CHAPTER XIII.

REPAIRS AND MAINTENANCE.

377. After an aeroplane has been assembled and flown, there are manifold duties connected with the maintenance of the aeroplane in a sound and airworthy condition. This entails a regular and systematic examination of all parts, as laid down in Air Ministry Weekly Order 25 of 1929 and K.R. & A.C.I., para. 702, with the consequence that adjustments and minor repairs are found necessary from time to time, quite apart from the repairs necessitated by a more or less serious mishap to the aeroplane such as might be occasioned by a forced landing. If an aeroplane is seriously damaged, but not sufficiently for it to be struck off charge, it is usual to strip the aeroplane completely, dismantle the damaged portion, substitute complete components for those badly damaged, and repair the parts which are only slightly injured. The repair and maintenance notes for the type usually specify the limit of repairable damage, and the details provided generally cover all normal eventualities. The repair and maintenance notes are either issued separately or incorporated in the aeroplane handbook.

378. The methods of repair vary in accordance with the type of construction used, and it is obvious that a repair which is suitable for one type of aeroplane will in most cases not be suitable for another type. It is highly important, therefore, that only those repairs should be used which have been approved for the particular type of aircraft, and which are enumerated in the repair notes.

379. Before repairs can be undertaken, it is usually necessary to have certain special tools which are required for the particular type of riveting or jointing employed. These tools, in addition to any jigs and special materials required, are normally available for the unit.

380. Whenever it can be arranged, approved repairs are made with patches which are cut and drilled ready for use. In certain instances, such as leading and trailing edge tubes, lengths of materials are supplied which have to be cut to the correct length and bent to the required curvature.

381. Before any attempt is made to repair a damaged structure, it is advisable to classify definitely the repair as replaceable, repairable or negligible. The repair notes usually define the limits of any of the three classifications.

382. The repairs normally undertaken by units do not entail any complicated processes, and the following paragraphs provide general comments for the information of those concerned.

Removal of rivets.

383. In many instances the repair is effected by cutting out the damaged part, extracting the old rivets and putting on some form of patch which utilises to some extent the old rivet holes. Great care must therefore be taken when extracting rivets not to damage or loosen the neighbouring parts. The method employed for extracting the rivets depends upon the type of rivet used.

384. For solid rivets the normal method is to file a flat on the head and drill the head, using a drill somewhat larger than the diameter of the rivet. The hole is carried to a depth a little less than the depth of the head. The head is then chiselled off, using a dolly to support the rivet on the reverse side. A small pin punch can be used to tap out the shank of the rivet, but if difficulty is experienced in extracting rivets, they should be drilled out. Excessive force should not be used in punching out. Tubular rivets should be drilled out, using a drill of the same size as the rivet to be removed, or a small countersunk rose cutter. The shank is then tapped out, using a pin punch or a piece of tube of the same diameter as the rivet being removed. Pierced and cup rivets should be extracted in a similar manner.

Renewal of rivets.

385. There will be occasions when rivet holes will have become enlarged owing to either the usage in service or to the faulty extraction of the rivet. In these circumstances, it is permissible on some aircraft to use a size larger rivet, and drill out the hole to suit. Unless definite instructions are issued to the contrary, new holes should be drilled and not punched, as punching reduces the strength of the material in the neighbourhood of the hole. Riveted joints should be so made that there is no possibility of movement between the faces of the parts joined. If working should take place, there is a strong probability of wear which results in elongation of holes and reduction in cross-sectional area of the rivets; therefore, when drilling a new hole for a rivet it is important that the correct size of drill should be used, and also that the correct amount of rivet should protrude through the hole for purposes of riveting over. All the essential information in this respect is usually included in the aircraft repair notes. If the manufacturers' limits are known, they should be followed, but the following information is given as a guide, should precise instructions not be available.

386. The exact diameter of the holes for solid mild steel rivets is not of great importance, because the shanks of the rivets expand during riveting and fill the hole, but the

smallest size of hole convenient for working should be used, giving no more than, say, about $\frac{1}{64}$ in. clearance for rivets of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. diameters. Solid stainless steel rivets require a more closely fitting hole, as the rivets harden immediately riveting commences with a consequence that the shanks of the rivets do not swell very much. A clearance of about ·003 in. should be sufficient, and the sizes of drills which are recommended are Nos. 41, 30, 21 and 11 for rivets of $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{5}{32}$ in. and $\frac{3}{16}$ in. diameters respectively. The shanks of solid light alloy rivets swell considerably during riveting and a definite clearance of about ·01 in. is required when riveting light-alloy plates, as otherwise a wavy or puckered surface is produced owing to the spreading of the material round the holes. Suitable sizes of drills are Nos. 37, 29, 19 and 8 for rivets of $\frac{3}{32}$ in., $\frac{1}{8}$ in., $\frac{5}{32}$ in. and $\frac{3}{16}$ in. diameters respectively. Tubular and pierced rivets should be a close fit in the holes, as the shanks are not definitely expanded as in solid rivets. It is advisable to ream the holes for tubular rivets if high stresses are likely, but if the rivet is not heavily loaded the holes should be drilled with about ·003 in. clearance, using about the same size of drill as is recommended for stainless steel rivets. When ferrules are not provided and the materials or fittings allow of the operation, specially for steel, the edges of the holes for tubular rivets should be slightly cut away to allow a small radius to be formed when turning over the head.

387. The riveting allowance necessary for forming snap heads on solid rivets when riveting thin materials with a hammer and snap, is about $1\frac{1}{4}$ to $1\frac{3}{4}$ times the diameter, the amount depending upon the hardness of the rivet and the clearance given, the larger allowance being used for the softer rivets. An allowance of about $\frac{3}{4}$ the rivet diameter is necessary for countersunk rivets. A greater allowance is sometimes made when the riveting is done with special tools, and when the materials being riveted are comparatively thick. As an instance, the allowance for snap head light-alloy rivets, when hand riveting materials with a total thickness equal to not more than the diameter of the rivet and using the clearances given above, is about $1\frac{1}{4}$ times the diameter of the rivet. When the materials being riveted together have a greater total thickness than the diameter of the rivet, then an additional allowance may be given of approximately ·03 in. for each $\frac{1}{16}$ in. increase in thickness. For tubular rivets practice varies widely, but for small sizes and for normal gauges of tube wall thickness, say between 20 g. and 24 g., when hand-riveting with a snap and dolly, an allowance equal to not more than half the diameter can be given. This should be sufficient to form a good head and avoid cracking at the lip. When a

spinning tool is used, the amount left for riveting over can be greater, and an allowance equal to $\frac{3}{4}$ the diameter of the rivet should not be excessive. When the special snaps and dollies are not available, the rivet should first be opened out with a 60° punch and the edge peaned over with light hammer blows.

388. The types of rivets employed vary considerably both in material and shape. Fig. 95 indicates the shapes of rivets normally used for aircraft construction, type A being more used than the remainder. Rivets A, B and C can be riveted over with a hammer, dolly and snap or any of the usual methods, but rivets D, E and F generally require some form of special punch or tool to form the head correctly, as the metal is not spread as in the solid type but is merely bent or spun over.

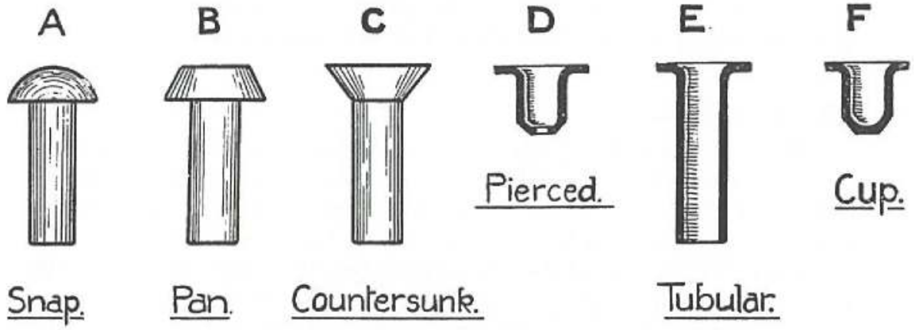

FIG. 95.—Types of rivets.

389. Riveted joints are made in several ways, depending mainly upon the strength and purpose for which the joint is required. The types of joint used are lap and butt, the latter having cover plates on one side or both. The types of riveting used are single, double, treble or quadruple according to the number of rows of rivets, and the rivets may have a chain or zigzag formation. Fig. 96 indicates the types of joints and the forms of riveting.

Bolt holes.

390. Unless it is to be subsequently reamed, it is usual to drill a hole slightly larger than the diameter of the bolt to be used, in order to allow for any small inaccuracies in the position of the hole or slight variations in the size of bolt. The clearance which is allowed for bolts in unimportant work is $\frac{1}{32}$ in. for all sizes above $\frac{1}{4}$ in. diameter and $\frac{1}{64}$ in. for this size and smaller sizes. This provides an easy fit for the bolts in all circumstances, but does not require exceedingly accurate workmanship.

391. When repairing aircraft the sizes of all bolt holes required are usually stated in the aircraft repair notes. In the absence of any definite instructions, it is advisable to fit all bolts, that is, the holes are drilled slightly smaller than is finally required and then reamed to obtain a good fit for the bolt. If a reamer of the correct size is not available, it is often possible to obtain a well fitting bolt by using a drill of the same size as the nominal diameter of the bolt and selecting a bolt which will fit the hole. This is possible owing to the minus manufacturing limits on the bolts, and the fact that holes drilled by hand in thin materials are usually larger by a few thousandths than the size of drill being used.

Cutting lubricants.

392. When drilling and tapping holes it will be found that certain materials are difficult to work unless some form of lubricant is used. The use of a lubricant is not so important for hand work as it is for machine work, but even for hand work its use is advised as it assists in keeping the edges on the tools by reducing the heat generated, and is also of great assistance in preventing the sticking or digging in, which is a prolific cause of broken drills and taps. The compounds used vary to some extent, a soluble oil, Stores Ref. 34B/100, is available for general machine work, but in the absence of this substance or of any definite instructions, the compounds given below can be recommended. Care must be taken to avoid the generation of excessive heat when using inflammable lubricants.

TABLE VI.

Material.	Hand working.	Machine working.	Proportions.
High tensile steels.	Turpentine or paraffin.	Borax, lard oil and water.	15 oz. Borax, 1 gal. lard oil to 4 gals. water.
Ordinary steels.	Oil	Carbonate of soda, lard oil or soft soap and water.	1 lb. soda, 1 qrt. lard oil or soft soap to 10 gals. water.
Light alloys	Paraffin ..	Paraffin	—
Brass ..	None ..	None	—
Copper ..	Soft soap ..	Lard oil and turpentine.	Equal.
Cast iron ..	None ..	None	—

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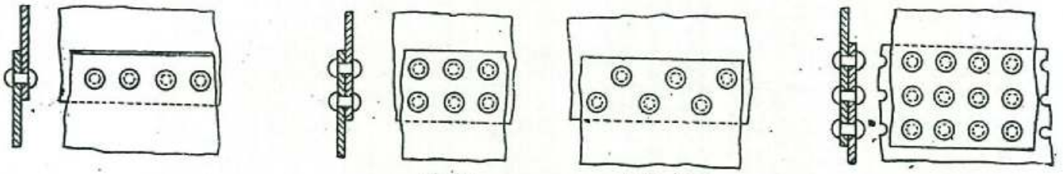
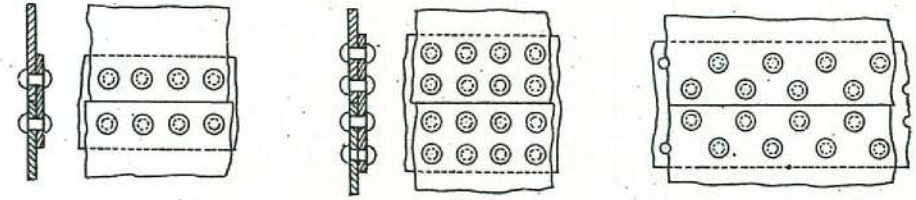


Lap Joint single chain riveted.

chain. zig-zag

Lap Joint double riveted.

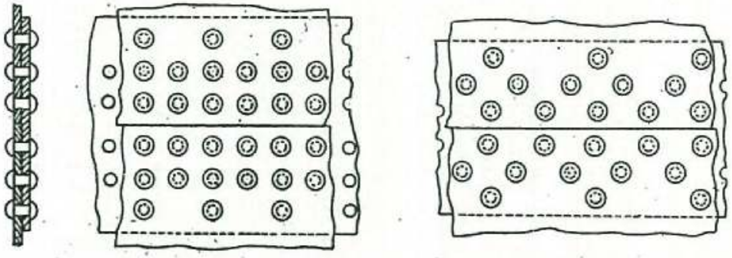
Lap Joint treble chain riveted.



Butt Joint single chain riveted.

chain. zig-zag.

Butt Joint double riveted.



chain. zig-zag centre riveting.

Butt Joint treble riveted.

FIG. 96.

RIVETED JOINTS.

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Oxy-acetylene welding.

393. Oxy-acetylene welding is a method adopted for joining metals by raising them to such a temperature that the parts in contact will fuse and flow together. The heat required for this type of welding is intensely local in character, and is produced by means of high or low pressure blow pipes which are fed from a suitable source of oxygen and acetylene gases. Oxy-acetylene welding is a scientific trade, and cannot with success be undertaken by anyone until the necessary knowledge and skill have been acquired. A very thorough knowledge of the basic principles of welding is essential, in addition to a comprehensive understanding of the characteristics of the materials employed. The manual dexterity and skill required for handling the blow pipes and plant is not inconsiderable and can only be acquired with practice. The range of materials which can be welded by this process is very wide, but under Service conditions welding for aircraft is normally employed only for those parts composed of steel. Certain steels are more suitable than others for welding and should therefore be utilised whenever possible.

394. Experience has shown that certain high-tensile alloy steels should not be welded, as their full strength cannot be developed after welding by heat treatment or any other process. For other ferrous materials, where heat treatment after welding is possible, any of the suitable B.E.S.A. or D.T.D. Specifications can be used. Where heat treatment cannot be undertaken, then the materials which are suitable are limited for aircraft structures to S.3 Sheet, S.21 bar, T.26, D.T.D. 41, 89, 89A and 113 tubes. Preheating may be necessary, especially if a casting is being welded, but subsequent heat treatment is essential if the materials being used originally obtained their strength by this process. The heat treatment employed may consist of hardening and tempering, tempering only, annealing and normalizing. All parts expand and contract considerably during welding, and therefore precautions must be taken to avoid where possible the troubles which ensue due to distortion and cracks.

395. Fluxes are used for most materials, and it is essential that the correct flux should be used if welding is to be successful. Three fluxes are in normal use, one type for cast iron, one for aluminium and one for brass.

396. Under normal conditions it is usual when welding to use a rod or wire of suitable size and material as a filler. The material of which the rod or wire is composed is of course of primary importance, but care should be taken to see that the correct size of filler is used, as if it is too small, excessive

oxidation will occur and if it is too large, it will tend to chill the material at the weld.

397. The strength of a welded joint in tension can be assumed for aircraft purposes to be about 66 per cent. of that of the material before welding, and in compression about 75 per cent. to 100 per cent., depending on the circumstances in which it is used. All the welded joints are normally so arranged that the failure of any one joint will not involve collapse of the structure under load.

398. It is essential, if the quality of the welding is to be good, that the plant employed should be kept clean and in good order and should not have a capacity which is too small for the demands made upon it. Welding work should not be undertaken casually but should be well thought out, and adequate preparations made accordingly.

399. It is essential, when repairing aircraft parts by welding, that only material identical with that originally employed should be used, and only methods adopted which are enumerated in the repair notes of the particular type of aircraft. For further information on oxy-acetylene welding, reference should be made to the handbook "Oxy-acetylene Welding and Cutting," Air Publication 880, 2nd edition.

Brazing.

400. Besides welding, there are two methods of making joints entailing the fusing of metals—brazing and soldering. Brazing requires a much higher temperature than soldering, but gives a stronger joint ; as a rule it is only used for joining iron or steel parts together. The parts are prepared by a thorough cleaning, and the scratches so produced should lie in the same direction as the direction of flow of the spelter. Joints to be brazed should never be made a close fit, but due allowance must be made for the spelter to flow along the joint as otherwise air pockets may be formed.

401. The source of heat must produce a smokeless flame such as that of a paraffin brazing lamp (of ample size) or a gas blow pipe. An oxy-acetylene flame should not be used. The parts being brazed should be surrounded by pieces of coke or brick, in order to hold the heat. The spelter, which is normally a soft form of brass or copper with a comparatively low melting point, may be obtained in three forms, brass, granulated and strip, and copper. Stores Ref. 30B/285, 30B/286 and 30B/287 respectively. The first two types are used for general iron and steel work. Borax is used as a flux, and is crushed, mixed with water, then added to the spelter and applied

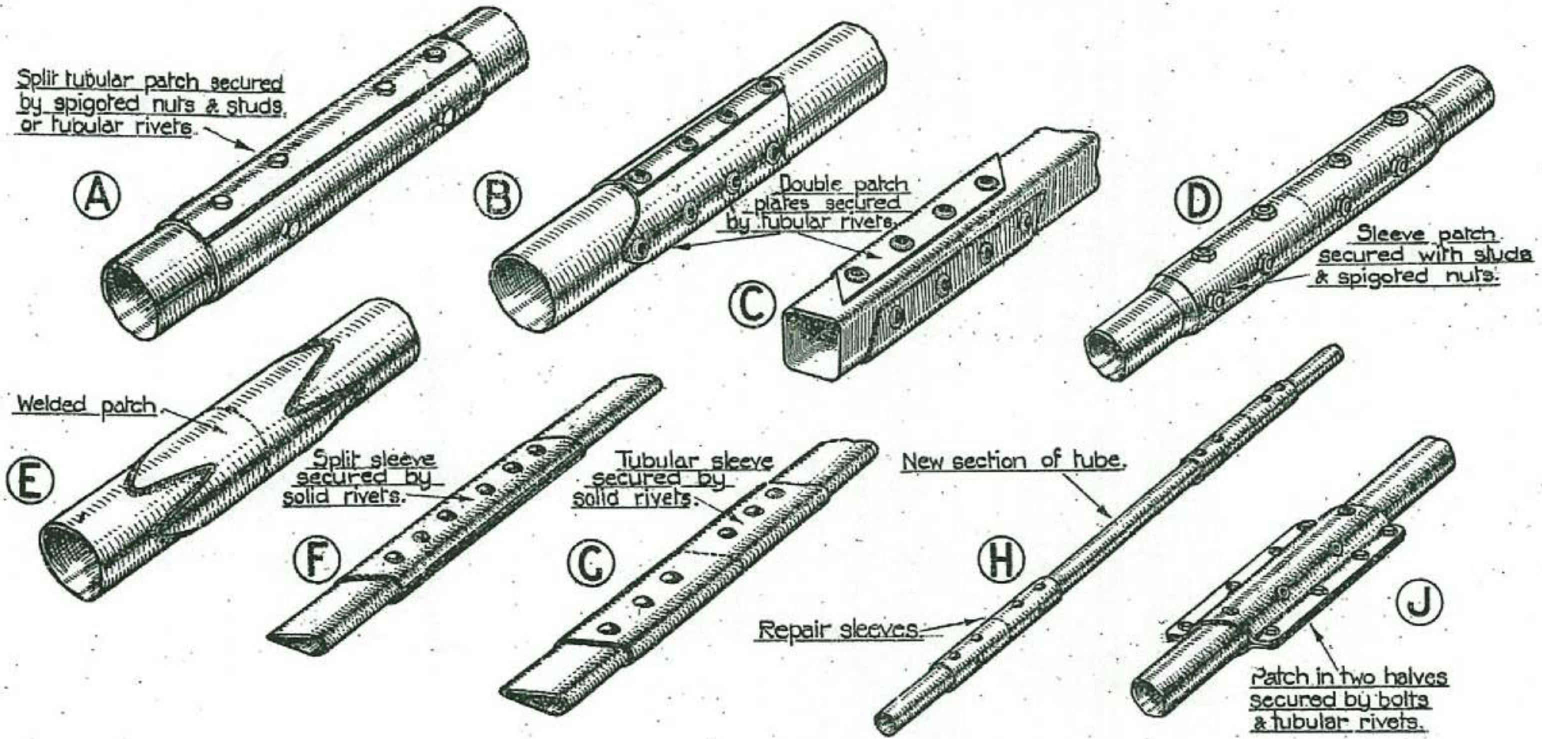

FIG. 97. REPAIRS TO SOLID DRAWN TUBES.

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as a paste to the parts to be joined. The flame is then played on the joint, gradually until the water has evaporated, then continuously until the spelter flows right into the joints. The spelter will not fuse until the parts are at a red heat.

402. Brazing can only be rarely applied to aircraft parts ; never to the high-tensile steels that obtain their strength by heat treatment or by working.

Soldering.

403. Soft soldering on aircraft structures is used in the attachment of tubes to end sockets and similar ways, generally in order to obtain additional stability at the joint. Three types of solder are supplied, plumber's, Stores Ref. 30B/282, silver, 30B/283 and electricians', 30B/545. The tinman's solder is used for all general work, the silver solder is used where a very strong joint is required, but where brazing would be inadvisable for the materials being joined. Electrician's solder has a resinous inset and is used for making electrical and other connections when the parts have been previously tinned or where the use of an ordinary flux would be inadvisable owing to its corrosive effect. The type of flux in general use is Fluxite, Stores Ref. 33C/244.

404. For successful soldering, it is necessary that the bit should be tinned and, unless an electric or other self-heating type is used, that it should be sufficiently heavy for the job. All parts to be soldered should be thoroughly cleaned and tinned before forming the joint, and sweated together. Care should be taken to employ a type of flux which has as little corrosive effect as possible, and all fluxes should be thoroughly cleaned off with petrol or hot water after a joint has been made. Silver solder is not frequently used, and the method of making a joint with this medium is similar to that employed for brazing. Joints formed by soldering only are not employed on aircraft structural members. Rivets, pins or bolts are always used in addition.

Repairs to solid drawn tubes.

405. Repairs to tubes can be effected by tubular sleeves, split sleeves or patch plates, and they are secured by riveting, bolting or welding, depending upon the type of construction used. When a tubular repair sleeve is used it can be internal, or external, as shown at D, fig. 97. In either case it is usual to serrate or turn down the ends of the tubular sleeve to avoid any sudden change in section. Care must be taken, when sliding on the sleeves, that the structure is not strained when separating the ends of the repaired tube where it is cut.

406. Split sleeves are applied externally in the manner shown at A, fig. 97. Patch plates are used for square or round tubes, and the methods of attachment are indicated at B, C and J, fig. 97. When a tube is so badly damaged that it is necessary to cut out a complete section, it is usual to replace the discarded portion by a length of tube similar in diameter, gauge and specification, and attached as shown at H, fig. 97. The tubes of welded structures can also be repaired by welding on patches arranged in a similar manner to that shown at E, fig. 97, but only when the original structure has been welded during assembly. Tubes which have a streamline shape, such as is used for leading and trailing edges, are repaired in much the same way as round tubes, that is, by using split sleeves or tubular sleeves of a suitable streamline shape, which are riveted into position as shown at F and G, fig. 97.

Strip steel repairs.

407. The normal method of repair of a strip steel structure is to rivet on a patch of special section strip steel which has been rolled or drawn to the section required. Built-up round tubes are repaired by the patch method shown at C, fig. 98, or by internal tubular sleeves as indicated at B, fig. 98. In both the instances shown, the type of repair is applicable if it has been found necessary to cut out a completely damaged section of the member, by elongating the repair material. Leading edge strips and similar sections are repairable, one method being indicated at A, fig. 98. Built-up strut sections are normally patched as shown at D, fig. 98.

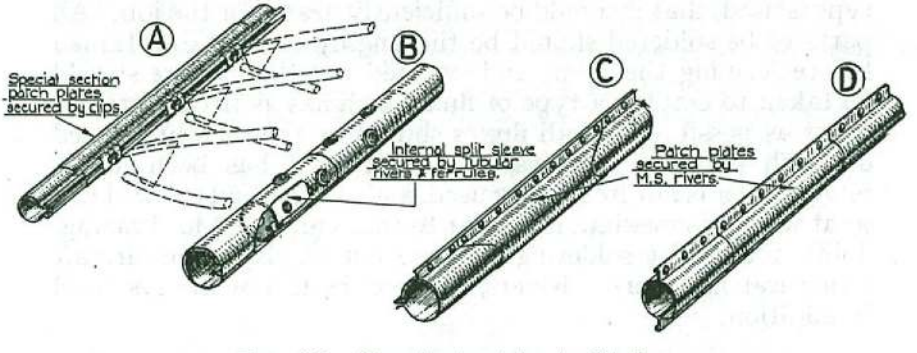

FIG. 98.—Repairs to strip steel tubes.

408. As strip steel structures are built up with many varied sections, it is impossible to do more than indicate the types of repairs which are undertaken.

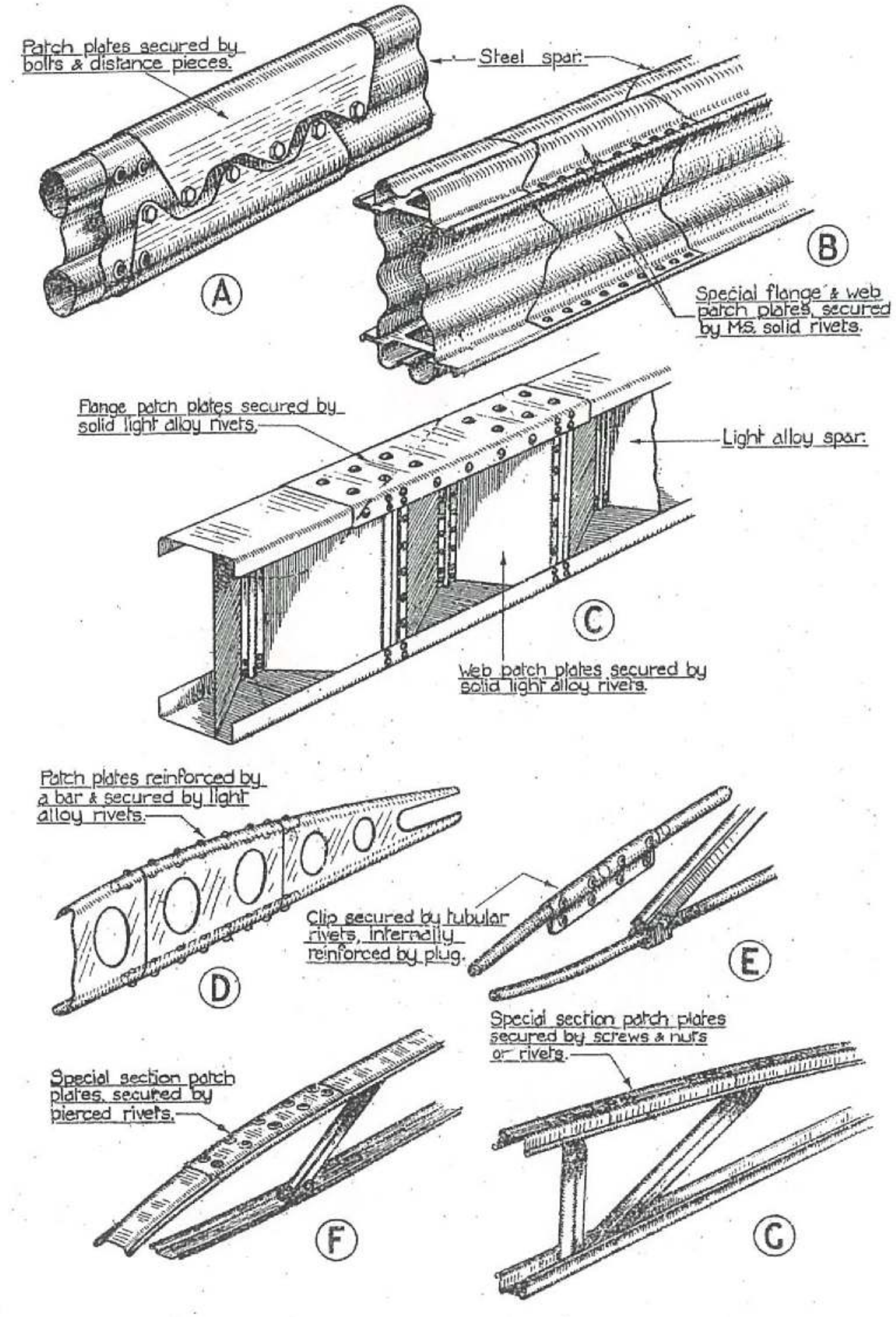

FIG 99. REPAIRS TO SPARS AND RIBS.

Spar repairs.

409. Most types of metal spars are repairable, but as these parts are the main strength members of the wings, considerable care is to be exercised to ensure reliability and truth of the member after repair. The method of repair is usually to rivet on rolled or drawn strips which conform to the shape of the flange or web, as shown at B and C, fig. 99.

410. Tubular spars are repaired in a similar manner to that employed for tubular struts, which has already been described. Special section tubular spars of the type illustrated at A, fig. 99, are repaired as indicated by patch plates of U-section, which are placed over the spar from above and below and riveted on to the spar at the neutral axis. Only those repairs authorised in the aircraft repair notes are to be attempted.

Ribs.

411. Unless the damage is slight, injured ribs are usually discarded and substituted by special replacement ribs. The method of repairing ribs depends greatly upon the type of construction, but in most cases it is effected by patch plates of suitably formed materials which are riveted over the damaged portion as shown at D, E, F and G, fig. 99.

Metal hull and float repairs.

412. Minor damage to the sections of metal hulls and floats is repaired by patch plates, which are riveted into position. The size and shape of the patches obviously depend upon the amount and position of the damage ; therefore, in most cases, the exact manner of repair can only be decided after examination. Repairs of metal hulls and floats are usually far simpler than the repair of equal damage to a similar wooden structure, and, if the repairs have been carried out correctly, there is generally no question whatever of any loss of strength. Except where extensive rebuilding is necessary, repairs should present no great difficulty, as the damage to metal structures is generally local in character. The method of repair should always follow as closely as possible the original method of construction.

413. When a hull or float is holed, it is not always essential to remove the complete plate, but a small patch can be riveted over the hole. All patch plates should be at least as thick as the plates being repaired. Where damage is more extensive and involves stringers, intercostals or formers, it is usual to cut out the members concerned and substitute members made up to suit. For quick repairs, small bolts can be used

instead of rivets. During repairs, it must be borne in mind that the frames, centre keel, side keelsons and intercostals are usually the most important parts of a hull, and on these members depend its shape and strength. The type of riveted joint used for the repair will normally be one of those shown in fig. 96, but the pitch and size of the rivets should be similar to those employed on the part of the structure to be repaired.

414. If it is necessary to extract rivets, they should be removed by cutting off the heads with a small sharp cold chisel and a light hammer, and punching out the shanks. When making holes for new rivets, they should be drilled and not punched, and holes which are unfair or not in alignment should not be drifted but should be drilled out and fitted with a larger rivet. As already explained in para. 386, the holes required for light alloy riveting should provide rather more clearance for the rivet than is necessary for steel riveting. Rivet holes should not be countersunk unless countersunk rivets are being used, but a countersinking tool may be employed for removing burrs. Either pan or snap-head rivets may be employed, but the snap-head type is generally used, and this type of head is usually formed when riveting up. Duralumin rivets must be softened before use by normalising, and riveted up within one hour of treatment.

415. All metallic surfaces in contact at a joint should be given a coat of approved protective substance such as an enamel, with a basis of tung oil varnish or cellulose, and the parts riveted up after the enamel has dried. Care should be taken during repairs not to damage the extremely thin anodic surface of aluminium alloys. After repairs to a hull or float, either internal or external, water tests should be made to ensure watertightness. For further information and details, reference should be made to " Notes on the repair of duralumin hulls and floats " provisional issue, October, 1928.

Protection against corrosion.

416. One of the greatest enemies of metal aircraft parts is corrosion. An infallible and everlasting remedy for corrosion which is of practical utility has yet to be found for the majority of ordinary metals. The greatest advance within recent years was the introduction of stainless steel. The use of this material, of which there are several varieties, appears to be a solution of many problems connected with corrosion. Materials used on aircraft which demand the greatest care from the aspect of corrosion are ordinary steels and light alloys. Steels by themselves do not corrode at a greater rate than many other metals, but as already pointed out in para. 166, on account of their greater tensile strength they

are generally used in much thinner gauges than other materials and are therefore more susceptible to deterioration owing to this cause. Light alloys which have a basis of aluminium or magnesium are inherently unstable metals, and, given an opportunity, will corrode very quickly. The corrosion which occurs in these materials is not always attributable to exterior causes, but it may be due to the interaction which occurs due to impurities in the metal. For both steels and light alloys, the basic principle of protection against corrosion is to exclude the air from contact with the metals. If, therefore, corrosion is to be avoided, it is imperative that the protective covering should remain intact, or if, owing to mishandling or Service usage, the protective covering has become damaged, it should be renewed immediately. The Air Ministry Technical Order dealing with this subject is 352 of 1930.

417. The types of corrosion which occur are surface corrosion and that due to interaction, and the forms in which it may become evident can be classified as surface, intercrystalline, and pitting. Surface corrosion is usually easily recognisable as a visible form of oxidation, which on steels appears as rust, on light alloys as white powder, and on copper alloys as green verdigris. Surface corrosion is mainly produced by external atmospheric conditions such as great humidity, and is very pronounced in the presence of sea air or sea water.

418. The intercrystalline and pitting forms of corrosion may also be due to the same cause, but are perhaps more noticeable when some kind of interaction is present, owing to surface contact between different types of metal, and sometimes even between metals of the same kind. The interaction which has been mentioned is electrolytic, that is, a minute difference of electrical potential is set up between the parts, or between the microscopic constituents of the metal, due to the presence of moisture and salts or acids, or other conducive circumstances. Intercrystalline corrosion in its early stages is not so easily recognisable, as it affects the internal structure of the material, but as surface corrosion or pitting usually accompanies intercrystalline corrosion, surface corrosion may sometimes be taken as an indication of the presence of intercrystalline corrosion. The effect of intercrystalline corrosion on light alloys is to deteriorate the material very quickly, and finally, although the material has the appearance of considerable body and a large proportion of its original strength, it can in many cases actually be broken up by hand pressure. Pitting is a form of corrosion which occurs mainly in small isolated areas, penetrates some distance into the material, and may in many instances be attributed to impurities in the material.

419. For ordinary steels the normal precautions against corrosion take the form of stove enamel, cellulose and air-drying enamels, of which the stove enamel is perhaps the best and most durable. As an additional precaution, which is very necessary in some instances, ordinary steel parts sometimes have an electro-deposited film of zinc or cadmium of the order of ·0005 in. (half a thousandth of an inch) thick. Non-corrosive steel parts which are properly made and heat-treated do not suffer from corrosion to any extent, except when used as exhaust manifolds or extension pipes, where the temperature has a very harmful effect.

420. Light alloys are very difficult to protect effectively, and even when the best means available are adopted a considerable amount of care is necessary if a long service life is to be attained. Aluminium alloys are protected by means of anodic oxidation process, which produces an adherent surface film of oxide which is capable of protecting the metal against corrosion to a considerable extent. The degree of protection is greatly enhanced by an additional covering, depending upon the conditions, of non-acid oil or grease, such as lanoline, or a lanoline basis preparation similar to D.T.D.121, or by a coat of a cellulose enamel similar to D.T.D.63 or a tung oil varnish. Magnesium alloys can be treated in several ways, the best being perhaps the chromate immersion treatment. This treatment produces a film on the metal in a similar manner to the film produced on aluminium alloys by the anodic treatment, but is much more frail and must be followed immediately by a protective covering such as D.T.D.121 as a temporary measure, or enamel when a more permanent covering is required. The use of the temporary corrosion preventative D.T.D.121 is not confined to light alloys, but can be used with advantage for any metals when a more permanent method cannot be employed, or is not necessary.

421. For seaplanes, in addition to the surface protective coverings, there are certain structural precautions which are usually taken. These precautions generally involve the use of non-corrosive steels wherever possible, and the avoidance of surface contact between metals which produce interaction. Surface contact between metal faces is prevented by interposing an insulating film of enamel or varnish. This does not of course entirely prevent interaction, as there is then a tendency towards an undesirable activity at attachment rivets or bolts, but if these are made of stainless steel, this effect is minimised. When ordinary steel fittings are attached to light alloy hulls and floats, it is necessary to take special care to avoid corrosion due to interaction. For this purpose, enamel-impregnated fabric is sometimes used, placed between the contact faces. For non-corrosive steel fittings the same

care is not required, but it is advisable to interpose a film of enamel to prevent direct contact. All mating surfaces, such as between riveted lap joints, should be coated with enamel, which is allowed to dry before riveting up.

422. The external protective covering for light-alloy hulls and floats normally consists of two coats of under coat enamel, Stores Ref. 33B/63, followed by one coat of V.85 (cellulose with added gums), Stores Ref. 33B/55, enamel, cellulose, marine. For internal use one coat of V.85 is all that is necessary, except at the cockpit positions when grey green cellulose enamel to Specification D.T.D.63, Stores Ref. 33B/50 and 51, is in general use. All seats, lockers and similar types of equipment are usually covered with clear varnish to Stores Ref. 33B/1. The flats (floorings) are painted with grey enamel, Stores Ref. 33A/62. Lanoline, D.T.D.121, or any non-acid grease which may be used to prevent corrosion is unsuitable for tropical conditions, as owing to the temperature encountered its effects are very temporary. Ordinary cellulose enamel also is not entirely satisfactory under these conditions, but tests are now being made with the cellulose enamel, D.T.D.63, which has an addition of an aluminium pigment and gums, which it is anticipated will satisfy most requirements.

Repair and maintenance of airscrews.

423. Airscrews are so designed that they will absorb, at the stated maximum revolutions per minute, the full horse-power output of the engines at the operational height of the aircraft. The airscrew design factor which mainly governs the R.P.M. of the engine, is the pitch or blade angle, and provided that the engine is running correctly and discounting the effects of atmospheric conditions, any persistent increase of R.P.M. observed could only be attributed to a decrease or flattening of this angle. Serious damage to wooden airscrews is seldom repairable, but minor defects in airscrews which are covered with cellulose lacquer can be repaired in the manner described in Air Ministry Technical Order 404 of 1929. Wooden airscrews may be reconditioned by re-tipping or re-finishing. The service life of airscrews may be lengthened considerably if minor damage to the cellulose covering is repaired as soon as it occurs. The airscrew need not be detached for this purpose. Damage to airscrews usually occurs when the engine is run up on the ground, and is caused by small stones and sand which are drawn into the airscrew disc. If the airscrew is flown after the film has been damaged, the timber may be worn away. If the erosion is slight, the damage can be repaired by the application of the required number of coats of cellulose lacquer, but if the timber is pitted to a depth of about $\frac{1}{16}$ in. or more, time will be saved by using plastic wood,

Stores Ref. 33A/336, as a filler before the final application of the cellulose lacquer.

424. The metal sheathing on wooden airscrews is not intended as a protection against mishandling. Therefore when an airscrew is detached from its hub it should not be stood on the tips of the blade, but should be laid flat or hung up on a peg.

425. When fitting a hub to a wooden airscrew, or an airscrew with a wooden boss, care should be taken to ensure that the hub flanges are tightened uniformly. This should be done by first lightly tightening opposite bolts in turn, and finally tightening all bolts in the same order. It is essential that the bolts securing the airscrew to the engine hub should be drawn up tightly. This is necessary because the drive from the engine is transmitted mainly by friction between the hub flanges and the airscrew boss. If the bolts are not drawn up tightly, a rapidly increasing slackness will develop in service which will probably result in broken hub bolts and other troubles. The tightness of bolts should be checked after the first ground run of the engine subsequent to the fitting of the airscrew, and afterwards from time to time.

426. Metal airscrews must be handled with care, especially when turning the engine over by hand, because the tips of the blades are comparatively thin and consequently the angular setting may be upset if roughly handled. Seriously damaged metal airscrews are seldom repairable by the unit, and any cracks, fractures, or other serious defects render the airscrew unserviceable. The protective covering of the hollow steel blades may be destroyed by the abrasive action of sand or dust; therefore, to prevent corrosion, blades of this type should be treated with the temporary rust-preventive, D.T.D.121, Stores Ref. 33C/301, (*see* Air Ministry Technical Orders 235 of 1929 and 352 of 1930). It is not necessary to protect light-alloy airscrews against corrosion when in use.

427. The normal inspection and maintenance of airscrews is undertaken as detailed in the schedule of aircraft maintenance.

Checking airscrews.

428. Wooden airscrews are manufactured to tolerances on dimensions and blade angles which are as small as practicable. Airscrews of this type, however, are susceptible after construction to changes in pitch, track and balance owing to the effects of shrinkage of the timber. Such changes do not necessarily render an airscrew unserviceable unless performance is appreciably affected or unless excessive vibration is experienced.

429. In order to carry out a satisfactory check of the dimensions and blade angles of airscrews, it is necessary to have a surface table of adequate size together with special measuring apparatus. Owing to its weight, size and cost, such equipment is only available at certain stations, where such a check can be carried out if required. The apparatus required includes, besides a large surface table, a steel protractor, a scribing block carrying a dial micrometer gauge, and a pair of hollow conical adaptors. A steel spindle which is a sliding fit in the bore of the adaptors is mounted on a base block so as to stand truly perpendicular to the table. The airscrew is lightly tightened down on to the spindle, rear face uppermost, with the adaptors arranged at top and bottom of the bore so as to bring the bore exactly parallel to the spindle. The surface table will then be at right angles to the bore and will constitute the datum line from which the various measurements are taken. The checks consist of measuring, by the usual methods employed in inspection rooms, all measurements given on the airscrew drawings, which must be available before this work can be carried out. In this connection attention is drawn to Appendix III, which gives possible extensions of tolerances on blade angles for wooden airscrews now in service,

430. The balance of an airscrew, however, can be easily checked by means of a simple form of balancing machine, Stores Ref. 4A/419. This machine takes the form of a rocking beam, pivoted upon hardened steel knife edges and supported in a frame of the wall bracket type. The beam has an overhung spindle rigidly connected to it for the reception of the airscrew, and mandrils fitting this spindle are supplied having outside diameters to accommodate different sizes of airscrew bores. The beam is cast with an I-section, approximately 17 in. by 5 in. in side view, with 3 rectangular apertures in the web. There is an upper knife edge in the front aperture and an upper and lower knife edge in the rear aperture. Owing to the overhung spindle, the weight of the airscrew gives a down-load on the front knife edge and an up-load at the lower knife edge at the rear. With the airscrew removed, the weight of the rear end of the beam is taken on the upper knife edge. As a slight amount of play has been arranged between the two rear knife edges, care must be taken not to damage them by any sudden application of load. The motion of the beam is damped by an adjustable oil dash-pot situated at the rear end of the frame. The rocking beam is capable of being locked in a vertical position by means of a sliding block attached to the frame, and has a pointer attached to its upper flange which indicates on a graduated scale the number of inch ozs. the airscrew is out of balance. When setting up the machine, the frame must be correctly levelled by means of the spirit level provided.

431. The beam must be initially adjusted to ensure that, with no load, the pointer is at zero. This adjustment is made by rotating the central screwed spindle of the traversing weight situated in the central aperture of the beam. In use, the beam is locked and the airscrew to be checked is assembled on the spindle by means of suitable mandrils, one at each end of the bore. Airscrews should be tested for balance with the blades of the airscrew in both the horizontal and the vertical positions. The balance of a wooden airscrew can be corrected, if the error is not large, by the application at advantageous positions of partial coats of the particular protective film employed. If the balance of the airscrew is such that it cannot be corrected by a few applications of the protective film, then the airscrew should be returned to stores depot for correction or rejection.

432. No attempt should be made to correct metal airscrews found to be out of balance, particularly those with interchangeable detachable blades. With such airscrews, moreover, opposite blades may in some instances, be found to differ slightly in length and track. Small differences of this nature are allowed in manufacture for the purpose of obtaining satisfactory balance and must not, therefore, be regarded as necessarily rendering airscrews of this type unsuitable for use.

433. The following method of testing an airscrew when fitted to an aeroplane is not a reliable method of checking the track of the airscrew but does give some indication whether an airscrew is badly out of truth or has been unevenly bedded on to the airscrew shaft by the tightening of the bolts through the airscrew boss. A trestle or other support is placed in such a position that it is a little in front of the path of the airscrew blades and level with a point about two-thirds along the blade away from the boss. The distance between the leading edge of the blade and some fixed point on the trestle is then measured for each blade, care being taken that all measurements are made in the same straight line, which should be approximately parallel to the airscrew shaft. For airscrews of about 8 ft. diameter the variations should be within ·25 in. Great care must be taken throughout to eliminate error due to fore-and-aft (axial) movement of the whole airscrew during turning.

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