METHOD OF CONTROLLING THE FUNCTION OF A CENTRIFUGAL PUMP AND VACUUM PUMP COMBINATION, AND A GAS-SEPARATING CENTRIFUGAL PUMP

The present invention relates to a method of controlling the function of a centrifugal pump and vacuum pump combination, and a gas-separating centrifugal pump. The method according to the invention is characterized in that the gas flow in the gas outlet duct (26) between the centrifugal pump and vacuum pump is controlled by a member restricting the flow.
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METHOD OF CONTROLLING THE FUNCTION OF A CENTRIFUGAL PUMP AND VACUUM PUMP COMBINATION, AND A GAS-SEPARATING CENTRIFUGAL PUMP

The present invention relates to a method of controlling the function of a gas-separating centrifugal pump and vacuum pump combination, and a gas-separating centrifugal pump. The apparatus according to the invention is particularly well suited to be used as a so called fluidizing centrifugal pump pumping pulp of medium consistency, but the method and the centrifugal pump utilizing it can be applied also in other applications in which the liquid to be pumped contains gas and solid matter.

Earlier known pumps which are used for the above purpose are described, inter alia, in U.S. Patents 4,776,758, 4,981,413, 5,078,573, 5,114,310, 5,116,198, 5,151,010, 5,152,663 and 5,366,347. All of the above-mentioned patents deal mainly with pumps for the wood processing industry, which separate gas from pulp suspensions of medium consistency and which are characterized in that, in addition to the conventional impeller, a vacuum pump, preferably a water ring pump, is mounted on the pump shaft in a chamber behind the impeller. Gas outlet openings, through which gas accumulating in front of the impeller of the centrifugal pump can flow to the space behind the impeller, are arranged in the back plate of the pump impeller, near the impeller shaft. Said space is in most cases connected to the suction opening of the vacuum pump through a gas outlet duct surrounding at least partly the pump shaft. When the vacuum pump creates a pressure difference between the space in front of the impeller and its own pumping chamber, the gas flows through the openings in the impeller and said gas outlet duct at least partly surrounding the shaft to the chamber of the vacuum pump. Because of the eccentricity of its chamber, the vacuum pump creates, in a manner known per
se, on the one hand suction so as to draw gas into its chamber and on the other hand a pressure difference between the atmosphere and its chamber on its outlet side so that the gas is discharged from the chamber of the pump. Usually the separated gas is discharged from the vacuum pump directly to the atmosphere.

Certain special requirements are set on the centrifugal pump and vacuum pump combinations used for pumping pulp suspensions of the wood processing industry, which have been extensively dealt with in the above-mentioned patents and can therefore here be dealt with relatively briefly.

Firstly, since the material to be pumped contains solid matter, i.e. fibres, provisions have to be made in the construction of the centrifugal pump and the vacuum pump connected to it for the possibility that fibres get into the gas outlet system. For that reason, the back side of the back plate are, for example, provided with back blades, in order to separate fibres from the material which has found its way to the space behind the impeller. As fibres can also get into the vacuum pump, flushing means are arranged both on the suction side and the outlet side of the pump in order to prevent clogging of the ducts by fibres.

Secondly, the conditions can vary considerably when pumping fibre suspensions. The consistency of the pulp, for instance, can vary by several percents and the inlet pressure of the pulp by several bars. As the gas removal in front of the impeller, in order to function reliably, requires a certain pressure difference, possibilities to take the inlet pressure into consideration must be provided, i.e. the suction of the vacuum pump has to be controllable. This is usually accomplished by arranging in connection with the suction duct a so called auxiliary
air duct through which extra air can be led to the vacuum pump when enough gas is not separated in front of the impeller. A valve which opens at a given pressure, e.g. 0.4 bar, is usually connected to the auxiliary air duct.

Thirdly, when pumping fibre suspensions the separated gas does not in most cases consist of pure air, but may often contain various malodorous or even to some degree poisonous or corrosive gases, which can not be led directly to the atmosphere. Fibres also get into the outlet of the vacuum pump to some extent, and it should be possible to recover them, so that the outlet pipe of the vacuum pump can not, even for that reason, be connected directly to the drain.

Attempts have been made to fulfil the first two of the above mentioned basic requirements by an arrangement according to U.S. Patent 5,366,347, which is based on the idea that a fluidizing centrifugal pump pumping pulp of medium consistency has to be able to operate under three different operating conditions.

In the first case, where the inlet pressure is low, below the atmospheric pressure, a great amount of gas is separated in front of the impeller, so that the capacity of the vacuum pump must be high and the pump has to be able to remove all the gas separated.

In the second case, where the inlet pressure is medium, only slightly above the atmospheric pressure, gas is separated in front of the impeller to some degree, and it must be possible to remove it through the vacuum pump without entraining fibres.
In the third case, where the inlet pressure is high, above 2 bar for instance, no gas is separated and the vacuum pump has nothing to remove.

Said patent suggests that the capacity of the vacuum pump be controlled by moving the housing of the vacuum pump in relation to the rotor of the vacuum pump. The idea is that the vacuum pump in the first operating condition sucks gas from the vacuum space in front of the impeller and is capable to transport it to a higher, i.e. atmospheric pressure. The pump functions in this case as it is originally meant to function.

In the second operating condition where the gas pressure of the separated gas is above the atmospheric pressure, the housing of the vacuum pump is moved in relation to the rotor into such a position that the vacuum pump creates a pressure difference in opposite direction to that of the first case. In other words, assuming that the inlet pressure of the pulp causes an absolute pressure of 1.5 bar in front of the impeller, the pressure difference in relation to the atmosphere is 0.5 bar. As the pressure difference is relatively great, a counter pressure of for instance 0.3 bar overpressure is produced by means of the vacuum pump, whereby the pressure in front of the impeller first has to surpass the counter pressure of the vacuum pump. The gas will in other words flow out to the atmosphere at a pressure difference of only 0.2 bar.

For the third operating condition, the said patent suggests that the eccentric housing of the vacuum pump be moved so as to be concentric with the shaft and the rotor of the vacuum pump. The pump does in other words not generate any pressure difference in either direction. Presumably, it is assumed that as, according to the applicant, no gas is separated in front of the impeller, also no fibres are able to pass into the gas outlet, in
spite of the great pressure difference. Obviously here the fact is forgotten that, when a considerable overpressure exists on the suction side of the centrifugal pump, it tends to burst out from the pump through all available passages. If the vacuum pump, as described in the U.S. Patent 5,366,347, is running "idle", i.e. the housing of the vacuum pump is concentric with the rotor and no valve is arranged on the outlet side of the vacuum pump, the absence of which in said U.S. Patent is stated to be an advantage, the pulp suspension under overpressure will obviously flow directly through the vacuum pump along the gas outlet channels.

The above mentioned problem could be solved in the pump according to said U.S. Patent 5,366,347 at least in two ways: either by arranging a valve on the outlet side of the vacuum pump so that the valve would be closed or throttled when the pump is running "idle", whereby consequently the whole gas outlet pipe system would be at least partly closed, or by improving the capability of the vacuum pump to produce counter pressure so that the maximal counter pressure generated by the pump would correspond to the highest possible overpressure on the suction side of the centrifugal pump. It has thus on one hand been suggested in said U.S. Patent that in case of a slight overpressure on the suction side of the centrifugal pump, the eccentricity of the housing of the vacuum pump be changed so that the vacuum pump produces a counter pressure great enough to "dampen" the overpressure. On the other hand, it is also suggested that the eccentricity of the housing of the vacuum pump be further decreased to zero when the overpressure on the suction side of the centrifugal pump increases. The latter idea is absurd, resulting in practice to a pump leaking abundantly. The matter can however easily be corrected by increasing the eccentricity of the housing of the vacuum pump as well, so that the counter pressure
produced by the vacuum pump increases when the overpressure of the centrifugal pump increases. In other words, by keeping the counter pressure produced by the vacuum pump the same as the inlet pressure, there will be no flow in either direction in the vacuum pump. The effect of the inlet pressure can naturally be reduced also by arranging a throttling valve on the outlet side of the vacuum pump, contrary to the teaching of said U.S. Patent, whereby the inlet pressure can be "dampened" by means of the throttling valve as well as by changing the eccentricity of the housing of the vacuum pump. In other words, the arrangement described in said U.S. Patent 5,366,347 can be corrected simply by providing a sufficient margin for the eccentricity adjustments considered to be required for the housing. All of the arrangements described in said patent can be used as such, and as regards the various embodiments, reference is made to the description and the figures of said U.S. Patent document 5,366,347.

The pump described in more detail in the U.S. Patent 5,366,347 does not even after the above mentioned corrections wholly correspond to the requirements which nowadays are set on the pumps in the mills. We already mentioned above that the gas to be removed often can contain malodorous or poisonous chemicals. Also a little liquid, a few litres per minute, and in some cases also fibres continually discharge from the vacuum pump. As it would be advantageous from an environmental point of view as well as considering recovery of fibres and chemicals to conduct the exhaust from the vacuum pump to a separate space instead of the drain, one should, when designing a centrifugal pump and a vacuum pump, bear in mind that the vacuum pump should be capable of discharging the gas, fibres and liquid to a pressured space or at least to a space located above the pump. The pump must, in other words, besides being capable of generating a vacuum on
its suction side, also be capable of producing a head or overpressure on its outlet side.

In the above mentioned patents, this possibility has either not been taken into consideration or has not, for other reasons, dealt with at all. In most of the patents, the control of the pump combination has not been dealt with in any way. In some patents, it has been mentioned that a stop valve can be arranged on the outlet side of the vacuum pump, by means of which the outlet can be throttled or, if required, even closed. This functions well until the valve really has to be fully closed. When closed, the valve causes cavitation and pressure shocks in the vacuum pump, whereby the risk that the vacuum pump will be damaged is high. Another possibility is to change the capacity of the pump, as described in U.S. Patent 5,366,347. Controlling the capacity, however, results in that the pump does not any longer have the head required to transport the gas and/or fibres and/or liquid forward. This can be explained by the following example. In the case where only a little gas is separated and only a small vacuum is needed for removing the gas from the centrifugal pump, the vacuum pump is adjusted to generate only a small pressure difference. From this follows that correspondingly only a small pressure difference is available on the outlet side of the pump, which is not enough if, for instance, the exhaust of the pump should be led to a space located about twenty meters higher, and sometimes even slightly pressurized.

The above problem has been solved by the method and apparatus according to our invention by arranging control means on the suction side of the vacuum pump, by means of which the vacuum generated by the vacuum pump in front of the impeller of the centrifugal pump can be controlled totally regardless of the capacity of the vacuum pump. In other words, although only a small vacuum effect is
directed towards the centrifugal pump side, the whole capacity of the vacuum pump is available for removal of separated gas, fibres and liquid.

The characterizing features of the method and apparatus according to the invention are apparent from the appended claims.

The method and apparatus according to the invention will be described more in detail in the following, with reference to the accompanying drawings, in which

FIG. 1 is an axial cross-sectional view of a prior art centrifugal pump provided with a vacuum pump, in which centrifugal pump the control system according to the invention is installed,

FIG. 2 illustrates a view of a preferred embodiment of the centrifugal pump according to the invention,

FIG. 3 illustrates a second preferred embodiment of the centrifugal pump according to the invention,

FIG. 4 illustrates a view of a third preferred embodiment of the centrifugal pump according to the invention, and

FIG. 5 illustrates a view of a fourth preferred embodiment of the centrifugal pump according to the invention.

FIG. 6 illustrates a view of a fifth preferred embodiment of the centrifugal pump according to the invention.

FIG. 7 illustrates a view of a sixth preferred embodiment of the centrifugal pump according to the invention.
FIGs 8a and 8b illustrate a seventh and an eighth preferred embodiment of the centrifugal pump according to the invention.

FIG. 9 illustrates a ninth preferred embodiment of the centrifugal pump according to the invention.

According to FIG. 1 a prior art centrifugal pump consists of a volute casing 10 and a pump body 40. The volute casing 10 comprises the suction opening 12 of the centrifugal pump and a substantially tangential outlet (not shown). The volute casing 10 surrounds the impeller 14 of the centrifugal pump, the impeller consisting of a so called back plate 16, working blades 18 attached to the surface on the side of the suction 12, the so called front surface, and back blades 20 attached to back side of the back plate. A plurality of gas outlet openings 22 are further arranged in the back plate 16 of the impeller 14. A back wall 24 of the pump, preferably detachable, is arranged between the volute casing 10 and the vacuum pump disposed inside the pump body 40, between which back wall and the shaft or, as shown in the figure, a cylindrical projecting part extending from the impeller, a gas outlet duct 26 is formed, in this embodiment enlarging to an annular chamber 28. In the embodiment shown on the drawing a flushing duct 30, which leads to the chamber 28, is arranged in the back wall 24 for cleaning of the gas outlet system. A fluidizing rotor 32, which preferably consists of blades 34 extending a distance apart from both the pump shaft and the wall of the suction opening 12 is arranged in the impeller of the centrifugal pump in such a case where the material to be pumped is a pulp suspension of medium consistency of the wood processing industry.

According to FIG. 1, a vacuum pump consisting of a housing 42 and a rotor 44 disposed therein is further
arranged inside the pump body 40. The housing 42 comprises in the embodiment according to the figure an integral back wall 46, which however may also be detachable, if desired. A separate detachable plate 48 or the back wall 24 of the centrifugal pump functions as the front wall (facing the centrifugal pump) of the housing 42, though it is also possible to construct the vacuum pump so that its front wall is an integral part of the housing of the vacuum pump and the back wall is detachable. The rotor 44 is attached to the shaft 49, as is also the impeller 14 of the centrifugal pump, and provided with blades 50, which, however, do not extend to the inner wall 52 of the housing 44. The blades 50 rotate a liquid ring 51 when the vacuum pump is in operation. The inner wall 52 of the housing 42, which surrounds the rotor 44, is eccentric so that the liquid ring rotated by the blades 50 in the housing causes changes of the volume of the spaces between the blades 50 depending on the mutual positions of the blades 50 and the inner wall 52 of the housing 42. The front wall 48 of the housing 42 is provided with a suction opening 54 for the vacuum pump which forms a part of the gas outlet duct between the centrifugal pump and the vacuum pump, which suction opening is crescentic and positioned in relation to the housing 42 so that, at the suction opening 54, the volume of the spaces between the blades 50 of the rotor 44 is increasing. This results in that a vacuum is generated between the blades of the rotor, owing to which the vacuum pump sucks gas into the spaces between the blades 50. In a corresponding point of the back wall 46 of the vacuum pump in the embodiment of FIG. 1, there is a so-called auxiliary air duct 56, through which the vacuum pump sucks gas exactly in a similar way into the space between the blades, if enough gas is not received from the centrifugal pump. A valve (not shown) which opens at a given pressure difference is usually connected to the auxiliary air duct 56. Said auxiliary air duct can also
be led through the back wall 24 of the centrifugal pump or through the front wall 48 of the vacuum pump to the chamber 28. An outlet duct 58 of the vacuum pump is also arranged in the back wall 46 of the vacuum pump, through which mainly gas, but also small amounts of liquid, and possibly also solid matter, is discharged. Said outlet duct 58 leads to the vacuum pump at a point which is about 180° apart from the suction opening 54, preferably in the back wall 46 of the vacuum pump, though it can also be positioned in the front wall 48 of the vacuum pump or the back wall 24 of the centrifugal pump separating the pumps, whereby it is located directly on the opposite side of the shaft in relation to the suction opening 54.

Examples of various possible pump constructions are shown in detail in the U.S. Patents 4,981,413, 5,078,573, 5,114,310, 5,116,198, 5,151,010, and 5,152,663 of A. AHLSTROM CORPORATION to which reference is made. The constructions shown in the above mentioned patents are examples of advantageous and useful arrangements but are not to be understood as representing all the constructions which are possible.

FIG. 2 shows a partial, detailed sectional view of a centrifugal pump according to a preferred embodiment of the invention. The figure shows the shaft 49 of the pump, the impeller 14 with its cylindrical projecting part, the rotor 44 of the vacuum pump and the back wall 24 of the centrifugal pump with its chamber 28, and the suction opening 54 in the back wall between the chamber 28 and the vacuum pump. The device 100 for controlling the suction flow of the vacuum pump according to the invention consists in this case of an annular pipe 60 made of rubber or the like resilient material which can be expanded hydraulically, pneumatically or the like manner, which pipe is disposed in a groove 62 in the
innermost edge in the radial direction of the back wall 24 of the centrifugal pump, preferably on the centrifugal pump side of the chamber 28. A pressure medium is led to the annular pipe 60, for instance through a duct arranged in the back wall 24. When the control device 100 is situated as shown in the figure, it is possible to lead the auxiliary air duct 64 through the back wall 24 of the chamber 28. The device functions so that, if the cross-sectional flow area from the centrifugal pump to the vacuum pump should be throttled, the pressure of the pressure medium is increased, whereby the annular pipe 60 expands and comes closer to the cylindrical projecting part of the impeller. When the pressure in the pipe 60 is released, the cross-sectional flow area is practically open and there is no obstruction to the flow from the centrifugal pump to the vacuum pump. A corresponding expansion pipe or the like can of course also be arranged in the annular chamber 28, whereby the pipe, when expanding, throttles not only the cross-sectional flow area but also directly the suction opening 54 of the vacuum pump.

FIG. 3 shows a partial, detailed sectional view of a centrifugal pump according to a second preferred embodiment of the invention. The figure shows the shaft 49 of the pump, the impeller 14 with its cylindrical projecting part, the rotor 44 of the vacuum pump and the back wall 24 of the centrifugal pump with its chamber 28, and the suction opening 54 in the back wall between the chamber 28 and the vacuum pump. The control device 100 according to the invention consists of a preferably radial, annular groove 72 arranged in the back wall 24 and at least one or preferably several closing flaps 70 disposed slidingly therein. There can be for instance one closing flap 70, whereby the gas outlet duct 26 between the centrifugal pump and the vacuum pump can be throttled only to an extent of 180° measured in the peripheral direction. Even
such a possibility must be taken into consideration, as one of the above mentioned U.S. Patents mentions a non-annular opening in the back wall 24, i.e. a flow duct which according to one embodiment consists of only a half annulus. When there are two closing flaps 70, they are preferably arranged on opposite sides of the shaft 49 and in the way that they overlap one another in the groove 72. The inner edge of the flaps 70 is preferably of the same curved shape as the periphery of the shaft or, as in the figure, or that of the cylindrical projecting part of the impeller. If there are several flaps 70, they are arranged to overlap according to the principle described in connection with the two laps or they are arranged to open and close in the same way as a shutter of a camera. When the closing flap is disposed between the chamber 28 and the centrifugal pump, it is possible to lead supplementary air into the chamber 28 in the way shown in FIG. 2. In addition to the way shown in FIG. 3, throttling of the cross-sectional flow area can also be accomplished by arranging corresponding closing flaps in a groove arranged in the bottom of chamber 28. The flaps can be operated for instance hydraulically, pneumatically or the like manner by rods extending from the outside to the flaps. The flaps can thus move linearly in the radial direction or turn around a joint against the shaft. It is further possible to arrange the bottom of said radial groove to ascend against the shaft, whereby the flaps can be moved against the shaft/projecting part of the impeller by sliding the flaps in peripheral direction along the bottom of the groove. It is to be noted that both in this embodiment and the following ones, the supplementary air duct is not described, as the position and operation thereof have been described clearly enough above. Thus, it is obvious that in all embodiments, a supplementary air duct may be arranged if so desired.
FIG. 4 shows a partial, detailed sectional view of a centrifugal pump according to a third preferred embodiment of the invention. The figure shows the shaft 49 of the pump, the impeller 14 with its cylindrical projecting part, the rotor 44 of the vacuum pump and the back wall 24 of the centrifugal pump with its chamber 28, and the suction opening 54 in the back wall between the chamber 28 and the vacuum pump. The control device 100 according to the invention consists of a closing plate 80, which is peripherally at least of the same size as the suction opening 54 of the vacuum pump. When the closing plate 80 is moved against the suction opening 54, the cross-sectional flow area from the chamber 28 to the vacuum pump decreases. The closing flap 80 can be arranged to be operated mechanically, hydraulically or pneumatically. One way is to arrange a space in the back wall 24 on both sides of the closing plate for a member which by means of a pressure medium changes its size, or for small pressure medium cylinders, for example, by means of which the closing plate can be moved axially. Another possibility is to arrange a spring return for the closing plate in such a way that, for example, the plate is moved for example against the spring towards the suction opening 54.

FIG. 5 shows a partial, detailed sectional view of a centrifugal pump according to a fourth preferred embodiment of the invention. The figure shows the shaft 49 of the pump, the impeller 14 with its cylindrical projecting part, the rotor 44 of the vacuum pump and the back wall 24 of the centrifugal pump with its chamber 28, and the suction opening 54 in the back wall between the chamber 28 and the vacuum pump. The control device 100 according to the invention consists of a groove 92 arranged in the bottom of chamber 28 and a radially sliding closing plate 90 arranged therein. The closing plate 90 and the groove 92 thereof are peripherally measured at least
substantially of the same size as the suction opening 54 of the vacuum pump. When the closing plate 90 is moved radially, the suction opening 54 of the vacuum pump either closes or opens depending on the direction of movement of the closing plate 90. The plate 90 can be arranged to be operated in the same way as in the embodiment according to FIG. 3. It is also possible, instead of throttling the suction opening 54 by moving the plate arranged in the bottom of chamber 28 radially, to move the plate in the peripheral direction.

FIG. 6b illustrates a partial sectional view of a centrifugal pump according to a fifth preferred embodiment according to the invention. The arrangement is viewed in the axial direction from the side of the centrifugal pump of the partial cross-section of FIG. 6a in such a way that the impeller 14 of the centrifugal pump and the back wall 24 of the centrifugal pump have been removed with the exception of the suction plate 124 disposed concentrically in the back wall. The pole 126 of the rotor of the vacuum pump can be seen as innermost in FIG. 6b. The circle around it illustrates a hole in the suction plate 124 for a shaft or a cylindrical projecting part of the impeller. The eccentric circle 128 indicated by a broken line illustrates the eccentric housing of the vacuum pump. The oblong curved opening 130 indicated by a broken line illustrates the outlet opening for the gas to be removed from the vacuum pump, located in the back wall of the housing of the vacuum pump. In the position illustrated by FIG. 6b the outlet opening is in the converging side of the eccentric housing 128 of the vacuum pump, i.e. on the pressure side, whereby the space between the liquid ring and the pole of the rotor converges in such a way that the gas in said space will be pressed out of the pump through the opening 130. The oblong curved opening 132 indicated by a continuing line is the suction opening of the vacuum pump. In the
circumstances illustrated by FIG. 6b, the opening 132 is positioned in such a way that the space between the liquid ring rotating in the housing and the pole of the rotor expands, in other words the pump sucks gas from the opening 132 to fill said space. In the circumstances of the figure, the front edge of the opening 132' is positioned substantially at the greatest eccentricity of the housing. The curved arrow R illustrates the rotating direction of the rotor of the vacuum pump. It is characteristic of this embodiment of the invention that flowing of gas from the centrifugal pump to the vacuum pump is controlled by turning the suction plate 124 from the position illustrated in FIG. 6b clockwise, for example, whereby the front edge 132' of the suction opening moves past the maximal eccentricity of the housing of the vacuum pump to the side where the pump begins to generate pressure. Hereby, the gas between the liquid ring and the pole of the rotor is pressed back to the suction side through the suction opening, i.e. towards the centrifugal pump. This results in at least the suction capacity of the vacuum pump being weakened, and, if the suction plate 124 is turned enough, in the suction being totally stopped. The turning of the suction plate 124 is easily effected for example by means of a shaft led to the separating surface of the back wall 24 and the suction plate 124 through the body of the centrifugal pump. The end of the shaft is thus preferably provided with a thread and the edge of the suction plate with teeth, so that when the shaft is turned, the suction plate turns. The turning of the shaft may be effected either manually or for example electrically by means of a motor, whereby the system may be, if needed, be provided with various control devices.

FIG. 7 illustrates a partial sectional view of a centrifugal pump according to a sixth preferred embodiment of the invention in the same way as FIGs 2 -
5. In the figure, the impeller 14 of the centrifugal pump, or rather the cylindrical projecting part thereof, is provided with a shoulder 140 and the back wall is provided with a guide surface 242, along which the preferably annular control member 244 may be moved either towards the shoulder 140 or away from it. Hereby, the suction towards the flow coming from the gas outlet opening(s) 142 of the impeller may be adjusted as great as desired. Motion of the control device 142 may be controlled by arranging a few levers 246 in the periphery of the annular control device within even distances from each other. For these levers, cavities are arranged in the back wall 24, in which cavities for example a spring member 248 is positioned on one side of the levers and for example a member 250 which can be expanded by means of pressure is positioned on the other side. Naturally, a pressure member 250 may be replaced by for example turnable eccentric levers or the like.

FIGs 8a and 8b illustrate arrangements according to a seventh and eighth preferred embodiment of the invention. Said arrangements are based on the movable control member 242 already described in the preceding embodiment. In these embodiments, the surface limiting the cross-sectional flow area together with the control member 242 is formed by a conical surface 150 (FIG. 8a) or a stepwise converging surface 152 of the cylindrical projecting part of the impeller 14. The arrangements related to moving of the control member 142 may be applied in the way described in the preceding figures.

Another control system which could be used is a device in which teeth extending substantially to the shaft/cylindrical projecting part of the impeller are formed in the inner edge of the back wall of the centrifugal pump so that they cover about half, preferably at
least half of the periphery. A turnable plate is used as counterpart, the teeth of which are preferably of the same size as those of the back wall, whereby the remaining cross-sectional flow area can be opened by turning the teeth so that they are in the flow direction on top of each other or be opened by arranging the teeth to engage.

Further, yet another potential control system can be realized by changing the clearances of the rotor of the vacuum pump, which means in practice that at least one end of the housing of the vacuum pump is moved relative to the rotor, or that at least one end and the rotor are both moved. When the spacing between the rotor, especially the blades of the rotor, and the housing is increased, the gas flow around the edges of the blades increases rapidly, whereby the suction generated by the pump decreases substantially. In practice, the most probable one of the control manners of the spacings described above is likely to be arranging of the front wall of the vacuum pump movable.

The function of the control device, or in other words said flow, is controlled either manually or preferably automatically as a function of the consistency of the material to be pumped, as a function of the inlet pressure of the material to be pumped, as a function of both the consistency of the material to be pumped and the inlet pressure, or the gas content of the material to be pumped. The control according to the inlet pressure can be accomplished for instance so that the control member is moved in a direction which throttles the cross-sectional flow area of the gas outlet duct when the inlet pressure increases. The flaps can be moved for instance by means of a pressure medium cylinder arranged in the back wall of the centrifugal pump, which cylinder pushes the flap towards the shaft against a spring force, or by
means of a cylinder, for instance a two-way cylinder, arranged outside the pump body.

It will thus be seen from the foregoing that a plurality of solutions have been developed by means of which the centrifugal pump and vacuum pump combination according to the invention can be made to function optimally in all possible operating conditions. It is for instance possible to discharge in a controlled manner a small amount of over-atmospheric gas and liquid and possible solid matter flowing along with it by means of the vacuum pump for instance to a pressurized cistern placed 30 meter above the same. The invention is not limited to the embodiments described and illustrated above, which are presented to give the reader a clear picture of the many solutions by means of which the control can be accomplished. It is to be understood that also other technical solutions are possible within the scope and spirit of the invention, which are defined in the appended claims.
CLAIMS

1. A method of controlling the function of a centrifugal pump and vacuum pump combination, in which combination the impeller (14) of the centrifugal pump and the rotor (44) of the vacuum pump are placed on the same shaft (49), the gas separated in the centrifugal pump from the material to be pumped being discharged from the centrifugal pump by means of the vacuum pump along a gas outlet duct (26) located between said centrifugal pump and said vacuum pump, characterized in that the gas flow in the gas outlet duct (26) between the centrifugal pump and vacuum pump is controlled.

2. A method as recited in claim 1, characterized in that said flow is controlled by changing the cross-sectional flow area of the gas outlet duct (26).

3. A method as recited in claim 1, characterized in that said flow is controlled by changing the cross-sectional flow area of the vacuum pump suction opening (54) located in the gas outlet duct (26).

4. A method as recited in claim 1, characterized in that said flow is controlled as a function of the consistency of the material to be pumped.

5. A method as recited in claim 1, characterized in that said flow is controlled as a function of the inlet pressure of the material to be pumped.

6. A method as recited in claim 1, characterized in that said flow is controlled as a function both of the consistency and the inlet pressure of the material to be pumped.
7. A method as recited in claim 1, characterized in that said flow is controlled as a function of the gas content of the material to be pumped.

8. A method as recited in claim 1, characterized in that the separated gas is returned to a pressure higher than the atmospheric pressure.

9. A method as recited in claim 1, characterized in that said flow is controlled by changing the spacing between the rotor of the vacuum pump and the wall of the housing.

10. A gas-separating centrifugal pump consisting mainly of a volute casing (10) and a pump body (40); the volute casing (10) comprising a suction opening (12) and a substantially tangential outlet and surrounding the impeller (14) which comprises at least one working blade (18) attached to the surface of the so called back plate (16) on the side of the suction opening (12) thereof, i.e. the front surface, at least one back blade (20) attached to the back side of the back plate, and at least one gas outlet opening (22) arranged in the back plate (16); the pump body (40) comprising a vacuum pump disposed therein, which consists of a housing (42) and a rotor (44) with blades (50) arranged on the same shaft (49) as the impeller (14); said housing (42) comprising a back wall (46), a front wall (48) of the vacuum pump provided with a suction opening (54) on the centrifugal pump side thereof, and an eccentric inner wall (52) of the housing (42) surrounding the rotor (44); the housing (42) further comprising a so called auxiliary air channel (56), and an outlet duct (58) of the vacuum pump; a back wall (24) of the pump comprising a gas outlet duct (26) being arranged between the volute casing (10) and the vacuum pump, characterized in that a control member (100) restricting the flow is arranged in said gas outlet duct (26).
11. A centrifugal pump as recited in claim 10, characterized in that said control member (100) is a plate (70, 80, 90) moving in a groove (72, 82, 92) arranged in the wall of the outlet duct (26).

12. A centrifugal pump as recited in claim 10 or 11, characterized in that said control member (100) is a plate (70, 80, 90) moving in the axial, radial or peripheral direction.

13. A centrifugal pump as recited in claim 10, characterized in that said control member (100) is a member (60) which may be expanded in the axial and/or radial direction, being arranged in the wall of the outlet duct (26).

14. A centrifugal pump as recited in claim 10, characterized in that a suction opening (132) which is turnable relative to the housing of the pump and positioned in the front wall of the vacuum pump is used as a control member (100).

15. A centrifugal pump as recited in claim 13, characterized in that said suction opening (132) is positioned in the turnable front wall (124) of the vacuum pump.

16. A centrifugal pump as recited in claim 10, characterized in that the control member (100) is a ring (242) which is turnable in the axial direction and which defines the throttling opening with the impeller or a part (140, 150, 152) thereof.

17. A centrifugal pump as recited in claim 10, characterized in that said control member (100) is a plate (90) turnable in the groove (72, 82, 92) arranged in the wall of the outlet duct (26).
18. A centrifugal pump as recited in claim 10, characterized in that there is an expansion part, a chamber (28) in the gas outlet duct (26).

19. A centrifugal pump as recited in claim 13, characterized in that the auxiliary air duct leads to said chamber (28).

20. A centrifugal pump as recited in claim 10, characterized in that a fluidizing rotor (32) protruding from the suction opening (12) of the pump is arranged in front of the impeller (14).

21. A centrifugal pump as recited in claim 10, characterized in that the outlet duct (58) of the vacuum pump is located in the back wall (46) of the vacuum pump.

22. A centrifugal pump as recited in claim 10, characterized in that the back wall (24) of the centrifugal pump and the front wall (48) of the vacuum pump are of one piece.

23. A centrifugal pump as recited in claim 10, characterized in that the back wall (24) of the centrifugal pump and the front wall (48) of the vacuum pump define the gas outlet duct (26).

24. A gas-separating centrifugal pump consisting mainly of a volute casing (10) and a pump body (40); the volute casing (10) comprising a suction opening (12) and a substantially tangential outlet and surrounding the impeller (14) which comprises at least one working blade (18) attached to the surface of the so called back plate (16) on the side of the suction opening (12) thereof, i.e. the front surface, at least one back blade (20) attached to the back side of the back plate, and at least one gas outlet opening (22) arranged in the back plate (16); the
pump body (40) comprising a vacuum pump being disposed therein, which consists of a housing (42) movable in relation to the shaft of the pump, and a rotor (44) with blades (50) arranged on the same shaft (49) as the impeller (14); said housing (42) comprising a back wall (46), a front wall (48) of the vacuum pump provided with a suction opening (54) on the centrifugal pump side thereof, and an eccentric inner wall (52) of the housing (42) surrounding the rotor (44); the housing (42) further comprising a so called auxiliary air channel (56) and an outlet duct (58) of the vacuum pump; a back wall (24) of the pump comprising a gas outlet duct (26) being arranged between the volute casing (10) and the vacuum pump; the housing (42) of the vacuum pump being movable in three different positions, of which positions the first is used when the inlet pressure of the centrifugal pump is low and gas is separated abundantly, the second when the inlet pressure is slightly above the atmospheric and less gas is separated, and the third when the inlet pressure is high, characterized in that the eccentricity of the housing of the vacuum pump is greater in the third position than in the second position.

25. A centrifugal pump as recited in claim 23, characterized in that there is a throttling valve on the outlet side of the vacuum pump.

26. A method of controlling the function of a centrifugal pump and vacuum pump combination, characterized in that the pressure difference over the vacuum pump is controlled mainly by changing the eccentricity of the housing of the vacuum pump in all operating conditions of the centrifugal pump.
# INTERNATIONAL SEARCH REPORT

## A. CLASSIFICATION OF SUBJECT MATTER

**IPC6:** F04D 7/04, F04D 9/00
According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC6:** F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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  *Z* document member of the same patent family

Date of the actual completion of the international search: 3 October 1996

Date of mailing of the international search report: 03-10-1996

Authorized officer: Lena Nilsson

Telephone No.: +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)
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