This invention relates to apparatus for forming propeller blades from hollow metallic blanks, and is a continuation in part of my application for Letters Patent of the United States for improvements in Propeller blade and method and apparatus for producing same, filed April 16, 1931, Serial No. 530,541.

Objects of the invention relate to an improved apparatus for forming propeller blades; to improve the method of supporting of this kind of forming by engagement only with its root end portion which is not deformed in the pressing operation so as to obviate the cooling effect which would otherwise be caused by contacting of the remaining parts of the blank which are to be deformed, with the dies and their supporting structures; to prevent unintended deformation in restricted areas of the finished product by a precooling of limited areas of the blank; to provide a yieldably mounted supporting structure for holding a heated propeller blade blank between, and in spaced relation to a pair of forming dies which is adapted to guide the movement of the blade, as the dies are brought together, so as to properly place the blade in the die depression; to provide a yieldably mounted support of this kind which is movable axially of the die depression for permitting inward movement of the root end of the blade during shrinking thereof upon cooling after it is pressed to the desired blade shape; and to provide a detachable holding member in a supporting structure of this character for receiving the flanged root end portion of the blank, which is adapted to be removed and replaced so as to condition the supporting structure for receiving blanks of different sizes and shapes.

Other objects include the provision of a die structure of novel configuration for pressing a propeller blade blank to blade shape; to provide such a die structure a portion of which may be employed in pressing blanks to blade shape regardless of the length of the blade; to provide such die structure in which the end portion thereof employed for pressing portions of the blade are readily removable and replaceable by corresponding portions adapted for use in forming blades of different characteristics; and to provide dies and apparatus for forming propeller blades which are fabricated from two or more sections so as to permit interchanging of the various forming parts of the die.

Other objects are to provide improved die holders of novel conformation for use in connection with pressing a propeller blade blank to blade shape which holders have passages for conducting a cooling medium therethrough so as to prevent overheating of and regulation of the temperature of the dies and their supporting structures during the repetitions of the compressing operations which occur within short time intervals in manufacturing propeller blades on a production basis; to provide improved means for mounting the dies in the die holders by means of which dies of various dimensions may be secured in place; and to provide means and apparatus whereby the rate of heat interchange between a heated blade blank and the forming dies therefore may be accurately and continuously controlled during production of such blades so as to effect the desired physical structure in the finished blade.

Other objects are to provide improved mechanism in propeller blade forming apparatus for forming a communicative connection between the interior of a tubular propeller blade blank and a source of pneumatic pressure so as to internally support the blank against collapsing during the compressing operation; to provide mechanism of this character which is adapted to quickly form a hermetically sealed connection to the open end of a heated propeller blade blank before a substantial reduction in the temperature of the blade occurs; to provide a sealing member for the open end of the tubular blank which has a greater area exposed to the source of pressure than that which is exposed to the internal pressure of the blank so as to create a substantial pressure differential on the outside of the sealing member so as to tend to firmly hold the latter in a hermetically sealed condition against the open end of the blank by pneumatic pressure; to provide sealing means of this kind in which the pressure differential is augmented by reductions in pressure in the interior of the blank such as are caused by leakage of air from the open end thereof.

Other objects of the invention are to provide a yieldably mounted supporting structure for receiving the flanged end of a propeller blade blank in which a passage is formed for conducting a cooling medium around the flanged end portion of the blade; and to provide a supporting structure of this kind which may be used in conjunction with die-holding members having cool...
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ing medium passages so as to cool the entire blade uniformly and with pneumatic pressure applying apparatus during a quenching operation in which the outer faces of the blade are pneumatically urged against corresponding surfaces of the die.

Other objects include the provision of dies for pressing a propeller blade blank to blade formation in which certain portions of the die depressions are of greater dimensions than the corresponding portions of the blades to be formed thereby; and to provide such dies in which that portion of the die depressions adapted to form the tip of the blade are of greater lateral and longitudinal dimensions than the corresponding portions of the blade to be formed thereby.

The above being among the objects of the present invention, the same consists of certain novel features of construction and combinations of parts to be hereinafter described with reference to the accompanying drawings, and then claimed, having the above and other objects in view.

In the accompanying drawings which illustrate a suitable embodiment of the present invention and in which like numerals refer to like parts throughout the several different views, Figure 1 is a side elevational view of a hollow metallic blank adapted to form a propeller blade when properly acted upon by suitable apparatus.

Figure 2 is a transverse sectional view taken on the line 2—2 of Fig. 1.

Figure 3 is a side elevational view of a propeller blade which has been formed from a blank of the character disclosed in Figs. 1 and 2.

Figure 4 is a transverse sectional view taken on the line 4—4 of Fig. 3.

Figure 5 is a fragmentary perspective view of an improved forming apparatus preferably employed for pressing the blank indicated in Fig. 1 to blade shape, showing parts thereof removed to disclose the underlying structure.

Figure 6 is a horizontal sectional view taken centrally through the forming apparatus as on the line 6—6 of Fig. 7, showing the dies thereof in closed position and illustrating the manner in which the blank is mounted and internally supported.

Figure 7 is a vertical sectional view taken on the line 7—7 of Fig. 6.

Figure 8 is a fragmentary partially broken top plan view of the apparatus illustrated in Fig. 6, a portion of the upper wall having been removed to disclose the cooling medium passages therein.

Figure 9 is a front end view of the forming apparatus showing the die holders and dies in their adjacent closed position.

Figure 10 is a transverse vertical sectional view taken on the line 10—10 of Fig. 6.

Figure 11 is a front end view, similar to Fig. 9, but showing the die holders and dies spread apart and the blank supported between the dies in spaced relation to both thereof.

Figure 12 is a fragmentary vertical sectional view taken on the line 12—12 of Fig. 8.

Figure 13 is a fragmentary perspective view of a quenching apparatus into which the forming apparatus above disclosed may be conveniently connected by the addition of accessory equipment and showing a further development of this phase of my invention.

Figure 14 is a front end elevation of the structure in Fig. 13.

Figure 15 is a fragmentary longitudinal sectional view taken vertically through the center of the structure shown in Figs. 13 and 14, as on the line 15—15 of Fig. 14.

Figures 16, 17, and 18 are views corresponding to a fragment of the views shown in Figs. 6, 7, and 10 respectively, showing a variation in the formation of the die depressions from that shown in the previous figures.

Referring to the drawings in Fig. 3 is shown a propeller blade of the hollow metallic type including a main body 100 having a tip 102 on one end thereof and a radial flange 105 at the other end thereof, the flange 105 serving as a means for securing the blade in a hub (not shown). The body 100 of the blade for the greater part of its length is of course formed to an airflow 15 section such as indicated in Fig. 4 to provide a leading edge 108, a trailing edge 110, a front or camber face 112 and rear or flat face 114. It is of course also understood that the body 100 of the blade is twisted or warped over its length so that each increment of length has substantially the same pitch with respect to the axis of rotation of the propeller of which it is to form a part. In accordance with the present invention, the blade shown in Fig. 3 is preferably formed from a blank of the general type indicated in Fig. 1, namely, a hollow metallic blank 112, which may be formed from any suitable metal but which, for the purpose of illustration only, may be considered as formed from a suitable low carbon steel and preferably of a type similar to the types known as S. A. E. 4130—X and S. A. E. 6135. As indicated in Fig. 2, the blank 112 is preferably of circular section and one end thereof is tapered down or reduced in diameter to form a small closed end or nose section 134 and the flange 105 is preferably formed at the opposite end prior to its being pressed to the blade formation indicated in Fig. 3. The wall thickness of the blank preferably decreases from the flange 105 toward the small closed end or tip but as pointed out in the application of which the present application is a continuation in part, the extreme tip end of the blank 112 is preferably, particularly in the larger sizes, provided with a tip end wall of increased thickness as compared to the adjacent portions of the blank. Also it is preferably, particularly in the larger sizes of blades, to provide a small nipple 111 on the extreme point of the closed end of the blank to prevent splitting of this end in subsequent die pressing operations.

An understanding of the method is obtained by pressing the blank to blade shape in the dies will be of aid in the proper understanding of the die structure and, accordingly, a short statement of this method is given at this point. It will be understood that the die structure includes two main parts relatively movable toward and away from each other, the adjacent faces of the parts having opposed depressions therein which cooperate, when the dies are in closed position, to form a recess of the exact shape and contour and, preferably, except for the outer stages of the blade, as will be explained in greater detail, the exact size of the desired finished blade. In this connection it may be noted that in the broader aspects of the present invention the die depressions may cooperate to form a depression conforming exactly throughout to the exact size and contour of the desired finished blade as hereinafter shown and described, but a more limited phase of my invention deals with making the outer or tip stages of the depressions wider and longer than the corresponding portions of the desired blade, this having been found desirable.
under certain conditions, and accordingly this last feature is shown as the preferred form in the drawings.

In operation, the blank is taken from a suitable furnace in a highly heated condition, the die being so arranged that the heated blank is placed between the die parts and its interior is placed under a suitable air pressure, and the dies are then brought together, causing the exterior of the blank to assume the shape of the walls of the die depressions. The purpose of placing the interior of the blank under pressure is to cause it to be expansively pressed outwardly into contact with the walls of the die depressions during the pressing operation, thereby insuring substantially complete contact between the blank and the walls of the depressions over the entire outer surface of the blank. The air pressure employed for this purpose, while high enough to insure the effectiveness of its purpose, is, of course, not sufficiently high to endanger bursting of the walls of the blank. It has been found that an air pressure of the order of 600 pounds per square inch is ample for the purpose described, but this pressure may vary in accordance with the size and wall thickness of the particular blank being worked upon. In applying such air pressure to the interior of the blank it is, of course, necessary for optimum results that such pressure be exerted at the desired maximum value substantially immediately upon admitting the air to the blank and be maintained at such value during the operation. For this reason it is preferable to employ an air receiver tank (not shown) in connection with the air supply and maintain the pressure in it at a sufficiently high figure to insure an ample supply of air for the operation at the desired value. In any case it will be apparent in connection with this phase of the operation that the temperature of the air to which the interior of the blank is subjected, of course, a certain relation between them, the temperature necessarily being such as to permit the necessary bending of the walls of the blank into blade forming position without causing any undesirable stress or fracture of the metal of the walls and, of course, sufficiently high to insure the internal pressure of the air forcing the blank into substantial contact with all surfaces of the die depressions when the dies are brought together, but preferably a temperature not so high as to permit the expansive force of the air to stretch the metal of the blank.

In placing the heated blank between the dies, it is further desirable to maintain the main body portion of the blank out of contact with the dies until the dies are actually brought together, for otherwise any area of the blank which contacted with the dies might be cooled to such an extent that when the dies were brought together that area would have become so rigid as not to properly conform to the shape of the corresponding depression wall area of the dies. Unequal cooling might also set up undesirable unequal stresses in the metal at various points in the blank. In view of the fact that the blank or root end portion of the dies results that the internal heat is not dissipated uniformly during the pressing operation, this portion of the blank is preferably employed for supporting the blank in the dies before the dies are brought together as it thus makes little difference whether it is pre-cooled or not.

Where the dies are employed for successively forming a large number of highly heated blanks to blade shape, by repeated contact with successive heated blanks the die parts in some cases are liable to be heated to such a degree as to become detrimental, and for this reason it may be preferable to provide suitable means for regulating the temperature of the die parts. This may conveniently be accomplished by circulating a controlled supply of water through the die parts. Furthermore, in view of the fact that a preferred method of quenching the blades is to place them between relatively cold die parts contacting substantially the entire outer surface of the blades, the same die parts as are employed for forming the blanks to blade shape may be employed in quantity production for the quenching operation if suitable means are provided for cooling the die parts. The water passages referred to above offer a suitable means for accomplishing the desired cooling of the die parts.

In the form shown in Figs. 5 to 12, inclusive, my improved propeller blade forming apparatus includes a lower block or die having a constant width between a recess or zone that normally rests upon the lower plate of a press, and is provided with a longitudinal recess 252 which is bounded by a vertical side wall 254 and an inclined side wall 256. As indicated in Fig. 7, the die holder 258 is cored internally or otherwise suitably provided with passages 259 for circulating a cooling medium substantially throughout its entire length and breadth. As best indicated in Fig. 10, the passages 259 are provided with a communicating inlet 260 and a communicating outlet 262 which, in practice, are connected to a convenient source of water supply and drain pipe respectively.

Formed on the front corner portions of the lower die holder 250 are upright posts 264 of substantially rectangular cross-section. An upper die holder 268 having a recess 268 which is complementary to the recess 252 of the lower die holder 250 is mounted in superimposed relation thereon. The opposite front corner portions of the upper die holder 268 are provided with recesses 270 for sidewise receiving the posts 264 of the lower die holder 250. The side wall 272 of the recess 268 is vertical and is located substantially in alignment with the side wall 264 of the stress of the lower recess 254, and the other side wall 274 of the recess 268 is inclined with respect to the side wall 264 of the other recess.

Seated in the recesses 272 and 280 of the die holders 250 and 268 are dies 276 and 217 respectively having longitudinally extending blade forming recesses 270 and 279 respectively formed in their opposed faces which recesses cooperate to form a single recess which conforms in size, shape, contour and pitch with the size, shape and contour, except for the nose end as will hereinafter be more fully explained, and pitch of the finished blade shown in Fig. 3 which it is desired to form. The die posts 276 and 277 are preferably split transversely of their length and intermedial their ends as at 280 and are detachably secured to their respective die holders by longitudinally extending pins or wedge members 284 and 286 (see Fig. 10) which are held in place by bolts 288 and 290 respectively screwed into the die holders 250 and 268 respectively. The dies are held against outward or lateral displacement from the recesses by the inclined walls of the posts and by the inclined sides of the gib 284 and 286.

By replacing those portions of the dies 276 and 217 inwardly of the line of split by portions of either greater or lesser length than those shown, 75
the same outer die portions may be employed to produce blades of different lengths. By this means a considerable saving in die costs may be realized in the production of blades of different lengths. It may be desired to employ various blade end die sections with varying tip end die sections and the construction described makes them easily interchangeable to produce any desired combination, without the necessity of making complete dies of all the various types needed.

The springs 328 normally hold the cross head 312, and the blank 112 when supported thereby, more or less centered between the dies and out of contact with both dies, as indicated in Fig. 11. The web 314 of the cross head 312 is provided with an enlarged central opening 330 of circular contour in which a collar 332, for receiving the shank portion of the tubular blank 112 adjacent to the flange of thereof, is detachably mounted by screws 334. The collar 332 is provided with preferably horizontally and laterally extending slots 336 which may register with the flattened portions toward the leading and trailing edges 15 which are formed on the resulting blade and permit the cross head to be withdrawn from and through the collar during removal of the blade from the forging apparatus. The forming apparatus may be readily conditioned for manufacturing blades of various dimensions by removing the collar 332 and replacing it with a collar of subential dimensions with respect to the natural radius of the respective edge portions of the blades formed therein. This permits the making of blades of various lengths with the pitch twist continuing uniformly together with the proper longitudinal and lateral conformation.

It is to be understood that except for the outer portions of the depressions 278 and 279 which may be made wider and longer than the corresponding portions of the blades to be produced thereby, as above pointed out, the perimeteal dimensions of the die depressions at any given transverse cross section through them is substantially equal to the perimetal dimensions of the corresponding section of the blank 112 to be shaped between them, so that when the blank is pressed to blade shape, no outward stretching or inward crowding of the metal of the blank occurs, such metal being merely bent to shape. The upper die holder 260 is internally cored or otherwise suitably provided with cooling medium passages 292 which communicate with a supply pipe 294 and a drain pipe 296 at the opposite sides of the holder. A pair of parallel plates 288 are located adjacent to the outer sides of the various posts 264 of the lower die holder and are rigidly secured thereto by bolts 300. The plates 288 protrude beyond the forward ends of the die holders and they are provided at their outer extremities with longitudinally extending cleats 302 which are secured in place by bolts 304. The cleats 302 form navel ways 306 between their inner sides and the front edges of the posts 264 in which side flanges 308 and 310 of a channel shaped support or cross head 312 having a web 314, are slidably received. As best shown in Figs. 8 and 12, the inner edge portions of the flanges 308 and 310 are provided with recesses 316 in which shoes 318 preferably comprising rectangular metal bars, are seated. The shoes 318 carry pins 320 which are received in apertures 322 formed in the posts 264 of the lower die holder 250 and the shoes are yieldably held in spaced relation to the posts 264 by springs 324 which surround the pins 320 and are seated in recesses 326 in the forward edges of the posts 264 and surrounding the apertures 322. These shoes 318 normally bear against the cross head 312 urging the same outwardly against the inner sides of the cleats 302.

As best shown in Fig. 11, the entire cross head 312 is yieldably supported on coil springs 328 which are seated upon the lower press platen 330. The springs 328 normally hold the cross head 312, and the blank 112 when supported thereby, more or less centered between the dies and out of contact with both dies, as indicated in Fig. 11.
of the bellows 346 and from the latter to the interior of the tubular blank through an orifice 356 in the head 348. The cross head, which is yieldably held in an elevated position by the springs 328, positions the blank in registration with the recesses 278 and 279 between them. The flanged end of the blank, of course, constantly maintains its engagement with the head 348 during movement of the cross head in the die closing operation. The closing movement of the dies is inwardly with respect to the dies against the action of the springs 324 which yieldably hold the cross head 32 upon which the flange 06 of the blank 2 bears, in spaced relation to the adjacent ends of the die holders. In this manner, setting up of internal quenching operations is performed in the manner previously mentioned, the provision of such cooling medium circulating passages further adapts the dies and die holders for use in a preferred subsequent quenching operation, as previously mentioned.

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The bellows 346 is larger in cross section at the lower end of the bellows 346 is larger in cross section at the lower end of the blank 2 bears, in spaced relation to the adjacent ends of the die holders. In this manner, setting up of internal quenching operations is performed in the manner previously mentioned, the provision of such cooling medium circulating passages further adapts the dies and die holders for use in a preferred subsequent quenching operation, as previously mentioned.

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Any leakage which may occur from the interior of the blank tends to increase this force differentially and accordingly increases the pressure upon the extremity of the blank preventing continued leakage. In practice, with the pressure of 300 pounds per square inch in the blank, a load of 6,000 pounds may be exerted on the flange by suitably proportioning the parts referred to, thus tending to insure sufficient pressure within the blank to cause it to hug the dies when they are closed.

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As best shown in Figs. 5 and 6, the breach block is releasably held in a closed position by a latch device which includes a vertical cylindrical journal 358 journaled on the flange 350 mounted on the face 398 of the cross head 12. This bar is provided with an axially extending V-shaped groove in its surface and it is provided with an outwardly extending radial pin 362 by which it may be rotated to bring the V-shaped groove into registration with a protruding edge or lip portion 364 on the free side of the breach block. Adjacent the projecting lip 364 of the breach block is a recess 365 in which the cylindrical portion of the bar 358 is received when the latter is held in locked position by the spring 368 engaging the pin 362. The breach block may be unlocked and swung to open position, shown in dotted lines in Fig. 6, by moving the pin 362 against the tension of the spring 368 and so rotating the bar 358 in a counterclockwise direction to allow the projecting lip 364 on the breach block to pass by the groove in the bar 358.

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In operation, either the upper or lower die holders may be moved so as to bring the dies together so that the lower die holder 350 is preferably held vertically upward with substantial force by mechanism (not shown) of the character customarily used in die forming operations. A tubular blank 112 of the type shown in Fig. 1, having a flange 106 on its open end is heated to a workable temperature in any suitable manner and is lifted, preferably by tongs inserted in the open end of the blank, and inserted through the central opening in the replaceable collar 332 while the cross head 312, lower die holder 260 and upper die holder 268 are in the relative positions shown in Fig. 11, and while the breach block 338 is open. In order to obtain uniformity of final product and insure optimum conditions of balance in the finished product, the heavy side of the blank, if any, as preferably determined and marked in previous operations is positioned on the centerline of the dies which form the flat face 1100 of the blade, these being the lower dies 276 and 278, as shown. The blank 112 is inserted through the central opening in the collar 332 until the flange 106 thereof engages the outer shoulder of the collar and then the breach block 338 is swung to a closed position with the boss of the head 348 of the bellows 346 extending into the open end of the blank, the gasket 350 being located between the flange 106 and the head 348.

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The cross head, which is yieldably held in an elevated position by the springs 328, positions the blank in registration with the recesses 278 and 279 of the dies 276 and 271, and holds the blank out of contact with the dies and their supporting structure so as to prevent pre-cooling of the local areas of the blade, as previously mentioned, although it may be that, at least before the breach block is shut, the blade being more or less loosely held in collar 332 may sag so as to contact the die at its tip, but this may not be harmful as the previously described thicker wall at the tip may prevent dangerous pre-cooling during the short period of contact if any. Furthermore, as previously mentioned, the nipple 111 will aid to prevent the extreme tip of the blade, which is subjected to the greatest bending effects in the blade during formation, from splitting open even though it may become cooled to a slight extent.

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Before the lower die holder 250 and die 276 are urged upwardly to form the blank to blade shape, the valve 354 is opened so as to admit air into the bellows 346 and to supply air to the interior of the tubular blank. The pressure in the interior of the bellows is applied directly on the inner side of the head 348, holding the head in air sealing relation against the flange 106 of the blank. A pressure of 300 pounds per square inch is generally employed where a blank of usual size is made of the ordinary range of low carbon steels and this pressure is preferably substantially immensely daintily built up in the blank so as to internally support the latter and to hold all portions of the wall in contact with the surfaces of the recesses in the dies when the lower die is urged upwardly from the position shown in Fig. 11. The lower 35 die, in moving upwardly, first engages the blank and rapidly moves it, together with the valve 354, upwardly against the weight of the blank and the force of the springs 328 until the dies 276 and 271 contact with each other and the blank which then assumes its desired blade shape in the depressions 278 and 279 between them. The flanged end of the blank, of course, constantly maintains its engagement with the head 348 during movement of the cross head in the die closing operation. The closing movement of the dies is so rapid that the dies contact the entire blank at or near the same time as possible. This is desirable in order to avoid unequal chilling which might occur if there was die contact at one point before another. This rapid and complete contact makes it possible to act upon the blank while all the metal is at a temperature to be readily shaped.

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As the blank cools and shrinks its tapered end is free to contract longitudinally in the tapered portions of the die recesses. The other end portion of the blank, however, is allowed to move inwardly with respect to the dies against the action of the springs 324 which yieldably hold the cross head 312, upon which the flange 106 of the blank 112 bears, in spaced relation to the adjacent ends of the die holders. In this manner, setting up of internal strains in the propeller blade during cooling thereof is minimized.

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The dies and die holders may be protected from overheating by repeated contact with successive blanks, when used continuously in such pressing operations, by circulating a cooling medium through the passages 256 in the lower die holder 70 and 292 in the upper die holder. As previously mentioned, the provision of such cooling medium circulating passages further adapts the dies and die holders for use in a preferred subsequent quenching operation, as previously mentioned.
When the pressed blank in the dies has cooled sufficiently to insure its retaining its now blade-like form, which will ordinarily be after a period of about one minute, the valve 334 is closed, and the air is released from the interior of the blade, and the breach block 338 is swung back, and the blank, which is now transformed to a blade, is removed, the notches 336 in the collar 332 functioning to take into account the increase in lateral dimensions of the blade as compared to corresponding dimensions in the blank.

Blades thus received from the dies are checked for length, and are then subjected to a suitable annealing treatment to remove all paint and scale from the outside of the blade. This annealing operation may be conveniently accomplished in any suitable and convenient manner.

While the blades thus formed are, for the most part, in commercially acceptable form, I find it desirable in order to make a more perfect product, to subject them to a heat treatment. This may be suitably accomplished by suspending each blade by its flange 105 in any suitable furnace and there subjecting it to a heat soaking process for a sufficient length of time to evenly diffuse the carbides in the metal when carbides are present therein, or for a sufficient length of time to effect other desirable changes in the structure of the metal. The length of this soaking treating, as well as the temperature at which it is carried on, will, of course, vary according to the particular metal of which the blade is formed, but for low carbon steels I have found that soaking the blade for approximately thirty minutes at a temperature in the neighborhood of 1625 to 1675 degrees Fahrenheit will suffice. This same soaking treatment, not only evenly diffuses the carbides in the metals, with other usual effects to the structure thereof but, furthermore, relieves any strains that may have been set up in the metal in the die-pressing operation.

The blade is now removed from the furnace and may again be placed while at high heat within the same dies just described, or equivalent dies, which are closed, and the blade is then subjected internally to air pressure as previously described. Air pressure in the neighborhood of 300 pounds per square inch is found to be satisfactory, although pressure of respective degree or below this figure, preferably above, may be employed as well. As before, a complete and rapid closure of the dies is desirable to produce the best result. This treatment not only forces out any small depressions or irregularities in the surface of the blade that may have failed to disappear in the original pressing operation, and not only will straighten the blade if the same has become warped at all in the soaking treatment due to the relieving of the strains in the metal but, more important, the air under pressure may force all portions of the blade surface into contact with the surfaces of the depressions of the dies, and in doing so causes a chilling of the metal of the blade and prevents separation and segregation of the carbides in the metal thereof, or other undesirable changes in the structure of the metal. At the same time that the main body portion of the blade is being chilled in the dies, a spray of water may be directed on the flange 106 thereof to cause a like effect. A period of about two minutes in the closed dies will usually be found ample to effect the desired chilling of the blade. While this operation of putting the exterior walls of the blade into contact with the relatively cold walls of the dies is a chilling operation on the blade, I prefer to call it a "die-quenching" operation, since the results are in all ways analogous to immersing hot steel in a cooling liquid.

This die-quenching effect on the blade serves the same purpose as conventional quenching treatments, and may be intensified, modified and/or controlled in several ways, and which is by the provision of water passages such as 265 and 292 in the die supports 260 and 265 each 10 provided with suitable inlets 260 and 264 respectively, and suitable outlets 262 and 266 respectively. This, or an equivalent method of cooling the dies may be found to be desirable if not essential where the time element between the 15 removal of one blade and the insertion of the next is limited, but it will be recognized that in any case the main requirement is an adequate temperature difference between the dies and the work to effect the proper quench, regardless of the method of obtaining such temperature difference. It will be obvious that it is possible to obtain any degree or rate of cooling to correspond to any degree or type of quench in various ways such as by varying the rate of passage of the fluid, multiplicity of blades through the dies, by varying the temperature of the dies themselves by either varying the rate of the cooling fluid passing through them or the temperature of such cooling fluid, and further by varying the temperature of the blank itself. Thus a quick, simple and economical method of quenching the blank is provided.

Instead of relying solely upon a spray of water to cool the flange end of the blade during the quenching operation, as above described, it may be desirable to so modify the die apparatus as to permit a more accurately controlled cooling of the flange end of the blade. This may be conveniently accomplished by using the lower and upper die holders 259 and 265, their respective dies 276 and 277, and the pair of forwardly extending parallel plates 298, shown in Figures 5 to 12, inclusive, in conjunction with the lower and upper cross head sections 370 and 372, respectively, shown in Figs. 13, 14, and 15. The cross head sections 370 and 372 are provided with side flanges 374 and 376, respectively, of which are located between the ends of the die holders 259 and 265 and the cleats 302 mounted on the front edges of the plates 298, as previously described. The cross head sections 370 and 372 are secured against vertical displacement from the lower and upper die holders with which they respectively register by dowel pins 310 mounted on the cross head sections and fitting loosely in cooperating apertures in the ends of the die holders. The loose fitting relation of the dowel pins in their apertures permits the sections to move axially of the die holders and the sections are yielded in spaced relation to the ends of the die holders by the same spring shoes 318 and springs 324, as described in connection with Figs. 5 to 12, inclusive, and which normally hold the forward edges of the flanges 374 and 376 of the cross head sections against the cleats 302 on the plates 298.

The weight of the lower cross head section 370 may be sufficient to keep it from rising from the lower die holder and it may not be necessary to provide the dowel pin 310 therefor.

Formed in the cross head sections 370 and 372 are complementary, semi-cylindrical recesses 380 and 382 in which are seated semi-cylindrical tu-
cular ring segments 384 and 386 having cooling medium passages 388 and 390, respectively. The ring segments 384 and 386 are provided with complementary seats 392 and 394 for receiving the root end portion or shank of the propeller blade and are detachably held in place on the cross head sections 370 and 372 by screws 386. The ring sections 384 and 386 are provided with inlet apertures 398 and outlet apertures 400 for permitting a cooling medium, such as water, to be circulated through the passages 388 and 390.
Formed on the side flanges 374 and 376 of the right hand side of the cross head sections 370 and 372 are hinge elements 402 and 404 on which a breach block 406 (see Fig. 14) is swingably mounted, substantially in the manner illustrated in Fig. 6. The breach block 406 and the bellows or syphon 408 which it carries, are substantially identical in construction to the breach block 338 and the bellows 348 which has been described in detail in connection with Figs. 3, 5, and 8. The bellows 408 communicate with an inlet pipe or nipple 20 of a valve 412 as shown in Fig. 14, for controlling the admission of air to the interior of the bellows and to the interior of a propeller blade with which the head 416 of the bellows 408 registers in operation.

33. In the arrangement the hot blank will not be initially supported by its shank so as to be held out of contact with the dies as shown in Fig. 11 since the rings 384 and 386 are not supported by the springs 338. The hot blank may then be laid directly on the lower die and the dies closed so suddenly and rapidly that uniform contact over the entire surface of the blank may be procured as promptly as possible.

In Figs. 10, 17, and 18 a slight modification of the previously described die structure is shown in which the die depressions in the dies are so formed as to conform exactly in size, shape and contour throughout with that desired in the finished blade instead of having the outer stages of the depressions longer and wider than the blade as shown in the figures. Since the only changes over the structure previously described is solely in connection with the dies 270 and 271, all the parts indicated in Figs. 6, 10, 17, and 18, with the exception of the dies themselves, bear the same numerals as in Figs. 5 to 12, inclusive, and the dies themselves bear the same numerals except that they carry the sub-letter “a”.

Accordingly, it will be noted that the die depressions 270a and 271a conform exactly in size, shape and contour with the desired size, shape and contour of the desired blade 10a; it, of course, being understood that the perimetrical dimensions of the combined depressions 270a and 271a taken in a plane perpendicular to the longitudinal axis of the blade at any stage of the length thereof, are substantially exactly equal to the perimetrical dimensions of the blank at the same stage of length before the blank is pressed to blade shape, so that no expansion or crowding in of the metal of the blank occurs during the pressing operation, but which results in the blank being bent into the desired shape.

It might be noted that in this case the nipple

111 is omitted from the end of the blank, although it will be apparent that this nipple may be provided if desired in this case and the depressions 270a and 271a modified sufficiently to permit its reception.

Formal claims may be made in the specific embodiments of the invention described without departing from the spirit and substance of the broad invention, the scope of which is commensurate with the appended claims.

1. Forming apparatus including a pair of relatively movable die holders, a pair of dies, one mounted in each holder, and a support for positioning a piece of work in operative relation with respect to said dies including a work holder shiftable in the direction of relative forming movement of said die holders during the forming operation of the latter.

2. Forming apparatus including an upper stationary die holder, a lower vertically movable die holder, a pair of dies, one in each of said die holders, a vertically shiftable cross head located in close proximity to said dies and having an opening for receiving the end portion of a blank, and yieldable members normally supporting said cross head in an elevated position so as to retain said blank in spaced relation to said dies when the latter are spread apart.

3. Forming apparatus including a pair of relatively movable die holders, a pair of dies, one mounted in each holder, a support shiftable bodily laterally and lengthwise of said dies in a direction toward one end thereof for positioning a blank between said dies, and yieldable means normally urging said support outwardly toward in a predetermined spaced position from the adjacent ends of said dies so as to accommodate resiliently restrained longitudinal contraction of said blank upon cooling.

4. Forming apparatus including a pair of relatively movable die holders, a pair of dies, one mounted in each holder, a support located at one end of said pair of dies for positioning a blank therebetween, said support being shiftable lengthwise of said dies and shifters being located at the end of the relative movement thereof, yieldable means for holding said support in a predetermined location with respect to the spread apart positions of said dies so as to prevent contacting of said blank therewith, and means for yieldably holding said support in spaced relation to the adjacent ends of said dies so as to permit longitudinal contraction of said blank upon cooling.

5. Forming apparatus including an upper stationary die holder, a lower vertically movable die holder, a pair of dies, one in each of said die holders, a cross-head shiftable vertically and lengthwise with respect to said dies and die holders and having an aperture for receiving a blank, springs yieldably supporting said cross head in an elevated position so as to retain said blank in spaced relation to both of said dies when the latter are spread apart, and resilient shoes bearing between said cross head and the adjacent ends of said die holders for yieldably holding said blank in spaced relation to the latter so as to permit lengthwise contraction of said blank upon cooling.

6. Forming apparatus including an upper sta-
tionary die holder, a lower vertically movable die holder, a pair of dies, one in each of said die holders, a vertically shiftable cross-head located in close proximity to the open ends of said dies and having an opening therein, a replaceable adapter detachably mounted in said opening for receiving an end of a blank and resilient members yieldably retaining said adapter intermediate the spread apart portions of said die holders so as to prevent premature contacting of said blank with said dies.

7. Forming apparatus including an upper stationary die holder, a lower vertically movable die holder, a pair of dies, one in each of said die holders, a cross-head located in close proximity to the open ends of said dies and shiftable bodily and laterally and lengthwise thereof, means on said cross head for supporting a blank, and resilient means yieldably holding said cross head in spaced relation to the open ends of said dies and adapted to accommodate resiliently restrained longitudinal contraction of said blank upon cooling.

8. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each die holder, a support adjacent one end of said pair of dies having an opening for receiving the open end of a tubular propeller blade blank and adapted to independently support the latter from the open end portion thereof, and a member swingably mounted on said support including means for registering with said opening forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

9. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each die holder, a support adjacent one end of said pair of dies having an opening for receiving the open end of a tubular propeller blade blank, a breach block swingably mounted on said support, and a member carried by said breach block for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

10. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each die holder, a support adjacent one end of said pair of dies having an opening for receiving the open end of a tubular propeller blade blank, a breach block swingably mounted on said support, and a yieldable member carried by said breach block for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

11. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each die holder, a support adjacent one end of said pair of dies having an opening for receiving the open end of a tubular propeller blade blank, a breach block swingably mounted on said support, and a siphon carried by said breach block for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

12. Propeller blade forming apparatus including a pair of relatively movable die holders, a pair of dies, one in each of said holders, a shiftable support located at one end of said pair of dies for positioning a tubular propeller blade blank therebetween, means for yieldably holding said support in a predetermined position relative to said dies so as to retain said blank out of contact with said dies when the latter are spaced apart, and means on said support for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

13. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each holder, spaced protruding elements on an end of one of said die holders, a cross-head shiftably mounted between said elements having an opening for receiving the open end portion of a tubular propeller blade blank, members yieldably holding said cross head in spaced relation to said die holders for permitting inward movement of the open end portion of said blank blank during shrinking thereof upon cooling, a breach block swingably mounted on said cross head for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

14. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each holder, spaced protruding elements on an end of one of said die holders, a cross head shiftably mounted between said elements having an opening for receiving the open end portion of a tubular propeller blade blank, members yieldably holding said cross head in spaced relation to said die holders for permitting inward movement of the open end portion of said blank during shrinking thereof upon cooling, a breach block swingably mounted on said cross head, and an expansible member carried by said breach block for forming a communicative connection between the interior of said blank and an external source of fluid pressure for internally supporting the blank during compression thereof to blade shape.

15. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each holder, spaced protruding elements on an end of one of said die holders, a cross head shiftably mounted between said elements having an opening for receiving the open end portion of a tubular propeller blade blank, a breach block swingably mounted on said cross head, and means for releasably holding said breach block in a closed position, a resilient member mounted on said breach block including a head portion registering with the open end of said blank and having an aperture in communication with the interior thereof for supplying a gaseous medium thereto, and means communicating with said resilient member and a source of pneumatic pressure.

16. Propeller blade forming apparatus including a pair of die holders, a pair of dies, one in each holder, spaced protruding elements on an end of one of said die holders, a cross head shiftably mounted between said elements having an opening for receiving the open end portion of a tubular propeller blade blank, a breach block swingably mounted on said cross head, and means for releasably holding said breach block in a closed position, an expansible member mounted on said breach block including a head portion registering with the open end of said blank and having an aperture communicating with the interior thereof for supplying a gaseous medium thereto, and means communicating with said expansible member and a source of pneumatic pressure, the side of said head adjacent said blank being 75
Forming apparatus including a pair of relatively movable die holders, each having a cooling medium circulating passage therethrough, a pair of dies, one in each of said die holders, a pair of cross head members each movably mounted on one end of said die holders having complementary recesses for receiving the root end portion and flange of said blank and each having a cooling medium passage surrounding its recesses, yieldable shoes normally holding said cross head members in spaced relation to the adjacent ends of said die holders, and means mounted on said cross head sections for forming a communicative connection between the interior of said tubular blank and an external source of fluid pressure.

Apparatus for forming a hollow article of irregular contour from a hollow blank including a pair of die holders, each having cooling medium circulating passages therethrough, a pair of dies, one in each of said die holders, a member at one end of said dies for supporting the root end of said blank and having cooling medium passages therethrough, a breach block swingably mounted on said member, and means carried by said breach block for forming a communicative connection with the open end of said blank and a source of fluid pressure of said breach block so as to internally support said hollow blank.

Apparatus for making a propeller blade from a tubular blank including a pair of die holders, each having cooling medium passages therethrough, a pair of dies, one on each of said die holders, a pair of cross head members each movably mounted on one end of said die holders having complementary recesses for receiving the root end portion and flange of said blank and each having a cooling medium passage surrounding its recess, yieldable shoes normally holding said cross head members in spaced relation to the adjacent ends of said die holders, a breach block swingably mounted on said cross head members, and expandable means carried by said breach block for forming a communicative connection between the interior of said blank and a source of fluid pressure upon closing of said breach block.

Forming apparatus including a pair of relatively movable die holders, a pair of dies, one in each of said die holders, a pair of cross head members each movably mounted on one end of said die holders, a cross head located in close proximity to the open ends of said dies and shiftable lengthwise thereof including a replaceable adapter detachably mounted on said cross head provided with an opening for receiving an end of a blank and having means for supporting said blank from one end thereof in a fixed relation to said cross head, and means for yieldably holding said cross head against movement toward the open ends of said dies including members compressible during longitudinal thermal contraction of said blank for releasing the strain thereon.

Forming apparatus including a pair of relatively movable die holders, a pair of dies, one mounted in each of said die holders, a cross head located at an end of said dies and shiftable bodily in the direction of relative movement of said die holders, said cross head being provided with means for receiving one end of a blank and supporting the latter end of said dies, and means for yieldably holding said blank in spaced relation to the adjacent ends of said die holders.
ing structure, a pair of dies supported thereon, a member on said supporting structure adjacent one end of said dies including means for supporting a blank having an open extremity from the end portion of said blank adjacent its open extremity, a breach block swingably mounted on said member, and an element carried by said breach block for forming a communicative connection between the interior of said blank and a source of fluid pressure for urging the exterior of said blank against said dies.

29. Apparatus for forming a tubular article having an open extremity including a supporting structure, a pair of dies supported thereon, a member on said supporting structure adjacent one end of said dies including means for supporting a blank having an open extremity from the end portion of said blank adjacent its open extremity, a breach block swingably mounted on said member, means for releasably holding said breach block in a closed position, and an expandable element carried by said breach block for forming a communicative connection between the interior of said blank and an external source of fluid pressure, said element being adapted to expand under the influence of said fluid pressure for maintaining a tight seal between the contacting portion thereof and said blank.

30. Apparatus for forming a propeller blade from a hollow metal blank comprising dies having die depressions which at an intermediate point in their length correspond to the size of the corresponding part of the blade while leaving the tip end free to slide therein when contracting while cooling, and associated means for holding the hub end of the blade adapted to give to allow the hub end to move in when the blade contracts during cooling.

31. Apparatus for forming a propeller blade from a hollow metal blank comprising dies having depressions which at an intermediate point in their length correspond to the size of the corresponding part of the blade while leaving the tip end and the hub end of the blade free to slide therein when contracting while cooling.

32. Apparatus for forming a hollow article having an open extremity including a supporting structure, dies supported thereon, a member located at one end of said dies and shiftable toward the latter including means for receiving an open extremity of a hollow blank and supporting the latter from the end portion thereof adjacent said open extremity, means yieldably holding said member in a predetermined spaced relation to the adjacent end of said dies, a breach block swingably mounted on said member, and means on said breach block registering with the open extremity of said blank for forming a communicative connection between the interior thereof and an external source of fluid pressure.

33. Forming apparatus including a pair of die holders each having a cooling medium circulating passage therein, a support for positioning a blank between said dies, said support being shiftable in a direction parallel to the direction of relative forming movement thereof, and means normally yieldably urging said support in a direction opposite to the relative forming movement of said dies so as to retain said blank in spaced relation to both of said dies while the latter are separated and inoperative.

34. Forming apparatus including a pair of relatively movable die holders, a pair of dies, one independently mounted in each die holder respectively, a support shiftable bodily relative to and in the direction of movement of said die holders and located at one end of said die holders and dies including means for initially supporting a piece of work from an end portion thereof located externally of said dies, and yieldable means acting upon said support for holding the latter in a predetermined position with respect to said dies so as to retain the work out of contact with said dies.

35. Means for forming a propeller blade from a hollow metallic blank of generally circular section comprising a plurality of die members having matching depressions in the opposed faces thereof, the perimetric dimensions of a transverse section through said matching depressions being substantially greater than the associated section of a corresponding section of the blank to be received therein, and the perimetric dimensions of a transverse section through said matching depressions being substantially exactly to that desired in a corresponding section of the blank.

36. Means for forming a propeller blade from a metallic blank comprising a plurality of die members having matching depressions in opposed faces thereof, the size, shape and contour of a section taken through said matching depressions over a portion of the length thereof being substantially identical to the size, shape and contour of a corresponding section taken through the desired finished blade, and the size of a section taken through said matching depressions over another portion of the length thereof being substantially greater than the size of a corresponding section taken through the desired finished blade.

37. Means for forming a propeller blade from a metallic blank comprising a plurality of die members having matching depressions in opposed faces thereof, the size, shape and contour of a section taken through said matching depressions over a portion of the length thereof being substantially identical to the size, shape and contour of a corresponding section taken through the desired finished blade, and the size of a section taken through said matching depressions over another portion of the length thereof being substantially greater than the size of a corresponding section taken through the desired finished blade, but of substantially the same thickness as the last mentioned.

38. Apparatus for pressing a hollow metallic blank to propeller blade shape comprising a plurality of die parts having matching depressions in their opposed faces generally conforming to the size, shape and contour of the desired finished blade, a section through said matching depressions over the root portion of said blade conforming substantially exactly to that desired in a corresponding section of the desired finished blade, and those portions of said depressions adapted to form the tip end portion of the finished blade being wider and longer than the corresponding portion of the desired finished blade.

39. Apparatus for pressing a hollow metallic blank to propeller blade shape comprising a plurality of die parts having matching depressions in their opposed faces generally conforming to the size, shape and contour of the desired finished blade, a section through said matching depressions over the root portion of said blade conforming substantially exactly to that desired in a corresponding section of the desired finished blade.
responding section of the desired finished blade, and those portions of said depressions adapted to form the tip end portion of the finished blade having opposed wall portions generally conforming to the desired contour of the major portion of the opposite faces of the corresponding portion of the blade, but being of greater width than the corresponding portion of said blade.

40. Apparatus for pressing a tubular blank to propeller blade shape including a pair of relatively movable die members having matching depressions therein adapted to receive said blank and the walls of which depressions are adapted to control the cross sectional shape of the blank when pressed to blade shape thereby, each of said members comprising at least two parts separable longitudinally of the corresponding depression intermediate the ends of the depressions, the size and contour of the matching depressions in said parts at one portion of said members conforming substantially exactly to that desired in the corresponding portion of the finished product, and the size of the matching depressions in said parts at another portion of said members varying from that desired in the corresponding portion of the desired finished product.

41. Apparatus for pressing a tubular blank to propeller blade shape including a pair of relatively movable die members having matching depressions therein adapted to receive said blank and the walls of which depressions are adapted to control the cross sectional shape of the blank when pressed to blade shape thereby, each of said members comprising at least two parts separable longitudinally of the corresponding depression intermediate the ends of the depressions, the size and contour of the matching depressions in an opposed pair of said parts for the root end portion of the blade conforming substantially to the size and contour desired for the root end portion of the finished blade, and the size of at least a portion of the matching depressions in another opposed pair of said parts adapted to form the tip end of said blank being greater than the dimensions desired in the tip end of the finished blade.

42. Means for forming a propeller blade from a hollow metallic blank of generally circular section, of tapered formation and having the smaller end thereof closed and provided with an axially extending nipple, comprising a plurality of die members having matching depressions in opposed faces thereof, the size, shape and contour of a section taken through said matching depressions over at least a portion of the length thereof being substantially identical to the size, shape and contour of a corresponding section taken through the desired finished blade, the length of said depressions being greater than the corresponding length desired in the finished blade whereby to provide clearance for said nipple during pressing of said blank to blade shape between said dies.