Aug. 27, 1963 H. E. ADAMS 3,102,083

PUMPING MEANS FOR DISTILLATION UNIT

Filed April 20, 1960 4 Sheets-Sheet 1

Fig. 1.

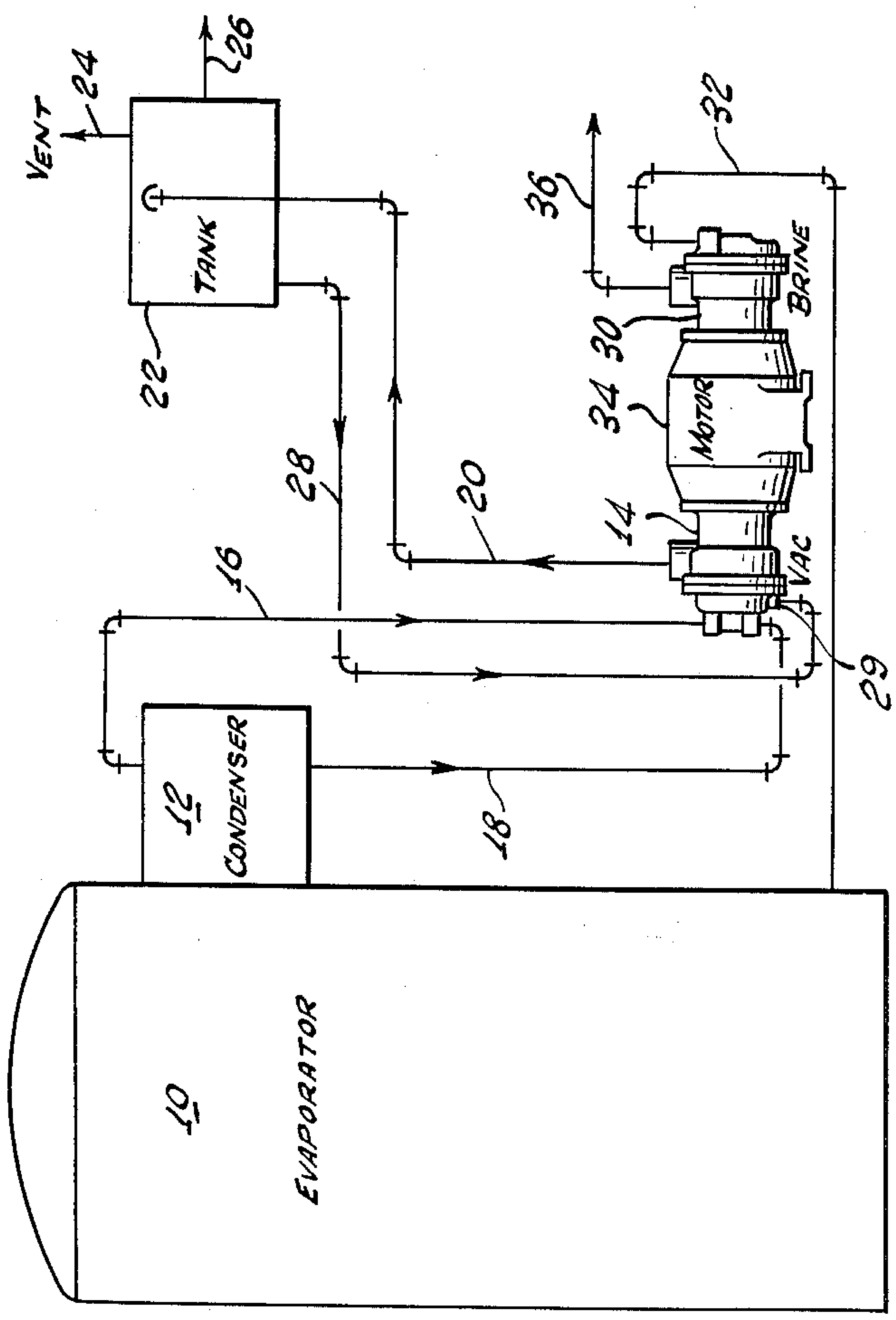

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Fig. 7.

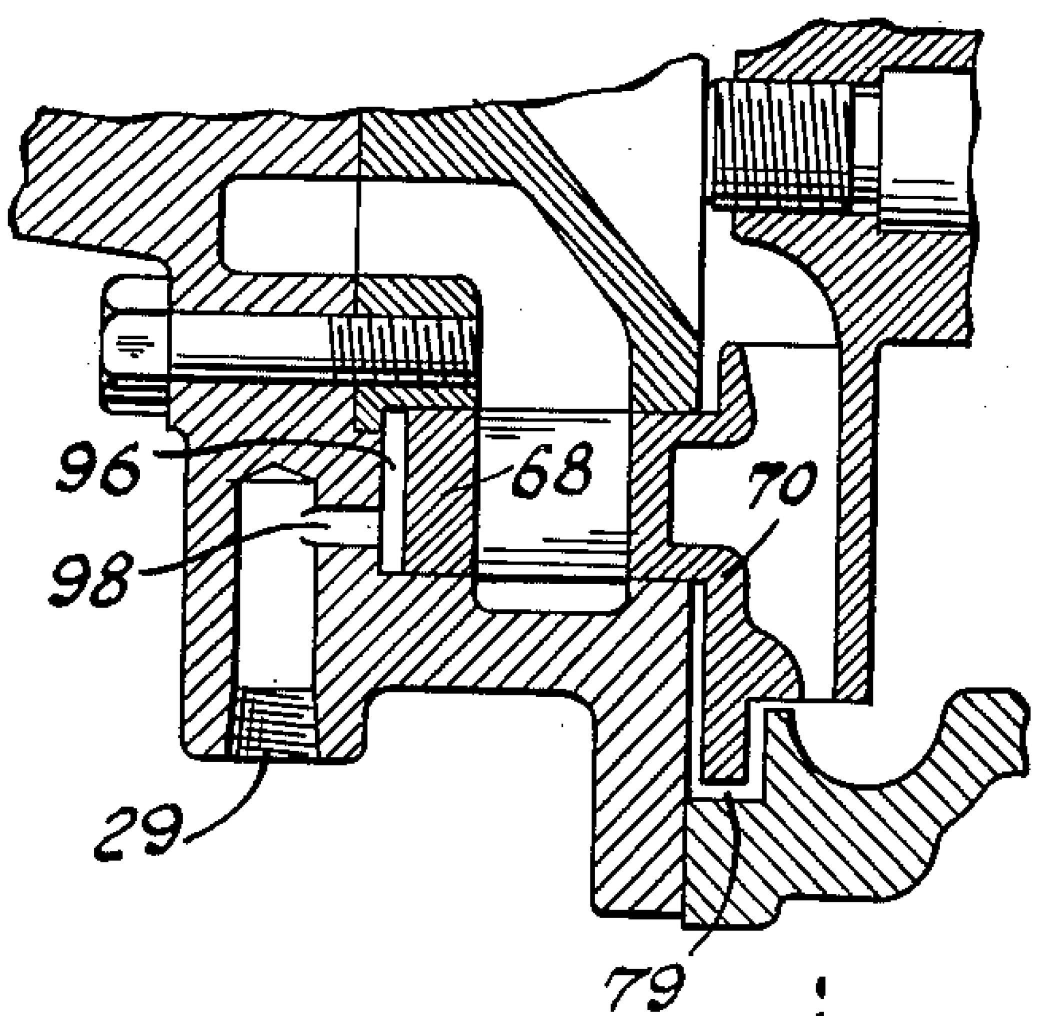

Fig. 2.

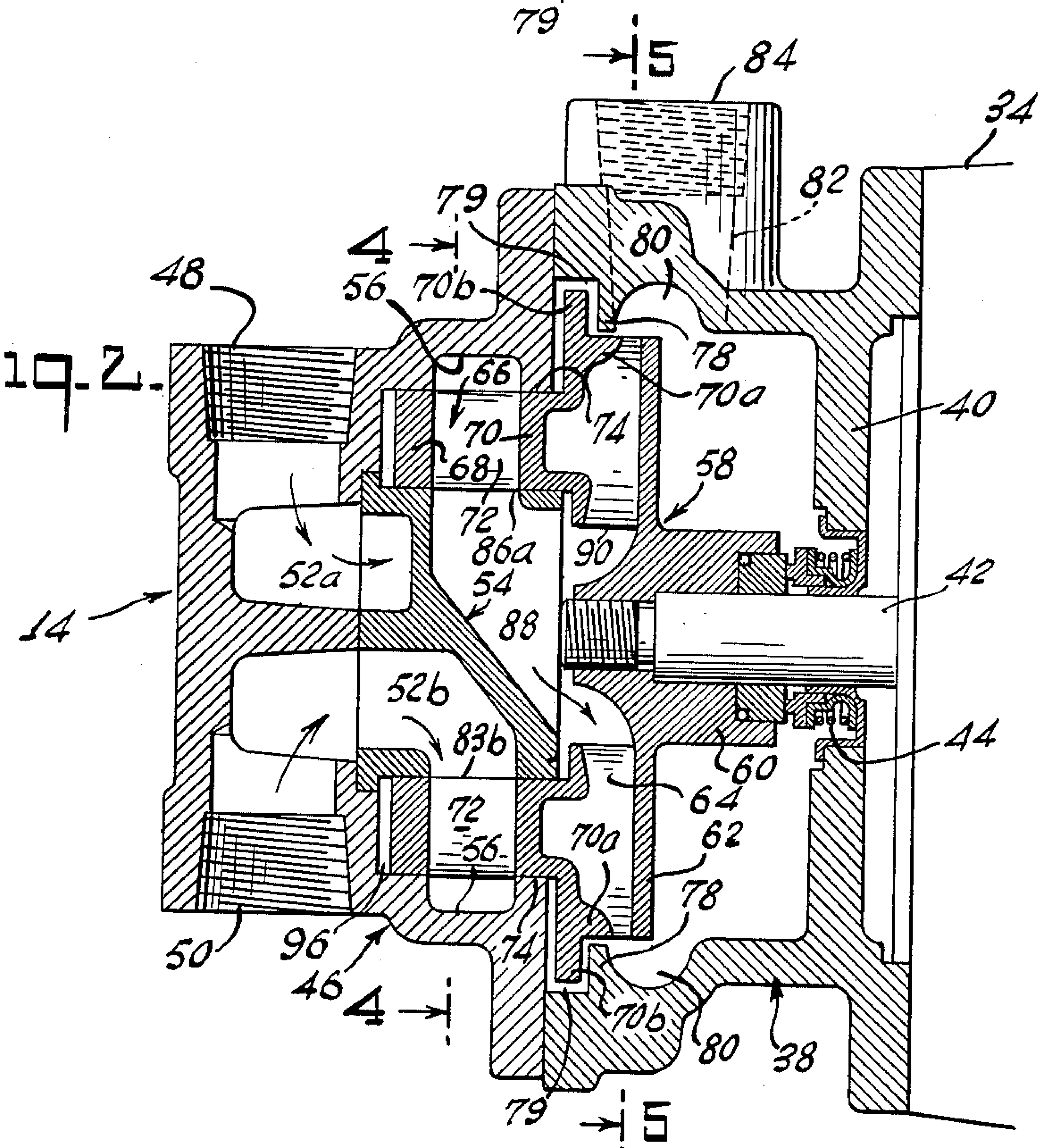

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Fig. 4.

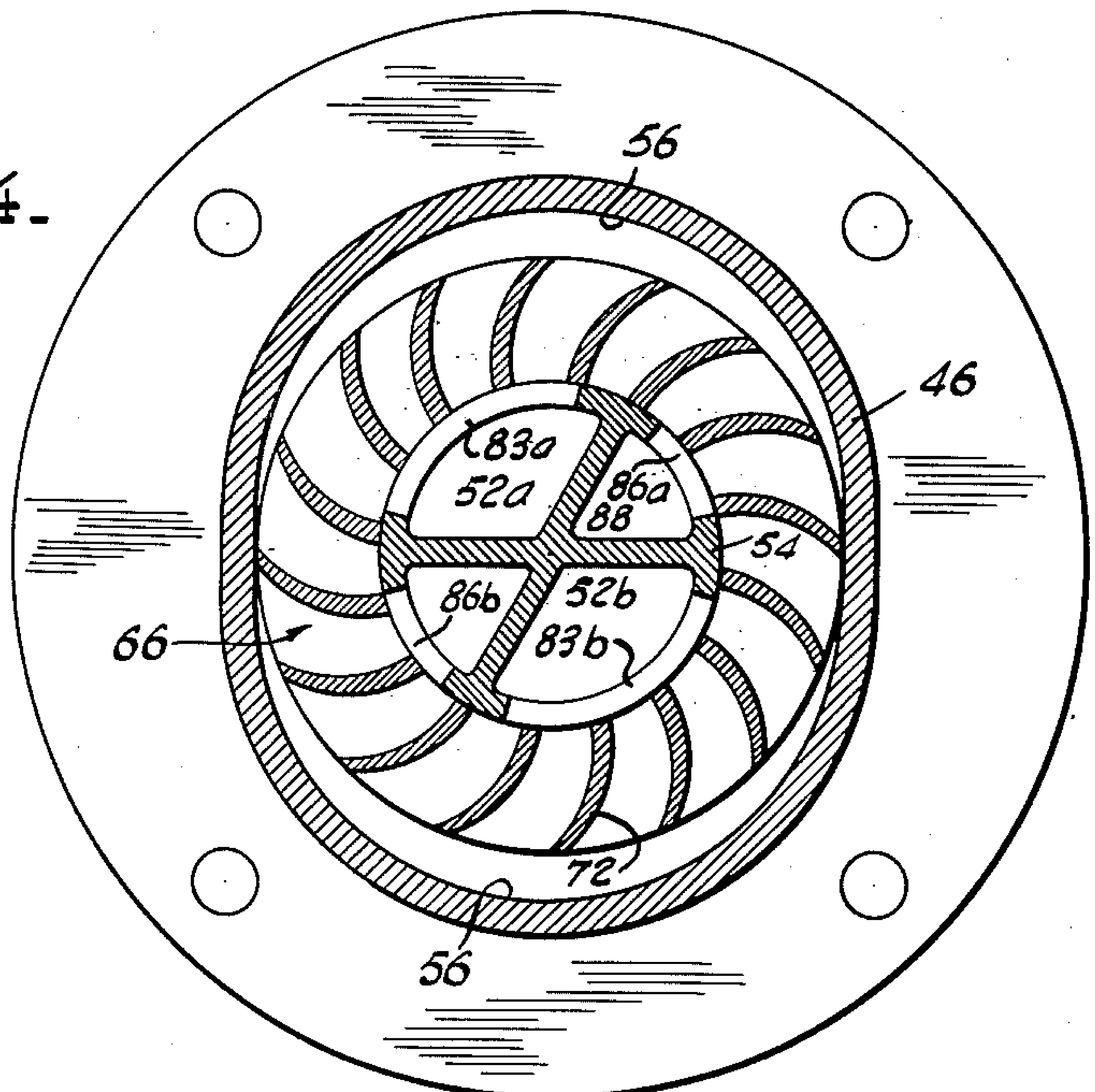

Fig. 3.

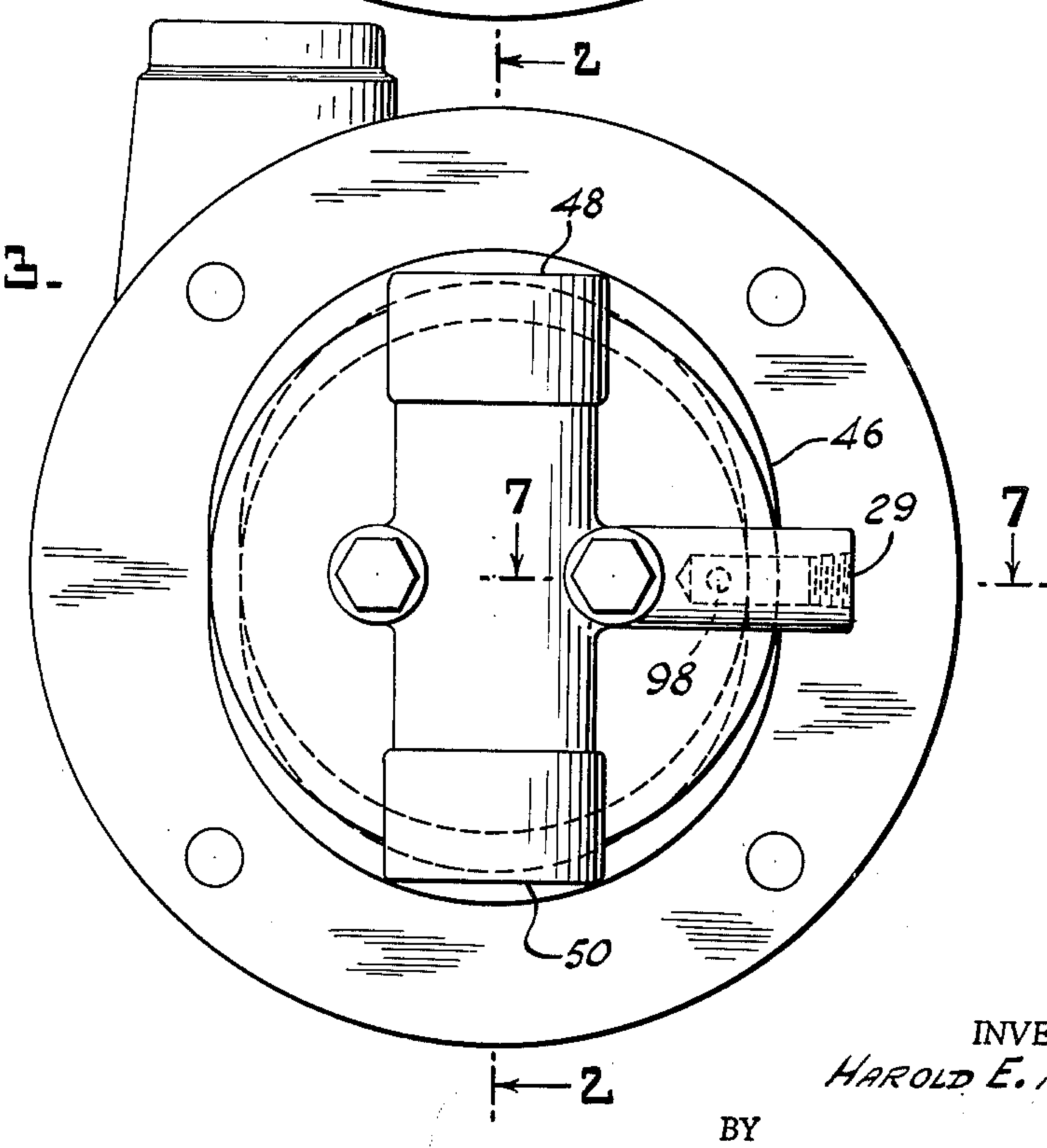

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Fig. 5.

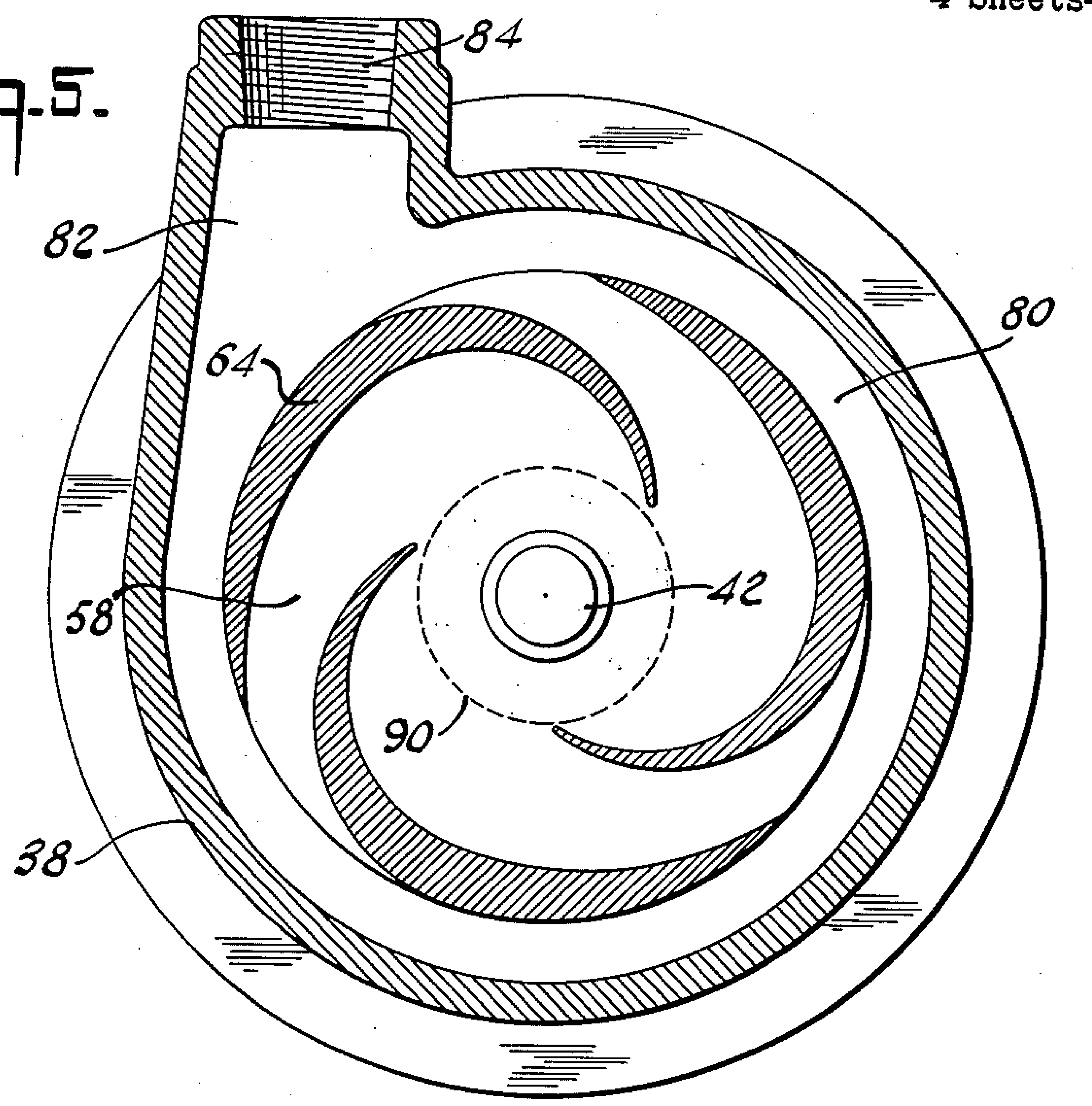
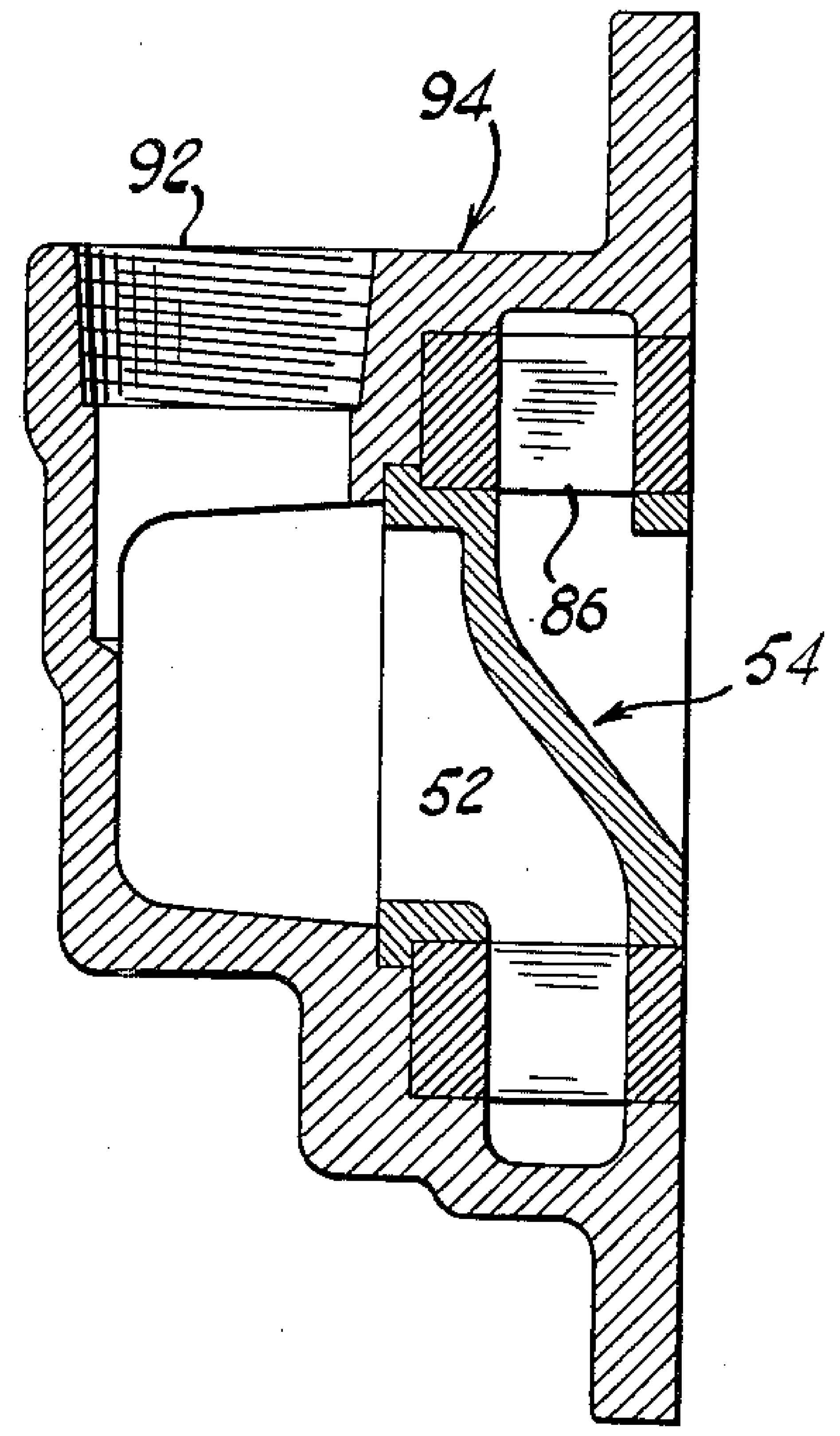


Fig. 6.



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PUMPING MEANS FOR DISTILLATION UNIT

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Filed Apr. 20, 1960, Ser. No. 23,552
8 Claims. (Cl. 202—52)

This invention relates in general to pumps and pump systems and in particular to a new and useful centrifugal-displacement type pump, capable of efficient operation when handling either gases, vapors, or liquids, or a combination thereof, and to an evaporative system employing such pump.

It should be appreciated that while the present invention is particularly directed to an improved type of rotary-centrifugal pump capable of continued efficient operation when pumping either gases entirely, vapors entirely, liquid entirely, or a combination of these, the invention is also directed to an improved evaporative system employing the improved pump construction and operating with efficiency not realized heretofor.

In evaporating units, particularly small size units such as those capable of distilling about 500 gallons of water per day, it is difficult to maintain the desired high vacuum on the condenser of such units with the ordinary pumping equipment available. In most instances, such apparatus requires up to three separate pumps, including a distillate pump, to handle the distillate which has been condensed after evaporation, a brine pump for the removal of the brine left in the evaporator, and an air removal pump to remove the non-condensible gases from the condenser. It is desirable that the evaporator operate with as high a vacuum condition as is possible in order to utilize low temperature heat sources. It is also desirable that the partial air pressure of the condenser be reduced to a minimum, which also places the liquid close to its vaporizing or boiling point. This proximity to the boiling point adds to the difficulty of pumping the liquids from both the evaporator and the condenser. Present day distillate pumps and evaporator brine pumps require some six feet of positive head to permit continuous water removal. This is a disadvantage because such installations are not feasible in small marine craft where such clearance height below the evaporator and condenser is not readily available.

In accordance with one aspect of the invention, the above-mentioned disadvantages of evaporator operation are overcome by the provision of an improved evaporator construction which includes a single pumping unit comprised of a single driving motor and two separate novel liquid-gas removal pumps associated therewith. Each of these pumps is similar in operation and each is capable of continuously and efficiently pumping gas, if such be the requirement, or pumping liquid in those instances where it is principally liquid that is delivered thereto. The pumps are advantageously connected so that the brine is continuously removed from the bottom of the evaporator by a pump on one end of the motor while the pump on the other end of the motor is used to continuously remove the distillate from the condenser and to simultaneously purge the air from the condenser so as to maintain vacuum thereon. This latter pump also has the advantage of compressing and recombining the air removed

from the condenser during the pumping process with the final distillate discharge.

An essential element of the evaporator system outlined above is the novel pump construction which permits installation of the pump at the same height as the evaporator without having to provide a positive suction head, and the ability of such pump to pump either gas or liquid efficiently.

The many desirable features of this invention are obtained by a novel combination of a liquid ring air compressor and a centrifugal liquid pump in series relationship so that each pumping element is enabled to operate under conditions previously considered impossible. It would normally not be expected that such a combination would be practical as you would not expect to place a centrifugal liquid pump as a second stage to an air compressor because, as is well known in the art, centrifugal liquid pumps are allergic to any air entering the suction. The combination, however, that I provide does have certain advantages in the manner employed and described in this application.

The basic liquid ring pump or compressor is well known in the art and needs no detailed description here. It is designed to pump and compress air or gas by the displacing action of its liquid ring as this ring is driven by a rotor within an eccentric or elliptical casing. The kinetic energy given to the liquid ring is given up or transformed into the work of compression on the gas handled by it. The gas, because of its relatively light density, is handled through the pump's passageways by the displacing action described before, at velocities in the order of from 2000 to 5000 feet per minute, as is common practice with air and gas compressors.

It is well known in the art that a machine to compress gas is inappropriate to handle liquid at the same rate and discharge pressure. The liquid cannot be handled at the same velocities that are permissible with gas. This is because of the great discrepancy in densities between gases and liquid. If a positive type compressor such as a piston pump were to receive solid water at its suction instead of gas, during its normal operation, it would result in either stopping the pump immediately or possibly blowing out its cylinder head or in other ways damaging the pump. If a conventional liquid ring pump is called upon to pump liquid alone at this same high velocity range of 2,000 to 5,000 feet per minute, which of course it will try to do the pump would not stop or break, as would be the case with a positive pump, but, instead, there is a sudden high surge in power and the pump would cavitate. This action on a liquid ring pump is sometimes referred to as "queering" or "stalling." If allowed to run any length of time in this condition, it would result in damage to the rotor blades and the pump casing by cavitation. Thus, a conventional liquid ring pump must always be supplied with air to prevent mechanical failure.

In view of the above phenomena, a liquid ring pump in the past has never intentionally been used on an application where its suction is liable to be shut off entirely or where air or gas are prevented from entering its inlet because of the lack of such gas. Such would be the case when the pump is used to remove the air and non-condensibles from the condenser in an evaporative system. As soon as most of the air in the condenser is removed, and the condition of virtually no gas flow occurs, the vacuum pump or compressor fills up with its cooling and sealing liquid and the turbulent or "queering" action results. The resulting destructive action, as stated above, is largely caused by cavitation on the interior parts rather than by failure from high power stresses, as would be the case of a positive displacement type pump.

In the combination of the invention, provision is made for the liquid ring compressor to also pump liquid only, without air, and without resulting cavitation or damage to the pump or compressor.

It is well known in the art that a centrifugal liquid pump cannot pump if there is any appreciable percentage of air by volume in the mixture entering its suction. In a standard centrifugal pump, this limit is approximately 3% by volume of air to liquid. This is also true if vapor is present in the suction. To avoid the presence of vapor, the suction is always pressurized sufficiently to suppress any vaporization occurring at the inlet. The amount of this pressurization is currently referred to as NPSH, or, net positive suction head above the vapor pressure of the liquid under the conditions at which it arrives at the pump suction. Conventional centrifugal pumps require about 20 feet net positive suction head for uninterrupted pumping. The best condenser pumps designed for this condition will operate satisfactorily with about 4 foot suction head as a minimum. Some special purpose centrifugal condenser pumps have been designed for operation at as low as 2 feet net positive suction head, but this is usually at a considerably reduced capacity for the size of the pump involved.

In this invention there is provided a combination of a centrifugal liquid pump and a liquid ring pump to pump liquids at their boil point or at zero net positive suction head. This novel combination of liquid ring pump and centrifugal liquid pump in the manner later described thus provides one centrifugal type machine capable of pumping gases, vapors, liquids, or combinations of these, efficiently and with a minimum suction head without damage to the pump structure.

It can be readily appreciated that in some instances it is difficult to obtain the necessary net positive suction head when using standard pumps or evaporators and condensers, particularly on shipboard where vertical height is sometimes difficult to obtain. My invention permits the pump to be bolted directly to the side of the evaporator itself. It is not necessary that this pump be mounted below the evaporator in order to obtain the usual required net positive suction head of other pumps.

In addition to removing the distillate from the condenser at or near its boiling point, it is also necessary to remove the air from the condenser to improve the condenser efficiency and to maintain as near a zero partial air pressure as is practical within the main section of the evaporator. It is also desirable to maintain as low a temperature level as possible in order to utilize low temperature heat sources for evaporative purposes and this further increases the high vacuum requirement placed upon the pumping equipment. In this manner the maximum amount of heat may be extracted from the initial available heat supply and because of the low temperature level at which the heat is extracted, there is less precipitation of salts and other minerals from the brine, with resultant less incrusting or scaling of the evaporator interiors.

Frequent cleaning is characteristic of the usual evaporators which operate at higher temperatures than the device of the present invention.

In striving for the lowest possible temperature within the condenser, the best equipment possible is required to produce this low temperature by increasing the vacuum on the condenser to as high a value as possible. On this type of application it is customary to employ high pressure steam jets for the removal of air from the condenser. Mechanical vacuum pumps and water ejectors are also employed for this purpose. All of these pumps discharge the air separately to atmosphere. Prior to the present invention, it was considered impractical to take advantage of the generally desirable standard liquid ring vacuum pump for such condenser air removal service. This difficulty was principally because the air quantity to be removed from the condenser is sometimes so low that the vacuum pump is operating at virtually zero capacity. Under this condition, the standard liquid ring pump is liable to "queer" with resultant damage to the pump due to cavitation produced when attempting to pump liquid without air, as has been previously described. The pump combination of this invention, which includes the desirable features of the liquid ring pump, will operate under this zero air capacity condition without damage.

Normal liquid ring pumps cannot operate with usable capacity when the liquid supplied to the pump as a sealing liquid approaches the temperature corresponding to the boiling point pressure of the liquid. Such pumps must operate at an absolute pressure considerably above the boiling point pressure, whereas, in the present pump construction, it is possible to operate at high vacuum with inlet seal temperatures approximately the same as the boiling point temperature and with the normal displacement capacity for the air-vapor mixture present.

Another advantage is that the apparatus constructed in accordance with this invention produces a higher vacuum than is possible with a standard liquid ring vacuum pump. The standard liquid ring pump, as has been indicated before, must have some gas or air present at its suction. In other words, there has to be a reasonable partial air or gas pressure available at the suction. This limits the practical operating vacuum, for instance, on single stage operation when using water seal at 60° F. to about 25 inches Hg. The pump cannot operate safely at higher vacuums because of possible "dead end" operation and "queering" or cavitation coming into play. The pump of this invention, however, can continue to operate at the shut-off pressure corresponding to the vapor pressure of its seal. It does not have to have air present under this condition for satisfactory operation, as is the case with the standard liquid ring pump. When using 60° F. water as a sealing means, for example, the pump can go to about 29.4 inches vacuum without cavitation damage, as compared to the 25 inches of a standard type.

The pump combination of the invention includes a housing including a lobed pumping chamber or chambers and a liquid pumping chamber, and including a cylindrical liquid ring rotor and a centrifugal liquid impeller of unitary construction mounted on a common drive shaft within the confines of the pumping chambers. The liquid ring pump portion is arranged to take suction directly from the apparatus from which the boiling liquid, the vapors, and gases are to be removed, and to discharge these at an intermediate pressure to the inlet of the liquid impeller. The unitary impeller-rotor is driven through the shaft by a hub portion having a disc to which are attached the radial blades of a second stage centrifugal liquid impeller and to the latter blades of which are also attached the shrouds and blades of the liquid ring impeller.

In accordance with the invention, the radial blades of the second stage liquid impeller are generally made equal to or larger than the blades of the liquid ring impeller and are also made larger than would normally be required for merely the pumping of liquid under the expected designed operating head.

The pump is further designed so that the passageways of the first stage liquid ring portion are as large as possible to facilitate the handling of liquid as well as gases, when required.

The liquid ring rotor and casing are designed to deliver a given displacement volume of gas over a designed intake and discharge pressure differential. In the case of a condenser, the intake pressure is that of the condenser, which may be in the order of 29 inches Hg vacuum, more or less, and the discharge pressure would be slightly above atmospheric pressure, including friction drop, etc., possibly 2 or 3 pounds gage pressure. The liquid ring pump also has the built-in capacity to handle in addition to the gas, the necessary liquid for sealing, cooling, and condensing purposes. The amount of this liquid capacity is still small relative to the total gas displacement volume rating of the liquid ring portion. The diameter of the liquid ring rotor blades, the displacement capacity of these blades, and the cooperating elliptical casing surrounding them, are all designed to do the aforementioned amount of work when running at a standard motor drive speed. The kinetic energy imparted to the liquid ring by the buckets or blades of the rotor is just sufficient to do this amount of work with a comfortable margin. If the pump is fed liquid only at this point, instead of gas, it could not deliver this liquid over the same total differential because the kinetic energy imparted to the liquid ring would be insufficient. In accordance with the invention, however, the liquid ring is only required to deliver the high density liquid mixture over a small pressure differential compatible with the kinetic energy imparted to the liquid ring.

The centrifugal liquid impeller is designed to operate at the same rotational speed, of course, and to deliver the required amount of liquid from the condenser at approximately 29 inches vacuum to a higher pressure above atmosphere than that required of the liquid ring portion. This higher pressure is designed into the impeller so that it may discharge against atmospheric pressure when handling a dense mixture of air and water having about 20% air by volume.

The liquid ring portion of the invention when handling normal air or gas quantities compresses these to a smaller volume and discharges them into the inlet of the centrifugal impeller. During this operation, the liquid ring pump handles the air and non-condensible gases over the complete designed differential, from the high vacuum to a pressure above atmosphere, as indicated before. Because of the high air content, the centrifugal impeller during this phase of the operation adds virtually no appreciable gas pressure difference. In other words, the liquid ring pump drives the gas through the blade passageways of the liquid centrifugal impeller. During this time, however, the liquid centrifugal impeller does relieve the liquid ring portion by pumping the entrained cooling and sealing liquid over the small differential across the centrifugal liquid impeller, thus relieving the liquid ring portion of the pump from the necessity of forcing this liquid through the passageways by its compressive action.

The rotating passageways of the centrifugal impeller have the further advantage of centrifugally separating the entrained liquid from the air-liquid mixture delivered to its inlet by the liquid ring portion. By thus separating the liquid from the air it provides a more efficient gas delivery by the fact that this separation reduces the friction drop that would normally be associated with the turbulent flow of a mixture of gases and liquids through a stationary passageway.

During this state of the operation, the centrifugal liquid impeller cannot add appreciable pressure difference to the overall mixture flow because of the very low density of this mixture as compared to the proportions and speed of the centrifugal impeller as designed to handle solid liquid. This condition exists on a condenser during the initial purging of the air within its structure. As the vacuum is built up on the condenser to the operating vacuum, the amount of air or gas to be handled is gradually reduced until only the air, due to leakage into the condenser, plus air released from the salt water, must be handled. If the condenser is particularly well designed, the amount of air to be removed is very small and virtually only that released from the salt water entering the evaporator.

In the operation of a pump constructed in accordance with this invention on a condenser, as the amount of air is reduced or the amount of liquid to be handled by the liquid ring pump is relatively increased either by the condensate to be handled or by the amount of recirculation, the density of the mixture at the discharge of the liquid ring pump is increased. As the proportion of air is further reduced to the total amount of liquid to be handled, the mixture at the inlet of the centrifugal approaches a value where the centrifugal liquid impeller can impart by its own action a significant pressure difference and at this point of the operation the centrifugal liquid impeller then begins to operate as a second stage to the liquid ring pump.

As the evacuation of condenser continues and the mixture approaches the dead end condition previously described, resulting in little or no air being present at the discharge of the liquid ring pump, the mixture is sufficiently dense by this time for the centrifugal impeller to pump this liquid over the normally designed-in pressure differential for the impeller when operating with liquid. The designed-in liquid head capacity for the centrifugal liquid impeller is purposely made greater than the differential between the condenser absolute pressure and atmosphere so as to provide an ample margin of performance, both at the time of pumping dense liquid and at the intermediate point where there is still some air entrained with the liquid. Thus, when this condition occurs on the operation of the condenser, the centrifugal liquid pump takes over as a second stage to the liquid ring pump, with the result that the interstage pressure, which is also the liquid ring discharge pressure, is drastically reduced. Under this condition, the liquid ring portion of the combination has only to operate over an inch or two of mercury pressure differential instead of the full thirty inch or more differential head from the condenser absolute pressure to atmosphere.

Under this very much reduced differential head, which may be in the order of ½ to 3 inches mercury pressure, the liquid ring pump has ample kinetic energy delivered to its ring to discharge all of the liquid coming to it across this reduced pressure differential without slowing down the liquid ring or causing it to go into the "stalled" or "queered" condition, as previously described on dead end condition with standard liquid ring pumps.

The pump structure of the invention provides particular benefits in its application to a novel evaporator system and apparatus, particularly evaporators of the type employed for the recovery of potable drinking water or other liquids used for human consumption. The novel pump construction utilizes the well known principles of the liquid ring compressor and the liquid centrifugal pump wherein no internal lubrication is required. Therefore liquid processed by the pumps will be free from contamination of lubricants or metal particles caused by rubbing contact, which is generally the case with other mechanical types of pumping equipment.

A further very useful contribution to the use of the distillate derived from an evaporator utilizing this pumping equipment is the fact that the air which has been removed from the initial liquid supplied to the evaporator is saved and is combined during the process of compression and pumping within my structure, and delivered with the final distillate product. It is well known that distilled water, for instance, has a flat taste. In other words, it is tasteless as compared with normal drinking water. One of the reasons for this is that as it comes from the condenser, all air has been removed from the liquid thus leaving it in this unpalatable condition. By re-combining the air with the distillate during the process of compression and pumping the final distillate product is restored to a palatable condition with its normal amount of absorbed air.

A further advantage derived from the use of this unit and which was touched on before is the fact that low sources of heat supply may be utilized with this high vacuum evaporator. Thus, the cooling water used for reducing the temperature of internal combustion engines may be utilized as a heat supply for this evaporator combination. The temperature of the circulating water discharged from the normal internal combustion engine is in the order of from 150 to 160° F. This temperature level is ample for use on my evaporator combination so that a relatively substantial amount of fresh water can be generated by the use of this waste heat which otherwise would not be utilized.

As an example of the value of this, it is roughly estimated that 1000 gallons per day of distilled fresh drinking water can be obtained with this equipment by the utilization of the waste heat in the cooling water discharged from a 100 horsepower engine. Thus it is seen that this type of equipment can have great utility on small boats, remote islands, etc. where fresh water supply is unavailable.

The centrifugal liquid impeller has the built-in characteristic that it is able to operate over the full pressure range when handling liquid. Like all conventional centrifugal pumps, however, it would not have the capability of pumping directly from the condenser to atmosphere when the absolute pressure of the condenser was approaching the saturation temperature of the liquid being pumped. The centrifugal impeller in such a case would require a net positive suction head in order to operate satisfactorily. In such an operation, therefore, the structure of the invention provides the net positive suction head required by the action of the liquid ring first stage of the combination. This net positive suction head requirement for the centrifugal is a small value compared to the normal design differential of the liquid ring pump. Since this pressure differential required for maintaining the suction head of the centrifugal is so small, it is possible for the liquid ring to supply such differential when pumping substantially all liquid without incurring any stalling or cavitation condition in the liquid ring pump. The liquid ring pump portion, furthermore, has the ability of pumping liquid at the boil point of the liquid over this small differential, whereas, it could not do this if called upon to pump such liquid over a larger or normal compressor differential.

It is well known in the art that the presence, even of small quantities of vapor at the entrance to a normal centrifugal pump, causes a breakdown in its performance. The formation of vapor at the entrance to the centrifugal pump is generally due to a drop in pressure of the liquid, caused by friction in the lines or at the entrance to the pump itself, with the resultant flashing of this vapor. The presence of the vapor reduces the overall density of the mixture within the centrifugal impeller to the point where the centrifugal pump portion cannot generate the required discharge pressure with this lighter mixture. This results in the stalling of the pump, with little or no delivery therefrom.

A standard liquid ring pump, on the other hand, is designed primarily to handle gases, some vapors, and some liquid for cooling purposes. It is primarily a gas handling pump and can handle gas over its normal designed pressure range. If, however, the liquid seal supplied to the pump is at a temperature approaching the seal's vaporizing pressure at the inlet to the pump, the additional pressure drop occurring at the entrance to the pump and its ports will cause vaporization of the sealing liquid. This vaporization progressively fills the displacement chambers of the liquid ring pump until it has no capacity to handle additional gas displacement. The flashing of the vapor at the inlet of the standard liquid ring pump occurs as indicated earlier, at an absolute pressure higher than the absolute vaporizing pressure characteristic of the seal used. This action is common to standard liquid ring pumps and is a recognized limitation. Thus it is seen that in this situation the standard liquid ring pump may have air or gas available at its

inlet but it is deprived of reaching this gas because of the excessive flashing of vapor from the seal at its inlet. This action also approximates the "dead end" operating condition, as previously described.

A pump constructed in accordance with the invention includes large passageways to and from the liquid ring portion of the combination, plus the second stage centrifugal pump, which permits the larger quantities of sealing and cooling liquid to be handled as distinguished from the limited amounts of sealing and cooling liquid that may be handled with conventional liquid ring pumps. This provision for greater liquid flow through the pump also provides a relatively lower temperature rise in the liquid ring for the same amount of work of compression and this factor in itself reduces the possibility of flashing in the ring liquid at the intake port. This flashing tendency is further reduced by the large passageways made available so that there is less pressure drop on the incoming gas and liquid.

Reduction in vapor flashing at the inlet is achieved by reducing the pressure differential over which the liquid ring pump has to work in the first stage of the two stage arrangement. This reduction in pressure differential, of course, reduces the amount of work that the liquid ring portion has to perform thereby further reducing the temperature rise in the large flow of liquid through its passageways.

There is a further assist in this operation. There is a slight reduction in the temperature of the liquid ring caused by any flashing or vaporizing at its inlet and, due to the low temperature difference at which the seal is operating, this cooling effect is of more material help than occurs when there are large temperature differences such as exist on a standard liquid ring pump. This cooling effect and the vaporizing of the seal vary with the thermal characteristics of the liquid being handled. This action depends upon the relationship of the latent heat of the liquid to the specific volume of its vapor at the temperature and pressure involved.

In view of the above provisions, such vapor as is flashed at the inlet to the liquid ring pump combination is smaller than the normal displacement capacity of the pump. The result is that the liquid ring portion handles or "swallows" its own flashed vapor and still has major capacity for withdrawing further quantities of liquid and vapor into its displacement chambers for compression and delivery to the interstage point. In the process of compression to the interstage point, its average seal tempertaure is low enough to condense the vapors during this compression cycle. This results in the discharge to the interstage point of stabilized liquid with sufficient net positive suction head at this interstage point for the centrifugal liquid pump to pick it up without flashing and to deliver it to atmosphere or to the desired higher pressure.

Accordingly, it is an object of this invention to provide an improved pump construction capable of handling liquids at inlet pressures approaching the boiling point pressure of the liquid being pumped.

A further object of the invention is to provide a pump capable of pumping liquid with a minimum of net positive suction head.

A further object of the invention is to provide a pump including a liquid ring compressor portion and a centrifugal liquid pumping portion, arranged for series operation.

A further object of the invention is to provide a pump including a liquid ring vacuum pump portion capable of operating with a sealing liquid approaching or equaling the boiling point pressure of the pump's inlet.

A further object of the invention is to provide a liquid ring vacuum pump combination which is capable of operating at shut-off or blanked off inlet suction without cavitation damage.

A further object of the invention is to provide a liquid ring pump combination that is capable of handling liquid without cavitation damage.

A further object of the invention is to provide a liquid ring pump and centrifugal liquid pump combination arranged to satsifactorily pump gases, vapors, liquids, or any combination thereof, with satisfactory life and operation.

A further object of the invention is to provide a liquid ring vacuum pump or compressor combination with improved efficiency.

A further object of the invention is to provide a combination pumping unit including a liquid ring vacuum pump and a liquid centrifugal for simultaneously handling liquid through one inlet connection and air or gas through a second inlet connection.

A further object of this invention is to provide an improved evaporator system.

A still further object of the invention is to provide an evaporator system including a single pumping unit arranged to purge air from the condenser system and including a suction connection for pumping liquid distillate from said condenser wherein the pump includes a first stage liquid ring compressor portion arranged to discharge to a second stage centrifugal liquid portion, the pump also being capable of pumping liquid at boiling point pressures.

A still further object of the invention is to provide an evaporator system including a pump for handling the liquid therein, mounted at the same level as the evaporator and capable of pumping the liquid therefrom at or near its boiling point pressure at zero net positive suction head.

A further object is to provide an evaporator system utilizing a low temperature heat source such as waste heat from an internal combustion engine cooling water discharge.

A further object is to provide an efficient evaporator system for operation at low temperature such as to avoid troublesome precipitation of minerals and salt within the evaporator.

A further object is to provide an evaporator with provision for delivery of palatable distillate with normal absorbed air content and free from pump lubricant contamination.

A further object of the invention is to provide an improved liquid and gas pump which is simple in design, rugged in construction, economical in manufacture, and efficient in operation.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects obtained by its use, reference should be made to the accompanying drawings and descriptive matter in which there are illustrated and described proved embodiments of the invention.

In the drawings:

FIG. 1 is a diagrammatic indication of an evaporator system constructed in accordance with the invention;

FIG. 2 is an enlarged transverse section of the vacuum pump **14** indicated in FIG. 1;

FIG. 3 is a left end elevation of the pump indicated in FIG. 2;

FIG. 4 is a section taken along lines **4—4** of FIG. 2;

FIG. 5 is a section taken along the lines **5—5** of FIG. 2;

FIG. 6 is a fragmentary transverse section similar to FIG. 2 indicating an alternate embodiment of the compressor inlet portion for either of the pumps indicated in FIG. 1; and

FIG. 7 is a fragmentary transverse section taken along lines **7—7** of FIG. 3.

Referring to the drawings, in particular, the invention embodied therein includes an evaporator **10** having a condenser portion **12** in the upper end of one side thereof. In the present embodiment, the evaporator **10** is used to evaporate brine water by interior heating means within the evaporator and the vapors are directed upwardly and laterally into the condenser **12**. The condenser **12** includes the usual cooling coil means for circulating a liquid such as water and the condensate which is formed is collected at the bottom thereof. The condensate or distillate is the fresh water which is produced by the unit and which is the useful product of the evaporation process.

In order to permit the evaporator **10** to operate in as efficient a manner as possible, it is essential that the condenser **12** be operated at as low a temperature and pressure as is possible commensurate with the available heat and cooling liquid supply. In order to maintain as low a temperature and absolute pressure as possible, it is essential that the condenser be continuously purged of accumulated gases and vapors, and maintained at a vacuum. The absolute pressure within the condenser is reduced by removing the entrained air, gases, and noncondensibles within the condenser. When air remains in the condenser its effect is to raise the total pressure therein.

In accordance with the invention, there is provided a vacuum pump or compressor pump generally designated **14**, which is capable of combined air removal and distillate pumping as well as the maintenance of the vacuum within the condenser.

The pump **14** is of particular construction to be described more fully hereinafter and includes one suction which is connected to a conduit **16** to the top of the condenser **12**, or at any other point of the condenser where it is possible to advantageously remove accumulated air. Distillate which collects in the bottom, or well, of the condenser **12** is connected through a conduit **18** to the other suction inlet of the pump **14**. The compressor-pump **14** operates in a novel manner, to be described more fully hereinafter, to discharge the compressed air and condensate into a discharge conduit **20** to an overhead tank **22**. The tank **22** serves as a separator to allow excess air to be vented through an opening **24** to the atmosphere. The excess liquid is delivered through a conduit **26** to a storage receiver or place of use for the evaporated water or distillate. Some of the liquid which is delivered to the tank **22** is recirculated through a line **28** back to a seal connection **29** so that it may be delivered to the pump for liquid sealing of the pump shrouds and for aiding in the condensation of the vapors which are passed through the pump. Vapors will also be passed through each of the conduits **16** and **18**, since the pressure within the condenser **12** is at or near the pressure at which the liquid will vaporize.

In accordance with the invention, the evaporator system further includes a pump generally designated **30** which is similar to the pump 4 and is capable of removing brine from the bottom of the evaporator **10** through a suction line **32**. Since the brine in the evaporator **10** is at or near boiling point when the evaporation cycle is in progress, it has been found that most pumps should require a positive pressure head at the suction. The pump **30** which will be described more fully hereinafter does not require such a head and may be located at the same level as the evaporator. It is driven by a motor **34** which is located between the pumps **14** and **30** and arranged to drive each of them by shafts which extend in opposite directions.

The evaporation cycle is carried out by furnishing brine to the evaporator over and above that required to produce vapor from which clear water is produced. The excess brine is constantly withdrawn and the salinity of the mixture is maintained within a reasonable range. The pump **30** pumps practically at the boiling temperature, even though it is located at approximately the same elevation as the evaporator 10. It discharges the brine through an overboard or sewer discharge line 36.

In accordance with the invention, the liquid and gas pump 14 includes a substanially cylindrical casing or housing portion generally designated 38 having an end wall 40 which abuts against and is bolted to the motor 34. The end wall 40 includes an opening to receive a shaft 42 of the motor 34. Mechanical shaft seal construction 44 is maintained at the opening of the wall 40 surrounding the shaft 42.

Bolted to the opposite end of the housing member 38 is a compressor lobe housing and inlet head generally designated 46. This lobe housing and inlet head 46 includes an upper inlet passage 48 and a lower inlet passage 50, each of which feeds into separate inlet passages 52*a* and 52*b*, formed in a cylindrical ported member generally designated 54 which is located at the center of the lobe portion of the housing. The passages 52*a* and 52*b* form separate inlets for each lobe of the pump and in this manner it is possible to obtain independent pumping action at each of the separate condenser locations served by lines 16 and 18.

In this embodiment the housing 46 has substantially elliptical inner walls 56 defining two lobe portions.

In accordance with the invention there is provided a rotor generally designated 58 which is threaded onto and secured to the shaft 42 for rotation therewith. The rotor includes a hub portion 60, a disc portion 62 extending radially outwardly therefrom, a liquid impeller blade portion 64 extending axially outwardly from the disc member 62, and a liquid ring rotor portion generally designated 66 including end shrouds 68 and 70 and rotor blades or buckets 72.

In accordance with the invention, the end shroud portion 70 extends axially and radially beyond a shroud seal portion 74 of the housing 46 and includes an inner peripheral wall 70*a* slightly spaced from an inwardly extended shroud or wall 78 of the housing 38 and a radially extending tip portion 70*b* to provide a centrifugal liquid sealing chamber 79 between an annular discharge chamber 80 and the liquid ring pump portion 66. The annular discharge chamber 80 formed in the housing 38 is connected by the discharge passage 82 to the final discharge nozzle 84.

In operation, liquid and liquid and gas mixture is taken in through the inlet 50 through the conduit 18 and primarily gas and vapor is taken in through the inlet 48 through the conduit 16. In order to insure that there is a quantity of liquid available for condensing and sealing purposes, some liquid is recirculated to the sealing connection 29 by means of the conduit 28 from the tank 22. It is directed to the seal chamber 96 formed between shroud 68 and casing 46 through sized orifice passage 98 and then into the lobed portion 56. Liquid which is taken into the first stage compressor portion of the pump is directed around the lobes by the buckets or blades 72 where the alternate inward and outward direction of the ring of liquid is effective to cause a pumping action and compression of the gases. Gas, liquid, and vapor are taken into the inlet passages 52*a* and 52*b* (FIG. 4) through each of the two inlet ports 83*a* and 83*b* defined in the member 54 at the location of the inner end of the blades 72, and condensed vapors and compressed gases are delivered through each of the two discharge ports 86*a* and 86*b* defined in the cylindrical ported member 54. The ported member 54 includes a discharge passageway 88 which communicates with the inlet or eye 90 of the liquid pumping impeller 58. The impeller discharges the liquid radially outwardly into the annular chamber 80 as described previously.

The sizes of the liquid ring compressor portion 66 and the blades 72 of the rotor 58, as well as the size of the housing 46, are chosen to handle a displacement volume of gas based on a given intake pressure in inches of mercury. It then compresses this volume while it condenses some of the vapor accompanying the gas and liquid and discharges it as substantially atmospheric pressure into the eye 90. The compressor 66, besides being capable of handling this volume of gas which it compresses, is further capable of handling the necessary liquid for sealing purposes and for cooling and condensing purposes. The ratio of the amount of this liquid capacity relative to the gas displacement capability of the pump, however, is very small.

When the liquid ring rotor 66 is handling mostly gas, as in the initial purging operation on a condensor, this gas is compressed within the rotor to the required atmospheric or greater pressure and discharged through its discharge port into the eye 90 of the centrifugal liquid impeller in the normal manner of liquid ring pump operation. This discharged mixture of gas and liquid will have less gas by volume than at the entrance 52 by the ratio of the compression ratio between inlet and discharge absolute pressures, plus whatever condensing effect may come into play within the liquid ring pump. During this operation, the liquid ring pump has the capability of discharging the compressed gas through the inlet 90 of the centrifugal liquid impeller, through the blade passageways 58 of the liquid impeller portion, through the collecting chamber 80 and out through the final discharge passageway 84. The centrifugal liquid impeller does not impart any appreciable pressure difference to the gas passing therethrough at this time but it does assist in pumping the liquid which is discharged with the gas by the liquid ring rotor. The centrifugal impeller also centrifugally separates the liquid from the gas during its passage through the rotating impeller so as to provide a clearer passageway for the gases in their trip through the impeller blades. This has the effect of reducing friction drop which otherwise would be excessive with a turbulent mixture of gas and liquid.

It should be appreciated that in accordance with this invention the size and shape of the buckets 72 in cooperation with the displacement built into the liquid ring as determined by the lobe portion of the housing are chosen to do the required amount of gas pumping as well as liquid circulating at a standard motor drive speed. The kinetic energy imparted through the blades by the motor 34 is just enough to do this work with a comfortable margin.

During the normal operation on a condenser and after the purging of the condenser of the initial amount of air, there is little or no air to be handled by the liquid ring pump and it attempts to handle liquid only. The designed proportions of the liquid ring pump are such that it does not have sufficient kinetic energy to handle liquid only over the same differential that it normally handles air. Provision is made in this structure whereby the pressure differential is reduced across the liquid ring pump when it is called upon to handle liquid only. This is accomplished by the combination with the second stage liquid impeller blades 64. This latter impeller is designed with excess head capacity over and above the pressure head conditions between the condenser and the final discharge point, which is slightly above atmospheric pressure.

The impeller blades 64 are sized to handle a dense liquid-air mixture from the absolute pressure of the condenser 12 to the separating tank 22. During the preliminary operation, when the mixture is lighter in density and during which time the liquid ring pump is handling air, the liquid centrifugal impeller adds virtually no pressure difference to the gas being delivered but as soon as this density is increased by the material reduction in air handled by the liquid ring pump, the centrifugal liquid impeller blades 64 act as a second stage to the liquid ring rotor, thus reducing the interstage pressure at the discharge ports 86*a* of the liquid ring compressor, to the point where the differential across the liquid ring compressor is sufficiently lowered such that the liquid ring can deliver solid liquid against this pressure differential without distress and without exceeding the available kinetic energy being delivered to its liquid ring by the motor **34**. The liquid impeller blades **64** discharge the dense air-liquid mixture into the passage **80** from where it is discharged through passage **82** to the discharge conduit **84** at prescribed head pressure.

The pump indicated at **30**, FIG. 1, is similar to the pump **14** but includes a single inlet **92** which serves each of the pump lobes (FIG. 6) and which is connected to the conduit **32**. The inlet **92** is formed in an end casing member generally designated **94**, as indicated in FIG. 6. Liquid, gas, and vapor which are pulled in through the inlet **92** are directed into a single passage **52** of the ported cylindrical member **54**. This passage **52** serves each of the inlet ports **83***a* and **83***b*. The pump is utilized to pump brine at its boiling point from the evaporator **10**. The same type of pump with a single inlet **92** may be utilized to pump from the condenser **12** where the single inlet would handle both the distillate and the air from the condenser. Some condenser constructions are advantageously connected in this manner.

It should be also noted that each of the pumps is shown and described as having two lobe portions **56**. However, a single eccentric casing may be used for a single lobe with a single inlet connection and a single discharge connection communicating with the inlet **90** of the second stage liquid impeller or a number of lobes over two may be employed. The single lobe construction may be as indicated in FIG. 6 showing the single inlet **92** and the single discharge **86** which in turn communicates with the inlet **90** of the second stage impeller.

It should be appreciated that the improved pump construction of the present invention has many other additionl applications other than the evaporator system fully described herein. For example, the pump may be used in a process system for returning drained hot condensate back to a boiler. In such instances, it was usual to use a pump system which includes a jet pump and a centrifugal pump arranged to operate in combination. The centrifugal pump draws water from a heat dissipating finned priming loop and discharges through the jet pump which educes a positive flow of condensate, gas and air from the process equipment drainage line and discharges the condensate directly to the boiler. In such systems, entrained non-condensible gases and air are eliminated from the circuit by means of a separation chamber set-up.

The present pump may replace the jet pump and centrifugal pump combination and operate very efficiently in handling liquids, gases and vapors or any combination thereof.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the invention principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

I claim:

1. In a brine evaporating system including means to continuously heat brine and vaporize the liquid thereof, and means to condense said vaporized liquid, the improvement comprising single pump means connected to said condenser means, including liquid ring compressor means to continuously remove gases and vapors from said condenser means, to condense said vapors and compress said gases to a pressure substantially above said condenser operating pressure, said pump means further including means to remove condensed liquid from said condenser and combine it with the vapors being removed as the latter are compressed and condensed, and liquid impeller means adjacent said compressor means arranged to discharge liquid and recombine gases from said compressor at increased pressures, whereby a maximum vacuum is maintained in said condenser means with a minimum net positive suction head at the inlet of said

pump means without the possibility of structural damage to the pump means due to high vacuum conditions within said condenser means.

2. In an evaporator according to claim 1 wherein said single pump means includes a housing defining an interior lobed compressor portion and a liquid pumping portion adjacent said lobed compressor portion having an annular discharge.

3. In an evaporator system according to claim 1 wherein said pump means includes separate inlet conduits one connected to the upper portion of said condenser means and the other connected to the lower portion of said condenser means.

4. In an evaporator including elongated tank means having means for continuously heating brine to vaporize the liquid therein, and a condenser connected to said elongated tank and having cooling means therein for condensing said vapors, the improvement comprising, a centrifugal displacement pump connected to said condenser, and including a liquid ring compressor portion having a discharge, and a centrifugal liquid pumping portion arranged in series with the discharge of said compressor portion arranged to receive said discharge into said centrifugal liquid pumping portion, and rotor means in each of said compressor and liquid pumping portions arranged to compress gases from said condenser to a pressure substantially higher than said condenser pressure, and to deliver liquid from said condenser to said liquid impeller portion at a pressure only slightly higher than said condenser pressure, said liquid impeller portion being capable of reducing the discharge pressure of said compressor portion when the latter is handling substantially all liquid.

5. In an evaporator system according to claim 4, wherein said compressor portion includes a central ported member having substantially diametrically opposite ported openings, said housing includes at least two lobe portions, and said rotor includes radically extending buckets rotatable around said ported member and including a separate inlet connecting the bottom of said condenser at the location of said condensed liquid therein and a separate inlet connecting the top of said condenser at the location of vapors and gases.

6. A method of operating an evaporator for the distillation of water from brine and in which the distillate is collected in a condenser and the brine is exposed to high temperatures and vacuum comprising, continuously withdrawing distillate from said condenser, simultaneously continuously withdrawing vapors and gases from said condenser, combining said distillate and said vapors and gases, and subjecting said vapors and gases to compression to condense said vapors, and compress said gases, and thereafter raising the pressure of said combined distillate, compressed gases and condensed vapors and discharging them at such increased pressure.

7. A method according to claim 6, including continuously removing concentrated brine from the lower portion of the evaporator as the evaporator is operated at high temperature and vacuum pressures.

8. In a distillation system including means to continuously heat a liquid to form vapor thereof, and means to condense said vaporized liquid, the improvement comprising single pump means connected to said condenser means, including liquid ring compressor means to continuously remove gases and vapors from said condenser means, to condense said vapors and compress said gases to a pressure substantially above said condenser operating pressure, said pump means further including means to remove condensed liquid from said condenser and combine it with the vapors being removed as the latter are compressed and condensed, and liquid impeller means adjacent said compressor means arranged to discharge liquid and recombine gases from said compressor at increased pressures, whereby a maximum vacuum is maintained in said condenser means with a minimum net posi-

tive suction head at the inlet of said pump means without the possibility of structural damage to the pump means due to high vacuum conditions within said condenser means.

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