CHAPTER 2. FABRIC COVERING

SECTION 1. PRACTICES AND PRECAUTIONS

2-1. GENERAL. Cotton and Irish linen fabrics were the airframe coverings of choice from WWI through the 1950's. However, increases in cost and the short lifespan of natural fabrics became the driving factors which resulted in almost 100 percent replacement of original airframe fabrics by man-made, STC-approved, polyester, and glass filament fabric.

2-2. PROBLEM AREAS.

a. Deterioration. Polyester fabric deteriorates only by exposure to ultraviolet radiation as used in an aircraft covering environment. When coatings completely protect the fabric its service life is infinite. Therefore, it is very important to thoroughly protect the structure from deterioration before covering and provide adequate inspection access to all areas of fabric-covered components to allow inspection for corrosion, wood rot, and mice infestation. Multiple drain holes in the lower ends of all fabric-covered sections also provide needed ventilation to remove condensation.

b. Tension. Polyester fabric obtains maximum tension on an airframe at 350 °F, and will not be excessive on aircraft originally covered with natural fabric and 12 coats of Nitrate or Butyrate Dope. However, dope applied over full heat-tauted fabric can develop excess tension after aging and damage light aircraft structures. Coatings other than dope will not increase fabric tension after aging. The heat-tauting instructions given in the manual of each STC-approved covering process should be followed.

2-3. AIRCRAFT FABRIC-SYNTHETIC.

a. STC-Approved Covering Materials. There is a wide selection of STC-approved covering materials available which utilize synthetic fabric falling within the generic class "Polyester" and may vary in characteristics. Difference in the fabric may be denier, tenacity, thread count, weight, shrink, tension, and weave style.

b. Polyester Filaments. Polyester Filaments are manufactured by polymerization of various select acids and alcohols, then extruding the resulting molten polymers through spinnerets to form filaments. The filaments are heat stretched to reduce to the desired denier or size. It is the heat stretching that imparts a memory in the filaments causing them to try and return to their original shorter length when reheated at a controlled temperature. Overheating will cancel the memory and melt the filaments.

c. Covering Procedures. Coating types, covering accessories, and covering procedures also may vary; therefore, the covering procedures given in the pertinent manuals must be followed to comply with the STC. The FAA STC-approved installation takes precedence over instructions in this advisory circular.

d. Installation. Initial installation of polyester fabric is similar to natural fabric. The fabric is installed with as little slack as possible, considering fittings and other protrusions. It may be sewn into an envelope, installed as a blanket, or installed by cementing to the airframe with a fabric cement. Each STC may differ in the cement seam overlap, type of sewn seam, heat shrinking procedures, and temperature.

2-4. AIRCRAFT FABRIC-NATURAL. Physical specifications and minimum strength requirements for natural fiber fabric, cotton and linen, used to recover or repair components of an aircraft, are listed in table 2-1. Tear resistance is an important factor when considering aircraft fabric. A test method such as ASTM D 1424 is recommended. Technical Standard Order TSO-C15d, entitled Aircraft Fabric, Grade A (AMS 3806D); and TSO-C14b, Aircraft Fabric, Intermediate Grade (AMS 3804C) current edition, respectively, describe the minimum standards that all fabric must meet to qualify as aircraft covering material.

2-5. RECOVERING AIRCRAFT. Recover or repair aircraft with a fabric of equal quality and strength to that used by the original aircraft manufacturer. It is recommended that fabric conforming to TSO-C15d or TSO-C14b be used to recover aircraft originally covered with lower strength fabric conforming to AMS 3802, current edition.

NOTE: Recovering or repairing aircraft with any type fabric and/or coating other than the type used by the original aircraft manufacturer is considered a major alteration. Obtain approval from the FAA on fabric and installation data. Cotton and linen rib lacing cord, machine and hand-sewing thread, and finishing tapes should not be used with polyester and glass fabric covering.

a. Reinforcing tape minimum tensile strength is listed in table 2-2. Reinforcing tape meeting specification MIL-T-5661, Type I, current edition, is acceptable. Reinforcing tape should have a minimum 40 lb. resistance without failure when static tested in shear against a single rib lace, or a pull-through resistance when tested against a single-wire clip, rivet, screw, or any other type of fabric-to-rib attachment. Reinforcing tape is used over the rib cab on top of the fabric and for inter-rib bracing.

b. Finishing Tape, sometimes referred to as surface tape, should have the same properties as the fabric used to cover the aircraft.

c. Lacing Cord shall have a minimum breaking strength of 40 lb. Lacing cord meeting the specifications listed in table 2-2 is acceptable. Rib lace cord should have a microcrystalline fungicidal wax, paraffin-free wax, or beeswax coating, or other approved treatment to prevent wearing and fraying when pulling through the structure.

d. Machine Thread shall have a minimum breaking strength of 5 lb. Thread meeting the specifications listed in table 2-2 is acceptable.

e. Hand-Sewing Thread shall have a minimum breaking strength of 14 lb. Thread meeting the specifications listed in table 2-2, is acceptable. When covering with STC-approved fabric covering material, use the type of sewing thread approved by the STC and manufactured under the specific PMA.

f. 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 to possibility of induced flutter.

2-6. PREPARATION OF THE STRUCTURE FOR COVERING. One of the most important items when covering aircraft is the proper preparation of the structure. Before covering, the airframe must be inspected and approved by a FAA-certified mechanic or repair station.

TABLE 2-1. Cotton and linen fabrics.

Materials	Specification	Minimum Tensile Strength New (undoped)	Minimum Tearing Strength New (undoped) (ASTM D 1424)	Minimum Tensile Strength Deteriorated (undoped)	Thread Count Per Inch	Use and Remarks
Airplane cloth mercerized cotton (Grade "A").	TSO-C15d, as amended, references Society Automotive Engineers AMS 3806d, as amended or MIL-C-5646	80 pounds per inch warp and fill.	5 pounds warp and fill.	56 pounds per inch.	80 min., 84 max. warp and fill.	For use on all aircraft. Required on aircraft with wing loading of 9 p.s.f. or greater or placard never exceed speed of 160 m.p.h. or greater.
Airplane cloth mercerized cotton.	TSO-C14b, as amended, references Society Automotive Engineers AMS-3804c, as amended.	65 pounds per inch warp and fill.	4 pounds warp and fill.	46 pounds per inch.	80 min., 94 max. warp and fill.	For use on aircraft with wing loading less than 9 p.s.f. and never exceed speed of less than 160 m.p.h.
Airplane cloth mercerized cotton.	Society Automotive Engineers AMS 3802, as amended.	50 pounds per inch warp and fill.	3 pounds warp and fill.	35 pounds per inch.	110 max. 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.
Aircraft linen.	British 7F1.					This material meets the minimum strength Requirements of TSO-C15.

a. Battery Box Treatment. An asphaltic, rubber-based acid-proof coating should be applied to the structure in the area of a battery box, by brush, for additional protection from battery acid. Control cables routed in the area of the battery box should be coated with paralketone.

b. Worn Holes. Oversized screw holes or worn size 4 self-tapping screw holes through ribs and other structures used to attach fabric may be redrilled a minimum 1-1/2 hole diameter distance from the original hole location with a # 44 (0.086) drill bit. Size 6 screws, drill bit size # 36 (0.1065), may be installed in stripped or worn holes drilled for size 4 screws, usually without redrilling. Worn holes for wire clips and wire barbs should be redrilled a minimum 1-1/2 hole distance from the original locations using a drill jig to ensure correct spacing, with the appropriate size drill bit. Drill bit size # 30 (0.128) may be used to redrill oversize holes for 1/8-inch diameter blind rivets a minimum 1-1/2 hole diameter distance from the original location.

TABLE 2-2. Cotton and Linen, Tapes and Threads.

Materials	Specification	Yarn Size	Minimum Tensile Strength	Yards Per Pound	Use and Remarks
Reinforcing tape, cotton.	MIL-T-566 1 E, Type 1 MIL-Y-1140H		150 pounds per 1/2 inch width.		Used as reinforcing tape on fabric and under rib lacing cord. Strength of other widths approx. in proportion.
Lacing cord, prewaxed braided cotton.	Federal T-C-57 1F		40 pounds.	310 minimum.	Lacing fabric to structures. Unless already waxed, must be lightly waxed before using.
Lacing cord, braided cotton.	MIL-C-5648A		80 pounds.	170 minimum.	Lacing fabric to structures. Unless already waxed, must be lightly waxed before using.
Lacing cord thread, high tenacity cotton.	MIL-T-5660B	Ticket No. 10.	62 pounds.	480 minimum.	Lacing fabric to structures. Unless already waxed, must be lightly waxed before using.
Machine thread cotton	Federal V-T-276H	20/4 ply	5 pounds.	5,000 nominal.	Use for all machine sewing.
Hand-Sewing thread cotton.	Federal V-T-276H Type III B	8/4 ply	14 pounds.	1,650 nominal.	Use for all hand-sewing. Use fully waxed thread.
Finishing (Surface) tape cotton.	Same as fabric used.		Same as fabric used.		Use over seams, leading edges, trailing edges, outer edges and ribs, pinked, raveled or straight edges.

c. Fairing Precautions. Aluminum leading edge replacement fairings installed in short sections may telescope during normal spar bending loads or from thermal expansion and contraction. This action may cause a wrinkle to form in the fabric, at the edge of the lap joint. Leading edge fairing sections may be fastened together with rivets or screws to prevent telescoping after installation. Trailing edges should be adequately secured to prevent movement and wrinkles.

d. Dope Protection. Solvents found in nitrate and butyrate dope will penetrate, wrinkle, lift, or dissolve most one-part wood varnishes and one-part metal primers. All wood surfaces that come in contact with doped fabric should be treated with a protective coating such as aluminum foil, cellulose tape, or dope-proof paint to protect them against the action of the solvents in the dope. This can also be accomplished by recoating with a suitable, solvent resistant two-part epoxy varnish, which will be impervious to solvent penetration and damage after curing. Clad aluminum and stainless steel parts need not be dope-proofed.

(1) A solvent-sensitive primer on ferrous metal and aluminum alloy components which will be in contact with fabric may be protected from solvent damage by overcoating with a two-part epoxy primer. Epoxy primer meeting MIL-P-53022B is acceptable.

(2) Small metal or wood surfaces, such as rib caps, to which fabric will not be dope bonded as a part of the particular fabric attachment procedure may be protected from dope damage by cellophane tape or aluminum foil.

e. Chafe Protection. Fabric and finishing tape is often cut through with sandpaper over sharp edges during the coating and finishing procedure and later polishing. All sharp metal edges or protruding screws, nails, rivets, and bolt heads should be covered with an anti-chafe tape to prevent cutting and wearing through the fabric after installation. Use appropriate non-bleeding cotton adhesive coated tape, finishing tape, or strips of fabric, cut from the fabric being used to cover the aircraft, doped in place.

(1) Small holes cut through the fabric to accommodate flying wires, control cables, and fittings, must be reinforced with finishing tape or fabric patches cut from the same fabric used for the covering.

(2) Areas needing additional chafe protection such as control cables routed firm against the fabric surface should be protected with patches cut from cotton duck, leather, or plastic. These patches may be sewn, doped, or cemented in place, as appropriate.

(3) Any drag and anti-drag wires in the wings should be protected from chafing at cross points.

f. Inter-Rib Bracing. Use a woven fabric tape of the same quality and width as that used for the rib lace reinforcing, where so incorporated in the wing design by the original aircraft manufacturer. When the original routing for the inter rib bracing is not known, the tape will be routed diagonally, alternating between the top and bottom of each rib cap on each successive rib, if a single pair, half way between the front and rear spars. The number of tape pairs will duplicate the original aircraft manufacturer's installation. Tapes will be routed continuously from the wing butt to the wingtip bow, with one turn of tape around each intermediate rib cap strip. Care should be given to position the tape so as not to interfere with control cables, bellcranks or push-pull rods.

g. Preparation of Plywood Surfaces for Covering. Prior to covering plywood surfaces, prepare the surface by sanding, cleaning, and applying sealer and dope. When plywood surfaces are to be covered with light weight glass fiber deck cloth instead of fabric, no sealer or dope should be applied to the plywood as it would inhibit penetration of epoxy resin.

(1) Sand plywood surfaces as needed to remove old loose dope or varnish residue to provide a clean bonding surface. Remove any oil, grease, or other contamination with a suitable solvent such as naphtha. Small, rough areas and irregularities in the plywood surface and around any plywood repairs may be filled and smoothed with an appropriate commercial grade wood filler. Filling large warp depressions on plywood surfaces with a wood filler for cosmetic purposes is not acceptable.

(2) After cleaning and sanding all plywood surfaces, seal the wood grain with a suitable solvent resistant two-part epoxy varnish. After the varnish has thoroughly dried, apply two brush or spray coats of clear dope, allowing sufficient drying time between coats.

2-7. FABRIC SEAMS. Seams parallel to the line of flight are preferable; however, spanwise seams are acceptable.

a. Sewn Seams.

(1) Machine-sewn seams should be double stitched using any of the styles illustrated in figure 2-1 A, B, C, or D. A machine-sewn seam used to close an envelope at a wingtip, wing trailing edge, empennage and control surface trailing edge, and a fuselage longeron may be made with a single stitch when the seam will be positioned over a structure. (See figure 2-1 E.) The envelope size should accommodate fittings or other small protrusions with minimum excess for installation. Thick or protruding leading edge sewn seams should be avoided on thin airfoils with a sharp leading edge radius because they may act as a stall strip.

(2) Hand sew, with plain overthrow or baseball stitches at a minimum of four stitches per inch, or permanent tacking, to the point where uncut fabric or a machine-sewn seam is reached. Lock hand sewing at a maximum of 10 stitch intervals with a double half hitch, and tie off the end stitch with a double half hitch. At the point where the hand-sewing or permanent tacking is necessary, cut the fabric so that it can be doubled under a minimum of 3/8 inch before sewing or permanent tacking is performed. (See figure 2-2.)

(3) After hand sewing is complete, any temporary tacks used to secure the fabric over wood structures may be removed.

(4) Cover a sewn spanwise seam on a wing's leading edge with a minimum 4-inch wide pinked-edged surface tape with the tape centered on the seam.

(5) Cover a spanwise-sewn seam at the wing trailing edge with pinked-edge surface tape that is at least 3 inches wide. For aircraft with never-exceed speeds in excess of 200 mph, cut V notches at least 1 inch in depth and 1/4 inch in width in both edges of the surface tape when used to cover spanwise seams on trailing edges of control surfaces. Space notches at intervals not exceeding 6 inches. On tape less than 3 inches wide, the notches should be 1/3 the tape width. In the event the surface tape begins to separate because of poor adhesion or other causes, the tape will tear at a notched section, thus preventing progressive loosening of the entire length of the tape which could seriously affect the controllability of the aircraft. A loose tape acts as a trim tab only on a movable surface. It becomes a spoiler on a fixed surface and has no effect at the trailing edge other than drag.

(6) Make spanwise-sewn seams on the wing's upper or lower surfaces in a manner that will minimize any protrusions. Cover the seams with finishing tape at least 3 inches wide, centering the tape on the seam.

(7) Sewn seams parallel to the line of flight (chordwise) may be located over ribs. However, careful attention must be given to avoid damage to the seam threads by rib lace needles, screws, rivets, or wire clips that are used to attach the fabric to the rib. Cover chordwise seams with a finishing tape at least 3 inches wide with the tape centered on the seam.

b. Doped Seams.

(1) For an overlapped and doped spanwise seam on a wing's leading edge, overlap the fabric at least 4 inches and cover with finishing tape at least 4 inches wide, with the tape centered at the outside edge of the overlap seam.

(2) For an overlapped and doped spanwise seam at the trailing edge, lap the fabric at least 3 inches and cover with pinked-edge surface tape at least 4 inches wide, with the tape centered on the outside edge of the overlap seam.

(3) For an overlapped and doped seam on wingtips, wing butts, perimeters of wing control surfaces, perimeters of empennage surfaces, and all fuselage areas, overlap the fabric 2 inches and cover with a finishing tape that is at least 3 inches wide, centered on the outside edge of the overlap seam.

(4) For an overlapped and doped seam on a wing's leading edge, on aircraft with a velocity never exceed (Vne) speed up to and including 150 mph, overlap the fabric 2 inches and cover with a finishing tape that is at least 3 inches wide, with the tape centered on the outside edge of the overlap seam.

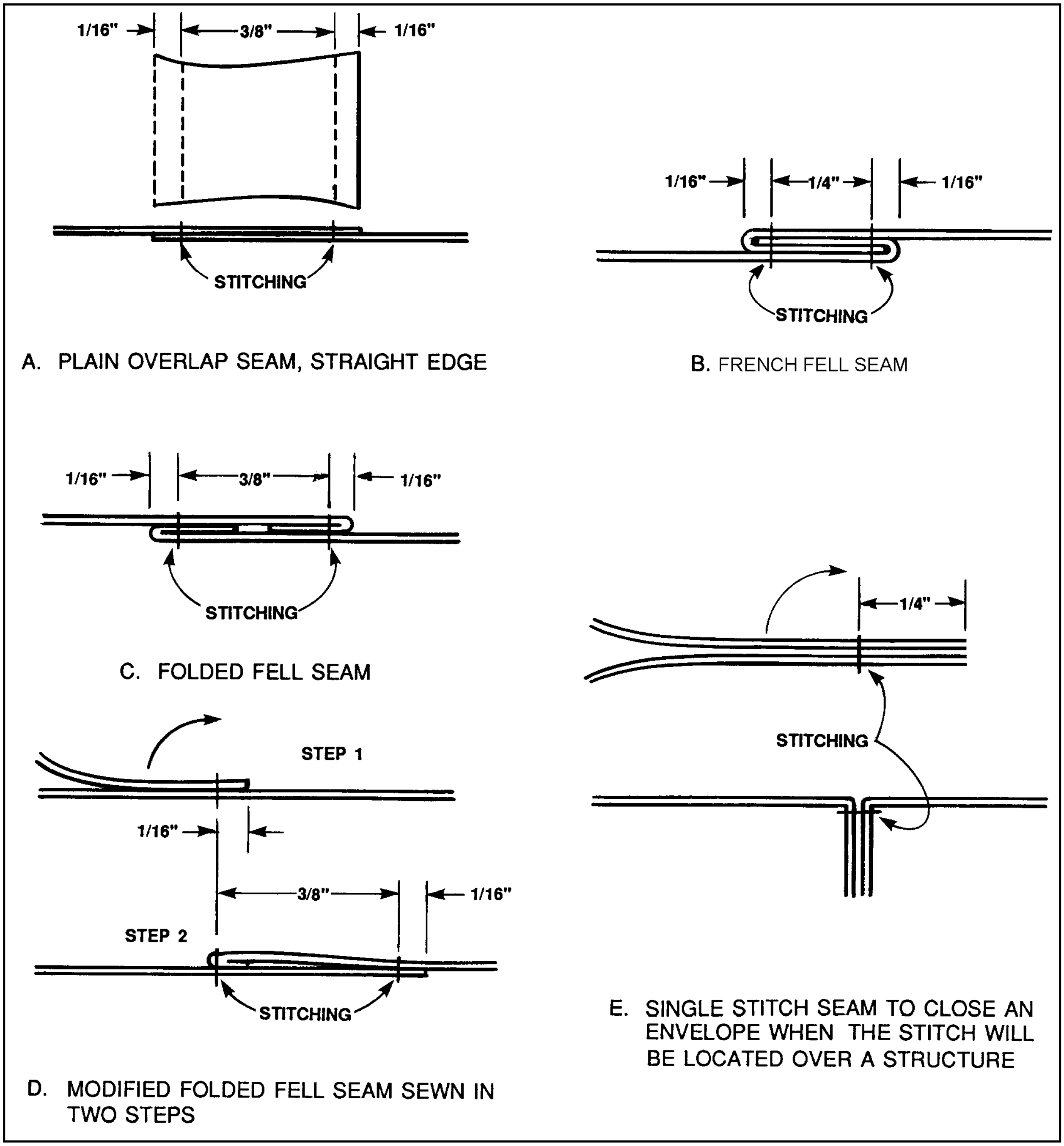
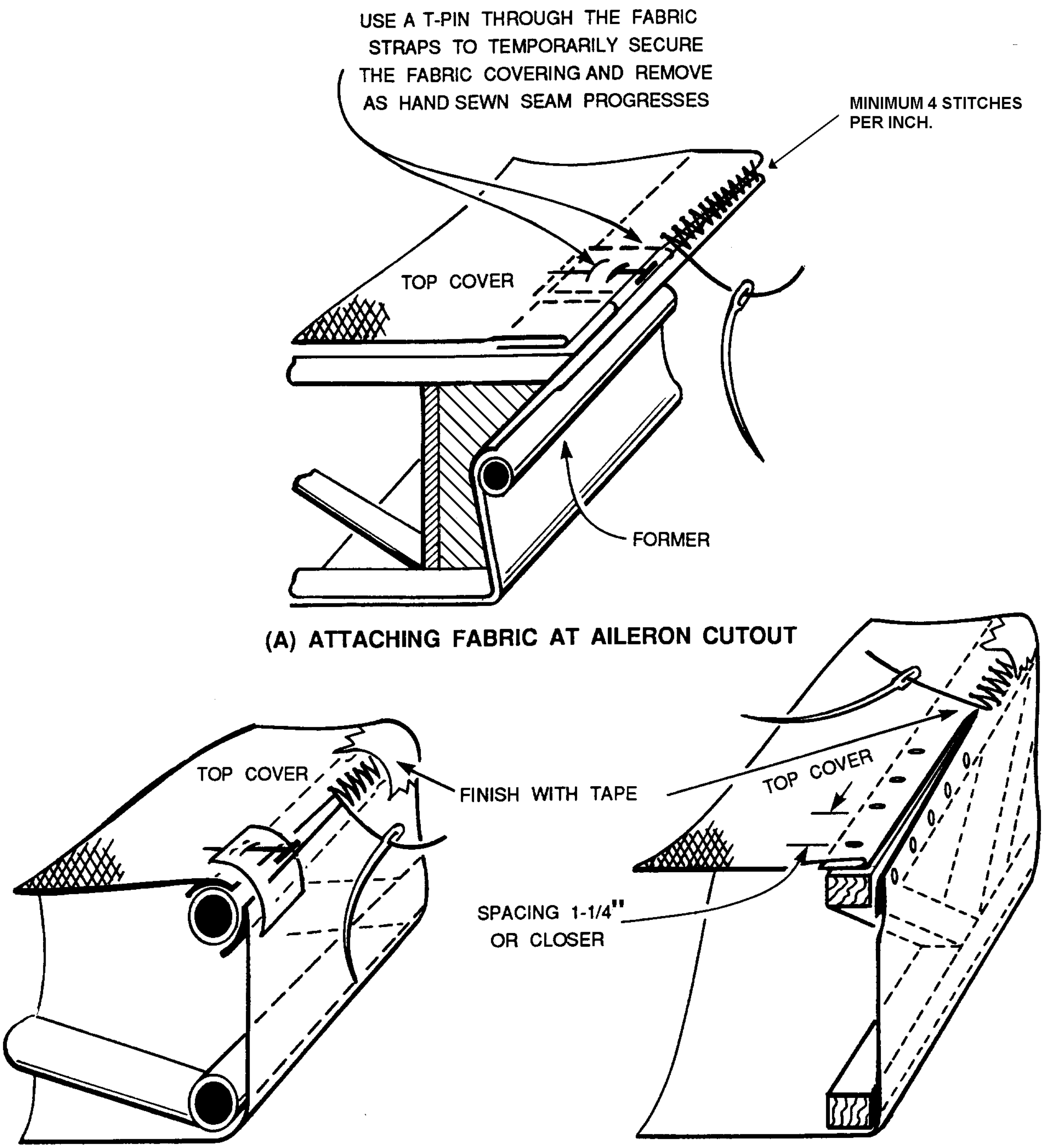


FIGURE 2-1. Fabric seams.



TEMPORARY TACKS MAY BE USED TO SECURE FABRIC IN POSITION FOR HAND-SEWN SEAMS OVER A WOOD STRUCTURE. PERMANENT TACKS MAY BE USED TO SECURE FABRIC AT WING BUTT STRUCTURES IN LIEU OF A HAND-SEWN SEAM AND SHOULD BE OF THE APPROPRIATE LENGTH AND GAUGE, AND MADE OF CORROSION RESISTANT STEEL OR BRASS.

FIGURE 2-2. Typical methods of attaching fabric.

(5) For an overlapped and doped seam on the perimeter of a wing (except a leading edge), perimeters of wing control surfaces, perimeters of empennage surfaces, and all areas of a fuselage, on aircraft with a Vne speed up to and including 150 mph, overlap the fabric 1 inch and cover with a finishing tape that is at least 3 inches wide, centered on the outside edge of the overlap seam.

2-8. COVERING METHODS. 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 being recovered or repaired. Carefully remove the old fabric from the airframe, noting the location of inspection covers, drain grommets, and method of attachment. Cotton or linen 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. The Envelope Method. A wing envelope may be developed by two methods. Machine sew together, side by side multiple fabric sections, cut to reach chordwise around the wing, starting and ending at the trailing edge with a minimum of 1 inch excess length. The sewn envelope is then positioned around the wing and secured with closely spaced T-Head pins at the wingtip and trailing edge. Excess material may then be trimmed. Carefully remove the envelope and complete by machine sewing at the wingtip and along the trailing edge, except where the geometry of the wing (aileron and flap cut out) would prevent the sewn envelope from being reinstalled. After reinstalling the envelope, the un-sewn sections and butt end are then closed by hand-sewn or overlapped and doped seams in accordance with the aircraft Vne speed. (Refer to paragraph 2-7 b.)

(1) An alternative method, when fabric of sufficient width is available, is to sew together, side-by-side, two sections of fabric, placing the seams spanwise on the leading edge, then fit and sew the wingtip and trailing edge in the same manner as the multiple piece chordwise envelope.

(2) An envelope may be developed for the fuselage in the same manner, with a final closing along a longeron by hand-sewn or overlapped and doped seams in accordance with the aircraft Vne speed.

b. The Blanket Method. A blanket is developed by sewing together, side-by-side, multiple sections of fabric with the seams chordwise or two wide sections of fabric, side-by-side, placing the seam spanwise on the leading edge, the same as an envelope. Close the three remaining sides with a hand-sewn seam or overlapped and doped seams in accordance with the aircraft Vne speed. Small components may be covered by wrapping one piece of fabric over a straight leading or trailing edge, then closing three sides with hand-stitched or overlapped and doped seams in accordance with the aircraft Vne speed.

NOTE: All overlapped and doped seams will be made only over underlying supporting structures extending the full width of the seam.

c. Machine-sewn alternate. An alternate to machine-sewn seams on a wing envelope or blanket is to use two sections of wide fabric spanwise. Attach the fabric with overlapped and doped seams at the leading and trailing edge, wingtip and wing butt, in accordance with the aircraft Vne speeds. (Reference paragraph 2-7 b.) Smaller components may be covered in the same manner. The fuselage may be covered with multiple fabric sections with overlapped and doped seams on the longerons or other wide fabric-forming structures in accordance with the aircraft Vne speed. (Reference paragraph 2-7 b.)

d. Holes in Fabric. Never cut any holes in the fabric for inspection panels, spar fittings, or drain grommets; or attach the fabric to the airframe with rib lacing screws, rivets, clips, or rib stitch cord until the fabric has been semi-tauted and stabilized with several coats of dope.

2-9. REINFORCING TAPE.

a. Reinforcing tape should be securely bonded to the fabric surface with dope before cord lacing or installation of hardware. Where multiple attachments are in close proximity, such as on a wing rib, continuous reinforcing tape should be installed, extending at least 1 inch past the last attachment at each end. Random or wide spacing, such as on fuselage stringers or empennage surfaces, may be reinforced with 2-inch lengths of reinforcing tape centered on the attachment location.

b. Reinforcing tapes should be of the appropriate width for hardware attachment such as screws, rivets, wire clips, etc., which pierce the center of the tape. Reinforcing tape under cord lacing should be the same width as the rib to which the fabric is laced and may be comprised of multiple widths positioned side-by-side to achieve the required width.

c. When the aircraft Vne speed is over 250 mph, anti-tear strips, cut from the same quality fabric used to cover the aircraft, are recommended for use under reinforcing tape on the entire top surface of the wing and on the portion of the wing's bottom surface in the propeller slipstream. The propeller slipstream is considered to be the propeller diameter plus one outboard rib. The anti-tear strip should be installed completely around the wing, beginning and ending at the trailing edge in the propeller slipstream, and installed from the trailing edge over the leading edge and back under to the front spar on the balance of the ribs. Anti-tear strips should extend 1/2 inch past the wing rib cap edges and be thoroughly bonded to the fabric with dope before the reinforcing tape is installed. (See figure 2-3.)

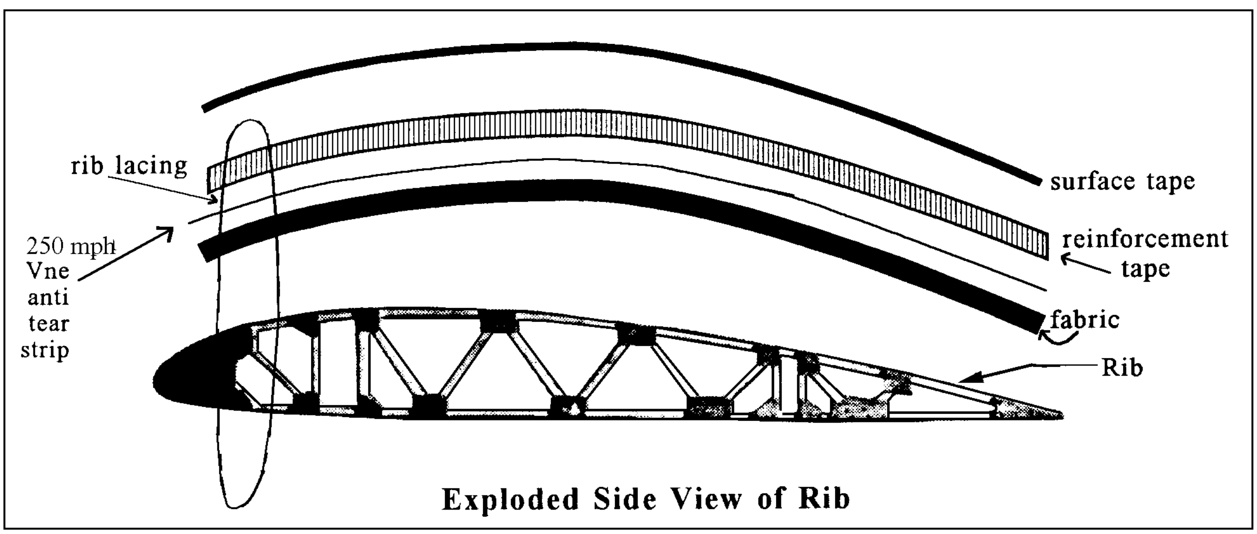


FIGURE 2-3. Exploded side view of rib.

2-10. LACING.

a. Fabric should be attached to aircraft components to prevent ballooning due to aerodynamic forces, in the identical manner and locations as used by the original aircraft manufacturer. Any deviation from the original method(s) of attachment, such as screws, rivets, wire clips, lacing cord, etc., are considered a major alteration and in conflict with the aircraft type design data. Obtain FAA approval on any deviation.

NOTE: When the type of rib lace knot used by the original aircraft manufacturer is not known, the modified seine knot shown in figure 2-4 through figure 2-9c will be used.

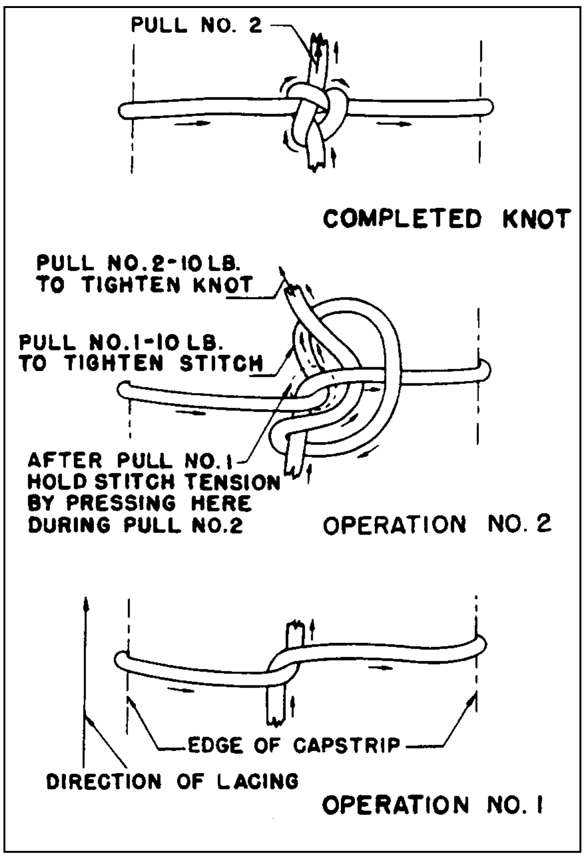


FIGURE 2-4. Standard external modified seine knot used for single and double rib lacing.

b. During the installation of lacing cord through a wing or any other component, special attention should be given to avoid interference with the routing of any control cable, bellcrank, or any other movable item. To prevent chafing and cutting of the lacing cord, control cables or any other movable items should be tensioned or positioned to their normal alignment before rib lacing and checked afterwards to ensure adequate clearance. When a lace cord will be chafed by a moving component, a blindstitch may be made around the top and bottom rib caps as illustrated in figure 2-11.

c. Stationary structures interfering with needle routing may be circumvented by aligning the needle forward or aft adjacent to the rib cap. Pull the needle through the wing and then return through the same hole and exit at the desired adjacent location.

NOTE: The first lace on a wing rib should be spaced from the leading edge fairing no more than 1/2 the required lace spacing for the balance of the rib.

d. Both surfaces of fabric covering on wings and control surfaces must be securely fastened to the ribs by lacing cord or any other method originally approved for the aircraft. Care must be taken to insure that all sharp edges against which the lacing cord may bear are protected by tape in order to prevent abrasion of the cord. Separate lengths of lacing cord may be joined by the splice knot shown in figure 2-10 or tied off. The first loop is tied with a square knot as illustrated in figure 2-5 and figure 2-9a, and the knot secured with a half hitch on each side after the lacing is pulled tight around the rib. The needle is then routed through the wing and around the rib cap at the

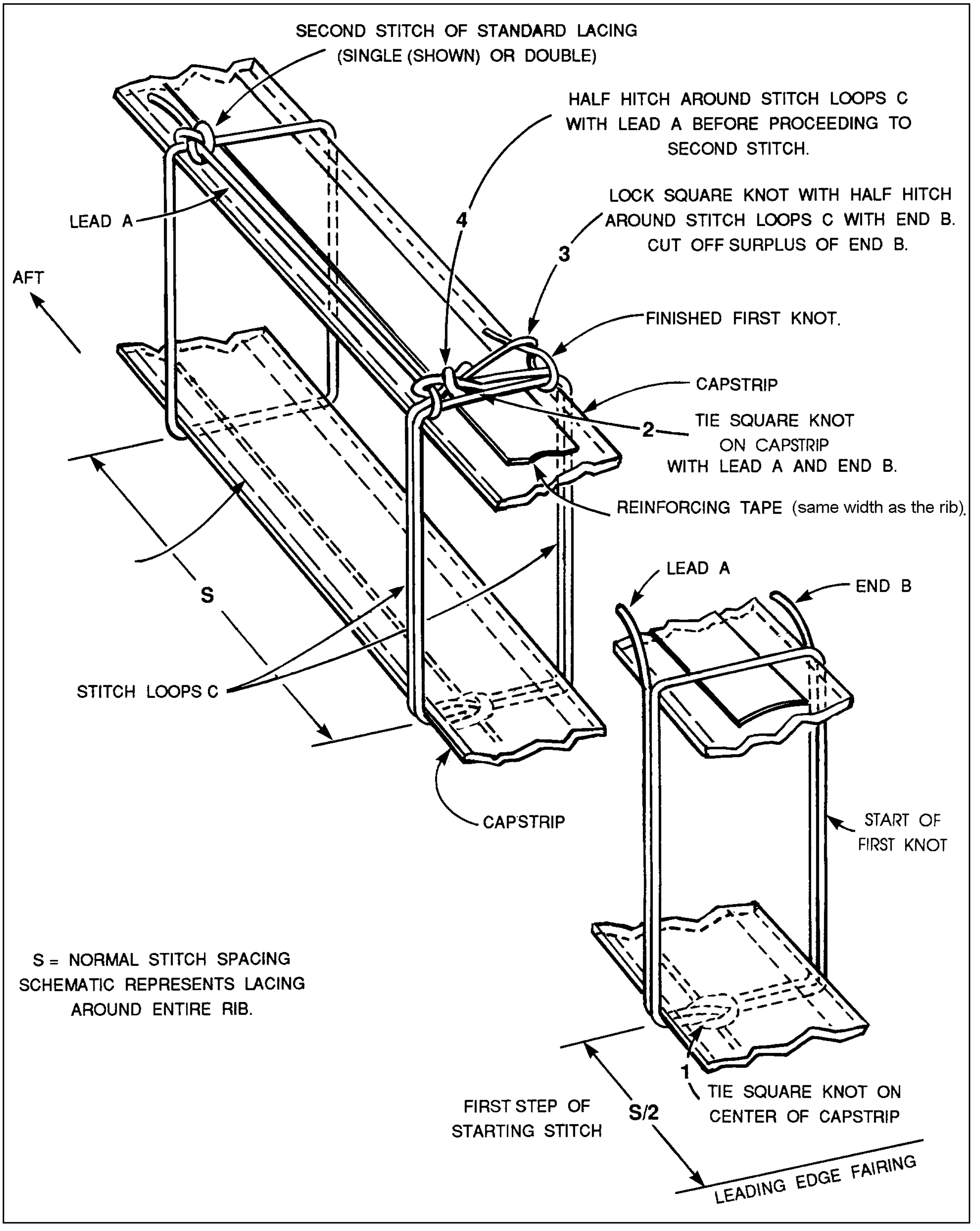


FIGURE 2-5. Starting stitch for rib lacing.

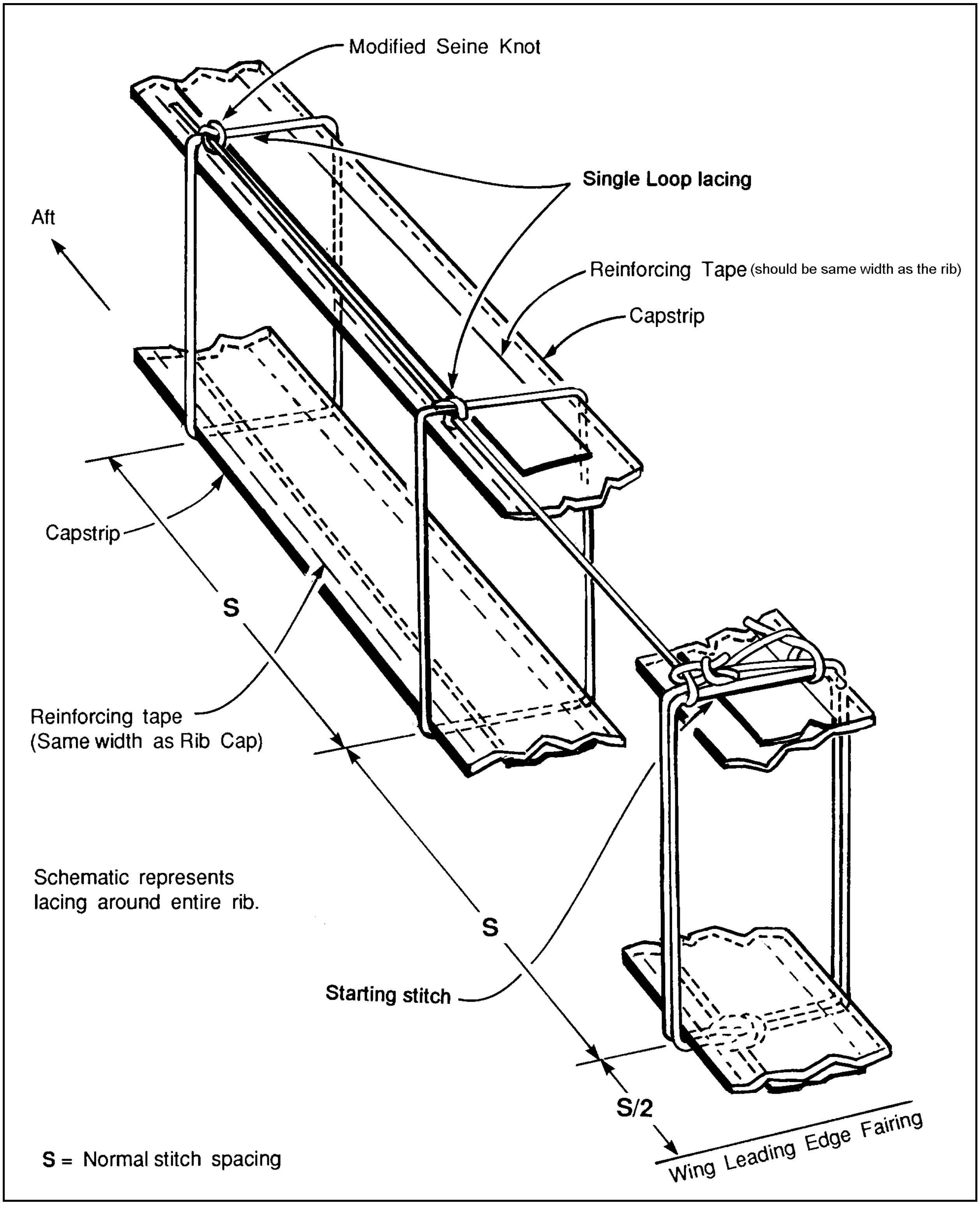


FIGURE 2-6. Standard single-loop lacing.

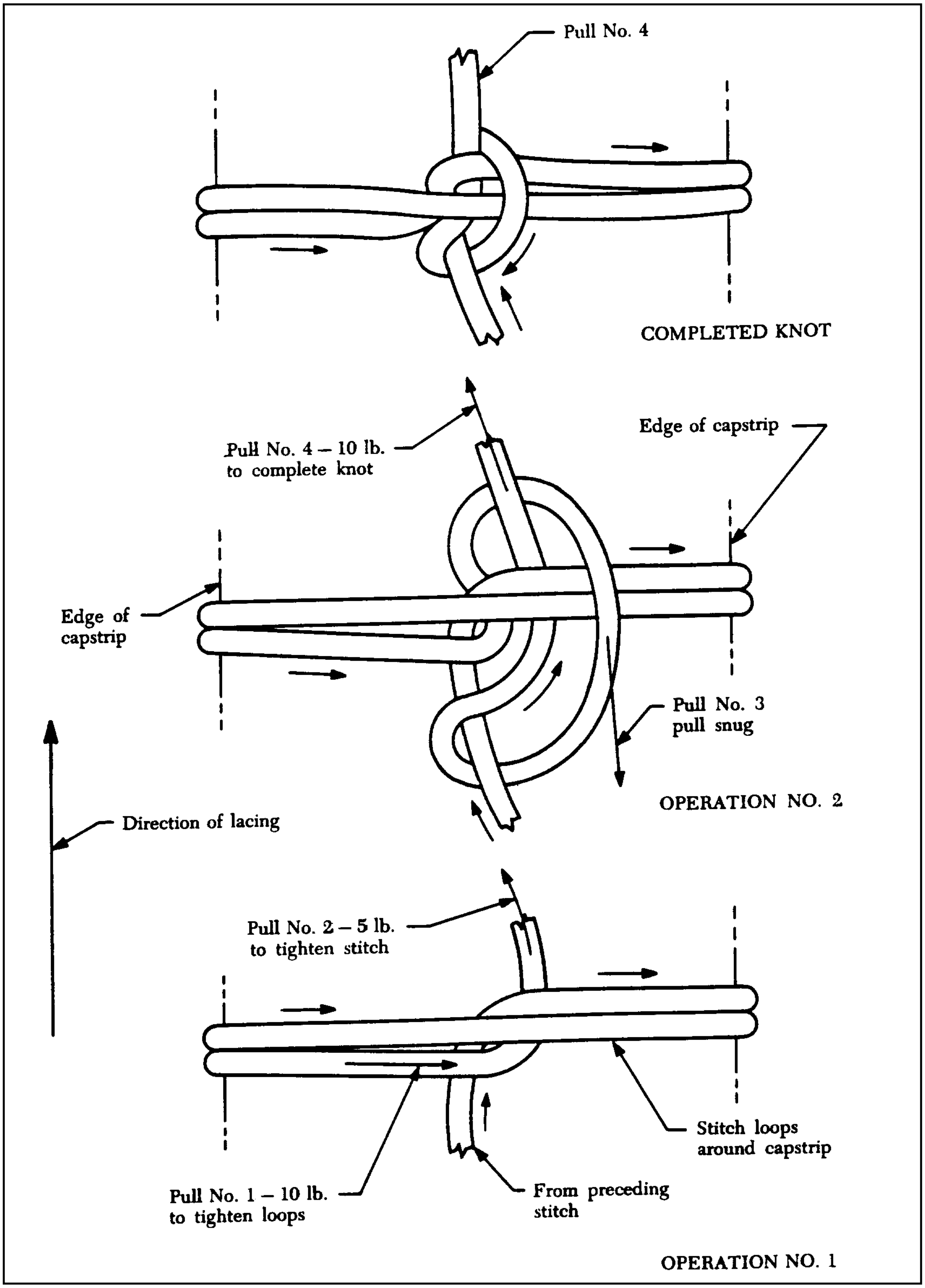


FIGURE 2-7. Standard knot for double-loop lacing.

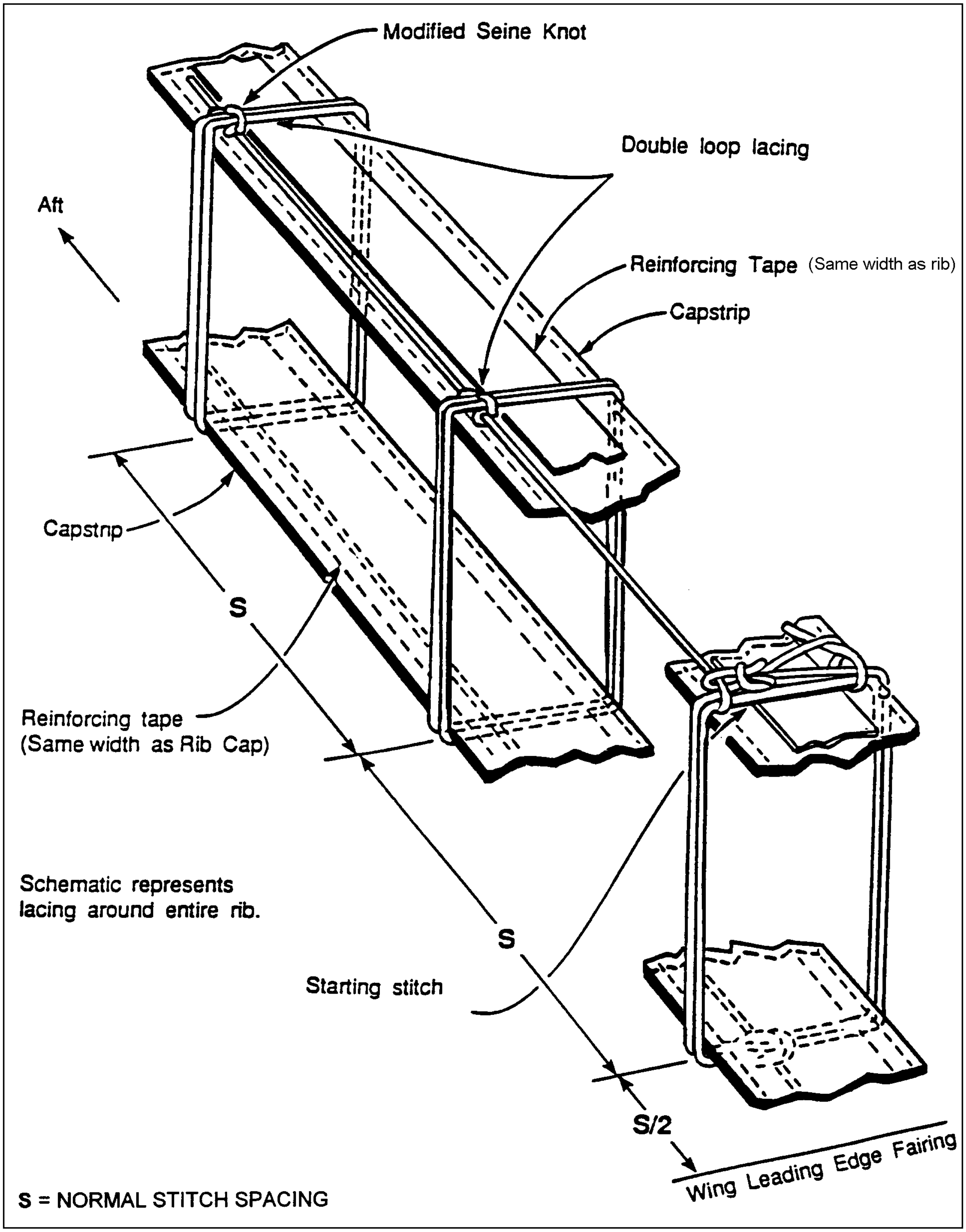
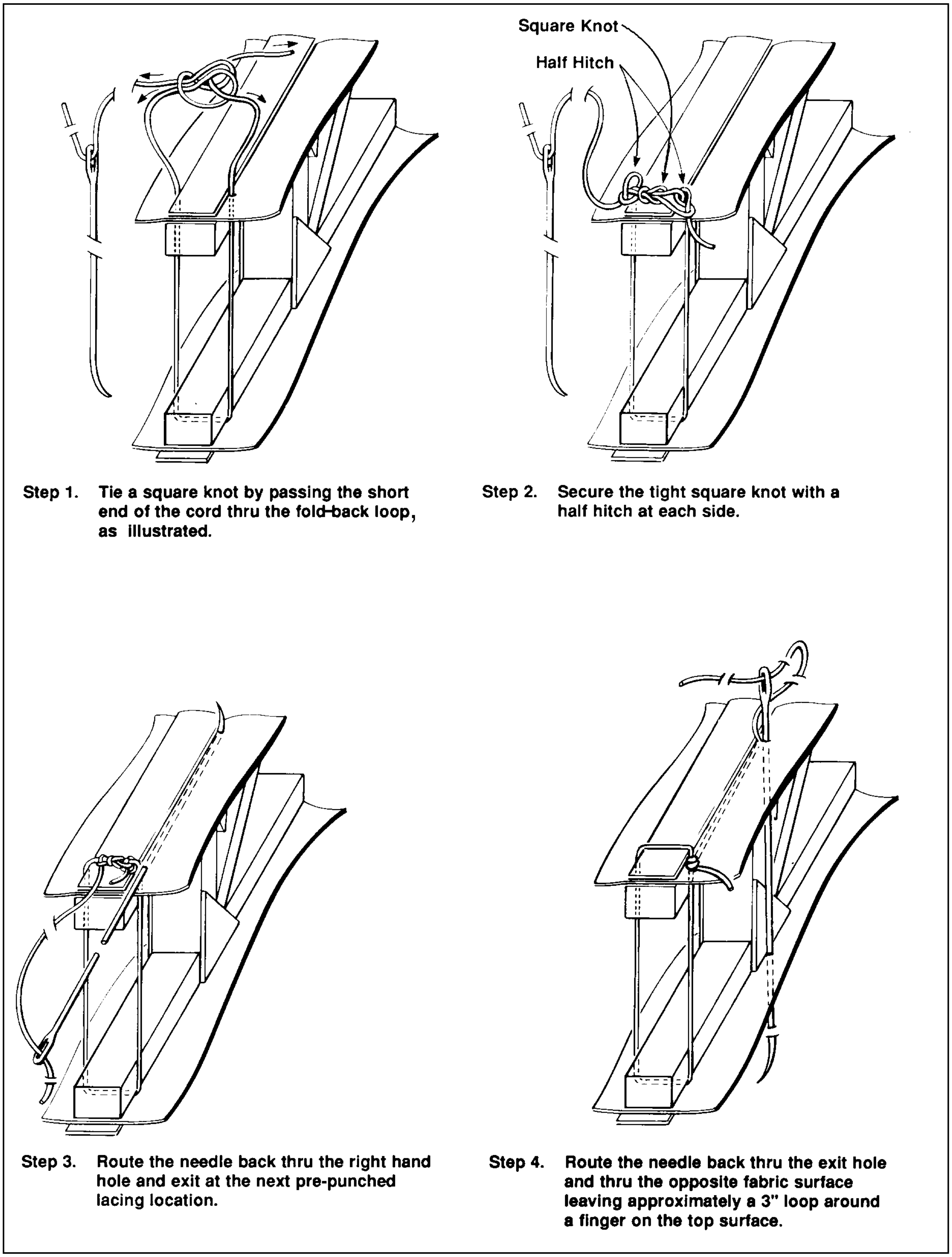


FIGURE 2-8. Standard double-loop lacing (optional).



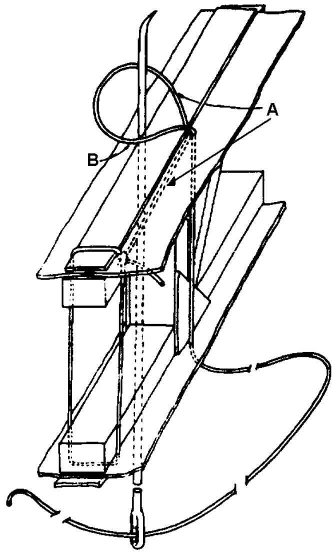
Step 1. Tie a square knot by passing the short end of the cord thru the fold-back loop, as illustrated.

Step 2. Secure the tight square knot with a half hitch at each side.

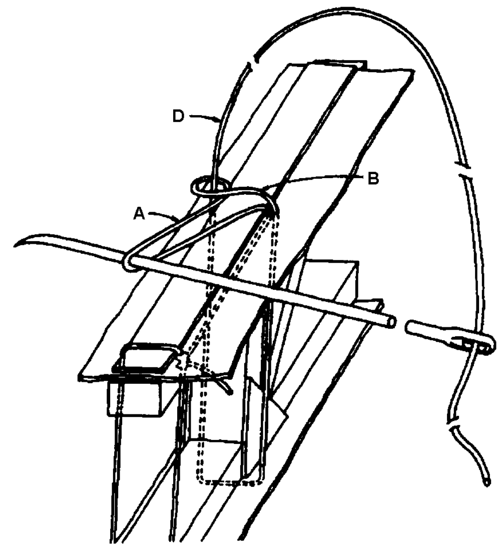
Step 3. Route the needle back thru the right hand hole and exit at the next pre-punched lacing location.

Step 4. Route the needle back thru the exit hole and thru the opposite fabric surface leaving approximately a 3" loop around a finger on the top surface.

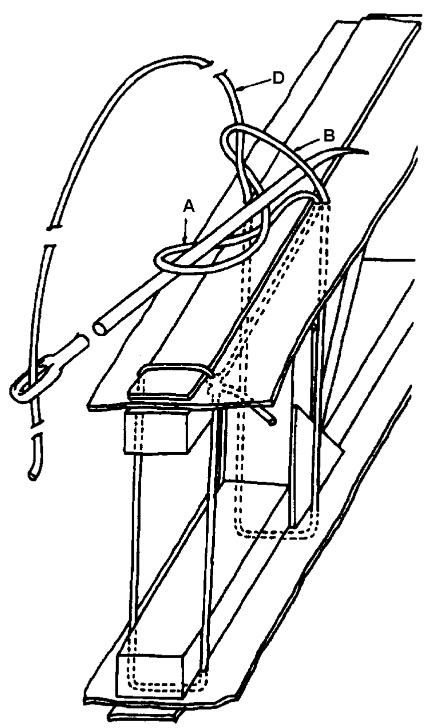
FIGURE 2-9a. Alternate sequence to tie a modified seine knot for rib lacing.



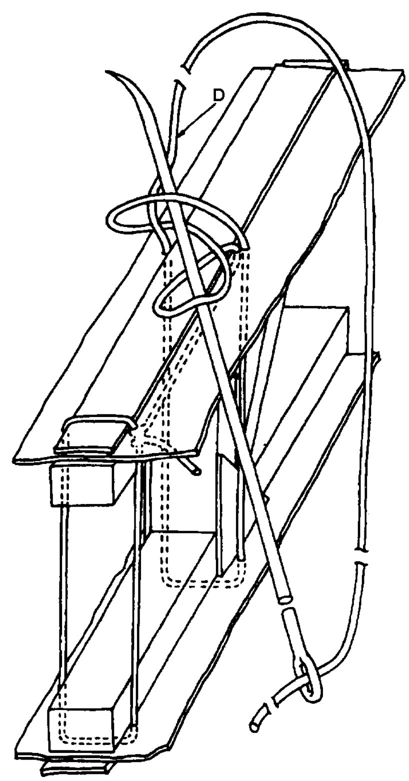
Step 5. As the needle is returned thru the top surface on the opposite side of the rib cap the loop is rotated to position cord section "A" to the forward side of the needle, then the needle is pulled thru.



Step 6. The needle tip is routed under cord section "B" to hook and pull cord section "A" aft.

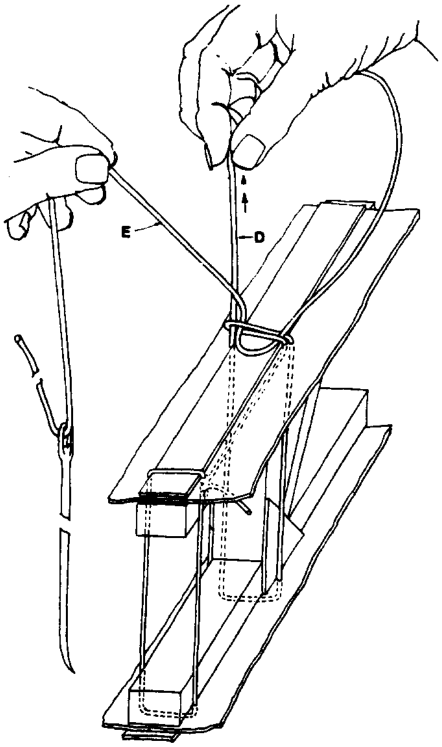


Step 7. The needle tip is then routed over the top of cord section "A" and under cord section "B."

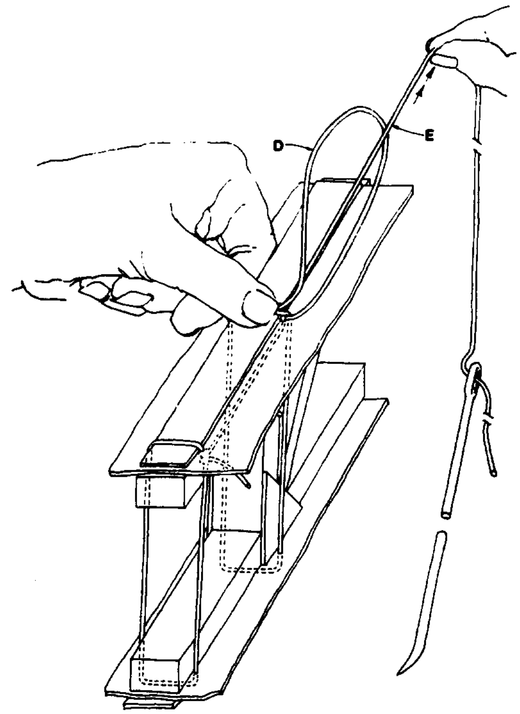


Step 8. The needle tip is then routed over cord section "D" and passed thru the lacing while holding cord section "D" perpendicular to the surface to avoid cord entanglement.

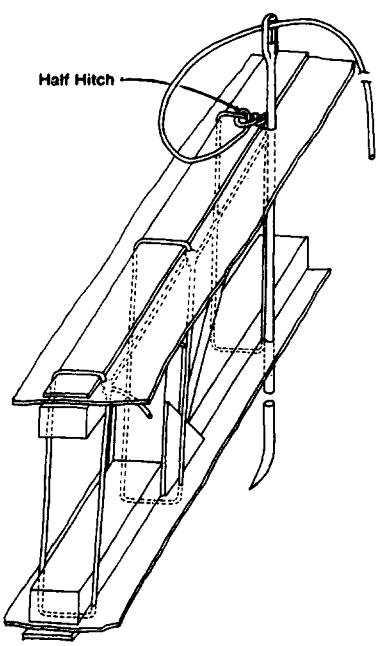
FIGURE 2-9b. Alternate sequence to tie a modified seine knot for rib lacing.



Step 9. Pull cord section “D” perpendicular to the fabric surface to remove all slack in the cord back to the last rib lacing knot while working the loose knot to the right side. Do not pull cord section “E.”



Step 10. After all slack is removed by pulling cord section “D,” switch hands and place a thumbnail on the loose knot formed on the right-hand side, then secure the knot by pulling firmly perpendicular to the fabric surface on cord section “E.”



Step 11. After completing all lacing in the same sequence, the end is secured with a half hitch after the modified seine knot. The knot is pulled to the inside by routing the needle thru the wing before cutting the cord to leave the end inside.

FIGURE 2-9c. Alternate sequence to tie a modified seine knot for rib lacing.

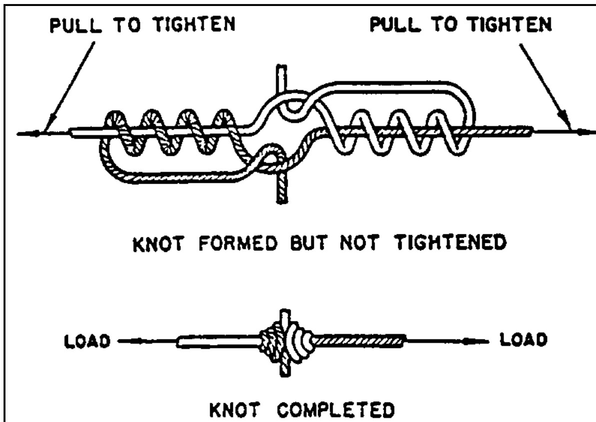
next rib lace location with the cord and knot remaining on top of the fabric surface as illustrated in figure 2-5, figure 2-6, and figure 2-8. An alternate method is to route the needle under the fabric and out through the next lace location, then back down through the wing as illustrated in figure 2-9a through figure 2-9c. A modified seine knot is then tied as illustrated in figure 2-4 through figure 2-9c.

(1) Rotate each lace loop to place the knot at the side of the rib cap to reduce the protrusion and aerodynamic interference before moving to the next lace location, or the cord routed under the fabric to the next lace location as illustrated in figure 2-9a through figure 2-9c. The end cord is then cut off leaving a minimum of 1/4 inch stub. Lacing tension should be uniform.

(2) Repeated pulling of long lengths of lacing cord may remove wax coating from the cord and cause fraying. Convenient lengths of rib lacing cord may be used to lace long or thick ribs. The end of each length is tied off with a half hitch as illustrated in figure 2-9c, or if needed, separate lengths of lacing cord may be joined by using the splice knot illustrated in figure 2-10.

(3) Lacing is installed through other components, where applicable, in the same manner as a wing. Single, wide space lace attachments, usually used on empennage surfaces, are tied with a square knot and half hitch on each side, the same as a starting wing rib lace illustrated in figure 2-9a, steps 1 and 2. The lace may be rotated to place the knot under the fabric before cutting the cord.

e. Blind lacing on a fuselage, wing rib caps above and below a fuel tank, and any other component, when used by the original aircraft manufacturer, should be reinstalled in the same location and spacing as installed by the original aircraft manufacturer. The lace cord is routed around the stringer, rib cap, or other structure using an appropriate length, single or double pointed, curved needle as illustrated in figure 2-11. Blind laces are tied with a square knot, then pulled tight and secured with a half hitch at each side. The lace may be rotated to place the knot under the fabric surface before cutting the cord.



The splice knot is made by crossing the ends of the cord, and making four complete wraps with the small end of the free piece around the end of the standing piece. The end is then doubled back through the formed loop. The other free end is wrapped and doubled back. The long ends of the cords are then pulled until the knot is tight. The short ends are cut close to the knot. This finishes the splice knot.

FIGURE 2-10. Splice knot.

2-11. STITCH SPACING.

a. Rib lace spacing on wings, formerly referred to as stitch spacing, should be no greater than the spacing used by the original aircraft manufacturer. When the original spacing cannot be determined the maximum spacing illustrated in figure 2-12 should be used on the wings and wing control surfaces.

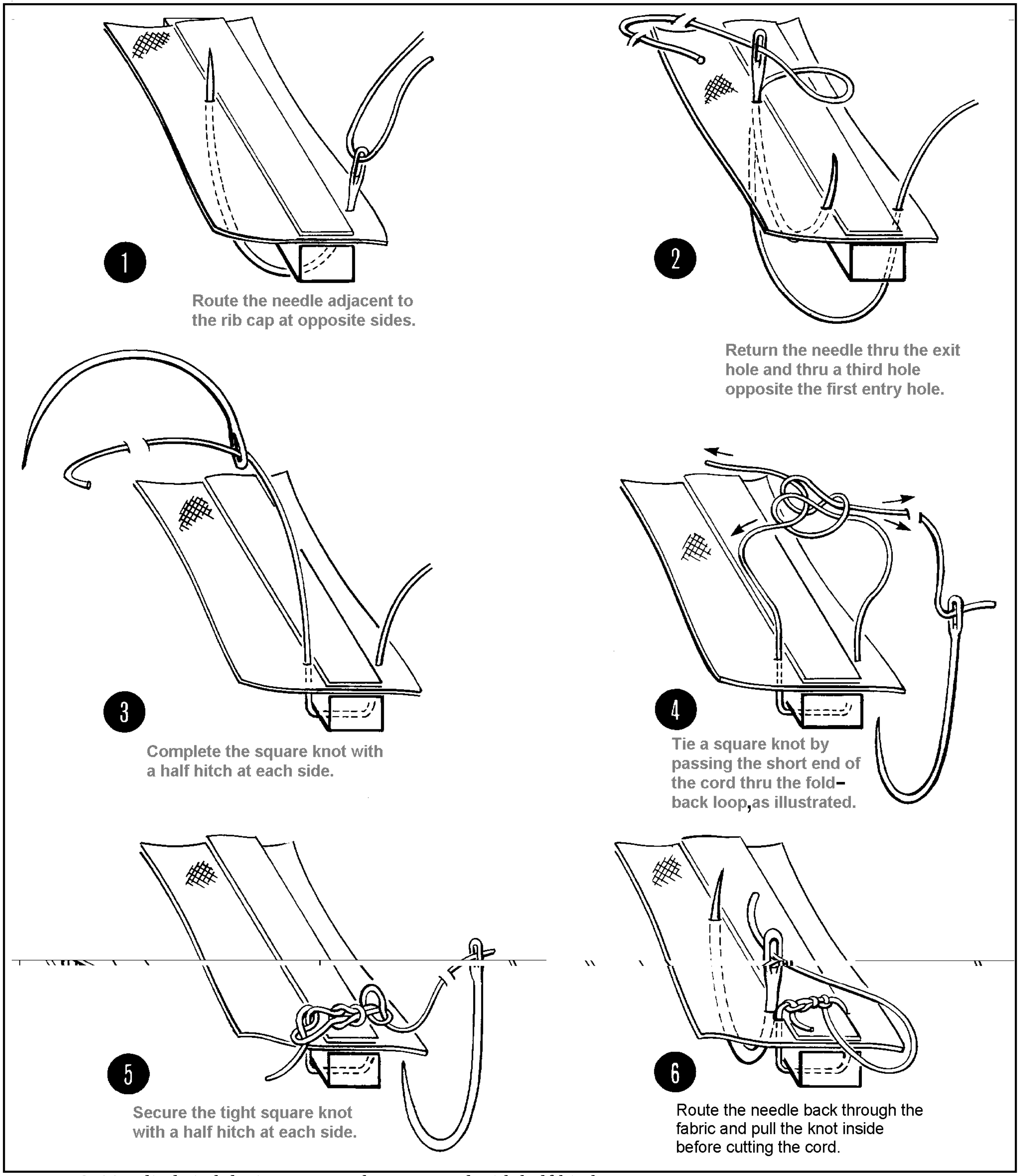


FIGURE 2-11. Blindstitch lacing - square knot secured with half hitches.

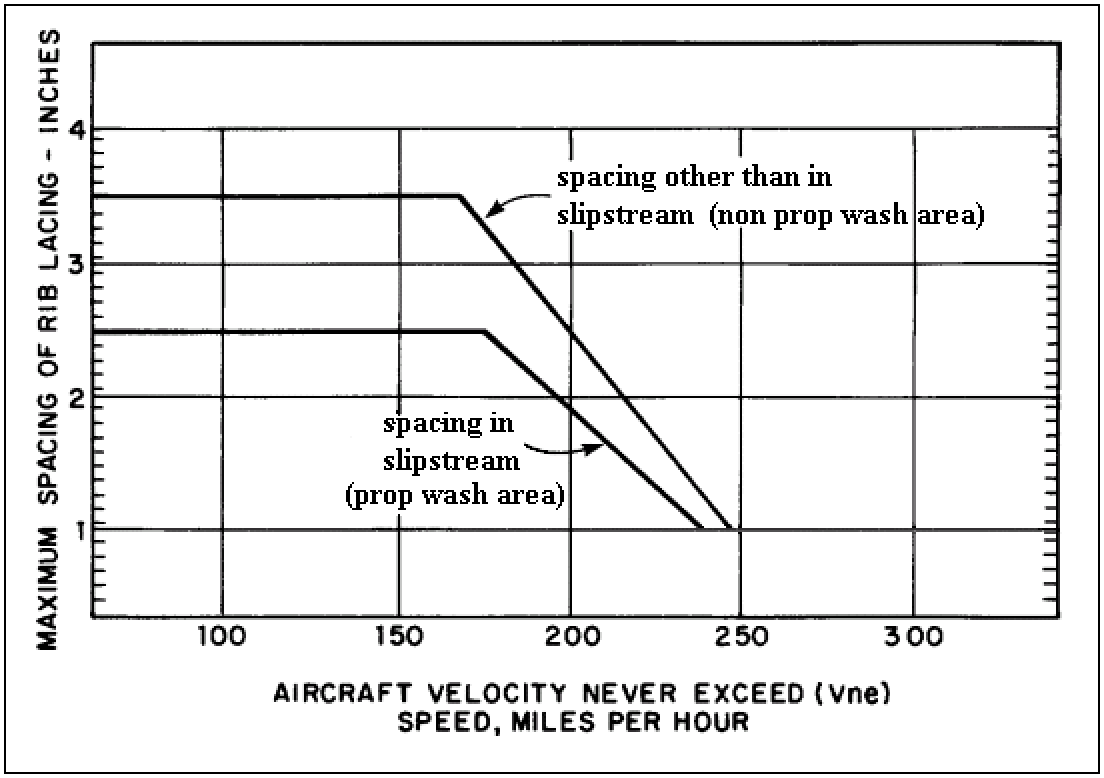


FIGURE 2-12. Fabric attachment spacing

b. When the original lace spacing on the empennage surfaces and fuselage, is not known, a maximum spacing of two times the spacing shown in figure 2-12 for the slipstream area (prop wash) on the wings may be used.

c. The installations of fabric attachments such as screws, rivets, wire clips, and rib lacing should be delayed until the fabric is stabilized and pulled taut with dope. This action is delayed to avoid pulling wing ribs and other structures out of alignment or tearing the fabric at attachment points as the fabric becomes taut. All lacing should be installed adjacent to the structure to which the fabric is being laced, to avoid tearing the fabric and/or creating slack in the cord loop when a load is applied. Where plastic washers were used by the aircraft manufacturer to provide increased pull-through resistance, under the heads of rivets or screws, the same diameter aluminum washer may be used as replacement. Aluminum washers are used because they are not affected by solvents found in adhesives or dopes, nor do they become brittle because of age or cold weather.

2-12. FASTENERS. Several light aircraft designs employ screws, rivets, or single-wire metal clips to secure the fabric to the wing.

a. Screws holding the old fabric can be removed after spinning a small sharpened tube around each screw or using a razor blade to cut and peel away the finishing tape. Care must be taken not to mark or scribe the underlying metal or wood structure. Blind rivets through ribs can be removed by drilling in the center to undercut the head.

b. Single-wire clips may be removed without damage to the rib by inserting a wide, thin screwdriver blade under the clip and carefully twisting. Apply a lifting force at the clip end to pull it up through the hole.

NOTE: It is important that any damage found to ribs, such as oversize rivet or screw holes, and cracks or breaks in the rib cap, should be tagged immediately for easy location and repair later.

c. When repairs are made to fabric surfaces attached by special mechanical methods, duplicate the original type of fastener. When self-tapping screws are used for the attachment of fabric to the rib structure, observe the following procedure:

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

(2) Extend the length of the screw beyond the rib capstrip at least two threads.

(3) Install a thin washer, preferably aluminum, under the heads of screws and dope pinked-edge tape over each screw head.

2-13. FINISHING TAPE.

a. Finishing tape (surface tape) is installed after the fabric has been pulled taut with the initial dope application. This procedure is performed to prevent ripples from forming in fabric panels adjacent to newly applied tapes. Ripple formation is caused by the inability of the combined tape and fabric to tighten uniformly with adjacent fabric when additional dope is applied.

b. In addition to the tape widths required to be installed over fabric seams specified in paragraph 2-7, finishing tape should be installed as weather protection over all rib lacing, screws, rivets, wire clips, or other devices used to secure fabric. This includes wings, control surface ribs, empennage surface ribs, and fuselage stringers, where so installed by the original aircraft manufacturer. Tape width should be sufficient to bond the fabric a minimum of 3/8 inch on each side of all fabric attachments. Two inch width tape is normally used. Tapes over wing rib lacing should extend a minimum of 1/2 inch past each end of any reinforcing tapes. Random or widely-spaced attachments may be covered by individual sections of fabric or finishing tape.

c. Installation of finishing tapes for additional wear resistance is recommended over the edges of all fabric-forming structures. This includes fuselage stringers, longerons, leading and trailing edges, false or nose ribs, control surfaces, and empennage ribs not already covered and protected by a finishing tape that is required to be on a fabric seam or fabric attached to the structure. Compound surfaces, such as wingtip bow and empennage surfaces, are more conveniently taped using bias cut finishing tape, which easily conforms to the compound contour, rather than notching linear cut tape to fit the surface. Bias cut tape will be reduced to approximately two thirds the original cut width when pulled tight around a wingtip bow and should be considered when selecting the width of tape for the various locations.

d. Finishing tapes are applied by coating the fabric surface over which the tape will be applied with dope, applying the tape over the wet dope film, then brushing the tape firmly onto the fabric surface. This action will assure a good bond by thoroughly saturating and wetting the finishing tape.

2-14. INSPECTION RINGS AND DRAIN GROMMETS.

a. Inspection Rings. Inspection access is provided adjacent to or over every control bellcrank, drag-wire junction, cable guide, pulley, wing fitting, or any other component throughout the aircraft which will be inspected or serviced annually. They are installed only on the bottom side of the wings except where installed on the top surface by the original manufacturer.

(1) Cutting the holes may be delayed until needed; however, all covers should be finished in matching colors with any trim lines and stored until needed. Spraying matching colors a year later is expensive and time consuming.

(2) The 3-9/16 inch inside diameter cellulose acetate butyrate (CAB) plastic inspection access rings have become popular and bond satisfactorily with Nitrate Dope or Fabric Cement. Any metal inspection hole reinforcements of a particular shape or special design or size, installed by the original manufacturer, should be reinstalled after cleaning.

(3) Tapes or patches over aluminum reinforcements are optional, but recommended in the prop-wash areas on the wings and forward fuselage bottom.

(4) Fabric patches over plastic rings are strongly recommended because plastic is not a stable material, becomes brittle at low temperatures, and fatigues and cracks from prop blast vibration. Plastic rings are often cracked during removal and installation of spring, clip-held covers. Patches with a minimum 1-inch overlap, should be installed with dope.

b. Drain Grommets. Atmospheric temperature changes cause the humidity in the air to condense on the inside of aircraft surfaces and pool in all low areas. Rainwater enters through openings in the sides and top, and when flying, everywhere throughout the structure. Taxiing on wet runways also splashes water up through any bottom holes. Therefore, provisions must be made to drain water from the lowest point in each fabric panel or plywood component throughout the airframe while in a stored attitude. Drain holes also provide needed ventilation.

(1) Install drain grommets on the under side of all components, at the lowest point in each fabric panel, when the aircraft is in stored attitude. Seaplane grommets, which feature a protruding lip to prevent water splashes through the drain hole, are recommended over drain holes subject to water splashing on land planes as well as seaplanes. The appropriate-size holes must be cut through the fabric before installing seaplane grommets. Plastic drain grommets may be doped directly to the fabric surface or mounted on fabric patches then doped to the covering. Installing a small fabric patch over flat grommets to ensure security is optional. Alternate brass grommets are mounted on fabric patches, then doped to the fabric.

(2) After all coating applications and sanding are completed, open all holes through flat drain grommets by cutting through the fabric with a small-blade knife. Do not attempt to open drain holes by punching with a sharp object because the drain hole will not remain open.

2-15.—2-19. [RESERVED.]

SECTION 2. APPLICATION OF DOPE

2-20. GENERAL. Nitrate dope and butyrate dope are manufactured by treating cellulose, derived from wood pulp or cotton linter with select acids, then dissolving in a blend of solvents and adding plasticizers for flexibility. After a brush or spray application on fabric, the film develops tension and strength as the solvents evaporate. The tension and strength will increase in proportion to the total film thickness. The fabric functions as a film former and carries no load until a crack develops in the dope film. An excessively-thick dope film will develop too much tension and may warp or damage a light airframe.

a. Viscosity adjustments for brush or spray applications may also vary between brands. When the viscosity adjustment ratio is not provided or is unclear, the product manufacturer should be contacted for detailed instructions. If instructions cannot be obtained or the source of the dope is unknown, the dope should be considered suspect and its use is not advised.

b. Dope, which has been stored for an extended period of time or under adverse conditions, should be suspected of becoming acidic and should be tested before being used on cotton or linen fabric. In some cases, fresh production dope has also been found to have a high acid content and will begin to deteriorate cotton or linen in a period of a few months. The acid content of nitrate or butyrate dope should not exceed 0.06 percent, calculated as acidic acid. An acidity test can be performed by most testing laboratories if high acid content is suspected.

c. Butyrate dope is superior to nitrate dope in weather exposure tests. However, nitrate dope provides better adhesion to natural fiber than butyrate dope. The adhesion of butyrate dope to natural fibers is adequate; it is not necessary to use nitrate dope for the first application and butyrate dope for all other applications. The presence of naphtha in nitrate dope, manufactured in accordance with canceled Mil Specs formulas, causes nitrate dope to be incompatible with butyrate dope; therefore, nitrate dope should not be applied over butyrate dope for repairs or refinishing; however, butyrate dope may be applied over nitrate dope.

NOTE: Nitrate or butyrate dope thinners and retarders should not be substituted for each other, nor should automotive coating-type thinners be used.

d. Clear dope produces the most tension and strength. Aluminum-pigmented dope will weigh slightly more than clear dope and develop less tension and strength for the same film thickness. Pigmented color finishes will produce the least tension and strength due to the higher ratio of plasticizers.

e. During the coating-buildup procedure, solvents released from each succeeding coat will penetrate and be absorbed into the previous dope film, temporarily releasing the tension and increasing the drying time between coats as the dope film becomes thicker. If elapsed time between coats exceeds several weeks at temperatures above 70 F, it is recommended that several spray coats of an appropriate dope thinner or dope with retarder and/or rejuvenator added be applied to the lightly-sanded, dried dope film to open the surface and provide cohesion for the next coat. This will reduce the possibility of surface cracks caused by dissimilar tension between the old and new dope film.

f. All dope coats through the final finish may be applied with a brush; however, brush marks will be noticeable in the finish. With increasing environmental concerns, high pressure airless and high-volume low-pressure (HVLP) paint spray equipment is recommended over conventional siphon and pressure pot spraying equipment. High pressure airless and HVLP paint spraying equipment will greatly reduce paint over-spray and fogging. A spray gun, single coat is applied by overlapping each consecutive pass 50 percent of the fan width. A double coat is applied by repeating the coating application in the same direction, or at a 90°€angle to the first coat (cross coat) before the first coat has flashed off or dried dust free. For safety and helpful tips for doping, see tables 2-3 and 2-4.

TABLE 2-3. Safety tips for dope/paint.

SAFETY TIPS.
Always ground the aircraft structure while sanding and painting.
Do not use an electric drill as a dope/paint mixer.
Wear leather-soled shoes in the dope/painting area.
Have an adequate, approved ventilation system.
Wear cotton clothes when doping or painting.
Wear an approved face mask or respirator when spraying.
Follow all the manufacturer's instructions.

TABLE 2-4. Tips for doping**.**

HELPFUL TIPS FOR DOPING.
Limits for optimum application of dope: relative humidity 20 to 60%; temperature range 65° to 75 °F.
Drying time will vary with temperature, humidity, amount of thinner used, and whether or not retarder was added to the mixture.
Do not recoat until the surface is completely dry and all active solvents have left the dope film.
Spray all coats except the first three or four clear coats, to avoid brush marks.
Over thinning is preferred to under thinning.
Addition of retarder will produce a smoother coat, but drying time between coats will be extended.
To get a clean line for the trim colors, apply a light coat of clear dope directly on the masking tape prior to painting. This will help eliminate the trim color from running under the masking tape.
Remember to always bring the dope to room temperature before using.
Rubbing compound and wax polish may be applied after all solvents have escaped (usually 2 weeks, depending upon the weather).

2-21. DOPE APPLICATION PROCEDURE (Natural Fabrics).

a. Step 1. After the cotton or linen fabric is installed in accordance with the procedures specified in paragraphs 2-7 and 2-8, the fabric is wetted with distilled water to remove wrinkles and fold creases, which will show in a gloss finish. Water may be applied by rubbing with a clean sponge or rag, or by using a paint spray gun. Do not use tap water. It may contain minerals which will contaminate the fabric.

(1) As water is absorbed by the fibers, the threads swell, resulting in temporary tauting of the fabric panel. The fabric should be allowed to dry before dope application, otherwise the water in the fibers will interfere with the dope penetration and adhesion.

(2) After the fabric has dried, the first coat of dope is applied, brushing in one direction to set the nap with a clean, non-shedding, 2-to 6-inch wide, semi-soft, long bristle paint brush.

(3) To offset the deteriorating effect of mildew or other fungus on natural fibers, especially in damp climates, it is recommended that a fungicide be added to the first coat of dope. The preferred fungicide is zinc dimethyldithiocarbamate powder, which should be prepared per the manufacturer's instructions. If no manufacturer's instructions are available the zinc powder may be stirred in at a ratio of 4 ounces, to one gallon of un-thinned nitrate or butyrate dope, after the powder is wetted to a paste with a 50/50 ratio of dope and thinner.

(4) Pre-mixed fungicidal dope, manufactured in accordance with the formula specified in MIL-D-7850, will have a transparent purple tint to indicate the fungicide additive. Dope manufactured with other colors to identify the manufacturers' products sold under proprietary trade names may or may not have a fungicidal additive.

(5) The viscosity of the dope should be adjusted to uniformly wet the fabric, indicated by the fabric becoming translucent so that it penetrates through the fabric but does not drip or run down the opposite side. Any dope-runs or pooling on the opposite side will shrink and distort the fabric, and may be visible on the finished surface.

(6) The ideal temperature for application of dope or other coatings is 65 to 75 F and the humidity should be less than 65 percent. As a general rule, each 10 F increase or decrease in ambient temperature will increase or decrease drying time by 100 percent. Dope should be allowed to warm to room temperature prior to attempting to adjust the viscosity.

b. Step 2. Depending upon the quality of the dope and the ratio of thinning, the fabric should start to become taut after the first brushed coat of dope has dried approximately 1 hour at 70 °F. A second, heavier coat is applied by cross brushing at 90°F to the first coat. Viscosity should be adjusted only as necessary to brush out a heavy uniform coat. If the fabric is not taut, with all sag removed, after the second coat has dried approximately 2 hours, a third coat may be applied.

c. Step 3. After the fabric has become semi-taut and stabilized with the initial dope application, and the rib lacing and other fabric attachments are completed as detailed in paragraphs 2-9 through 2-12, it is ready for "dressing out" as described in paragraphs 2-13 and 2-14.

d. NOTE: "Dressing out" means applying all the finishing tapes, reinforcing patches, inspection access ports, and drain grommets, etc.

e. Step 4. After the covering is a dressed out, one or more coats of clear dope are brushed over all finishing tapes and fabric reinforcing patches. This will balance the thickness of the dope film with the previously coated areas of the fabric. It is very important that the porosity of the fabric be filled while brushing to avoid pinholes showing in the finish.

f. Step 5. After drying at least 2 hours at 70 °F, a third heavy coat of clear dope is applied over the entire surface, preferably with a paint spray gun if brush marks are to be avoided. After the third coat of dope has dried at least 2 hours at 70 °F, the fabric should be taut and the dope film should show a gloss, depending upon the dope quality and the ratio of thinner added. If not, a fourth coat of clear dope may be applied, in the same manner as the third coat.

NOTE: Three to four clear coats of dope film showing a uniform gloss combined with the aluminum-pigmented coats and finish coats is considered satisfactory for light aircraft up to 9 lb. per square foot wing loading. Five to eight clear coats, depending upon the quality of the dope and resulting film thickness, are recommended for higher wing loading aircraft to assure the covering does not stretch and lose tension.

g. Step 6. After the clear coats are found to be satisfactory, two heavy cross-coats of aluminum-pigmented dope are applied with a spray gun to provide protection from ultraviolet (UV) rays. Tests have shown that UV radiation will deteriorate cotton, linen, and polyester fabric; however, polyester fabric deteriorates at a rate half that of cotton or linen under identical exposure conditions. UV radiation does not deteriorate glass fabric. Aluminum-pigmented dope blocks UV radiation and provides a sanding base. A gauge of ultraviolet protection in the field is to block all visible light from penetrating through the fabric. Drying time between the two coats should be at least 1 hour at 70 °F.

(1) An option to premixed aluminum dope is to use aluminum-pigment paste. Aluminum paste should be prepared per the manufacturer's instructions. If no manufacturer's instructions are available, mix 3 ounces (by weight), of 325-mesh aluminum-pigment paste, to 1 gallon of unthinned, clear dope. The aluminum paste should first be mixed to a cream consistency with a 50/50 ratio of dope and thinner before mixing into the unthinned clear dope. A higher ratio of aluminum-pigment added to the dope may cause a loss of primer-coat and finish-coat adhesion, and peeling may occur especially when high tack tape is used to mask for the trim colors and registration numbers.

(2) The viscosity of the mixed aluminum-pigmented dope should be adjusted for satisfactory spray gun application.

h. Step 7. After two coats of aluminum-pigmented dope have dried at least 4 hours at 70 °F, the surface may be wet sanded with # 280 grit (or finer) waterproof sandpaper. The aluminum-pigmented dope should be sanded only to develop a smooth surface, not sanded completely off to the clear dope undercoats. Do not sand over screwheads, rib lacing, or any structural sharp edges that will quickly cut through fabric and require patching. Additional coats of aluminum-pigmented dope may be applied and sanded, depending on the final finish desired. The last coat should not be sanded to assure ultraviolet protection along the edges of the finishing tapes and reinforcing patches is maintained.

i. Step 8. Three coats of pigmented color finish are applied with a paint spray gun, allowing adequate drying time between coats. The color finish may be wet sanded between coats, if desired, with a fine grit waterproof sandpaper. Adding blush retarder to the final dope finish will improve the gloss. After drying several weeks, a rubbing compound may be used to buff the finish and increase the gloss. A periodic application of a wax polish will help protect the finish from the weather and environmental pollution.

NOTE: Drain holes should be opened soon after all finishing is complete to insure drainage and to aid ventilation of the structure.

(1) When exposed to the sun, dark colors absorb more sun energy and convert that energy to heat more easily than light colors. High temperatures dry out wood structures and deteriorate organic materials in an aircraft structure. Preferably the lighter color shades are applied first and then overcoated with darker trim and registration number colors.

(2) Only high-quality, solvent-resistant crepe paper or polypropylene masking tape should be used to avoid finish bleed under the tape edge. Newspaper printing ink may transfer to a fresh finish and should not be used for masking paper. Plastic sheeting should not be used as a dust cover on a fresh finish due to possible bonding and damage.

2-22. COVERING OVER PLYWOOD. Exposed, stressed plywood surfaces, such as wings, must be protected from weather deterioration with fabric at least equal to that used by the original manufacturer. If the quality is not known, intermediate-grade fabric, meeting TSO-C14b specification, is acceptable. Fabric may be installed in sections with a 1/2 inch edge overlap without covering the overlap with finishing tape. Fabric may also be installed with the edges butted together, and the seam covered with a minimum 1-inch wide finishing tape. The seams may be oriented in any direction, in reference to the line of flight. However, overlapped seams, not covered with a finishing tape, should be oriented rearward. Fabric should be wrapped completely around a wing's leading and trailing edges and other components, where possible, to provide fabric-to-fabric continuity around all edges to avoid a poorly-bonded fabric edge from peeling from the plywood surface causing serious aerodynamic consequences.

a. After the plywood surface is prepared, and the two pre-coats of clear dope have dried as recommended in paragraph 2-6 g, the fabric is pulled snug and bonded with clear dope around the perimeter of the fabric section. The fabric is then wetted with distilled water to remove fold creases, in the same manner described for fabric panel areas. After the water has evaporated, a heavy coat of low-viscosity clear dope is brushed firmly through the fabric to soften the underlying dope pre-coat, insuring a good bond. Brushing techniques should be accomplished by moving the brush from one side across to the opposite side to remove all air bubbles and thoroughly saturate the fabric. This is indicated by the plywood grain being easily visible through the translucent fabric. Except for very small imperfections or small dents in the plywood surface, voids are not permissible between the fabric and plywood surfaces. Voids may allow the fabric to balloon from the plywood surface, creating adverse handling characteristics.

b. After the first dope coat has dried at least 1 hour at 70 °F, a second heavy coat of clear dope is applied by brush to fill the fabric weave and prevent pinholes. The installation of finish tape around the perimeter of the plywood surfaces, leading edges, and other wear points, is optional but recommended for wear and chafe protection. The application of aluminum-pigmented dope coating, sanding, and finish coats will be the same as that specified for fabric panel areas. Reinforcement grommets are not required on drain holes through plywood surfaces.

2-23. COATING APPLICATION DEFECTS.

a. Blushing. The appearance of light shaded dull areas on the surface as dope dries is the result of moisture in the atmosphere condensing on a surface due to the cooling effect of the fast-evaporating components of dope thinner escaping from the coating. Blushing can occur at any temperature when the humidity is above 65 percent. There are several ways to remedy this problem. The drying time may be slowed by adding up to 1 quart of blush retarder to 1 gallon of dope or by increasing the temperature of the dope room and eliminating any cooling draft from blowing across the surface. Blushed surfaces may be reworked by spraying several, closely-timed coats of a 50/50 blend of blush retarder and dope thinner to soften and return the dope surface to the original liquid state. Blush retarder, mixed with dope, may delay the full drying time by several days, but will eventually escape from the dope film if the room temperature is maintained an average of 70 °F.

b. Pinholes. Voids between the fabric threads that are not filled with the first coats of dope are called pinholes. They may be caused by fabric contamination, such as oil or finger prints, but are usually the result of improper dope application. Pinholes are usually found in a second layer of fabric such as finishing tapes and reinforcing patches or over underlying, non-porous structures; such as leading edges, turtle decks, and plywood surfaces. Any non-porous structure under fabric will act as a backstop and will resist complete dope penetration into the fabric. Microscopic cavities between the backstop and fabric collect escaping solvent vapors during the drying process and balloon up through the surface leaving pinholes, or become pinholes when the top of the balloon is sanded. Moisture, in the fabric or on the backstop surface, also interferes with complete dope penetration, resulting in pinholes. The remedy for pinholes, at any stage before the final finish coat, is to add blush retarder to low viscosity dope and carefully brush over the affected surfaces to penetrate into and fill the pinholes. Discontinue brushing after five or six strokes to avoid leaving brush marks.

c. Orange Peel. A rough spray gun-applied finish, similar to the texture of an orange peel, may be caused by one or more of the following conditions:

(1) Viscosity of material being sprayed is too high.

(2) Air temperature is too high.

(3) Spraying in direct sunlight, onto a hot surface or in a drafty/windy condition, which causes a fast solvent evaporation.

(4) Spray gun, tip, cap, and/or needle are not properly matched for the type material being sprayed.

(5) Volume of air available from the compressor not sufficient for spray gun.

(6) Wrong thinner used and drying too fast.

(7) Spray gun not properly adjusted. The spray gun should be adjusted to a uniform spray pattern with the material atomized to deposit fine, wet particles that merge and form a smooth film.

d. Blisters. One or more of the following conditions my cause blisters:

(1) Freshly coated surface placed in hot sunlight or high temperature area to accelerate drying time, causing the vapor from rapidly evaporating solvents to be trapped.

(2) Excessive high air pressure used to spray heavy coats which “blasts” air bubbles into the coating.

(3) Water or oil in air supply.

e. Runs, Sags, and Curtains. These defects may be caused by one or more of the following conditions:

(1) Viscosity of material being sprayed is too low.

(2) Coats applied too heavily.

(3) Insufficient drying time between coats.

(4) Spray gun held too close to work surface.

(5) Improperly adjusted spray gun.

f. Spray Gun Laps and Streaks. These defects may be caused by one or more of the following conditions:

(1) Spray gun not properly adjusted to spray a wet, smooth surface.

(2) Overspray on a partially-dried surface.

(3) Spray pattern not sufficiently overlapped on each pass.

(4) Viscosity of material being sprayed is too high.

(5) Metallic finishes sprayed too heavily allowing metallic pigments to move or flow after deposit, causing a marbled appearance.

2-24.—2-29. [RESERVED.]

SECTION 3. INSPECTION AND TESTING

2-30. GENERAL. All components of the covering should be inspected for general condition. Loose finishing tape and reinforcing patches; chafing under fairings; brittle, cracking, peeling, or deteriorated coatings; fabric tears and rock damage; broken or missing rib lacing; and rodent nests are unacceptable. The entire fabric covering should be uniformly taut with no loose or wrinkled areas, or excess tension which can warp and damage the airframe.

a. Excess Tension. There are no methods or specifications for measuring acceptable fabric tension other than observation. Excess tension may warp critical components, such as longerons, wing rib, and trailing edges out of position, weakening the airframe structure.

(1) Excess tension with cotton, linen, and glass fiber fabric covering is usually caused by excessive dope film on a new covering, or continuous shrinking of an originally satisfactory dope film as the plasticizers migrate from the dope with age. Heat from sun exposure accelerates plasticizer migration.

(2) Excess tension with polyester fabric, coated with dope, is usually caused by the combined tension of the heat tautened polyester fabric and continuous shrinking of the dope film as the plasticizers migrate from the dope with age.

b. Loose Fabric. Fabric that flutters or ripples in the propeller slipstream, balloons, or is depressed excessively in flight from the static position, is unacceptable.

(1) Loose or wrinkled cotton, linen, and glass fabric covering may be caused by inadequate dope film; poor quality dope; fabric installed with excess slack; or by a bent, broken, or warped structure.

(2) Loose or wrinkled polyester fabric covering, finished with coatings other than dope, may be caused by inadequate or excessive heat application; excess slack when the fabric was installed; or bent or warped structure. Polyester fabric which does not meet aircraft quality specifications will very likely become loose after a short period of time.

(3) Glass fabric covering should be tested with a large suction cup for rib lacing cord failure and reinforcing tape failure caused by chafing on all wing ribs and other structural attachments throughout the airframe. Particular attention should be given to the area within the propeller slipstream. If failure is indicated by the covering lifting from the static position, the rib lacing cord and reinforcing tape must be reinstalled with double the number of original laces.

NOTE: Temporary wrinkles will develop in any fabric coated and finished with dope, when moisture from rain, heavy fog, or dew is absorbed into a poor-quality dope film, causing the film to expand. Temporary wrinkles may also develop with any type of thick coatings, on any type of fabric, when an aircraft is moved from a cold storage area to a warm hangar or parked in the warming sunshine, causing rapid thermal expansion of the coating.

c. Coating Cracks. Fabric exposed through cracks in the coating may be initially tested for deterioration by pressing firmly with a thumb to check the fabric's strength. Natural fibers deteriorate by exposure to ultraviolet radiation, mildew, fungus from moisture, high acid-content rain, dew, fog, pollution, and age. Polyester filaments will deteriorate by exposure to UV radiation.

(1) Glass fabric will not deteriorate from UV exposure, but will be deteriorated by acid rain, dew fallout, and chaffing if loose in the prop blast area.

(2) Cotton, linen, and glass fabric coverings are dependent solely on the strength and tautening characteristics of the dope film to carry the airloads. Dope coatings on heat-tautened polyester fabric will also absorb all the airloads because the elongation of polyester filaments are considerably higher than the dope film. Polyester fabric that is coated with materials other than dope, is dependent solely on the heat tautening and low-elongation characteristics of the polyester filaments to develop tension and transmit the airloads to the airframe without excess distortion from a static position.

(3) Cracks in coatings will allow any type of exposed fabric to deteriorate. Cracks should be closed by sealing or removing the coatings in the immediate area and replace with new coatings, or recover the component.

2-31. FABRIC IDENTIFICATION. Cotton Fabric meeting TSO-C15 or TSO-C14 can be identified by an off-white color and thread count of 80 to 94 for TSO-C14b and 80 to 84 for TSO-C15d in both directions.

a. Aircraft linen conforming to British specification 7F1 may be identified by a slightly darker shade than cotton fabric and irregular thread spacing. The average thread count will be about the same as Grade A fabric (TSO-C15d). The non-uniformity of the linen thread size is also noticeable, with one thread half the size of the adjacent thread. When viewed under a magnifying glass, the ends of the cotton and linen fiber nap may be seen on the backside. The nap is also seen when the coating is removed from the front or outside surface. A light-purple color showing on the back side of cotton or linen fabric indicates a fungicide was present in the dope to resist deterioration by fungus and mildew.

b. Polyester fabric conforming to TSO-C14b or TSO-C15d is whiter in color than cotton or linen. The fabric styles adapted for use as aircraft covering have a variety of thread counts, up to ninety-four (94), depending on the manufacturing source, weight, and breaking strength. Polyester is a monofilament and will not have any nap or filament ends showing.

c. Glass fabric is manufactured white in color, and one source is precoated with a blue-tinted dope as a primer and to reduce weave distortion during handling. Thread count will be approximately 36 threads per inch. Glass fabrics are monofilament and will not have any nap or filament ends showing unless they are inadvertently broken.

d. When a small fabric sample can be removed from the aircraft and all the coatings removed, a burn test will readily distinguish between natural fabric, polyester, and glass fabric. Cotton and linen will burn to a dry ash, polyester filaments will melt to a liquid and continue burning to a charred ash, and glass filaments, which do not support combustion, will become incandescent over a flame.

2-32. COATING IDENTIFICATION. Nitrate or butyrate dope must be used to develop tension on cotton, linen, and glass fabrics. When a small sample can be removed, burn tests will distinguish nitrate dope-coated fabric from butyrate dope-coated fabric by its immediate ignition and accelerated combustion. Butyrate dope will burn at less than one-half the rate of nitrate dope. Coating types other than nitrate or butyrate dope may have been used as a finish over dope on cotton, linen, and glass fiber fabric coverings.

a. If the fabric type is determined to be polyester, coating identification should start by reviewing the aircraft records and inspecting the inside of the wings and the fuselage for the required fabric source identification stamps for covering materials authorized under the STC. The manual, furnished by the holder of the STC-approved fabric, should be reviewed to determine whether the coatings are those specified by the STC.

b. Coating types, other than those authorized by the original STC, may have been used with prior FAA approval, and this would be noted in the aircraft records. The presence of dope on polyester can be detected by a sample burn test.

2-33. STRENGTH CRITERIA FOR AIRCRAFT FABRIC. Minimum performance standards for new intermediate-grade fabric are specified in TSO-C14b, which references AMS 3804C. Minimum performance standards for new Grade A fabric are specified in TSO-C15d, which references AMS 3806D.

a. The condition of the fabric covering must be determined on every 100-hour and annual inspection, because the strength of the fabric is a definite factor in the airworthiness of an airplane. Fabric is considered to be airworthy until it deteriorates to a breaking strength less than 70 percent of the strength of new fabric required for the aircraft. For example, if grade-A cotton is used on an airplane that requires only intermediate fabric, it can deteriorate to 46 pounds per inch width (70 percent of the strength of intermediate fabric) before it must be replaced.

b. Fabric installed on aircraft with a wing loading less than 9 lb. per square foot (psf), and a Vne less than 160 mph, will be considered unairworthy when the breaking strength has deteriorated below 46 lb. per inch width, regardless of the fabric grade. Fabric installed on aircraft with a wing loading of 9 lb. per square foot and over, or a Vne of 160 mph and over, will be considered unairworthy when the breaking strength has deteriorated below 56 lb. per inch width.

c. Fabric installed on a glider or sailplane with a wing loading of 8 lb. per square foot and less, and a Vne of 135 mph or less, will be considered unairworthy when the fabric breaking strength has deteriorated below 35 lb. per inch width, regardless of the fabric grade.

2-34. FABRIC TESTING. Mechanical devices used to test fabric by pressing against or piercing the finished fabric are not FAA approved and are used at the discretion of the mechanic to base an opinion on the general fabric condition. Punch test accuracy will depend on the individual device calibration, total coating thickness, brittleness, and types of coatings and fabric. Mechanical devices are not applicable to glass fiber fabric that will easily shear and indicate a very low reading regardless of the true breaking strength. If the fabric tests in the lower breaking strength range with the mechanical punch tester or if the overall fabric cover conditions are poor, then more accurate field tests may be made. Cut a 1-1/4-inch wide by 4-inch long sample from a top exposed surface, remove all coatings and ravel the edges to a 1-inch width. Clamp each end between suitable clamps with one clamp anchored to a support structure while a load is applied (see table 2-1) by adding sand in a suitable container suspended a few inches above the floor. If the breaking strength is still in question, a sample should be sent to a qualified testing laboratory and breaking strength tests made in accordance with American Society of Testing Materials (ASTM) publication D5035.

NOTE: ASTM publication D1682 has been discontinued but is still referred to in some Aerospace Material Specification (AMS). The grab test method previously listed in ASTM D1682, sections 1 through 16, has been superseded by ASTM publication D5034. The strip testing method (most commonly used in aircraft) previously listed in ASTM D1682, sections 17 through 21, has been superseded by ASTM publication D5035.

2-35. REJUVENATION OF THE DOPE FILM. If fabric loses its strength, there is nothing to do but remove it and recover the aircraft. But if the fabric is good and the dope is cracked, it may be treated with rejuvenator, a mixture of very potent solvents and plasticizers, to restore its resilience. The surface of the fabric is cleaned and the rejuvenator sprayed on in a wet coat, and the solvents soften the old finish so the plasticizers can become part of the film. When the rejuvenator dries, the surface should be sprayed with two coats of aluminum-pigmented dope, then sanded and a third coat of aluminum-pigmented dope applied, followed with the colored-dope finish. When repairing, rejuvenating, and refinishing covering materials approved under an STC, instructions in the manual furnished by the material supplier should be followed.

2-36.—2-41. [RESERVED.]

SECTION 4. REPAIRS TO FABRIC COVERING

2-42. GENERAL. All materials used to make repairs to fabric covering must be of a quality at least equal to the original materials. Workmanship and repair methods must be made in a manner that will return the fabric covering to its original airworthy condition.

a. Any combination of seams hand-sewn and overlapped and doped may be used to make repairs and install new fabric sections. (See paragraph 2-7.)

b. All pigmented dope coats, including aluminum-pigmented coats, should be removed to the clear dope preliminary coats before installing a new fabric section or finishing tape on the old fabric. The appropriate dope thinner (see paragraph 2-20) may be applied with a brush to soften the old dope. The softened coats can then be removed down to the clear dope coats by scraping with a dull-bladed knife while supporting the fabric from the back side. Removing the old dope by sanding is optional.

c. Avoid allowing dope to run down the back side of the fabric or drip through the wing onto the back side of the opposite surface, which will cause cosmetic damage and will show in a high gloss finish.

d. Repairing a new fabric section over two adjacent wing ribs is considered a major repair. A log book entry and an FAA Form 337 must be processed accordingly.

e. All fabric patch edges not covered with a finishing tape should have a pinked edge or a 1/4-inch raveled edge.

f. Where the edge of a new fabric section will be located within 1 inch of a structural member to which the fabric is attached by rib lacing or other methods, the new fabric section should be extended 3 inches past the structural member.

NOTE: Before installing new finishing tape, duplicate the original rib lacing or other attachments without removing the original rib lacing or attachment. Removing the original finishing tape is optional.

g. When installing large sections of fabric on a wing or other components, all machine-sewn and/or overlapped and doped seams should be made in accordance with the guidelines specified in paragraphs 2-7 and 2-8.

h. When repairing a covering material other than cotton or linen, which was approved with the manufacturer's type certificate (TC), or approved under the authority of an STC, follow the repair instructions furnished by the aircraft manufacturer or supplier of the STC-approved covering materials.

2-43. REPAIR OF TEARS AND ACCESS OPENINGS. When all the original fabric is intact, an opening may be repaired by sewing the two sides together with a curved needle as illustrated in figures 2-13 and 2-14. The fabric edges should be pulled together uniformly with no wrinkles. Before sewing, remove the old dope coats down to the clear dope coats a distance of 2 inches on each side of the opening. The hand-sewn thread quality should be at least equal to that specified in table 2-2 and treated with wax (paraffin-free or beeswax) to prevent fraying, or use the proper thread on the STC application. After sewing, apply a coat of clear dope over the cleaned area and install a 3-inch wide finishing tape, centered over the stitches.

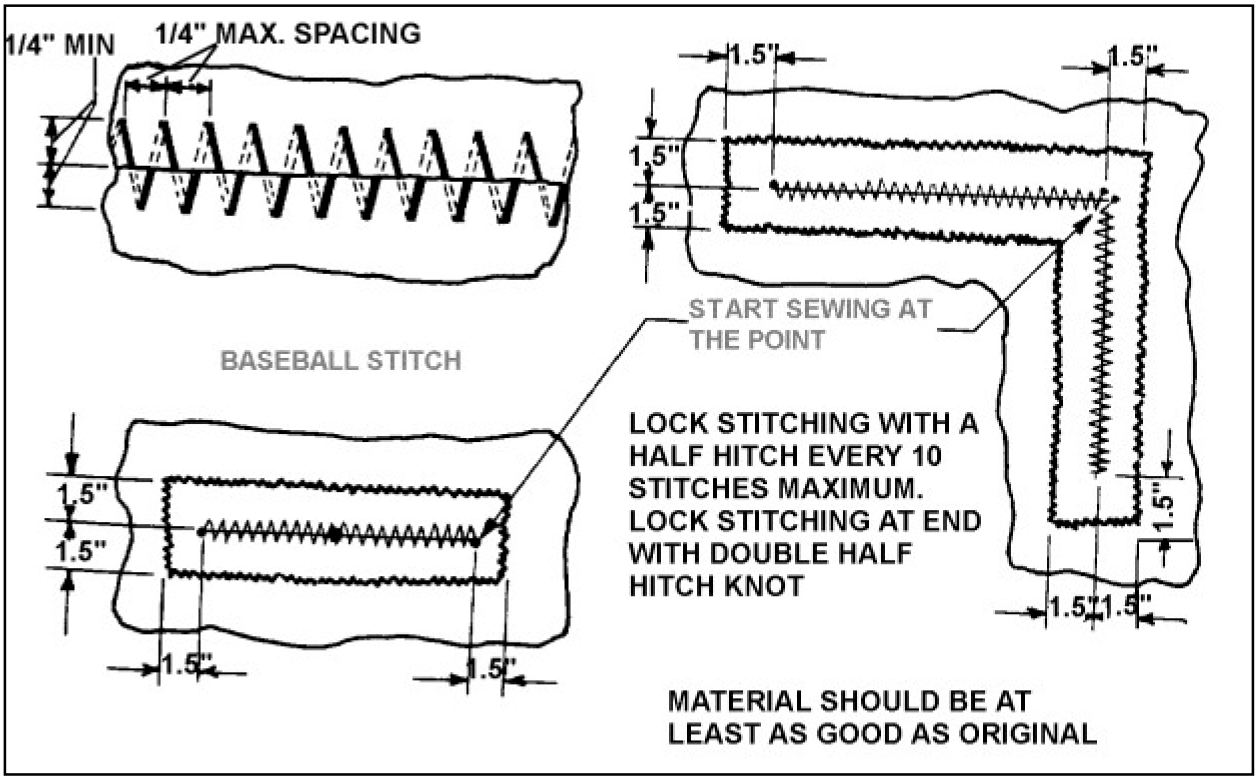


FIGURE 2-13. Repair of tears in fabric.

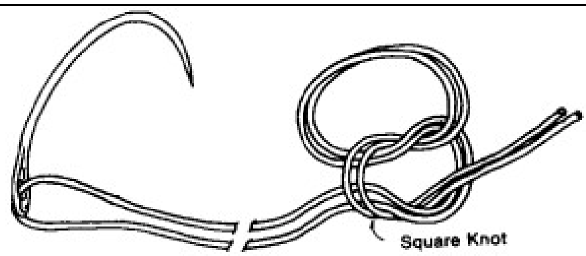
a. Finishing tapes should be well saturated with dope and smoothed out with no voids or wrinkles during installation. After drying for 1 hour at 70 °F, additional coats of clear dope followed with pigmented dope are applied as detailed in paragraph 2-21.

b. If the opening is more than 8 inches long but less than 16 inches long in any direction, the finishing tape width should be increased to 4 inches.

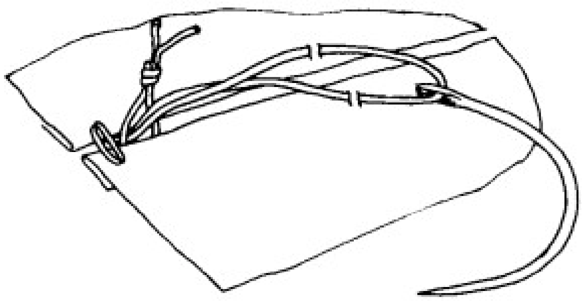
c. The finishing tape width should be increased to 6 inches if the opening is more than 16 inches long in any direction, is located on a wing top surface, or the aircraft Vne speed is greater than 150 mph.

2-44. SEWN-PATCH REPAIR. Openings that cannot be repaired by closing with stitches may be repaired by sewing in a new fabric section. The edges of the fabric around the opening should be trimmed straight on four sides to facilitate the installation of straight sections of finishing tape over the stitches.

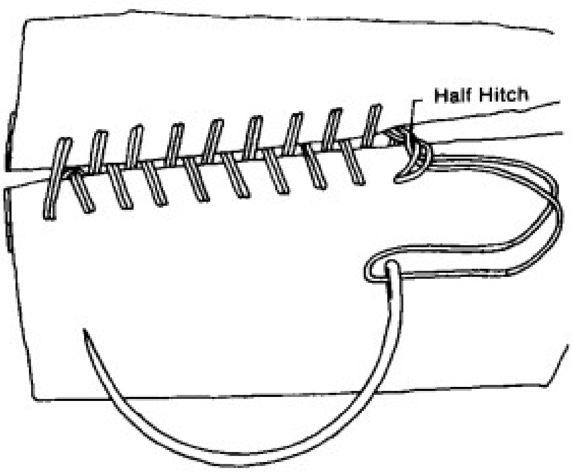
a. After cutting out the damaged section and removing the coatings as detailed in paragraph 2-42, the new fabric section should be sized to allow folding both edges of the fabric back 1/2-inch to increase the stitch tear resistance. Temporarily attach the four corners in position with thread. Start with a double thread with a square knot at the end (see figure 2-14) and continue stitching in the manner described in figures 2-13 and 2-14. When the stitching is complete, wet the new fabric section as described in paragraph 2-21 to remove any creases. After drying, apply one coat of clear dope on the new fabric, as described in paragraph 2-21. When the first coat of dope has dried 1 hour at 70 °F, apply a 3-inch wide finishing tape, centered over the stitches. The finishing tape should be well saturated with



Step 1. Tie the thread ends together with a square knot.



Step 2. Start the stitch by routing through the loop, positioning the square knot on the inside.



Step 3. Complete the hand-stitch and secure the stitching with a half hitch at a maximum each 10 stitches.

FIGURE 2-14. Hand-stitch detail.

dope and smoothed out with no voids or wrinkles. Additional coats of clear dope and pigmented dope are then applied to obtain the desired tautness and finish, as described in paragraph 2-21.

b. If the opening is more than 8 inches but less than 16 inches long in any direction, the finishing tape should be 4 inches wide.

c. The finishing tape width should be 6 inches wide if the opening is over 16 inches long in any direction, is located on a wing top surface, or the aircraft Vne speed is greater than 150 mph.

2-45. DOPED-ON PATCH REPAIR. An opening not over 8 inches in length in any direction, on an aircraft with a Vne speed less than 150 mph, may be repaired with a 2-inch overlapped and doped patch. The opening should be trimmed to eliminate any irregular edges and old pigmented dope coats removed as described in paragraph 2-42.

a. When installing a fabric patch over a small opening, the loose edge of the fabric around the opening may be secured by extending a series of small threads, from the edge across the opening, to the opposite side. After the patch is completed, the threads may be clipped and removed through an access port or left in place.

b. The fabric patch is installed by applying a coat of clear dope around the opening, then positioning the patch over the opening. Brush out any void or wrinkles while saturating only the fabric overlap area. After the first coat of clear dope around the edge has dried 1 hour at 70 °F, wet the fabric patch to remove any creases as described in paragraph 2-21. After drying, apply additional coats of clear dope and pigmented dope over the entire patch as described in paragraph 2-21.

c. If the opening is less than 8 inches in length in any direction and the aircraft Vne speed is greater than 150 mph, a 2-inch wide finishing tape should be installed on all sides, centered on the edge of the 2-inch overlap patch.

d. If the opening is more than 8 inches but less than 16 inches in length, in any direction on an aircraft with a Vne speed less than

150 mph, it may be repaired with a doped patch, which is overlapped 1/4 of the opening maximum dimension. The maximum overlap should not exceed 4 inches.

e. If the opening is more than 8 inches but less than 16 inches in length in any direction, the repair is located on a wing top surface, and the aircraft Vne speed is greater than 150 mph, the patch overlap should be 4 inches and a 2-inch wide finishing tape installed on all sides, centered on the edge of the patch.

f. If the opening is more than 16 inches in length in any direction and the Vne speed is less than 150 mph, the patch overlap should be 4 inches and the finishing tape should be 4 inches in width, centered on the edge of the patch.

g. If the opening is more than 16 inches in length in any direction and the Vne speed is greater than 150 mph, the patch overlap should be 4 inches and the finishing tape should be 6 inches in width, centered on the edge of the patch.

2-46.—2-51. [RESERVED.]