March 19, 1963 K. F. WESSLING 3,081,936

CHECK VALVE FOR VACUUM PUMP

Original Filed Dec. 2, 1958 3 Sheets-Sheet 1

Fig. 1

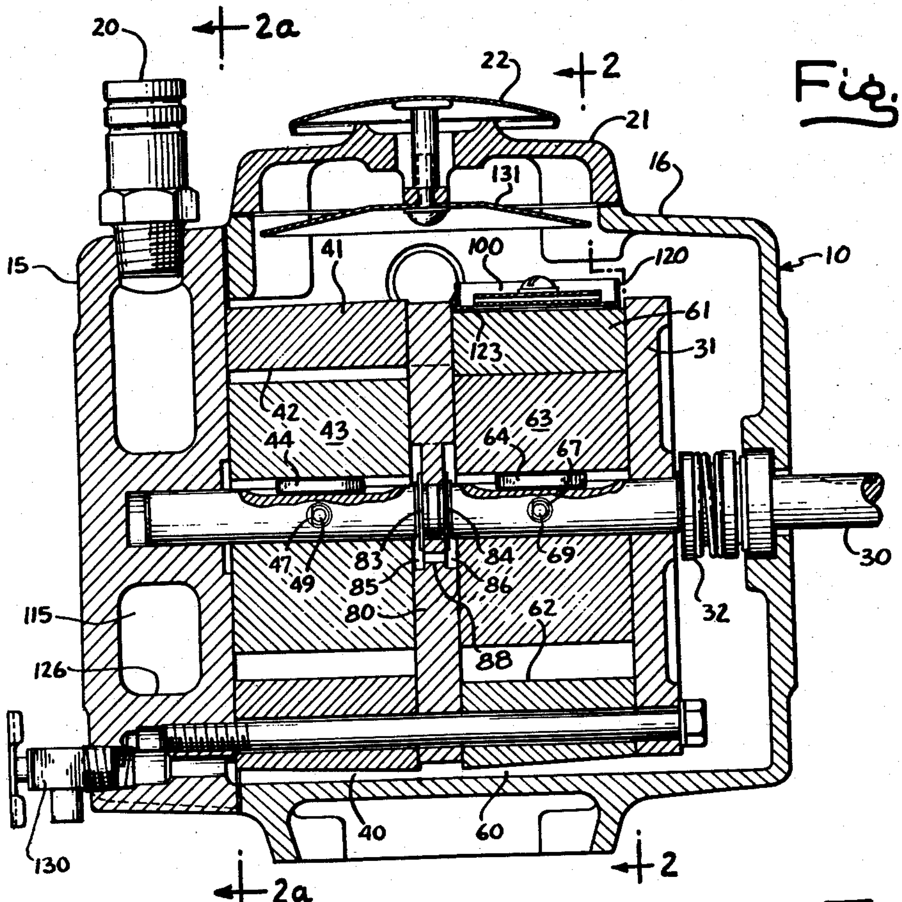
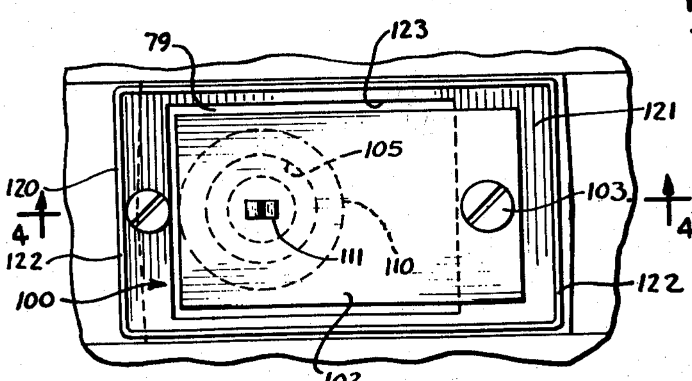


Fig. 3



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3 Sheets-Sheet 2

Fig. 2

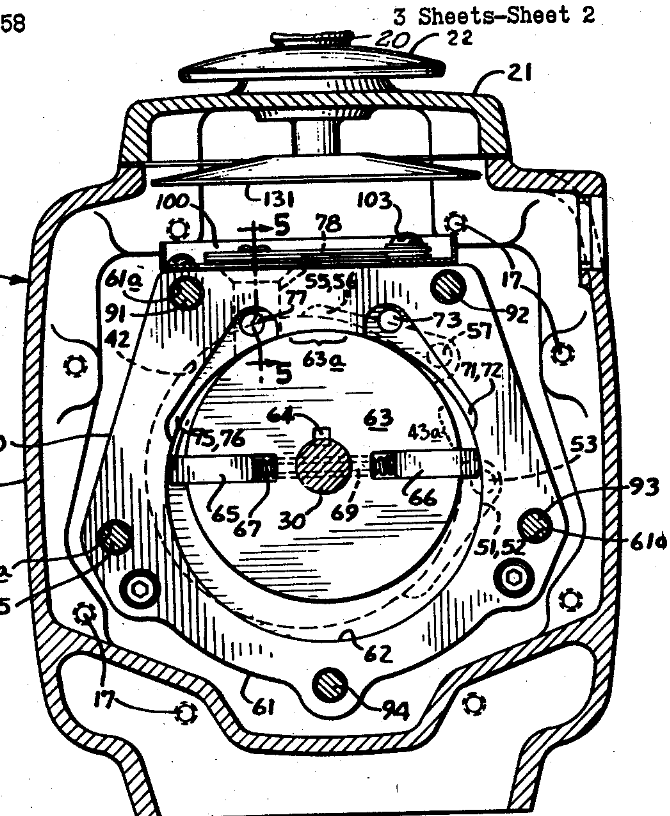


Fig. 2a

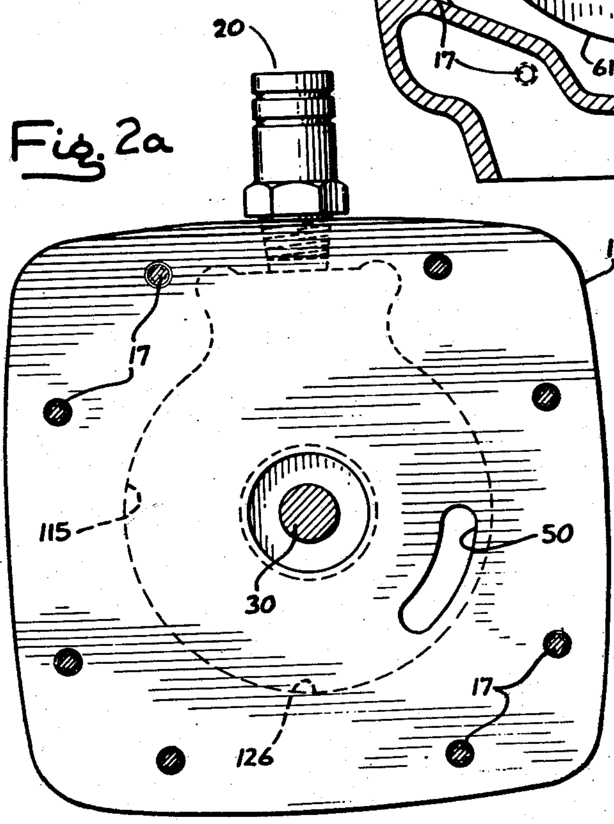
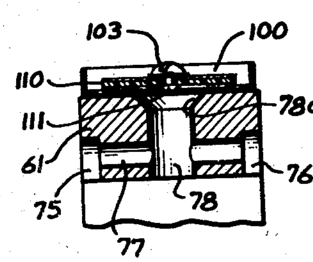


Fig. 5



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Original Filed Dec. 2, 1958 3 Sheets-Sheet 3

Fig. 4

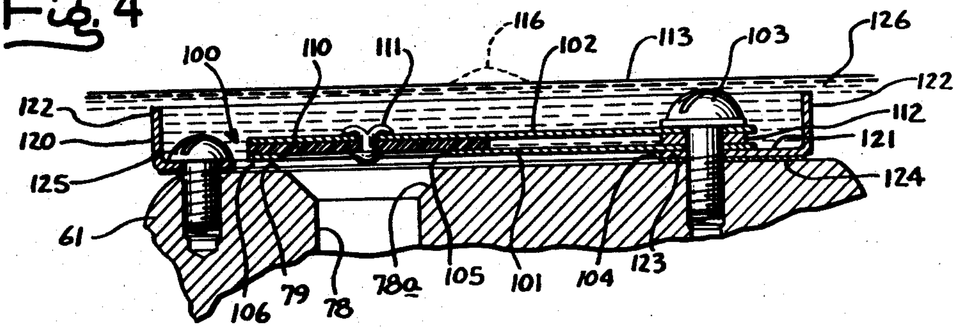


Fig. 6a

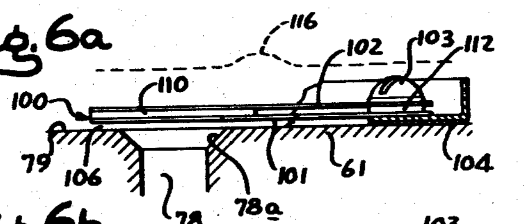


Fig. 6b

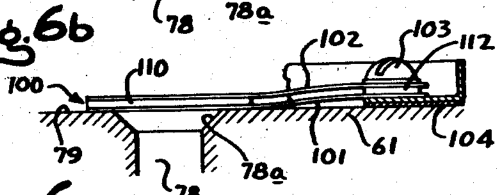


Fig. 6c

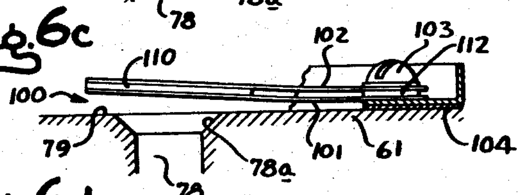


Fig. 6d

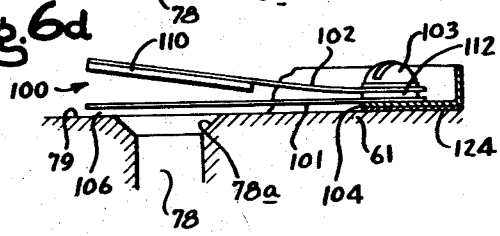
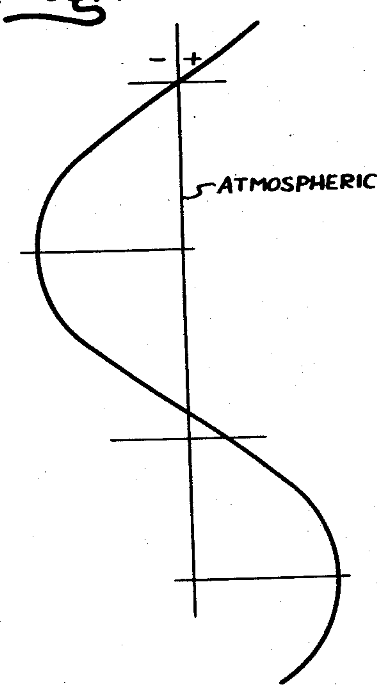


Fig. 7



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CHECK VALVE FOR VACUUM PUMP

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Original application Dec. 2, 1958, Ser. No. 777,666, now Patent No. 3,040,793, dated June 26, 1962. Divided and this application Nov. 9, 1959, Ser. No. 851,647

4 Claims. (Cl. 230—229)

The present invention relates generally to check valves for vacuum pumps and more particularly to a check valve for a vane type pump capable of pumping down to pressures on the order of 1/10 micron or better. Such a vane type pump is disclosed in my copending application Serial No. 777,666, now Patent No. 3,040,793, of which the present application is a division.

It is an object of the invention to provide a vacuum pump check valve which is highly efficient in operation and which runs quietly, free from the clatter characteristic of conventional pump valves.

It is a more detailed object to provide a novel check valve construction which is capable of holding a high vacuum, which is required to cycle at a high repetitive rate, and which has novel means for insuring prompt opening and cushioned closing.

It is an additional object of the invention to provide a valve construction which is positive and efficient in operation but which has novel provision for controlled reverse leakage of oil during part of each vacuum pumping cycle.

Other objects and advantages of the invention will become apparent upon reading the attached detailed description of the reference to the drawings in which:

FIGURE 1 is an axial section taken vertically through a two stage vane type vacuum pump in which the present invention is incorporated.

FIG. 2 is a transverse section taken along the line 2—2 in FIG. 1. FIG. 2*a* is a section taken along the line 2*a*—2*a* in FIG. 1.

FIG. 3 is an enlarged top view of the valve member and surrounding tray.

FIG. 4 is a section taken along the line 4—4 in FIG. 3.

FIG. 5 is a section taken along the line 5—5 in FIG. 2.

FIGS. 6*a*–6*d* are a series of stop motion views showing the operation of the check valve when pumping air prior to reaching rated vacuum.

FIG. 7 shows the variations of pressure at the outlet port of the pump for the steps of motion set forth in FIGS. 6*a*–6*d*.

While the invention has been described in connection with a preferred embodiment it will be understood that I do not intend to limit the invention to such embodiment, but intend to cover the alternative and equivalent constructions which may be included within the spirit and scope of the appended claims.

Turning now to the drawings, the check valve is shown included in a two-stage rotary vane type vacuum pump for which it has been found to be well suited. However, no attempt has been made to limit the invention to such a preferred construction, since such a valve may also be employed in other types of vacuum pumps. In the pump shown it may be noted in FIGS. 1 and 2 that the housing includes an end member **15** which seats a cup-shaped enclosure **16** having a flange secured by suitable screws **17.** Mounted on the top of the end member **15** is an inlet port **20.** For providing access, the top surface of the housing **16** is enclosed by an access plate **21** which carries a vent cap **22** thereon of flat disc shape.

As is usual in vacuum pumps, the inlet port **20** is connected to the system to be evacuated and, upon driving of the pump by a motor, the air or gas withdrawn from the system is discharged from under the vent cap. In the following discussion it will be assumed that air is being pumped.

The internal construction of the pump is shown in the remainder of the figures and particularly FIG. 1. Extending longitudinally through the pump is a shaft **30,** one end of which is journaled in the end member **15** and the other end of which is journaled in a bearing or end plate **31.** A seal indicated at **32** is interposed between the shaft and the enclosure **16** to prevent escape of the sealing and lubricating oil.

Surrounding the shaft at its left hand end is a first stage or pumping unit **40** having a stator **41** in the form of a ring made of cast iron or the like having an irregular outline and a circular opening **42** which is eccentric with respect to the shaft **30.** Mounted within the opening **42** is a rotor **43** in the form of a metal disc having accurately ground endfaces, the rotor being in contact with the stator at a terminal region **43*a*.** The rotor **43** is secured to the shaft by a key **44** and is slotted to accommodate radially extending vanes which are spring pressed outwardly against the stator by means of coil spring **47,** assembled on a radially extending pin **49.**

For the purpose of admitting air from the inlet **20** into the space between the rotor and stator it may be understood that an opening (not shown) is provided in the wall of the end member **15.** Moreover, for conducting the air, the edges of the opening **42** are grooved or relieved to provide inlet ports **51, 52** which are interconnected by an axially extending passage **53** (FIG. 2). For discharge of air from the first stage **40,** outlet ports are formed in the stator of similar thickness and contour and symmetrically located on the opposite side of the region of contact **43*a*** between stator and rotor. These outlet ports are indicated at **55, 56** and interconnected by a passage **57** (FIG. 2).

The second stage or pumping unit, indicated at **60** in FIGS. 1 and 2 is substantially identical to the first. It includes a stator **61** having a central opening **62** accommodating a rotor **63** which is in contact with the stator at the terminal region **63*a*.** The rotor is keyed to the shaft **30** by a key **64.** Slidably mounted in the rotor are vanes **65, 66** outwardly pressed by spring **67,** on a guide pin **69.** The second stage has inlet ports **71, 72** formed on the inner surface of the stator and interconnected by a passage **73,** as well as outlet ports **75, 76** interconnected by a passage **77.**

Interposed between the two stages **40, 60** is a center plate **80** having flat, finely machined side surfaces which bear against the side surfaces of the rotors **43, 63.** For providing communication between the outlet port **56** of the first stage and the inlet port **71** of the second, it will be understood that the center plate **80** has an appropriate passage or transfer port (not shown). To keep the shaft **30** from moving endwise relative to the center plate **80,** the shaft is provided with thrust washers **83, 84** which are accommodated in annular recesses **85, 86** machined on each side of the center plate as shown. For the purpose of supplying lubricant between the stages and thereby to insure that the first stage is lubricated by oil leaking into the second stage, the center plate **80** is provided with an opening **88** which interconnects the recesses **85, 86** (FIG. 1).

In accordance with the present invention, a novel check valve is provided at the outlet port **78** of the second stage, including a leaf spring which in its normal, unstressed state is spaced from the land around the port **78** and which provides intentional leakage of oil into the pump mechanism during a portion of each pumping cycle. Further in accordance with the invention I employ a composite leaf spring construction including a lower leaf spring and an upper leaf spring arranged flatly face-to-face with the lower leaf spring having an opening therein registered with the outlet port and the upper leaf spring having a combined sealing and cushioning member for sealing the opening in the lower leaf spring to produce a novel and quiet sealing action. Thus, referring to the drawings and particularly to FIGS. 3 and 4, a check valve **100** is provided having a lower leaf spring **101** and an overlying or upper leaf spring **102** arranged flatly adjacent thereto. The leaf springs are mounted at their stationary ends by machine screw **103** or the like. In carrying out the present invention the lower leaf spring **101** is spaced, as shown, above the land **79** which surrounds the outlet port **78** of the second pumping stage, spacing being provided by a spacer **104** surrounding the mounting screw. Registering with the outlet port *78a*, and formed in the end of the spring **101** is a circular opening **105** having a diameter which is substantially the same as that of the mouth of the port, which mouth may be desirably formed by chamfering as indicated at *78a*. It will be apparent that because of the spacer **104** the lower spring **101**, in its unstressed state, is spaced above the land **79** by an amount indicated at **106**.

Interposed between the leaf springs **101**, **102** for sealing the opening **105** in the first leaf spring is a sealing and cushioning disc **110** which is preferably secured to the upper leaf spring **102** by a rivet **111** or the like. A spacer **112** between the springs at their fixed ends separates them an amount which is substantially equal to the thickness of the sealing member **110**.

With regard to the materials of construction of the check valve described above, for use in a pump of the size shown, the leaf spring **101**, **102** are preferably formed of flat clock spring stock having a thickness of approximately 0.010 inch. The sealing member **110** which may have a thickness of 0.030 inch, is formed of plastic material, preferably a polytetrafluoroethylene resin widely available under the name of "Teflon," although other materials having approximately the same physical characteristics may be employed. Preferably the material should have a hardness within the range of D50 to D65 as measured by the A.S.T.M. method D676. The deformation under load should not exceed 4–8 percent when subjected to a pressure of 1200 p.s.i. in a period of twenty-four hours in accordance with A.S.T.M. method D621. The modulus of elasticity should preferably be on the order of 58,0000 p.s.i. in accordance with A.S.T.M. method D638, the above figures being set forth for the guidance of those wishing to employ substitute materials without departing from the present invention.

With regard to the leakage gap indicated at **106** in FIG. 4, my observations show that using conventional lubricating and sealing oil and with the valve submerged to a shallow depth under an oil level **113** this gap may be on the order of 0.060 inch in a pump of the size shown here.

It is found that employing a valve constructed along the lines set forth a number of important and unexpected advantages are derived. Notably, the valve operates quietly free of the clatter which characterizes conventional pumps. It will be appreciated by one skilled in the art that vacuum pumps employed in laboratories are frequently left connected to an evacuating system for long periods of time and the clatter set up by one or more of the vacuum pumps in constant operation is bothersome and distracting to those working in a laboratory. The present design of pump, by contrast, produces only slightly more noise than the motor which drives it and a large number of pumps may be operated simultaneously in the same room without raising the noise level to an objectionable degree.

Pumps equipped with the above valve construction are efficient and are found to make maximum use of the sealing and lubricating oil, permitting high vacuums to be drawn and sustained over long periods of time without any detectable wear of the valve elements and without any change in the operating characteristics. The high

efficiency of the valve is particularly surprising in view of the fact that it includes what may be termed a "built-in leak." That is to say, when the leaf springs occupy the normal, unstressed position illustrated in FIG. 4, the gap **106** provides sufficient area for substantial leakage of oil into the port **78**. During the portion of the operating cycle when the pressure within the port **78** is at or only slightly below atmospheric pressure, the vacuum is not sufficient to overcome the spring force to effect closure of the valve. Consequently oil is sucked through the gap and down into the second stage of the pump. The oil which is thus drawn in effectively seals the rotor to the stator so that there is no leakage or bypassing of air from outlet to inlet. During a subsequent portion of the pumping cycle, the oil which has been drawn in is forcibly expelled and the cycle is repeated.

While the features and advantages of the check valve described above have been found to be important to the operation, the operative phenomena are the subject of continuing investigation. Nevertheless, for further understanding, reference may be made to a series of stop motion views FIGS. *6a*–*6d* which show the operation of the valve when pumping air and prior to the time that a complete vacuum is drawn. In FIG. 7, and arranged adjacent the stop motion figures, there is shown an approximate plot of pressure variations relative to atmospheric pressure which occur within the outlet port **78**, keeping in mind that the purpose of FIG. 7 is to show the direction of pressure variation during the cycle rather than to indicate the magnitude of the variation.

Thus referring to FIG. *6a* it will be assumed that the pressure in the port **78** has just gone through atmospheric and is slightly below atmospheric. The force is, however, not sufficient to draw the leaf springs downwardly into contact with the land surrounding the port. Consequently oil is drawn in through the gap **106** into the port and into contact with the rotor. As the vacuum in the port **78** increases, both the springs **101**, **102** are drawn down tight into contact with the land **79** so that no further oil can enter. As the cycle continues, the active vane in the rotor **63** causes the air between rotor and stator to be compressed so that the pressure in the outlet port **78** rises above atmospheric pressure as shown in FIG. *6c*. This causes unseating of the leaf springs from the land. Experience shows that the metallic surface on the underside of the spring **101** is separated from the metallic surface of the land **79** with ease. However, the plastic-to-metal seal between the sealing member **110** and the upper surface of the leaf spring **101** is not quite so readily broken, so that the leaf spring **101** remains in contact with the sealing member during the initial portion of its upward movement. Since the lower spring tends to resist moving upwardly by reason of its resilience, a point in the movement will be reached where the upper spring separates from the lower as shown in FIG. *6d*, whereupon the lower spring is free to assume its initial "at rest" condition shown in FIG. *6a*. The upper spring, however, remains distorted upwardly until the "blow off" is complete following which it, too, will be restored to the initial position shown in FIG. *6a* in readiness for the ensuing cycle of operation. During the time that the valve is in operation, air bubbles will be seen escaping from under the tips of the springs **101**, **102**, with the bubbles becoming smaller in size as a high vacuum is drawn. Indicative of proper operation of the valve it is noted in operation that the surface of the oil becomes humped as indicated by the dotted outline **116** in FIGS. 4 and *6a*. Such "humps" indicate that oil is being pumped back and forth by reason of vibration of the leaf springs.

As the vacuum increases, the excursion of the leaf springs will be accordingly reduced, but even under conditions of full rated vacuum the springs continue to vibrate, in a practical pump, through a distance on the order of a 1/32 inch and observation shows that under such high vacuum conditions oil continues to be pumped in and out of the pump through the port **78** during each cycle of operation.

Further in accordance with the present invention, the check valve is accommodated in a shallow well or recess formed in the upper surface of the stator **61** thereby to limit the total amount of oil which may be drawn reversely through the pump. In the present instance this function is taken care of by providing a surrounding dam or tray **120** having a mounting portion **121** and a sidewall **122**. In order to provide clearance about the leaf springs **101**, **102**, the mounting portion **121** is formed with a rectangular opening **123** as shown in FIG. 3. Arranged under the tray **120** is a gasket **124**, the thickness of metal and gasket serving to space the lower spring from the orifice by the 0.060 inch previously mentioned. Thus at one end the tray is held by the mounting screw **103**; at the other end a screw **125** is provided.

During normal operation of the pump the oil level **113** is preferably such as to cover the check valve **100** reliably, say to a depth on the order of 1/16 to 1/8 inch. However use of the tray **120** insures that the check valve is kept under a reliable depth of oil while nevertheless severely limiting the amount of oil which may be sucked reversely back into the system. As illustrated in FIG. 4, the limited amount of oil which can be sucked back to the system in the present construction is indicated by the cross hatched area **126**, the line of the oil being at or only slightly above the upper edge of the tray **120**. Thus, as soon as sufficient oil has passed through the port **78** to drop the oil level to the upper edge of the tray, no further oil can flow into the tray and the bulk of the oil is prevented from being sucked back into the pump. This insures that the reversely sucked oil will be accommodated by the space **115** in the end member **15** even though such space is of relatively limited volume. If the tray were not utilized, sufficient available oil would completely fill all recesses of the exhaust stage thus preventing a motor-powered start. Thus in the present construction, in spite of the use of a valve having an intentional "gap" through which oil can flow on shutdown, the oil is prevented from blocking rotation when the pump is again operated. The present valving arrangement therefore not only insures high efficiency during operation but high reliability in "start up."

I claim as my invention:

1. In a vacuum pump a combination comprising a frame, a pump unit in said frame having an inlet port and an exhaust port surrounded by a land portion, a check valve covering said exhaust port, said check valve including an upper leaf spring and a lower leaf spring arranged flatly face-to-face, said lower leaf spring being slightly spaced away from the land surrounding said port when the leaf springs are in their unstressed condition, and said lower spring having an opening therein centered with respect to said exhaust port, a cushioning and sealing member interposed between said springs for sealing the opening in the lower spring when a vacuum is drawn in the inlet port, and means providing an oil bath for submerging said springs at a shallow depth under oil during the operation thereof.

2. In a vacuum pump a combination comprising a frame, a pump unit in said frame having an inlet port and an exhaust port, a check valve covering said exhaust port, said check valve including a flat leaf spring secured at one end and covering said exhaust port, means providing an oil bath for submerging said spring at a shallow depth under oil during the operation thereof, said leaf spring being slightly spaced away from said exhaust port when the leaf spring is in its unstressed condition so that oil is sucked reversely through said check valve during a portion of each pumping cycle of the pump unit, and means surrounding said spring for damming and thereby limiting the flow of oil drawn reversely through said exhaust port when the pump inlet is left connected to an evacuated system.

3. In a vacuum pump a combination comprising a frame, a pump unit in said frame having an inlet port and an exhaust port, a check valve covering said exhaust port, said check valve including a flat leaf spring secured at one end and covering said exhaust port, means providing an oil bath for submerging said spring at a shallow depth under oil during the operation thereof, said leaf spring being slightly spaced away from said exhaust port when the leaf spring is in its unstresssed condition so that oil is sucked reversely through said check valve during a portion of each pumping cycle of the pump unit, and means surrounding said spring for damming and thereby limiting the flow of oil drawn reversely through said exhaust port when the pump inlet is left connected to an evacuated system, the frame of the pump being hollowed out adjacent the inlet port for accommodating the oil drawn through said exhaust port.

4. In a vacuum pump the combination comprising a frame providing an inlet port, a pumping unit in said frame, said pumping unit having an exhaust port surrounded by a land portion and said pumping unit being so constructed and arranged that a finite amount of air drawn through the inlet port is trapped and compressed into a small volume for discharge at the exhaust port, a pair of flat elongated leaf springs arranged one above the other with one of the ends of the springs being anchored to said pumping unit and the other being positioned to overlie said exhaust port, the lowermost spring being so mounted that when the same is in its unstressed condition the end of the spring is spaced a small amount above the land surrounding said exhaust port and said lowermost spring having an opening therein corresponding to the shape of the exhaust port, said upper spring having a sealing disc thereon and so mounted that the disc bears without pressure against the lowermost spring when the upper spring is in an unstressed state.

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