METHOD AND APPARATUS FOR PUMPING WITH A LIQUID-RING IN SERIES WITH A JET EJECTOR

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ABSTRACT OF THE DISCLOSURE
A jet ejector serially preceding a liquid-ring pump is operated with a jet driving medium formed of gas mixed with a vapor that condenses to a liquid identical with the liquid used in the liquid ring of the pump. With a liquid ring of water, the vapor component of the jet mixture is taken from the water that collects in a water separator connected to the outlet side of the pump, and the water is converted to steam by heating before it is passed to the jet ejector. The steam generation is regulated in dependence upon the liquid-ring temperature of the pump.

My invention relates to a pumping apparatus composed of a liquid-ring pump in series with a preceding jet ejector. Such pumping apparatus are known, for example, from German Patent 968,232 and U.S. Patent 3,064,878.

It is an object of the invention to secure in a simple manner and with a minimum of equipment a satisfactory volumetric efficiency of the jet pump down to very low pressures, particularly below the minimum vacuum pressure heretofore reliably attainable.

Another object of my invention is to minimize the danger of cavitation occurring in the liquid-ring portion of the pump, thus further contributing to improved efficiency, particularly at low operating pressures.

Still another object of the invention is to minimize the drop in efficiency or substantial loss of efficiency occurring as a result of an increase in operating temperature of the liquid-ring pump.

To achieve these objects, and in accordance with a feature of my invention, I form the driving medium for the jet ejector, in apparatus comprising such an ejector ahead of a liquid-ring pump, from a mixture of gas and vapor, the vapor being condensable to a liquid that is compatible or identical with the liquid of which the ring in the pump is constituted.

According to another feature of my invention, the driving medium for the jet ejector is directly taken from the operating liquid that forms the ring within the pump, or from both the operating liquid and the working medium of the apparatus. Preferably, the jet driving medium thus taken from one or both of the media employed with the pumping system, is recycled through a closed circulatory path so that boiling of drainage channels is avoided.

By virtue of the vapor content of the jet driving medium, the depletion of the liquid ring by evaporation is prevented. This ring, rather than continuously replenished by the condensing vapor stemming from the jet that immediately precedes the pump, this improves the volumetric efficiency of the pump, especially at low pressures.

It is in some cases of advantage to add non-condensable gases, for example the gaseous working medium, to the driving vapor for the ejector jet. In this manner, any deteriorating cavitation occurring within the pump is prevented. The same features also result in improving the efficiency of the pumping equipment. This applies particularly if one employs as operating liquid for the pump, and hence as driving vapor for the ejector jet, a medium whose heat of evaporation is lower than that of water and whose molecular weight is larger than that of water. Furthermore, the above-described gas-vapor mixture requires the production and supply of only as much vapor as is needed for attaining optimal efficiency.

For many purposes it is preferable to use water as operating liquid in the pump, and to employ as driver medium for the jet ejector a mixture of steam and gaseous working medium at atmospheric pressure. For example, when the working medium is a mixture of vinyl chloride gas and steam to be exhausted, the operating liquid for forming the ring inside the pump is preferably water. In this case, the driving medium for the jet ejector may also consist of vinyl chloride gas and steam, or it may only consist of steam.

Referring to a liquid-ring pump operating with water, it is further preferable to use as component driver medium a portion of the operating water delivered by the liquid-ring pump, and to heat this portion of water in a vessel or heat exchanger to thus produce the steam or vapor for the ejector jet. The heating of the vessel can be controlled by hand. For industrial operation, however, it is advisable to provide a regulator which varies the heating power in dependence upon the temperature of the pump or upon the vapor pressure of the operating liquid in the pump.

The invention will be further elucidated with reference to embodiments illustrated by way of example on the accompanying drawing in which:

FIG. 1 shows schematically and in section a complete pumping apparatus comprising a water-ring pump and a mixing jet ejector operating with gas and steam; and
FIG. 2 shows in section a modification of a mixing jet ejector applicable in apparatus otherwise corresponding to the one shown in FIG. 1.

The apparatus according to FIG. 1 comprises a liquid-ring pump 1 of conventional type. The pump has a housing in which a rotor 2 is eccentrically rotatable on a shaft 3 and carries a number of vanes. The interspace between the rotor and the housing is partially filled with water. Rotation of the rotor causes the water to be flung outwardly and to form a rotating water ring which, together with the vanes, forms a series of chambers. During rotation, each individual chamber increases and thereafter decreases its volume. As the chambers increase their volume, they induce gaseous working medium from an inlet 28 through lateral slits (not shown). When the chambers thereafter decrease their volume and compress the gas contained therein, they communicate through other slits (not shown) with the outlet 29 of the pump. Together with the compressed gas, some of the water from ring 4 passes into the outlet 29 and reaches a water separator 5 in which it is separated from the gas. The operating water needed for continuously replenishing the ring 4 in pump 1 is supplied through a pipe 34 and also reaches the ring together with the gas being inducted into the inlet 28, as will be more fully described.

For increasing the volumetric efficiency of the liquid-ring pump at low pressures, for example below 100 torr, an ejector jet 12 is connected in series between the inlet 28 of pump 1 and the duct or vessel 18 from which the gas to be exhausted or compressed is being supplied, the gas supply being represented by an arrow 27. The driver medium for the jet nozzle 14 of the ejector is schematically indicated by an arrow 33. This driver medium is accelerated in the nozzle 14 to a multiple of the sonic speed. Due to the ejector effect, the gas (arrow 27) is entrained from the vessel 18 to be evacuated and becomes mixed with the driving medium 33 in the diffuser portion 13 of the ejector. Thus, the gas mixed with the driver medium becomes densified, for example to a pre-pressure between about 30 and about 200 torr, before it reaches the suction inlet 28 of the pump 1.
The above-described operation of the liquid-ring pump further increases the pressure of the gas before it is discharged through the pressure outlet 29 together with some of the operating liquid of the ring 4 is formed. After separation of the entrained water in separator 5, the dry gas, represented by arrows 26, escapes. The entrained water is deflected by a baffle 6 and collects at the bottom 25 of the separator from which it is drained back through line 34 to the pump 1.

For obtaining particularly low induction (vacuum) pressures, for example down to about 0.5 torr, one or more additional jet ejectors may be connected parallel to each other ahead of the pump 1, this being known as such and more fully described and illustrated, for example, in the copending application of G. Hoffmeister, Ser. No. 588,870, filed June 20, 1966 now U.S. Patent 3,369,735 and assigned to the assignee of the present invention.

Used as driving medium 33 for the jet ejector 12 is a gas-vapor mixture. This mixture is such that the vapor pressure of the working medium inside the liquid-ring pump, this medium here being composed of the working medium and of the gas-vapor mixture supplied as driver medium, corresponds at least to the vapor pressure of the liquid ring so that no further liquid can evaporate out of the ring. In spite of the amount of vapor additionally delivered by the pump, the efficiency of the equipment at low pressures remains considerably above the efficiency of the same pumping equipment if operated without the share of vapor in the driver jet.

The driver mixture 33 of steam 24 and gas 32 is produced at the input side of the ejector 12. Valves 15 and 16 permit blocking the gas and steam supply respectively, or controlling the respective quantities supplied. The gas can be taken from the gas 26 being delivered at the output side of the separator 5, this being also exemplified by the equipment shown in FIG. 1.

For producing the steam, represented by an arrow 24, the collected amount of water 25 in the separator 5 communicates with a heatable vessel 7 serving as an evaporator. The liquid contained in the vessel, in this case water, is heated electrically by means of a heater winding 21 and furnishes the required steam 24 through a line 17. The desired mixing ratio is simply adjusted by correspondingly adjusting or controlling the current flowing through the heater winding 21. Such control can be effected by hand with the aid of tables or diagrams showing the setting required for the particular temperature of the pump-operating water. It is preferred, however, to provide a regulating device 8 by means of which the electric heating power supplied to heater 21 is controlled in dependence upon the action of a temperature sensor 10, such as a thermocouple, responsive to changes in temperature of the water in the pump. If desired, however, the liquid to be evaporated may be taken directly from the pressure or suction side of the pump 1 or out of the liquid ring 4 so that nothing further is required for securing the corresponding pressure in the evaporator vessel 7. The quantity of liquid to be supplied from the pump can then be controlled in dependence upon the pressure obtaining in the evaporator vessel 4 or in dependence upon the liquid level in the vessel.

Steam produced by electric heating is sometimes rather expensive. This might make it appear preferable to run the jet ejector only with non-condensable gas as the driver medium. Such operation, however, is sensitive to increasing temperatures of the operating liquid or to increasing vapor pressures of this liquid. For example, if the pumping equipment, operating with water, is rated for 20 torr suction, the temperature of an operating liquid of 15°C., the quantity inducted by the apparatus will drop down to zero when the water temperature rises, for example in summer, to 25°C. In contrast thereto, the method and apparatus according to the invention are largely independent from such increases in operating temperature or vapor pressure.

For proper performance of apparatus in accordance with the invention, the driving medium need not necessarily operate at the above-mentioned pressure of 1 atmosphere (normal air pressure). The apparatus rather operates also at higher or lower pressures of the driving medium.

In the modified portion of the apparatus illustrated in FIG. 2, the mixing jet ejector comprises two parallel portions 12a and 12b. The ejeetor portion 12a has its nozzle connected only with the line that supplies steam 24, whereas the nozzle of the other ejector portion 12b is connected only with the line that supplies gas 32. The respective steam and gas quantities are adjustable with the aid of valves 16a and 15a. Both component ejectors merge shortly ahead of the suction inlet conduit 28 of the liquid-ring pump, so that the same effect is obtainable as with a mixing ejector of the type illustrated in FIG. 1.

To those skilled in the art it will be obvious upon a study of this disclosure that my invention permits of various other modifications and may be given embodiments differing from those illustrated and described herein, without departing from the essential features of the invention and within the scope of the claims annexed hereto.

1. The method of pumping gas with a liquid-ring pump in series with a preceding jet ejector, which comprises forming the driving mixture for the jet ejector from gas mixed with vapor, and passing the gas-vapor mixture through the jet ejector so as to entrain the gas being pumped, said vapor being condensable to a liquid compatible with the liquid ring of the pump.

2. The method according to claim 1 wherein the vapor of the gas-vapor mixture is that of liquid identical with that of the liquid ring of the pump.

3. The method according to claim 1 wherein the respective vapor pressures of the driver medium and the liquid ring are approximately equal.

4. The method according to claim 1, which comprises applying to the driver medium an ejector-entering pressure approximately equal to the output pressure of the pump.

5. Pumping apparatus comprising a liquid-ring pump, a jet ejector serially preceding the pump, means for supplying gaseous means for supplying liquid compatible with the liquid ring, said ejector being connected to both of said supply means and adapted to form a jet from the mixture of said gas and said vapor.

6. Pumping apparatus comprising duct means for fluid working medium, a liquid-ring pump, a jet ejector serially connected between said pump and said duct means and having the same delivery direction as said pump, driver-medium supply means connected to said ejector, liquid duct means communicating with the liquid ring of said pump, said driver-medium supply means having an evaporator connected to said liquid duct means for causing the jet to comprise vapor condensable to ring liquid in the pump.

7. Pumping apparatus, according to claim 6, for gaseous working medium, comprising means connecting said duct means for said working medium with said jet ejector so as to cause the jet to be formed of gas taken from said working medium mixed with vapor of said pump liquid.

8. In pumping apparatus according to claim 7, said liquid being water, a water separator being serially connected with said pump at the outlet side thereof, said liquid duct means connecting said separator with said pump for returning separated water to the liquid ring, said separator comprising a heatable container communicating with said separator.

9. Pumping apparatus according to claim 8, comprising regulating means connected to said container and responsive to the operating temperature of said pump for controlling the gas-to-vapor ratio in dependence upon said operating temperature.
10. Pumping apparatus according to claim 8, comprising a temperature sensor responsive to the liquid-ring operating temperature, and evaporation regulating means connected with said evaporator and comprising said sensor for controlling the gas-to-vapor ratio in dependence upon said operating temperature.

11. In pumping apparatus according to claim 9, said evaporator having a heater, and said heater being connected to said regulating means to be controlled thereby.

12. In apparatus according to claim 5, said ejector comprising two ejector nozzles arranged in parallel, one of said nozzles being connected to said gas supply means, the other nozzle being connected to said vapor supply means so as to receive respectively different driver media.

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