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(54) HEAT EXCHANGER, USE THEREOF AND METHOD OF HEATING A FLUID

- (57) The present invention relates to a heat exchanger (1) for heating a fluid (20) to an exit temperature (76). The heat exchanger comprises a closed heating chamber (60) comprising a heating liquid (28) and one or more heating elements (30) configured for heating the heating

liquid (28), and one or more flow pipes (40) having a pipe inlet (42) and a pipe outlet (44) configured for receiving a fluid (20). The one or more flow pipes (40) are arranged in the closed chamber in contact with the heating liquid (28).

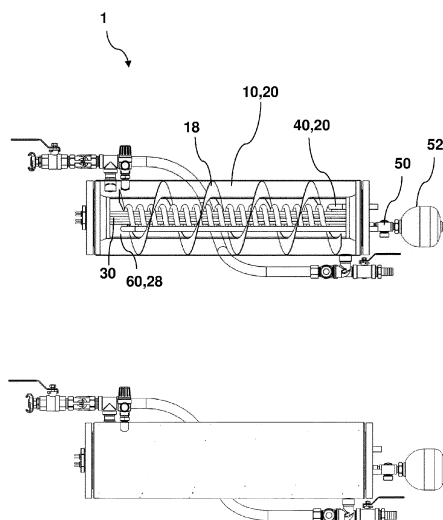


Fig. 3

Description**Field of the Invention**

5 **[0001]** The present invention relates to a heat exchanger for heating a fluid to an exit temperature. The heat exchanger comprises a closed heating chamber comprising a heating liquid and one or more heating elements configured for heating the heating liquid, and one or more flow pipes having a pipe inlet and a pipe outlet configured for receiving a fluid. The one or more flow pipes are arranged in the closed chamber in contact with the heating liquid.

Background of the Invention

10 **[0002]** Pressurised steam cleaners and hot water washers are utilized in a variety of situations for cleaning purposes. Such systems generally include a reservoir tank which include at least one heating element. This tank is connected to the inlet of a pump, and subsequently heated if elevated temperature is needed. And then discharged under pressure through the nozzle of a wand.

15 **[0003]** Equipment of this type is controlled primarily by switching the pump on and then manipulating the wand as necessary to spray the object being cleaned.

20 **[0004]** The exit temperature of the pressurized fluids in such pressurised systems are typically limited to a temperature of 60-80 degrees Celsius depending on the exit pressure and the composition of the fluid. The limitation is generally set by the high-pressure pump. Generally, a reservoir of fluid to be used in one cleaning cycle is heated and subsequently pressurized in a high-pressure pump. The maximum temperature of the fluid is set by the cavitation point of fluid delivered to the high-pressure pump.

25 **[0005]** Exemplary uses of pressurized hot water or steam cleaners and washers are the marine and offshore industries for cleaning off oil, barnacles, algae, mud, salt and other residues from surfaces. Some of the drawbacks includes heating a large fluid reservoir and hence a long start-up time and large reservoir tanks taking up space and especially the limitation of temperature.

30 **[0006]** In the case of cleaning systems with electrical heaters, it is especially important that the heating elements always be substantially filled or covered during operation to avoid uneven heating and thus premature burnout of the resistance elements.

35 **[0007]** US2015016811 AA discloses a circulation heater using a heater body comprising a cast body having resistance heating elements therein and having spirally wound flexible heater tubing wrapped about the heater body. After casting, the heater body is machined to form at least one spiral channel for receiving the heater tube therein. Teflon or other flexible and preferably resiliently compressible tubes are used to allow insertion of the tubing into the pre-cut heater channel and the heater body is formed of cast aluminium or other suitable cast material.

Object of the Invention

40 **[0008]** One objective of the present invention is to overcome one or more drawbacks of prior art including achieving a heat exchanger with a faster start-up time, reduced energy consumption and higher exit temperatures.

45 **[0009]** A further objective is to achieve more compact high-temperature systems and high-temperature, high-pressure systems.

50 **[0010]** A further objective is to achieve a heat exchanger suitable to be used for heating of both liquid and fluid.

Description of the Invention

55 **[0011]** One or more of the above objectives are achieved by a heat exchanger for heating a fluid to an exit temperature.

60 **[0012]** The heat exchanger comprises a closed heating chamber comprising a heating liquid and one or more heating elements. The heating elements are configured for heating the heating liquid.

65 **[0013]** The heat exchanger furthermore comprises one or more flow pipes having a pipe inlet and a pipe outlet. The one or more flow pipes being configured for receiving a fluid.

70 **[0014]** The flow pipes are configured for transporting the received fluid.

75 **[0015]** The one or more flow pipes are arranged in the closed heating chamber in contact with the heating liquid, such that the fluid, when in the one or more pipes is heated by the heating liquid to the exit temperature.

80 **[0016]** In one aspect, the heating elements may be arranged in direct contact with the heating liquid.

85 **[0017]** The heating chamber may be a high-pressure tank.

90 **[0018]** One effect of using a heating fluid for heating the fluid is that a liquid - fluid (liquid-to-fluid or fluid-to-liquid) heat transfer can be achieved, which is a very effective heat transfer process. Furthermore, utilizing the heat from the heating elements to continuously heating the heating liquid in the chamber in combination with the effective heating of the fluid

in the one or more pipes achieves for a heat exchanger to be operated with a small heating reservoir i.e. the heating liquid in the closed heating chamber.

[0019] A further effect of the heat exchanger is that a fast start-up time is achieved because of the small reservoir.

[0020] In one aspect, the heating elements may be electric heating elements, which may be preferred for reduced explosion risk when compared to heat burners.

[0021] Another effect of using a closed heat chamber is that the heating liquid is isolated from the circulated fluid to be used for a given purpose. The heating liquid in this embodiment should be chosen in accordance with the heating elements and the operation temperature. The operation temperature of the heating liquid depends on the intended exit temperature and/or pressure of the circulated fluid to be achieved and the flow rate of the circulated fluid.

[0022] The heat exchanger may be configured for operating with fluids or compositions of fluids comprising water, steam, oil, gas, amongst others.

[0023] Fluid refers to any substance that flows i.e. both liquids and gases. Thus, a liquid - gas heat exchanger may be achieved for heating steam. Steam is widely used within the marine and energy sector for not only cleaning purposes but also other engineering applications such as liquid heating, defreezing etc.

[0024] In one aspect, the heating liquid may be chosen from a group of water-based liquids with additives preventing freezing, such as glycol or a mix of water and glycol.

[0025] In another aspect, the heating liquid may be chosen from a group of oil-based liquids such as hydraulic oil, gear oil or similar.

[0026] These exemplary fluidic and liquid solutions are meant as such without limiting the invention to be operated with one or more of these liquid- and/or fluidic solutions.

[0027] The fluid to be circulated in the pipes may be a liquid.

[0028] In one embodiment the heat exchanger comprises a circulation device configured for creating a fluid flow through the one or more pipes with a flow direction from the pipe inlet to the pipe outlet.

[0029] The circulation device may be configured to create the flow through pressure or suction.

[0030] One effect of this embodiment is that the flow rate of the fluid may be controlled to achieve a desired exit temperature. Thus, the exit temperature may be regulated by regulating the flow rate in the pipe(s).

[0031] Another effect is that a heat exchanger for pressurized fluid may be obtained with a simple construction.

[0032] In one embodiment, the heat exchanger comprises a pre-heating chamber with a chamber inlet and a chamber outlet.

[0033] The chamber outlet is fluidly connected to the pipe inlet in a flow path with flow direction from the chamber outlet to the pipe inlet.

[0034] The pre-heating chamber is configured for preheating the fluid from the chamber inlet to the chamber outlet.

[0035] One effect of pre-heating the fluid is that the surplus heating from external sources may be utilized for obtaining a more energy effective process. By pre-heating the fluid before entering the pipe(s), that flow rate in the pipe(s) may be increased as the temperature increase to be achieved in the pipe(s) is reduced. This leads to an even faster heat-exchange system or a heat exchanger with a further reduced heat reservoir.

[0036] In a further embodiment of the heat exchanger with the pre-heating chamber, the closed heat chamber is arranged in contact with the pre-heating chamber for liquid-to-fluid heat transfer between the heat chamber and the pre-heating chamber for pre-heating the fluid when in the pre-heating chamber.

[0037] In one aspect, the preheating chamber may be arranged to fully or at least to partly surround the heating chamber.

[0038] In this embodiment, the waste heat or at least part of the waste heat from the heating chamber is utilized for pre-heating the fluid to be heated additionally in the pipe(s)

[0039] In one aspect, the pre-heating chamber may be arranged in direct contact with the heating chamber, for optimized heat transfer by exploiting the benefits of an effective liquid - fluid heat transfer.

[0040] In one embodiment, the heat exchanger comprises a controller and a mix valve arranged fluidly connected between the chamber outlet and the pipe inlet. The mix valve has an external fluid inlet configured to be connected to an external fluid source.

[0041] The controller is configured for controlling the flow of the external fluid into the mix valve.

[0042] One effect of the external fluid inlet of the mix valve and the controller is that the composition of the fluid can be altered in the heat exchanger in a controlled manner.

[0043] In one embodiment of the heat exchanger, the fluid is a liquid, and the circulation device is a high-pressure pump arranged between the chamber outlet and the pipe inlet.

[0044] One effect of this embodiment is that the circulating liquid is heating after pressurizing, which achieves for obtaining a high-pressure, high-temperature liquid using standard components, including standard high-pressure pumps in combination with a small heating reservoir in form of the heating liquid in the closed heating chamber.

[0045] This may even be achieved with a pre-heated circulated liquid as long as the cavitation point of the liquid in the pump is not crossed.

[0046] One effect of this embodiment is that a high-pressure heat exchanger can be obtained using a single chamber

comprising the heating element(s), pipe(s) for high-pressure application and two liquids; the heating liquid and the circulated liquid. I.e. a simple and compact construction.

[0047] In one aspect, the pipe may be made of conventional materials used for high-pressure applications such as stainless steel in various grades.

[0048] In a further embodiment of the heat exchanger operated with the high-pressure pump, the heat exchanger furthermore comprises a temperature sensor and a controller.

[0049] The temperature sensor is configured for measuring the temperature of the fluid at a point along the flow path between the chamber outlet and the high-pressure pump.

[0050] The controller is configured for controlling the flow of the external fluid into the mix valve based on the measured temperature.

[0051] One effect of this embodiment is that the temperature of the fluid entering the high-pressure pump can be controlled to avoid cavitation in the high-pressure pump, as the external fluid inlet allows for adjusting the temperature of the fluid by mixing an external fluid with a lower or higher temperature, that the temperature of the fluid entering the mix valve.

[0052] The possibility of adjusting the temperature of the fluid entering the high-pressure pump is beneficial for omitting the risk of cavitation in the high-pressure pump due to fluid entering the pump with a temperature above a threshold temperature causing cavitation of the fluid in the high-pressure pump.

[0053] Thus, this feature may be particularly relevant for high-temperature operation of the heat exchanger, where the high-pressure heat exchanger is to be used with an exit temperature above temperatures, which typically causes cavitation in high-pressure pumps.

[0054] Hence, in the case where the circulated fluid is used as the heating fluid, the temperature of the circulated fluid in the chamber may be heated above the cavitation threshold temperature to ensure the correct exit temperature of the pressurized fluid. However, the fluid entering the high-pressure pump should be below the cavitation threshold temperature when entering the high-pressure pump, which thus can be achieved by adding an external fluid having a lower temperature.

[0055] The threshold temperature may be 80 degrees Celsius, 70 degrees Celsius, 60 degrees Celsius or a temperature within these intervals depending on the specific high-pressure pump, the fluid composition, fluid pressure, pipe dimension, flow speed etc.

[0056] In one embodiment of the exchanger, the pipe(s) form(s) a helical path arranged around the one or more heating elements.

[0057] One effect of the helical path is that the flow path in the pipe is extended while maintaining a uniform distance to the heating element.

[0058] In one aspect, the heating elements may have an elongated shape and the helical path may be arranged along the length of the heating elements.

[0059] In one aspect the pipe(s) may be arranged with the pipe inlet at the inlet end of the chamber and with the outlet at the outlet end of the chamber. Or in alternative configurations depending on how the fluid in the pipe is efficient heated.

[0060] In one embodiment of the heat exchanger, the pre-heating chamber comprises flow guides adapted to guide the flow in the chamber for optimal heating of the circulated fluid in the chamber.

[0061] The flow guides may for example be implemented by use of dividers formed on the inner surface of the chamber for causing obstruction of the flow, mixing of fluid flows, reduction of speed in specific areas or other beneficial effects optimizing the pre-heating of the fluid in the chamber by optimized heat distribution and/or heat transfer.

[0062] In one embodiment, the heat exchanger comprises a heat insulating jacket encircling the heating chamber and/or the pre-heating chamber in full or at least partly.

[0063] This may be beneficial for optimal energy-saving operation of the heat exchanger, for reduced heat loss to the ambient surroundings, for re-heating the heat exchanger within a short downtime, but also for security reasons for limiting the surface temperature of the heat exchanger.

[0064] The insulating jacket may be made of a high heat-insulating materials such as stone/rock wool or comparable materials, gas-filled or vacuum chamber(s) etc.

[0065] In one embodiment, the heat exchanger comprises a pressure relief valve arranged in communication with the heating chamber.

[0066] Implementing a pressure relief valve can improve the security of the heater, as the pressure in the heating chamber rises concurrently with the temperature of the fluid in the chamber.

[0067] In one embodiment, the high-pressure heat exchanger may comprise a pressure reservoir connected to the pressure relief valve. I.e. an accumulator with a membrane such that the accumulator volume increases with higher pressure by expanding the membrane.

[0068] The pressure reservoir may be connected to or forming part of the heating chamber for receiving expanded heating liquid.

[0069] The reservoir chamber addresses the issue of expansion of the heating fluid as temperature increases.

[0070] Using a pressure reservoir can ensure a closed system, where the pressure in the heat chamber can be adjusted concurrently with changes in the pressure e.g. as a result of increased temperature with reduced risk of deformation of the chamber, the pipe(s) and/ or the heating elements. Furthermore, the pressure reservoir achieves reusing pressure changes for aligning the pressure in the heat chamber as the temperature drops/elevates.

[0071] One or more of the objectives of the invention are achieved by a method of heating a fluid to an exit temperature comprising acts of:

- heating a heating liquid using one or more heating elements,
- supplying a flow of fluid to one or more pipes with a fluid inlet temperature, and
- flowing the fluid through the one or more pipes.

[0072] In the method, the pipe(s) is arranged in contact with the heating liquid, such that the fluid when in the pipe(s) is heated by the heating liquid to the exit temperature.

[0073] The effects and advantages achieved with the disclosed method may generally be in accordance with the effects and advantages achieved by the disclosed embodiments of the heat exchanger. The effects and advantages will therefore not be discussed or elaboration on in further details here.

[0074] The method may be implemented in any suitable existing system or in a system retrofitted hereto.

[0075] In one embodiment, the method comprises additional acts of pre-heating the fluid to the fluid inlet temperature and/or pressurising the fluid before entering the one or more pipes.

[0076] In one embodiment, the method comprises a further act of cooling the circulated fluid after pre-heating and before pressurising the circulated fluid. This may be achieved by adding additional non-pre-heated fluid to the fluid after pre-heating and before pressurising the circulated fluid for lowering the temperature of the fluid to be pressurised.

[0077] In one aspect of the method the fluid flow in the pre-heating chamber is guided for optimal pre-heating of the fluid while in the chamber.

[0078] In one embodiment, the method comprises a further act of using the heat exchanger according to any one of the above-disclosed embodiments.

[0079] One or more of the objectives of the invention may be achieved by a high-pressure cleaning system comprising the heat exchanger operated with a high-pressure pump.

[0080] One or more of the objectives of the invention are achieved by use of the heat exchanger according to one or more of the embodiments disclosed herein for a high-pressure cleaning system.

[0081] The effects and advantages achieved with a high-pressure cleaning system comprising the heat exchanger operated with a high-pressure pump or working according to the disclosed method with pressurized fluid may generally be in accordance with the effects and advantages achieved by the disclosed heat exchanger. The effects and advantages will therefore not be discussed or elaboration further.

Description of the Drawing

[0082] The invention will now be explained with reference to the accompanying drawings wherein:

Figs. 1-2 illustrate three embodiments of a heat exchanger with a single chamber.

Figs. 3-5 illustrate one embodiment of a high-pressure heat exchanger with a pre-heating chamber.

Figs. 6-7 illustrate methods of heating a fluid.

Detailed Description of the Invention

No	Item
1	heat exchanger
10	pre-heating chamber
12	chamber inlet
14	chamber outlet
18	flow guides
20	fluid
22	flow path
24	flow direction
28	heating liquid
30	heating element

(continued)

	No	Item
	32	mix valve
5	34	circulation device e.g. pump or high-pressure pump
	36	external fluid inlet
	40	pipe
	42	pipe inlet
10	44	pipe outlet
	50	pressure relief valve
	52	pressure reservoir (accumulator?)
	54	controller
	56	temperature sensor
15	58	heat insulating jacket
	60	heat chamber
	72	fluid inlet temperature
	76	exit temperature
20	80	high-pressure cleaning system.
	100	method
	102	supplying
	104	heating
	106	flowing
25	108	cooling
	110	pressurising
	112	pre-heating

[0083] Exemplary examples will now be described more fully hereinafter with reference to the accompanying figures. The present examples may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the examples are merely described below, by referring to the figures, to explain aspects of the invention.

[0084] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0085] In the figures, when a layer, area, element, or plate is referred to as being "on", "connected to" another layer, area, element, or plate, it may be directly on the other layer, area, element, or plate, or intervening layers, areas, elements, or plates may be present there between. Conversely, when a layer, area, element, or plate is referred to as being "directly on", "directly connected to" another layer, area, element, or plate, there are no intervening layers, areas, elements, or plates there between.

[0086] Like reference numerals refer to like elements throughout. Like elements will, thus, not be described in detail with respect to the description of each figure. It should also be noted that the figures are only intended to facilitate the description of the examples.

[0087] They are not intended as an exhaustive description of the claimed invention or as a limitation on the scope of the claimed invention. In addition, an illustrated example needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular example is not necessarily limited to that example and can be practiced in any other examples even if not so illustrated, or if not so explicitly described.

[0088] Fig. 1 illustrates two embodiments of a heat exchanger 1 with a single chamber.

[0089] The two illustrated embodiments differ in the arrangement of the pipe(s) 40 relative to the heating elements 30 and the shape of the pipe(s) 40, where the embodiment illustrated in figure 1A has pipe(s) 40 arranged with a main flow direction along the length of the heating elements 30, while in figure 1B, the pipe 40 is arranged helically or in a spiral around the heating elements 30. The arrangement of the fluid inlets and outlets also differs in the two embodiments.

[0090] This illustrates how the features in and in connection with the heating chamber 60 can be arranged in various ways in accordance with the use of the heat exchanger and the shape of the components used. The components could generally be standard (off-the-shelf) components.

[0091] In the following, the one or more pipes and the one or more heating elements will be referred to in singular-form for simplicity.

[0092] The illustrated high-pressure heat exchangers 1 comprises a heating chamber 60 comprising heating elements 30, heating liquid 28 and a pipe 40 arranged inside the chamber 60. The pipe has a pipe inlet 42 and a pipe outlet 44.

The bold arrows illustrate the flow direction 24 of the fluid 20.

[0093] The pipe 40 is arranged in contact with the heating liquid 28 in the chamber 60, such that the fluid in the pipe is indirectly heated by the liquid in the chamber.

[0094] A circulation device 34 is arranged after the pipe in the flow path 22 for obtaining a flow of the fluid through the pipe. The circulation device 34 may in an alternative embodiment be arranged in the flow path before the pipe.

[0095] Fig. 2. Illustrates yet another embodiment of the heat exchanger as illustrated in figure 1A with a mix valve 32 and a temperature sensor 56 arranged in the flow path 22 before the circulating device 34 e.g. a high-pressure pump.

[0096] The mix valve has an external fluid inlet 36 configured to be connected to an external fluid source, such that the composition or temperature of the fluid 20 can be altered by mixing the fluid 20 with an external fluid.

[0097] The illustrated embodiment furthermore comprises a controller 54 which may be configured for receiving data-input from the temperature sensor 56 of the measured temperature. The controller 54 may be further configured to control the fluid flow of the fluid 20 and an external fluid based on the temperature of the fluid 20. Alternatively, the controller 54 may be configured for controlling the fluid flow of the fluid 20 and an external fluid in accordance with an intended fluid composition to be achieved in the pressure pump 34.

[0098] Figs. 3-5 illustrate one embodiment of a heat exchanger 1 with a closed heating chamber 60 comprising a heating fluid 28 and the heating elements 30 similar to the embodiment illustrated in fig. 1B. The heat chamber 60 acts as a heat reservoir.

[0099] The fluid 20 is circulated in the pre-heating chamber 10 arranged around and in contact with the heat chamber 60. This embodiment utilizes the well-known concept of liquid-to-fluid (liquid - fluid) heat transfer between the heating liquid 28 and the circulated fluid 20 when in the pre-heating chamber 10, and between the heating liquid 28 and the fluid 20 when in the pipe 40.

[0100] The embodiment is illustrated with cut-out parts of the heat-exchanger and assembly thereof. Figure 3, top illustrates the embodiment in assembled form. In this embodiment, the pre-heating chamber 10 furthermore comprises flow guides 18 arranged helically around the heat chamber 60 for guiding the circulated fluid 20 for achieving an extended travel path in the pre-heating chamber from inlet 12 to outlet 14.

[0101] The illustrated heat exchanger furthermore comprises a pressure relief valve 50 in communication with the heat chamber 60 and a pressure reservoir 52 connected to the pressure relief valve.

[0102] Fig. 6 illustrates one method 100 of heating a high-pressure fluid 20 to an exit temperature 76.

[0103] The method comprises an act of heating 104 a heating fluid 28 in a closed heating chamber 60. This may be achieved by use of one or more heating elements.

[0104] The method 100 furthermore comprises acts of:

- supplying 102 a flow of fluid 20 to a pipe with a fluid inlet temperature 72, and
- flowing 106 the fluid 20 through the pipe.

[0105] The method may be performed using any one of the embodiments of the illustrated or described heat exchanges 1, where the pipe 40 is arranged in contact with the heating liquid 28, such that the fluid 20 when in the pipe 40 can be heated by the heating liquid 28 to the exit temperature 76.

[0106] Fig. 7 illustrates another method 100 of heating a high-pressure fluid 20 to an exit temperature 76. The same method acts as for the method illustrated in fig. 6 but comprises additional acts of pre-heating 112 the fluid to the fluid inlet temperature 72 and/or pressurising 110 the fluid before entering the pipe 40.

[0107] Fig. 7 illustrates a further embodiment of the method 10 with an additional act of cooling 108 the fluid 20 after leaving the chamber but before pressurising 110 the circulated fluid. This act must preferably be performed before pressurizing the fluid 20, and therefore the sequence of this act is illustrated with arrows illustrating that this is a time-/process related act.

Claims

1. Heat exchanger (1) for heating a fluid (20) to an exit temperature (76), said heat exchanger comprises:

- a closed heating chamber (60) for comprising a heating liquid (28) and comprising one or more heating elements (30) configured for heating the heating liquid (28), and
 - one or more flow pipes (40) having a pipe inlet (42) and a pipe outlet (44) configured for receiving and transporting a fluid (20),
- wherein the one or more flow pipes (40) are arranged in the closed chamber to be in contact with the heating liquid (28),
- wherein the heating exchanger is configured for heating the fluid (20) received and transported in the one or

more pipes (40) by the heating liquid (28) to the exit temperature (76), and wherein the heat exchanger (1) further comprises:

- a circulation device (34) configured for creating a fluid flow through the one or more pipes (40) with a flow direction from the pipe inlet (42) to the pipe outlet (44), and
- a pre-heating chamber (10) with an inlet (12) and an outlet (14), wherein the chamber outlet (14) is fluidly connected to the pipe inlet (42) in a flow path (22) with flow direction (24) from the chamber outlet (14) to the pipe inlet (42), and

wherein said pre-heating chamber is configured for preheating the fluid (20) from the chamber inlet (12) to the chamber outlet (14).

2. The heat exchanger (1) according to claim 1, wherein the closed heat chamber (60) is arranged in contact with the pre-heating chamber (10) for fluid-to-fluid heat transfer between the heat chamber (60) and the pre-heating chamber (10) for pre-heating the fluid (20) when in the pre-heating chamber (10).

3. The heat exchanger (1) according to any one of claims 1 or 2 comprising one or more pressure relief valves (50) arranged in communication with the heating chamber (60).

4. The heat exchanger (1) according to anyone of the preceding claims comprising a pressure reservoir connected to or forming part of the heating chamber (60) for receiving expanded heating liquid (28).

5. The heat exchanger (1) according to any one of the preceding claims, wherein the circulation device (34) is a high-pressure pump arranged between the chamber outlet (14) and the pipe inlet (42).

6. The heat exchanger (1) according to any one anyone or more of the preceding claims, wherein the fluid (20) is a liquid.

7. The heat exchanger (1) according to anyone or more of the preceding claims comprising:

- a mix valve (32) arranged fluidly connected between the chamber outlet (14) and the pipe inlet (42), said mix valve (32) has an external fluid inlet (36) configured to be connected to an external fluid source, and
- a controller (54) configured for controlling the flow of the external fluid into the mix valve (32).

8. The heat exchanger (1) according to claim 7, comprising a temperature sensor (56) configured for measuring the temperature of the fluid (20) at a point along the flow path (22) between the chamber outlet (14) and the high-pressure pump (34), and wherein the controller (54) is configured for controlling the flow of the external fluid into the mix valve (32) based on the measured temperature.

9. The heat exchanger (1) according to anyone or more of the preceding claims, wherein the one or more pipes (40) form a helical path arranged around the one or more heating elements (30).

10. The heat exchanger (1) according to anyone or more of the preceding claims, wherein the pre-heating chamber comprises flow guides adapted to guide the flow in the pre-heating chamber for achieving an extended travel path in the pre-heating chamber from inlet (12) to outlet (14)

11. The heat exchanger (1) according to anyone or more of the preceding claims, wherein the pre-heating chamber is arranged circular around the heating chamber to encircle the heating chamber (60).

12. A method (100) of heating a fluid (20) to an exit temperature (76) comprising acts of:

- heating (104) a heating liquid (28) to at least the exit temperature (76) in a closed heat chamber (60) using one or more heating elements (30),
- supplying (102) a flow of fluid (20) to one or more pipes (40) with a fluid inlet temperature (72),
- flowing (106) the fluid (20) through the one or more pipes (40),
- wherein the one or more pipes (40) are arranged in contact with the heating liquid (28), such that the fluid (20) when in the one or more pipes (40) is heated by the heating liquid (28) to the exit temperature (76), and
- pre-heating (112) the fluid (20) to the fluid inlet temperature (72), and/or
- pressurising (110) the fluid (20) before entering the one or more pipes (40),

wherein the fluid (20) is pre-heated by heat transfer from the heating liquid (28).

5 **13.** The method (100) according to claim 12, comprising a further act of adding additional non-pre-heated fluid to the fluid after pre-heating (112) and before pressurising (110) the circulated fluid for lowering the temperature of the fluid to be pressurised.

14. The method (100) according to claim 12 or 13 comprising a further act of using the heat exchanger (1) according any one or more of claims 1-11.

10 **15.** A high-pressure cleaning system (80) comprising the heat exchanger (1) according to anyone or more of claim 5.

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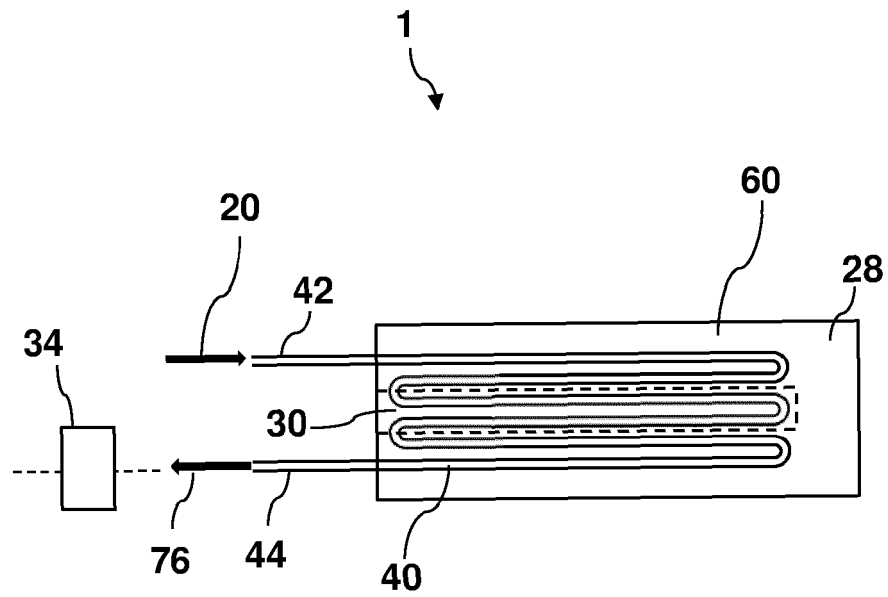
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1A)



1B)

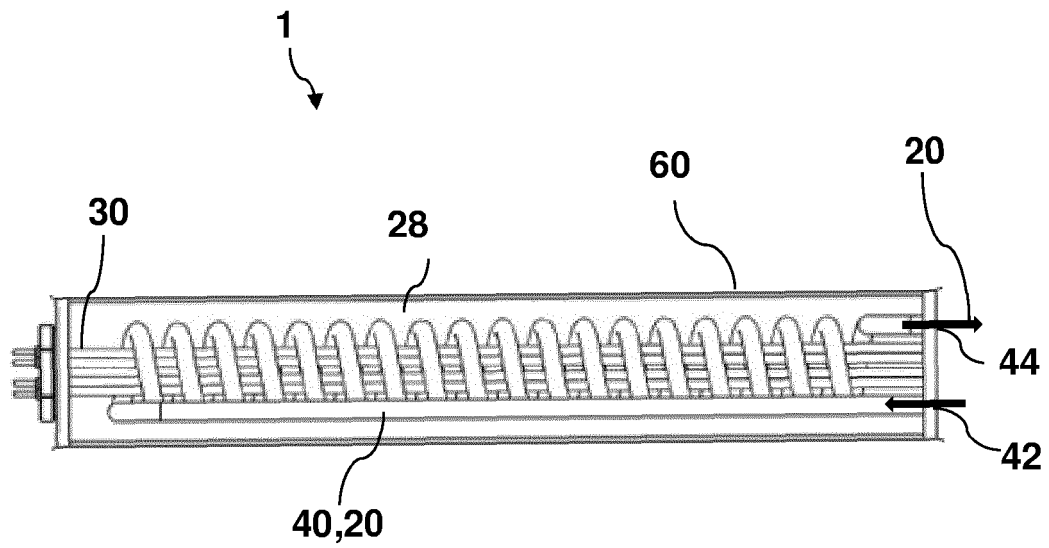


Fig. 1

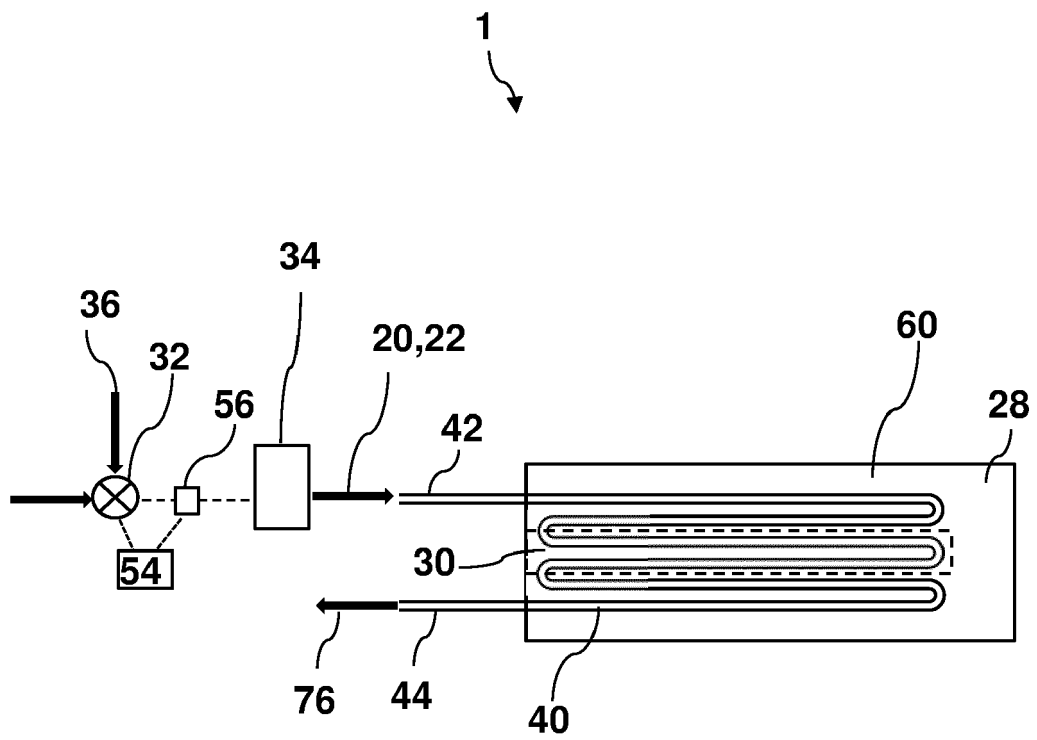


Fig. 2

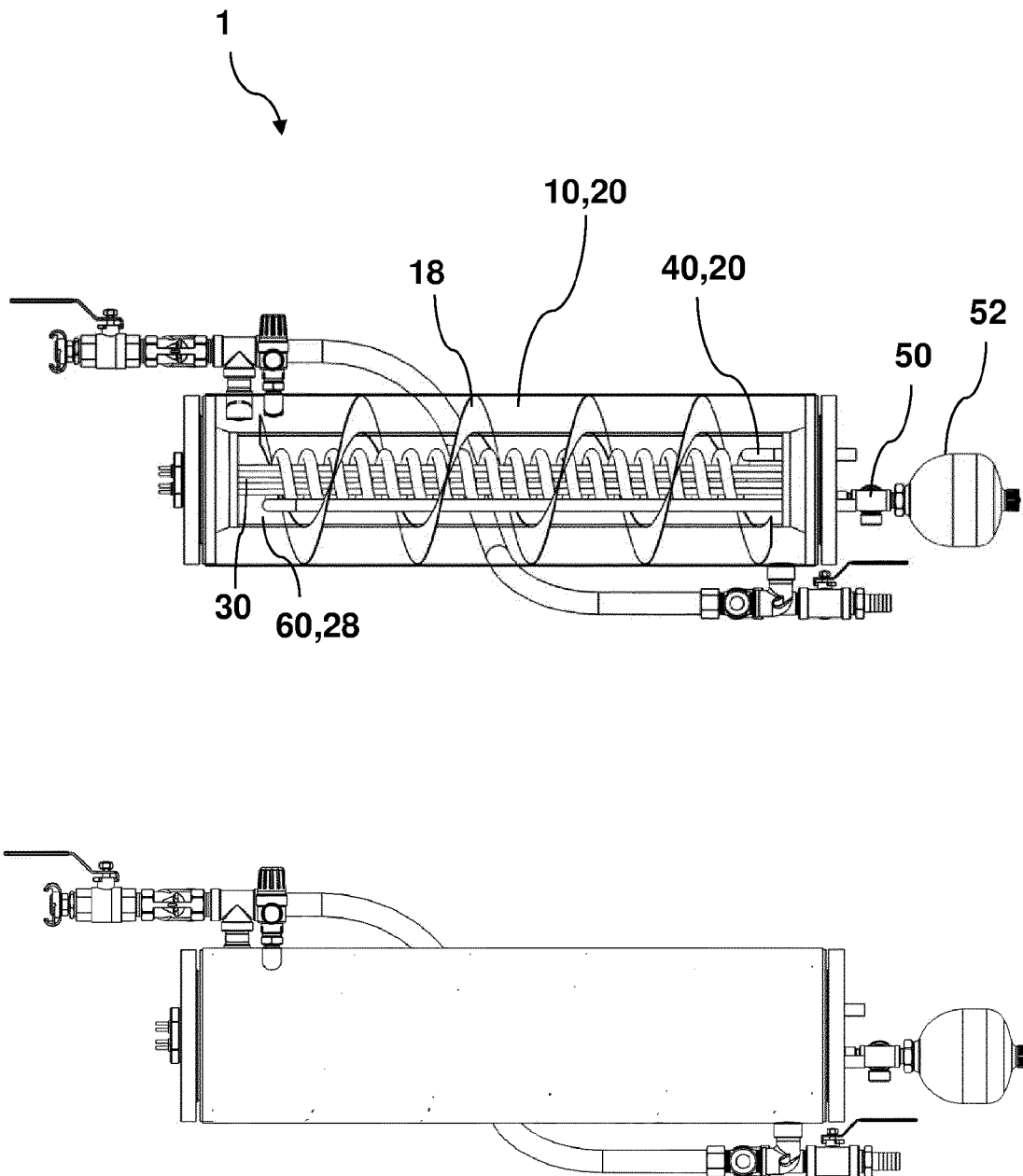


Fig. 3

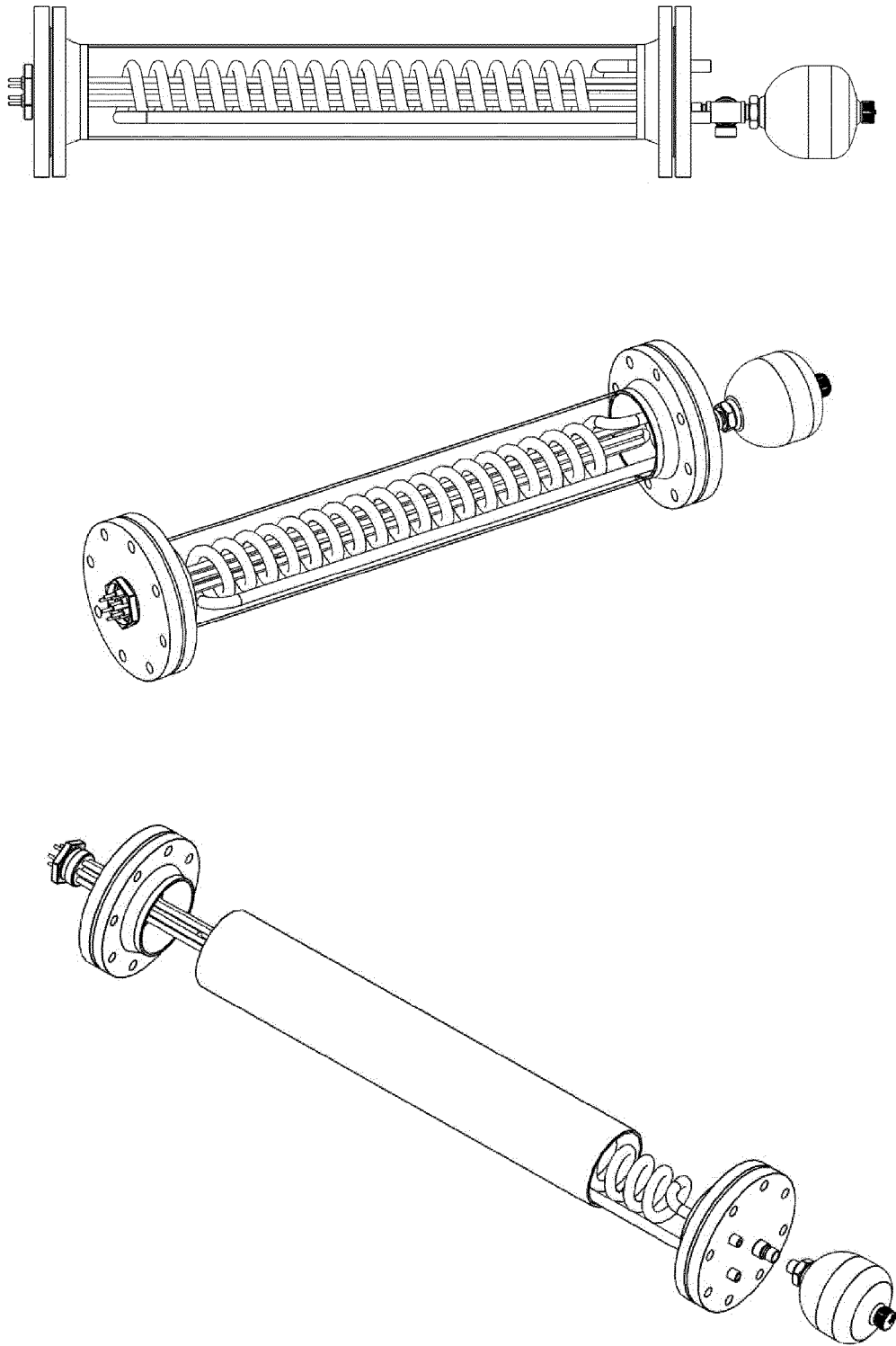


Fig. 4

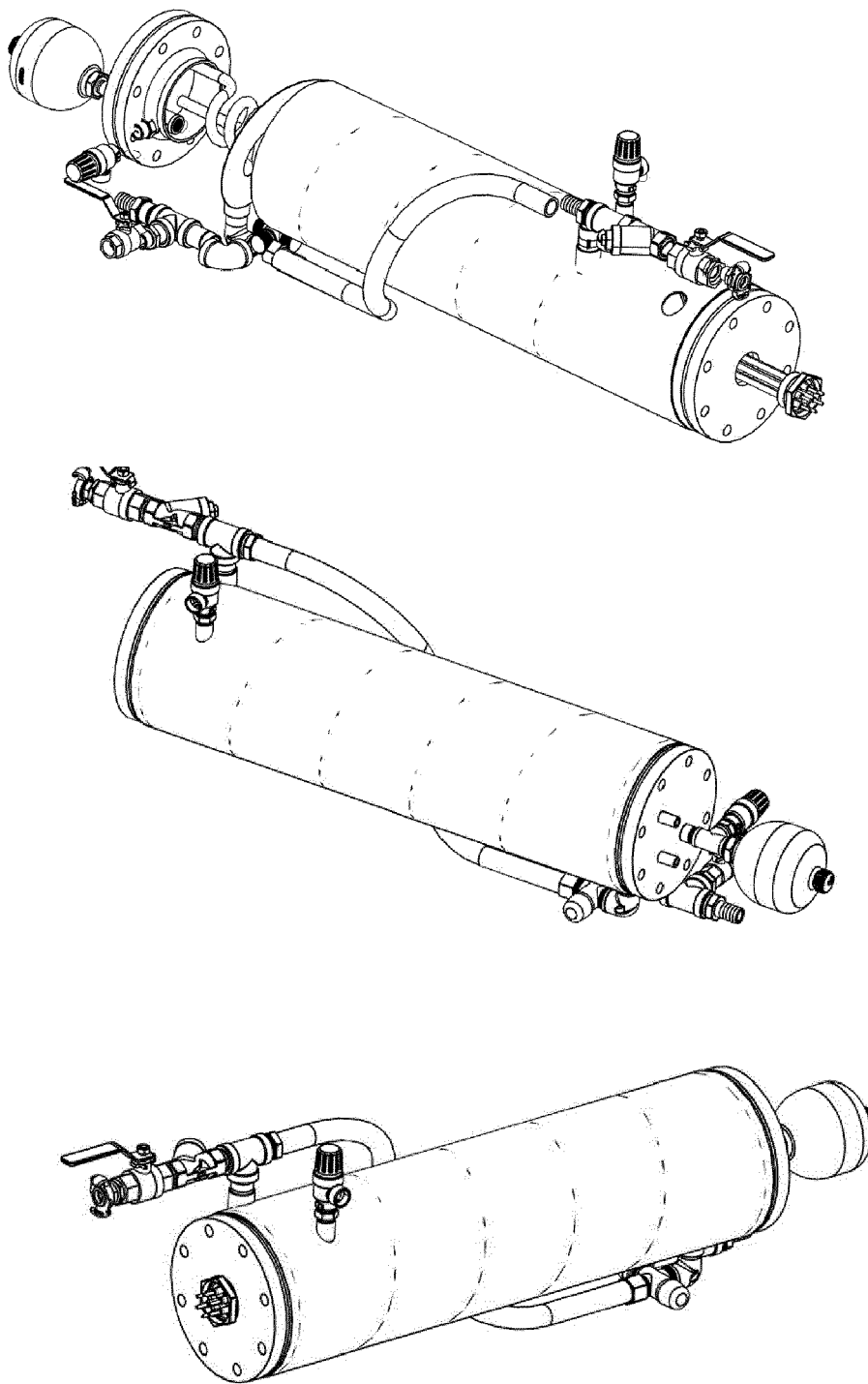


Fig. 5

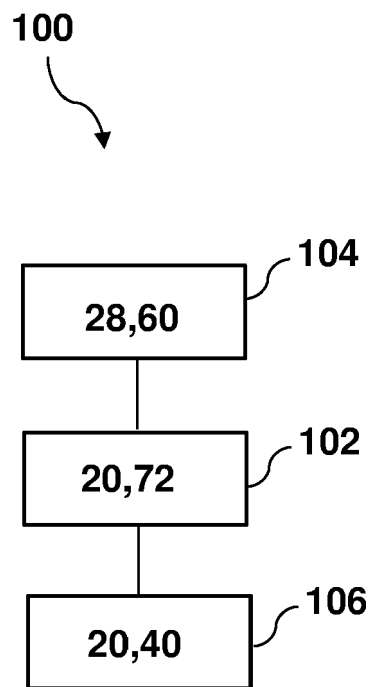


Fig. 6

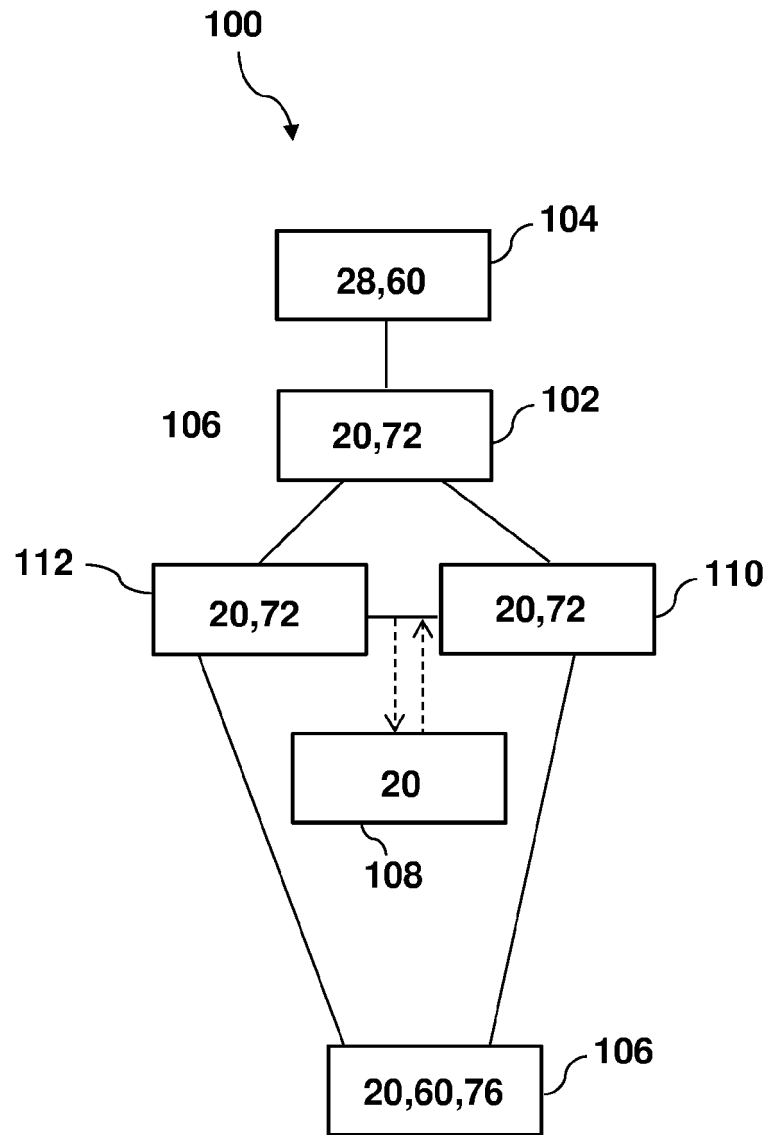


Fig. 7



EUROPEAN SEARCH REPORT

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Place of search Munich		Date of completion of the search 12 December 2023	Examiner Riesen, Jörg
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