LOFTING AND LAYOUT

USE OF THE LOFT

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USE OF THE LOFT

GENERAL REQUIREMENTS

INTRODUCTION

1. **Varied Procedures.**—The manufacture of aircraft, which includes airplanes, seaplanes, and flying boats, comprises many varied procedures from the design to the finished product. These procedures are continually being studied and improved as occasion demands. The procedure which is considered in this treatise is confined to lofting. Lofting includes the use of the loft and the construction of loft lines. The term *lofting* and many other associated terms used in the aircraft industry were adopted from the shipbuilding industry. The term *loft* is a contraction of the words *mold loft*, which originally meant a large upper floor, or loft, of a building where molds, or patterns, were made. The loft is usually located for convenience near the fabricating shop, which first makes use of the products of the loft.

2. The procedure of lofting is closely related principally to the procedures of engineering and design; to reproduction or the transference of loft lines to metal templets; to laying out and making of templets; to mock-ups or models, and patterns; to certain tooling and forming; and to methods of checking the various parts that comprise the airplane. In some aircraft plants the ramifications of lofting are more extensive than in other plants.

3. **Advantage of Lofting.**—Lofting hastens the procedure of converting the ideas of the engineer into information to aid the shop in making the various parts of an airplane or other aircraft. This is a decided advantage over the previous methods of transmitting information to the shop by means of numerous detail drawings. The loft lays out the design to full scale, while the engineering drawings are made to a small scale. When

the shop used the small-scale drawings it had to interpret them on the basis of full scale before making the required forms, assemblies, fixtures, and other aids used in the construction of the various parts and sections of the airplane. Various individuals would be liable to interpret the small-scale drawings differently, especially in the case of a faired line having double curvature.

4. The lofting method of presenting a full-size layout of an airplane eliminates many of the difficulties encountered in the shop, and reduces to a great extent the number of engineering drawings necessary in the small-scale drafting methods.

Another recognized advantage of lofting is that of acquainting the engineering groups more directly with the problems and procedures of the shop. This especially applies to engineers and draftsmen who have had no shop experience. Such acquaintance between the engineering groups and the shop groups fosters a closer relationship and cooperation, which results in speedier and better production. At the same time the engineering and drafting groups learn much about lofting shop practice.

5. Lofting not only relieves the engineering and drafting groups of the necessity of making a great many detail drawings, but relieves the shop groups of the necessity of interpreting such drawings to full size for construction purposes. The lofting method is also used to advantage in the making of templets for readily constructing mock-ups, which usually are full-size three-dimensional models of parts and sections of the airplane.

ORGANIZATION AND CONSTRUCTION

6. Typical Organization of Loft.—While the organizations of various lofts differ in some respects, the organization of a loft in a typical case is composed of four general groups. These are known as the lines group, the templet layout group, the rework group, and the inspection group. The lines group does the actual lofting and laying down of lines. The templet group works from the lines and from engineering detail prints to produce flat patterns of parts to be formed by the shop. The rework group keeps all templets abreast of the changes in the

engineering prints, and of new methods of fabrication developed by the shop. The inspection group inspects all templets that are made by the templet layout group and the templets that have been changed by the rework group.

7. Construction of Lofts.—Lofts in the aircraft industry are of various types of construction. The loft floor may be constructed on or form the floor of the loft building, or it may be elevated above the floor of the building, in which case it becomes a loft platform or table. The tops of the loft patterns or tables may be at different distances above the floor of the loft building. Each aircraft company constructs its loft in the way that it believes is most suitable for its purposes.

8. In the first type of construction, the loft floor may be made of straight and vertical-grain spruce flooring, tongued and grooved, and laid over a substantial base. It must be carefully and rigidly constructed in order to avoid shrinkage or warpage due to changing moisture content, which would distort the lines upon it. A size that has been found convenient for aircraft use is 20×60 feet, and if likely to be moved at any time during its useful life, the floor should be made in three sections and bolted together. A heavy sub-floor should first be laid, on a frame at least 6 inches thick, the floor planks running on the diagonal. The frame may be placed directly on the floor of the building. The frame and the sub-floor may be given two coats of paint to avoid absorption of moisture; this should be done before the main floor is laid.

9. The working floor may be made of 1-inch boards, preferably about 4 inches wide. It is desirable that the boards be as wide as possible without warping, in order to reduce the number of cracks between them. This floor may be laid on the diagonal, the boards running at 90 degrees to the planks of the sub-floor. This will avoid confusion between the cracks and vertical station lines that may later be laid off on the floor. After laying, any imperfections should be filled with plastic wood, and the floor thoroughly sanded by machine.

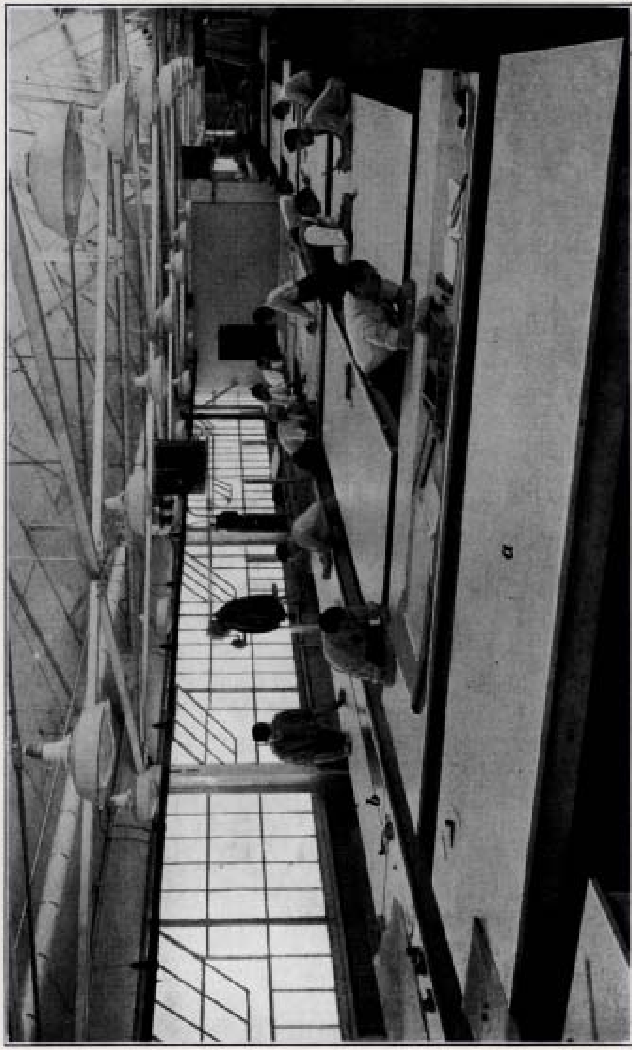

Fig. 1

10. The floor finish must be durable, and the surface may be left slightly gritty in order to give enough tooth to take the lines well. This can best be obtained by painting the floor with at least three coats of carbon black lead paint to which a little pumice has been added.

11. Typical Loft Tables.—The loft tables shown in Fig. 1 are of the long and narrow type, which can be used only for long and narrow layouts made directly on the surface of the top of the table, as *a*, or on metal sheets, as *b*. The loft tables shown in Fig. 2 are of the square type and, because of their greater surface area, they can be used for large layouts, such as *a*, or a number of small layouts, as *b*, *c*, and *d*. Each type of table must have a solid and level top supported by a rigid understructure.

12. Typical Loft Floor.—A portion of a typical loft floor, together with a number of tools used in laying off lines, is shown in Fig. 3. In this case the loft boards are all separate panels, as *a*, made of plymetal $\frac{3}{8}$ inch thick. The tops of the panels are coated with white or any light-tinted paint, on which penciled or scribed lines will show clearly. Holes are drilled and countersunk in the panels, which are screwed to metal strips fastened to the top of a wooden base. The panels are adjustable and so arranged that any panel can be taken out and another panel put in its place, without disturbing the alinement of the panels or the lines scribed on them.

LOFT APPARATUS AND TOOLS

13. Purpose of Apparatus and Tools.—The loftsman must have at his disposal apparatus and tools for the purpose of accurately constructing horizontal, perpendicular, parallel, or curved lines, as well as lines at any prescribed angle to one another. Some of the tools and apparatus are shown in Fig. 3.

14. Scales and Protractors.—Steel scales, such as *b* and *c*, Fig. 3, may be of various convenient lengths, as 1, 2, 3, and 4 feet. They may be graduated in $\frac{1}{50}$ and $\frac{1}{100}$ inch on one side and $\frac{1}{32}$ and $\frac{1}{64}$ inch on the other side so as to accommodate

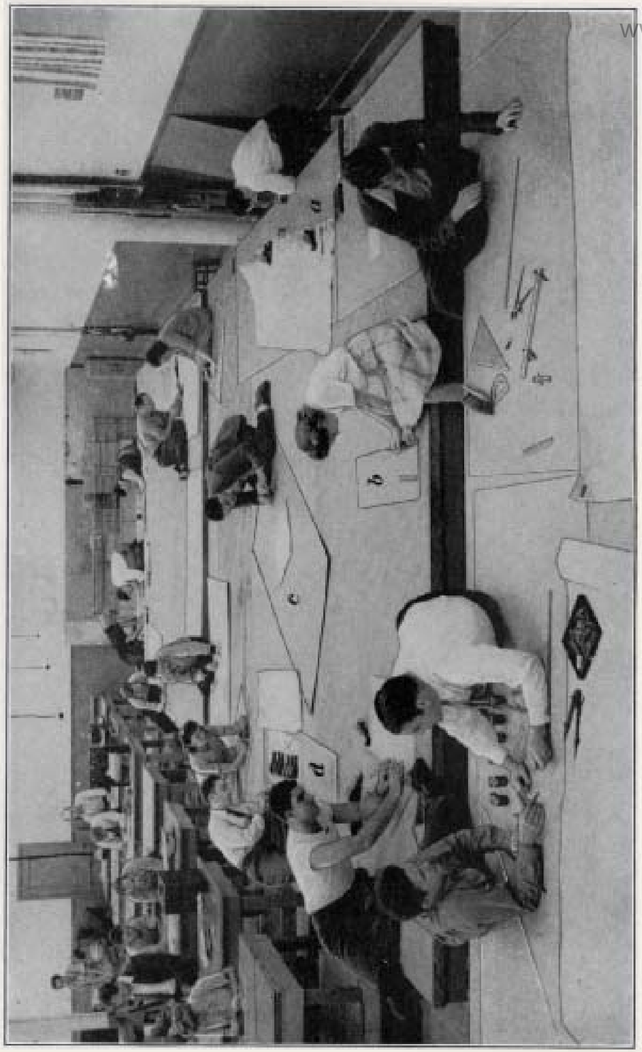

Fig. 3

various measurements. The protractor, as *d*, is a semicircular celluloid instrument graduated in degrees, generally through a range of 180 degrees, and is used in laying out angles. There are many types of protractors, some of which are metal and have adjustable arms or blades pivoted at a center point at the base of the degree scale. The short end of the blade may be set at any degree on the 180-degree arc, and the long end of the blade used in laying off the required angle.

15. Ducks, Splines, and Curves.—Weights of various sizes and shapes, such as *e*, Fig. 3, known as ducks, are usually made of lead and are provided with a bent wire the point of which fits into a groove in a spline. The weight of the duck and the point of the wire in the groove hold the spline in the required position. A spline is a flexible strip of suitable material such as wood, metal, cellulose, pyralin, or plexiglas, which can be curved to form faired lines. Splines are of various lengths, as shown at *f* and *g*.

16. Irregular curves, commonly called French curves, may also be made of any suitable material, and in a variety of shapes covering a wide range of curves. Some of these French curves are shown at *h*, Fig. 3. They are used for drawing shorter curves than those drawn by means of the spline.

17. Trammels, Straightedges, and Pantographs.—Trammels are used for measuring distances too great for the ordinary dividers. They may be of different lengths, as shown by *i* and *j*, Fig. 3. The trammel consists principally of a bar, usually made of wood, on which are fitted two steel points that are adjustable along the bar. The trammel points may be used to pick up a dimension, erect a perpendicular, or scribe a large arc or circle.

18. Straightedges for drawing straight lines may be of various lengths and types, as shown at *k* and *l*, Fig. 3. The one shown at *l* is a heavy straightedge that is provided with two T-shaped handles for lifting and carrying it from place to place. The straightedge is also used as a base for triangles in erecting perpendicular lines or angles.

Fig. 3

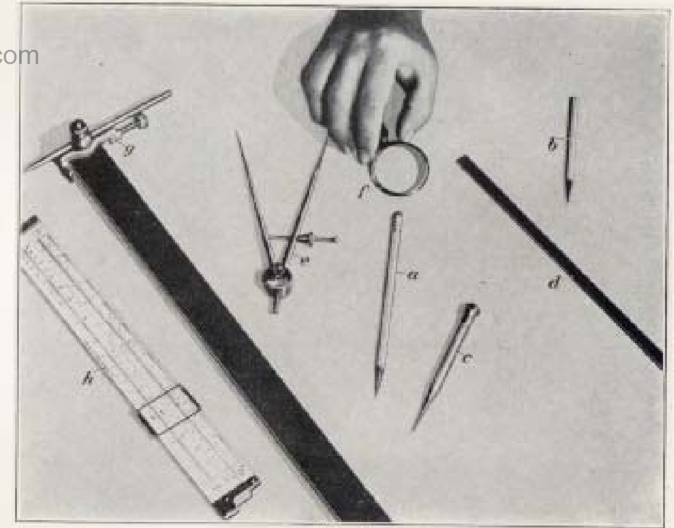

Fig. 4

19. A pantograph, a type of which is shown at *m*, Fig. 3, is a duplicating device that will trace the outline of a given object to any desired scale, either larger or smaller. There are various types of pantographs, but the principles are the same in all of them.

20. Miscellaneous Small Tools.—Various small lofting tools are shown in Fig. 4. Lead pencils, as *a*, may be of various degrees of hardness for drawing lines. A 5-H may be used for laying out construction lines and a 2-H for lettering, sketching, or detailing. A soft black or colored pencil *b* is used to make broad markings on a layout. A steel scriber *c* is a pointed tool used to scribe, or draw, in lines and layouts on various surfaces.

21. A ruler *d* is used for drawing short straight lines. Spring dividers *e*, Fig. 4, have a screw arrangement that accurately spaces the legs for exact measurements. Dividers are often used for transferring a dimension from a scale to a layout.

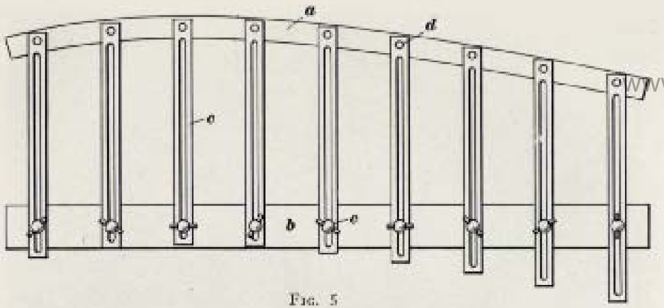

Fig. 5

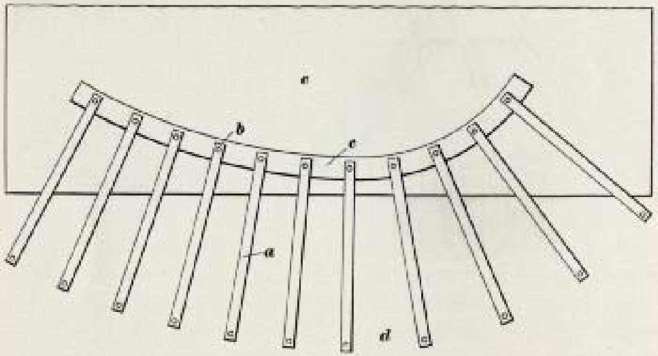

Fig. 6

This operation, known as picking up a measurement, has certain advantages, as follows: The measurement can be used more than once; the possibility of error is reduced; and the need of using a scale and scriber repeatedly for the same dimension is eliminated.

22. A magnifying glass *f*, Fig. 4, enlarges the graduations on a scale as an aid for accurate measuring. It is used with a scriber and scale to pick up accurately a dimension with dividers. A steel scale holder, to which the scale is clamped at an angle of 60 degrees with the surface of the layout board, facilitates the reading of the graduations of the scale at the line of contact with the layout sheet or board. A trammel *g* has been previously described. The trammel takes the place of the dividers when long measurements are concerned. A slide rule *h* is composed of a series of specially constructed scales, one of which is movable, arranged side by side. It is a means of saving time and labor when problems involve multiplication, division, or proportion.

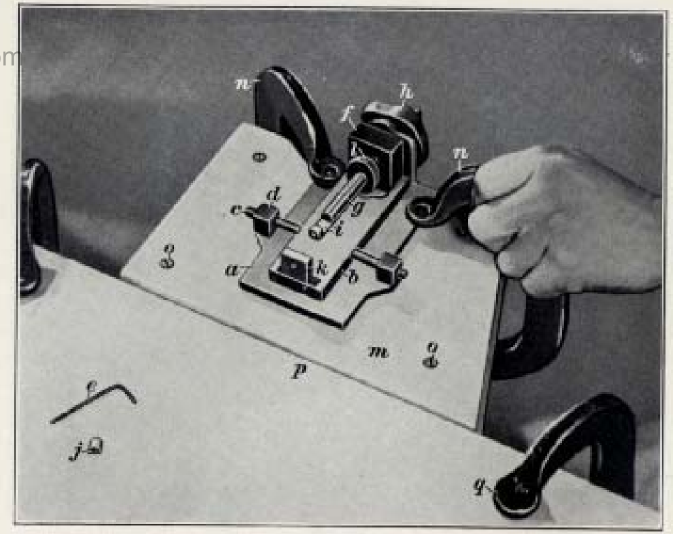

Fig. 7

23. Special Tools.—The banjo shown in Fig. 5 is a device that may be used for transferring a curve from one location to another. The type illustrated consists of a batten *a* connected at intervals to a stiff straightedge *b* by adjustable sliders *c*, fastened to the batten by pins, as *d*, and to the straightedge by thumbnuts, as *e*. The batten *a* is pulled to the contour of the curve to be transferred by means of the adjustable sliders *c*, and is held to the contour by tightening the thumbnuts *e*. Then the apparatus is moved to the location to which the curve is to be transferred and the curve is drawn in by a pencil run along the contour edge of the batten.

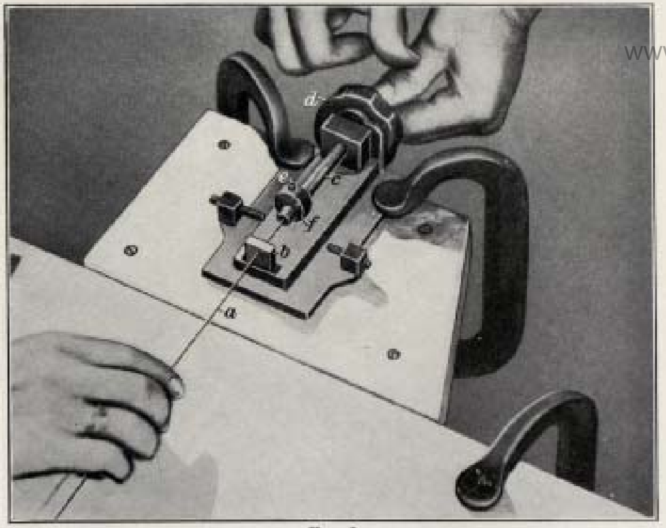

Fig. 8

Fig. 9

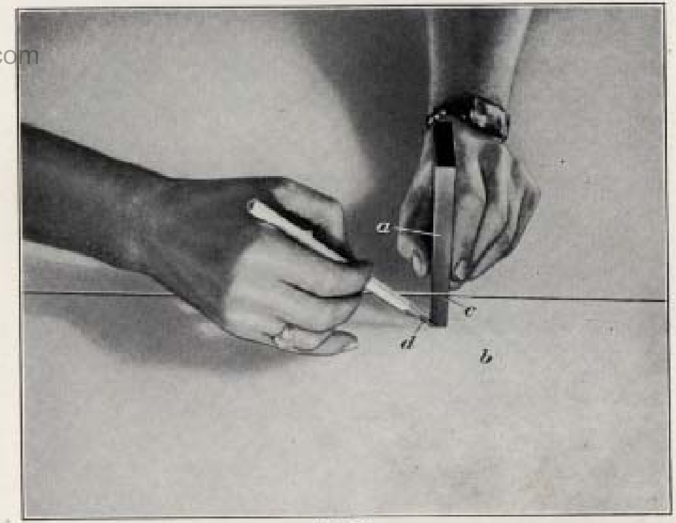

Fig. 10

24. Another type of banjo, shown in Fig. 6, is made by connecting a number of short sticks, as *a*, by means of pins *b* to a batten *c*, the sticks being placed at intervals. The batten *c* is bent to follow a curved line on the loft floor, such as an outline of a bulkhead, or transverse partition, and held in place by nailing the other ends of the sticks to the floor *d* while the line is transferred to a board *e* slipped under the batten.

25. Take-Off Sticks.—Sticks or battens, about 1 inch square and known as "take-off" sticks, are used in transferring points from one view to another, and sometimes for preserving offsets, or measurements, when it is not desirable to draw the body, or transverse-section, plan. The four surfaces of the batten are used in continuous rotation to mark off the height from the base line to significant points on a body plan. One stick is used for each cross-section and marks on it are accompanied by a notation describing it in a definite way. For instance, if a hull is the body being lofted, each take-off stick will be numbered to correspond to the bulkhead or section to which

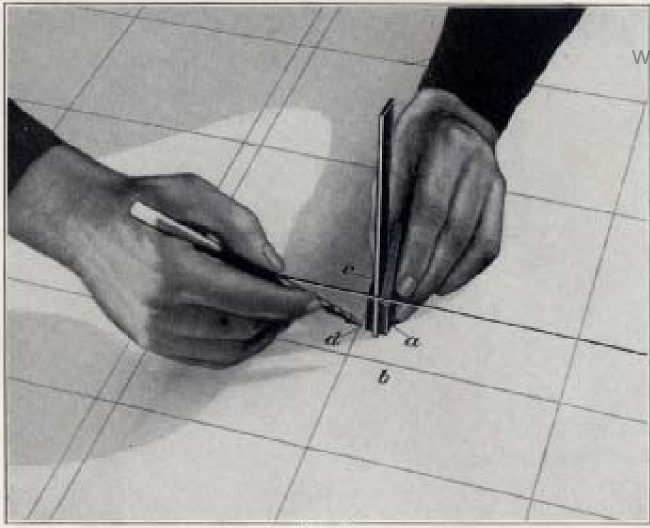

FIG. 11

it applies, and successive marks on it will be designated "keel," "keelson No. 1," "keelson No. 2," "chine," "longitudinal No. 1," etc., denoting the intersection of these members with the section under consideration. A set of sticks will then contain sufficient information for laying off the body plan later, without its being necessary to determine each point by scaling and reference to a table of offsets.

26. A keel is either an external or internal longitudinal member in the center of the bottom of a float or hull. A keelson is an internal longitudinal member in the bottom of a float or hull, to which the keel is attached; or it may be the keel itself, in which case it is known as the center vertical keel. A chine is the intersection of the sides with the bottom or the deck of a hull. A longitudinal member, also known as a sister keelson, is approximately parallel to the keelson and is for the purpose of supporting the bottom between the keel and the chine.

27. Wire Adjuster.—When a straight line that is longer than can be drawn with the longest available straightedge is required, a sufficient length of wire held at each end by a wire adjuster, such as that shown in Fig. 7, is used.

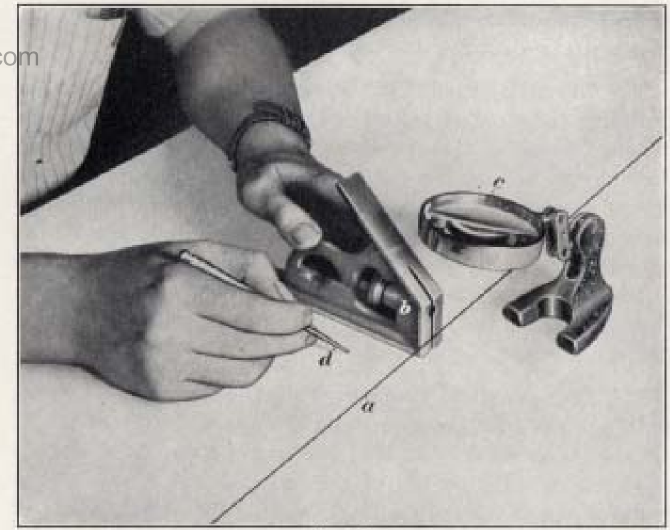

FIG. 12

The wire adjuster consists of a base *a* on which is mounted a movable frame *b* which is alined by means of setscrews, as *c*, operating in lugs, as *d*, and turned by a wrench *e*. Extending through a thick flange *f* is the threaded part of a rod *g*, which engages a handwheel *h*. Near the end of the unthreaded part of the rod is a notch *i* into which fits a clamping piece *j*. A hole large enough for the wire extends through the flange *k* and the full length of the rod. The collar *l* is moved along the rod and over the clamping piece, which holds the wire securely when the setscrew in the collar is tightened on the piece.

28. Platform for Wire Adjuster.—The wire adjuster is fastened to a platform *m*, Fig. 8, by two clamps *n*. The platform is fastened by screws, as *o*, to supporting boards underneath it. The supporting boards are widened where they extend under the overhanging edge of the top *p* of the table, and are secured to the top by means of clamps *q*. A wire adjuster with its supporting platform is fitted at each end of the table.

29. Threading and Stretching Wire.—The method of threading and stretching the wire is shown in Fig. 8. The wire *a* is first threaded through the hole in the flange *b* and then through the hole in the rod *c*. It is pulled a short distance beyond the handwheel *d*, and then secured by turning the setscrew in the collar *f*. The setscrew presses tightly against the top of the clamping piece, previously described. The pressure of the clamping piece against the wire prevents the wire from slipping. When the handwheel is turned the wire is stretched taut, as shown in Fig. 9.

30. Projecting and Checking Points.—The method of projecting points from the wire to the surface of the layout board, or table, is shown in Fig. 10. The end of a flat metal block *a* is placed squarely on top of the layout board *b* and moved until the square edge of the block contacts the wire *c*, which, in this case, is about 1 inch above the top of layout board, throughout its whole length. Then points are marked on the board with a flat-pointed pencil *d*, at convenient intervals along the wire.

31. After the points have been spotted, they are checked as shown in Fig. 11. In checking the projected points the wide head of a try-square *a* is set flat on the layout board *b* and the edge of the blade of the square is placed in contact with the wire *c*, which must not be deflected. Then by means of a very hard and sharp pencil, or a scriber *d*, the points projected from the wire to the layout board are checked for accuracy. These points are later connected by a straightedge.

32. Determining Points for Long Straight Line.—One method of determining points for drawing a long straight line is shown in Fig. 12. A piece of music wire *a* is stretched very taut ½ inch above the surface of the lofting table. The loftsman moves the head of a combination-square *b* into contact with the wire. A magnifying glass *c* is used to find the exact point of contact. Then a mark is made on the surface of the lofting

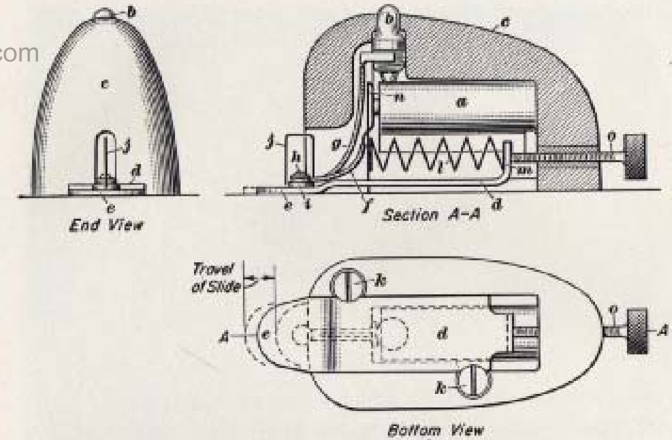

FIG. 13

table with a pencil or scriber *d*, held against the front of the base of the combination-square. The combination-square is moved at convenient intervals along the surface of the table and a mark is made at each point. After a sufficient number of marks have been made, a straightedge is used to draw a line connecting the marks. The line must be checked and rechecked, because it is difficult to ascertain just where the square makes contact without deflecting the wire.

33. Mouse Used in Loft.—To overcome the uncertainty in determining points for a long straight line as taken from a stretched wire, a device called a "mouse" has been developed. The mouse, which is shown in the three views indicated in Fig. 13, consists of a small flashlight battery *a* and a bulb *b* housed in a wooden body *c*, roughly resembling the shape of a mouse, whence it receives its name. The mouse is placed at approximately 90 degrees to the stretched wire and close to it, and the necessary adjustment is made by moving a metal slide *d* terminating in an arc-shaped lip *e*. Insulated wires *f* and *g* lead from the battery and the light socket to a binding post *h* set in the lip *e*, and are insulated from each other and from the binding post. One of the wires, or leads, however, is in contact with

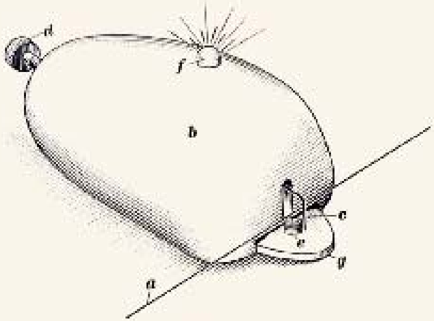

FIG. 14

a copper washer *i* through which contact is made with a feeler wire *j* or whisker, attached to the other lead. Any pressure against the feeler wire forces it against the copper washer, completing the circuit, thereby causing the bulb to light.

34. The slide *d*, Fig. 13, is held in position by the slide retaining screws *k*, which are fastened to the wooden base of the mouse. One end of a slide-return spring *l* is attached to the upturned flange *m* at the inner end of the slide, while the other end of the spring is attached to a metal support *n*, the ends of which are imbedded in the wooden sides of the mouse.

35. An adjusting screw *o*, Fig. 13, passes through a threaded bushing fitted in the rear end of the wooden mouse so that it may be freely turned. The point of the screw bears against the flange of the slide, and as the screw is turned to the right by means of its knurled head, the slide is moved forward out of the mouse and the spring is compressed. As the screw is turned to the left, releasing the spring, the pressure of the spring against the flange causes the slide to move back into the mouse.

36. Procedure in Using Mouse.—The procedure in using the mouse is shown in Fig. 14. A loftsman rigs a wire *a* approximately one-half inch above the surface of the loft table. The mouse *b* is then placed approximately ninety degrees with the wire and with the feeler *c* close to the wire. The adjusting

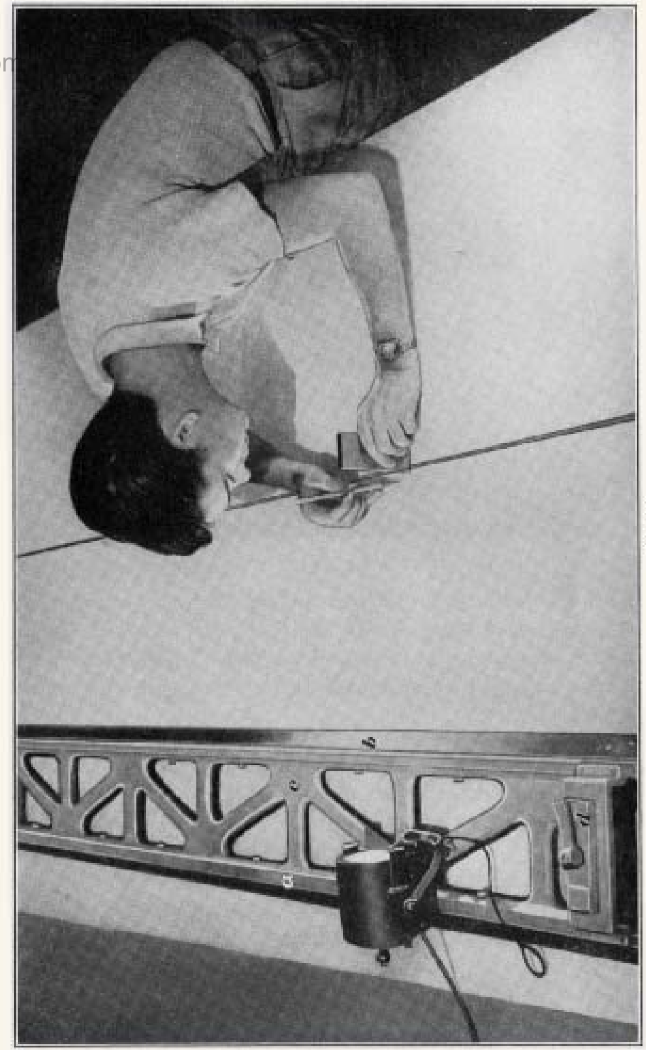

FIG. 15

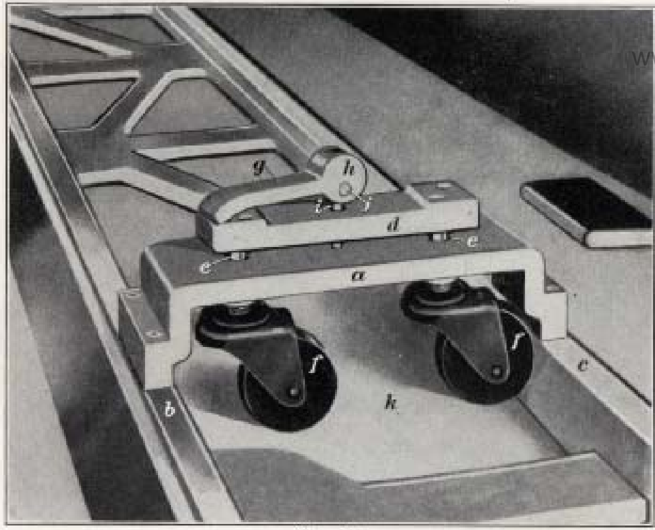

Fig. 16

screw *d* is turned until the feeler is deflected by the wire, which is very taut, and the point of the feeler contacts the copper washer *e*, thus closing the circuit through the leads, battery, and socket previously described, and causing the light to glow in the bulb *f*.

37. The adjusting screw *d*, Fig. 14, is then backed off just to the point where contact between the feeler and the washer is broken and the light in the bulb goes out. The loftsman then knows that he is in contact with the wire but is not deflecting it, and he scribes a mark at the point of the lip *g* of the slide on the loft table. The process is repeated along the wire as often as is necessary to give a series of points that may be connected by a straightedge.

38. Roller Type of Straightedge.—The straightedge used for connecting the series of points projected from the wire, may be of the ordinary flat-steel type, or it may be of a heavy cast structural roller type, as shown in Fig. 15. The framework

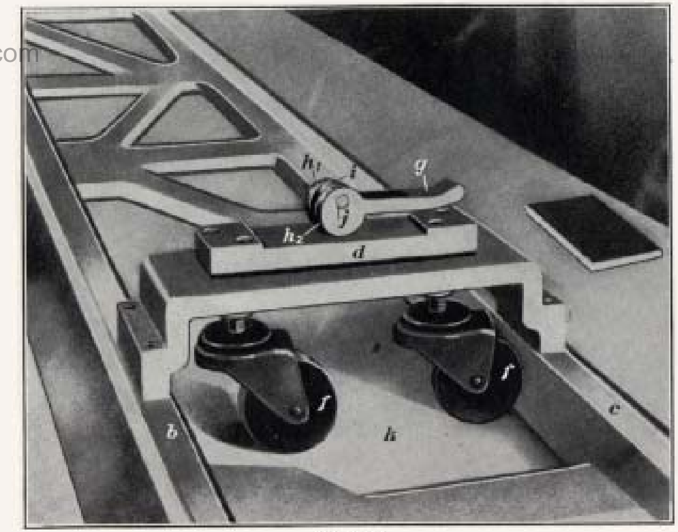

Fig. 17

consists of two longitudinals *a* and *b*, the latter of which is the straightedge, and is beveled so as to facilitate the drawing or scribing of a line. These longitudinals are connected and made very rigid by means of a truss structure *c* between them. Since this type of straightedge is very heavy it is provided with a device, as *d*, one near each end of the structure, for raising it from the table so that it may be moved by means of rollers underneath the raising device.

39. Raising and Lowering Device.—The raising and lowering device with which the structural-type straightedge is provided is shown in Fig. 16. The device is mounted on a flanged bridge *a*, which is bolted to the longitudinals *b* and *c*. On top of the bridge is a movable base block *d*. Fastened to each end of the base block is a rod *e*, one end of which is connected to a set of swivel rollers *f*. One end of the operating lever *g* is provided with a cam arrangement *h*, which actuates a rod *i* on a trunnion *j*. When the lever *g* is pushed down toward the beveled straightedge longitudinal *b*, the rollers *f* are raised from

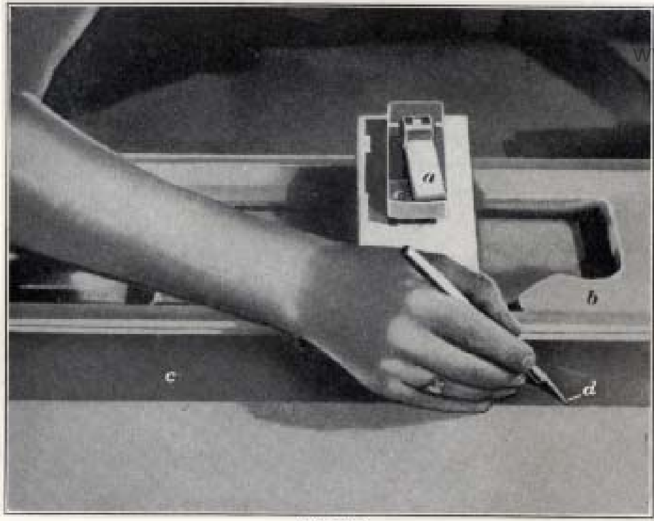

FIG. 18

the top of the table *k*, and the structure is lowered until it contacts the surface of the table.

40. The cam arrangement is shown in greater detail in Fig. 17. This view shows that there are two cams h_1 and h_2, between which is housed the actuated rod *i* on the trunnion *j*, previously described. When the lever is pushed down and away from the straightedge longitudinal *b*, the cams depress the movable base block *d*, which in turn depresses the rollers *f* so that they contact the floor *k*, thereby raising the structural framework from the floor. Since the framework is now supported by the rollers it may be moved to another location on the table.

41. Straightedge in Position for Drawing Line.—When the straightedge is positioned, as shown in Fig. 18, along the points already marked on the layout board or table, the lever *a* is pushed down by the loftsman in a direction away from him. This lowers the structural framework *b* so that the beveled part *c* of the straightedge contacts the layout board exactly at the

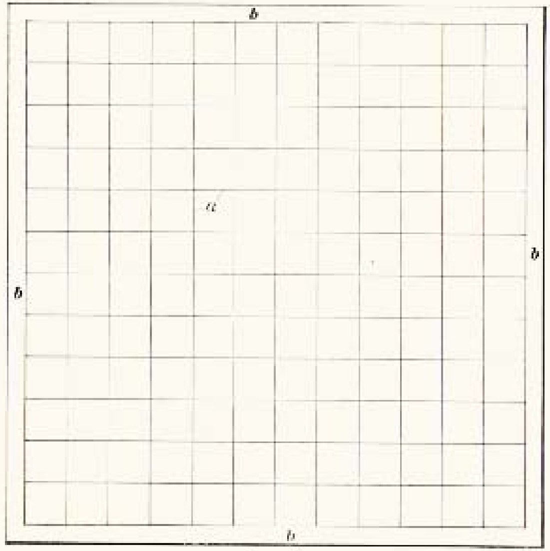

FIG. 19

marked points. Then the loftsman uses a pencil *d* in connecting all the points by a straight line.

42. Apparatus for Laying Out Grid Lines.—A layout of grid lines is shown in Fig. 19. The grid lines are usually laid out in 5-inch squares, but may in some cases be laid out in 10-inch or even 20-inch squares, depending on the requirements of the layout. However, a grid composed of 5-inch squares is considered in this case. The grid lines, as *a*, may be drawn or scribed by means of a metal scriber run along an ordinary straightedge fixed at points 5 inches apart around the edges *b* of a grid board. When the points are connected with lines scribed crosswise, the squares are formed.

43. The grid lines are laid out more accurately in squares by using a special jig scribing apparatus, accurate to a tolerance of ± .005 inch. This apparatus, as shown in Fig. 20, consists of a metal straightedge *a*, which is fastened at the ends by pins *b*

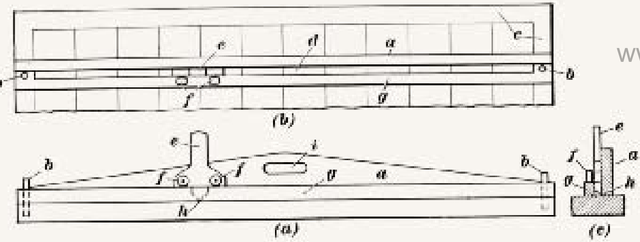

Fig. 20

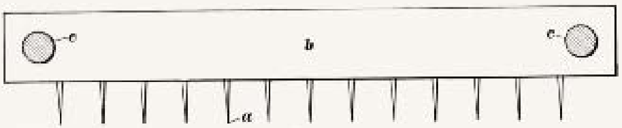

Fig. 21

set in holes spaced on 5-inch centers along the edges of the layout board *c*. Set in a slot *d* running almost the length of the frame of the apparatus is a tool *e*, fitted with rollers *f* so that it may be moved along a track *g* included in the framework. One flat side of the tool is guided by the inside of the track, and the other flat side is guided by the inside of the straightedge. The scribing end *h* of the tool has a diamond point which contacts the painted metal sheet and, as the tool is moved along the track, the diamond point makes a sharp distinct line on the surface of the sheet. The handhole *i* in the frame is used for lifting and moving the apparatus from place to place, since it must be moved and fixed at each set of holes as each line is scribed. When all of the required lines have been scribed across the metal sheet in one direction, the apparatus must be positioned for scribing similar lines across the sheet in the other direction, thus completing the 5-inch squares of the grid.

44. Another type of apparatus for scribing grid lines on a metal layout sheet is shown in Fig. 21, in which steel scribers, as *a*, having sharp points exactly 5 inches apart, are fixed in a head *b*, which may be of wood. Guide rods *c*, which run through the head, are the same distance apart and at the same

height above the loft table, throughout their length. They are rigidly secured at their ends to a framework, which is fastened in the correct position on top of the table. Cross-bars connecting the ends of the rods keep the rods uniformly spaced. The head is slid along the guide rods, and the points of the scribers, all of which are in contact with the grid board, simultaneously scribe all the lines correctly spaced in one direction. Then the apparatus is shifted and fixed in place for scribing the lines in the other direction. The advantage of this apparatus is that only two movements of the head along the guide bars are necessary to complete the grid.

LOFT LAYOUTS

PARTS OF AIRCRAFT

45. Introduction.—An aircraft is any weight-carrying device or structure designed to be supported by air, either by dynamic action or by buoyancy. For example, an airplane is a mechanically driven aircraft, heavier than air, fitted with fixed wings, and supported by the dynamic action of the air. A seaplane is any airplane designed to rise from and alight on the water. This general term applies to both boat and float types, though the boat type is usually designated as a flying boat. A flying boat is a form of seaplane supported, when resting on the surface of the water, by a hull or hulls providing flotation in addition to serving as fuselages. For the single hull type, lateral stability is usually provided by wing-tip floats.

A float is a completely enclosed, water-tight structure attached to an aircraft in order to give it buoyancy and stability when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float.

46. Principal Outer Parts of Airplane.—The principal outer parts of a typical airplane are shown in Fig. 22. They are the fuselage, wings, nacelles, and empennage. Each of these major parts has certain appendages, and the functions of the parts and their appendages are briefly described.

47. Fuselage.—The fuselage *a*, Fig. 22, is the body structure, of approximately streamline shape. At the forward end is the

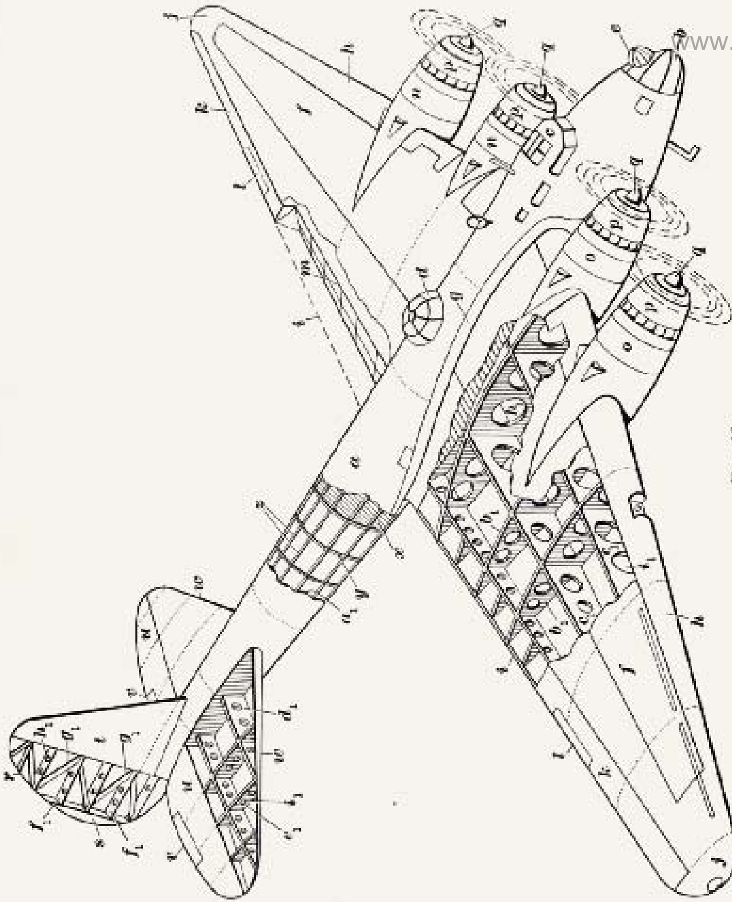

Fig. 22

fuselage nose *b*. At the after end of the fuselage is the tail cone, which is not seen in the illustration. The enclosure *c* is for the pilots; the turret *d* is for the navigator; and the turret *e* is for a gunner. Attached to the fuselage are the wings *f*. The part *g* between the fuselage and the wings is known as the wing fillet.

48. Wings.—The forward edge *h*, Fig. 22, of the wings is known as the leading edge and the after edge *i* as the trailing edge. The ends *j* of the wings are known as wing tips. Along the trailing edge are the ailerons *k*, which are hinged or pivoted movable parts to impress a rolling moment on the airplane. The aileron tabs *l*, which are set into the ailerons, are for the purpose of controlling the position of the ailerons.

49. In the cutaway section of one wing, Fig 22, is shown one of the wing flaps *m*. Wing flaps are movable surfaces connected to the rear portion of the wings, generally inboard of the ailerons. They are connected to the wings either by means of a hinge, a slide track, or both. The flap surface is moved down or back, and occasionally both down and back, to create added lift and drag when the airplane is being landed.

50. Nacelles.—Attached to each of the wings, Fig. 22, are the nacelles *n* and *o*, which enclose the power plants. The cowling *p* is the part of the nacelles that encloses the motors. The spinners *q* are of approximately conical or paraboloidal form. They are fitted coaxially with the propeller boss and revolve with the propellers.

51. Empennage.—The tail group of the airplane, known as the empennage, consists of the rudder, elevators, stabilizers, and vertical fin. The rudder *r*, Fig. 22, is a movable airfoil, or streamline body, the function of which is to impress a yawing, or sidewise, moment on the aircraft in normal flight. The rudder is fitted with a rudder-tab *s*. By changing the angular setting of the tab, the pilot can adjust the position of the rudder. The vertical fin *t*, to which the rudder is hinged, is attached to the fuselage in order to secure stability. The elevators *u* are movable auxiliary airfoils, the function of which is to impress a pitching moment on the aircraft. The elevators are fitted with elevator tabs, as *v*. By changing the angular setting of the tabs, the pilot can adjust the position of the elevators. The stabilizers *w*, to which the elevators are hinged, are normally fixed airfoils the function of which is to lessen the pitching motion of the airplane.

52. Principal Inner Parts of Airplane.—The inside of an airplane is usually constructed of numerous parts. Only the principal structural parts of the fuselage, wings, stabilizers, and rudder, are shown in the cutaway sections in Fig. 22.

53. The interior of a fuselage may be of the truss, monocoque, or semi-monocoque type of construction. The truss type of construction is composed of various members, such as tubes or other structural shapes, utilized as braces. In all variations of this type, the members of primary strength are the longerons, which are usually continuous fore-and-aft from the engine mount to the rudder post. The longerons, usually four in number, are separated in both the vertical and horizontal planes by struts, and maintained rigid by diagonal tie-rod or strut bracing.

54. The monocoque, or stressed skin, type of construction consists of ribs, frames, beltframes, or bulkheads, but usually without longitudinal members other than the shell, or skin, itself. The shell is designed to take the primary stresses, the frames and bulkheads resisting local deformation and distributing concentrated loads.

55. The primary difference between the semi-monocoque type of construction and the monocoque type is that, in the semi-monocoque type, longerons take the bending stresses, leaving the shell to take only the shearing stresses.

56. Some fuselages are constructed partly of the truss and monocoque types; others are constructed partly of the truss and semi-monocoque types; and still others may embody all three types of construction. The fuselages or hulls of almost all large airplanes and flying boats are composed principally of bulkheads and stringers.

57. The principal structural parts of the fuselage shown in Fig. 22 are the bulkhead *x*, cross-hatched for clarity; the belt frames, as *y*; and the stringers, as *z*. Over the framework formed by bulkheads, belt frames, and stringers is the skin, or metal covering a_1, of the fuselage.

58. The principal structural parts of the wings are the ribs b_1, Fig. 22, which are transverse sections; and the beams, or spars c_1, which are the longitudinal sections. The skin, or covering, of the wing is attached to the framework composed of these sections. The principal structural parts of the stabilizer are the ribs, as d_1, and the beams, as e_1. The ribs and beams support the covering of the stabilizer. The internal structure of the rudder is composed of ribs, as f_1, and braces, as g_1. The ribs and beams in all of the structures are provided with lightening holes h_1 and i_1 so as to reduce their weight.

59. Principal Outer Parts of Seaplane.—The principal outer parts of a typical seaplane are shown in Fig. 23. The fuselage *a*, wings *b*, nacelle *c*, and empennage *d* are in principle similar to those of an airplane. The floats *e* are attached to the wings by means of struts and bracings, shown at *f*. Between and connected to the floats are bracings, shown at *g*. The floats are provided with steps, as *h*, and rudders *i*. A step is an abrupt break in the bottom of the float or hull to lessen suction, assist planing, and improve longitudinal control while the seaplane is moving through or on the water. The water rudders *i* are for maneuvering the seaplane in close quarters while in the water.

In the case of a single-float seaplane, it is necessary to provide small floats near the wing tips. The small floats prevent the seaplane from turning over while in the water.

60. Principal Inner Parts of Seaplane.—The principal interior structure of the fuselage of a typical seaplane may be composed of a series of bulkheads, as shown in Fig. 24. The principal interior structure of the wing is composed of spars and ribs, which may be of various types of construction to suit the necessary requirements.

61. Principal Outer Parts of Flying Boat.—The principal outer parts of a typical flying boat are shown in Fig. 25. The hull *a* is provided with two steps *b* and *c*, and a concave bottom *d*. The steps serve the same purpose in a hull as they do in floats, as previously described. The flying boat illustrated, as is general with large flying boats, is a monoplane type built with

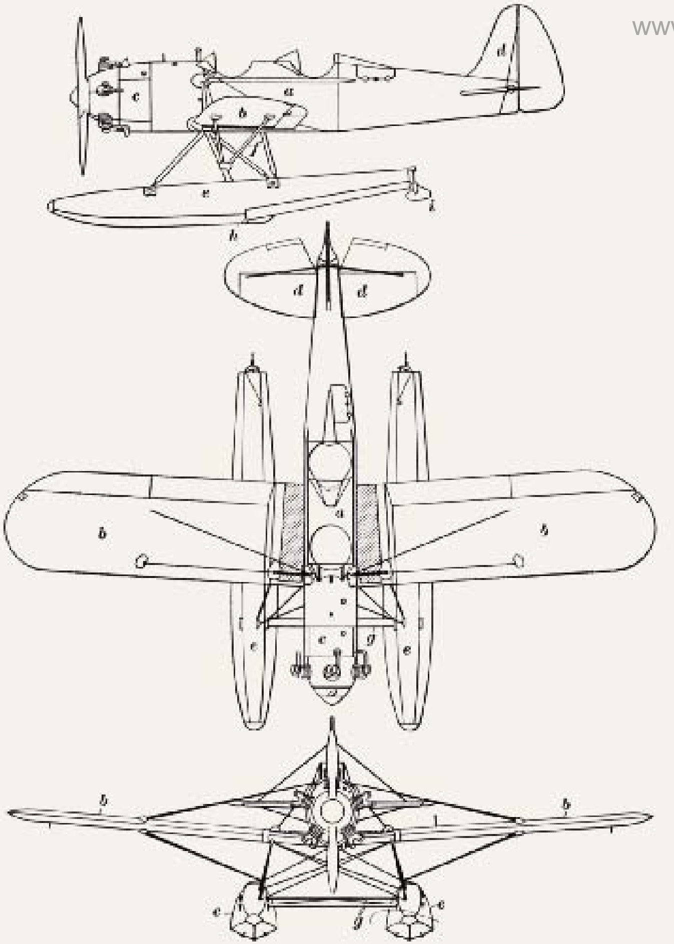

FIG. 23

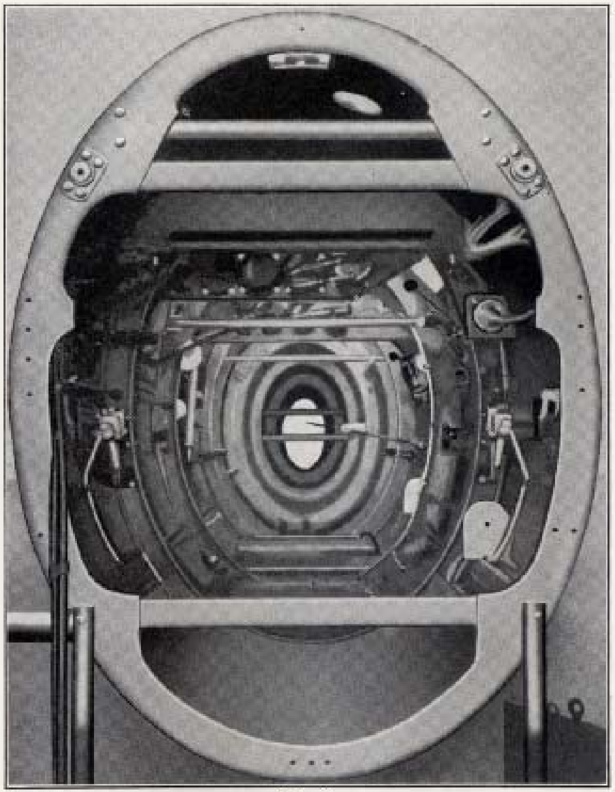

FIG. 24

high wings, as *e*. Some large flying boats have retractable wing-tip floats, which either fold up so that they are almost entirely enclosed by the wing, or else actually form the wing tip as shown at *f*. Either of these arrangements lessens or eliminates the resistance of the floats and float bracing, and adds appreciably to the speed of the flying boat while in the air. The nacelles, as *g*, are set into the wing. The tail assembly is the twin-fin type, as shown at *h*.

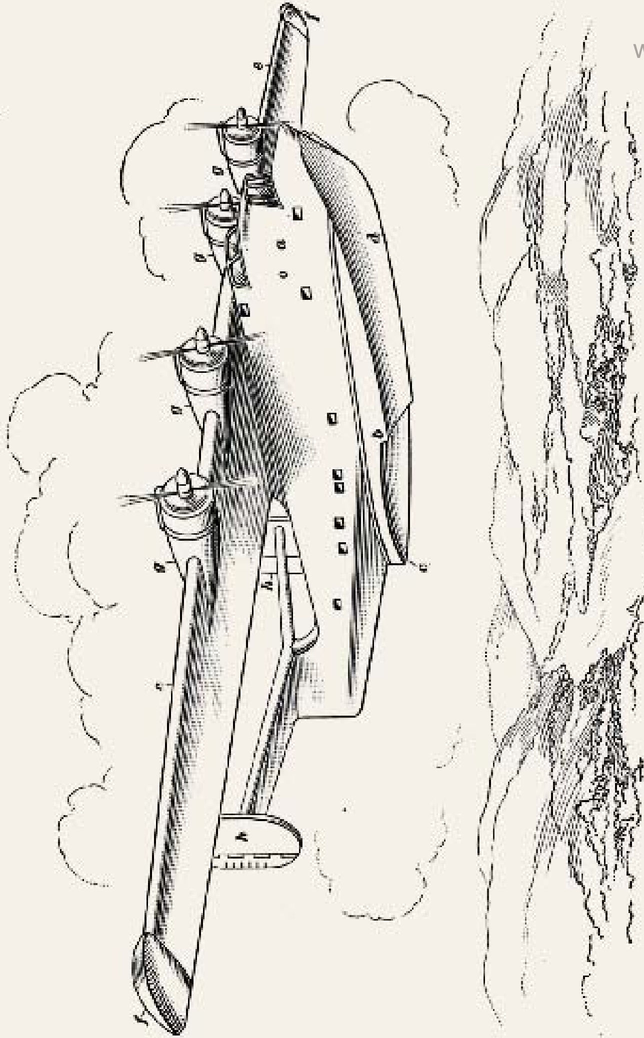

FIG. 25

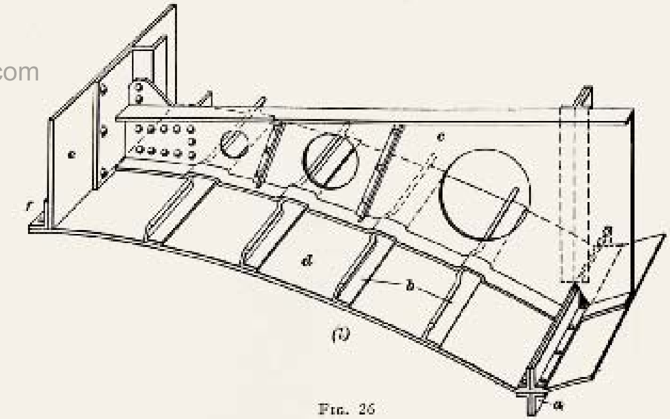

FIG. 26

62. Principal Interior Structure of Flying Boat.—The principal interior structure of the bottom part of a hull, or a flying boat is composed of a keel, keelsons, and frames or ribs. Such typical structures may be as shown in Fig. 26, and in Fig. 27 (*a*) and (*b*), in which *a* denotes the keel, *b* the keelsons, and *c* the frames or ribs. The bottom shell, or skin, is denoted by *d* and the sides by *e*. The chine *f* is the connection between the bottom and the sides.

The interior of the hull is also provided with bulkheads and stringers and the interior of the wings with spars and ribs similar to those of an airplane

MAKING LAYOUTS

63. Duties of Loft.—The duties of lofts may vary in different aircraft plants. The most important duty of a loft, in a typical case, is to develop full-scale layouts from the information supplied by the Engineering Department. In developing these full-scale layouts the loft serves another vital purpose, namely, the fairing of the lines. From these full-scale layouts a large percentage of all basic information for the shop, Engineering Department, and the factory in general is obtained.

64. The loft makes the layouts for the major portion of the assembly fixtures, and for the remainder it contributes the

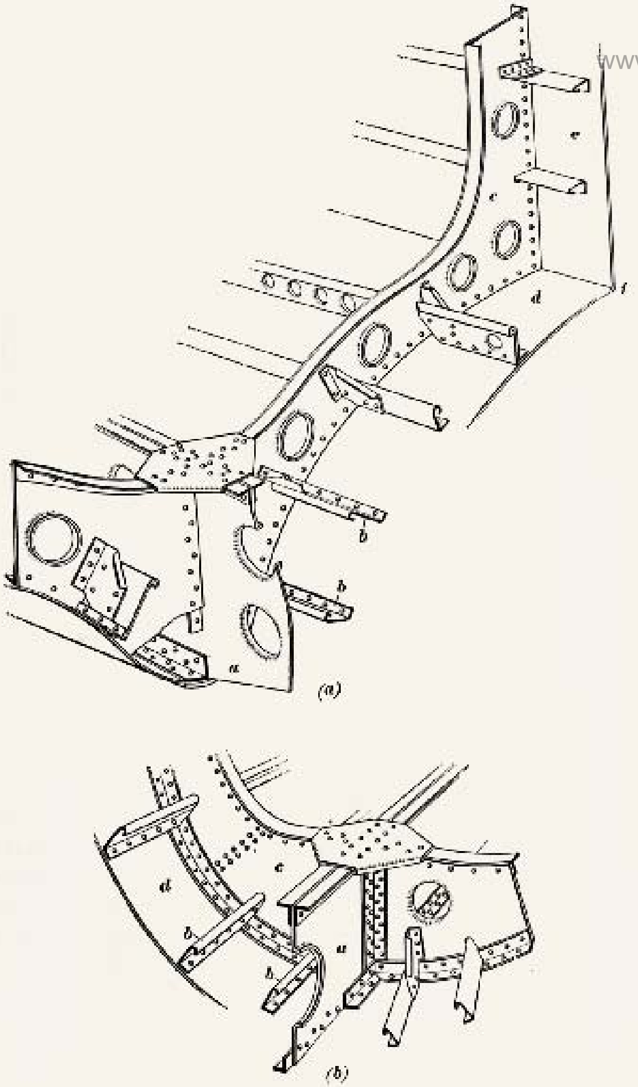

FIG. 27

information from which they are built. The term *fixture* is often applied to any work-holding device that is secured to a bench or a machine while work is being performed on a part. Tool design relies on the loft for many of the basic dimensions necessary to build the large fixtures that the loft has no direct responsibility in building.

65. All templets are made in the loft, or the information from which they are made is supplied by the loft. In the aircraft industry the word *templet* is commonly used to identify a thin metal plate, or plate of other suitable material, which may be used as a guide or pattern and generally includes the profile, contour, layout of holes or the bend lines of a part, or an assembly layout of several parts. In the case of form blocks, for instance, the blocks are made from a templet made in the loft, but the actual tool, the form block, is made in the shop. A form block is a block of suitable material made to the inside dimensions of formed parts to be produced, taking into consideration the forming characteristics of the metal to be worked.

66. By making these templets with as much information as possible on them the loft serves another purpose. Blueprints are eliminated to a large extent, as the parts may be checked directly to the templet more quickly and accurately. The information on the blueprint is condensed and is not so easy for the shop man to read as when it is on the templet.

Another important function of the loft is to check the work released by the Engineering Department. All work going through the loft, from large assemblies to small details, is checked completely when laid out full size in relation to other parts of the same assembly.

67. General Loft Procedure.—The preliminary design group of the Engineering Department is responsible for the design of the wind-tunnel model. The wind-tunnel model is a small-scale model of the actual full-size airplane and is tested in a wind tunnel, or elongated chamber, through which air is forced at high velocity, to determine certain characteristics of the airplane in flight. When the model design is approved, the basic lines drawing of the airplane, which was used to construct the model, is turned over to the various groups concerned with completing the design and the structure.

68. The wing group takes the basic information pertaining to the wing and locates the bulkheads, spars, and other basic structure. The fuselage group, or hull group in the case of a flying boat, does likewise, and, in addition, it makes a small-scale drawing of the fuselage or hull faired as well as possible by such a drawing. This small-scale drawing of the fuselage or hull group, usually $\frac{1}{12}$ size, is then sent to the loft. The information necessary to determine the wing, which includes the root, tip, span, or other basic information, is likewise sent to the loft from the wing group. The root is the basic section at the inboard end of a wing, or the end nearest the fuselage. The tip is the basic section at the outboard end of the wing. The span is the maximum distance from tip to tip of the wing, or it may be designated as the distance from the root section to the tip or last rib-section of the wing.

69. With this information at hand the loft begins the task of making the master layouts and tools, and supplying the basic information from which the jigs and fixtures are to be made in the shop. A jig is a rigid structure or mechanism, of either wood or metal, which holds parts in place while they are in some phase of fabrication prior to assembly, or which holds component parts of a structure while it is being assembled or disassembled. The chief difference between a jig and a fixture, in the language of the loft, is that a fixture in most cases is a lower-priced and simpler mechanism, and is likely to be a single-purpose tool for holding parts during certain machine or hand operations.

70. The first duty of the loft is to lay out the mock-up, and then fair the lines of the wing and the fuselage or hull. This completed, master contour templets are made at all the stations of the fuselage or hull, and at all the ribs of the wing. These templets are all made to the theoretical mold line, which

follows the intersection of the inside of the skin and the outside of the structure.

71. The loft then makes ordinate charts of the lines of the fuselage or hull and the wing. These charts should be as complete as possible in every detail. For the fuselage or hull chart, the location of the wing, stabilizer, enclosures, turrets, and other parts should be as complete as possible, so that any basic information pertaining to the fuselage or hull can be had from the one chart. For the wing, the basic ordinates, slopes of per cent lines, station dimensions, and other information should be equally complete.

72. While this work is being done in the loft, the Engineering Department releases blueprints to the Tool Planning Department, which determines the tools necessary to manufacture the part. The tool planners then write tool orders to that effect. These tool orders are received in the loft, and the next task the loft performs is that of checking the tools. The tools are made from the information supplied by the Engineering Department through the medium of drawings and master layouts.

73. Wooden assembly fixtures are laid out on table tops, and when the layout is completed, wooden blocks are fastened to the table tops to hold the parts of the assembly in correct relation while the assembler rivets them in place. The templets of the detail parts are then made from the wooden assembly-fixture layouts, and the assembly fixture and the templets are released at the same time. Often there is no assembly fixture required for the manufacture of the part or parts shown on the drawing, and, in that case, the templets are made directly from the information supplied on the drawing.

LAYOUT PRACTICE

74. Preparation of Lines Layouts.—Lines layouts may be prepared in several ways depending on the main purpose they are to serve. For instance, as in the case of a wing layout that is developed basically from per cent lines, the only purpose the master layout would serve would be to fair the basic sections.

After the basic sections are faired the wing may be calculated, that is, any section throughout the wing may be determined positively and accurately by the use of a calculating machine. If it is necessary to fair a fuselage or hull that has a constantly changing indefinite shape throughout its length, the fairing must be done from the forward to the after end. This may be done in several ways and by several different processes. One of the most common methods used is that of trial and error. This consists of a three-view layout the purpose of which is to fair the section lines in the plan view, the side view, and the transverse view.

75. One type of layout used by the loft to determine the contours of a fuselage or hull is either a full-size or a half-size layout. This type takes up a great deal of space on the loft floor and is not the most accurate way of fairing the lines, but it has some very definite advantages. One advantage is that all installations may be put on the layout in correct relation to the other major assemblies of the fuselage or hull. Also, clearances, rotations, fits, and other similar details may be readily checked on this type of layout.

76. The procedure for making this type of layout is to take the small-scale drawing from the Engineering Department and increase it to the size desired. This layout is usually made on a wood surface because of its size, but for more accuracy it may be laid out on sheets of metal spliced together to form one big sheet.

77. Another method of laying out fuselage or hull lines is by foreshortening; that is, by reducing the scale of measurements for the length as compared with full-scale measurements for the width. This method is by far the most accurate way of fairing the lines, but has its disadvantages in that it is difficult when using this method to incorporate installations.

78. The procedure for making this type of layout is to make a three-view drawing of the fuselage on graph paper. The station dimensions should be foreshortened in relation to the

ordinates in the ratio of one to four. In this manner the contours are accentuated and the lines faired with greater ease.

79. The best method of making the layout is to combine both methods previously described. Under this combined method the loft fairs the lines by foreshortening. It then takes the sections of the fuselage or hull that need to be detailed, such as the pilot's enclosure, intersection of wing and fuselage or hull, and other necessary sections, and develops them full size from the foreshortened lines. This is done on a sheet of metal which is kept as a master templet and a permanent record.

80. The contours of the wing at the rib stations should always be calculated from the basic information, and then compiled in a data book so that the wing information is readily available and is absolutely accurate. However, there are cases when layouts must be made, and in such cases they are, whenever possible, foreshortened front and plan view layouts. These layouts look true into the chord, or base line of the airfoil at the leading edge, but the stations are closer together than on the actual wing, usually by the ratio of one to ten. In some cases such as trailing-edge rib layouts, where clearances must be determined, a true layout is made looking into the chord plane at the tip. The chord plane is the plane passing through the chord lines.

81. In addition to those described, there are other layouts, mostly of intersections, rotations, and the like. These are almost invariably laid out in true three-view relationship and, wherever possible, to full scale.

82. Preparation of Wooden Assembly Layouts. The information used in the preparation of wooden assembly layouts originates for the most part in the engineering groups. This information comes to the loft in the form of a blueprint and from this, and the master-contour templets, the layout is made.

83. The procedure to be followed is first to lay out a suitable grid. If the wooden assembly layout is of a station of the wing or fuselage, the loft has master-contour templets. In this case the grid may consist of the few water-lines shown on the master-contour templet, and also the center line, in the case of the fuselage. If it happens to be a wing station, the grid need only be the chord line. If there is no complete master-contour templet for the particular assembly, a sufficiently complete grid should be laid out to ascertain enough points to complete the necessary contours and other lines.

84. After the mold line of the particular assembly has been drawn on the wooden assembly layout, the next step is to detail all the parts that are shown on the drawing. This is done similarly to ordinary drafting procedure with the exception that an HB pencil is used to produce a neat but very black line. Later these layouts are photographed or similarly reproduced and are kept indefinitely as master references. The need for care in laying out is apparent.

85. After the wooden assembly layout is completed and checked, it is shellacked to hold the lines, and the templets are then checked to it. After the templets are inspected, both the wood assembly layout and the templets are released from the loft to the shop at the same time.

86. Preparation of Templets.—Information used in laying out templets comes from the wooden assembly layout board, blueprints, and master loft lines. Templets are scribed on $\frac{1}{16}$-inch galvanized iron that has been painted black, and are cut out in the cutting department.

87. In transferring information from the wooden assembly layout to the templet, tracings may be used but only with great care. If they are used, reference lines and check lines must be put on the tracing at frequent intervals, and the tracing should be used immediately after it has been traced. This will eliminate errors resulting from stretching or shrinking of the tracing paper. Tracings should never be used for a part that is over 2 feet in length. For large templets the information should be laid out anew on the templet stock, taking care to make an exact duplication. Or better still, a photographic or similar method

of duplication will prevent errors, which may occur when duplicating by hand.

88. For templets embodying the contours of any part of an airplane or other aircraft, such as the hatch areas, the landing or beaching gear areas, and the like, information should be obtained specifically from master loft lines in order to maintain essential uniformity in the lines of the airplane. If a lines layout is not available, contact should be made with the lines group leader or the chief loftsman to determine the necessity of making a layout.

89. Tolerances.—The loft, as it is primarily a maker of tools, has no definite tolerances. All work produced by the loft must be as accurate as possible, so that the tolerances that are stated on the drawings may be used in the shop where they are required. The loft Inspection Department, as a general rule, checks to one-half of $\frac{1}{64}$ inch, or expressed decimally, to approximately .007 inch. Exceptions are made in special cases governed by design limitations.

90. Simplified Riveting.—With the aid of the loft, the amount of riveting information on drawings is considerably lessened. Riveting standards covering general rules requisite for strength are first drawn up by the Engineering Department. These standards list for each size rivet the pitch or center distance between rivets, number of rows, distance between rows, and the minimum distance between rivet and edge of plate, termed "landing." They will also indicate the size of rivet to be used for each gage of plate, and the standard practice in riveting watertight and non-watertight joints.

91. By reference to these standards, the loftsman can show on his templets both position and size of rivets for all seams, without further information. Rivets attaching members, other than plating, to each other or to gussets should be called for on drawings by size and number required, and their general position or rivet pattern indicated to scale but without dimensions. The loftsman can then lay off these details on his templets in accordance with standard practice with reference to pitch and edge distance.

92. General Instructions.—The general instructions that follow cover the practices of one of the largest aircraft plants, and may not apply to all plants. Each plant may have general instructions to suit its own requirements.

1. As soft a pencil as possible, such as an HB or F grade, should be used in laying out lines. Either grade mentioned will make a pronounced black line which will also be sharp and clean. The painted surface of the layout sheet should not be cut with a hard pencil or scriber, because, if it is necessary to make changes, a cut surface will result in a marred layout.

2. Use only upper case, or capital letters, and make all lettering read from the same side of the layout. Use no measurement marks or indications of any sort whatsoever. If there is any question about this the leading man should be consulted.

3. All layouts shoud be made full scale with the exception of a few master layouts, which must be reduced in scale because of the size of metal available.

4. Avoid fancy lettering, unnecessary lines, views that are detailed on the prints, dimensions, and notes whenever possible. In all cases the information on the layouts must be accurate and legible, and convey the necessary information for the shops. All unnecessary drafting must be eliminated. Do not cross-hatch. Do not detail corrugations; instead, simply note "direction of corrugation" and indicate the direction by an arrow.

5. Make sure that every part of the assembly is given a dash number. A dash number is a number preceded by a dash, as –1, –2, –3, and so on, used to locate and identify each part of an assembly.

Call out the rivets by code. The term "call out" means refer to, give, or show. On right-hand layouts show only enough rivets to locate drill templets. Do not call out spotweld locations on wooden assembly-fixture layouts. All necessary flange angles should be shown. They should be given to the nearest $\frac{1}{2}$ degree on both wood assembly-fixture layouts and templets.

6. All templets made in conjunction with wood assembly-fixture layouts should have sufficient reference lines to locate them accurately on the wood assembly-fixture layouts, in order to facilitate inspection. In cases where parts have locating holes, such holes in the drill templet, the marking-and-locating hole templet and the form-block templet must be very carefully coordinated.

7. Locating holes should clear all rivets, bend radii, and edges of material by $\frac{1}{2}$ inch whenever possible. Locating pins $\frac{1}{4}$ inch in diameter should be used on material .125 inch and up in thickness. All other locating pins should be $\frac{3}{16}$ inch in diameter whenever possible. Only in exceptional cases is it permissible to use locating pins $\frac{1}{8}$ inch in diameter.