FORMING METHODS

FORMING BY STRETCH PRESS

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APPLICATION AND EQUIPMENT

STRETCH-PRESS APPLICATION

1. **Use of Stretch Press.**—Design changes and the limited production of any one model of military aircraft require manufacturing processes involving inextensive yet flexible tooling. Stretch-press forming meets these requirements by offering a substantial reduction in tool costs, as compared to those for draw presses. Being adaptable to the rapid fabrication of a wide variety of double-curvature parts, the stretch press is well suited for production requirements that are intermediate between those that can be met by the drop hammer and those requiring the high production processes of the automotive industry. Once a stretch press is set up, an average part requires approximately two minutes for loading, stretching, and unloading.

2. By means of the stretch press both soft and hard stock can be formed, but the use of hard stock, such as *24 ST,* is recommended since heat treating is thus eliminated. By means of the stretch-press much larger sheets can be formed into double contours than by the hydro-press. The large size of the parts that can be formed reduces the number of separate parts that go into a sub-assembly, with a corresponding reduction in the time of assembly. The chief limitation of the stretch-press method is that only contours relatively symmetrical and with only slight reverse bends can be formed. A second disadvantage is that a certain percentage of scrap, on most work as high as one-third of the sheet, is unavoidable since the ends of the sheet must be long enough to be held in clamps. The common practice is to add about 16 inches to the length and 2 inches to the width for the gripping and trimming allowances. Thus, in Fig. 1, the

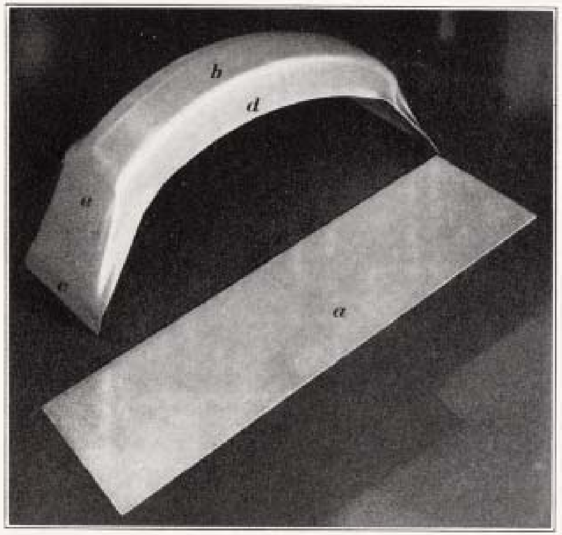


Fig. 1

sheet *a* is stretched to form the part *b*. The ends *c*, at which the material was clamped and the sides *d* must be trimmed off and scrapped; however, some of the material at *c*, which must also be trimmed off, can be salvaged and used for small parts. On some work, 10 extra inches on the length and ½ inch on the width are sufficient. However, the waste is somewhat greater when the end trim is not at right angles to the side trim.

The scrap may be reduced to some extent by forming two or more parts from a single sheet in one stretch and then cutting them apart; thus, only a single clamping allowance need be made. Some unsymmetrical and also some right-hand and left-hand parts can be formed in this way. Common practice though is to form both right-hand and left-hand parts on the same die and then to snap half of them through to produce parts of opposite hand to that of the die. That is, half of the parts are actually turned inside out by holding the bulge or formed area stationary while the edges are snapped or jerked across to the opposite side of the bulge.

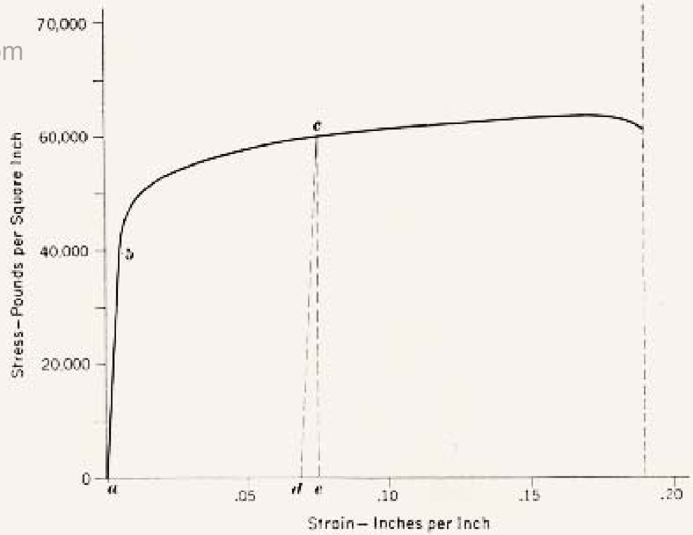


Fig. 2

3. Principle of Stretch-Press Forming.—In principle and operation, stretch-press forming differs considerably from drawing on a double-action press. On a stretch press the aluminum-alloy sheet, instead of being forced into or through a die by the action of a punch, is clamped at opposite ends and stretched over a form, or die, until the elastic limit of the material is exceeded. This stretching of the material beyond its elastic limit, that is, into the plastic range, eliminates excessive springback and causes the material to set to the shape of the die. The reduction of springback by stretching beyond the elastic limit is illustrated in the *24ST* Alclad stress-strain diagram shown in Fig. 2. When the material is stressed below its elastic limit, that is, within the range *ab*, there will be complete elastic recovery, or springback, along the line *ab* to the original condition of the material. When the material, however, is stressed into the plastic range, such as to the point *c*, the elastic recovery will occur along a line *cd* that is parallel to the line *ab*, and permanent set will take place. The residual strain, or deformation, of the material will then be represented by the value *ad*. The difference between the total strain *ae* and the residual strain *ad* is the springback strain *de*, which is small in comparison to the total strain.

4. Direction of Springback.—Another important feature of springback is the direction in which it acts. A comparison of the direction of springback in parts that have been either bent or stretched is shown in Fig. 3. When a part is formed by bending,

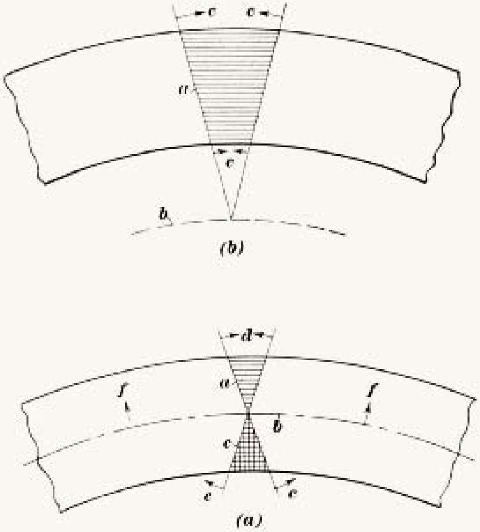


Fig. 3

as in view (*a*), the material *a* in the area outside of the neutral plane *b* is stretched, whereas the material *c* in the area inside of the neutral plane is compressed. The material under tension is represented by the lined area, and that under compression by the cross-hatched area. Since there is no lengthwise movement along the neutral plane, the material at this point is under neither tension nor compression. When the bending force is removed, the material *a* that is under tension tends to recover in the directions indicated by the arrows *d*, and the material *c* that is under compression tends to recover in the directions of the arrows *e*.

The resultant force, as represented by the arrows *f*, causes severe springback and changes the curvature of the part.

When a part is formed by stretching, however, all the material *a*, view (*b*), is stretched since the neutral plane *b* is below the plane of the material. When the stretching force is removed, the material tends to recover in the directions indicated by the arrows *c*. Since the recovery is in the plane of the material and parallel with the curvature, it does not distort the part beyond usable limits.

5. Elongation of Material.—The forming of material in a stretch press elongates the sheet and reduces its thickness as much as from 5 to 7 per cent; however, the increase in tensile strength resulting from stretching the material beyond its elastic limit compensates for the loss in thickness. When the sheet is stretched, care must be taken not to impose a load that would tear the material. Since the stretching operation is conducted in the plastic range, the stress required to stretch all parts of the sheet to contour approaches the ultimate strength of the metal but must not exceed it.

The maximum elongation of the material determines how much the material may be stretched before breaking. For *24ST* Alclad the maximum elongation is generally specified at about 18 or 19 per cent, but this value having been determined on a 2-inch gage length on a tensile test specimen, is not applicable to stretch-forming in which the work may be several feet in length. Tests on long sheets have shown that the maximum elongation that may be used in stretch forming of either *24SO* or *24ST* Alclad is from 8 to 10 per cent. Under average operating conditions 8 per cent is generally used as the maximum allowable elongation, since a 10 per cent elongation can be obtained only by extra-careful polishing and lubrication of the die, and by observing every possible precaution in the stretching operation. If either *24SO* or *24ST* is stretched partially to form the material and is then heat-treated and stretched again to complete the forming operation, the maximum elongation may be as great as 12 per cent. Actually, an elongation of only a small per cent usually suffices to produce permanent set of the metal.

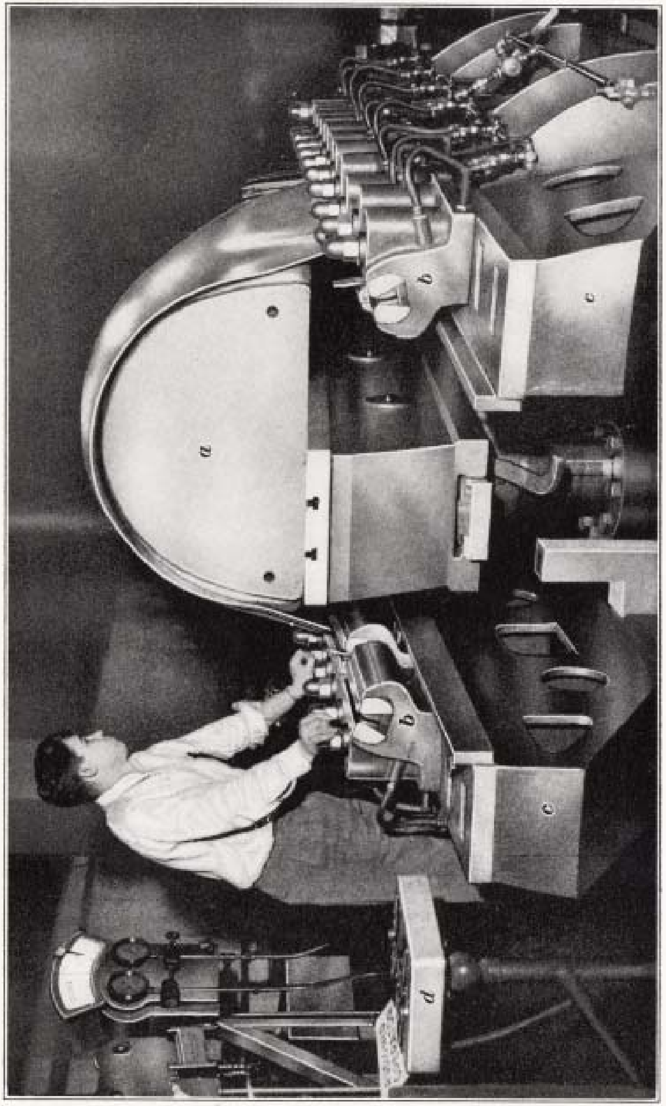


FIG. 4

6. The condition of the edge of the material also affects the elongation. Polished or even routed edges permit an appreciably greater elongation without failure than edges left in the rough, as when the material is sheared, since the stress concentrations resulting from the notch effect of sheared edges appear to cause early failure. Tests made by one aircraft company on sheets 50 inches long and with polished edges, gave maximum elongation values that were considerably higher than those obtained from tests made on sheets of the same length but with sheared edges. The maximum elongation values obtained under such tests are given in Table I.

TABLE I

MAXIMUM ELONGATION VALUES OF ALUMINUM SHEETS*

Material	Maximum Elongation for 50 Inches (Per Cent)	
	Sheared Edges	Polished Edges
24ST	4.5	8.5
24SO	9.5	10.5
52SO	13	16.5
53SW	11	16.5
61SW	8	17.5

* Courtesy of Lockheed Aircraft Corp.

7. Stretch-Press Operation.—The die, shown at *a* in Fig. 4, is set on a central table which is moved vertically by two separately controlled hydraulic cylinders located under the ends of the table. The table is pivoted at its center to a piston-type guide to allow tilting it when tapered sections are stretched. Stretch presses are made in three sizes having capacities of 75, 150, and 300 tons. The press illustrated has a capacity of 150 tons. The larger 300-ton presses also have two hydraulic cylinders; whereas, the smaller 75-ton presses have only one central cylinder and, therefore, cannot have their tables tilted.

The sheet metal is clamped at both ends in a row of individual pneumatic or hydraulic clamps *b* mounted on clamp supports *c*. These supports are controlled from a push-button control-panel

Fig. 5

d and may be set parallel to or at any angle up to 15 degrees with the table. The individual clamps also may be swiveled up to 25 degrees, to allow them to be set in a curve, as shown in Fig. 5, so that the free edges of the sheet are gripped in such a manner throughout its width that it bellies up over the area of deep curvature at *e*, Fig 6, thereby reducing the stretch on those areas.

The clamps grip the sheet by a wedging action between beveled shoes forced upward into tapered slots; thus the greater the pull on the sheet, the tighter the clamps grip. When the pull on the sheet and the air or oil pressure in the clamps are released, the clamps automatically open and release the material. During the stretching operation some of the clamps can be loosened slightly by means of their separate valves to allow the sheets to slip a little and thus prevent tearing at highly stressed points; this practice is not common but may be tried and followed where it proves successful.

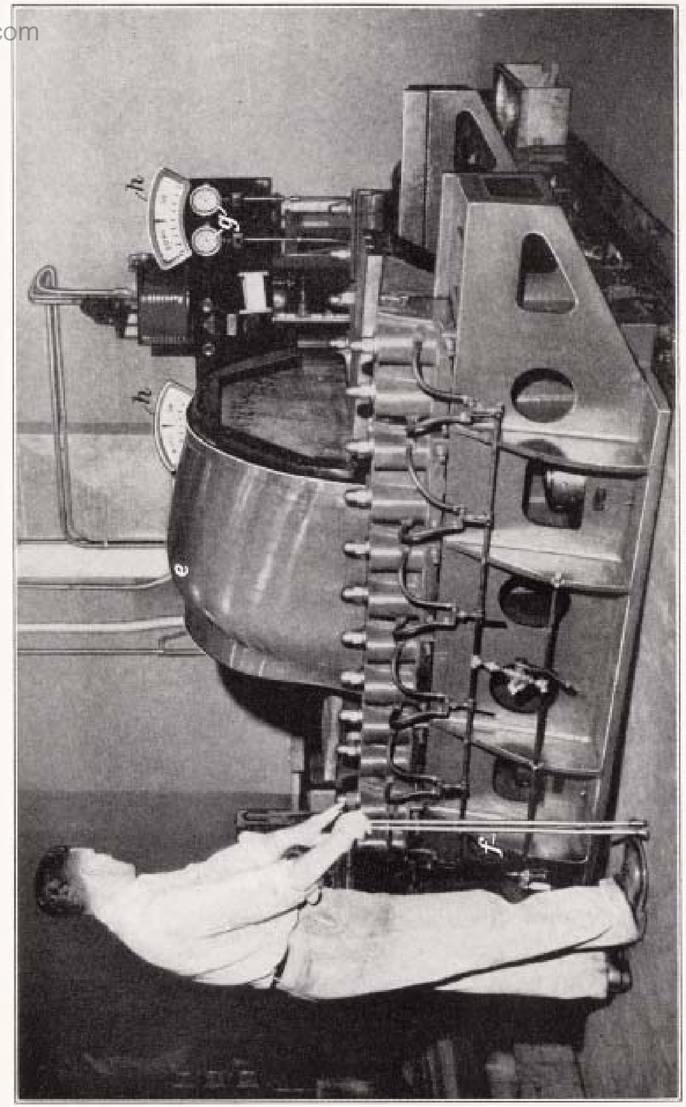


Fig. 6

8. To stretch the material to shape, the table is brought up at maximum speed by means of two levers *f*, Fig. 6, which control the movement of the pistons in the hydraulic cylinders. When the die contacts the sheet and builds up pressure, the speed can be reduced to suit the peculiarities of the die. Then either of two methods of operation may be used. The pressure that is required to form a part, as shown by gages *g*, can be determined by stretching a trial part and the pressure adjusting valve then set at that value; or the pressure can be set at its maximum value, the material stretched to shape, and the trip rod set for the required table travel as shown by gages *h*. The latter method is generally used as it is the faster.

To speed-up production still more, adjustable table stops may be set to prevent the table from lowering more than is actually necessary to release the formed part and provide clearance for inserting the new sheet. It is also common practice to stretch more than one sheet at a time; on 300-ton presses as many as six sheets may be placed, one on top of another, on the die. The number of sheets that may be stretched in any particular press depends both on the shape of the die and on the thickness of the sheets. Any change of contour caused by piling the sheets on top of each other is so slight that it may be disregarded.

9. The results from stretch-pressing depend to a large extent on the ability of the operator. He should know the characteristics of the material and be able to judge when it reaches its maximum deformation. On some machines he can assist in the stretching by moving the clamp supports toward or away from the table while the material is being stretched. If folds or wrinkles develop during the operation, they should be removed by hand hammering. But wrinkles can generally be avoided by careful design of the die and study of the material as it is stretched.

Whenever possible, the pressure should be applied in such a way that the stretching is equalized and the pressure distributed evenly over the surface of the sheet. Also the edges of the blank sheet may be trimmed to the approximate developed shape of the part and the clamps attached in a similar manner, such as in a

curve as already shown in Fig. 5, in order to maintain a constant tension and simultaneous contact of the sheet with the die at as many points as possible.

10. Die Lubricants.—Before the sheet metal is placed in the press, the die must be covered with a lubricant, such as vaseline, a light grease, or drawing compound made up of half vegetable and half mineral oil. The lubricant should not break down below 150° F. and should provide viscous lubrication up to a normal pressure of about 5,000 pounds per square inch. Water-soluble grinding compound is also sometimes used, but when this is done, it is necessary to remove the compound from the parts *within four hours* after they are formed or it will oxidize the surface of the aluminum-alloy sheet. The ordinary degreasing process will not remove the compound; instead the sheets are washed in hot water, which also warms the sheets so that they dry without the formation of water spots.

11. Die Materials.—The common materials for stretch-press dies are Kirksite, concrete faced with plaster, and hardwood. Lead, iron, and fiber have also been used successfully. Whatever material is used, it must be strong enough to withstand the pressures involved in stretch pressing. Kirksite is the most widely used material since it can be easily cast to shape, it can be reclaimed by melting worn-out dies, and it can be worked to a smooth surface to permit the sheet metal to slide over it with little friction.

Plaster dies, which also have been very satisfactory, are made of reinforced concrete faced with a mixture of mixing plaster and a special hard plaster known as Hydrocal. The plaster die is shellaced and mounted in the stretch press. To give the die a long-wearing surface a sheet of low-carbon steel, such as S.A.E. 1010, is stretched over the die and left there during the forming of the parts. A plaster die may be used for fairly large runs without the sheet-steel covering, but the steel both increases the life of the die and reduces the friction between the die and the aluminum-alloy sheets. It also protects the face of the die while in storage.

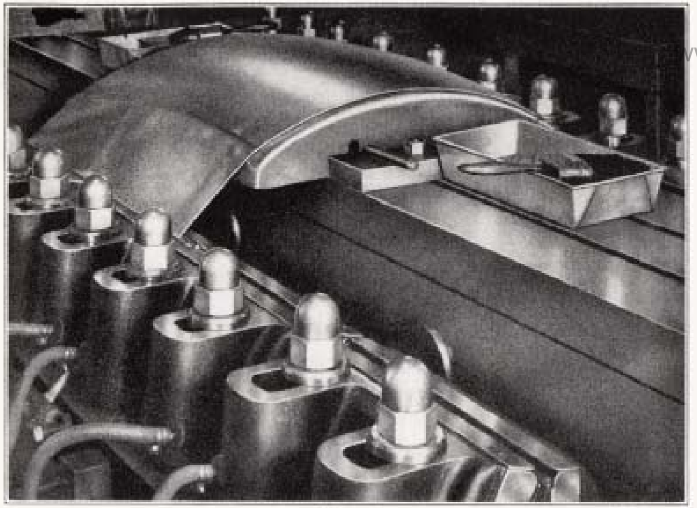


FIG. 7

Plaster dies are relatively inexpensive, costing approximately from 35 to 40 cents per cubic foot for construction and materials. The development of the die may require an additional 40 or 50 hours over the time required to make the die, and the use of con-

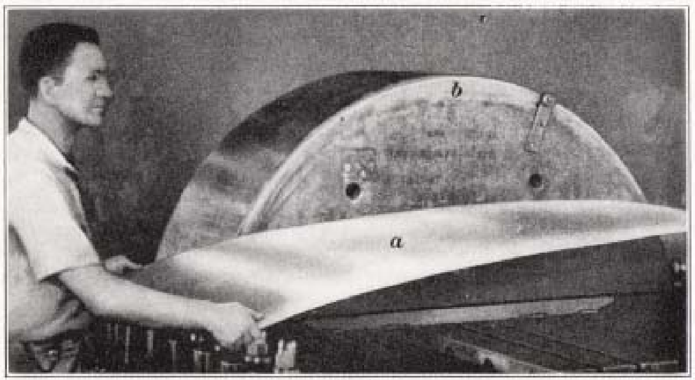


FIG. 8

siderable sheet material for testing the contour of the die. In a great many cases the material that has been used for testing a large die and which, therefore, cannot be used in production, and also material that has been stretched over a large die and then not used because of design changes or defects in the parts, may be trimmed and used for tooling purposes on a smaller die.

12. Wood dies are not used to as great an extent as they formerly were. They shrink, particularly if stored for long periods, but they give good results on short runs, wear well enough to produce relatively small quantities, say up to two dozen parts, and can be easily modified. Edges where the forming is severe may be reinforced by steel strips or inserts. Wood dies may be built up in sections or made as a solid piece. The latter type is preferable, even though more expensive, as with the sectional dies the joints may open under the stretching pressure. The life of wood dies may be increased by stretching sheet steel over them on the press.

13. Types of Dies.—Stretch-press dies are of two types, namely, pillow-block dies and distorted dies. As shown in Fig. 7, the former type has the actual shape of the finished part, which when removed will retain the shape of the die. Such a formed part is shown in Fig. 1. These dies are generally made of Kirksite. Distorted dies, however, have a distorted shape; that is, they do not have the true shape of the finished part but are so made that when the stretched part is released, it will assume the correct form. Such dies are generally made of concrete and plaster, and are used for forming parts that are too long to be stretched to their finished shape in the press.

For example, if a skin section of relatively small double-curvature and several feet long, as shown at *a* in Fig. 8, is to be formed, the die *b* may be made to the shape that the part will assume when the two ends are drawn together at the bottom until they are at a distance apart equal to the maximum length of the die. Thus, the die shown in Fig. 9 has a cross-section that has a much greater curvature *abc* than has the finished part along its length *abc*, Fig. 10. The die may be straight across its face or it may

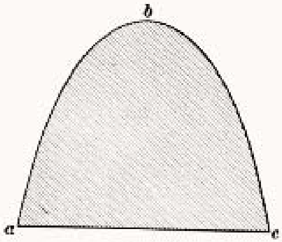


Fig. 9

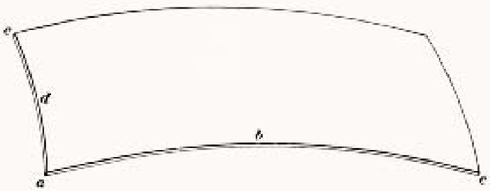
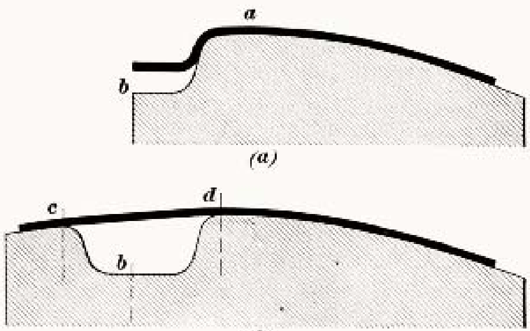


Fig. 10



(b)

Fig. 11

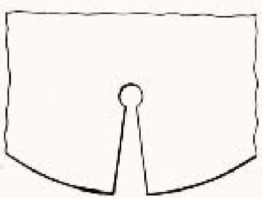


Fig. 12

be cross-contoured, depending on the amount of cross-contour arc that is desired on the finished part. When the sheet is stretched over the distorted die and then taken from the press and straightened out, it will assume its correct finished shape. The lengthwise contour on the part will be less than the corresponding curvature on the die; whereas, the cross-contour on the part will be greater than the cross-contour on the die. Any variation from the required curvature in either direction can be corrected by changing the contour of the die.

14. Transverse Forming.—When a sheet is gripped at both ends and stretched, the stress is lengthwise along the sheet and there is little tendency for the sheet to stretch in a transverse direction. Thus with an ordinary die it is not always possible to finish the part completely by the stretching action; in such cases it may be necessary to finish-form the part by handwork with a rubber or rawhide mallet. Forming the part completely by stretching, however, is preferred and may be accomplished by designing the die with a return curve along the sides so that the metal will be pulled down between the two high sections. For example, if a sheet *a* were stretched over the die shown in Fig. 11 (*a*), it would not form completely to the edge *b*. Redesigning this die to the form shown in view (*b*) would create a tension on the sheet between the points *c* and *d* and force it to follow the curve. As the material beyond point *b* would then be trimmed off, this design involves considerable waste but the hand forming would be eliminated and production increased. The choice of design must, therefore, be based on the number of parts to be formed and the comparison between the value of the time consumed by the hand work and that of the material scrapped.

15. Stretching Large Skin Sections.—A valuable application of stretch pressing is the forming of large skin sections that curve to suit the shape of the wing, or whatever other part of the structure the sections fit over. If such large curved sections are stretched directly from rectangular sheets, there is a tendency for the material along the edges to wrinkle and probably to tear,

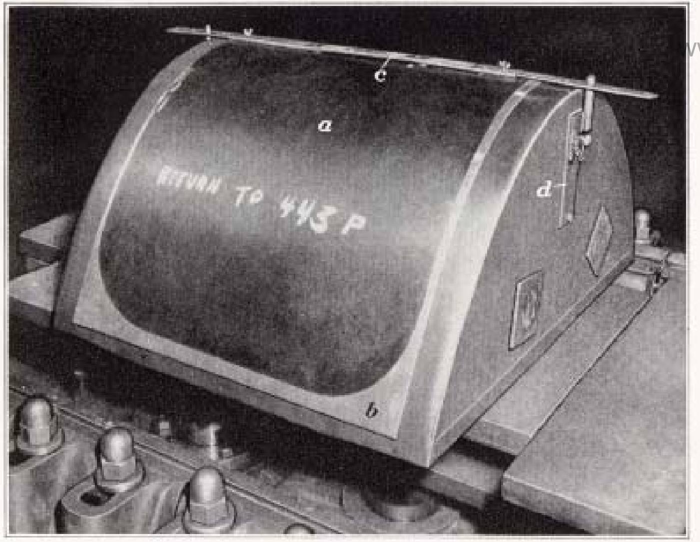


Fig. 13

especially when considerable stretching is required to form the parts. This condition can be avoided either by cutting the sheets to their approximate developed shape, or by making cut-outs along the edges to permit the edges of the sheet to be clamped in a curve. These cut-outs are made of keyhole shape, as shown in Fig. 12, to prevent any concentration of stress in the point of the vee. The edges of the sheets are also well burred to eliminate any concentration of stress in deep scratches on the edge. The sheets whether trimmed to a curve or given cut-outs may then be clamped in a curve around the edges, so that a constant tension is maintained throughout the width of the sheet.

16. Locating Trim Lines.—Since the contour of the surface of a double-curvature part changes from one area to another, the trim lines on the stretched sheets must be marked accurately so that the finished part will be of the correct curvature. These trim lines may be located by different methods; all, however, utilizing a templet made to the same size and shape of the part and

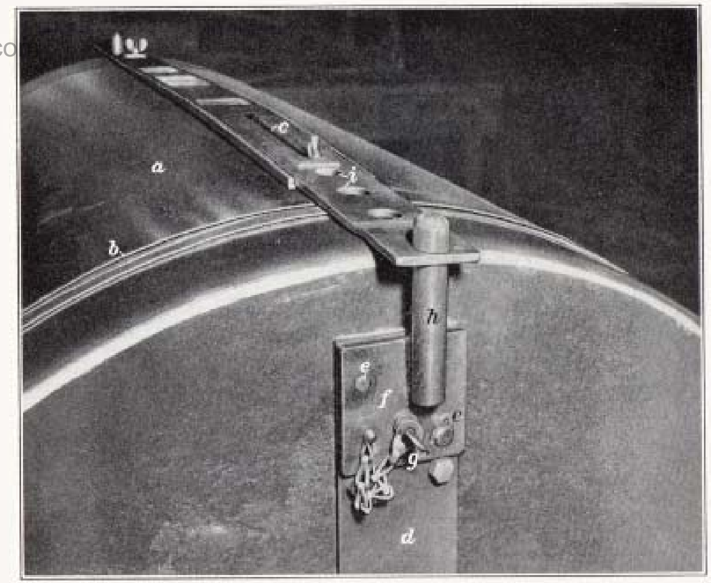


Fig. 14

known as the trim, or the apply-trim, templet. By one method, as shown in Fig .13, the apply-trim templet *a* is placed over the formed part *b* while the part is on the die, either during the stretching operation or after the die has been removed from the press to make way for other work. In the latter case, all the parts would be stretched before removing the die, and the parts again laid on the removed die and the templet applied. The templet *a* is located in its proper position by means of a gage *c* that is bolted to the templet and adjustable in length for use on dies of various widths. The templet and gage are set over the formed part and located from a gage plate *d* on the side of the die. The plate *d*, also shown in Fig. 14, which is an enlarged end view of the assembly shown in Fig. 13, has two locating pin holes for the dowel pins *e* on the plate *f*. When the plate *f* is attached to the gage plate *d* by means of the thumbscrew *g*, the pin *h* locates it accurately crosswise on the die by entering one of the end holes *i* on the gage, and positions the apply-trim

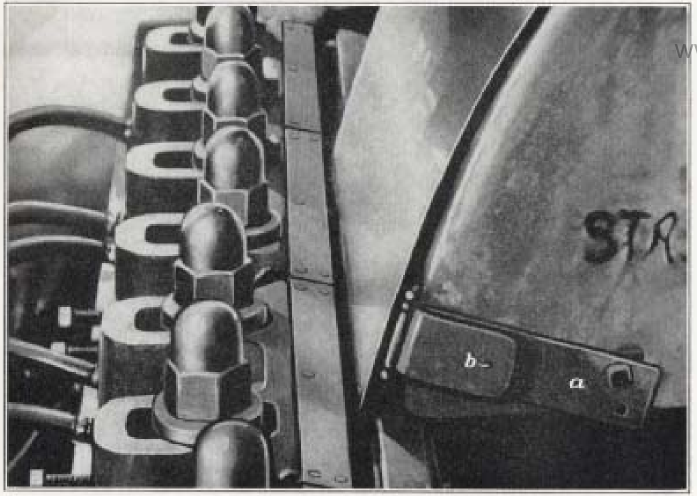


FIG. 15

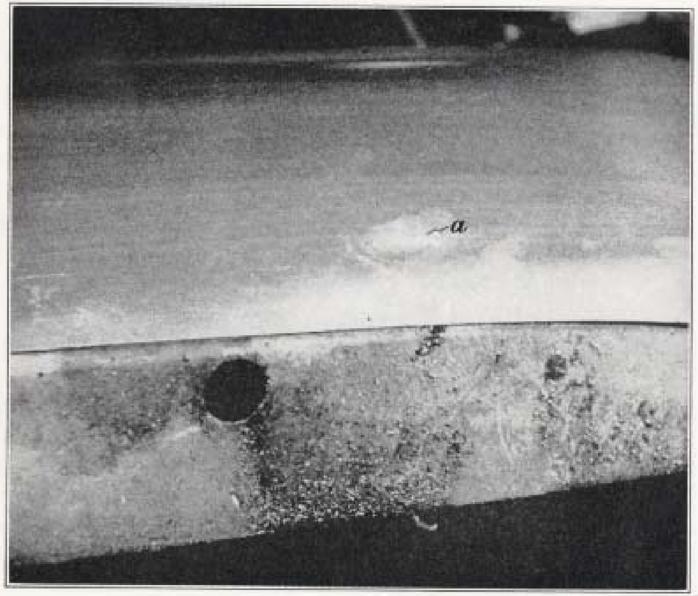


FIG. 16

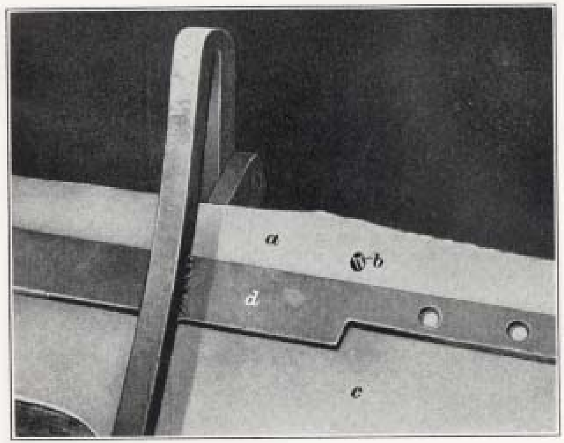


FIG. 17

templet *a* on the formed sheet. Lines are then marked around the templet.

17. Another method of locating the apply-trim templet is by the use of hinge markers, such as shown at *a* in Fig. 15. These markers carry small marking punches *b* and are bolted to the sides of the die. When the press ram is at the top of its stroke, and the sheet stretched to shape, the markers are swung over the sheet to leave indentations. Holes are then punched at these points. The apply-trim templet has corresponding holes so that the templet and the formed sheet can be fastened together by Cleco fasteners, which are spring-type clamps inserted in the registering holes, and the trim lines are marked.

18. A method that may be used on a Kirksite die is to set small projections in the face of the die. Then when the part is stretched, the material directly over each projection is hammered lightly to leave dimples in the sheet, as shown at *a* in Fig. 16. Holes are punched at these points and the part is rough trimmed by hand and then located by these holes in the trim fixture. In Fig. 17 the part *a* is shown located in the fixture on the pin *b*.

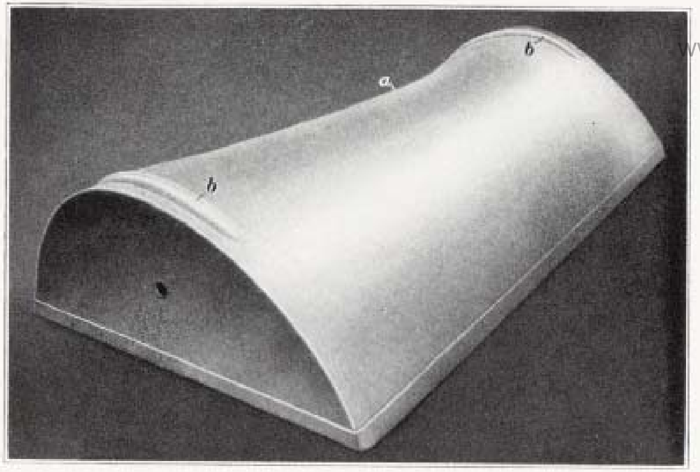


FIG. 18

Then the trim templet *c*, which is fastened to a revolving leaf, or framework, *d* that is hinged to the main part of the fixture, is swung down on the sheet and the part is marked for trim along the edge of the templet. This method is faster than using Cleco fasteners but requires the construction of the fixture.

19. Forming Reverse Contours.—Reverse contours can be formed on a stretch press if the die is designed so that the formation of wrinkles is prevented along the central part of the sheet. An example of reverse contour is a tail cone fillet. This part is formed of .020-inch *24ST* on the die shown in Fig. 18. The reverse curve *a* on the die will tend to cause the material to slip along the curve and wrinkle in the middle as soon as the material along the sides is stretched. This wrinkling can be prevented by using locking beads *b* at both ends of the die. Then at the beginning of the stretch the material will be drawn into these beads, and held crosswise so that it can not slip along the reverse curve of the die and form wrinkles. The material may be further restrained from slipping into the concave area by using no lubricating oil on the outer edges of the die.

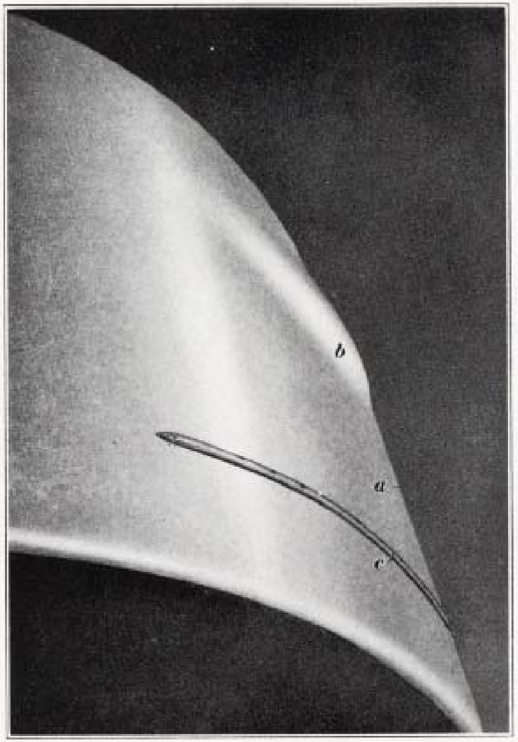


FIG. 19

Similar use of locking beads may prevent wrinkles on parts that have no reverse contours. Thus, in Fig. 19, wrinkles would form over the area *a* because of the sharp curve from the higher part *b*. Such wrinkles may be prevented by beads *c* that lock the material long its edges.

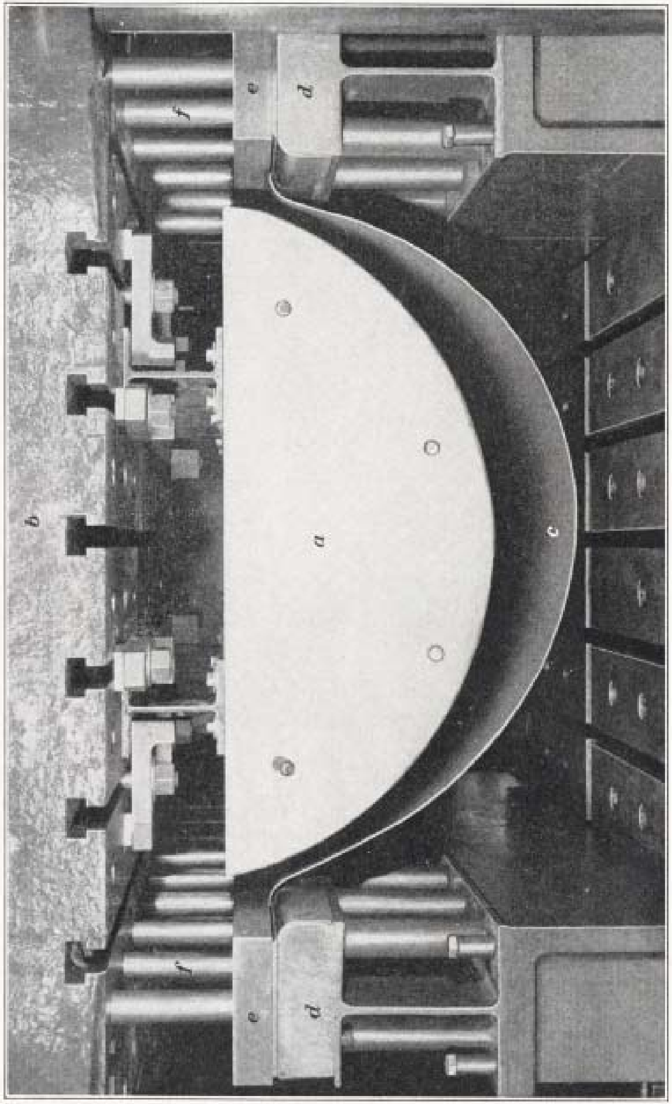


Fig. 20

STRETCH-FORMING IN DOUBLE-ACTION PRESS

20. Application of Double-Action Press.—When no specially designed stretch presses are available, double-action hydraulic presses can be adapted to stretch-forming. A set-up for the stretch-forming of nacelle skins in a double-action press is shown in Fig. 20. These skins can be formed in the *ST* condition at the rate of ninety per hour. The die *a*, which is made of Kirksite, is attached to the main ram *b* of the press. The aluminum-alloy sheet *c* is held at both ends between heavy, flat rails *d* and hold-down plates *e*. The stock must be draped between the clamps and made long enough that the die, as it descends, will stretch the metal sufficiently to produce a permanent set, but not enough to rupture it. The required length can be determined by trial or calculation, and should be kept the same for all sheets to obtain uniform results. Then to form the part, the die should be well lubricated and lowered to stretch the metal in much the same manner as with a regular stretch press.

21. Details of Clamps.—The clamping pressure on the sheet stock is exerted by rods *f*, Fig. 20, which pass from the hold-down plates *e* up through the main ram to the hold-down ram, or blank-holder. Because of the heavy pressure that is thus available, both the rails *d* and the plates *e* are made with smooth surfaces and need not be serrated to provide sufficient frictional restraint to hold the sheet metal. The use of the smooth surfaces is advantageous in that any serrations or other irregularities of the holding surfaces tend to tear the sheet when it attempts to yield locally within the clamps as it is being stretched. Actually, the range of forming can be extended by allowing the sheet to slip between the clamping plates over certain critical areas.

22. For successful forming, it is essential that the rails *d*, Fig. 20, have a large smooth radius, preferably 1 inch or more, in order to prevent excessively large strains in the sheet metal as a result of its being bent around the radius. Also, the rails for most work must have straight sides, but they may be set

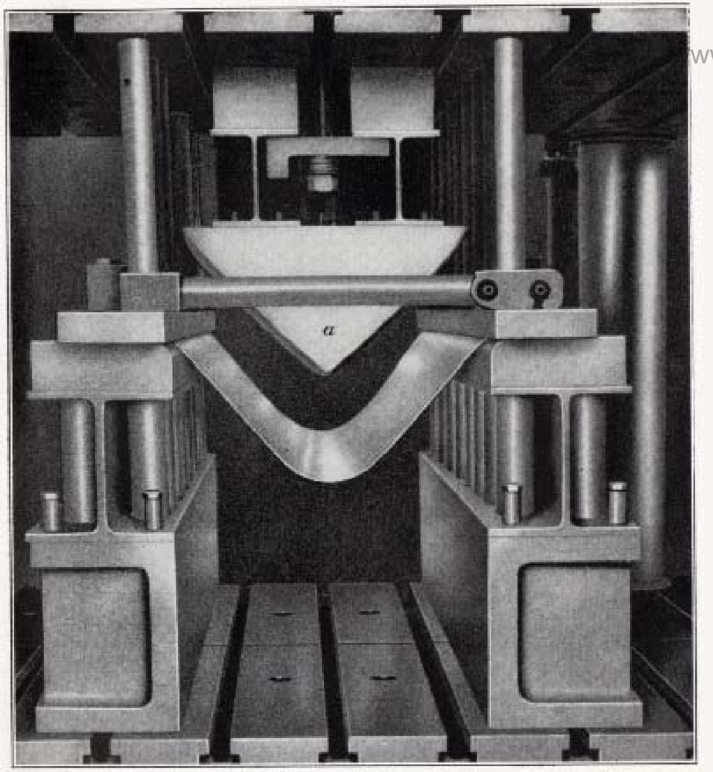


FIG. 21

at an angle instead of parallel with each other. Sufficient clearance must be provided between the rails and the die to avoid severe bending and pinching of the material. If these conditions are met, no trouble should be experienced from the bending of the material over the edges of the rails.

23. Stretch-Forming Shallow Contours.—When parts of very shallow curvature are to be stretch-formed, it is often more satisfactory to form the parts in pairs. For example, in Fig. 21 is illustrated the forming of shallow-contoured empennage skin panels. These parts could not be satisfactorily stretched as single

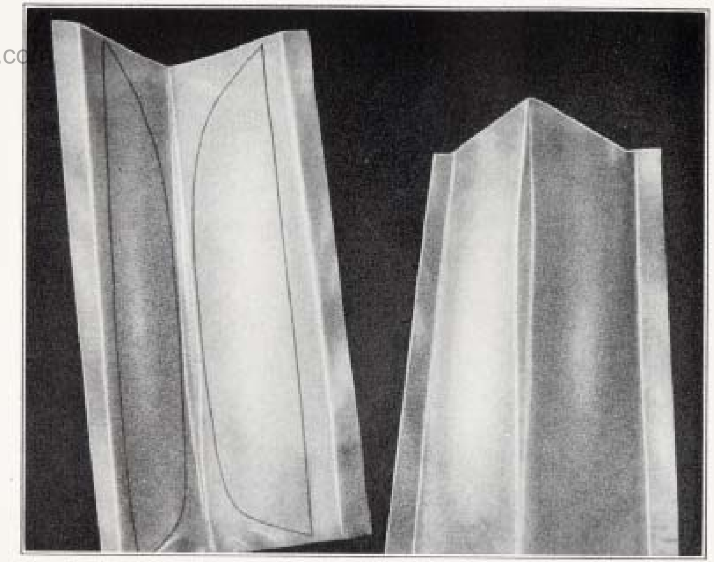


FIG. 22

pieces, because the contour is too flat. When such exceptionally shallow-contoured surfaces are stretched, there is a tendency to overform the center of the part. Therefore, more satisfactory results are obtainable by forming two parts at a time with a V-shaped die *a*, and cutting them apart at the trim lines shown marked on the surface of the shaped part as shown in Fig. 22. This particular part was formed in two stretching operations from .020-inch *24SO* sheet. To limit the distortion, it was stretched partially, heat-treated, and then stretched to its final shape before the material age-hardened. This method of forming parts in pairs not only provides a good means of forming shallow-contoured parts, but also results in a saving of material since both parts are formed with practically the same amount of scrap material as would be required for the forming of a single part.

24. Another method that can be successfully applied to stretch-form parts of shallow contour in a double-action press is to use a die that is deeper than is required by the contour. As shown in Fig. 23, the die *a* has an extra depth *b* that is provided to stretch the sheet metal the required amount in order to form the shallow contour across the bottom section *cd* of the

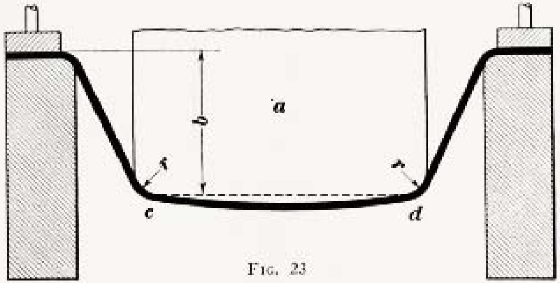


FIG. 23

die. Its construction is similar in this respect to that of a pillow-block die. The radius *r* on the corners of the die should be at least $1\frac{1}{2}$ inches to insure satisfactory forming of the sheet metal to the shape of the die, and to eliminate any possibility of tearing the material as it forms around these corners.

25. Two-Die Set-Up.—To speed-up production and to reduce waste, parts can be stretch-formed two at a time in a double-action press by using, as shown in Fig. 24, a pair of identical dies *a* and *b* attached to the main ram. As in an ordinary set-up with only one die, the sheet metal is gripped between the hold-down plates *c* and the rails *d*, but when two dies are used, an additional rail *e* is placed in the center to support the sheet metal at that point. For parts that are slightly conical, such as the fuselage skin, shown in Fig. 25, the dies should be reversed, end for end, that is, the larger sections of the dies should be on opposite ends, to allow the material to flow over the center rail more uniformly. For satisfactory operation, the dies must be positioned carefully on the ram so that they contact the sheet simultaneously at both ends. When very severe stretch-forming is necessary to form the parts, the material may first be stretched partially, then annealed, and, finally, finish-stretched. Several stages may sometimes be necessary.

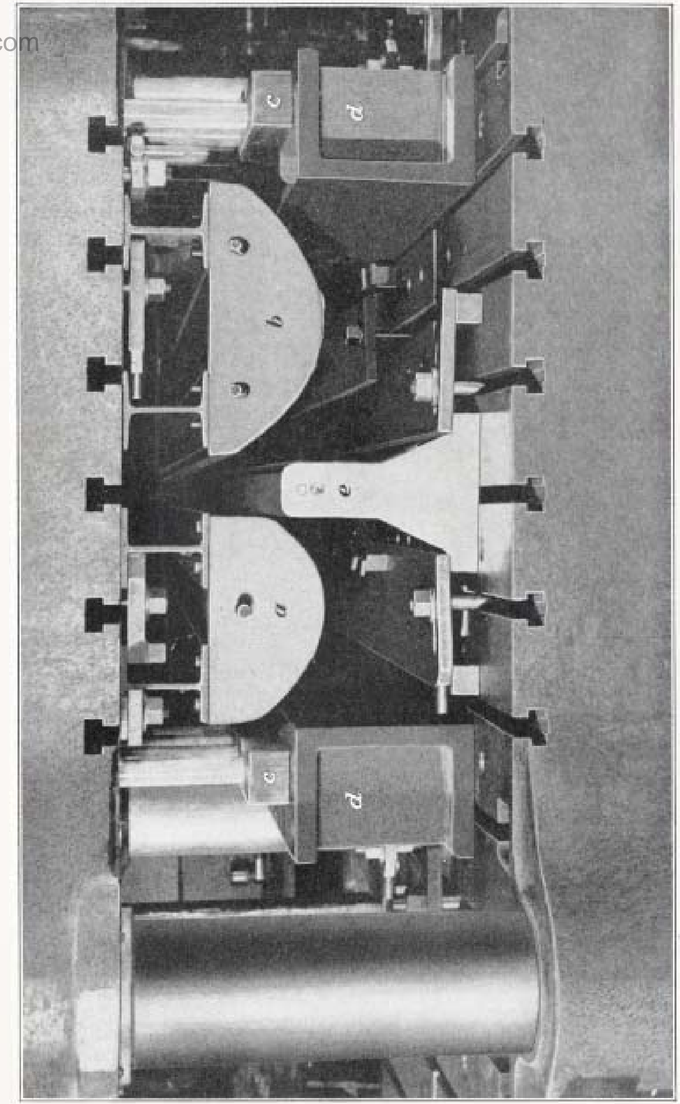


FIG. 24

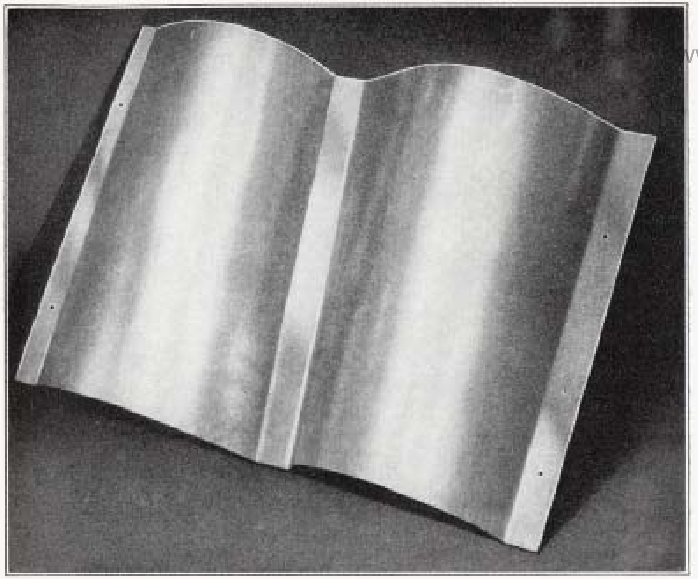


FIG. 25

STRETCH-FORMING EXTRUDED SECTIONS

26. Stretch-Forming Center-Wing Rib Chords. Extruded hat sections, such as center-wing rib chords, may be formed by drawing them around a form block of the required shape, and then hand working them to the finished contour. This method is known as wrap-forming. Greater accuracy and faster production, however, are obtainable by stretch-pressing. When such sections are formed in a stretch press there is practically no springback, since the material is stretched until it takes a permanent set and will remain in that condition for assembly. When forming rib chords on a wrap former, however, it is necessary to allow for springback in making the forming tools and, because of the difference in springback in different lots of material, this allowance is not uniformly accurate. Also, stretch-pressing these chords increases production from three or four per hour up to about seventy-five per hour.

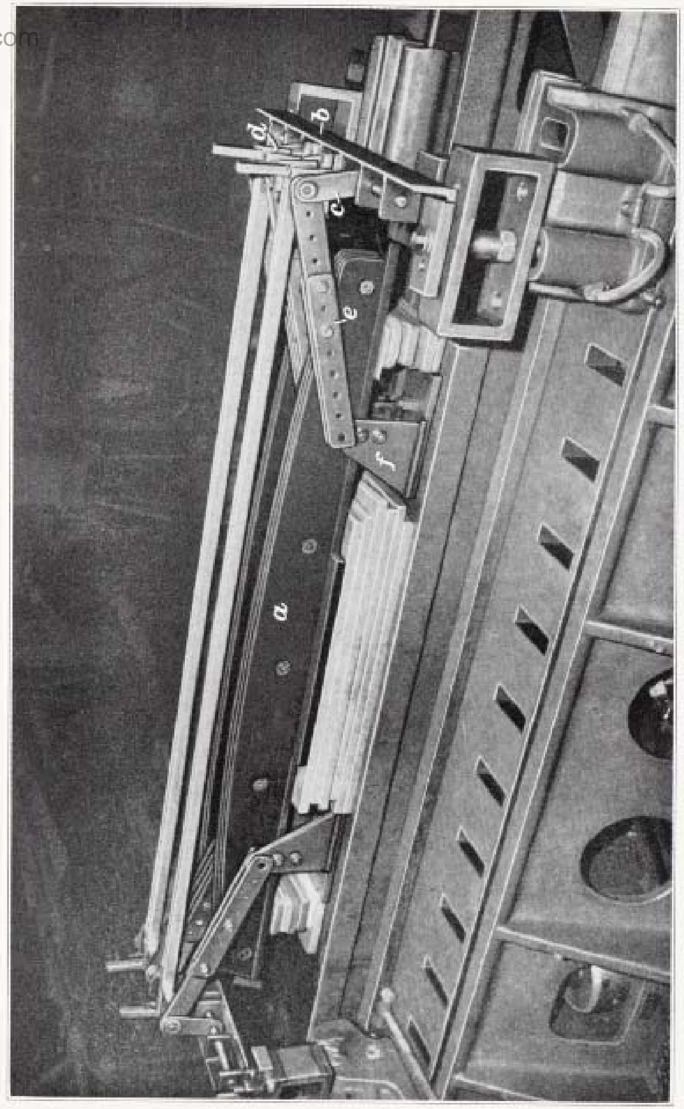


FIG. 26

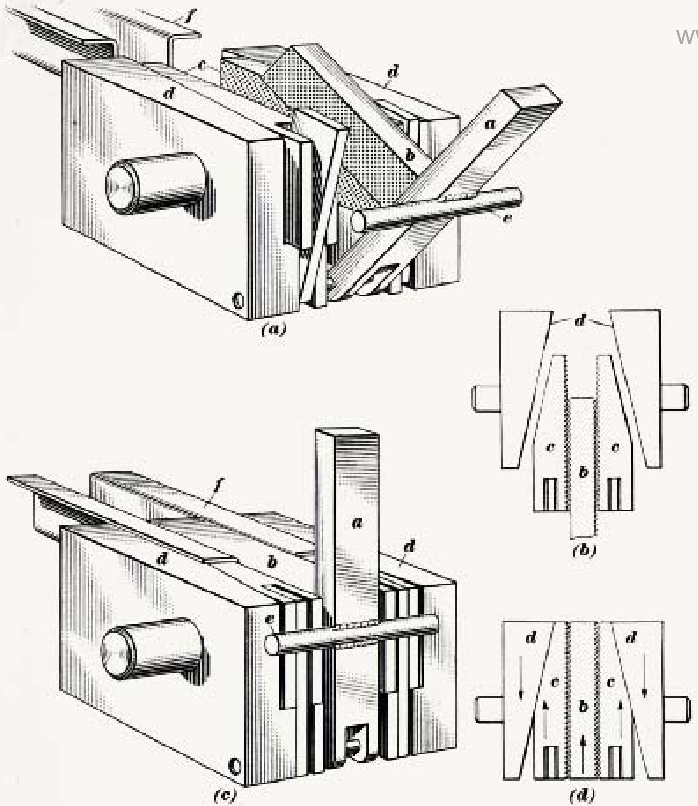


Fig. 27

27. When formed in a stretch press the rib chords are stretched in a toggle fixture mounted lengthwise on the table of a 300-ton press, as shown in Fig. 26. The two forming dies, the nearer of which is shown at *a*, are made of masonite and are blocked up to the proper height to give the required travel for the forming operation. The dies need not be fastened to the table since the part is symmetrical in shape and there is no tendency for movement of the die during forming. The adapter bar *b*, which supports the clamping and toggle fixtures, is made up of heavy structural angle with webs welded to the inside. These

webs are drilled for a 1-inch rod, around which the links *c* turn to allow the clamps *d* to float back and forth. The toggle levers *e*, connected to the links *c*, are made in two parts and are drilled with a series of holes for varying their lengths, and their supports *f* are drilled and fitted with three sets of pins. By adjusting the length of the levers and mounting them on different pins on the supports, the fixture can be adapted to form chords of different lengths.

28. The clamps holding the rib chords are opened and closed by a hand lever on each clamp. In Fig. 27, the clamp assembly is shown open in the perspective view (*a*), and in the top view (*b*); while it is shown closed in the perspective view (*c*), and in the top view (*d*) each lever *a* has attached to it a serrated block *b* that grips the inside of the chord. Two wedge-shaped jaws *c*, also serrated for gripping the outside of the material, are forced into the taper *d* by a rod *e* attached to the hand lever. The resulting wedging action closes the jaws on the stock *f* and provides a clamping pressure that increases as the material is stretched.

29. The chords are formed in the heat-treated condition before they have had time to age and harden. To delay aging, they are stored in a refrigerator near the stretch press between the time at which they are heat-treated and that at which they are stretched. Because of the heat treatment, the chords are twisted and distorted when placed in the press. Therefore, as the table first rises, as in Fig. 28, the toggle levers *e* are provided to move the links *c* toward an upright position, thus placing an initial stretch on the chords and removing any twist in them. Wood strips, or filler sticks, *g* are then placed inside the hat-section chords to prevent their collapsing during the forming operation. The table is raised still further until the sections fit the forming blocks, as shown in Fig. 29, and the material is stretched beyond its elastic limit so that there will be little springback.

To remove the chords from the fixture, one end of each chord is broken off near the clamp by inserting the sharpened tang of an old file in the center and cutting through the walls of the

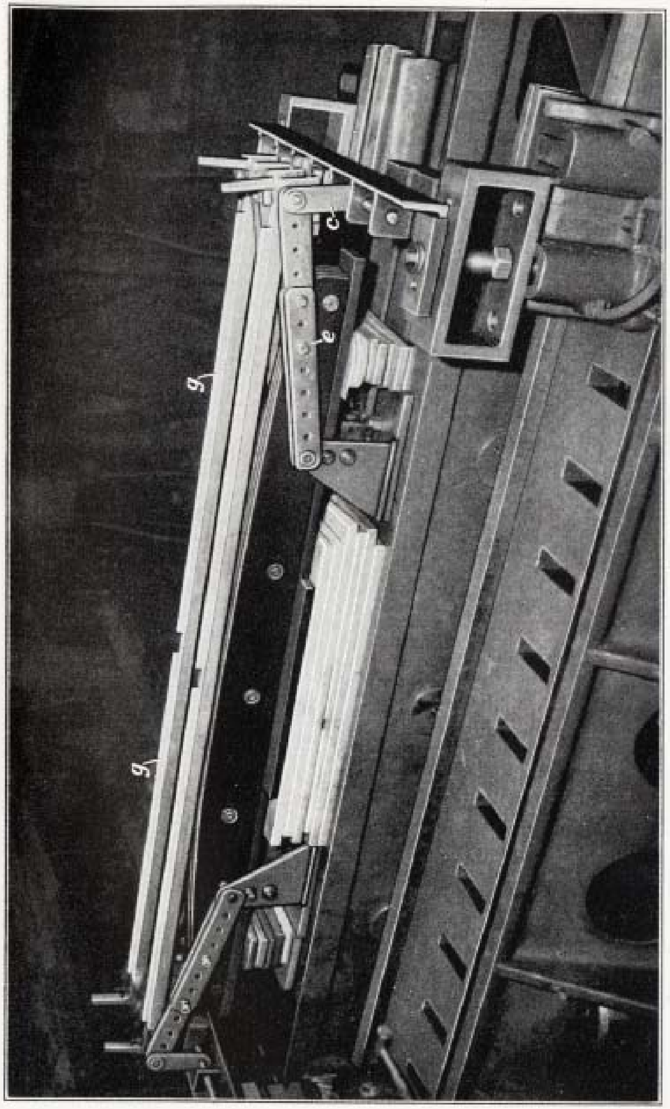


Fig. 28

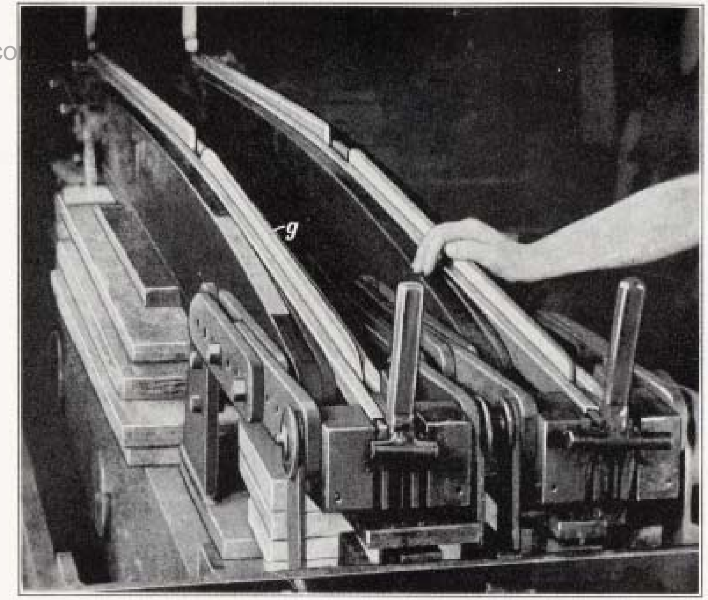


Fig. 29

section. As soon as the walls are ruptured, the tension in the chord causes the section to snap. The pressure is thus relieved on the clamps, causing them to open. Unclamping without first relieving the pressure is difficult since the stretching action on the chords wedges the clamps tightly in place.

30. The contour of each rib chord is checked by means of a checking fixture. First the fixture is set up, as in Fig. 30, by using a master checking board, or templet, *a*. The stops *b* are adjusted to fit the curved edge of the templet and securely clamped. Then the templet *a* is removed and the chord is applied to the checking fixture, as shown in Fig. 31. Since the tolerance on the contour is only .015 inch, the chord must conform quite closely to the curve established by the fixture stops.

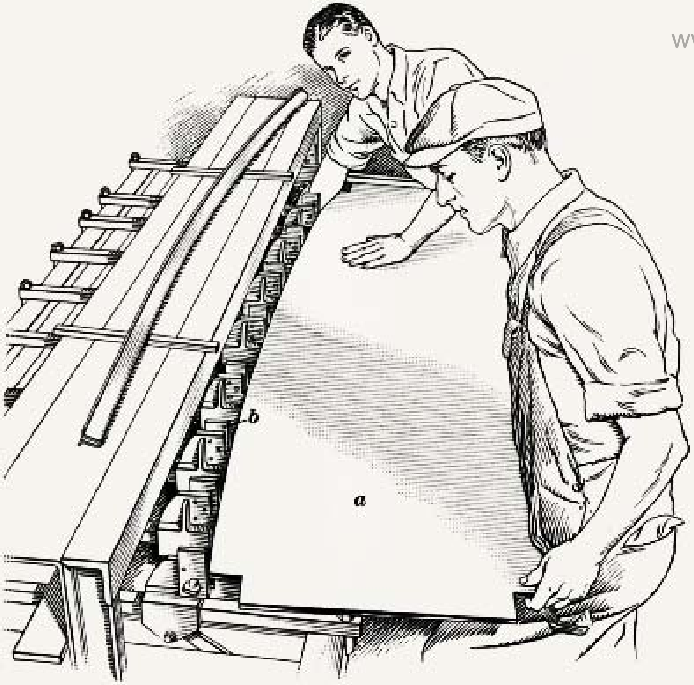


Fig. 30

31. Stretch-Forming Flap Cut-Out Rib Chords.—The forming of wing-flap cut-out rib chords is similar to that of center-wing rib chords, except that on the flap chord there is a sharper contour on one end than on the other; therefore, the forming is unbalanced and more severe. Also the section is formed differently in that the flanges are on the inside of the contour, instead of on the outside as on the center-rib chord.

The forming fixture, as shown in Fig. 32, is mounted crosswise on the table of a 75-ton stretching press. The masonite forming dies *a* are clamped securely to the table because of the uneven pull necessary to form the part, the curve at the end *b* of each die being sharper than that at the rear. The clamps *c* are hand operated, in the same manner as those on the center-

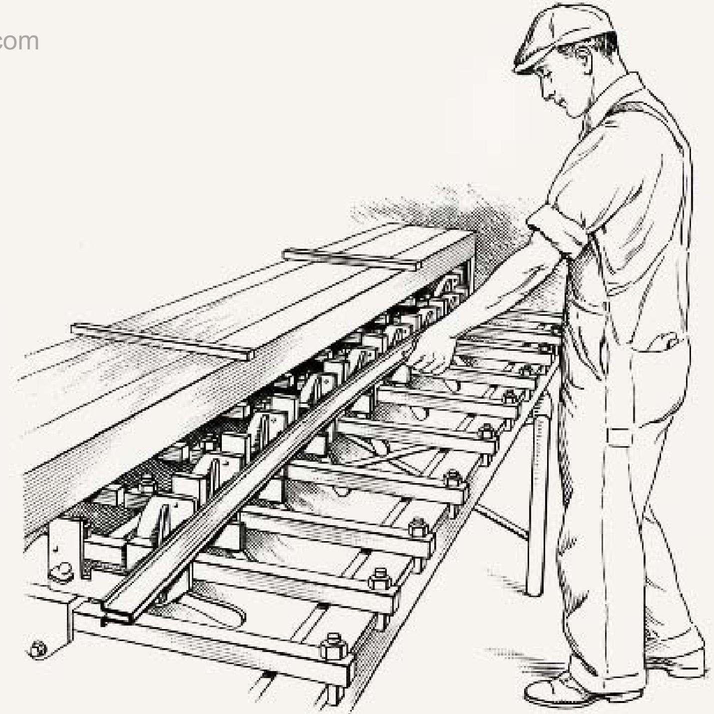


Fig. 31

chord fixture, but are slightly different in their clamping action and release more readily, since in this case it is not practical to break the flange to release the clamps. The clamp on the right-hand fixture is in its closed position and that on the left-hand fixture is open and shows the hat-section *d* located on the base *e* of the clamp.

32. The clamps are supported by links *f*, shown more clearly in Fig. 33, and are guided as the table rises to the position shown by cams *g* cut in the boiler plate *h*, Figs. 32 and 33, fastened to the side of the forming die. The cam on the left-hand side is more pronounced than that on the right-hand side and

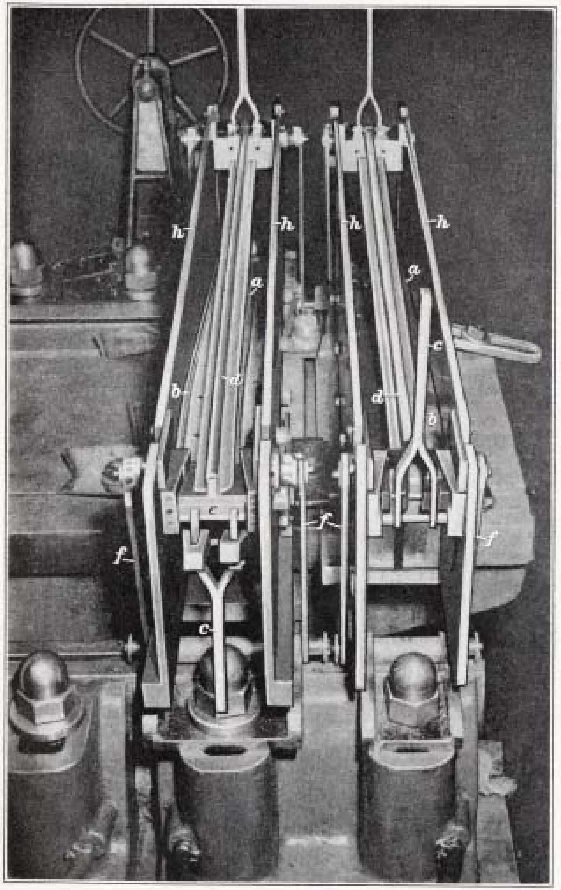


Fig. 32

gives the extra motion required to form the sharp curve on the chord. On this set-up no filler strips are needed to prevent collapse of the section, since the hat section is upside down and a tongue formed on the die supports the section during forming. With this dual fixture, approximately a hundred parts per hour can be formed. Because of a reverse curve along the straighter

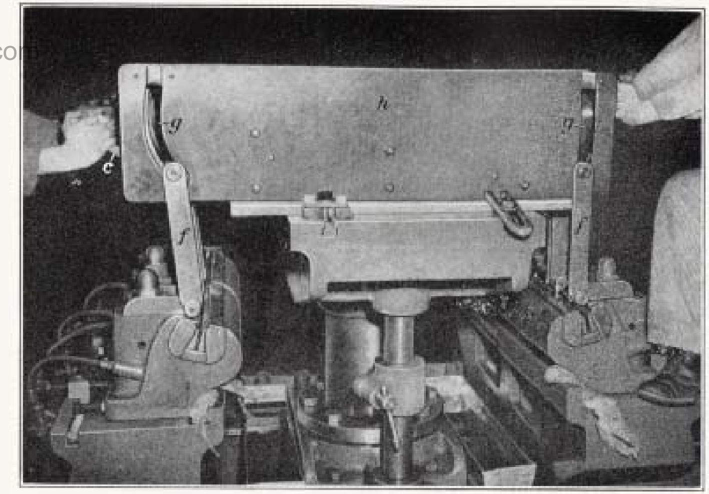


Fig. 33

portion of the finished part, and because of flat spots required to allow the longitudinal stiffeners to come in contact with the chord, a press-brake restrike die is used to give the final shape to the chords.

33. Stretch-Forming Nose-Rib Chords.—Nose-rib chords may be formed on a stretch press in two stages: First, they are partially formed, annealed stock being used because of the severe forming around the nose; then they are heat-treated, refrigerated until needed, and finish-formed in a second fixture. Even though two forming operations are required, the method is an improvement over the previous method of forming in which the chord was made in two parts in a drop hammer, the parts then being heat-treated, reformed by hand and riveted together.

34. The fixture used in the first forming operation is shown in Fig. 34. The masonite forming die *a* is clamped to the table of a 75-ton stretch press. Levers *b* are attached to the forming die and are also attached by the links *c* and the adapter plate *d*

Fig. 34

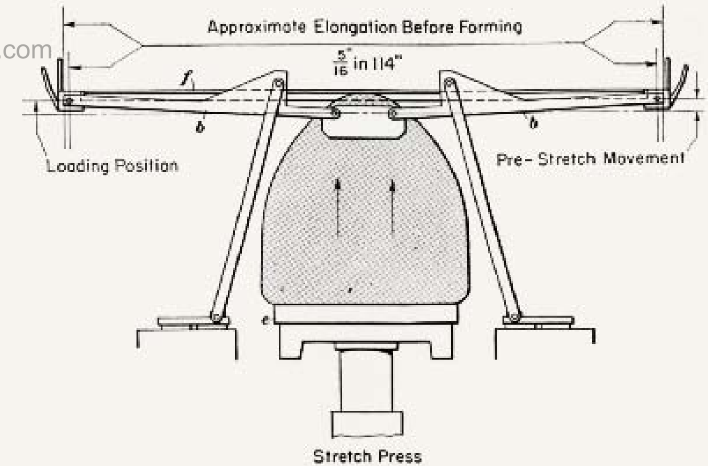


Fig. 35

to the clamp supports from which the press clamps have been removed. To remove any twist in the section being formed, it is necessary that the part be given an initial stretch, and that a constant pressure be maintained while the forming operations is in progress.

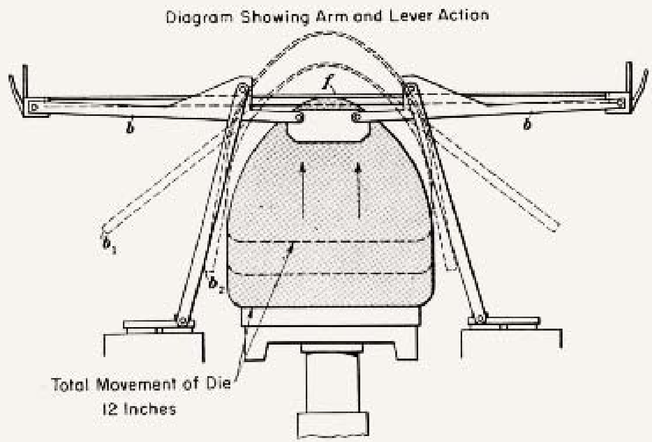


Fig. 36

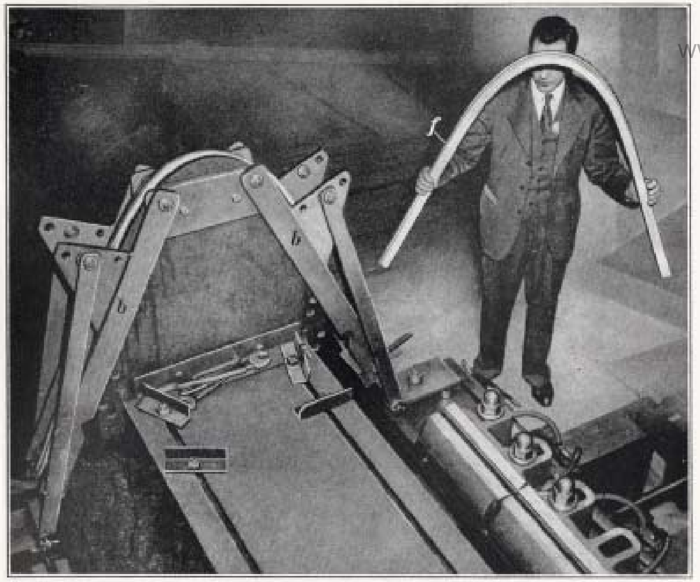


Fig. 37

The levers b in their loading position are, as shown more clearly in Fig. 35, slightly higher at their outer ends than at their inner ends where they are attached to the forming die. Therefore, when the table e is raised, the linkage draws the levers b first into a level position and thus stretches the material f before any forming occurs. This elongation is approximately $\frac{5}{16}$ inch in 114 inches. Then to prevent collapse of the section f during its forming around the die, a link fiber filler g, Fig. 34, is inserted in the section. This filler need not be so restrained on the ends since the pressures set up on the inside of the section forces it to follow the material as it is being formed.

35. As the table is raised still further, as shown in Fig. 36, the levers b pass from their horizontal positions downward through positions b_1, b_2, and b_3 toward the forming die, the attaching clamps being omitted from the illustration for the

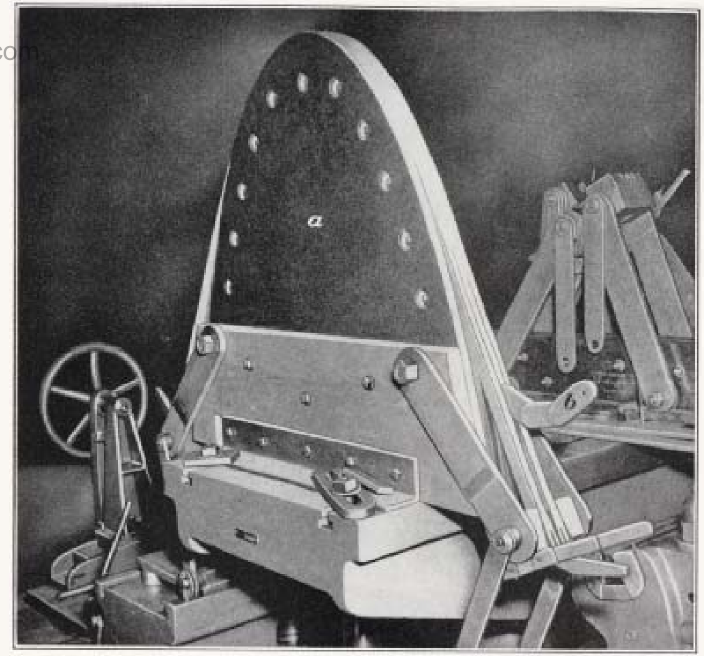


Fig. 38

sake of clearness. The positions of the levers when the chord has been completely formed to the die is shown in Fig. 37. Here the levers b have been drawn by the linkage to their lowest positions. The shape of the resulting part is shown at h. The chords are next heat-treated and stored in a refrigerator until they are removed just before the second forming operation.

36. The fixture for the second operation is shown in Fig. 38. The forming die a has a greater curvature than the die used in the first forming operation. The leverage and clamps are arranged in practically the same way. The link filler b, shown protruding from the part must again be used to prevent collapse of the section. The material in this final forming operation is stretched beyond its elastic limit and sets to its finished shape.

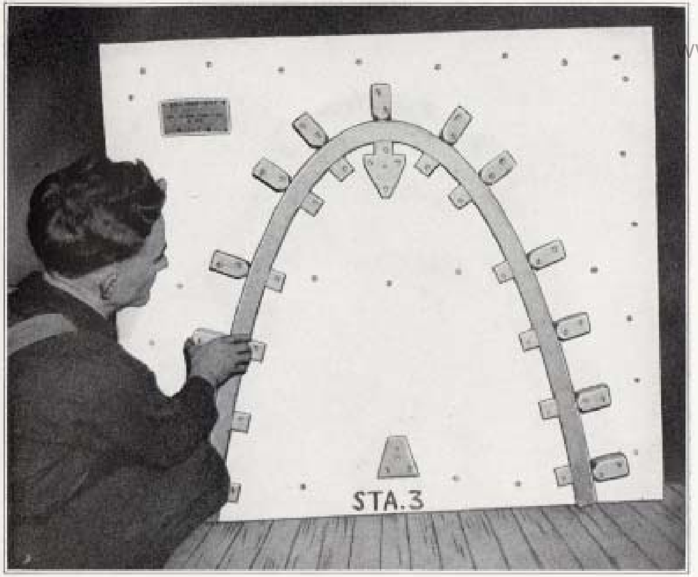


FIG. 39

The chords are then checked in the fixture shown in Fig. 39, which is arranged with blocks set to gage both the inside and outside curves of the nose chord.

Another necessary operation is the flattening of a portion of the nose rib at the point where the longitudinal stiffener is attached. No mechanical means are provided to form these flats, but the die is cut out, and the stretch-press operators bump in these flat spots with a mallet as the material takes is final set.

37. Stretch-Forming Channel Sections.—An ingenious application of stretch-pressing is the final forming of channel sections that have previously been wrap-formed. When such a section is wrap-formed, the springback of the material prevents it from setting to the shape of the die. Even though the die may be under-cut to compensate for springback, the formed parts will vary. Therefore, after the section has been wrap-formed, it is heat-treated, refrigerated, and stretched in a stretch press.

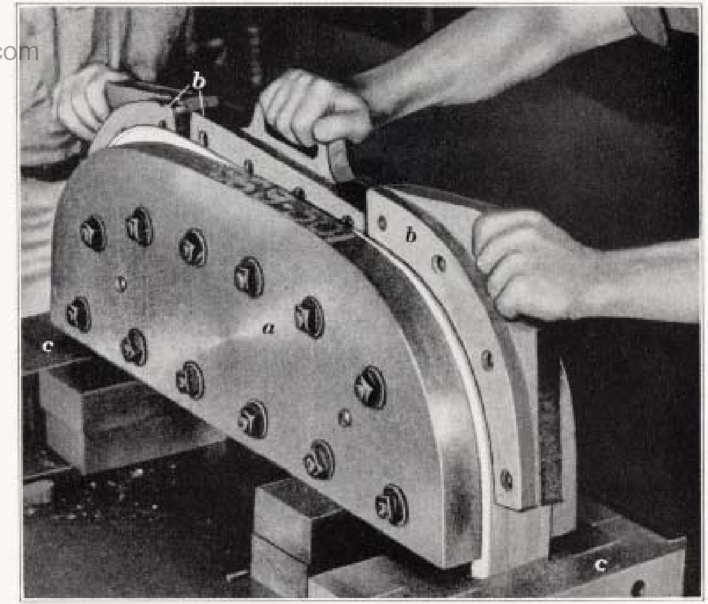


FIG. 40

Because of the long, flat portion in the middle of the piece, it is not stretch-formed from straight channel stock since the flat part would prevent adequate elongation of the material along that area. In the stretching operation the forming die *a*, Fig. 40, receives the partially formed section in the groove along its center. Three blocks *b* are placed in the channel to prevent collapse of the section as the stretch is made. Then with the ends of the channel gripped in the clamps *c*, the material is stretched until it sets to the curve of the forming die.