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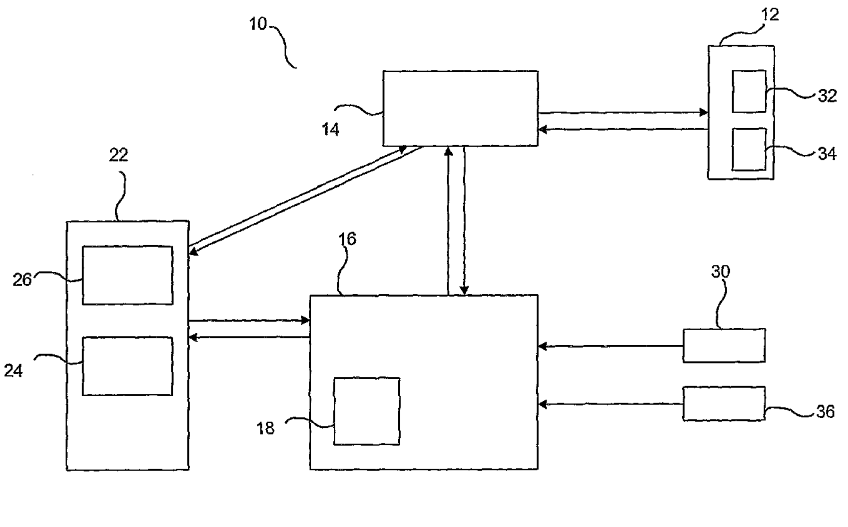
(54) Title: METHOD AND DEVICE FOR OPERATING A PUMP STATION



(57) Abstract: The present invention relates to control systems and methods for improving the handling of sewage or waste water in a pump station having at least one variable speed pump and for increasing the overall efficiency of the pump or the pumps of the station. The inventive method comprises the steps of: sensing a plurality of operating parameters of the pump station; determining a pump behaviour of the pump by utilizing the operating parameters; and operating the pump according a running pattern selected on basis of said calculated pump behaviour and/or said sensed operating parameters. A system for operating the pump according to the running patter is also disclosed. Furthermore, a computer program product loadable into a memory of a digital computer device, including software code portions for performing the inventive method is described.

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Method and device for operating a pump station

Technical field

The present invention relates to control systems and methods for pumping sewage or waste water in a pump station

State of the art

In a typical fluid- or liquid-pumping application the goal is to transport the fluid from a vessel or basin. One or more pumps are used to compensate for inflows and disturbances caused by events external to the station or system, and these pumps are selectively activated or ran and controlled to maintain the state of the system within it's predetermined range.

In the example of sewage stations, sewage water is led into a basin from, for example, sewage systems, roadway drains, etc. One or more pumps are arranged to pump water from the basin in order to maintain the level within predetermined limits. Generally, when a station includes more than one pump, the pumps are arranged in a parallel orientation. Sensors are arranged to measure operating parameters such as the pump power and/or the water level. The sensors and pump motors are connected to a control system of the pump station, which includes means for starting and stopping the motors in response to operating conditions. Furthermore, the control system comprises alarms, displays, logic circuitry, and disk drives and/or semiconductor memory for storing data and programs. In addition, the system can include communication means for communicating by means of, for example, radio or telemetry, information, such as parameters that characterize operating conditions of the station, with a monitoring system. The information may comprise data or calculated parameters that characterize the operating conditions of the pump station, alarms and desired changes of the program controlling the station or the system.

The control systems and methods used in pumping stations are commonly focused on maintaining desired operating conditions reliably, but without specifically addressing operating efficiency. For example, the pump speed has a significant impact on the overall energy consumption of the system.

Therefore, a number of methods for selecting the pump speed or pumps to be activated have been developed.

In variable-speed systems, pump speed is generally regulated so as to maintain a specified level (with a level span to enable regulation), which is an non-effective running pattern of a pump with respect to the energy consumption.

Moreover, problems on account of clogging of the pumps due to that, for example, waste products get stuck in the impeller are common and lead to reduced hydraulic efficiency of the system and to higher costs for service and maintenance and even failures. Often clogging is not discovered until the pump failures with the result that the pump cannot be cleaned by means of an automatic cleaning procedure. The pump has to be cleaned manually, which entails large costs since the pump has to be shut down. It also leads to operational disturbances of the pump station. At present, there is no automatized method for detecting clogging of impeller. Running regular cyclic cleaning sequences is one way of handling clogging but such regular sequences are, however, not efficient due to the fact that occurrence of clogging by nature is irregular. Therefore, these methods are often unable to detect the occurrence of clogging at an early stage.

<u>Brief description of the invention</u>

Thus, one object of the present invention is to provide a method and a system for operating a pump station in an efficient way with respect to energy consumption.

It is another object of the present invention to provide a method and a system for operating a pump station in an efficient way with respect to operation reliability.

It is still another object of the present invention to provide an adaptive method and system for operating a pump station.

These and other object are achieved according to the present invention by providing a method, a computer program product, and a system having the features defined in the independent claims. Preferred embodiments are defined in the dependent claims.

In the context of the present invention, the term “pump speed” is defined as the numbers of revolutions per time unit of the pump.

According to a first aspect of the invention there is provided a method for operating at least one pump of a pump station having at least one variable-speed pump. The method comprises the steps of:
sensing a plurality of operating parameters of the pump station;
determining a pump behaviour of the pump by utilizing the operating parameters; and operating the pump according a running pattern selected on basis of the calculated pump behaviour and/or the sensed operating parameters.

According a second aspect of the present invention there is provided a system for operating at least one pump of a pump station having at least one variable-speed pump. The system comprises sensing means arranged to sense a plurality of operating parameters of the pump station/system; processing means in communication with said sensing means, which processing means is arranged to determine a pump behaviour of the pump by utilizing said operating parameters; and control means in communication with the processing means, which control means is arranged to operate the pump according to a running pattern selected on basis of the calculated flow and/or power behaviour.

According to a further aspect of the present invention, there is provided a computer program product loadable into a memory of a digital computer device, including software code portions for performing the method of according to the first aspect of the present invention when said computer program product is run on said computer device.

Thus, the present invention is based on the insight of utilizing operation parameters present within a system for operating a pump station including at least one variable-speed pump in an adaptive manner in order to improve or optimize the sewage handling and/or the operation of the pump or the pumps. By determining the flow and power behaviour of the pump or the pumps, a running pattern can be selected on basis of the calculated flow and power behaviour that entails a significant improvement regarding the energy consumption of the pump or the pumps, allows for a compensating of flow peaks, and provides for an efficient anti-clogging handling of the pump or the pumps or the pump configuration.

In one embodiment of the present invention, a measure of the flow of the pump, Q(n), is determined as a function of the speed of the pump, where Q is a measure of the flow and n the pump speed, i.e. the number of revolutions per time unit, and a measure of the power of the pump, P(n), is determined as a function of the speed of the pump, where P is a measure of the power and n the number of revolutions per time unit, by utilizing the sensed operating parameters.

According to preferred embodiments, a measure of the specific energy of the pump E(n) is obtained by utilizing said flow equation and the power equation, wherein the specific energy is defined as $E(n)=P(n)/Q(n)$. By operating the pump or each pump or each pump configuration at the minimum specific energy or within a defined window at the minimum specific energy, the energy consumption can be reduced significantly. In other words, the pump is operated in accordance with a running pattern that provides the lowest possible energy consumption. The energy consumption is reduced because the pump is operated at a lower speed, which reduces the loss of energy since the friction in the system is proportional to the square of the velocity of the fluid. Alternatively, a running pattern of the pump or the pumps can be selected that uses the sewage water volume as a buffer, thereby damping inflow variations. Furthermore, abnormal deviations in the operation of the pump or the pumps with regard to power behaviour or flow behaviour can be used in order to detect the build up of clogging at an early stage.

According to preferred embodiments, an automatic cleaning procedure is initiated at detection of abnormal deviations in the operation of the pump or the pumps with regard to power behaviour or flow behaviour in order to remove a clogging item. Thereby, problems on account of clogged impellers leading to reduced hydraulic efficiency of the system and to higher costs for service and maintenance and failures can be identified and be prevented and reliability with respect to clogging is improved significantly by this introduction of sequences of active cleaning of the impeller.

As realized by the person skilled in the art, the methods according to the present invention, as well as preferred embodiments thereof, are suitable to realize or implement as a computer program or a computer readable medium, preferably within the contents of a control means or a processing means of a pump station or system.

Further objects and advantages of the present invention will be discussed below by means of exemplifying embodiments.

Brief description of the drawings

Above-mentioned and other features and advantages of the present invention will be apparent from the following detailed description of preferred embodiments, merely exemplifying, in conjunction with the attached drawing, wherein:

Fig. 1 schematically shows a system at a pumping station in which the method according to the present invention may be implemented;

Fig. 2 schematically shows a sewage water basin at a pumping station;

Fig. 3 shows a flow diagram of the general principles of the method according to the present invention;

Fig. 4 shows a flow diagram of an embodiment of a sequence for determining the flow and power equation of a pump in accordance with the present invention;

Fig. 5a shows a normalized diagram of the specific energy, the power behaviour, and the flow behaviour of a pump of a pump station as a function of the relative speed of the pump;

Fig. 5b shows a normalized diagram of the specific energy, the power behaviour, and the flow behaviour of a pump of another pump station with a higher geodetic head as a function of the relative speed of the pump;

Fig. 6 shows a flow diagram of an embodiment of a detection function for detecting clogging of the pump; and

Fig. 7 shows a flow diagram of another embodiment of a detection function for detecting clogging of the pump.

Description of preferred embodiments

In the following, there will be disclosed preferred embodiments of a method for operating a pump or a pump configuration of a pump station having at least one variable-speed pump and a system for operating such a pump or pump configuration.

With reference first to Fig. 1, a system at a pump station for operating a pump in which the method according to the present invention may be implemented will be described. The system 10 of Fig. 1 includes at least one variable-speed pump 12. Preferably the pump 12 is a variable frequency drive controlled pump (VFD pump), for pumping a liquid, for example, sewage water at a pumping station. The system to be discussed herein is directed to a lift station for pumping sewage water or waste water from a wet well or a basin, but is not intended to be limited thereto, and indeed the principles herein are applicable to any fluid pumping system. Furthermore, the system is also adaptable for use with more than one pump.

Moreover, the system 10 comprises control means 14, which controls or drives the pump 12 to, for example, increase or decrease the speed in order to pump a larger or a smaller amount of water, respectively. Preferably, the control means is a variable frequency drive unit. The control means 14 is, in turn, controlled by processing means 16, which includes storage means 18. The storage means 18 may include a random access memory (RAM) and/or a non-volatile memory such as read-only memory (ROM). As will be appreciated by one of ordinary skill in the art, storage means may include various types of physical devices for temporary and/or persistent storage of data which includes solid state, magnetic, optical and combination devices. For example, the storage means may be implemented using one or more physical devices such as DRAM, PROMS, EPROMS, EEPROMS, flash memory, and the like.

Furthermore, the system includes a number of sensing means 30, 32, 34, and 36 arranged for sensing different operating parameters of the pump or pumps 12 and/or the pump station 10. According to an embodiment, the system includes level sensing means 30 for sensing the level of liquid in the well or basin (see Fig. 2), means for sensing the speed of the pump 32, power sensing means 34 for sensing the power input of the pump. Optionally, the system may also include inflow and/or outflow sensing means 36 is arranged to sense the inflow of liquid to the basin 40. As the man skilled in the art realizes there are a number of other conceivable parameters and signals that can be used in the present invention including sensing inflow, outflow and power with different types of sensors such as flow sensors, current sensors, level sensors using a variety of physical principles.

As will be appreciated by one skilled in the art, means for sensing the speed of the pump 32 and current sensing means 34 can either be integrated in the pump 12 or can be external sensors connected to the pump.

The processing means 16 is arranged in communication with the sensing means 30, 32, 34, and optionally 36, either directly or via the control means 14, in order to obtain input signals from each sensing means 30, 32, 34, and 36. In addition, the processing means 16 may be arranged in communication with an operator unit 22 including a keyboard 24, which allows the operator to input, for example, control commands, and a display or screen 26 for presenting information related operation of the pump or the pumps, for example, time history of the operating parameters, or status information of the pump or the pumps. Accordingly, the operator can monitor the operation of the pump of the pumps as well as different operating parameters associated to the operation thereof via the display 26. According to another embodiment, the display is a touch sensitive screen and in this case a number of soft-keys can be arranged on the screen in order to present different commands at different presented interfaces on the display 26. Furthermore, the operator unit may comprise storage means (not shown), which, in turn, may include a random access memory (RAM) and/or a non-volatile memory such as read-only memory (ROM). As will be appreciated by one of ordinary skill in the art, storage means may include various types of physical devices for temporary and/or persistent storage of data which includes solid state, magnetic, optical and combination devices. For example, the storage means may be implemented using one or more physical devices such as DRAM, PROMS, EPROMS, EEPROMS, flash memory, and the like.

Turning now to Fig. 2, a sewage water basin at a pumping station in which a system, such as the system described above can be employed, in which the method according to the present invention may be implemented will be described. This may, for example, be a VDF controlled sewage system in a municipal lift station for pumping waste water from a wet well.

According to an embodiment, the pump 12 or the pumps is (are) arranged at the well or basing 40 to pump or lift the sewage water 41 from the basin 40 to, for example, a subsequent basin or well via a pump inlet pipe 43 and a pump outlet pipe 44. Sewage water is fed into the basin 40 via an inlet 42. Often, the inflow of sewage water have a predictable daily, weekly, and seasonal variation, but it is not however always the case as the inflow may be affected by, for example, weather conditions. Level sensing means 30 is arranged to sense the level of the sewage water 41 in the basin 40, which level sensing means also is connected to the processing means 16. Optionally, inflow and/or outflow sensing means 36 may also be connected to the processing means 16.

With reference now to Fig. 3, the general principles of the method for operating a pump of a pump station having at least one variable-speed pump according to the present invention will be described.

In operation of the system, a plurality of operating parameters of the pump or the pumps and the pump station are constantly monitored and sensed by means of a number of sensing means at step 60. These include i.a. level sensing means 30 for sensing the level of liquid in the well or basin, means for sensing the speed of the pump 32, current sensing means 34 for sensing the current input of the pump, and, optionally, inflow and/or outflow sensing means 36 for sensing the inflow of liquid to the basin. That is, a number of operating parameters associated with the operation of a certain pump or indicating the effect of the operation of the pump on the pump station, for example, on the level of the sewage water 41 in the basin 40 are obtained, in particular, the level of the liquid in the basin; the speed of the pump; and the current consumption of the pump at this certain speed. Preferably, if there are more than one pump, a set of operating parameters is obtained for each pump and each allowed pump configuration. The sensed and/or monitored parameters can be stored directly in a storage means of, for example, the processing means 16 for subsequent processing or they can be presented for an operator on the display 26 of the operator unit 22. At step 62, the obtained operating parameters are processed in the processing means 16 in order to determine a flow behaviour Q(n), as a function of the speed of said pump, where Q is the flow and n is the speed of the pump or, in case there are more than one pump, each pump, and a power behaviour P(n), as a function of the speed of said pump, where P is the power and n the speed of the pump or, in case there are more than one pump, each pump, which will be described in detail below. At step 64, the flow behaviour and power behaviour of the pump or of each pump is stored. As noted above, the operating parameter is stored and they can either be stored in this step or prior to the processing of the parameters. At step 66, the pump or, in case the are more than one pump, each pump is operated according a running pattern selected on basis of said calculated pump behaviour and/or the sensed operating parameters, which will be described in more detail below. This may include:

- optimizing due to clog free running of the pump, i.e. pump a given inflow of sewage water while minimizing disturbances by detecting, at an early stage, detecting abnormal deviations indicating clogging of the pump and perform automatic cleaning of clogging items; and/or
- optimizing the operation of the pump due to minimized flow variation, i.e. pump any given inflow of sewage water at a low energy level while minimizing the flow variation.

Alternatively, the running pattern may include

- optimizing due to clog free running of the pump, i.e. pump a given inflow of sewage water while minimizing disturbances by detecting, at an early stage, detecting abnormal deviations indicating clogging of the pump and perform automatic cleaning of clogging items; and/or
- optimizing the operation of the pump due to specific energy, i.e. pump at given inflow of sewage water at lowest possible energy consumption of the pump or in other words select a running pattern that creates low specific energy.

It should be noted that the optimizing with respect to clog free running can be combined with either optimizing the operation of the pump due to specific energy or optimizing the operation of the pump due to minimized flow variations.

Referring now to Fig. 4, the steps of a preferred sequence in order to determine the flow and power equation of a pump in accordance with the present invention will be discussed in more detail. First, at step 70, a maximum or start level of the sewage water in the basin is set or determined, below which level regulation is carried out. This level should be set high up in the basin in order to provide as low geodetic height as possible. Preferably, a lowest level is also set or determined. Then, at step 72, the level of sewage water is allowed to reach the predetermined maximum level and the pump is ran at a first speed of a set of different speeds so that the level of sewage water sinks. Preferably, the first speed is the maximum speed. When a stable measure of the net flow of the basin, Q_{net}, has been obtained for the first speed of the set of different speeds, the operation of the pump is interrupted at step 74. Simultaneously, a measure of the input power of the pump is measured, P_{in}. Thereafter, at step 76, the level of the sewage water is allowed to rise (to the predetermined maximum level or during a reasonable long period of time) so that a stable measure of the inflow to the basin, Q_{in}, has been obtained for the first speed of the set of different speeds. At step 78, the outflow of the basin for the first speeed of the set of different speeds is determined according to:

$$Q_{out} = Q_{net} - Q_{in}. \qquad (1)$$

Subsequently, at step 80, it is checked whether the outflow, Q_{out}, has been determined for all different speeds of the set of different speeds. If no, the above mentioned steps 70 to 78 are repeated for each remaining speed of the set. For example, the set may comprise the maximum speed, 90 % of the maximum speed, and 80 % the maximum speed. It should however be noted that the pumping action of the pump must have an observable influence of the level of the sewage water at each speed. On the other hand, if yes, a flow equation and a power equation for the pump are determined at step 82 according to the following:

$$Q_{out}(n) = Q_{out,0}+Q_{out,1}*n+Q_{out,2}*n^2 \qquad (2)$$

$$P_{in}(n) = P_{in,0}*n+P_{in,1}*n^2+P_{in,2}*n^3, \qquad (3)$$

where $Q_{out,\,i}$ and $P_{in,\,i}$ are outflow of the basin and the input power of the pump at the i^{th} measurement, respectively, and n is the speed. Then, at step 84, a measure of the specific energy for the pump is determined according to the following:

$$E(n) = P_{in}(n)/Q_{out}(n). \qquad (4)$$

Finally, at step 86, a window of different speeds of the pump is calculated by identifying the minimum value of the specific energy E(n) determined by means of equation (4), i.e. a pattern of speed versus level as well as start and stop levels is determined. In the above mentioned it is assumed that the level of the sewage water has a small or even insignificant influence of the result and that the inflow is reasonable constant during the measurement period. The above discussed sequence can be repeated with appropriate time intervals, T_i, in order to update any changes. Preferably, a weighted floating mean value is employed. Furthermore, it should be noted that in case of more than one pump in the system, the corresponding equations should be calculated for each pump or combination of pumps in order to obtain an efficient running pattern for the system as a whole that enables an optimized pumping activity.

With reference now to Figs. 5a and 5b, exemplifying diagrams illustrating the specific energy for two different pumps of a pump station as a function of the relative speed of the pumps will be described. The curves shown are normalized and the specific energy is indicated with unbroken lines, the power with dashed lines, and the flow with dotted lines. In Fig. 5a, the specific energy, the power, and the flow of a pump of a first pump of a pump station is shown, and the optimal speed, as discussed above, is where the specific energy has a minimum value, indicated by reference 90. From this an optimal running pattern can be obtained as will be shown hereinafter. In Fig. 5b, the specific energy as a function of the numbers of revolutions or the relative speed of a second pump is illustrated. As can be seen, there is no minimum value of the specific energy and a lower speed entails a higher specific energy. In this case, it is more efficient to operate the pump according to an on-off regulation.

According to a further embodiment of the present invention, the pumping of the sewage water is optimized due to the specific energy by means of the calculated or determined equations (2)-(4). Employing an on-off regulation, the start level is set to the maximum level and the stop level to a level where a highest possible outflow and no inflow gives an acceptable running time, for example about 2 minutes, or the minimum level, whichever event that occurs first. At VFD regulation (Variable Frequency Drive), a minimum value of the speed and a start value of the speed are set. For example, the minimum value of the speed may be set to the optimal speed as determined above since the specific energy curve shows a sharper slope towards lower speed than towards higher. The start value of the speed may be a value between the maximum and optimal speed. The sewage water should be pumped so that a major or at least large amount of water is pumped as efficient as possible. That is, a major part of the sewage water volume should be pumped at the speed in the window of speed as discussed above with reference to Fig. 5a

According to another embodiment of the present invention, the pumping of the sewage water is optimized due to an even flow of sewage water by means of the calculated or determined equations (2)-(4). Employing an on-off regulation, the start level is set to the maximum level and the stop level to a level where a highest possible outflow and no inflow gives an acceptable running time, for example about 2 minutes, or the minimum level, whichever event that occurs first. In this case, the volume of sewage water (and possible parts of the pipe system) may be used a buffer, which provides a larger difference between high and low levels. The minimum speed is lower than the optimal speed, for example, a number of revolutions per time unit, n_{min}, where

$$E = 1.5*E(n=n_{max}) \qquad (5),$$

where n_{max} is the maximum speed of the pump, i.e. the maximum number of revolutions per time unit. Further, n_{min} is modified with a factor according to the following:

$$n_{min} = n_{min}(1+0.1*((n_{max}-n_{opt})/n_{max})) \qquad (6),$$

where n_{min}, n_{opt} are the minimum number of revolutions per time unit and the optimal number of revolutions per time unit (i.e. the speed at the minimum specific energy), respectively. In this case the start level of the sewage water is about 10 percent above the minimum level (at minimum speed). In a station provided with more than one pump and more than one pump is required for a certain application, the interval can be divided up and equations for one pump at maximum speed and one VDF regulated pump have to be determined. In this case the single pump value of the n_{min} can be utilized for several pumps and n_{min} and n_{max} levels in sequence with a small overlap with a start level of about 10 percent above the maximum level of the pump operated at n_{max}. Alternatively, a number of pumps can be VFD regulated in parallel, which in principle similar to operating one large pump. It should be noted that the regulation cannot be performed using a nearly fixed level of sewage water in the basin because the sewage water is not utilized as a buffer.

According to yet another embodiment of the present invention, the calculated or determined equation (3) is used in a detection function for detecting clogging of the pump, which function now will be described with reference to Fig. 6. As discussed above, problems on account of clogged impellers of pumps lead to reduced hydraulic efficiency of the station and to higher costs for service and maintenance and/or failures. The measure of input power, i.e. produced by means of equation (3), is used as indicating parameter according to the following:

$$P_{actual} > x^*P(n) \qquad (7),$$

where P_{actual} is the actual measured input power, x is a predetermined margin factor, and P(n) is equation (3) determined above. Preferably, x is set to a value greater than 1 and more preferably greater than the natural variations but smaller than what is defined by the engine protection, for example, to a value of 1.05-1.9, and more preferably to a value of 1.1-1.5.

At step 100, the actual measured input power of the pump is monitored using the current sensing means 34, which, for example, can be made on a constant basis or at defined intervals, and the signal indicating the input power of the pump is communicated to the processing means 16. Then, at step 102, it is checked whether the measured input power of the pump, P_{actual}, exceeds the known relation between input power and speed, P(n), times the predetermined margin factor, x, i.e. whether the relation (7) is met or not. If no, the system returns to normal operation at step 103. On the other hand, if yes, an automatic cleaning procedure of the pump is initiated at step 104. Thereafter, at step 106, it is again checked whether the relation (7) is met. If yes, the system proceeds to step 108 where it is checked whether too many attempts to clean the pump has been performed. This is a predetermined number of attempts, which may be a pre-programmed number or a number selected by the operator. If it is determined that the predetermined number of attempts not have been exceeded, the system returns to step 104 and the automatic cleaning procedure is maintained. If yes, the system proceeds to step 112 and an alarm function is initiated by the processing means 16. The operator can be notified of this event by means of an alarm indication or message on the display 26 of the operator unit 22. According to alternative embodiment, a timer times out after a predetermined period of time of running the automatic cleaning procedure and the operator is notified of the event by means of, for example, a message on the display 26. Thereby, the operator is informed of that the automatic cleaning procedure not has had the desired effect, i.e. the automatic cleaning was not efficient enough for removing the clogging of the pump. The operator can then take further measures for removing the clogging, for example, stop the operation of the pump and perform a manual cleaning of the pump. According to another embodiment, the operator is notified by means of an alarm function, for example, a light twinkling red. Subsequently, the system returns to normal operation at step 103. On the other hand, at step 106, if $P_{actual} < x^*P(n)$, the system proceeds to step 110 and the automatic cleaning procedure is stopped. Finally, at step 103, the system returns to normal operation.

According to still another embodiment of the present invention, the calculated or determined equation (2) is used in a detection function for detecting clogging of the pump, which detection function will be described with reference to Fig. 7. As discussed above problems on account of clogged impellers of pumps lead to reduced hydraulic efficiency of the station and to higher costs for service and maintenance and/or failures. In this embodiment, the flow equation, i.e. equation (2) is used as indicating parameter in accordance with the following:

$$Q_{actual} < Q(n)/y \qquad (8),$$

where Q_{actual} is the actual measured flow, y is a predetermined margin factor between 1.5 and 2, and Q(n) is equation (2) determined above. Preferably, y is set to a value greater than 1 and more preferably set to a value greater than the natural variations, for example, to a value of 1.3-2.2, and more preferably to a value of 1.5-2.

At step 120, the detection procedure is initiated and the level of the sewage water 41 in the basin 43 is pumped down from an initial level to the predetermined minimum level, which minimum level may differ as discussed above. This may be performed at appropriate intervals, for example, after a predetermined number of operational hours. In certain cases, the regulation scheme may be such that this occurs without this minimum level is reached anyway. Then, at step 122, the change of level is measured (as a measure of the net flow) and communicated to the processing means 16. Thereafter, at step 124, pump is stopped and the inflow is measured using the change of level in the same way as described above with reference to Fig. 3 and communicated to the processing means 16. At step 126, the actual flow Q_{actual} is then determined as the sum of the measured difference between the measured net flow and inflow in the processing means 16. Subsequently, at step 128, it is checked whether the determined actual flow, Q_{actual}, is lower than the known relation between flow and speed, Q(n), divided with the predetermined margin factor y, i.e. whether the relation (8) is met or not. If no, the system returns to normal operation at step 129. On the other hand, if yes, an automatic cleaning procedure of the pump is initiated at step 132. Thereafter, at step 134, it is again checked whether the relation (8) is met. If yes, the system proceeds to step 138 where it is checked whether too may attempts to clean the pump has been performed. This is a predetermined number of attempts, which may be a pre-programmed number or a number selected by the operator. If it is determined that the predetermined number of attempts not have been exceeded, the system returns to step 132 and the automatic cleaning procedure is maintained. On the other hand, if yes, the system proceeds to step 140 and an alarm function is initiated by the processing means 16. The operator can be notified of this event by means of an alarm indication or message on the display 26 of the operator unit 22. According to an alternatively embodiment, a timer times out after a predetermined period of time of running the automatic cleaning procedure and the operator is notified of the event by means of, for example, a message on the display 26. Thereby, the operator is informed of that the automatic cleaning procedure not has had the desired effect, i.e. the automatic cleaning was not efficient enough for removing the clogging of the pump. The operator can then take further measures for removing the clogging, for example, stop the operation of the pump and perform a manual cleaning of the pump. According to another embodiment, the operator is notified by means of an alarm function, for example, a light twinkling red. Subsequently, the system returns to normal operation at step 129. On the other hand, if $Q_{actual} < Q(n)/y$ at step 134, the system proceeds to step 136 and the automatic cleaning procedure is stopped and the time flag is reset, i.e. the predetermined period of time start again. Finally, at step 129, the system returns to normal operation.

Although specific embodiments have been shown and described herein for purposes of illustration and exemplification, it is understood by those of ordinary skill within the art that the specific embodiments shown and described may be substituted for a wide variety of alternative and/or equivalent implementations without departing from the scope of the present invention. Those of ordinary skill in the art will readily appreciate that the present invention could be implemented in a wide variety of embodiments, including hardware and software implementations, or combinations thereof. This application is intended to cover any adaptations or variations of the preferred embodiments discussed herein. Consequently, the present invention is defined by the wording of the appended claims and equivalents thereof and, thus, the intention is that the invention is not to be regarded as limited to only the structural or functional element described in the embodiments, but to the attached claims.

CLAIMS

1. A method for operating at least one pump of a pump station having at least one variable-speed pump, the method comprising the steps of:
sensing a plurality of operating parameters of the pump station;
determining a pump behaviour of said at least one pump by utilizing said operating parameters; and
operating said at least one pump according a running pattern selected on basis of said calculated pump behaviour and/or said sensed operating parameters.

2. Method according to claim 1, wherein said method further comprises the step of storing said operating parameters and/or said pump behaviour.

3. Method according to claim 1 or 2, wherein said step of determining a pump behaviour comprises the steps of:
determining a flow behaviour of said at least one pump by utilizing said operating parameters; and
determining a power behaviour of said at least one pump by utilizing said operating parameters.

4. Method according to claim 1, 2, or 3, wherein said pump is arranged to pump liquid from a basin, the liquid having a variable level in the basin, wherein the step of sensing comprises the steps of
sensing the level of said liquid in said basin;
sensing the speed of said pump; and
sensing a current consumption of said pump.

5. Method according to any one of claims 1-4, wherein the step of determining a pump behaviour further comprises the steps of:
determining a measure of the flow of said pump, Q(n), as a function of the speed of said pump, where Q is the flow and n is the speed of said pump, and determining a measure of the power of said pump, P(n), as a function of the speed of said pump, where P is the power and n is the speed of said pump, by utilizing said sensed operating parameters.

6. Method according to any one of claims 1-5, wherein the step of sensing comprises the step of sensing the inflow to the basin.

7. Method according to claim 5 or 6, wherein the step of determining a flow behaviour and a power behaviour comprises the step of:
determining a flow equation based on said measure of the flow at each of a set of different speeds of said pump and a power equation based on said measure of the power at each of said set of different speeds of said pump.

8. Method according to claim 7, wherein the step of determining a flow equation and a power equation comprises the steps of:
a) setting a maximum level of said liquid in the basin;
b) running said pump at a first speed of said set such that the level of the liquid sinks from said maximum level;
c) interrupting the operation of the pump when a measure of the flow has been obtained;
d) allowing the level of the liquid to rise until a measure of the inflow to the basin has been obtained;
e) determining the outflow from said basin as the sum of the flow and the inflow; and
f) repeating step b) - e) at each of the speeds of said set of speeds.

9. Method according to claim 8, further comprising the step of repeating the steps a) – f) at moments separated by predetermined time intervals, wherein a measure of the flow and a measure of the power are obtained at each moment.

10. Method according to any one of claims 5 to 9, further comprising the step of determining a measure of the specific energy of said pump E(n) by utilizing said flow equation and said power equation, wherein the specific energy is defined as $E(n)=P(n)/Q(n)$.

11. Method according to claim 10, further comprising the steps of:
identifying a minimum value of the specific energy; and

calculating the running patter for said pump using said minimum value of the specific energy.

12. Method according to claim 11, further comprising the steps of:
setting a maximum level of said liquid in said basin;
setting a minimum level of said liquid in said basin;
setting a start level of said liquid in said basin at which said pump is activated;
setting a stop level of said liquid in said basin at which said pump is de-activated; and
setting a minimum speed of said pump using said running pattern of said pump.

13. Method according to claim 12, further comprising the step of:
monitoring the power behaviour and flow behaviour of said pump; and
initiating an automatic cleaning procedure of said pump if said power behaviour or said flow behaviour indicate clogging of said pump.

14. Method according to claim 13, further comprising the steps of:
setting a margin factor x, wherein x is a preset margin factor and is a number > 1;
initiating the cleaning procedure if P > x*P(n), wherein P is the sensed power of the pump; and
interrupting said cleaning procedure when P < x*P(n).

15. Method according to claim 13, further comprising the steps of:
running said pump such that the level of the liquid is lowered to the predetermined lower level;
registering the level change as a measure of the net flow;
interrupting the operation of said pump and registering the level change as a measure of the inflow;
obtaining the measure of the flow from said registered measure of the net flow and inflow;
setting a margin factor y, wherein y is a preset margin factor and is a number > 1;

initiating the cleaning procedure if Q < Q(n)/y, wherein Q is the measured flow; and
interrupting said cleaning procedure when Q > Q(n)/y.

16. Method according to any one of preceding claims, further comprising the step of
performing the steps of claims 1-15 for each pump or each pump configuration of said pump station.

17. A system for operating at least one pump of a pump station having at least one variable-speed pump, the system comprising
sensing means arranged to sense a plurality of operating parameters of the pump station/system;
processing means in communication with said sensing means, said processing means being arranged to determine a pump behaviour of said at least one pump by utilizing said operating parameters; and
control means in communication with said processing means, said control means being arranged to operate said at least one pump according to a running pattern selected on basis of said calculated flow and/or power behaviour.

18. System according to claim 17, wherein said processing means comprises memory means arranged to store said operating parameters and/or said pump behaviour.

19. System according to claim 17 or 18, wherein said processing means is arranged to determine a flow behaviour and a power behaviour of said at least one pump by utilizing said operating parameters.

20. System according to any one of claims 17-19, wherein said pump is arranged to pump liquid from a basin, the liquid having a variable level in the basin, wherein said system further comprises
level sensing means arranged to sense the level of the liquid in said basin;
means for sensing the speed of said pump; and

current sensing means arranged to sense the current consumption of said pump.

21. System according to any one of claims 17-20, wherein said processing means is arranged to determine a measure of the flow of said pump, Q(n), as a function of the speed of said pump, where Q is the flow and n is the speed of said pump, and a measure of the power of said pump, P(n), as a function of the speed of said pump, where P is the power and n is the speed of said pump, by utilizing said sensed operating parameters.

22. System according to claim 20 or 21, wherein said system further comprises inflow sensing means arranged to sense the inflow to said basin.

23. System according to any one of claims 20-22 , wherein said processing means is arranged to determine a flow equation based on said measure of the flow at each of a set of different speeds of said pump and a power equation based on said measure of the power at each of said set of different speeds of said pump.

24. System according to claim 23, wherein said processing means is arranged to

a) actuate said control means to run said pump at a first speed of said set such that the level of the liquid sinks from a preset maximum level;

b) actuate said control means to interrupt the operation of the pump when a measure of the flow has been obtained;

c) actuate said control means to allow the level of the liquid to rise until a measure of the inflow to the basin has been obtained;

d) determine the outflow from said basin as the sum of the flow and the inflow; and

e) repeat step a) - d) at each of the speeds of said set of speeds.

25. System according to any one of claims 17-24 , wherein said system further comprises a timer unit and said processing means being arranged to repeat the steps a) – e) at moments separated by predetermined time intervals,

wherein a measure of the flow and a measure of the power are obtained at each moment.

26. System according to any one of claims 21-25, wherein said processing means is arranged to determine a measure of the specific energy of said pump E(n) by utilizing said flow equation and said power equation, wherein the specific energy is defined as E(n)=P(n)/Q(n).

27. System according to claim 26, wherein said processing means is arranged to

identify a minimum value of the specific energy; and

calculate the running pattern for said pump using said minimum value of the specific energy.

28. System according to claim 27, wherein said processing means comprises:

means for setting a maximum level of said liquid in said basin;

means for setting a minimum level of said liquid in said basin;

means for setting a start level of said liquid in said basin at which said pump is activated;

means for setting a stop level of said liquid in said basin at which said pump is de-activated; and

means for setting a minimum speed of said pump using said running pattern of said pump.

29. System according to claim 28, wherein said processing means is arranged to

monitor the power behaviour and flow behaviour of said pump; and

influence said control means to initiate an automatic cleaning procedure of said pump if said power behaviour or said flow behaviour indicate that clogging of said pump are building up.

30. System according to claim 29, wherein said processing means is arranged to:

influence said control means to initiate the cleaning procedure if P > x*P(n), wherein P is the sensed power of the pump and x is a preset margin factor and is a number > 1; and
influence said control means to interrupt said cleaning procedure when P < x*P(n).

31. System according to claim 29, wherein said processing means is arranged to:
influence said control means to run said pump such that the level of the liquid is lowered to the predetermined lower level;
register the level change as a measure of the net flow;
influence said control means to interrupt the operation of said pump;
register the level change as a measure of the inflow;
obtain the measure flow from said registered measure of the net flow and inflow;
set a margin factor y, wherein y is a preset margin factor and is a number > 1;
initiating the cleaning procedure if Q < Q(n)/y, wherein Q is the measured flow; and
interrupt said cleaning procedure when Q > Q(n)/y.

32. System according to any one of preceding claims 17-31, wherein the system is arranged to operate each pump or pump configuration of a pump station in accordance with the method of claims 1-15.

33. Computer program product loadable into a memory of a digital computer device, including software code portions for performing the method of one of claim 1-15 when said computer program product is run on said computer device.

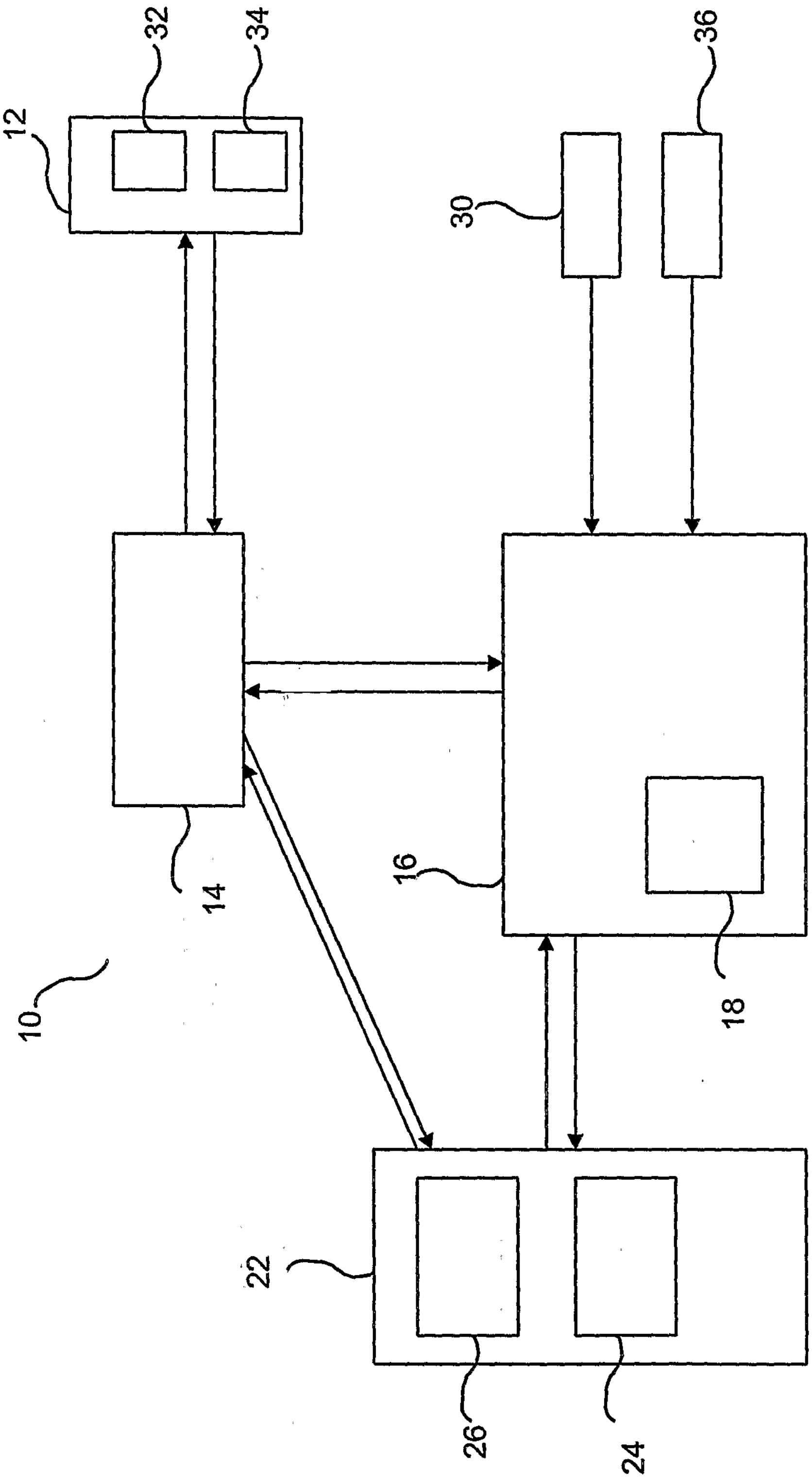

Fig. 1

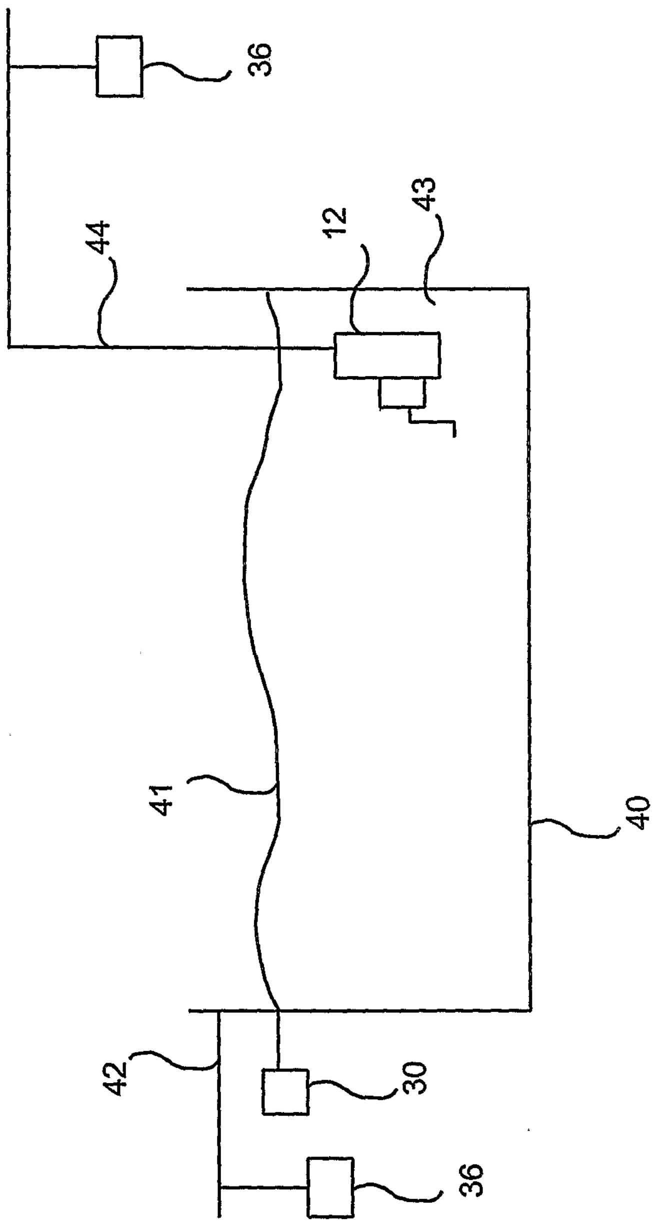

Fig. 2

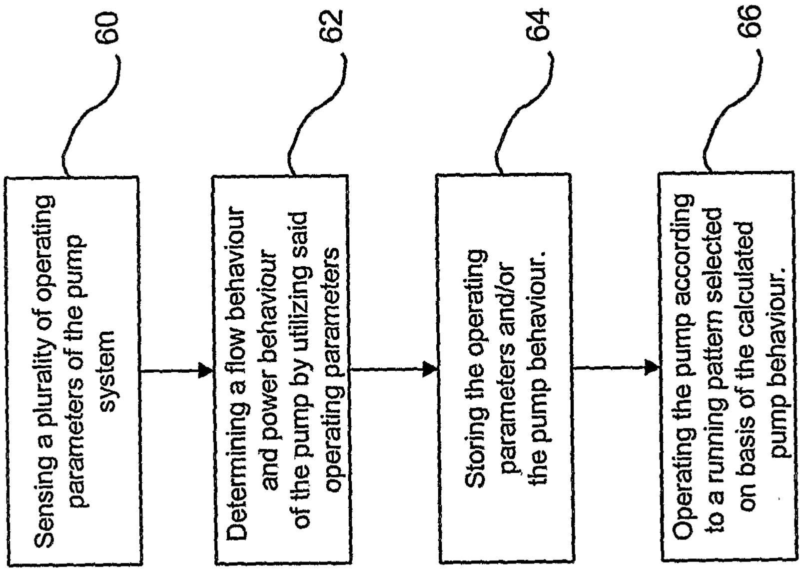
Sensing a plurality of operating parameters of the pump system
Determining a flow behaviour and power behaviour of the pump by utilizing said operating parameters
Storing the operating parameters and/or the pump behaviour.
Operating the pump according to a running pattern selected on basis of the calculated pump behaviour.
60
62
64
66

Fig. 3

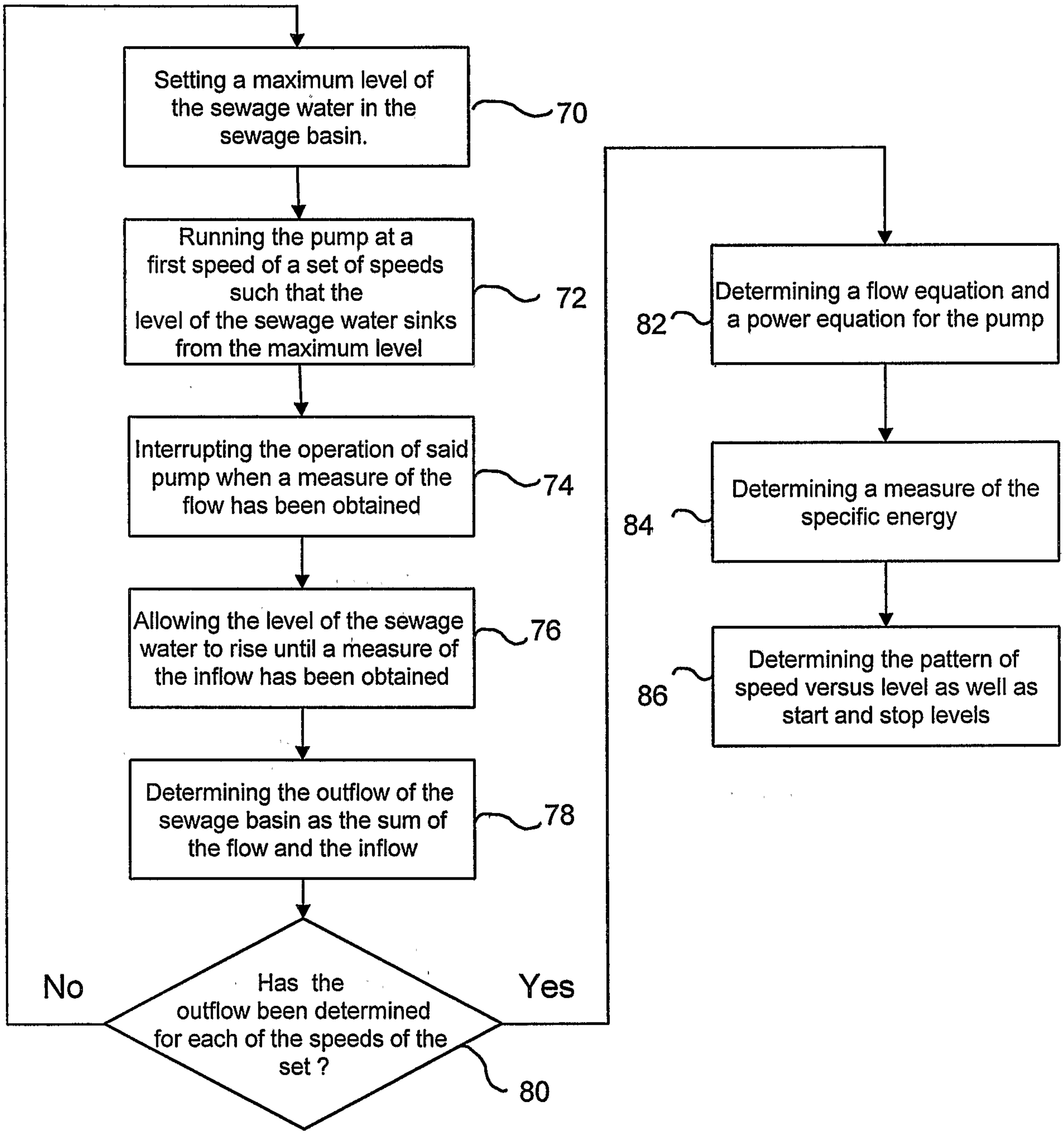
Setting a maximum level of the sewage water in the sewage basin.
70
Running the pump at a first speed of a set of speeds such that the level of the sewage water sinks from the maximum level
72
Interrupting the operation of said pump when a measure of the flow has been obtained
74
Allowing the level of the sewage water to rise until a measure of the inflow has been obtained
76
Determining the outflow of the sewage basin as the sum of the flow and the inflow
78
Has the outflow been determined for each of the speeds of the set ?
80
No
Yes
Determining a flow equation and a power equation for the pump
82
Determining a measure of the specific energy
84
Determining the pattern of speed versus level as well as start and stop levels
86

Fig. 4

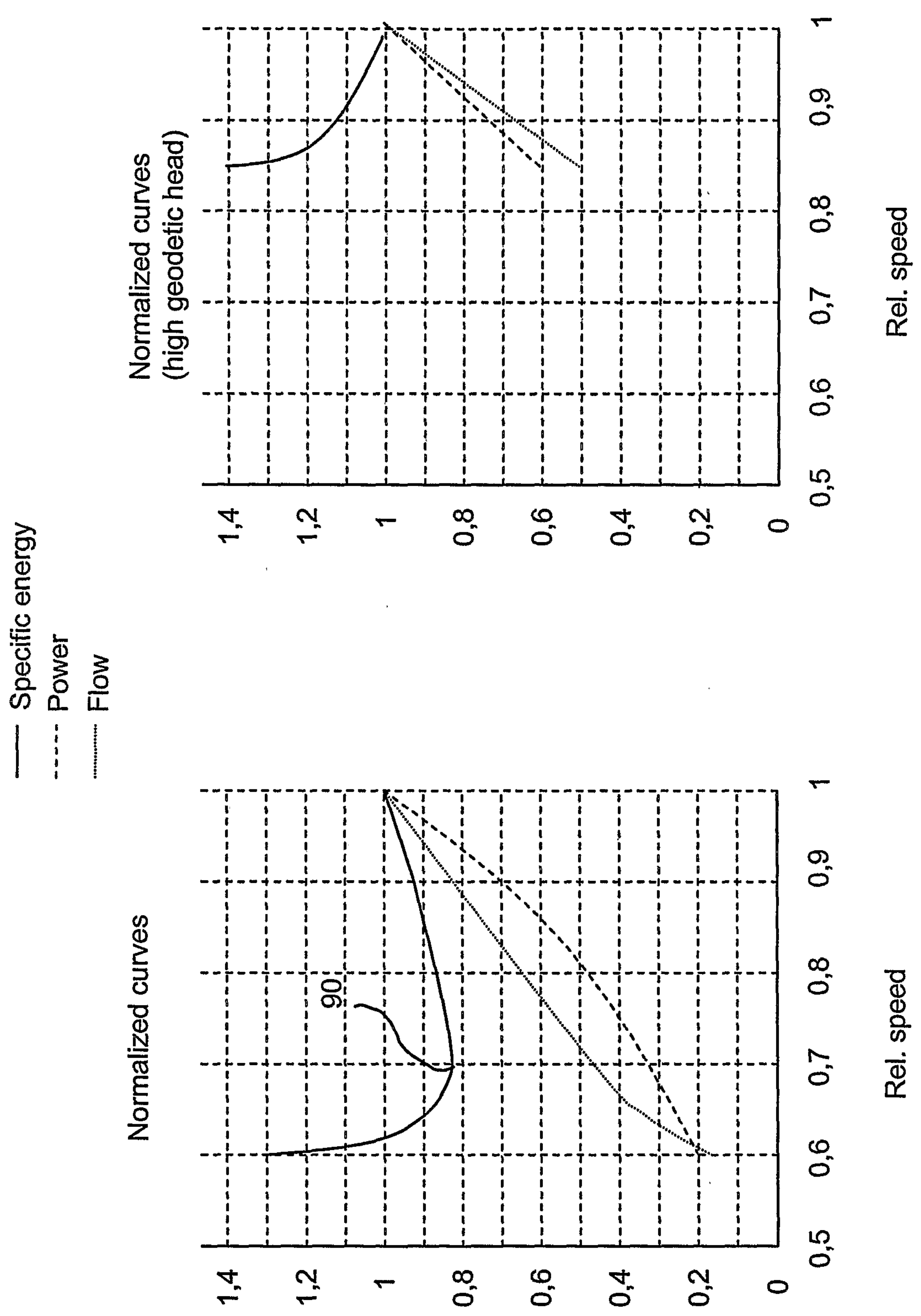
Specific energy
Power
Flow
Normalized curves
(high geodetic head)
1,4
1,2
1
0,8
0,6
0,4
0,2
0
0,5
0,6
0,7
0,8
0,9
1
Rel. speed
Normalized curves
90
1,4
1,2
1
0,8
0,6
0,4
0,2
0
0,5
0,6
0,7
0,8
0,9
1
Rel. speed

Fig. 5b

Fig. 5a

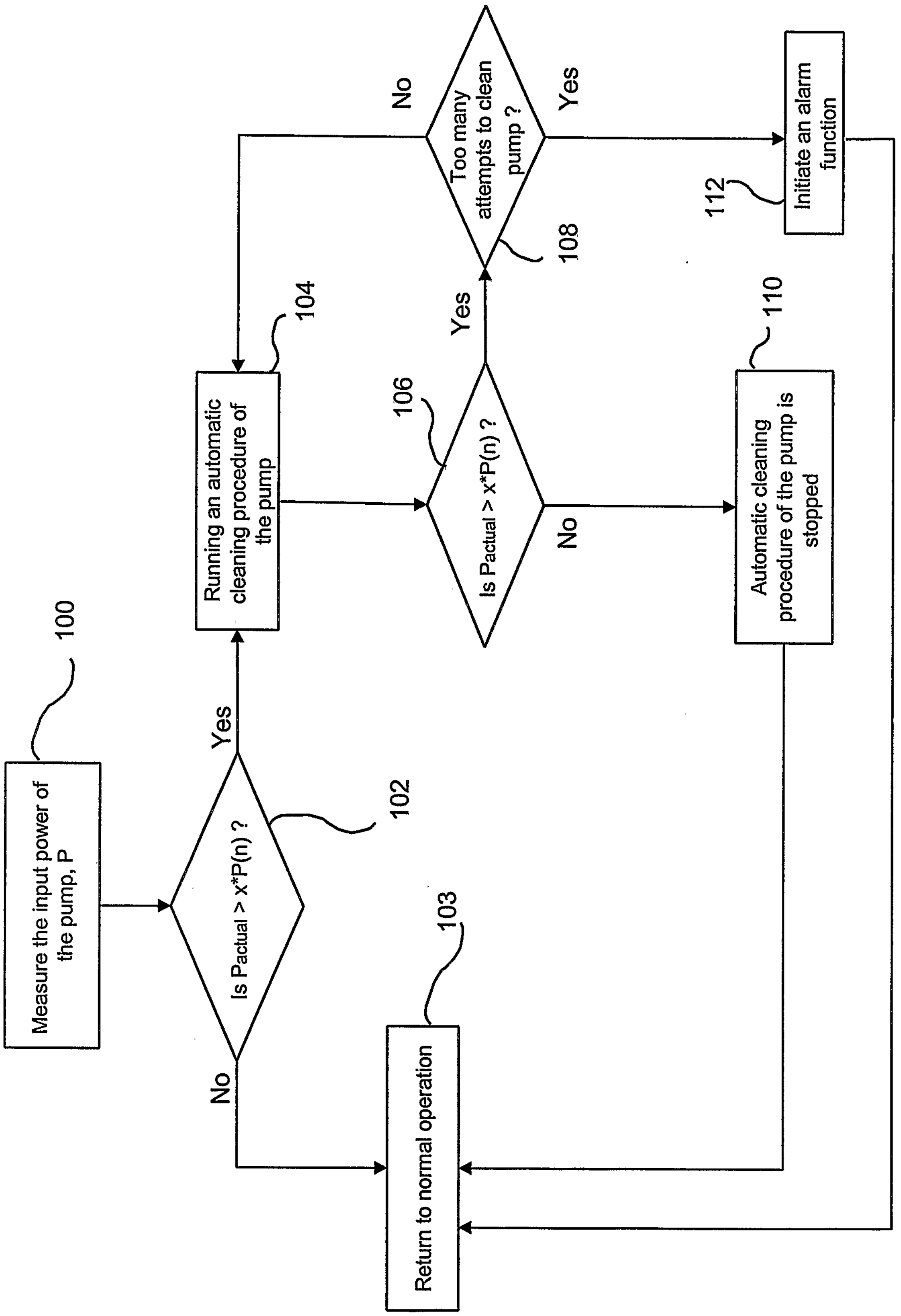
Measure the input power of the pump, P
100
Is Pactual > x*P(n) ?
102
Yes
No
Return to normal operation
103
Running an automatic cleaning procedure of the pump
104
Is Pactual > x*P(n) ?
106
Yes
No
Too many attempts to clean pump ?
108
No
Yes
Automatic cleaning procedure of the pump is stopped
110
Initiate an alarm function
112

Fig. 6

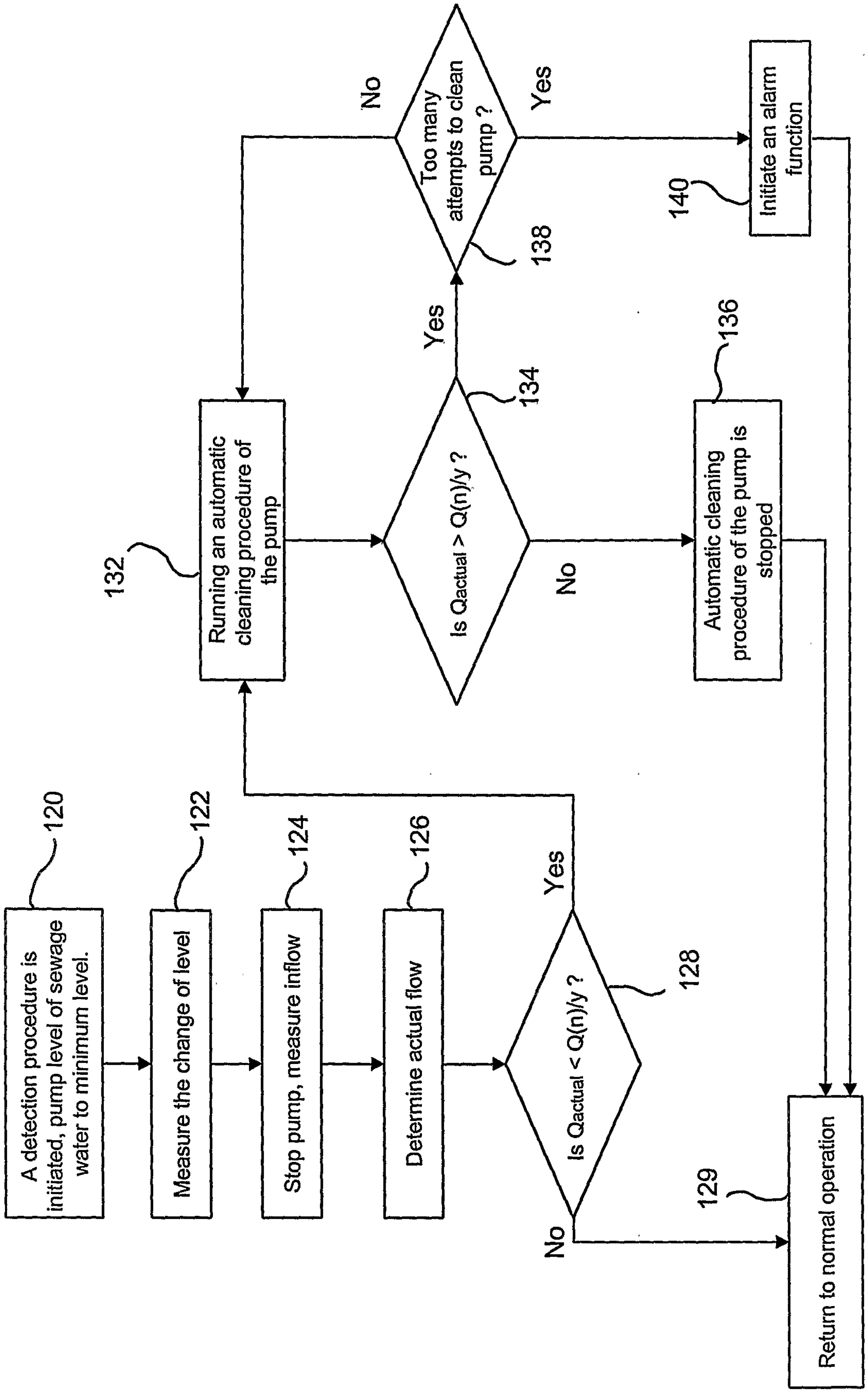
A detection procedure is initiated, pump level of sewage water to minimum level.
120
Measure the change of level
122
Stop pump, measure inflow
124
Determine actual flow
126
Is Qactual < Q(n)/y ?
128
Yes
No
129
Return to normal operation
Running an automatic cleaning procedure of the pump
132
Is Qactual > Q(n)/y ?
134
Yes
No
Automatic cleaning procedure of the pump is stopped
136
Too many attempts to clean pump ?
138
No
Yes
Initiate an alarm function
140

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 2005/001212

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F04B, F04D, G01R, G05D, G01M

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)

EPO-INTERNAL, WPI-DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6178393 B1 (W.A.IRVIN), 23 February 2001 (23.02.2001), column 3 - column 4; column 15, line 10 - line 15 --	1-33
X	US 4945491 A (J.B.RISHEL), 31 July 1990 (31.07.1990), column 12, line 15 - line 31	1-12,16-28, 32-33
Y	 --	13-15,29-31
Y	US 6481973 B1 (K.STRUTHERS), 19 November 2002 (19.11.2002), column 1, line 55 - column 2, line 24 --	13-15,29-31

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 November 2005	30-11-2005
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Sture Elnäs /OGU Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 2005/001212

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4999117 A (J.PALMU ET AL), 12 March 1991 (12.03.1991), figure 2 --	1-33
X	US 6167965 B1 (J.BEARDEN ET AL), 2 January 2001 (02.01.2001), column 1, figures 2C,2D --	1-12,17-28
X	US 4843575 A (H.CRANE), 27 June 1989 (27.06.1989), column 3, line 24 - line 46; column 5, line 54 - line 65 --	1-12,17-28
X	US 4370098 A1 (J.E.MCCLAIN ET AL), 25 January 1983 (25.01.1983), column 2, line 49 - line 64 --	1-12,12-28
A	US 5497664 A1 (J.N.JORRITMA), 12 March 1996 (12.03.1996), figure 2 --	1-33
A	US 2110714 A1 (AUTOMATIC CONTROL SYSTEM), 8 March 1938 (08.03.1938), page 2, column 1, line 60 - line 65 -- --------	1-33

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001212

Continuation of cover sheet

F04B 49/06 (2006.01)

G05D 29/00 (2006.01)

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				ES	2013523	A	01/05/1990
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				FI	882711	A	09/12/1989
				GB	2221073	A,B	24/01/1990
				GB	8912759	D	00/00/0000
				NO	166547	B,C	29/04/1991
				NO	892318	A	11/12/1989
				SE	469434	B,C	05/07/1993
				SE	8902063	A	09/12/1989
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				US	6587037	B	01/07/2003
				US	6798338	B	28/09/2004
				US	20010032721	A	25/10/2001
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				CA	2230691	A	06/03/1997
				GB	2320588	A,B	24/06/1998
				GB	2338801	A,B	29/12/1999
				GB	9804366	D	00/00/0000
				GB	9920437	D	00/00/0000
				NO	980882	A	27/04/1998
				WO	9708459	A	06/03/1997
US	4843575	A	27/06/1989	US	4584654	A	22/04/1986
US	4370098	A1	25/01/1983	NONE			
US	5497664	A1	12/03/1996	NONE			
US	2110714	A1	08/03/1938	NONE			