June 14, 1960 H. E. ADAMS 2,940,657

VACUUM PUMP AND COMPRESSOR

Filed July 27, 1956 5 Sheets-Sheet 1

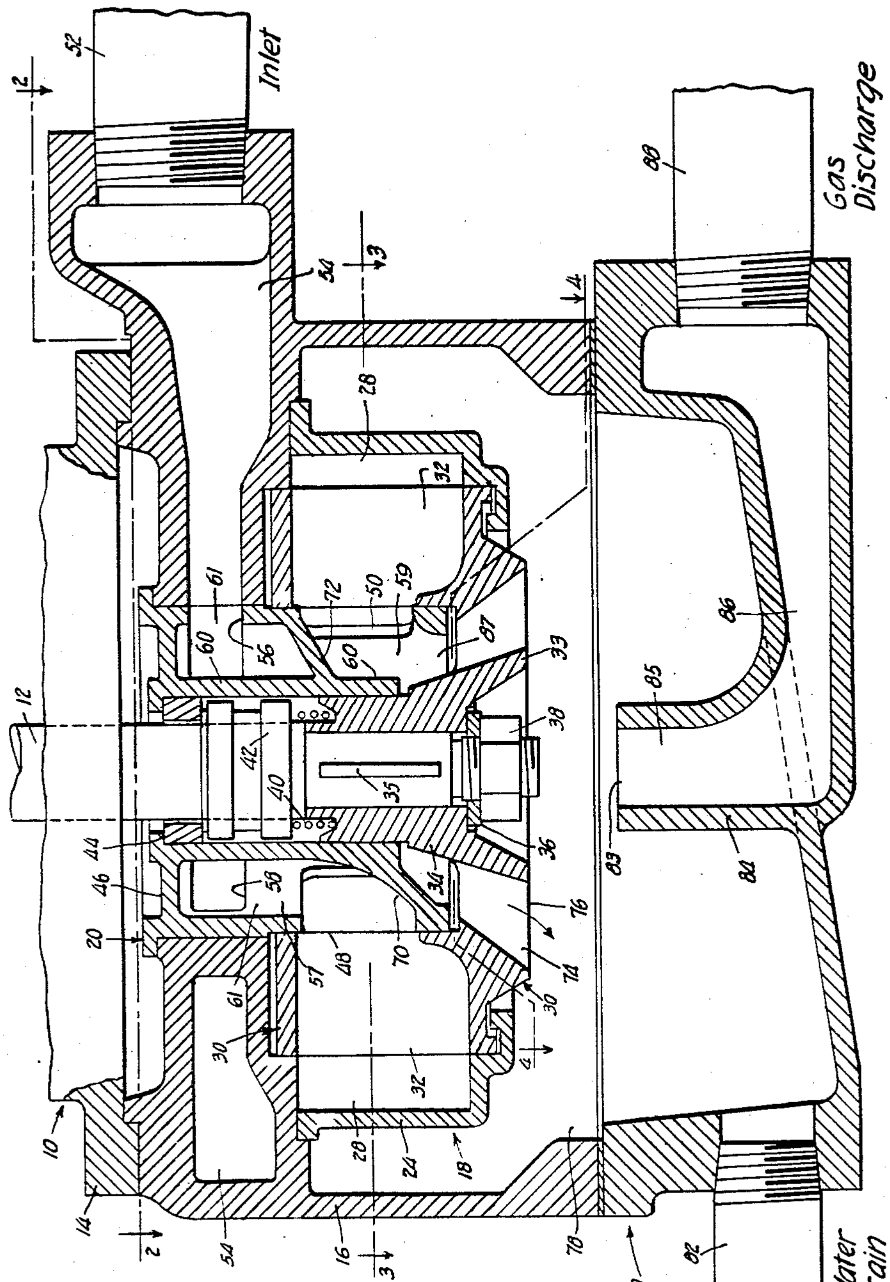

Fig. 1.

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VACUUM PUMP AND COMPRESSOR

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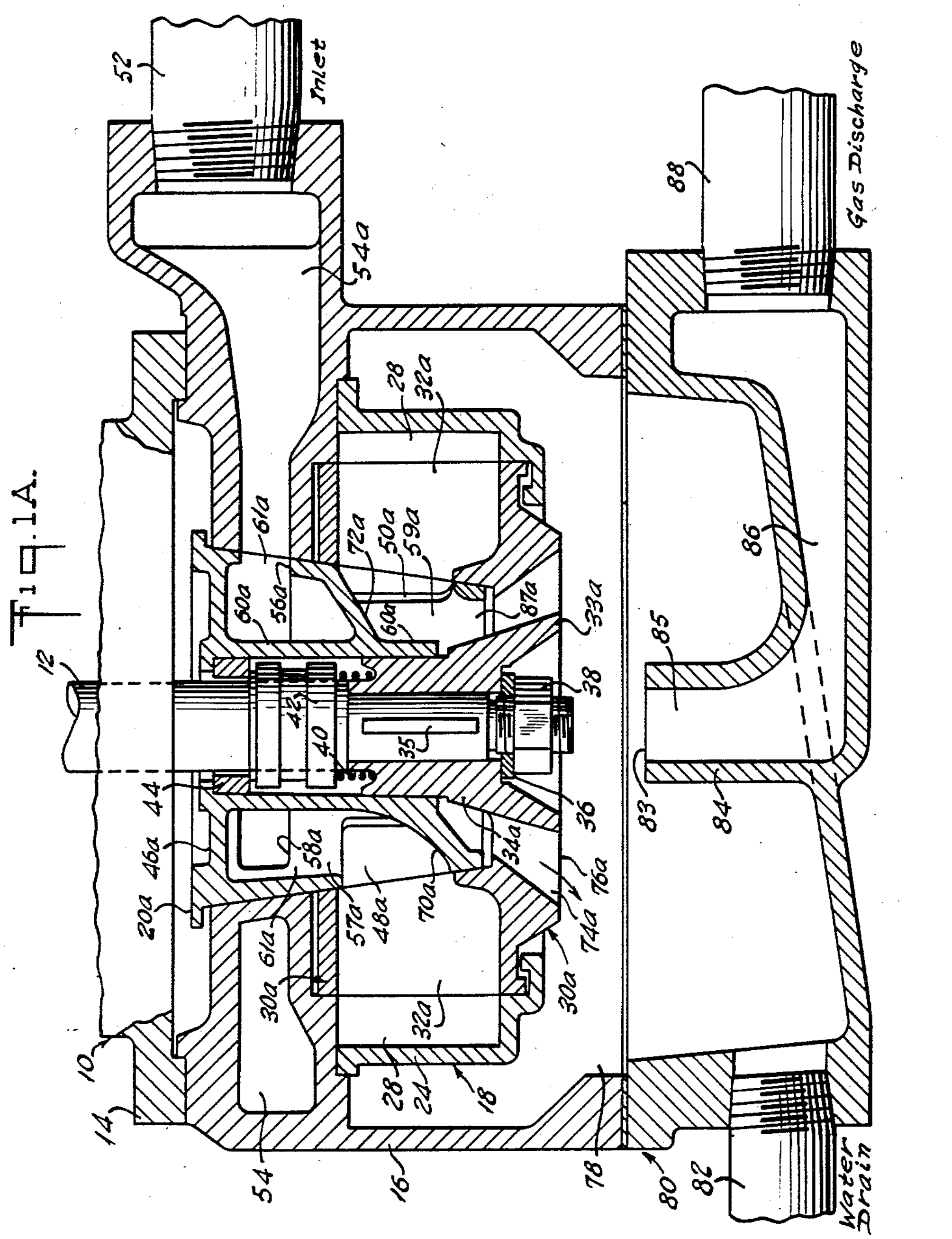

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VACUUM PUMP AND COMPRESSOR

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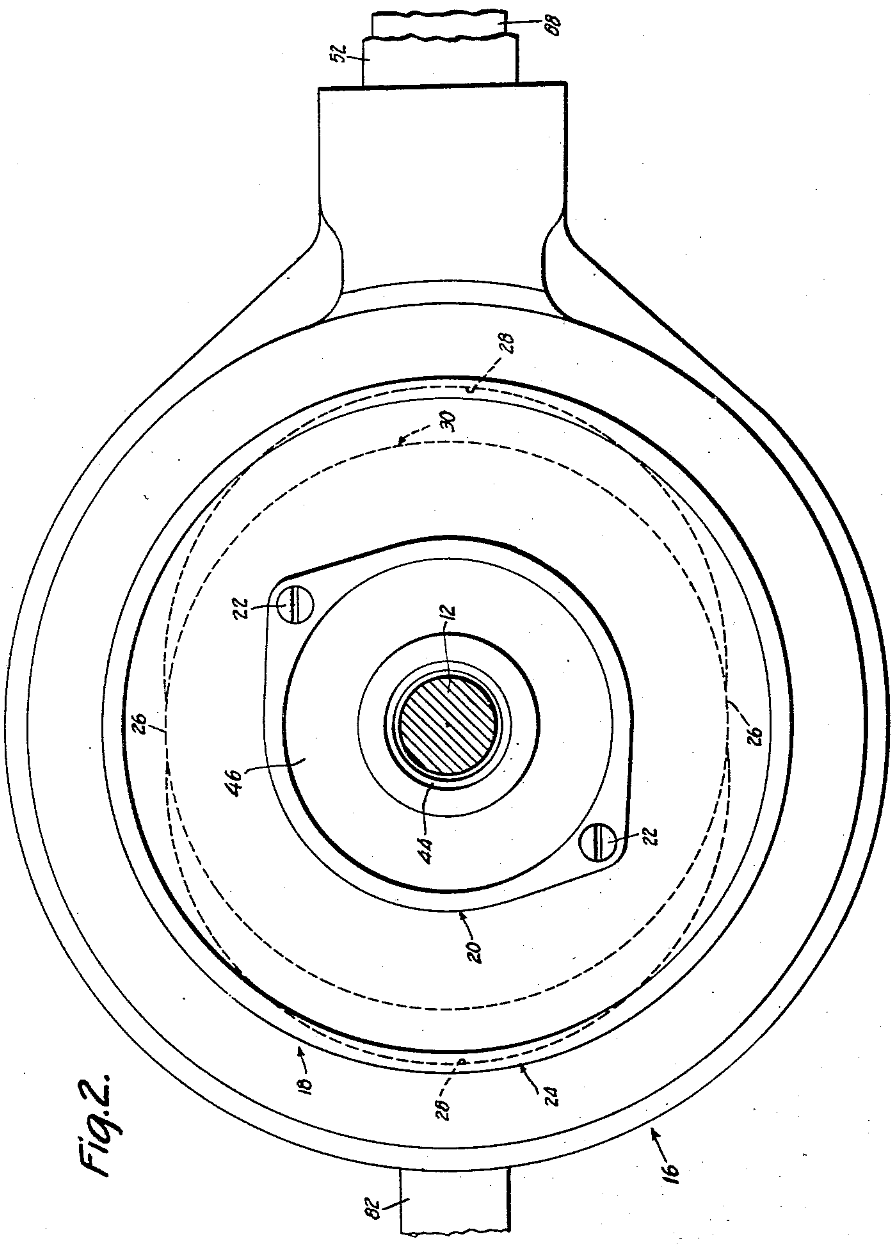

Fig.2.

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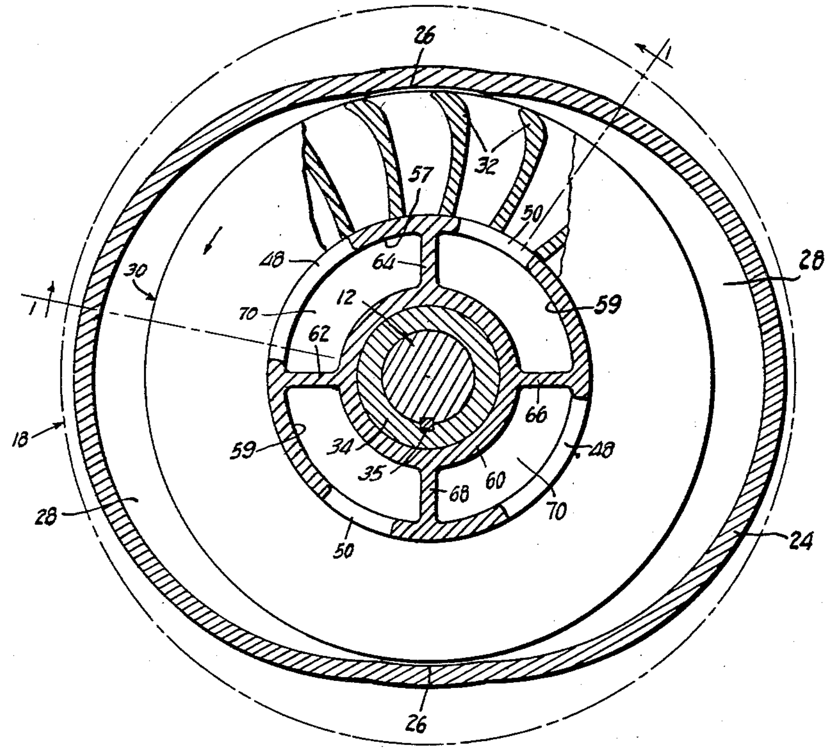
Fig.3.



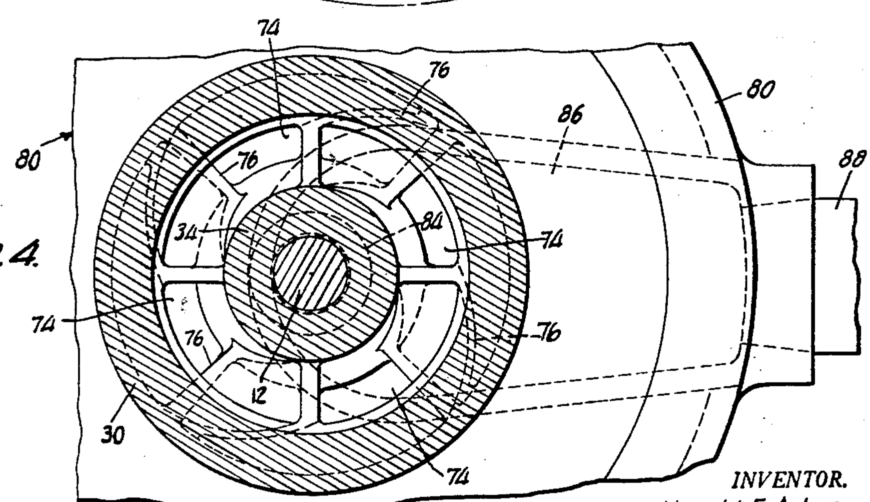


Fig.4.

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VACUUM PUMP AND COMPRESSOR

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Fig. 5.

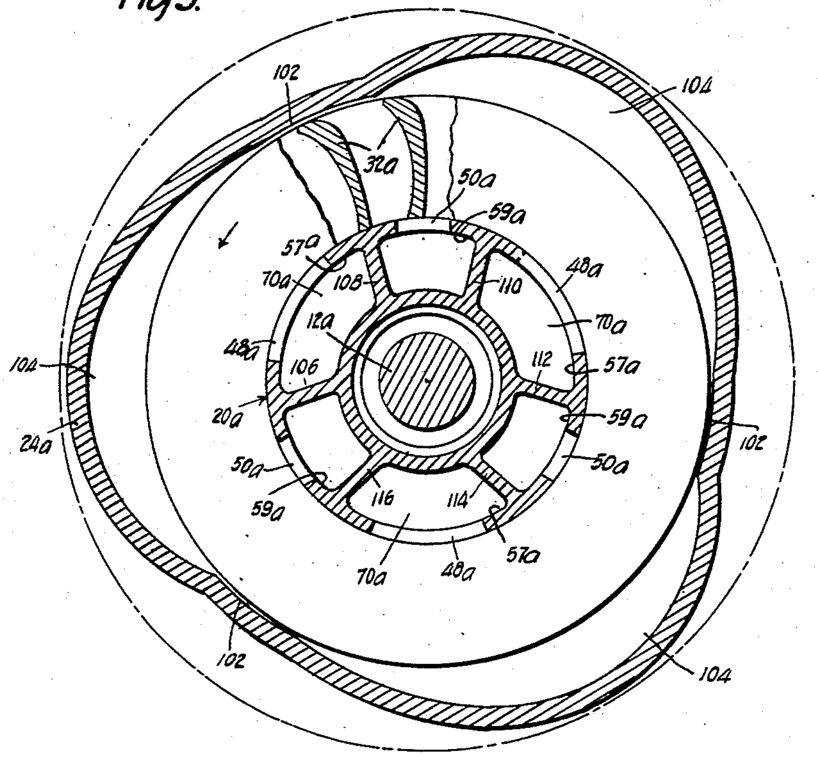
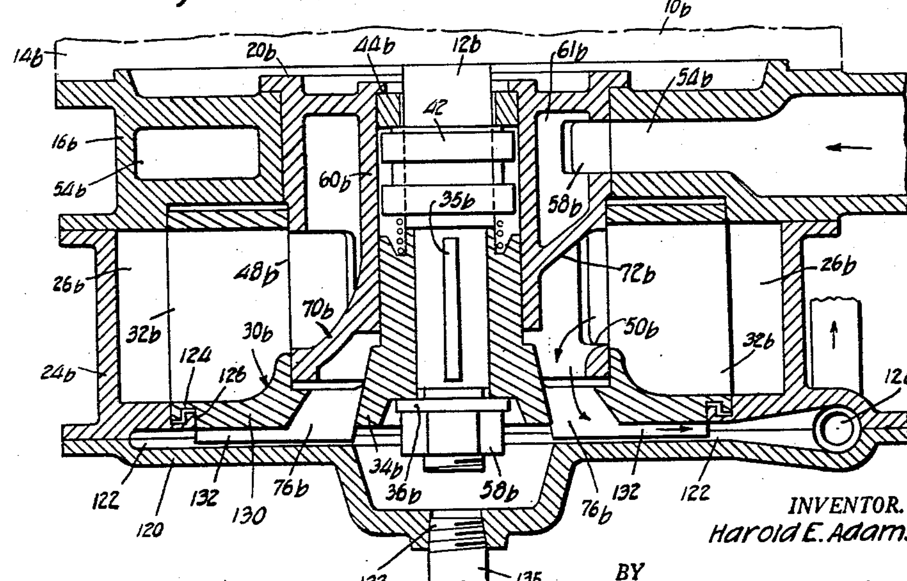


Fig. 6.



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VACUUM PUMP AND COMPRESSOR

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15 Claims. (Cl. 230—79)

This invention relates to vacuum pumps and compressors of the liquid ring type. In pumps of this kind a pumping chamber is commonly bounded externally by a casing and internally by a ported member of circular cross-section, of either conical or circular shape. The casing is formed to provide lobes and lands in alternation. A rotor, divided into pockets or buckets, surrounds the ported member and drives a ring of water which is caused to surge outward and inward alternately, and which constitutes the pumping means. The ported member is provided with an inlet port and an outlet port for each lobe, and since there are generally two lobes, this means that four ports are provided altogether.

The central ported member is kept as small as possible in diameter in order to obtain a favorable ratio of outside to inside rotor diameter. Within this constricted central ported member, passageways are provided which conduct the mixture of gas, vapor and liquid to each of the inlet ports and similar conduits within this same confined area conduct these mixtures from the other two outlet ports. There is, therefore, a congestion of passageways, all of which pass through one end of the limited diameter of the port member. From the common inlet and discharge end of the ported member, the passages are extended into the head or body of the pump where the intake passages are brought together as branches of a common intake passage, and the discharge passages are brought together as branches of a common discharge passage.

In combining these passageways, rather complicated conduits result. One set of passageways must cross over the other to effect the combination. The passageways, of course, add to the complication and cost of the pump. Because of space limitations, particularly in the limiting diameter of the ported member, the velocities through these passageways are generally high and this results in a friction drop which lowers the overall efficiency of the compressor. Some of the work of compression developed within the compressor is utilized to expel both the excess sealing liquid and the compressed gas through the system of intricate discharge passageways. Because of the deviousness and the restricted nature of these passageways, coupled with the high frictional losses that are characteristic of two phase mixtures of gas and liquid, a great deal of the compressive energy is spent in expelling the mixture from the pump.

It is a primary object of the invention to provide for large straight-through passageways in the central port member and to eliminate the complicated conduits now necessary within the head.

To this end it is an important feature of the invention that the inlet is connected directly with one end of the central ported member, and the outlet is connected directly with the opposite end thereof. By this arrangement, the entire inner diameter of the central ported member may be devoted at one end to the less restricted passage of the vapor, gas and liquid coming from the common inlet connection as it flows directly to each of the two inlet ports within the central port member and the entire diameter of the opposite end of this same port member is available for the unrestricted discharge of the outgoing vapor, gas and liquid from the discharge ports.

It is a further important feature that a discharge impeller, formed by the rotor hub, is provided at the discharge end of the central ported member for picking up the discharged mixture and impelling it away from the discharge ports. With this simplification, the cross-over passages and other complicated conduits are eliminated, the cost of the pump is greatly reduced, the efficiency is increased by the reduction of friction losses, the capacity may be increased, and other important advantages are made possible.

In the improved pump, axial blades provided in the rotor hub act directly on the discharge mixture so as to remove it continuously from the central outlet port area and thus keep this area free to receive the compressed gas and liquid as discharged through the discharge ports. The work of getting this discharge mixture of liquid and gas out of the pump is done more efficiently by the direct action of the axial flow impeller than by the present indirect method of extracting energy from the compressed gas. The work of compression, which is what the compressor is used for, is therefore one hundred percent available for its desired service, and is not penalized in getting rid of the two phase mixture from the pump structure.

It is a further object to increase the pumping capacity which can be obtained from a given rotor size. Some of the earlier liquid ring pumps were of single lobe construction. This gave but a single intake and compression cycle during a revolution. According to modern practice, the liquid ring pump is generally made of two lobe construction. It has the advantage of providing two pumping cycles per revolution, and also of providing opposed dynamically balanced displacement chambers. As previously indicated, however, an important drawback of the two lobe construction of present pumps has lain in the restricted, tortuous and complicated character of the inlet and discharge passages.

With the improved arrangement of passages, it is possible to provide a three-lobe construction with more adequate inlet and outlet flow capacity and with less complexity of structure than has heretofore been realized in the case of two-lobe pumps. Such a construction provides three complete pumping cycles per revolution, thus increasing the capacity for a rotor of given diameter by 50% or more. In the three-lobe pump according to the present invention, it is possible to obtain the required passageways through the central port member by opening each of the three inlet ports to a common passageway through one end of the port member and discharging through the three discharge ports to a single common outlet passageway at the opposite end.

A further advantage of the new construction resides in the simplification of the separator problem. In a liquid ring compressor, the liquid seal used for cooling and for proper operation is progressively discharged with the compressed gas. Before the gas can be used, the entrained liquid must be removed. This liquid removal is conventionally done by a separator placed in the discharge line. Such separators add to the cost of the overall unit and in some cases add a parasitic drop in the line.

In accordance with the present invention, the central part of the rotor is utilized in effecting separation of the liquid and gas. The rotor-impeller imparts a centrifugal component to the mixture. While causing this mixture to be discharged into a simple cylindrical chamber, the heavier liquid particles are thrown outward centrifugally but the lighter gas is crowded toward the center of the chamber. By placing the gas discharge in the central region of the chamber and the liquid discharge in the peripheral region, a very good separation is accomplished. The drawings illustrate a vertical arrangement of the pump, but it will operate equally as well in the horizontal position.

An important field of utility of liquid ring compressors lies in the field of fuel booster pump units which are required to receive boiling fuel and transmit it at increased pressure and in a stable liquid state to the main fuel pump of an aircraft engine. In such a booster pump unit, the bulk of the fuel is handled in liquid form by a centrifugal pump. Vapors given off by the boiling fuel would cause the centrifugal pump to become vapor-bound, but for the fact that the centrifugal liquid pump is designed to separate and collect the vapors and a liquid ring compressor is provided to draw off, compress and recondense the vapors, and then deliver them forward for recombination with the fuel output of the centrifugal pump. In this kind of unit, it is desirable that the liquid ring compressor be capable of delivering the condensate at a pressure equal, or nearly equal, to the output pressure of the centrifugal pump.

It is an object of the invention to provide a liquid ring compressor especially adapted for a service of the kind outlined. To this end, it is a feature that the rotor of the liquid ring compressor is provided not only with the axial impeller blades previously referred to, but also with impeller vanes on the side of the rotor, so that a two-stage arrangement is made available for boosting the pressure of the condensate discharged by the compressor. This arrangement can also be used to advantage in other applications where the liquid has to be discharged at a higher pressure than the compressor discharge.

Other objects and advantages will hereinafter appear.

In the drawing forming part of this specification:

Fig. 1 is a fragmentary view in vertical section of an illustrative two lobe form of liquid ring compressor which embodies features of the invention, the section being taken on the line **1—1** of Fig. 3, looking in the direction of the arrows;

Fig. 1A is a view substantially similar to Fig. 1 but indicating another embodiment of ported member instead of the cylinder **20**.

Fig. 2 is a horizontal sectional view taken on the line **2—2** of Fig. 1, looking in the direction of the arrows;

Fig. 3 is a sectional view taken on the line **3—3** of Fig. 1, looking in the direction of the arrows;

Fig. 4 is a fragmentary sectional view, partly broken away, the section being taken on the line **4—4** of Fig. 1, looking in the direction of the arrows;

Fig. 5 is a horizontal sectional view of an illustrative three-lobe liquid ring compressor embodying features of the invention; and

Fig. 6 is a fragmentary view in vertical section of a further modified form of compressor in which the rotor is caused also to act as a compound impeller for maintaining or increasing the pressure of the output delivered by the compressor.

The illustrative embodiment of Figs. 1 to 4 comprises a driving motor **10** whose output shaft **12** extends vertically downward beyond the casing **14** of the motor. A jacket member **16** is fitted and affixed to the motor casing **14** at the lower end thereof. The jacket **16** surrounds a compressor **18** which, in turn, surrounds the lower end of the shaft **12**. The jacket **16** forms an intake head or manifold for the compressor **18** at the intake side thereof and a substantial part of a separator chamber for the compressor at the discharge side thereof.

The inner boundary of the compressor pumping chamber is formed by a flanged cylinder **20** which is connected by a suitable means, such as screws **22** (Fig. 2) to a portion of the jacket **16**. The outer boundary of the compressor pumping chamber is formed by a casing **24** which is shaped internally to provide lands and lobes in alternation, there being two lands **26**, and two lobes **28** (Fig. 3). A rotor **30** having the usual vanes **32**, has its hub **34** mounted on the shaft **12** and driven therefrom through a key **35**. The rotor **30** is conventionally retained on the shaft as by a washer **36** and a nut **38**. A conventional mechanical shaft seal assembly **42** is assembled between spring **40** and a shoulder **44** which forms part of the inner wall part **46** of the cylinder **20**.

As is well understood, the vanes divide the rotor into a series of pockets or buckets which are open at their inner and outer ends. As a bucket traverses the expanding part of a lobe, it discharges a portion of liquid into the crescent shaped space between the rotor periphery and the casing **24**, causing gas to be sucked into the inner end of the bucket through an intake port **48** formed in the peripheral wall of the cylinder **20**. As the bucket traverses the contracting part of the lobe, liquid from the crescent shaped space is forced back into the bucket, causing the bucket to become substantially full of liquid once more. This compresses the gas at the inner end of the bucket and forces it out of the bucket and into the cylinder **20** through a discharge port **50** formed in the peripheral wall of the cylinder **20**. The illustrative compressor follows the principles of the prior art but embodies novel structural features which differentiate it in principle of operation from compressors of the prior art.

An inlet pipe **52** is threaded into a single passage **54** of the jacket **16**. The passage **54** surrounds the upper end of the cylinder **20** and communicates freely with the interior of the cylinder through openings **56** and **58**, which are formed in the circumferential wall of the cylinder. The upper end of the cylinder **20** is closed by an end wall **46**. At the level of the openings **56** and **58**, the space within the cylinder **20** forms a single intake chamber **61**. At the level of the rotor the space within the cylinder **20** is sub-divided by four longitudinally extending partitions **62**, **64**, **66** and **68**. The passages **57** between **62** and **64** and between **66** and **68** are intake passages. They are in free communication with the intake chamber **61**, but are closed off at their lower ends by inclined transverse webs **70**. The intake ports **48** place the passages **57** in communication with the respective lobes of the pumping chamber. The passages **59** between **64** and **66** and between **68** and **62** are discharge passages. They are closed off at their upper ends from the intake chamber **61** by inclined transverse webs **72**, but are open at their lower ends. The discharge ports **50** place the respective lobes of the pumping chamber in communication with the discharge passages **59**. An inner sleeve portion **60** of the cylinder **20**, integral with the partitions **62**, **64**, **66** and **68** and with the webs **70**, **72**, surrounds a portion of the hub **34** of the rotor **30**.

In Fig. 1A there is illustrated an alternate embodiment of pump in which the cylinder **20** is replaced by a frusto-conical member **20***a*. All of the remaining portions of the frusto-conical member **20***a* are similar to the cylinder **20** and are similarly designated, but include the addition of the suffix "*a*." Parts which are indicated both in Fig. 1 and Fig. 1A are similarly designated despite the fact that the shapes of some of them will have to be altered slightly to function with the change of shape of the ported member.

The rotor hub **34** is formed at its lower end with passages **74** which define canted impeller blades or vanes **76** between them. The rotor hub is thus caused to serve as an axial impeller for transmitting liquid, vapor and gas from the passages **64—66** and **68—62** into a separating chamber **78** which is jointly defined by the jacket **16** and a fitting **80**. As has been mentioned, the axial impeller serves by its rotary motion to exert a centrifugal action, so that the liquid is thrown outward and the gas is forced toward the center. The fitting **80** is provided at its periphery with a threaded opening for the reception of a liquid discharge conduit **82**. An upstanding tubular part **84**, with a restricted passage **85** and an opening 83 at the top is provided centrally of the fitting 80 and communicates through a passage 86 with a gas discharge conduit 88. The rotor hub 34 is provided with a conical umbrella-like extension 33, which extends beyond the opening 83 thus deflecting liquid away from the opening 83. The opening 83 and diameter 85 are restricted to provide high air velocity therethrough, so as to effectively muffle the noise arising from the action of the compressor. The above recited details provide a most efficient combination gas-liquid separator and compressor muffler in a very limited space as compared with present day practice.

It will be apparent that the gas and liquid are delivered without resort to cross-overs or constrictions into a common intake chamber 61 located within the cylinder 20, and that they pass directly and without impediment from the chamber 61 through the unrestricted intake passages 57 which lead directly to the intake ports 48 of the pumping chamber. It is also apparent that the discharge liquid and gas pass into straight, unrestricted discharge passages 59 which lead directly to a common discharge chamber 87, and that the discharge from that chamber is assisted by the axial impeller which is formed by the rotor hub 34.

The above arrangement which provides for separate intake and discharge at opposite ends of the pump represents a very great simplification which results in more efficient operation, the ability to handle greater capacity through the central opening, and in a substantial saving of manufacturing cost.

Although the pump has been described as it is shown, with the drive shaft 12 extending vertically, it could be used with equal advantage if the shaft were horizontally disposed. The drain 82, in such a case, would desirably be disposed at the lower side of the pump and directed downward.

In Fig. 5 disclosure is made of a three lobe compressor embodying features of the invention. The pump may be generally like the pump of Figs. 1 to 4 except for differences in detail of the pump casing and the central ported member, which are necessary to the conversion from a two lobe to a three lobe construction. No general description of the pump of Fig. 5 will be given. Corresponding reference numerals have been applied to corresponding parts with the subscript *a* added in each instance. Parts which are shown in Figs. 1 to 4 but omitted from the showing of Fig. 5 are to be understood as present in the Fig. 5 embodiment.

In Fig. 5 the casing 24*a* is formed to provide three lands 102 and three lobes 104, the lobes and lands being provided in alternation, and each combination of one lobe and an adjacent land extending through an arc of 120° with respect to the rotor axis as a center.

Each lobe may have its outer boundary formed as an arc of a circle whose center is offset from the axis of the rotor. Preferably, and as shown, however, each lobe is made unsymmetrical with respect to the point of maximum lobe depth, so that the intake period is extended through a greater arc than the discharge period, and the intake is effected more gradually than the discharge.

A central ported member 20*a* is provided with an intake port 48*a* and a discharge port 50*a* in communication with each lobe there being three intake ports and three discharge ports altogether. The member 20*a* is provided at one end with a common intake chamber communicating with intake passages 57*a* and at the opposite end with a common discharge chamber communicating with discharge passages 59*a*. Intermediate the ends, the member 20*a* is formed with partitions 106, 108, 110, 112, 114 and 116. Intake passages 57*a* are defined by the partitions 106 and 108, 110, and 112, and 114 and 116. These passages are shut off from communication with the discharge chamber at the discharge end of the member 20*a* by cross partitions 70*a*, but formed straight, direct unobstructed channels of communication from the common inlet chamber to the respective intake port 48*a*. Discharge passages 59*a* are defined between partitions 108 and 110, 112 and 114, and 116 and 106, respectively, these passages being closed off from communication with the common inlet chamber, but forming straight, direct, unobstructed channels of communication between the respective discharge ports 50*a* and the common discharge chamber 87*a*.

The pumps of Figs. 1 to 4 and of Fig. 5 are unique in the field of liquid ring pumps, in that they provide, for the first time, in plural lobe pumps, intake and discharge channels which are neither devious, nor unduly confined. This constitutes an important advance in pumps of two lobe construction and makes practically available for the first time, the advantages of pumps of three lobe construction.

In Fig. 6, disclosure is made of a pump of two lobe construction which is generally like that of Figs. 1 to 4, but which is modified at the discharge end to provide a compound centrifugal impeller as a unitary part of the compressor rotor. This type of pump is designed primarily for use in circumstances requiring that the liquid discharged from the compressor be discharged to a higher pressure than the compressor discharge. Such a situation may occur, for example, in booster fuel service on aircraft. The vapor and non-condensible gases from liquid fuel which may have been caused to boil because of altitude and because of the suction exerted upon it at the intake of the centrifugal booster pump, may be drawn off from the intake of the centrifugal pump impeller by the compressor, compressed to the point of recondensation and reabsorption, and discharged as liquid at a pressure equal to the discharge pressure of the centrifugal liquid pump for recombination with the liquid fuel forwarded by the centrifugal liquid pump to the main fuel pump.

The pump of Fig. 6 is substantially the same as the pump of Figs. 1 to 4, with the exception that the compressor rotor has been modified to provide a two stage impeller for the recondensed vapors. Corresponding parts have been designated by corresponding reference numerals with the subscript *b* added in each instance, and no general description will be given. The description will be confined substantially to those parts which are specifically different from the showing of Figs. 1 to 4.

The part 16*b* does not form a jacket around the compressor casing 24*b* but simply serves as an intake manifold for the compressor. The compressor casing 24*b* is secured at one side to the intake manifold and at the opposite side to a supplementary casing member 120 with which it forms a centrifugal pumping chamber 122 and a discharge volute 128. The hub 34*b* of the rotor 30*b* is formed as before to define an axial impeller. In this case, however, the axial impeller blades 76*b* are extended at their lower end to make continuously formed blades 132, extending below and attached to the shroud 130 of the rotor 30*b* and extending to a diameter approaching that of the rotor 30*b*. These blades 132 operate in a casing formed by the lower piece 120 and discharge liquid into the volute chamber 122 to a final liquid discharge 128. A peripheral seal is formed between the volute 122 and the lobes 26*b* by the labyrinth seal arrangement afforded by the groove 124 and flange 126. Liquid picked up by the vanes 76*b* from the discharge area 50*b* is further centrifugally driven by blades 132 to the volute 122 and discharged out through the final discharge 128. The non-condensible gases and vapors are centripetally driven to the center of the fitting 120 where they are discharged through the threaded opening 133 and the connected gas discharge conduit 135, when desired.

Should the separate discharge of the non-condensible gases and vapors be not required, the threaded opening 133 can be stopped off with a plug, and the non-condensible gases and vapors may then be discharged with the liquid thru the volute 122 and the final discharge connection 128.

The blades 132 extend outward as far as necessary to give the final discharge pressure from the volute 128. These blades 132, can, therefore, quite readily maintain or increase the pressure at which the liquid is discharged by the compressor. Coupled with the axial impeller feature, the rotor is caused to provide a two-stage centrifugal impeller for maintaining or boosting the pressure of the liquid delivered by the compressor.

Another very desirable feature exhibited by this invention is the ability of the vacuum pump or compressor to handle large quantities of liquid along with the gas being compressed over and above that possible with present day designs.

Although in the forms of the invention shown and described herein the members 20, 20a and 20b are externally of cylindrical form, the use of members which are externally of conical form is equally contemplated. In such an organization the large end of the cone is desirably made the intake end and the small end of the cone is made the discharge end. This is advantageous because the gases and vapors occupy much less space after compression and do not, therefore, require as great a flow area as when uncompressed.

I have described what I believe to be the best embodiments of my invention. I do not wish, however, to be confined to the embodiments shown, but what I desire to cover by Letters Patent is set forth in the appended claims.

I claim:

1. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said inner ported member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, and a rotor rotatable in said pumping chamber.

2. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said casing being formed interiorly to provide a single intake chamber connecting one end of said inner ported member, said inner ported member having a substantially unrestricted intake passage leading directly from said intake chamber to the respective intake ports, and said casing being formed interiorly to provide a single discharge chamber at the opposite end thereof said inner ported member having a substantially, unrestricted discharge passage leading directly from the respective discharge ports to said discharge chamber, and a rotor rotatable in said pumping chamber.

3. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor, a drive shaft for the rotor, and an axially extending ported member of circular cross-section surrounding the drive shaft and forming the inner boundary of the pumping chamber, said rotor being operable in said chamber between said inner boundary and said outer boundary, said member having an intake port and a discharge port for each lobe of the pumping chamber, said ported member being formed interiorly at one end, exclusively to provide intake paths directly from extremity of said member to the intake ports, and at the opposite end, exclusively to provide discharge paths directly from the discharge ports to the opposite extremity of said member, the rotor having a hub disposed across the discharge extremity of said member and formed to provide passages and impeller blades in alternation, for causing the rotor hub blades to serve also as an axial discharge impeller.

4. A liquid ring pump as set forth in claim 3, which further includes a separator at the discharge end of the ported member to which liquid and gas from the ported member are delivered by the impeller action of the impeller blades and in which the liquid and gas are centrifugally separated from one another under the centrifugal force imparted by said impeller blades, the separator including a liquid discharge means in its peripheral portion and a gas discharge means in its central portion.

5. A liquid ring pump as set forth in claim 3, in which the drive shaft and the ported member are substantially vertically disposed, the intake end of the ported member is the upper end and the discharge end of said member is the lower end, and which further includes a separator at the discharge end of the ported member to which liquid and gas from the ported member are delivered by the impeller action of the impeller blades and in which the liquid and gas are centrifugally separated from one another under the centrifugal force imparted by said impeller, the separator including a liquid discharge means in its lower peripheral portion and a gas discharge means in its upper central portion, and an umbrella-like baffle covering and surrounding the mouth of the gas discharge means but spaced therefrom.

6. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor operable in the chamber, a drive shaft for the rotor, and an axially extending ported member of circular cross-section surrounding the drive shaft and forming the inner boundary of the pumping chamber, said rotor being operable in said chamber between said inner boundary and said outer boundary, said member having an intake port and a discharge port for each lobe of the pumping chamber, said ported member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, the rotor having a hub disposed across the discharge end of said member and formed to provide passages and impeller blades in alternation, for causing the rotor to serve also as an axial discharge impeller, means forming a centrifugal pumping chamber at the discharge side of the compressor beyond the axial impeller, and vanes carried by the rotor in said chamber for augmenting the centrifugal action of the axial impeller, to form a second pumping stage.

7. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor operable in the chamber, a drive shaft for the rotor, and an axially extending ported member of circular cross-section surrounding the drive shaft and forming the inner boundary of the pumping chamber, said rotor being operable in said chamber between said inner boundary and said outer boundary, said member having an intake port and a discharge port for each lobe of the pumping chamber, said ported member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, the rotor having a hub disposed across the discharge end of said member and formed to provide passages and impeller blades in alternation, for causing the rotor to serve also as an axial discharge impeller, means forming a centrifugal pumping chamber at the discharge side of the compressor beyond the axial impeller, and vanes carried by the rotor in said chamber for augmenting the centrifugal action of said axial

impeller, the vanes carried by the rotor being disposed to extend outward substantially to the periphery of the rotor, to form a second pumping stage.

8. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a compressor chamber and of a form to provide at least three lobes, an inner ported member of circular cross section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, means forming a common intake chamber at one end of said ported member and a common discharge chamber at the opposite end thereof, the ported member being formed internally at one end exclusively to provide direct, unobstructed communication from the intake chamber to the several intake ports, and at the opposite end exclusively to provide direct, unobstructed communication from the several discharge ports to the common discharge chamber, and a rotor rotatable in said pumping chamber.

9. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said inner boundary member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, said intake and discharge paths each occupying substantially the entire cross section of the ported member, and a rotor rotatable in said pumping chamber.

10. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said inner boundary member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, the construction and arrangement being such that the gas and vapor to be pumped pass in one axial direction along the intake path to the intake ports and in the same axial direction along the discharge path away from the discharge ports, there being no doubling back and therefore no crossing or crowding of intake and discharge paths within the ported member, said rotor being operable in said pumping chamber between said inner and outer boundaries, a central rotor hub at the discharge end of said ported member formed as an axial flow centrifugal impeller and disposed to receive and to transmit at undiminished pressure all the liquid delivered under pressure from the pumping chamber into the discharge end of the ported member, while transmitting with said liquid the gases and vapors compressed in the pumping chamber and delivered under pressure therefrom.

11. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said inner boundary member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, the construction and arrangement being such that the gas, liquid and vapor to be pumped pass in one direction along the intake path to the intake ports and in the same direction along the discharge path away from the discharge ports, there being no doubling back and therefore no crossing or crowding of intake and discharge paths within the ported member, said rotor being operable in said pumping chamber between said inner and outer boundaries, a central rotor hub at the discharge end of said ported member formed as an axial flow centrifugal impeller and disposed to receive and to transmit at undiminished pressure all the liquid delivered under pressure from the pumping chamber into the discharge end of the ported member, while transmitting with said liquid the gases and vapors compressed in the pumping chamber and delivered under pressure therefrom, and means forming a combined muffler and separator chamber just beyond and around the discharge end of said axial impeller and including a central delivery means for gases of restricted flow area and a peripheral delivery means for liquid.

12. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor, an inner ported member of circular cross-section forming the inner boundary of the pumping chamber and having an intake port and a discharge port in communication with each lobe of the pumping chamber, said inner boundary member being formed interiorly to provide an intake path directly from one end of said member to the intake ports, and to provide a discharge path directly from the discharge ports to the opposite end of said member, the construction and arrangement being such that the gas and vapor to be pumped pass in one direction along the intake path to the intake ports and in the same direction along the discharge path away from the discharge ports, there being no doubling back and therefore no crossing or crowding of intake and discharge paths within the ported member, said rotor being operable in said pumping chamber between said inner and outer boundaries, a central rotor hub at the discharge end of said ported member formed as an axial flow centrifugal impeller and disposed to receive and to transmit at undiminished pressure all the liquid delivered under pressure from the pumping chamber into the discharge end of the ported member, while transmitting with said liquid the gases and vapors compressed in the pumping chamber and delivered under pressure therefrom, said liquid ring pump including an outer casing which extends beyond the end of the axial impeller and in surrounding relation thereto, and a member complementary to the casing and cooperative therewith to form a combined muffler and separating chamber, said chamber having a gas delivery means of restricted cross-section whose intake is centrally located and unitary with said complementary member, and a liquid delivery means peripherally located.

13. A liquid ring pump comprising, in combination, a casing constituting the outer boundary of a pumping chamber and formed with a plurality of lobes, a rotor, a drive shaft for the rotor, and an axially extending ported member of circular cross-section surrounding the drive shaft and forming the inner boundary of the pumping chamber, said rotor being operable in said chamber between said inner boundary and said outer boundary, said member having an intake port and a discharge port for each lobe of the pumping chamber, said ported member being formed interiorly at one end, exclusively to provide intake paths directly from one extremity of said member to the intake ports, and at the opposite end exclusively to provide discharge paths directly from the discharge ports to the opposite extremity of said member, the rotor having a hub disposed across the discharge extremity of said member and formed to provide passages and impeller blades in alternation, for causing the rotor hub blades to serve also as an axial discharge impeller and a combined muffler and separating chamber disposed to receive all the liquid, gas and vapor delivered by the axial discharge impeller, and including separate

discharge members for liquid and for gases, respectively, the latter being sufficiently restricted to induce a high gas velocity for effectively muffling noises arising from the compressor action.

14. A liquid ring pump as set forth in claim 1 in which the inner ported member is externally cylindrical in form, and a rotor rotatable in said pumping chamber.

15. A liquid ring pump as set forth in claim 1 in which the inner ported member is externally frusto conical in form.

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