June 18, 1946. A. J. PHELAN ET AL 2,402,204

APPARATUS FOR ASSEMBLING CENTRIFUGAL IMPELLERS

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Fig. 1.

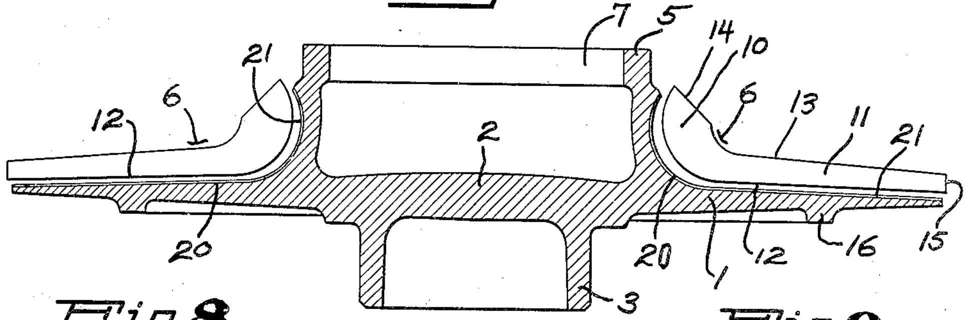


Fig. 8.

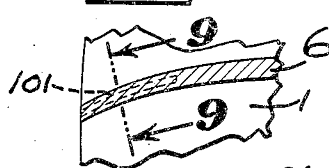


Fig. 2.

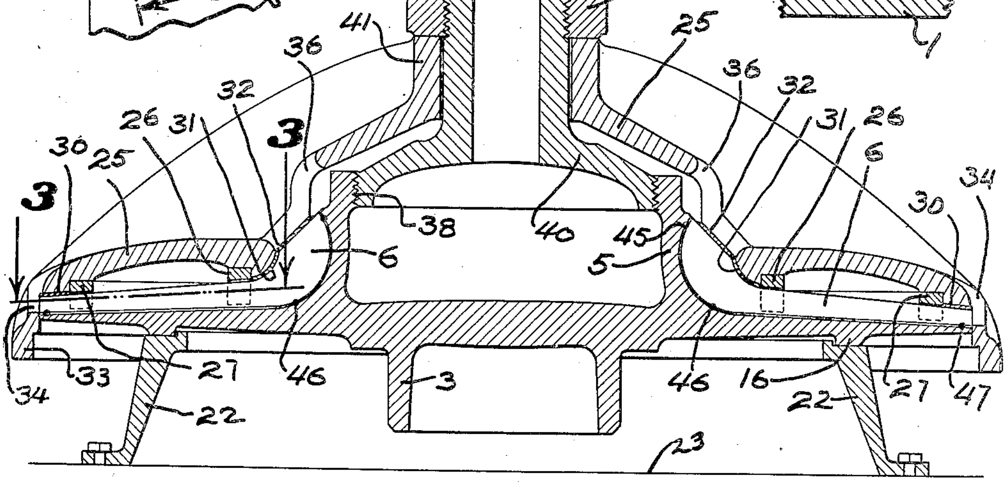
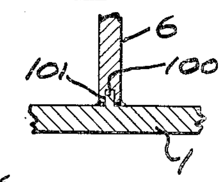


Fig. 9.



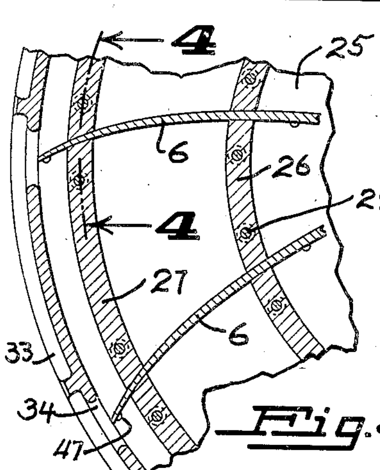
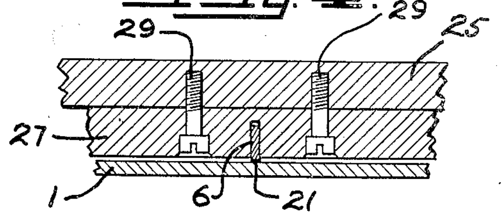


Fig. 3.

Fig. 4.



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APPARATUS FOR ASSEMBLING CENTRIFUGAL IMPELLERS

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Fig. 5.

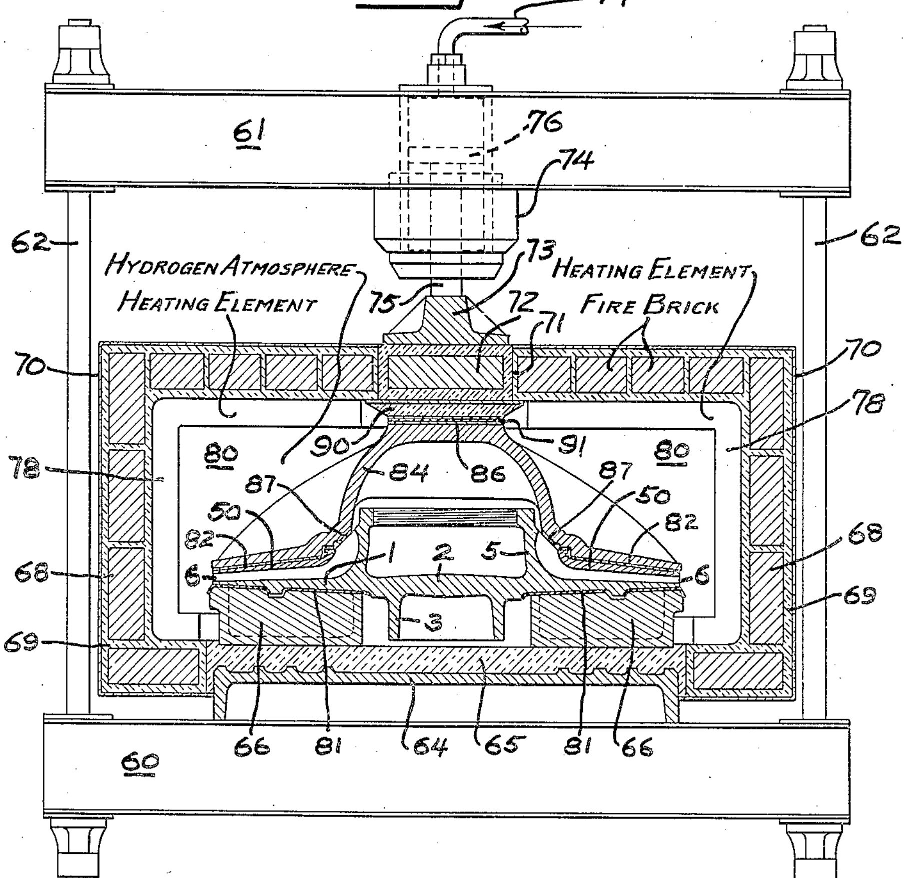


Fig. 6.

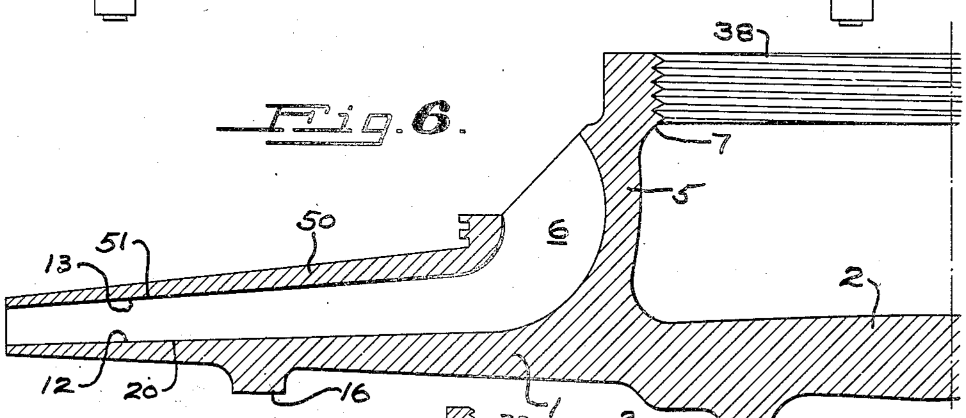
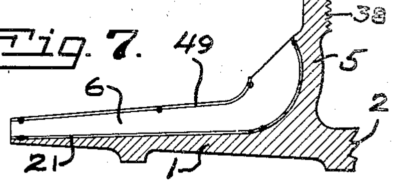


Fig. 7.



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Patented June 18, 1946 **2,402,204**

UNITED STATES PATENT OFFICE

2,402,204

APPARATUS FOR ASSEMBLING CENTRIFUGAL IMPELLERS

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Application November 19, 1941, Serial No. 419,752

4 Claims. (Cl. 113—59)

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Our invention relates to centrifugal impellers and more particularly to a centrifugal impeller assembled wholly by a copper brazing method in suitable fixtures. The centrifugal impeller and means and method of assembly thereof herein to be described, has a specific use in the gas combustion turbine shown, described and claimed in the following prior filed applications:

Name	Title	Serial No.	Filed
Pavlecka	Gas turbine	403,338	July 21, 1941
Pavlecka and Northrop	Compressor	413,751	Oct. 6, 1941
Do	Airplane power plant.	418,476	Nov. 10, 1941

Among the objects of our invention are: To provide a light, strong and integral centrifugal impeller; to provide a means and method of assembling a centrifugal impeller; to provide a means and method of forming a centrifugal impeller by copper brazing in a hydrogen atmosphere; to provide a complement of fixtures whereby a centrifugal impeller may be assembled by copper brazing, without the use of bolts or similar materials; to provide a means and method of assembling a rotor disc, centrifugal vanes and a cover into a unitary impeller structure by brazing; to provide a centrifugal impeller having clean, smooth and fully machined contours and air passages, and to provide a simple, efficient and light-weight centrifugal impeller adapted for high speed operation.

Our invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing our novel method. It is therefore to be understood that our method is applicable to other apparatus, and that we do not limit ourselves, in any way, to the apparatus of the present application, as we may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

In the prior applications cited above, a gas combustion turbine is disclosed wherein two centrifugal impellers are utilized in series to provide the supply of compressed air for the gas combustion. Inasmuch as the preferable use for such a turbine is for the propulsion of aircraft, it is essential that the impellers in the compressor be of highest strength, of light-weight, be perfectly balanced, and have clean air passages to obtain maximum efficiency.

Broadly as to method our invention comprises

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the assembly of centrifugal vanes on a rotor disc with the application of a cover to the vanes, the disc, vanes and cover being brazed into a single unit by the use of copper in a hydrogen furnace, this brazing being accomplished under pressure. Preferably, the copper is interposed between mating surfaces in the form of a thin strip of exact size and position, so that after the brazing has taken place only an insignificant copper fillet is present at the junction of the mating surfaces. For certain work this fillet may remain. For other work it can be removed for exceptionally clean air channels.

The more detailed assembly steps comprise the turning of a mating surface on a rotor member, together with the assembly of the blades in a turning fixture, followed by the turning of mating surfaces on the blades. The blades are then placed in position on the rotor disc with a thin copper strip therebetween, and tack-brazed or tack-welded in position. The opposite mating edges of the vanes are then formed to exact size by grinding, to avoid disturbance of vanes due to shock-loading thereof by intermittent cutting which would be encountered in annular turning. A cover plate is then annularly turned to mate with the exposed vane edges and copper strips are applied to these vane edges. Thereafter the cover plate is placed in position over the vanes so that there will be a copper strip between all the vane edges and the mating surfaces of the cover or rotor disc, as the case may be.

The entire assembly is then placed in a hydrogen furnace and a constant pressure applied thereto. The assembly is heated until brazing takes place. The pressure meanwhile forces out the copper from between the vanes and the cover and disc, to form an exactly dimensioned structure. The insignificant fillet thus formed may remain in place for most ordinary work of the impeller, or may be removed by a gouging or polishing operation for most efficient condition of the air passages of the finished impeller.

After the vanes are brazed to the cover and to the rotor disc, the outer surfaces of the impeller may then be machine finished. This method produces an impeller wherein all surfaces, exterior and interior are machined, and wherein the various elements of the impellers are brazed into a single properly dimensioned operating unit without the use of bolts or similar tie members.

Broadly as to apparatus, our invention comprises a rotor disc having a vane surface machined thereon. Edges of a plurality of centrifugal vanes fit this surface, and the vanes are held in place by tack-brazing or by tack-welding, with a thin strip of copper between the vane edges and the mating surface on the disc. The opposite vane edges fit a machined cover surface, and copper strips are applied to the vane surfaces by tack-brazing or tack-welding. The cover is then placed to the vanes, and the entire assembly is placed in a holding fixture positioned within a hydrogen furnace until melting of the copper strips occurs.

While the assembly is in the hydrogen furnace, means are provided to apply pressure to the fixture so that as the copper melts, clearances are taken up and the members forced into an exact fit. Upon cooling, the rotor disc, the vanes and the cover are firmly brazed into a single operating unit, and, if desired, the small fillets formed at the edges may be removed to provide clean air channels.

Thus, we have provided an impeller wherein the interior is completely machined.

In the drawings, which show one preferred embodiment of our invention:

Fig. 1 is a view, partly in section and partly in elevation, of a rotor disc together with two impeller vanes drawn adjacent the positions they are to occupy when welded to the disc.

Fig. 2 is a view, partly in section and partly in elevation, showing how the impeller vanes are held in position on the rotor for tack-brazing or welding.

Fig. 3 is a view, partly in section and partly in elevation, taken as indicated by the line 3—3 in Fig. 2.

Fig. 4 is a view, partly in section and partly in elevation, taken as indicated by the line 4—4 in Fig. 3.

Fig. 5 is a view, partly in elevation and partly in section, showing the assembled impeller in position in a hydrogen furnace ready for the brazing operation.

Fig. 6 is a view, partly in elevation and partly in section, of the finished impeller.

Fig. 7 is a view, partly in section and partly in elevation, of a portion of the impeller showing the copper strips in place.

Fig. 8 is a fragmentary view, partly in elevation and partly in section, showing a means of interlocking the blades with the impeller discs.

Fig. 9 is a sectional view taken as indicated by the line 9—9 in Fig. 8.

Referring directly to the drawings for a more detailed description of our invention, beginning with Fig. 1 to show the sequence of operation: A rotor disc 1 is provided, having a central flange 2 and hollow hubs 3 and 5 on opposite sides thereof. The hollow hub 5 is larger than hollow hub 3 and is positioned on the side of the rotor disc, to which impeller vanes 6 are to be attached. The end of hub 5 is also provided with an inner shoulder 7 which is later to be threaded. Vanes 6 are curved as is well known in the centrifugal compressor art, and comprise a curved basal portion 10 and an outwardly extending portion 11. Each blade also has a rotor edge 12, a cover edge 13, an angular entrance edge 14, and an exit edge 15. Disc 1 is also provided on its outer face with a positioning ridge 16.

As a plurality of blades 6 are to be brazed to rotor disc 1 in equally spaced positions around the rotor disc, the first step toward that end is to mount the rotor disc in a lathe and by simple annular machining to produce vane face 20 to which the vanes 6 are to be brazed. The required number of vanes 6 are then mounted in a turning fixture, placed in a lathe and by simple annular machining thereof the contour of edges 12 is formed to exactly mate with surface 20 on the rotor. In this manner a perfect mating of the contours of the vane edges 12 with the rotor disc contour 20 may be obtained.

The next stage in the assembly is the positioning on the machined surface 20 of the rotor disc 1, of a plurality of sheet copper strips 21, these strips being cut to be the width and length of vane edges 12, which are to be brazed to surface 20 of rotor 1. These copper strips 21 are preferably about .010 thick and are tack-brazed to the surface 20 of disc 1 in the proper circumferential positions, one strip for each blade to be mounted on surface 20. Opposite edges 13 of vanes 6 are not at this time machined to final finish, but are provided with excess metal so that the final finish may take place after the vanes have been fastened on the rotor disc.

Passing now to Figs. 2, 3, and 4 for a description of how the vanes 6 are primarily held in place on the rotor disc, we have provided a base fixture 22 mounted on a foundation 23, on which rotor disc 1 may be placed with vane surface 20 of this disc facing upwardly. Positioning ridge 16 is used to prevent lateral motion of the disc on the fixture.

The full complement of vanes 6 is then mounted in a vane fixture 25. Vane fixture 25 is provided on the under surface thereof with an inner spacing ring 26, and an outer spacing ring 27, these rings being provided with vane slots 28. The rings are held to the under surface of fixture 25 by bolts 29. Rings 26 and 27 receive vanes 6 and hold them in proper position with relation to rotor disc 1. Sheet-lead pads 30 are positioned between the vanes and fixture 25 adjacent the outer ends of the vanes, with sheet-lead pads 31 between the inner ends of the vanes and the fixture, these pads being used because of the fact that the edges 13 of the vanes are not yet machined. The pads will therefore take up any slight irregularities in contour. Vane base pads 32 of sheet-lead are applied between fixture 25 and angular vane edges 14 to force the vanes inwardly.

Fixture 25 with its vanes is inverted over disc 1, the fixture being provided with a drop rim 33 extending over the exterior edge of the rotor 1. Vane tip apertures 34 are provided adjacent end edge 15 of each vane. Fixture 25 is continued upwardly around hub 5 on the outside thereof, and vane base apertures 36 are provided on each side of entrance edges 14 of each vane. Threads 38 are provided on shoulder 7 of rotor hub 5 and an upward extension member 40 is screwed into these threads. Fixture 25 terminates upwardly in a cylindrical portion 41, sliding freely on extension 40. Extension 40 is provided with end threads 42 and a nut 43 is utilized to force fixture 25 against upper edges 13 and 14 of vanes 6 and thereby force each vane 6 into intimate contact with the copper strips 21 positioned between each vane and the surface 20 of rotor disc 1.

After this locking together of the parts in their proper position is accomplished, the vanes 6 are tack-brazed, preferably in three places, to rotor 1. This is accomplished by inserting the brazing torch for example, through openings 36 and brazing each vane to the rotor 1 at an entrance edge spot 45. The brazing torch is then inserted further into this opening 36, and the vane is brazed to rotor 1 at a curvature spot 46. The brazing torch is also inserted through end openings 34 and the vane brazed to the rotor 1 at a vane end spot 47.

Thus each vane at this time is securely held in position on the rotor 1 although not in final position, due to the thickness of the copper strips 21.

Fixture 25 and extension 40 may then be removed from the rotor disc 1 and the rotor disc 1 removed from foundation member 22, carrying with it now a full complement of impeller vanes 6.

The partially assembled impeller is then ready to have the finishing operation performed on edges 13 of the vanes to which edges an impeller cover is to be brazed. This machining operation is performed preferably by grinding in order to minimize disturbance of the vanes on the rotor disc, due to shock-loading which would be encountered by the intermittent cutting of a lathe tool, in case annular turning of the vane edges were to be attempted. By grinding however, this shock-loading may be entirely eliminated, and edges 13 of the vanes may be readily finished to size and contour without disturbing the tack-brazing of the vanes to the rotor.

After surfaces 13 of the vanes have been machined to their finished dimensions while mounted on rotor 1, the rotor and its tack-brazed vanes is provided with copper strips 49 required for the brazing of the edges 13 to a cover 50. These latter copper strips however, are not applied to cover 50 but are applied directly to edges 13 of the vanes, and are tack-brazed in proper position thereon.

Cover 50 has a vane mating surface 51 which has been machined by annular turning to mate properly with the final finished dimensions and contour of edges 13 of the vanes, and this cover is then positioned on the vanes 6, resting on the copper strips 49 that have been applied to edges 13 of the vanes. The assembled, but not yet brazed, impeller is then ready to go into a hydrogen furnace for the final brazing operation. This hydrogen furnace will next be described, and is shown in Fig. 5.

A heavy base member 60 is provided supporting an overhead member 61 by upright bars 62. Mounted on base 60 is a metal pressure plate 64, preferably circular in plan form, carrying a layer of heat insulating material 65 on which is mounted an impeller support member 66 having an upper surface thereon roughly shaped to receive and properly support the outer surface of rotor disc 1. It will be noted that shoulder 16 may again be utilized to properly position the impeller on the impeller support 66. Pressure plate 64 and insulation 65 form part of the lower wall of the oven, the remainder of the bottom of the oven, the side walls thereof, and most of the top being of conventional structure of circular plan form and comprising fire-brick 68, held together by properly fire-resistant mortar 69, and enclosed by a thin metal cover 70.

The top of the oven is provided with a central opening 71 through which a pressure cylinder 72 is freely movable, this pressure cylinder, however, being of heat insulating material and sufficiently strong to transmit to the interior of the oven, hydraulic pressure through an exterior metal pressure fitting 73 from a hydraulic cylinder 74 by means of a piston rod 75 operated in conventional manner by a piston 76 within the cylinder 74, as is well known in the art. The cylinder is supplied with oil or the like from inlet 77.

The interior of the oven is provided with electrical heating elements 78 of the proper capacity to bring the interior of the oven up to proper brazing temperatures, as will be discussed later, and a supply of hydrogen is provided so that all the air within the oven may be displaced by hydrogen, as is well known in the art. The usual method is to supply a continuous flow of hydrogen into the interior of the oven, and to provide a jet for the exit of the hydrogen, and then to light the hydrogen emerging from the jet so that it can at all times be told that the oven is receiving its full complement of hydrogen gas.

The oven may be opened in any convenient manner, such as by end doors 80 set in one end of the oven. The impeller rotor disc is placed on the support member 66, with the cover 50 in place on the vanes. We prefer to insert asbestos pads 81 between support 66 and the outer, now lower, face of rotor disc 1. Similar asbestos pads 82 are placed between the outer, and in this position, upper surface of cover 50 and a clamping dome 84, which extends upwardly around hub 5 of the impeller rotor disc to terminate in an upper surface 86 immediately below pressure cylinder 72. We also prefer to provide asbestos pads 87 between the dome 84 and the angular entrance edges 14 of each vane so that the vanes will be moved inwardly by vertical pressure.

Thus the assembled but not yet brazed impeller is clamped between the basal support member 66 and the dome 84, with asbestos pads between the clamping members and the impeller structure. These asbestos pads are utilized to prevent any possibility of any brazing occurring between the metal clamping members and the exterior surfaces of the assembled impeller. Further, we prefer to form support member 66 and dome 84 of high nickel-chromium heat resisting alloy ribbed and finned to provide maximum strength with the least weight in order to conserve heat.

The entire assembly of clamping members and impeller is then properly centered in the oven beneath the hydraulic press arrangement, and the top surface 86 of the dome is connected with pressure cylinder 72 of the hydraulic press by means of an asbestos cushion 90 and shims 91, so that there will be no slack in the hydraulic drive.

The oven doors 80 are then closed, the hydrogen atmosphere fully established, and the current to the heating element 75 is switched on. Pressure is continuously applied to the elements of the rotor by the use of suitable liquid injection into cylinder 74. As the temperature gradually rises and as this temperature approaches 2100° F., the copper strips 21 and 49 melt and brazing is accomplished with the parts moved by the application of the hydraulic pressure into press-fit engagement, both radially and axially. The material selected for the impeller element is preferably of steel such as SAE 4340 and therefore is not substantially affected by the heating to 2100° F.

As the copper melts, a perfect braze is accomplished and the tacking spots which have previously been made, merely melt into the final brazing. The copper which is between the vane edges and the impeller rotor and cover, is squeezed out as it melts to form a very slight fillet on each side of these edges, and the vanes come to rest, under pressure, with exact mating relationship of the machined edges of the rotor and cover to which they are opposed. Thus the impeller after the final brazing has been accomplished is of exact dimensions, is brazed into a complete unified structure, which can operate as a unit without the use of any bolts, rivets or equivalent tie members. The interior surfaces are entirely machined and the fillet caused by the copper in the strips being forced outwardly, may easily be removed by running a small gouge or similar tool along the junction of the vanes and the rotor and cover, this tool being readily inserted from the periphery for the straight runs of the edges, and from the basal openings for the curved portions of the edges. After the impeller is removed from the oven, as shown in Fig. 6, it can then be mounted in the lathe so that the exterior of the surfaces of the rotor and the cover may be machined into the desired final dimensions, including the removal of ridge 16.

Thus we have provided a centrifugal impeller having clean machined surfaces throughout, both inside and outside the impeller. The impeller is formed solely by brazing without the use of additional tie members. The impeller in this manner may be made very light in weight, exceedingly accurate as to dimensions, the air channels are clean, and the impeller may be perfectly balanced. The copper brazing provides adequate strength in use, particularly as temperatures even approaching the brazing temperatures, are never encountered in the normal use of the impeller. However, it is to be noted that the melting temperature of copper is high, and for that reason impellers made as described herein can be used in the high pressure end of a compressor, as has been described in the applications cited above, even though the exit air temperatures should rise, due to the air compression, to the neighborhood of 500°–600° F.

It can be seen from the above description of our method of copper brazing that the application of external pressure, particularly an external pressure which is continued as the copper melts, provides a complete, strong connection with exact mating of opposed surfaces. Hitherto, it has been thought feasible to copper-weld only parts held in a press-fit engagement prior to the application of the copper thereto. Nowhere, so far as we are aware, has copper brazing been practiced by the application of continuous external pressure to parts spaced by thin copper sheet. Hitherto, clamped parts have been copper brazed, but this method has not been found to be completely satisfactory, in that the preload due to clamping almost invariably diminishes with temperature, due to heat sagging of the clamp. The pressure between parts then diminishes, and the danger of misalinement arises. Gravitational clamping, using merely the weight of the parts, again has not proved to be satisfactory, because misalinement may still arise and also because the pressure thus produced is not sufficient for successful brazing. However, by our method, where hydraulic pressure is utilized, continuously operating before, during, and after the melting of the copper strips, so that the parts are forced into exact mating engagement as the copper strips melt, with all the parts held completely in alinement, it can be seen that even though the parts before the brazing occurs are spaced, the forces acting on the parts a' such as to copper-weld the parts with a press-fit engagement, with copper uniformly bonding the parts throughout the engaged surfaces.

In case rotational stresses are so great as to

call for more than dependence on the copper alone for the joint between the vanes, disc 1, and cover 50, shear ribs 100 may be provided for each vane on either or both disc and cover following the outer curvature of the vanes, these ribs 100 fitting slots 101 cut in the vane edges, as shown in Figs. 8 and 9. After brazing has occurred, the shear and other stresses are taken by the ribs as well as by the copper, and the vanes cannot straighten out even when rotated at high speeds.

We claim:

1. Apparatus for brazing a centrifugal impeller assembly involving an impeller disc, a vane cover, vanes positioned between said disc and cover, copper strips between mating edges of said vanes and adjacent surfaces of said disc and cover, said apparatus comprising a hydrogen furnace wherein said disc, cover and vanes are positioned, means for heating said furnace, and positioning means for supporting said disc on the bottom of said furnace, and said second means comprises a dome positioned over said cover and extending upwardly to terminate adjacent the top of said furnace, a movable heat insulating section of the top of said furnace engaging the termination of said dome, and means for applying pressure to said section, said disc positioning means and said dome being of metal, with non-metallic pads positioned between said positioning means and disc and between said dome and cover to prevent brazing therebetween, said dome having a surface exerting pressure on exposed portions of said vanes through additional non-metallic pads, said vanes being curved with respect to said disc and requiring an inwardly radial movement to mate with said disc, the surfaces of said dome exerting pressure against said exposed portions of said vanes being angular to move said vanes radially inward under pressure applied to said dome.

2. Apparatus for brazing a centrifugal impeller comprising the assembly of a disc spaced by blades from a cover with copper strips positioned between opposite vane edges and adjacent disc and cover surfaces respectively, comprising a furnace having insulating walls and heating elements for receiving said assembly with the axis of said assembly vertical, a dome positioned to apply pressure to said cover, a movable insulating portion positioned to apply pressure to said dome, and a hydraulic cylinder having a piston connected to said movable insulating portion by a piston rod and pressure block.

3. Apparatus in accordance with claim 2 wherein said disc is supported on a block and wherein an asbestos pad separates said block from said disc, and wherein an asbestos pad separates said cover from said dome, such apparatus including means for creating an atmosphere of a reducing gas around said assembly during heating.

4. Apparatus in accordance with claim 2 wherein said disc is supported on a block and wherein an asbestos pad separates said block from said disc, wherein an asbestos pad separates said cover from said dome, and wherein said vanes are provided with curved basal portions and angular edges, said dome transmitting pressure to said vane edges through angularly positioned pads.

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