CHAPTER V.

WOOD AND COMPOSITE CONSTRUCTION.

General.

129. In modern designs of aircraft for service use, wood is seldom employed for the main members, its use being confined to subsidiary structure and fairings. There are perhaps two main reasons for this, and they are, firstly, that the kind of timber used is not grown in England in sufficient quantities to provide adequate supplies, and has therefore to be imported. This would prove to be a serious handicap in any national emergency in which a large number of aircraft were required immediately. Secondly, wooden aircraft structures are very much affected by extremes of atmospheric conditions and are therefore expensive to maintain in tropical or sub-tropical countries.

130. It is, however, doubtful if under normal conditions, wood will be entirely eliminated in the construction of aircraft of all types; therefore, a short description of the more usual forms of construction is given.

Wooden construction.

131. In comparison with all-metal aircraft, the wooden type is undoubtedly cheaper to produce in any but very large quantities, not so much on account of the cost of materials, as of labour and the plant required for manufacture. Also wooden aircraft structures are generally slightly lighter than the corresponding metal type, though this greatly depends upon the size and type of the aircraft. In the light plane class, say up to 2,000 lb., wood has a distinct advantage over metal on the score of weight, but in the medium weight range, although wooden aircraft are usually lighter than metal aircraft of the same type, it is much a matter of the duties of the aircraft and the care with which the metal aircraft has been designed. In the larger aircraft, all-metal construction is generally considered to be superior to wood as regards weight. Wooden aircraft structures can absorb vibrations and minor shocks without material damage to a greater extent than can metal, but under large shock loads, say in the event of a crash, wood is more apt to splinter and totally collapse. Repairs are made comparatively easily to wooden structures, and as a rule do not require the skill generally necessary for repairing metal parts.

Composite construction.

132. Composite aircraft are those aircraft which have some of the main members formed of wood and some of metal.

This type of construction has the advantage that the material best suited to the individual parts can be used. Composite aircraft may have metal spars with wooden ribs or completely wooden wings, but with the fuselage made wholly, or partly of metal. Many modern aircraft are built in this way, as this type of construction usually provides a very rigid structure with a long life. The cost of production varies in accordance with the number and type of metal parts employed, but, if economy has been observed, the cost in labour and materials is little more than that of wood, and the weight should not greatly exceed that of a corresponding wooden structure.

Timber.

133. All timber for use in aircraft construction is very carefully selected and stored, but even so a considerable wastage occurs, due to the many diseases and defects such as shakes, checks, knots, gum pockets, seasoning cracks, dote, spiral grain, and so on.

134. On account of its light weight, straight grain, strength and easy working, spruce is the most widely used form of timber for aircraft use. Other woods are used, such as mahogany, ash, and cedar, but owing to their weight these kinds are normally only used for airscrews and packing blocks and other parts of the aircraft where special hardness or strength is required. Ply wood is used extensively for fairings and other parts, and is valued on account of its strength, pliability and general adaptability for aircraft purposes, but is comparatively heavy.

135. Wooden aircraft components very quickly deteriorate if they are subjected to extremes of humidity or dryness of the atmosphere. The glued joints are the first to suffer if it is too damp, and timber shrinkage occurs if the conditions are too dry. Timber shrinkage causes disruption of the glued joints, and slackness of all metal fittings.

136. Constant periodic inspection is necessary during the storage of wooden airframes or aircraft components, and as far as possible a constant temperature of between 50° and 60° F. is to be maintained in the storage sheds, if the parts are to be properly preserved.

Glued joints.

137. Glued joints play a great part in the construction of wooden aircraft, and the condition of the glued joints is some measure of the serviceability of the aircraft. For this reason special measures are taken with the glued joints of any main member, to assist as far as is possible in the maintenance of the joints under any conditions of service. The usual

method adopted is to cover the joint with a strip of tape, which is glued and then well varnished. Great care has to be taken when making glued joints to ensure that the glue is acting as an efficient fixative, and the precautions to be taken vary with the type of glue used. Cold glues are in more general use than hot glues, and these have to be applied in the manner stated in the specification for the particular kind of glue. A glued joint properly made, between two pieces of light timber, can be as strong as the timber itself. This does not apply to joints made on the end grains, or between pieces of hard or close-grained timber. Joints made with cold glue are not quite so strong in the first instance as those made with ordinary glue, but as cold glues are generally considered to be more waterproof, the joints made with these substances would probably be in better condition after some period of service.

138. The supply of straight-grained timber in lengths suitable for members such as longerons, is strictly limited. Therefore, two shorter pieces of timber are sometimes spliced together to make up the length required. On all members subject to bending, the splice is placed at the point of contra-flexure, or that portion of the member where the least bending occurs. Struts are very rarely spliced. The length of the

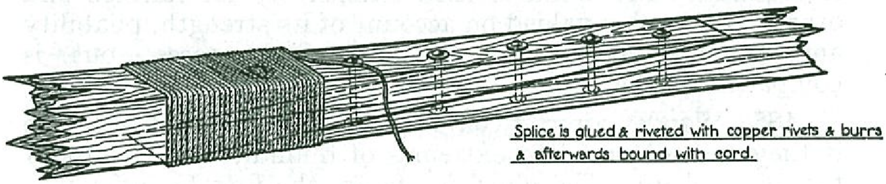


FIG. 31.—Splice in wooden member.

tapered portion of the member forming the splice is never less than nine times the width of the member at the join. Fig. 31 shows a typical splice in a longeron. It will be noted that rivets and binding cord are used in addition to glue. The additional precautions are not required for strength alone, but are provided to prevent, as far as possible, any deterioration of the glued joints under adverse conditions.

Wooden planes.

139. In their general aspect, that is, considering the actual structural design as apart from the materials used, there is a marked similarity between the planes of all biplanes, and this is especially so with regard to wooden planes. Fig. 32 represents a typical example of a wooden plane with the fabric

stripped off. In this case, it will be noted that solid spindled, or I-section spars have been used, and also that certain of the

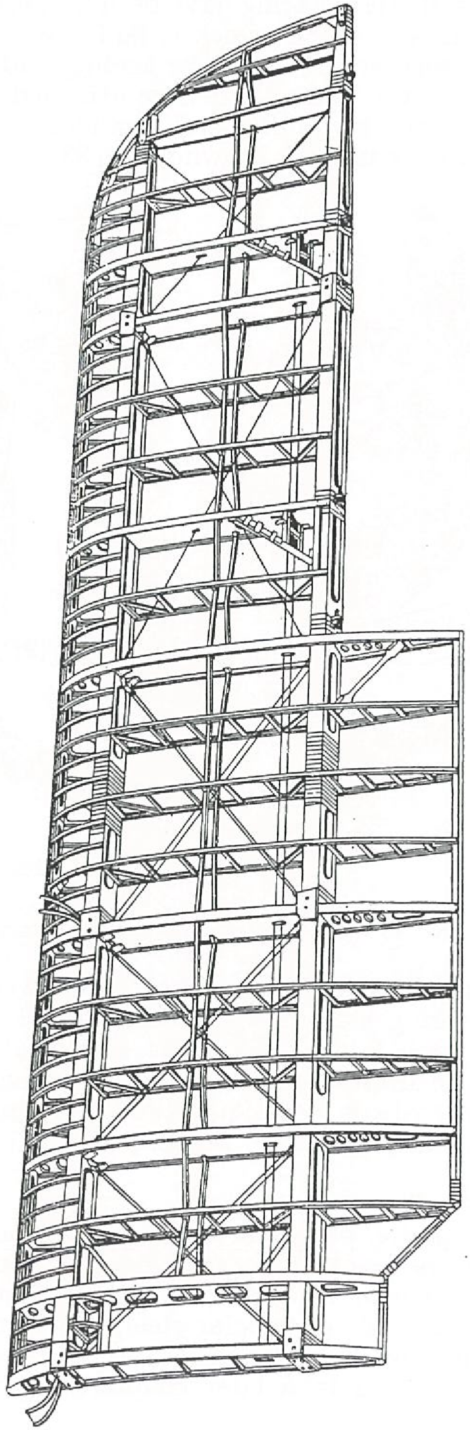


Fig. 32.—Typical wooden plane.

ribs are solid and act as the drag struts, instead of these parts forming a separate item as they often do. Also, that the three inner sections of cross bracing have been duplicated to comply with the " cut wire case," which is laid down as a necessary condition for service aircraft. The leading and trailing edges are made of spruce, and the ribs are attached to these parts and to the spars by gluing and bradding. Some typical interplane strut fittings are shown in fig. 33.

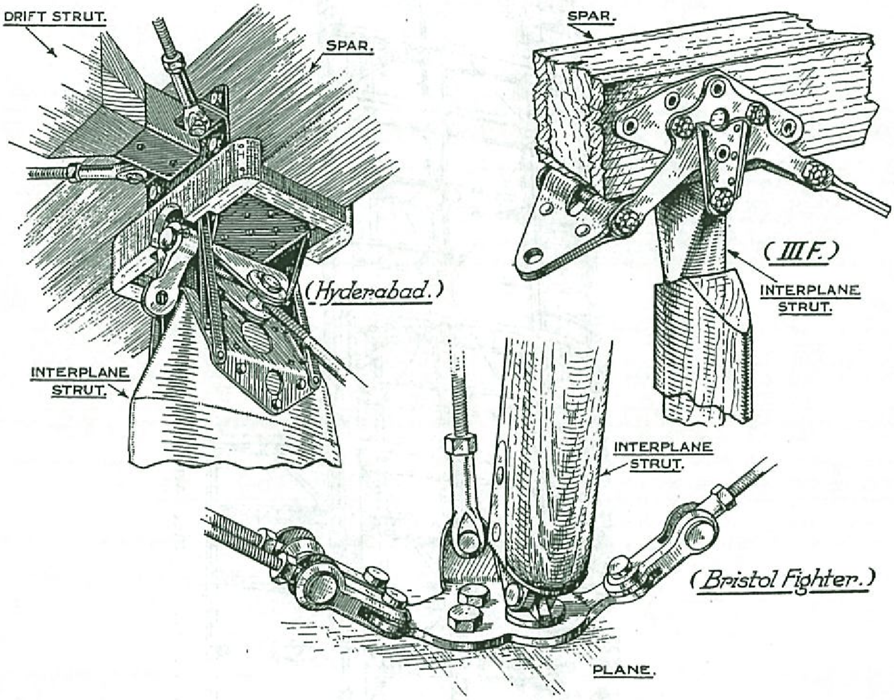


FIG. 33.—Wooden interplane strut fittings.

140. With the few exceptions of those aircraft which use the wing covering as a strength member, all aircraft planes are covered with fabric. Only the best quality of linen is used for service aircraft, and the manner in which this material is sewn to the ribs is very important, and must be done in certain specified ways which are described in a later chapter.

Composite planes.

141. Composite planes are constructed on similar lines to wooden planes, with the exception that usually the spars are of metal. The metal spars used on composite planes are in some instances made of tubular steel, but in most cases the spars are built up in much the same way as for all-metal planes, as described in a later chapter. A tubular spar is

generally made up from a single length of tube of the appropriate diameter and gauge, which is sleeved externally at the attachment points by sliding on short additional lengths of closely fitting tube.

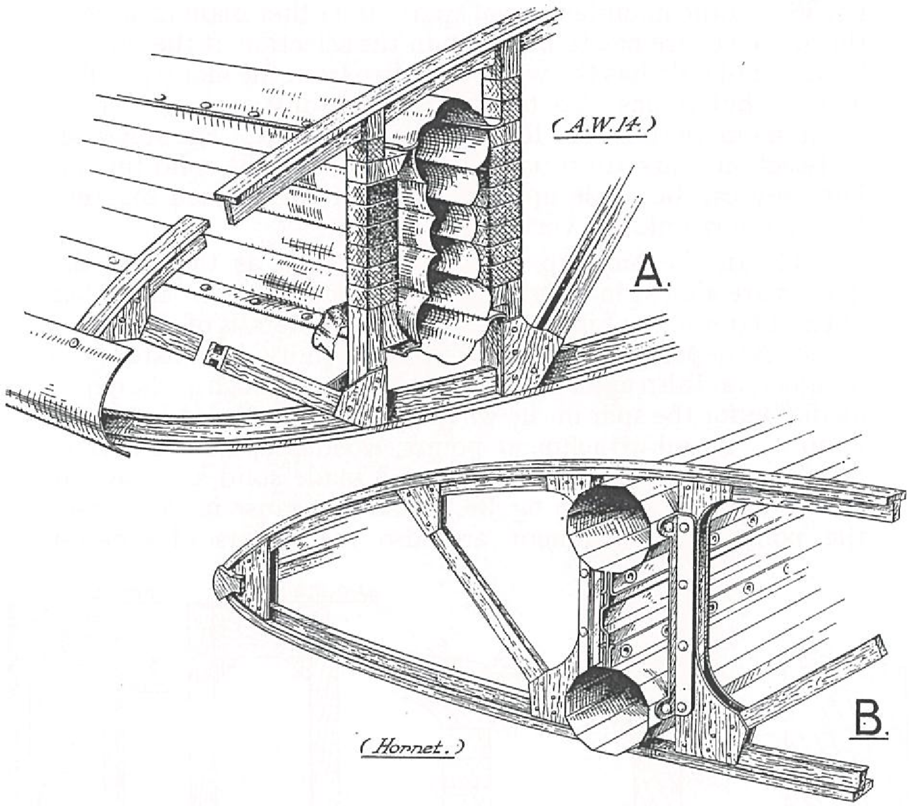


FIG. 34.—Composite plane rib attachments.

142. The wooden ribs are usually quite normal in design, and are sometimes attached to the spar with some form of metal clip such as that shown at B, fig. 34, and in other cases are arranged as indicated at A. Fig. 35 indicates a type of fitting employed when the outer wing spar is of wood, and the centre section of metal.

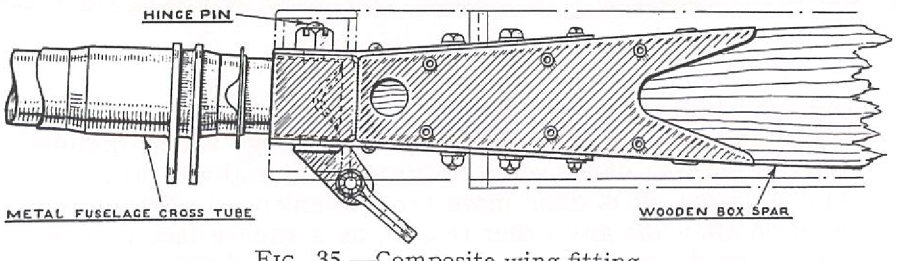


FIG. 35.—Composite wing fitting.

Wooden spars.

143. The most important of the main members of an aircraft are the spars, and the forms the wooden spars take are normally either solid, box or I-section, of which examples are given in fig. 36. In the manufacture of spars, and other main members, the greatest care has to be taken in the selection of the timber, because not only has the wood to be free from the many possible defects, but it has also to be free from any excessive spiral grain, no more than 1 in 10 or 12 being allowed. The spindled, or I-section spars are usually machined from the solid timber, but they can be made up from strips of wood glued together forming horizontal or vertical laminae.

144. In the built-up type of spar, such as the box, the flanges are almost invariably of spruce and the webs are either of this material or of three ply. The actual details of the design of the spar depend to some extent upon the individual taste of the designer, and also upon considerations of detail such as the depth available for the spar in the wing section, and the loads coming upon it. At all attachment points, wooden spars are usually increased in section, squared off and made solid as shown at the lower illustration in fig. 36. This is because in most cases the points of attachment are also the points of greatest

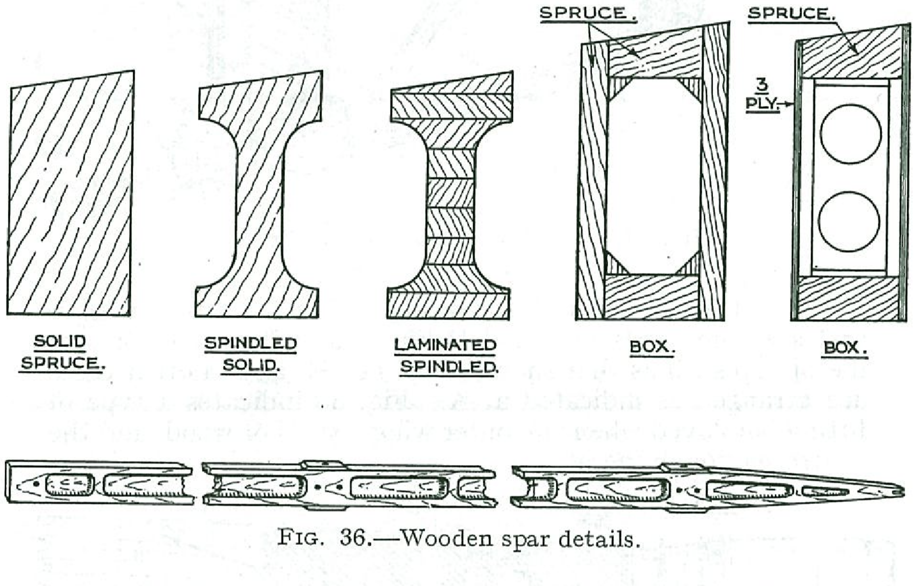


Fig. 36.—Wooden spar details.

concentration of loads in the spar, and the necessity of drilling the spars for the bolts attaching the fittings would unduly weaken the spar unless some additional material was provided. The squaring off is done more for convenience in design and erection than for any other reason, as a square face is more easy to work from than an inclined one. Hard wood packing blocks, glued and screwed on, are usually employed at the fitting attachment points. Spruce packing blocks are occasionally used, if the area of contact between the metal fitting and the wood is sufficiently large to allow of it, but hard wood is preferable in all cases, as this kind of wood is less liable to crush or shrink in service.

145. The spars of biplanes are usually parallel in section but tapered off at the wing tip, but the shape of monoplane spars depends upon whether it is a pure or a semi-cantilever type. In pure cantilever wings the spars generally follow the wing thickness which most designers arrange to be tapered, having the greatest thickness at the centre, or wing root. Semi-cantilever spars may or may not vary in thickness of section, depending upon the shape of the wing and the reasons governing the designer's selection of the type of construction, such as economy in manufacture, efficiency in service and general appearance.

Wood and composite struts.

146. Wood struts for use on aircraft vary considerably in cross-section and other details of design, depending to a great extent upon whether they are used externally or internally. A few of the more usual types of hollow sections are given in fig. 37. For the sake of economy, struts are usually made

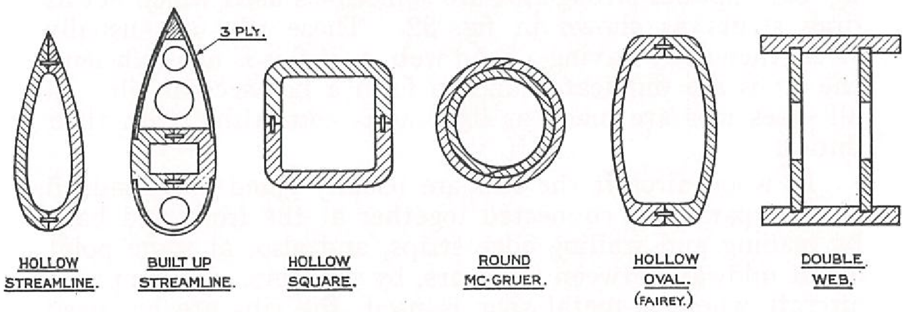


FIG. 37.—Hollow wood strut sections.

parallel in section, but they may have their ends tapering and can be either solid or hollow. In all cases it is usual to have some form of metal end fittings for the attachment of the struts to the adjoining structure. Interplane struts have normally a streamline section, and the end fittings form sockets which not only provide the bearing surface required for the pin joints, but also protect the ends of the wooden strut and guard against splitting or spreading as shown in fig. 33. Other forms of strut, such as are used in fuselages, are in many cases attached only by side plates with or without wooden corner chocks to position the ends, as indicated in fig. 41.

Composite struts are made of wood and metal, and some typical sections are shown in fig. 38.

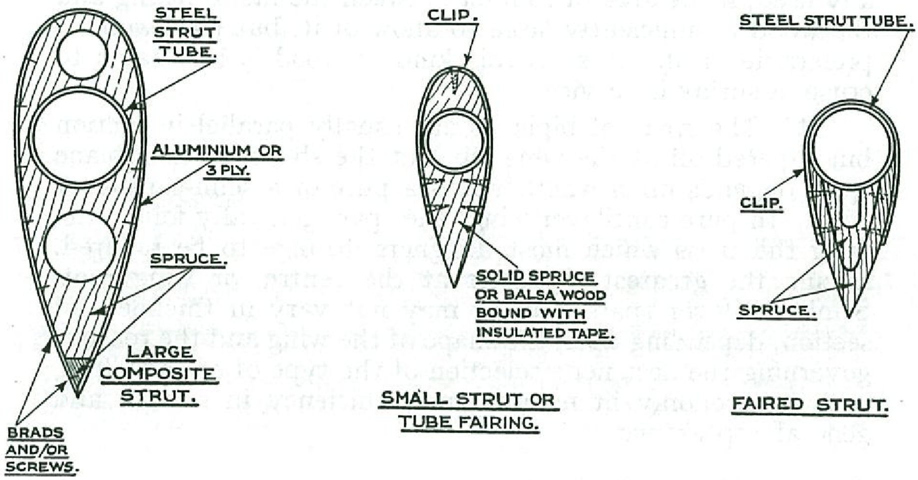


FIG. 38.—Composite strut sections.

Wooden ribs.

147. For the most part wood ribs are built up entirely from spruce, or are composed of a spruce flange and a three-ply web, a typical example of the former method being given in fig. 39. Special strong ribs are sometimes used which act as drag struts as shown in fig. 32. These ribs are usually strengthened by having a solid web, or if this is not sufficient, the webs are duplicated and so form a box-section rib. In all cases ribs are made as light as is compatible with their duties.

In wood aircraft the ribs are usually glued and bradded to the spars, and connected together at the front and back by leading and trailing edge strips, and also, at some point about midway between the spars, by stringers. In composite aircraft where a metal spar is used, the ribs are arranged

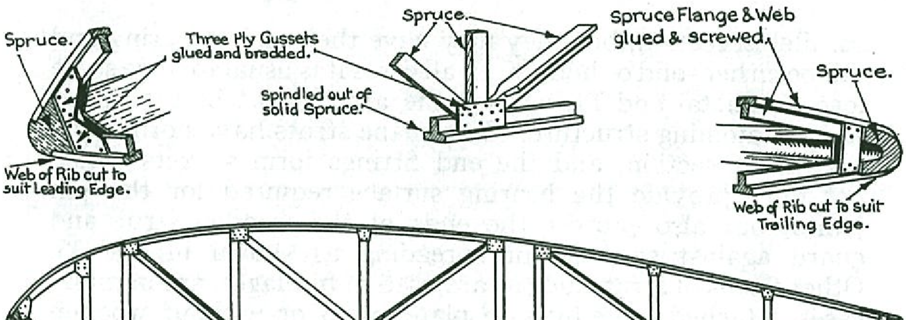
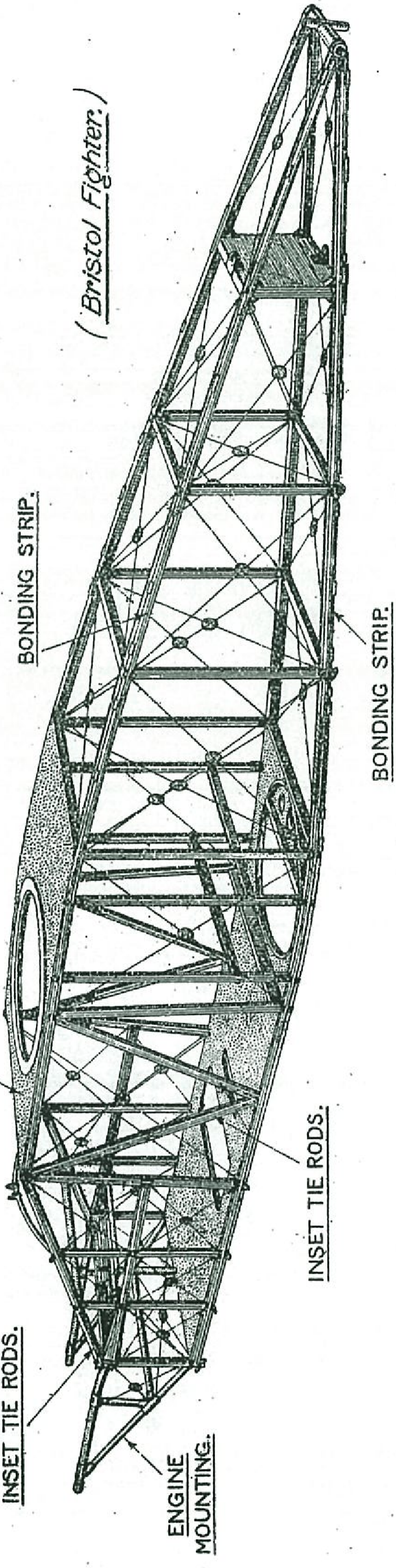


FIG. 39.—Typical deep section wooden rib.



(Bristol Fighter.)

FIG. 40. WOODEN FUSELAGE.

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very similarly except that a different form of attachment to the spar is used, as already described in para. 142.

148. Before any design of rib is approved for use in service aircraft, two or more specimens are tested to destruction with a distributed load for the two extreme conditions of flight usually encountered in aircraft fitted with wings of normal section, that is, with the centre of pressure right forward, and right aft.

Wooden fuselage construction.

149. A normal type of wood fuselage is shown in fig. 40 ; in this case the wooden longerons are separated by wood struts and braced diagonally by swaged rods. Metal fittings, disposed at the junctions of the struts and longerons, serve as a means of attachment, and fig. 41 shows some typical fittings. The longerons are usually rectangular in section, spindled out between the struts to obtain as light a structure as is compatible with strength. Longerons may be composed

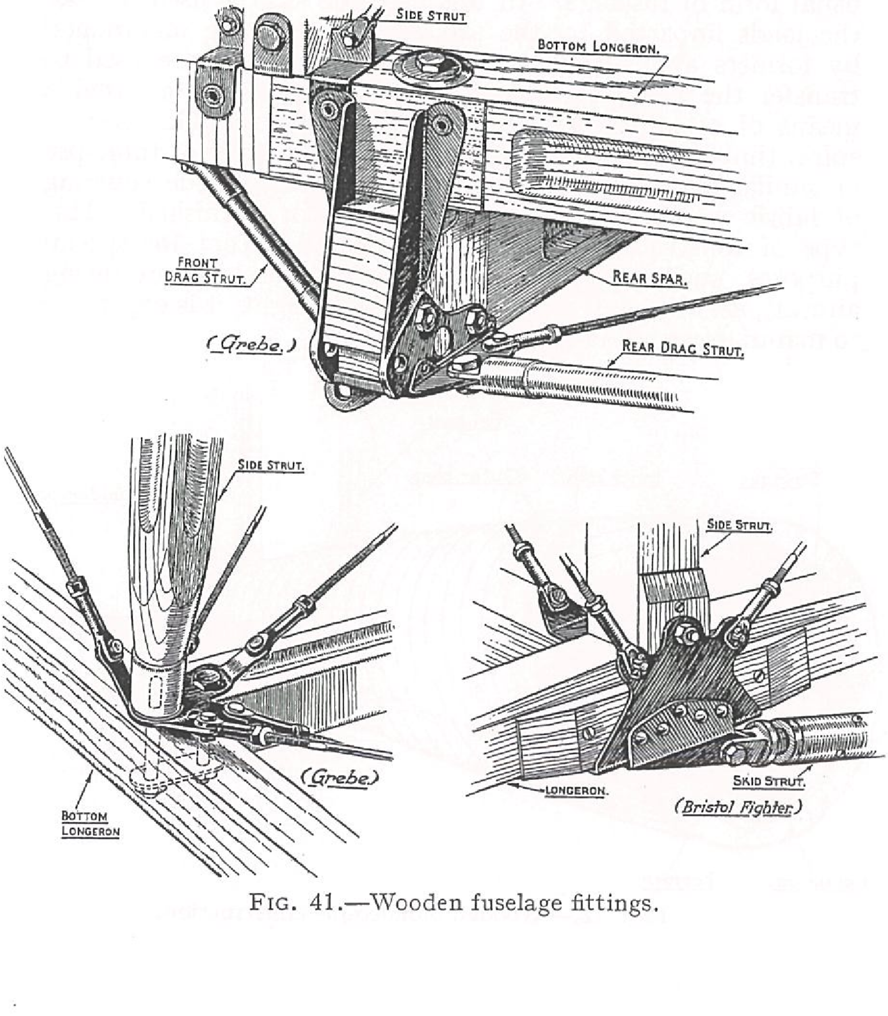

FIG. 41.—Wooden fuselage fittings.

of one length of timber or two, and in the latter case may be spliced or connected together by metal fittings.

150. In some instances, wood fuselages are built with single struts or three-ply panels in place of the cross bracing wires. The strut form of bracing is seldom used throughout the fuselage, but is generally only employed in those bays where the type of loading or some other special considerations makes it necessary, as fixed struts preclude any of the rigging adjustments usually required for wooden aircraft structures. With the three-ply panel, or semi-monocoque, type of construction, the three-ply usually replaces the diagonal wires only in the longitudinal bays, and is a comparatively heavy form of structure as its reinforcement by struts is still necessary, especially where any form of compression load comes upon the three-ply.

151. The true wood monocoque, shown on fig. 42, is a type of construction which is different in principle from the usual form of fuselage. In this case the skin is used to take the loads imparted by the tail, the shape being maintained by formers and stringers. Additional members are used to transfer the heaviest loads through the fuselage or provide means of attachment. The skin may be a double layer of spiral timbers as shown, or may be a single layer of three-ply or similar material. It is usual to have an outside covering of fabric which is glued on and doped or varnished. This type of construction is now seldom used except for special purposes, such as seaplane hulls or the fuselages of racing aircraft, as, although it is very strong and light, it is expensive to manufacture and repair.

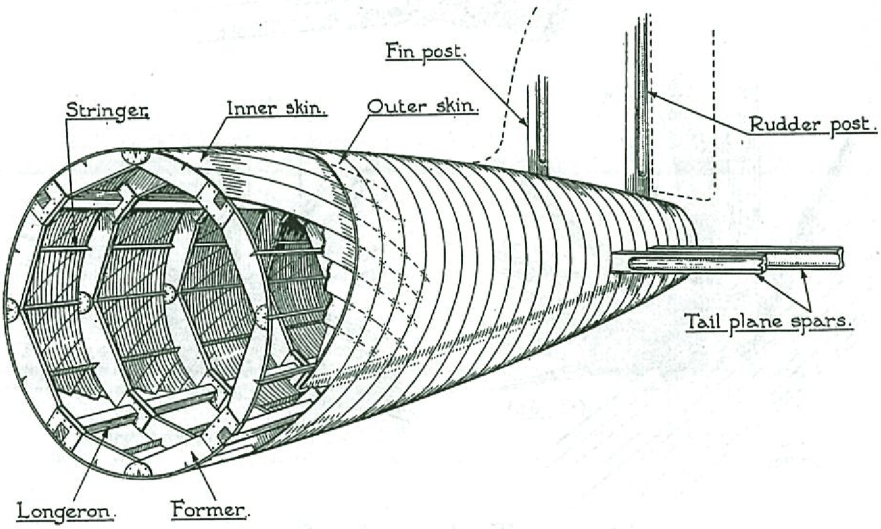

FIG. 42.—Wooden monocoque construction.

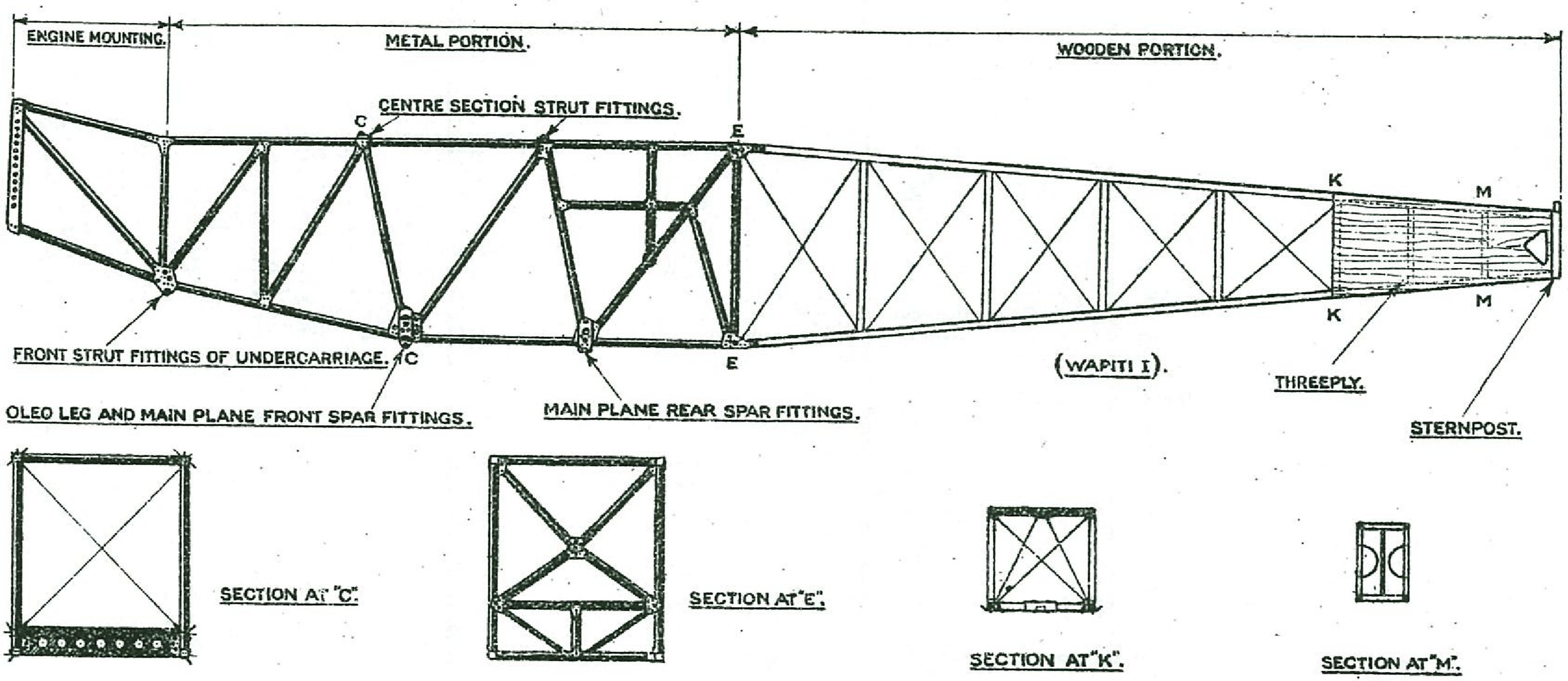

FIG. 43. COMPOSITE FUSELAGE.

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Composite fuselage construction.

152. Composite fuselages take a variety of forms, but the usual compromise is that in which the front end of the fuselage is of metal whilst the rear portion is of wood. Fig. 43 shows a typical composite fuselage of this kind. The fittings used on the wood and the metal portions must obviously be made suitable for the particular type of construction employed, the only difference in the type of fittings used being at the junction between the wood and the metal. Fig. 44 gives a few fittings of this nature.

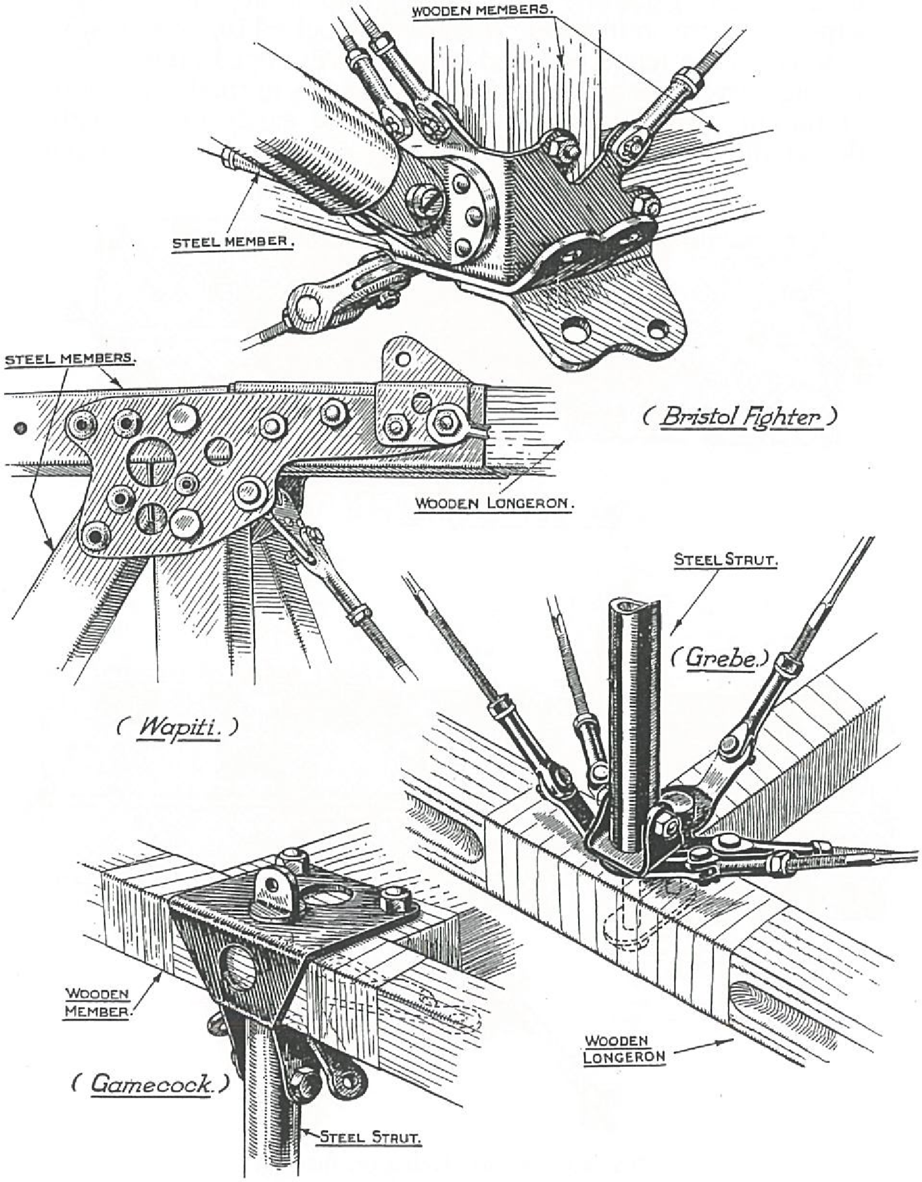

FIG. 44.—Composite fuselage fittings.

Wooden fuselage fairings.

153. In most types of construction, the shape of the fuselage, as observed on a complete aeroplane, is seldom the shape of the actual fuselage frame, but is a structure superimposed on the main fuselage frame in order to fair off and give the body a streamline shape. In the majority of cases the body form is enlarged at the top at the cockpit positions, in order to give greater accommodation than is usually provided by the fuselage frame itself. The enlargement is achieved, generally, by building up a strong three-ply superstructure on formers, which is then bolted to, or otherwise secured to the longerons, and covered with doped fabric. The fairing surrounding the engine mounting is normally made of aluminium, and is so arranged as to be easily and quickly detachable, thereby giving ready access to the engine

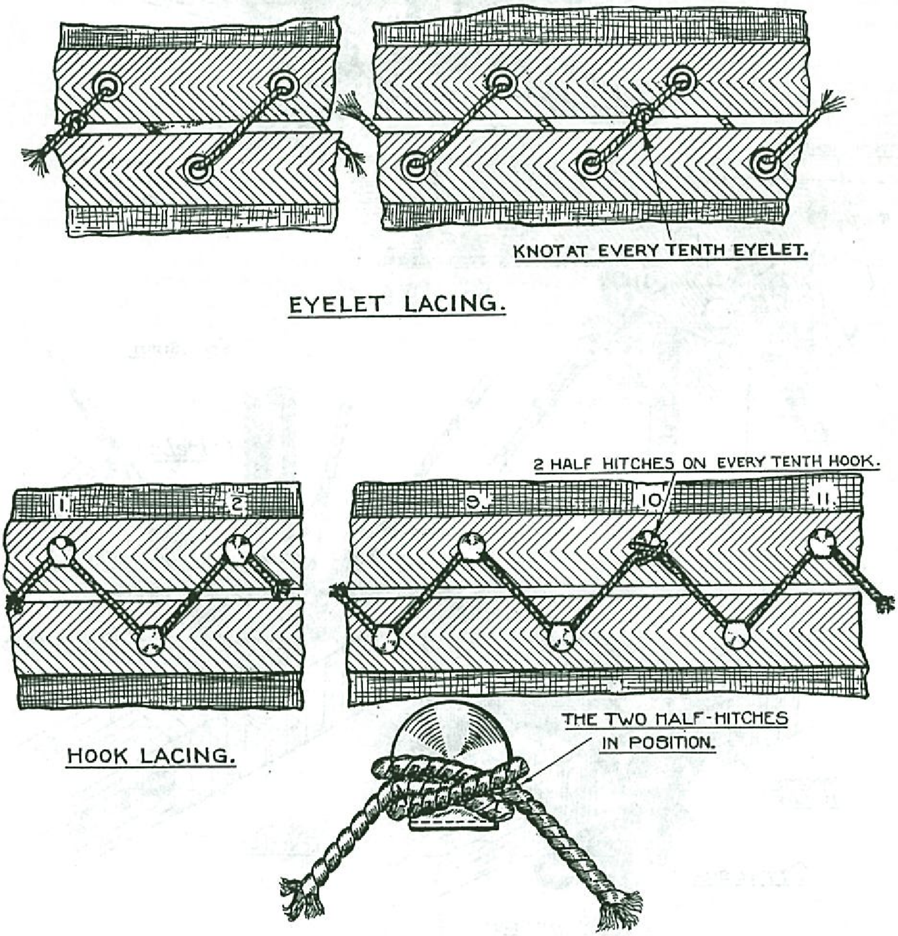

FIG. 45.—Fabric lacing on fuselages.

installation. The remainder of the fairing is composed of doped fabric laced on over some form of lightly built framework. The type of lacing employed is shown in fig. 45, the plain eyelet holes being preferable to the hook eyelets shown in the lower illustration.

Fittings on wooden aircraft.

154. Fittings for wooden aircraft are seldom machined from solid material, but are usually made up from plates or tubes bent to the desired shape, and where necessary welded, brazed, bolted or riveted together. The material from which the fittings are made varies with the purpose for which the fittings are designed, but they are generally composed of steel. Figs. 33, 41 and 44, show some typical fittings. Occasionally a light alloy, such as duralumin, or one of the non-ferrous alloys is used. High-tensile steel is very seldom used, except for such parts as wiring lugs, as it is usually necessary to have a comparatively large area of plate in contact with the wooden members, and the size of the fittings being large on this account, sufficient strength is generally provided by low-tensile material. Large contact areas are required between the plate fitting and the wood in order to reduce the bearing pressure between the wood and the metal to a pressure which is suitable for the timber, or if a number of wood screws are used for attachment, to obtain adequate spacing of the screws. A reasonably large spacing between the screws is necessary to avoid splitting the wood, and also to obtain a good distribution of the transferred load.

155. Plate fittings are made from one piece of comparatively thick material or from two or more pieces riveted, edge-welded, or otherwise connected together, and the plates are either left solid or lightened out. If low-tensile material is utilised for wiring lugs, then it is usually unnecessary to take any special measures to give a sufficient bearing area for the pins or other attachments, but where it is found essential a pad is welded, brazed, sweated or riveted on to the main plate, as shown at A, fig. 46. In other cases a special large-diameter pin is used as given at D. Where high-tensile steel is used for wiring lugs attached to low-tensile fittings, the connection is made by riveting, or by placing the high-tensile plates under the heads of one or more of the attachment bolts, or, in many instances, by adopting both these measures as indicated at E, fig. 46. If the high-tensile material is thin, then an adequate bearing area is obtained, by some designers, by riveting steel eyelets of lower tensile strength into the pin hole as shown at B and E. Where the high-tensile material is comparatively thick, the lugs are usually made up as at C.

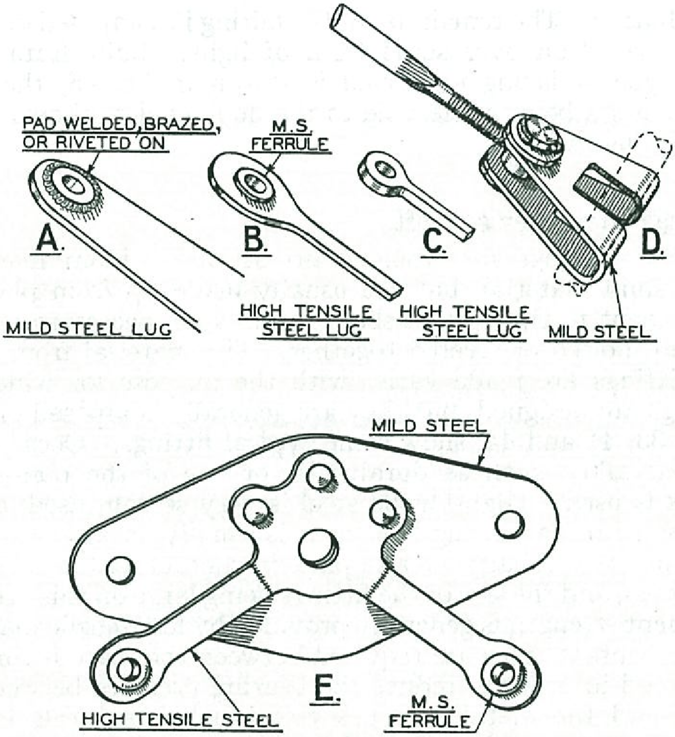

Fig. 46.—Wiring lugs.

Wooden undercarriages and tail skids.

156. Undercarriages for wooden or composite aircraft of modern design are generally of metal construction, and the details are therefore similar to those used for metal aircraft. Wooden undercarriages are to some extent still used and they do not vary greatly in their general design. The details may alter considerably, but in most cases, as shown in Fig. 47,

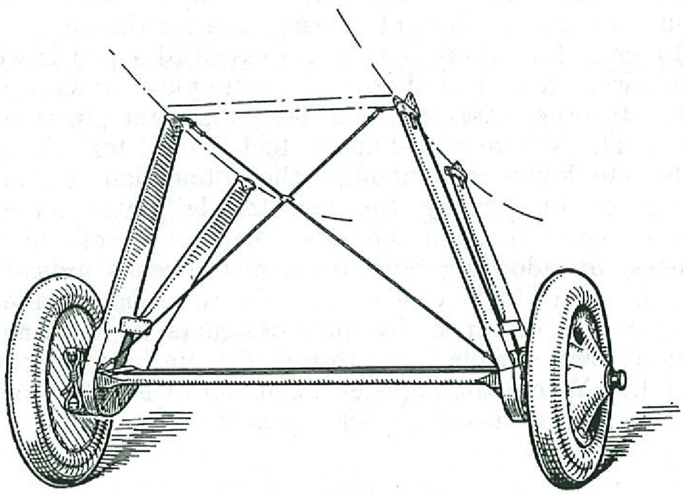

Fig. 47.—Wooden undercarriage.

wooden V-struts are used, braced transversely with diagonal wires. Elastic cord shock-absorbers are usually provided for the axle, which is allowed vertical movement, generally in guides formed in the bottom junction of the V-struts. The axles, which are usually covered by a wooden fairing, are formed from high-tensile steel tube, which has been specially prepared and heat-treated for the purpose.

157. Wooden tail skids are usually constructed of ash or similar hard wood and shod with steel plates. Rubber shock-absorbers are often provided arranged with the rubber either in tension or compression, but steel springs or oleo cylinders are common alternatives. Two examples are shown in fig. 48. The skids are in some cases made capable of following the track of the aircraft and in others the skid is made steerable.

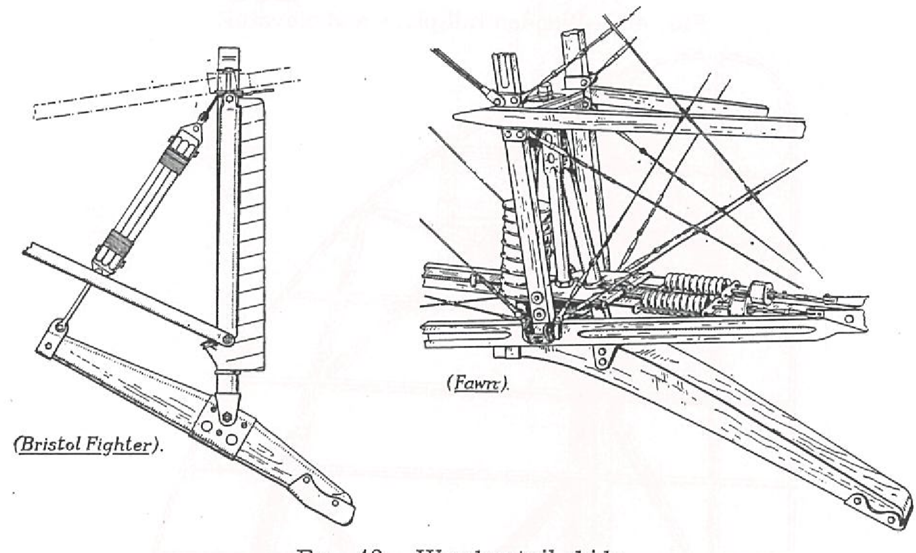

FIG. 48.—Wooden tail skids.

Wooden tail units.

158. Tail planes for wooden aircraft are generally made up in a similar manner to the main planes, having two wooden spars (usually of the solid spindled-out type) and wooden ribs. Some form of incidence adjustment is normally provided. The elevators usually have the same type of construction as the tail plane and are generally hinged to the rear spar by means of standard eye and fork end bolts. The fins and rudders follow much the same practice as the tail plane and elevators. Typical skeleton arrangements of a tail plane and elevator and a fin and rudder are given in figs. 49 and 50.

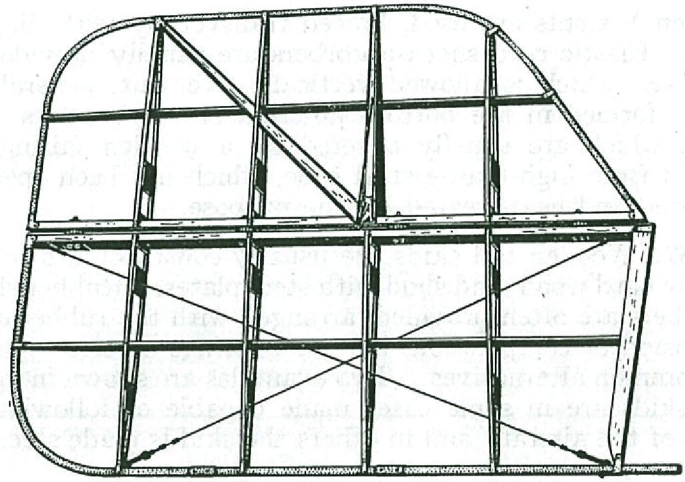

FIG. 49.—Wooden tail plane and elevator.

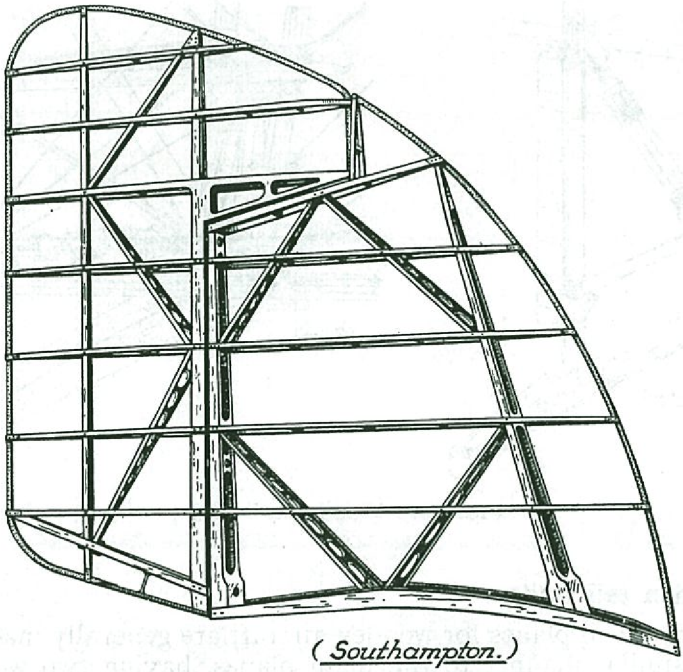

FIG. 50.—Wooden fin and rudder.

Wooden airscrews.

159. Wooden airscrews for service use are usually made up from mahogany to Specification 3V.7. Walnut Specification 3V.5 is also an approved material but is less frequently used. The majority of airscrews have two blades but when four-bladed airscrews are provided it is usual for these to be made up in two parts each having two blades and a boss of half

the normal thickness. The two halves are dowelled together and bolted to the airscrew hub at 90° to one another.

160. Wooden airscrews are built up in laminae, that is, there are six to eight separate planks which are glued and pressed together, each plank having an angular displacement with respect to its neighbour, much like a partly-opened fan. In this way the complete blade form can be evolved with the minimum amount of timber wastage. The planks used for the laminae are selected with great care, and are so cut that the grain of the wood lies as nearly as possible along the length of the blade, 1 in 15 being the maximum permissible grain inclination. The laminae are usually from $\frac{3}{4}$ in. to 1 in. in thickness. They must be unwarped and free from other defects.

161. Special precautions are taken with the gluing and pressing to ensure perfectly formed joints, and the surfaces to be glued are lightly grooved or scored with a special tool, prior to the application of glue or cement. When ready for shaping, the laminated block is usually roughly shaped in a special profile machine which cuts away the surplus timber and reduces the block to approximately the dimensions required. The finishing off is normally done by hand. After shaping and before subsequent operations, the airscrew is subjected to an inspection for defects and general finish, including angles, dimensions, track, alignment, balance. After boring and drilling, the identification marks are stamped on the periphery of the boss between the blades. The identification marks consist of drawing and issue numbers, with prefix or suffix letters, if any, the diameter and pitch (prefixed by the letters D and P respectively), name and series of engine, serial numbers, month and year of manufacture, and the approval stamp of the authorised inspector.

162. A metal sheathing is attached to the blades, which covers the leading edge for about the outer two-thirds and extends round the tip. This sheathing is secured to the blades by wood screws or rivets, the heads of which are sunk slightly below the surrounding surface of the sheathing, and are finally flooded over with soft solder. The object of the sheathing is to protect the airscrew from damage caused by rain, sea-water or spray, and by the small stones and other matter which may be drawn into the airscrew disc. It is essential that airscrews should be coated with a waterproof protective. The usual protective materials are fabric, glued on and covered with several coats of the best coach varnish, or cellulose lacquer. The latter substance is applied in the manner described in Air Ministry Technical Order 404 of 1929, four coats of undercoating, Stores Ref. 33B/52, being applied and three coats of finishing lacquer, Stores Ref. 33B/53, before the sheathing is attached. The sheathing itself is given three coats of finishing lacquer after being secured to the blade.