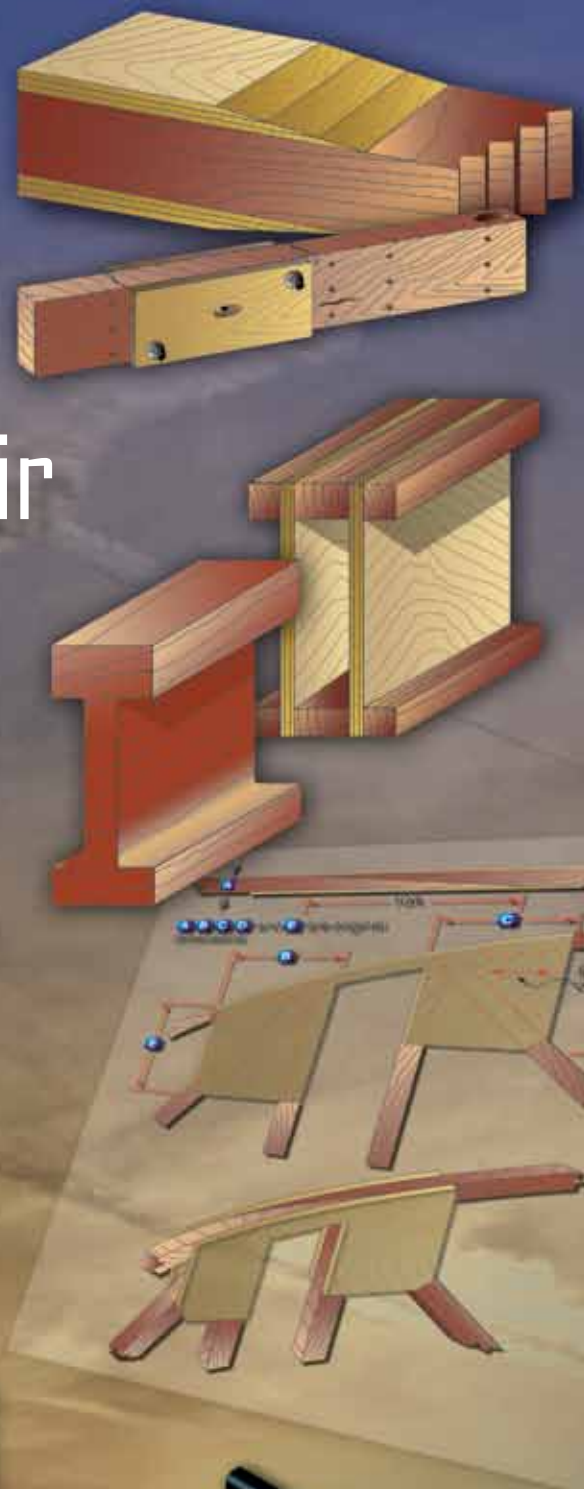
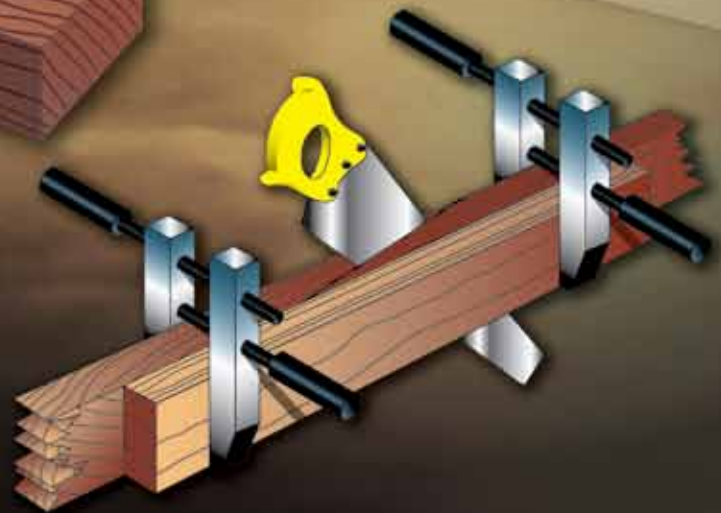
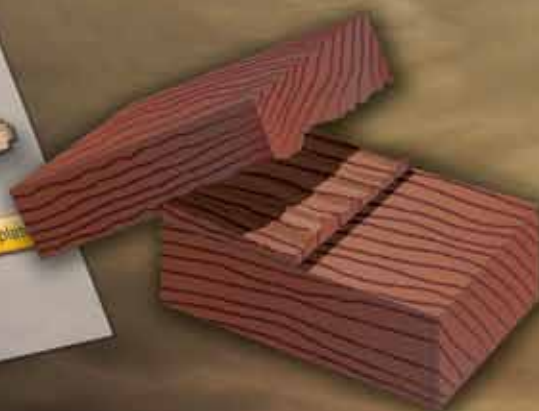
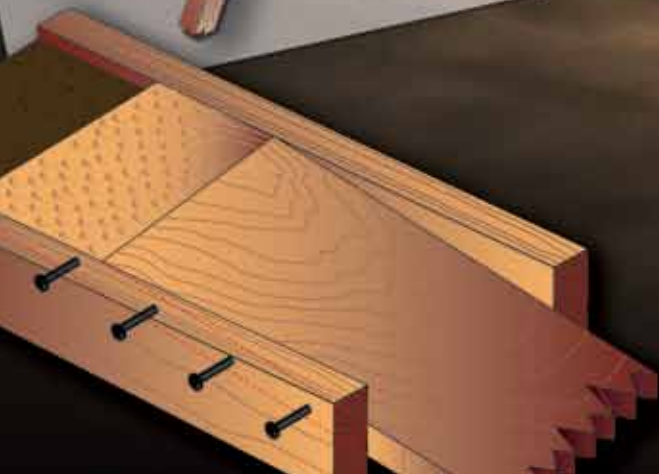
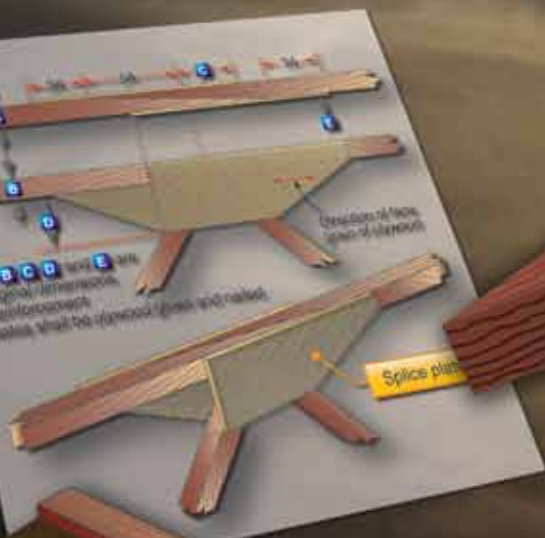


Chapter 6

Aircraft Wood and Structural Repair

Aircraft Wood and Structural Repair

Wood was among the first materials used to construct aircraft. Most of the airplanes built during World War I (WWI) were constructed of wood frames with fabric coverings. Wood was the material of choice for aircraft construction into the 1930s. Part of the reason was the slow development of strong, lightweight, metal aircraft structures and the lack of suitable corrosion-resistant materials for all-metal aircraft.



In the late 1930s, the British airplane company DeHavilland designed and developed a bomber named the Mosquito. Well into the late 1940s, DeHavilland produced more than 7,700 airplanes made of spruce, birch plywood, and balsa wood. [Figure 6-1]



Figure 6-1. British DeHavilland Mosquito bomber.

During the early part of WWII, the U.S. government put out a contract to build three flying boats. Hughes Aircraft ultimately won the contract with the mandate to use only materials not critical to the war, such as aluminum and steel. Hughes designed the aircraft to be constructed out of wood.

After many delays and loss of government funding, Howard Hughes continued construction, using his own money and completing one aircraft. On November 2, 1947, during taxi tests in the harbor at Long Beach, California, Hughes piloted the Spruce Goose for over a mile at an altitude of 70 feet, proving it could fly.

This was the largest seaplane and the largest wooden aircraft ever constructed. Its empty weight was 300,000 pounds with a maximum takeoff weight of 400,000 pounds. The entire airframe, surface structures, and flaps were composed of laminated wood with fabric covered primary control surfaces. It was powered by eight Pratt & Whitney R-4360 radial engines, each producing 3,000 horsepower. [Figure 6-2]



Figure 6-2. Hughes Flying Boat, H-4 Hercules named the Spruce Goose.

As the aircraft design and manufacturing evolved, the development of lightweight metals and the demand for increased production moved the industry away from aircraft constructed entirely of wood. Some general aviation aircraft were produced with wood spars and wings, but today only a limited number of wood aircraft are produced. Most of those are built by their owners for education or recreation and not for production.

Quite a number of airplanes in which wood was used as the primary structural material still exist and are operating, including certificated aircraft that were constructed during the 1930s and later. With the proper maintenance and repair procedures, these older aircraft can be maintained in an airworthy condition and kept operational for many years.

Wood Aircraft Construction and Repairs

The information presented in this chapter is general in nature and should not be regarded as a substitute for specific instructions contained in the aircraft manufacturer's maintenance and repair manuals. Methods of construction vary greatly with different types of aircraft, as do the various repair and maintenance procedures required to keep them airworthy.

When specific manufacturer's manuals and instructions are not available, the Federal Aviation Administration (FAA) Advisory Circular (AC) 43.13-1, Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair, can be used as reference for inspections and repairs. The AC details in the first paragraph, Purpose, the criteria necessary for its use. In part, it stipulates that the use of the AC is acceptable to the FAA for the inspection and minor repair of nonpressurized areas of civil aircraft.

It also specifies that the repairs identified in the AC may also be used as a basis for FAA approval of major repairs when listed in block 8 of FAA Form 337, Major Repair and Alteration, when:

1. The user has determined that it is appropriate to the product being repaired;
2. It is directly applicable to the repair being made; and
3. It is not contrary to manufacturer's data.

Certificated mechanics that have the experience of working on wooden aircraft are becoming rare. Title 14 of the Code of Federal Regulations (14 CFR) part 65 states in part that a certificated mechanic may not perform any work for which he or she is rated unless he or she has performed the work concerned at an earlier date. This means that if an individual does not have the previous aviation woodworking experience

performing the repair on an aircraft, regulation requires a certificated and appropriately rated mechanic or repairman who has had previous experience in the operation concerned to supervise that person.

The ability to inspect wood structures and recognize defects (dry rot, compression failures, etc.) can be learned through experience and instruction from knowledgeable certificated mechanics and appropriately qualified technical instructors.

Inspection of Wood Structures

To properly inspect an aircraft constructed or comprised of wood components, the aircraft must be dry. It should be placed in a dry, well-ventilated hanger with all inspection covers, access panels, and removable fairings opened and removed. This allows interior sections and compartments to thoroughly dry. Wet, or even damp, wood causes swelling and makes it difficult to make a proper determination of the condition of the glue joints.

If there is any doubt that the wood is dry, a moisture meter should be utilized to verify the percentage of moisture in the structure. Nondestructive meters are available that check moisture without making holes in the surface. The ideal range is 8–12 percent, with any reading over 20 percent providing an environment for the growth of fungus in the wood.

External and Internal Inspection

The inspection should begin with an examination of the external surface of the aircraft. This provides a general assessment of the overall condition of the wood and structure. The wings, fuselage, and empennage should be inspected for undulation, warping, or any other disparity from the original shape. Where the wings, fuselage, or empennage structure and skins form stressed structures, no departure from the original contour or shape is permissible. [Figure 6-3]

Where light structures using single plywood covering are concerned, some slight sectional undulation or bulging between panels may be permissible if the wood and glue are sound. However, where such conditions exist, a careful check must be made of the attachment of the plywood to its supporting structure. A typical example of a distorted single plywood structure is illustrated in Figure 6-4.

The contours and alignment of leading and trailing edges are of particular importance. A careful check should be made for any deviation from the original shape. Any distortion of these light plywood and spruce structures is indicative of deterioration, and a detailed internal inspection has to be made for security of these parts to the main wing structure. If deterioration is found in these components, the main wing structure may also be affected.

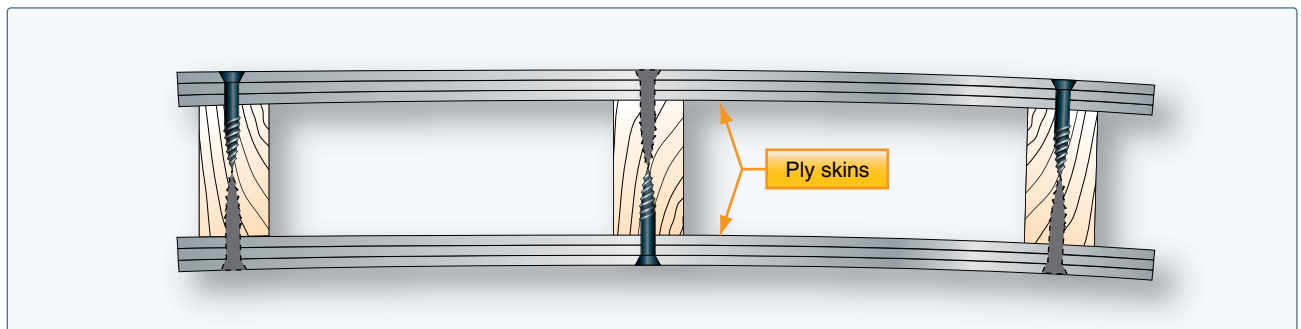


Figure 6-3. Cross sectional view of a stressed skin structure.

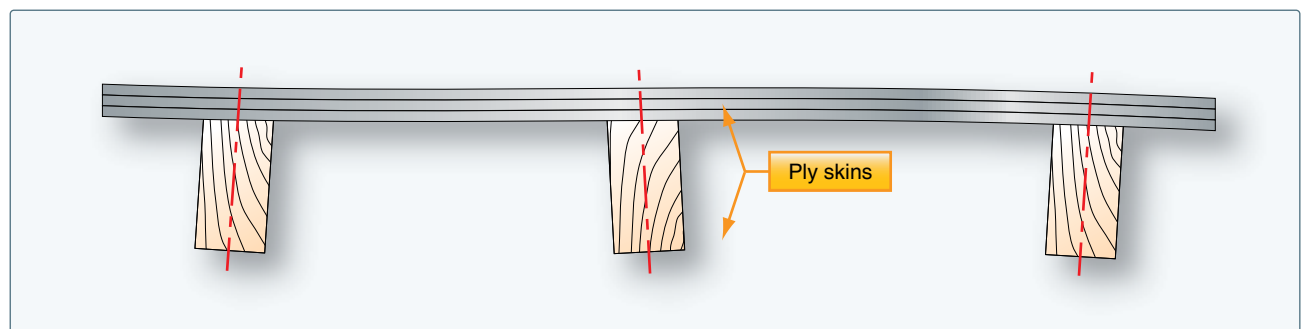


Figure 6-4. A distorted single plywood structure.

Splits in the fabric covering on plywood surfaces must be investigated to ascertain whether the plywood skin beneath is serviceable. In all cases, remove the fabric and inspect the plywood, since it is common for a split in the plywood skin to initiate a similar defect in the protective fabric covering.

Although a preliminary inspection of the external structure can be useful in assessing the general condition of the aircraft, note that wood and glue deterioration can often take place inside a structure without any external indications. Where moisture can enter a structure, it seeks the lowest point, where it stagnates and promotes rapid deterioration. A musty or moldy odor apparent as you remove the access panels during the initial inspection is a good indication of moisture, fungal growth, and possible decay.

Glue failure and wood deterioration are often closely related, and the inspection of glued joints must include an examination of the adjacent wood structure. NOTE: Water need not be present for glue deterioration to take place.

The inspection of a complete aircraft for glue or wood deterioration requires scrutiny of parts of the structure that may be known, or suspected, trouble spots. In many instances, these areas are boxed in or otherwise inaccessible. Considerable dismantling may be required. It may be necessary to cut access holes in some of the structures to facilitate the inspection. Do such work only in accordance with approved drawings or instructions in the maintenance manual for the aircraft concerned. If drawings and manuals are not available, engineering review may be required before cutting access holes.

Glued Joint Inspection

The inspection of glued joints in wooden aircraft structures presents considerable difficulties. Even where access to the joint exists, it is still difficult to positively assess the integrity of the joint. Keep this in mind when inspecting any glue joint.

Some common factors in premature glue deterioration include:

- Chemical reactions of the glue caused by aging or moisture, extreme temperatures, or a combination of these factors, and
- Mechanical forces caused mainly by wood shrinkage, and
- Development of fungal growths.

An aircraft painted in darker colors experiences higher skin temperatures and heat buildup within its structure. Perform a more detailed inspection on a wooden aircraft structure immediately beneath the upper surfaces for signs of deteriorating adhesives.

Aircraft that are exposed to large cyclic changes of temperature and humidity are especially prone to wood shrinkage that may lead to glue joint deterioration. The amount of movement of a wooden member due to these changes varies with the size of each member, the rate of growth of the tree from which it was cut, and the way the wood was converted in relation to the grain.

This means that two major structural members joined to each other by glue are not likely to have identical characteristics. Over a period of time, differential loads are transmitted across the glue joint because the two members do not react identically. This imposes stresses in the glue joint that can normally be accommodated when the aircraft is new and for some years afterwards. However, glue tends to deteriorate with age, and stresses at the glued joints may cause failure of the joints. This is a fact even when the aircraft is maintained under ideal conditions.

The various cuts of lumber from a tree have tendency to shrink and warp in the direction(s) indicated in the yellow area around each cut in *Figure 6-5*.

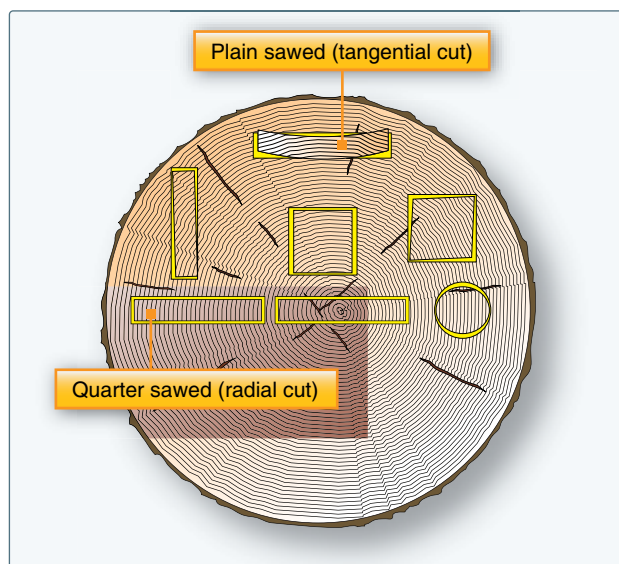


Figure 6-5. Effects of shrinkage on the various shapes during drying from the green condition.

When checking a glue line (the edge of the glued joint) for condition, all protective coatings of paint should be removed by careful scraping. It is important to ensure that the wood is not damaged during the scraping operation. Scraping should cease immediately when the wood is revealed in its natural state and the glue line is clearly discernible. At this point in the inspection, it is important that the surrounding wood is dry; otherwise, you will get a false indication of the integrity of the glue line due to swelling of the wood and subsequent closing of the joint.

Inspect the glue line using a magnifying glass. Where the glue line tends to part, or where the presence of glue cannot be detected or is suspect, probe the glue line with a thin feeler gauge. If any penetration is observed, the joint is defective. The structure usually dictates the feeler gauge thickness, but use the thinnest feeler gauge whenever possible. The illustration indicates the points a feeler gauge should probe. [Figure 6-6]

Pressure exerted on a joint either by the surrounding structure or by metal attachment devices, such as bolts or screws, can cause a false appearance of the glue condition. The joint must be relieved of this pressure before the glue line inspection is performed.

A glued joint may fail in service as a result of an accident or because of excessive mechanical loads having been imposed upon it. Glued joints are generally designed to take shear loads. If a joint is expected to take tension loads, it is secured by a number of bolts or screws in the area of tension loading. In all cases of glued joint failure, whatever the direction of loading, there should be a fine layer of wood fibers adhering to the glue. The presence of fibers usually indicates that the joint itself is not at fault.

Examination of the glue under magnification that does not reveal any wood fibers, but shows an imprint of the wood grain, indicates that the cause of the failure was the predrying of the glue before applying pressure during the manufacture of the joint. If the glue exhibits an irregular appearance with star-shaped patterns, this is an indication that precuring of the glue occurred before pressure was applied, or that pressure

had been incorrectly applied or maintained on the joint. If there is no evidence of wood fiber adhesion, there may also be glue deterioration.

Wood Condition

Wood decay and dry rot are usually easy to detect. Decay may be evident as either a discoloration or a softening of the wood. Dry rot is a term loosely applied to many types of decay, but especially to a condition that, in an advanced stage, permits the wood to be crushed to a dry powder. The term is actually a misnomer for any decay, since all fungi require considerable moisture for growth.

Dark discolorations of the wood or gray stains running along the grain are indicative of water penetration. If such discoloration cannot be removed by light scraping, replace the part. Disregard local staining of the wood by dye from a synthetic adhesive hardener.

In some instances where water penetration is suspected, a few screws removed from the area in question reveal, by their degree of corrosion, the condition of the surrounding joint. [Figure 6-7]

Another method of detecting water penetration is to remove the bolts holding the fittings at spar root-end joints, aileron hinge brackets, etc. Corrosion on the surface of such bolts and wood discoloration provide a useful indication of water penetration.

Plain brass screws are normally used for reinforcing glued wooden members. For hardwoods, such as mahogany or ash,

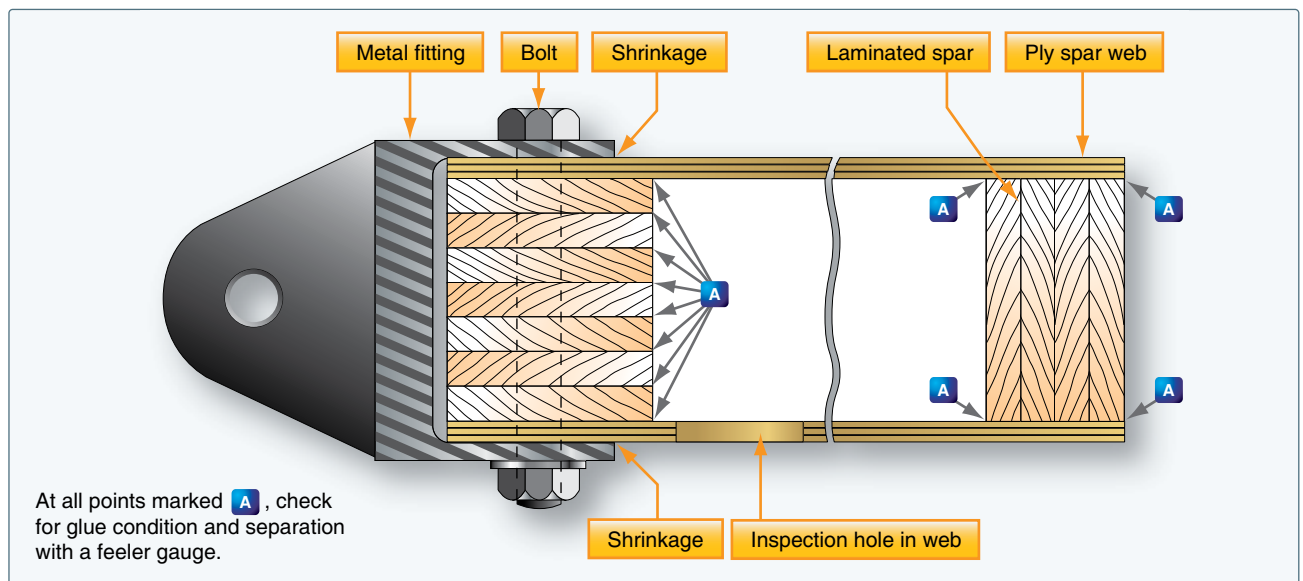


Figure 6-6. Inspection points for laminated glue joints.

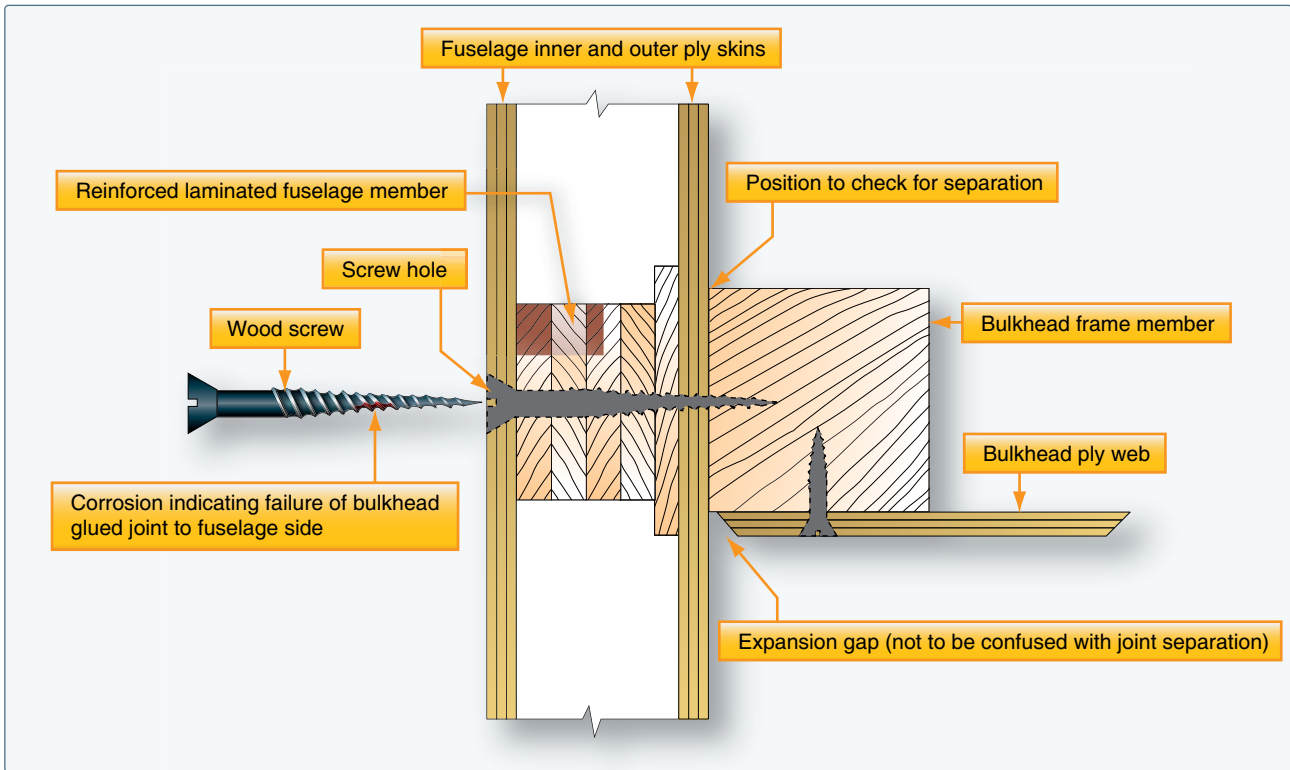


Figure 6-7. Checking a glued joint for water penetration.

steel screws may be used. Unless specified by the aircraft manufacturer, replace removed screws with new screws of identical length, but one gauge larger in diameter.

Inspection experience with a particular type of aircraft provides insight to the specific areas most prone to water penetration and moisture entrapment. Wooden aircraft are more prone to the damaging effects of water, especially without the protection of covered storage. Control system openings, fastener holes, cracks or breaks in the finish, and the interfaces of metal fittings and the wood structure are points that require additional attention during an inspection. Additionally, windshield and window frames, the area under the bottom of entrance and cargo doors, and the lower sections of the wing and fuselage are locations that require detailed inspections for water damage and corrosion on all aircraft.

The condition of the fabric covering on plywood surfaces provides an indication of the condition of the wood underneath. If there is any evidence of poor adhesion, cracks in the fabric, or swelling of the wood, remove the fabric to allow further inspection. The exposed surface shows water penetration by the existence of dark gray streaks along the grain and dark discoloration at ply joints or screw holes.

Cracks in wood spars are often hidden under metal fittings or metal rib flanges and leading edge skins. Any time a reinforcement plate exists that is not feathered out on its ends, a stress riser exists at the ends of the plate. A failure of the primary structure can be expected at this point. [Figure 6-8]

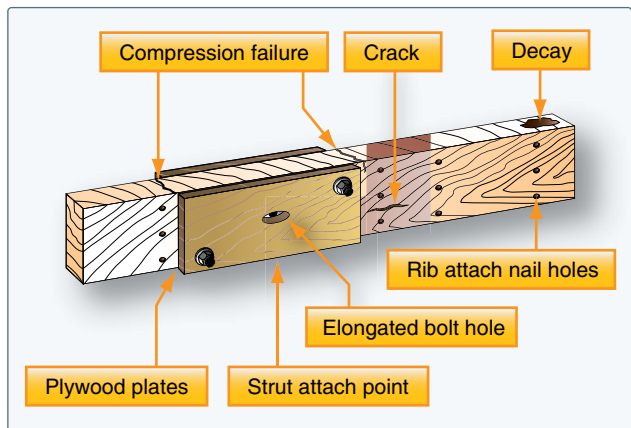


Figure 6-8. Areas likely to incur structural damage.

As part of the inspection, examine the structure for other defects of a mechanical nature, including any location where bolts secure fittings that take load-carrying members, or

where the bolts are subject to landing or shear loads. Remove the bolts and examine the holes for elongation or surface crushing of the wood fibers. It is important to ensure the bolts are a good fit in the holes. Check for evidence of bruises or crushing of the structural member, which can be caused by overtorquing of the bolts.

Check all metal fittings that are attached to a wood structure for looseness, corrosion, cracks, or bending. Areas of particular concern are strut attach fittings, spar butt fittings, aileron and flap hinges, jury strut fittings, compression struts, control cable pulley brackets, and landing gear fittings. All exposed end grain wood, particularly the spar butts, should be inspected for cracking or checking.

Inspect structural members for compression failures, which is indicated by rupture across the wood fibers. This is a serious defect that can be difficult to detect. If a compression failure is suspected, a flashlight beam shown along the member, and running parallel to the grain, will assist in revealing it. The surface will appear to have minute ridges or lines running across the grain. Particular attention is necessary when inspecting any wooden member that has been subjected to abnormal bending or compression loads during a hard landing. If undetected, compression failures of the spar may result in structural failure of the wing during flight. [Figure 6-9]

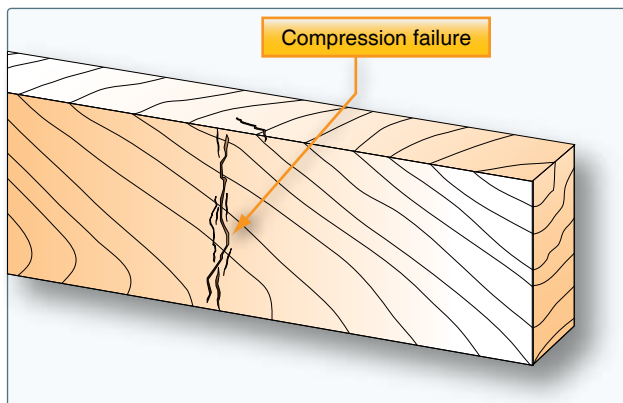


Figure 6-9. Pronounced compression failure in wood beam.

When a member has been subjected to an excessive bending load, the failure appears on the surface that has been compressed. The surface subject to tension normally shows no defects. In the case of a member taking an excessive direct compression load, the failure is apparent on all surfaces.

The front and rear spars should be checked for longitudinal cracks at the ends of the plywood reinforcement plates where the lift struts attach. [Figure 6-8] Check the ribs on either side of the strut attach points for cracks where the cap strips pass over and under the spars, and for missing or loose

rib-to-spar attach nails. All spars, those in the wing(s) and empennage, should be inspected on the face and top surface for compression cracks. A borescope can be utilized by accessing existing inspection holes.

Various mechanical methods can be employed to enhance the visual inspection of wood structures. Tapping the subject area with a light plastic hammer or screwdriver handle should produce a sharp solid sound. If the suspected area sounds hollow and dull, further inspection is warranted. Use a sharp metal awl or thin-bladed screwdriver to probe the area. The wood structure should be solid and firm. If the area is soft and mushy, the wood is rotted and disassembly and repair of the structure is necessary.

Repair of Wood Aircraft Structures

The standard for any repair is that it should return the aircraft or component to its original condition in strength, function, and aerodynamic shape. It should also be accomplished in accordance with the manufacturer's specifications and/or instructions, or other approved data.

The purpose of repairing all wood structural components is to obtain a structure as strong as the original. Major damage probably requires replacement of the entire damaged assembly, but minor damage can be repaired by removing or cutting away the damaged members and replacing them with new sections. This replacement may be accomplished by gluing, glue and nails, or glue and screw-reinforced splicing.

Materials

Several forms of wood are commonly used in aircraft.

- Solid wood or the adjective "solid" used with such nouns as "beam" or "spar" refers to a member consisting of one piece of wood.
- Laminated wood is an assembly of two or more layers of wood that have been glued together with the grain of all layers or laminations approximately parallel.
- Plywood is an assembled product of wood and glue that is usually made of an odd number of thin plies, or veneers, with the grain of each layer placed 90° with the adjacent ply or plies.
- High-density material includes compreg, impreg, or similar commercially made products, heat-stabilized wood, or any of the hardwood plywoods commonly used as bearing or reinforcement plates.

Suitable Wood

The various species of wood listed in Figure 6-10 are acceptable for structural purposes when used for the repair of aircraft. Spruce is the preferred choice and the standard

by which the other wood is measured. *Figure 6-10* provides a comparison of other wood that may be suitable for aircraft repair. It lists the strength and characteristics of the wood in comparison to spruce. The one item common to all the species is that the slope of the grain cannot be steeper than 1:15.

All solid wood and plywood used for the construction and repair of aircraft should be of the highest quality and grade. For certificated aircraft, the wood should have traceability to a source that can provide certification to a military specification (MIL-SPEC). The term “aircraft quality” or “aircraft grade” is referred to and specified in some repair documents, but that grade wood cannot be purchased from a local lumber company. To purchase the material, contact one of the

specialty aircraft supply companies and request a certification document with the order. The MIL-SPEC for solid spruce is MIL-S-6073 and for plywood it is MIL-P-6070B.

When possible, fabricated wood components should be purchased from the aircraft manufacturer, or someone who may have a Parts Manufacturer Approval (PMA) to produce replacement parts for the aircraft. With either of these sources supplying the wood components, the mechanic can be assured of installing approved material. At the completion of the repair, as always, it is the responsibility of the person returning the aircraft to service to determine the quality of the replacement wood and the airworthiness of the subsequent repair.

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 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 if reductions are substantiated. Difficult to work with hand tools. Some tendency to split and splinter during fabrication and much greater care in manufacture is necessary. Large solid pieces should be avoided due to inspection difficulties. Satisfactory for gluing .
Noble fir (Abies procera, also known as Abies nobilis)	Slightly exceeds spruce except 8% deficient in shear	1.15	Satisfactory characteristics of workability, warping, and splitting. May be used as direct substitute for spruce in same sizes if shear does not become critical. Hardness somewhat less than spruce. Satisfactory for gluing.
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. Satisfactory for gluing.
Northern white pine, also known as Eastern white pine (Pinus strobus)	Properties between 85% and 96% those of spruce	1.15	Excellent working qualities and uniform in properties, but somewhat low in hardness and shock-resistance. Cannot be used as substitute for spruce without increase in sizes to compensate for lesser strength. Satisfactory for gluing.
Port Orford white cedar (Chamaecyparis lawsoniana)	Exceeds spruce	1.15	May be used as substitute for spruce in same sizes or in slightly reduced sizes if reductions are substantiated. Easy to work with hand tools. Gluing is difficult, but satisfactory joints can be obtained if suitable precautions are taken.
Yellow poplar (Liriodendron 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-resistance. Satisfactory for gluing.

Figure 6-10. Selection and properties of wood for aircraft repairs.

To help determine the suitability of the wood, inspect it for defects that would make it unsuitable material to repair or construct an aircraft. The type, location, and amount or size of the defects grade the wood for possible use. All woods used for structural repair of aircraft are classified as softwood. Softwood is typically used for construction and is graded based on strength, load carrying ability, and safety. Hardwoods, on the other hand, are typically appearance woods and are graded based on the number and size of clear cuttings from the tree.

Defects Permitted

The following defects are permitted in the wood species used for aircraft repair that are identified in *Figure 6-10*:

1. Cross grain—Spiral grain, diagonal grain, or a combination of the two is acceptable if the grain does not diverge from the longitudinal axis of the material more than specified in *Figure 6-10* 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 frequently assists in determining grain direction.
2. Wavy, curly, and interlocked grain—Acceptable, if local irregularities do not exceed limitations specified for spiral and diagonal grain.
3. Hard knots—Sound, hard knots up to 3/8-inch in diameter are acceptable if: (1) they are not 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 portions of low stress); (2) they do not cause grain divergence at the edges of the board or in the flanges of a beam more than specified in *Figure 6-10* column 3; and (3) they are in the center third of the beam and not closer than 20-inches to another knot or other defect (pertains to 3/8-inch knots; smaller knots may be proportionately closer). Knots greater than 1/4-inch must be used with caution.
4. Pin knot clusters—small clusters are acceptable if they produce only a small effect on grain direction.
5. Pitch pockets—Acceptable in center portion of a beam if they are at least 14-inches apart when they lie in the same growth ring and do not exceed 1 1/2-inches in length by 1/8-inch width by 1/8-inch depth, and if 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.
6. Mineral streaks—acceptable if careful inspection fails to reveal any decay.

Defects Not Permitted

The following defects are not permitted in wood used for aircraft repair. If a defect is listed as unacceptable, please refer to the previous section, Defects Permitted, for acceptable conditions.

1. Cross grain—unacceptable.
2. Wavy, curly, and interlocked grain – unacceptable.
3. Hard knots—unacceptable.
4. Pin knot clusters—unacceptable, if they produce large effect on grain direction.
5. Spike knots—knots running completely through the depth of a beam perpendicular to the annual rings and appear most frequently in quarter-sawed lumber. Reject wood containing this defect.
6. Pitch pockets—unacceptable.
7. Mineral streaks—unacceptable, if accompanied by decay.
8. 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 caused by artificially induced stress. Reject wood containing these defects.
9. Compression—very detrimental to strength and is difficult to recognize readily, compression wood is characterized by high specific gravity, has the appearance of an excessive growth of summer wood, and in most species shows little contrast in color between spring wood and summer wood. If in doubt, reject the material or subject samples to toughness machine test to establish the quality of the wood. Reject all material containing compression wood.
10. Compression failures—caused from overstress 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 appears as streaks substantially at right angles to the grain on the surface of the piece, and vary from pronounced failures to very fine hairlines that require close inspection to detect. Reject wood containing obvious failures. If in doubt, reject the wood or make a further inspection in the form of microscopic examination or toughness test, the latter being more reliable.

11. Tension—forming on the upper side of branches and leaning trunks of softwood trees, tension wood is caused by the natural overstretching of trying to pull the branches and leaning trunk upright. It is typically harder, denser, and may be darker in color than normal wood, and is a serious defect, having higher than usual longitudinal shrinkage that may break down due to uneven shrinkage. When in doubt, reject the wood.
12. Decay—rot, dote, red heart, purple heart, etc., must not appear on any piece. Examine all stains and discoloration carefully to determine whether or not they are harmless or in a stage of preliminary or advanced decay.

Glues (Adhesives)

Because adhesives play a critical role in the bonding of aircraft structure, the mechanic must employ only those types of adhesives that meet all of the performance requirements necessary for use in certificated aircraft. The product must be used strictly in accordance with the aircraft and adhesive manufacturer's instructions. All instructions must be followed exactly, including the mixing ratios, the ambient and surface temperatures, the open and closed assembly times, the gap-filling ability, or glue line thickness, the spread of the adhesive, whether one or two surfaces, and the amount of clamping pressure and time required for full cure of the adhesive.

AC 43.13-1 provides information on the criteria for identifying adhesives that are acceptable to the FAA. It stipulates the following:

1. Refer to the aircraft maintenance or repair manual for specific instructions on acceptable adhesive selection for use on that type aircraft.
2. Adhesives meeting the requirements of a MIL-SPEC, Aerospace Material Specification (AMS), or Technical Standard Order (TSO) for wooden aircraft structures are satisfactory, providing they are found to be compatible with existing structural materials in the aircraft and fabrication methods to be used in the repair.

New adhesives have been developed in recent years, and some of the older ones are still in use. Some of the more common adhesives that have been used in aircraft construction and repair include casein glue, plastic resin glue, resorcinol glue, and epoxy adhesives.

Casein glue should be considered obsolete for all aircraft repairs. The adhesive deteriorates when exposed to moisture and temperature variations that are part of the normal operating environment of any aircraft.

NOTE: Some modern adhesives are incompatible with casein adhesive. If a joint that has previously been bonded with casein is to be reglued using another type adhesive, all traces of the casein must be scraped off before a new adhesive is applied. If any casein adhesive is left, residual alkalinity may cause the new adhesive to fail to cure properly.

Plastic resin glue, also known as a urea-formaldehyde adhesive, came on the market in the middle to late 1930s. Tests and practical applications have shown that exposure to moist conditions, and particularly to a warm humid environment, under swell-shrink stress, leads to deterioration and eventual failure of the bond. For these reasons, plastic resin glue should be considered obsolete for all aircraft repairs. Discuss any proposed use of this type adhesive on aircraft with FAA engineering prior to use.

Resorcinol glue, or resorcinol-formaldehyde glue, is a two-component synthetic adhesive consisting of resin and a catalyst. It was first introduced in 1943 and almost immediately found wide application in the wood boat-building and wood aircraft industry in which the combination of high durability and moderate-temperature curing was extremely important. It has better wet-weather and ultraviolet (UV) resistance than other adhesives. This glue meets all strength and durability requirements if the fit of the joint and proper clamping pressure results in a very thin and uniform bond line.

The manufacturer's product data sheets must be followed regarding mixing, usable temperature range, and the open and close assembly times. It is very important that this type of glue is used at the recommended temperatures because the full strength of the joint cannot be relied on if assembly and curing temperatures are below 70 °F. With that in mind, higher temperatures shorten the working life because of a faster cure rate, and open and closed assembly times must be shortened.

Epoxy adhesive is a two-part synthetic resin product that depends less on joint quality and clamping pressure. However, many epoxies have not exhibited joint durability in the presence of moisture and elevated temperatures and are not recommended for structural aircraft bonding unless they meet the acceptable standards set forth by the FAA in AC 43.13-1, as referenced earlier in this chapter.

Definition of Terms Used in the Glue Process

- Close contact adhesive—a non-gap-filling adhesive (e.g., resorcinol-formaldehyde glue) suitable for use only in those joints where the surfaces to be joined can be brought into close contact by means of adequate

pressure, to allow a glue line of no more than 0.005-inch gap.

- Gap-filling adhesive—an adhesive suitable for use in those joints in which the surfaces to be joined may not be close or in continuous contact (e.g., epoxy adhesives) due either to the impracticability of applying adequate pressure or to the slight inaccuracies of fabricating the joint.
- Glue line—resultant layer of adhesive joining any two adjacent wood layers in the assembly.
- Single spread—spread of adhesive to one surface only.
- Double spread—spread of adhesive to both surfaces and equally divided between the two surfaces to be joined.
- Open assembly time—period of time between the application of the adhesive and the assembly of the joint components.
- Closed assembly time—time elapsing between the assembly of the joints and the application of pressure.
- Pressing or clamping time—time during which the components are pressed tightly together under recommended pressure until the adhesive cures (may vary from 10 to 150 pounds per square inch (psi) for softwoods, depending on the viscosity of the glue).
- Caul—a clamping device, usually two rigid wooden bars, to keep an assembly of flat panel boards aligned during glue-up. It is assembled with long bolts and placed on either side of the boards, one on top and another below, and parallel with the pipe/bar clamps. A caul is usually finished and waxed before each use to keep glue from adhering to it.
- Adhesive pot life—time elapsed from the mixing of the adhesive components until the mixture must be discarded, because it no longer performs to its specifications. The manufacturer's product data sheet may define this as working time or useful life; once expired, the adhesive must not be used. It lists the specific temperature and quantity at which the sample amount can be worked. Pot life is a product of time and temperature. The cooler the mix is kept, within the recommended temperature range, the longer it is usable.

Preparation of Wood for Gluing

Satisfactory glue joints in aircraft should develop the full strength of the wood under all conditions of stress. To produce this result, the conditions involved in the gluing operation must be carefully controlled to obtain a

continuous, thin, uniform film of solid glue in the joint with adequate adhesion to both surfaces of the wood. These conditions required:

1. Proper and equal moisture content of wood to be joined (8 to 12 percent).
2. Properly prepared wood surfaces that are machined or planed, and not sanded or sawed.
3. Selection of the proper adhesive for the intended task, which is properly prepared and of good quality.
4. The application of good gluing techniques, including fitment, recommended assembly times, and adequate equal pressure applied to the joint.
5. Performing the gluing operation under the recommended temperature conditions.

The surfaces to be joined must be clean, dry, and free from grease, oil, wax, paint, etc. Keep large prepared surfaces covered with a plastic sheet or masking paper prior to the bonding operation. It is advisable to clean all surfaces with a vacuum cleaner just prior to adhesive application.

Smooth even surfaces produced on planers and joiners with sharp knives and correct feed adjustments are the best surfaces for gluing solid wood. The use of sawn surfaces for gluing has been discouraged for aircraft component assembly because of the difficulty in producing a surface free of crushed fibers. Glue joints made on surfaces that are covered with crushed fibers do not develop the normal full strength of the wood.

Some of the surface changes in plywood, such as glazing and bleed-through, that occur in manufacture and may interfere with the adhesion of glue in secondary gluing are easily recognized. A light sanding of the surface with 220-grit sandpaper in the direction of the grain restores the surface fibers to their original condition, removes the gloss, and improves the adhesion of the glue. In contrast to these recognized surface conditions, wax deposits from cauls used during hot pressing produce unfavorable gluing surfaces that are not easily detected.

Wetting tests are a useful means of detecting the presence of wax. A finely sprayed mist or drops of water on the surface of wax-coated plywood bead and do not wet the wood. This test may also give an indication of the presence of other materials or conditions that would degrade a glue joint. Only a proper evaluation of the adhesion properties, using gluing tests, determines the gluing characteristics of the plywood surfaces.

Preparing Glues for Use

The manufacturer's directions should be followed for the preparation of any glue or adhesive. Unless otherwise specified by the glue manufacturer, clear, cool water should be used with glues that require mixing with water. The recommended proportions of glue, catalyst, and water or other solvent should be determined by the weight of each component. Mixing can be either by hand or machine. Whatever method is used, the glue should be thoroughly mixed and free of air bubbles, foam, and lumps of insoluble material.

Applying the Glue/Adhesive

To make a satisfactorily bonded joint, it is generally desirable to apply adhesive to both surfaces and join in a thin even layer. The adhesive can be applied with a brush, glue spreader, or a grooved rubber roller. Follow the adhesive manufacturer's application instructions for satisfactory results.

Be careful to ensure the surfaces make good contact and the joint is positioned correctly before applying the adhesive. Keep the open assembly time as short as possible and do not exceed the recommended times indicated in the product data sheet.

Pressure on the Joint

To ensure the maximum strength of the bonded surfaces, apply even force to the joint. Non-uniform gluing pressure commonly results in weak areas and strong areas in the same joint. The results of applied pressure are illustrated in *Figure 6-11*.

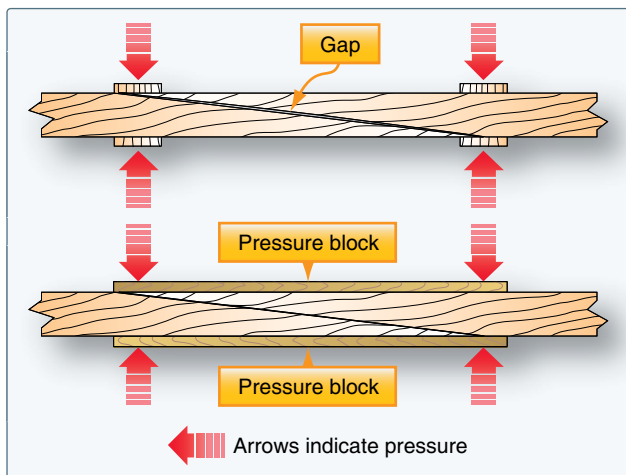


Figure 6-11. Even distribution of gluing pressure creates a strong, gap-free joint.

Use pressure to squeeze the glue out into a thin continuous film between the wood layers, to force air from the joint, to bring the wood surfaces into intimate contact with the glue, and to hold them in this position during the setting of the glue.

Pressure may be applied by means of clamps, elastic straps, weight, vacuum bags, or other mechanical devices. Other methods used to apply pressure to joints in aircraft gluing operations range from the use of brads, nails, and screws to the use of electric and hydraulic power presses.

The amount of pressure required to produce strong joints in aircraft assembly operations may vary from 10 to 150 psi for softwoods and as high as 200 psi for hardwoods. Insufficient pressure to poorly machined or fitted wood joints usually results in a thick glue line, indicating a weak joint, and should be carefully avoided.

High clamping pressure is neither essential nor desirable, provided good contact between the surfaces being joined is obtained. When pressure is applied, a small quantity of glue should be squeezed from the joint. This excess should be removed before it sets. It is important that full pressure be maintained on the joint for the entire cure time of the adhesive because the adhesive does not chemically re-link and bond if it is disturbed before it is fully cured.

The full curing time of the adhesive is dependent on the ambient temperature; therefore, it is very important to follow the manufacturer's product data sheets for all phases of the gluing operation from the shelf life to the moisture content of the wood to the proper mixing of the adhesive to the application, and especially to the temperature. The successful assembly and fabrication depends on the workmanship and quality of the joints and following the glue manufacturer's instructions.

All gluing operations should be performed above 70 °F for proper performance of the adhesive. Higher temperatures shorten the assembly times, as does coating the pieces of wood with glue and exposing openly to the air. This open assembly promotes a more rapid thickening of the glue than pieces being mated together as soon as the spreading of the glue is completed.

Figure 6-12 provides an example of resorcinol resin glue and the allowable assembly times and gluing pressure when in the open and closed assembly condition. All examples are for an ambient temperature of 75 °F.

Figure 6-13 provides examples of strong and weak glue joints resulting from different gluing conditions. A is a well glued joint with a high percentage of wood failure made under proper conditions; B is a glue-starved joint resulting from the application of excessive pressure with thin glues; C is a dried glue joint resulting from an excessively long assembly time and/or insufficient pressure.

Glue	Gluing Pressure	Type of Assembly	Maximum Assembly Time
Resorcinol resins	100–250 psi	Closed	Up to 50 minutes
	100–250 psi	Open	Up to 12 minutes
	Less than 100 psi	Closed	Up to 40 minutes
	Less than 100 psi	Open	Up to 10 minutes

Figure 6-12. Examples of differences for open and closed assembly times.

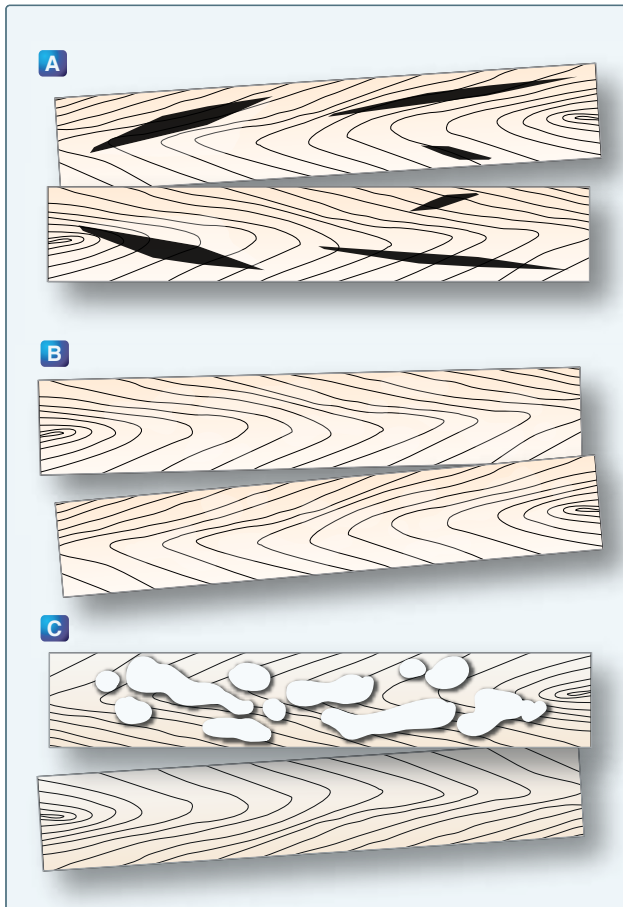


Figure 6-13. Strong and weak glue joints.

Testing Glued Joints

Satisfactory glue joints in aircraft should develop the full strength of the wood under all conditions of stress. Tests should be made by the mechanic prior to gluing a joint of a major repair, such as a wing spar. Whenever possible, perform tests using pieces cut from the actual wood used for the repair under the same mechanical and environmental conditions that the repair will undergo.

Perform a sample test using two pieces of scrap wood from the intended repair, each cut approximately 1" × 2" × 4". The pieces should be joined by overlapping each approximately 2 inches. The type of glue, pressure, and curing time should be the same as used for the actual repair. After full cure, place the test sample in a bench vise and break the joint by exerting

pressure on the overlapping member. The fractured glue faces should show a high percentage of at least 75 percent of the wood fibers evenly distributed over the fractured glue surface. [Figure 6-14]

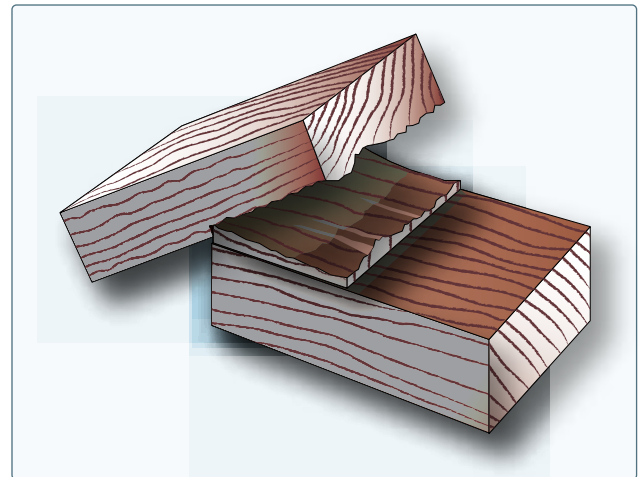


Figure 6-14. An example of good glue joint.

Repair of Wood Aircraft Components

Wing Rib Repairs

Ribs that have sustained damage may be repaired or replaced, depending upon the type of damage and location in the aircraft. If new parts are available from the aircraft manufacturer or the holder of a PMA for the part, it is advisable to replace the part rather than to repair it.

If you make a repair to a rib, do the work in such a manner and using materials of such quality that the completed repair is at least equal to the original part in aerodynamic function, structural strength, deterioration, and other qualities affecting airworthiness, such as fit and finish. When manufacturer's repair manuals or instructions are not available, acceptable methods of repairing damaged ribs are described in AC 43.13-1 under Wood Structure Repairs.

When necessary, a rib can be fabricated and installed using the same materials and dimensions from a manufacturer-approved drawing or by reference to an original rib. However, if you fabricated it from an existing rib, you must provide evidence to verify that the dimensions are accurate and the materials are correct for the replacement part.

You can repair a cap strip of a wood rib using a scarf splice. The repair is reinforced on the side opposite the wing covering by a spruce block that extends beyond the scarf joint not less than three times the thickness of the strips being repaired. Reinforce the entire splice, including the spruce reinforcing block, on each side with a plywood side plate.

The scarf length level is 10 times dimension A (thickness of the rib cap strip) with the spruce reinforcement block being 16 times dimension A (the scarf length plus extension on either end of the scarf). The plywood splice plates should be of the same material and thickness as the original plates used to fabricate the rib. The spruce block should have a 5:1 bevel on each end. [Figure 6-15]

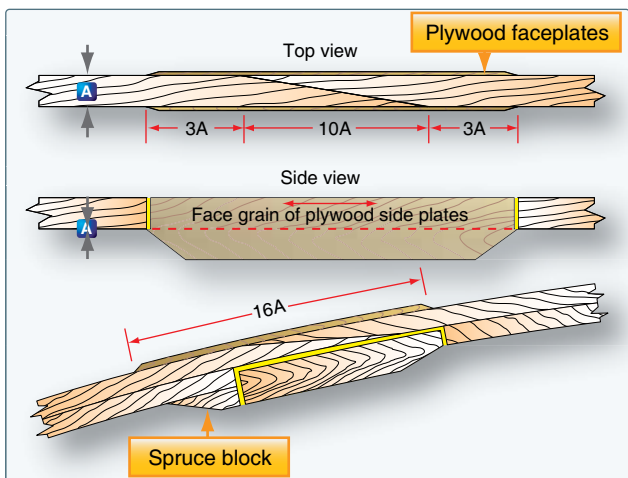


Figure 6-15. A rib cap strip repair.

These specific rib repairs describing the use of one scarf splice implies that either the entire forward or aft portion of the cap strip beyond the damage can be replaced to complete the repair and replace the damaged section. Otherwise, replacement of the damaged section may require a splice repair at both ends of the replaced section of the cap strip using the indicated dimensions for cutting and reinforcing of each splice.

When a cap strip is to be repaired at a point where there is a joint between it and cross members of the rib, make the repair by reinforcing the scarf joint with plywood gussets, as shown in Figure 6-16.

If a cap strip must be repaired where it crosses a spar, reinforce the joint with a continuous gusset extending over the spar, as shown in Figure 6-17.

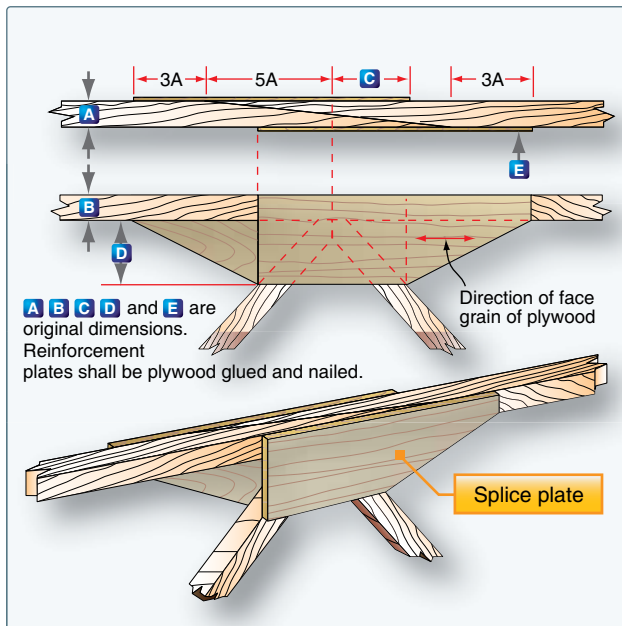


Figure 6-16. Cap strip repair at cross member.

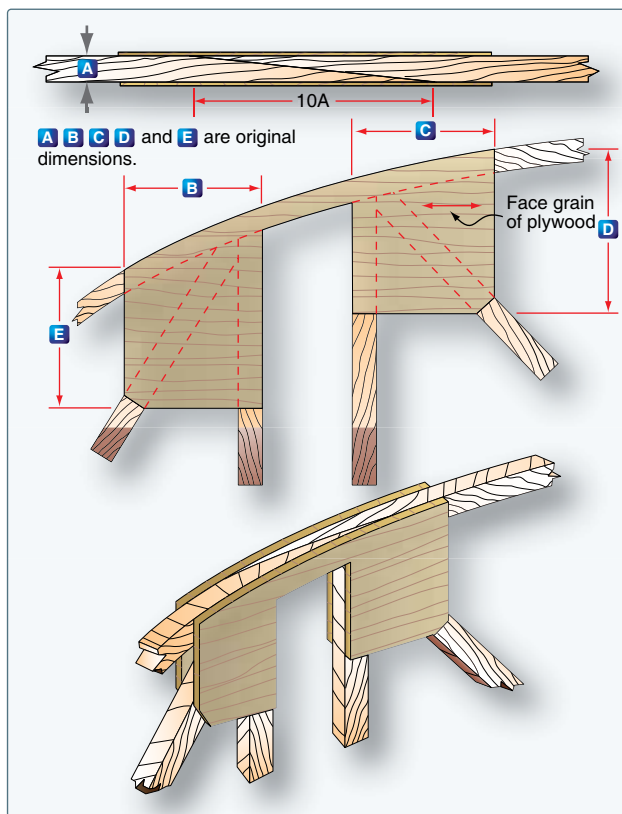


Figure 6-17. Cap strip repair at a spar.

The scarf joints referred to in the rib repairs are the most satisfactory method of fabricating an end joint between two solid wood members. When the scarf splice is used to repair a solid wood component, the mechanic must be aware of the direction and slope of the grain. To ensure the full strength of the joint, the scarf cut is made in the general direction of the grain on both connecting ends of the wood and then correctly oriented to each other when glued. [Figure 6-18]

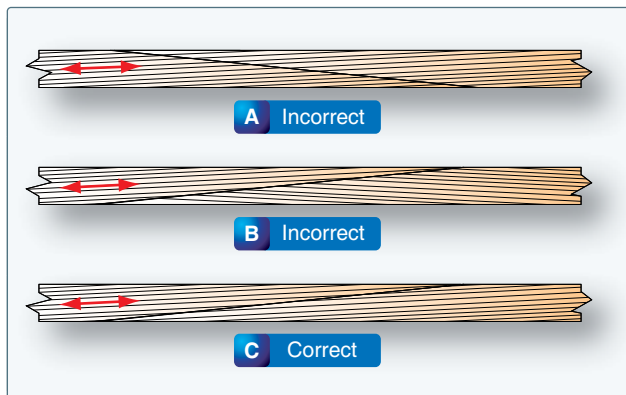


Figure 6-18. Relationship of scarf slope to grain slope.

The trailing edge of a rib can be replaced and repaired by removing the damaged portion of the cap strip and inserting a softwood block of white pine, spruce, or basswood. The entire repair is then reinforced with plywood gussets and nailed and glued, as shown in Figure 6-19.

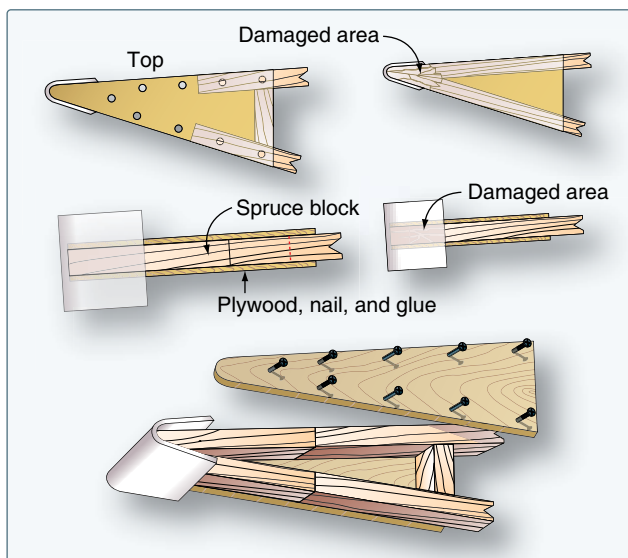


Figure 6-19. Rib trailing edge repair.

Compression ribs are of many different designs, and the proper method of repairing any part of this type of rib is specified by the manufacturer. All repairs should be performed using recommended or approved practices, materials and adhesives.

Figure 6-20A illustrates the repair of a compression rib of the I section type (i.e., wide, shallow cap strips, and a center plywood web with a rectangular compression member on each side of the web). The rib damage suggests that the upper and lower cap strips, the web member, and the compression members are cracked completely through. To facilitate this repair, cut the compression members as shown in Figure 6-20D and repair as recommended using replacement sections to the rear spar. Cut the damaged cap strips and repair as shown in Figure 6-20, replacing the aft section of the cap strips. Plywood side plates are then bonded on each side diagonally to reinforce the damaged web as shown in Figure 6-20, A-A.

Figure 6-20B illustrates a compression rib of the type that is a standard rib with rectangle compression members added to one side and a plywood web to the other side. The method used in this repair is essentially the same as in Figure 6-20A, except that the plywood reinforcement plate, shown in Figure 6-20B-B, is continued the full distance between the spars.

Figure 6-20C illustrates a compression rib of the I type with a rectangular vertical member on each side of the web. The method of repair is essentially the same as in Figure 6-20A, except the plywood reinforcement plates on each side, shown in Figure 6-20C-C, are continued the full distance between the spars.

Wing Spar Repairs

Wood wing spars are fabricated in various designs using solid wood, plywood, or a combination of the two. [Figure 6-21]

When a spar is damaged, the method of repair must conform to the manufacturer's instructions and recommendations. In the absence of manufacturer's instructions, contact the FAA for advice and approval before making repairs to the spar and following recommendations in AC 43.13-1. If instructions are not available for a specific type of repair, it is highly recommended that you request appropriate engineering

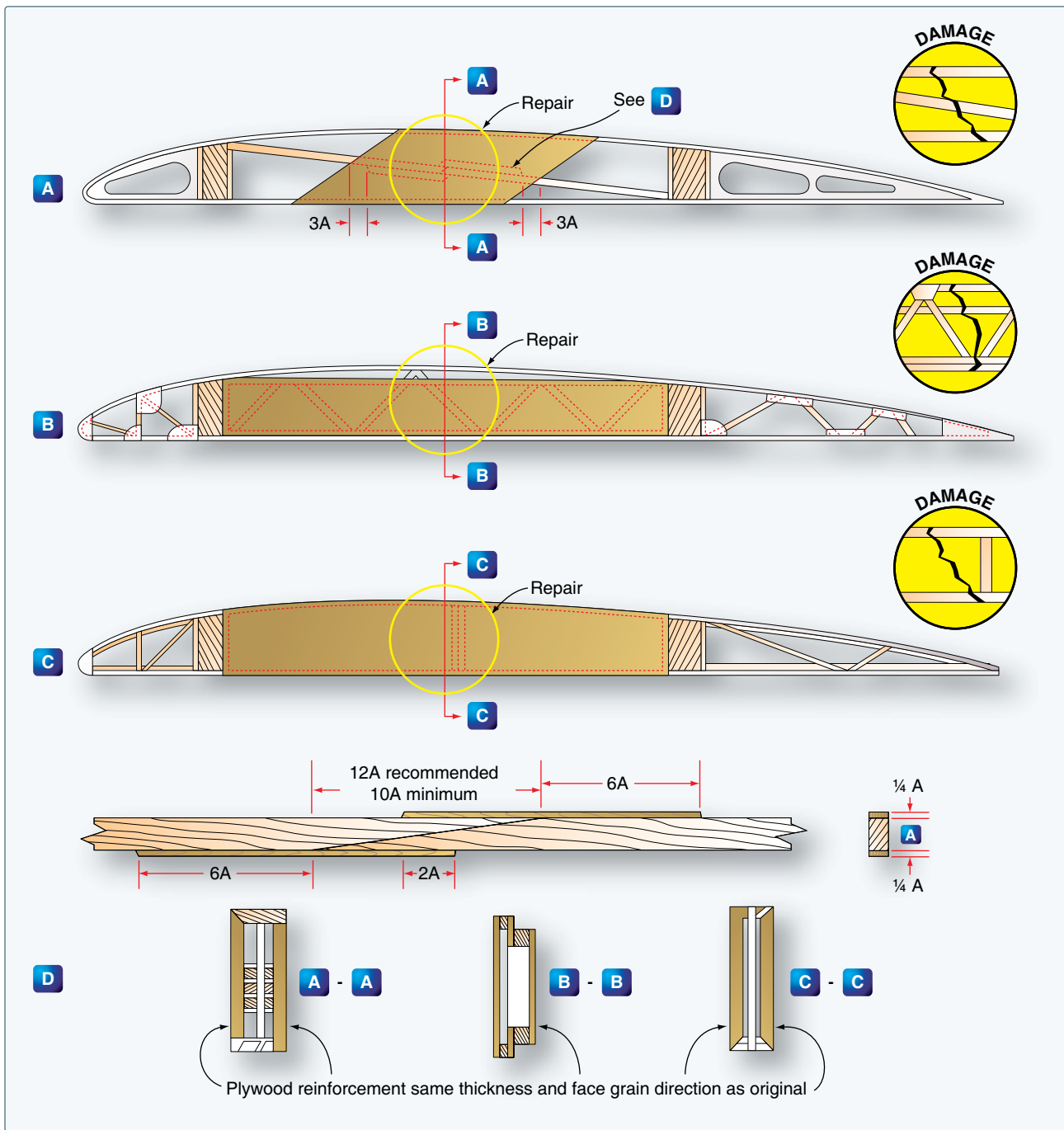


Figure 6-20. Typical compression rib repair.

assistance to evaluate and provide guidance for the intended repair.

Shown in *Figure 6-22* is a recommended method to repair either a solid or laminated rectangle spar. The slope of the scarf in any stressed part, such as a spar, should not be steeper than 15 to 1.

Unless otherwise specified by the aircraft manufacturer, a damaged spar may be spliced at almost any point except at wing attachment fittings, landing gear fittings, engine mount fittings, or lift-and-interplane strut fittings. These fittings may not overlap any part of the splice. The reinforcement plates of the splice should not interfere with the proper attachment or alignment of the fittings. Taper reinforcement plates on the ends at a 5:1 slope [*Figure 6-23*].

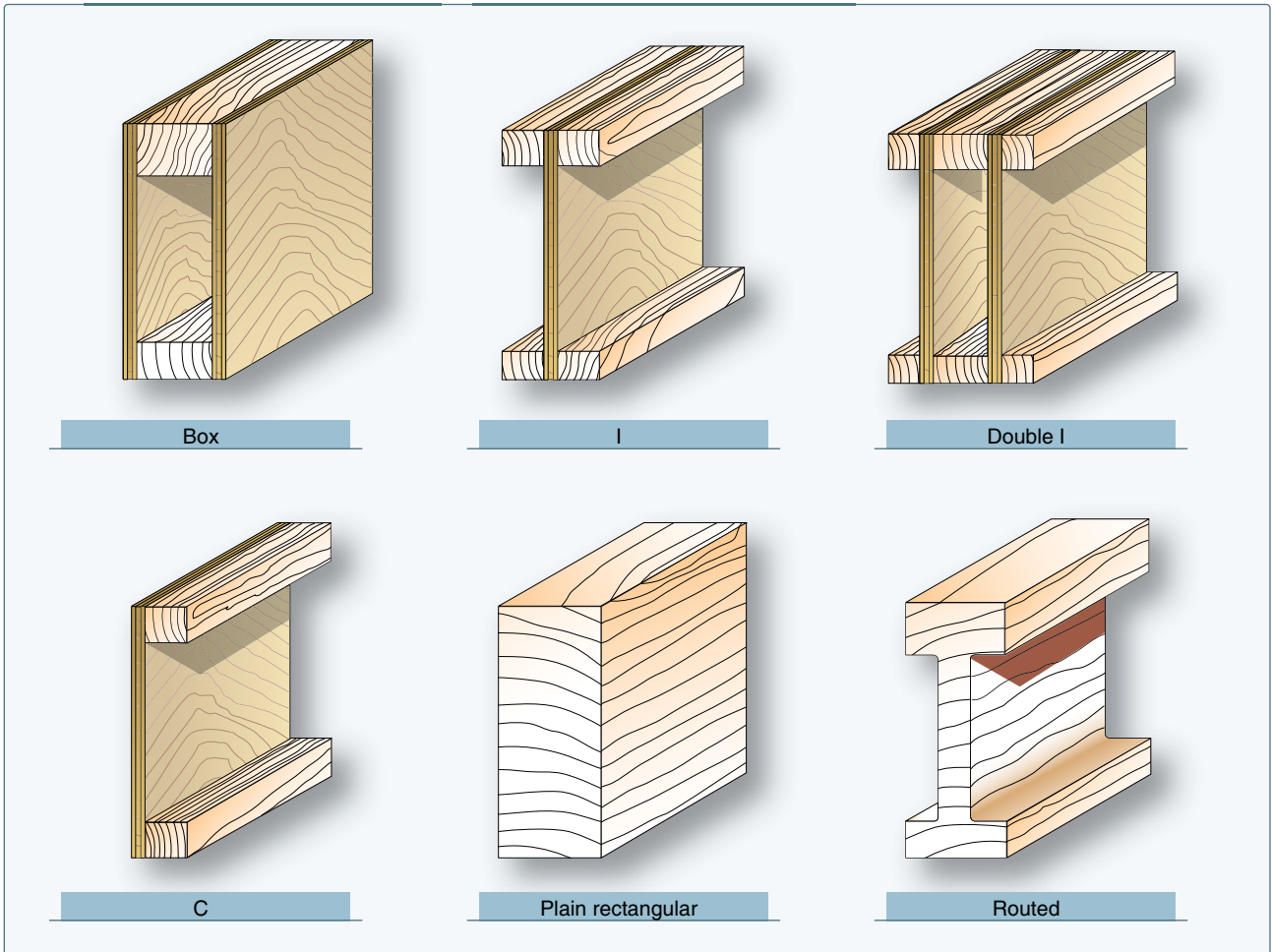


Figure 6-21. Typical splice repair of solid rectangular spar.

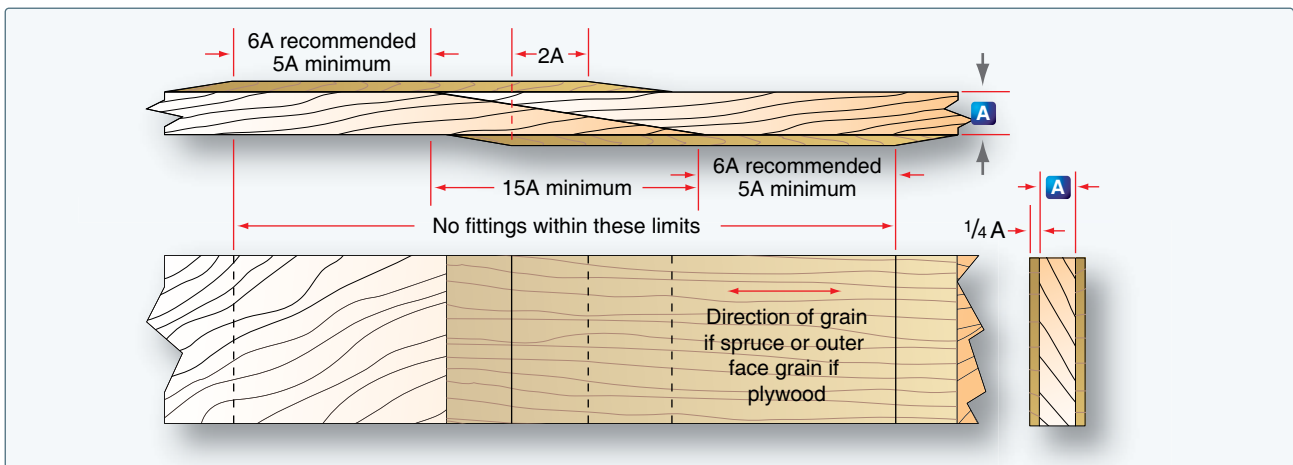


Figure 6-22. Typical scarf repair of solid rectangular spar.

The use of a scarf joint to repair a spar or any other component of an aircraft is dependent on the accessibility to the damaged section. It may not be possible to utilize a scarf repair where recommended, so the component may have to be replaced. A scarf must be precisely cut on both adjoining pieces to

ensure an even thin glue line; otherwise, the joint may not achieve full strength. The primary difficulty encountered in making this type of joint is obtaining the same bevel on each piece. [Figure 6-24]

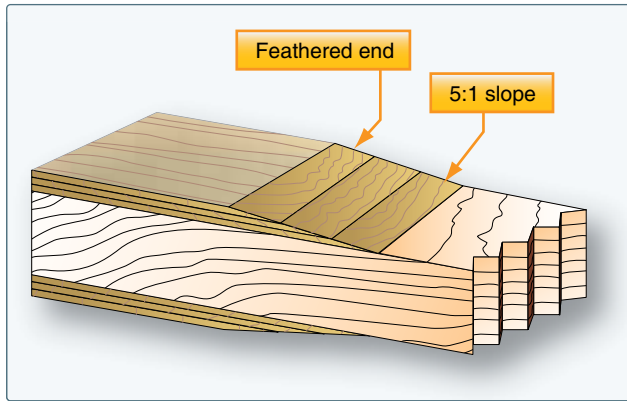


Figure 6-23. Tapered faceplate.

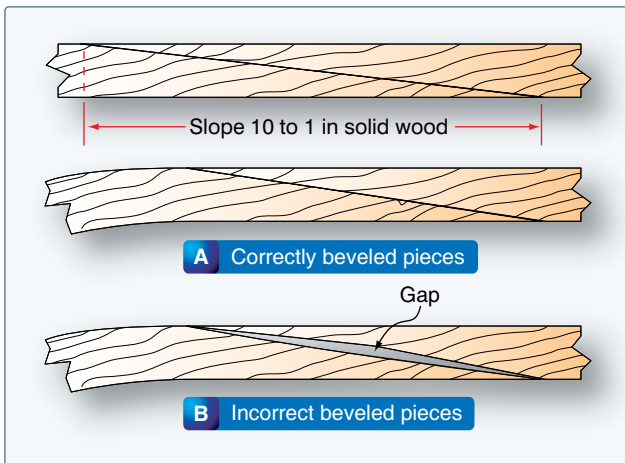


Figure 6-24. Beveled scarf joint.

The mating surfaces of the scarf must be smooth. You can machine smooth a saw cut using any of a variety of tools, such as a plane, a joiner, or a router. For most joints, you need a beveled fixture set at the correct slope to complete the cut. *Figure 6-25* illustrates one method of producing an accurate scarf joint.

Once the two bevels are cut for the intended splice, clamp the pieces to a flat guide board of similar material. Then, work a sharp, fine-tooth saw all the way through the joint. Remove the saw, decrease pressure, and tap one of the pieces on the end to close the gap. Work the saw again through the joint. Continue this procedure until the joint is perfectly parallel with matching surfaces. Then, make a light cut with the grain, using a sharp plane, to smooth both mating surfaces.

Another method of cutting a scarf uses a simple scarf-cutting fixture that you can also fabricate for use with a router. Extend the work piece beyond the edge so the finished cut results in a feathered edge across the end of the scarf. [*Figure 6-26*]

There are numerous tools made by individuals, and there are commercial plans for sale with instructions for building scarf-

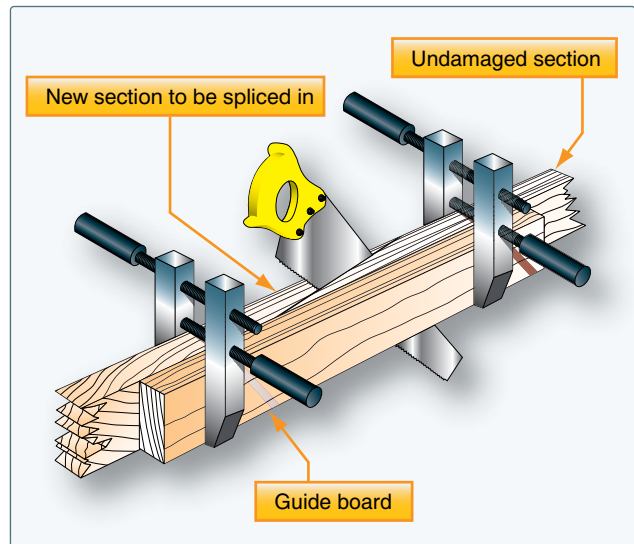


Figure 6-25. Making a scarf joint.

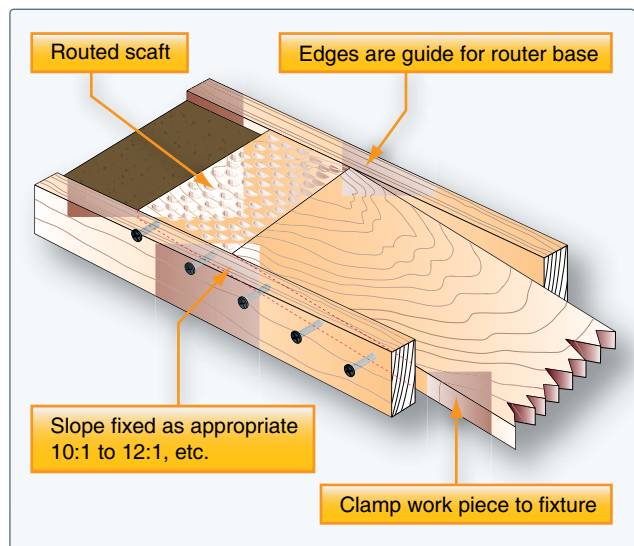


Figure 6-26. Scarf cutting fixture.

cutting tools. Most of them work, but some are better than others. The most important requirement for the tool is that it produces a smooth, repeatable cut at the appropriate angle.

Local damage to the top or bottom edge of a solid spar may be repaired by removing the damaged portion and fabricating a replacement filler block of the same material as the spar. Full width doublers are fabricated as shown and then all three pieces are glued and clamped to the spar. Nails or screws should not be used in spar repairs. A longitudinal crack in a solid spar may be repaired using doublers made from the proper thickness plywood. Care must be taken to ensure the doublers extend the minimum distance beyond the crack. [*Figure 6-27*]

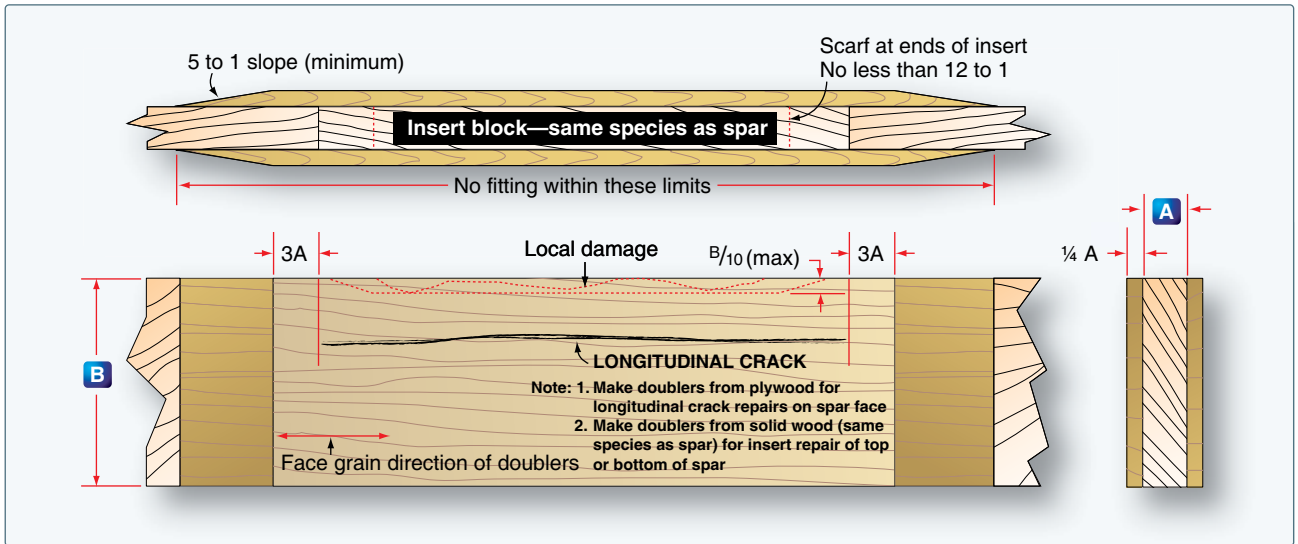


Figure 6-27. A method to repair damage to solid spar.

A typical repair to a built-up I spar is illustrated using plywood reinforcement plates with solid wood filler blocks. As with all repairs, the reinforcement plate ends should be feathered out to a 5:1 slope. [Figure 6-28]

cuts must be of the correct slope for the repair with the face grain running in the same direction as the original member. Not more than two splices should be made in any one spar.

Repair methods for the other types of spar illustrated at the start of this section all follow the basic steps of repair. The wood used should be of the same type and size as the original spar. Always splice and reinforce plywood webs with the same type of plywood as the original. Do not use solid wood to replace plywood webs because plywood is stronger in shear than solid wood of the same thickness. The splices and scarf

When a satisfactory repair to a spar cannot be accomplished, the spar should be replaced. New spars may be obtained from the manufacturer or the holder of a PMA for that part. An owner-produced spar may be installed provided it is made from a manufacturer-approved drawing. Care should be taken to ensure that any replacement spars accurately match the manufacturer's original design.

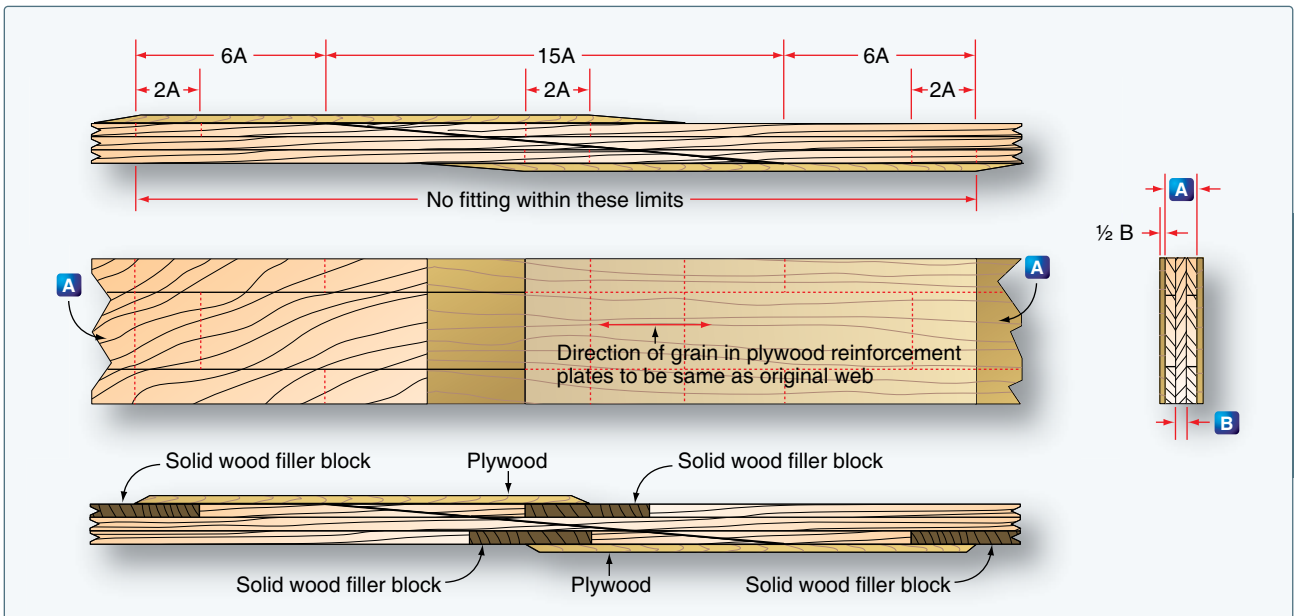


Figure 6-28. Repairs to a built-up I spar.

Bolt and Bushing Holes

All bolts and bushings used in aircraft structures must fit snugly into the holes. If the bolt or bushing is loose, movement of the structure allows it to enlarge the hole. In the case of elongated bolt holes in a spar or cracks in close proximity to the bolt holes, the repair may require a new section to be spliced in the spar, or replacement of the entire spar.

All holes drilled in a wood structure to receive bolts or bushings should be of such size that inserting the bolt or bushing requires a light tapping with a wood or rawhide mallet. If the hole is so tight that heavy blows are necessary, deformation of the wood may cause splitting or unequal load distribution.

For boring accurate smooth holes, it is recommended that a drill press be utilized where possible. Holes should be drilled with sharp bits using slow steady pressure. Standard twist drills can be used in wood when sharpened to a 60° angle. However, a better designed drill was developed for wood boring called a lip and spur or brad point. The center of the drill has a spur with a sharp point and four sharp corners to center and cut rather than walk as a conventional drill sometimes does. It has the outside corner of the cutting edges leading, so that it cuts the periphery of the hole first and maximizes the chance that the wood fibers cut cleanly, leaving a smooth bore.

Forstner bits bore precise, flat bottomed holes in wood, in any orientation with respect to the wood grain. They must be used in a drill press because more force is needed for their cutting action. Also, they are not designed to clear chips from the hole and must be pulled out periodically to do this. A straight, accurate bore-through hole can be completed by drilling through the work piece and into a piece of wood backing the work piece.

All holes bored for bolts that are to hold fittings in place should match the hole diameter in the fitting. Bushings made of steel, aluminum, or plastic are sometimes used to prevent crushing the wood when bolts are tightened. Holes drilled in the wood structure should be sealed after being drilled. This can be accomplished by application of varnish or other acceptable sealer into the open hole. The sealer must be allowed to dry or cure thoroughly prior to the bolts or bushings being installed.

Plywood Skin Repairs

Plywood skin can be repaired using a number of different methods depending on the size of the hole and its location on the aircraft. Manufacturer's instructions, when available, should be the first source of a repair scheme. AC 43.13-1

provides other acceptable methods of repair. Some of those are featured in the following section.

Fabric patch

A fabric patch is the simplest method to repair a small hole in plywood. This repair is used on holes not exceeding 1-inch in diameter after being trimmed to a smooth outline. The edges of the trimmed hole should first be sealed, preferably with a two-part epoxy varnish. This varnish requires a long cure time, but it provides the best seal on bare wood.

The fabric used for the patch should be of an approved material using the cement recommended by the manufacturer of the fabric system. The fabric patch should be cut with pinking shears and overlap the plywood skin by at least 1-inch. A fabric patch should not be used to repair holes in the leading edge of a wing, in the frontal area of the fuselage, or nearer than 1-inch to any frame member.

Splayed Patch

A splayed patch is a flush patch. The term splayed denotes that the edges of the patch are tapered, with the slope cut at a 5:1 ratio to the thickness of the skin. This may be used for small holes where the largest dimension of the hole to be repaired is not more than 15 times the skin thickness and the skin is not more than 1/10-inch thick. This calculates to nothing larger than a 1/2-inch trimmed hole in very thin plywood.

Using the sample 1/10-inch thick plywood and a maximum trimmed hole size of 1 1/2-inches, and cutting a 5:1 scarf, results in a 2 1/2-inches round section to be patched. The patch should be fabricated with a 5:1 scarf, from the same type and thickness plywood as the surface being repaired.

Glue is applied to the beveled edges and the patch is set with the grain parallel to the surface being repaired. A pressure plate of thicker plywood cut to the exact size of the patch is centered over the patch covered with waxed paper. A suitable weight is used for pressure until the glue has set. The repair is then sanded and finished to match the original surface. *[Figure 6-29]*

Surface Patch

Plywood skins not over 1/8-inch thick that are damaged between or along framing members may be repaired with a surface or overlay patch. Surface patches located aft of the 10 percent chord line, or which wrap around the leading edge and terminate aft of the 10 percent chord line, are permissible. You can use surface patches to patch trimmed holes up to a 50-inch perimeter, and may cover an area as large as one frame or rib space.

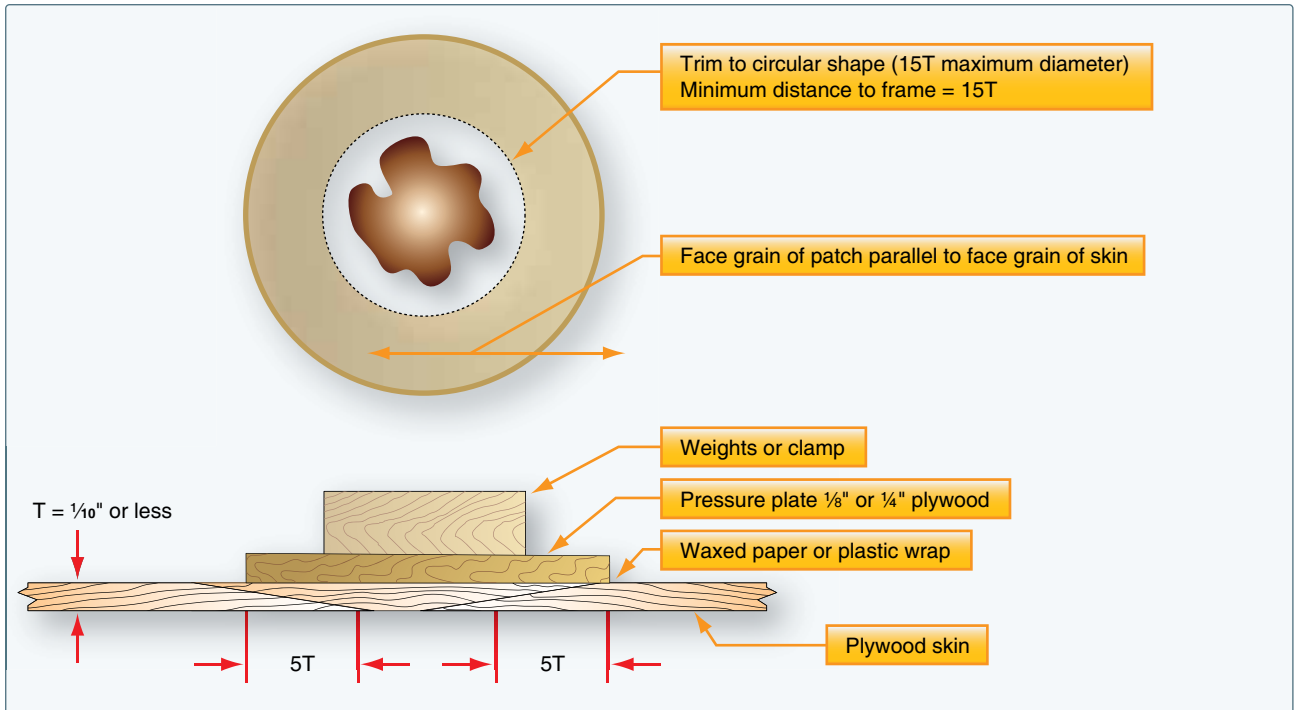


Figure 6-29. *Splayed patch.*

Trim the damaged area to a rectangle or triangular shape with rounded corners. The radius of the corners must be at least 5 times the skin thickness. Doublers made of plywood at least 1/4-inch thick are reinforcements placed under the edge of the hole inside the skin. Nail and glue the doublers in place. Extend the doublers from one framing member to another and strengthen at the ends by saddle gussets attached to the framing members. [Figure 6-30]

The surface patch is sized to extend beyond the cutout as indicated. All edges of the patch are beveled, but the leading edge of the patch should be beveled at an angle at least 4:1 of the skin thickness. The face-grain direction of the patch must be in the same direction of the original skin. Where possible, weights are used to apply pressure to a surface patch until the glue has dried. If the location of the patch precludes the use of weight, small round head wood screws can be used to apply glue pressure to secure the patch. After a surface patch has dried, the screws can be removed and the holes filled. The patch should be covered with fabric that overlaps the original surface by at least 2-inches. The fabric should be from one of the approved fabric covering systems using the procedures recommended by the manufacturer to cement and finish the fabric.

Plug Patch

Two types of plug patch, oval and round, may be used on plywood skins. Because the plug patch is only a skin repair,

use it only for damage that does not involve the supporting structure under the skin.

Cut the edges of a plug patch at right angles to the surface of the skin. Cut the skin also to a clean round or oval hole with edges at right angles to the surface. Cut the patch to the exact size of the hole; when installed, the edge of the patch forms a butt joint with the edge of the hole.

You can use a round plug patch where the cutout repair is no larger than 6-inches in diameter. Sample dimensions for holes of 4-inches and 6-inches in diameter appear in *Figure 6-31*.

The following steps provide a method for making a round plug patch:

1. Cut a round patch large enough to cover the intended repair. If applicable for size, use the sample dimensions in *Figure 6-31*. The patch must be of the same material and thickness as the original skin.
2. Place the patch over the damaged spot and mark a circle of the same size as the patch.
3. Cut the skin inside the marked circle so that the plug patch fits snugly into the hole around the entire perimeter.
4. Cut a doubler of soft quarter-inch plywood, such as poplar. A small patch is cut so that its outside radius

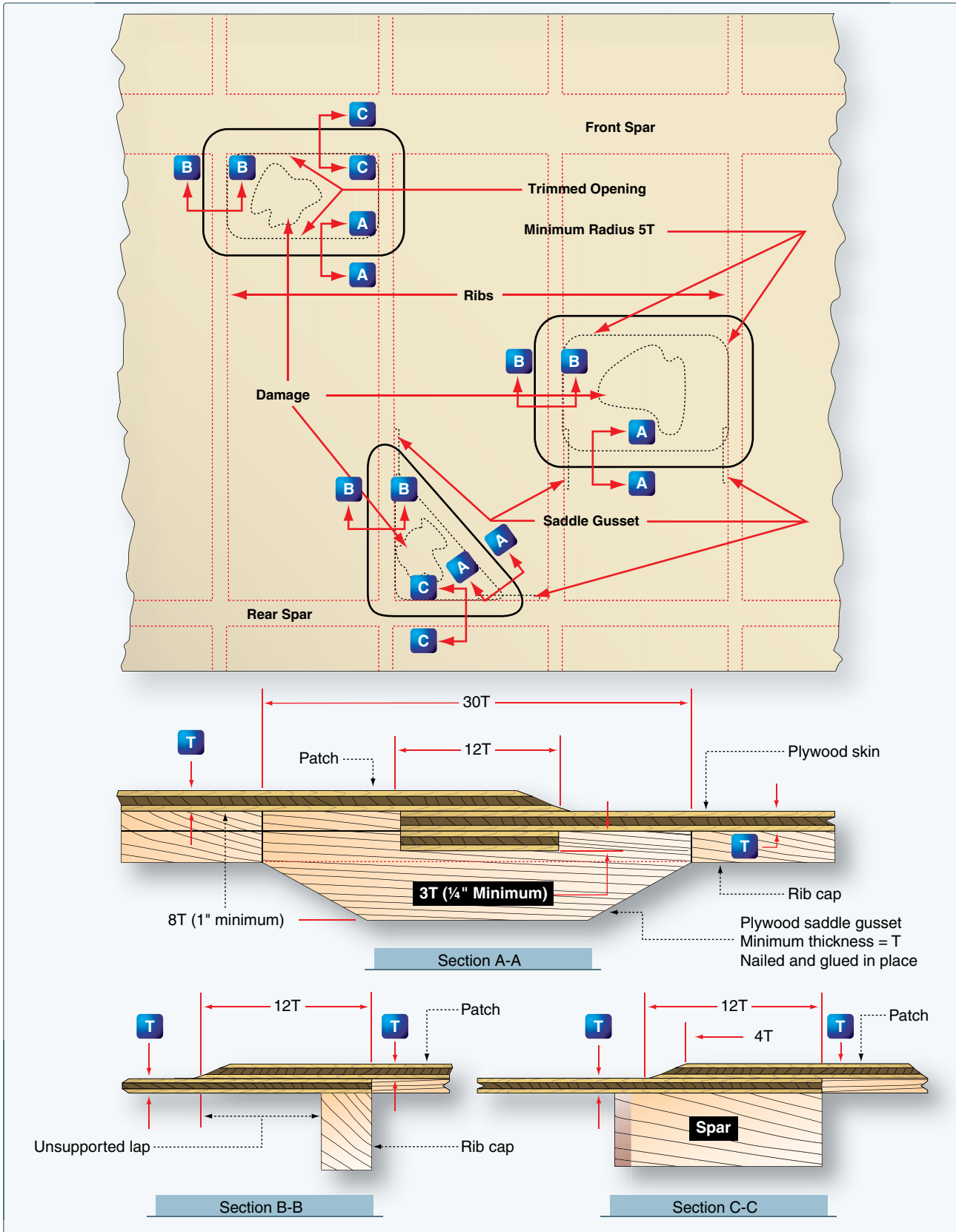


Figure 6-30. Surfaces patches.

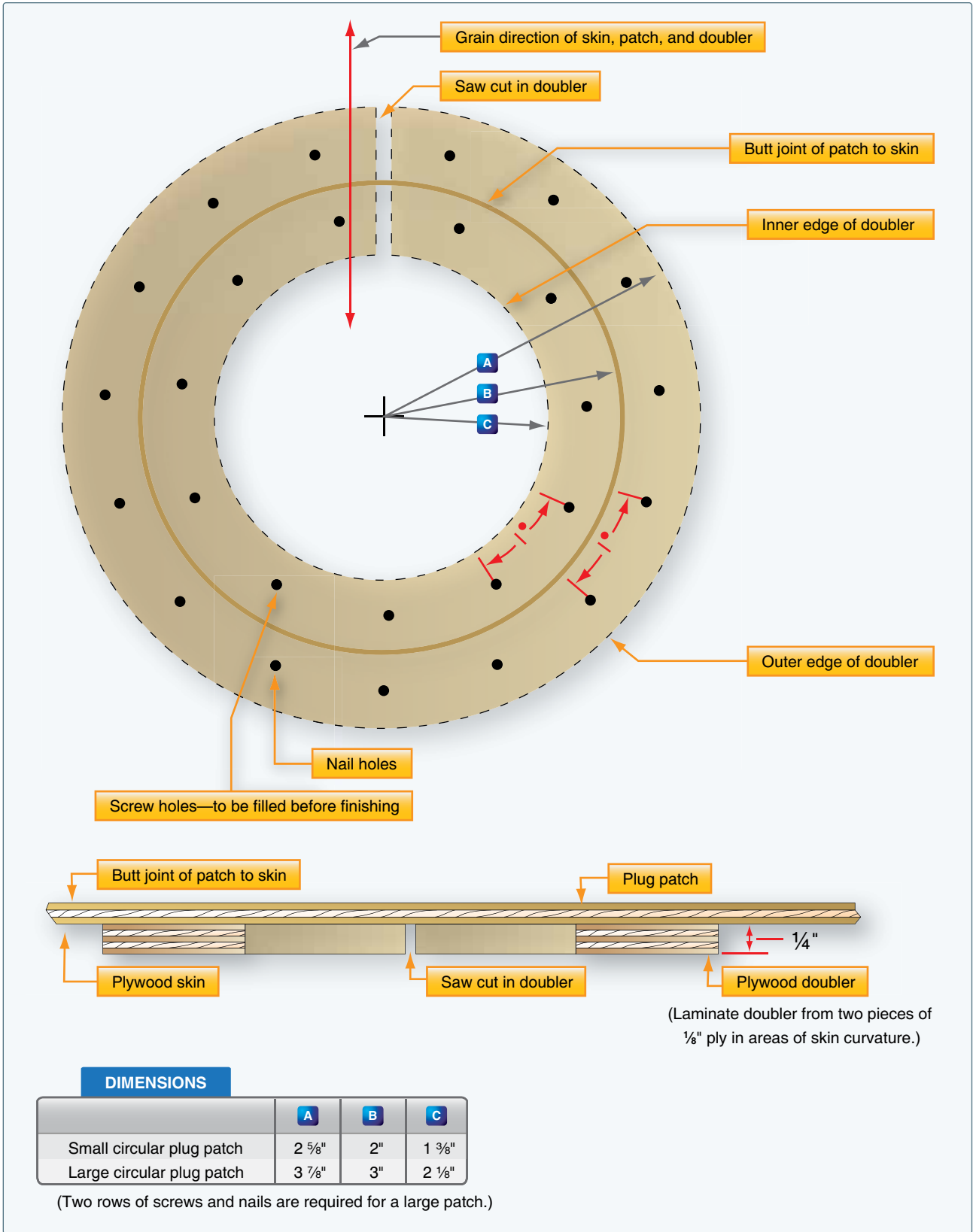


Figure 6-31. Round plug patch assembly.

is $\frac{5}{8}$ -inch greater than the hole to be patched and the inside radius is $\frac{5}{8}$ -inch less. For a large patch the dimensions would be increased to $\frac{7}{8}$ -inch each. If the curvature of the skin surface is greater than a rise of $\frac{1}{8}$ -inch in 6-inches, the doubler should be preformed to the curvature using hot water or steam. As an alternative, the doubler may be laminated from two pieces of $\frac{1}{8}$ -inch plywood.

- Cut the doubler through one side so that it can be inserted through the hole to the back of the skin. Place the patch plug centered on the doubler and mark around its perimeter. Apply a coat of glue outside the line to the outer half of the doubler surface that will bear against the inner surface of the skin.
- Install the doubler by slipping it through the cutout hole and place it so that the mark is concentric with the hole. Nail it in place with nailing strips, while holding a bucking bar or similar object under the doubler for backup. Place waxed paper between the nailing strips and the skin. Cloth webbing under the nailing strips facilitates removal of the strips and nails after the glue dries.

- After the glue has set for the installed doubler, and you have removed the nail strips, apply glue to the inner half of the doubler and to the patch plug. Drill holes around the plug's circumference to accept No. 4 round head wood screws. Insert the plug with the grain aligned to the surface wood.
- Apply the pressure to the patch by means of the wood screws. No other pressure is necessary.
- After the glue has set, remove the screws and fill the nail and screw holes. Sand and finish to match the original surface.

The steps for making an oval plug patch are identical to those for making the round patch. The maximum dimensions for large oval patches are 7-inches long and 5-inches wide. Oval patches must be cut, so when installed, the face grain matches the direction of the original surface. [Figure 6-32]

Scarf Patch

A properly prepared and installed scarf patch is the best repair for damaged plywood and is preferred for most skin

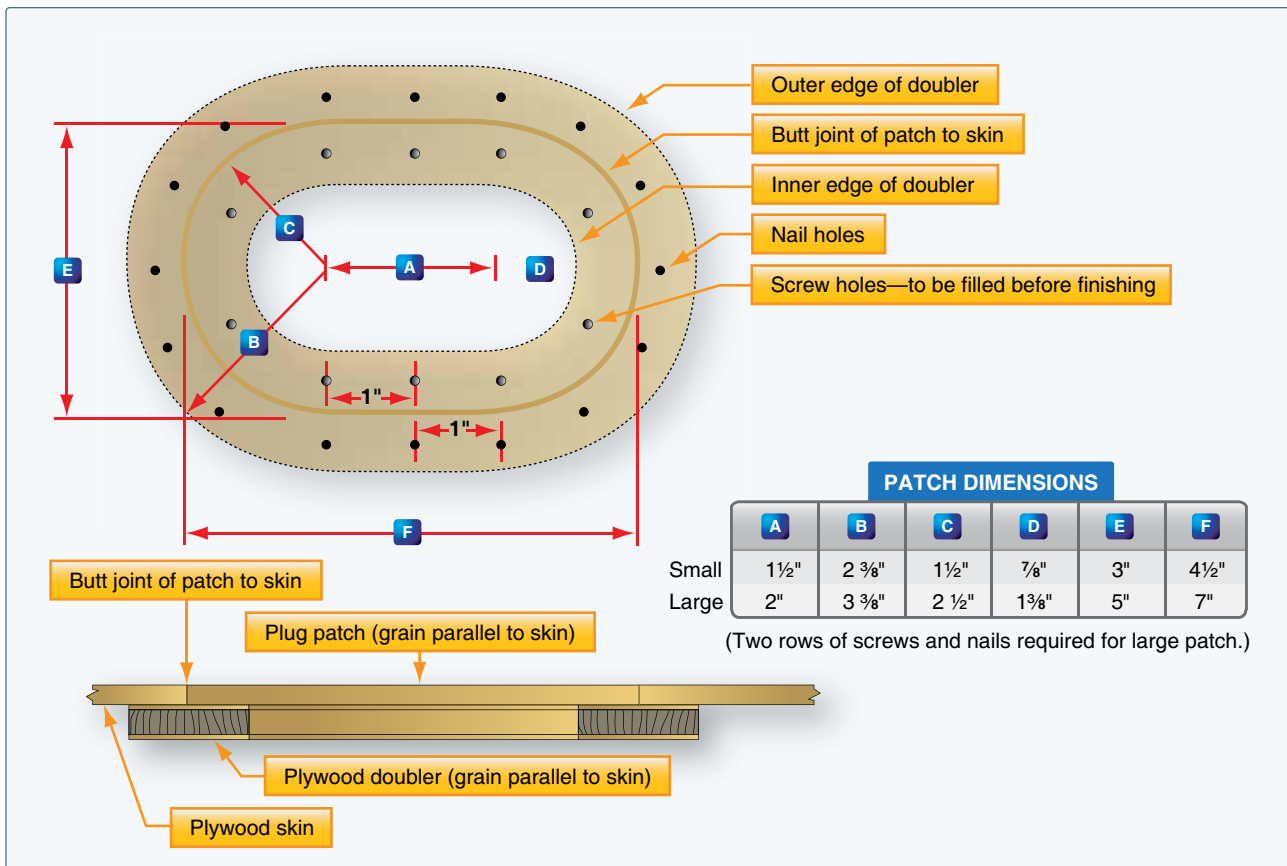


Figure 6-32. An oval plug patch.

repairs. The scarf patch has edges beveled at a 12:1 slope; the splayed patch is beveled at a 5:1 slope. The scarf patch also uses reinforcements under the patch at the glue joints.

Much of the outside surface of a plywood aircraft is curved. If the damaged plywood skin has a radius of curvature not greater than 100 times the skin thickness, you can install a scarf patch. However, it may be necessary to soak or steam the patch, to preform it prior to gluing it in place. Shape backing blocks or other reinforcements to fit the skin curvature.

You can make scarf cuts in plywood with various tools, such as a hand plane, spoke shave, a sharp scraper, or sanding block. Sawn or roughly filed surfaces are not recommended because they are normally inaccurate and do not form the best glue joint.

The Back of the Skin is Accessible for Repair

When the back of a damaged plywood skin is accessible, such as a fuselage skin, repair it with scarf patches cut and installed with the grain parallel to the surface skin. Details for this type of repair are shown in *Figure 6-33*.

Figure 6-33, Section A-A, shows methods of support for a scarf between frame members using permanent backing and gussets. When the damage follows or extends to a framing member, support the scarf as shown in section B-B. When the scarf does not quite extend to a frame member, support the patch as shown in section C-C.

Damage that does not exceed 25 times the skin thickness ($3\frac{1}{8}$ -inches for $\frac{1}{8}$ -inch thick skin) after being trimmed to a circular shape can be repaired as shown in section D-D, provided the trimmed opening is not nearer than 15 times the skin thickness to a frame member ($1\frac{1}{8}$ -inches for $\frac{1}{8}$ -inch thick skin).

A temporary backing block is carefully shaped from solid wood and fitted to the inside surface of the skin. A piece of waxed paper or plastic wrap is placed between the block and the underside of the skin. The scarf patch is installed and temporarily attached to the backing block, being held together in place with nailing strips. When the glue sets, remove the nails and block, leaving a flush surface on both sides of the repaired skin.

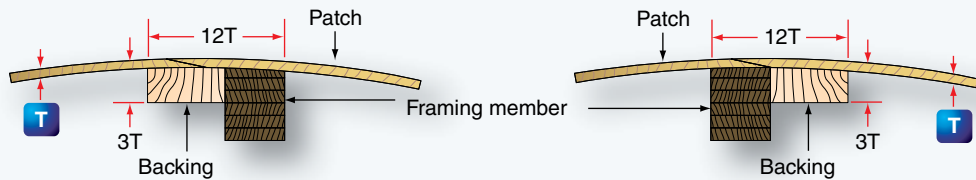
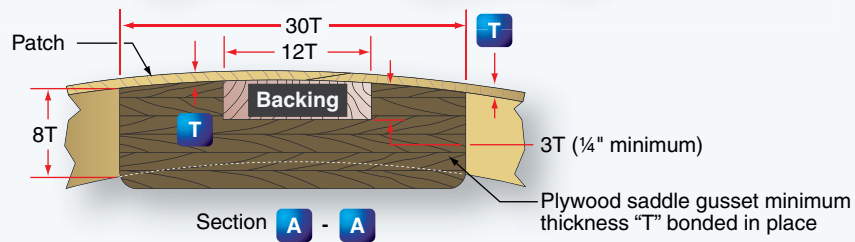
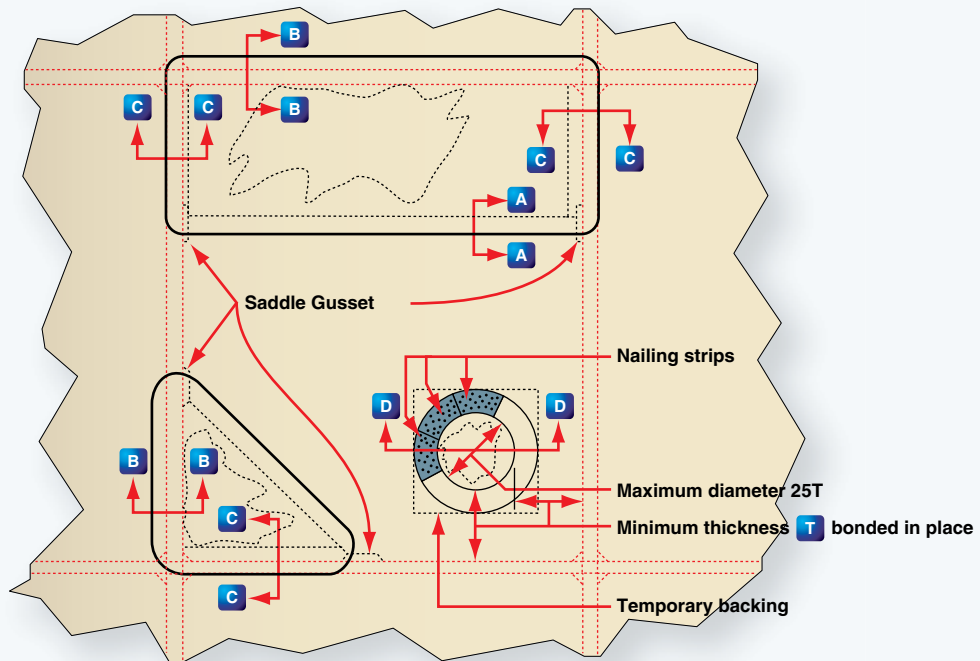
The Back of the Skin Is Not Accessible for Repair

To repair a section of the skin with a scarf patch when access to the back side is not possible, use the following steps to facilitate a repair, as shown in *Figure 6-34*.

Cut out and remove the damaged section. Carefully mark and cut the scarf around the perimeter of the hole. Working through the cutout, install backing strips along all edges that are not fully backed by a rib or spar. To prevent warping of the skin, fabricate backing strips from soft-textured plywood, such as yellow poplar or spruce, rather than a piece of solid wood.

Use nailing strips to hold backing strips in place while the glue sets. Use a bucking bar, where necessary, to provide support for nailing. A saddle gusset of plywood should support the end of the backing strip at all junctions between the backing strips and ribs or spars. If needed, nail and bond the new gusset plate to the rib or spar. It may be necessary to remove and replace an old gusset plate with a new saddle gusset, or nail a new gusset over the original.

Unlike some of the other type patches that are glued and installed as one process, this repair must wait for the glue to set on the backing strips and gussets. At that point, the scarf patch can be cut and fit to match the grain, and glued, using weight for pressure on the patch as appropriate. When dry, fill and finish the repair to match the original surface.



Clamp and bond backing to frame and skin
Section **B - B**

Clamp and bond backing to frame and skin
Section **C - C**

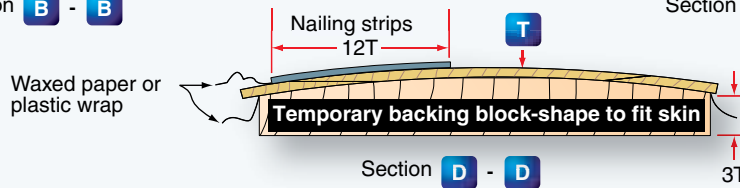


Figure 6-33. Scarf patches, back of skin accessible.

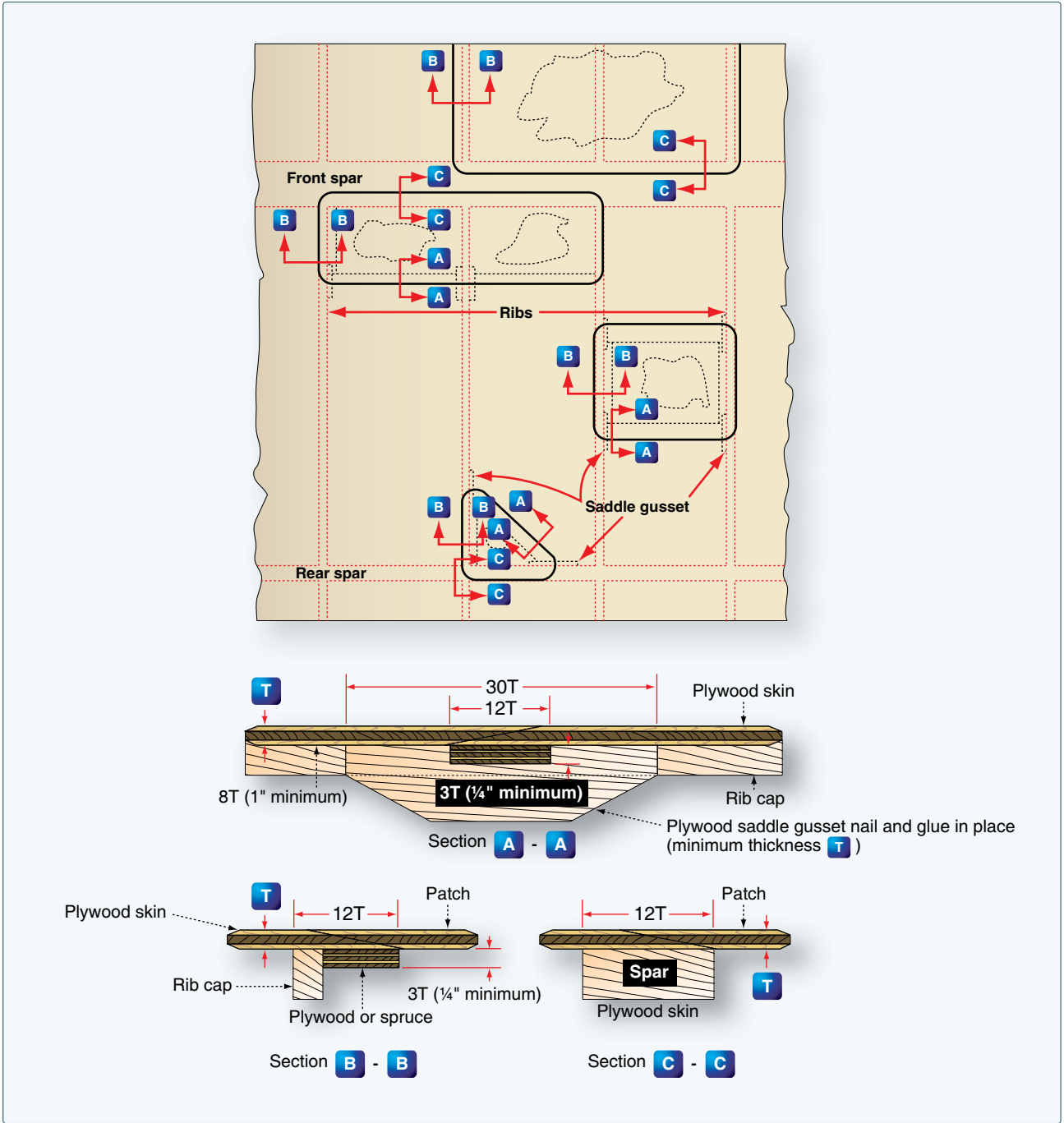


Figure 6-34. Scarf patches, back of skin not accessible.

