FORMING METHODS

FORMING BY DROP HAMMER

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FORMING BY DROP HAMMER

EQUIPMENT, PRACTICE, AND DESIGN

DROP-HAMMER EQUIPMENT

1. **Use of Drop Hammer.**—The intricate shapes of compound curvature, as required for many aircraft parts, necessitate the use of three machines, namely, the drop hammer, the stretching press, and the hydro-press. As the stretching press is limited in its application, the bulk of forming is done in the drop hammer and the hydro-press. The present tendency is to design parts for forming in the double-action hydro-press, but the drop hammer still handles the greater production. While there are certain parts that can be produced either by the double-action press or by the hammer, each machine has its own definite applications. Many times a part can be started on a press and finish-struck on a hammer. As a general rule, the double-action press, both because of its cost and the more expensive dies required, should be used only for those parts to be manufactured in great quantities or for those actually requiring its services, such as when *SO* material must be shrunk* beyond 6 per cent. *SO*, as is explained in another pamphlet of this series, is the designation given to wrought aluminum-alloy in its soft-temper state.

The drop hammer, however, is well adapted to short production runs on parts where high precision is not required, and is especially suitable for handling large parts and for forming severe shapes. It furnishes a flexible means for experimental work and can be utilized in forming a large variety of different materials. The parts so formed are fairly consistent and accurate, and to some extent are interchangeable. Further-

*Throughout this pamphlet, and other pamphlets of this series, some form of the word "shrink" is used to describe the process of compressing the metal at certain points when forming parts of aluminum-alloy sheets, as this term is in general use in the aircraft industry.

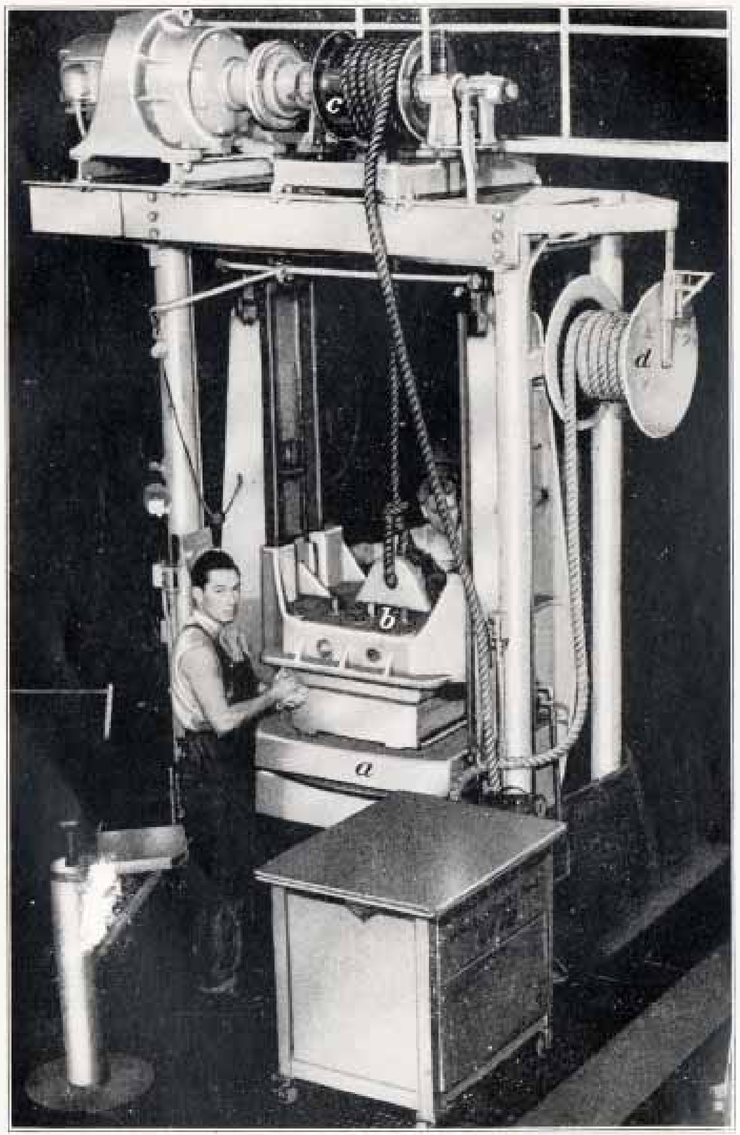

FIG. 1

more, as it is impracticable at present to freeze airplane design, use of the drop hammer facilitates such changes because of the low cost and simplicity of the tooling.

2. Types of Drop Hammers.—In the aircraft industry, three types of drop hammers are used: the rope-operated, the pneumatic, and the hydraulic. The rope-operated hammer is the oldest type, but in some shops it is being replaced by pneumatic, or air-operated, hammers. Hydraulic hammers are used to a much less extent than either rope hammers or air machines.

Most of the rope hammers in use in aircraft plants have been designed and built by the aircraft manufacturers themselves, since no hammer equipment readily convertible to such work was available. The hammers vary in size from 1 to 5 tons, the weight indicating roughly the largest punch that can be used. The size of the bed, however, more closely indicates the size of the part that can be formed. The beds vary from 30 by 36 inches on the 1-ton hammer to 60 by 66 inches on the 5-ton hammer.

3. Essentially, a rope hammer, an example of which is shown in Fig. 1, consists of a heavy base, or anvil, *a* on which is mounted the die. Side vertical columns carry the hammer headways. The head *b* on which the punch is mounted travels vertically in these ways and is operated either by a single rope or by a pair of ropes that make several turns around a revolving water-cooled drum *c*, which is mounted on a superstructure over the machine. The other ends of the ropes are fastened to the head. Both ropes may be handled by the operator, or they may be connected below the drum to a single pull rope. When the free ends of the ropes are given a downward pull, the ropes snub fast on the drum and cause it to wind up the other ends, thus raising the head. To drop the head, the tension on the ropes is released. Some type of safety latch is required to lock the head in its raised position. Also desirable is a photoelectric cell arrangement to prevent premature fall of the hammer.

When continuous operation is desired, such as for forming cowl sheets and fuselage frames in feeder dies, the head can be operated automatically by attaching one end of a coil spring to the head and the other end to the ropes. Then, as the head falls, the ropes are pulled downward far enough to raise the head for the next blow. By adjusting the position of the spring, the height of drop can be varied to give the required force of blow.

4. Since the ropes slip on the revolving drum, there is a certain amount of wear on them. To reduce the friction between the rope and the drum and make the ropes last longer, a vegetable grease should be used; mineral greases must be avoided as they are detrimental to the life of the rope. The ropes generally fail in the sections wrapped around the drum where friction occurs. To facilitate replacement, long ropes are used with the unused part wound on a reel, such as *d*, Fig. 1, or in the original coil at the side of the hammer. When a rope fails, the section attached to the head is cut off behind the bad spot, and good rope is pulled from the coil, wound around the drum, and fastened to the head.

5. Air-operated hammers, as represented by Cecostamps, are more flexible than rope hammers with regard to the kind of blow struck. The inherent design of the rope hammer requires that the operator have considerable skill, since the force of the blow is determined entirely by the weight of the head and punch, and the height from which they drop. To determine the proper force for each blow in a production progression and to follow the progression with a rope hammer is difficult. An air hammer, however, can be so controlled as to strike a single blow of desired force, a predetermined sequence of varied blows, or repeated blows of the required force and rapidity. The metal can be gently squeezed into the die for the preliminary forming or it can be struck light or heavy blows. With an air hammer, more blows per minute can be struck than with a rope hammer, since the air pressure on the piston imparts a faster down stroke than can gravity acting alone, the head is lifted faster by air than by mechanical means, and the strokes can be made shorter because of the greater speed and power of the hammer head.

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FIG. 2

6. Squeezing or preforming the material into the die before a heavy blow is struck provides a certain amount of drawing action, and also shows the operator where wrinkles are liable to form. It also permits him to hammer out with a mallet those wrinkles already formed that would probably lap over. This squeezing action on the air hammer shown in Fig. 2, which is set up for forming a filler-well doubler *a*, is obtained by bringing the head down slowly to the work by a slow movement of the control lever *b* and then moving the lever down as far as it will go. The pressure so obtained with an air pressure of approximately 100 pounds per square inch in the cylinder *c*, varies from about 1 ton on the small machine to over 40 tons on the largest one. To set the material, a heavy blow may then be struck by moving the lever down rapidly when the head is in its raised position. The head of an air hammer can also be operated automatically by means of a curved cam bar which forms one leg of a bell-crank that presses against a plate attached

TABLE I

SIZES OF AIR HAMMERS

Dimensions of Head		Stroke Inches	Minimum Ram Die Area Inches	Compressor Capacity Cubic Feet of Free Air per Minute
Between Guides Inches	Front to Back Inches			
15	12	30		25
30	24	36		60
48	36	42	34 x 25½	142
48	48	42	34 x 34	175
66	36	48	46½ x 25½	185
66	48	48	46½ x 34	231
66	60	48	46½ x 42½	275
96	48	48	68 x 34	389
96	60	48	68 x 42½	478
96	96	48	68 x 68	680
120	48	48	85 x 34	478
120	60	48	85 x 42½	562
120	96	48	85 x 68	778
120	120	48	85 x 85	880
156	60	60	110 x 42½	790

to the head. The movement of the head causes the bell-crank to swing around its pivot and to operate the air valve.

7. Capacities of Air Hammers.—Air hammers are made in a wide variety of sizes, as shown in Table I, in order to cover the metal-forming requirements of the aircraft industry. The sizes needed depend on the variety of production, and on the size of parts to be formed by the hammer. In selecting a hammer to be used for any particular part, the size of the punch must be considered. For each machine there is a minimum punch, or die, area, as given in the fourth column of the table. If a smaller die set is used, the hammer head is liable to break. When it becomes necessary to use a die set smaller than is recommended, a bolster, or shoe, of adequate area should be used between the punch and the ram.

8. The selection of the hammer depends also on the compressor capacity required, as indicated in the last column of Table I. These air requirements represent those needed for the basic number of strokes per hour, that is, for the number of useful blows generally experienced per hour. As the work varies in size and character, so will the basic strokes vary, diminishing in number as the work requires longer periods of time between blows for handling, inspection, and hand working. Since the larger hammers operate more slowly than do small hammers, more rapid production can be maintained with the latter, and they should be utilized whenever possible.

9. Drop-Hammer Foundations.—Various types of drop-hammer foundations are used to absorb the shock caused by the hammer blow. The rope hammer requires a more effective foundation than does the air hammer, since the latter has its side members connected to the base and yoke by bolts and tension springs, one of which is shown at the left of the lever in Fig. 2, in order to reduce the shock, and no such springs are employed on rope hammers. The most common foundation consists of a heavy inertia block of reinforced concrete, of about twice the weight of the hammer. The base of the hammer is bolted to this block, which is mounted on heavy coil springs in a concrete-lined pit. This construction permits the shock to be absorbed by the inertia block and transferred to the ground through the coil springs. In some cases, cork is used instead of springs.

DROP-HAMMER PRACTICE

10. Forming in Drop Hammer.—The forming of sheet metal in a drop hammer is a drawing process involving the stretching of the metal in one direction, and compressing it in a direction at right angles to the stretch. The metal is taken slightly past its yield point in progressive stages until the depth of draw is reached. For the ordinary die, where such action occurs, the metal is spoken of, in terms used in the aircraft shop, as being shrunk into the die. Simple parts may be formed in one-hit dies in which the metal is shaped in a single hit, which term is used in aircraft shop parlance to describe a blow of the hammer. The shock of the hit also upsets and stabilizes the metal, thus reducing warpage during heat treatment. On intricate shapes, however, slow, gradual working is required until the last stage, when the final shock upsets the metal.

11. Hammer drawing is limited, not by stretching the metal to the tearing point, but by the formation of wrinkles around the edge of the piece. When a sheet is free over its entire surface and is not held on a particular spot on the die, as by a pressure pad or by rubber, it will be drawn by the punch into the die where shrinking will occur. It is this shrinkage of the dural or Alclad sheet that causes the difficulty in hammer forming, since neither material shrinks readily but rather tends to wrinkle, especially when no support is given to the flanges of the material. It is therefore necessary to remove the wrinkles by hand work. It is also common practice in many operation sequences to iron out the wrinkles by a power planishing hammer after the piece has been practically formed.

12. In Fig. 3 is shown an example of wrinkling of aluminum-alloy sheet under the hammer. This particular part, a door panel stiffener made of *24SO* Alclad, is a rectangular pan-shaped object. Around the corners, as at *a*, the wrinkles must

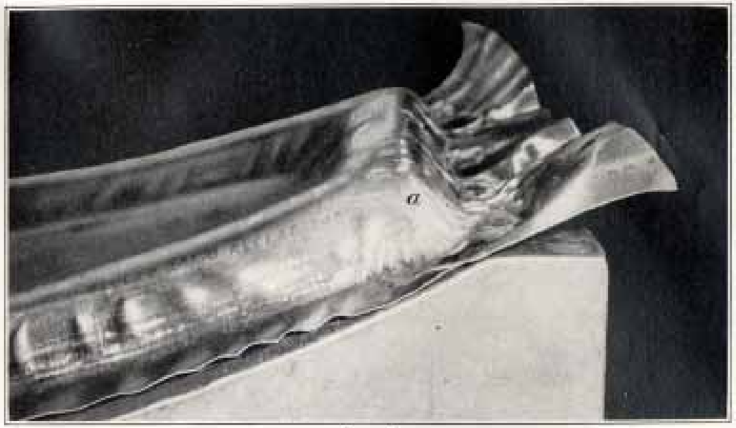

FIG. 3

be hand-hammered between hits so that the metal will not fold over and form laps. An example of how a part may be ruined by the formation of a lap in the metal is shown in Fig. 4. In

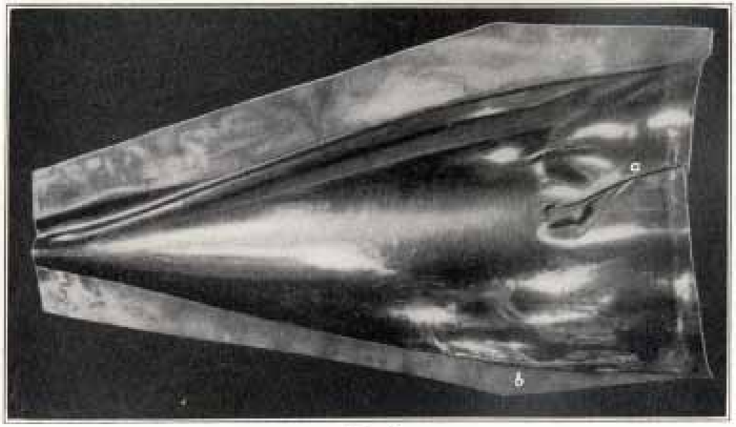

FIG. 4

this case, the lap *a* was formed because the blank was not held securely enough on the edge *b*, so that the material was drawn into the die too quickly and folded over.

13. Properties of Materials Formed in Drop Hammers. Aluminum, dural, and Alclad sheets of all types may be formed in drop hammers, but the common alloys so formed are *3SO*, *3S½H*, *24SO*, *24SO* Alclad, *52SO* and *52S½H*. Soft tempers are required in order to afford a yield point sufficiently low that shrinking instead of buckling will occur. Thus *3SO* has much better shrinking characteristics than has *3S½H*. Where extreme stretch and shrink are required on unstressed parts, *3SO* may be replaced by *2SO* which has an elongation of from 35 to 40 per cent. Alloys in the Alclad condition, such as *24SO* Alclad, can be worked even better than the plain aluminum alloy, as the Alclad coating seems to act as a lubricant, thereby making the forming less severe. Hard stocks, *24ST* and *24ST* Alclad, are rarely used in drop-hammer drawing, because of spring-back and work-hardening difficulties.

Parts made from annealed stock having heat-treatable characteristics are heat-treated to the desired strength after forming. Then, before the metal can age and develop its full hardness, these parts are generally restruck to correct any warpage that may have taken place in them, and to insure their conforming to the contour of the die.

The most practical gage for drop-hammer forming is .051 inch. Sheets of less than .025-inch gage cannot be formed satisfactorily without excessive wrinkling, whereas those of a gage over .064 inch work-harden too rapidly for efficient forming.

14. Work-Hardening of Aluminum Alloys.—In working aluminum alloys, it is important to realize that the cold working increases the hardness and the compressive yield point of the material. All alloys do not work-harden to the same degree; thus *2SO* and *3SO* work-harden only slightly, whereas *24SO*, *52SO*, and *52S½H* work-harden readily. Therefore, during the forming process, an aluminum alloy that work-hardens considerably requires annealing between the drawing operations. In making many parts, it is necessary, before the parts are completed, to anneal the material several times, either in a furnace in the heat-treating department, or in a lead pot located near the hammer. In the latter method, commonly called the quick anneal, the hammer operator immerses the part for a moment

in molten lead held at a temperature of from 640° to 650° F. Local areas of a piece can also be annealed by heating with a gas torch, but this method gives non-uniform results and is therefore not recommended.

15. Hand hammering the metal to remove wrinkles also causes work-hardening and tends to make the buckling worse. When the material is struck again in the drop-hammer, a greater force is required to shrink it into the next stage, and the material is more likely to tear at the drawing radius. Therefore, as far as possible, the wrinkles are concentrated in the outer flange which is trimmed off the finished part by a band or circular saw, shears, shaper, or other convenient means. In some cases, depressions may be cast in the die itself, as shown at *a*, Fig. 5, to take up the excess flange metal. Some parts may also be trimmed after partial forming in order to reduce the wrinkling effect.

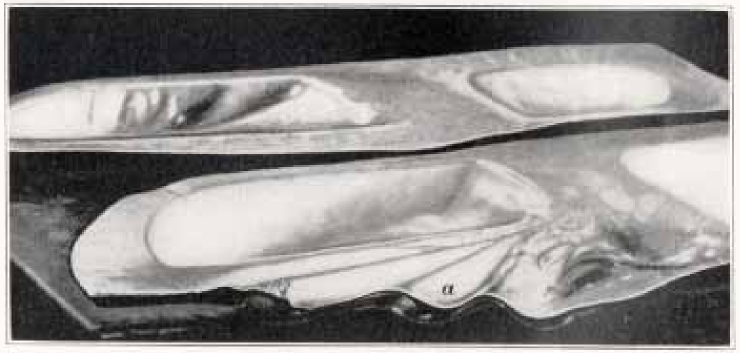

FIG. 5

16. Die Materials.—The former practice in the aircraft industry was to use a lead punch and a zinc die. However, where the draws were deep or the metal fairly heavy, or where many stampings were required, the zinc die had a short life. Repeated blows of the hammer stretched, cracked, or battered the die out of shape. Therefore, zinc has been replaced by Kirksite, an alloy of zinc, aluminum, copper, and magnesium. Kirksite has several times the impact strength of zinc and is lighter, harder, and stronger.

The punch is generally made of lead with from 6 to 10 per cent of antimony added for hardness. For those cases, however, where the punch is to undergo exceptionally severe service, the punch also may be made of Kirksite. On the general run of work, a lead punch will last approximately from one-fifth to one-third as long as the Kirksite die.

Another alloy that is being used to some extent as a die material is known to the trade as Terromatrix. This alloy has a low melting point (250° F.), and has practically no shrinkage when cast.

Other die materials also used are dural, cast iron, and cast steel, but they are used to a much less extent than are lead and Kirksite, and then only for exceptionally large production runs of heavy-gage metal, or for stainless steel. For severe service, either cast iron or cast steel is satisfactory, being much stronger and harder than lead or Kirksite. However, such dies cannot be readily worked to shape with hand tools, require extreme care in casting, and are not easily modified to meet design changes. Plastic materials are also being tried for hammer dies, but, at present, their use is in the experimental stage.

17. Die Lubricant.—When aluminum alloy sheet is drawn over the surface of a die, its slipping is facilitated by the use of a lubricant, preferably a vegetable oil or a lard oil. Besides aiding the drawing action, the oil to some extent protects the surface of the material from scratches. Scratching of the material may also be prevented by placing a sheet of cellophane on top of the die. A film of polyvinyl alcohol on the die may be used for the same purpose, but this practice is not generally followed.

18. Mounting Dies in Hammers.—The punch of a die set is fastened to the hammer head by means of studs, which may be cast directly into the punch or screwed into threaded inserts cast in the punch. With the latter method, the studs can be removed from the punch and the die set can more readily be stored. Good practice is to provide a minimum of two $\frac{3}{8}$-inch inserts, and at least one insert for each square foot of top area of the punch or for each cubic foot of volume, depending on whichever is greater.

19. In making the set-up, the punch and die are placed on the anvil together and located so that the studs in the punch line up with the mating holes in the hammer head. The head is then lowered and checked for facing against the top of the punch, as it should rest evenly over the entire surface. High spots should be dressed off, and any low spots built up by adding molten lead. The punch is then bolted to the head, leaving the

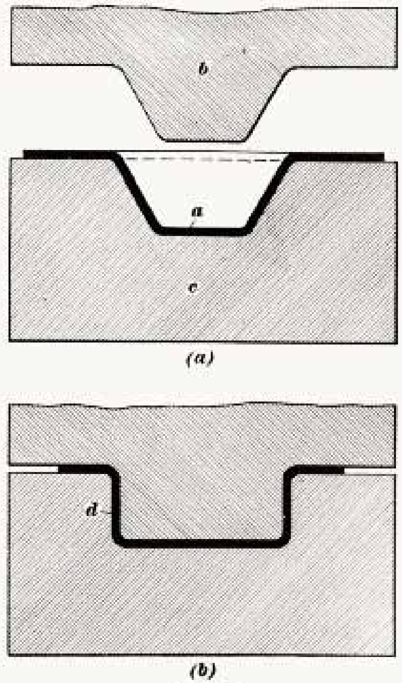

Fig. 6

die in approximately its correct position. A flat die with practically no side thrust can be fastened to the anvil by clamps bearing on shoulders which are cast on the base of the die. However, when there is a definite side thrust on the die, and also generally when rubber is used, the die must be so retained that there can be no sidewise movement under the force of the blows. In this method of fastening the die, taper pins or bolts are set into holes in the hammer anvil, and a layer of molten lead is poured around the die base and the pins or bolts. As the base of the die has a taper of about 5 degrees, the lead together with the pins or bolts holds the die firmly in its proper place on the anvil, and prevents it from being raised with the head.

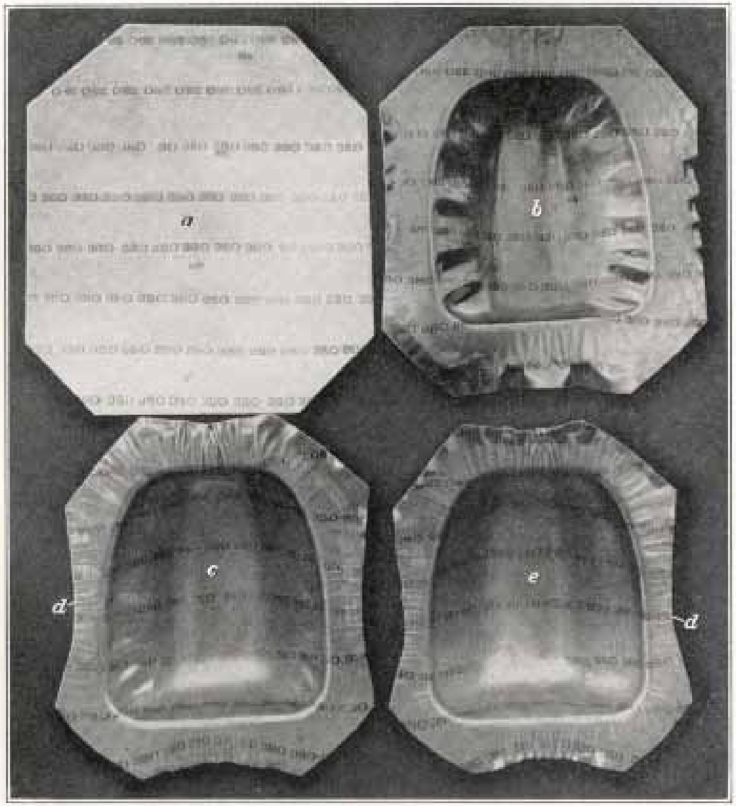

Fig. 7

20. Progressive Dies.—Parts that have deep draws, fairly sharp corners, or a deep reverse curvature are often made in a series of dies, known as progressive dies. The complete set may consist of one starting and one finishing die, but generally one or more intermediate dies are required. In Fig. 6 is shown the principle of progressive dies; the die in view (*a*) is the starter

in which the part *a* is drawn between the punch *b* and the die *c* into a conical hat shape. In the next step, as shown in view (*b*), the part is drawn to its finished shape. The finishing die must be given a draft of from 1 to 3 degrees along its sides, such as *d*, so that the drawn part can be removed from the depression; the punch is given an equal draft.

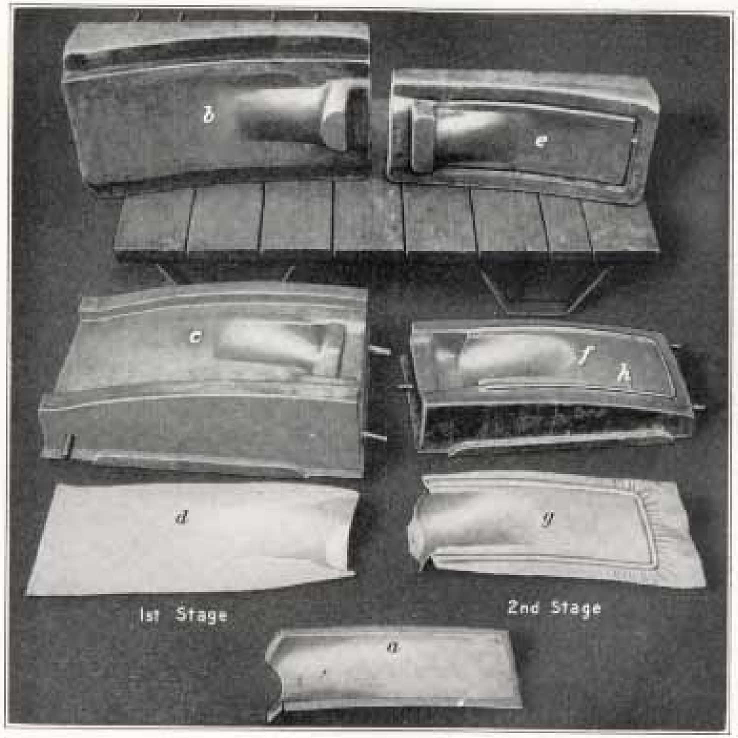

Fig. 8

21. The pieces in Fig. 7 illustrate the process of forming in progressive dies. The blank *a* is cut from .064 inch *3SO* stock. In the first, or starter, die, the piece is drawn to a shape *b*, with wrinkles forming around its flange and inside its depression. Then, in the second, or intermediate, die, the part is drawn to the shape *c*. At this stage, the lengthwise flow of the metal is indicated by the fact that the *3SO* designation lines are no longer

straight and parallel, but are curved and are farther apart at the bottom of the depression. The draw sidewise is shown by the drawing in of the sides at *d*. In the finish die, the part *e* is struck to shape with the wrinkles concentrated in the flange, which is to be cut off.

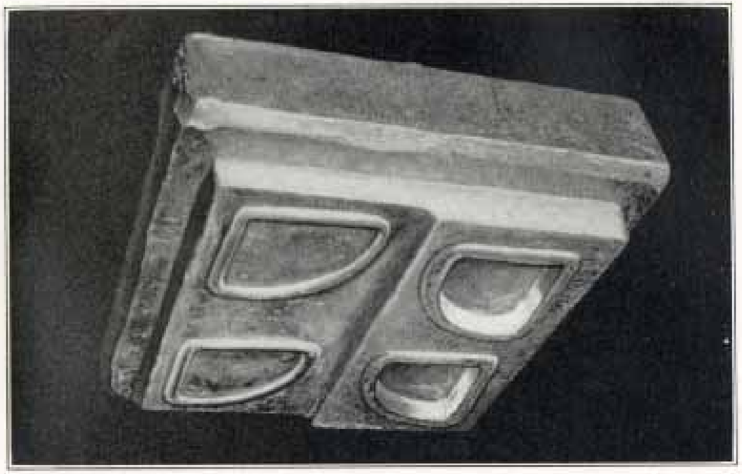

FIG. 9

22. Two-Stage Progressive Die.—A typical example of a two-stage progressive die is illustrated in Fig. 8. The finished piece *a* is a tail-pipe shroud. With the starter punch *b* and the die *c*, the sheet stock is drawn to the shape *d*. Then, in the second stage, with the punch *e* and die *f*, the shroud is finish drawn, as illustrated at *g*. The bead *h* around the die *f* serves to restrain the metal from shrinking into the die and so concentrates the wrinkles in the border. The bead and border on the finished part are trimmed off.

23. Integral Progressive Die.—Progressive dies may also be built integral, that is, with both the starter and finisher in one die. The punch for such a set for a stiffener is shown in Fig. 9, and the die in Fig. 10. With this die, two stiffeners are stamped at each hit of the hammer. Two blanks, such as that shown at *a*, are placed in the starter dies on the left-hand part of the die. Locating pins are used to hold the blanks in their proper positions. Then, after the first hit, the partly formed stiffeners are placed on the finish dies, as at *b*, and new blanks on the starter dies. With the second hit, two stiffeners *c* are finished. For small parts of this character, the starter and finisher dies are

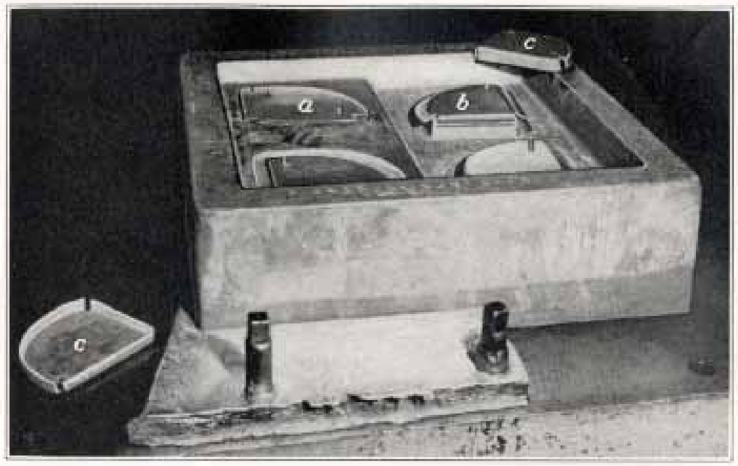

FIG. 10

generally built integral, both to increase the rate of production and to keep the die cost as low as possible.

24. Advantages of Progressive Dies.—Both separate and integral progressive dies are inexpensive, since no definite size or shape is needed in the preliminary dies employed in the progression. Any approximate contour that brings the blank closer to the finished shape is acceptable as long as excessive wrinkling is avoided. Another advantage of progressive forming is that the use of preforming dies prolongs the life of the finishing die. However, the time required to change the dies must be considered in estimating the cost of production, as the use of starter dies necessitates additional set-up operations. When relatively few parts are to be formed, the set-up time may be a major item.

According to one aircraft company, studies made on the drop hammer indicated that the average set-up and tear-down allowance is 27.7 minutes for die sets ranging from 650 to 7,300 pounds. For dies under 1,000 pounds, the allowance is 18.7 minutes; for dies from 1,000 to 4,000 pounds, 23.8 minutes; and for dies over 4,000 pounds, 32.1 minutes.

25. Draw-Ring Forming.—Symmetrical parts involving a deep draw may also be formed in stages, by using plywood draw rings instead of progressive dies. The blank, as shown in dotted outline at *a*, Fig. 11, is laid on the die, and a steel ring *b*

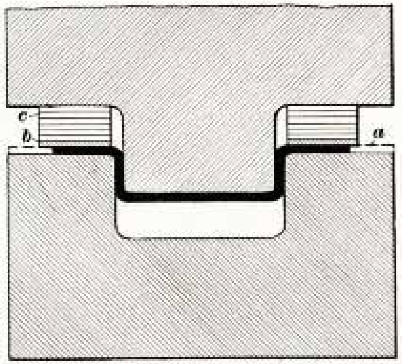

Fig. 11

and a number of plywood rings *c* of approximately the shape of the finished flange are placed on top of the blank. Then, as the hammer head drops, the base of the punch strikes the stack of plywood rings and the punch enters the die only a small amount, an inch or less. The impact of the punch on the plywood rings applies a hold-down pressure to the steel ring *b*, but this pressure will not support the flange of the material sufficiently to prevent all buckling and wrinkling. Such progressive forming, however, correctly starts the flow of metal into the die so that wrinkles and overlapping folds are eliminated to a large extent. After each blow of the punch, one or more rings are removed, thus permitting the punch to enter the die farther and farther until it bottoms on the final drop, at which time the piece is struck to the finished shape. Between blows, the wrinkles must usually be worked out by hand hammering. At these intermediate stages, the complicated areas especially are handworked to direct or correct the flow of the metal into these

Fig. 12

areas, so that the metal is not overstressed and cracked. An inspection of the first part formed will show where the metal has not drawn properly, and on subsequent pieces, the metal around such areas can be preformed by handwork. Also, rubber blocks can be used in conjunction with plywood rings to draw out particular areas.

26. Examples of Draw-Ring Forming.—A typical part formed by using progressive dies and draw rings on the starter is the *3SO* drop-tank fairing, a number of which are shown in Fig. 12. Making this part involves a fairly deep draw, and, in

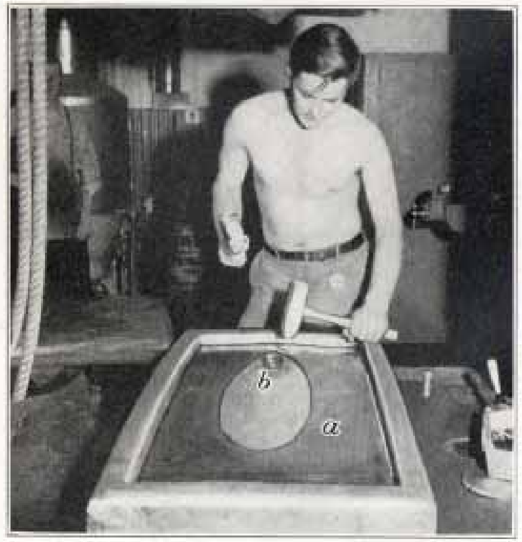

Fig. 13

FIG. 14

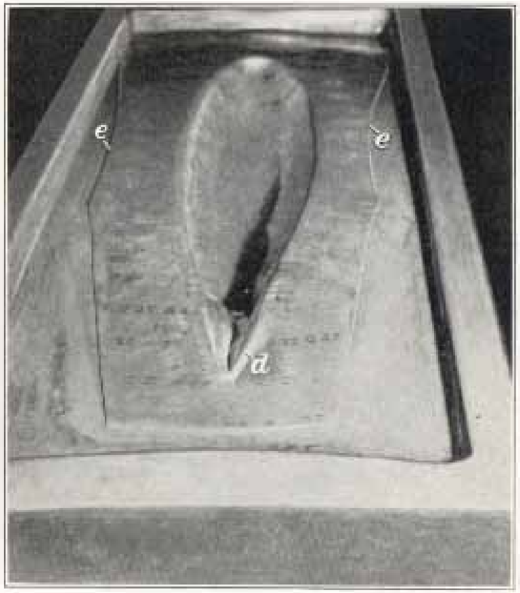

FIG. 15

addition, a still deeper draw must be made at *a* to form a surface for mounting a fitting for attaching the fuel line. To form a depression of this type, the metal must be drawn from the adjacent material. Therefore, it is necessary, before placing the steel ring *a*, Fig. 13, on the blank, to lubricate the material for about three-fourths its length. No lubrication should be applied to the blank at the point opposite the deep-drawn area *b*, in order that the pressure-plate action will be greater at this

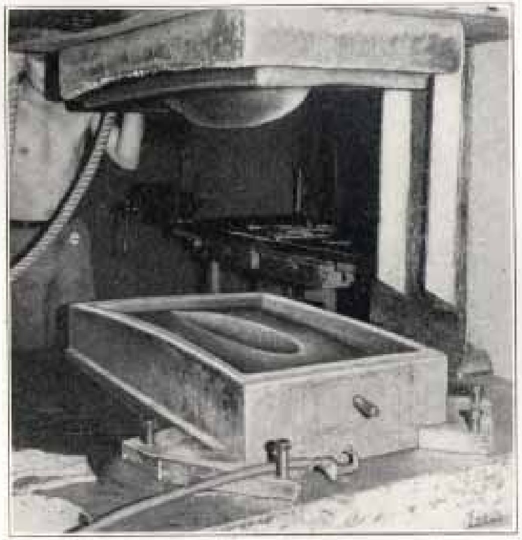

FIG. 16

point. The metal will slip under the draw rings, even with no lubrication, but the pressure on it will be great enough to prevent wrinkles, as the metal is pressed or "shrunk" into the die. The area *b* is also prestretched by hand because of the sharp double curvature involved. With the steel ring in place, a straight peen hammer is held against the sheet at this point, and struck by a soft hammer until the desired indentation is obtained. Plywood rings *c*, Fig. 14, are next placed on top of the steel ring and the fairing is gradually drawn to shape, as the rings are removed between hits. A safety suction-cup device is recommended for removing the rings. The deep-drawn area

FIG. 17

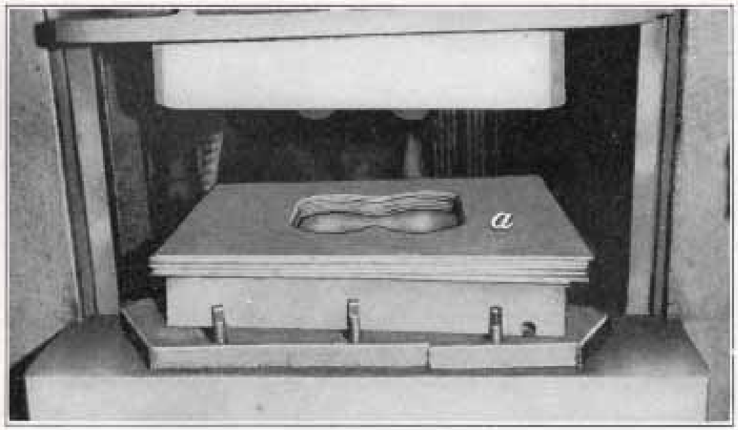

FIG. 18

around the point of the depression will wrinkle, as shown at *d*, Fig. 15, and require hand work to avoid laps or tears. The material at this stage is not fully formed, but some stretching has taken place and the sheet has slipped over the die, as indicated by the somewhat deformed outline at *e*. Two final blows, one on the steel ring and the last directly on the fairing, as shown in Fig. 16, bring the part accurately to shape.

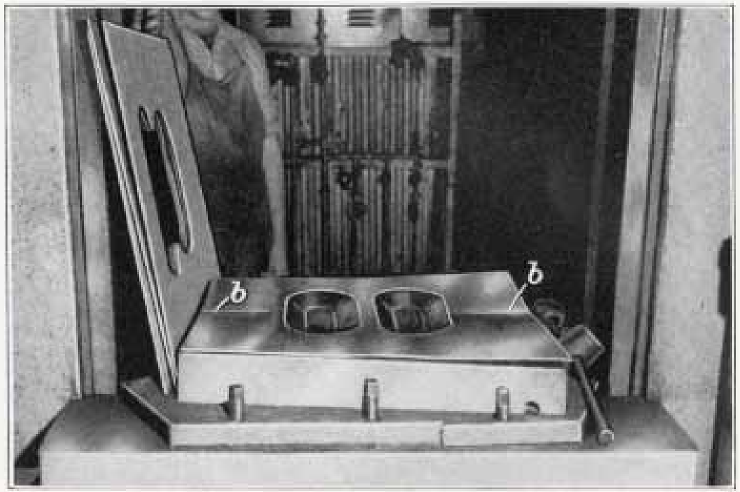

FIG. 19

27. Another typical plywood draw-ring operation is the forming of the cabin-door frame *a*, Fig. 17. This part has been drawn in the starter die, and is to be transferred to a finish die to complete the forming operation. The wrinkling and buckling that have resulted from the preliminary forming in the starter die will be greatly eliminated in the finish die. A convenient means of handling the steel and the plywood rings, when the finished piece is to be removed and a new piece inserted, is to attach a chain *b* at each end of the hammer head to the eye-bolts *c* in the steel ring *d*, and then to lift the rings from the work by raising the hammer head.

28. When draws are to be made that would wrinkle too much for one-hit, or single blow, dies, but do not require a great

FIG. 20

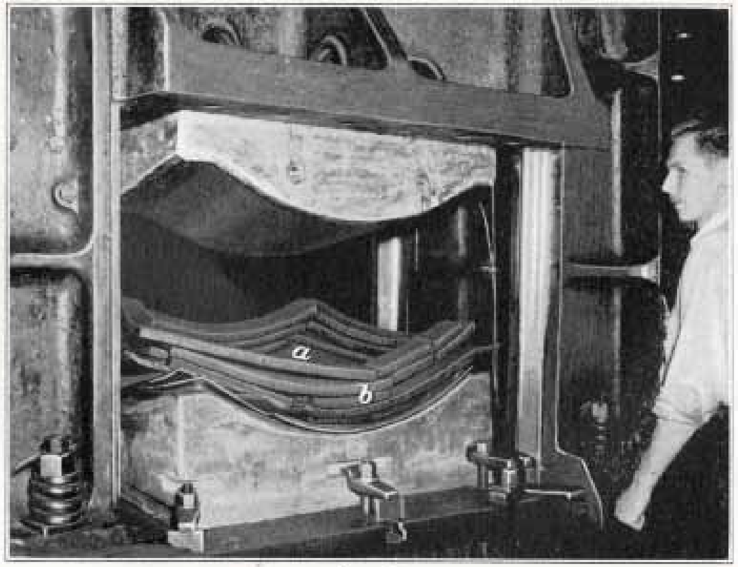

FIG. 21

flange pressure, plywood rings may be used without a steel ring. In Fig. 18 is shown the set-up for a stiffener section that may be drawn in this manner. The plywood rings *a* are placed directly on the blank, and the material is drawn to the form shown in Fig. 19. Then, before making any further hits, the wrinkles at *b* must be hand-worked down so that laps do not

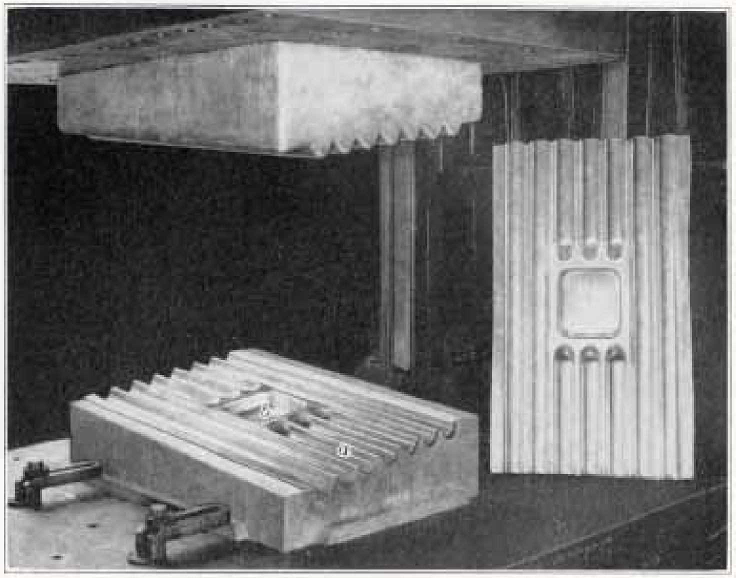

FIG. 22

form. This hand work is repeated before the last hit. Removing these wrinkles by mallet causes the material to buckle badly, as shown in Fig. 20, but the final hit corrects this buckling effect.

29. Rubber-Pad Forming.—Whenever the finished form is to be of such a shape that there is danger of the metal tearing or folding, both soft and hard rubber can be used to assist in preforming, that is, to "coax" the metal into the difficult corners. Another reason for the use of rubber is that it equalizes the blow of the punch, so that the ram travels straight in its ways. Where to use the rubber and how much to use depend on the shape of the part, and must be determined by trial.

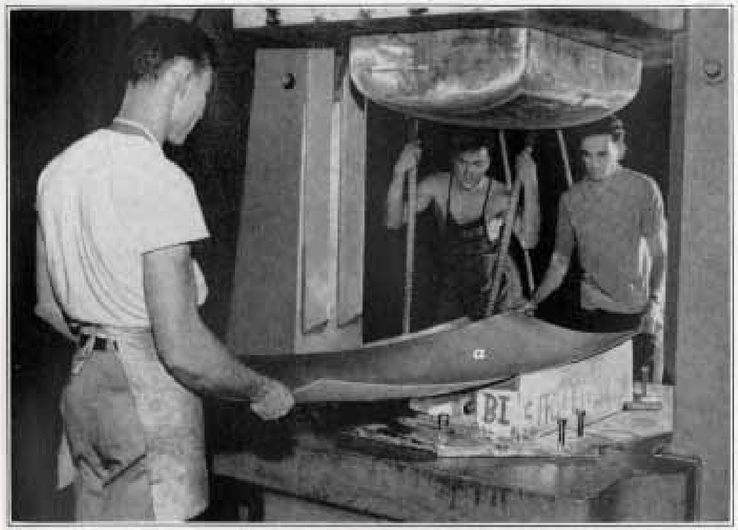

Fig. 23

In Fig. 21, so-called hard-rubber blocks are used to replace plywood draw rings for progressive drawing. A rubber blanket *a* is placed directly over the material to help shrink it into the die depression, and stacks of rubber blocks *b* are laid along the flange of the part. These blocks have the same pressure-pad action as do plywood rings, and are removed between hits as the drawing progresses until the final hit is made directly on the metal part. The term hard-rubber is used to describe the hardest form of flexible rubber employed in connection with drop-hammer forming, and is not intended to imply that the rubber is actually hard or rigid.

30. The filler-well doubler, shown together with the die set-up in Figs 2 and 22, is a good example of a part that may be formed by the use of a rubber pad. The corrugations *a* will form without trouble, as the material is simply stretched into the die depressions and then set when the punch bottoms. The well *b*, however, must be drawn into its depression; with slow, careful, working, this drawing may be made with no rubber, but using a square rubber pad over the material at the center area facilitates the shrinkage of the metal. The rubber not only has a draw-ring action around the flange of the well, but also helps to draw the metal into the corners of the die depression and to bottom the stock. Since the sides of the well are not designed to be perpendicular to the surface of the sheet, the face of the die must be slanted to make the sides of the well parallel to the direction of motion of the head.

31. Drawing With Retaining Collar.—Another means of drawing metal by restraining the edge of the piece to prevent the formation of wrinkles, is by using a retaining collar, or pressure pad. This collar is made of steel and holds the blank against the die. As the punch descends, the metal is drawn

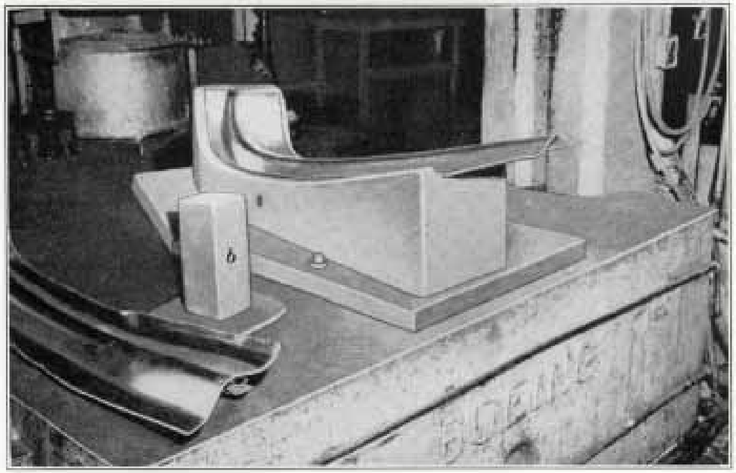

Fig. 24

from under the pad and into the die depression. Enough pressure is exerted by the collar to prevent wrinkling. This type of die is used generally only for symmetrical pan-shaped parts. The collar may be either clamped or bolted to the top surface of the die. An arrangement whereby the collar can be quickly removed for insertion of the blank consists of U-shaped, wedge-like clips that slip under the head of each bolt. With the clips removed, the collar can be lifted off the die without unscrewing the bolts

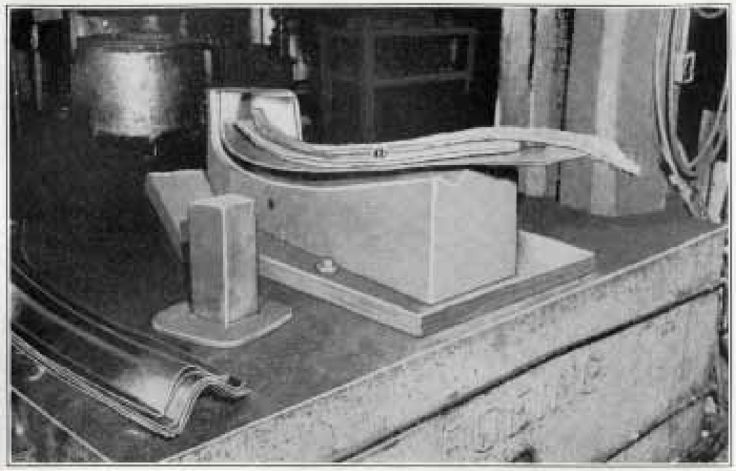

FIG. 25

FIG. 26

32. Feeder Dies.—It is not always practicable or economical to provide progressive dies or to use draw rings for forming parts that cannot be formed by a single blow. In such cases, it may be possible to form the part in a feeder, or feed-in, die. This type of die is used for double-curvature parts, such as for leading-edge capstrips, and for nacelle fairing, an example of which is shown at *a*, Fig. 23. The material for the nacelle is

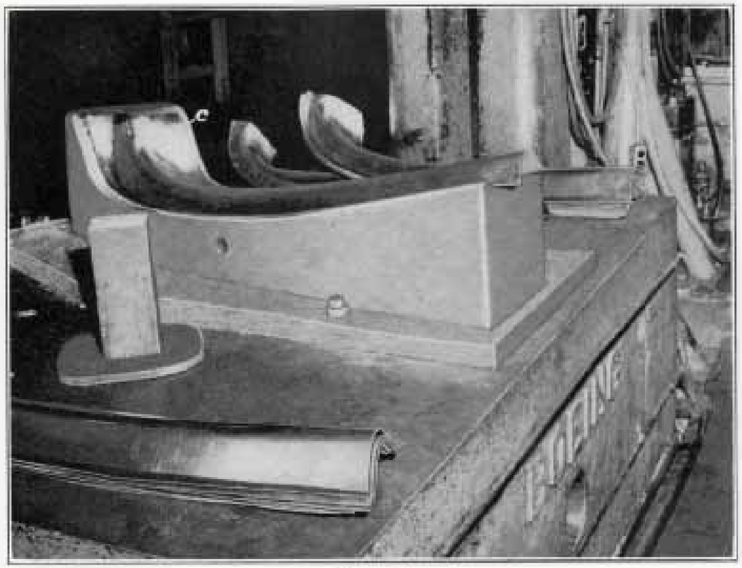

FIG. 27

fed gradually over the die as a series of relatively light hits form it to shape. At the entering edge at the front of the machine, the die forms the part with a slight curvature. Then, as the material is passed through the die, the curvature is increased to the final shape at the back edge of the die. The double curvature of the piece is attained by making the die low at the center, and curving the edges from the front to the back. After such parts are formed in feeder dies and then heat-treated, they may be crown-rolled to give them the correct curvature.

33. Another feeder die is shown in Fig. 24. In the first operation, three blanks of *24SO* metal are partially formed.

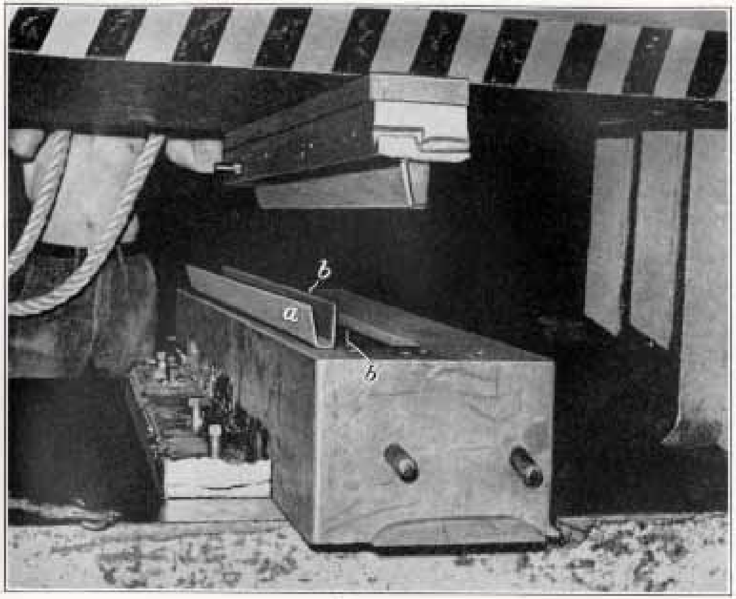

FIG. 28

Rubber pads *a* are laid on the blanks over the raised part of the die, so that the blanks will be held along this ridge and bent to the approximate shape of the die depression, as shown by the single part in Fig. 25. The operator then feeds the part into the die and so forces it to follow the curvature of the die. Since the material must be forced both upward and to one side while the hammer head strikes a series of blows, considerable pressure is required; this pressure is applied, as shown in Fig. 26, by a wooden block *b* held against the end of the part by the operator. As the part is fed into the die, the inner leading corner *c*, Fig. 27, wrinkles to some extent, and to prevent those wrinkles from extending into the finished part, the corner area is trimmed off as soon as they form.

34. Bending in Drop Hammer.—Many operations that involve bending rather than drawing, as in the case of long, tapering, channel sections, may be done in a drop hammer, rather than on a press brake, when the tolerance is less than $\frac{1}{32}$ inch, which is the minimum tolerance generally obtainable on the

press brake. In Fig. 28, the formed part *a* is a hinge channel for a wheel door. It has a broader crown at one end than at the other and, consequently, the sides at the broad end are lower than at the narrow end. The punch, as well as the die, is made of Kirksite, because of its small wedge-shaped section, its close tolerance of .008 inch, and the heavy material to be formed, the stock being .091 gage *24SO*. For such severe service, a lead punch would not retain its shape, or give the required tolerance to the work. To form the piece, a rectangular strip of stock is laid on the die and positioned by pins *b*. Because of the sharp bend, three hammer operations are required. After

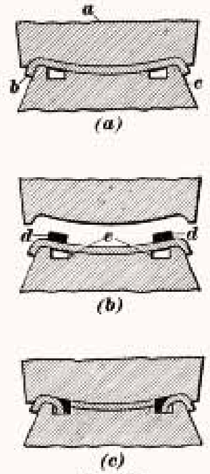

FIG. 29

the first hit, the stock is annealed to overcome work-hardening; it is then hit again, and heat-treated; after which the piece is returned to the hammer for a final hit to remove any distortion that may have occurred during the heat treating.

35. Drop-Hammer Shearing.—The drop hammer may be used for shearing as well as for forming, but it is an uncommon operation. The method is the same as that used on the single-action hydro-press. The punch *a* first forms the stock *b* on the die *c*, as shown in Fig. 29 (*a*). The outer edge of the piece is then to be trimmed off, leaving the finished central part.

Rubber blocks *d* are placed on the formed part, as shown in view (*b*), and over the annular shearing cavity *e*. As the shearing blow is made, as in view (*c*), the rubber forces the metal over the shearing edge. To provide for the sharpening of the edge the center section of the die is made about $\frac{1}{16}$ inch larger in diameter than the finished part, and it is brought to size when the inner edge is ground.

DESIGN FOR DROP-HAMMER FORMING

36. Design Considerations.—The present practice in the aircraft industry is not to design a part specifically to be formed in a drop hammer, but rather to adapt the part for drop-hammer forming if it cannot be done economically on any other machine. For example, when a certain part is to have sharp bends, which cannot be formed on a hydro-press, the entire part should be formed on a hammer, because experience has shown that pieces which will fracture on the hydro-press can be worked successfully on the hammer. However, since drop-hammer work involves a drawing action, sharp radii must be avoided as much as possible because of the excessive work-hardening of the metal and the liability that the part will crack. Sharp radii also cause excessive die wear. In all cases, the largest possible radius should be used consistent with the design requirements. Also the tolerance on the curvature should not be specified too closely, since requiring the shop to hold closely to prescribed curvature will result in excessive production costs. Generally, the minimum radius on any part formed by the drop hammer should be equal to at least twice the minimum bend radius for the particular metal being used. The chart, Fig. 30, gives the relative minimum size of radii required and that recommended, as governed by the size of the finished part.

37. In the sketch shown in the lower right-hand corner of the chart, Fig. 30, *A* and *B* represent the inside dimensions of the formed part, and R_1, R_2, and R_3 represent the radii of the curved portions, expressed in inches. Three pairs of curves appear on the chart, each pair showing the minimum and aver-

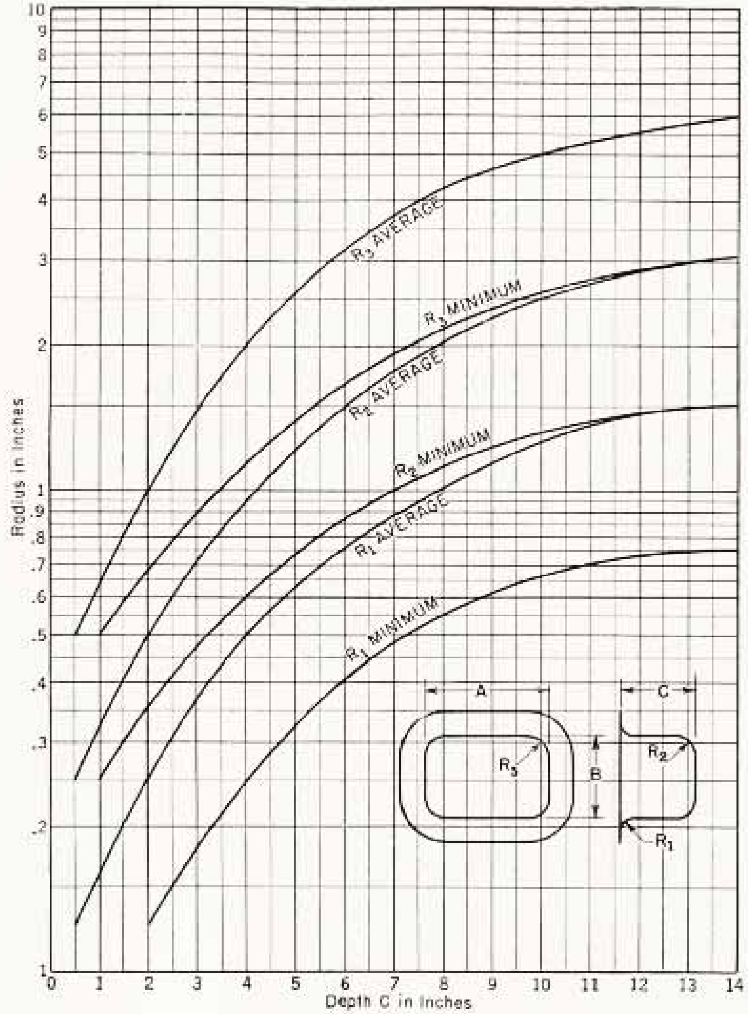

Fig. 30