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Method and Apparatus for Filling a Pressure Tank with a Fluid

The present invention relates to a method and an apparatus for filling a pressure tank with a fluid.

Such methods and apparatus are known, for example, in systems for coating substrates, such as CDs.

With these systems, a lacquer that is disposed in a pressure tank is moved via a riser to a coating station by the pressure that is in the pressure tank. At the coating station, the lacquer is applied to the CDs that are to be coated by means of an outlet or discharge valve. In this connection, for a uniform and continuous coating of these CDs it is important that the pressure of the lacquer that is to be dispensed at the outlet valve preferably has a constant predetermined value.

With the heretofore known systems, however, such a uniform and a continuous coating of these CDs was not possible during the filling or refilling of the pressure tank with lacquer, so that the coating process had to be interrupted during the refilling process. During the filling or refilling of the pressure tank with lacquer, the pressure tank was relieved to ambient pressure and the lacquer was then introduced into the tank via a fill opening. However, with this procedure undesired interruptions of the coating processes, as well as a high consumption of nitrogen, which is generally utilized to bring the pressure tank back to the desired pressure after the filling process result.

US-A-3,893,625 discloses a system according to which a fluid is conducted out of a pressure tank and is returned via a return tank into the pressure tank. The return tank and the pressure tank are interconnected via a fluid line as well as a gas line. During



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operation of the apparatus, the pressure tank, which is filled with fluid, is first pressurized via an appropriate control unit. This pressure then causes the fluid in the pressure tank to be conducted out and to be conveyed to a coating station. Fluid that is not needed is conveyed in a suitable manner to a collection tank and is subsequently conveyed into the return tank. After a certain filling state has been reached in the return tank, the connection to the collection tank is interrupted and subsequently essentially simultaneously the fluid line, as well as the gas line, are opened to the pressure tank. By opening the gas line between the pressure tank and the return tank, a pressure equalization is achieved between the two tanks. Since the return tank is disposed above the pressure tank, the fluid in the return tank now flows into the pressure tank. The fluid line and the gas line are subsequently closed.

It is therefore an object of the present invention to enable filling of a pressure tank with a fluid without the necessity for interrupting the use of the pressure tank.

The stated object is inventively realized by a method according to claim 1 or an apparatus according to claim 6. In a method for filling a pressure tank, with a fluid from a refill tank that is disposed higher than the pressure tank whereby the tanks are interconnected by a gas connecting line and a fluid feed line, and the following steps are provided, regulating i.e. controlling in a closed loop the pressure in the pressure tank, via a proportional valve that is disposed in a gas inlet line of the pressure tank, while the connecting lines to the refill tank are closed, by regulating the pressure in the refill tank to the pressure in the pressure tank, and by opening the connecting line between refill tank and the pressure tank. By regulating the pressure in the refill tank to the pressure in the pressure tank it is possible to fill the pressure tank with fluid without having to first relieve the pressure therein. Furthermore, the pressure conditions within the pressure tank are not changed by the filling process, since the same pressure exists in both tanks,

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so that the function and the use of the pressure tank are not adversely affected. Since the refill tank is disposed higher than the pressure tank, there is a hydrostatic pressure difference that causes the fluid to run into the pressure tank without thereby changing the gas pressure within the pressure tank. By closing the gas inlet line between the proportional valve and the pressure tank, during the regulation of the pressure in the refill tank to the pressure in the pressure tank via the proportional valve there results the advantage that for the regulation of the pressure in the refill tank the same components are used as for the regulation of the pressure tank without thereby adversely affecting the pressure in the pressure tank. Although a readjustment of the pressure in the pressure tank is not possible during the regulation of the pressure in the refill tank, a critical pressure change within the pressure tank that limits the function of the pressure tank lasts longer than does the regulation of the pressure in the refill tank to the pressure in the pressure tank. After reaching the same pressure in the refill tank, the gas inlet line can again be opened, so that no adverse impact upon the system occurs as a result of the brief closing. By separating the outlet line and the fluid feed line it is possible to convey fluid out of the pressure tank in a controlled manner even during the filling process, since the pressure in the outlet line is essentially not changed.

The pressure in the pressure tank is advantageously adjusted to a desired pressure value that is determined as a function of measurement results of a first pressure sensor that is disposed in an outlet line of the pressure tank, in order to achieve an automatic adaptation of the system to variable disturbance factors, such as the filling height of the fluid in the tank as well as filter pressure losses of a filter that is typically disposed in the outlet line. In this connection, the desired pressure value is advantageously not altered as long as the gas inlet line between the proportional valve and the pressure tank is closed, since a readjustment of the pressure in the pressure tank at this point in time is not possible, and a change of the desired pressure value would lead to

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adjustment of the refill tank to a pressure that is different than that of the pressure tank. This would lead to undesired pressure fluctuations or changes when the connecting line between the refill tank and the pressure tank is opened.

The pressure in the gas inlet line is advantageously measured in order to provide the actual pressure that is required for a regulation of the pressure in the pressure tank or of the pressure in the refill tank. The measurement of the actual pressure tank as well as for the refill tank, as a result of which a greater precision can be achieved and the cost for an additional pressure sensor can be saved. Furthermore no dynamic line and/or filter pressure losses occur in the gas inlet line, so that a stable regulation response of the proportional valve is achieved without fluctuations.

Pursuant to a further, preferred embodiment of the invention, the desired pressure valve is determined as a function of a differential pressure sensor as long as the connecting lines between the refill tank and the pressure tank are opened; this differential pressure sensor is disposed between the gas inlet line and the outlet line of the pressure tank. By using a differential pressure sensor between the gas inlet line and the outlet line of the pressure tank, the filling state height that varies during the filling can be taken into account, and the desired pressure valve can be accordingly adjusted. Furthermore, the use of a differential pressure sensor enables an automatic indication when the filling process is concluded.

An apparatus for filling a pressure tank with fluid from a refill tank that is disposed higher than the pressure tank, and whereby the tanks are interconnected by a gas inlet line and a fluid feed line, comprises in accordance with the invention a proportional valve in the gas inlet line to introduce a pressurized gas into the pressure tank and/or into the refill tank, a first valve that is disposed between the proportional valve and the pressure tank and outside a connection between the proportional valve

and the refill tank, a second valve that is disposed between the proportional valve and the refill tank, and outside a connection between the proportional valve and the pressure tank, and a third valve that is disposed in the fluid feed line. Such an apparatus again makes it possible to bring the pressure within the refill tank to the same pressure that exists in the pressure tank without thereby affecting the pressure in the pressure tank. Subsequently, a connection can be established between the refill tank and the pressure tank, so that the fluid that is in a refill tank can flow into the pressure tank due to a hydrostatic pressure difference, without altering the gas pressure conditions in the pressure tank. Again, the advantages mentioned in conjunction with the method result.

Preferably provided in an outlet line of the pressure tank is a first pressure sensor, which is in communication with a control unit that with the aid of the measurement results of the pressure sensor determines a desired pressure value for the proportional valve. As already indicated previously, this enables an adaptation of the system to variable disturbance factors, such as tank filling state and filter pressure losses. The apparatus preferably has a second pressure sensor that is disposed in the gas inlet line in order to provide an actual pressure value for a regulation of the proportional valve, which value is not influenced by dynamic line and filter pressure losses.

The apparatus is preferably provided with a differential pressure sensor between the gas inlet line and the outlet line in order during the filling of the

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pressure tank with the fluid to enable an automatic adaptation of the system parameters to the changing tank filling height.

Pursuant to a further, preferred embodiment of the invention, the refill tank can be connected via coupling elements to the gas inlet line and to the fluid refill line. This makes it possible to fill the refill tank remote from the pressure tank, and in addition the refill tank can be used for the sequential filling of a plurality of pressure tanks. In this connection, the coupling elements are advantageously provided with sensors that provide an automatic indication when the coupling elements are closed. Pursuant to one embodiment of the present invention, the second and the third valves can be automatically closed by release of the coupling elements in order not to adversely affect the system of the pressure tank in the event that the coupling elements are inadvertently released. The coupling elements are preferably quick or snap-type couplings.

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The present invention will be explained subsequently with the aid of a preferred specific embodiment with reference to the drawings; in the drawings:

- Fig. 1 shows an inventive apparatus for filling a pressure tank with a fluid;
- Fig. 2 shows an alternative form of the apparatus for filling the pressure tank with a fluid;
- Fig. 3 shows a flow diagram for the operating sequence of a refilling process.

Figure 1 shows a lacquering or coating system 1 for CD's. The coating system 1 is provided with a pressure tank 4 having a gas inlet line 5, an outlet line 6, and a fluid feed line 7. The gas inlet line opens into an upper region of the pressure tank 4, while the outlet line 6 and the fluid feed line 7 extend into a lower region of the pressure tank and open into this region. The pressure tank 4 is partially filled with a lacquer or coating material 8 for coating the CD's. Due to the weight of the lacquer 8, it fills a lower portion of the pressure tank 4. In the region located above the lacquer, there is disposed a pressurized gas 10, such as nitrogen.

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The pressure tank 4 is filled with the nitrogen 10 from a nitrogen supply 12 which communicates with the inlet line 5. A valve unit 14 having a proportional valve 15 and an internal pressure sensor 16, which is disposed between the proportional valve 15 and the pressure tank 4, is located in the inlet line 5 between the nitrogen supply 12 and the pressure tank 4.

A valve 17 for closing and opening the gas inlet line 5 is provided in said line between the valve unit 14 and the pressure tank 4.

A differential pressure sensor 18 is provided next to the upper side of the pressure tank 4 between the inlet line 5 and the outlet line 6, and is adapted to measure the pressure difference between the two lines.

Disposed in the outlet line 6, downstream from the differential pressure sensor 18, as viewed in the direction from the pressure tank 4, is a filter 22 as well as a pressure sensor 24 that is in communication with the outlet line 6, and an outlet or discharge valve 26. Downstream of the valve 26 (as seen from the pressure tank 4), the outlet line 6 opens into a coating station 28 in which CD's are supplied with the lacquer 8 when the valve 26 is opened.

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Provided in the gas inlet line 5 is a further valve 30, which is embodied as a one/two way valve and which is not disposed in a direct connection between the valve unit 14 and the pressure tank 4. Rather, the valve 30 is disposed in a portion of the gas inlet line 5 that ends in a coupling element of a quick or snap-type coupling 32. The valve 30 is adapted to either connect the coupling end of the gas inlet line 5 with the valve unit or to terminate this connection and to connect the coupling end of the gas inlet line 5 with the atmosphere.

By means of the snap-type coupling 32, the gas inlet line can be coupled to a connecting line 35 which communicates with a refill tank 36. The refill tank 36 is filled with lacquer 8, and can be supplied with pressurized gas via the gas inlet line 5 and the connecting line 35, whereby the connecting line 35 opens into an upper region of the refill tank 36.

The pressure tank 36 is disposed on a rolling carriage 38, with which it can be transported. The refill tank 36 is disposed higher than the pressure tank 4.

The refill tank 36 is provided with a fluid outlet line 40 that ends in a coupling element of a quick or snap-type coupling 42, whereby the

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outlet line can be connected via the snap-type coupling 42 with an end of the fluid feed line 7 that is remote from the pressure tank 4. A valve 44 for opening and closing the fluid feed line 7 is provided therein between the snap-type coupling 42 and the pressure tank 4.

The coating system is provided with a control unit 45 that is connected to various components of the coating system and communicates with them. To simplify the illustration, a plurality of blocks are provided in Figure 1 that are designated SW, each of which represents the control unit 45.

The rolling carriage 38 can be connected with the control unit 45 by means of a quick or snap-type coupling 47 in order to provide an indication when the refill tank is properly coupled to the coating system 1.

An input terminal 48 is provided for the control unit 45 in order to be able to input, for example, a desired pressure value.

The control unit 45 is connected to the internal pressure sensor 16 of the valve unit 14 and receives therefrom the pressure p_{int} measured in the gas inlet line 5. From the differential pressure sensor 18, the control unit 45 receives a differential pressure value Δp on the basis of the measured pressure difference between the gas inlet line 5 and the outlet line 6. From the pressure sensor 24, the control unit 45 receives a pressure value p_{ext} measured in the outlet line 6.

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From the measured pressure values as well as from the desired pressure value prescribed via the input terminal 48, the control unit 45 determines a corrected desired pressure value $p_{soll,korr}$, which it conveys to the proportional valve 15 of the valve unit 14 for regulating the pressure in the gas inlet line 5. The pressure p_{int} measured in the gas inlet line 5 is also conveyed from the pressure sensor 16 as an actual pressure to the proportional valve 15 for regulating the same.

The determination of the corrected desired pressure value $p_{soll,korr}$ is described in detail in applicant's application filed on the same day and having the title "Method and Apparatus for Dispensing a Fluid from a Pressure Tank". To avoid repetition, such application is incorporated by reference herein to the extent pertinent to the present subject matter.

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By means of suitable connections, the control unit 45 controls the opening and closing of the valves 17, 26, 30, and 44.

Figure 2 similarly schematically shows a coating system 1 for CD's. In Figure 2, the same reference numerals are used as in Figure 1 to describe the same or equivalent components.

To avoid repetition, with reference to Figure 2 only the differences between the two figures will be described.

Instead of a one/two way valve 30 as is provided in Figure 1, in the system of Figure 2, two separate valves 50, 51 are used that are alternately switched in order to connect the coupling end portion of the gas inlet line 5, via the valve 50, with the remainder of the gas inlet line 5, or to vent the line to atmosphere via the valve 51.

The control unit 45 has an input portion 45 into which pressure values of the internal pressure sensor 16 of the differential pressure sensor 18 and of the pressure sensor 24 are introduced. The control unit 45 is furthermore provided with a processing unit 55 in which various control parameters are calculated. By means of an output unit 56, the control unit 45 controls the opening and closing of the various valves 17, 26,

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44, 50, and 51. In addition, a desired pressure value $p_{\text{soll,korr}}$ is prescribed via the control unit 56 to the valve unit 14, in particular to the proportional valve 15; the desired pressure value is determined with the aid of the introduced pressure values of the internal pressure sensor 16, of the differential pressure sensor 18 and of the pressure sensor 24.

The operation of the coating system 1 will now be described with the aid of the flow diagram of Figure 3. In a starting position of the system illustrated by the block 60, the valve 44 is closed and the valve 30 to the atmosphere is opened, or the valve 50 is closed and the valve 51 is opened. The refill tank is not connected to the coating system 1. The valve 17 is opened, and a coating of the CD's located in the coating station 28 is effected by opening and closing the valve 26, whereby the lacquer disposed in the pressure tank 4 is pressed to the coating station 28 by the pressure in the pressure tank 4. With regard to the operating sequence of the coating, and the regulation of the pressure within the system, in order to avoid repetition reference is again made to the aforementioned application having the title "Method and Apparatus for Dispensing a Fluid from a Pressure Tank", which is incorporated by reference to the extent relevant to the subject matter of the present application.

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If it is established that the level of the lacquer 8 in the pressure tank 4 has dropped to a level that requires a refilling of the lacquer 8, in block 62 a refill tank 36 that is filled with lacquer 8 is connected via the snap-type couplings 32, 42 with the ends of the gas inlet line 5 and of the fluid feed line 7. In this connection, the snap-type couplings 32, 42 are provided with capacitance sensors in order to immediately provide an indication and if necessary to provide a closing of the valves 30 or 50 and 44 in the event that the snap-type couplings have been inadvertently uncoupled.

Subsequently, in a block 64 the valve 17 is closed so that the pressure tank 4 is isolated relative to the valve unit 14. At the same time, within the control unit 45 the determination of the corrected desired pressure value $p_{\text{soll,korr}}$ is interrupted and the input terminal 48 is blocked in order to prevent an input of a changed desired pressure value. Despite the interrupted gas supply, the pressure is maintained in the pressure tank 4 without a readjustment being possible at this point in time. The coating processes of CDs in the coating station 28 are nonetheless continued, since the pressure in the pressure tank does not drop to a point to where readjustment would be required until after approximately fifty dispensing cycles.

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In block 66, the valve 30 or the valve 50 is opened, and the valve 51 is closed in order to provide a connection between the valve unit 14 and the refill tank 36 via the gas inlet line 5 and the connecting line 35. Subsequently, the pressure in the refill tank 36 is regulated to the last desired pressure value $p_{\text{soll,korr}}$ determined prior to closing of the valve 17.

When this pressure is reached, in block 68 the valve 17 is again opened. A simultaneous regulation of the pressure in the pressure tank 4 and in the refill tank 36 is now effected via the valve unit 14. Minimal pressure differences that resulted due to the fact that no readjustment of the pressure in the pressure tank took place as long as the valve 17 was closed, are compensated for without adversely affecting the system. At this point in time, the determination of a corrected desired pressure value $p_{\text{soll,korr}}$ is again undertaken.

Subsequently, in block 70, the valve 44 in the fluid feed line 7 is opened. Due to the hydrostatic pressure difference between the lacquer 8 in the refill tank 36 and the lacquer 8 in the pressure tank 4, the lacquer flows from the refill tank 36 into the pressure tank 4. Due to the thereby changing filling height of the lacquer 8 in the pressure tank 4, the corrected desired pressure value is determined during this phase only as a function of the measurement results of the differential pressure sensor 18, since the latter provides a sensitive indication for the changing tank filling height. Thus, the system can be adapted to the changing filling height.

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In block 72, with the aid of measurement results from the differential pressure sensor 18, the conclusion of the filling process is determined. The conclusion of the filling process is recognized in that the following equation is fulfilled:

$$d(\Delta p)/dt = 0$$

In other words, the change of the differential pressure at the differential pressure sensor becomes 0, which indicates that no more lacquer is being refilled and there is thus no longer any change in the filling heights.

If it is determined that the conclusion of the tank filling has not yet been achieved, in block 74 the valve 44 is kept open and the corrected desired pressure value $p_{\text{soll,korr}}$ continues to be adapted via the differential pressure Δp . As long as the conclusion of the tank filling is not achieved, this state is maintained. In the event that the conclusion of the tank filling is not achieved in a specified period of time that is longer than the normal duration for a filling process, the system can

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provide a warning signal, thereby indicating a failure during the filling of the pressure tank 4.

If the conclusion of the tank filling is achieved within the time period, in a block 76 the valve 44 is closed. Subsequently, in the block 78, the valve 17 is first closed and then either the one/two way valve 30 (pursuant to Figure 1) is set to a venting position, or (pursuant to Figure 2) the valve 50 is closed and the valve 51 is opened. During this changeover, the valve 17 is to remain closed in order to isolate the pressure tank from pressure surges that might occur within the gas inlet line 5. It may be necessary after the changeover of the valve 30, or the valves 50 and 51, to readjust the pressure within the gas inlet line 5. The valve 17 is subsequently again opened, and the control unit 45 again changes to normal determination of the corrected desired value $p_{soll,korr}$.

The control unit 45 subsequently again changes to the normal determination of the corrected desired pressure value $p_{soll,korr}$.

Subsequently, the refill tank 36 is uncoupled in the block 80.

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The invention has been described above with the aid of preferred specific embodiments without, however, being limited thereto. For example, it is not necessary to uncouple the refill tank 36; rather. It could also remain stationary and be permanently connected with the gas inlet line 5 or the fluid feed line 7.

Patent Claims

1. Method of filling a pressure tank (4), which is provided with an outlet line (6), with a fluid (8) from a refill tank (36) that is disposed higher, whereby the tanks are interconnected via a gas connecting line (35) and a fluid feed line (7), having the following method steps:
 - Regulating or controlling the pressure in the pressure tank (4) with a pressurized gas from a pressurized gas source (12) via a proportional valve (15) that is disposed in a gas inlet line (5) that communicates with a gas connecting line (35), while the gas connecting line (35) and the fluid feed line (7) are closed to the refill tank (36);
 - Closing the gas inlet line (5) between the proportional valve (15) and the pressure tank (4).
 - Regulating the pressure in the refill tank (36) to the pressure in the pressure tank (4) via the proportional valve (15); and
 - Opening the gas connecting line (35) and the fluid feed line (7) between the refill tank (36) and the pressure tank (4).
2. Method according to claim 1, characterized in that the pressure in the pressure tank (4) is regulating to a desired pressure value ($p_{\text{solI,korr}}$) that is determined as a function of measurement results

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- of a first pressure sensor (24) that is disposed in an outlet line (6) of the pressure tank (4).
3. Method according to claim 2, characterized in that the desired pressure value ($p_{soll,korr}$) is not changed as long as the gas inlet line (5) between the proportional valve (15) and the pressure tank (4) is closed.
 4. Method according to one of the preceding claims, characterized in that the desired pressure value ($p_{soll,korr}$), as long as the connecting lines between the refill tank (36) and the pressure tank (4) are open, is determined as a function of the measurement results of a differential pressure sensor (18) that is disposed between the gas inlet line (5) and the outlet line (6) of the pressure tank (4).
 5. Method according to one of the preceding claims, characterized by measuring the pressure in the gas inlet line (5).
 6. Apparatus for filling a pressure tank with a fluid (8), including
 - A pressure tank (4) having an outlet line (5);
 - A refill tank (36) that is disposed higher and that is connected with the pressure tank via a gas connecting line (35) and a fluid feed line (7);
 - A pressurized gas supply (12);
 - A proportional valve (15) in a gas inlet line (5) that communicates with the gas connecting line (35) for the

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introduction of a pressurized gas (10) from the pressurized gas supply into the pressure tank (4) and/or into the refill tank (36);

- A first valve (17), which is disposed between the proportional valve (15) and the pressure tank (4) and outside a connection between the proportional valve (15) and the refill tank (36);
 - A second valve (30;50), which is disposed between the proportional valve (15) and the refill tank (36) and outside a connection between the proportional valve (15) and the pressure tank (4);
 - A third valve (44), which is disposed in the fluid feed line (7).
7. Apparatus according to claim 6, characterized by a first pressure sensor (24) in an outlet line of the pressure tank (4), which is in communication with a control unit (45) that with the aid of the measurement results of the first pressure sensor (24) determines a desired pressure value ($p_{soll,korr}$) for the proportional valve (15).
8. Apparatus according to one of the claims 6 or 7, characterized by a second pressure sensor (16) which is disposed in the gas inlet line (5).

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9. Apparatus according to one of the claims 6 to 8, characterized by a differential pressure sensor (18), which is disposed between the gas inlet line (5) and the outlet line (6).
10. Apparatus according to one of the claims 6 to 9, characterized in that the refill tank (36) can be connected via coupling elements (32,42) with the gas inlet line (5) and the fluid refill line (7).
11. Apparatus according to claim 10, characterized in that the coupling elements (32,42) are provided with sensors.
12. Apparatus according to claim 10 or 11, characterized in that the second and third valves (30;50,44) can be automatically closed by release of the coupling element (32,42).
13. Apparatus according to one of the claims 10 to 12, characterized in that the coupling elements (32,42) are quick or snap-type couplings.