

March 8, 1966

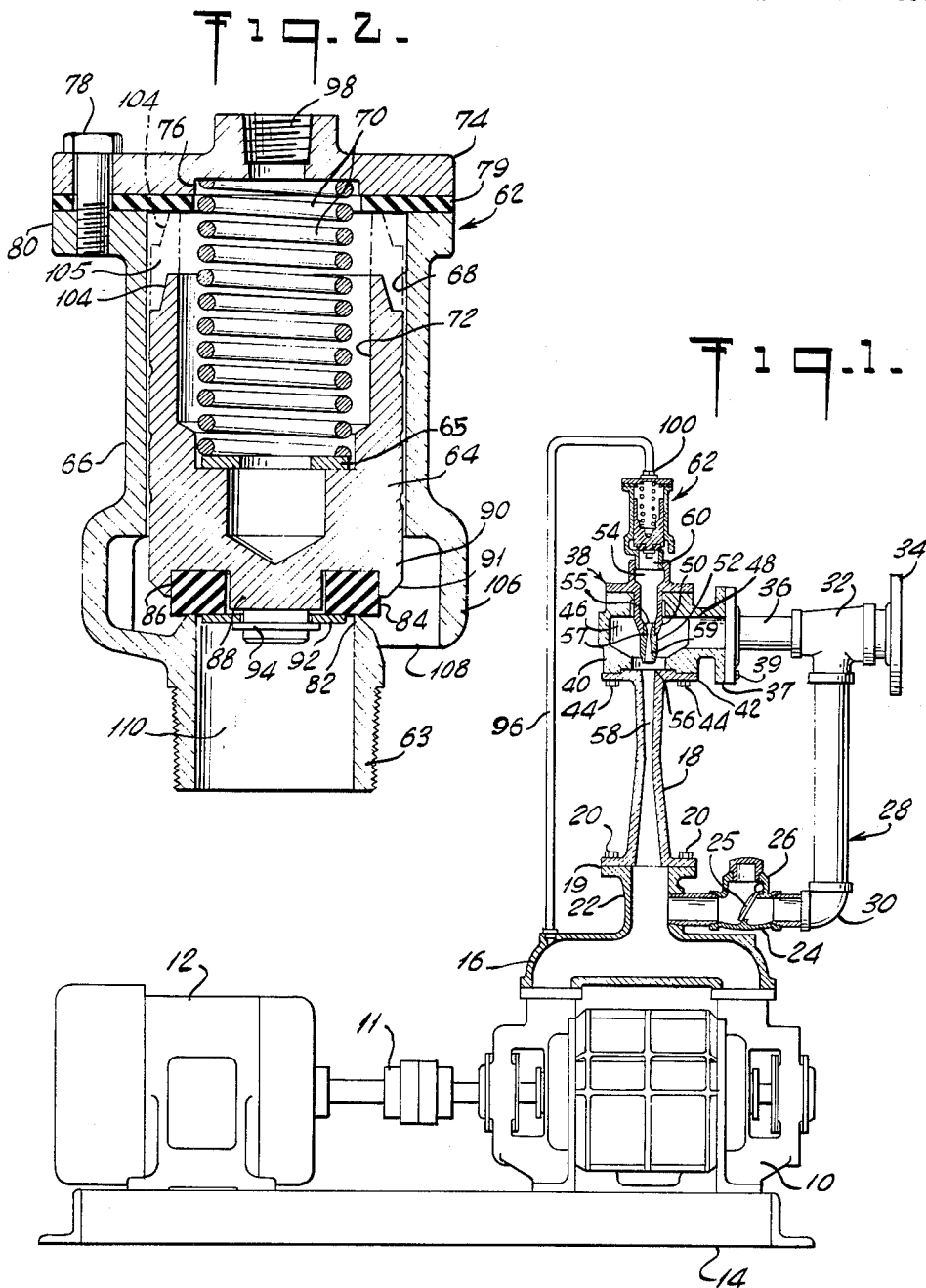
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HIGH VACUUM EJECTOR PUMP WITH AUTOMATIC CUT-IN VALVE

Filed March 18, 1963

2 Sheets-Sheet 1



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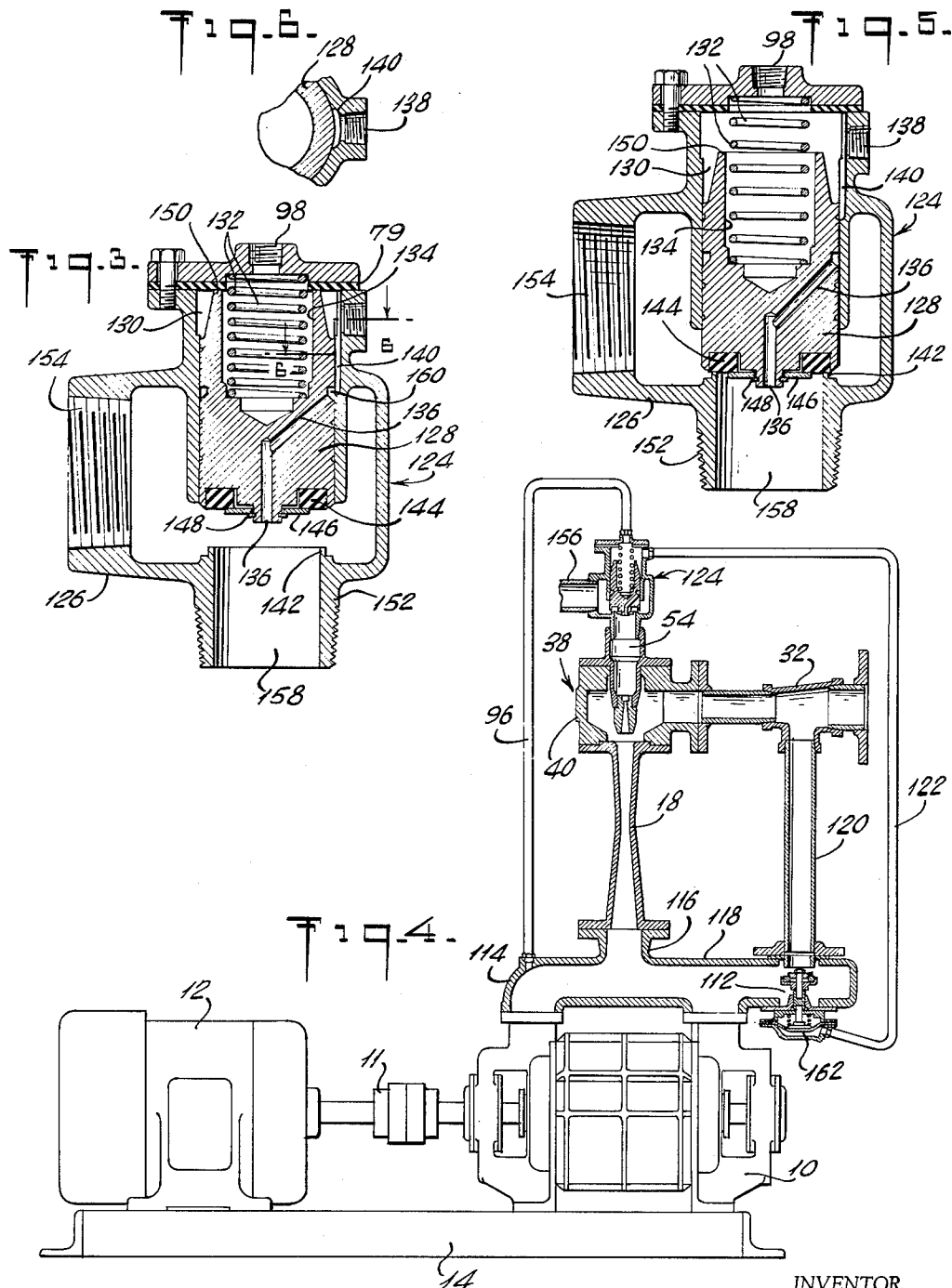
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HIGH VACUUM EJECTOR PUMP WITH AUTOMATIC CUT-IN VALVE

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Filed Mar. 18, 1963, Ser. No. 265,944

8 Claims. (Cl. 230—45)

This invention relates to improvements in high vacuum pumping systems utilizing a liquid ring vacuum pump in series with an atmosphere air ejector pump, and in particular to a system which automatically actuates the ejector pump when the vacuum in the system has reached predetermined conditions.

The present invention employs a high performance evacuation system such as represented by Patent No. 3,064,878. Such a system employs an air ejector pump connected in series with a conventional liquid ring vacuum pump. In the system represented by the prior art a primary vacuum pump produces a vacuum of predetermined degree during the hogging operation. At this point the ejector pump is introduced into the system and actuated, thereby enabling the overall system to attain a higher degree of vacuum than that reached by the primary vacuum pump alone.

Heretofore, in the prior art it was necessary to utilize a complicated system of manually operated valves to introduce the ejector pump into the system. In addition, the prior art required an operator to cut in the ejector pump when the primary pump had produced a maximum vacuum. It can be understood that such a system, requiring the constant supervision of an operator, added to the cost of the operation of the system.

The present invention simplifies and improves the reliability of prior systems for controlling the operation of an air ejector with a liquid ring pump. This is accomplished by introducing into the system an ejector actuating valve with its corresponding valve elements and conduits to implement the automation and reduce the complexity of the ejector pump cut in system.

In accordance with the invention, the ejector pump is retained in its non-operating position until the vacuum of the system has reached a predetermined degree, at which point the ejector valve is actuated thereby providing access by the ejector pump to the atmosphere. Thus the ejector pump is brought into operation automatically at a predetermined degree of vacuum, produced by the primary pump, in the system.

It is, therefore, an object of the present invention to provide an automatic high vacuum evacuation system.

It is another object of this invention to provide a method and means for an improved vacuum system.

It is still another object of the present invention to provide a valve for actuating an ejector pump at a predetermined degree of vacuum in the system.

It is a further object of the present invention to provide a simpler and more reliable high vacuum evacuation system.

The present invention utilizes an ejector pump including a supersonic jet diffuser element; a fluid combining chamber and a nozzle element having optimum fluid flow at supersonic velocity which will be in excess of mach number unity. When the ejector pump is actuated after the primary pump has evacuated the system to a predetermined degree of vacuum a supersonic fluid flow is produced in the pump. The supersonic flow is sustained by the combination of a primary and secondary stream of fluid, the primary fluid being withdrawn from the container to be evacuated by the primary pump and the secondary stream withdrawn from a source such as the atmosphere, through the utilization of the vacuum produced

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by the primary pump and the control valve which is an object of the present invention.

The two streams are mixed in a passage of predetermined size and shape where the mixed stream is decelerated, thereby increasing the pressure of the system and reducing the amount of work required to operate the primary pump.

When ordinary air expands through a supersonic type nozzle from 14.7 pounds per square inch absolute (p.s.i.a.) to pressure in the vicinity of a half-inch of mercury absolute, it attains a velocity several times that of sound. Neglecting friction the total pressure on the upstream side of the nozzle is equal to that on the downstream side. The upstream side pressure is all static and the downstream pressure is all velocity pressure. This high velocity air has the ability to entrain additional air or other gases and vapors, and to accelerate them from stagnation or rest to a relatively high velocity. This part of the process is one of mixing fluids during which the velocity of the motive air and entrained air is still supersonic after mixing, but considerably lower than the velocity of the secondary fluid or motive air at the nozzle.

The mixture, still at supersonic velocity, enters a diffuser portion which greatly reduces its velocity and increases its pressure at the discharge end of the tube. The action taking place in the diffuser portion is the reverse of that which takes place in the nozzle. In the nozzle static pressure or head is changed to velocity head while in the diffuser velocity head is changed to pressure head. The phenomenon can be applied expediently to an atmospheric air operated device discharging into the suction of a liquid ring vacuum pump.

If, for example, a supersonic jet diffuser of the invention is set up to discharge into the inlet of a liquid ring pump of the kind illustratively described herein, the vacuum at the supersonic jet diffuser suction may be 29.5 inches of mercury and simultaneously a vacuum at the suction of the primary pump may be about 26 inches of mercury. This would compare with a normal vacuum at the pump suction for the pump alone of 28.5 inches of mercury and an effective vacuum of the same value. The addition of the supersonic jet diffuser increases the effective vacuum and at the same time reduces the pump suction vacuum. At this lower intake vacuum useful life of the pump or of the evacuation system and its air handling ability are both greatly increased.

While certain objects have been set forth above, other and further objects will become apparent upon reading the following specification together with the accompanying drawing forming a part hereof.

In the drawings:

FIG. 1 is a side elevational view, partly in section, of a high vacuum evacuation system according to the invention; and

FIG. 2 is an enlarged cross section view of the control valve of FIG. 1;

FIG. 4 is a side elevational view, partly in section of a further embodiment of the system shown in FIG. 1;

FIG. 3 is an enlarged cross sectional view of the control valve of FIG. 4 with the piston unseated;

FIG. 5 is an enlarged cross sectional view of the control valve of FIG. 4 with the piston seated;

FIG. 6 is a section taken along line 6—6 of FIG. 3.

Referring now to the drawings, there is shown in FIG. 1 a primary vacuum pump 10 driven by motor 12 through a drive coupling 11. Vacuum pump 10 may be a conventional liquid ring pump, and in the embodiment described herein a single lobe water ring vacuum pump is employed. The pump and motor are mounted by conventional means upon a common support 14.

A detailed description of the primary pump is not included in this specification since details of such a pump

are not broadly of importance in the present case and useful application of the novel automatic control principle of the invention can be made with any vacuum pump system employing an ancillary ejector pumping means.

An intake manifold 16 connected to the dual inlets of primary pump 10 and extending upward therefrom is in fluid communication with a diffuser element 18 through flanges 19 and fixedly secured thereto by means of bolts 20 affixed to upper section 22 of the manifold 16. In fluid communication with section 22 and extending outwardly therefrom is an extension 24. Extension 24 includes a check valve 26 which serves to disable by-pass conduit 28 as described more fully hereinbelow. By-pass conduit 28 is connected to extension 24 through elbow 30. T-section 32 provides a suitable three way connection between conduit 28, system connection 34 and conduit 36. Conduit 36 in turn is suitably connected to the input of ejector pump 38 through the utilization of flanges 37 and bolts 39.

Ejector pump 38 includes a housing 40 having diffuser element 18 connected thereto through flange 42. Flange 42 is integrally formed with one end of the diffuser element 18, the diffuser being held in fixed relation to housing 40 by means of bolts 44 suitably affixed to the housing through flange 42. Housing 40 includes a primary stream chamber 46 in fluid communication with diffuser element 18 and systems connection 34 through input passage 48, conduit 36 and T-section 32. Depending downwardly within chamber 46 is a threaded element 50. Ejector nozzle 52 is threadedly engaged to element 50. A secondary stream chamber 54 is formed within the element 50 directly above ejector nozzle 52.

Threaded element 50 and the ejector nozzle 52 are are positioned in axial alignment with diffuser element 18, thereby forming a communicating passage between the primary stream chamber 46 and the secondary stream chamber 54. The outlet of ejector nozzle 52 is spaced apart from flared portion 56 of diffuser 18 thereby forming a terminal area at the converging inlet mixing portion 58 of diffuser 18. Ejector nozzle 52 is provided with a flared portion 55 at one end thereof which forms a convergent portion merging into a restricted portion 57 which in turn merges with a divergent portion 59 with the larger end of divergent portion 59 being spaced from flared portion 56.

In the embodiment described herein there is no particular advantage in employing the ejector pump 38 until a vacuum of substantially above 24 inches has been obtained through the utilization of primary pump 10 during the hogging operation. Up until this point has been reached, after the primary pump has been actuated, the primary fluid stream flows from the system being evacuated through system connection 34, T-section 32, by-pass conduit 28, elbow 30, extension 24 and into manifold 16. A portion of the fluid also flows through the parallel path formed by conduit 36, chamber 46 and diffuser element 18. The stream flows from manifold 16 through primary pump 10 and is then vented into the surrounding atmosphere through an exhaust tube (not shown).

Threadedly engaged to housing 40 and positioned directly above secondary stream chamber 54 is a control valve 62, shown more clearly in FIG. 2. Threaded extension 63, integrally formed with and depending downwardly from a housing element 66, serves to engage housing 40. Piston 64, enclosed by housing element 66, is fitted within cylindrical chamber 68 to slide freely there-through. A coiled spring 70 is suitably positioned in piston 64 at the bottom portion of piston chamber 72. The upper portion of coil spring 70 abuts flange 74 within a recessed portion 76. Bolts 78 are employed to secure flange 74 to collar 80 of control valve 62. A gasket 79 is interposed between flange 74 and collar 80 to provide a fluid tight connection therebetween. Adjusting washer 65, shown in FIG. 2 at the bottom of piston chamber 72,

may be of various thicknesses to thereby provide a means to adjust spring 70. Thus, if a change in the condition of the vacuum requires a different compression in the spring, the washer may be changed to provide the proper compression. Coil spring 70 thus exerts a force against piston 64 which normally tends to hold the piston against valve seat 82. A resilient gasket element 84 is seated within annular recess 86, said recess being defined by post 88 and annular lip 90, said lip having a chamfered portion 91. The gasket 84 is held in place by a suitable washer 92 and fastener 94.

A control valve conduit 96 is suitably secured at one end to inlet manifold 16 to thereby provide a communicating passage to the upper portion of control valve 62 through orifice 98. The other end of control valve conduit 96 engages control valve 62 through suitable connector 100.

Piston 64 includes an annular upper edge portion 104 which, when the piston is forced upwardly against the top portion of the chamber, seats against gasket 79 thereby shutting off all leakage into the system through conduit 96 and orifice 98. The annulus 105 formed by portion 104 and the inner surface of housing element 66 serves to provide a reserve air capacity at atmospheric pressure which is built up by a slight leakage past the piston. At the lower end of housing element 66 there is integrally formed therewith a finger element 106. Element 106 defines a port 108 which is open to the ambient atmosphere, thereby allowing the atmosphere to apply its pressure against gasket element 84.

In the operation of the present invention, when a vacuum of substantially 26 inches has been produced, in the chamber (not shown) connected to flange 34, by the primary pump, a secondary or ejector pump will be automatically actuated as explained herebelow. It will be understood that the vacuums described herein are for purposes of illustration only and other suitable degrees of vacuum may be utilized by the present invention.

As the vacuum is built up in the system by primary pump 10 during the hogging operation, the same degree of vacuum will be provided on both sides of piston 64 through control valve conduit 96 and orifice 98 and through diffuser 18, air jet element 52, secondary stream chamber 54 and threaded extension 63. It will be noted, however, that the area of the piston exposed to the vacuum at its upper end, through orifice 98, is greater than the area exposed to the vacuum at its lower end through orifice 110. The combination of the unequal size of the vacuum exposed areas of the piston and the pressure exerted by the ambient atmosphere on the lower piston portion thereof exerts a force which tends to compress the spring 70 and open the valve. However, this force is resisted by coil spring 70 which holds the valve closed until sufficient force is exerted on the bottom portion of the piston to overcome the tension exerted by the spring and lift it off valve seat 82. The point at which the piston begins to move off the valve seat is predetermined by the requirements of the particular system to which the device is applied. In the present embodiment, a vacuum of 26 inches has been chosen. Thus the attainment of 26 inches in the system through pump 10 causes piston 64 to move off its valve seat. At this point the entire bottom area of the piston will become exposed to atmospheric air pressure. This will accelerate the upward movement of the piston causing it to rise rapidly to the top of its travel and seat against the top portion of the piston unit.

Check valve 26, a gravity actuated valve, is arranged to close off by-pass conduit 28 following the unseating of piston 64 from its closed position. The force of gravity urges clapper 25 to its closed position and the slight difference in pressure between the two sides of the check valve serves to hold the clapper tightly closed. It is essential to the maintenance of the high vacuum of the pump that the check valve be held absolutely tight. Thus,

the total primary stream of fluid will be diverted through conduit 36, and input passage 48 into primary stream chamber 46. It will be noted that the by-pass is not essential to the operation of the device. However, if a by-pass is not utilized during the hogging operation, such an operation will be slowed due to the relatively small size of the remaining fluid passage.

It can be seen that immediately following the unseating of piston 64 the atmosphere, forming a secondary stream, will flow through port 108 and orifice 110 into secondary stream chamber 54. Thus, a secondary stream is provided which then passes through air jet nozzle 52 and into chamber 46 where the secondary stream entrains the gas drawn through input passage 48. The combined primary and secondary streams are subsequently carried through the diffuser element 18 to intake manifold 16.

When the vacuum in the system falls, as will be the case when the primary pump is shut off, coil spring 70 will again exert sufficient force to overcome the atmospheric pressure and close the valve to thereby shut off access of the ambient atmosphere to the ejector pump. Control valve 62 may, of course, be adjusted to accommodate for various pressures to suit the conditions under which the system is operated.

In FIG. 4 there is shown a further embodiment of the present invention employing a conventional positive action diaphragm-operated valve 112 in lieu of the check valve 26 shown in FIG. 1.

An intake manifold 114 is connected to the dual inlets of primary pump 10 and is connected at its neck portion 116 to diffuser element 18. Extension 118 of manifold 114 includes valve 112. By-pass conduit 120 connects extension 118 to T-section 32. Pipe 122 is connected at one end to valve 112 and at its other end to automatic valve 124.

Automatic valve 124 (see FIGS. 3 and 5) includes a housing 126 which encloses a piston 128 positioned in cylindrical chamber 130 in a manner which allows the piston to slide freely therethrough. A coil spring 132 is suitably positioned in piston 128 at the bottom of piston chamber 134. Spring 132 is employed in the same manner as spring 70 (in FIGS. 1 and 2) and described hereinabove. A channel 136 running through piston 128 provides a passage to a threaded aperture 138 through groove 140 when the piston is lifted off valve seat 142 as shown in FIG. 3. An annular ring 144, held in place by a suitable washer 146 and fastener 148 serves to provide a proper seal when piston 128 rests on valve seat 142. Piston 128 also includes an annular upper edge portion 150, which when the piston is forced upwardly against the washer 79 shuts off all leakage into the system through conduit 96 and orifice 98.

Housing 126 includes a threaded extension 152. Thus there is provided a means for threadedly engaging valve 124 to housing 40 and positioning valve 124 directly above secondary stream chamber 54. A threaded opening 154 provides access to the ambient atmosphere or may be connected through a pipe 156 to fluid sources such as primary pump discharge or as may be desired.

FIG. 4 shows the relative positions of valve 112 and the piston 128 when the pump system is shut down or when it is operating at only modest vacuum levels. In this condition valve 124 is closed while valve 112 is open to present a parallel intake path to manifold 114 via the ejector 38 as well as via the conduit 120. After the pump is started and when the vacuum reaches the point at which it becomes advantageous to utilize the ejector pump, the vacuum in the intake manifold 114, is transmitted through conduit 96 to the top of the automatic valve 124 to draw piston 128 to the top of its stroke. The upward movement of piston 128 is rapid because the pressure at 154 acts upon the entire lower area of the piston as soon as it raises off the seat 142. The upward transfer of the piston 128 is effective to open conduit 158 to the atmosphere thereby permitting the ejector pump to begin functioning.

Simultaneously chamber 130 is closed off from access to conduit 96, and a port 160 is opened thereby allowing the passage of atmospheric air through channel 136, groove 140, aperture 138 and pipe 122 to the lower side of the diaphragm 162. Because of this large differential pressure on diaphragm 162, valve 112 transfers quickly and positively to shut off the pump intake path through conduit 120 when the ejector is in operation.

It will be understood from the foregoing, therefore, that a high efficiency evacuation system has been provided which includes automatic actuating means for controlling the operation of a secondary ejector pump after a predetermined degree of vacuum has been attained by a primary pump. Such a device substantially reduces the cost of operating the system and in addition increases its efficiency. Furthermore, the device of the present invention is much simpler and more reliable than the previous devices which have been employed in the prior art.

The spectrum of application of the device comprehended by the present invention includes air, gas and vapor removal, and processes such as drying, evaporating, distilling, deaerating, cooking, etc., where relatively high vacuums are required.

While specific drawings have been presented herein it is to be understood that the various views are for the purpose of illustration only and that changes and modifications may be made in the apparatus without departing from the spirit of the invention.

I claim:

1. A high vacuum evacuator system comprising a primary vacuum pump having an inlet and an outlet, a suction conduit adapted to be placed in communication with a device which is to be evacuated, an ejector pump interposed between and communicating with said suction conduit and said inlet of said primary vacuum pump for operating in series with said primary vacuum pump for creating in said suction conduit a pressure lower than that which could be achieved by the primary vacuum pump itself, valve means operatively connected to said pumps and having a closed position cutting off communication between said ejector pump and a source of motive fluid therefor, so that when said valve means is in its closed position said ejector pump does not operate, said valve means automatically responding to achievement of a predetermined degree of vacuum by said primary vacuum pump for substantially instantaneously moving from said closed position to a fully open position rendering said ejector pump substantially instantaneously fully operative, so that said ejector pump will then provide in said suction conduit a lower pressure than that achieved by said primary vacuum pump.

2. A system as in claim 1 wherein said valve means includes a piston having one end surface exposed to the vacuum produced by the primary vacuum pump and an opposite end surface having in a closed position of said valve means an inner area of smaller size than said one end surface exposed to said vacuum and an outer area surrounding said inner area and exposed to said source of motive fluid for said ejector pump.

3. A system as in claim 2 wherein said valve means includes a spring tending to keep said valve means closed until a predetermined vacuum is achieved by said primary vacuum pump.

4. A high vacuum evacuator system comprising a primary vacuum pump having an inlet and an outlet, a suction conduit adapted to be connected with a device which is to be evacuated, an ejector pump interposed between and communicating with said inlet of said primary vacuum pump and said suction conduit for acting in series with said primary vacuum pump for producing in said suction conduit, and a device connected thereto, a pressure lower than could be achieved by said primary vacuum pump itself, said ejector pump having a diffuser portion directly connected to said inlet of said primary vacuum pump and having upstream of said diffuser portion an air

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inlet through which air from the outer atmosphere is adapted to enter into said ejector pump to act as a motive fluid therefor, valve means having a closed position closing said air inlet and said valve means communicating with said inlet of said primary vacuum pump for being displaced by the vacuum in said primary vacuum pump from said closed position to an open position uncovering said air inlet when said primary vacuum pump achieves a predetermined low pressure, said valve means when initially displaced away from said closed position thereof being exposed to the outer atmosphere so as to be automatically displaced substantially instantaneously to a fully open position rendering said ejector pump fully operative in a substantially instantaneous manner.

5. A system as recited in claim 4 and wherein an adjustable spring means urges said valve means to its closed position so that the pressure at which said ejector pump is rendered operative is determined by said adjustable spring means.

6. In a high vacuum evacuation system, a primary vacuum pump to create an initial portion of the desired high vacuum, and an ejector pump to create a final portion of the desired high vacuum, and valve means operatively connected to said pumps to render said ejector pump inoperative at low vacuum levels corresponding to said initial portion and of the desired high vacuum and responding automatically to the degree of vacuum provided by said primary vacuum pump for substantially instantaneously rendering said ejector pump fully operative at a high vacuum level corresponding to said final portion of the desired high vacuum.

7. A high vacuum evacuator system comprising a primary vacuum pump having an inlet and an outlet, a suction conduit adapted to be placed in communication with a device which is to be evacuated, an ejector pump interposed between and communicating with said suction conduit and said inlet of said primary vacuum pump for operating in series with said primary vacuum pump for creating in said suction conduit a pressure lower than that which could be achieved by the primary vacuum pump itself, a by-pass conduit communicating with said inlet of said primary vacuum pump and with said suction conduit upstream of the place where said suction conduit communicates with said ejector pump, first valve means operatively connected to said pumps and having a closed position cutting off communication between said ejector pump and a source of motive fluid therefor, so that when said first valve means is in its closed position said ejector pump does not operate, said first valve means automatically responding to achievement of a predetermined degree of vacuum by said primary vacuum pump for substantially instantaneously moving from said closed position to a fully open position rendering said ejector pump substantially instantaneously fully operative, so that said ejector pump will then provide in said suction conduit a lower pressure than that achieved by said primary vacuum pump, and second valve means in said by-pass conduit responding automatically to opening of said first valve means for closing said by-pass conduit, said second valve means opening

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said by-pass conduit when said first valve means is closed, so that until said predetermined degree of vacuum is achieved by said primary vacuum pump, the fluid withdrawn from said suction conduit will flow through said by-pass conduit to said primary vacuum pump, said second valve means being a check valve.

8. A high vacuum evacuator system comprising a primary vacuum pump having an inlet and an outlet, a suction conduit adapted to be placed in communication with a device which is to be evacuated, an ejector pump interposed between and communicating with said suction conduit and said inlet of said primary vacuum pump for operating in series with said primary vacuum pump for creating in said suction conduit a pressure lower than that which could be achieved by the primary vacuum pump itself, a by-pass conduit communicating with said inlet of said primary vacuum pump and with said suction conduit upstream of the place where said suction conduit communicates with said ejector pump, first valve means operatively connected to said pumps and having a closed position cutting off communication between said ejector pump and a source of motive fluid therefor, so that when said first valve means is in its closed position said ejector pump does not operate, said first valve means automatically responding to achievement of a predetermined degree of vacuum by said primary vacuum pump for substantially instantaneously moving from said closed position to a fully open position rendering said ejector pump substantially instantaneously fully operative, so that said ejector pump will then provide in said suction conduit a lower pressure than that achieved by said primary vacuum pump, and second valve means in said by-pass conduit responding automatically to opening of said first valve means for closing said by-pass conduit, said second valve means opening said by-pass conduit when said first valve means is closed, so that until said predetermined degree of vacuum is achieved by said primary vacuum pump, the fluid withdrawn from said suction conduit will flow through said by-pass conduit to said primary vacuum pump, said second valve means being a diaphragm operated valve.

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