FORMING METHODS

FORMING BY DRAW BENCH, POWER ROLLS, AND SPINNING

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FORMING BY DRAW BENCH, POWER ROLLS, AND SPINNING

FORMING BY DRAW BENCH

1. **Use of Draw Bench.**—The draw bench is used in the aircraft industry for forming long, narrow parts of uniform cross-section, such as the angles, channels, C sections, and hat sections used for stringers and stiffeners. It is used also for such specialized operations as the forming of streamline tubing from round tubing and the closing of continuous hinges. By pulling thin strip stock through either draw dies or a series of rolls designed to produce the desired shape, many complex sections can be formed. Parts too long for brake forming can be drawn in this manner. The draw bench method is rapid in operation, since an average of 250 feet of strip stock can be drawn in one hour. The finished work is accurate and uniform and can be handled economically in either large or small quantities.

2. **Aluminum Alloys Formed in Draw Bench.**—Both annealed and hard aluminum alloys can be formed in the draw bench. When draw dies are used, the stock is drawn in the *SO* condition and heat treated after drawing. Experimental work, however, is now in progress on the forming of *ST* material in draw dies; the difficulty encountered in hard-stock drawing is the springback of the metal. When roller dies are used, *ST* material may be drawn, but here again the springback is troublesome in that it may cause warping of the section. When *SO* material is drawn in roller dies, the springback is eliminated and the wear on the rolls is less than with hard stock. The number of operations, however, can be reduced by drawing heat-treated stock before it has age-hardened, since no straightening operation is then required. Roller dies are used par-

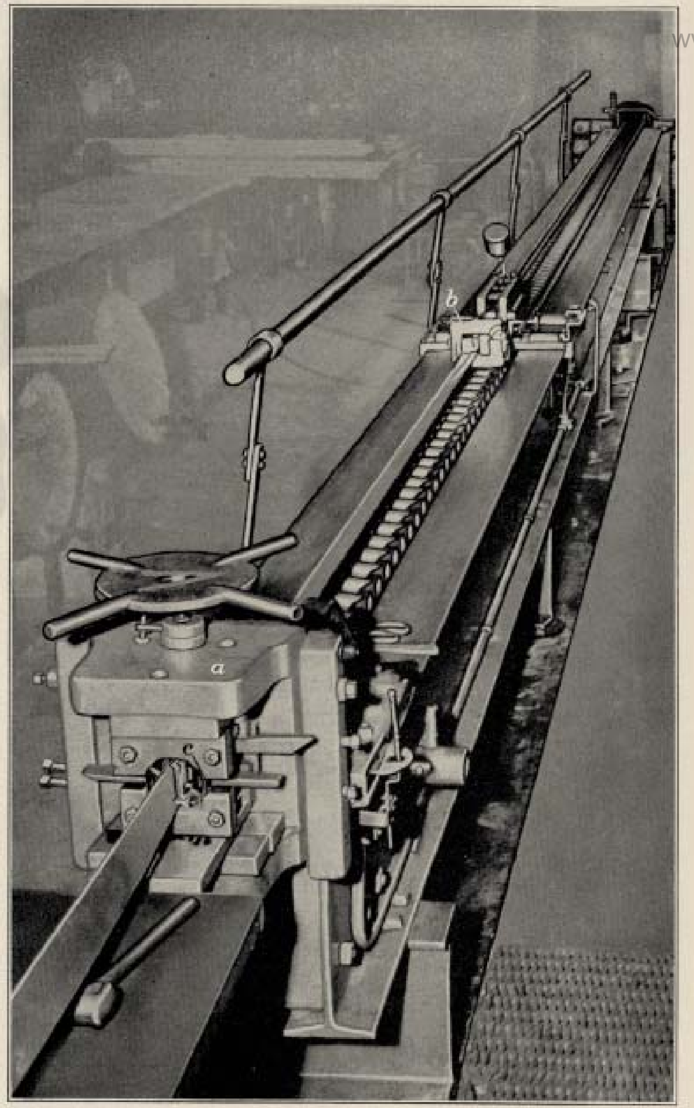


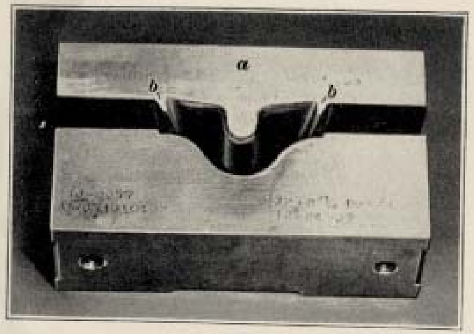
Fig. 1

Fig. 2

ticularly when Alclad stock is to be drawn, since there is less tendency than with draw dies to damage the protective coating of aluminum.

3. **Draw-Bench Operation.**—The draw bench, as shown in Fig. 1 has a horizontal bed that may be 50 feet or more in length. Mounted on the bed are the die head *a* and the drawhead, or table carriage, *b*. The draw dies *c*, shown more clearly in Fig. 2, are mounted in the head *a*. Stock from a reel is lubricated, either by a brush or by running it over an oiled pad or through oiled rollers, and is then fed through the draw dies *c* by hand. Either the stock is tapered to a point and passed through the dies, or the dies are opened by means of the pilot wheel *d* and the stock is pressed into the slot. The drawhead *b* is then rolled up to the dies and the stock is clamped in its jaws.

Beneath the draw head is an endless roller chain *e* that is driven over two sprockets, one located at each end of the bed. The rear of the drawhead has a hook, or dog, that may be dropped into any opening in the chain. When the dog is thus



(b)

(a) Fig. 3

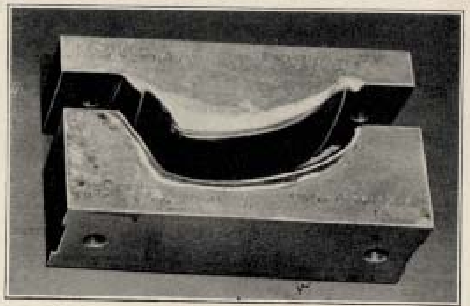
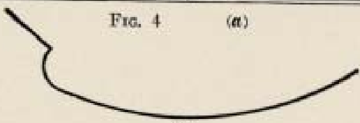
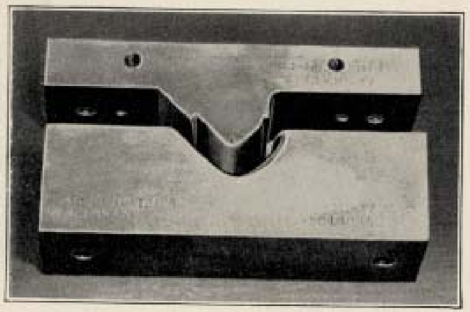


Fig. 4 (a)



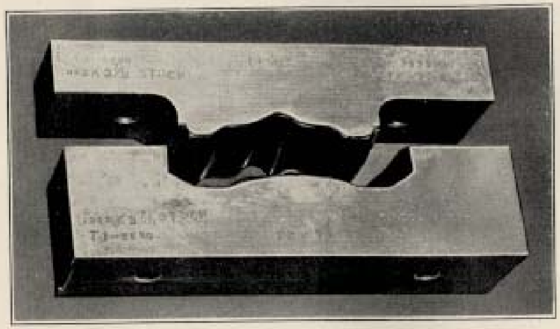
(b)



(b)

(a) Fig. 5

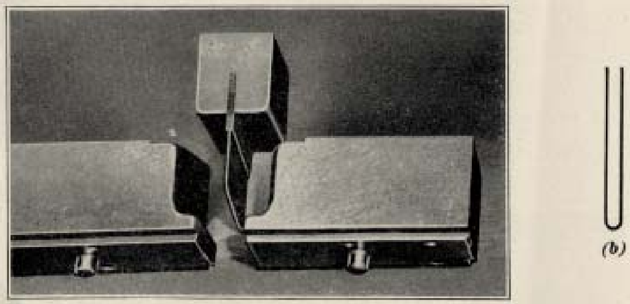
engaged, the drawhead is drawn along the bed and pulls the stock through the die. At the end of the bed the dog disengages automatically and the stock is cut off near the die. If the stock has previously been cut to length, the dog is disengaged when the material passes from the die.



(a) Fig. 6

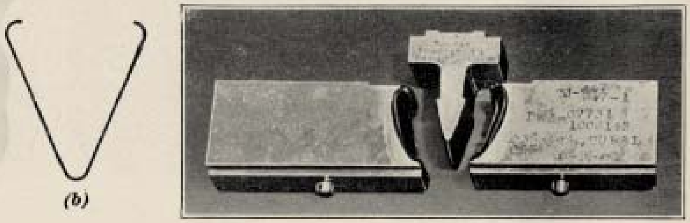
(b)

4. **Draw Dies.**—Draw dies of many different shapes are used in the aircraft industry. Those dies most commonly used, together with cross-sections of the parts formed, are shown in Figs. 3 to 9. The die in Fig. 3 (*a*) forms from flat strip stock, the hat section shown in view (*b*). The stock is formed gradually to shape as it is drawn through the die. On the upper part *a* of the die, two wings *b* are provided to guide the strip stock as it is drawn to shape. The strip stock must be just wide enough to form the section but may be of any length desired. In the same manner, the dies shown in (*a*), Figs. 4, 5, and 6, are used to form their respective parts outlined in (*b*). All of these dies are made in two pieces, the top piece being mounted in the sliding part of the die head and the bottom piece on the stationary base.



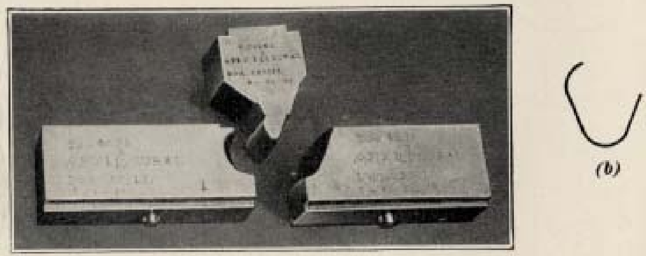
(b)

(a) Fig. 7



(b)

(a) Fig. 8



(b)

(a) Fig. 9

The dies shown in (*a*), Figs. 7, 8, and 9, however, are made in three pieces. With these dies, the middle piece is mounted in the sliding part of the die head, whereas the two lower pieces are mounted on the base of the head. The method of using the dies to form their respective parts outlined in (*b*), is similar to that of the preceding dies.

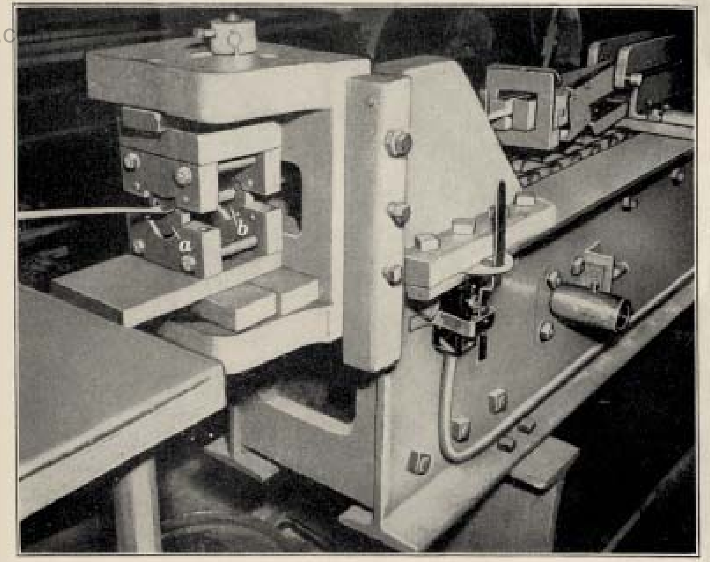


Fig. 10

5. The dies illustrated are made of either tool or plow steel. They are provided with very small clearances over the gage of metal to be drawn. The minimum radii to which the sheet metal may be drawn with dies of this type are smaller than the standard radii because the metal assumes the shape gradually as it enters the die, instead of being formed suddenly as in a press brake. At the entrance of each die, the slot is made wide, but it narrows down to the required size where the metal leaves the die. Tapering the die slot in this manner permits an easier flow of the metal into the form desired.

6. **Multiple-Draw Dies.**—When a complex form is required, multiple-draw dies consisting of two or three die sets may be used. Such dies are arranged progressively so that the strip stock is bent gradually, taking on a greater bend as it passes through each set of dies. The gradual forming of the metal avoids undue stress that might crack or tear it. An operation of this type requiring two sets of dies is shown in Fig. 10.

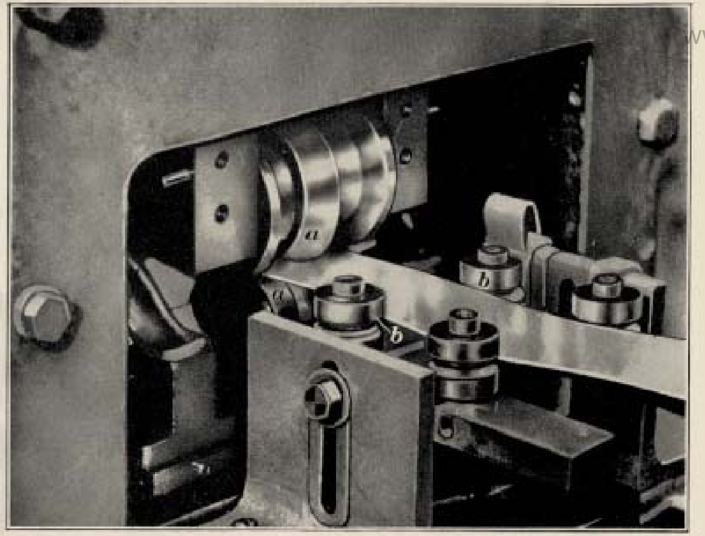


Fig. 11

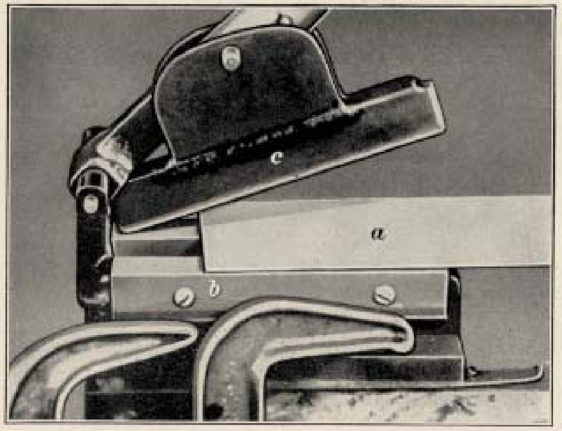


Fig. 12

The two die sets *a* and *b* are spaced apart far enough so that the metal can flow freely from the first die *a* to the second die *b*, and are then bolted together and set as a unit in the die head of the machine. The first die preforms the stock to a shallow U-shape, and the second die finish-forms the U-shaped section.

7. Roller Dies.—A roller-die set-up in a draw bench is shown in Fig. 11. The rolls *a*, which are usually made of case-hardened steel, are not powered since the strip stock is pulled through them by the draw head. The raw material to be formed is sheared to the required width. Then to start the material into the dies, it is necessary to bend the end to a V-shape by the hand former shown in Fig. 12. The stock *a* is laid over the V-shape base *b*, and the punch *c*, which is attached to a long handle, is forced by hand to bend the material down into the depression of the base. The stock is then fed through the roller guides *b* and the rolls *a*, Fig. 11, to the jaws of the draw head. To lubricate the stock, it is first run over an oiled pad located just ahead of the roller guides.

8. Multiple-Roller Dies.—When a complex section is to be rolled, it may be necessary to use more than one pair of roller dies. The sections thus rolled may vary from simple right-angle bends to multiple curves, including hat-sections that have short return bends at their edges to secure additional rigidity. Each set of roller dies is designed to impart a new shape to the metal as it passes through the dies. Thus, in Fig. 13, two sets of dies are shown. The die *a* imparts a slight bend to the stock, and the die *b* gives it the final shape. Stock of such cross-section can be clamped in the draw head by bedding it in a V-shape base and setting in a wedge-shaped block, as at *a* in Fig. 14. The clamp screw *b* is then screwed down on the block, and the draw is made.

9. Drawing Streamline Tubing.—Aluminum-alloy tubing may be streamlined in a draw bench by drawing round tubing through a die of the proper shape. Such a die, which is used to form streamline tubing from round tubing of $1\frac{1}{2}$-inch

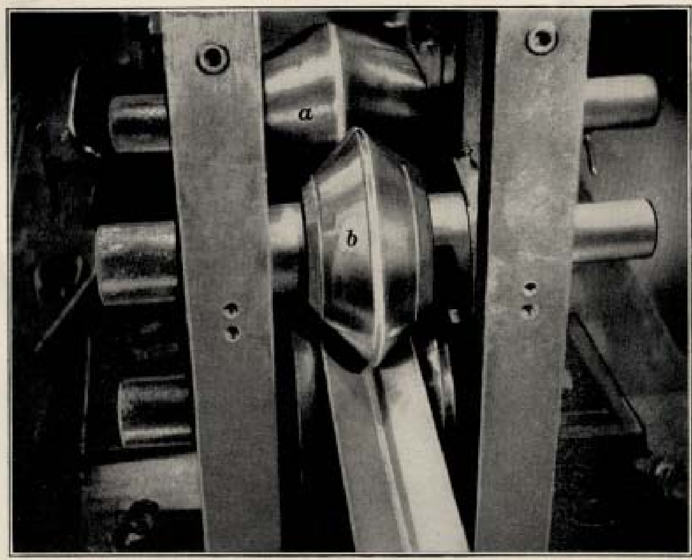


Fig. 13

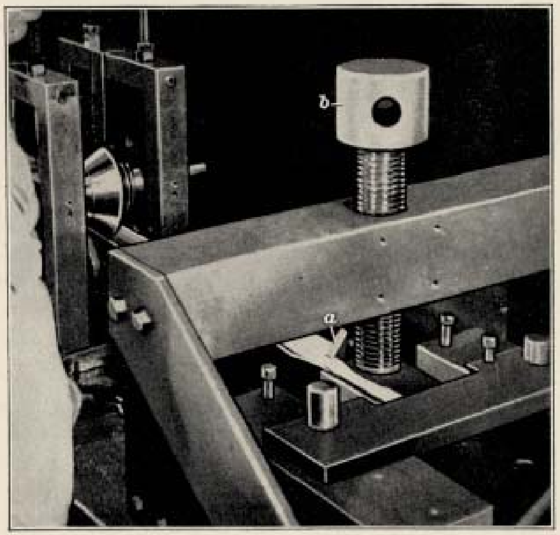


Fig. 14

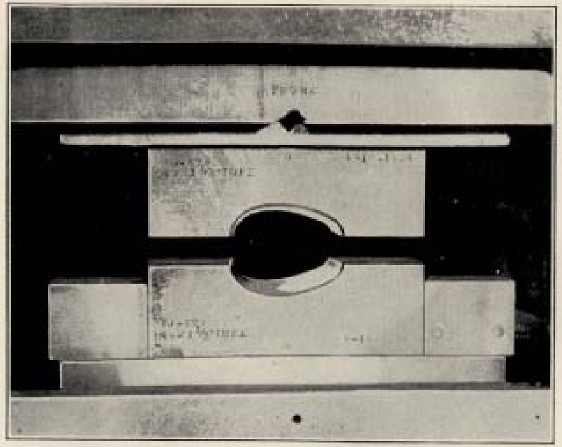


Fig. 15

diameter and .049-inch wall thickness, is shown in its open position in Fig. 15. The die opening, as clearly shown, tapers from the front to the rear edge in order to form the tubing gradually. If this die were used alone, however, the wall of the tubing would collapse as the forming was done. Therefore, to provide adequate support for the tubing wall, a short, streamline-shaped mandrel must be positioned within the tubing at a point opposite the die.

10. The die set-up is shown in Fig. 16. The round tubing is placed in the open die, and the upper part of the die is slowly lowered by the pilot wheel *a* until the end of the tubing is given its streamlined shape, as shown at *b*. Then, with a hammer and a small block of wood, the mandrel *c* is driven into the tubing far enough that the end of the tubing can be flattened and gripped in the jaws of the draw head. The end is flattened by removing the tubing from the die and hammering it flat on a solid surface, preferably not on any part of the machine. The tubing is replaced in the die, and the rod holding the mandrel is anchored at its far end so that the mandrel will remain opposite the die. The flattened end *a* of the tubing is then gripped in the

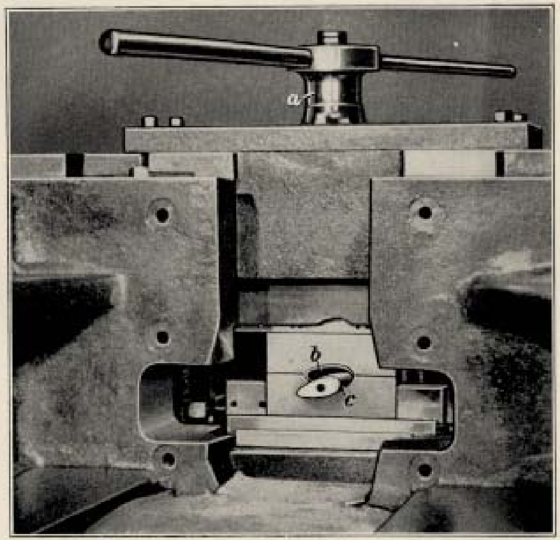


Fig. 16

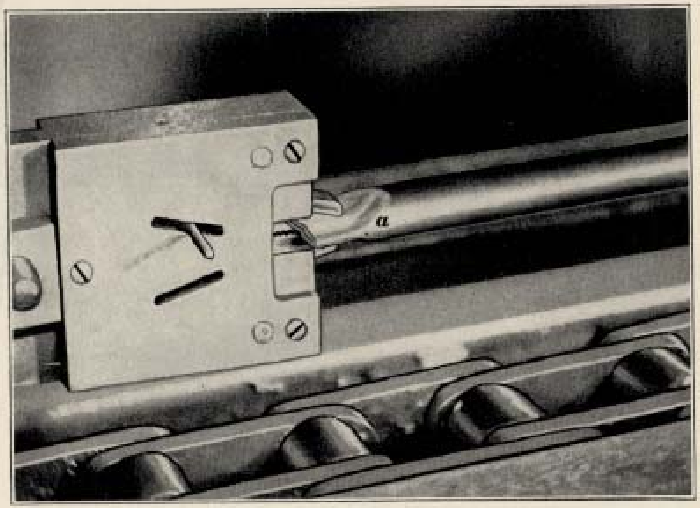


Fig. 17

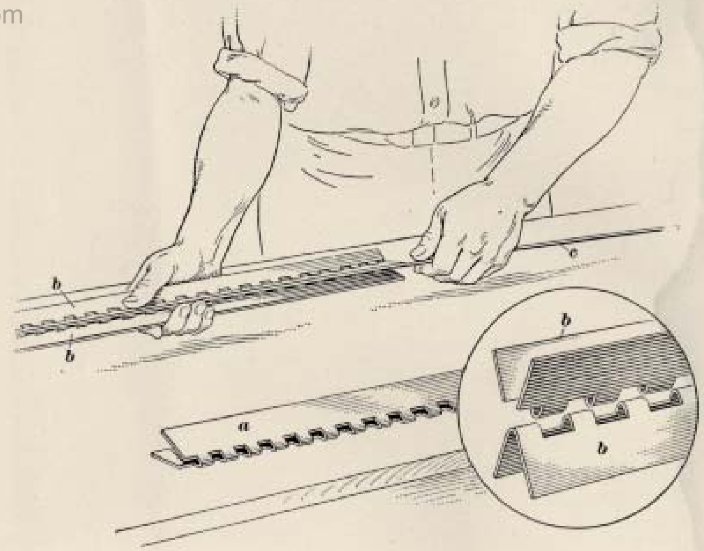


Fig. 18

jaws of the draw head as shown in Fig. 17, the tubing is well lubricated, and the dog of the draw head is engaged to draw the tubing through the die to form the desired streamline shape.

11. Closing Continuous Hinges.—One of the most important draw-bench operations in the aircraft industry is the finish-forming of piano-type hinges. The strip material is first blanked out on a punch press and then bent to a V-shape on a press brake. A hinge that has been thus blanked and bent is shown at *a*, Fig. 18. This hinge must now be closed. Two such hinges, shown at *b*, are fitted together and a wire mandrel *c* is inserted in them lengthwise. The wire mandrel must be anchored at its far end away from the die head so that it will be drawn just through the die and held in that position to provide internal support for the head of the hinges. The wire is anchored by fastening a nut to its far end and running it through a stationary, drilled plate. Then as the

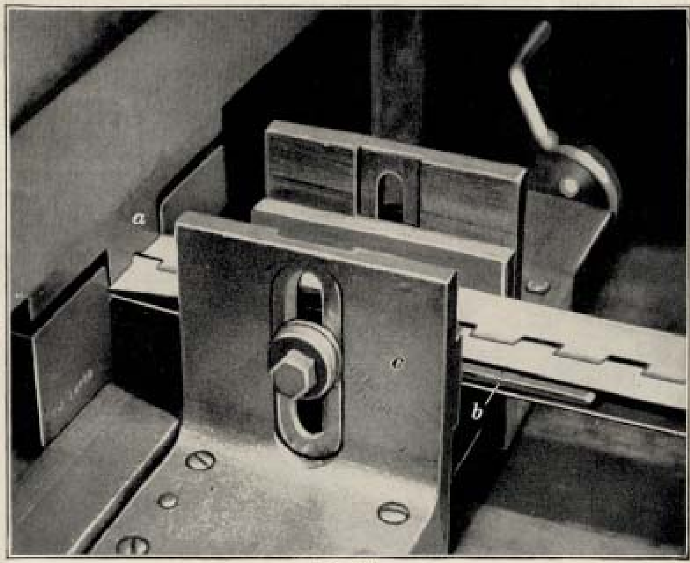


Fig. 19

mandrel is drawn forward, its motion is limited by the position of the plate, since the hole in the plate is made small enough that the nut can not pass through it.

12. The hinges are then brushed well with oil and fed into the draw die *a*, Fig. 19, pulled through with tongs, and gripped in the jaws of the draw-head. To guide the hinges into the die opening, side guides *b* are set to the proper height on the standard *c*. Then as the hinges are drawn through the die, they are formed around the mandrel in the center, closed on their outer edges, and pulled off the mandrel so that they can separate easily. A slight amount of springback occurs as the hinges are released from the die.

13. Straightening Drawn Parts.—When parts are formed of annealed stock, they must be heat-treated after forming and then straightened to remove the distortion that is caused by both the forming and the heat-treatment. The parts are

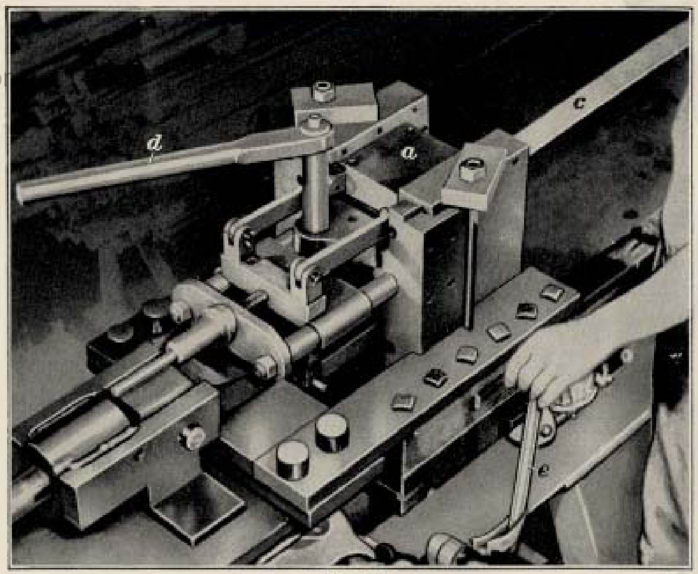


Fig. 20

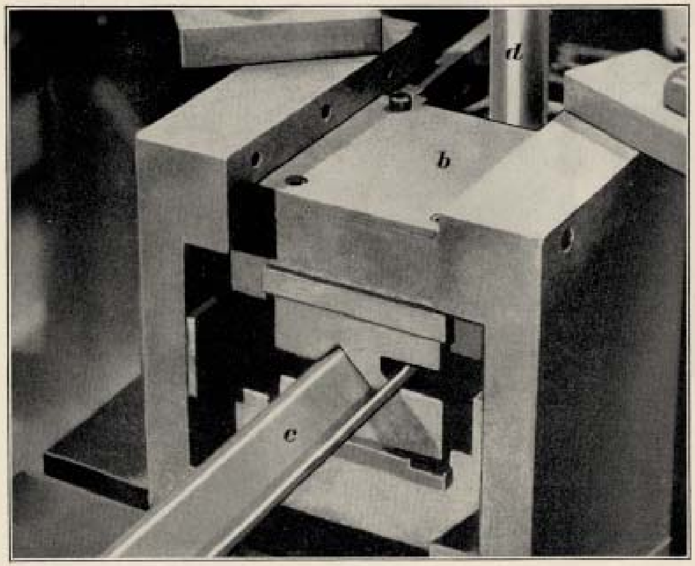


Fig. 21

straightened by stretching them lengthwise until the stretching force exceeds the elastic limit, so that the material will set to shape and also will work-harden to its maximum hardness.

A pneumatic machine especially designed for stretching drawn parts consists of a long, horizontal bed on which are mounted the drawhead *a*, Fig. 20, and the stationary head *b*, Fig. 21. The part *c* is inserted in the jaws of the heads and clamped by closing the jaws with the levers *d*. The jaws must be made to fit the section being stretched, which in this case is a Z section. The draw head is then moved lengthwise along the bed by means of the lever *e*, Fig. 20, thus stretching the material until it sets. Since the machine is pneumatically operated, it is rapid in operation. It also gives more satisfactory results than are obtainable when the parts are returned to the draw bench for stretching, since the motion of the draw head of the pneumatic machine, and therefore the amount of elongation, can be more closely controlled than on the draw bench.

FORMING BY POWER ROLLS

ROLLER-DIE PROCESS

14. Application of Roller-Die Process.—One of the fastest methods of forming long, narrow parts of the same cross-section throughout their length is by the use of roller dies in roll forming machines. By this process, strip stock of any length desired can be formed within its limiting bend radii, in one continuous piece at speeds averaging about 30 feet per minute. The sections that can be roll-formed vary from simple channels to deep hat sections with return bends at their outer edges. The parts formed by rolling are, in general, more uniform than those formed in either press brakes or draw benches. The corners on parts formed in a brake are work-hardened by the quick bending operation, whereas rolled parts are formed gradually without the sudden work-hardening. Rolled parts also are less strained than parts formed in draw dies on a draw bench. Other advantages of the process are that the strip stock that is used in roll forming is lower in cost than sheet and no shearing operation is required previous to the rolling. The cost of the dies and of the set-up of the machine are extremely high, but the operating cost is low in comparison to that of the draw bench. The present tendency in the aircraft industry is to substitute the roll forming machine for the draw bench whenever the quantity of parts warrants its use.

15. Operation of Roll Forming Machine.—The roll forming machine consists of a series of horizontal, power-driven spindles arranged in pairs with one above the other. The roller dies, or forming rolls as they are more commonly called, are mounted on these spindles. The lower spindles are fixed, whereas the upper spindles are adjustable vertically at each end for setting up the machine.

Flat strip stock, as shown in Fig. 22, is fed in at one end of the machine between side guides *a*, through a cutter *b* that may be set to shear the stock to the proper width, through the feeder rolls *c* which in this case are not used, and then through

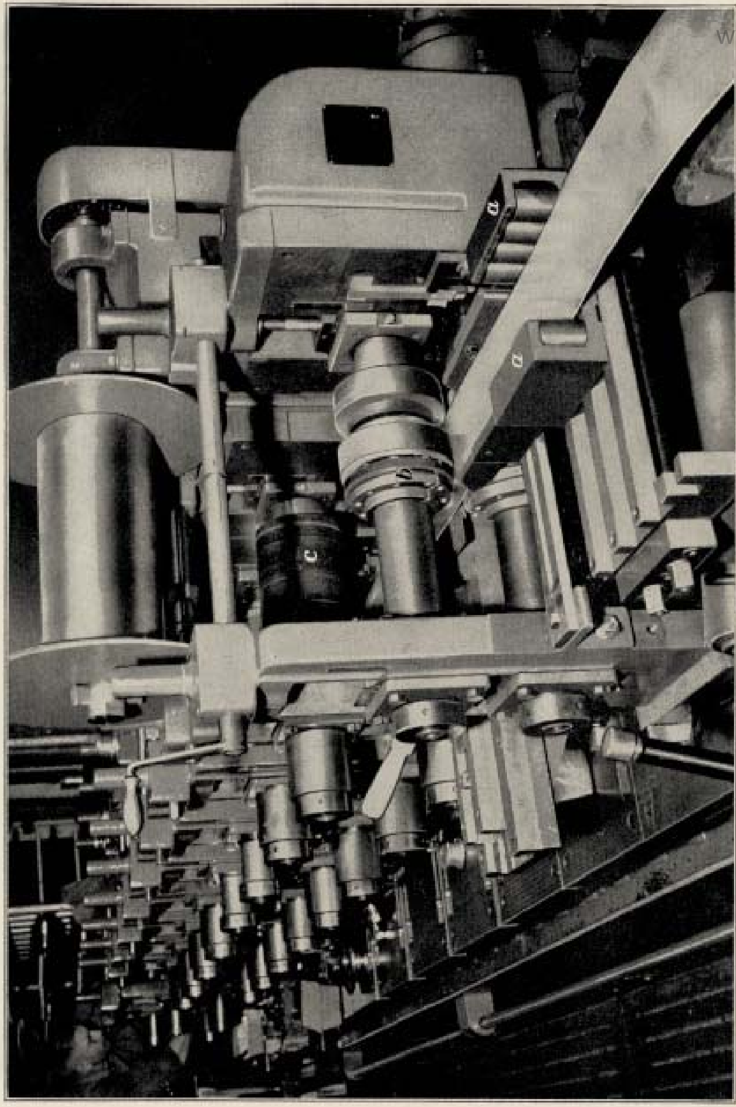


Fig. 22

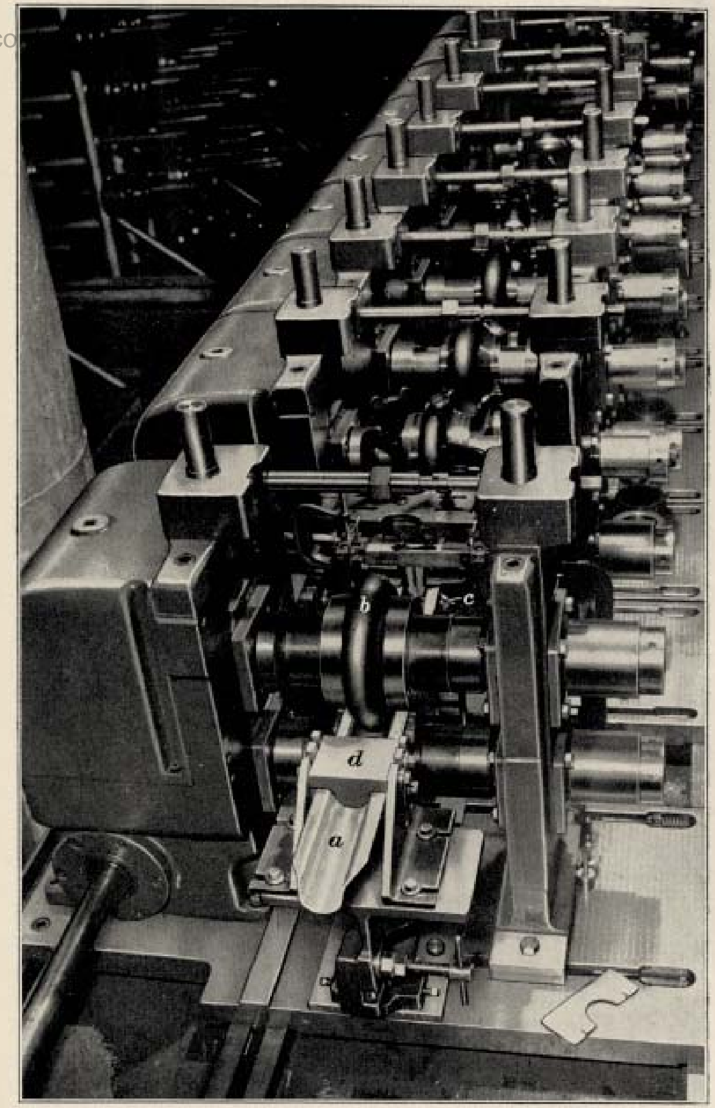


Fig. 23

the forming rolls. These rolls are arranged progressively so that in the first set of rolls the stock is formed only slightly from its flat shape; thereafter, each set increases the forming until the required shape is reached. At the opposite end of the machine, shown in Fig. 23, the hat section *a* after passing through all the rolls, except the last set *b*, is over-formed by the side rolls *c* to eliminate springback and is then sized back to the required shape in the last set *b*. The section after passing from the last set of rolls is run through a straightening shoe *d* to remove any buckles that may have formed in rolling.

16. Roll Design.—In the design of rolls the first step is to determine the number of passes, or pairs of rolls, needed and their shape to provide the amount of forming desired. These factors depend to a great extent on the material being formed. Standard practice with metals other than aluminum alloys, such as steel, brass, or copper, is to "kill," or set, the metal in the first few pairs of rolls by over-rolling considerably and then in the following rolls to shape the section back to that desired. This method, however, is too severe for the aluminum alloys, since they should be cold-worked gradually to avoid cracks and strains. Careful tooling, therefore, is required to assure that the cold work is applied progressively as the metal passes from one pair of rolls to the next. When alloys in the *ST* condition are formed, springback must also be considered in the tooling; it can be corrected by over-rolling in the intermediate rolls, usually just before the last pass, and then sizing back in the final pair of rolls. This over-rolling procedure is unnecessary for *SO* stock since its springback is negligible as compared to that of *ST* material.

17. The designing of rolls for aluminum alloys has been in the past, and still is, largely a trial-and-error procedure. Companies that are engaged in such work usually have a few men that do all the roll designing and who, over a period of years, have built up their own design methods. In practically every case these methods have no scientific approach but are the result of experience only. The designer may know that with a clearance at one point and by gripping the metal at another point satisfactory forming can be done, or that a part can be rolled from the flat strip to the finished shape only by using four, five, or six intermediate stages in order not to form too much at any one stage.

The present tendency, however, is to put roll designing on a more scientific basis. Thus, one aircraft company has worked out a combination of empirical and mathematical methods for determining the series of fairing lines between the pairs of rolls. These lines represent the distribution of cold work relative to the working characteristics of the aluminum alloys, and form the basis from which the progressive steps for forming the desired section can be laid out in a sequence along a common center line. By selecting reference points, such as the centers of the flange radii, and plotting these points on the fairing lines, the section profiles for each stage can be drawn in regular sequence. Since there is a slight transverse stretch or shrinkage of the metal as it is being rolled, any fairing formula should provide for this stretch or shrinkage as well as the shaping of the section. Other factors that should be considered in working out such a formula are the section perimeter, gage of metal, and allowances for springback.

18. Another method that has worked out well requires no fairing formula as it is purely geometrical. It is based on the assumption that all reference points on the section should travel in straight lines from the flat strip to the finished shape. An example of such a layout is shown in Fig. 24. The profile of half the required section is first laid out at *a b*. The whole section need not be shown because it is symmetrical around its center line. The next step is to select the number of passes, six in this case, even though eight passes might be better as the cold working would be more gradual. The last, or sixth, pass is the final shape already shown. The positions of the other passes are then laid out by making the distance between them equal to the actual distance between the passes on the roll forming machine. The position of the flat strip is represented by the line a_1b_1, the length of which is made equal to the developed length of the half section ab. Reference points c, d, e, and f are laid out on the finished section, and corresponding points c_1, d_1, e_1, and f_1 are located on the line a_1b_1 by making the distances between them equal to the distances between the points on the section ab. Thus, the distance a_1c_1 is made equal to the distance ac, c_1d_1 equal to cd, and so on for the rest of the reference points. Straight lines bb_1, cc_1, dd_1, ee_1, and ff_1 are drawn between corresponding reference points. These lines are actually the fairing lines of the rolls.

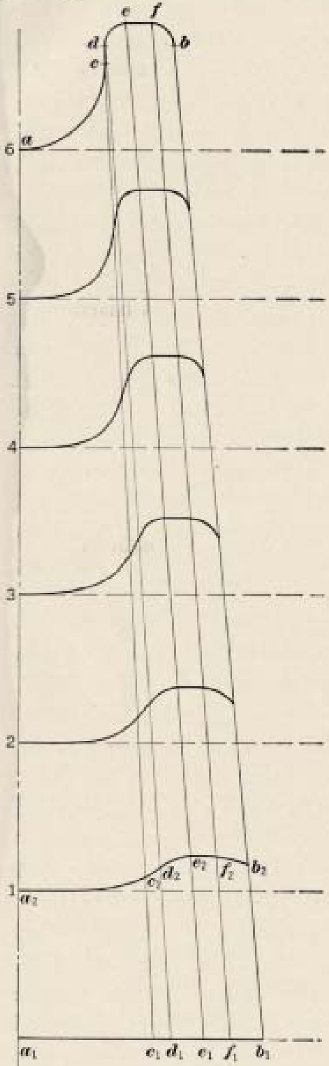


FIG. 24

19. The section profiles can then be drawn by keeping the reference points on the fairing lines and the distances between the reference points the same as the original distances. For stage 1, the part a_2c_2 of the profile is drawn as a smooth curve equal in length to a_1c_1. As the reference line cc_1 is at an angle to the common center line aa_1, the point c_2 must be located above the horizontal line through a_2 if the point c_2 is to be located on the line cc_1 and the length of a_2c_2 made equal to the length of a_1c_1. In a like manner, points d_2 and e_2 are located on their respective fairing lines, and lines c_2d_2 and d_2e_2 drawn

through the points. Since the part ef of the profile is straight, it is kept flat throughout rolling although the bends on both sides may curve into it. Therefore, the line e_2f_2 is drawn straight and horizontal. The point b_2 may then be located in the same way as point c_2, and the line f_2b_2 drawn. By following the same procedure, the profiles for the intermediate stages can be obtained. To simplify the manufacture of the rolls, some of the profiles may be modified slightly. For example, the first pass may be made with only one bend on each side of the center line and the flange bf may be formed in just the last two stages, instead of gradually in all the stages.

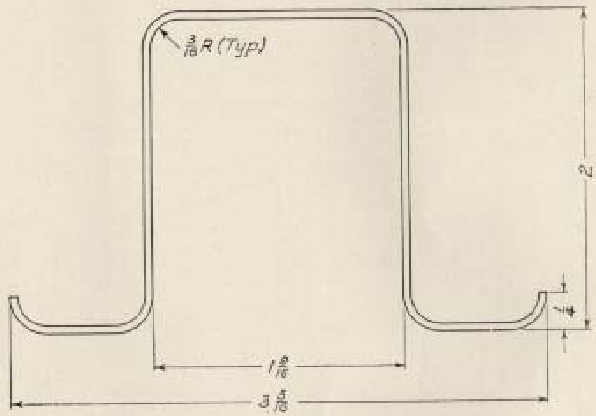


FIG. 25

20. Example of Roll Design.—A hat section that is typical of the many designs formed by rolling is shown in Fig. 25. This section, which is to be formed of .040 inch *24SO* Alclad, has a depth of 2 inches, an inside width of $1\frac{9}{16}$ inches, and an overall width of $3\frac{5}{16}$ inches. The width of the flat strip stock, originally $7\frac{3}{8}$ inches, is sheared in the machine to 7.118 inches, which is the developed width of the section. By a layout somewhat similar to the one shown in Fig. 24, the profiles of the stages are obtained as shown in Fig. 26. The section is formed progressively in six passes. In the first pass the edges of the

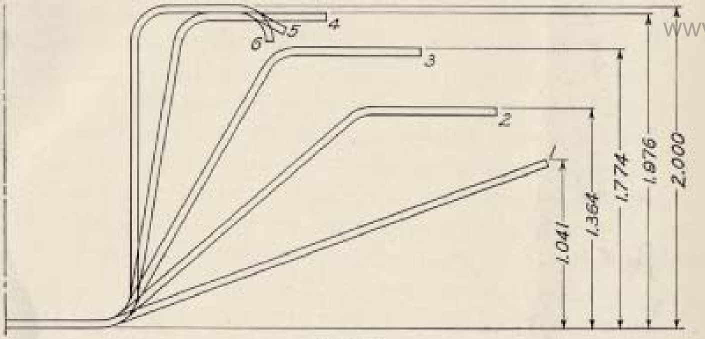


FIG. 26

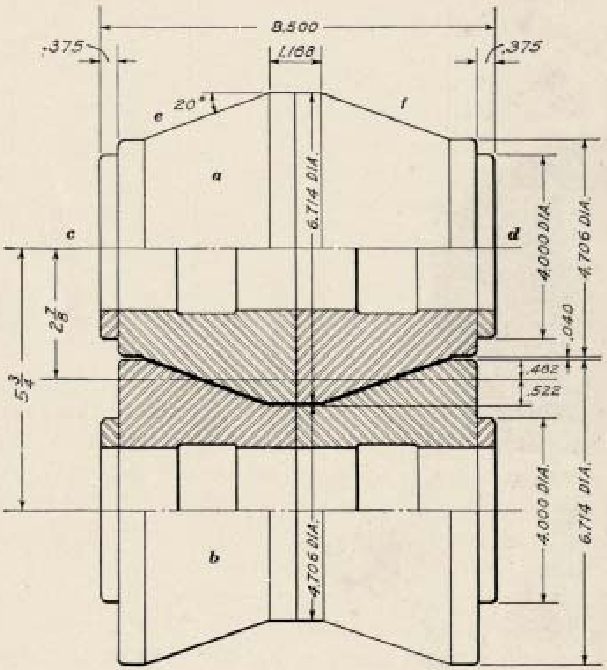


FIG. 27

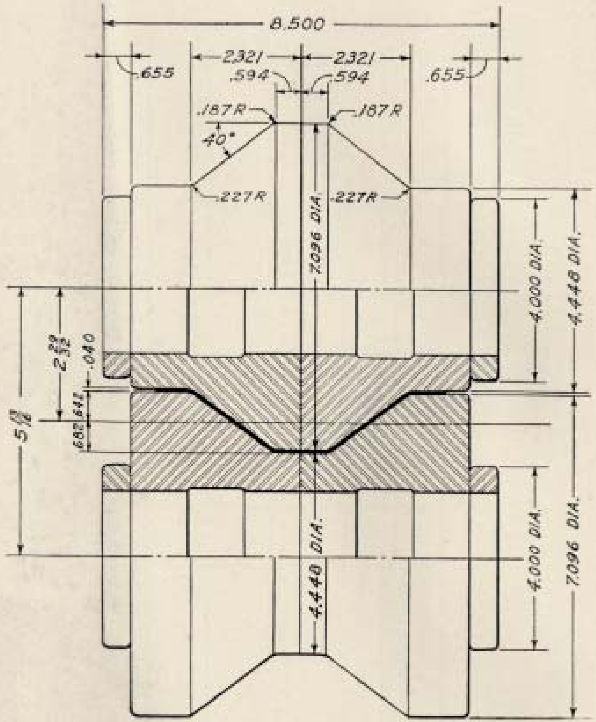


FIG. 28

flat strip are bent up to an angle of 20 degrees; in the second pass the angle of the first bend is increased to 40 degrees and the second bend is started; in the third and fourth passes the angles of bend are increased to 60 and 80 degrees respectively; in the fifth pass the angles of bend are increased to 90 degrees and the flange is bent over to 30 degrees; and in the sixth pass the flange is completed. This design obtained progressive forming by equalizing the angles of bend, rather than by keeping the reference points of the section traveling along straight fairing lines.

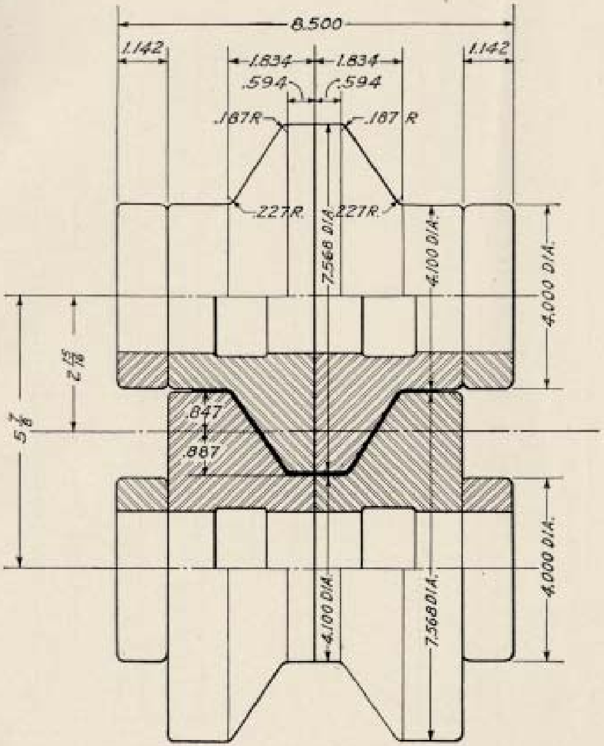


Fig. 29

21. From the profiles of the lay-out, the shapes of the rolls for each spindle can be obtained. Thus, in Fig. 27 is shown the roll lay-out for the first pass, the upper roll *a* and the lower roll *b* being shown in partial section. They are made with an overall length of 8.5 inches and of the same pitch radius, $2\frac{7}{8}$ inches, as shown by the dimension from the center line of the roll *a* to the pitch line *c d* and by the shaft center distance of $5\frac{3}{4}$ inches. The angle of bend on each roll is 20 degrees, as required by the original lay-out, and the length of the

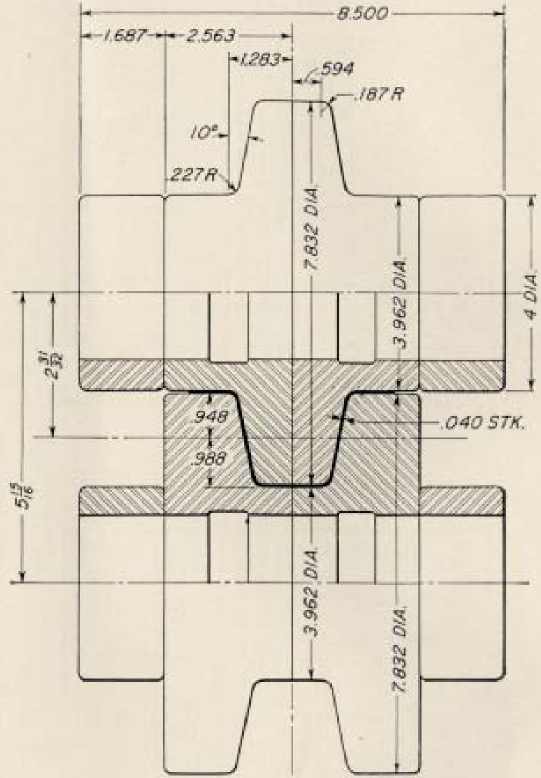


Fig. 30

straight part between the centers of the bends *e* and *f* is 1.188 inches. This distance between centers is kept the same in all six pairs of rolls. On many surfaces a grinding allowance of .015 is made. The rolls are machined from S.A.E. 1020 forgings, heat treated, ground, and polished. The heat treatment consists of case-hardening to a depth of approximately $\frac{3}{32}$ inch and a hardness of from 60 to 65 Rockwell C. The other succeeding rolls, shown in Figs. 28 to 32, are machined to their required shape and size, and are heat-treated, ground, and polished in the same way.

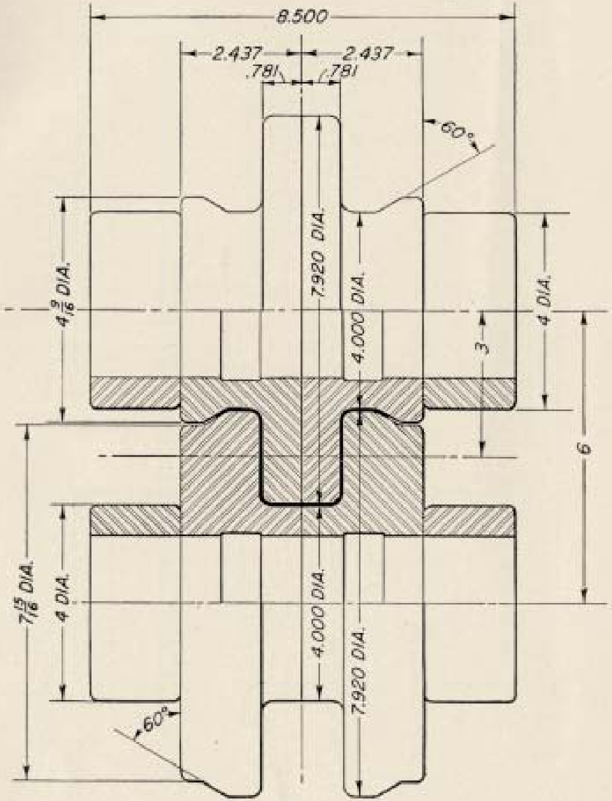


FIG. 31

From one pass to the next, the pitch radii of the rolls increase by $\frac{1}{32}$ inch and the center distances increase by $\frac{1}{16}$ inch. This increase in radii and center distance results in greater rolling speed along the pitch, or drive, line *cd*, Fig. 27, in succeeding passes. The increasing speed places the section being rolled under tension and reduces the liability of the section buckling between passes. Some roll designers, however, believe that increasing the speed in succeeding passes is unneces-

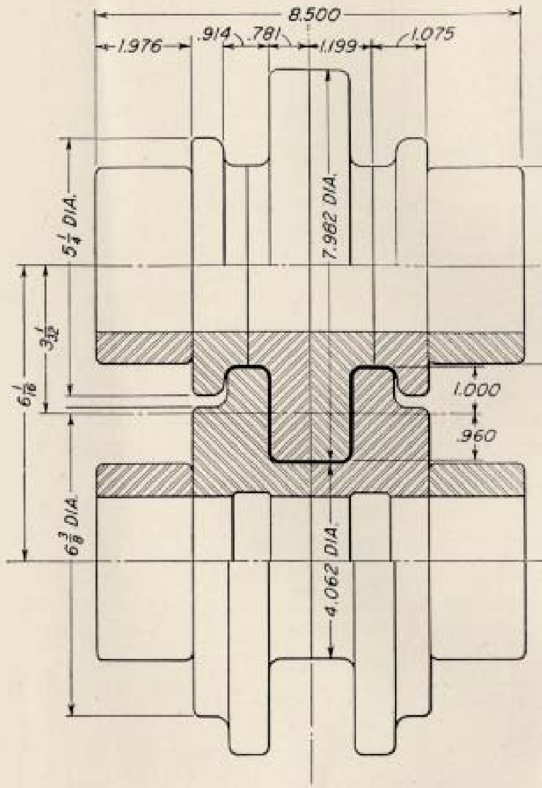


FIG. 32

sary and therefore keep all rolls of the same pitch radius and center distance.

22. Between the second and third and between the third and fourth passes of the design illustrated, roller side guides are used to facilitate the flow of the metal from one pass to the next and to prevent any buckling of the flanges. Then beyond the last pass a straightening shoe is needed to remove any buckles that might have developed in the rolling. The design of the shoe is shown in Fig. 33. In (*a*) are given three views

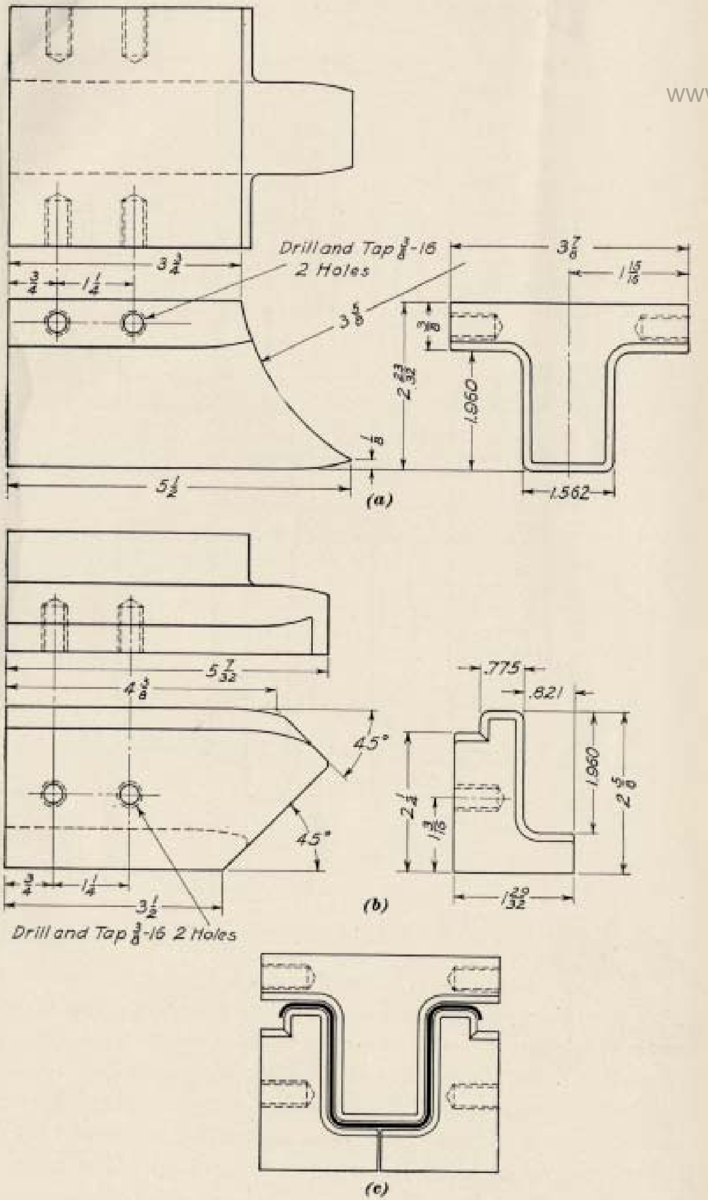


Fig. 33

of the upper part of the shoe, and in (*b*) three views of its lower part. The position of the hat section as it passes through the shoe is shown in (*c*).

The shoe is made of S.A.E. 1020 steel. All its working surfaces are ground, highly polished, and chrome-plated to a depth of .002 inch. The chrome plating permits the stock to pass through the shoe with no marring or scratching of its surface; this condition is of particular importance with Alclad stock since any scratches that penetrate through the aluminum coating destroy the corrosion resistance of the alloy.

23. Roll Design For Stainless Steel.—Stainless steel can be roll-formed progressively in the same way as the aluminum alloys. The case-hardened steel rolls that are used for rolling aluminum alloys, however, are not always satisfactory for rolling stainless steel because of the pick-up experienced on the sheet metal. Therefore, the working surfaces of the rolls may be faced with a bronze overlay to reduce the pick-up. The rolls are made of S.A.E. 1045 steel and are machined undersize on their working surfaces to allow a 1/8-inch minimum thickness of bronze. After the bronze is deposited on the rolls, the bronzed surfaces must be machined, ground, and polished to the finished dimensions required.

24. The flat strip stock is formed progressively through the eight stages, Fig. 34 (*a*) to (*h*). The finished section has an overall width of .736 inch and is bent up at both edges, with an inside radius of .154 inch, to an angle of 6½ degrees with vertical lines passing through the centers of the bends. The distance between the centers of the two bends is .328 inch. The developed width of the stock, which is .050 inch thick, is 1.414 inches.

In the first pass, view (*a*), the edges of the strip *b* are bent up at 30 degrees and the distance between the centers of the bends is 1.226 inches. As the stock passes to the succeeding rolls, the angle of the bends increases and the distance between their centers decreases. Thus, in the second pass, view (*b*),

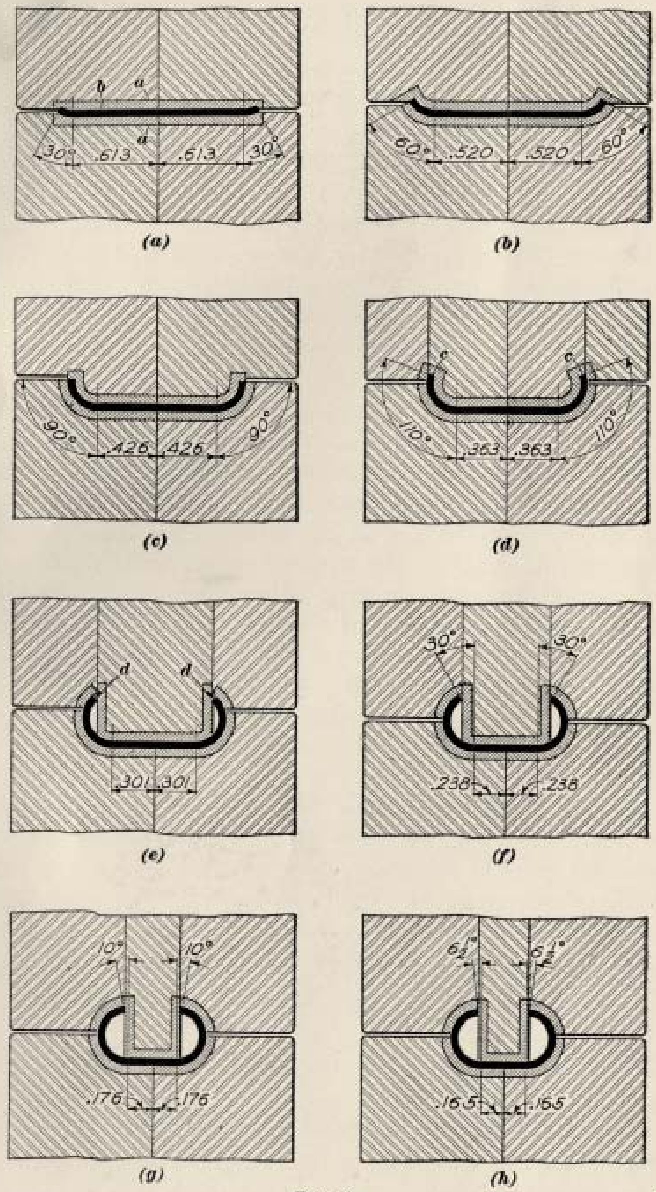


Fig. 34

the angle of bend is 60 degrees and the center distance is only 1.040 inches, and in the third pass, view (*c*), the bend angle is 90 degrees and the center distance is .852 inch. In the fourth pass, view (*d*), the edges of the strip are curved up into recesses *c* in the upper roll, and in the following passes the stock is formed still further into recesses in the upper rolls. In each of these passes, as in view (*e*), the stock is held along its center part by the circular section of the upper roll while its edges are forced into the recesses of the roll by compressive stresses acting in the directions indicated by the arrows *d*. In like manner, the edges of the stock are formed through succeeding stages, by the compressive stresses exerted by the upper rolls, to its finished shape shown in the last pass.

CONTOURING ROLLS

25. Use of Contouring Rolls.—Contours, such as the leading-edge or trailing-edge skins for wings and stabilizers, can be formed in press brakes, but they can be formed more rapidly in contouring rolls that have been especially designed for that purpose. A contouring machine designed for such use is shown in Fig. 35. All sheet metals can be formed in this machine with their limiting bend radii, but no compound curvatures can be formed.

The chief advantages of this forming method are that no tooling is required, there is no set-up cost, and the operating cost is moderate. The method also is suitable for work in any quantities and is thus available for either experimental or production work. The chief disadvantages are that the machine is somewhat slow in operation, it is not capable of extremely accurate work, and the results depend to a great extent on the skill of the operator. Another disadvantage is that the spring-back of the material makes this method of forming difficult on bends of large radius. Despite these disadvantages, the contouring rolls are well suited for production of parts in the quantities required in aircraft plants.

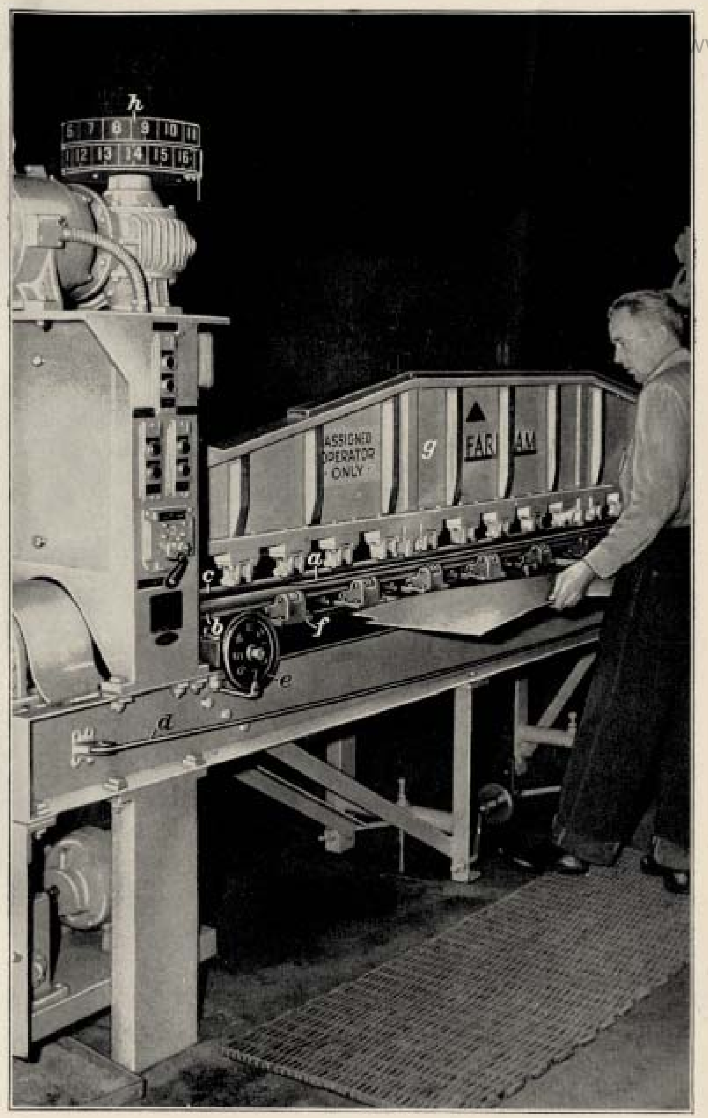


FIG. 35

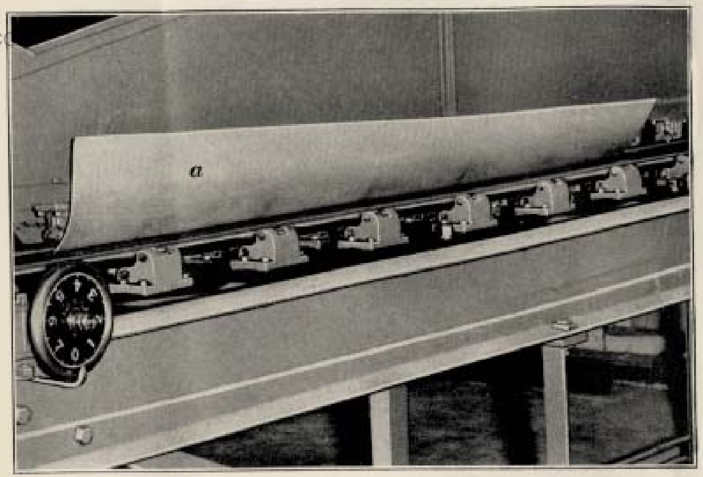


FIG. 36

26. Operation of Contouring Rolls.—On the machine illustrated in Fig. 35, the aluminum-alloy sheet *a* is rolled to shape between two lower rolls *b* and an upper roll *c*. The rolls are driven by an electric motor through universal joints that allow adjustment of the rolls, and their motion is controlled by a rope *d* that passes completely around the machine. The lower rolls are adjustable separately in a horizontal plane by two hand wheels *e* at each end of the machine, one being in front and the other in back of the machine, and they are prevented from sagging or springing upward by small backing rolls *f*. The upper roll has similar backing rolls to prevent its being sprung upward by the rolling pressure. This roll is adjustable in a vertical plane. The beam *g* carrying the upper roll is controlled by push buttons, located either on the left-hand column as shown or on a separate control panel. The vertical adjusting screws for the beam have at their upper ends double dials *h*, one of which indicates the number of screw revolutions and the other the parts of a revolution in sixteenths; thus the two sets of dials show definitely the position of the upper roll.

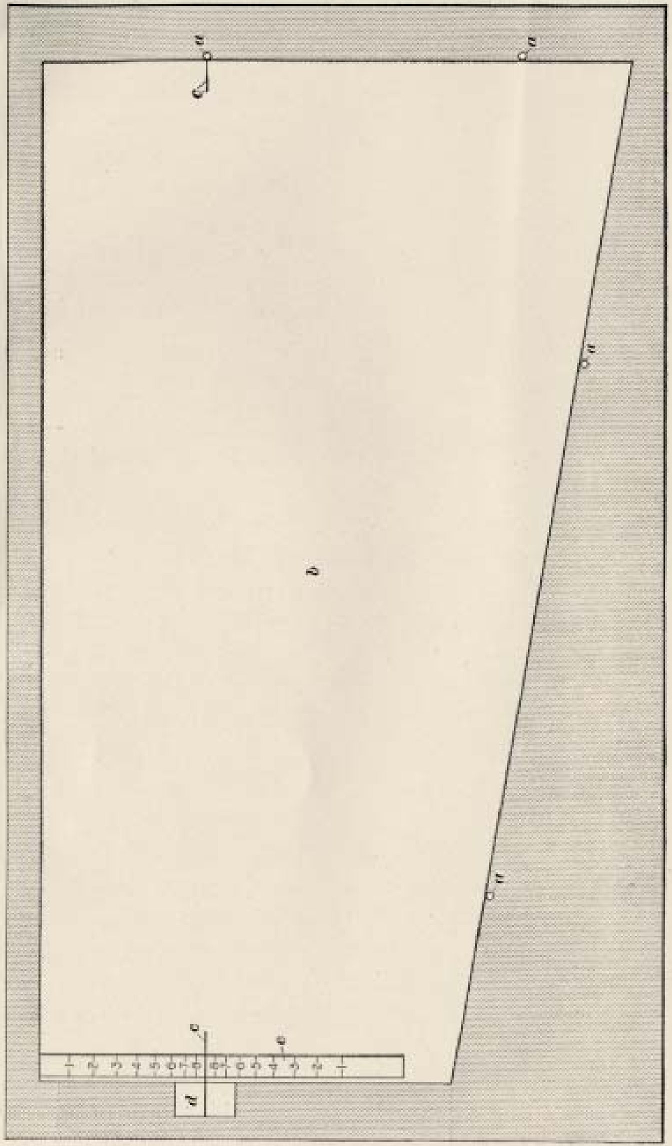


Fig. 37

27. Rolling Leading-Edge Skins.—Leading-edge skins, as shown at *a*, Fig. 36, have a lengthwise taper and a curvature that is not a true radius, but rather a combination of different radii blended together. The contours, however, can be resolved into a series of successive radii which are close enough for practical purposes, even though the actual radii are constantly and progressively changing. When the successive radii have been determined, the sheet to be formed is laid out for the various distances over which the radii are to be effective.

28. A convenient method of making the lay-out is shown in Fig. 37. A simple fixture is built by driving nails *a* in the top of a wooden table. These nails are so located that when the sheet *b* is positioned against them, the center line *c* at one end of the sheet may be marked opposite one of the nails. At the other end of the sheet the center line *c* is located from a line on a piece of paper *d* that is pasted to the table. Then a strip of masking tape *e* is pasted on the sheet metal and is marked off to correspond to the distances over which the successive radii are effective. In this case, there are eight points on either side of the center line to indicate how far the sheet should be run through the rolls at the respective settings of the upper roll, as indicated on the double dials. When the sheet is formed, the masking tape may be stripped off and used on the next sheet. Many operators do not use tape, but mark each sheet with crayon.

29. When tapered sections are formed, the two lower rolls are generally set parallel to each other and the upper roll is tilted to give the change in radii. All three rolls, however, may be set at an angle when heavy material is being rolled or when close confinement of the metal is required to eliminate excessive springback. Forming the first part is largely done by trial and error. The upper roll is lowered far enough to bend the material to the first radius as the sheet is passed back and forth through the machine. In the same way the material is rolled to the second radius. This operation is repeated until the part is formed completely as shown in Fig. 36. Because of the

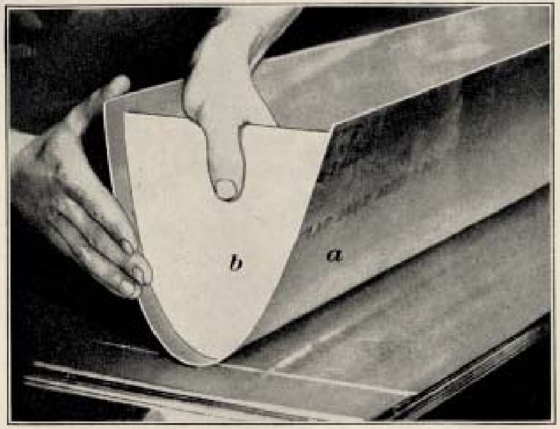


Fig. 38

Fig. 39

series of successive radii, eight different dial settings are required in this case.

30. When the radius at the bend is too small to be formed by the upper roll, a round auxiliary bar may be used in the last operation. This bar is made with a vee in its top surface to receive the upper roll of the machine. With the bar in place, the beam that carries the upper roll is lowered straight down as in press-brake forming.

The finished skin *a*, Fig. 38, is finally checked at both ends by templets *b* applied to the inside of the bend. When the first part is formed, the readings on the beam dials should be recorded for each setting; thereafter, on the following parts, the machine may be set from the records and the parts passed through the rolls.

31. Rolling Gasoline-Tank Cradle.—Contouring rolls are used for the forming of many parts besides edge skins. Such a typical application is the roll-forming of the gasoline-tank cradle *a*, Fig. 39. First, the lightening holes *b* in the flat sheet are blanked, and the sheet is then formed in the contouring rolls. The finished part is flat in the middle and is bent up at both ends. As the sheet is first fed into the rolls, the top roll is lowered and the sheet is run back and forth through the machine to form the bend at one end. Then the upper roll is raised, the sheet is run on through to the beginning of the second bend, and that bend is made in the same manner as the first one. The finished piece is then checked to a templet of the correct contour.

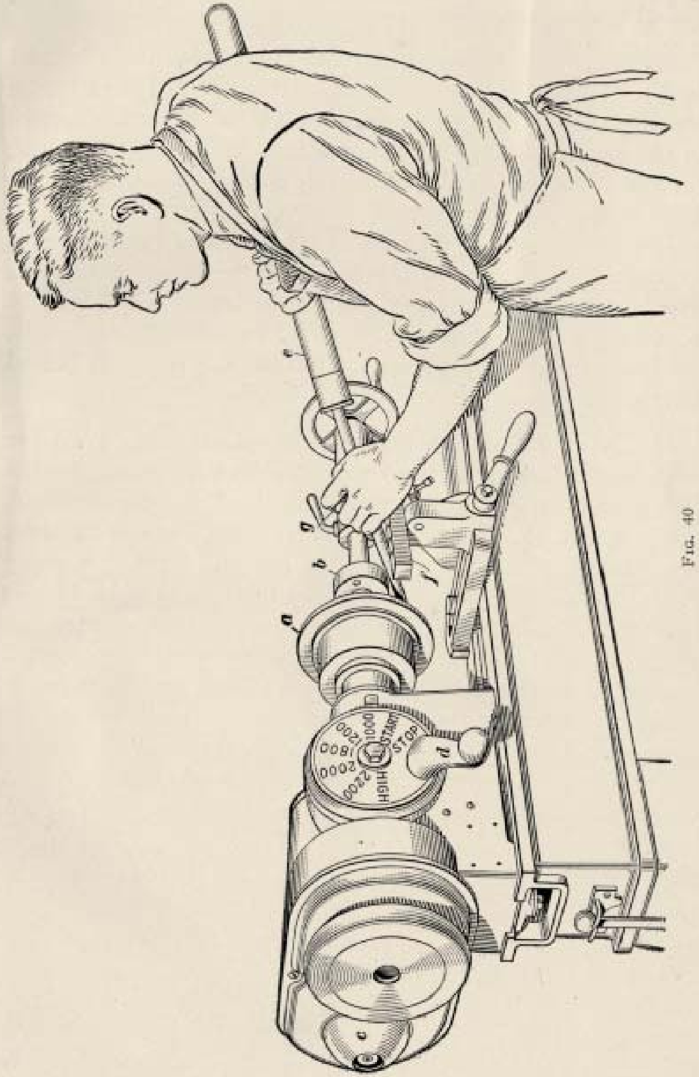


Fig. 40

FORMING BY SPINNING

32. **Metal Spinning Process.**—Metal spinning is the shaping of a disk of metal to a hollow form while the disk is revolving rapidly in a lathe. The shapes that may be spun include caps, cones, cylinders, and any irregular contour that can be generated by a line revolving about an axis; that is, the process is limited to symmetrical articles that are circular in cross-section. Spinning may be done in regular spinning lathes or in lathes converted to that purpose. One of the former type is illustrated in Fig. 40. The disk of metal is clamped to the chuck *a* by a friction block, or pad, that is free to rotate on the ball-bearing tail center *b*. An electric motor *c* provides speeds, as controlled by the lever *d*, up to 2,400 revolutions per minute. To spin the metal to the shape of the chuck, pressure is applied over the area of the disk by a hand tool *e* supported on the spinning rest *f* and braced against the fulcrum pin *g*.

33. Since spinning is a hand operation, as shown, the rate of production is low and the process has therefore been largely replaced by drawing for large quantity production. As the tooling, however, is inexpensive and can be made quickly, spinning is still used when low tool cost is a factor. The process is particularly adapted to a limited production, at the most to a thousand parts. Many parts that would be difficult, impossible, or too expensive to be formed by other methods may be spun successfully. The high formability by spinning results from the progressive nature of the operation; that is, the metal is broken down gradually and then spun to the shape of the chuck.

Even though spinning is a hand operation, the finished parts are uniform in size and appearance. The dimensional accuracy is reasonably close; the usual tolerance is $\pm\frac{1}{32}$ inch, although on larger parts greater tolerances may be required. On critical diameters it is even possible to maintain a tolerance of $\pm.010$ inch. The thickness of the metal can be held to within $\pm.10$ inch of the specified thickness for gages up to and including .040 inch and to within $\pm.015$ inch for gages over .40 inch.

34. Aluminum Alloys Formed by Spinning.—The aluminum alloys that have the best spinning characteristics are *2SO* and *3SO*. The former spins more easily than the latter, but *3SO* is stronger and therefore often preferred. Unlike *2SO*, *3SO* may require intermediate annealing during the operation if deep spinning is to be done. The alloys *52SO* and *61SO* spin nearly as well as *2SO* and *3SO*, but must also be re-annealed if deep spinning is required. The alloys *24SO* and *24SO* Alclad also spin well, although they too have to be re-annealed during forming. The Alclad coating will not rub off under average spinning conditions, but may do so if the spinning is exceptionally severe. Hard stock, such as *24ST*, does not spin satisfactorily. It is general practice to use *2SO*, *3SO*, *25SO*, or *61SO* whenever possible.

35. Spinning Tools.—For hand spinning, a hardwood handle is fitted with a metal bit about 18 inches long. Their combined length should be about 30 inches to afford the leverage needed for the spinning pressure. For spinning aluminum and other non-ferrous alloys, the bits are made of tool steel of from $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter, whereas brass or bronze bits are used for spinning carbon steel, and cast-iron or alloy steel bits for spinning stainless steel.

A variety of tools are required for the different spinning operations. The most commonly used tool is flat and is shaped somewhat like a spoon with a rounded nose and corners. One side of the top is for breaking down and spinning the sheet metal to the chuck, and the other side is for smoothing the spun part. A mirrorlike finish on all the contact surfaces is desirable to prevent scratching of the sheet metal. The flat tool is practically the only one needed for forming aluminum alloys. The special tools that are used are the diamond-point tool for trimming excess metal from the lip of the spun part and for rounding off sharp edges, the point tool for spinning into curves of small radii, the beading tool, which is a concave roller, for beading and curling edges, and the planishing tool for removing marks left by other tools. A hardwood back-stick about 12 to 14 inches long is needed to support the back of the

sheet-metal disk and prevent wrinkling during the first break-down operations.

36. Spinning Chucks.—The chucks, or forms, over or into which the metal is spun are generally made of hard maple, but for extra-long service and greater accuracy cast-iron chucks are used. For parts requiring very smooth surfaces, and for spinning sharp corners and into recesses, steel chucks are most suitable. Small wood chucks are made in one piece, whereas larger ones are built up in sections. The latter are more expensive to make, but are stronger and have a longer life. If the spun piece can be removed easily, one-piece chucks are satisfactory; however, when the part is shaped so that its opening is smaller than its body, a collapsible chuck built up in sections must be used. For some parts it is necessary to use a succession of chucks to attain the required shapes. In this case, the first chucks used are known as break-down chucks.

37. Size of Blank.—The first step in the spinning operation is to determine the diameter of the blank by either trial or calculation. Trial blanks of two or three slightly different sizes may be cut and spun to arrive at the best size to cut the rest of the blanks. It is more desirable, however, to calculate the size. A general rule that may be used is that the area of the blank should equal the developed area of the finished part plus allowances for trimming and for any material cut out of the spun part. In case the finished part is spun thinner than the sheet-metal blank, no allowance for trimming need be made. Another rule sometimes used is that the diameter of the blank should be made equal to the largest diameter of the finished part plus its height. The blank diameter may also be made equal to the developed length from edge to edge of the part measured on a section through its axis.

38. Gage of Material.—The gage of the material that should be used for any particular part depends on the type of material and the depth of the spun part. Thus, for *24SO* Alclad, the minimum gage should be .032 inch for parts up to $2\frac{1}{2}$ inches deep, .040 inch for parts from $2\frac{1}{2}$ to 4 inches deep, and .051 inch

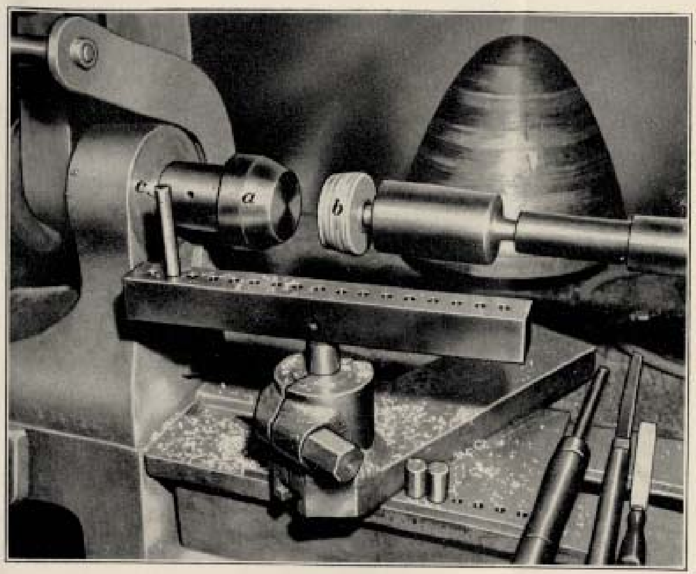


FIG. 41

for parts from 4 to 8 inches deep. Deeper parts requiring thicker material should not be spun of *24SO* Alclad. On the contrary, *3SO* may be spun in sheets as thin as .020 inch for parts up to 2½ inches deep, .025 inch for parts from 2½ to 4 inches deep, and .040 for parts from 8 to 12 inches deep.

Since spinning generally involves a reduction in thickness of the material, the gage of the blank should be approximately 30 per cent greater than the thinnest allowable section of the spun part. The change in thickness varies with the type and gage of the sheet metal, the material of the chuck, the shape of the part, and the skill of the operator.

39. Spinning Small Parts.—A spinning lathe still used for making parts in one aircraft plant is shown in Fig. 41. The sheet-metal disk is clamped against the metal chuck *a* by the friction block *b*. It is important that this block revolve freely and at the same speed as the chuck; otherwise, the slippage will burn the alloy sheet. The friction block should not be

FIG. 42

larger than the base of the spun part, and should be shaped to fit it. The block may have a pin set in its center to fit into a corresponding hole in the chuck if it is permissable to drill the blank. With this arrangement, no centering is necessary. If the blank is solid, however, it must be centered by revolving the lathe slowly and bearing against the edge of the blank with the back-stick. The blank should then be well lubricated with oil, soap, or tallow by means of a brush or a soaked cloth. The fulcrum pin *c* is set near the disk, and the nose of the tool placed just below center. Then, as shown in Fig. 42, the operator breaks down the disk by exerting a forward pressure while drawing the tool backward. During this breakdown operation, the back-stick *a* is held against the back of the disk *b* at a point opposite the nose of the tool *c*. The metal should be spun firmly against the chuck before any pressure is applied to the outer edge. The pressure must be moderate and applied gradually to avoid wrinkling the disk or spinning it too thin. The fulcrum pin *d* must be moved from time to time to provide a better leverage. Moving the tool from and toward the center alternately with care prevents bulging and excessive thinning

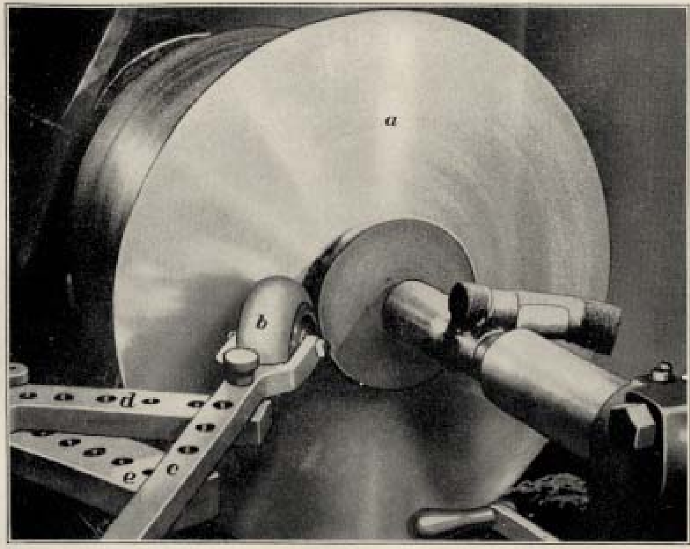


FIG. 43

of the metal. When the part has been spun nearly to its finished shape, it should be trimmed with the diamond-point tool and then spun to lie closely to the chuck. If the part is spun too tightly to the chuck, it may be loosened by going over it with the planishing tool.

40. Spinning Large Parts.—When large parts are to be spun, it is necessary to use tools that permit the application of greater pressure than is necessary for small parts. Such a spinning operation is shown in Fig. 43. In this case the blank *a* is to form the nose of a drop tank. The spinning tool *b* is of the roller type and is supported by a long lever *c* that is pinned to the end of another long lever *d*. The latter lever is in turn pinned to the spinning rest *e*. By this arrangement the operator can exert considerable pressure against the blank as he bears against both levers. As with small parts, the blank is worked slowly and gradually to the shape of the chuck. After the part has been partially spun, its edge should be trimmed by a diamond-point tool, as shown in Fig. 44. Then the part may be spun down to fit the chuck.

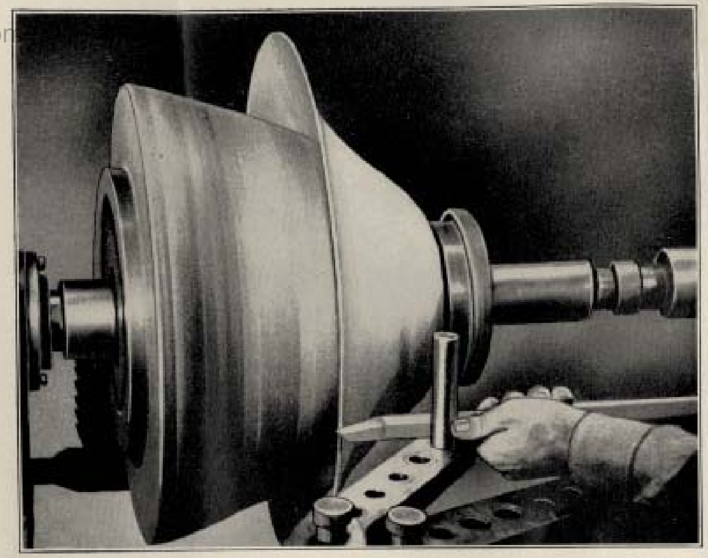


FIG. 44

41. Tube Spinning.—Tubes can be closed and sealed completely at one end by spinning, they can be tapered by spinning the metal down over a form, or they can be flanged by clamping the stock in a hollow chuck and spinning the end of the tube back against the block. On such a flanged tube, as shown in Fig. 45, the original diameter of the tube is denoted by *a*, the flange width by *b*, the original thickness of the tubing wall by *c*, and the thickness of the spun flange by *d*. The thickness *d* should not be spun to less than 70 per cent of the original wall thickness *c*. The radius *r* to which the flange can be spun is the minimum bend radius of the

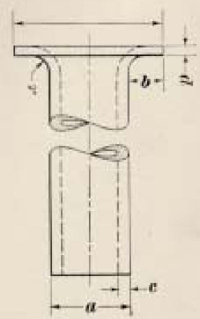


FIG. 45

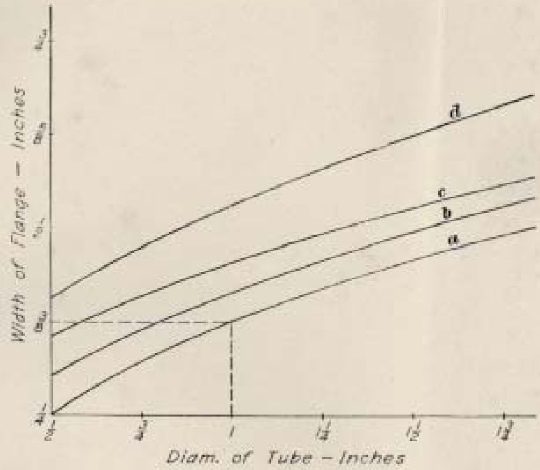


FIG. 46

material. The permissable width b of the flange depends on the original diameter of the tube. The four curves in Fig. 46 give the maximum flange widths, a, b, c, and d that may be spun on *52SO* and *2S½H* tubes having wall thicknesses of .035 and .049 inch, respectively. Thus, the maximum flange width that may be spun on a *52SO* tube of 1-inch diameter and .035-inch wall thickness is ⅜ inch as shown on curve a.