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(54) Benævnelse: **FREMGANGSMÅDE OG SYSTEM TIL TEMPERATURSTYRET DISPENSERING AF GAS**

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DESCRIPTION

BACKGROUND

[0001] The present invention relates to a method and system for dispensing a compressed gas into a receiving vessel, and more specifically to a method and system for dispensing a compressed gas as in particular hydrogen into a receiving vessel, such as a vehicle fuel tank, rapidly but nevertheless safely.

[0002] When dispensing a compressed gas into a receiving vessel, care has to be taken that the receiving vessel does not overheat. Overheating may occur as a result of adiabatic compression of the gas. If the gas is hydrogen or helium, the reverse Joule-Thompson effect will also contribute in heating the vessel. Gas filling protocols, in particular hydrogen fueling protocols, that are most commonly in use are based on worst case assumptions when selecting appropriate filling rates. Since receiving vessels seldom have worst case properties, and vessel conditions are seldom worst case conditions, and therefore the commonly used protocols are often excessively conservative and result in prolonged time for dispensing the compressed gas.

[0003] U.S. Pat. No. 6,619,336 (Cohen et al.) improves the dispensing operation in that the pressure and temperature are determined and the density of the gas in the receiving vessel is calculated therefrom. This actual density is compared with a vessel-rated density to control the flow of the compressed gas in response to the comparison. If the actual density in the receiving vessel is greater than or equal to the rated density, minus a tolerance, gas flow is halted, and either resumed, if the actual density should have fallen below the rated density within a predetermined time interval, or terminated.

[0004] U.S. Pat. No. 7,178,565 (Eichelberger et al.) incorporates the ambient temperature to mitigate overheating the receiving vessel. Depending on the ambient temperature one of several predetermined rates of pressure rise, i.e. a pressure ramp rate, in the receiving vessel is selected. Furthermore, a temperature indicative for the temperature of the gas in the receiving vessel is measured during filling. The ramp rate is maintained at the selected value until the measured temperature reaches a preset upper limit. Upon reaching this temperature limit, an electronic controller commands a pressure control valve to temporarily pause at the instantaneous pressure level. The pause remains in effect until the instantaneous temperature at the receiving vessel has dropped to a predetermined value below the set temperature, at which time the pressure ramp rate is increased to its former high dispensing rate.

[0005] Start/stop methods, however, confuse the customer each time the dispensing process stops and restarts.

[0006] US 2007/0079892 A1 (Cohen et al.) discloses controlling the flow rate of the compressed gas by means of a pipe organ style flow control device composed of a plurality of fluid conveyance lines in parallel with each other and having differing orifice coefficients for transmitting gas at different flow rates therethrough. Each of the fluid conveyance lines can be opened and closed by means of a respective control valve commanded by a programmable flow controller including a desired ramp rate. A pressure monitor downstream of the fluid conveyance lines measures the pressure of gas being directed into the receiving vessel. The flow controller compares the desired pressure ramp rate with the measured pressure and controls the flow rate of gas through the fluid conveyance lines in response to the comparison. Monitoring temperature is not disclosed.

[0007] US 2013/0014854 A1 discloses dispensing of a compressed gas into a receiving tank at a flow rate according to a prescribed filling flow map and proposes to reduce a prescribed flow rate if an abnormality is determined with respect to a temperature sensor installed inside the receiving tank. Occurance of an abnormality is determined if a difference of a temperature between a supply temperature and a tank temperature becomes equal to or exceeds a predetermined threshold temperature. JP 2002-115796 A discloses a method and a system according to the preamble of the claims 1 and 9.

[0008] It is an object of the present invention to provide a method and system for dispensing a gas into a receiving vessel in a safe and time efficient manner.

[0009] It is desirable to dispense gas into the receiving vessel as quickly as possible, without violating the vessel temperature limit, which typically is 85°C for vehicle fuel tanks.

[0010] A further object is to smooth out the dispensing process, i.e. to dispense gas into the receiving vessel at a dispensing rate which is steadier than with the conventional methods and systems, so that the customer experiences consistent flow rates and sounds during the dispensing process.

[0011] There is also a need for a method and system for dispensing a compressed gas, in particular hydrogen, into the fuel tank of a combustion engine or fuel cell vehicle in a time efficient manner without overheating the fuel tank.

BRIEF SUMMARY

[0012] The present invention accomplishes rapid dispensing of compressed gas into a receiving vessel by prescribing a target temperature profile for the receiving vessel and regulating the flow rate of the compressed gas such that the temperature profile that the receiving vessel undergoes during dispensing conforms to the prescribed target temperature profile. Overheating the receiving vessel is safely prevented, since by conforming or matching the temperature profiles, the maximum temperature limit is avoided. In contrast to known dispensing methods and systems the invention focuses on a critical process variable, namely temperature, and prescribes a temperature profile in terms of this variable and regulates dispensing of the compressed gas to conform or match, i.e. to approach or achieve the desired target temperature profile.

[0013] Subject of the invention is a method of dispensing compressed gas into a receiving vessel which employs a system comprising a supply of compressed gas, a fluid conveyance for operatively connecting the supply of compressed gas to the receiving vessel, a flow control device capable of varying the flow rate of compressed gas through the fluid conveyance, and a flow controller for controlling the flow control device. The method includes at least the steps of:

1. (a) passing compressed gas from the supply through the fluid conveyance into the receiving vessel,
2. (b) providing a target temperature from a target temperature profile for the receiving vessel, the target temperature profile for the receiving vessel providing target temperatures during dispensing,
3. (c) determining an apparent temperature which is representative for an instantaneous temperature of the receiving vessel,
4. (d) determining a deviation between the apparent temperature and the target temperature from the target temperature profile,
5. (e) varying the flow rate of compressed gas during dispensing by means of the flow control device in response to the deviation to conform an apparent temperature profile of the receiving vessel to the target temperature profile and
6. (f) repeating steps (b) to (e) during dispensing, i.e. while passing the compressed gas into the receiving vessel, wherein the apparent temperature profile is produced from the apparent temperatures.

[0014] Also a subject of the invention is a system for dispensing a compressed gas into a receiving vessel, the system comprising:

1. (a) a supply of compressed gas,
2. (b) a receiving vessel,
3. (c) a fluid conveyance for operatively connecting the supply to the receiving vessel,
4. (d) a flow control device capable of varying the flow rate of compressed gas through the fluid conveyance,
5. (e) a temperature sensor for determining apparent temperatures for the receiving vessel and generating temperature signals based on the apparent temperatures, and
6. (f) a flow controller for controlling the flow control device responsive to the temperature signals from the temperature sensor,
7. (g) wherein the flow controller is configured to store a target temperature profile for the receiving vessel, the target temperature profile for the receiving vessel providing target temperatures during dispensing,
8. (h) wherein the flow controller is configured to calculate, successively during dispensing, deviations between the apparent temperatures and associated target temperatures from the target temperature profile,

9. (i) and wherein the flow controller is configured to command the flow control device to vary the flow rate of compressed gas in response to the deviations to conform an apparent temperature profile of the receiving vessel based on the apparent temperatures to the target temperature profile.

[0015] The invention provides a feedback control wherein the target temperature of the target temperature profile is a reference variable and an apparent temperature representative for an instantaneous temperature of the receiving vessel is a controlled process variable, and the flow controller determines a deviation between the reference variable and the controlled variable and creates an actuating or correcting variable for the flow control device in order to decrease the deviation.

[0016] The target temperature profile for the receiving vessel comprises a series of target temperatures. The target temperature profile is provided as a path of target temperatures versus pressure and/or elapsed dispensing time. The target temperature profile increases from a starting target temperature to a final target temperature. It can be linear or based on a model of vessel heating. The target temperature (as the ordinate variable) increases preferably along a path concave with respect to the abscissa variable, e.g. as a function of pressure and/or elapsed dispensing time.

[0017] The starting target temperature can be derived from or may coincide with an apparent temperature representative for the instantaneous temperature of the receiving vessel at the time the receiving vessel is connected with the supply or before or together with starting the dispensing process. Determination of the starting target temperature can in particular be based on a measurement of a temperature. The final target temperature can be a preset upper temperature limit of the respective receiving vessel. The final target temperature may in particular be a rated maximum vessel temperature minus a safety margin. If the rated maximum temperature is, for example, 85°C, which is a typical rated maximum temperature of a land vehicle fuel gas tank, the final target temperature would be lower than 85°C and might be selected within a range, for example, between 80 and 84 °C. The system may have the capability to identify the respective receiving vessel and select the final target temperature appropriately adapted to the respective receiving vessel. In typical applications however, the receiving vessels to be filled have the same or almost the same rated maximum vessel temperature, and the final target temperature can be identical for all of these vessels.

[0018] The target temperature profile may be provided by means of an equation for the target temperature. It can in particular be generated based on a process variable of the dispensing process and determined real-time during dispensing. The target temperature may be predetermined over one or more first sections of the path and generated as a function of a process variable over one or more second sections of the path.

[0019] Pressure is an expedient choice of a process variable to base the vessel temperature profile on. Subject-matter of the invention is accordingly a pressure-based embodiment in which the target temperature is provided as a function of an apparent pressure, which is representative for the instantaneous pressure of the gas in the receiving vessel and may be derived by pressure measurement. A method in which the profile is generated over at least a part of the dispensing process, preferably over the complete dispensing process, may accordingly include the steps of:

1. (a) passing compressed gas from the supply through the fluid conveyance into the receiving vessel,
2. (b) determining an apparent pressure representative for an instantaneous pressure of the gas in the receiving vessel,
3. (c) generating a target temperature as a function of the apparent pressure,
4. (d) determining an apparent temperature representative for an instantaneous temperature of the receiving vessel,
5. (e) determining a deviation between the apparent temperature and the target temperature,
6. (f) varying the flow of compressed gas by means of the control device in response to the deviation to conform the apparent temperature profile of the receiving vessel to the target temperature profile,
7. (g) and repeating steps (b) to (f) during the dispensing process.

[0020] The target temperature profile can in a mixed mode be provided as a function of both pressure and elapsed dispensing time. In the mixed mode the dispensing process can comprise one or more first time intervals and one or more second time intervals and the target temperature provided as a function only of time over the one or more first time intervals and as a function only of pressure over the one or more second time intervals. In a variant of the mixed mode the target temperature profile is provided as a function of time over the complete dispensing process or only part of the dispensing process but verified by one or more pressure checks during dispensing. The time dependent function may be altered subject to those pressure checks. In a further variant of the mixed mode a function describing the target temperature profile contains a pressure dependent term and a time dependent term, for example as additive terms.

[0021] The steps to be repeated are repeated at least once, i.e. are performed at least twice during the dispensing process. Preferably the respective steps are repeated more than once during the dispensing process in order to shorten the time required for dispensing the compressed gas. The more frequently the respective cycle is passed through, the more the dispensing process can be shortened. If one divides the time required to fill the receiving vessel, t_{total}, to a desired final pressure in a number n of equal time intervals, the frequency f = cycles/t_{total} at which the cycles are passed through is preferably at least 5 with $n \geq 5$, and more preferred at least 10 with $n \geq 10$, at least one cycle being performed in each of the n time intervals. Typically, the respective cycle of steps is repeated at least once per second.

[0022] The determination of the apparent temperature can in particular be based on a temperature measurement. The temperature measured can be the temperature of the compressed gas inside the receiving vessel, which requires temperature measurement inside the receiving vessel. In such embodiments a temperature sensor is in direct contact with the compressed gas. As a substitute, the temperature of a structural part of the receiving vessel, e.g. the shell of the vessel, may be measured. A temperature sensor for that purpose can be attached to or build into the respective structural vessel part, or the heat radiated by the receiving vessel can be measured. Instead of measuring a temperature in or of the receiving vessel, the temperature can be measured in or at the fluid conveyance, for example, in or at a hose of the fluid conveyance or a connection assembly by which the fluid conveyance is connected to the receiving vessel to fill the vessel and which can be disconnected from the receiving vessel once the dispensing operation is completed. The temperature can in principle be measured anywhere as long as the temperature measured is representative for the instantaneous temperature of the gas in the receiving vessel, i.e. allows to back-reference to the instantaneous temperature of the receiving vessel or the gas in the receiving vessel. However, the closer to the vessel shell or interior of the vessel the temperature is measured, the smaller the safety margin can be chosen, and the quicker the vessel can be filled.

[0023] The supply may be used to fill a plurality of interconnected receiving vessels. The supply may be connected via the fluid conveyance with a first one of the receiving vessels, the one or more further receiving vessels being filled via this first receiving vessel. More expediently, the two or more receiving vessels may be filled in parallel via a manifold. If, for example, each of the interconnected receiving vessels is equipped with a temperature sensor for sensing an apparent temperature of the respective vessel, the dispensing process is preferably based on the highest of the apparent temperatures. In such cases, the receiving vessel system, e.g. a vehicle comprising the plurality of interconnected vessels, may decide which of the different apparent temperatures is the highest and will accordingly have to be used to determine the deviation between the apparent temperature and target temperature. Alternatively, the flow controller can be adapted to receive an apparent temperature of each or selected ones of the interconnected receiving vessels, determine which of these apparent temperatures is the highest and select this temperature value for the determination of the deviation.

[0024] The deviation between the apparent temperature and the target temperature can be determined directly as the difference between the target temperature and the apparent temperature or as any other measure representative for the mathematical difference, for example as the ratio of apparent temperature to target temperature or vice versa. Since the deviation may be defined as the difference between the target temperature and the apparent temperature, the deviation may have a value of zero. The flow of the compressed gas can be regulated directly in response to the difference between the two temperature values or in response to a percentage deviation or in response to only the prefix of the difference, only to mention examples. The flow controller is adapted to control the control device accordingly.

[0025] In preferred pressure-based embodiments the apparent pressure is based on a pressure measurement. The pressure which is measured can in particular be the pressure of the gas inside the receiving vessel. Similar to the apparent temperature, however, the apparent pressure may instead be measured in or at the fluid conveyance, for example in or at a hose of the fluid conveyance or a connection assembly by which the fluid conveyance is releasably connected to the receiving vessel during the dispensing process. The apparent pressure can be used to generate the receiving vessel temperature profile, as explained earlier. In alternative pressure-based embodiments in which the target temperatures are provided versus pressure, the apparent pressure can be used to assign the respective apparent temperature to the associated target temperature of the vessel temperature profile for the determination of the temperature deviation.

[0026] The supply of compressed gas may be composed of a single source, e.g. a single compressor or more expediently a single pressurized supply vessel. The supply can however also comprise a plurality of sources of compressed gas, e.g. a plurality of compressors or a plurality of pressurized supply vessels, or a combination of at least one supply vessel and one or more compressors. The one or at least one of the plurality of supply vessels contains the gas at a pressure as high or higher than the pressure in the receiving vessel upon completion of the dispensing process, at least in embodiments which do not employ a compressor. Embodiments comprising a compressor do however not require a supply vessel, at least not a supply vessel at the site where the respective receiving vessel is filled. A compressor can for example be connected to a stationary supply line, e.g. a public or private gas distribution system, to compress the gas delivered therethrough to the pressure level required for dispensing.

[0027] A flow control valve, in particular a solenoid valve, is a suitable type of flow control device. In principal, a flow control device capable of varying the flow rate in increments will be sufficient. More suitable, however, is a control device capable of varying the flow rate of compressed gas continuously between a lower and an upper volume or mass flow rate. The flow control device can in particular be adapted to vary a flow cross-sectional area within the fluid conveyance. A fluid conveyance comprising only one conduit may comprise one or more flow control devices in that conduit, which is/are capable of varying the flow rate of compressed gas through that conduit alone or in a matched combined manner. If the fluid conveyance comprises two or more conduits in parallel to each other, one or more flow control devices can be provided in each of the conduits and commanded by the flow controller to match the target temperature profile. In principal, the flow control device can also be a variable speed and/or variable geometry compressor commanded by the flow controller such that the flow rate of compressed gas is regulated by means of the variable compressor to match the target temperature profile.

[0028] The flow controller is expediently an electronic flow controller commanding the flow control device via a wired or wireless communication. The flow controller can, in particular, be a programmable logic controller (PLC) or a computer-based controller. It can be composed of only a single unit or two or more units. If the target temperature profile is provided by some type of an input device, e.g. a computer, via a wired or wireless communication to, for example, a PLC, the combination of input device and PLC is regarded as the flow controller. A PLC or computer-based controller is preferably involved but may be replaced by a hard-wired controller.

[0029] Advantageous features are also described in the sub-claims and the combinations of the same.

$T_{target} = T_{target}(p_{110}, T_{max}, P_0, T_0, T_{target, final}, P_{target, final})$,

[0030] Claim 7 is disclosed here specifically in connection with the invention of providing a receiving vessel temperature profile and regulating the flow of the compressed gas to conform to that profile. Monitoring of the apparent temperature provides the advantage that a false temperature signal can be detected. A false temperature signal can be caused, for example, by a defective temperature sensing equipment of a receiving vessel or at the side of a receiving vessel, in particular of a vehicle including the receiving vessel, or a defective connection. Monitoring the apparent temperature may include the steps of determining a first apparent temperature in a first time interval and a second apparent temperature in a second time interval, the first apparent temperature and the second apparent temperature each being representative for an instantaneous temperature of the receiving vessel and the second time interval following the first time interval. Monitoring may furthermore include determining an apparent difference between the first apparent temperature and the second apparent temperature, and comparing the apparent difference with a vessel temperature profile forthe receiving vessel derived from a model of vessel heating, the profile or model being implemented in the controller.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0031] The invention is explained below by way of example with reference to figures. Features disclosed there, each individually and in any combination of features, advantageously develop the subjects of the claims and also the embodiments and aspects described above.

FIG. 1 shows a gas dispensing system in accordance with the invention.

FIG. 2 shows a plot of target temperature and apparent temperature together with pressure ramp rate each versus elapsed dispensing time.

FIG. 3 shows a plot of target temperature, apparent temperature, and pressure ramp rate, each versus apparent pressure.

DETAILED DESCRIPTION

[0032] The ensuing detailed description provides preferred exemplary embodiments only, and is not intended to limit the scope, applicability, or configuration of the invention. Rather, the ensuing detailed description of the preferred exemplary embodiments will provide those skilled in the art with an enabling description for implementing the preferred exemplary embodiments of the invention, it being understood that various changes may be made in the function and arrangement of elements without departing from scope of the invention as defined by the claims.

[0033] The articles "a" and "an" as used herein mean one or more when applied to any feature in embodiments of the present invention described in the specification and claims. The use of "a" and "an" does not limit the meaning to a single feature unless such a limit is specifically stated. The article "the" preceding singular or plural nouns or noun phrases denotes a particular specified feature or particular specified features and may have a singular or plural connotation depending upon the context in which it is used. The adjective "any" means one, some, or all indiscriminately of whatever quantity. The term "and/or" placed between a first entity and a second entity means one of (1) the first entity, (2) the second entity, and (3) the first entity and the second entity. The term "and/or" placed between the last two entities of a list of 3 or more entities means at least one of the entities in the list including any specific combination of entities in this list.

[0034] In the claims, letters may be used to identify claimed steps (e.g. (a), (b), and (c)). These letters are used to aid in referring to the method steps and are not intended to indicate the order in which claimed steps are performed, unless and only to the extent that such order is specifically recited in the claims.

[0035] FIG. 1 illustrates an example embodiment of a vessel filling system 100 according to the invention. The system 100 comprises a compressed gas supply 102 in the form of a supply vessel, a receiving vessel 108, and a fluid conveyance 103 operatively connecting the receiving vessel 108 to the supply 102. A heat exchanger 105 may be operatively disposed in the fluid conveyance 103 between the supply vessel 102 and the receiving vessel 108. The receiving vessel 108 is equipped with pressure and temperature sensing equipment comprising a pressure sensor 110 and a temperature sensor 112 with associated transducers. The system 100 furthermore comprises a flow control device 104 disposed in the fluid conveyance 103, and a flow controller 114 which communicates with the pressure sensor 110 and the temperature sensor 112 to receive pressure signals from the pressure sensor 110 and temperature signals from the temperature sensor 112. The fluid conveyance 103 is comprised of a single conduit. It may however comprise one or more further conduits in parallel with each other, for example, similar to the fluid conveyance disclosed in US 2007/0079892 A1. The flow control device 104 is exemplified as a flow control valve, preferably a solenoid valve. The flow control device 104 can be any type of flow control device capable of varying a flow cross-sectional area of the fluid conveyance 103 incrementally or, preferably, continuously.

[0036] The controller 114 communicates with the flow control device 104 to command the control device 104 in response to signals received from the pressure and temperature sensors

110 and 112. The control device 104 and flow controller 114 are configured to control the flow rate of the compressed gas from the supply 102 to the receiving vessel 108. The controller 114 can, in particular, be adapted to control the control device 104 and hence the gas flow rate such that the receiving vessel 108 is filled at a temperature adapted rate of pressure rise, a temperature adapted pressure ramp rate, i.e. an increase of gas pressure in the receiving vessel 108 per time unit measured in e.g. MPa/minute. The controller 114 can in particular be a PLC, capable of selecting the pressure ramp rate.

[0037] The pressure ramp rate is selected to control the temperature of the receiving vessel 108, determined by means of the temperature sensor 112, to conform to a prescribed target temperature profile i.e. a temperature rise path. The control method can be any standard control method such as feedback and/or PID control. In the example embodiment, in which an apparent temperature T_{112} can be measured by means of the temperature sensor 112, the flow rate of the compressed gas can be regulated by the controller 114 and control device 104 in a feedback control method, as desired. The temperature sensor 112 measures the temperature of the gas within the receiving vessel 108. The gas temperature can be taken directly as the apparent temperature T_{112} since it represents the temperature of critical vessel structures of the receiving vessel 108 in good approximation. The measured gas temperature can however instead be adjusted, e.g. according to a model of heat transfer between the gas and the surrounding vessel structure. Instead of measuring the gas temperature the temperature sensor 112 may in modified variants directly measure the temperature of a heat critical structure of the receiving vessel 108, and may in such variants for example be located at or in a shell structure of the vessel or measure heat radiated by the shell of the receiving vessel 108.

[0038] The temperature rise path, i.e. the target temperature profile, can be any rise path equation, based on models of vessel heating. A target temperature profile provided as a temperature rise equation can be a function of the apparent pressure P_{110} representative for the instantaneous pressure in the receiving vessel 108. The apparent pressure P_{110} is determined by means of the pressure sensor 110. The pressure sensor 110 may in particular be located such that it directly measures the pressure of the gas within the receiving vessel 108.

[0039] The target temperature profile may in particular obey the equation:

$$T_{target} = T_{target}(p_{110}) = T_{max} - X * p_{110}^{Y}$$

wherein

T_{target}

is a target temperature of the target temperature profile [°C], here $T_{target}(p)$

T_{max}

is a rated maximum vessel temperature [°C], e.g. 85°C

p_{110}

is the apparent pressure determined e.g. by measurement in the receiving vessel 108

$X = e^{(LN(J)/(H-1))}$ (unitless)

$Y = (LN(C) / X) / LN(P_{target, final})$ (unitless)

$H = LN(P_0) / LN(P_{target, final})$ (unitless)

$J = C^H/A$ (unitless)

$A = T_{max}$ - initial temperature T_0 of the receiving vessel [°C]

P_0 = initial pressure in the receiving vessel [MPa]

$C = T_{max}$ - desired final target temperature $T_{target, final}$ [°C]

$P_{target, final}$ = desired final target pressure in the receiving vessel at end of fill [MPa]

[0040] The above equation or another appropriate equation in which the target temperature profile, i.e. the target temperatures, are generated real-time during dispensing is implemented in the controller 114, either as a hard-wired circuit or preferably as a programmed routine. When the controller 114 receives the apparent pressure p_{110} and the apparent temperature T_{112}, it generates the target temperature T_{target} in accordance with the implemented temperature rise equation and compares the instantaneous pair of temperatures, namely the target temperature T_{target} and the apparent temperature T_{112}, to determine a deviation ΔT of the apparent temperature T_{110} from the target temperature T_{target}. Depending on the prefix and/or the amount of the deviation, e.g. the plain difference of the apparent temperature T_{112} from the target temperature T_{target}, the controller 114 creates an actuating variable AV to command the flow control device 104 such that the deviation ΔT is decreased. The controller 114 commands the control device 104 to decrease the flow rate of the compressed gas should the comparison reveal that the apparent temperature T_{112} is too high and commands the control device 104 such that the flow rate is increased if the apparent temperature T_{112} is too low.

[0041] The controller 114 may command the control device 104 such that the apparent temperature T_{112} is kept below the target temperature T_{target} to the extent of a certain temperature safety margin. Such a control is also regarded as "conforming" the temperature profile. If the apparent temperature is, for example, +5/-15°C from the target temperature profile, the apparent temperature profile may be considered to conform to the target temperature profile. The apparent temperature profile may more closely conform to the target temperature profile, for example, +5/-10°C or +1/-5°C from the target temperature profile. The apparent temperature profile is produced from the apparent temperatures, that is it results from the apparent temperatures of the receiving vessel during dispensing. The apparent temperature profile may comprise the apparent temperatures during dispensing or a values calculated from the apparent temperatures. The apparent temperature may be stored in computer memory, but storing of the apparent temperature profile is not required.

[0042] The rated maximum vessel temperature T_{max} will typically be a preset temperature valid for all types of vessels which can be filled by the system 100. The system 100, for example the flow controller 114, may however also be capable of identifying the rated maximum vessel temperature of the receiving vessel 108 to be filled, respectively, and select T_{max} accordingly.

[0043] The coefficients X and Y are based exclusively on preset or preselectable values and process variables which are determined only once shortly before, at, or shortly after starting to feed the compressed gas and fill the receiving vessel 108. These values and process variables are T_{max}, the initial temperature T_0 of the receiving vessel 108, the initial pressure P_0 in the receiving vessel 108, the desired final target temperature and the desired pressure in the receiving vessel 108 at the end of filling. The initial temperature T_0 can in particular be the apparent temperature T_{112} measured by means of the temperature sensor 110 shortly before, at, or shortly after starting the dispensing process. The initial pressure can be determined e.g. measured shortly before, at, or shortly after the start of feeding the compressed gas and filling the receiving vessel, and can be p_{110} at that time. The desired final target temperature is a preselected upper temperature value of the temperature profile and is a temperature value below T_{max}. The desired pressure in the receiving vessel 108 at the end of filling is a preselected upper pressure value of the receiving vessel 108. The desired pressure at the end of fill can be a preset value of the flow controller 114 or be determined by the flow controller 114 based on identification data optionally received from the receiving vessel 108, either automatically upon connection or inputted by an operator. Once T_{max} has been selected, e.g. as a preset value or as a value received from the receiving vessel 108 or from a system in which the vessel 108 is embedded as for example an automobile or truck, and the coefficients X and Y calculated, the apparent pressure p_{110} is the only variable of the temperature rise equation while filling proceeds.

EXAMPLE

[0044] FIG. 2 is a plot derived from an example dispensing process according to the invention. It is a plot of target temperature T_{target} in accordance with the above temperature rise equation, receiving vessel temperature T_{112}, and the pressure ramp rate, i.e. the rate of pressure change within the receiving vessel 108, measured in MPa per minute. On the x-axis the elapsed dispensing time is plotted in minutes and seconds, wherein 0:00.30 are 30 seconds, 0:01:00 is one minute and so forth, of elapsed time. In the example filling process the receiving vessel 108 has been filled under field conditions up to a target temperature of 60°C. The sections of the graphs belonging to temperatures above 60°C have been derived by extrapolation of the data gathered during the example dispensing process.

[0045] As can be derived from the plot, a good match is achieved by rising the ramp rate in a first phase of the filling process up to a peak and decreasing it slowly from the peak in a consecutive second phase of the filling process to a value which can be kept relatively constant during the remainder of the filling process.

[0046] In FIG. 3 the target temperature T_{target}, the apparent temperature T_{112} and the ramp rate are plotted versus the pressure within the receiving vessel 108, for which in particular the apparent pressure p_{110} can be taken. The graphs of FIG. 3 - vessel temperature, target temperature and ramp rate - represent exclusively data from the example dispensing process performed under field conditions.

REFERENCES CITED IN THE DESCRIPTION

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P A T E N T K R A V

1. Fremgangsmåde til dispensering af en komprimeret gas i en modtagebeholder (108) som anvender en forsyning (102) af komprimeret gas, en fluidtransport (103) som operativt forbinder forsyningen (102) med modtagebeholderen (108), en strømningsstyre-indretning (104) som er i stand til at variere strømningshastigheden af komprimeret gas gennem fluidtransporten (103), og en strømningsstyreanordning (114) til at styre strømningsstyreindretningen (104), hvilken fremgangsmåde omfatter trinnene:

(a) at føre komprimeret gas fra forsyningen (102) gennem fluidtransporten (103) ind i modtagebeholderen (108); og

(b) at bestemme en tilsyneladende temperatur (T_{112}) som er repræsentativ for en øjeblikkelig temperatur af modtagebeholderen (108);

k e n d e t e g n e t ved

(c) at tilvejebringe en måltemperatur ($T_{mål}$) fra en måltemperaturprofil for modtagebeholderen (108), hvor måltemperaturprofilen er tilvejebragt som en kurve af måltemperaturer i forhold til tryk, hvor måltemperaturprofilen for modtagebeholderen tilvejebringer måltemperaturer som forøges under dispensering fra en startmåltemperatur til en endelig måltemperatur;

(d) at bestemme en afvigelse mellem den tilsyneladende temperatur (T_{112}) og måltemperaturen ($T_{mål}$) fra måltemperaturprofilen;

(e) at variere strømningshastigheden af komprimeret gas under dispensering ved hjælp af strømningsstyreindretningen (104) som reaktion på afvigelsen for at tilpasse en temperaturprofil som modtagebeholderen (108) gennemgår under dispensering til måltemperaturprofilen; og

(f) at gentage trin (b) til (e) under dispenseringsfremgangsmåden;

(g) hvor strømningshastigheden af komprimeret gas varieres i trin (e) som reaktion på afvigelsen for at tilpasse en tilsyneladende temperaturprofil af modtagebeholderen til måltemperaturprofilen, hvor den tilsyneladende temperaturprofil frembringes fra de tilsyneladende temperaturer; og

(h) hvor trin (c) indbefatter at bestemme et tilsyneladende tryk (p_{110}) som er repræsentativt for det øjeblikkelige tryk i den komprimerede gas i modtagebeholderen (108), og at bestemme måltemperaturen ($T_{mål}$) ved at generere måltemperaturen som en funktion ($T_{mål}(p_{110})$) af det tilsyneladende tryk.

2. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, yderligere omfattende ét, to hvilke som helst af eller alle tre af de følgende trin (i) til (iii):

(i) trinnet at bestemme et indledende tilsyneladende tryk (P_0) som er repræsentativt for et indledende tryk i den komprimerede gas i modtagebeholderen (108) før der føres komprimeret gas ind i modtagebeholderen (108), hvor måltemperaturprofilen bestemmes afhængigt af det indledende tilsyneladende tryk (P_0),

(ii) trinnet at bestemme en indledende tilsyneladende temperatur (T_0) som er repræsentativ for en indledende temperatur i modtagebeholderen (108) før der føres komprimeret gas ind i modtagerbeholderen, hvor måltemperaturprofilen bestemmes afhængigt af den indledende tilsyneladende temperatur (T_0),

og

(iii) trinnet at tilvejebringe en maksimal temperatur (T_{maks}) som er repræsentativ for en maksimal tilladt temperatur af modtagebeholderen (108), hvor måltemperaturprofilen bestemmes afhængigt af den maksimale temperaturen (T_{maks}).

3. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor den komprimerede gas dispenseres ind i modtagebeholderen (108) ved en trykstigningshastighed og trykstigningshastigheden varieres (i) for at tilpasse temperaturprofilen af modtagebeholderen (108) til måltemperaturprofilen og/eller (ii) for at mindske afvigelsen mellem de tilsyneladende temperaturer (T_{112}) og måltemperaturerne ($T_{mål}$).

4. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor måltemperaturprofilen bestemmes afhængigt af mindst én af en ønskede endelige måltemperatur ($P_{mål,\ endelig}$) og et ønsket endeligt måltryk ($T_{mål,\ endelig}$) af den komprimerede gas i modtagebeholderen ved afslutning af dispensering.

5. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor måltemperaturprofilen er tilvejebragt som en funktion, $T_{mål} = Mål\ (p_{110}, T_{maks}, P_0, T_0, T_{mål,\ endelig}, P_{mål,\ endelig})$, hvor

p_{110} er et tilsyneladende tryk som er repræsentativt for det øjeblikkelige tryk af gassen i modtagebeholderen (108),

T_{maks} er en maksimal temperatur som er repræsentativ for en maksimal tilladt temperatur af modtagebeholderen (108),

P_0 er et indledende tilsyneladende tryk som er repræsentativt for et indledende tryk af den komprimerede gas i modtagebeholderen (108) før der føres komprimeret gas ind i modtagebeholderen (108),

T_0 er en indledende tilsyneladende temperatur som er repræsentativ for en indledende temperatur i modtagebeholderen (108) før der føres komprimeret gas ind i modtagebeholderen (108),

$T_{mål,\ endelig}$ er en ønsket endelig måltemperatur, når dispensering afsluttes, og

$P_{mål,\ endelig}$ er et ønsket endeligt måltryk, når dispensering afsluttes.

6. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor måltemperaturprofilen er tilvejebragt som en funktion af et tilsyneladende tryk (p_{110}) af den komprimerede gas i modtagebeholderen (108) som følger:

$T_{mål} = T_{mål}(p_{110}) = T_{maks} - X * p_{110}^{Y}$

hvor

p_{110} er det tilsyneladende tryk som er repræsentativt for det øjeblikkelige tryk af gassen i modtagebeholderen (108),

T_{maks} er en maksimal temperatur som er repræsentativ for en maksimal tilladt temperatur i modtagebeholderen (108), og

X, Y er koefficienter som er beregnet ud fra den maksimale temperatur (T_{maks}), et indledende tilsyneladende tryk (P_0) i modtagebeholderen (108), som er repræsentativt for et indledende tryk af den komprimerede gas i modtagebeholderen før der føres komprimeret gas ind i modtagebeholderen, en indledende tilsyneladende temperatur (T_0), som er repræsentativ for en indledende temperatur i modtagebeholderen før der føres komprimeret gas ind i modtagebeholderen, og en ønsket endelig måltemperatur ($T_{mål,\ endelig}$) når dispensering er afsluttet, og et ønsket endeligt tryk ($T_{mål,\ endelig}$) når dispensering er afsluttet.

7. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, yderligere omfattende

- trinnene at overvåge en tilsyneladende temperatur (T_{112}) som er repræsentativ for den øjeblikkelige temperatur i modtagebeholderen (108), og at oprette en alarm og/eller at afslutte påfyldningsoperationen hvis den tilsyneladende temperatur (T_{112}) ikke stiger eller ændres som forventet som dispensering skrider frem;

- eller trinnene at overvåge (i) en tilsyneladende temperatur (T_{112}) som er repræsentativ for den øjeblikkelige temperatur i modtagebeholderen (108), og (ii) et tilsyneladende tryk (p_{110}) som er repræsentativt for det øjeblikkelige tryk af gassen i modtagebeholderen (108), og at oprette en alarm og/eller at afslutte påfyldningsoperationen hvis den tilsyneladende temperatur (T_{112}) ikke stiger eller ændres som forventet når det faktiske tryk stiger (p_{110}).

8. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, yderligere omfattende trinnene

(i) at bestemme en målforskel ($\Delta T_{mål}$) mellem en første måltemperatur ($T_{mål,1}$) som er tilvejebragt i et første tidsinterval, og en anden måltemperatur ($T_{mål,2}$) som er tilvejebragt i et andet tidsinterval af påfyldningsprocessen, hvor det andet tidsinterval følger det første tidsinterval,

(ii) at bestemme en første tilsyneladende temperatur ($T_{112,1}$) i det første tidsinterval og en anden tilsyneladende temperatur ($T_{112,2}$) i det andet tidsinterval, hvor den første tilsyneladende temperatur og den anden tilsyneladende temperatur hver er repræsentativ for en øjeblikkelig temperatur af modtagebeholderen (108),

(iii) at bestemme en tilsyneladende forskel (ΔT_{112}) mellem den første tilsyneladende temperatur og den anden tilsyneladende temperatur,

(iv) at sammenligne den tilsyneladende forskel (ΔT_{112}) med målforskellen ($\Delta T_{mål}$), og

(v) at oprette alarmen og/eller afslutte påfyldningsoperationen hvis den tilsyneladende forskel (ΔT_{112}) er mindre end målforskellen ($\Delta T_{mål}$) og forholdet mellem målforskellen og den tilsyneladende forskel ($\Delta T_{mål}$ / ΔT_{112}) er større end et tærskelforhold, hvor tærskelforholdet er fortrinsvis mindst 2 (to).

9. System til dispensering af komprimeret gas ind i en modtagebeholder, hvilket system omfatter:

(a) en forsyning (102) af komprimeret gas;

(b) en modtagebeholder (108);

(c) en fluidtransport (103) til operativt at forbinde forsyningen (102) med modtagebeholderen (108);

(d) en strømningsstyreindretning (104) som er i stand til at variere strømningshastigheden af komprimeret gas gennem fluidtransporten (103);

(e) en temperatursensor (112) til detektion af tilsyneladende temperaturer (T_{112}) som er repræsentative for de øjeblikkelige temperaturer i modtagebeholderen (108), og frembringelse af temperatursignaler baseret på de tilsyneladende temperaturer (T_{112});

(f) en tryksensor (110) til detektion af tilsyneladende tryk (p_{110}) som er repræsentative for de øjeblikkelige tryk af komprimeret gas i modtagebeholderen (108), og frembringelse af tryksignaler baseret på de tilsyneladende tryk (p_{110}); og

(g) en strømningsstyreanordning (114) til styring af strømningsstyreindretningen (104) som reagerer på temperatursignalerne fra temperatursensoren (112);

(h) hvor strømningsstyreanordningen (114) er konfigureret til at lagre en måltemperaturprofil for modtagebeholderen (108), hvor måltemperaturprofilen er en kurve af måltemperaturer i forhold til tryk, hvor måltemperaturprofilen for modtagebeholderen (108) tilvejebringer måltemperaturer ($T_{mål}$) under dispensering, hvor måltemperaturerne forøges fra en starttemperatur til en endelig måltemperatur;

(i) hvor strømningsstyreanordningen (114) omfatter en generator til at bestemme måltemperaturerne ($T_{mål}$) ved at danne måltemperaturerne, efter hinanden under dispensering, som en funktion ($T_{mål}(p_{110})$) af tryksignalerne;

(j) hvor strømningsstyreanordningen (114) er konfigureret til at beregne, efter hinanden under dispensering, afvigelser mellem de tilsyneladende temperaturer (T_{112}) og de tilhørende måltemperaturer ($T_{mål}$) fra måltemperaturprofilen;

(k) og hvor strømningsstyreanordningen (114) er konfigureret til at styre strømningsstyreindretningen (104) for at variere strømningshastigheden af komprimeret gas som reaktion på afvigelserne for at tilpasse en tilsyneladende temperaturprofil af modtagebeholderen (108) baseret på de tilsyneladende temperaturer (T_{112}) til måltemperaturprofilen.

10. System ifølge det foregående krav, hvor:

strømningsstyreanordningen omfatter en datahukommelse til lagring af temperaturdata indbefattende måltemperaturerne og de tilsyneladende temperaturer ($T_{mål}$) og en komparator til bestemmelse af afvigelserne.

11. System ifølge et hvilket som helst af de foregående krav, hvor strømningsstyreanordningen (114) omfatter en komparator til bestemmelse af afvigelserne mellem de tilsyneladende temperaturer (T_{112}) and måltemperaturerne ($T_{mål}$).

12. System ifølge det foregående krav, hvor strømningsstyreanordningen (114) omfatter en datahukommelse til lagring af temperaturdata og trykdata inklusive måltemperaturen ($T_{mål}$) og det tilsyneladende tryk (p_{110}), hvor generatoren er konfigureret til at generere måltemperaturen ($T_{mål}$) i overensstemmelse med en programmeret eller fastfortrådet formel som indeholder det tilsyneladende tryk (p_{110}) som en variabel, og én eller flere koefficienter (X, Y) som hver er konstante under dispenseringsfremgangsmåden.

13. System ifølge det foregående krav,

hvor koefficienterne (X, Y) er afledt af mindst ét af et indledende tilsyneladende tryk (P_0) og en indledende tilsyneladende temperatur (T_0), hvor det indledende tilsyneladende tryk (P_0) er repræsentativt for et indledende tryk af den komprimerede gas i modtagebeholderen (108) ved eller tæt på starten af dispenseringsfremgangsmåden, og den indledende tilsyneladende temperatur (T_0) er repræsentativ for en indledende temperatur af modtagebeholderen (108) ved eller tæt på starten af dispenseringsfremgangsmåden,

og/eller hvor koefficienterne (X, Y) er afledt af mindst ét af det ønskede endelige måltryk ($P_{mål,\ endelig}$) og en ønsket endelig måltemperatur ($T_{mål,\ endelig}$), hvor det ønskede endelige måltryk er repræsentativt for trykket af den komprimerede gas i modtagerbeholderen (108) når dispensering er afsluttet, og hvor den ønskede endelige måltemperatur er repræsentativ for temperaturen af den komprimerede gas i modtagerbeholderen (108) når dispenseringen er afsluttet, hvor det ønskede endelige måltryk og/eller den ønskede endelige måltemperatur er forudbestemt som én eller flere af en forudindstillet, valgbar, og modtagelig værdi.

DRAWINGS

FIG. 1

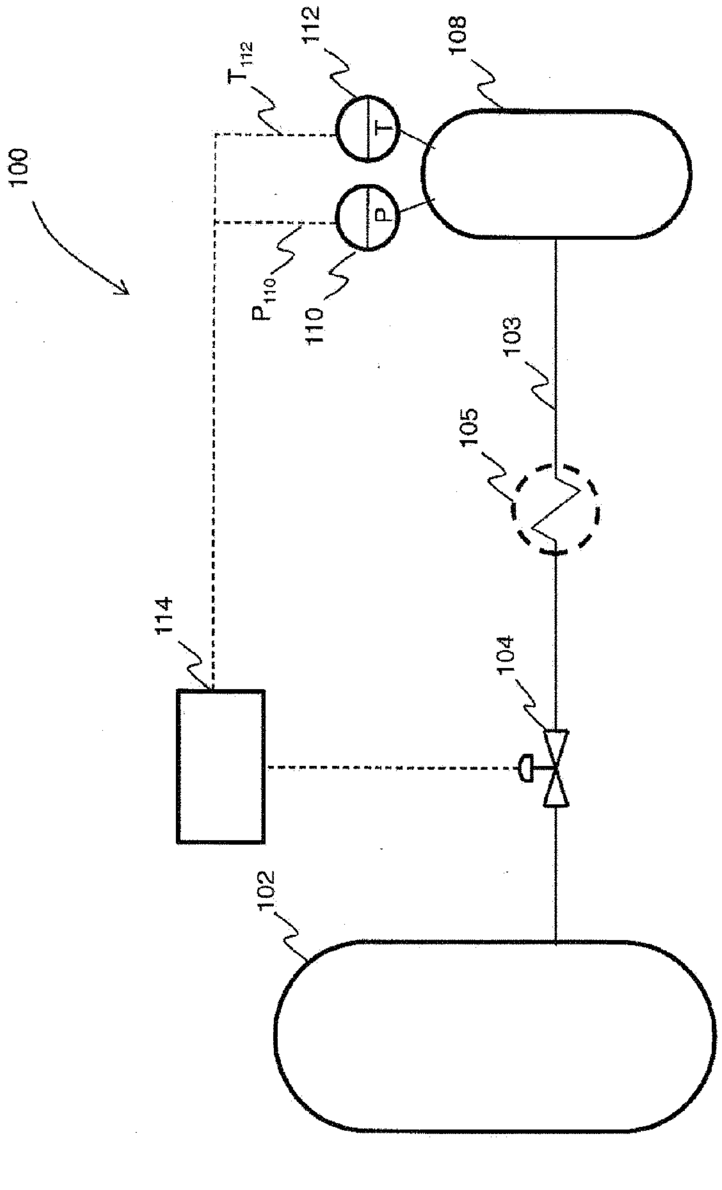


FIG. 2

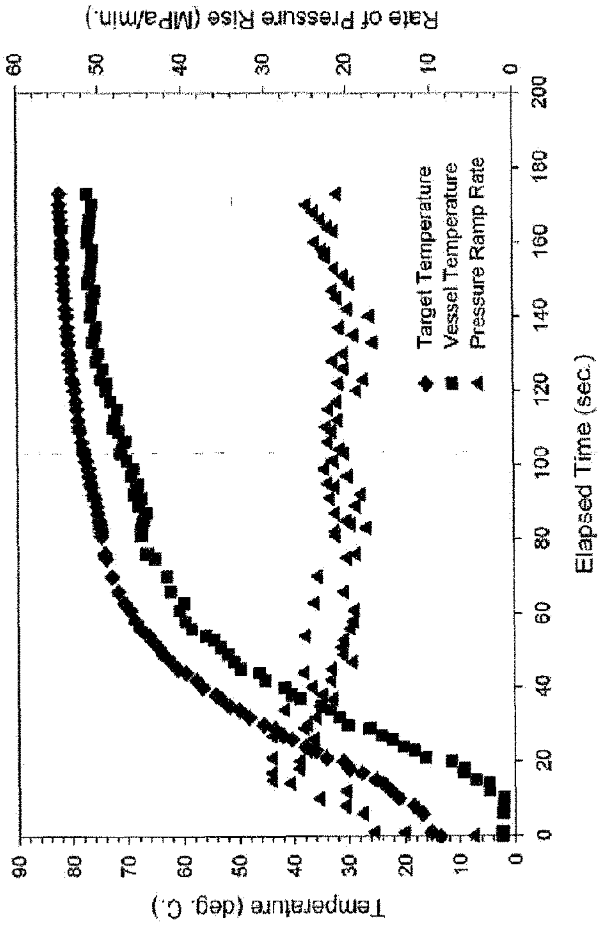
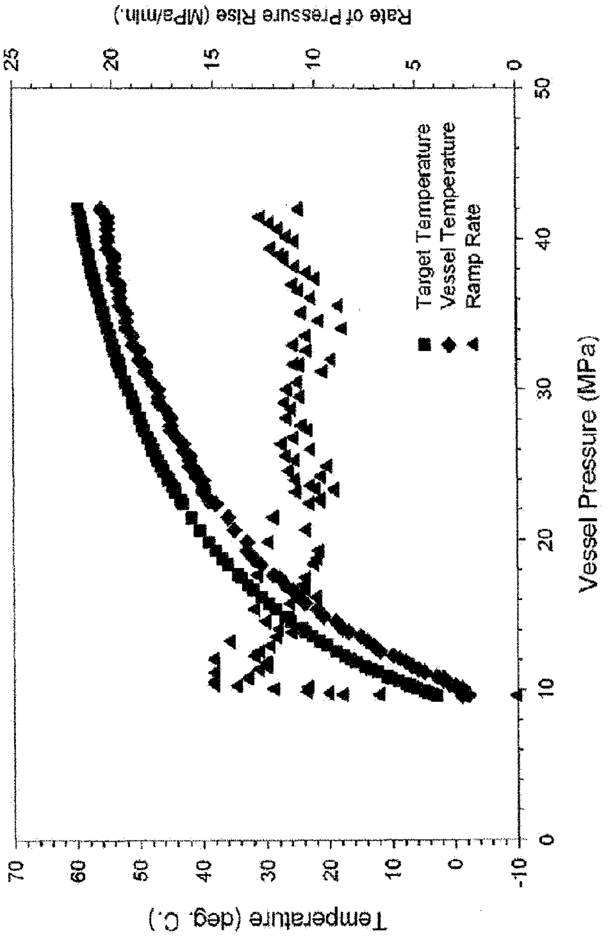

Temperature (deg. C.)
Rate of Pressure Rise (MPa/min.)
Elapsed Time (sec.)
Target Temperature
Vessel Temperature
Pressure Ramp Rate
0
10
20
30
40
50
60
70
80
90
100
120
140
160
180
200

FIG. 3


Temperature (deg. C.)
Rate of Pressure Rise (MPa/min.)
Vessel Pressure (MPa)
Target Temperature
Vessel Temperature
Ramp Rate