BLANKING AND PUNCHING

BLANKING BY SHEARING, SAWING AND NIBBLING

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BLANKING BY SHEARING, SAWING, AND NIBBLING

SHEARING

1. Cutting of Sheet Metal.—The cutting of sheet metal, especially of aluminum alloys, is one of the most common and most important operations in aircraft production. Since the aluminum-alloy sheets supplied from the manufacturer are almost never of the size needed, they must be cut, or blanked, to the required size. Also, after the sheet-metal parts are formed to shape, they must be trimmed of any excess metal.

The sheet metal may be cut, or blanked, by any one of several methods, such as by shearing, routing, sawing, or nibbling, or by the use of blanking dies on hydro, hydraulic, or crank presses. The method that should be used in each specific case depends on the operation required, the kind of metal and its thickness, the accuracy and edge finish desired, and the shape and number of parts.

2. Use of Square Shears.—When blanks are to have all edges straight, the square power shears furnish a rapid means of cutting them. The chief advantage of shearing is that no special tooling is required. The operator is supplied with the required dimensions of the blank or with a templet which is used for setting the stock gages on the shears. The blanks can then be cut rapidly and accurately, a tolerance of $\frac{1}{64}$ inch being generally specified on sheared parts. Shearing is an extremely flexible method, as it requires only a short set-up time and is suitable for either small or large quantities. Also, any change in design can readily be met by simply making a new templet. Shearing is considered so successful as a production process that it is employed for making small, flat parts of simple profile even though large quantities are required. Its chief disadvantage is that parts with sheared edges have less formability than those with smoother edges, such as those, for example, that are

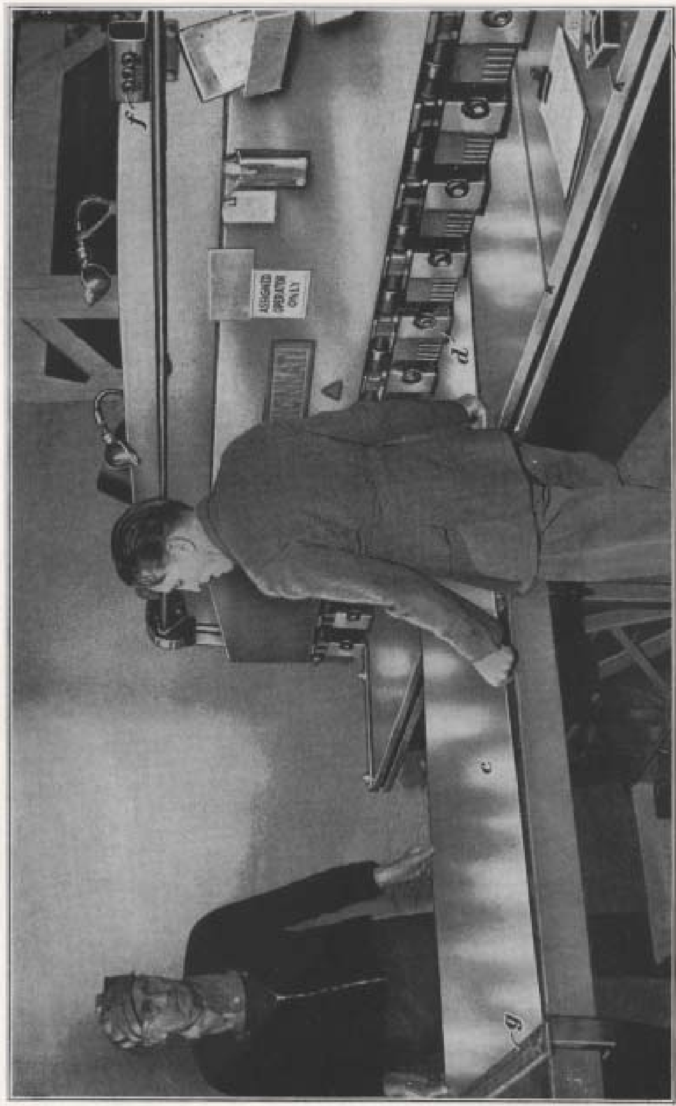


Fig. 1

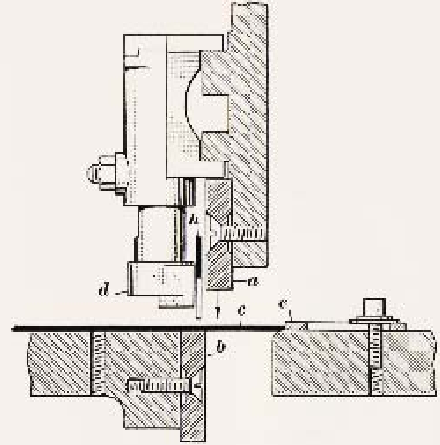


Fig. 2

produced by routing, since the irregular, sheared edges set up stress concentrations that sometimes result in cracking during the forming process.

3. Operation of Square Shear.—The square shear consists basically of a horizontal, stationary knife blade past which another knife blade is moved vertically. The machine is equipped with gages, hold-downs, and other accessories necessary for efficient operation. A large shear is shown in Fig. 1, and a set of assembled blades in Fig. 2. The upper blade *a* is attached to the ram of the machine, and the lower blade *b* is attached to the base. The upper blade is set at a slight angle to the lower blade so that the cutting edge has a shearing or a gradual slicing action. The sheet stock *c* is fed under the upper blade to a predetermined distance and sheared by tripping the foot treadle which causes the upper knife to move down past the lower knife. The accuracy of the operation does not depend on special skill or manipulation, but is due to the hold-downs, or fingers, *d* and the rake of the upper knife blade. When the foot treadle is first tripped, the holddowns descend and clamp the sheet flat against the top of the table. Then as the upper blade descends, it presses the stock against the lower blade with a pressure great enough to shear the strip.

4. The hold-downs, which are hydraulic on this machine, exert a uniform pressure along the full length of the stock and thereby prevent slippage of the metal, regardless of any variation in its thickness. On some machines the hold-downs are mechanically operated, but most operators prefer the hydraulic holddowns since all the plungers exert a uniform pressure that can be varied easily so as not to mark soft sheets, such as aluminum alloy, with high holddown pressures. As a further precaution, especially for Alclad stock, special leather or rubber pads are applied to the holddown plungers. Likewise, the metal table can be covered with some material, such as fiber, canvas, or a phenolic plastic, to prevent scratching the sheet metal. A cover such as the fiber or phenolic plastic is more serviceable than canvas, since the latter is easily torn by the sheet metal. Canvas will ordinarily last for about a week, whereas a phenolic cover will last about 3 weeks. When a section of the phenolic cover becomes roughened, it can be replaced without replacing the whole cover.

5. Stock Gages.—To have fast, accurate operation, gages, or stops, *e*, Fig. 2, should be provided for locating the sheet-metal stock quickly. Both front and back gages are supplied on most machines. They may be set parallel to or at an angle with the knife blades for making either square or angular cuts. For convenient operation, the back gage, which is an adjustable bar extending across the machine in back of the blades, may be set from the front of the machine by means of a push-button control *f*, Fig. 1, or it may be set by a hand wheel at the rear of the machine. In either case, the gage can be set directly to $\frac{1}{64}$ inch, or finer if desired. The front gage is similar to the back gage in its use, and generally consists of a bar sliding in a pair of slotted arms extending out from the front of the machine. In this case, the front gages *g* are cross-bars clamped to the work table. A side gage is also used when cutting at right angles to the gaging edge of the sheet. Other special gages that

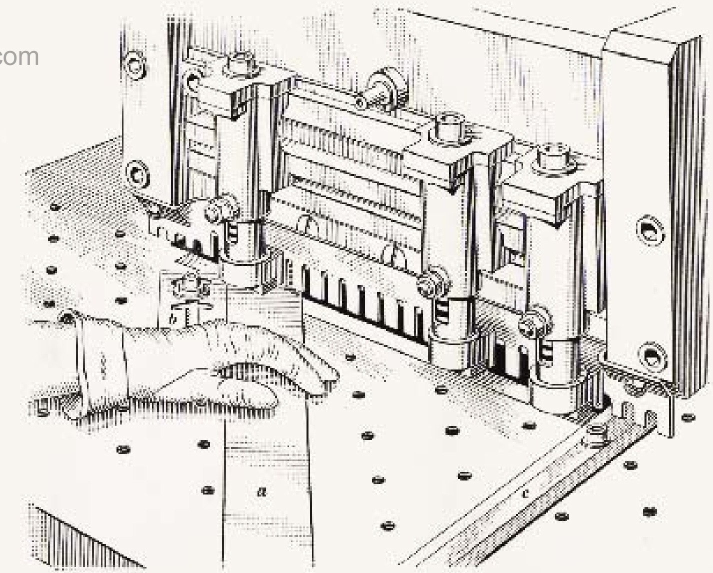


Fig. 3

may be used are the slitting gage for shearing in successive cuts sheets longer than the knife blades, and the light-beam gage for shearing to a scribed line. The latter type operates by casting a sharp shadow along the scribed line.

A safety guard *h* is provided to protect the operator.

6. Cutting Small Parts in High-Speed Shear.—Cutting small parts that have been presheared in a large machine can be done rapidly in a small, high-speed shear. With this machine there is no die cost, as there would be with a punch press, and no time is lost while the tooling is being made. Straight pieces can be sheared from strip stock with great rapidity, and if a number of different cuts are to be made on the same piece, the stock gages can be arranged so that the work can be slid quickly from one position to another without lifting it from the table. An operation of this kind is shown in Fig. 3. The aluminum-

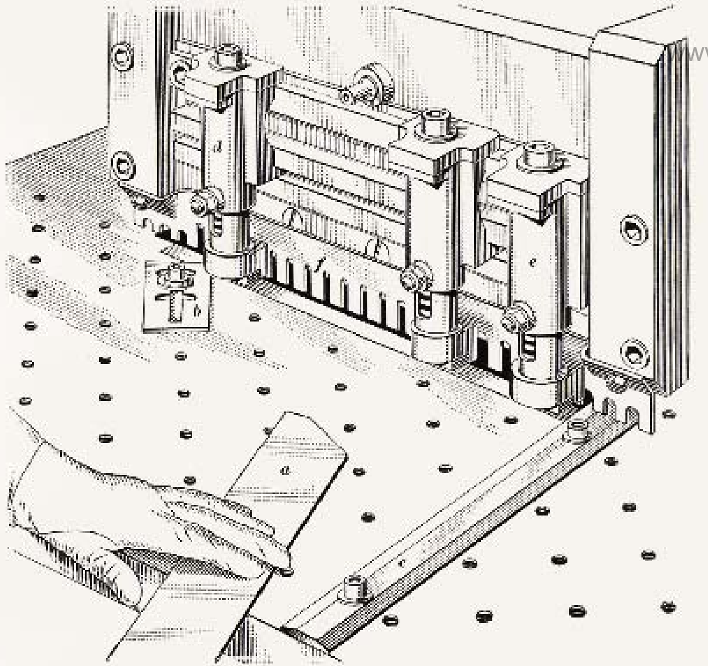


FIG. 4

alloy stripstock *a*, which has previously been sheared to the proper width on a large machine, is to be cut into a number of small, rectangular parts, with one corner sheared off at an angle. Two cuts are required to produce each part. To insure that these cuts are made at their correct angles, two guides *b* and *c* are clamped to the table which is arranged with a series of tapped holes for that purpose. The angular cut is made first by locating the strip stock against the guide *b* and also against a back gage which cannot be seen. One corner of the stock is cut at an angle, as shown in Fig. 4. The stock is then slid against the guide *c* for the squaring cut. A back gage is again used to locate the stock endwise. By a series of such alternating cuts, the strip can be sheared quickly into small parts.

While the two cuts are being made, the stock is held by spring-operated holddowns *d* and *e*, which are adjustable along their cross-rail. A comb-like guard fence *f* is set in front of the knife blades to prevent the operator from getting his fingers caught between the knives. Instead of such a comb fence, shears are often fitted across their front with a transparent plastic shield that prevents any accident to the operator, yet permits him to see more clearly any lines scribed on the sheet being sheared.

7. Re-Entrant Cuts on Square Shears.—Although by far the greater number of cuts made on square shears are exterior cuts, it is possible to make re-entrant cuts under certain conditions. For example, in cutting out the piece shown in Fig. 5, the three straight exterior sides *a* can be easily sheared. However, shearing sides *b* and *c* is more difficult but can be done by first drilling or punching a hole, at least $\frac{1}{4}$ inch in diameter, at the apex of the corner and then shearing into it. The upper blade is set at an angle by means of its vertical adjustment so that it descends just far enough to cut the necessary distance across the sheet; that is, the upper blade does not pass the lower blade for its full length, as in square shearing, but only far enough to cut to the drilled hole. Since this slitting operation is slow, however, it should be avoided whenever possible.

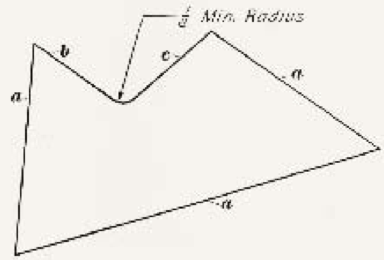
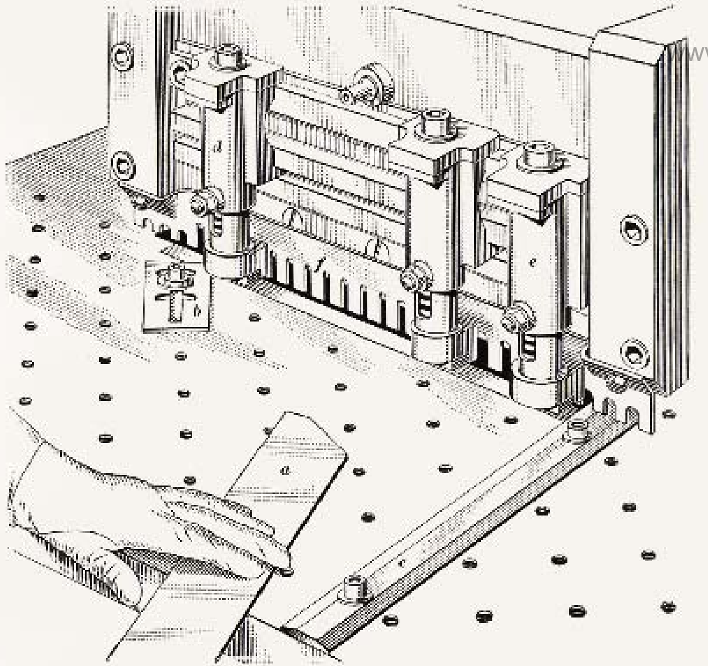


FIG. 5

8. Circular Shears.—Circular, or rotary, shears, which operate by shearing the sheet metal between two circular knife blades, are used to a limited extent in the aircraft industry for cutting blanks from flat sheet stock with the aid of templets that are of the required size and shape. Circular shears, however, are used far more for trimming formed sheet-metal parts. They are slow in operation and not especially accurate, but



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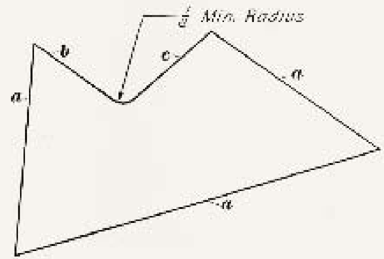

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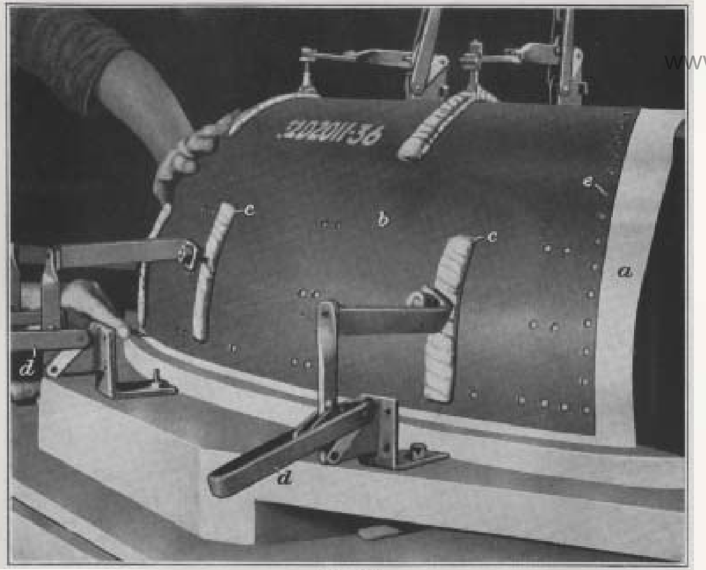

Fig. 8

placed in the fixture that was assembled to facilitate the application of the trim templet *b*. The templet is held firmly against the part by clamps *c* that are operated by their individual levers *d*. Curving the clamps to fit the different contours aids in holding the part firmly in the fixture. Besides having the same shape as the finished part so that it can be used for marking the trim lines, this particular templet also has holes *e* and serves as a drill templet. The holes in the templet are larger than those to be drilled, so that the hand drill that is used can be provided with a hole positioner around the drill.

The hole positioner *a*, Fig. 9, is tapered and can readily be centered in the templet holes. It is mounted on a spring *b* extending from the body of the drill *c*. As the drill is pushed down to drill the hole, the spring closes and allows the drill to pass through far enough to finish the hole. When all the holes, as indicated by the templet, have been drilled, trim lines on the part are marked with pencil around the outside edges

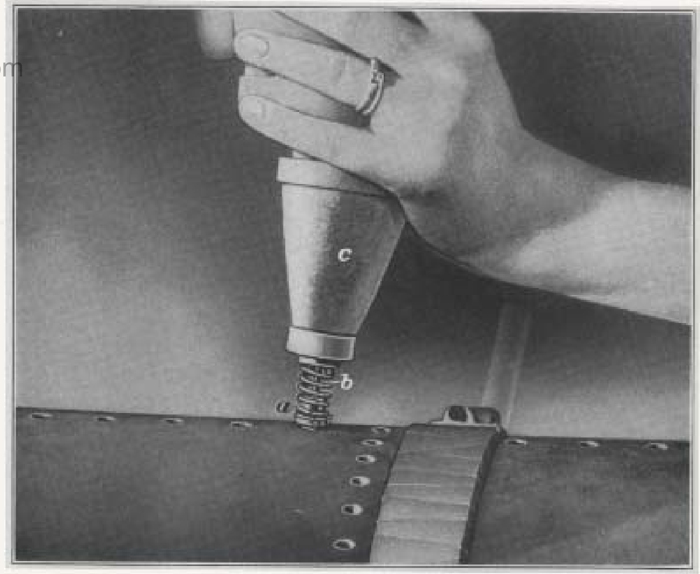

Fig. 9

of the templet. The part is then removed from the fixture and finish trimmed either in circular shears or by other methods.

11. Unishears.—Unishears are made in two types—the portable and the stationary. Each type consists basically of two small blades, set vertically opposite each other. The upper blade which is sharpened at an angle so that its cutting edge is diagonal to that of the lower blade, is oscillated rapidly, by an eccentric motion, past the lower blade, thereby shearing the material in a series of small cuts.

The portable unishear shown at *a* in Fig. 10 is operated by following a trim line marked on the part. It should be held upright and moved slowly along the line. On this particular part, a window frame, the center portion is to be cut out. To enable the operator to begin the cut, a hole large enough to receive the blade guide *b* must first be drilled at one corner of the cut. Parts up to .064 inch in thickness that are too large

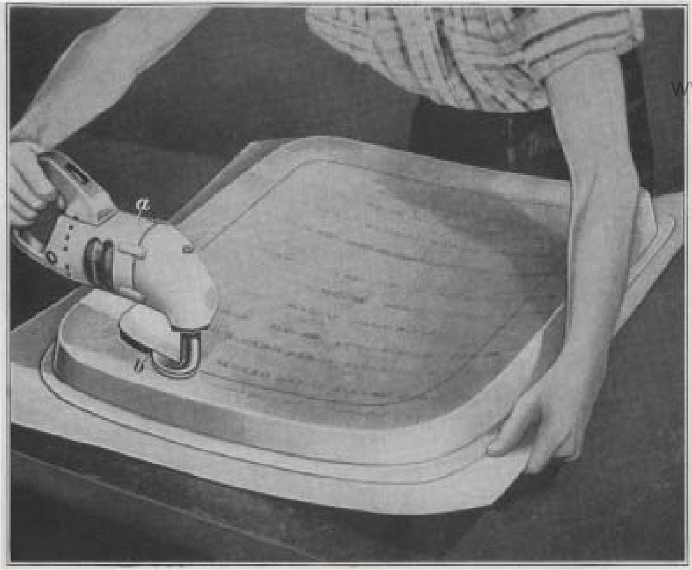

FIG. 10

to handle, parts that are not rigid enough for handling, and parts requiring trimming cuts that can not be made by other methods, can be sheared readily with portable unishears.

12. On the stationary type of unishears, the operator feeds the stock to the blades in much the same manner as with the circular shears. Since no guides or stops are provided, the sheet stock must be marked along the line of cut, usually by running a pencil around the layout templet. The sheet is then fed through the cutters, as shown in Fig. 11, at a speed of about 15 feet per minute.

Both straight and curved cuts can be made with a unishear on various metals. Sheet steel up to .125 inch in thickness can be cut readily, whereas the maximum thickness of aluminum-alloy sheet that can be sheared is less because of its tendency to buckle. Since the shearing is actually a tearing action that tends to bend down the unsupported side of the sheet, metal

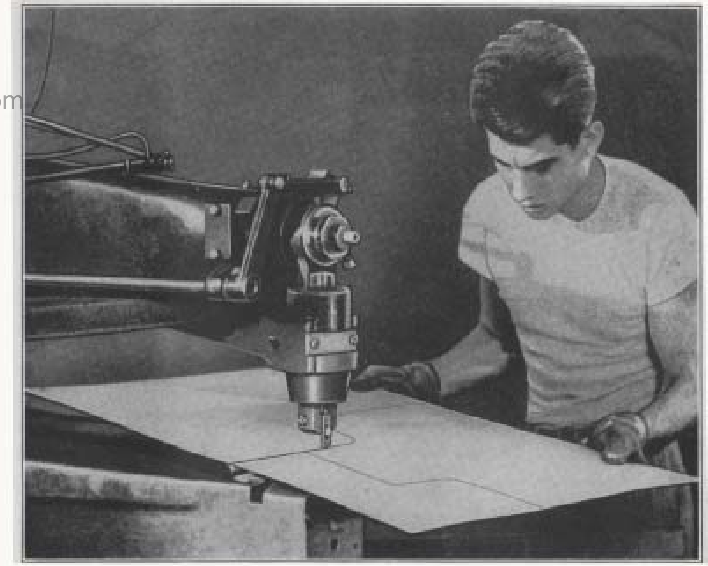

FIG. 11

that lacks stiffness is difficult to cut on the unishear. The shearing action also causes distortion of the metal, especially in slender parts. The stationary unishear is therefore used mostly for trimming formed parts that are strong enough to withstand the warping effect, and for cutting sheets into blanks for subsequent forming. The accuracy of the sheared parts depends on the skill of the operator and can generally be maintained to within a tolerance of .03 inch. The edge condition, however, is usually not acceptable on finished parts, because of the slight nicks, especially on the curves, but it can be remedied when necessary by burring the sheared edges.

13. Hand-Operated Shears.—In all aircraft plants, a considerable amount of sheet metal is cut by hand-operated shears of either the hand or bench type. Several kinds of hand shears, or metal snips, are used for rough-trimming formed parts and for cutting out small quantities of blanks from sheet-metal stock. Straight hand shears are used for making straight cuts that are too short to warrant the use of a square shear and for cutting out curved parts of fairly large radius. More-irregular shapes are generally cut with aircraft hand shears, which are made in both right-hand and left-hand types. The right-hand shear makes a curved cut to the left, whereas the left-hand shear cuts to the right.

14. Bench shears are also commonly used for trimming formed parts. This type of shear consists of a fixed blade and a movable blade that is attached to a handle and hinged at its back end, so that it can be pulled by hand past the fixed blade to cut the sheet metal. These shears are made with either straight or curved blades, depending on the kind of cuts to be made. The cutting should be done by making a series of short cuts in order to avoid tearing the sheet at the end of each cut. The curved-blade type, which is known as the throatless shear, cuts with less distortion than does the straight-blade shear, and leaves an edge that generally requires no burring or filing. It is often used for the finish trimming of parts that have first been rough trimmed in a band saw or a unishear. Either before or after rough trimming, a trim templet is applied to each part and trim lines are scribed around the trim templet to act as a guide in the finish trimming operation.

15. Edge Burring.—When sheet metal is sheared, or blanked out by other methods, the edges of the blanks are liable to be uneven or rough because of sharp fragments of metal left along the edges. These fragments, or burrs, should be removed before the forming operation to prevent cracks from developing at these points, especially where the sheet is bent at a rough spot. The burrs can be removed by scraping, filing, or by machine methods. Two types of edge scrapers, or burring tools, are in common use. One consists of a piece of hardened steel, approximately 6 inches long, with a V-shaped notch in one end that is drawn lightly along the edge of the sheet to scrape off the burrs. The other type has two small, hardened cutting wheels that are attached, tangent to each other, to a handle.

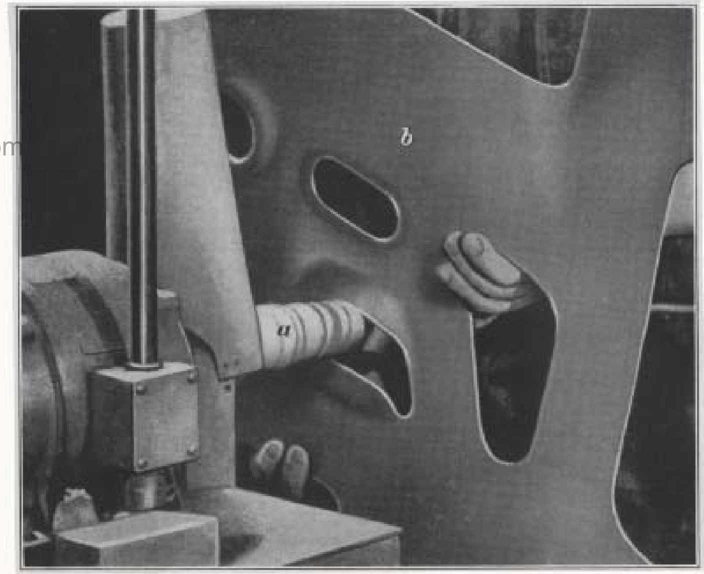

FIG. 12

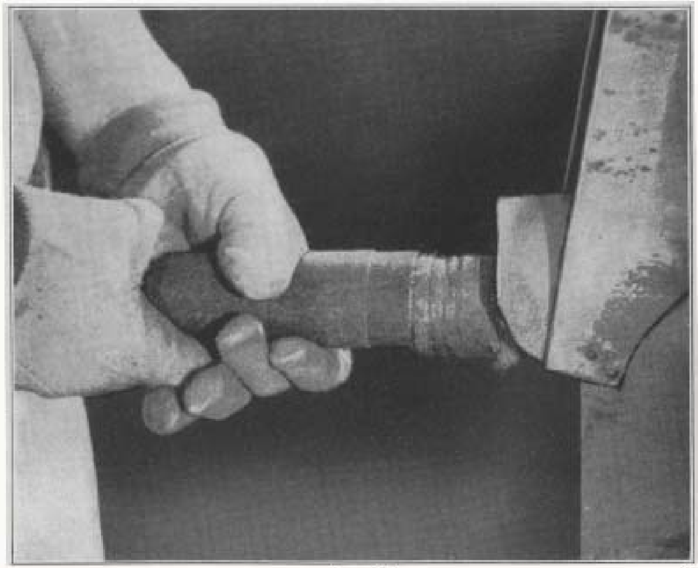

FIG. 13

To burr a sheet, the wheels are slid along its edges, but not too heavily since too much pressure may remove enough metal to chamfer the sheet.

16. A convenient method of burring sheet-metal parts is illustrated in Fig. 12. The spindle *a* of the burring machine is wrapped with steel wool which is then covered with an abrasive, such as emery cloth. The emery cloth is applied to the spindle by rolling it cone-shaped, sliding it over the steel wool, as shown in Fig. 13, and tying it tightly in place. The sheet-metal part *b*, Fig. 12, which in this case has been routed to shape, is burred by running its edges around the rotating burr so that the emery cloth sands off the rough projections. Since the edges of the part cut through the emery cloth, the steel wool underneath polishes them to a smooth finish. The use of such a machine makes the slower hand-burring operation unnecessary. Another burring machine that works well consists of two serrated rolls through which the sheets are passed to remove the burrs.

SAWING

17. Band Saws.—The band saws used in the aircraft industry for cutting both ferrous and non-ferrous metals are of two types, namely, the ordinary wood-shop band saws, and the special contour saws, such as the Do-All and other makes. The wood-shop saws are used for rough trimming formed parts that are later to be finish trimmed on a shaper, for cutting aluminum-alloy bar, plate, or extruded stock, and for performing similar operations. The contour saws can be employed for cutting aluminum-alloy stock that is too heavy for the ordinary band saw, but they are used far more for the precision cutting of aluminum alloys and steel, such as is required in die and templet production. Band saws can be used for close work by special care in feeding, but the resulting edge condition is rough and not satisfactory on finished parts.

18. The usual band saw consists of an endless blade traveling in the manner of a belt over two wheels, or disks, set one above the other. These disks, which are equipped with brakes for quick stopping, range from 12 to 36 inches in diameter, with the 30-inch size being most popular for the general run of aircraft work. Many band saws have only one operating speed, which is usually about 1,500 feet per minute for sawing aluminum-alloy sheet. The speed of the larger machines, however, may run up to several thousand feet per minute, and some means of changing the speed is desirable. The lower disk, which is motor driven, drives the saw blade down past the work that is placed on a table located between the two disks. The blade *a*, Fig. 14, passes through the center of the table *b*, which can be set at right angles to the blade for vertical cuts or at an angle to the blade for angular cuts. To prevent chatter and vibration, the blade should be supported by a guide *c*.

When a large part, such as the aluminum-alloy door frame *d*, must be trimmed on its inside contour, it is often convenient to place the part down over the upper disk and set the table at an

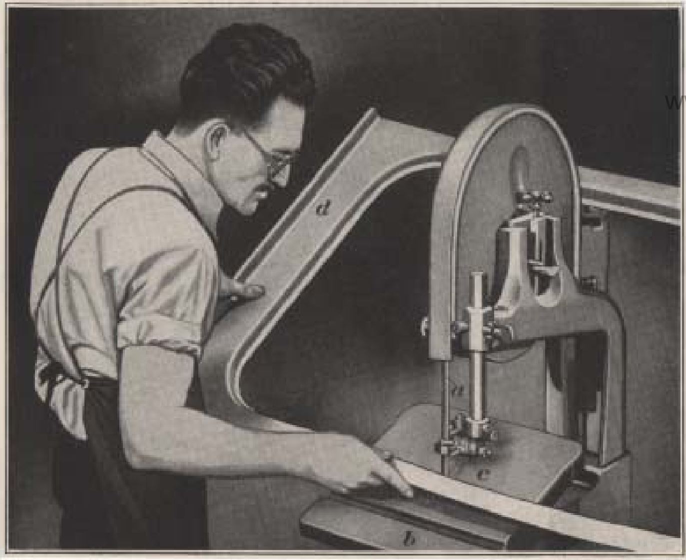

FIG. 14

angle that will afford good support for the lower edge of the part. If the part is too small to be placed over the upper disk when its inside edge is to be trimmed on a band saw, the endless blade must be cut, threaded through the hole, and then welded. Special welding devices are provided on contour saws for this purpose, but trimming of inside edges usually can more conveniently be done by other methods. When several parts are ganged and cut at one time on a band saw, they must be fastened securely together to prevent the blade from weaving in the cut.

19. When formed parts are trimmed on a band saw, the table of the saw may be equipped with a small pedestal for supporting the part. Thus the table *a* of the saw in Fig. 15 has clamped on it a small pedestal *b* that is slid over the saw blade. The formed part *c*, which is a skin panel for a bomb-bay door, is then supported on this pedestal and the flanges are trimmed off. Without such a pedestal, many parts cannot be well sup-

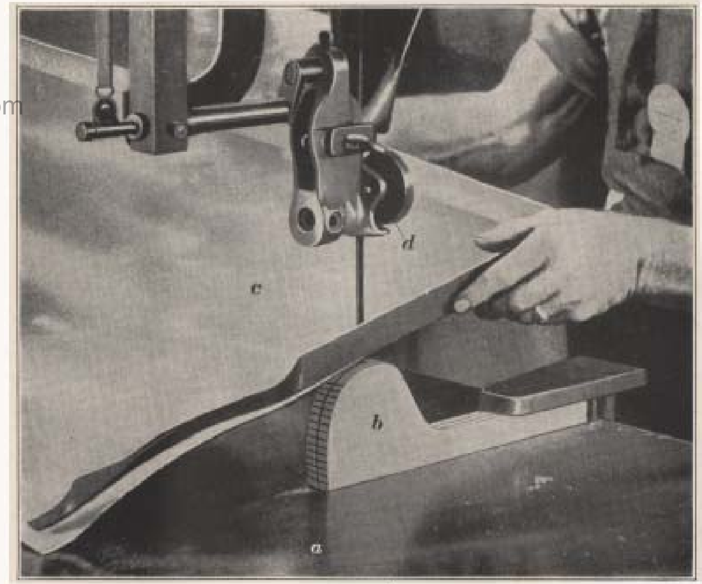

FIG. 15

ported on the table at the point of cutting and therefore would vibrate too much for accurate trimming. On this saw too, the blade is supported just above the work by a roller guide *d* that also acts as a guard.

20. Band-Saw Blades.—The band-saw blade that should be used for any particular operation depends on the kind and shape of the material to be cut. For aluminum alloys, the blade should be medium hard and have from 12 to 32 teeth per inch of the straight or wave type. Straight teeth are set to alternate, one tooth to the right and the next to the left, whereas wave teeth alternate in groups of teeth. As a general rule, a soft alloy requires fewer teeth per inch than does a hard alloy, and thin stock requires a greater number of teeth per inch than does thick stock so that at least two teeth will always be in contact with the work. The least number of teeth per inch that will cut satisfactorily should be selected to reduce friction and to obtain the maximum chip clearance. The amount of chip clearance is especially important for *SO* stock since such soft material has a tendency to clog the teeth.

21. Band saws may be fitted with a variety of blades of different widths, the type to be used depending on whether straight or contour cutting is to be done. General practice is to use as wide a blade as possible in order to get maximum blade strength for heavy feeds, but the curvature to be cut limits the width of the blade that can be used. In Table I is shown the proper width for the corresponding minimum radius of curvature, the teeth in this case having a width of .042 inch with approximately .007 inch on a side. By careful handling, smaller radii than those specified in the table can be cut with these blades.

The 90° radius listed in the table for a $\frac{1}{16}$-inch saw blade indicates that with a saw of this type, an approximately right-angle corner can be cut.

TABLE I

MINIMUM RADII FOR VARIOUS WIDTHS OF SAW BLADES

Width of Saw Blade—Inches	Minimum Radius of Curvature—Inches
$\frac{1}{16}$	90°
$\frac{3}{32}$	$\frac{1}{16}$
$\frac{1}{8}$	$\frac{1}{8}$
$\frac{3}{16}$	$\frac{5}{16}$
$\frac{1}{4}$	$\frac{5}{8}$
$\frac{3}{8}$	$1\frac{7}{16}$
$\frac{1}{2}$	$2\frac{1}{2}$

22. Butt-Welding Fixture on Contour Saw.—When inside cuts on a part are to be made with a contour saw, the blade of the saw is cut, threaded through a hole that has previously been cut out or drilled, and then welded together. First, a slide in the table is removed and the upper part of the blade is taken from

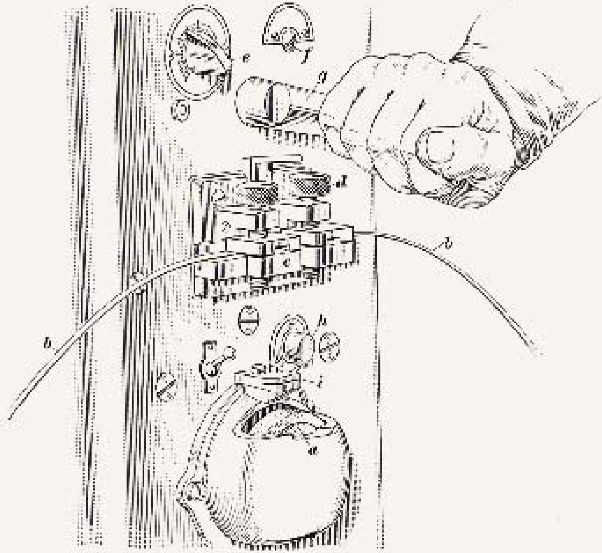

FIG. 16

its guides. The blade is then cut with ordinary hand clippers and the lower part of the blade is passed through the hole in the work. The ends of the blade are next squared on the grinding wheel *a*, Fig. 16, either by grinding each end on the side of the wheel, or by grinding them on the face of the wheel. Very little grinding is necessary when the blade has been cut carefully. It is good practice to grind both ends in one operation by holding them together so that the teeth point in opposite directions. The two ends will then match perfectly when turned over, regardless of the angle of grinding.

23. The ends of the blade *b* are clamped in the butt-welding fixture *c*, Fig. 16, with the rear edge of the blade against the ledge back of the terminals. This ledge lines up the ends, so that the blade will be straight after welding. The two ends should meet at the center of the welding gap, with no offset either in thickness or across the width. An overlapping weld will not hold, and if the teeth of the blade are not in line, the blade

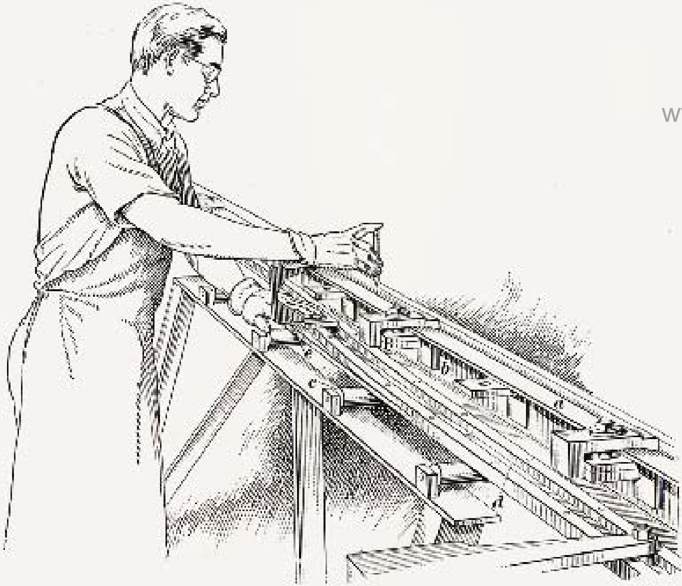

Fig. 17

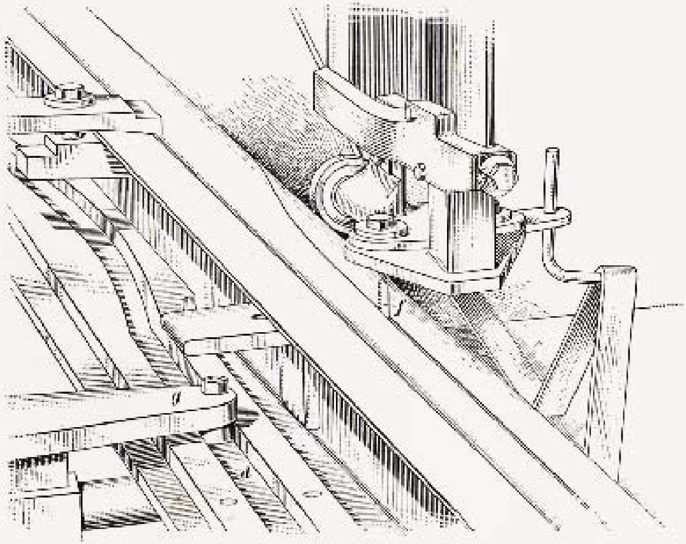

Fig. 18

will not saw smoothly. When a blade of $\frac{1}{4}$ inch or less in width is welded, the upper gap of the fixture *b*, instead of the lower one as shown, is used, the ends of the blade being clamped by screwing the thumb screws *d* and their attached plates upward. For blades from $\frac{1}{16}$ to $\frac{3}{16}$ inch in width, a gap of approximately $\frac{1}{64}$ inch should be left between the ends to avoid piling up metal at the weld.

The spring pressure of the moving jaw is selected, according to the width of blade, by the knob *e*, and the line voltage is regulated by the screw-driver adjustment switch *f*. The switch lever *g* is then pressed down until the weld is made and has cooled below a red heat.

24. Since the steel in the welded area air-hardens and becomes brittle, the weld must be annealed to obtain the original hardness. The blade is reset in the clamp *c*, Fig. 16, in the annealing position, which is at the front of the lower gap. The button *h* is pressed to heat the blade to a dull, cherry red and then released to allow the blade to cool. As slow cooling is desirable, the button can be pressed intermittently at progressively longer intervals until the weld is completely cool. A heat that is too high, such as a bright red, results in a brittle weld and should be avoided. The flash of the weld is then ground off on the grinding wheel until the welded section of the blade is no thicker than the blade itself, so that it will pass freely through the saw guides. The thickness at the welded section is tested in the gage *i*. To avoid twisting the blade in order to grind the top side of the weld, the wheel guard is cut away at the bottom. One side of the weld can then be ground on the top of the wheel, and the other side on the bottom. The weld should be ground off until the blade fits easily into the gage slot.

25. Special Band-Saw Applications.—By the use of various types of fixtures, band saws may often be used for special applications. A fixture designed to hold and guide wingspar caps while they are being sawed is shown in Fig. 17. The spar cap *a* is clamped to a long table *b* that can be moved lengthwise on rollers *c*. Along one side of the table there is a templet with

Fig. 19

a groove *d* that has the same lengthwise contour as the desired cut. As the table carrying the spar cap is fed toward the band saw, a stationary guide that fits in the groove moves the table cross-wise on the rollers according to the contour of the groove.

After the spar cap is clamped in place on the fixture, the line of cut is marked by a bracket *e*. This backet has a pencil inserted in one end, and on the other end it has a guide block that fits in the groove *d*. By moving the bracket along the groove and keeping the pencil in contact with the work, the line of cut can be drawn. This line serves as a check on the actual cut being made. Thus, in Fig. 18, the band-saw blade *f* is cutting exactly on the line as the work is being fed lengthwise to the saw and guided cross-wise by the guide *g* in the groove *d* of the fixture.

26. Table Saws.—Another wood-shop machine that is used to good advantage in the aircraft industry for cutting soft metals is the table circular saw. This type of saw is employed for cutting solid stock, extrusions, and formed parts up to a depth of 3 inches. The circular saw blade is supported on a horizontal arbor beneath the table, with only the cutting segments protruding above the table. To make angular cuts, some saws have tables that tilt, whereas on other machines the saw blade and its arbor can be tilted the required amount. The work is held against steel table guides or special work holders while it is fed to the saw blade.

The use of a table saw for cutting a formed part is illustrated in Fig. 19. The blade *a* is adjusted vertically so that it projects just far enough to make the required cut. The part *b* is placed on the wooden fixture *c*, which has a guide fitting in a slot in the table top. The fixture can then be fed forward to saw the rear corner *d* of the part to the same shape as that to which the front corner *e* has already been cut in a previous, similar operation. The saw blade is lubricated occasionally with the block of paraffin *f*. Heavier cutting operations may require a more effective lubricant, such as a light oil mixed with kerosene, or any of the compounded cutting fluids recommended by their manufacturers.

27. Sliding-Frame Saws.—On sliding-frame saws, a circular saw blade and its motor are mounted in a frame that can be moved as a unit across a long table. The saw is moved forward and backward by hand, and for cross-cutting operations is drawn across the stock, which may be an extrusion, tubing, or a similar part. The blade can be tilted vertically or the arm can be swung about horizontally, so that the saw can cut either single or compound angles as desired. Since this type of saw is used on parts of small cross-section, no lubrication need be used.

28. Miscellaneous Saws. Other saws that find use in the aircraft industry are the swing saw and the power hack saw. Dural extrusions and tubing can be quickly cut by swing saws, which are so mounted in a frame that they can be swung down by a hand lever to bring the blade in contact with work lying on the table of the machine. Angular cuts may be made by tilting the saw blade. Power hack saws are used for cutting many different metals and find their greatest application in cutting raw

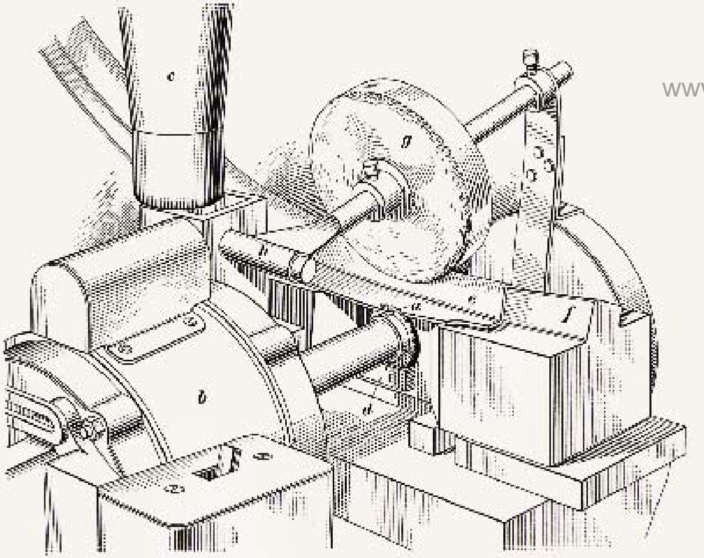

FIG. 20

stock into convenient lengths. They are not used for cutting sheet metal, but primarily for cutting rod and bar stock in the machine shop.

29. Special Trimming Saw. Many aircraft plants have built special saws for particular operations that are difficult or impossible to perform on the regular types of saws. An example of such an operation is the trimming of a part that has been formed to a double contour. As shown in Fig. 20, a circular saw blade *a* is mounted on the spindle of an electric motor *b* that operates at about 1,725 revolutions per minute. The saw is lubricated by gravity feed from an oil reservoir *c* to a sump *d* just beneath the blade. As the saw blade passes through the soluble-oil mixture in the sump, it picks up enough oil for proper lubrication and cooling. The sump is built into some of the work fixtures that are used on this machine.

The part *e* to be trimmed is guided past the saw blade on the Kirksite, or zinc-alloy, fixture *f*. A rubber disk *g*, which is pivoted at *h* and weighted at the outer end of its shaft, holds the work firmly against the fixture and prevents its springing up as the cut is being made. For trimming other parts, the work fixture may be replaced by fixtures that are adapted to the parts, the rubber hold-down disk may be changed to another size if necessary, and the pressure exerted on the work by the hold-down disk may be varied to suit the part by changing the weights on the end of the shaft.

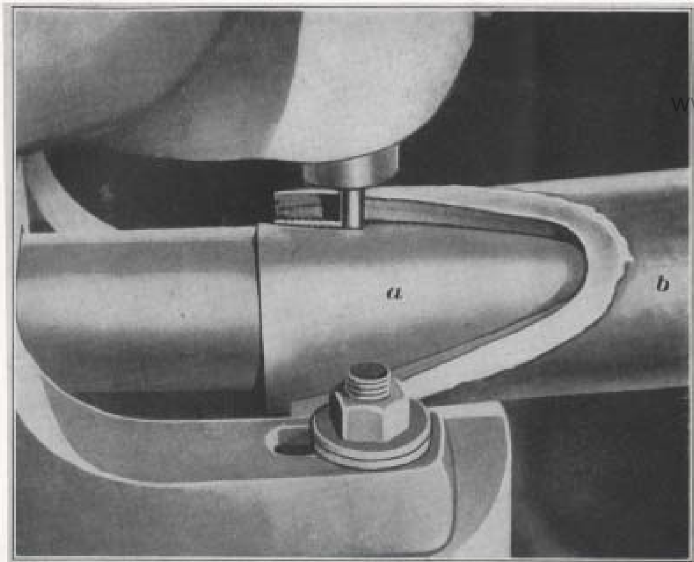

FIG. 21

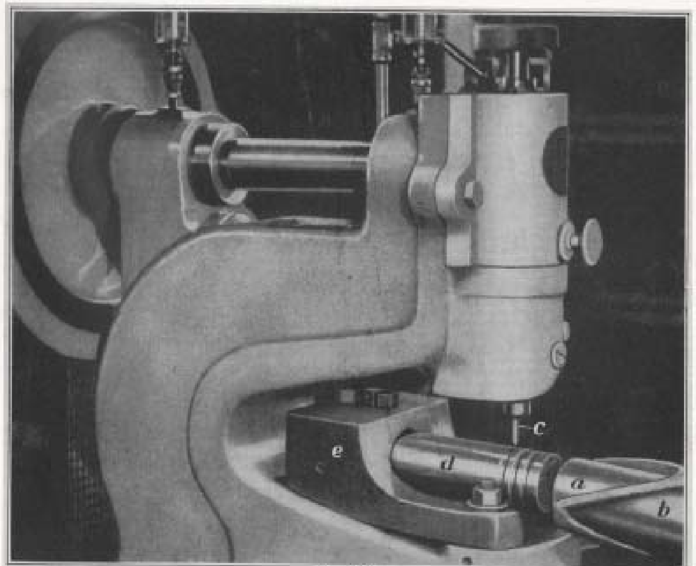

FIG. 22

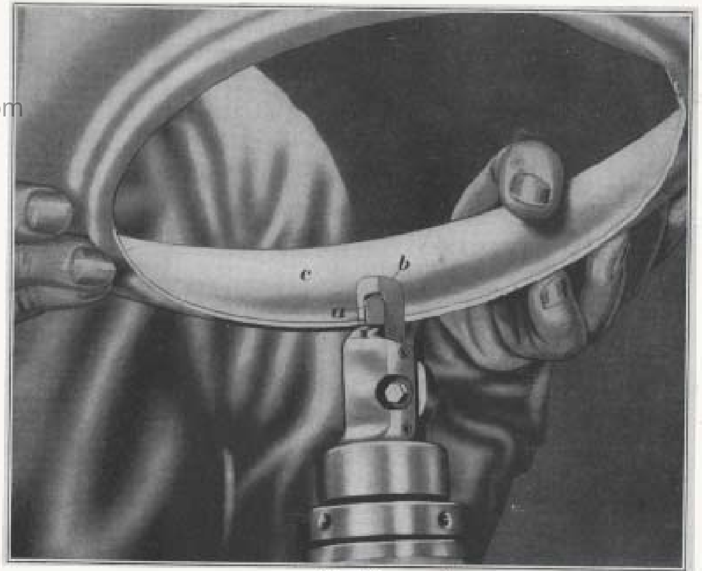

FIG. 23

NIBBLING

30. Machine Nibbling.—Nibbling machines are used for the rough cutting of parts made from heavy gage steel and aluminum-alloy sheet, for some trimming operations, and for cutting the ends of tubes to fit into truss structures. The nibbling machine shown in Fig. 21, is set up for cutting the end of the tube *a* with the aid of the nibbler pattern, or templet, *b* to a fish-mouth shape for welding into the structure. This machine operates on the same principle as a punch press. The cutting is done by a ram-operated punch *c*, generally $\frac{3}{16}$ or $\frac{1}{4}$ inch in diameter, that fits into a hole in the die *d* and cuts out a series of overlapping holes as the metal is fed into it. The die *d* is held at one end in the block *e*, and is made of such size that the tube will just fit over it and be well supported during the nibbling operation.

A cut being made is shown in Fig. 22. The operator feeds the tube *a* and templet *b* over the die in such a manner that the punch will cut along the edge of the templet to make the required cut-out. Even though small bites are taken from the metal, the edge will be slightly serrated and, for purposes other than welding, will require filing or finishing on a disk or belt sander.

The type of nibbling shown in Fig. 23 has no upper ram carrying the punch; instead, the cutting is done by a punch *a* reciprocating past a cutting edge on the die *b*. The part *c* is fed between the punch and die and then rotated to trim along the inner edge.

31. Hand Nibbling.—Nibbling of tubing and sheet-metal parts can also be done by hand nibblers that operate much in the same manner as the nibbling machines. The hand nibblers are driven by integral electric motors and are fed into the work by hand. Outside and inside edges can be trimmed easily by following trim lines scribed on the formed part or by guiding the nibbler around a templet that is clamped to the work. Holes as small as 1 inch in radius can be cut out without cutting in from the edges of the stock.