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THE CONSTRUCTIONAL DESIGN OF METAL FLYING-BOAT HULLS

PART I

WORKSHOP NOTES ON THE BUILDING OF METAL HULLS

PART II

By M. Langley

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THE CONSTRUCTIONAL DESIGN OF METAL FLYING-BOAT HULLS.*

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PART I.

Introduction

The scope of Part I is strictly that indicated in the title. It approaches the subject rather from the point of view of the naval architect than from that of the aerodynamical expert. Nothing is said of the form, lines and stability problems of hull design nor of the aerodynamics of the flying boat as a whole.

Many excellent papers on these branches of the subject have appeared during the last few years. Part II of this paper deals with the actual workshop process of building a hull.

Materials

Pippard in "Note on the Comparison of Metals as Aeroplane Structural Materials" (British Reports and Memoranda No. 729) has compared Steel and Duralumin on a basis of strength for weight. Jones in "Notes on Magnesium and Its Alloys" (The Journal of the Royal Aeronautical Society, December, 1926) has extended his method to include Elektron.

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Although duralumin is at present the only material used in hull building, these papers are worth study, particularly in view of the present research into the anticorrosive protection of magnesium alloys. If this research should meet with success one can foresee that duralumin may have a very serious rival.

Two other future "probables" may be mentioned. The first of these is "Alclad," a product of the Aluminum Company of America, and an account of it appears in N.A.C.A. Technical Note No. 259 (August, 1927). It consists of a sheet of aluminum alloy of considerable strength, both sides of which are metal-sprayed with pure aluminum. The material is heat-treated, and diffusion of the alloy into the pure metal takes place, thus ensuring perfect cohesion.

The purpose of the aluminum coating is to protect the alloy from corrosion, and some remarkable results are claimed. It is said to be much superior in this respect to aluminum alloy with the surface anodically treated.

No figures are, however, given for its physical properties, and further particulars are awaited with interest.

The second but more distant "probable" is Beryllium alloy, some particulars of which were given in The Scientific American, November, 1927. Pure beryllium is one-third lighter than, four times as elastic as, aluminum, 25 per cent more elastic than steel. It will scratch glass like hard steel. When alloyed with aluminum in the proportion of beryllium 70 per cent and aluminum 30 per cent, the product is said to be one-fifth lighter than aluminum, to be far more resistant to corrosion, and to have a much greater tensile strength than duralumin. Its cost is at present prohibitive, but if and when that difficulty is overcome it may be an extremely useful metal.

For the present, however, we have only duralumin to consider. No official standard figures for its strength, except the ultimate tensile, are available. The following figures are averages of those used for stressing by four different aircraft firms in this country: Ultimate tensile, 23 tons sq.in.; maximum shear stress, 14½ tons sq.in.; maximum bearing stress, 27 tons sq.in.; yield and compression, 16 tons sq.in. Young's modulus is 4700 tons sq.in., its specific gravity is 2.8 and its weight 175.3 lb. per cu.ft., or 0.101 lb. per cu.in.

The principal casting alloy now used is "Alpax," whose composition is: Manganese not more than .5 per cent, iron not more than .75 per cent, silicon not more than 10-14 per cent, aluminum the rest. Its ultimate tensile strength is 12 tons per sq.in., elongation 7 per cent, and specific gravity 2.68. It makes very satisfactory castings down to 0.10 inch thick and, unlike duralumin, it can be welded either to itself or to pure aluminum. It machines well, and on this account is frequently used instead of duralumin where a part is required to be welded to aluminum.

S c a n t l i n g s

In the present stage of metal-hull design no tradition or general practice of scantlings has yet sprung up. There has been no coordination among the various designers engaged in this work except that due to the supervision of the Air Ministry. Nor has a reliable method of predicting the strength of a hull by mathematical methods been found.

I believe that the stress department of one flying-boat firm makes some attempt to calculate the strengths of the planing bottoms of hulls, taking as a basis the Aeronautical Research Committee's Reports and Memoranda No. 683. This report gives the results of some experiments carried out on an old F_3 hull and an H 16 hull to determine the maximum loading which may occur on the planing bottom. How far these results are applicable to modern designs, and of what value are stress calculations based on them, is problematical.

A later paper from the same source, Reports and Memoranda No. 926, give the results of impact tests on a P_5 flying boat hull. Since the worst case recorded on these tests shows a load of little over half those of F_3 and H 16 hulls the issue is only confused, and no safe conclusions for untested designs may be drawn. Those who are interested in this aspect of the problem should refer to papers by Professor Abel (Trans. I.N.A. 1923,* Vol. LXV, p. 161), and Professor Inglis (Trans. I.N.A. 1925,* Vol.

*Transactions of Institution of Naval Architects (British).

LXVII, p. 145), in which are discussed the behavior of stiffened thin plating under water pressure.

Under this heading I shall therefore only give some average figures for a typical 45-foot hull, to be built in duralumin, with longitudinal shell plating, and framed rather on the principle of the Isherwood ships, i.e., with deep frames widely spaced and longitudinal stringers close together. Apart from the flying boats built by Short Bros., Ltd., under their own patents, most of the hulls built in this country have been based on this method.

Figures 1 and 2 show scantling sections of such a hull.

The planing bottom in its most highly stressed part forward of the main step is plated with 14 s.w.g. (.080 in.) sheet, the remainder being 16 s.w.g. (.064 in.) except towards the stern where it is reduced to 18 s.w.g. (.048 in.). The top-side plating is 16 s.w.g. (.064 in.) to 18 s.w.g. (.048 in.), with 20 s.w.g. (.036 in.) at the top ends. A good "shift of butts" should be made in the shell, that is to say, butts in adjacent strakes should be separated by one or more frame spaces. Even butts in alternate strakes should not occur in the same frame space. A butt is always liable to be a point of weakness and so they should be well separated rather than concentrated in one zone.

The transverse frames have an average spacing of 24 in., being closer together at the forward end and doubled at the main plane spar positions. They are constructed as shown in Figures 3 and 4, and are 18 s.w.g. (.048 in.) thick amidship and 20 s.w.g. (.036 in.) at the ends.

Certain of the frames should be made without lightening holes in the floor portion, to act as bulkheads. The number which are treated like this is a matter of calculation, and should be so arranged that if a leak occurs in one compartment the flying boat would not settle or trim sufficiently to allow the water to flow over the top of the floor into the next compartment and so sink it immediately.

It is usual to cut notches in the frames to allow the stringers to pass through unbroken from stem to stem. In view of the success of the latest Isherwood developments and of the opinions expressed by Professor Abel (Trans. I.N.A. 1923, Vol. LXV, page 161) this hardly seems necessary.

I would suggest that a continuous keel and dorsal together with a side keelson, and four intercostal girders on each side would be sufficient to help out the shell in carrying the main longitudinal stress.

The intermediate stringer angles whose function is to prevent local buckling of the shell need only run between frames and not even be attached thereto. The standing flanges of these stringer bars or channels should be shaped off at an angle of 30° as shown in Figure 5.

The shell angles of the longitudinal girders should, however, be continuous and be notched into the frame webs. The intercostal plates mounted on them should be attached to the frame webs by short angles, say 5/8 in. x 5/8 in. x 16 s.w.g. (.064 in.) and the whole connection finished off as shown in Figure 6. This applies equally to the side girders and to the side keelsons.

The center keelson and dorsal are quite continuous both in plates and angles. These are the first members to be erected, and the frames are made in halves, port and starboard, to be attached on each side. (See Figs. 7 and 8).

Where, owing to the limitations of plate sizes, it is necessary to make a break in the keel and dorsal plates, the break should be made good by butt straps (See Fig. 9). Such breaks should, of course, occur between frames. These will give an opportunity for reducing the center keelson from its midship thickness of 18 s.w.g. (.048 in.) to 20 s.w.g. (.036 in.) at the ends. It will hardly be necessary to make any special provision for a break in the bottom angles of the keelson or top angles of the dorsal as the plating will transmit the load past the point of break.

Cuts in the angles on the free open edges of the keel or dorsal should be covered by a butt strap. Care should be taken when designing to see that such cuts and breaks occur at as widely varying places as possible. It would be a great point of weakness, for example, if a break in each of the four angles and also of the plate of a girder were all allowed in the same frame space.

Similarly, it may not be found possible to run an unbroken length of chine bar from stem to step, etc., although it is better to do so. If a break should be necessary it ought not to occur in the same frame space as a butt in the adjacent shell plates.

The construction of the steps presents points of particular difficulty, since duralumin cannot be hammered or beaten into the same awkward shapes which are possible in steel. Nor has a satisfactory method yet been found of welding it. All the riveting must be perfectly accessible and there must be no corners where moisture can accumulate without detection.

Experience has shown that leakage is more likely to occur at the step than anywhere else in the hull not only because it is one of the most highly stressed parts but also on account of the constructional difficulties. To devise a really satisfactory method of overcoming these troubles probably calls for more ingenuity and real skill in detail design than any other part of the flying boat.

Three methods present themselves at once, two of which the author knows have been used. All three have serious objections against them.

The first is to build a step of the open type as shown in Fig. 10 and to fill in the corners with solid aluminum alloy blocks, secured by tap rivets. The tap rivet should not be screwed quite home but finished off by hammering over the head, after which surplus metal may be chipped or filed off. A tiny notch may be filed in the edge of the rivet hole into which the head may form, thus locking the rivet.

The second method is to build the step in the more orthodox manner shown in Figure 11, covering the corners with cap pieces welded up from noncorrodible steel sheet. These fittings should be well stove enameled, the joints being made up with tacky enamel or varnished fabric. Stainless steel rivets should if possible be used in order to reduce the number of points of contact of varying metals on the more exposed outer surface.

The third method is similar to the second except that thin aluminum alloy castings are used instead of stainless steel. Such castings should be thoroughly examined for faults and great care should be taken in riveting to prevent cracks developing.

With the exception of hatchways or cockpit openings the remainder of the detail design presents no particular difficulties. Any large openings in the shell create points of great weakness in the longitudinal strength of a hull and adequate compensation must be provided. The skin of the flying boat at any such openings should have doublings fitted, especially at the corners. A main longitudinal girder should be arranged to run along near the edge of the openings on each side and it must not only be strengthened at the openings themselves but tapered away in strength for some distance at the ends of each opening.

Strong transverse bridge pieces or strengthened frames should be placed at each end of any opening to which such broken members as the dorsal may be anchored. Lastly, the edge of the opening should have a coaming angle well riveted to it all the way round. Figure 12 represents a cockpit or hatchway constructed in this manner.

Though it is not strictly a part of the flying boat structure, the flooring of the cabin portion deserves mention and unless it is borne in mind during the early stages of the design considerable difficulty may be met with when the time comes for fitting it. It will be seen in Figure 3 that the floor portion of the web frame runs straight across from side to side. Double wide-flanged angles are riveted across the top edge and on these the flooring rests. The flooring must be very readily portable for inspection purposes and should give ample ventilation of the inner bottom of the flying boat.

Though some designers favor simple, closely-spaced wooden battens or duralumin channels bolted to the frames, others use corrugated or pyramid plate in duralumin on aluminum stiffened underneath with channels. These plates are in such sized sections that they may be entirely unshipped through the hatchways and they are fastened to the frames with quick-release catches or bolts.

The Restrictions of Duralumin on Constructional Design

The heat treatment of duralumin is now getting to be well understood in all aircraft works and the differences between annealing at 360°C and heat treatment at 480°C, are realized. Since the design of a hull is alone being considered, the practical problems of these treatments will not be discussed but only those points which affect the design.

The designer must always remember the limitations of his material and not expect the impossible from the workman.

Whenever shaping and beating are required the metal must be annealed. And after working, it must be restored to strength by heat treatment.

During the soft phase through which the metal passes following heat treatment, it is quite as pliable as after annealing. But this phase lasts only an hour or two before age hardening sets in.

A very great saving will be effected by recognition of this fact in designing units as simple as possible. With careful design there are many units on which all shaping could be completed within that hour and thus annealing would not be required for them. Instead of it being the usual thing for all parts to be annealed it should be reserved for special cases.

The parallel in shipbuilding is the use of the plate furnace for oxter, propeller boss and stem foot plates only.

As metal flying-boat building passes from an experimental to a production basis this will become increasingly important, and those designers who think in terms of fantastic shapes with elaborate flares and curves, will find themselves outclassed by the more economical methods of their rivals.

Steel Fittings

Steel fittings taking towing gear, under center-section struts, and the tail unit must be made of the stainless variety.

Since they are likely to be highly stressed they must be bedded on to sufficiently stiff and large duralumin doubling plates to spread the stress efficiently. These doublings should be in two or more laminations, stepped up in size and riveted to the hull skin over frames.

The steel fittings may then be bolted through, with the bolt heads bedding into some stiffening angle inside.

Riveting

The following sizes are in common use:

Thickness of plates to be joined	Dia. of rivet
12-14 s.w.g. (.104-.080 in.)	3/16 in.
16 s.w.g. (.064 in.)	5/32 in.
18-20 s.w.g. (.048-.036 in.)	1/8 in.

Spacing

It is usual to pitch the rivets 4 diameters apart in all water-tight work, such as laps and butts of shell, attachment of shell to frames, stringers, etc., and in important structural members as keel, and keelson butts, floor plate and frame web butts. Elsewhere a spacing of 8 diameters is used.

Butts, Laps, etc.

Owing to the relatively lower shear strength of duralumin compared with steel, riveted laps cannot be of quite the same proportions. The center line of rivets should never be nearer to the edge of plate than 2 diameters, and rows of rivets should be 3 diameters, center to center.

Butts and laps of keel and keelsons should be treble riveted, and butts and edges of shell plating, laps and butts of floor plates and frame webs double riveted. From this it will be seen that the following widths of butt straps and laps hold:

Thickness of plating	Diameter of rivet	Width of lap			Width of strap		
		Single	Double	Treble	Single	Double	Treble
14	3/16"	3/4"	1-5/16"	1-7/8"	1-1/2"	2-5/8"	3-3/4"
16	5/32"	5/8"	1-3/32"	1-9/16"	1-1/4"	2-3/16"	3-1/8"
18-20	1/8"	1/2"	7/8"	1-1/4"	1"	1-3/4"	2-1/2"

Butt straps should be at least as thick as the plates they join. Chain riveting should be used everywhere except in flanges of angles where the width of flange may suggest reeling. Owing to the thin materials used, countersinking is not found satisfactory.

A precaution which the designer should take is to arrange all seams and laps as near to stringers or frames as is possible. This will in some measure prevent stretching during hammering up and will stiffen the plating against drumming.

The Adaptation of Shipyard Methods

Flying-boat building is little more than shipbuilding on a smaller scale and if our designers are going to meet the competition of cheap production of excellent designs on the Continent, they must turn to the experience of our generations of shipbuilders.

It will not be found that metal construction in any way lightens the load of the designer and draftsman when compared with wood construction. Much greater exactitude is necessary and the design must be considered in detail. An all-metal hull should not be put in hand until the smallest parts have been worked out on paper. Metal does not lend itself to subsequent modification and everything must be foreseen.

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WORKSHOP NOTES ON THE BUILDING OF METAL HULLS*

PART II.

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*From The Aeroplane, July 25, 1928.

material. We have a fair comparison in the difference between a modern constructional engineer on steel frame building work, and the jobbing carpenter and bricklayer who used to get on almost equally well with or without architect's drawings.

In the works, however, economics may be effected by the standardization and efficient layout of plant to secure the minimum movement of material between processes. Wherever possible, standard jigs and tools should be made up and it will be found that a greater degree of accuracy and interchangeability of spares will be obtained.

As has already been pointed out, the design department should see that hand work is eliminated on every possible occasion, and whenever a process such as annealing can be passed over, this should be done. One of the most important qualities in a metal-work draftsman is the power of visualizing every bit of work which must be done to the detail he is designing, and to help the workman to dodge every unnecessary process. Too often one can see all this forgotten in the heat of developing some pet scheme with great unconcern of the difficulties and expense involved in its development. The number of different angle and channel sections used for stiffeners and lugs should be kept down ruthlessly and those permitted should be standardized.

Process of Building

The first thing to be done in the works is the laying off of the lines full size in the mold loft. The offsets supplied by the drawing office could hardly be given with a greater accuracy than .10 inch since they are usually prepared from a line drawing done in a scale of 1/12 full size. Much time will be saved both in the works and drawing office, if the body offsets are given to frame stations and not to the usual equidistant ones which have no structural meaning at all.

The actual process of laying off will not be described, since it presents no novel features and is fully understood by any shipwright used to boat or ship work. An admirable textbook on the subject is Attwood and Cooper's "Laying Off, or the Geometry of Shipbuilding" (Longman, Green and Co.). One point does deserve mention, however, and that is the importance of having a perfectly flush mold-loft floor, free from excessive cracks and knots and of ample size. This is a thing which may be insufficiently realized by those without actual loft experience.

The floor should be of at least 1½-inch thick, hard straight-grained pine in wide planks, close-butted together with the fastenings so arranged that the surface may be dressed periodically. For each 45-foot hull a space of 55 ft. x 20 ft. should be provided and if several designs are going through at about the same time, it should be remembered that it may be necessary to leave the lines of each one down on the floor, for as long as the flying boat is on the stocks.

The lines having been faired in the usual way with all frames, stringers, floor lines and shell plating edges added, a check on all the offsets should be returned to the drawing office, and wood templates prepared for the shops. A "scrive board" should be made at the same time. This will differ from a shipyard scrive board in that the work is of such small size that actual "scriving" or cutting of the lines will not give the degree of accuracy required.

The board may be made in the form of a table with a surface of three-ply or some light-colored veneer glued and screwed to a heavy top. The frame lines should then be drawn in pencil and the surface varnished to preserve them.

From these frame lines templates or molds are prepared. The only information taken from the scrive board is the outside contour of the frame. Each frame should be templated in parts to represent its components - the floor plate, the side frame, the deck beam, the deck and chine corner brackets - the remaining information being taken from the drawings.

It should then be possible to lay each template on a piece of sheet of the appropriate thickness and to transfer all the particulars on to it for cutting and shaping.

When only one flying boat is being built, the templates may be in thin wood, doing no more than giving the outside shape of the finished plate. Other particulars may be added direct from the drawing.

But when the building is on a production basis, it is advisable to have the templates in sheet steel of, say, 18 s.w.g. (.048 in.) containing the positions of all holes, so that they may be clamped to the plates and used as drilling jigs in addition to giving the outside contour.

A further wooden mold, three-quarters to an inch thick, may be made from the scrive board to each frame line, round which the shell angle of the frame may be bent to its correct contour.

Reference to the drawings show that in the particular design given, these contour lines are, for the most part, straight. It is possible to design a hull with the deck camber, the radius of the deck corner brackets and the flare under the chine, constant throughout most of the length, thus reducing the number of molds necessary, cheapening and simplifying the construction.

At this stage the leveling of the frame shell flanges to follow the fore and aft run of the flying boat should be done. For this, it is necessary to turn to the scrive board again and to use a bevel measurer of the type shown in Figure 13.

Suppose that the bevel of the frame at B as shown on the scrive board (Fig. 14) is required. Then the arrow mark on the bevel measurer is applied to a point A opposite B on the next frame, the adjustable distance Y made equal to the frame spacing and the point of the movable leg L is brought up to B.

The angle of L to the vertical leg of the bevel measurer gives the required bevel.

Since the bevel, particularly on the frames at the ends of the flying boat, is likely to vary considerably between the dorsal and keel, the bevel measurer should be used at four or five different positions on every frame.

On setting up the keel and dorsal one may follow the practice of boat and launch builders in using a stout pine mold cut out to the longitudinal profile of the hull. This should be erected and shored up in the actual position in which the flying boat is to be built, under cover and with a convenient runway above to lift the hull, when complete, on to a trolley for removal. The keel and dorsal plates may then be built into it complete, their top and bottom flange angles added and the whole riveted together. In the meantime the frame webs and angles should have been prepared on the bench and be ready to erect on to the keel and dorsal in complete half units (port and starboard).

A constant watch must be kept by the shipwrights on the fairness of the hull as the work proceeds. Distortion of the vessel in the transverse direction is likely to occur as the various weights are added bit by bit. The verticality and straightness of the profile mold should be checked all the way along its length every day, and any sagging corrected at once.

In the same way, the frames must be checked before they are finally riveted up. Until the stringers are actually riveted into the structure, ribbands will of course be necessary to support the frames.

These should take the form of pitch-pine battens running the length of the flying boat and clipped to every frame, there being one, two or three inches from the eventual position of each continuous stringer.

As will be seen from Figure 15, the rigidity of the frame to ribband attachment depends on the tightness of the bolt. If the frame distorts fore and aft the bolt may be slackened off slightly, the frame tapped back into position, and the bolt tightened again. It is usual in full-sized shipbuilding to lay off the ribbands carefully in the mold loft before they are actually required, and to mark on them the exact position of every frame.

The importance of a day-to-day inspection of the hull for local distortion or sagging cannot be overestimated. If, say, a shell plate has been templated from a structure which has fallen out of truth, then the plate must either be scrapped or an unfair line expected in the finished flying boat. And that unfairness becomes all the more evident when covered by a sheet of shell plating.

When the frames are finally riveted up they are ready for the positions of stringer angles and plate edges to be marked on them. These are transferred from the loft floor or scrive board to the frames in the usual shipyard manner by means of flexible laths girthing the frames.

Again, following shipyard practice, these lines must be faired in on the hull by clipping light battens along the frame marks from end to end, adjusting them until they are satisfactory. The only thing which can ensure real fairness in these lines is the eye of an experienced shipwright.

The next item is the cutting of such notches as are necessary to pass the continuous stringer and girder angles through. Once the keelsons and side intercostal girders are built in, a start may be made with the shell plating. A photograph of one of the earlier metal hulls, at this stage of its construction, may be seen in Figure 16.

Since the hull is "clinker straked," that is, with the lower edge of each strake of plating as "sight edge" except for the keel, the first strakes put on are the garboard ones (those each side of the keel). Until such time as the plating is nearly completed and the profile mold can be cut away, the keel plate cannot be added. It is the last thing riveted on before painting the inside.

The plating is continued strake by strake. Each plate is first cut to shape, this being picked up, if necessary, by means of a template from the framing. It is then beaten or rolled to fit the contour, the lower edge joggled over the previous strake and temporarily clipped into position again. The run of the frames and continuous stringers can now be marked on, and the plate taken down again for drilling. The drilling for the short interframe stiffeners should also be done at this stage, and these stiffeners riveted on after anodic treatment but before the plate is finally re-erected.

The plate is now clipped into position again on the framework, and acting as its own drilling jig, the rivet holes drilled in the frame and stringer flanges. Before riveting it should be bolted up with service bolts in at least every fourth hole. To rivet each plate on as soon as erected is rather liable to lead to distortion of the framework. On these grounds and also probably to distribute the work more economically, it is advisable therefore to leave the riveting until most of the shell plating is bolted in position. Riveting is dealt with in a later paragraph and no more need be said about it here.

It is during the shaping and fitting of the shell plating that most of the defects due to designing a hull with elaborate flares and curves show themselves. In the first cutting of the plate, "sny" (a concave edge to the plate) may be found. This is difficult to allow for and not simple to cut exactly, besides putting up the percentage of scrap metal. Again in the shaping, rolling to single curvature is very much easier than beating to convexity, which calls for all the skill of experienced panel beaters, particularly as duralumin, even when annealed repeatedly, is always liable to crack under hammering. The metal must be heat-treated either when rolled or beaten, but rolling calls for no additional annealing if it can be done during the "soft phase."

When the shell plating is completed there remains little to be done to the hull except the addition of cockpit combings, fittings, towing rings, etc., all of which are fairly straightforward and call for no particular comment.

As is the rule in most aircraft works, all workmen engaged in or on the machine should wear plimsoles. Even so, the anodic surface of the metal is liable to wear very thin in one or two places which are constantly being walked upon.

The hull is now ready for painting and weighing before being handed over to the riggers for assembly with the main wings, engine, tail and control units. All the main attachment fittings for these parts, even when in steel, should have been erected before the flying boat leaves its building berth. Subsequent drilling and riveting is both uneconomical and unsatisfactory.

Program of Processes

The various processes through which each piece of plate or angle passes on its way from store to final erection are as follows:

(1) Cutting out the blank in its flat developed shape.

(2) Annealing to 360°C or heat treatment to 480°C, depending on the amount of work to be done in shaping.

(3) Rolling, beating or drawing to shape. Punching of flanged lightening holes, etc.

(4) If the article has been annealed then heat treatment to 480°C must follow here.

Some means of recognizing the exact state of all metal in the workshops should be adopted to distinguish between parts which have been completely heat-treated and those which have only been annealed. The charge hand on the salt-bath plant should be held responsible for stamping all annealed material as such and only deleting that marking when it is eventually returned to him for heat treatment. Without this it is exceedingly difficult for the inspection and progress departments to keep track of all units, relying solely on the word of the workmen concerned.

(5) After heat treatment some slight reshaping may be necessary but it must be done quickly before age-hardening sets in.

(6) The article should now be anodically treated and greased with lanoline. Every small unit must be treated separately before riveting into assemblies, however small these may be.

(7) The unit is ready for erection or riveting into some assembly which in its turn is erected into the flying boat.

R i v e t i n g

Hand riveting should be avoided not only on account of its expense, but also because of the unsatisfactory workmanship in which it usually results. The heads are badly formed or cracked and the plating often damaged severely by the die.

Pneumatic riveting gives very satisfactory results, provided that reasonable care is exercised and the anodic surface of the surrounding plating is not disturbed. The hammer may be of a similar type to that used in shipyards for light calking. The "dolly" must be heavy enough and should be shaped to take the rivet head.

Better workmanship might be obtained with a single pressure riveting tool similar in action to the hydraulic machines used on constructional steel-work. But the principle would be difficult to apply to shell riveting since the opposite ends of the rivets are usually separated by so much structure.

As much of the work as possible should be done on the bench by a single-pressure tool of this type before erection. For instance, the half-frames may be finished off complete and all interframe stiffeners attached to the shell plates.

During the riveting the following precautions should be taken:

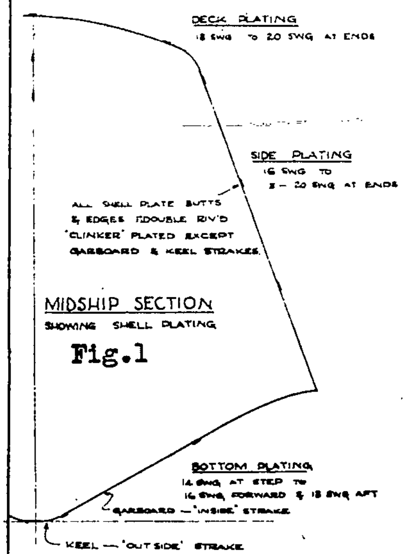
(1) A number of rivets in a row should not be hammered up one by one in their order. The first should be in the middle of the row, then one at each end, then intermediate ones again and so on.

(2) Service bolts should not be spared. Before a line of rivets is put in, every fourth hole should be bolted up and it is even advisable to bolt up a blank hole next on each side of the one into which the rivet is being put.

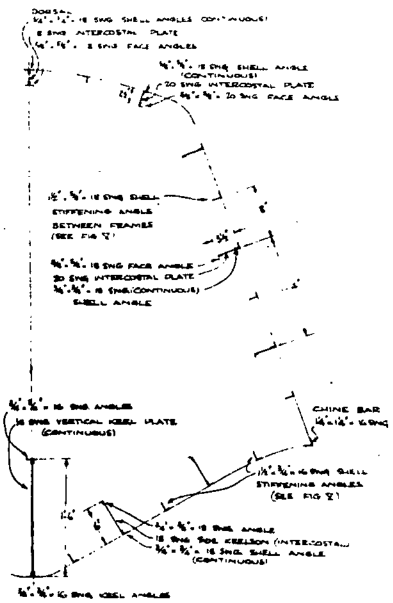
If these precautions are not observed, it will be found that owing to the thinness of the plating, stretching and creeping will take place under the hammering. A stretched seam will be bowed outwards or inwards; and in flight, where reversals of loading occur, "drumming" will possibly take place and the rivets collapse.

Heat Treatment of Rivets

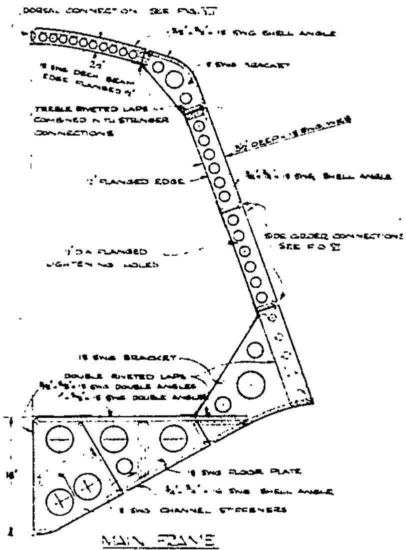
Rivets are not usually annealed since they cannot be heat-treated after hammering into position. It is found that if they are heat-treated and quenched they are, for at least an hour or two, as soft as if they had been annealed. This, then, is the usual procedure. They are heat-treated, quenched and used at once. Thus they can develop their full strength on aging. It is therefore not advisable to heat-treat too many at once, since if the rivets have once hardened they will crack under hammering.



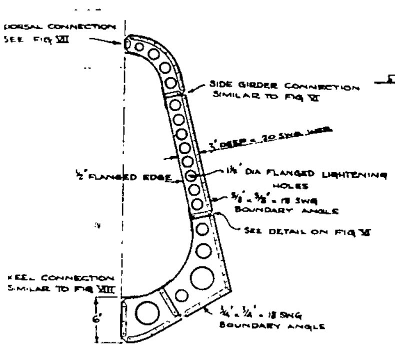
MIDSHIP SECTION
SHOWING SHELL PLATING
Fig.1



LONGITUDINAL MEMBERS
Fig.2



MAIN FRAME
Fig.3



WEB FRAME AFT OF REAR STEP
Fig.4

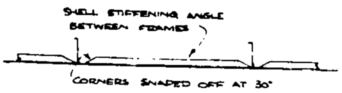


Fig.5

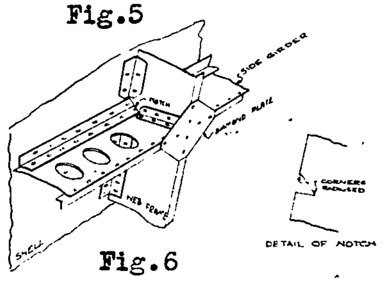


Fig.6

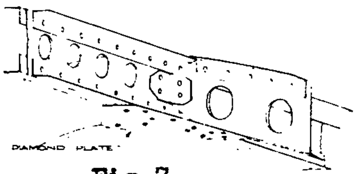


Fig.7

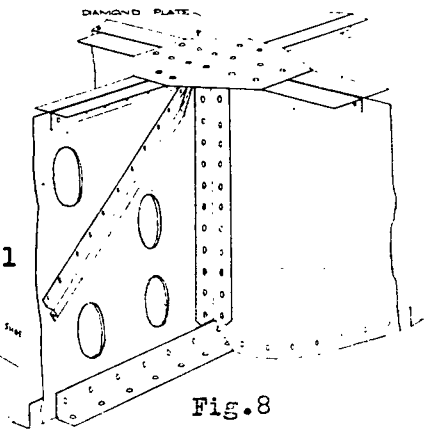


Fig.8

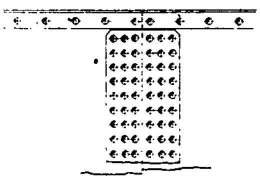


Fig.9

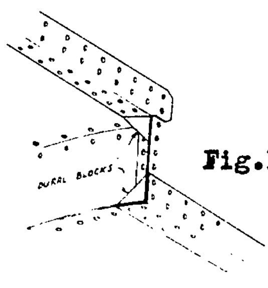


Fig.10

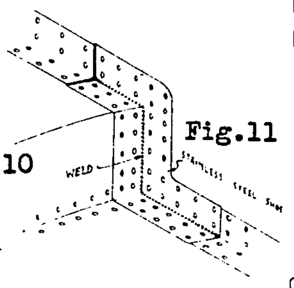


Fig.11

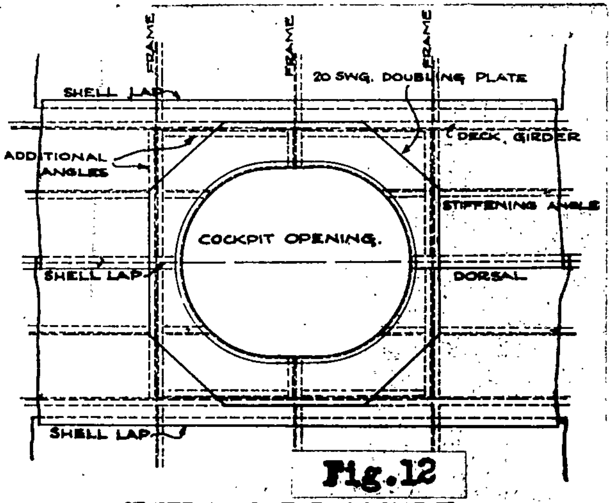


Fig.12

STIFFENING FOR COCKPIT

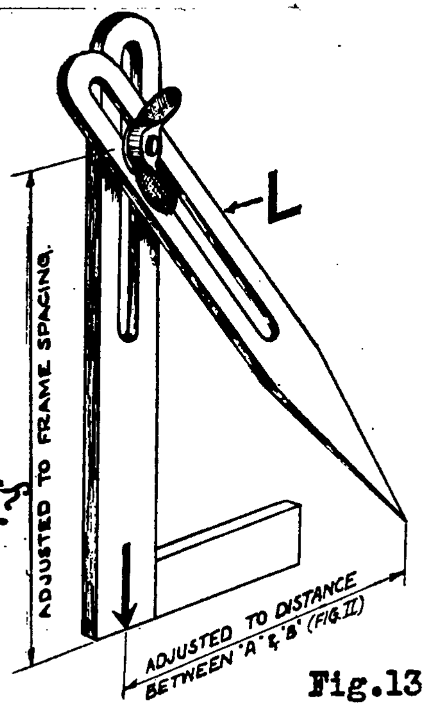


Fig.13

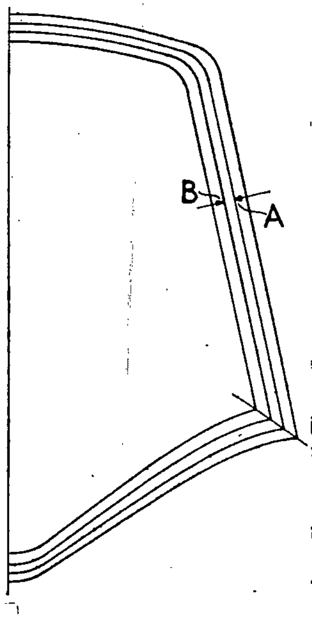


Fig.14

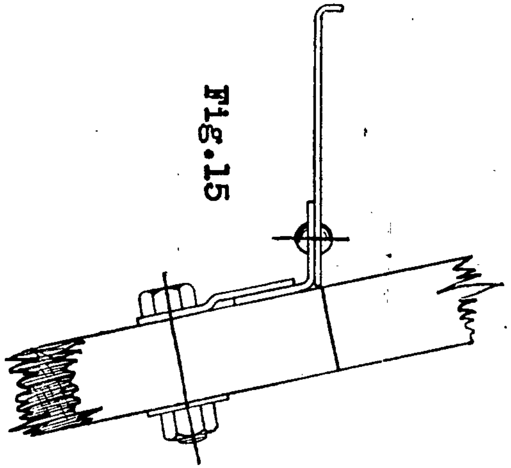


Fig.15

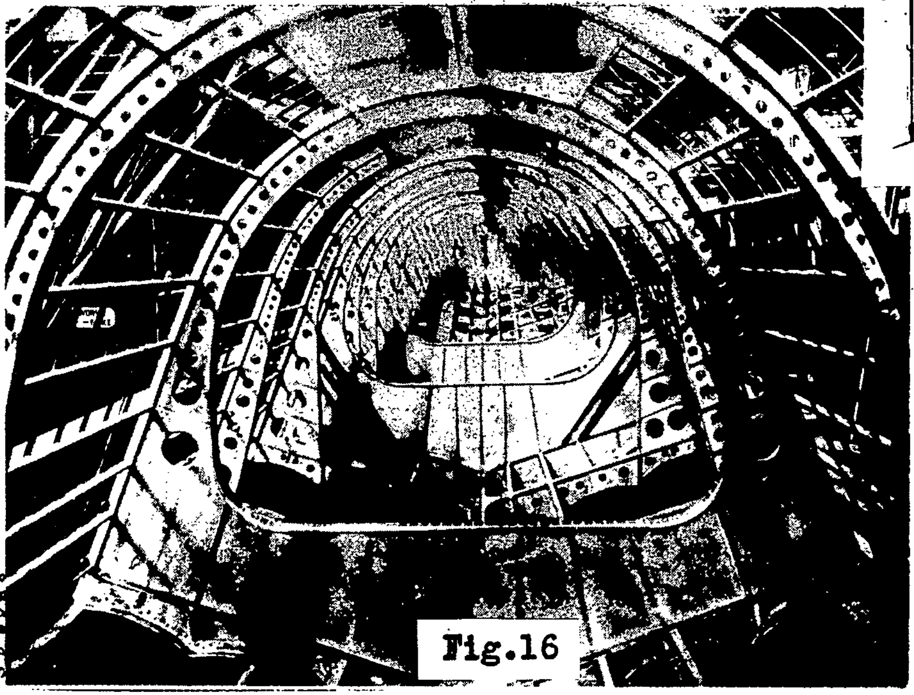


Fig.16