A method for controlling a pump arrangement comprising a fluid delivering pump having a pump drive, a bypass line having a bypass valve for routing fluid back from an outlet side of the pump to a reservoir is disclosed. During ramping up the pump drive to a predetermined target rotational speed, the bypass valve is controlled to reduce a volume flow through the pump so that the volume flow, at a respective delivery height, lies between a cavitation volume flow and the cavitation volume flow increased by a predetermined maximum volume flow deviation.
METHOD FOR CONTROLLING A PUMP ARRANGEMENT, AND PUMP ARRANGEMENT

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a method for controlling a pump arrangement which is used, for example, in cryotechnical plants. The invention further relates to an arrangement comprising one or more pumps for providing pressurized cryogenic liquid, the arrangement being suitable, for example, for use in an air liquefaction plant.

[0002] Open-loop and closed-loop control of pump drives to predetermined target values such as a desired output pressure, as a function of various measurable values, for example a pressure difference between pump inlet and pump outlet, volume flows or mass flow rates, a rotational speed of the pump drive or similar values, is necessary particularly in large-scale fluid-processing plants. The use of three-phase asynchronous motors as pump drives is common in this context. Cryogenic pumps, i.e. pumps which deliver cryogenic liquids at temperatures lower than −170 °C., are operated by corresponding three-phase asynchronous machines. Especially in cryogenic applications, such as air separation units, a cryogenic liquid or liquefied air is brought to a predetermined operating pressure by cryogenic pumps and subsequently supplied to other plant components, e.g. to a heat exchanger.

[0003] In order to keep the pressure in the cryogenic liquid as reliable and uniform as possible, redundant pumps are mostly operated in parallel, in order to maintain the necessary pressure in the low-temperature system in case of failure of one of the pumps. For example, pairs of redundant pumps may be provided, with one working pump being continuously in operation and, in case of failure, a substitute pump starting and replacing the performance of the failed pump. So-called “slow-roll” operating modes are known for such substitute pumps, with the drive motor being active, the pump performs, however, only minimal delivery work.

[0004] In order to prevent the pressure in the high-pressure range of the corresponding system from decreasing excessively in case of failure of the working pump, it is necessary to set the redundant substitute pump as quickly as possible to an operating condition which corresponds to the original operating condition of the operating pump. This means that generally the rotational speed of the substitute pump must reach the rotational speed of the failed pump as quickly as possible. Usually, the rotational speed of the pump performing delivery is determined by operation specifications of the plant in question and is adjusted in a closed-control loop. The rotational speed of an asynchronous motor is essentially predetermined by the three-phase frequency at which it is operated. For this reason, in conventional closed-loop control systems, a frequency converter is used, which provides the three-phase frequency for the motor driving the pump. A corresponding closed-loop control unit determines the three-phase frequency for the pumps or asynchronous motors depending on the product present on the output side of the pump.

[0005] If one pump fails, a substitute pump must be accelerated to the required rotational speed as quickly as possible. However, especially during the power-up phase, a corresponding pump drive does not always develop its peak torque, which delays the substitute pump’s achieving its desired delivery result. Thus, undesired fluctuations of pressure and flow rate may occur in the delivered product at the pump output.

[0006] It is therefore an object of the present invention to provide an improved procedure of ramping up a pump arrangement.

SUMMARY OF THE INVENTION

[0007] Accordingly, a method for controlling a pump arrangement comprising a fluid-delivering pump having a pump drive, and a bypass line having a bypass valve, is provided. The bypass line is to return fluid to a reservoir provided at the pump inlet. During the ramping-up procedure of the pump drive to a predetermined target rotational speed, the bypass valve is controlled so that the volume flow through the pump at a corresponding delivery height lies between a cavitation volume flow and the cavitation volume flow increased by a predetermined maximum deviation of the volume flow.

[0008] For example, a control line as close as possible to the cavitation boundary can be defined for the operating point of the pump, which results in a favourable reduction of the volume flow which, in turn, rules out the possibility of cavitation occurring.

[0009] Especially when cryogenic pumps are in operation, it is necessary to prevent cavitation, which can be achieved by adjusting the volume flow rate to be higher than the cavitation volume flow. Moreover, the proposed closed-loop control of the bypass valve causes the volume flow to be reduced at least partially during ramping-up, and is close to a lower cavitation boundary curve. The bypass valve is preferably controlled in such a way that the volume flow at a corresponding delivery height is situated in a volume flow range between a lower limit volume flow and the cavitation volume flow increased by the predetermined maximum deviation of the volume flow.

[0010] It is possible, for example, to define a control curve for the volume flow which runs essentially parallel to the lower cavitation boundary. The lower limit volume flow then lies between the control curve and the cavitation boundary for example, and an upper limit volume flow lies to the right of the control curve within a corresponding delivery height/volume flow diagram. The range is specified so that the cavitation volume flow is never undercut, not even in the case of overshootings in the closed-loop control.

[0011] Reducing the volume flow leads to a lower hydraulic braking torque, which facilitates acceleration to the target rotational speed. This indirectly minimizes the hydraulic braking torque during the power-up phase.

[0012] For example, an implementation of the method as a cavitation limiting controller applies appropriate to control the bypass valve on the basis of the difference between a pump inlet pressure and an outlet pressure and the current volume flow. By implementing the method in accordance with the invention, advantage can be taken of the fact that the ramping-up procedure of the pump drive runs essentially along a cavitation boundary. This ensures a particularly low volume flow. Preferably, for example, a current volume flow is calculated as a function of the pressure difference between an inlet and an outlet side of the pump and/or the current rotational speed of the pump drive.
In a variant of the method described above, at least one of the following method steps is performed:

Providing an opened bypass valve or opening the bypass valve. The operating situation is frequently such that the bypass valve is opened 100% at the time of failure of one pump. A pump provided as a substitute pump in slow-roll or stand-by mode normally features an open bypass. Based on this situation, the volume flow is then minimized in order to bring the corresponding substitute pump to the predetermined rotational speed as quickly as possible.

Determining a target rotational speed for a pump drive as a function of a predetermined outlet pressure. A higher-level pressure controller provides, for example, a rotational speed for the pump depending on the queried product in the output line. The use of several pumps in parallel arrangement which supply a common high-pressure fluid line is also conceivable. A corresponding pressure controller then provides a target rotational speed for these pumps.

Reducing the flow rate through the bypass valve in order to increase the delivery height of the pump, and reducing the volume flow while keeping the rotational speed of the pump drive within a predetermined maximum range during an initial power-up phase. For example, a maximum rotational speed change of 10%, preferably 5%, may be desired during the initial power-up phase. The bypass valve should be closed so quickly as to ensure that the rotational speed is not increased significantly. For example, if the entire ramp-up time of the corresponding pump amounts to 10 seconds, closing can be effected within one second. By reducing the flow rate while increasing the delivery height, the operating point of the pump approaches the cavitation boundary, i.e., it moves in the direction of the lowest possible volume flow without inducing cavitation. Preferably, an operating point of the pump along a delivery height-volume flow characteristic at a constant rotational speed is used during the initial power-up phase. For example, the bypass valve can be ramped, i.e., its orifice varied by a predetermined value in a predetermined time. It is also possible to set a target value for the controller acting on the bypass valve, with the valve position varying correspondingly over time during this initial power-up phase.

Increasing the rotational speed of the pump drive during a second power-up phase by controlling via the bypass valve so that in case of an increase in the delivery height, the volume flow exceeds the cavitation volume flow. In this context, the cavitation volume flow corresponds to a minimum volume flow required to avoid cavitation at a corresponding delivery height. During the second phase, a minimum acceptable volume flow rate is assured without inducing cavitation. In the second power-up phase, the pump is thereby preferably operated at an operating point which runs essentially in parallel to a cavitation boundary of a set of delivery height-volume flow characteristic lines of the pump.

Closing the bypass valve once a predetermined delivery height or a predetermined outlet pressure has been reached during a third power-up phase. For example, as soon as the pressure required by a pressure controller has been reached on the outlet side, the volume flow can also be increased again, which is effected by closing the bypass valve. On principle, this process can be repeated until a pressure controller acting on the bypass valve records a maximum pressure. Then the bypass valve would have to be opened.

On principle, other operational situations may also necessitate the closing of the bypass valve. If, for example, fluid is withdrawn on the outlet side, the closed-loop control can induce a reduction of the bypass valve orifice.

The method is suited for use with an asynchronous motor as a pump drive with a three-phase frequency which corresponds to the predetermined target rotational speed. The current rotational speed can also be approached approximately by taking the synchronous rotational speed into account. The resulting slip can be neglected.

Moreover, a pump arrangement comprising at least one pump, one reservoir and one control device is provided. Here, the pump has a pump drive, and the reservoir is coupled to the pump on the outlet side via a bypass line. The bypass line is equipped with a bypass valve. The reservoir also supplies a fluid to be delivered to the pump inlet side. The control device is designed in such a way that a method described above is performed.

The pump arrangement can comprise a cavitation limit control device which controls the bypass valve as a function of the current volume flow through the pump and a current rotational speed of the pump drive of the pump. A closed-loop control can also be effected as a function of the pressure difference between input and output sides, the current rotational speed and/or the delivery height. The cavitation limit control device is provided in order to prevent damage due to cavitation from occurring in particular with cryogenic fluids. Moreover, a pressure controller recording the outlet pressure can be provided, which controls the bypass valve so that a predetermined maximum outlet pressure is not exceeded. However, control by the cavitation limit control device should have priority.

One or several corresponding pump arrangements are particularly suitable for use in air separation units having cryogenic pumps. The control device can also specify the target rotational speed of the corresponding cryogenic pump as a function of the operating specifications for a process for air separation.

Especially during locking-in or ramping-up of substitute pumps, the hydraulic torque can be minimized by proceeding in accordance with the invention. This accelerates the ramping-up procedure. Fluctuations of pressure or the volume flow rate are reduced significantly. The method can also be used and implemented for any substitute or operating pump in cryogenic pump applications working in parallel.

One variant of the invention provides a computer program product which induces implementation of a corresponding method for controlling a pump drive on a software-controlled computer or control unit. A PC or a computer of a control room for the closed-loop and open-loop control of plants can be used as software-controlled computer or control unit, with the corresponding software being installed. The software product can, for example, be implemented in the form of a data medium such as a USB stick, floppy disc, CD-ROM, DVD, or can be implemented on a server unit as a downloadable program file.

Further advantageous designs of the invention are the object of the sub-claims as well as the examples of embodiments of the invention described below. In the following, the invention is explained in detail by means of preferable embodiments with reference to the figures enclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1: a representation of a plant having a plurality of controllable pumps for providing a pressurized cryogenic fluid;
FIG. 2: a schematic representation of a pump arrangement suitable for the implementation of one variant of the ramping-up method in accordance with the invention; and

FIG. 3: a delivery height-volume flow diagram illustrating power-up phases of a pump drive.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] In air separation units with internal compression, for example, cryogenic air or liquids (LIN, LOX, LAR—liquid nitrogen, oxygen, argon) are brought to an operating pressure by pumping or delivery, and are routed to a heat exchanger of the air separation unit (ASU) in question within which the corresponding cryogenic liquid is evaporated. In order to enable the respective process to be continued in case of failure of one of the pumps, redundant pumps are provided as substitute pumps in the case of failure of the working pump, properly speaking. It is also conceivable that several individual plant components are supplied with pressurized cryogenic liquid from a common reservoir or tank. This is represented schematically in FIG. 1, for example.

[0031] A common high-pressure liquid line 1 is provided, which is supplied with high-pressure liquid by the three pumps 2, 3, 4. The pumps are supplied with the corresponding product via a supply line 5 from a joint reservoir or tank 6. For each pump, a bypass return line 7, 8, 9, each with a pressure-controlled valve 10, 11, 12, is provided. Furthermore, each pump 2, 3, 4, is secured against the joint high-pressure liquid line 1 via a cut-off valve 13, 14, 15.

[0032] In the example of FIG. 1, three plant components are connected to the joint high-pressure liquid line 1. For example, two heat exchangers 16, 17 of air separation units and a back-up system 18 are connected to the joint high-pressure liquid line 1. On the gas side, the product pressure is controlled respectively by the pressure-controlled valves 19, 20. The product quantity required respectively is also controlled via valves 21, 22. Analogously, high-pressure liquid is withdrawn from the joint line 1 by the back-up system 18 via a valve 24 driven by a controller 23.

[0033] Via a control device 25, the pressure required is controlled by activating the pumps 2, 3, 4 in the joint high-pressure line 1. In normal mode, for example, the pump bypasses 8, 9 are closed, and an appropriate three-phase frequency is pre-determined for the pumps or the asynchronous motors implemented in them. The substitute pump 2 then, for example, runs in slow-roll mode, and the corresponding bypass valve is opened 100%. As a rule, the number of pumps 2, 3, 4 is provided corresponds to the number of plant components 16, 17 being supplied by the joint high-pressure line 1. If application of the back-up system becomes necessary, the third pump must also be powered up.

[0034] If one pump fails, a redundant substitute pump must power up as quickly as possible, in order to minimize the pressure fluctuations in the joint liquid line 1. In normal mode, the controller or the open-loop control unit 25 sets a predetermined three-phase frequency m on the pumps as a function of the operation specifications of the other plant components connected.

[0035] FIG. 2 shows a schematic sectional view of a pump arrangement, as it can be configured in FIG. 1 for the pumps 2, 3, 4. Here, identical references correspond to the elements represented in FIG. 1. Pump 2 is driven by a motor 26 with the respective rotational speed controlled via a control signal CT3 by an evaluation device 27. The pressure controller 25 which measures the outlet pressure of the joint liquid line 1 delivers a target rotational speed NZ to the evaluation device 27. Moreover, the current rotational speed nakt of the motor 26 is provided via a speed sensor 28.

[0036] On principle, as a function of the current rotational speed nakt and the desired rotational speed nz, the motor 26 can preferably be run within an operating range in which its torque is on principle at its maximum value. In the starting phase, i.e., when the drive 26 of a substitute pump 2 is switched on, this can be achieved, for example, by operating the drive 26, which is designed as an asynchronous motor, in the proximity of its breakover point.

[0037] Moreover, a cavitation limit control is provided which comprises a cavitation limit control device 30 delivering a control signal CT1 to the control device or interrogator device 32 which operates the bypass valve. Furthermore, a pressure gauge 29 is provided on the pump inlet side, which measures the inlet pressure p0 and delivers it to the cavitation limit control device 30. Likewise, a pressure controller 31 is provided on the outlet side which, on the one hand, delivers the cavitation limit controller 30 with the outlet pressure po and, on the other hand, communicates a control signal CT2 to the control device 32 to open the bypass valve. If the maximum admissible outlet pressure is exceeded. The various control mechanisms such as cavitation limit control and pressure controller 31 for the bypass valve 10 can be effected on principle independently of one another, with the cavitation limit controller 30 supplying a control signal CT1 which has priority over the control signal CT2. Thus, it is possible for the controller 32 always to perform a maximum selection between the values of the control signal CT1 from the cavitation limit control 30 and the control signal CT2 from the pressure controller 31. This ensures that cavitation is prevented while the output pressure is nevertheless controlled reliably.

[0038] The controller 31 represented as a pressure controller (PIC) can be also designed as a manual controller (HLC) in other versions of a corresponding pump arrangement.

[0039] The delivery rate Q0 provided by the pump results from the volume flow V and the specific delivery work Y, which represents the work involved in the flow. This can be represented by the following equation:

\[ Q \propto \rho V \cdot g \cdot H \cdot \Delta p \cdot \eta \]

wherein \( \rho \) is the density of the fluid, g the acceleration of gravity and H the delivery height which can be derived from the specific delivery. The delivery height H can also be approximated via the pressure difference between the outlet pressure and the inlet pressure \( \Delta p = \rho_0 - p_0 \). The corresponding variables are accessible via corresponding sensors or controllers, as shown in FIG. 2.

[0040] The hydraulic power \( P_h \) to be procured by the pump results from the mechanical output power \( P_m \) multiplied by the efficiency \( \eta \). To ensure minimum delivery is demanded of the pump during the power-up phase, thus permitting a quick increase in rotational speed, it is suggested, for example, to reduce the volume flow V, or to keep it at a low level. The mechanical output power results from the torque MH developed by the pump drive 26, multiplied by the angular velocity \( \omega = \rho \cdot V \cdot \Delta p \).

[0041] Thus, a low volume flow V has a lower required torque MH or braking torque through the pump drive 26. This applies especially to pumps with a flat characteristic. FIG. 3 shows, on the basis of a delivery height-volume flow diagram,
a possible development of the operating point of a pump during ramping-up in accordance with a variant of the method to power up a pump drive 26.

[0042] FIG. 3 shows the corresponding characteristic lines n1, n2, n3, n4, n5 in the delivery height-volume flow diagram, with n1-n5 standing for various rotational speeds of the pump drive 26. The volume flow V is indicated on the X axis, and the delivery height H on the Y axis. Normally, the delivery height H is proportional to n^2 if a constant efficiency η can be assumed. As the rotational speed n increases, the surfaces enclosed by the characteristic lines n1-n5 in the plane increase as well. Thus, for example, n1 in terms of possible slow-roll rotational speed can correspond to 45%-50% of the maximum desired rotational speed n5. In addition, two cavitation boundaries KG1 and KG2 are shown. If the volume flow V undercuts the cavitation boundary KG1 at a predetermined rotational speed, e.g. n2, there is a high risk of cavitation, and thus a risk of destruction of the pump. The resulting braking moment can be illustrated based on FIG. 3 by the rectangular surface which is defined, in the case of a predetermined operating point, e.g. BP1, by the operating point and the origin of the diagram.

[0043] The current volume flow V can be determined from a diagram of the pump manufacturer via the rotational speed n and the pressure difference Δp. As these variables are supplied to the cavitation limit controller 30, as shown in FIG. 2, the latter is able to prevent the cavitation boundary KG1 from being undercut by opening the bypass valve 10. In normal operation, if sufficient product is withdrawn from the liquid line 1, the bypass valve is normally completely closed; the cavitation limit controller 30 indicates an orifice opened 0% via the control signal CT1.

[0044] In a first power-up phase, which is suggested in FIG. 3 by P1 as a dashed arrow, the bypass valve 10 is controlled so that the rotational speed only fluctuates by a low value Δn, based on the current speed n1, and that starting from BP1, an operating point BP2 is reached which features a volume flow increased by the minimum required volume flow of the cavitation boundary line KG1 (cavitation volume flow) at the predetermined delivery height. Thus, a maximum deviation of the rotational speed nakt of 10%, preferably 5%, can be defined. A distance from the cavitation volume flow is ensured which corresponds to a control line. The resulting distance is such that even extraordinary fluctuations in pump operation cannot cause a volume flow below the cavitation boundary.

[0045] When the bypass valve 10 is completely open, it is closed during the first power-up phase P1, or the flow rate is reduced. During this first power-up phase P1, the rotational speed is increased only slightly by Δn, with the volume flow V being reduced significantly, which results in a lower hydraulic braking torque PM.

[0046] In the further ramping-up procedure in a second power-up phase P2, the position of the bypass valve 10 is controlled departing from the operating point BP2 so that an operating point BP3 is reached which has a higher volume flow and a higher delivery height H than the operating point BP2. Essentially, the bypass valve is controlled so that the operating point is parallel to the cavitation boundary KG1. To this effect, a distance in the volume flow is kept from the cavitation boundary. The corresponding control parameters permitting control of the the pump in accordance with the second power-up phase P2 can be determined experimentally and optimized for example in dynamic simulations.

[0047] Moreover, a control line RL is shown which runs parallel to the upper cavitation boundary KG1 at a distance of ΔV=+ΔV, with ΔV>ΔV. Thus, an area VB is defined around the control line RL which should not be exceeded by the operating point during the second power-up phase P2. In this case, a lower limit volume flow results from RL−ΔV and an upper limit volume flow from RL+ΔV. In this context, the control line RL corresponds preferably to a volume flow V, which is 2%-10% above the respective cavitational volume flow. dV depends on the control parameters, the control accuracy and the actual implementation of the plant. It should be ensured that the area to the right of the cavitation line for the operating point is as narrow as possible.

[0048] In a third power-up phase P3, the outlet pressure of the pump has risen sufficiently, so that fluid is supplied to the product system or the delivery line 1. Now, the volume flow V increases more significantly and the bypass valve closes. This is performed, for example, by the pressure controller 31 which is set to Set-Point-High (SPH). The operating point BP4 is reached by increasing the rotational speed. Here, the operating point BP4 is at a delivery height or corresponds to an outlet pressure which corresponds to the target value of the pressure controller 25 acting on the pump speed. This is suggested by the dash-dotted line PIC25. The other horizontal, dash-dotted line PIC31 in the delivery height-volume flow diagram of FIG. 3 corresponds to the target value of the pressure controller 31 acting on the bypass valve.

[0049] Due to the development of the operating point along the trajectories P1, P2, P3 and by passing the operating points BP1, BP2, BP3, BP4, an especially low volume flow is reached during the power-up phase. Thus, the motor needs only develop a low torque or provide low hydraulic power. Subsequently, power-up or starting of accordingly controlled pumps is speeded up.

[0050] Thus, the invention provides a method which can be implemented in the corresponding closed-loop control or control room computers of plants and permits minimization of the ramp-up duration of a pump drive, especially of cryogenic internal compression centrifugal pumps. The method can be used for individual pumps and for redundant substitute pumps with several pumps operated simultaneously, and reduces the fluctuations of pressure and product rates on the output side. The method can also be integrated in a straightforward fashion into existing control concepts and is independent of the number of pumps used and operated. A corresponding analog cavitation limit control for the upper cavitation limit KG2 prevents moreover, in the case of large-size bypass valves, possible damage due to cavitation on the pump impeller concerned, if e.g. a substitute pump is running in slow-roll mode. For example, in other operating situations, an area can be determined analogously just below the upper cavitational volume flow KG2 where an operating point should exist.

[0051] Although the present invention has been explained on the basis of examples for preferred embodiments, it is not limited to these, but can be modified in many ways. Especially the represented topologies of the closed-control loops can be varied. Application on cryogenic pumps is also not to be considered restrictively.
We claim:

1. A method for controlling a pump arrangement comprising:
   providing a pump arrangement including at least one pump
   having a pump drive, and a bypass line having a bypass
   valve for routing fluid back to a reservoir from an outlet
   side of the pump;
   ramping up the pump drive to a predetermined target rota-
   tional speed; and
   controlling the bypass valve for reducing a volume flow
   through the at least one pump so that the volume flow, at
   a respective delivery height, lies between a cavitation
   volume flow and the cavitation volume flow increased
   by a predetermined maximum deviation of the volume
   flow.

2. The method according to claim 1, wherein controlling
   the bypass valve comprises: controlling the bypass valve in
   such a way that the volume flow at a corresponding delivery
   height is situated in a volume flow range which lies between
   a lower limit volume flow and the cavitation volume flow
   increased by the predetermined maximum deviation of the
   volume flow.

3. The method according to claim 1, comprising:
   providing a pump with an open bypass valve;
   specifying a target rotational speed for a pump drive as a
   function of a predetermined outlet pressure;
   reducing the flow rate through the bypass valve for increas-
   ing the delivery height of the pump and reducing the
   volume flow with a predetermined maximum change of
   the rotational speed of the pump drive during a first
   power-up phase;
   controlling the bypass valve for increasing the rotational
   speed of the pump drive so that with increasing delivery
   height, the volume flow is higher than the cavitation
   volume flow, which corresponds to a minimum volume
   flow necessary to avoid cavitation at a respective deliv-
   ery height, during a second power-up phase;
   and
   closing the bypass valve once a predetermined delivery
   height or a predetermined outlet pressure has been reached
during a third power-up phase.

4. The method according to claim 3, comprising:
   operating an operating point of the pump in the first power-
   up phase essentially along a delivery height-volume
   flow curve of the pump at a constant rotational speed.

5. The method according to claim 3, comprising:
   operating an operating point of the pump in the second
   power-up phase essentially in parallel to a cavitation
   boundary of a set of delivery height-volume flow curves
   of the pump.

6. The method according to claim 3, comprising:
   determining a current volume flow as a function of a pres-
   sure difference between an inlet side and an outlet side
   of the pump and the current rotational speed of the pump
   drive.

7. The method according to claim 1, comprising:
   operating an asynchronous motor as pump drive with a
   three-phase frequency corresponding to the predeter-
   mined target rotational speed.

8. A pump arrangement comprising:
   at least one pump having a pump drive;
   a reservoir providing fluid to be delivered on an inlet side
   of the at least one pump;
   a bypass line having a bypass valve for routing fluid from
   an outlet side of the at least one pump to the reservoir;
   and
   a control device adapted to ramp up the pump drive of the
   at least one pump to a predetermined target rotational
   speed, and to control the bypass valve for reducing a
   volume flow through the pump so that the volume flow,
av respective delivery height, lies between a cavita-
tional volume flow and the cavitation volume flow in-
creased by a predetermined maximum deviation of the
volume flow.

9. The pump arrangement according to claim 8, wherein
   the control device is adapted to specify a target rotational
   speed for a pump drive as a function of a predetermined outlet
   pressure.

10. The pump arrangement according to claim 8, wherein
    the control device is adapted to reduce the flow rate through
    the bypass valve for increasing the delivery height of the
    pump and for reducing the volume flow with a predetermined
    maximum change of the rotational speed of the pump drive
during a first power-up phase.

11. The pump arrangement according to claim 10, wherein
    the control device is adapted to control the bypass valve for
    increasing the rotational speed of the pump drive so that with
    increasing delivery height, the volume flow is higher than the
    cavitation volume flow, which corresponds to a minimum
    volume flow necessary to avoid cavitation at a respective
delivery height, during a second power-up phase.

12. The pump arrangement according to claim 11, wherein
    the control device is adapted to close the bypass valve once a
    predetermined delivery height or a predetermined outlet
    pressure has been reached during a third power-up phase.

13. The pump arrangement according to claim 8, compris-
    ing a cavitation limit control device adapted to control the
    bypass valve as a function of a current volume flow through
    the pump and a current rotational speed of a pump drive of
    the pump.

14. The pump arrangement according to claim 13, compris-
    ing a pressure control device adapted to detect the outlet
    pressure and to control the bypass valve so that a predeter-
    mined maximum outlet pressure is not exceeded, wherein the
    cavitation limit control device is prioritized over the pressure
    control device.

15. An air separation plant comprising at least one pump
    arrangement including:
    at least one cryogenic pump having a pump drive;
    a reservoir providing fluid to be delivered on an inlet side
    of the at least one cryogenic pump;
    a bypass line having a bypass valve for routing fluid from
    an outlet side of the at least one cryogenic pump to the
    reservoir; and
    a control device adapted to ramp up the pump drive of the
    at least one cryogenic pump to a predetermined target
    rotational speed as a function of operating specifications
    for an air separation process, and to control the bypass
    valve for reducing a volume flow through the at least one
    cryogenic pump so that the volume flow, at a respective
delivery height, lies between a cavitation volume flow
and the cavitation volume flow increased by a predetermined maximum deviation of the volume flow.