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(71) Applicant: **TotalEnergies OneTech**
92400 Courbevoie (FR)

(72) Inventors:
- **SERTONS, Ted**
  3433 PG NIEUWEGEIN (NL)
- **VAN'T WEL, Arthur**
  3433 PG NIEUWEGEIN (NL)
- **REMIE, Peter**
  3433 PG NIEUWEGEIN (NL)
- **HAGEDOORN, Arjan**
  4816 EC BREDA (NL)

(74) Representative: **Casalonga**
Casalonga & Partners
Bayerstraße 71/73
80335 München (DE)

(54) FLOW CONTROL SOLENOID VALVE BLOCK, ASSOCIATED COMPRESSING UNIT, DISPENSING SYSTEM AND METHOD

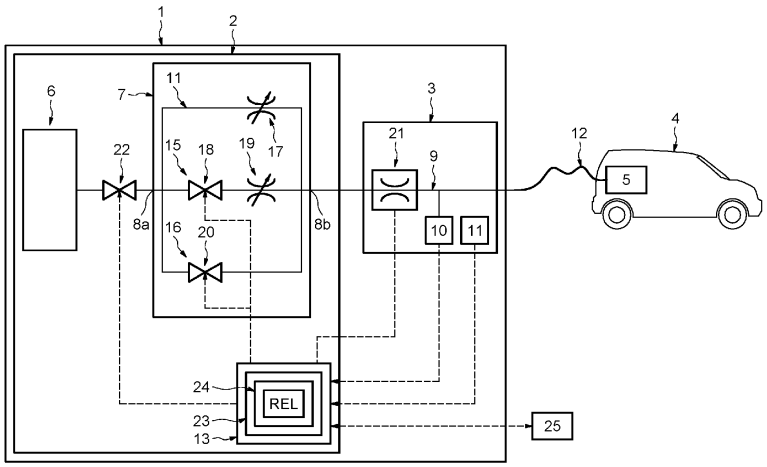
(57) The flow control solenoid valve block (7) for compressed natural gas comprises only first, second and third supply lines (14, 15, 16) in parallel.

The first supply line (14) comprises a first adjustable orifice (17).

The second supply line (15) comprises a first valve (18) and a second adjustable orifice (19) connected to the first valve (18) so that gas flowing through the first valve (18) flows through the second adjustable orifice (19).

The third supply line (16) comprises a second valve (20).

FIG.1



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Description

[0001] The present invention concerns flow control solenoid valve blocks for feeding compressed natural gas to a dispensing unit during refuelling of a gas tank.

[0002] The present invention also relates to a compressing unit comprising such a flow control solenoid valve block and a method for controlling such a flow control solenoid valve block.

[0003] Generally, a compressing unit or a dispensing unit for refuelling a gas tank of a vehicle comprises a pressure regulator to control the maximum pressure of gas flowing in the gas tank for example of a vehicle.

[0004] The pressure regulator of a compressing unit may be a mechanical pressure regulator provided with a spring-controlled mechanism tensioned to reach a fixed pressure setpoint to which the regulator will allow gas to flow through. In order to fulfil the regulation requirements, the pressure regulator is set to deliver a gas pressure of 200 bar at a temperature of 15 degrees Celsius. The regulated gas pressure cannot be adjusted leading to a partial refuelling of the gas tank. Therefore, the gas tank is not completely filled up at any ambient temperature higher than 15 degrees Celsius.

[0005] Alternatively, pneumatic pressure regulator may be implemented in a compressing unit rather than a mechanical pressure regulator.

[0006] To control the pneumatic pressure regulator, natural gas is used and released in the atmosphere leading to undesirable release of methane into the atmosphere.

[0007] Compressed air can also be used to control the pneumatic pressure regulator.

[0008] However, to compress air, additional components are required which are susceptible to mechanical failure.

[0009] One aim of the present invention is to overcome at least in part these drawbacks.

[0010] According to an aspect, a flow control solenoid valve block for compressed natural gas is proposed.

[0011] The flow control solenoid valve block comprises only first, second and third supply lines in parallel in which:

- the first supply line comprises a first adjustable orifice,
- the second supply line comprises a first valve and a second adjustable orifice connected to the first valve so that gas flowing through the first valve flows through the second adjustable orifice, and
- the third supply line comprises a second valve.

[0012] The three supply lines permit to accurately control the gas pressure during refuelling of the gas tank so that the gas end pressure is variable and adjusted in real time in order to always deliver the gas at the maximum allowed gas end pressure at the highest possible flow according for example to ISO 16923-2016.

[0013] The flow control solenoid valve block allows to fine tune the compressed natural gas flowing through the flow control solenoid valve block without releasing any gas into the atmosphere.

[0014] It permits to reduce the refuelling duration of a gas tank to be refuelled.

[0015] Preferably, the third supply line comprises only the second valve.

[0016] Advantageously, the first and second valve are solenoid valves.

[0017] The reaction duration of the control block is smaller as for example the reaction duration of a proportional valve, in order to avoid pressure peaks.

[0018] Preferably, the first adjustable orifice of the first supply line is smaller than the second adjustable orifice of the second supply line.

[0019] The compressed gas flow flowing through the third supply line is bigger than the compressed gas flow flowing through the second supply line which is bigger than the compressed gas flow flowing through the first supply line.

[0020] According to another aspect, a compressing unit for supplying a dispensing unit with compressed natural gas is proposed.

[0021] The compressing unit comprises a gas storage and a flow control solenoid valve block as described previously to fluidly connect the gas storage and the dispensing unit, the compressing unit further comprising control means configured to control the first and second valves of the flow control solenoid valve block according to the pressure measured by a pressure sensor of the dispensing unit and to the ambient temperature measured by a temperature sensor of the dispensing unit.

[0022] Preferably, the compressing unit further comprises at least one filling valve provided at an input of the flow control solenoid valve block and controlled by the control means to stop supplying gas to the flow control solenoid valve block when the pressure measured by the pressure sensor is equal to a predetermined gas end pressure, the gas end pressure being variable and dependent of the ambient temperature measured by the temperature sensor.

[0023] Advantageously, the control means comprise a relationship between the gas end pressure and the ambient temperature, the control means determining the predetermined gas end pressure from the measured temperature and the relationship.

[0024] According to another aspect, a dispensing system is proposed.

[0025] The dispensing system comprises the compressing unit as defined previously and a dispensing unit for refuelling a gas tank with compressed natural gas from the gas storage, the dispensing unit fluidly connecting an output of the flow control solenoid valve to the gas tank and comprising a pressure sensor and a temperature sensor, the dispensing unit, the pressure sensor and the temperature sensor being connected at the output of the flow control solenoid valve block and to the control

means for controlling the first and second valves of the flow control solenoid valve.

[0026] According to another aspect, a method for controlling a flow control solenoid valve block is proposed.

[0027] The method comprises first, second and third supply lines in parallel, the first supply line comprising a first adjustable orifice, the second supply line comprising a first valve and a second adjustable orifice connected to the first valve so that gas flowing through the first valve flows through the second adjustable orifice, and the third supply line comprising a second valve, the flow control solenoid valve block fluidly connecting a gas storage and a gas tank to be filled, the method comprising the following steps:

- supplying the flow control solenoid valve block with gas from the gas storage, the gas flowing from the gas storage to the gas tank through the first supply line of the flow control solenoid valve block,
- controlling the first and the second valves of the second and third lines of the flow control solenoid valve block according to the pressure value at the output of the flow control solenoid valve block connected to the gas tank, and
- stopping supplying the flow control solenoid valve block with gas when the pressure value at the output of the flow control solenoid valve block is equal to a predetermined gas end pressure, the predetermined gas end pressure being variable and dependent of the ambient temperature.

[0028] Advantageously, if the measured pressure at the output of the flow control solenoid valve block is below the gas end pressure value minus a first threshold, opening the first valve of the second supply line so that the gas also flows through the first valve and the second adjustable orifice of the second supply line, increasing the gas flow speed.

[0029] Preferably, if the measured pressure at the output of the flow control solenoid valve block is above the gas end pressure value minus the first threshold, closing the first valve of the second supply line.

[0030] Advantageously, if the measured pressure at the output of the flow control solenoid valve block is below the gas end pressure value minus a second threshold, opening the second valve of the third supply line so that the gas also flows through the third supply line, increasing the gas flow speed even more.

[0031] Preferably, if the measured pressure at the output of the flow control solenoid valve block is above the gas end pressure value minus the second threshold, closing the second valve.

[0032] Advantageously, stopping supplying the flow control solenoid valve block with gas comprises closing a filling valve between the gas storage and the flow control solenoid valve block to stop supplying the flow control solenoid valve block with gas.

[0033] Preferably, the first threshold is smaller than a second threshold.

[0034] Advantageously, the method further comprises the determination of the predetermined gas end pressure from the ambient temperature and a relationship between the gas end pressure and the ambient temperature.

[0035] The present invention and its advantages will be better understood by studying the detailed description of specific embodiments given by way of non-limiting examples and illustrated by the appended drawings on which:

- Figure 1 illustrates an embodiment of a dispensing system,
- Figure 2 illustrates an example of a relationship linking a measured temperature and the gas end pressure, and
- Figure 3 illustrates an embodiment of a method for refuelling a gas tank.

[0036] Figure 1 illustrates an embodiment of a dispensing system 1 comprising a compressing unit 2 and a dispensing unit 3 for refuelling a vehicle 4 comprising a gas tank 5 to be refuelled.

[0037] The dispensing unit 3 refuels the gas tank 5 of the vehicle 4 with compressed natural gas supplied by the compressing unit 2.

[0038] The compressing unit 2 comprises a gas storage 6 filled with compressed natural gas (CNG), a flow control solenoid valve block 7 comprising an input 8a connected to the gas storage 6 and an output 8b connected to a dispensing line 9 of the dispensing unit 3. The dispensing unit 3 is connected to the gas tank 5 of the vehicle.

[0039] The dispensing unit 3 further comprises a pressure sensor 10 which is provided on the dispensing line 9 and a temperature sensor 11 measuring the ambient temperature, i.e the outside air temperature. In the illustrated example, the temperature sensor 11 is mounted on the dispensing unit 3. Alternatively, the temperature sensor 11 may be mounted on another part of the compressing unit.

[0040] The dispensing unit 3 further comprises a hose 12 connecting the dispensing line 9 to the gas tank 5 of the vehicle 4.

[0041] The compressing unit 2 comprises control means 13 connected to the flow control solenoid valve block 7, the pressure sensor 10 and the temperature sensor 11.

[0042] The flow control solenoid valve block 7 comprises only first, second and third supply lines 14, 15, 16 in parallel.

[0043] The first supply line 14 comprises a first adjustable orifice 17. The second supply line 15 comprises a first valve 18 and a second adjustable orifice 19 connected to the first valve 18 so that gas flowing through the first valve flows through the second adjustable orifice 19. The third supply line 16 comprises only a second valve 20.

[0044] A first end of each supply line 14, 15, 16 is connected to the input 8a of the flow control solenoid valve block. A second opposite end of each supply line 14, 15, 16 is connected to the output 8b. During refuelling of the gas tank 5, the gas flows first through the first adjustable orifice 17 of the first supply line 14.

[0045] The control means 13 controls the first and second valves 18, 20 according to the measured pressure by the pressure sensor 10 and the measured temperature by the temperature sensor 11. The measured value of pressure and temperature are transmitted to the control means 13.

[0046] The first and second valves 18, 20 are electrically command valves so that no additional equipment to command the valves 18, 20 is needed, for example an equipment to compress air used to control air-controlled valves.

[0047] The first and second valves 18, 20 may be solenoid valves, for example on/off solenoid valves.

[0048] The first adjustable orifice 17 of the first line 14 is smaller than the second adjustable orifice 19 of the second line 15. The first and second adjustable orifices 17, 19 may be adjusted manually.

[0049] The compressed gas flow flowing through the third supply line 16 is bigger than the compressed gas flow flowing through the second supply line 15 which is bigger than the compressed gas flow flowing through the first supply line 14.

[0050] The dispensing unit 3 further comprises a flowmeter 21 provided on the dispensing line 9. In the illustrated example, the flowmeter 21 is located upstream the pressure sensor 10. Alternatively, the flowmeter 21 may be downstream the pressure sensor 10.

[0051] The flowmeter 21 measures the gas flow flowing to the gas tank 5 and transmits the measured value for example to the control means 13.

[0052] The adjustable orifices 17, 19 may be adjusted so that when the first and second valves 18, 20 are closed, a minimum gas flow rate flows through the first adjustable orifice 17 of the control block 7 and when the first valve 18 is open, a predetermined flow gas flow rate flows through the first and the second adjusted orifices 17, 19. For example, the adjustable orifices 17, 19 are adjusted when the flowrate measured by the flowmeter 21 is too high, for example above a pre-set flow rate value. If the pressure in the dispensing line 9 is too high, the control means 13 may trigger a pressure alarm.

[0053] For example, the adjustable orifices 17, 19 may be adjusted manually in order to obtain a flow of gas equal to 2 kg/min for line 14 and 6 kg/min for line 15.

[0054] The compressing unit 2 further comprises one filling valve 22 between the gas storage 6 and the input 8a. The filling valve 22 is connected to the input 8a of the flow control solenoid valve block 7 and to an output of the gas storage 6. The compressing unit 2 may comprise more than one filling valve 22, the compressing unit 2 may for example comprise tree filling valves 22 in parallel, each filling valve being connected to the input 8a.

[0055] The filling valve 22 is controlled by the control means 13 to stop supplying gas to the flow control solenoid valve block 7 when the pressure measured by the pressure sensor 10 is equal to a predetermined gas end pressure Pend.

[0056] The gas end pressure Pend is variable and depends of the ambient temperature measured by the temperature sensor 11.

[0057] The control means 13 may comprise a processing unit 23 and a memory 24 storing a relationship REL between the gas end pressure Pend and the ambient temperature measured by the temperature sensor 11.

[0058] According to the ambient temperature measured by the sensor 11 and the relationship REL, the processing unit 23 determines the gas end pressure Pend, and control the first valve 18 and the second valve 20 so that the pressure measured by the sensor 10, which is nearly equal to the pressure in the gas tank 5, is equal to the predetermined gas end pressure Pend at the end of the filling of the gas tank 5.

[0059] Figure 2 illustrates an example of the relationship REL.

[0060] The relationship REL may be a linear relationship linking the measured ambient temperature Tmes by the sensor 11 and the gas end pressure Pend. For a measured ambient temperature of 15°C, the gas end pressure Pend is equal to 200 bar and for a measured ambient temperature of 55°C, the gas end pressure Pend is equal to 250 bar.

[0061] The control means 13 may be connected to a remote human machine interface 25 for example for monitoring the dispensing system 1 and triggering an alarm if the dispensing system 1 has a failure.

[0062] Figure 3 represents an embodiment of a method for controlling the flow control solenoid valve block 7 to refuel the gas tank 5 of the vehicle.

[0063] It is assumed that the filling valve 22 is closed, the first and second valves 18, 20 are closed, the gas tank 5 is fluidly connected to the dispensing line 9, the gas end pressure Pend is initially set for example at 200 bar, and the gas tank pressure 5 is less than the initial gas end pressure minus a second threshold TH2.

[0064] In step 30, a request to start the refuelling is received by the control means 13.

[0065] Then in step 31, at the start of the refuelling of the gas tank 5, the filling valve 22 is open by the control means 13. The flow control solenoid valve block 7 is supplied with gas from the gas storage 6, the gas flowing from the gas storage 6 to the gas tank 5 through the first supply line 14.

[0066] If the pressure measured by the pressure sensor 10 is below the gas end pressure value Pend minus a first threshold TH1 smaller than the second threshold TH2 (step 32), at step 33, the control means 13 open the first valve 18 of the second supply line so that the gas also flows through the first valve 18 and the second adjustable orifice 19 of the second supply line 15. The gas flows both the first and second supply lines 14, 15 and it

continues between steps 30 and 31.

[0067] The first threshold TH1 may be for example equal to 10 bar and the second threshold TH2 may be for example equal to 20 bar.

[0068] If the pressure measured by the pressure sensor 10 is above the gas end pressure value Pend minus the first threshold TH1 (step 32), at step 34, the control means 13 close the first valve 18 and it continues between steps 30 and 31.

[0069] If the pressure measured by the pressure sensor 10 is below the gas end pressure value Pend minus the second threshold TH2 (step 35), at step 36, the control means 13 open the second valve 20 so that gas also flows through the third supply line 16. The gas may take the supply line of least resistance and thus flows over the third supply line 16 and it continues between steps 30 and 31.

[0070] If the pressure measured by the pressure sensor 10 is above the gas end pressure value Pend minus the second threshold TH2 (step 35), at step 37, the control means 13 close the second valve 20 so that gas does not flow through the third supply line 16 anymore flowing over the second supply line 15 and it continues between steps 30 and 31.

[0071] The control means 13 monitor the measured pressure which increases during the refuelling of the gas tank 5.

[0072] If the pressure measured by the pressure sensor 10 is below the gas end pressure value Pend (step 38), it continues between step 31 and steps 32, 35 and 38.

[0073] If the pressure measured by the pressure sensor 10 is equal to the gas end pressure value Pend (step 38), at step 39, at the end of the refuelling of the gas tank 4, the control means 13 close the filing valve 22 stopping supplying the flow control solenoid valve block with gas. The gas tank 5 is filled up and it continues at step 30.

[0074] During refuelling of the gas tank 5, the control means determine and modify the gas end pressure from the measured temperature by the sensor 11 and the relationship REL.

[0075] The control block 7 comprising three supply lines is compact and easy to implement.

[0076] As the first and second valves 18, 20 are on/off valves, the reaction duration of the control block 7 is smaller as for example the reaction duration of a proportional valve, in order to avoid pressure peaks.

[0077] The three supply lines 14, 15, 16 permit to accurately control the gas pressure during refuelling of the gas tank 5 by controlling the first and second valves 18, 20.

[0078] Advantageously, the first and second valves 18, 20 can be controlled remotely by the human machine interface 25 through the control means 13, for example in case of failure of the dispensing system 1.

[0079] The human machine interface 25 monitors the dispensing system 1 for example to alarm in case of failure of the dispensing system 1.

[0080] As the gas end pressure Pend is variable and adjusted in real time, the dispensing system 1 always delivers the gas at the maximum allowed gas end pressure according to regulations, for example ISO 16923-2016, PGS25 and UN R110, increasing the refuelling grade of the gas tank 5 and reducing the refuelling duration of the gas tank 5.

Claims

1. Flow control solenoid valve block (7) for compressed natural gas comprising only first, second and third supply lines (14, 15, 16) in parallel, wherein:

   - the first supply line (14) comprises a first adjustable orifice (17),
   - the second supply line (15) comprises a first valve (18) and a second adjustable orifice (19) connected to the first valve (18) so that gas flowing through the first valve (18) flows through the second adjustable orifice (19), and
   - the third supply line (16) comprises a second valve (20).

2. Flow control solenoid valve block according to claim 1, wherein the third supply line (16) comprises only the second valve (20).

3. Flow control solenoid valve block according to claim 1 or 2, wherein the first and second valves (18, 20) are solenoid valves.

4. Flow control solenoid valve block according to any of the preceding claims, wherein the first adjustable orifice (17) of the first supply line (14) is smaller than the second adjustable orifice (19) of the second supply line (15).

5. Compressing unit (2) for supplying a dispensing unit with compressed natural gas, comprising a gas storage (6) and a flow control solenoid valve block (7) according to any of the preceding claims to fluidly connect the gas storage (6) and the dispensing unit, the compressing unit (2) further comprising control means (13) configured to control the first and second valves (18, 20) of the flow control solenoid valve block according to the pressure measured by a pressure sensor (10) of the dispensing unit and to the ambient temperature measured by a temperature sensor (11) of the dispensing unit.

6. Compressing unit (2) according to claim 5, further comprising at least one filling valve (22) provided at an input (8a) of the flow control solenoid valve block (7) and controlled by the control means (13) to stop supplying gas to the flow control solenoid valve block when the pressure measured by the pressure sensor (10) is equal to a predetermined gas end pressure

(Pend), the gas end pressure being variable and dependent of the ambient temperature measured by the temperature sensor (11).

7. Compressing unit (2) according to claim 6, wherein the control means (13) comprise a relationship (REL) between the gas end pressure (Pend) and the ambient temperature, the control means (13) determining the predetermined gas end pressure (Pend) from the measured temperature and the relationship (REL).

8. Dispensing system (1) comprising the compressing unit (2) according to any of the preceding claims 5 to 7, and a dispensing unit (3) for refuelling a gas tank (5) with compressed natural gas from the gas storage (6), the dispensing unit (3) fluidly connecting an output of the flow control solenoid valve (7) to the gas tank (5) and comprising a pressure sensor (10) and a temperature sensor (11), the dispensing unit (3), the pressure sensor (10) and the temperature sensor (11) being connected at the output (8b) of the flow control solenoid valve block (7) and to the control means (13) for controlling the first and second valves (17, 18) of the flow control solenoid valve.

9. Method for controlling a flow control solenoid valve block (5) comprising first, second and third supply lines (14, 15, 16) in parallel, the first supply line (14) comprising a first adjustable orifice (17), the second supply line (15) comprising a first valve (18) and a second adjustable orifice (19) connected to the first valve (18) so that gas flowing through the first valve (18) flows through the second adjustable orifice (19), and the third supply line (16) comprising a second valve (20), the flow control solenoid valve block (7) fluidly connecting a gas storage (6) and a gas tank (5) to be filled, the method comprising the following steps:

- supplying the flow control solenoid valve block (7) with gas from the gas storage (6), the gas flowing from the gas storage (6) to the gas tank (5) through the first supply line (14) of the flow control solenoid valve block (7),
- controlling the first and the second valves (18, 20) of the second and third lines (15, 16) of the flow control solenoid valve block (7) according to the pressure value at the output (8b) of the flow control solenoid valve block connected to the gas tank (5), and
- stopping supplying the flow control solenoid valve block (7) with gas when the pressure value at the output (8b) of the flow control solenoid valve block is equal to a predetermined gas end pressure (Pend), the predetermined gas end pressure being variable and dependent of the ambient temperature.

10. Method according to claim 9, wherein if the measured pressure at the output (8b) of the flow control solenoid valve block (7) is below the gas end pressure (Pend) value minus a first threshold (TH1), opening the first valve (18) of the second supply line so that the gas also flows through the first valve (18) and the second adjustable orifice (19) of the second supply line (15).

11. Method according to claim 9 or 10, wherein if the measured pressure at the output (8b) of the flow control solenoid valve block (7) is above the gas end pressure (Pend) value minus the first threshold (TH1), closing the first valve (18) of the second supply line (15).

12. Method according to any of the preceding claims 9 to 11, wherein if the measured pressure at the output (8b) of the flow control solenoid valve block (7) is below the gas end pressure value (Pend) minus a second threshold (TH2), opening the second valve (20) the third supply line so that the gas also flows through the third supply line (16).

13. Method according to any of the preceding claims 9 to 12, wherein if the measured pressure at the output (8b) of the flow control solenoid valve block (7) is above the gas end pressure value minus the second threshold (TH2), closing the second valve (20).

14. Method according to any of the preceding claims 9 to 13, wherein stopping supplying the flow control solenoid valve block with gas comprises closing a filling valve (22) between the gas storage (6) and the flow control solenoid valve block (7) to stop supplying the flow control solenoid valve block (7) with gas.

15. Method according to any of the preceding claims 9 to 14, further comprising the determination of the predetermined gas end pressure (Pend) from the ambient temperature and a relationship (REL) between the gas end pressure and the ambient temperature.

FIG.1

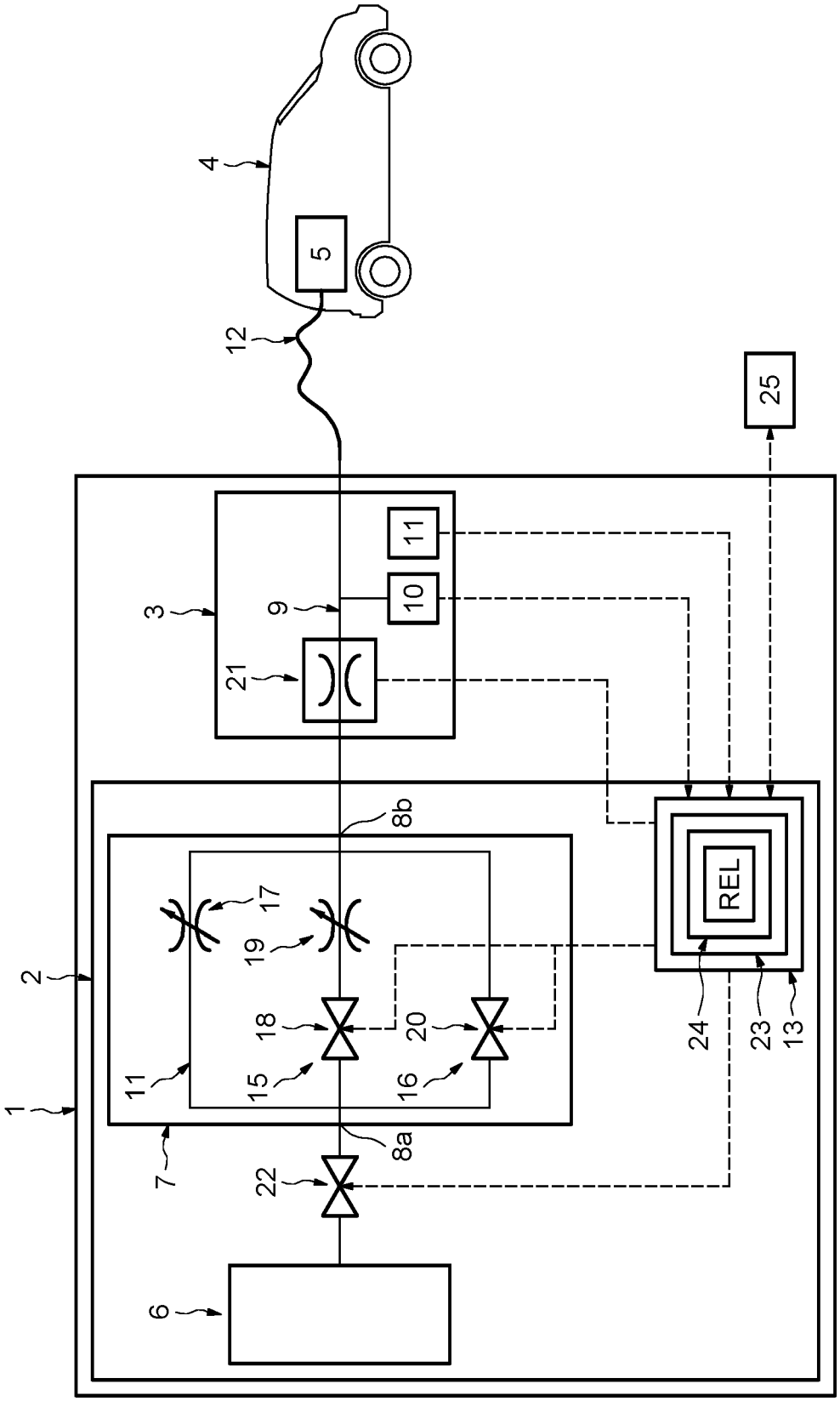


FIG.2

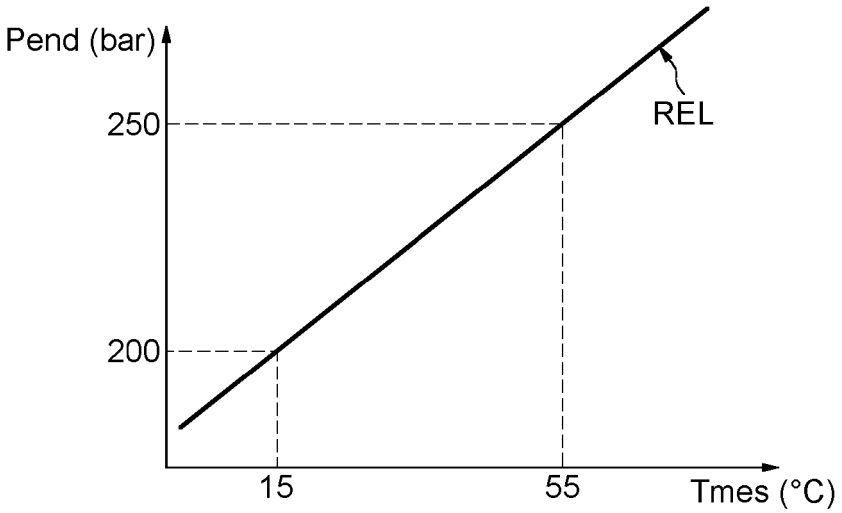
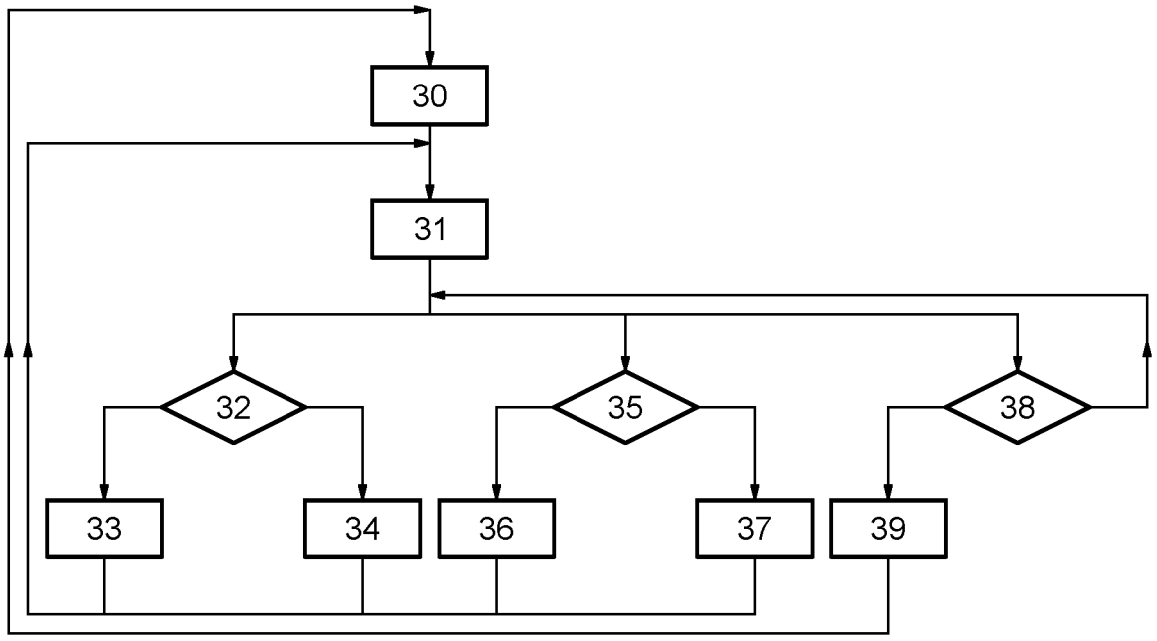


FIG.3



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EUROPEAN SEARCH REPORT

Application Number
EP 21 30 5935

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1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 December 2021	Forsberg, Peter

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