C. V. KERR.

AIR COMPRESSOR.

APPLICATION FILED JAN. 10, 1914.

1,233,275.

Patented July 10, 1917.

2 SHEETS—SHEET 1.

FIG_2.

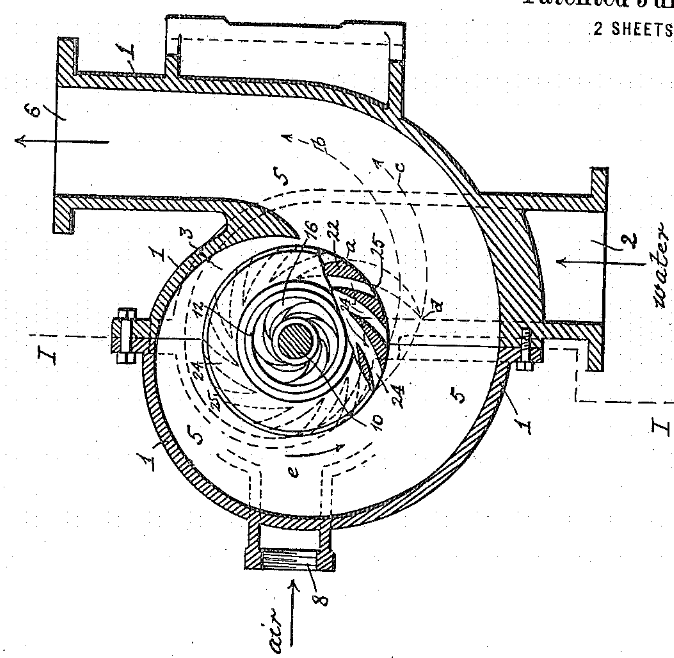
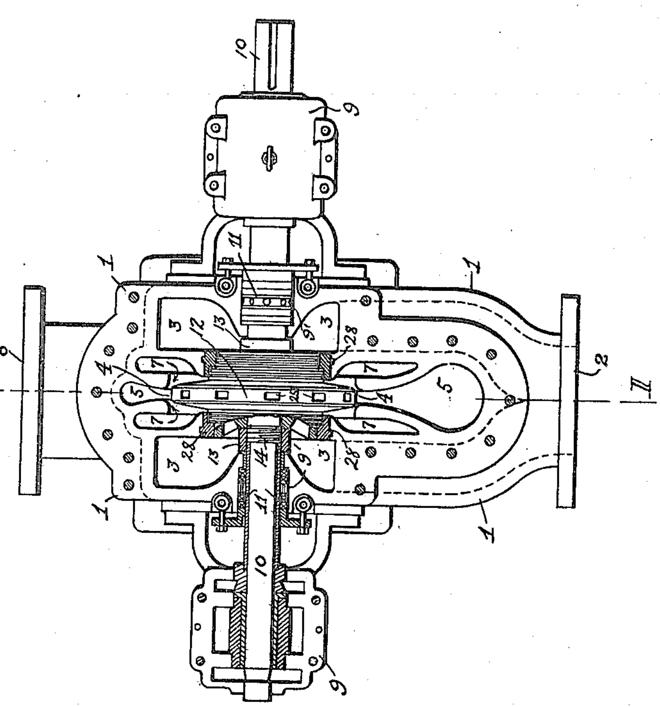


FIG_1.



Witnesses

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2 SHEETS—SHEET 2.

FIG. 4.

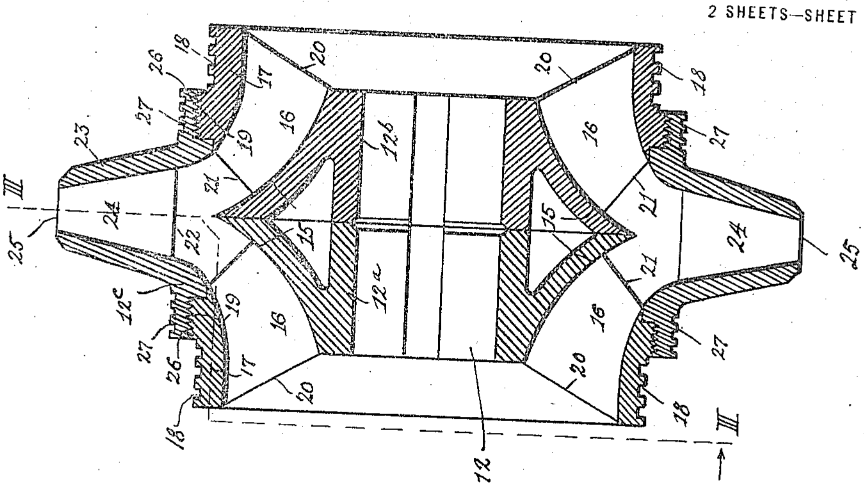


FIG. 3.

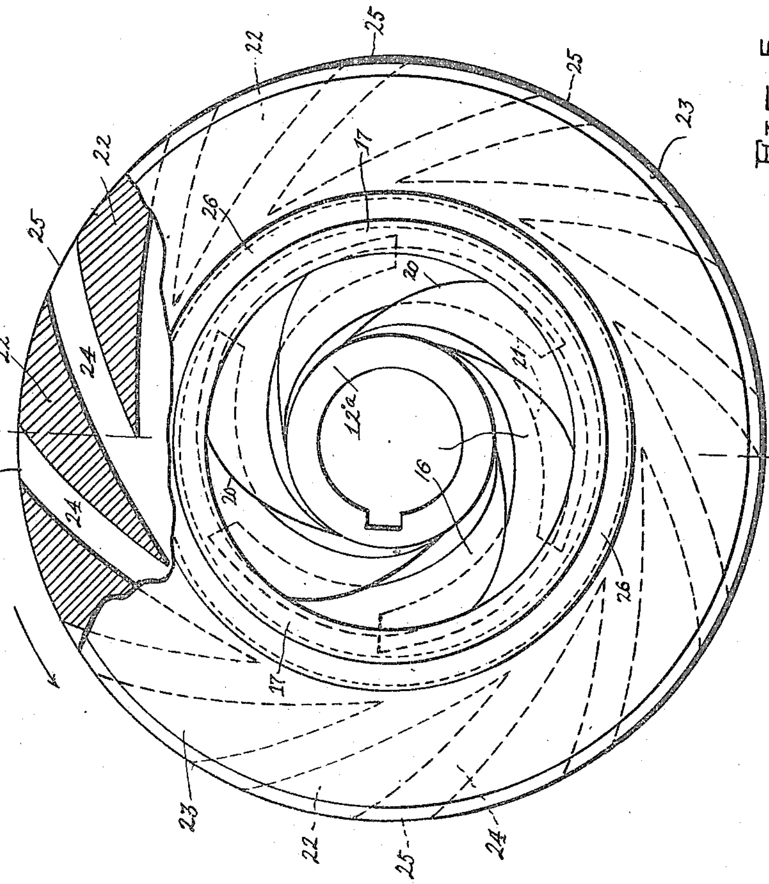
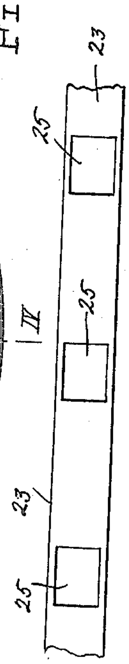


FIG. 5.



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UNITED STATES PATENT OFFICE.

CHARLES VOLNEY KERR, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO THE AMERICAN WELL WORKS, OF AURORA, ILLINOIS, A CORPORATION OF ILLINOIS.

AIR-COMPRESSOR.

1,233,275. Specification of Letters Patent. Patented July 10, 1917.

Application filed January 10, 1914. Serial No. 811,304.

To all whom it may concern:

Be it known that I, CHARLES V. KERR, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Air-Compressors, of which the following is a specification.

My invention relates to improvements in air compressors of the centrifugal type in which water coöperates with a rotary impeller to entrain the air disposed near the impeller, and compress said air by means of a series of rapidly moving and separated jets or pistons of water issuing from a series of nozzle openings in the periphery of the impeller, and forcing said water and compressed air into a specially constructed and arranged discharge outlet within the compressor casing.

The objects of my invention are:

First; to arrange and construct the chambers and impeller within the casing of the compressor, so that the air may be efficiently taken up by a series of jets or pistons of water, and said jets or pistons will be surrounded by the air which acts as a cushion and prevents the same from interfering with or impinging against each other.

Second; to construct and arrange the chambers and impeller within the casing, so that the water received by the impeller entrains the air in such a manner, as to reduce to a minimum the friction of rotation of the impeller against the water and air within the casing.

Third; to construct and arrange the water and air chambers of the casing with respect to the particular form of impeller, so that the sections of air taken up, acted upon and compressed by the water issuing from the impeller, are entirely surrounded by water, whereby the heat created during the compression of the air is conveyed to the surrounding water, and said air is compressed isothermally.

Fourth; to construct an impeller and arrange the same with respect to the water and air chambers of the casing so that the same is particularly adapted for an air compressor, which will use a minimum of water and permit the air to be efficiently entrained, constantly acted upon and uniformly compressed at the entire periphery of the impeller.

The invention consists of structural features and relative arrangements of the elements which will be hereinafter more fully described and particularly pointed out in the appended claims.

In the accompanying two sheets of drawing, similar reference characters indicate the same parts in the several figures; in which—

Figure 1 is a transverse section of the compressor on line I—I of Fig. 2, showing one side of the impeller in section, and a bearing in elevation;

Fig. 2 is a section on line II—II of Fig. 1 with a section of the impeller in section;

Fig. 3 is an enlarged side view of the impeller partly in section, taken on line III—III of Fig. 4;

Fig. 4 is a section of the impeller taken on line IV—IV of Fig. 3; and

Fig. 5 is a plan view of the development of a section of the rim of the impeller.

Referring to the drawings, 1 is a suitable casing divided on line I—I of Fig. 2, and is provided with a water inlet 2 which is preferably branched or divided into two symmetrical volute chambers 3, 3, for reasons to be hereinafter explained. The interior or central section of the casing has formed therein the rounded or annular opening 4 which leads into the discharge conduit 5, also preferably of volute shape and increasing in cross-sectional area. Said conduit 5 communicates with the outlet passageway having discharge opening 6, as shown in Figs. 1 and 2. Formed in the casing and concentrically arranged on each side of the annular opening 4 and discharge conduit 5, is an air receiving chamber 7 having an air inlet or opening 8 which is connected with the outside atmosphere, or any other source of gas, which it is desired to compress, said inlet or opening 8 being arranged substantially in the same transverse central plane normal to the shaft 10 and passing through the volute discharge conduit 5, water inlet 2 and discharge opening 6, whereby the air or gas to be exhausted or compressed is conveyed into each of the air chambers 7, 7, in such a path and direction as to avoid any eddies being formed or abrupt change of direction of the air or gas being taken in said chambers 7, 7, thereby enabling said air or gas to assume the proper velocity and direction of movement in a single plane, to be efficiently taken up by the water moving in substantially the same plane and passing from the impeller 12 into the discharge conduit 5, to be hereinafter more fully described.

Divided bearing heads 9, 9, are suitably secured or bolted over the lateral openings 9′, 9′, in the divided casing 1, in such a position as to firmly carry and support the impeller shaft 10. Said bearing heads may be provided with the usual chambers or lubricant reservoirs and oiling rings common in this class of centrifugal pumps, and need not be shown or further described, as they form no essential features of the present invention.

The impeller shaft 10 passes through the casing 1 and suitable stuffing boxes 11, 11, provided with the usual water sealed glands, if so desired, and is rotatably supported in the bearings 9, 9, as shown. Said shaft 10 may be connected to any form of high speed steam turbine, or electric motor by means of a flexible coupling, as shown for example, in my U. S. Patent No. 1,073,690, dated September 23, 1913.

Attached by a suitable key or other means, well known in this class of inventions, to said shaft, is an impeller 12, preferably made in three sections 12^a, 12^b and 12^c, as shown in detail in Figs. 3, 4 and 5. The sections 12^a and 12^b comprise right and left hand spiroidal sections for the first stage to be hereinafter described. While I have shown sections 12^a and 12^b as cored, the same may be solid or in one piece, if so desired, and said sections 12^a and 12^b are secured in place by means of sleeves 13, 13, firmly attached to the shaft 10 by engaging left and right hand screw threads 14, on the shaft 10, adjacent to the impeller 12, as shown in Fig. 1, whereby said sections 12^a and 12^b are rigidly held together in a fixed relation and prevented from slipping longitudinally on the shaft 10.

The impeller 12 may be made of semi-steel, crucible steel, or non-corroding alloy or bronze, and when the two sections 12^a and 12^b are properly placed together or assembled, a periphery of V-shape or conoidal section 15, is formed, as shown in Fig. 4, having a certain and predetermined angle with the axis of the impeller. Vanes or blades 16, 16, are placed on the conoidal periphery or section 15, and are so arranged and machined as to form right and left hand spiroidal working surfaces, as shown in Figs. 3 and 4, said surfaces being generated by moving a line making a constant angle with the axis of the impeller while moving along a helical directrix, which directrix is inclined at a determined angle to a plane normal to the axis of the impeller. The outer edges of the blades or vanes 16, 16, of each section 12^a and 12^b, are supported and held together by a shroud ring 17 which is preferably cast integral with the impeller sections 12^a and 12^b, said shroud rings being provided with baffle grooves 18 near their outer edges, while their inner edges have a right or left hand threaded section 19 for purposes to be hereinafter described.

20, 20 are the inlet edges of the blades or vanes 16, 16, which are spiral instead of radial, and 21, 21, indicate the discharge edges of the first stage, said inlet edges or faces 20 being so arranged as to form an angle with the normal outside face or plane of the impeller 12.

In the form of impeller sections 12^a and 12^b, illustrated in Figs. 3 and 4, six blades or vanes 16, are used on each side, which number may be varied to suit conditions and capacity, if so desired, and will be fully within the scope of my invention. I have found that this form of impeller sections 12^a and 12^b is not only theoretically correct, but it also permits the vanes or spiroidal working surfaces 16, 16, to be readily machined or smoothed, thereby reducing the frictional resistances and insuring uniform and efficient action. Furthermore, by providing two sections 12^a and 12^b, instead of a single casting, the same can be cheaply manufactured, easily handled and adjusted, and made perfectly rigid and balanced by being engaged and held together by a multiblade centrifugal section 12^c, as will be hereinafter described, so that said sections 12^a and 12^b retain their correct form and relationship under the unusually high speeds. While my preferred form is shown in Figs. 3 and 4, in which the blades or vanes 16, 16 on each section 12^a and 12^b are directly opposite each other, I have found that this particular arrangement is not necessary for the successful operation of the pump, and said blades or vanes 16 may be staggered, by simply turning on the shaft 10, one of the sections 12^a or 12^b of the impeller 12, through any angle, but preferably to one-half the peripheral distance between the apexes of the blades or vanes 16. Surrounding the sections 12^a and 12^b is a multiblade centrifugal section 12^c which is preferably of one piece and of the form shown in Figs. 3 and 4, provided with a series of separated blades 22, 22, independent of the number of blades in sections 12^a or 12^b, and arranged within the annular and outwardly converging extension 23, and forming a series of separated and independent spiral passageways 24, 24, arranged in an outwardly diverging direction with respect to each other and terminating in a corresponding number of separated nozzle openings 25, 25, in the periphery of the centrifugal section 12^c of the impeller 12. The blades 22 in this centrifugal section 12^c have also spiroidal working surfaces, generated by a line remaining parallel to the impeller shaft, while moving outwardly along a spiral directrix. Said section 12^c is provided on its inner side with right and left hand screw threads 26 which are adapted to be engaged by the corresponding threads 19 on the sections 12^a and 12^b, and firmly hold said sections 12^a and 12^b and 12^c together in a unitary structure, and at the same time said threads 19 and 26 prevent said sections from separating, as during the operation of the compressor the turning effort of the impeller tightens the parts together. The outsides of the lateral extensions of the centrifugal section 12^c are provided with a series of baffle grooves 27, 27, similar to those on the outside of the shroud rings 17, 17, for purposes to be presently described.

The section 12^c is so constructed and arranged that when the same is secured to the sections 12^a and 12^b, as herein described, and said impeller 12 is properly adjusted on the shaft 10, the inner surfaces of the passageways 24, 24, form smooth and unbroken continuations of the passageways in the sections 12^a and 12^b, and the series of nozzle openings 25, 25 are centrally disposed and in proximity to the annular opening 4 of the casing 1, and leading to the discharge conduit 5. The outer extension or centrifugal section 12^c of the impeller 12 is surrounded by and projects into the annular passage which connects the divided air receiving chambers 7, 7, one situated on each side of the discharge conduit 5, as shown in Fig. 1.

The inner walls of the casing 1 between the water chambers 3, 3, and air chambers 7, 7, and adjacent to the baffle grooves 18 and 27 in sections 12^a, 12^b and 12^c of the impeller 12, are provided with wear rings 28, 28, whereby is formed a labyrinth packing between the suction or water chambers 3, 3, and the air receiving chambers 7, 7, for purposes to be hereinafter explained.

During the operation of the impeller 12, rotating in the direction of the arrow *e* shown in Fig. 2, the water flows through the intake or inlet 2, and is divided and carried into two volute suction or water chambers 3, 3, and is then properly taken up in its first stage by the spiral shaped inlet edges 20, 20, on opposite sides of the impeller sections 12^a and 12^b, which enter into the streams of water like a wedge splitting wood, and the spiroidal shaped working faces of the blades or vanes 16, 16, then act flat-wise upon the water instead of edgewise, as in the usual form of helical or centrifugal pumps, and the water in leaving the outer edges 21, 21, of the blades 16, is spirally discharged through a well rounded rotary and annular orifice without any change of direction or appreciable frictional losses, directly into the inlet of the second stage or multi-blade centrifugal 12^c, having the same rotary velocity as the first stage sections 12^a and 12^b, where said water is taken up by the blades 22, 22, within the rotary nozzle and divided into a series of rapidly rotating and outwardly moving spiral columns of water passing through the passage-ways 24, 24 of the impeller section 12^c, and discharged through the nozzle openings 25, 25, and thrown from the periphery of the impeller 12 in the form of a series of separated water jets or pistons, into the volute discharge conduit 5, in a spiral direction, as indicated in Fig. 2 by the dotted arrows *b* and *c*. The dotted curve *a*—*d* not only shows the relative position of particles of water as they move outward when thrown off from a point *a* on the periphery of the impeller 12, but rather one of the many wave fronts of the pistons or jets of water sweeping outwardly into the discharge conduit 5 of the casing 1.

After the above described movement of the water from the impeller 12 into the discharge conduit 5, is satisfactorily effected, if air to be compressed is admitted by means of the inlet 8, arranged in the same transverse plane normal to the shaft as the water inlet 2 and discharge opening 6, into the divided air chamber 7, said air will be drawn from said chambers 7, 7, in a proper direction and velocity and made to pass efficiently around and between the series of jets or pistons of water as they sweep out or leave the nozzle openings 25, 25, of the rapidly rotating impeller 12, into the discharge conduit 5, and said air will be caught at points entirely around the impeller section 12^c, between said series of jets or pistons of water and entirely surround the said jets or pistons, and swept outwardly and into the conduit 5, and compressed to the same pressure as the water discharged. The mixture of water and compressed air is forced out of the discharge 6 and is made to pass directly into a closed pressure reservoir, not shown, where separation of the air and water may take place under the discharge pressure, and be drawn off separately for any desired use, the air for pneumatic hoists and hammers, and the water for ordinary factory purposes.

It will be noted that the air being entirely surrounded by the water, is cooled and compressed isothermally at the temperature of the water pumped, thus saving the shrinkage in volume, which would follow if the air were compressed without being cooled as the pressure increased, and hence the compressor operates under conditions of highest efficiency at the constant temperature of the water.

A further advantage in the present form of compressor in having the jets or pistons of water leaving the impeller 12 surrounded by air, is that said jets or pistons of water are prevented from impinging against each other as said jets or pistons slow down in passing through the annular opening or nozzle 4 into the volute discharge conduit 5, and said entrained air acts as a cushion between the rapidly moving jets or pistons of water, and enables the water and air to move through the opening 4 and out of the conduit 5, with the highest velocity and efficiency, and producing no interfering eddies or churning action in the discharge.

If it is desired to stop the compression of air, one simply shuts off the supply of air to the inlet 8 and the impeller section 12^c will continue to be surrounded by and rotate in air at a reduced pressure, and the action of the compressor will automatically vary, depending upon the variable demand for water pressure or compressed air.

The baffle grooves 18 and 27 on the impeller 12 form a labyrinth packing between suction chambers 3, 3, and the air chambers 7, 7, and the air in said chambers 7, 7, will normally tend to leak slowly through these baffle grooves from the chambers 7, 7, to chambers 3, 3, and surround the impeller section 12^c, and at the same time reduce the water friction about the impeller to a minimum, which is usually a great loss of energy in a centrifugal pump.

It will also be readily seen that the same form of impeller 12 and casing having a single suction and discharge chamber, could be adopted for a single suction compressor, without avoiding the essential features of the present invention of a duplex form of impeller, but the double suction form however is preferred, as it not only has the double capacity of the same speed, but the action of the water and air on the impeller 12 has a self balancing tendency and will retain the impeller nozzle openings 25 in proper relation with respect to the annular opening 4 leading to the discharge conduit 5.

While I have shown a double stage impeller, a single stage could be used, but I prefer the duplex spiroidal impeller type, as described, for the reason that as the rotative speed of the compressor is to be high and intended especially for steam turbine drive, the spiral first stage picks up the water to a better advantage at high speed and more jets or pistons of water can be employed in the second stage, thereby increasing the capacity for air compression.

Diffusion vanes could also be used in conjunction with the impeller, but I have found them not essential for the efficient operation of the compressor, and the centrifugal blades could also be used for the first stage or inlet, but I find the spiroidal type as herein shown and described, far superior and better adapted to pick up the water and act upon it in making the turn from the axial to the radial direction, while the centrifugal type is ideal for the second stage or discharge.

By dividing the casing 1 and bearings 9, as shown in Figs. 1 and 2, it will be readily seen that after one side or half of the casing and bearing caps are removed, the impeller 12, and its shaft 10, can be easily lifted out of the casing, and the compressor examined or repaired, if necessary. It will also be seen that owing to the disclosed relation of the volute water suction chamber or chambers 3, 3, air chambers 7, 7, the annular opening 4, volute discharge 5, and the arrangement of the impeller sections 12^a, 12^b and 12^c, with respect to said chambers, opening, and discharge, the water is directed into and moves with the duplex impeller, in a perfect spiral path, and the air in the chambers 7, 7, is permitted to be entrained at the entire circumference or periphery of the impeller, whereby both the water and air take up the rapid movement of the impeller without any churning action and producing a smooth and efficient operation of the compressor.

From the foregoing disclosure, it will be observed that the casing with its chambers and conduits, the bearings, shaft, impeller sections, and blades or vanes, are easily accessible and the construction of the compressor is such that all the parts of the same may be cheaply and accurately manufactured, quickly installed and adjusted or replaced, so as to insure steady and continuous operation under the highest of speeds and with excellent efficiency.

I do not herein claim the construction and arrangement of vanes or blades of the first stage of the impeller sections 12^a and 12^b, *per se*, as that is the subject-matter of a separate and co-pending application filed by me on August 27, 1913, Serial No. 786,946.

What I claim is:—

1. A compressor comprising a rotary shaft, a casing around said shaft and having a water inlet and a discharge conduit in a plane normal to said shaft, a suction conduit at the side of the discharge conduit, an annular opening having a cross-section in the form of an outwardly diverging nozzle integral with and merging in the discharge conduit, an impeller on said shaft having an outer centrifugal section provided with a series of separated nozzle openings in its periphery and rotatably supported centrally with respect to the annular openings, said nozzle openings being adjacent to the annular opening, a chamber for receiving air in said casing interposed between said discharge conduit and the suction conduit and having an air inlet arranged in substantially the same normal plane as the water inlet and discharge conduit, said air chamber arranged adjacent to said centrifugal section of the impeller and having communication

with the annular opening by an annular passage between the periphery of the centrifugal section and the inner side of the casing adjacent the annular opening.

2. A compressor comprising a rotary shaft, a casing surrounding said shaft and having a water inlet and discharge conduit in a plane normal to said shaft, a suction conduit on each side of the discharge conduit, an annular opening having a cross-section in the form of an outwardly diverging nozzle integral with and merging in the discharge conduit, a double suction impeller on said shaft having an outer centrifugal section provided with a nozzle opening in its periphery and rotatably supported centrally with respect to the annular opening, said nozzle opening being adjacent to the annular opening, a chamber for receiving air in said casing interposed on each side of said discharge conduit and between the suction conduits and having an air inlet arranged in substantially the same normal plane as the water inlet and discharge conduit, said air chambers arranged adjacent the periphery of said centrifugal section of the impeller and having communication with the annular opening by an annular passage between the periphery of the centrifugal section and the inner side of the casing adjacent the annular opening.

3. A compressor comprising a rotary shaft, a casing around said shaft and having a water inlet and a discharge conduit, in a plane normal to said shaft, a suction conduit on each side of the discharge conduit, an annular opening having a cross-section in the form of an outwardly diverging nozzle integral with and merging in the discharge conduit, a double suction impeller on said shaft having an outer centrifugal section provided with a series of separated nozzle openings in its periphery and rotatably supported centrally with respect to the annular opening, said nozzle openings being adjacent to the annular opening, a chamber for receiving air in said casing interposed on each side of said discharge conduit and between the suction conduits and having an air inlet arranged in substantially the same normal plane as the water inlet and discharge conduit, said air chambers arranged adjacent to and surrounding the outer portion of said centrifugal section of the impeller and having communication with the annular opening by a narrow passage between the periphery of the centrifugal section and the inner side of the casing adjacent the annular opening.

4. A compressor comprising a rotary shaft, a casing around said shaft and having a water inlet and volute discharge conduit in a plane normal to said shaft, a volute suction conduit on each side of the discharge conduit, an annular opening having a cross-section in the form of an outwardly diverging nozzle integral with and merging in the discharge conduit, a double suction impeller on said shaft having inner spiroidal sections and an outer centrifugal section connected to and communicating with said spiroidal sections, said centrifugal section provided with a series of separated nozzle openings in its periphery and rotatably supported centrally with respect to the annular opening, said nozzle opening being adjacent to the annular opening, a chamber for receiving air in said casing interposed on each side of said discharge conduit and between the suction conduits and having an air inlet arranged in substantially the same normal plane as the water inlet and discharge conduit, said air chambers arranged adjacent to and surrounding the outer portion of said centrifugal section of the impeller and having communication with the annular opening by an annular passage between the periphery of the centrifugal section and the inner side of the casing adjacent the annular opening.

5. A compressor comprising a rotary shaft, a casing around said shaft and having a water inlet and volute discharge conduit in a plane normal to said shaft, a volute suction conduit on each side of the discharge conduit, an annular opening having a cross-section in the form of an outwardly diverging nozzle integral with and merging in the discharge conduit, a double suction impeller on said shaft having inner communicating spiroidal sections and an outer centrifugal section connected to and communicating with said spiroidal section, said centrifugal section provided with a series of internal separated spiral passageways terminating in a series of separated nozzle openings in the periphery of the impeller and rotatably supported centrally with respect to the annular opening, said nozzle openings being adjacent to the annular opening, a chamber for receiving air in said casing interposed on each side of said discharge conduit and between the suction conduits and having an air inlet arranged in substantially the same normal plane as the water inlet and discharge conduit, said air chambers arranged adjacent to and surrounding said centrifugal section of the impeller and having communication with the annular opening by an annular passage between the periphery of the centrifugal section and the inner side of the casing adjacent the annular opening.

6. A rotary impeller for compressors having a conoidal ridge on which is a series of vanes arranged as spiroidal surfaces, and a hollow annular centrifugal section rigidly connected with the vanes and provided with a series of separated and independent passages arranged in an outwardly diverging direction with respect to each other and terminating in nozzle openings at the periph-

ery of the impeller and adapted to receive the fluid directly from the vanes and convey the same through the passages and out of the nozzle openings with increased velocity from that with which the fluid is conveyed from the spiroidal surfaces.

7. A rotary impeller for compressors having a conoidal ridge on which is a series of vanes arranged as right and left hand spiroidal surfaces having a spiroidal entering edge and arranged to discharge the fluid spirally outward and toward each other, and a hollow annular centrifugal section rigidly connected with the vanes and provided with a series of separated and independent passages arranged in an outwardly diverging direction with respect to each other and terminating in nozzle openings at the periphery of the impeller and adapted to receive the fluid directly from the vanes and convey the same through the passages and out of the nozzle openings with increased velocity from that with which the fluid is conveyed from the spiroidal surfaces.

8. A rotary impeller for compressors having an imperforate conoidal ridge on which is a series of vanes arranged as spiroids and a hollow annular centrifugal section rigidly connected with the periphery of the vanes and arranged normal to the axis of the impeller and provided with a series of separated and independent spiral passages arranged in an outwardly diverging direction with respect to each other and terminating in nozzle openings at the periphery of the impeller, and adapted to directly receive the fluid from the vanes and convey the same through the passages and out of the nozzle openings with increased velocity from that with which the fluid is conveyed from the spiroidal surfaces.

9. A rotary impeller for compressors comprising a rotary shaft, two independent conoidal surfaces surrounding and held against rotation on said shaft and symmetrically arranged with respect to the axis of said shaft and having their bases adjoining each other which form a central comb or ridge, a series of vanes or blades arranged as spiroidal surfaces on each of said conoidal surfaces, a shroud ring surrounding and connected with the blades for each of the conoidal surfaces and having screw threads on its outer surface, and a hollow annular centrifugal section surrounding and having screw threads on its internal periphery engaging the threads on the shroud rings and holding the said independent conoidal surfaces against separation and longitudinal movement on said shaft, said centrifugal section being arranged normal to the axis of the shaft and provided with a series of separated and independent spiral passages arranged in an outwardly diverging direction with respect to each other and terminating in nozzle openings at the periphery of the impeller and adapted to receive directly the fluid from the vanes and convey the same through the centrifugal section and out of the nozzle openings with increased velocity from that with which the fluid is conveyed from the spiroidal surfaces.

10. A rotary impeller for compressors having an imperforate conoidal ridge on which is a series of vanes arranged as right and left hand spiroids, shroud rings surrounding and connected with the peripheries of the vanes, said shroud rings having baffle grooves on their peripheries, and a hollow annular centrifugal section having baffle grooves on its exterior surface adjacent to the baffle grooves on the shroud rings rigidly connected with the shroud rings of the vanes and arranged normal to the axis of the impeller and provided with a series of separated and independent spiral passages arranged in an outwardly diverging direction with respect to each other and terminating in nozzle openings at the periphery of the impeller, and adapted to directly receive the fluid from the vanes and convey the same through the centrifugal section and out of the nozzle openings with increased velocity from that with which the fluid is conveyed from the spiroidal surfaces.

In testimony whereof I affix my signature in presence of two witnesses.

CHARLES VOLNEY KERR.

Witnesses.
EDWIN M. CORYELL,
JOHN J. O'CONNELL.