of the propeller metal hub manufacturer or the engine manufacturer as applicable. Obtain from the engine or propeller hub manufacturer suitable flange bushings with threaded or smooth bores, as illustrated in methods (A) or (B) of figure 12.7. Drill the flange and insert the bushings as recommended by the engine manufacturer. Drill the rear face of the propeller to accommodate the bushings, and protect the holes with 2 coats of aluminum paint or other high moisture-resistant coating. Use bolts of the same size as those originally used. Any of the following combinations may be used: (1) safety bolt and castellated nut, (2) safety bolt (drilled head) and threaded bushing, or (3) undrilled bolt and self-locking nut. Where it is desirable to use oversized bolts, obtain suitable aircraft standard bolts 1/16 inch larger than the original bolts. Enlarge the crankshaft propeller flange holes and the propeller hub holes sufficiently to accomodate the new bolts without more than 0.005-inch clearance. Such reboring will be permitted only once. Further repairs of boltholes may be in accordance with the methods (A) or (B) of figure 12.7.

NOTE: Methods (A) or (B) are preferred over the oversized bolt method, because a propeller hub flange redrilled in accordance with this latter method will always require the redrilling of all new propellers subsequently used with the redrilled flange.

590. CONTROL SYSTEMS. Components used to control the operation of certificated propellers should be inspected, repaired, assembled, and/or tested in accordance with the manufacturer's recommendations. Only those repairs which are covered by the manufacturer's recommendations should be made, and only those replacement parts which are approved under FAR Part 21 should be used.

591. DEICING SYSTEMS. Components used in propeller deicing systems should be inspected, repaired, assembled, and/or tested in accordance with the manufacturer's recommendations. Only those repairs which are covered by the manufacturer's recommendations should be made, and only those replacement parts which are approved under FAR Part 21 should be used.

592.–602. RESERVED.

FIGURE 11.1.—Wire and circuit protector chart.

Wire AN gauge copper	Circuit breaker amp.	Fuse amp.
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	25 (30)	20
10	35 (40)	30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

Figures in parentheses may be substituted where protectors of the indicated rating are not available.

Basis of chart:

(1) Wire bundles in 135° F. ambient and altitudes up to 30,000 feet.

(2) Wire bundles of 15 or more wires, with wires carrying no more than 20 percent of the total current-carrying capacity of the bundle as given in Specification MIL-W-5088 (ASG).

(3) Protectors in 75° to 85° F. ambient.

(4) Copper wire Specification MIL-W-5086 (ASG) or equivalent.

(5) Circuit breakers to Specification MIL-C-5809 or equivalent.

(6) Fuses to Specification MIL-F-15160 or equivalent.

malfunction can be hazardous, use a switch specifically designed for aircraft service. These switches are of rugged construction and have sufficient contact capacity to break, make, and carry continuously the connected load current. Snap-action design is generally preferred to obtain rapid opening and closing of contacts irrespective of the speed of the operating toggle or plunger, thereby minimizing contact arcing.

b. ***Switch Ratings.***

(1) Nominal Rating. The nominal current rating of the conventional aircraft switch is usually stamped on the switch housing and represents the continuous current rating with the contacts closed. Derate switches from their nominal current rating for the following types of circuits:

(a) High in-rush. Circuits containing incandescent lamps can draw an initial current which is 15 times greater than the continuous current. Contact burning or welding may occur when switch is closed.

(b) Inductive. Magnetic energy stored in solenoid coils or relays is released when the control switch is opened and may appear as an arc.

(c) Motors. Direct current motors will draw several times their rated current during starting, and magnetic energy stored in their armature and field coils is released when the control switch is opened.

(2) Switch Selection. Figure 11.2 provides an approximate method for selecting the proper nominal switch rating when the continuous load current is known. The procedure is essentially a derating to obtain reasonable switch efficiency and service life.

(3) Switch Installation. Hazardous errors in switch operation may be avoided by logical and consistent installation. Mount "on-off" two position switches so that the "on" position is reached by an upward or forward movement of the toggle. When the switch controls movable aircraft elements, such as landing gear or

FIGURE 11.2.—Switch derating factors.

Nominal system voltage	Type of load	Derating factor
24 V.D.C.	Lamp	8
24 V.D.C.	Inductive (Relay-Solenoid)	4
24 V.D.C.	Resistive (Heater)	2
24 V.D.C.	Motor	3
12 V.D.C.	Lamp	5
12 V.D.C.	Inductive (Relay-Solenoid)	2
12 V.D.C.	Resistive (Heater)	1
12 V.D.C.	Motor	2

NOTES:

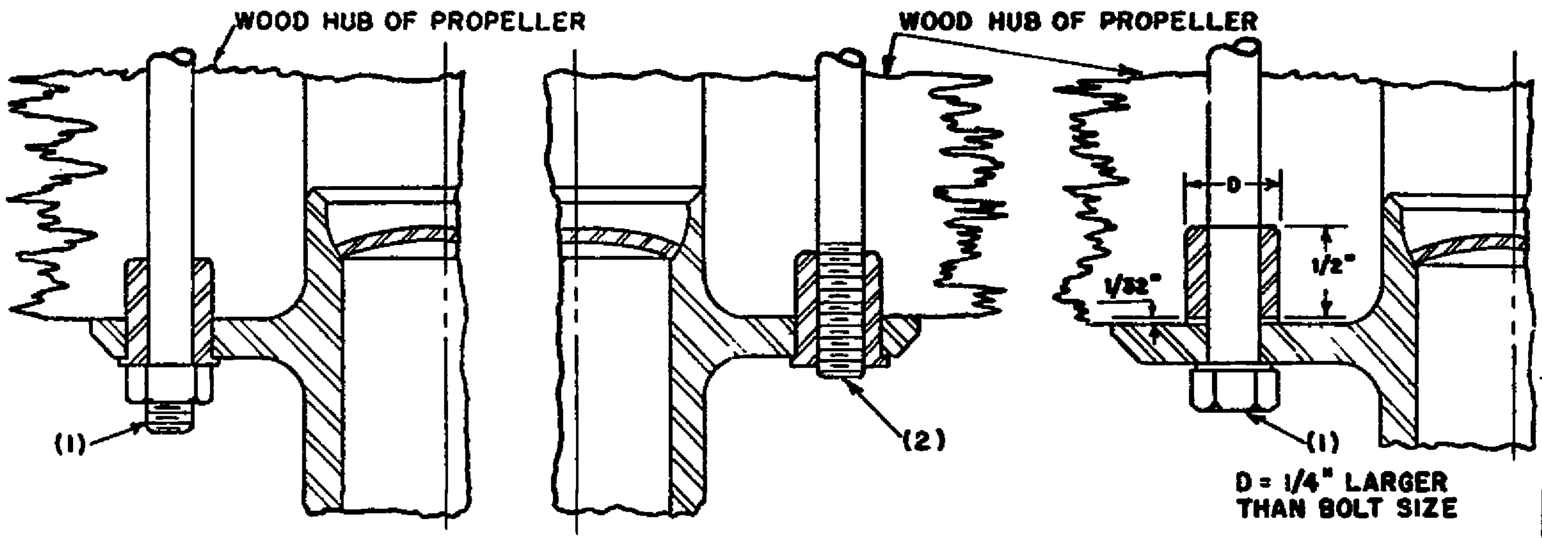
1. To find the nominal rating of a switch to operate a given device, multiply the continuous load current required by the device by the derating factor corresponding to the voltage and type of load.

2. To find the continuous load current that a switch of a given nominal rating will handle efficiently, divide the switch nominal rating by the derating factor corresponding to the voltage and type of load.

flaps, the toggle should move in the same direction as the desired motion. Inadvertent operation of switches can be prevented by mounting suitable guards over the switches.

(4) **Relays.** Relays are used as a switching device where a weight reduction can be achieved, or to simplify electrical controls. It should be remembered that the relay is an electrically operated switch, and therefore subject to dropout under low system voltage conditions. Concerning contact ratings, the discussion of switch ratings in paragraph 430b(1) is generally applicable to relays.

431.-441. RESERVED.



METHOD (A)

METHOD (B)

REPAIR OF DAMAGED OR ELONGATED BOLTHOLES IN PROPELLER HUB FLANGES.

REPAIR OF ELONGATED BOLTHOLES IN PROPELLER.

(1) DRILLED BOLT WITH CASTELATED NUT OR UNDRILLED BOLT WITH SELF-LOCKING NUT.

(2) BOLT WITH HEAD DRILLED FOR SAFETY WIRING.

NOTE: THESE REPAIRS ARE PERMITTED ONLY ON THE DRIVING FLANGE OF THE PROPELLER HUB AND THE ADJACENT FACE OF THE PROPELLER.

FIGURE 12.7.—Repair of fixed-pitch hub and propeller with elongated or damaged boltholes.

Section 4. OVERHAUL OF PROPELLERS

603. HUB AND HUB PARTS. Disassemble propellers submitted for overhaul and clean all hub parts in accordance with the manufacturer's recommendations. Make an inspection of the parts to determine that the critical dimensions are within the manufacturer's specified tolerances. Take particular care to check the 90° relation between shaft bore and blade socket centerline and track of the blade sockets, as these are the dimensions which are most likely to be affected by accidents. Reject and replace any hub which is sprung, worn, or damaged. Stress risers such as cuts, nicks, or tool marks must be carefully stoned or the part rejected. Carefully inspect splines and cone seats for signs of wear, and check splines with a single key "no-go" gauge made to plus 0.002 inch of the base drawing dimensions for spline land width. If the gauge enters more than 20 percent of the spline area, reject the hub. Cones and cone seats may show discoloration, pitting, and corrosion. Generally, corrosion and discolored spots may be removed by light lapping. Pitting is not grounds for rejection, if 75 percent of the bearing area is not affected and the pitted areas are well dispersed about the cone bearing area. After cleaning, minutely inspect steel hubs and parts for cracks by the wet or dry magnetic particle method at every major overhaul period. It is not necessary to remove the plating or special external finish for this inspection unless so specified in the manufacturer's recommended practice.

Steel hubs which adapt fixed-pitch propellers to all taper crankshafts are susceptible to cracks along the keyway which often extend into the flange lightening holes. Carefully inspect these hubs by the magnetic particle method at engine overhaul periods. Any crack is cause for rejection.

604. PLATING FOR HUBS AND PARTS. Replate hubs and parts from which the plating has been removed after they have been satisfactorily inspected. All replating must be of the same material as the original plating and be done in accordance with the manufacturer's recommendations. Chrome or nickel plating is not an acceptable substitute for cadmium or zinc plating. The use of zinc chromate primer on the external surfaces followed by a coating of aluminum lacquer in lieu of cadmium plating is considered acceptable where recommended by the manufacturer. However, this type of finish will require replacement more frequently than cadmium plating.

605. INSPECTION OF ALUMINUM PROPELLERS AND BLADES. Carefully inspect aluminum propellers and blades for cracks and other injuries. A transverse (chordwise) crack or flaw of any size is cause for rejection. Refer any unusual condition or appearance revealed by these inspections to the manufacturer. Acceptable inspection methods are the acid-etching process, the anodizing process, the fluorescent penetrant process, or the dye penetrant process. Where applicable, supplement one process with another. Etching is accomplished by immersing the blade in a warm 20 percent caustic soda solution and cleaning with a warm 20 percent nitric acid solution, with a warm water rinse between the caustic bath and the acid bath, and also a warm water rinse following the acid bath. Remove all effects of the etching by polishing. Maintain the caustic and acid solution at a temperature of from 160° F. to 180° F. Some blades incorporate parts made of steel and other materials, and the caustic soda and the nitric acid must not be allowed to come in contact with these parts. The blade surfaces are then examined with a magnifying glass of at least three-power. A crack will appear as a distinct black line. The fluorescent penetrant method is recommended as a supplement to the caustic etch for the inspection of the shanks (roots or hub ends) of adjustable pitch blades.

a. *Suspected cracks or defects* should be repeatedly local etched until their nature is determined. With a No. 00 sandpaper, or fine crocus cloth, clean and smooth the area containing the apparent crack. Apply a small quantity of caustic solution to the suspected area with a swab or brush. After the area is well darkened, thoroughly wipe it with a clean (dampened) cloth. Too much water may entirely remove the solution from a crack and spoil the test. If a crack extending into the metal exists, it will appear as a dark line or mark, and by using a magnifying glass, small bubbles may be seen forming in the line or mark. Immediately upon completion of the final checks, remove all traces of the caustic solution by use of the nitric acid solution. Wash the blade thoroughly with clean (fresh) water.

b. *The chromic acid anodizing process* is superior to caustic etching for the detection of cracks and flaws and should therefore be used, whenever it is available, for general inspection of blades, for material defects, and for final checking of repairs performed during overhaul. Immerse the blades in the anodizing bath as far as possible, but all parts not made of aluminum alloy must be kept out of the chromic acid bath or be separated from the blade by nonconductive wedges or hooks. Follow the anodizing treatment by a rinse in clear, cold, running water from 3 to 5 minutes, and dry the blades as quickly as possible, preferably with an air blast. Allow the dried blades to stand for at least 15 minutes before examination. Flaws (cold shuts or inclusions) will appear as fine black lines. Cracks will appear as brown stains caused by chromic acid bleeding out onto the surface. The blades may be sealed for improved corrosion resistance by immersing them in hot water (180° F. to 212° F.) for one-half hour. In no case, immerse the blades in hot water before the examination for cracks, since heat expands cracks and allows the chromic acid to be washed away.

606. ASSEMBLY. Accomplish the assembly of the propeller hub and blade in accordance with the manufacturer's recommendations. Replace clevis pins, bolts, and nuts which show wear or distortion. Never use cotter pins and safety wire a second time. The use of self-locking nuts is permissible only where originally used or approved by the manufacturer.

607.-617. RESERVED.

Section 5. ASSEMBLY OF PROPELLER TO ENGINE

618. FIXED-PITCH PROPELLERS. Loose hub bolts and bolts installed through the lightening holes in the integral hub flange of certain engine crankshafts cause the majority of the serious difficulties experienced with fixed-pitch propellers. Either of the conditions, if not corrected, will ultimately cause the loss of the propeller.

a. ***Loose hub bolts*** cause elongated boltholes and damage to the hub bolts. When not corrected, the bolts break off, or friction causes enough heat to affect the glue and chars the wood. After successive running, checks start at the boltholes. These checks are caused, or at least accentuated, by shrinkage of the wood due to the excessive heat generated. If allowed to progress, the propeller usually flies apart or catches on fire.

b. ***On some engines*** equipped with a crankshaft having an integral propeller hub flange, the outer edge of the lightening holes are at the same radius as the corresponding edge of the propeller hub boltholes. When inserting the bolts through the propeller, care must be exercised so that the bolts are inserted through the proper holes in the flange. Cases have been reported where the bolts were inserted through the larger lightening holes and, accordingly, the bolt nuts bore only on the outer edges of the lightening holes. In such cases, continuous running of the propeller may cause the boltheads or nuts to slip off the flange and through the large openings in the flange, resulting in the subsequent loss of the propeller.

c. ***Both the conditions discussed*** above are very easy to detect, and must be corrected immediately. In case the hub flange is integral with the crankshaft, first ascertain the bolts are properly installed, then make the inspection for bolt tightness in the same manner as for any other propeller hub. Use an open-end wrench to determine hub bolt tightness; and, if the nuts can be turned, remove the cotter keys and retorque the nuts to the desired setting. Tighten hub bolts, preferably with a torque wrench, to the recommended values which usually range from 15 to 24 foot-pounds. If no torque wrench is available, an ordinary socket wrench may be used. This socket wrench should have a 1-foot extension lever and the wrench pulled up with the recommended force 12 inches away from the center of the bolt which is being tightened. The tightening is best accomplished by tightening each bolt a little at a time, being sure to tighten alternate bolts which are diametrically opposite. Exercise care not to overtighten the hub bolts, thereby damaging the wood underneath the hub flanges. Avoid the practice of overtightening bolts to draw a propeller into track. Safety the nuts by means of cotter keys of proper size or heavy safety wire twisted between each nut. A continuous length of single safety wire is not acceptable, as wire failure will result in all nuts becoming unsafetied.

619.–629. RESERVED.

Section 6. PRECAUTIONS

630. BLADE-TIP IDENTIFICATION. Many persons have been fatally injured walking into whirling propellers. Painting a warning strip on the propeller serves to reduce chances of such injuries. Cover approximately 4 inches of the propeller tips on both sides with an orange-yellow nonreflecting paint or lacquer. Open the drain holes in the metal tipping of wood blades after the tips have been painted.

631. GROUND-HANDLING PRACTICES. Wood propellers are especially susceptible to damage from improper handling. When moving an airplane, avoid bumping the propeller. The practice of pushing or pulling on a propeller blade to move an airplane should be avoided; it is extremely easy to impose forces on a blade in excess of those for which the blade is designed. It is continually necessary to ascertain that the glue joints are in good condition, and that the finish on the entire propeller will protect the propeller from absorbing moisture. Place two-bladed wood propellers, whether on or off an airplane, in a horizontal position to prevent unbalance from moisture absorption. A good precaution is to cover the propeller with a well-fitted waterproof cover when not in use. It is very important to protect the shank section of wood blades from moisture changes to prevent swelling and subsequent loosening in the metal sleeve. In the case of varnished blades, it is advisable to occasionally apply varnish around the shank at the junction of wood and metal. In the case of the plastic-covered blade, repair cement may be applied around the same joint.

632. COMPOSITION PROPELLER SERVICE LIMITS. In certain cases where the blade has been manufactured from laminated planks of composition material, longitudinal cracks or splitting between laminations have been observed after several hundred hours of operation. Do not permit these cracks to progress beyond the limits established by the manufacturer.

633.–643. RESERVED.

Section 7. MAINTENANCE OF ROTOR BLADES

644. GENERAL. The design, materials, construction, and performance requirements for rotorcraft main and tail rotor blades vary considerably from those used in the manufacture and operation of airplane propellers. Major dissimilarities also exist among the blades fabricated for the various makes and models of rotorcraft currently in operation. For these reasons, it is of utmost importance that the specific maintenance requirements of each rotorcraft manufacturer be consulted prior to performing any maintenance. In all instances, the restoration of blades will be determined by the repair limitations provided in the blade manufacturer's current service and maintenance manual data. The information in this section may serve as a general guide for maintaining the airworthiness of rotorcraft blades.

a. *Leading Edge Strip.* Examine leading edge abrasion strips (A in figures 12.8, 12.9 and 12.10) for nicks, cuts, gouges, or worn spots resulting from abrasion. Damage of this type can usually be considered minor provided the injuries are not concentrated in one area, do not penetrate the strip, or do not affect the aerodynamic performance of the blade.

The limits for leading edge strip bond separations or edge voids (B in Figure 12.8) are established by the blade manufacturer. When a separation is suspected, carefully examine the blade assembly and determine whether it is within the manufacturer's tolerances for continued operation. If it is permissible for the blade to remain in service, recheck that blade area at frequent intervals thereafter to assure that the separation is not progressing beyond allowable limits.

Inspect the rotor blade for evidence of paint deterioration in the area where the aft edge of the leading edge metal strip terminates. If the surface of the paint in this area is cracked, blistered, or missing, carefully examine the metal surface of the blade for evidence of electrolytic corrosion or pitting (C in Figure 12.8). Treat minor cases of localized corrosion promptly by cleaning and coating the area with a preservative that will arrest further surface deterioration until the blade can be completely refinished. When the area of corrosion appears to be extensive or pitting is deep, remove the blade for complete evaluation of the damage.

b. *Blade Surface.* Examine the blade upper and lower surfaces between the leading edge strip and the trailing edge for evidence of cracks (B in figures 12.9 and 12.10). Cracks of any magnitude in this area are cause for blade removal if allowable crack limitations are not prescribed by the blade manufacturer. Trailing edge cracks in blades having bonded trailing edges are also cause for removing the blade for service. Blades incorporating rivets along the trailing edge that have cracks at the edge (C in figures 12.9 and 12.10) which terminate at a rivet hole or cracks that extend between two adjacent rivets (D in figures 12.9 and 12.10) are not permissible and the blade should be removed from further service until repairs are made.

Inspect the adhesive bonding at the blade root end doublers (E in figures 12.9 and 12.10), skin to spar joint (A in figure 12.11), and the trailing edge (C in figure 12.11) for evidence of bond separation. This may initially appear as a hairline crack and any indication of a separation is cause for removing the blade from service to thoroughly examine and evaluate the condition prior to attempting repair.

Check the entire bonded (honeycomb core) area of the blade for evidence of bond separations or voids (B in figure 12.11). In many instances these can be detected by a difference in sound heard while the surface of the blade is being tapped with a light object such as a coin. A dull or dead sound is indicative of a void or separation. The acceptability of voids or sepa-

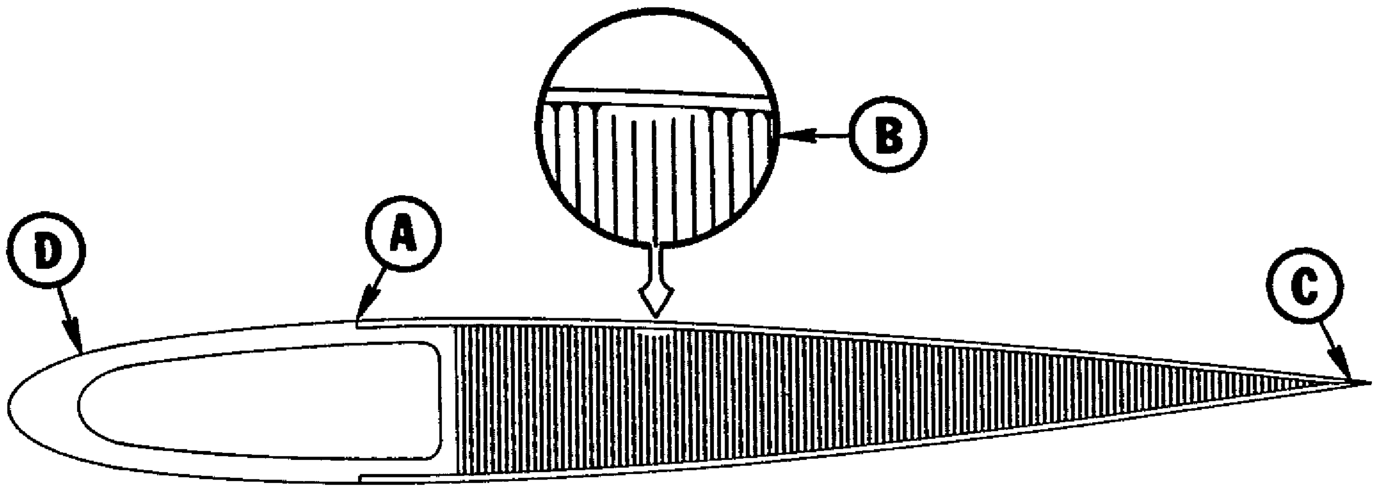


FIGURE 12.11.—Blade cross-section.

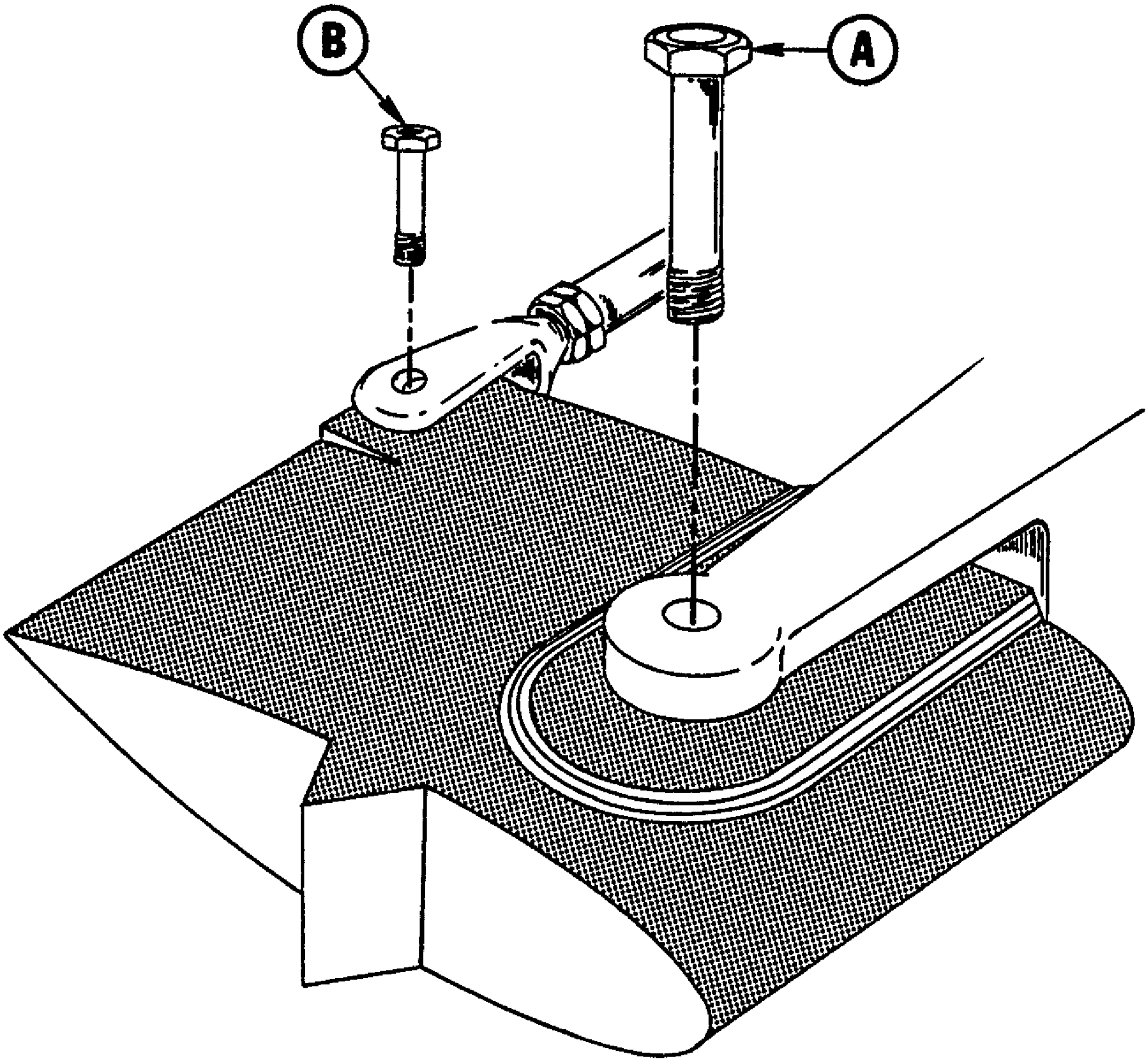


FIGURE 12.12.—Blade retention and link attach points.

rations depends upon their location and the size of the area involved. Consult the applicable blade manufacturer's service manual for the allowable limits.

NOTE: The presence of water in the honeycomb core of a blade is cause for retiring a blade from service.

Examine the blade trim tabs for security of attachment and evidence of cracks in the area where they are bent (D in figure 12.8). When either of these conditions exists, take appropriate corrective action prior to approving the blade for return to service.

c. *Main Spar or Beam.* Inspect all of the exposed surfaces of blade spars for such damage as cuts, nicks, scratches, or erosion. When the blade leading edge is an integral part of an extruded spar or beam (D in figure 12.11), carefully examine the blade edge for wear resulting from abrasives. Use a penetrant method of inspection when checking the exposed surfaces of the metal spar or beam for cracks. If the spar is not exposed, an X-ray or comparable type of inspection is recommended. Any spar or beam crack is cause for removing a blade from service. Other types of spar damage must be evaluated, and if permissible, repaired in accordance with data provided in the applicable manufacturer's service manual.

d. *Blade Retention.* Examine the blade main retention components and drag (lead/lag) link attach points (A and B in figure 12.12) for evidence of looseness. If there are any indications of excessive play, remove the main retention and drag link attaching bolts or pins and check them for wear or stretch. Use a dye penetrant or magnetic particle method to inspect the bolts or pins for cracks. Check the threads for evidence of necking or distortion. Examine the main and drag link bushings for wear or elongation. Carefully inspect the area around the bushing holes for evidence of cracks or delamination. Consult the manufacturer's overhaul or service manual to determine what main retention and drag link attachment wear tolerances are acceptable.

e. *Blade Tip Assembly.* Inspect the tip area of the blade for evidence of abrasive erosion. If this condition is readily visible and appears to be deep or covers an appreciable area, the blade should be removed from service in order to fully evaluate the degree of wear. Accomplish repairs in accordance with the manufacturer's recommendations if the wear limits for continued operation are exceeded.

Check the blade tip for loose rivets or bond separation. If either condition is evident, remove the blade from service and perform the necessary repairs. Any deformation of the blade tip must be corrected in the manner specified by the manufacturer of the blade.

If a blade tip cap is installed, remove it and carefully examine the blade balance weights for security of attachment. Check the condition of the tip cap screws and anchor nuts prior to replacing the cap.

f. *Blade Life.* Most rotor blade manufacturers prescribe permissible limits for wear, repairs, and hours of operation for specific blade models. Close adherence to these limitations is recommended, to assure continued airworthiness and reliability of the blades.

645.-655. RESERVED.

Chapter 13. WEIGHT AND BALANCE

656. GENERAL. The removal or addition of equipment results in changes to the center of gravity and empty weight of the aircraft, and the permissible useful load is affected accordingly. Investigate the effects of these changes, otherwise the aircraft flight characteristics may be adversely affected. Information on which to base the record of weight and balance changes to the aircraft may be obtained from the pertinent aircraft specification, the prescribed aircraft operating limitations, airplane flight manual, and the aircraft weight and balance report.

Removal or addition of minor items of equipment such as nuts, bolts, rivets, washers, and similar standard parts of negligible weight on fixed-wing aircraft do not require a weight and balance check. Since rotorcraft are in general more critical with respect to control with changes in c.g. positions, the procedures and instructions in the particular model maintenance or flight manual should be followed.

657. TERMINOLOGY. The following terminology is used in the practical application of weight and balance control.

a. *Maximum Weight.* The maximum weight is the maximum authorized weight of the aircraft and its contents as listed in the specifications.

b. *Empty Weight.* The empty weight of an aircraft includes all operating equipment that has a fixed location and is actually installed in the aircraft. It includes the weight of the airframe, powerplant, required equipment, optional and special equipment, fixed ballast, full engine coolant, hydraulic fluid, and the fuel and oil as explained in paragraph 658 f and g. Additional information regarding fluids which may be contained in the aircraft systems and which must be included in the empty weight will be indicated in the pertinent aircraft specifications whenever deemed necessary.

c. *Useful Load.* The useful load is the empty weight subtracted from the maximum weight of the aircraft. This load consists of the pilot, crew if applicable, maximum oil, fuel, passengers, and baggage, unless otherwise noted.

d. *Weight Check.* A weight check consists of checking the sum of the weights of all items of useful load against the authorized useful load (maximum weight less empty weight) of the aircraft.

e. *Datum.* The datum is an imaginary vertical plane from which all horizontal measurements are taken for balance purposes with the aircraft in level flight attitude. The datum is indicated on most FAA Aircraft Specifications. On some of the older aircraft, where the datum is not indicated, any convenient datum may be selected. However, once the datum is selected, all moment arms and the location of the permissible c.g. range must be taken with reference to it. Examples of typical locations of the datum are shown in figure 13.1.

f. *Arm (or Moment Arm).* The arm is the horizontal distance in inches from the datum to the center of gravity of an item. The algebraic sign is plus (+), if measured aft of the datum, and minus (−) if measured forward of the datum. Examples of plus and minus arms are shown in figure 13.2.

g. *Moment.* Moment is the product of a weight multiplied by its arm. The moment of an item about the datum is obtained by multiplying the weight of the item by its horizontal distance from the datum. A typical moment calculation is given in figure 13.3.

h. *Center of Gravity.* The center of gravity is a point about which the nose-heavy and tail-heavy moments are exactly equal in magnitude. If the aircraft were suspended from there, it would have no tendency to pitch in either di-

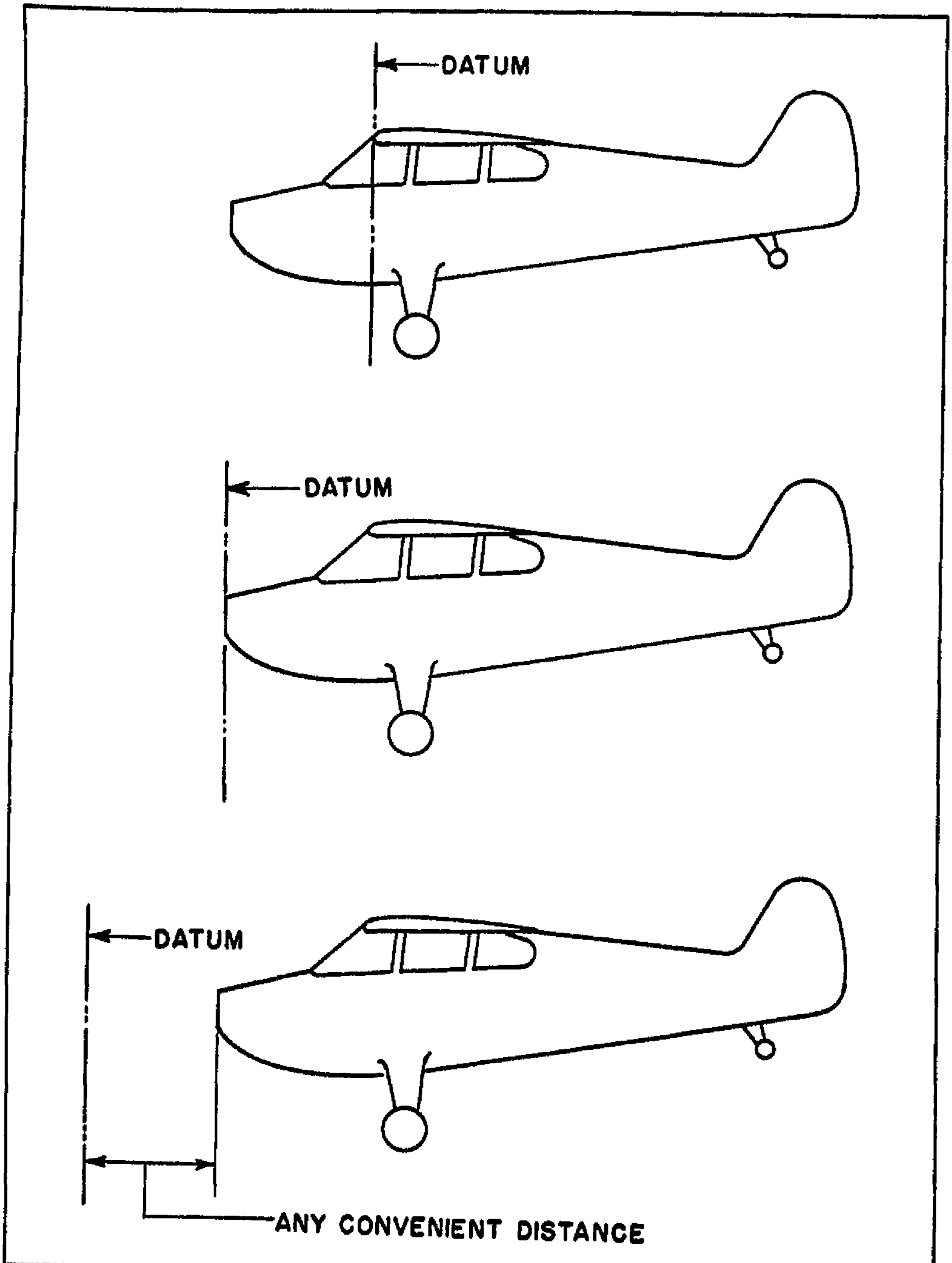


FIGURE 18.1.—Typical datum locations.

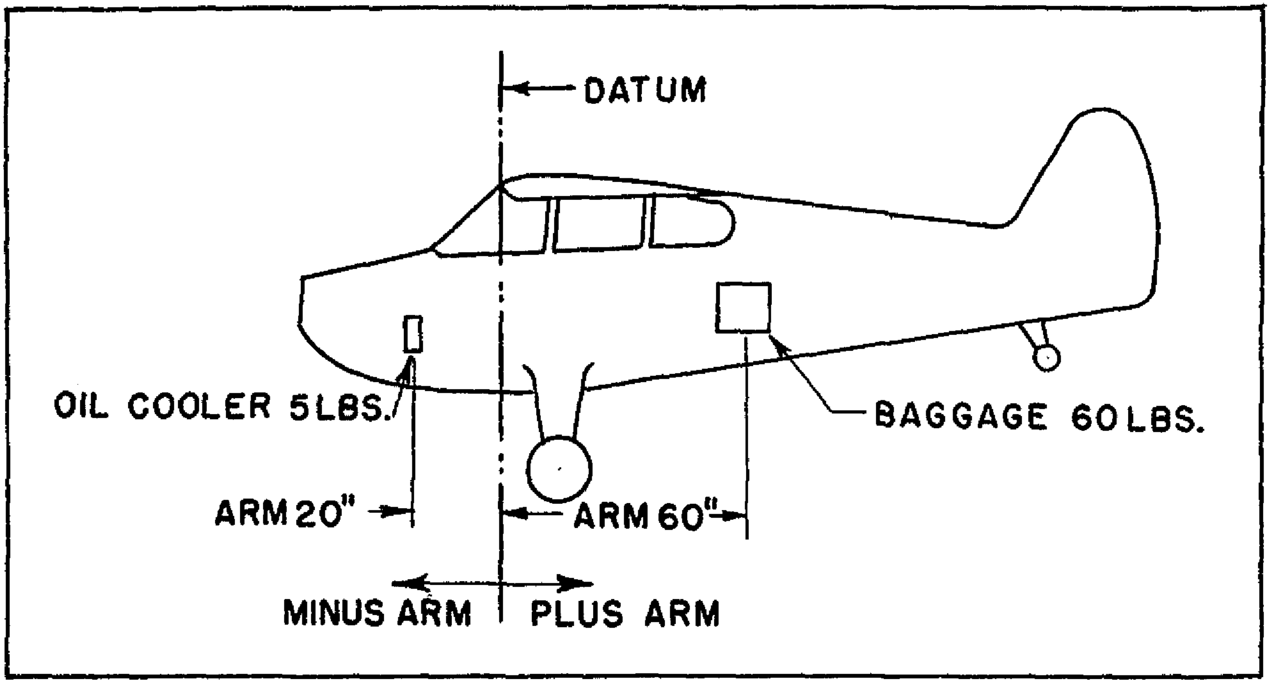


FIGURE 13.2.—Illustration of arm (or moment arm).

rection (nose up or down). The weight of the aircraft (or any object) may be assumed to be concentrated at its center of gravity. (See figure 13.3.)

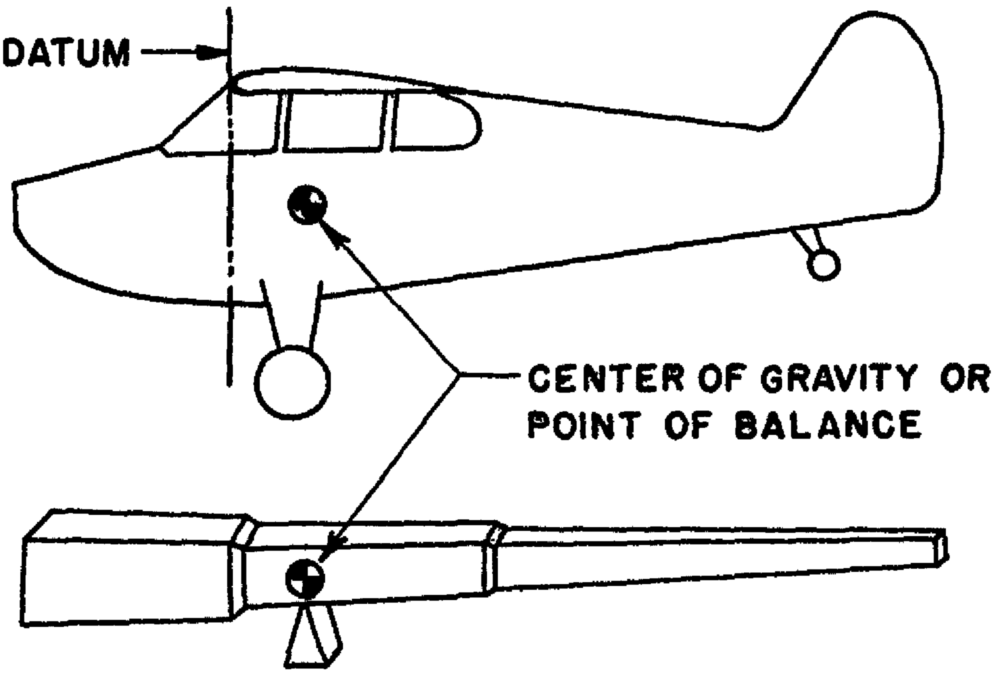
i. *Empty Weight Center of Gravity.* The empty weight c.g. is the center of gravity of an aircraft in its empty weight condition, and is an essential part of the weight-and-balance record. Formulas for determining the center of gravity for tail and nosewheel type aircraft are given in figure 13.4. Typical examples of computing the empty weight and empty weight c.g. for aircraft are shown in figures 13.5 and 13.6.

j. *Empty Weight Center-of-Gravity Range.* The empty weight center-of-gravity range is determined so that the empty weight c.g. limits will not be exceeded under standard specification loading arrangements. In cases where it is possible to load an aircraft in a manner not covered in the Aircraft Specification (i.e., extra tanks, extra seats, etc.), complete calculations as outlined in paragraph 661. The empty weight c.g. range, when applicable, is listed on the Aircraft Specifications. Calculation of empty weight c.g. is shown in figures 13.5 and 13.6.

k. *Operating Center-of-Gravity Range.* The operating c.g. range is the distance between the forward and rearward center of gravity limits indicated on the pertinent aircraft specification. These limits were determined as to the most forward and most rearward loaded c.g. positions at which the aircraft meets the requirements of the Federal Aviation Regulations. The limits are indicated on the specification in either percent of mean aerodynamic chord or inches from the datum. The c.g. of the loaded aircraft must be within these limits at all times as illustrated in figure 13.7.

l. *Mean Aerodynamic Chord (MAC).* For weight and balance purposes it is used to locate the c.g. range of the aircraft. The location and dimensions of the MAC will be found in the Aircraft Specifications, Aircraft Flight Manual, or the Aircraft Weight and Balance Report.

m. *Weighing Point.* If the c.g. location is determined by weighing, it is necessary to obtain horizontal measurements between the points on the scale at which the aircraft's weight is

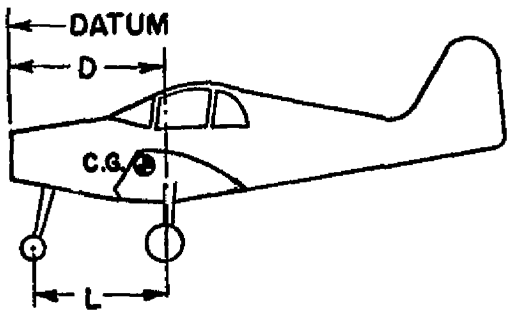


The entire aircraft weight may be considered to be concentrated at the center of gravity. Therefore, the moment of the aircraft about the datum is the weight of the aircraft times the horizontal distance between the C.G. and the datum.

Example: If the weight of this airplane is 2000 lbs. and the arm from the datum to the center of gravity is 16 inches, the moment of the aircraft about the datum is 2000 x 16 or 32,000 in. lbs.

FIGURE 18.8.—Example of moment computation.

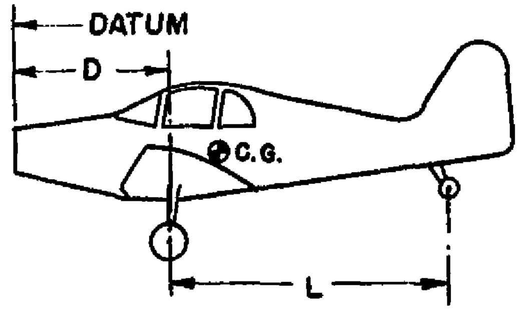
concentrated. If weighed, using scales under the landing gear tires, a vertical line passing through the centerline of the axle will locate the point on the scale at which the weight is concentrated. This point is called the "weighing point." Other structural locations capable of supporting the aircraft, such as jack pads on the main spar, may also be used if the aircraft weight is resting on the jack pads. Indicate these points clearly in the weight and bal-



NOSE WHEEL TYPE AIRCRAFT

DATUM LOCATED FORWARD OF THE MAIN WHEELS

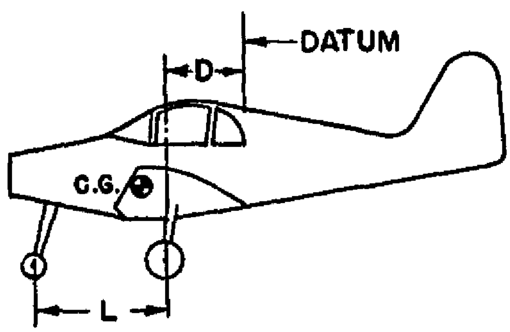
$$C.G. = D - \left(\frac{F \times L}{W}\right)$$



TAIL WHEEL TYPE AIRCRAFT

DATUM LOCATED FORWARD OF THE MAIN WHEELS

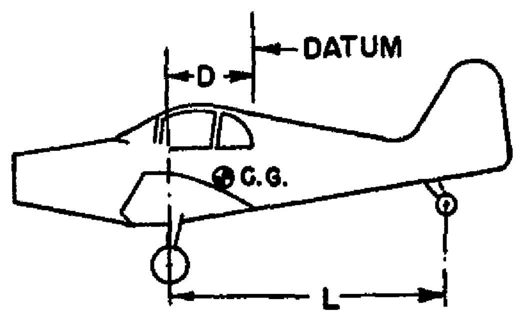
$$C.G. = D + \left(\frac{R \times L}{W}\right)$$



NOSE WHEEL TYPE AIRCRAFT

DATUM LOCATED AFT OF THE MAIN WHEELS

$$C.G. = -\left(D + \frac{F \times L}{W}\right)$$



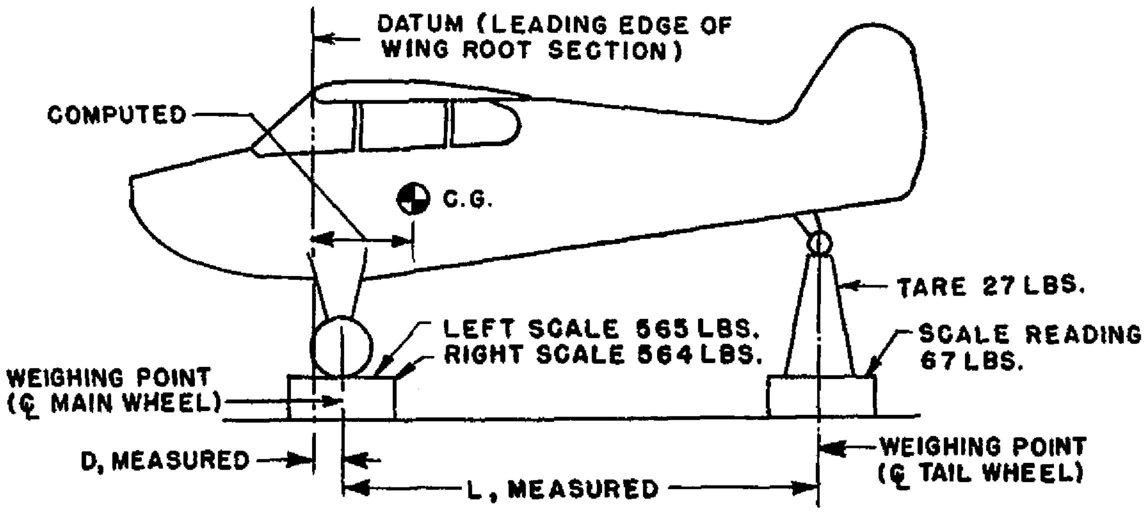
TAIL WHEEL TYPE AIRCRAFT

DATUM LOCATED AFT OF THE MAIN WHEELS

$$C.G. = -D + \left(\frac{R \times L}{W}\right)$$

CG = Distance from datum to center of gravity of the aircraft.
W = The weight of the aircraft at the time of weighing.
D = The horizontal distance measured from the datum to the main wheel weighing point.
L = The horizontal distance measured from the main wheel weighing point to the nose or tail weighing point.
F = The weight at the nose weighing point.
R = The weight at the tail weighing point.

FIGURE 13.4.—Empty weight center-of-gravity formulas.



TO FIND: EMPTY WEIGHT AND EMPTY WEIGHT CENTER OF GRAVITY

Datum is the leading edge of the wing (from aircraft specification)
(D) Actual measured horizontal distance from the main wheel weighing point ℄ main wheel) to the Datum---3''
(L) Actual measured horizontal distance from the rear wheel weighing point (℄ rear wheel) to the main wheel weighing point------------------------------------222''

SOLVING: EMPTY WEIGHT

Weighing Point	Scale Reading #	Tare #	Net Weight #
Right	564	0	564
Left	565	0	565
Rear	67	27	40
Empty Weight (W)			1169

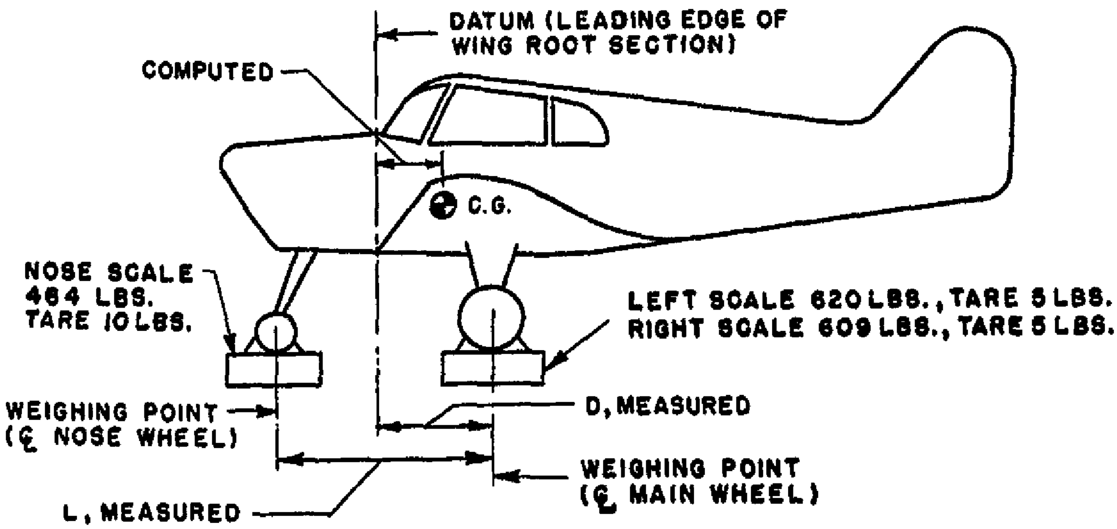
SOLVING: EMPTY WEIGHT CENTER OF GRAVITY

Formula: $C.G. = D + \frac{R \times L}{W} = 3'' + \frac{40 \times 222}{1169} = 3'' + 7.6'' = 10.6''$

Reference for formula, Figure 13.4

This case is shown properly entered on a sample weight and balance report form, Figure 13.17

FIGURE 13.5.—Empty weight and empty weight center of gravity—tail-wheel type aircraft.



TO FIND: EMPTY WEIGHT AND EMPTY WEIGHT CENTER OF GRAVITY

Datum is the leading edge of the wing (from aircraft specification)
(D) Actual measured horizontal distance from the main wheel weight point (℄ main wheel) to the Datum-- 34.0''
(L) Actual measured horizontal distance from the front wheel weighing point (℄ front wheel) to the main wheel weighing point-------------------------------------- 67.8''

SOLVING: EMPTY WEIGHT

Weighing Point	Scale Reading #	Tare #	Net Weight
Right	609	5	604
Left	620	5	615
Front	464	10	454
Empty Weight (W)			1673

SOLVING: EMPTY WEIGHT CENTER OF GRAVITY

Formula: $C.G. = D - \frac{F \times L}{W} = 34'' - \frac{454 \times 67.8}{1673} = 34'' - 18.3'' = 15.7''$

Reference for formula, Figure 13.4.

Figure 13.6.—Empty weight and empty weight center-of-gravity—nose-wheel type aircraft.

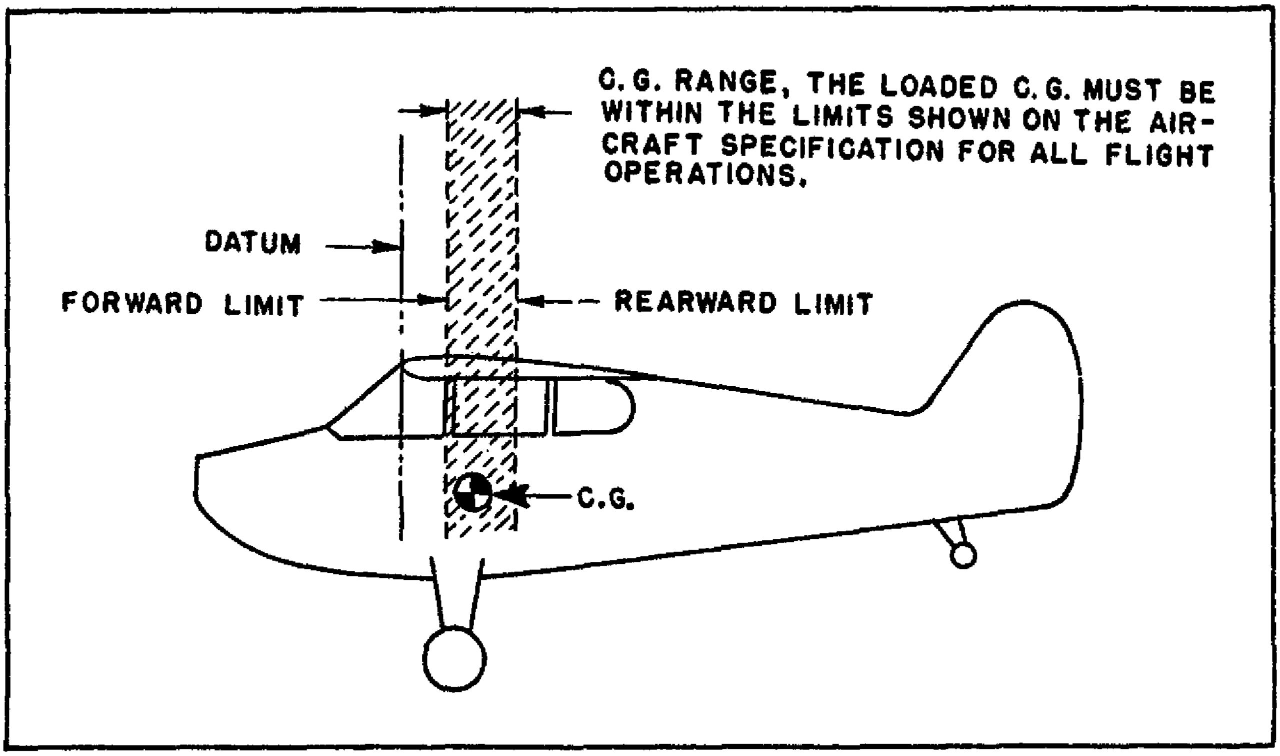


FIGURE 13.7.—Operating center-of-gravity range.

ance report when used in lieu of the landing gear. Typical locations of the weighing points are shown in figure 13.8.

n. ***Zero fuel weight*** is the maximum permissible weight of a loaded aircraft (passengers, crew, cargo, etc.) less its fuel. All weights in excess of maximum zero fuel weight must consist of useable fuel.

o. ***Minimum Fuel.*** Minimum fuel for balance purposes is no more than the quantity of fuel necessary for one-half hour of operation at rated maximum continuous power, and is the maximum amount of fuel used in weight and balance computation when low fuel may adversely affect the most critical balance condition.

p. ***Full Oil.*** Full oil is the quantity of oil shown in the aircraft specifications as oil capacity. Use full oil as the quantity of oil when making the loaded weight and balance computations.

q. ***Tare.*** Tare is the weight of chocks, blocks, stands, etc., used when weighing aircraft, and is included in the scale readings. Tare is deducted from the scale reading at each respective weighing point where tare is involved to obtain the actual aircraft weight.

658. WEIGHING PROCEDURE. Accepted procedures when weighing an aircraft are:

a. Remove excessive dirt, grease, moisture, etc., from the aircraft before weighing.

b. Weigh the aircraft inside a closed building to prevent error in scale reading due to wind.

c. To determine the center of gravity, place the aircraft in a level flight attitude.

d. Have all items of equipment included in the certificated empty weight installed in the aircraft when weighing. These items of equipment are a part of the current weight and balance report. (See paragraph 662.)

e. Properly calibrate, zero, and use the scales in accordance with the scale manufacturer's instructions. The scales and suitable support for the aircraft, if necessary, are usually placed

i. Note tare when the aircraft is removed from the scales.

659. WEIGHT AND BALANCE COMPUTATIONS. It is often necessary, after completing an extensive alteration, to establish by computation that the authorized weight or c.g. limits as shown on the FAA Aircraft Specifications are not exceeded. Paragraph b. explains the significance of algebraic signs used in balance computations.

The Aircraft Specifications contain the following information relating to the subject:

1. Center of gravity range.
2. Empty weight c.g. range when applicable.
3. Leveling means.
4. Datum.
5. Maximum weights.
6. Number of seats and arm.
7. Maximum baggage and arm.
8. Fuel capacity and arm.
9. Oil capacity and arm.
10. Equipment items and arm.

FAA Type Certificate Data Sheets do not list the basic required equipment prescribed by the applicable airworthiness regulations for certification. Refer to the manufacturer's equipment list for such information.

a. Unit Weight for Weight and Balance Purposes.

Gasoline	6 pounds per U.S. gal.
Turbine fuel	6.7 pounds per U.S. gal.
Lubricating oil	7.5 pounds per U.S. gal.
Crew and passengers	170 pounds per person.

b. Algebraic Signs. It is important to retain the proper algebraic sign (+ or −) through all balance computations. For the sake of uniformity in these computations, visualize the aircraft with the nose to the left. In this position any arm to the left (forward) of the datum is "minus" and any arm to the right (rearward) of the datum is "plus." Any item of weight added to the aircraft either side of the datum is plus weight. Any weight item removed is a minus weight. When multiplying weights by arms, the answer is plus if the signs are alike, and minus if the signs are unlike.

The following combinations are possible:

Items added forward of the datum—
(+) weight × (−) arm = (−) moment.
Items added to the rear of the datum—
(+) weight × (+) arm = (+) moment.
Items removed forward of the datum—
(−) weight × (−) arm = (+) moment.
Items removed rear of the datum—
(−) weight × (+) arm = (−) moment.

The total weight of the airplane is equal to the weight of the empty aircraft plus the weight of the items added, minus the weight of the items removed.

The total moment of the aircraft is the algebraic sum of the empty weight moment of the aircraft and all of the individual moments of the items added and/or removed.

660. WEIGHT AND BALANCE EXTREME CONDITIONS. The weight and balance extreme conditions represent the maximum forward and rearward c.g. position for the aircraft. Include in the weight and balance data information showing that the c.g. of the aircraft (usually in the fully loaded condition) falls between the extreme conditions.

a. Forward Weight and Balance Check. When a forward weight and balance check is made, establish that neither the maximum weight nor the forward c.g. limit listed in the Aircraft Specifications is exceeded. To make this check, the following information is needed:

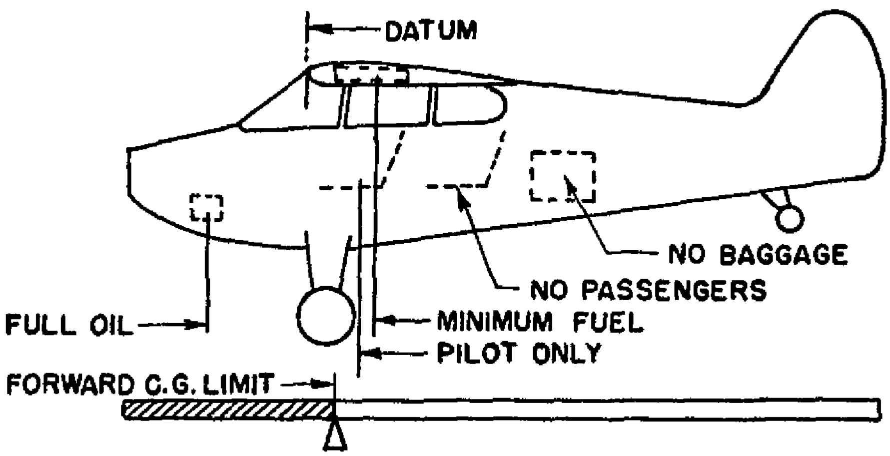
(1) The weights, arms, and moment of the empty aircraft.

(2) The maximum weights, arms, and moments of the items of useful load which are located ahead of the forward c.g. limit; and

(3) The minimum weights, arms, and moments of the items of useful load which are located aft of the forward c.g. limit.

A typical example of the computation necessary to make this check, using the above data, is shown in figure 13.10.

b. Rearward Weight and Balance Check. When a rearward weight and balance check is made, establish that neither the maximum weight nor the rearward c.g. limit listed in the



TO CHECK: MOST FORWARD WEIGHT AND BALANCE EXTREME.

GIVEN: Actual empty weight of the airplane-------------- 1169#
Empty weight center of gravity ----------------- +10.6''
*Maximum weight --------------------------- 2100#
*Forward C.G. limit -------------------------- + 8.5''
*Oil, capacity 9 qts. ---------------------------- 17# at - 49
*Pilot in farthest forward seat equipped with controls (unless otherwise placarded) ----------- 170# at + 16''
*Since the fuel tank is located to the rear of the forward C.G. limit, minimum fuel should be included. $\frac{\text{METO HP}}{12} = \frac{165}{12} = 13.75$ gal. x 6# ------- 83# at + 22''

*Information should be obtained from the aircraft specification.

Note: Any items or passengers must be used if they are located ahead of the forward C.G. limit.
Full fuel must be used if the tank is located ahead of the forward C.G. limit.

CHECK OF FORWARD WEIGHT AND BALANCE EXTREME

	Weight (#)	x Arm ('')	= Moment (''#)
Aircraft Empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Pilot	+ 170	+ 16	+ 2720
Fuel	+ 83	+ 22	+ 1826
Total	+ 1439 (TW)		+ 16104 (TM)

Divide the TM (Total Moment) by the TW (Total Weight) to obtain the forward weight and balance extreme.

$$\frac{TM}{TW} = \frac{16104}{1439} = +\ 11.2''$$

Since the forward C.G. limit and the maximum weight are not exceeded, the forward weight and balance extreme condition is satisfactory.

FIGURE 13.10.—Example of check of most forward weight and balance extreme.

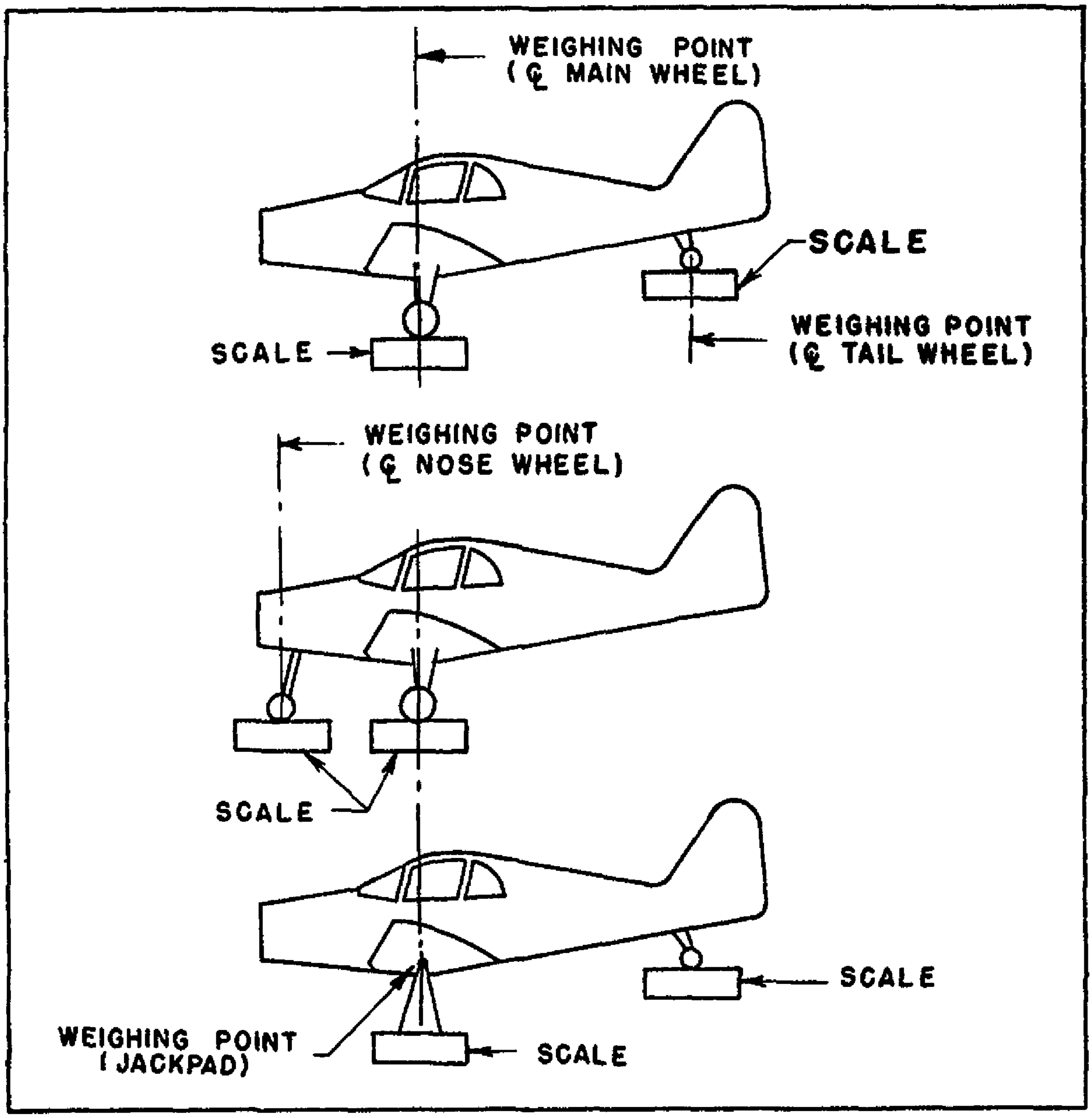
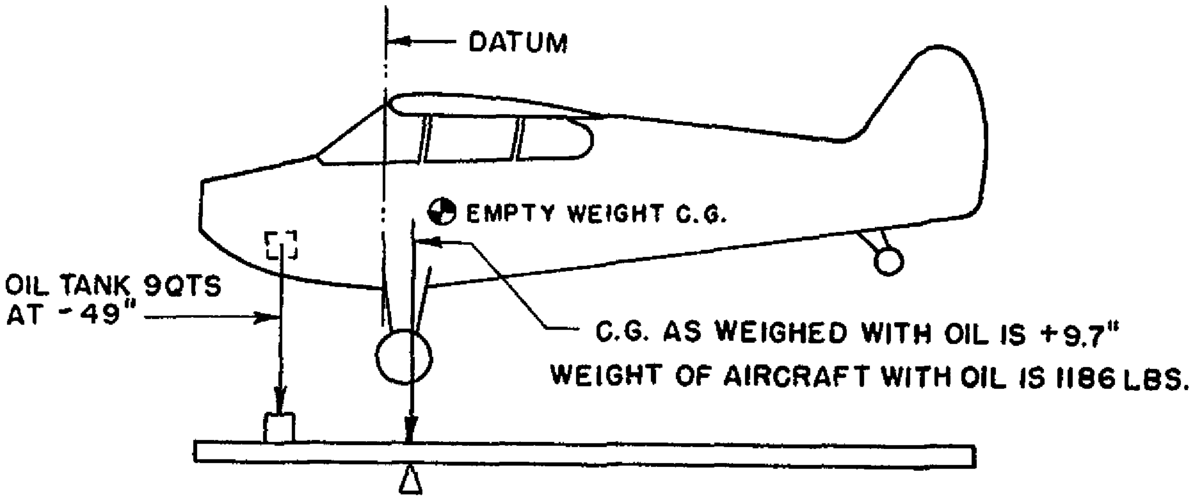


FIGURE 13.8.—Weighing point centerline.

under the wheels of a landplane, the keel of a seaplane float, or the skis of a skiplane. Other structural locations capable of supporting the aircraft, such as jack pads, may be used. Clearly indicate these points in the weight and balance report.

f. Unless otherwise noted in the aircraft specification, drain the fuel system until the quantity indicator reads "zero" or empty with the aircraft in level flight attitude. The amount of fuel remaining in the tank, lines, and engine is termed "residual fuel" and it is to be included in the empty weight. In special cases, the aircraft may be weighed with full fuel in tanks provided a definite means of determining the exact weight of the fuel is available.

g. Unless otherwise noted in the aircraft specification, the oil system should be completely



EMPTY WEIGHT AND EMPTY WEIGHT CENTER OF GRAVITY
(when aircraft is weighed with oil)

GIVEN:

Aircraft as weighed with full oil------ 1186 lbs.
Center of gravity---------------------- 9.7''
Full oil capacity 9 qts.----------------- 17 lbs.

SOLVING:

	Weight # x	Arm'' =	Moment ''#
Aircraft as weighed	+ 1186	+ 9.7	+ 11504
Less oil	- 17	-49.0	+ 833
Total	+ 1169(A)		+ 12337(B)

Empty Weight (A) = 1169 pounds.

Empty Weight Center of Gravity $\frac{B}{A} = \frac{12337}{1169} = +10.6''$

FIGURE 13.9.—Empty weight and empty weight center-of-gravity when aircraft is weighed with oil.

drained with all drain cocks open. Under these conditions, the amount of oil remaining in the oil tank, lines and engine is termed "residual oil," and it will be included in the empty weight. When weighed with full oil, actual empty weight equals the actual recorded weight less the weight of the oil in the oil tank (oil weight = oil capacity in gallons × 7.5 pounds). Indicate in all weight and balance reports whether weights include full oil or oil drained (see figure 13.9).

h. Do not set brakes while taking scale reading.

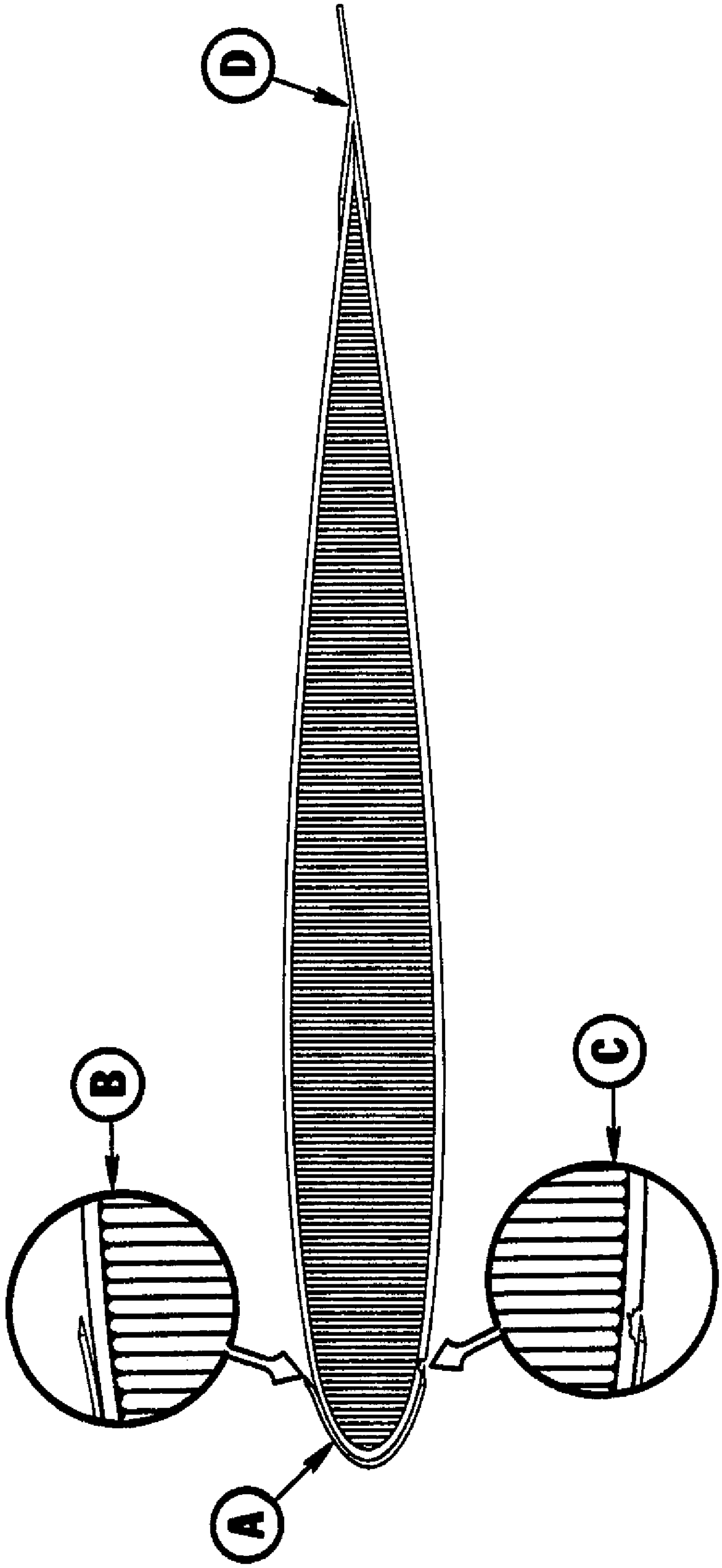


FIGURE 12.8.—Blade leading edge and trim tab.

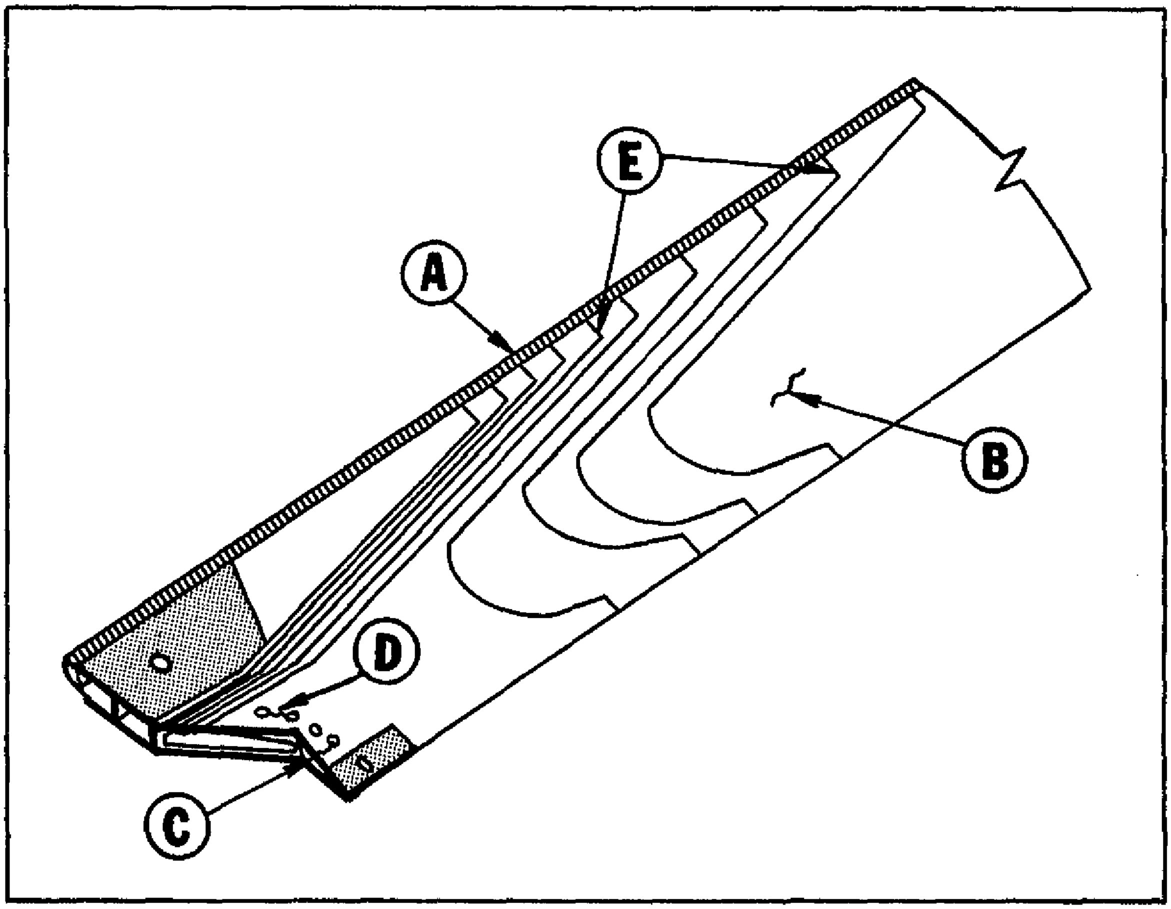


FIGURE 12.9.—Blade bonding and crack location.

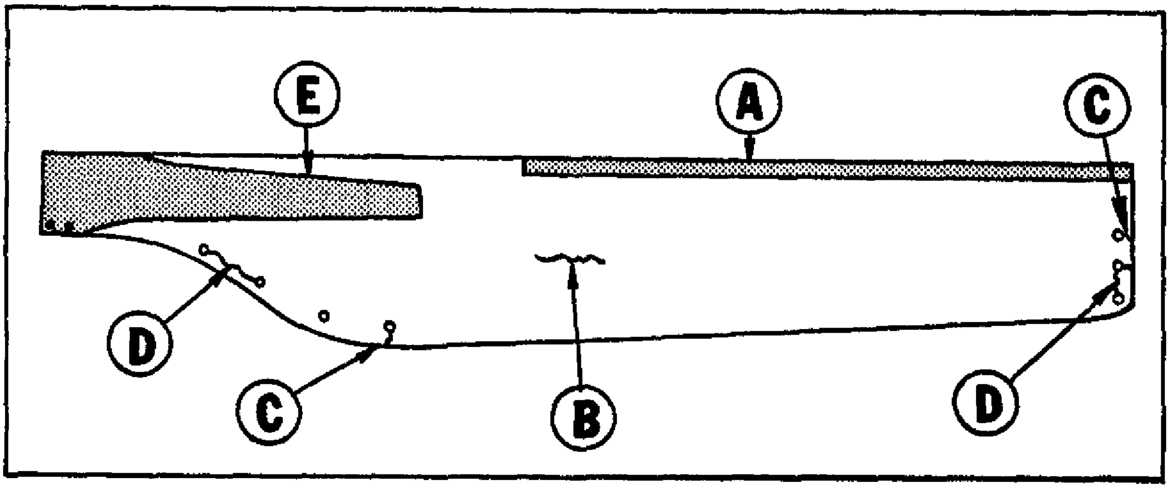
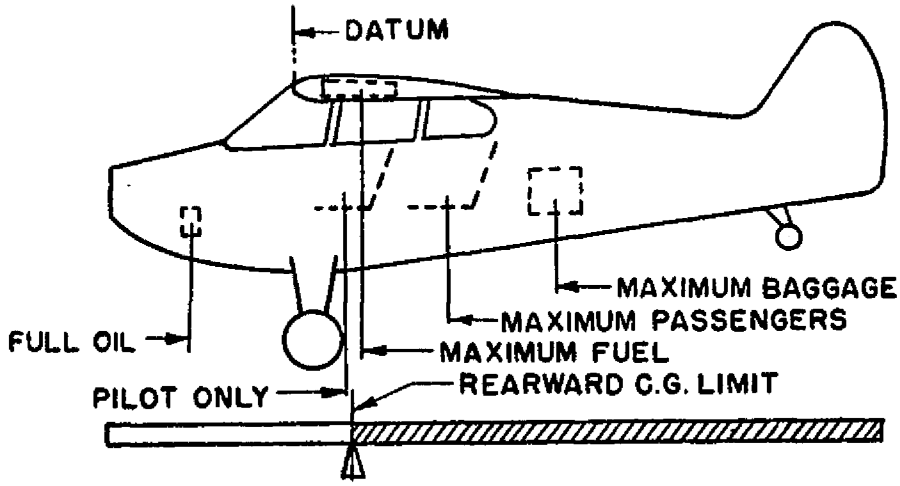


FIGURE 12.10.—Blade damage location.



TO CHECK: MOST REARWARD WEIGHT AND BALANCE EXTREME.

GIVEN: Actual empty weight of the airplane --------- 1169#
Empty weight center of gravity ------------- 10.6''
*Maximum weight ------------------------- 2100#
*Rearward C.G. limit ---------------------- 21.9''
*Oil capacity 9 qts. ----------------------- 17# at - 49''
*Baggage, placarded do not exceed 100 lbs. --- 100# at + 75.5''
*Two passengers in rear seats, 170 x 2 ------ 340# at + 48''
*Pilot in most rearward seat equipped with controls (unless otherwise placarded) ------- 170# at + 16''
*Since the fuel tank is located aft of the rearward C.G. limit full fuel must be used --- 240# at + 22''

* Information should be obtained from the aircraft specification.

Note: If fuel tanks are located ahead of the rearward C.G. limit minimum fuel should be used.

CHECK OF REARWARD WEIGHT AND BALANCE EXTREME

	Weight (#)	x Arm ('')	= Moment (''#)
Aircraft empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Pilot (1)	+ 170	+ 16	+ 2720
Passengers (2)	+ 340	+ 48	+ 16320
Fuel (40 gals.)	+ 240	+ 22	+ 5280
Baggage	+ 100	+ 75.5	+ 7550
Total	+2036 (TW)		+ 43428 (TM)

Divide the TM (Total Moment) by the TW (Total Weight) to obtain the rearward weight and balance extreme.

$$\frac{TM}{TW} = \frac{43428}{2036} = +21.3''$$

Since the rearward C.G. limit and the maximum weight are not exceeded, the rearward weight and balance extreme condition is satisfactory.

FIGURE 13.11.—Example of check of most rearward weight and balance extreme.

EXAMPLE OF THE DETERMINATION OF THE NUMBER OF PASSENGERS AND BAGGAGE PERMISSIBLE WITH FULL FUEL

GIVEN:

Actual empty weight of the aircraft	1169#
Empty weight center of gravity	10.6"
Maximum weight	2100#
Datum is leading edge of the wing	
Forward center of gravity limit	8.5"
Rearward center of gravity limit	21.9"
Oil capacity, 9 qts.; show full capacity	17# at -49"
Baggage, maximum	100# at +75.5"
Two passengers in rear seat, 170# x 2	340# at +48"
Pilot in most rearward seat equipped with controls (unless otherwise placarded)	170# at +16"
Full fuel, 40 gals. x 6#	240# at +22"

	Weight(#)	x Arm(")	= Moment("#)
Aircraft empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Full fuel	+ 240	+ 22	+ 5280
Passengers, 2 rear	+ 340 *	+ 48	+ 16320
Pilot	+ 170	+ 16	+ 2720
Baggage	+ 100	+ 75.5	+ 7550
Total	+ 2036 (TW)		+ 43428 (TM)

Divide the TM (total moment) by the TW (total weight) to obtain the loaded center of gravity.

$$\frac{TM}{TW} = \frac{43428}{2036} = +21.3''$$

The above computations show that with full fuel, 100 pounds of baggage and two passengers in the rear seat may be carried in this aircraft without exceeding either the maximum weight or the approved C.G. range.

This condition may be entered in the loading schedule as follows:

GALLONS OF FUEL	NUMBER OF PASSENGERS	POUNDS OF BAGGAGE
Full	2 Rear	100

* Only two passengers are listed to prevent the maximum weight of 2100 lbs. from being exceeded.

FIGURE 13.12.—Loading conditions: determination of the number of passengers and baggage permissible with full fuel.

aircraft specification is exceeded. To make this check, the following information is needed:

(1) The weight, arms, and moments of empty aircraft;

(2) The maximum weights, arms, and moments of the items of useful load which are located aft of the rearward c.g. limit; and

(3) The minimum weights, arms, and moments of the items of useful load which are located ahead of the rearward c.g. limit.

A typical example of the computation necessary to make this check, using the above data, is shown in figure 13.11.

661. LOADING CONDITIONS AND/OR PLACARDS. If the following items have not been covered in the weight and balance extreme condition checks, or are not covered by suitable placards in the aircraft, additional computations are necessary.

These computations should indicate the permissible distribution of fuel, passengers, and baggage which may be carried in the aircraft at any one time without exceeding either the maximum weight or c.g. range. The conditions to check are:

a. With full fuel, determine the number of passengers and baggage permissible.

b. With maximum passengers, determine the fuel and baggage permissible.

(1) Examples of the computations for the above items are given in figures 13.12, 13.13, and 13.14 respectively. The above cases are mainly applicable to the lighter type personal aircraft. In the case of the larger type transport aircraft, a variety of loading conditions is possible and it is necessary to have a loading schedule.

662. EQUIPMENT LIST. A list of the equipment included in the certificated empty weight may be found in either the approved Airplane Flight Manual or the weight and balance report. Enter in the weight and balance report all required, optional and special equipment installed in the aircraft at time of weighing and/or subsequent equipment changes.

a. Required equipment items are items so listed in the pertinent aircraft specification.

b. Optional equipment items are so listed in the pertinent aircraft specification and may be installed in the aircraft at the option of the owner.

c. Special equipment is any item not corresponding exactly to the descriptive information in the aircraft specification. This includes such items as flares, instruments, ashtrays, radios, navigation lights, carpets, etc.

d. Required and optional equipment may be shown on the equipment list making reference to the pertinent item number listed in the applicable specification only when they are identical to that number item with reference to description, weight, and arm given in the specification. Show all special equipment items by making reference to the item by name, make, model, weight, and arm. When the arm for such an item is not available, determine by actual measurement.

(1) **Equipment Changes.** The person making an equipment change is obligated to make an entry on the equipment list indicating items added, removed, or relocated with the date accomplished, and identify himself by name and certificate number in the aircraft records.

Examples of items so affected are the installation of extra fuel tanks, seats, or baggage compartments. Figure 13.15 illustrates the effect on balance when equipment items are added within the acceptable c.g. limits and fore and aft of the established c.g. limits. Moment computations for typical equipment changes are given in figure 13.16 and are also included in the sample weight and balance sheet in figure 13.18.

663. SAMPLE WEIGHT AND BALANCE REPORT. Suggested methods of tabulating the various data and computations for determining the c.g., both in the empty weight condition and fully loaded condition, are given in figures 13.17 and 13.18, respectively, and represent a suggested means of recording this information. The data presented in figure 13.17 have previously been computed in figures 13.10 and

EXAMPLE OF THE DETERMINATION OF THE POUNDS OF FUEL AND BAGGAGE PERMISSIBLE WITH MAXIMUM PASSENGERS

	Weight (#)	x Arm (")	= Moment ("#)
Aircraft empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Pilot	+ 170	+ 16	+ 2720
Passenger, 1 front	+ 170	+ 16	+ 2720
Passengers, 2 rear	+ 340	+ 48	+ 16320
Fuel (39 gals.)	+ 234	+ 22	+ 5148
Baggage	---	---	---
Total	+ 2100		+ 38466

Divide the TM (total moment) by the TW (total weight) to obtain the loaded center of gravity.

$$\frac{TM}{TW} = \frac{38466}{2100} = +18.3''$$

The above computations show that with the maximum number of passengers, 39 gallons of fuel and zero pounds of baggage may be carried in this aircraft without exceeding either the maximum weight or the approved C.G. range.

This condition may be entered in the loading schedule as follows:

GALLONS OF FUEL	NUMBER OF PASSENGERS	POUNDS OF BAGGAGE
* FULL	* 2 rear	* 100
39	1(F) 2(R)	None

* Conditions as entered from Figure 13.12
(F) Front seat
(R) Rear seat

FIGURE 13.13.—Loading conditions: determination of the fuel and baggage permissible with maximum passengers.

13.11 for the extreme load conditions, and figure 13.16 for equipment change and represent suggested means of recording this information.

664. INSTALLATION OF BALLAST. Ballast is sometimes permanently installed for c.g. balance purposes as a result of installation or removal of equipment items and is not used to correct a nose-up or nose-down tendency of an aircraft. It is usually located as far aft or as far forward as possible in order to bring the c.g. position within acceptable limits with a minimum of weight increase. Permanent ballast is often

EXAMPLE OF THE DETERMINATION OF THE FUEL AND THE NUMBER AND LOCATION OF PASSENGERS PERMISSIBLE WITH MAXIMUM BAGGAGE

	Weight (#)	x Arm (")	= Moment ("#)
Aircraft empty	+ 1169	+ 10.6	+ 12391
Oil	+ 17	- 49	- 833
Pilot	+ 170	+ 16	+ 2720
Passenger (1) rear	+ 170	+ 48	+ 8160
Passenger (1) front	+ 170	+ 16	+ 2720
Fuel (40 gals.)	+ 240	+ 22	+ 5280
Baggage	+ 100	+ 75.5	+ 7550
Total	+ 2036		+ 37988

Divide the TM (total moment) by the TW (total weight) to obtain the loaded center of gravity.

$$\frac{TM}{TW} = \frac{37988}{2036} = +18.7$$

The above computations show that with maximum baggage, full fuel and 2 passengers (1 in the front seat and 1 in the rear seat) may be carried in this aircraft without exceeding either the maximum weight or the approved C.G. range.

This condition may be entered in the loading schedule as follows:

GALLONS OF FUEL	NUMBER OF PASSENGERS	POUNDS OF BAGGAGE
* Full	* 2 Rear	*100
** 39	*1(F) 2(R)	**None
Full	1(F) 1(R)	Full

* Conditions as entered from Figure 13.12
** Conditions as entered from Figure 13.13
(F) Front seat
(R) Rear seat

FIGURE 13.14.—Loading conditions: determination of the fuel and the number and location of passengers permissible with maximum baggage.

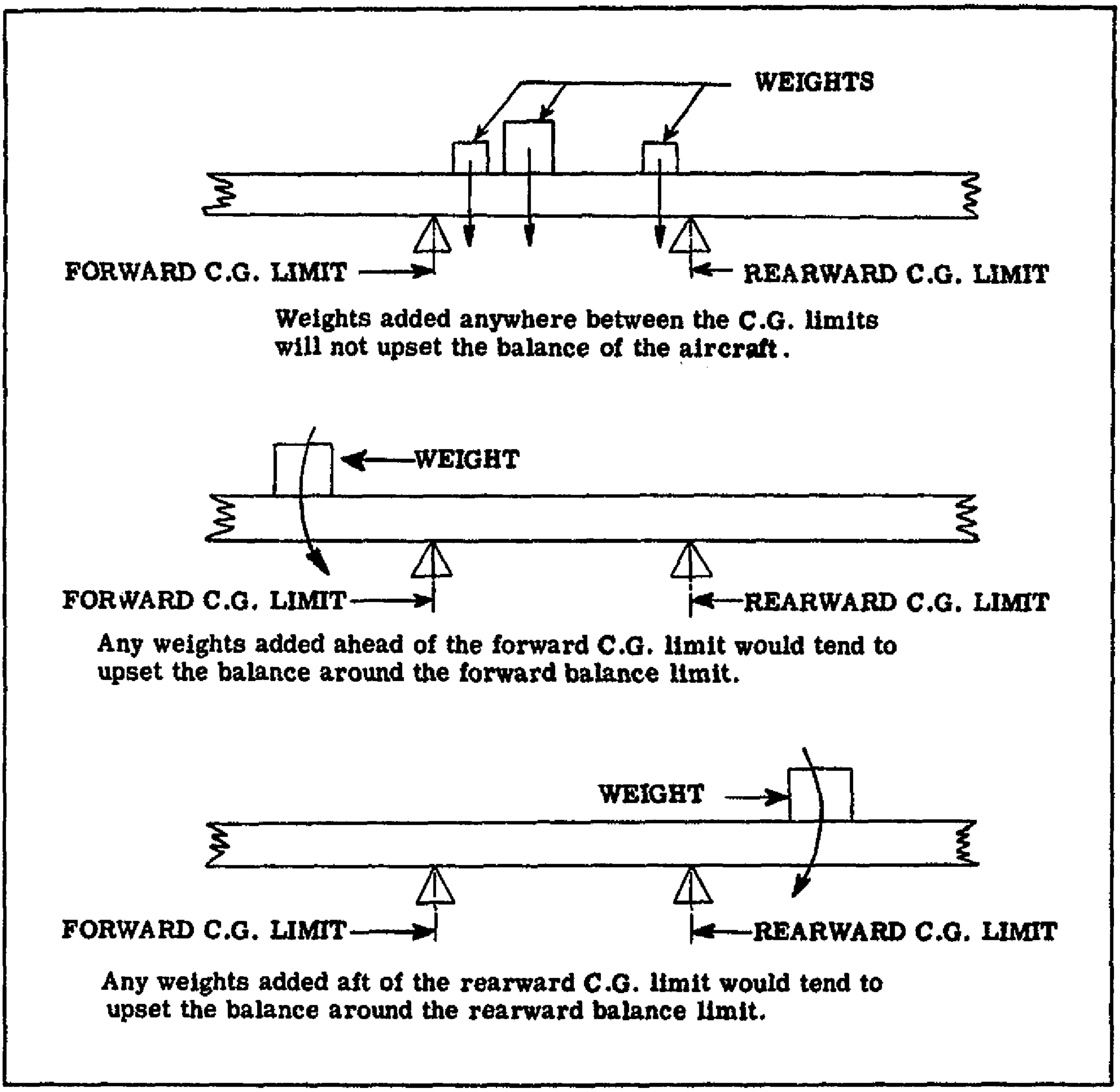
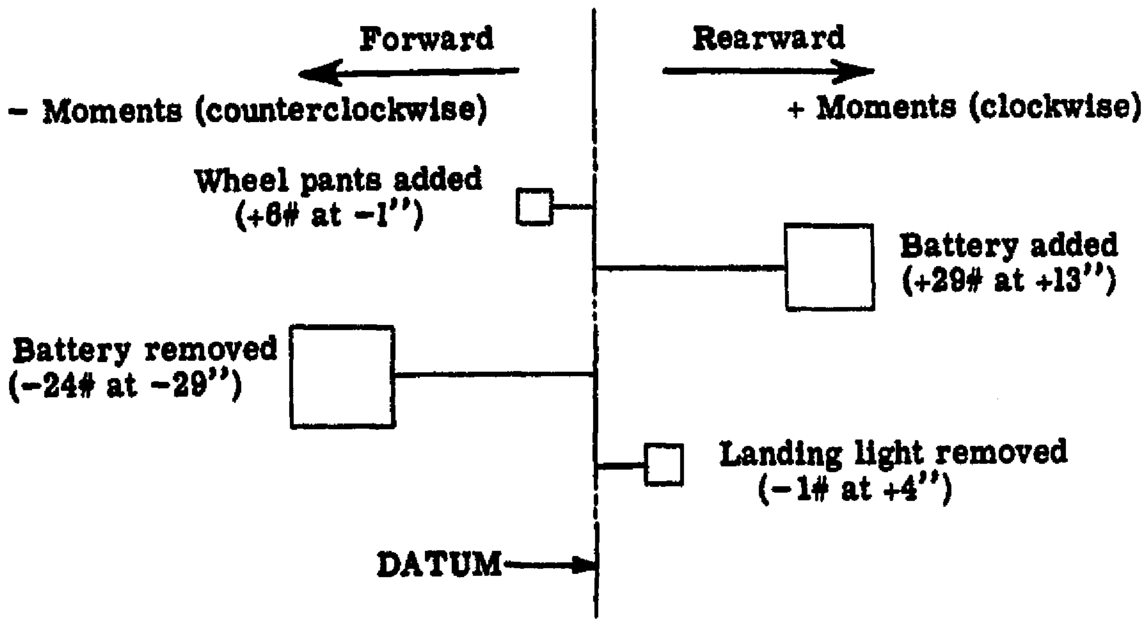


FIGURE 13.15.—Effects of the addition of equipment items on balance.



	Weight (#)	x Arm (")	= Moment ("#)
ADDED			
Item 204 wheel pants	+ 6	– 1	– 6
Item 302b Battery	+ 29	+13	+377
REMOVED			
Item 302a Battery	– 24	–29	+696
Item 303 Landing light	– 1	+ 4	– 4

This condition is shown properly entered on a sample weight and balance report on Figure 13.18 under Equipment Change.

FIGURE 13.16.—Example of moment and weight changes resulting from equipment changes.

MAKE MA-700 MODEL A SERIAL # 0000 REGISTRATION # N1234
DATUM IS leading edge of wing.

COMPUTE AS FOLLOWS IF AIRCRAFT WEIGHED

1. Leveling means: level top longeron between front and rear seats.
2. Main wheel weighing point is located (______"FORWARD)(+ 3 " AFT) of datum.
3. Actual measured distance from the main weight point centerline to the tail (or nose) point centerline 222 ".
4. Oil over and above "ZERO" tank reading = (a. — Gals.)(b. — Lbs.)(c. — In.)

ACTUAL EMPTY WEIGHT

	Weight Point	Scale Reading	- Tare	= Net Weight
5.	Right	564	0	564
6.	Left	565	0	565
7.	Tail	67	27	40
8.	Nose	—	—	—
9.	Total Net Weight			1169

CENTER OF GRAVITY AS WEIGHED

10. C.G. relative to main wheel weighing point:
(a) Tail wheel airc. (item 3, 222) X (Item 7, 40) / (Item 9, 1169) = + 7.6 = C.G.

(b) Nose wheel airc. (Item 3 —) X (Item 8 —) / (Item 9 —) = ______ = C.G.

11. C.G. relative to datum:
(a) Tail wheel airc. (Item 10a, + 7.6) added to (Item 2, + 3) = + 10.6" = C.G.
(b) Nose wheel airc. (Item 10b, ____) added to (Item 2, ____) = ______ = C.G.

COMPUTE IF AIRCRAFT WEIGHED WITH OIL (Item 4)

	Weight	X Arm	= Moment
Aircraft	(9)	(11)	
Less Oil	(4b)	(4c)	
Empty Totals	(a)		(b)

12. (b)/(a) ---------- = (c)----------" = Empty weight C.G.

REPAIR AGENCY ______________ ______________ DATE ______________
Name Number

FIGURE 13.17.—Sample weight and balance report to determine empty weight center-of-gravity.

EQUIPMENT LIST

*Required or Optional Item Numbers as Shown in Aircraft Specification						
1	2	101	102	103	104	105
106	201	202	203	301	302(a)	303
401(a)	402	—	—	—	—	—

Special Equipment				
Item	Make	Model	Weight	Arm
3 Flares 1½ Min.	XYZ	03	25#	150"
Enter above those items included in the empty weight.				

WEIGHT AND BALANCE EXTREME CONDITIONS

Approved fwd limit 8.5 " Approved max. weight 2100# Approved aft limit 21.9"

Item	FORWARD CHECK			REARWARD CHECK		
	Weight X	Arm =	Moment	Weight X	Arm =	Moment
Airc. Empty	+ 1169 (9 or 12a)	+ 10.6 (11 or 12c)	+ 12391	+ 1169 (9 or 12a)	+ 10.6 (11 or 12c)	+ 12391
Oil	+ 17	- 49	- 833	+ 17	- 49	- 833
Pilot	+ 170	+ 16	+ 2720	+ 170	+ 16	+ 2720
Fuel	+ 83	+ 22	+ 1826	+ 240	+ 22	+ 5280
Passenger(s)				+ 340	+ 48	+ 16320
Baggage				+ 100	+ 75.5	+ 7550
TOTAL	+ 1439 = TW		+ 16104 = TM	+ 2036 = TW		+ 43428 = TM

$\frac{TM}{TW} = \frac{16104}{1439} = +11.2" =$ Most Forward C.G. location

$\frac{TM}{TW} = \frac{43428}{2036} = +21.3" =$ Most rearward C.G. location

LOADING SCHEDULE

Gallons of Fuel	Number of Passengers	Pounds of Baggage
40	2(R)	100
The above includes pilot and capacity oil.		

EQUIPMENT CHANGE

Computing New C.G.			
Item, Make, and Model*	Weight X	Arm =	Moment
Airc. Empty	+ 1169 (9 or 12a)	+ 10.6 (11 or 12c)	+ 12391
204 added	+ 6	- 1	- 6
302(b) added	+ 29	+ 13	+ 377
302(a) removed	- 24	- 29	+ 696
303 removed	- 1	+ 4	- 4
NET TOTALS	- 1179 = NW		+ 13454 = NM

$\frac{NM}{NW} = \frac{13454}{1179} = + 11.4" =$ New C.G.

*ITEM NUMBERS WHEN LISTED IN PERTINENT AIRCRAFT SPECIFICATION MAY BE USED IN LIEU OF "ITEM, MAKE, AND MODEL".

PREPARED BY ____________________ DATE ____________________

FIGURE 13.18.—Sample weight and balance report including an equipment change for aircraft fully loaded.

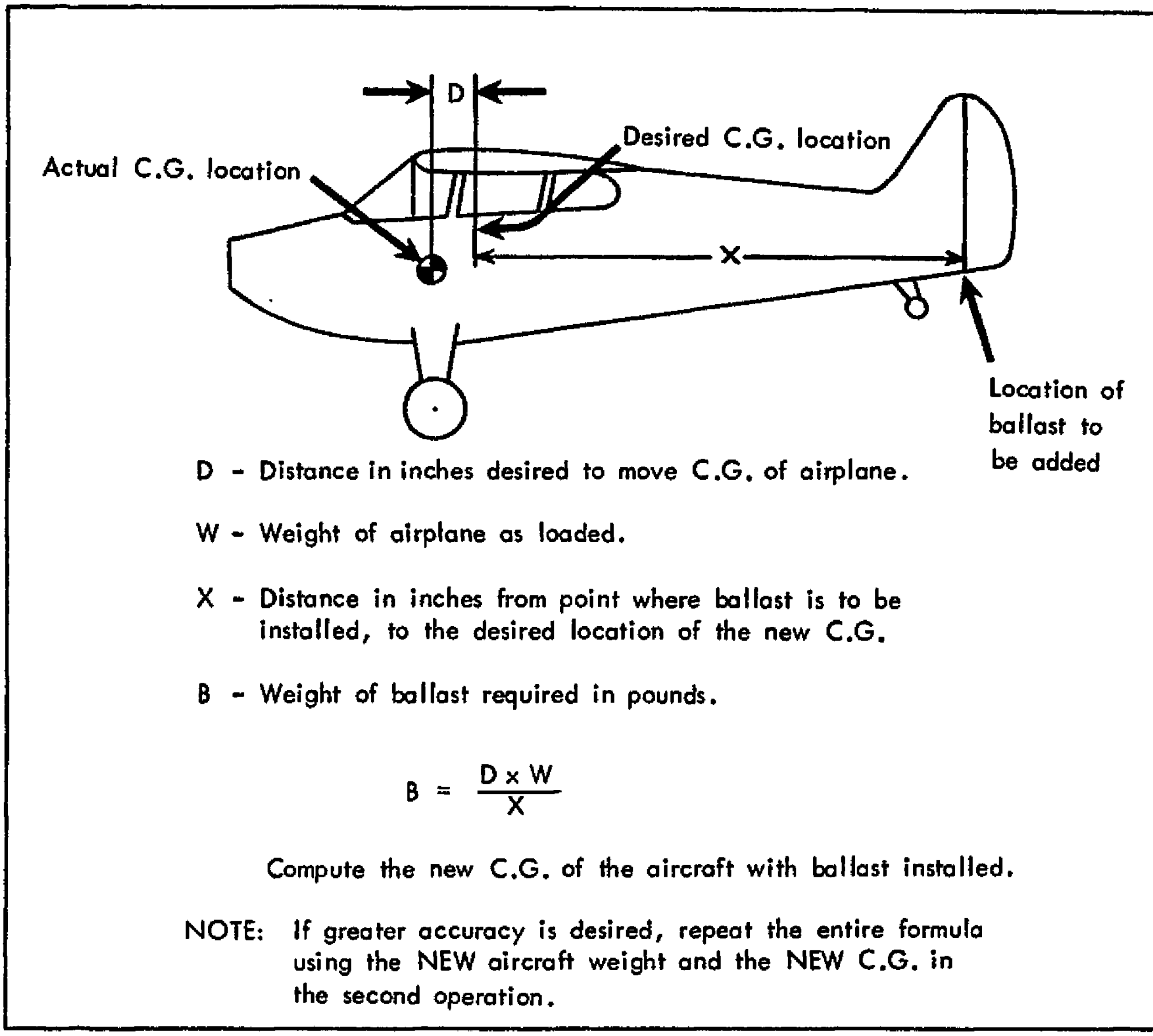


FIGURE 13.19.—Permanent ballast computation formula.

in the form of lead plate wrapped around and/or bolted to the fuselage primary structure (tail-post, longerons, or bulkhead members). Permanent ballast invariably constitutes a concentrated load; therefore, the strength of the local structure and the attachment of the ballast thereto should be investigated for the design loading conditions pertinent to the particular aircraft. Placard permanent ballast "Permanent ballast—do not remove." It is not desirable to install permanent ballast by pouring melted lead into the tail-post or longerons, due to difficulties that may be encountered in subsequent welding repair operations. It should be noted that the installation of permanent ballast results in an increase of aircraft empty weight. See figure 13.19 for ballast computation. When disposable ballast is carried, the local strength of the compartment in which the ballast is carried and the effect of the ballast on aircraft balance and weight should be investigated.

665. LOADING SCHEDULE. The loading schedule should be kept with the aircraft and usually forms a part of the airplane flight manual. It includes instructions on the proper load distribution, such as filling of fuel and oil tanks, passenger seating, restrictions of passenger movement; distribution of cargo, etc.

a. Other means of determining safe loading conditions, such as the use of a graphical index, load adjuster, etc., are acceptable and may be used in lieu of the information in paragraph 661.

b. Compute a separate loading condition when the aircraft is to be loaded in other than the specified conditions shown in the loading schedule.

666.–676. RESERVED.

Chapter 14. ENGINES AND FUEL SYSTEMS

Section 1. ENGINES

677. GENERAL. Persons should avail themselves of the manufacturer's manuals, service bulletins, and instruction books regarding the repair and overhaul, inspection, installation, and maintenance of aircraft engines. The repair and overhaul of engines are too many and varied for the different types and models of engines to mention here in specific detail.

678. INSPECTION. All moving and/or highly-stressed parts and those subjected to high temperature should have a critical visual inspection at the time of overhaul. It is often necessary to supplement the visual inspection by employing one of the following procedures:

a. Wet or dry magnetic dust inspection of magnetic materials,

b. Wet or dry penetrant inspection of nonmagnetic materials,

c. X-ray or sonic inspection of any material, or

d. Hydrostatic inspection testing of fluid lines and internal passages and assemblies such as cylinder heads.

679. POWERPLANT SUDDEN STOPPAGE. For the purpose of this section, powerplant sudden stoppage refers to any momentary slowdown or complete stoppage of the main shaft of an aircraft powerplant; when the stoppage of a reciprocating or turboprop engine is the result of the rotating propeller striking a foreign object; or when the stoppage of a turbine engine is the result of ingestion of foreign objects or material. Any aircraft powerplant that has been subjected to sudden stoppage should be inspected to the extent necessary to assure continued safe operation. These procedures will serve as a guide for locating damage that may occur whenever an aircraft powerplant has been subjected to sudden deceleration or stoppage.

To fully evaluate any unsatisfactory findings resulting from this type of inspection, it will be necessary to refer to the applicable manufacturer's service and overhaul data. In addition, many of the prime aeronautical engine manufacturers now have specific recommendations on the subject of sudden stoppage involving their products. To assure continued airworthiness and reliability, it is essential that such data be used. In the event the manufacturer has not specified an instruction to follow, the following may be used as a guideline.

a. Reciprocating Engine (Direct Drive).

(1) Powerplant Exterior Inspection. Remove the engine cowling and examine the engine for visible external damage and audible internal damage.

(a) Rotate the propeller shaft to determine any evidence of abnormal grinding or sounds.

(b) With the propeller removed, inspect the crankshaft flange or splines for signs of twisting, cracks, or other deformation. Remove the thrust-bearing nut and seal and thoroughly inspect the threaded area of the shaft for evidence of cracks.

(c) Rotate the shaft slowly in 90° increments while using a dial indicator or an equivalent instrument to check the concentricity of the shaft.

(d) Remove the oil sump drain plug and check for metal chips and foreign material.

(e) Remove and inspect the oil screens for metal particles and contamination.

(f) Visually inspect engine case exterior for signs of oil leakage and cracks. Give particular attention to the propeller thrust-bearing area of the nose case section.

(*g*) Inspect cylinders and cylinder holddown area for cracks and oil leaks. Thoroughly investigate any indication of cracks, oil leaks or other damage.

(2) **Powerplant Internal Inspection.**

(*a*) On engines equipped with crankshaft vibration dampers, remove the cylinders necessary to inspect the dampers and inspect in accordance with the engine manufacturer's inspection and overhaul manual. When engine design permits, remove the damper pins, and examine the pins and damper liners for signs of nicks or brinelling.

(*b*) After removing the engine-driven accessories remove the accessory drive case and examine the accessory and supercharger drive gear train, couplings, and drive case for evidence of damage.

1. Check for cracks in the case in the area of accessory mount pads and gear shaft bosses.

2. Check the gear train for signs of cracked, broken, or brinelled teeth.

3. Check the accessory drive shaft couplings for twisted splines, misalignment and runout.

(3) **Accessory and Drive Inspection.** Check the drive shaft of each accessory, i.e., magnetos, generators, external supercharger, and pumps for evidence of damage.

(4) **Engine Mount Inspection.**

(*a*) Examine the engine flex mounts when applicable for looseness, distortion, or signs of tear.

(*b*) Inspect the engine mount structure for bent, cracked, or buckled tubes.

(*c*) Check the adjacent airframe structure for cracks, distortion, or wrinkles.

(*d*) Remove engine mount bolts and mount holddown bolts and inspect for shear, cracks, or distortion.

(5) **Exhaust-driven Supercharger (Turbo) Inspection.** Sudden stoppage of the powerplant can cause the heat in turbine parts to heat soak the turbine seals and bearings. This excessive heat causes carbon to develop in the seal area and varnish to form on the turbine bearings and journals.

(*a*) Inspect all air ducts and connections for air leaks, warpage, or cracks.

(*b*) Remove compressor housing and check the turbine wheel for rubbing or binding.

(6) **Propeller Inspection Repair.** Any propeller that has struck a foreign object during service should be promptly inspected in accordance with the propeller manufacturer's prescribed procedures for possible damage resulting from this contact with the foreign object and, if necessary, repaired according to the manufacturer's instructions. If the propeller is damaged beyond the repair limits established by the propeller manufacturer and a replacement is necessary, install the same make/model or alternate approved for this installation. Refer to the aircraft manufacturer's optional equipment list, applicable FAA Aircraft Specification, Data Sheet, or Supplemental Type Certificate Data.

b. ***Reciprocating Engine (Geared Drive).*** Inspect the engine, propeller and components as in preceding paragraphs.

(1) Remove the propeller reduction gear housing and inspect for:

(*a*) Loose, sheared, or spalled cap screws or bolts.

(*b*) Cracks in the case.

(2) Disassemble the gear train and inspect the propeller shaft, reduction gears and accessory drive gears for nicks, cracks, or spalling.

c. ***Turbine, Engine, Ingestion Inspection.*** When the components of the compressor assembly or turbine section are subjected to ingestion damage, refer to the engine manufacturer's inspection and overhaul manual for specific inspection procedures and allowable tolerances. In general, an inspection after ingestion of foreign materials consists of the following areas:

(1) Inspect the external areas of the engine cases, attached parts and engine mounts for cracks, distortion, or other damage.

(2) Inspect the turbine disc for warpage or distortion.

(3) Inspect turbine disc seal for damage from rubbing or improper clearance.

(4) Inspect compressor rotor blades and stators for nicks, cracks, or distortion.

(5) Check rotor and main shaft for misalignment.

(6) Inspect shaft bearing area for oil leaks.

(7) Inspect the hot section for cracks or hot spots.

(8) Inspect the accessory drives as prescribed under paragraph a(2)(b).

NOTE: Turbine disc seal rubbing is not unusual and may be a normal condition. Consult the engine manufacturer's inspection procedures and table of limits.

d. *Turboprop Engine Inspection.*

(1) When sudden stoppage is the result of compressor ingestion of foreign material, inspect the engine as follows:

(a) Inspect the powerplant as described in paragraph c, "Turbine Engine, Ingestion Inspection."

(b) Inspect the reduction gear section as described in paragraph b(1) and b(2) where reduction gear damage is suspected.

(2) When sudden stoppage is the result of the propeller striking foreign objects, inspect the engine as follow:

(a) Inspect the reduction gear section as described in paragraph b(1) and b(2).

(b) Inspect mainline shafts and coupling shafts for runout and spiral cracks.

(c) Inspect bearings for brinelling.

(d) Inspect engine compressor and turbine blades for tip clearance.

e. *Approval for Returning Engine to Service.*

(1) Correct all discrepancies found in the foregoing inspection in accordance with the engine manufacturer's service instructions.

(2) Test run the engine to determine that the engine, propeller, and accessories are functioning properly.

(3) After shutdown, check the engine for oil leak and check oil screens for signs of contaminants.

(4) If everything is normal the engine is ready for preflight runup and test flight.

680. CRANKSHAFTS. Carefully inspect for misalignment and replace if bent beyond the manufacturer's permissible service limit. Make no attempt to straighten crankshafts damaged in service without consulting the engine manufacturer for appropriate instructions. Worn journals may be repaired by regrinding in accordance with manufacturers' instructions. It is recommended that grinding operations be performed by appropriately rated repair stations or the original engine manufacturer to assure adherence to aeronautical standards. Common errors that occur in crankshaft grinding are the removal of nitrided journal surface, improper journal radii, unsatisfactory surfaces, and grinding tool marks on the journals. If the fillets are altered, do not reduce their radii. Polish the reworked surfaces to assure removal of all tool marks. Most opposed engines have nitrided crankshafts and manufacturers specify that these crankshafts must be nitrided after grinding.

681. REPLACEMENT PARTS IN CERTIFICATED ENGINES. Only those parts which are approved under FAR Part 21 should be used. Serviceable parts obtained from the engine manufacturer, his authorized service facility, and those which are FAA/PMA approved meet the requirements of FAR Part 21 and are acceptable for use as replacement parts. It is suggested that the latest type parts as reflected on the current parts list be obtained. Parts from military surplus stocks, which are applicable to the specific engine may be used provided they were originally accepted under the military procurement agency's standards, are found to be serviceable, and are not prohibited from use by the Administrator.

a. *Parts for obsolete engines* for which new parts are no longer obtainable from the original manufacturer or his successor are sometimes fabricated locally. When it becomes necessary to do this, physical tests and careful measurements of the old part may provide adequate technical information. This procedure is usually regarded as a major change which requires engine testing and is not recommended except as a last alternative.

b. *Parts from certain military surplus* tank or ground power unit engines are used on engines used in restricted aircraft and amateur-built aircraft. Users of such parts are cautioned to determine that they do not exceed the design limits of the engine. For example, a particular tank engine utilized a piston design that developed a compression ratio well in excess of the crankshaft absorption rate of the aircraft engine counterpart—result, crankshaft failure.

682. CYLINDER HOLDDOWN NUTS AND CAPSCREWS. Great care is required in tightening cylinder holddown nuts and capscrews. They must be tightened to recommended torque limits to prevent improper stressing and to insure even loading on the cylinder flange. The installation of baffles, brackets, clips, and other extraneous parts under nuts and capscrews is not considered good practice and should be discouraged. If these baffles, brackets, etc., are not properly fabricated or made of suitable material, they may cause loosening of the nuts or capscrews even though the nuts or capscrews were properly tightened and locked at installation. Either improper prestressing or loosening of any one of these nuts or capscrews will introduce the danger of progressive stud failure with the possible loss of the engine cylinder in flight. Do not install parts made from aluminum alloy or other soft metals under cylinder holddown nuts or capscrews.

683. REUSE OF SAFETYING DEVICES. Do not use cotter pins and safety wire a second time. Flat steel-type wristpin retainers and thin lockwashers likewise should be replaced at overhaul unless the manufacturer's recommendations permit their reuse.

684. SELF-LOCKING NUTS FOR AIRCRAFT ENGINES AND ACCESSORIES. Self-locking nuts may be used on aircraft engines provided the following criteria are met:

a. Where their use is specified by the engine manufacturer in his assembly drawing, parts list, and bills of material,

b. When the nuts will not fall inside the engine should they loosen and come off,

c. When there is at least one full thread protruding beyond the nut,

d. When the edges of cotter pin or lockwire holes are well rounded to preclude damage to the locknut,

e. Prior to reuse, the effectiveness of the self-locking feature is found to be satisfactory,

f. Where the temperature will not exceed the maximum limits established for the self-locking material used in the nut. On many engines the cylinder baffles, rocker box covers, drive covers and pads, and accessory and supercharger housings are fastened with fiber insert locknuts which are limited to a maximum temperature of 250° F. Above this temperature the fiber insert will usually char and consequently lose its locking characteristic. For locations such as the exhaust pipe attachment to the cylinder, a locknut which has good locking features at elevated temperatures will give invaluable service. In a few instances, fiber insert locknuts have been approved for use on cylinder holddown studs. This practice is not generally recommended, since especially tight stud fits to the crankcase must be provided, and extremely good cooling must prevail so that low temperatures exist at this location on the specific engine for which such use is approved.

g. All proposed applications of new types of locknuts or new applications of currently used self-locking nuts must be investigated since many engines require specifically designed nuts. Such specifically designed nuts are usually required for one or more of the following reasons to provide:

(1) Heat resistance,

(2) Adequate clearance for installation and removal,

(3) For the required degree of tightening or locking ability which sometimes requires a stronger, specifically heat-treated material, a heavier cross-section, or a special locking means,

(4) Ample bearing area under the nut to reduce unit loading on softer metals, and

(5) To prevent loosening of studs when nuts are removed.

h. Information concerning approved self-locking nuts and their use on specific engines is usually found in engine manufacturer's manuals or bulletins. If the desired information is not available, it is suggested that the engine manufacturer be contacted.

685. WELDING OF HIGHLY STRESSED ENGINE PARTS. In general, welding of highly-stressed engine parts is not recommended for parts that were not originally welded. However, under the conditions given below, welding may be accomplished if it can be reasonably expected that the welded repair will not adversely affect the airworthiness of the engine when:

a. The weld is externally situated and can be inspected easily,

b. The part has been cracked or broken as the result of unusual loads not encountered in normal operation,

c. A new replacement part of obsolete type engine is not available,

d. The welder's experience and equipment employed will insure a first-quality weld in the type of material to be repaired and will insure restoration of the original heat treat in heat-treated parts. Refer to Chapter 2 for information on process details.

686. WELDING OF MINOR ENGINE PARTS. Many minor parts not subjected to high stresses may be safely repaired by welding. Mounting lugs, cowl lugs, cylinder fins, covers, and many parts originally fabricated by welding are in this category. The welded part should be suitably stress-relieved after welding.

687. METALLIZING. Metallizing internal parts of aircraft engines is not acceptable unless it is proven to the Federal Aviation Administration that the metallized part will not adversely affect the airworthiness of the engine. Metallizing the finned surfaces of steel cylinder barrels with aluminum is acceptable, since many engines are originally manufactured in this manner.

688. PLATING. Restore plating on engine parts in accordance with the manufacturer's instructions. In general, chromium plating should not be applied to highly stressed engine parts. Certain applications of this nature have been found to be satisfactory; however, engineering evaluation of the details for the processes used should be obtained.

a. Dense chromium plating of the crankpin and main journals of some small engine crankshafts has been found satisfactory, except where the crankshaft is already marginal in strength. Plating to restore worn low-stress engine parts such as accessory driven shafts and splines, propeller shaft ends, and seating surfaces of roller- and ball-type bearing races is acceptable.

b. Porous chromium plated walls of cylinder barrels have been found to be satisfactory for practically all types of engines. Dense or smooth chromium plating without roughened surfaces, on the other hand, has not been found to be generally satisfactory.

(1) Cylinder barrel pregrinding and chromium plating techniques used by the military are considered acceptable for all engines, and military approved facilities engaged in doing this work in accordance with military specifications are eligible for approval by the Federal Aviation Administration.

(2) Chromium plated cylinder barrels have been required for some time to be identified in such a manner that the markings are visible with the cylinder installed. Military processed cylinders are banded with orange enamel above the mounting flange. It has been the practice to etch on either the flange edge or on the barrel skirt the processer's initials and cylinder oversize. Most plating facilities use the orange band as well as the permanent identification marks.

(3) A current list of engine and maximum permissible cylinder barrel oversize follows:

Engine manufacturer	Engine series	Maximum oversize (in.)
Air Cooled Motors (Franklin).	No oversize for sleeved cylinders.	
	Solid cylinders	0.020
Continental Motors	R-670, W-670, R9A	0.020
	All others	0.015
Jacobs	All	0.020
Kinner	All	0.015
Pigman, LeBlond, Rearwin, Ken Royce.	All	0.025
Lycoming	All	0.015
Menasco	All	0.010

(Table continues on next page.)

Pratt & Whitney	R-2800B, C, CA, CB	0.025
	*R-985 and R-1830	0.030
	All others	0.020
Ranger	6-410 early cyls. 6-390	0.010
	6-410 late cyls. 6-440 (L-440) series.	0.020
Warner	All	0.015
Wright	All	0.020

*(The above oversize limits correspond to the manufacturer's requirements, except for P&W R-985 and R-1830 series engines.)

(4) The following is a list of known agencies, and their identifying initials, performing cylinder barrel plating for the military service.

Agencies	*Initials*
Hol-Chrome Corporation	HCC
San Antonio Air Materiel Area	SAX
Koppers Co. (American Hammered Piston Ring).	KC
McQuay-Norris	MQN
VanDer Horst Corporation	VDH
Terry Industries	TIX
Lement Chromium	LC
Pennington Channel Chrome	PCC
Spar-Tan Engineering Company	SEC
Superior Aero Chrome	SAC

(5) Cylinder barrels which have been plated by an agency whose process is approved by the FAA and which have not been preground beyond maximum permissible limits will be considered acceptable for installation on certificated engines. It will be the responsibility of the owner or the repairing agency to provide this proof. In some cases, it may be necessary to remove cylinders to determine the amount of oversize since this information may be etched on the mating surface of the cylinder base flange.

689. ENGINE ACCESSORIES. Overhaul and repair of engine accessories in accord with the engine and the accessory manufacturers' instructions are recommended.

690. CORROSION. Accomplish corrosion preventive measures for temporary and dead storage in accord with the instructions issued by the pertinent engine manufacturer. Avoid the use of strong solutions which contain strong caustic compounds and all solutions, polishes, cleaners, abrasives, etc., which might possibly promote corrosive action. (Refer to Chapter 6.)

691. ENGINE RUN-IN. After an aircraft engine has been overhauled, it is recommended the pertinent aircraft engine manufacturer's run-in instructions be followed. Observe the manufacturer's recommendations concerning engine temperatures and other criteria.

Repair processes employed during overhaul often necessitate amending the manufacturer's run-in procedures. Follow the approved amended run-in procedures in such instances.

692. COMPRESSION TESTING OF AIRCRAFT ENGINE CYLINDERS. The purpose of testing cylinder compression is to determine the internal condition of the combustion chamber by ascertaining if any appreciable leakage is occurring.

a. ***Types of Compression Testers.*** The two basic types of compression testers currently in use are the direct compression and the differential pressure type testers. The optimum procedure would be to utilize both types of testers when checking the compression of aircraft cylinders. In this respect, it is suggested that the direct compression method be used first and the findings substantiated with the differential pressure method. This provides a cross-reference to validate the readings obtained by each method and tends to assure that the cylinder is defective before it is removed. Before beginning a compression test, consider the following points:

(1) When the spark plugs are removed, identify them to coincide with the cylinder. Close examination of the plugs will reveal the actual operating conditions and aid in diagnosing problems within the cylinder. Paragraph 693d. of this section contains more information on this subject.

(2) The operating and maintenance records of the engine should be reviewed. Records of previous compression tests are of assistance in determining progressive wear conditions and help to establish the necessary maintenance actions.

(3) Before beginning a compression check, precautions should be taken to prevent the accidental starting of the engine.

b. ***Direct Compression Check.*** This type of compression test indicates the actual pressures within the cylinder. Although the particular defective component within the cylinder is difficult to determine with this method, the consistency of the readings for all cylinders is an indication of the condition of the engine as a whole. The following are suggested guidelines for performing a direct compression test.

(1) Thoroughly warm up the engine to operating temperatures and perform the test as soon as possible after shutdown.

(2) Remove the most accessible spark plug from each cylinder.

(3) Rotate the engine with the starter to expel any excess oil or loose carbon in the cylinders.

(4) If a complete set of compression testers is available, install one tester in each cylinder; however, if only one tester is being used, check each cylinder in turn.

(5) Rotate the engine at least three complete revolutions using the engine starter and record the compression reading.

NOTE: It is recommended that an external power source be used, if possible, as a low battery will result in a slow engine-turning rate and lower readings. This will noticeably affect the validity of the second engine test on a twin-engine aircraft.

(6) Recheck any cylinder which shows an abnormal reading when compared with the others. Any cylinder having a reading approximately 15 p.s.i. lower than the others should be suspected of being defective.

(7) If a compression tester is suspected of being defective, replace it with one known to be accurate, and recheck the compression of the affected cylinders.

c. ***Differential Pressure Compression Check.*** The differential pressure tester is designed to check the compression of aircraft engines by measuring the leakage through the cylinders caused by worn or damaged components. The operation of the compression tester is based on the principle that, for any given airflow through a fixed orifice, a constant pressure drop across that orifice will result. The restrictor orifice dimensions in the differential pressure tester should be sized for the particular engine as follows:

1. Engines up to 1,000 cubic inch displacement .040 orifice diameter, .250 inch long, 60° approach angle.

2. Engines in excess of 1,000 cubic inch displacement .060 orifice diameter, .250 inch long, 60° approach angle.

A typical schematic diagram of the differential pressure tester is shown in figure 14.1.

As the regulated air pressure is applied to one side of the restrictor orifice with the air valve closed, there will be no leakage on the other side of the orifice and both pressure gauges will read the same. However, when the air valve is opened and leakage through the cylinder increases, the cylinder pressure gauge will record a proportionally lower reading.

(1) **Performing the Check.** The following procedures are listed to outline the principles in-

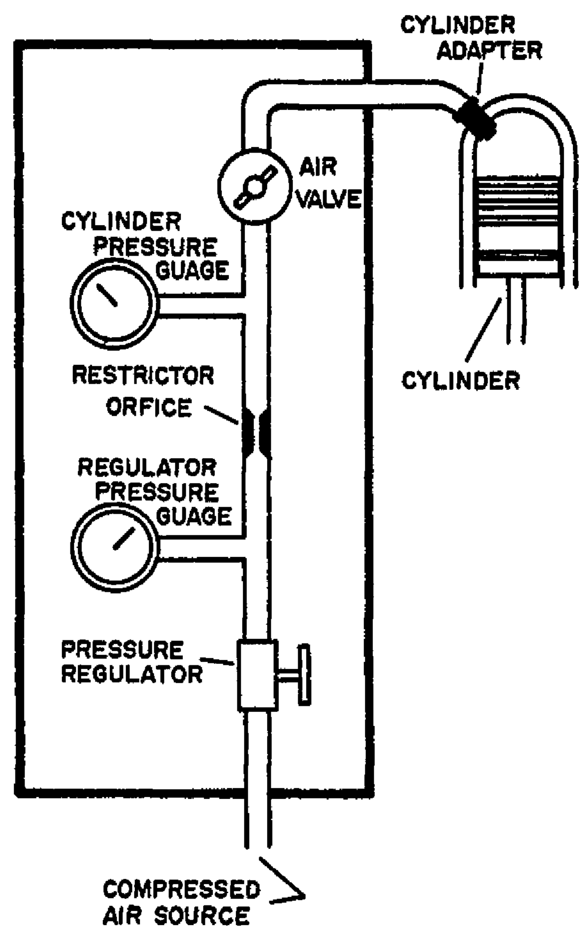


FIGURE 14.1.—Schematic of typical differential pressure compression tester.

volved, and are intended to supplement the manufacturer's instructions for the particular tester being utilized.

(*a*) Perform the compression test as soon as possible after the engine is shut down to ensure that the piston rings, cylinder walls, and other engine parts are well lubricated.

(*b*) Remove the most accessible spark plug from each cylinder.

(*c*) With the air valve closed, apply an external source of clean air (approximately 100 to 120 p.s.i.) to the tester.

(*d*) Install an adapter in the spark plug bushing and connect the compression tester to the cylinder.

(*e*) Adjust the pressure regulator to obtain a reading of 80 p.s.i. on the regulator pressure gauge. At this time, the cylinder pressure gauge should also register 80 p.s.i.

(*f*) Turn the crankshaft by hand in the direction of rotation until the piston (in the cylinder being checked) is coming up on its compression stroke. Slowly open the air valve and pressurize the cylinder to approximately 20 p.s.i.

CAUTION

Care must be exercised in opening the air valve since sufficient air pressure will have built up in the cylinder to cause it to rotate the crankshaft if the piston is not at TDC.

Continue rotating the engine against this pressure until the piston reaches top dead center (TDC). Reaching TDC is indicated by a flat spot or sudden decrease in force required to turn the crankshaft. If the crankshaft is rotated too far, back up at least one-half revolution and start over again to eliminate the effect of backlash in the valve operating mechanism and to keep piston rings seated on the lower ring lands.

(*g*) Open the air valve completely. Check the regulated pressure and adjust, if necessary, to 80 p.s.i.

(*h*) Observe the pressure indication on the cylinder pressure gauge. The difference between this pressure and the pressure shown by the regulator pressure gauge is the amount of leakage through the cylinder. A loss in excess of 25 percent of the input air pressure is cause to suspect the cylinder of being defective; however, recheck the readings after operating the engine for at least 3 minutes to allow for sealing of the rings with oil.

(*i*) If leakage is still occurring after a recheck, it may be possible to correct a low reading. This is accomplished by placing a fiber drift on the rocker arm directly over the valve stem and tapping the drift several times with a hammer to dislodge any foreign material between the valve face and seat.

NOTE: When correcting a low reading in this manner, rotate the propeller so the piston will not be at TDC. This is necessary to prevent the valve from striking the top of the piston in some engines. Rotate the engine before rechecking compression to reseat the valves in the normal manner.

693. SPARK PLUGS. The spark plug provides the high voltage electrical spark to ignite the fuel/air mixture in the cylinder. The types of spark plugs used in different engines will vary in regard to heat range, reach, thread size and other characteristics required by the particular installation.

a. Heat Range. The heat range of a spark plug is a measure of its ability to transfer heat to the cylinder head. The plug must operate hot enough to burn off the residue deposits which can cause fouling, yet remain cool enough to prevent a preignition condition from occurring. The length of the nose core is the principal factor in establishing the plug's heat range. "Hot" plugs have a long insulator nose thereby creating a long heat transfer path, whereas "cold" plugs have a relatively short insulator to provide a rapid transfer of heat to the cylinder head. (See figure 14.2.)

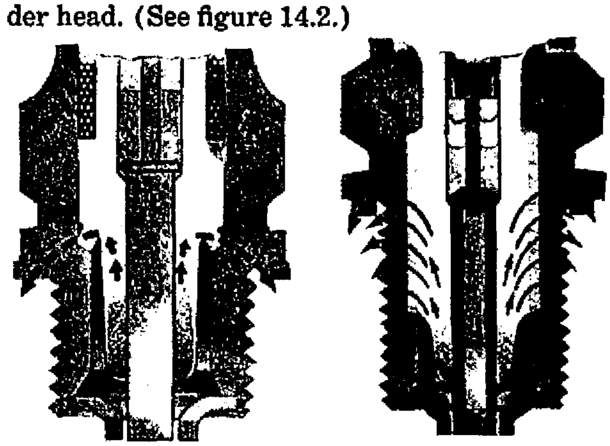


FIGURE 14.2.—Spark plug heat ranges.

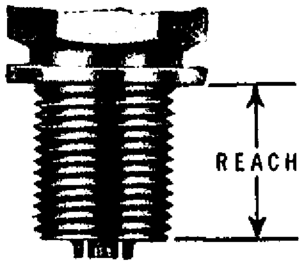


FIGURE 14.3.—Spark plug reach.

b. *Reach.* The spark plug reach (figure 14.3) is the threaded portion which is inserted into the spark plug bushing of the cylinder. A plug with the proper reach will insure that the electrode end inside the cylinder is in the best position to achieve ignition. Spark plug seizure or improper combustion within the cylinder will probably occur if a plug with the wrong reach is used.

c. *Installation Procedures.* When installing spark plugs, observe the following procedure:

(1) Visually inspect the plug for cleanliness and condition of the threads, ceramic, and electrodes.

NOTE: Never install a spark plug which has been dropped.

(2) Check the plug for the proper gap setting using a round wire feeler gauge as shown in figure 14.4. In the case of used plugs, procedures for cleaning and regapping are usually contained in the various manufacturers' manuals.

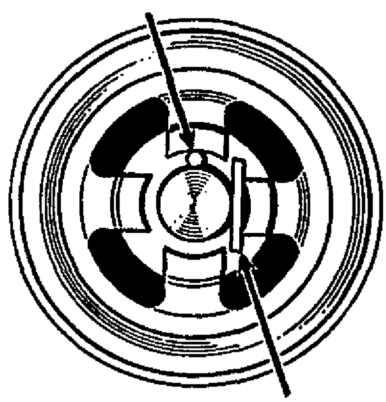


FIGURE 14.4.—Method of checking spark plug gap.

(3) Check the plug and cylinder bushing to ascertain that only one gasket is used per spark plug. When a thermocouple-type gasket is used, no other gasket is required.

(4) Apply antiseize compound sparingly to the shell threads, but do not allow the compound to contact the electrodes as the material is conductive and will short out the plug. If desired, the use of antiseize compound may be eliminated on engines equipped with stainless steel spark plug bushings or inserts.

(5) Screw the plug into the cylinder head as far as possible by hand. If the plug will not turn easily to within 2 or 3 threads of the gasket, it may be necessary to clean the threads.

NOTE: Cleaning inserts with a tap is not recommended as permanent damage to the insert may result.

(6) Seat the proper socket securely on the spark plug and tighten to the torque limit specified by the engine manufacturer before proceeding to the next plug.

CAUTION

A loose spark plug will not transfer heat properly and, during engine operation, may overheat to the point where the nose ceramic will become a "hot spot" and cause preignition. However, avoid overtightening as damage to the plug and bushing may result.

(7) Connect the ignition lead after wiping clean with methylethylketone (MEK), acetone, or similar material. Insert the terminal assembly into the spark plug in a straight line. (Care should be taken as improper techniques can damage the terminal sleeves.) Screw the connector nut into place until finger tight; then tighten an additional one-quarter turn while holding the elbow in the proper position.

(8) Perform an engine runup after installing a new set of spark plugs. When the engine has reached normal operating temperatures, check the magnetos and spark plugs in accordance with the manufacturer's instructions.

d. *Operational Problems.* Whenever problems develop during engine operation which appear to be caused by the ignition system, it is recommended that the spark plugs and ignition harnesses be checked first before working on the magnetos. The following are the most common spark plug malfunctions and are relatively easy to identify:

(1) Fouling.

(a) Carbon fouling (figure 14.5a) is identified by the dull black, sooty deposits on the electrode end of the plug. Although the primary causes are excessive ground idling and rich idle mixtures, plugs with a cold heat range may also be a contributing factor.

(b) Lead fouling is characterized by hard, dark, cinderlike globules which gradually fill up the electrode cavity and short out the plug. (See figure 14.5b). The primary cause for this condition is poor fuel vaporization combined with a high tetraethyl-lead content fuel. Plugs with a cold heat range may also contribute to this condition.

(c) Oil fouling is identified by a wet, black carbon deposit over the entire firing end of the plug as shown in figure 14.5c. This condition is fairly common on the lower plugs in horizontally opposed engines, and both plugs in the lower cylinders of radial engines. Oil fouling is normally caused by oil drainage past the piston rings after shutdown. However, when both spark plugs removed from the same cylinder are badly fouled with oil and carbon, some form of engine damage should be suspected, and the cylinder more closely inspected. Mild forms of oil fouling can usually be cleared up by slowly increasing power while running the engine until the deposits are burned off and the misfiring stops.

(2) Fused Electrodes. There are many different types of malfunctions which result in fused spark plug electrodes; however, most are associated with preignition either as the cause or the effect. For this reason, any time a spark plug is found with the following defects, further investigation of the cylinder and piston should be conducted.

FIGURE 14.5a.—Typical carbon fouled spark plug.

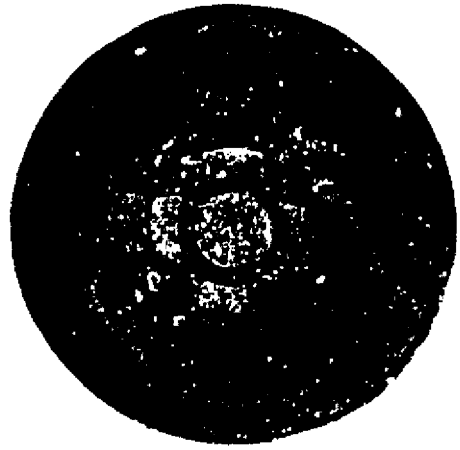


FIGURE 14.5b.—Typical lead fouled spark plug.

FIGURE 14.5c.—Typical oil fouled spark plug.

(a) Cracked Nose Ceramics. Occasionally, the ceramic nose core will crack, break away, and remain trapped behind the ground electrode. This piece of insulation material will then build up heat to the point where it will ignite the fuel/air mixture prematurely. The high temperatures and pressures encountered during this condition can cause damage to the cylinder and piston and ultimately lead to fusing and shorting out of the plug.

(b) Copper Runout. Some erosion or "cupping" of the exposed center electrode copper core is normal and will gradually decrease with the service life of the plug until it practically ceases. This condition, depicted in figure 14.6a, is not a cause for rejection until the erosion has progressed to a point more than 3/32 inch below the tip of the center electrode.

The high temperatures and pressures associated with preignition can cause the condition shown in figure 14.6b. In this instance, the copper center electrode melted and flowed out, bridged the electrodes, and caused a shorted condition.

(3) Bridged Electrodes. Occasionally, free combustion chamber particles will settle on the electrodes of a spark plug and gradually bridge the electrode gap, resulting in a shorted plug. Small particles may be dislodged by slowly cycling the engine as described for the oil-fouled condition; however, the only remedy for more advanced cases is removal and replacement of the spark plug. This condition is shown in figure 14.7.

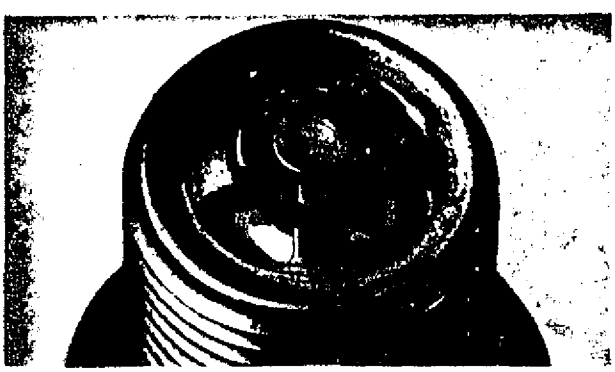


FIGURE 14.6a.—Typical eroded spark plug.

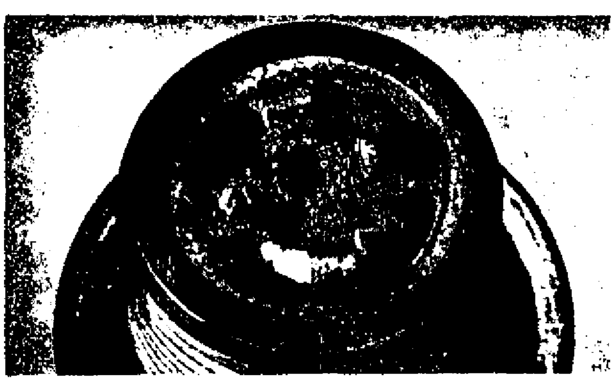


FIGURE 14.6b.—Typical spark plug with copper runout.

FIGURE 14.7.—Typical spark plug with bridged electrodes.

(4) Metal Deposits. Whenever metal spray is found on the electrodes of a spark plug, it is an indication that a failure of some part of the engine is in progress. The location of the cylinder in which the spray is found is important in diagnosing the problem, as various types of failures will cause the metal spray to appear differently. For example, if the metal spray is located evenly in every cylinder, the problem will be in the induction system, such as an impeller failure. If the metal spray is only found on the spark plugs in one cylinder, the problem is isolated to that cylinder and will generally be a piston failure. In view of the secondary damage which occurs whenever an engine part fails, any preliminary indication such as metal spray should be thoroughly investigated to establish the cause and correct it.

(5) Flashover. It is important that spark plug terminal contact springs and moisture seals be checked regularly for condition and cleanness to prevent "flashover" in the connector well. Foreign matter or moisture in the terminal connector well can reduce the insulation value of the connector to the point where ignition system voltages at higher power settings may flash over the connector well surface to ground and cause the plug to misfire. If moisture is the cause, hard starting can also result. The cutaway spark plug shown in figure 14.8

FIGURE 14.8.—Spark plug well flashover.

illustrates this malfunction. Any spark plug found with a dirty connector well may have this condition, and should be reconditioned before reuse.

e. *Pre-reconditioning Inspection.* All spark plugs should be inspected visually prior to reconditioning to eliminate any plug with obvious defects. A partial checklist of common defects includes:

(1) Ceramic chipped or cracked either at the nose core or in the connector well.

(2) Damaged or badly worn electrodes.

(3) Badly nicked, damaged, or corroded threads on shell or shielding barrel.

(4) Shielding barrel dented, bent, or cracked.

(5) Connector seat at the top of the shielding barrel badly nicked or corroded.

694. IGNITION HARNESSES. Aircraft quality ignition harness is usually made of either medium or high temperature wire. The type used will depend upon the manufacturing specification for the particular engine. In addition to the applicable manufacturer's maintenance and repair procedures, the following is a quick-reference checklist for isolating some of the malfunctions inherent to ignition harnesses.

a. Carefully inspect the lead conduit or shielding. A few broken strands will not affect serviceability, but if the insulation in general looks worn, replace the lead.

b. When replacing a lead, if the dressing procedure is not accomplished properly, strands of shielding may be forced through the conductor insulation. If this occurs, a short will exist in the conductor; therefore, it is essential this task be performed properly.

c. The high temperature coating used on some lightweight harnesses is provided for vibration abrasion resistance and moisture protection. Slight flaking or peeling of this coating is not serious, and a harness assembly need not be removed from service because of this condition.

d. Check the spark plug contact springs for breaks, corrosion, or deformation. If possible, check the lead continuity from the distributor block to the contact spring.

e. Check the insulators at the spark plug end of the lead for cracks, breaks, or evidence of old age. Make sure they are clean.

f. Check to see that the leads are positioned as far away from the exhaust manifold as possible and are supported to prevent any whipping action.

g. When lightweight harnesses are used and the conduit enters the spark plug at a severe angle, use clamps as shown in figure 14.9 to prevent overstressing the lead.

695. MAGNETO INSPECTION. Whenever ignition problems develop and it is determined that the magneto is the cause of the difficulty, the following are a few simple inspection procedures which may locate the malfunction quickly. However, conduct any internal inspection or repair of a magneto in accordance with the manufacturer's maintenance and overhaul manuals.

a. Inspect the distributor block contact springs. If broken or corroded, replace.

b. Inspect the felt oil washer if applicable. It should be saturated with oil. If it is dry, check for a worn bushing.

c. Inspect the distributor block for cracks or a burned area. The wax coating on the block should not be removed. Do not use any solvents for cleaning.

d. Look for excess oil in the breaker compartment. If oil is present, it may mean a bad oil seal or bushing at the drive end. This condi-

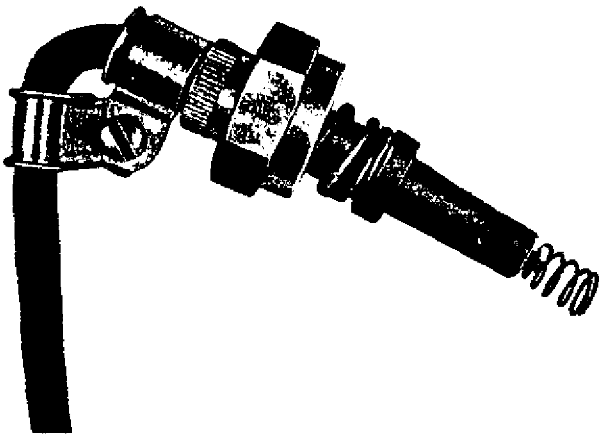


FIGURE 14.9.—Typical method of clamping leads.

tion could require complete overhaul, as too much oil may foul and cause excessive burning of the contact points.

e. Look for frayed insulation on the leads in the breaker compartment of the magneto. See that all terminals are secure. Be sure that wires are properly positioned.

f. Inspect the capacitor visually for general condition, and check the mounting bracket for cracks or looseness. If possible, check the capacitor for leakage, capacity, and series resistance.

g. Examine the points for excessive wear or burning. Discard points which have deep pits or excessively burned areas. Desired contact surfaces have a dull gray, sandblasted (almost rough) or frosted appearance over the area where electrical contact is made. Figure 14.10 shows how the normal contact point will look when surfaces are separated for inspection. Minor irregularities or roughness of point surfaces are not harmful (see figure 14.11); neither are small pits or mounds, if not too pronounced. If there is a possibility of the pit becoming deep enough to penetrate the pad (figure 14.12), reject the contact assembly.

Generally, no attempt should be made to dress or stone contact point assemblies; however, if provided, procedures and limits contained in the manufacturer's manuals may be followed.

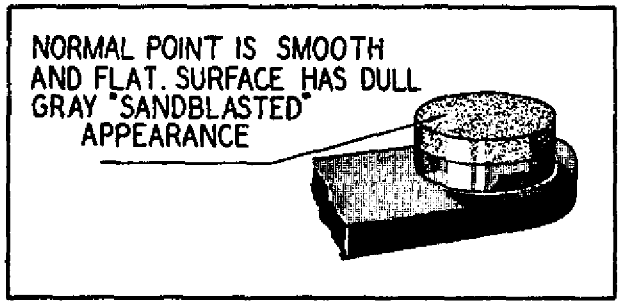


FIGURE 14.10.—Normal contact point.

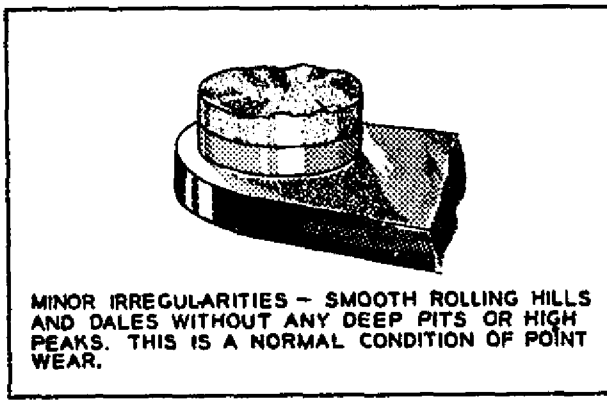


FIGURE 14.11.—Point with minor irregularities.

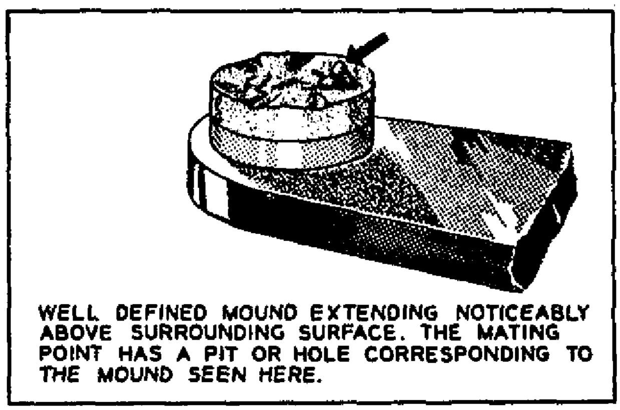


FIGURE 14.12.—Point with well-defined mound.

CAUTION

When inspecting the contact points for condition, do not open further than absolutely necessary. Excess tension on the spring will weaken it and adversely affect the performance of the magneto.

h. Adjustment of magneto point gap must be correct for proper internal timing of magneto. (See applicable manufacturer's publications for internal timing procedures.)

i. Check breaker cam to assure cleanness and smoothness. Check cam screw for tightness. If new points have been installed, blot a little oil on the cam. In addition, check contact point assembly to ascertain that the cam follower is securely fastened.

j. If the impulse coupling is accessible, inspect for excessive wear on the contact edges of the body and flyweights. In addition, check the flyweights for looseness on the axles.

k. Further examination of the impulse coupling body may disclose cracks caused by exceedingly tight flyweight axle rivets.

l. Check the magneto ventilators for proper functioning and obstructions. If drilled plugs are used, they should be in the lowest vent hole of the magneto to serve as a drain for condensation and oil.

696. MAGNETO-TO-ENGINE TIMING. While the actual process of timing magnetos to an engine is covered in the engine manufacturer's technical manuals, the following general procedures may be applied:

a. Before installing a new magneto, the correct "E" gap setting specified by the magneto manufacturer should be verified.

b. When setting or checking the magneto-to-engine timing, always turn the crankshaft steadily in the normal direction of rotation to eliminate any error caused by gear backlash.

c. Recheck magneto-to-engine timing after any point gap adjustment, or after replacement of the breaker points.

d. Never advance the magneto timing beyond the engine timing specification recommended by the engine manufacturer.

e. The possibility of a timing error exists if a timing indicator which attaches to the propeller shaft or spinner of geared engines is used. Engine timing specifications are always given in degrees of crankshaft travel, and cannot be applied directly to geared propeller shafts because of the gear ratio. Therefore, the correct position of the propeller shaft, if used for timing, must be determined by multiplying the crankshaft timing angle in degrees before top center (BTC) by the propeller gear ratio.

697.–707. RESERVED.

Section 2. FUEL SYSTEMS

708. GENERAL. Maintain, service, and adjust aircraft fuel systems and fuel system components in accordance with the applicable manufacturer's maintenance instructions. Certain general fuel system maintenance principles are outlined below.

709. FUEL LINES AND FITTINGS. When fuel system lines are to be replaced or repaired, consider the following fundamentals in addition to the applicable airworthiness requirements. Additional inspection and repair practices for aircraft tubing systems may be found in paragraph 393.

a. ***Compatibility of Fittings.*** All fittings are to be compatible with their mating parts. Although various types of fittings appear to be interchangeable in many cases they have different thread pitch or minor design differences which prevent proper mating and may cause the joint to leak or fail.

b. ***Routing.*** Make sure that the line does not chafe against control cables, airframe structure, etc., or come in contact with electrical wiring or conduit. Where physical separation of the fuel lines from electrical wiring or conduit is impracticable, locate the fuel line below the wiring and clamp it securely to the airframe structure. In no case may wiring be supported by the fuel line.

c. ***Alignment.*** Locate bends accurately so that the tubing is aligned with all support clamps and end fittings and is not drawn, pulled, or otherwise forced into place by them. Never install a straight length of tubing between two rigidly mounted fittings. Always incorporate at least one bend between such fittings to absorb strain caused by vibration and temperature changes.

d. ***Bonding.*** Bond metallic fuel lines at each point where they are clamped to the structure. Integrally bonded and cushioned line support clamps are preferred to other clamping and bonding methods.

e. ***Support of Line Units.*** To prevent possible failure, all fittings heavy enough to cause the line to sag should be supported by means other than the tubing.

f. ***Support Clamps.***

(1) Place support clamps or brackets for metallic lines as follows:

Tube O.D.	*Approximate distance between supports*
1/8"–3/16"	9"
1/4"–5/16"	12"
3/8"–1/2"	16"
5/8"–3/4"	22"
1"–1 1/4"	30"
1 1/2"–2"	40"

(2) Locate clamps or brackets as close to bends as possible to reduce overhang (see figure 14.18).

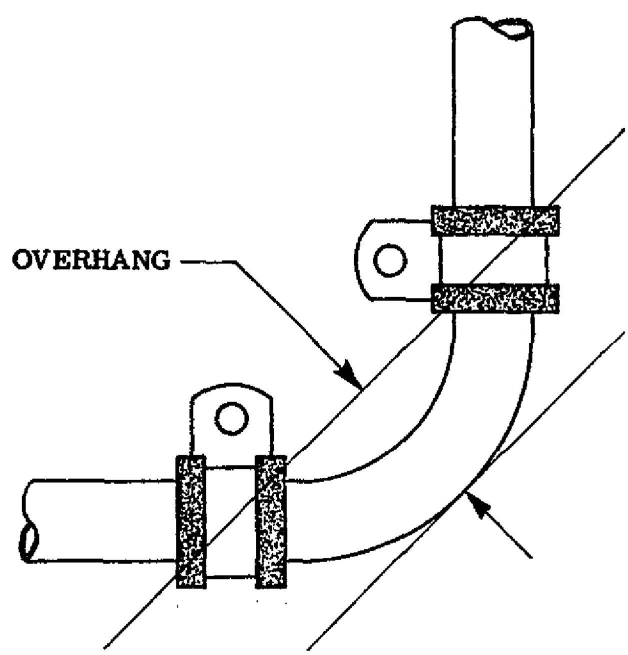


FIGURE 14.18.—Location of clamps at tube bends.

710. FUEL TANKS AND CELLS. Welded or riveted fuel tanks that are made of commercially pure aluminum, 3003, 5052, or similar alloys, may be repaired by welding. Tanks made from heat-treatable aluminum alloys are generally assembled by riveting. In case it is necessary to rivet a new piece in a tank, use the same material as used in the tank undergoing repair, and seal the seams with a compound that is insoluble in gasoline. Special sealing compounds are available and should be used in the repair of tanks. Inspect fuel tanks and cells for general condition, security of attachment, and evidence of leakage. Examine fuel tank or cell vent line, fuel line, and sump drain attachment fittings closely.

CAUTION

Purge defueled tanks of explosive fuel/air mixtures in accordance with the manufacturers' service instructions. In the absence of such instructions, utilize an inert gas such as CO_2 as a purgative to assure the total deletion of fuel/air mixtures.

a. ***Integral Tanks.*** Examine the interior surfaces and seams for sealant deterioration and corrosion (especially in the sump area). Follow the manufacturer's instructions for repair and cleaning procedures.

b. ***Internal Metal Tanks.*** Check the exterior for corrosion and chafing. Dents or other distortion, such as a partially collapsed tank caused by an obstructed fuel tank vent, can adversely affect fuel quantity gauge accuracy and tank capacity. Check the interior surfaces for corrosion. Pay particular attention to the sump area, especially those which are made of cast material. Repairs to the tank may be accomplished in accordance with the practices outlined in Chapter 2 of this handbook.

c. ***Removal of Flux After Welding.*** It is especially important, after repair by welding, to completely remove all flux in order to avoid possible corrosion. Promptly upon completion of welding, wash the inside and outside of the tank with liberal quantities of hot water and then drain. Next, immerse the tank in either a 5 percent nitric or 5 percent sulfuric acid solution. If the tank cannot be immersed, fill the tank with either solution, and wash the outside with the same solution. Permit the acid to remain in contact with the weld about one hour and then rinse thoroughly with clean water. Test the efficiency of the cleaning operation by applying some acidified 5 percent silver nitrate solution to a small quantity of the rinse water used last to wash the tank. If a heavy white precipitate is formed, the cleaning is insufficient and the washing should be repeated.

d. ***Flexible Fuel Cells.*** Inspect the interior for checking, cracking, porosity, or other signs of deterioration. Make sure the cell retaining fasteners are properly positioned. If repair or further inspection is required, follow the manufacturer's instructions for cell removal, repair, and installation. Do not allow flexible fuel cells to dry out. Preserve them in accordance with the manufacturer's instructions.

711. FUEL TANK CAPS, VENTS, AND OVERFLOW LINES. Inspect the fuel tank caps to determine that they are the correct type and size for the installation.

a. ***Vented caps,*** substituted for unvented caps, may cause loss of fuel or fuel starvation. Similarly, an improperly installed cap that has a special venting arrangement can also cause malfunctions.

b. ***Unvented caps,*** substituted for vented caps, will cause fuel starvation and possible collapse of the fuel tank or cell. Malfunctioning of this type occurs when the pressure within the tank decreases as the fuel is withdrawn. Eventually, a point is reached where the fuel will no longer flow, and/or the outside atmospheric pressure collapses the tank. Thus, the effects will occur sooner with a full fuel tank than with one partially filled.

c. ***Check tank vents and overflow lines*** thoroughly for condition, obstructions, correct installation, and proper operation of any check valves and ice protection units. Pay particular attention to the location of the tank vents when such information is provided in the manufacturer's service instructions. Inspect for cracked or deteriorated filler opening recess drains, which may allow spilled fuel to accumulate within the wing or fuselage. One method of inspection is to plug the fuel line at the outlet and observe fuel placed in the filler opening recess. If drainage takes place, investigate condition of the line and purge any excess fuel from the wing.

d. ***Assure that filler opening markings*** are stated according to the applicable airworthiness requirements and are complete and legible.

712. FUEL CROSSFEED, FIREWALL SHUTOFF, AND TANK SELECTOR VALVES. Inspect these valves for leakage and proper operation as follows:

a. ***Internal leakage*** can be checked by placing the appropriate valve in the "off" position, draining the fuel strainer bowl, and observing if fuel continues to flow into it. Check all valves located downstream of boost pumps with the pump(s) operating. Do not operate the pump(s) longer than necessary.

b. ***External leakage*** from these units can be a severe fire hazard, especially if the unit is located under the cabin floor or within a similarly confined area. Correct the cause of any fuel stains associated with fuel leakage.

c. ***Selector Handles.*** Check the operation of each handle or control to see that it indicates the actual position of the selector valve. Assure that stops and detents have positive action and feel. Worn or missing detents and stops can cause unreliable positioning of the fuel selector valve.

d. ***Worn Linkage.*** Inaccurate positioning of fuel selector valves can also be caused by worn mechanical linkage between the selector handle and the valve unit. An improper fuel valve position setting can seriously reduce engine power by restricting the available fuel flow. Check universal joints, pins, gears, splines, cams, levers, etc., for wear and excessive clearance, which prevent the valve from positioning accurately or from obtaining fully "off" and "on" positions.

e. ***Assure that required placards*** are complete and legible. Replace those that are missing or cannot be read easily.

713. FUEL PUMPS. Inspect, repair, and overhaul boost pumps, emergency pumps, auxiliary pumps, and engine-driven pumps in accordance with the appropriate manufacturer's instructions.

714. FUEL FILTERS, STRAINERS, AND DRAINS. Check each strainer and filter element for contamination. Determine and correct the source of any contaminants found. Replace throwaway filter elements with the recommended type. Examine fuel strainer bowls to see that they are properly installed according to direction of fuel flow. Check the operation of all drain devices to see that they operate properly and have positive shutoff action.

715. INDICATOR SYSTEMS. Inspect, service, and adjust the fuel indicator systems according to the manufacturer's instructions. Determine that the required placards and instrument markings are complete and legible.

716. TURBINE FUEL SYSTEMS. The use of turbine fuels in aircraft has resulted in two problem areas not normally associated with aviation gasolines: (1) Entrained water (microscopic particles of free water suspended in the fuel) and (2) microbial contaminants.

a. ***Entrained water*** will remain suspended in aviation turbine fuels for a considerable length of time. Unless suitable measures are taken, the fine filters used in turbine fuel systems will clog with ice crystals when the temperature of the fuel drops below the freezing temperature of the entrained water. Some fuel systems employ heated fuel filters or fuel heaters to eliminate this problem. Others rely upon anti-icing fuel additives.

b. ***Microbial contamination*** is a relatively recent problem associated with the operation and maintenance of turbine engine fuel systems. The effects of these micro-organisms are far reaching. They can cause powerplant failure due to clogging of filters, lines, fuel controls, etc., and the corrosive acids which they produce can lead to structural failure of integral tanks. Microbial contamination is generally associated with fuel containing free water introduced by condensation or other extraneous sources.

c. *Maintain* turbine engine fuel systems and use anti-icing and antibacterial additives in accordance with the manufacturer's recommendations.

717.–727. RESERVED.

Section 3. EXHAUST SYSTEMS

728. GENERAL. Any exhaust system failure should be regarded as a severe hazard. Depending upon the location and type of failure, it can result in carbon monoxide (CO) poisoning of crew and passengers, partial or complete engine power loss, or fire. Exhaust system failures generally reach a maximum rate of occurrence at 100 to 200 hours' operating time, and over 50 percent of the failures occur within 400 hours.

729. MUFFLER/HEAT EXCHANGER FAILURES. Approximately one-half of all exhaust system failures are traced to cracks or ruptures in the heat exchanger surfaces used for cabin and carburetor air heat sources. Failures in the heat exchanger's surface (usually the muffler's outer wall) allow exhaust gases to escape directly into the cabin heat system. The failures are, for the most part, attributed to thermal and vibration fatigue cracking in areas of stress concentration; e.g., tailpipe and stack inlet attachment areas (figures 14.14 thru 14.17).

Failures of the spot welds which attach heat transfer pins, as shown in figure 14.15A, can result in exhaust gas leakage. In addition to the carbon monoxide hazard, failure of heat exchanger surfaces can permit exhaust gases to be drawn into the engine induction system and cause engine overheating and power loss.

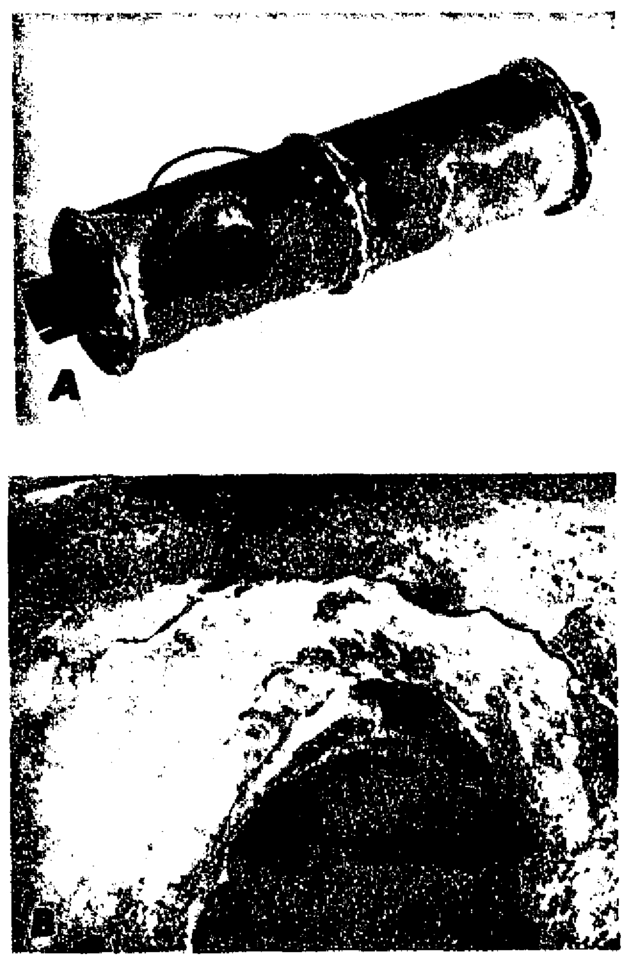
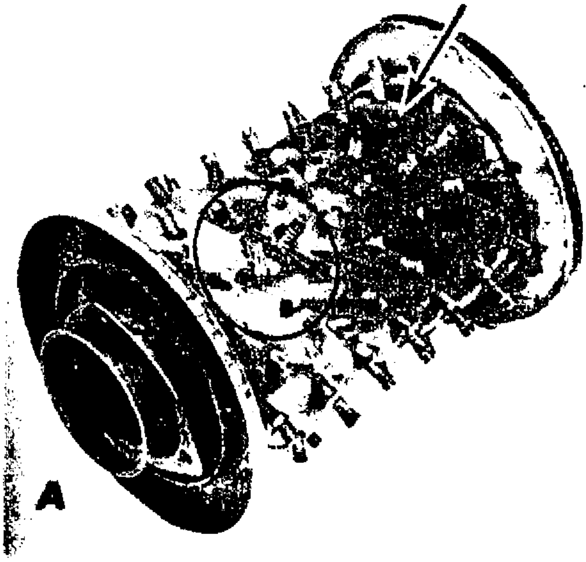


FIGURE 14.14.—Typical muffler wall fatigue failure at exhaust outlet. (A. Complete muffler assembly with heat shroud removed; B. Detail view of failure.)

730. MANIFOLD/STACK FAILURES. Exhaust manifold and stack failures are also usually fatigue-type failures which occur at welded or clamped joints; e.g., stack-to-flange, stack-to-manifold, muffler connections, or crossover pipe connections. Although these failures are primarily a fire hazard, they also present a carbon monoxide problem. Exhaust gases can enter the cabin via defective or inadequate seals at firewall openings, wing strut fittings, doors, and wing root openings. Manifold/stack failures, which account for approximately 20 percent of all exhaust system failures, reach a maximum rate of occurrence at about 100 hours' operating time. Over 50 percent of the failures occur within 800 hours.

731. INTERNAL MUFFLER FAILURES. Internal failures (baffles, diffusers, etc.) can cause partial or complete engine power loss by restricting



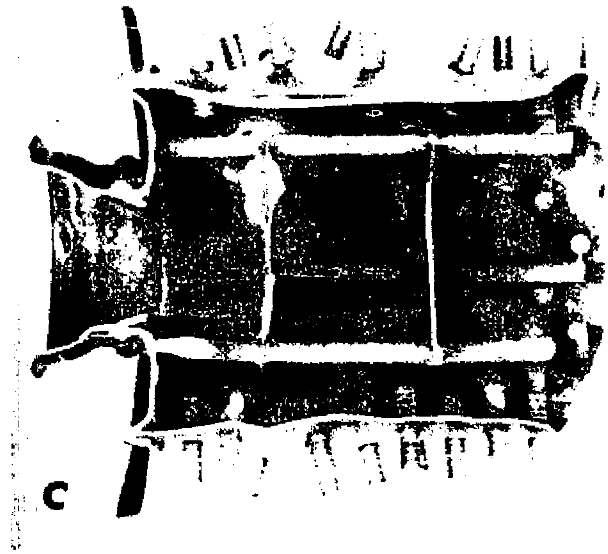
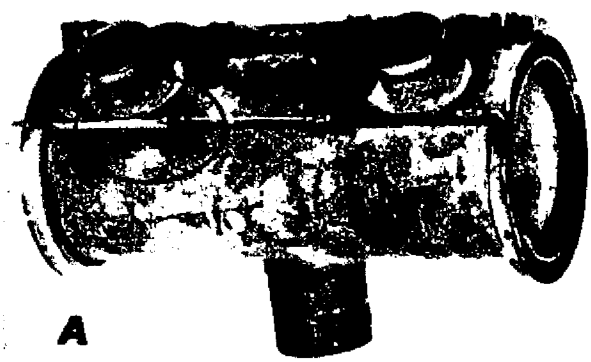


FIGURE 14.15.—Typical muffler wall failure. (A. Complete muffler assembly with heat shroud removed; B. Detail view of failure; C. Cross section of failed muffler.)



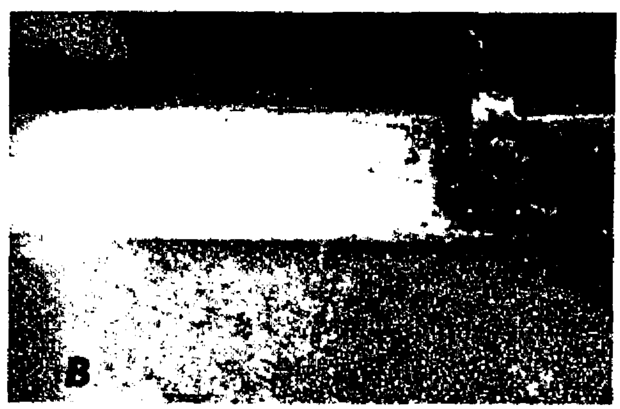


FIGURE 14.16—Typical muffler wall fatigue failure. (A. Complete muffler assembly with heat shroud partially removed; B. Detail view of failure.)

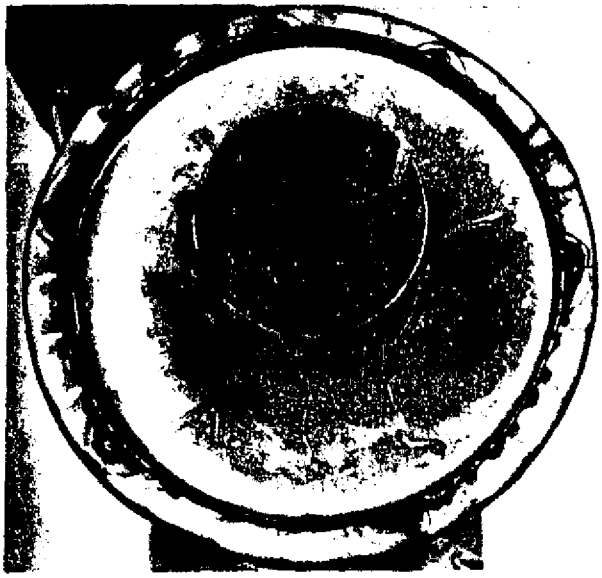


FIGURE 14.17.—Typical fatigue failure of muffler end plate at stack inlet.

FIGURE 14.18.—Section of muffler showing typical internal baffle failure.

the flow of the exhaust gases (figures 14.18 thru 14.21). As opposed to other failures, erosion and carbonizing caused by the extreme thermal conditions are the primary causes of internal failures. Engine backfiring and combustion of unburned fuel within the exhaust system are probable contributing factors. In addition, local hot spot areas caused by uneven exhaust gas flow results in burning, bulging, and rupture of the outer muffler wall (figure 14.15). As might be expected, the time required for these failures to develop is longer than that for fatigue failures. Internal muffler failures account for nearly 20 percent of the total number of exhaust system failures. The highest rate of internal failures occur between 500 and 750 hours of operating time. Engine power loss and excessive backpressure caused by exhaust outlet blockage may be averted by the installation of an exhaust outlet guard as shown in figures 14.22a, and 14.22b. The outlet guard may be fabricated from 3/16" stainless steel welding rod. Form the rod into two "U" shaped segments, approximately 3 inches long and weld into the exhaust tail pipe as shown in figure 14.22a so that the guard will extend 2 inches inside the exhaust muffler outlet port. Installation of an exhaust outlet guard does

FIGURE 14.19.—Loose pieces of failed internal baffle.

FIGURE 14.20.—Failed internal baffle partially obstructing muffler outlet.

FIGURE 14.21.—Failed internal baffle completely obstructing muffler outlet.

not negate the importance of thorough inspection of the internal parts of the muffler or the necessity of replacing defective mufflers.

732. INSPECTION. Inspect exhaust systems frequently to ascertain complete system integrity.

CAUTION

Marking of exhaust system parts—NEVER USE LEAD PENCILS, GREASE PENCILS, ETC., TO MARK EXHAUST SYSTEM PARTS. Carbon deposited by those tools will cause cracks from heat concentration and carbonization of the metal. If you must mark on exhaust system parts, USE CHALK, PRUSSIAN BLUE OR INDIA INK that is carbon free.

a. Prior to any cleaning operation, remove cowling as required to expose the complete exhaust system. Examine cowling and nacelle areas adjacent to exhaust system components for telltale signs of exhaust gas soot indicating possible leakage points. Check to make sure that no portion of the exhaust system is being chafed by cowling, engine control cables, or other components. The exhaust system often operates at red-hot temperatures of 1000 degrees F. or more; therefore, parts such as ignition leads, hoses, fuel lines, and flexible air ducts, should be protected from radiation and convection heating by heat shields or adequate clearance.

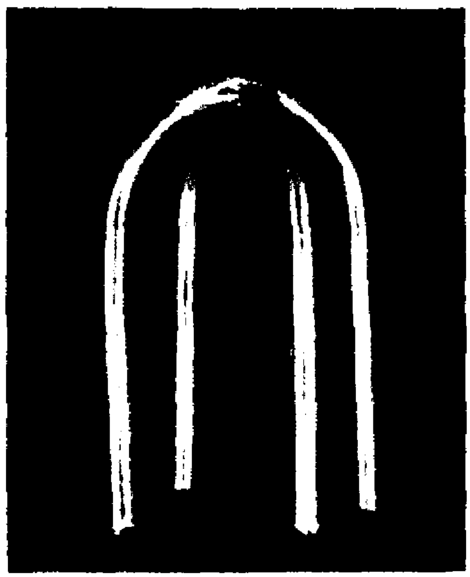


FIGURE 14.22a.—Example of exhaust outlet guard.

b. Remove or loosen all exhaust shields, car-

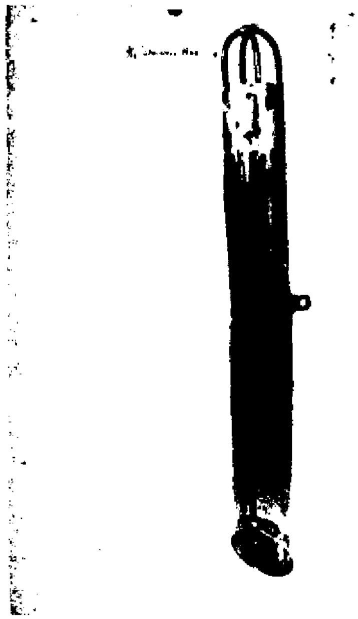


Figure 14.22b.—Example of exhaust outlet guard installed.

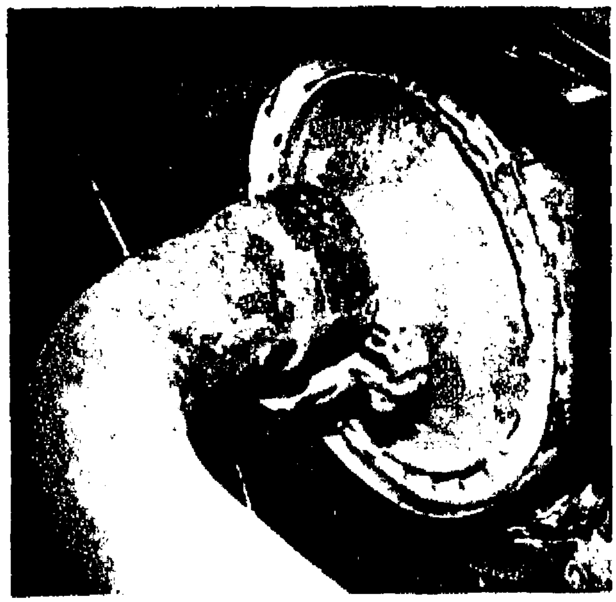


Figure 14.23.—*Effect of improperly positioned exhaust pipe/muffler clamp.*

buretor and cabin heater muffs, shrouds, heat blankets, etc., as required to permit inspection of the complete system.

c. Perform necessary cleaning operations and inspect all external surfaces of the exhaust system for cracks, dents, and missing parts. Pay particular attention to welds, clamps, supports, and support attachment lugs, bracing, slip joints, stack flanges, gaskets, flexible couplings, etc. (See figures 14.23 and 14.24.) Examine the heel of each bend, areas adjacent to welds, any dented areas, and low spots in the system for thinning and pitting due to internal erosion by combustion products or accumulated moisture. An ice pick or similar pointed instrument is useful in probing suspected areas. Disassemble the system as necessary to inspect internal baffles or diffusers.

d. Should a component be inaccessible for a thorough visual inspection or hidden by nonremovable parts, remove it and check for possible leaks by plugging its openings, applying approximately 2 p.s.i. internal pressure, and submerging it in water. Any leaks will cause bubbles that can be readily detected. Dry thoroughly before reinstallation.

733. REPAIRS. It is generally recommended that exhaust stacks, mufflers, tailpipes, etc., be replaced with new or reconditioned components rather than repaired. Welded repairs to exhaust systems are complicated by the difficulty of accurately identifying the base metal so that the proper repair materials can be selected. Changes in composition and grain structure of the original base metal further complicate the repair. However, when welded repairs are necessary, follow the general procedures outlined in paragraph 68 of this handbook. Retain the original contours and make sure that the completed repair has not warped or otherwise affected the alignment of the exhaust system. Repairs or sloppy weld beads which protrude internally are not acceptable since they cause local hot spots and may restrict exhaust gas flow. When repairing or replacing exhaust system components, be sure that the proper hardware and clamps are used. Do not substitute steel or low temperature self-locking nuts for brass or special high temperature locknuts used by the manufacturer. Never reuse old gaskets. When disassembly is necessary, replace gaskets with new ones of the same type provided by the manufacturer.

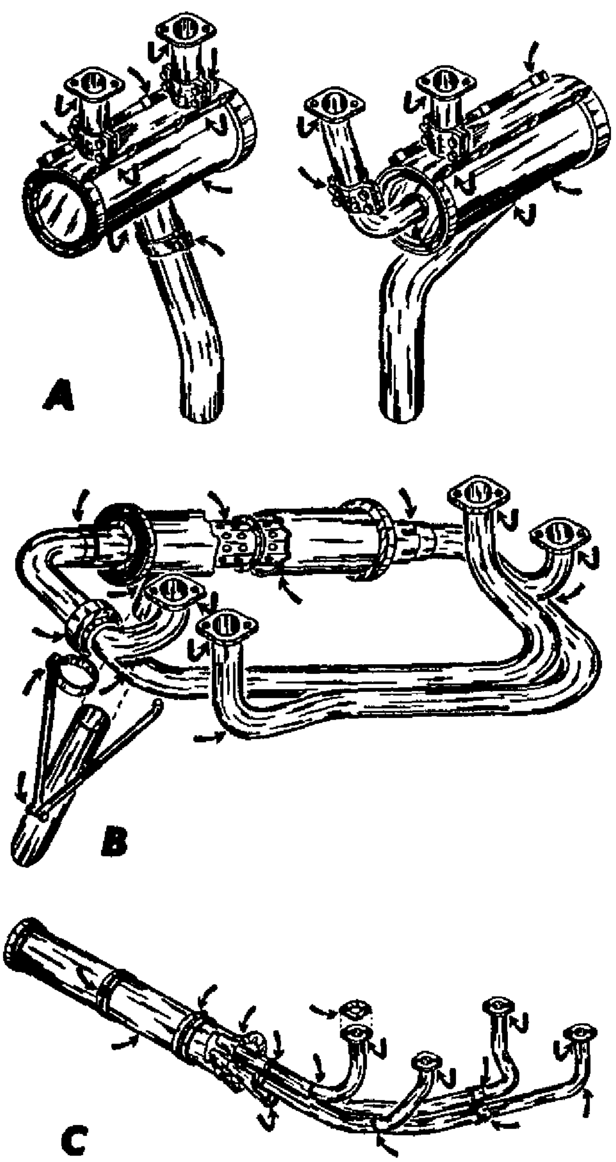


FIGURE 14.24.—Primary inspection areas (A. Separate system; B. Crossover type system; C. Exhaust/augmentor system.)

734. TURBOSUPERCHARGER. When a turbosupercharger is included, the exhaust system operates under greatly increased pressure and temperature conditions. Extra precautions should be taken in the exhaust system's care and maintenance. During high altitude operation, the exhaust system pressure is maintained at or near sea level values. Due to the pressure differential, any leaks in the system will allow the exhaust gases to escape with torchlike intensity that can severely damage adjacent structures. A common cause of turbosupercharger malfunction is coke deposits (carbon buildup) in the waste gate unit causing erratic system operation. Excessive deposit buildups may cause the waste gate valve to stick in the closed position, causing an overboost condition. Coke deposit buildup in the turbosupercharger itself will cause a gradual loss of power in flight and low deck pressure reading prior to takeoff. Experience has shown that periodic decoking, or removal of carbon deposits, is necessary to maintain peak efficiency. Clean, repair, overhaul, and adjust turbosupercharger system components and controls in accordance with the applicable manufacturer's instructions.

735. AUGMENTOR SYSTEMS. Inspect augmentor tubes periodically for proper alignment, security of attachment, and general overall condition. Regardless of whether or not the augmentor tubes contain heat exchanger surfaces, they should be inspected for cracks along with the remainder of the exhaust system. Cracks can present a fire or carbon monoxide hazard by allowing exhaust gases to enter nacelle, wing or cabin areas.

736.–746. RESERVED.

Chapter 15. RADIO AND ELECTRONIC SYSTEMS

Section 1. MAINTENANCE OF RADIO AND ELECTRONIC SYSTEMS

747. GENERAL. The safety of aircraft operated in the National Airspace System is dependent in a large degree upon the satisfactory performance of the airborne radio and electronic systems. Reliability and performance of the system(s) is proportional to the quality of maintenance received and the knowledge of those who perform such maintenance. It is, therefore, important that maintenance be accomplished using the best techniques and practices to assure optimum performance.

The term "system" as used in this chapter means those units of antenna, power source, sensors, receivers, transmitters, and indicators which together perform a function of communications or navigation.

This chapter is not intended to supersede or replace any Federal Aviation Administration regulation or specific manufacturer's instructions pertaining to radio and electronic equipment maintenance. Chapter 11 supplements the information provided in this chapter.

748. MAINTENANCE OF EQUIPMENT. Inspect units or radio/electronic equipment, assemblies, wiring and control systems for damage, general condition, and proper functioning to assure the continuous satisfactory operation of the system. Test, adjust, and repair radio and electronic equipment and systems in accordance with the manufacturer's maintenance instructions, manuals, and applicable Federal Aviation Regulations.

749. REPLACEMENT OF COMPONENTS. Replace damaged or defective components of radio or electronic units with identical items or items equivalent to the original in electrical and mechanical characteristics, operating tolerances, and the ability to function in the physical environmental conditions encountered in the operation of the aircraft.

750. INSPECTION OF INSTALLATIONS. Some items to look for and checks to be made during the inspection are:

a. Damaged or overheated equipment, connections, or wiring.

b. Poor electrical bonding.

c. Improper support of wiring and conduit.

d. Dirty equipment and connections.

e. Loose connections, terminals, plugs, and receptacles.

f. Condition of fuses, circuit breakers, and electric lamps.

g. Insufficient clearance of equipment from mounting rack, insecure or improper mountings.

h. Broken or missing antenna insulators, lead-through insulators, springs, safety wires, etc.

i. Miscellaneous irregularities such as loose quick-disconnects, metal objects in terminal strips or junction boxes, tightness of connections in plugs and receptacles, broken wire bundle lacing, pinched or dented conduit, broken or inadequate cable clamps, etc.

751. CLEANING. Frequent cleaning of radio and electronics equipment is recommended. Dust, dirt, and lint contribute to overheating of equipment, poor ventilation, and malfunctioning. Equipment chassis may be cleaned with a blast of dry air and a small brush. Special attention should be given that ventilation openings in equipment housings are open and free from obstructing lint and dust.

752. CONTACT CLEANERS. When cleaning radio equipment internally, spray cleaners can be used effectively, especially on switching assemblies. There are many contact cleaners on the market which, while they work well on micarta wafer switches, can cause irreparable damage to plastic wafer switches. Do not use contact cleaners on plastic wafer switches unless recommended or known to be harmless to the plastic.

753. OPERATIONAL CHECKS. An operational check is recommended during 100-hour or periodic inspections of radio and electronic systems. Although individual units of equipment may receive bench checks at various times, the proper functioning of a system can best be determined by an operational check in the aircraft. The various units of communications, navigation, weather radar, DME, and transponder systems are interdependent upon each other for proper operational performance.

754.-765. RESERVED.

Section 2. MAINTENANCE OF WIRING AND CABLES

766. WIRING AND CABLE INTEGRITY. Inspect interconnecting wiring, cables, and conduit between various pieces of electronic equipment to determine that they do not rub against the airframe or each other under vibration conditions encountered in flight. Inspect open wiring and cabling for fraying, damage or distortion resulting from heavy objects being placed on it, being stepped on, or being used as handholds.

767. PROTECTION FROM FLUIDS. Separate wiring or cables for flammable fluids lines or those which carry fluids which have a deteriorating effect on wire insulation. Wiring or cables should be routed above such lines and securely clamped to the aircraft structure. An arcing fault between an electric cable and a fluid line may puncture the line and result in a fire.

768. WIRE AND CABLE CLAMPS. Inspect wire and cable clamps for proper tightness. Where cables pass through structure or bulkheads, inspect for proper clamping or grommets. Inspect for sufficient slack between the last clamp and the electronic equipment to prevent strain at the cable terminals and minimize adverse effects on shock mounted equipment.

769. CONDUIT. Conduit is manufactured in metallic and nonmetallic materials and in both rigid and flexible forms. Primarily its purpose is for mechanical protection of the cable within. Inspect conduit for proper end fittings, absence of abrasion at the end fittings, and proper clamping. Inspect for distortion, adequate drain points which are free of dirt, grease, or other obstructions, and freedom from abrasion or damage due to moving objects such as aircraft control cables or shifting cargo.

770. PLASTIC WIRE SLEEVING. Inspect plastic wire sleeving for damage due to abrasion, solvents, or hydraulic fluids.

771. ELECTRICAL TAPE. The chemical base of most plastic electrical tape is polyvinylchloride (PVC). This tape is not flame resistant unless it is specially processed to make it so. Some manufacturers are producing flame-resistant PVC tape and have obtained Fire Underwriter's Laboratory (UL) approval which is shown on the wrapping of the container. Unless the tape shows such approval, it should not be used until its flame resistance properties have been determined. A simple test can be made by applying a flame to a sample of unknown tape and comparing its burning qualities to a sample of flame-resistant tape.

Flame resistant or not, PVC will decompose at temperatures above 221° F. (105° C.) with rapid loss of insulating qualities. It is not recommended for use in compartments where temperatures normally approach 221° F. (105° C.) nor in designated fire zones unless precautions are taken to prevent short circuits to the airframe, shielded wires in bundles, or any other electrical ground, in the event of decomposition.

772.–782. RESERVED.

Section 3. JUNCTION BOXES AND TERMINAL STRIPS

783. JUNCTION BOXES. Inspect junction boxes for "oil canning" of the cover and sides, internal shorts due to distortion of the box, internal cleanliness, absence of stray metallic objects, proper grommeting where wires or cables enter the box, and freedom of drain holes from foreign objects or material.

784. INTERNAL ARRANGEMENT. Electric cable inside the box should be laced or clamped in such a manner that terminals are not hidden, relay armatures are not fouled, and motion relative to any equipment is prevented. Where marginal clearances are unavoidable, an insulating material should be interposed between current-carrying parts and any grounded surface.

785. TERMINAL STRIPS. Inspect terminal strips which provide connection of radio and electronic systems to the aircraft electrical system for loose connections, metallic objects which may have fallen across the terminal strip, dirt and grease accumulation, etc. Such conditions can cause arcing which may result in a fire.

786. PLUGS AND RECEPTACLES. Inspect this type of power connector for loose soldered connections, proper insulation of metallic parts, and fraying of wires in the plug and receptacle inserts.

787.–797. RESERVED.

Section 4. POWER SOURCES AND DISTRIBUTION SYSTEMS

798. BATTERY ELECTROLYTE CORROSION. Electrolyte spilled during ground servicing should be neutralized at once with solutions of sodium bicarbonate (for acid electrolyte) or boric acid, vinegar, or a 3 percent solution of acetic acid (for alkaline electrolyte). Residue should be washed off with clean water and the area thoroughly dried.

799. GENERATORS AND ALTERNATORS. Inspect generators and alternators and their associated wiring and distribution systems for wear, damage, general condition, and proper functioning to assure the continued satisfactory operation of the electrical system. Frequent visual inspections, operating checks of all electrical circuits and equipment, and replacement or repair when deficiencies are found are effective in minimizing electrical troubles and hazards in aircraft.

800. ALTERNATOR DIODES. Alternators employ diodes for the purpose of converting the alternating current to direct current. These diodes are electronic devices and are particularly susceptible to damage if abused. A diode will allow passage of current in one direction with little resistance, but will allow passage of current in the opposite direction only if the voltage applied exceeds that value for which the device was designed. A voltage surge in the line, if it exceeds the design value, will destroy the diode very quickly.

801. DIODE PROTECTION. The best protection against diode destruction by voltage surges is to make certain that the battery is never disconnected for the aircraft electrical system when the alternator is in operation. The battery acts as a large capacitor and tends to damp out voltage surges. Make certain that the battery is never connected with reversed polarity. This will subject the diodes to a direct short circuit and will generally destroy them instantly.

802. ALTERNATOR/BATTERY CONNECTIONS. Some alternators require that the battery be connected in the circuit initially before it will produce any output.

803. STATIC ELECTRICAL POWER CONVERTERS. Static power converters employ solid state devices to convert the aircraft primary electrical source voltage to higher values for the operation of radio and electronic equipment. They contain no moving parts and are relatively maintenance free. Various types are available for AC to DC or DC to AC conversion. Exercise care in locating and mounting static converters to insure adequate ventilation for cooling purposes. Heat radiating fins should be kept clean of dirt and other foreign matter which may impair their cooling properties.

804. CLEANING AND PRESERVATION. Frequent cleaning of electrical and electronic equipment to remove dust, dirt, and grime is recommended. Fine emery cloth may be used to clean terminals and mating surfaces if they appear corroded or dirty. Crocus cloth or very fine sandpaper should be used to polish commutators or slip rings. Use of emery cloth on commutators is not acceptable because metallic particles from the cloth may cause shorting and burning.

805. MISCELLANEOUS CHECK ITEMS. Make frequent checks for miscellaneous irregularities such as loose terminal connections, poorly soldered or loosely swaged terminals, missing safety wire, loose quick-disconnects, broken wire bundle lacing, broken or inadequate wire clamps, and insufficient clearance between exposed current-carrying parts and ground. Replacement or repair should be accomplished as a part of routine maintenance.

806. ADJUSTMENT AND REPAIR. Accomplish all adjustment, repair, overhaul, and testing of electrical equipment and systems in accordance with the recommendations and procedures set forth in maintenance instructions or manuals published by the aircraft and equipment manufacturers.

807. ELECTRICAL SWITCH INSPECTION. Special attention should be given to electrical circuit switches, especially the spring-loaded type, during the course of normal airworthiness inspection. An internal failure in this type of switch may allow the switch to remain closed even though the toggle or button returns to the "off" position. During inspection, attention should also be given to the possibility that improper switch substitution may have been made.

808. RADIO EQUIPMENT OPERATION. Determine that the radio and electronic equipment operates satisfactorily throughout the voltage range of the aircraft electrical system under taxi, takeoff, slow cruise, normal cruise, and landing operating conditions.

809.-819. RESERVED.

Section 5. NOISE SUPPRESSION

820. GENERAL. Elimination or suppression of sources of radio interference within the aircraft is necessary in order to obtain the optimum performance of airborne radio equipment. This is done by bonding, shielding, and the use of static dischargers.

821. BONDING. Radio equipment should be bonded to the aircraft in order to provide a low impedance ground and to minimize radio interference from static electricity charges. Bonding jumpers should be as short as practicable and be installed in such a manner that the resistance of each connection does not exceed 0.003 ohm. Where a jumper is for radio-noise prevention only and not for current-carrying purposes, a resistance of 0.01 ohm is satisfactory.

822. SHIELDING. The most effective method of minimizing engine ignition radio interference is to shield the ignition system. Use a metallic braid covering and special end connectors for ignition wires between the magneto and spark plugs. The primary leads to the magneto and the magneto switch itself should be shielded. Provide shielded type spark plugs and a shielded metal cover for the magneto if it is not so equipped. All connections in the shielding should be tight metal-to-metal contact.

823. SPARK PLUGS. The engine ignition noise may be suppressed by replacing the spark plugs with resistor spark plugs of a type approved for the engine if it is not feasible to shield the engine ignition system.

824. FILTERS. If an intolerable radio noise level is present despite shielding of the ignition wiring and plugs, it may be necessary to provide a filter between the magneto and magneto switch to reduce the noise. This may consist of a single by-pass capacitor or a combination of capacitors and choke coils. When this is done, the shielding between the filter and magneto switch can usually be eliminated and the special shielded magneto switch need not be used.

Inspect supporting brackets and wiring details for magneto filters for conformance with standard aircraft electrical practice. The reliability of the magneto filter installation should be at least equivalent to that of the remainder of the magneto ground lead installation.

825. PRECIPITATION STATIC. Precipitation static is a general term applied to noise in radio receiving systems caused by precipitation. It is not always caused by true precipitation, such as ice, snow, or rain. Dust, sand, or other airborne particles may cause it. It may be the result of ionization in the exhaust of jet engines. As a result of precipitation static charging, the electrical potential of the aircraft rises until it reaches the corona threshold. Corona is the discharge of electric current from an object into the surrounding air and occurs as short pulses of current and produces a noise spectrum which contains appreciable energy at radio frequencies. The noise produced is coupled into the aircraft antennas.

826. STATIC DISCHARGERS. Static dischargers are installed on aircraft to bleed off precipitation static before the potential reaches the corona threshold. These dischargers are normally mounted on the control surfaces and other extremities of the aircraft. The three major types in use are: (1) flexible, vinyl-covered, carbon-impregnated braid, (2) semiflexible metallic braid, and (3) null-field.

827. MAINTENANCE OF STATIC DISCHARGERS. Inspect flexible and semiflexible dischargers for physical security of mounting attachments, wear or abrasion of wicks, missing wicks, etc. Inspect flexible, vinyl-covered wicks to assure that one inch of the inner braid extends beyond the vinyl covering. Null-field discharges are epoxy bonded to the aircraft structure. Measure the resistance of the bond to determine compliance with the manufacturer's recommended tolerances, and inspect for physical damage.

828.–838. RESERVED.

Section 6. ANTENNAS

839. FIXED AND TRAILING WIRE ANTENNAS. Inspect fixed and trailing wire antennas for cracked or broken insulators, broken tension springs, and missing end thimbles. Inspect feed-through and strain insulators for damage due to arcing or corona discharge. Replace damaged insulators. If insulated wire is used for the fixed antenna, inspect the insulating covering for pinholes resulting from corona discharge or lightning. Inspect fixed antenna masts for security of mounting and absence of skin cracks in the mounting area.

840. WHIP AND BLADE ANTENNAS. Inspect security of mounting, condition of sealant around antenna base, and physical damage resulting in bending or deformation of the antenna itself.

841. FLUSH MOUNTED ANTENNAS. Many high performance aircraft use flush mounted antennas where the antenna itself is recessed in the fuselage or other portions of the aircraft structure. The recesses in which such antennas are mounted are covered with fiberglass or other material which allows the passage of radio frequency energy. Inspect such covers frequently for integrity of seals and cracks in the covering. If the covers are painted, they should be painted with a type of paint which will not interfere with the passage of radio frequency energy.

842. COAXIAL CABLES AND FITTINGS. Inspect coaxial cable antenna connectors for proper fastening. Certain types of connectors depend on the positioning of the center pin by its physical connection to the center conductor of the cable. Frequent connecting and disconnecting of the connector causes this pin to position so that it does not make contact with the female connector. If the connectors become physically separated from each other or the unit, equipment failure will result. Cable connectors may be clamped or safetied so that they do not become separated.

843. RADOMES. A radome is a covering whose primary purpose is to protect a radar antenna from the elements. It is a part of the airframe, but must have certain electrical as well as physical properties. Electrically, a radome must permit the passage of the radar transmitted signals and return echoes with minimum distortion and absorption. In order to do this it must have a certain electrical thickness. A variation in electrical thickness can make the difference between an efficient radome and one that can reduce radar range, distort displays, and cause inaccurate directions and false targets. Hence, a radome must be properly maintained and repaired to deliver optimum performance.

844. RADOME INSPECTION. Inspection of aircraft having weather radar installations should include a visual check of the radome surface for signs of surface damage, holes, cracks, chipping, and peeling of paint, etc. Attach fittings and fastenings, neoprene erosion caps, and lightning strips, when installed, should also be inspected.

a. Scuff marks on the radome are usually an indication of impact damage from birds, foreign objects, or hangar/ramp equipment. Further detailed inspection is required to determine whether physical damage has occurred.

b. Surface cracks on the radome paint do not always indicate structural damage, but may be due to paint shrinking or becoming brittle. If accompanied by impact marks, static discharge or lightning burn marks, or evidence of oil canning, a more detailed inspection is required to determine whether physical damage has occurred.

c. Paint chipping usually results from in-flight encounter with hail, surface static discharges, or lightning. A detailed external and internal inspection of the radome should be made for fractures or delamination of the radome structure.

d. Paint peeling on the radome is usually caused by flight in heavy precipitation or by improperly applied paint coatings. If detected in its early stages, usually no damage results. Corrective action should be taken to prevent further erosion and water absorption. A rapid breakdown of the structure will occur when trapped moisture freezes resulting in greatly reduced efficiency of radar operation.

e. Neoprene erosion caps provide protection from rain erosion; however, they do conceal the radome surface and make impact damage difficult to detect. When in doubt about impact damage, remove the radome and inspect the inside surface. Other erosion cap inspection items are air bubbles, surface fraying, and loose edges around the cap.

f. Lightning diverter strips are intended to protect the radome from lightning damage, and prevent radio interference from static charge build-up on the radome. Proper grounding of these strips to the aircraft structure should be assured each time a radome is inspected or repaired. Damaged or burned-out strips should be replaced.

845. RADOME MAINTENANCE AND REPAIR. Any repair to a weather radome should be accomplished according to manufacturer's recommended procedures by qualified personnel using the equipment and materials recommended by the manufacturer. The use of improper materials and repair techniques may result in reduced performance and accuracy of the weather radar system.

a. Plastic nose caps should not be installed over a radome unless the manufacturer recommends such installation. Such caps may cause radar beam distortion, weak signal returns, poor definition, and radar display clutter. Moisture leaks or condensation between the plastic cap and radome can block or distort the signal without the cause for such condition being apparent.

b. Radome protective coating should be a type, and contain only materials, recommended by the radome manufacturer. Metallic paints or undercoating can set up reflections in the radar system which may damage the equipment.

c. Solvents should not be used to wash the radome. They may weaken the bond between the radome and the neoprene erosion cap.

d. Chemical type paint strippers should not be used. They will attack the resins used in the radome construction, and may weaken its structural integrity.

e. The testing of a radome after maintenance or repair is a determination that must be made by the person approving it for return to service since he is responsible for its airworthiness. All repairs to radomes are not necessarily major repairs, and minor repairs may not require testing. The decision to test should be based upon the nature and complexity of the repair.

846. LOOP ANTENNAS. Loop antennas are designed for use with a particular receiver. Connecting wires between the loops and receivers are also designed for the specific equipment. Use only components meeting the specification characteristics of the receiver manufacturer. The outstanding characteristic of a loop antenna is its directional sensitivity which makes it useful as an accurate navigational device.

847. LOOP QUADRANTAL ERROR. Compensation of a loop for quadrantal error requires technical knowledge of the equipment and its operational use and should be accomplished only by a qualified technician. Quadrantal error is that error caused by the metal in the fuselage, wings, etc., distorting the electromagnetic field of a received signal and resulting in azimuth reading inaccuracies which are greatest between the four cardinal points with respect to the centerline of the aircraft.

848. COMPENSATION FOR QUADRANTAL ERROR. It will be necessary to check the direction of the radio bearings every 45 degrees from the fore-and-aft axis of the aircraft (preferably every 15 degrees) after installation of the loop in order to determine and compensate for the deviations caused by distortion of the radio field pattern due to the wing, engine nacelle(s), antennas, and other parts of the aircraft. If the loop is of the type which includes compensating means, it is important that no compensation be present in the loop at the time this calibration is made. If the loop has no provision for adjustment of quadrantal error, the calibration data should be used for the preparation of a correction card to be mounted in the cockpit near the indicator to provide the pilot with corrected bearing information.

849. GROUND CALIBRATION. The calibration may be made on the ground for installations in which the loop is on top of the aircraft, but the accuracy of the calibration should be checked in the air. However, for installations in which the loop is beneath the fuselage, the use of the flight method is necessary if accuracy is to be obtained.

850. AIR CALIBRATION. Air calibration of loops are best made on a day when the wind is less than 8 miles per hour and the air is smooth, using a medium or high-powered radio station between 25 and 100 miles distant. The station should normally provide good bearings with little or no fluctuation of the indicator pointer. Do not make the calibration within two hours of sunrise or sunset or when wide fluctuations of bearings are noted.

851. CALIBRATION POINTS. Select a landmark or series of landmarks such as a road, railroad tracks, section lines, etc., which will provide a direct line toward the radio station. Powerlines and railroads on or adjacent to the landmarks can distort the radio path, so make a check to determine whether or not distortion is present. This can be done by crossing the reference line at various angles while maintaining fixed courses by means of the directional gyro. If the bearing changes rapidly as the line is approached, distortion is present and should be eliminated by flying at a higher altitude, or by selecting a new reference landmark.

852. CALIBRATION PROCEDURE. Fly directly toward the station along the reference line with the aircraft in level flight at an altitude low enough to avoid parallax error. When passing over some predetermined point or intersecting line to the reference, record simultaneously the indicator bearing and the directional gyro reading. Repeat the above procedure until sufficient readings have been taken at all required bearings. Since the radiocompass deviation changes to some extent with frequency, take calibration data at several frequencies to ensure greater accuracy in use.

853. CALIBRATION DATA. Calibration data obtained for a particular type of airplane is usable without modification for all aircraft of that type if the location of the loop and other antennas are the same. Since all aircraft of the same type may not have the same radio installations, an accurate diagram with antenna dimensions and exact loop location will add to the usefulness of the recorded data.

854.–863. RESERVED.

Chapter 16. INSTRUMENTS

Section 1. MAINTENANCE OF INSTRUMENTS

864. GENERAL. The complexity of modern instruments, integrated flight systems, autopilots, air data computers, and inertial guidance systems necessitates complex maintenance procedures, sophisticated test equipment and qualified personnel. The safety of aircraft operated in the National Airspace System is dependent in a large degree upon the satisfactory performance of airborne instrument systems. It is, therefore, important that maintenance be accomplished using the best techniques and practices to assure optimum performance.

The term "system" as used in this chapter means those units of power source, sensors, transmitters, indicator, and controllers which together perform a function of display, interpretation, or control of the functions of an aircraft, its systems or the environment in which it operates.

865. DEFINITION. The definition of an instrument is contained in Part 1 of the Federal Aviation Regulations.

866. MAINTENANCE OF INSTRUMENTS. Repairs and overhaul of aircraft instruments should be made only by an FAA approved facility having proper test equipment, adequate manufacturer's maintenance manuals and service bulletins, and qualified personnel. Details concerning the repair and overhaul of various instruments differ considerably. Test, repair, and adjust instruments and instrument systems in accordance with the manufacturer's maintenance instructions, manuals, and applicable Federal Aviation Regulations. Consult the airframe manufacturer for specific maintenance instructions involving instruments that are installed or supplied by them.

867. TEST/ADJUSTMENT OF INSTRUMENTS. Certain instruments, such as altimeters and vertical speed (rate-of-climb) indicators are equipped with simple adjusting means. They are readily accessible and do not require any special tools to operate. The adjustment should be accomplished by qualified personnel, using proper test equipment and adequate reference to the manufacturer's maintenance manuals.

a. *The Altimeter.* Most altimeters can be reset to correlate the barometric scale with the altitude indication using only a screwdriver. Manufacturer's instructions usually caution that this operation be done only once or twice. Under FAR 43.9, the event must be properly recorded in the aircraft's permanent maintenance records. Only small corrections should be made. Large corrections should be regarded as an indication of possible malfunction of the instrument and appropriate tests be made.

(1) When correlating the altitude indication with the barometric scale, it is recommended that only two small adjustments be made without a scale error test.

(a) On initial installation of a new or properly overhauled instrument, a correction of up to 40 feet may be made.

(b) After the first flight, or series of flights, an additional correction of up to 40 feet may be made.

NOTE: Allow the altimeter approximately 8 hours to stabilize at the prevailing atmospheric pressure before making this adjustment.

(c) If an adjustment of over 40 feet, or any adjustment other than (a) and (b) above is needed, the altimeter should be sent to an instrument repair facility for testing, or should be tested in accordance with subparagraph (4) of this paragraph.

(2) To determine if a scale error test is necessary, rotate the barometric setting knob

until the CURRENT altimeter setting is indicated. The altimeter setting should be obtained from an FAA control tower or other accurate source. Compare the altimeter reading with the known altitude. A scale error test should be made, after adjustment, if the difference is greater than 40 feet.

NOTE: Exact altitude of the altimeter should be determined, since the elevation from point to point on an airport may vary by a substantial amount.

(3) A recommended procedure for setting the barometric scale to correlate with altitude is as follows:

(a) Rotate the barometer setting knob until the altimeter indicates the known altitude. (See note above.)

(b) Following manufacturer's instructions, release the locking mechanism of the barometric setting device. Making sure the barometric setting knob is not rotated, pull the knob out until it is disengaged from the internal gearing.

(c) Rotate the knob to the CURRENT altimeter setting, then gently press the knob back until the internal gearing is meshed and engage the locking mechanism.

(d) Check the operation of the barometric setting mechanism by rotating the knob. Movement should be smooth; no grinding or sticking should be apparent.

(e) Rotate the knob to the pressures indicated below. The altimeter reading should change as shown within ±25 feet:

31.00" Hg	+910 feet
30.00" Hg	Reference setting
29.00" Hg	−936 feet

(4) If an adjustment exceeds 40 feet or any adjustment other than (1)(a) and (b) of this paragraph is needed, the altimeter should be tested for scale error. Air carriers' altimeters are tested in accordance with their approved maintenance procedure and all other altimeters in accordance with Appendix E, Part 43, using test equipment whose description and maintenance are at least equivalent to that contained in Advisory Circular 43-203A.

b. ***Vertical Speed Indicators.*** Most vertical speed indicators can be set to zero by mean of a slotted shaft adjustment, using only screwdriver.

(1) It is recommended that only two adjust ments be made without a scale error test Under FAR 43.9, the event must be properl recorded in the aircraft's permanent mainte nance records.

(a) On initial installation of a new o properly overhauled instrument, a correctio of up to 5% of full scale may be made.

(b) After the first flight, or series o flights, an additional correction of up to 5% of full scale may be made.

NOTE: Allow the instrument approximately 15 minute to stabilize at the prevailing atmospheric pressure be fore making this adjustment.

(2) If an adjustment of more than 5% o any adjustment other than (1)(a) and (b) o this paragraph is needed, the instrumen should be tested for scale error. Air carriers vertical speed indicators are tested in accord ance with their approved maintenance proce dure and all other indicators in accordanc with manufacturer's procedures, using tes equipment whose description and maintenanc are at least equivalent to that contained i Advisory Circular AC 43-203A.

868. REPLACEMENT OF COMPONENTS. Replac damaged or defective instruments with identi cal serviceable components or component equivalent to the original in electrical an mechanical characteristics, operating toler ances, and the ability to function in th physical environmental conditions encountere in the operation of the aircraft. Be sure al shipping plugs and gyro caging devices tha may have been installed for shipping purpose are removed before installing an instrument Check new installations carefully prior to applying electrical power or connecting tes equipment to avoid damaging sensitive mechanisms. Test the new instrument after installation for proper functioning (where applicable).

869.-879. RESERVED.

Section 2. INSPECTION AND CHECKS

80. **GENERAL.** Proper operation of aircraft nstruments is important to safe flight. Inpection is an important part of instrument naintenance. Inspection of instruments and nstrument systems should include at least the ollowing items (where applicable):

a. *Inspect* external pitot-static equipment for ooor condition, cleanliness and deformation.

b. *Inspect instruments* for poor condition, nounting, marking, broken or loose knobs, bent r missing pointers, and (where applicable) mproper operation.

c. *Check power-off indications* of instrument oointers, tape scales, and warning flags for oroper indications.

d. *Apply power and check* for excessive mehanical noise, erratic or intermittent operaion, failure to indicate, sluggishness or indicaion of excessive friction.

e. *Check that erection or warmup time* is not excessive, caging functions are normal, and warning flags and indicating lights and test circuits are operable.

f. *Note the operation* of instruments during engine runup (where applicable). Check for intermittent or improper operation of any instrument.

g. *Inspect all systems* for improper installaion, poor general condition, apparent and obvious defects, and insecurity of attachment.

881. **PERIODIC INSPECTION.** Periodic inspections should be performed in accordance with applicable parts of the Federal Aviation Regulations.

882. **ADDITIONAL INSPECTIONS.** Periodic inspections may be supplemented by additional inspections based on the intended function of the aircraft and frequency of use. These additional inspections may be performed at any time to help maintain an airworthy aircraft. A suggested list of additional items is:

a. *Check tubing connections* and airframe mounts for security and condition.

b. *Check pneumatic tubing* for leaks, corrosion, erosion, cracks, bends and pinching, and evidence of chafing.

c. *Check the instrument lighting system* for range of illumination, burned out bulbs, and defective controls.

d. *Check electrical connections,* fuses, fuse clips and circuit breakers for proper size, security and condition.

e. *Check wiring* for excessive bends, chafing, excessive tension, improper support or broken lacing and ties.

f. *Check for evidence of overheating or contamination* of equipment by foreign matter or water. Dust, dirt, and lint contribute to overheating of equipment, poor ventilation, and malfunctioning. Special attention should be given that ventilation openings in equipment housings are open and free from obstructing lint and dust.

883.–893. **RESERVED.**

Section 3. INSTRUMENT POWER SOURCES

894. ELECTRICAL COMPATIBILITY. When replacing an instrument with one which provides additional functions or when adding new instruments, check the following electrical parameters (where applicable) for compatibility:

a. Voltage (AC/DC).

b. Voltage polarity (DC).

c. Voltage phase(s) (AC).

d. Frequency (AC).

e. Grounding (AC/DC).

f. System impedance matching.

g. Compatibility with system to which connected.

895. VACUUM SYSTEMS. The differential pressure to operate vacuum instruments is supplied by an engine driven vacuum pump or on a turbine engine by a pressure bleed operated venturi tube. Variation in pressure may be achieved by a pressure regulator valve according to the design requirements of the instruments; e.g., 4 1/2 inches mercury differential pressure for horizon gyro and 2 inches mercury differential pressure for a turn-and-bank indicator.

a. *Filters.* Inspect the air filters in the vacuum system and clean or change them at any time that the vacuum system differential pressure reaches established limits. Clean or change all system filters at the same time and make any necessary pressure adjustment.

b. *Tubing.* A noncollapsible, flexible tubing should be used in vacuum systems when vibration isolation is required or desired.

896.-906. RESERVED.

Section 4. PITOT-STATIC SYSTEMS

907. SYSTEM COMPONENTS. Conventional design of the pitot-static system consists of pitot-static tubes or pitot tubes with static pressure ports or vents and their related heaters, if any, and includes lines, tubing, water drains and traps, and selector valves. Pressure actuated indicators such as the altimeter, airspeed, and rate-of-climb indicators, and control units such as air data transducers, and automatic pilots may be connected to the system.

908. PITOT-STATIC TUBES AND LINES. The pitot tube is installed with the axis parallel to the longitudinal axis of the aircraft unless otherwise specified by the manufacturer. When lines are attached or removed from a bulkhead feed-through fitting or at a union, precautions must be taken to assure that the line attached to the opposite end is not loosened, twisted, or damaged by rotation of the fitting. Such fittings normally are provided with a hex flange for holding.

909. PRESSURE PORTS OR VENTS. Static pressure ports or vents should be mounted flush with the fuselage skin. Inspect for elevation or depression of the port or vent fitting. Such elevation or depression may cause airflow disturbances at high speeds and result in erroneous airspeed indications.

910. CLEANING OF SYSTEM. Inspect air passages in the systems for water, paint, dirt, or other foreign matter. Probe the drains in the pitot tube to remove dirt or other obstructions. Tubing diameter should be checked when a problem is experienced with drainage of the pitot-static system or freezing at altitude. If this diameter is less than 3/8 inch, it should be replaced with larger tubing. Water may not drain freely from smaller diameter lines. Water or obstructions may be removed from the lines by disconnecting them near the instrument and blowing clean, dry air through them. No instruments should be connected to the system during this process.

911. HEATER ELEMENTS. Some pitot-static tubes have replaceable heater elements, while others do not have replaceable elements. Check replacement of the heater element or the entire tube for proper operation by noting either ammeter current or that the tube or port gets hot to the touch.

912. SYSTEM LEAK TESTING. Pitot-static leak tests should be made with all instruments connected to assure that no leaks occur at instrument connections. Such tests should be made whenever a connection has been loosened or an instrument replaced.

913. STATIC SYSTEM TEST. Advisory Circular AC 43-203A describes an acceptable means of complying with static system tests required by FAR Part 91, section 91.170, for airplanes operated in controlled airspace under IFR. (This circular also provides information concerning the test equipment used, and precautions to be taken when performing such tests.) Aircraft not operated in controlled airspace under IFR should be tested in accordance with the aircraft manufacturer's instructions.

If the manufacturer has not issued instructions for testing static systems, the following may be used:

a. Connect the test equipment directly to the static ports, if practicable. Otherwise, connect to a static system drain or tee connection and seal off the static ports. If the test equipment is connected to the static system at any point other than the static port, it should be made at a point where the connection may be readily inspected for system integrity. Observe testing precautions given in paragraph 915.

b. ***Apply a vacuum*** equivalent to 1,000 feet altitude, (differential pressure of approximately 1.07 inches of mercury or 14.5 inches of water) and hold.

c. ***After one minute, check*** to see that the leakage has not exceeded the equivalent of 100 feet of altitude (decrease in differential pressure of approximately 0.105 inches of mercury or 1.43 inches of water).

914. PITOT SYSTEM TEST. Pitot systems should be tested in accordance with the aircraft manufacturer's instructions. If the manufacturer has not issued instructions for testing pitot systems, the following may be used:

a. ***Test the pitot system*** by sealing the drain holes and connecting the pitot pressure openings to a tee to which a source of pressure and a manometer or reliable airspeed indicator is connected.

b. ***Apply pressure*** to cause the airspeed indicator to indicate 150 knots (differential pressure 1.1 inches of mercury or 14.9 inches of water), hold at this point and clamp off source of pressure. After 1 minute, the leakage should not exceed 10 knots (decrease in differential pressure of approximately 0.15 inches of mercury or 2.04 inches of water). **Warning: Do not apply suction to pitot lines.**

915. PRECAUTIONS IN TESTING. Observe the following precautions in all pitot-static system leak testing:

a. ***Perform all other work*** and inspections before leak testing.

b. ***Use a system diagram.*** It will prevent applying reverse pressure to any instrument, and help determine the location of a leak while observing instrument indications.

c. ***Be certain that no leaks exist in the test equipment.***

d. ***Run full range tests only if you are thoroughly familiar*** with the aircraft instrument system and the test equipment.

e. ***Pressure in the pitot system*** must always be equal to or greater than that in the static system. A negative differential pressure across an airspeed indicator can damage it.

f. ***The rate of change or the pressure applied*** should not exceed the design limits of any pitot or static instruments connected to the systems.

g. ***After the conclusion of the leak test,*** be certain that the system is returned to its normal flying configuration, such as removing tape from static ports and pitot tube drain holes and replacing the drain plugs, etc.

916.–926. RESERVED.

Section 5. MECHANICAL ADJUSTMENT OF MAGNETIC DIRECTION INDICATORS

927. CORRECTION FOR ERRORS. When a magnetic direction indicator does not provide satisfactory directional indications, it can be adjusted by the "ground swinging" technique to compensate for errors.

928. GROUND SWINGING. The ground swinging technique is as follows:

a. Move aircraft to a location free from influence of steel structures, underground pipes and cables, reinforced concrete, or other aircraft.

b. Place the aircraft in level flying position.

c. Check indicator for fluid level and cleanliness. If fluid is required, the compass is defective.

d. Remove compensating magnets from chambers or reset the fixed compensating magnets to neutral positions, whichever is applicable, before swinging.

e. Check the pivot friction of the indicator by deflecting the card with a small magnet. The card should rotate freely in a horizontal plane.

f. Align the aircraft with the North magnetic heading and compensate with compensating magnets. Repeat for the East magnetic heading. Then place on South and West magnetic headings and remove half of the indicated error by adjusting the compensators. Engine(s) should be running.

g. Turn the aircraft on successive 30° headings through 360°. Prepare a placard to show the correction to be applied at each of these headings. When significant errors are introduced by operation of electrical/electronic equipment or systems, the placard should also be marked at each 30° heading showing the correction to be applied when such equipment or systems are turned on or energized.

929. REMOTE GYRO COMPASS SYSTEMS. Adjustment and compensation of remote indicating gyro compasses, polar path compasses, and other systems of this type may also be accomplished using the "ground swinging" technique. Reference should be made to the manufacturer's manual for special tools, instructions, and procedures.

930.-940. RESERVED.

Section 6. PRESERVATION AND PACKAGING

941. PRESERVATION. Preserve all instruments, serviceable or unserviceable, in accordance with the manufacturer's recommendations or other acceptable standards. Protect the unit against humidity, extreme temperatures, dust, rough handling or other damage until it is repaired or installed in an aircraft. The method used should be pickling, wrapping, sealing in plastic covering, rigid boxes with plastic or foam padding, or other methods appropriate to the instrument or subassembly.

942. STORAGE. Instruments should be stored in a location and a manner which provides maximum protection from physical damage. Serviceable instruments should remain packaged until installed in an aircraft. If a drying agent is used, the package should be dated so that the drying agent may be inspected for condition. Inspect units that remain in storage for extended periods of time for general condition and integrity of packaging and preserving materials.

943. SHIPPING. Protect the instrument from damage during shipment by sealing it in a moisture proof covering and protecting it with a drying agent. Use plastic foam, rubberized hair, or foam rubber molded to the configuration of the instrument case to support it inside a rigid shipping container. Large units may be shock-mounted on fitted pallets or racks and protected with covers.

944.–954. RESERVED.

Appendix 1
CROSS REFERENCE TABLE OF PARAGRAPH NUMBER CHANGES FROM AC 43.13-1

Former Paragraph	*Revised Paragraph*	*Former Paragraph*	*Revised Paragraph*
1		61	96
2		62	97
3		63	98
4		64	99
5		65	100
6		66	101
7		67	102
8		68	103
9			Reserved 104–114
10		69	115
11		70	Reserved 116–126
12		71	127
13		72	128
14		73	129
15		74	130
16		75	131
17		76	132
18		77	133
19		78	134
20		79	135
21		80	136
22			Reserved 137–147
23		81	148
24		82	149
25		83	150
	Reserved 26–36	84	151
26	37	85	152
27	38	86	153
28	39		Reserved 154–164
29	40	87	165
30	41	88	166
31	42	89	167
32–40	Reserved 43–53	90	168
41	54	91	169
42	55		Reserved 170–180
43	56	92	181
	Reserved 57–67	93–99	Reserved 182–192
44	68	100	193
45	69	101	194
46	70	102	195
47	71	103	196
48	72	104	197
49	73	105	198
50	74	106	199
51	75	107	200
52	76		Reserved 201–211
53	77	108	212
54	78	109	213
55	79	110	214
56	80	111	215
57	81	112–119	Reserved 216–226
58	82	120	227
59	83	121	228
	Reserved 84–94	122	229
60	95	123	230

Former Paragraph	*Revised Paragraph*
124	231
125	232
126	233
127	234
128	235
129–139	Reserved 236–246
140	247
141	248
142	249
143	250
144	251
145	252
146	253
147–159	Reserved 254–264
160	265
161	266
162	267
	Reserved 268–278
163	279
164	280
165	281
166	282
167	283
	Reserved 284–294
168	295
169	296
170	297
171	298
172	299
173	300
174	301
	Reserved 302–312
175	313
176	314
177–189	Reserved 315–325
190	326
191	327
192	328
193	329
194	330
194A	331
195	332
	Reserved 333–343
196	344
197	345
198	346
199	347
200	348
	Reserved 349–359
201	360
202	361
203	362
204	363
205–209	Reserved 364–374
210	375
211	376
212	377
213	378
214	379
215	380
216–219	Reserved 381–391
220	392
221	393
222	394
223–229	Reserved 395–405
230	406
231	407
232	408
233	409
234	410
235	411
236	412
	Reserved 413–423
237	424
238	425
239	426
240	427
241	428
242	429
243	430
	Reserved 431–441
244	442
245	443
246	444
247	445
248	446
249	447
250	448
251	449
252	450
253	451
254	452
	Reserved 453–463
255	464
256	465
257	466
	Reserved 467–477
258	478
259	479
260	480
261	481
262	482
263	483
264	484
265	485
	Reserved 486–496
266	497
267	498
268	499
269	500
270	501
271	502
	Reserved 503–513
272	514
273	515
274	516

Former Paragraph	Revised Paragraph
275	517
276	518
277	519
	Reserved 520–530
278	531
279	Deleted
280	Deleted
281	532
282	533
283	534
284	535
285	536
286	537
287	538
288	539
289–299	Reserved 540–552
300	553
301	554
302	555
	Reserved 556–566
303	567
304	568
305	569
306	570
307	571
	Reserved 572–582
308	583
309	584
310	585
311	586
312	587
313	588
314	589
315	590
316	591
	Reserved 592–602
317	603
318	604
319	605
320	606
	Reserved 607–617
321	618
	Reserved 619–629
322	630
323	631
324	632
	Reserved 633–643
325	644
326–339	Reserved 645–655
340	656
341	657
342	658
343	659
344	660
345	661
346	662
347	663
348	664

Former Paragraph	Revised Paragraph
349	665
350–359	Reserved 666–676
360	677
361	678
361A	679
362	680
363	681
364	682
365	683
366	684
367	685
368	686
369	687
370	688
371	689
372	690
373	691
373A	692
373B	693
373C	694
373D	695
373E	696
	Reserved 697–707
374	708
375	709
376	710
377	711
378	712
379	713
380	714
381	715
382	716
	Reserved 717–727
383	728
384	729
385	730
386	731
387	732
388	733
389	734
389A	735
	Reserved 736–746
390	747
391	Deleted
392	748
393	749
394	750
395	751
396	752
397	753
398–405	Reserved 754–765
406	766
407	767
408	768
409	769
410	770
411	771
412–414	Reserved 772–782

Former Paragraph	*Revised Paragraph*
415	783
416	784
417	785
418	786
419–421	Reserved 787–797
422	798
423	799
424	800
425	801
426	802
427	803
428	804
429	805
430	806
431	807
432	808
433–436	Reserved 809–819
437	820
438	821
439	822
440	823
441	824
442	825
443	826
444	827
445–447	Reserved 828–838
448	839
449	840
450	841
451	842
452	843
453	844
New	845
454	846
455	847
456	848
457	849

Former Paragraph	*Revised Paragraph*
458	850
459	851
460	852
461	853
462–472	Reserved 854–863
473	864
474	865
475	866
476	867
477	868
478	Reserved 869–879
479	880
480	881
481	882
482–484	Reserved 883–893
485	894
486	895
487–491	Reserved 896–906
492	907
493	908
494	909
495	910
496	911
497	912
498	913
499	914
500	915
501–511	Reserved 916–926
512	927
513	928
514	929
515–516	Reserved 930–940
517	941
518	942
519	943
520–550	Reserved 944–954

Appendix 2
CROSS REFERENCE TABLE OF ILLUSTRATION NUMBER CHANGES

Former Number	*Revised Number*
	2.1 (New figure)
	2.2 (New figure)
2.1	2.3
2.2	2.4
2.3	2.5
2.4	2.6
2.5	2.7
2.6	2.8
2.7	2.9
2.8	2.10
2.9	2.11
2.10	2.12
2.11	2.13
2.12	2.14
2.13	2.15
2.14	2.16
2.15	2.17
2.16	2.18
2.17	2.19
2.18	2.20
2.19	2.21
2.20	2.22
2.21	2.23
2.22	2.24
2.23	2.25
2.24	2.26

Former Number	*Revised Number*
2.25	2.27
2.26	2.28
2.27	2.29
2.28	2.30
2.29	2.31
2.30	2.32
2.31	2.33
2.32	2.34
2.33	2.35
2.34	2.36
2.35	2.37
2.36	2.38
2.37	2.39
2.38	2.40
2.39	2.41
2.40	2.42
2.41	2.43
2.42	2.44
	4.24 (New figure)
5.2a	5.3
14.21a	14.22a
14.21b	14.22b
14.22	14.23
14.23	14.24

No other illustration numbers were changed.

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