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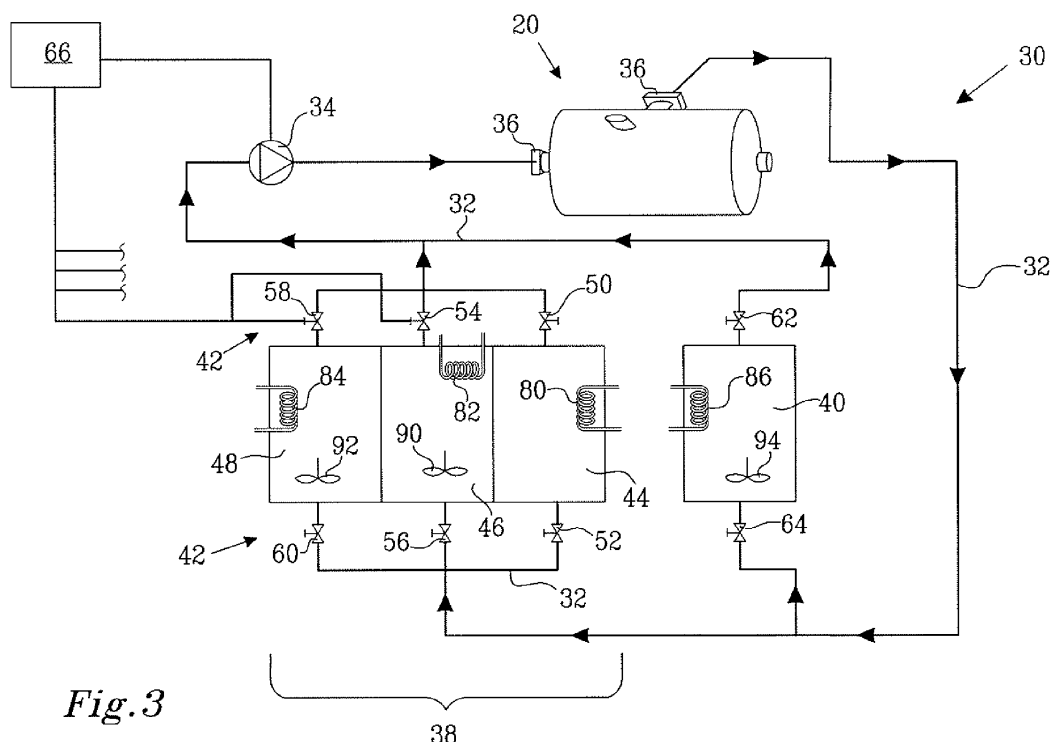
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(54) **Method of coating a part of a heat exchanger and heat exchanger**

(57) A method of coating an internal surface of an assembled heat exchanger is provided. The heat exchanger (2) comprising a first passage for a first heat exchange fluid, and a second passage for a second heat exchange fluid. The first and second passages are separated by at least one heat transfer element. The heat transfer element has a first surface facing the first passage. The method comprises; pre-treating the first sur-

face by circulating at least one pre-treatment liquid through the first passage of the heat exchanger (2) and a pre-treatment liquid storage (38) separate from the heat exchanger, and electroless nickel plating the first surface by circulating a solution comprising nickel ions through the first passage of the heat exchanger (2) and a solution container (40) separate from the heat exchanger (2). A heat exchanger comprising a nickel plating is also disclosed.



Description

TECHNICAL FIELD

[0001] The present invention relates to a method of coating an internal surface of an assembled heat exchanger and a heat exchanger comprising a surface having a nickel plating.

BACKGROUND

[0002] Heat exchangers may be used for heat exchange between two fluids. Typically, a heat exchanger has an inlet and an outlet for each of the two fluids. Inside the heat exchanger one flow passage is provided for each fluid. The flow passages are kept apart by one or more heat transfer elements, through which heat is transferred from one fluid to the other fluid. For instance, in plate heat exchangers the heat transfer elements are formed by heat transfer plates, and in spiral heat exchangers heat transfer elements are formed by spiral sheets.

[0003] Different kinds and types of fluids may pass through a heat exchanger. Some fluids are erosive, e.g. because of particles contained in the fluid. The heat transfer elements of a heat exchanger are thus subjected to wear during use with such fluids. Also, fluids may pass through a heat exchanger for various purposes. For instance, in some heat exchangers a fluid may be caused to boil. Thus, the heat transfer elements of heat exchangers have different requirements depending on the fluids flowing through a heat exchanger and the purpose of a heat exchanger.

[0004] Heat transfer elements may thus be manufactured from various different materials, the material being suitable for a particular heat exchanger application. Also, heat transfer elements may be coated with different kinds of materials, the coating material being suitable for a particular heat exchanger application.

[0005] US 6513581 discloses plate and spiral heat exchangers wherein surfaces have been coated by means of electroless chemical deposition. A metal/phosphorus and metal/polymer layer is formed by dipping a workpiece comprising the surface to be coated into a metal electrolyte solution.

[0006] WO 92/16310 discloses a method of providing heat transfer plates of a plate heat exchanger with a layer of surface protecting plastic material. In an assembled heat exchanger a gaseous medium containing the plastic material is introduced into interspaces between the heat transfer plates. The plastic material may be introduced in the form of mist or in evaporated form. The plastic material is caused to deposit onto the heat transfer plates in the interspaces.

[0007] WO 96/06705 is concerned with brazed heat exchangers which are brazed with a copper brazing material. The copper brazing material is not able to withstand a heat exchange fluid containing ammonia. A method of protecting the brazing joints of a brazed heat exchanger

is thus disclosed in WO 96/06705. According to the method a protective coating is diffused into the brazing joints of an assembled heat exchanger. According to the method the coating material, either fluid tin or a water solution of silver nitrate, is poured through the four connecting ports of a plate heat exchanger into the plate heat exchanger to completely fill the plate heat exchanger. The coating material is allowed to circulate in the plate heat exchanger and is then emptied out of the heat exchanger. The tin, or the silver, diffuses into the copper brazing joints.

SUMMARY

[0008] An object of embodiments is to provide a method of efficiently plating heat transfer elements of a heat exchanger.

[0009] According to an aspect of the invention, the object is achieved by a method of coating an internal surface of an assembled heat exchanger. The heat exchanger comprises a first passage for a first heat exchange fluid, and a second passage for a second heat exchange fluid. The first and second passages are separated by at least one heat transfer element. The heat transfer element has a first surface facing the first passage and a second surface facing the second passage. The method comprises: pre-treating the first surface by circulating at least one pre-treatment liquid through the first passage of the heat exchanger and a pre-treatment liquid storage separate from the heat exchanger, and electroless nickel plating the first surface by circulating a solution comprising nickel ions through the first passage of the heat exchanger and a solution container separate from the heat exchanger.

[0010] Since the pre-treatment liquid and the electroless plating solution comprising nickel ions are circulated, each through a dedicated storage and container, respectively, and the first passage of the heat exchanger, the first surface is homogeneously nickel plated in a rational and easily controlled process. The circulation of the pre-treatment liquid through the dedicated storage and the first passage means that the pre-treatment liquid will be applied to relevant areas of the heat transfer element to prepare the first surface for electroless nickel plating. The circulation of the electroless plating solution through the first passage and the solution container means that the solution containing nickel ions flows along/over the first surface and solution from the solution container is constantly provided to the first surface. This achieves favourable conditions for the electroless nickel plating. Furthermore, an easily performed method in comparison with nickel plating by dipping of separate heat transfer elements into different baths is provided. Also, by performing the nickel plating on an assembled heat exchanger entails that the nickel plating may be performed as a later production step when manufacturing a heat exchanger. Thus, the nickel plating will not risk being damaged by production steps or handling of heat transfer elements between production steps. Furthermore, a used heat ex-

changer may be re-plated using to the present method. As a result, the above mentioned object is achieved.

[0011] The heat exchanger may be for instance a spiral heat exchanger or a plate heat exchanger. By assembled heat exchanger it is to be understood that the heat exchanger may comprise a number of heat transfer elements, which elements are placed in relation to each other such that the first and second passages are formed and heat transfer between the two fluids may be performed. That is, parts of the heat exchanger which do not have a heat transferring function or not a function of limiting the first and second passages, such as frame parts, support arrangements, etc. may be attached after the electroless nickel plating has been performed. The heat transfer elements may be permanently assembled, e.g. by means of brazing or welding. The pre-treating and the electroless nickel plating may be seen as separate steps of the method. The pre-treating is performed before the electroless nickel plating. Pre-treating may include cleaning the first passage and/or rinsing the first passage and/or activating the first surface. Activating may be performed to further prepare the first surface for the electroless nickel plating. The pre-treatment liquid storage may comprise several containers suitably one for each pre-treatment liquid. The pre-treatment liquid storage may have the function of an intermediate storage for different pre-treatment liquids in the several containers. In case water is used as pre-treating liquid, the water may be supplied from a water container or from a water source, such as a water tap. The electroless nickel plating will form a nickel plating on the first surface. The nickel plating may be non-diffusing into the first surface of the heat transfer element, i.e. the nickel plating being on top of the first surface. The nickel plating on the first surface may be one of for instance; a nickel/phosphorous plating, a nickel/polymer plating, a nickel/polytetrafluoroethylene (PTFE) plating, nickel/diamond plating, a nickel/Boron plating, a nickel/silver plating, a nickel/gold plating or combinations thereof.

[0012] According to embodiments the pre-treating may comprise: Circulating one of a pre-treatment liquid in the form of water, a solvent, an acid, or a liquid comprising solid particles through the first passage. Water may be circulated through the first passage, inter alia between other liquids/solutions are circulated in the first passage. The water will thus rinse previously used liquids from the first passage. The solvent may be a solvent which dissolves fat or grease. An acid may clean or active the first surface. The solid particles in a liquid comprising solid particles will form an abrasive, which may be useful for preparing the first surface for the electroless nickel plating.

[0013] According to embodiments the pre-treating may comprise: Circulating water through the first passage and a water container, or by directing water from a water source through the first passage, and cleaning the first surface by circulating a solvent, or a liquid which comprises solid particles, through the first passage and a container for the solvent, or a container for the liquid

which contains solid particles. In this manner the rinsing with water may clean the first passage and the first surface at least to some extent, and thereafter the solvent or the liquid which contains solid particles may clean the first surface to a further degree. As mentioned above, rinsing with water may be performed again after the cleaning with the solvent or with the liquid comprising solid particles. The rinsing and the cleaning may be seen as steps of the method.

[0014] According to embodiments the pre-treating may comprise: A surface activating step for activating the first surface before the electroless nickel plating by circulating an activating liquid through the first passage and a container for the activating liquid. In this manner the first surface may easily be activated before the electroless nickel plating.

[0015] According to embodiments circulating the pre-treatment liquid and circulating the solution may be performed by one or more pumps forming part of a conduit system, the conduit system further comprising a releasable connection to the heat exchanger, the pre-treatment liquid storage, the solution container, and a valve arrangement for directing either the pre-treatment liquid, or the solution, through the pump and the heat exchanger. In this manner pre-treatment liquid may first be circulated through the first passage and the pre-treatment liquid storage by means of the pump and the valve arrangement set in a first position. Thereafter, the valve arrangement may be set in a different position to circulate the electroless plating solution through the first passage and the solution container. Again, circulation is performed by the pump. When one heat exchanger has been nickel plated it is removed from the releasable connection and a further heat exchanger to be electroless nickel plated is connected to the releasable connection and the circulation of the pre-treatment liquid and the electroless nickel plating solution is repeated. Thus, an efficient and easily administered method for nickel plating surfaces of heat exchangers is achieved.

[0016] According to embodiments the solution may be an aqueous solution comprising nickel ions, a chemical reducing agent, and a catalyst. The solution may comprise at least one of phosphorous ions, boron ions, polytetrafluoroethylene (PTFE) particles, or diamond particles. The solution may comprise further additives, e.g. for stabilizing the solution or regulating the pH of the solution.

[0017] According to embodiments the method may comprise heating the solution in the solution container by means of a heating element. In this manner the electroless nickel plating solution may be kept at a temperature, or within a temperature interval, at which the electroless nickel plating process is suitably performed.

[0018] According to embodiments the method may comprise heating the pre-treatment liquid in the pre-treatment liquid storage by means of a heating element. In this manner the pre-treatment liquid may be kept at a temperature, or within a temperature interval, at which

the pre-treating is suitably performed.

[0019] According to embodiments the method may comprise stirring the solution in the solution container by means of a stirring element. In this manner the electroless nickel plating solution may be kept at an even temperature and/or at an even concentration in the solution container.

[0020] According to embodiments the method may comprise stirring the pre-treatment liquid in the pre-treatment liquid storage by means of a stirring element. In this manner the pre-treatment liquid may be kept at an even temperature and/or at an even concentration in the pre-treatment liquid storage.

[0021] According to embodiments the method may comprise: Removing an old nickel plating layer from the first surface by circulating a removing liquid through the first passage of the heat exchanger and a container for the removing liquid, before the pre-treating is performed. In this manner the method may be used to re-plate a used heat exchanger with electroless nickel plating.

[0022] According to embodiments the heat exchanger may comprise at least two permanently joined heat transfer elements, the first and second passages being separated by at least a first heat transfer element of the at least two permanently joined heat transfer elements. The method may suitably be performed on assembled heat exchangers with permanently join heat transfer elements.

[0023] An object of the embodiments is to provide a heat exchanger comprising a first passage for a first heat exchange fluid, and a second passage for a second heat exchange fluid, the first and second passages being separated by at least one heat transfer element, the heat transfer element having a first surface facing the first passage, the first surface having a nickel plating applied in accordance with above mentioned method aspects and embodiments.

[0024] According to embodiments the heat transfer element of the heat exchanger is welded to a further heat transfer element having a first surface facing the first passage, at least part of the first passage being formed between the heat transfer element and the further heat transfer element.

[0025] According to example embodiments the heat transfer element of the heat exchanger is brazed to a further heat transfer element having a first surface facing the first passage, at least part of the first passage being formed between the heat transfer element and the further heat transfer element.

[0026] Further features of, and advantages of, embodiments will become apparent when studying the appended claims and the following detailed description. Those skilled in the art will realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention, as defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The various aspects of embodiments, including its particular features and advantages, will be readily understood from the following detailed description and the accompanying drawings, in which:

Fig. 1 illustrates a spiral heat exchanger according to embodiments,

Fig. 2 illustrates a cross section of a plate heat exchanger according to embodiments,

Fig. 3 illustrates embodiments of a system for electroless nickel plating an assembled heat exchanger, Figs. 4 and 5 illustrate embodiments of methods of coating an internal surface of an assembled heat exchanger, and

Fig. 6 illustrates a container and two valves.

DETAILED DESCRIPTION

[0028] The present invention will now be described more fully with reference to the accompanying drawings, in which example embodiments are shown. However, this invention should not be construed as limited to the embodiments set forth herein. Disclosed features of example embodiments may be combined as readily understood by one of ordinary skill in the art to which this invention belongs. Like numbers refer to like elements throughout.

[0029] Well-known functions or constructions will not necessarily be described in detail for brevity and/or clarity.

[0030] Fig. 1 illustrates a spiral heat exchanger 20 according to embodiments. The spiral heat exchanger 20 comprises heat transfer elements in the form of two spiral shaped sheet metal pieces 22, 24, which are welded together. A first passage 8 for a first heat transfer fluid and a second passage (not shown) for a second heat transfer fluid are provided between the spiral shaped sheet metal pieces 22, 24. Each sheet metal piece 22, 24 has a first surface 12 facing the first passage 8 and a second surface (not shown) facing the second passage. The first surface 12 of each heat transfer element is provided with a nickel plating, which has been applied to the first surface 12 after the heat exchanger 20 has been assembled.

[0031] The heat exchanger 20 is provided with inlet and outlet pipe sections 26 (two out of four pipe sections are illustrated). In use two heat exchange fluids are conducted to and from the first and second passages through the pipe sections 26.

[0032] Fig. 2 illustrates a cross section of a plate heat exchanger 2 according to embodiments. Heat transfer elements in the form of heat transfer plates 4 are arranged in a stack 6. A first passage 8 for a first heat transfer fluid and a second passage 10 for a second heat transfer fluid are provided in the stack 6. A passage 8, 10 is in this embodiment formed by several plate interspaces. Except for the outer plates of the stack 6, each

heat transfer plate 4 has a first surface 12 facing the first passage 8 and a second surface 14 facing the second passage 10. The first surface 12 of each heat transfer element is provided with a nickel plating, which has been applied to the first surface 12 after at least the heat transfer plates 4 of the plate heat exchanger 2 have been assembled. The heat transfer plates 4 of the heat exchanger 2 have been permanently joined by means of brazing. The heat transfer plates 4 may alternatively have been joined by means of welding.

[0033] Four port channels 16, two of which are shown, extend through the stack 6 and communicate with the first and second passages 8, 10. Inlet and outlet pipe sections 18 provide means for directing the first and second heat transfer fluids into the plate heat exchanger 2. Each of the first and second passages 8, 10 communicates with two port channels. Of the two port channels communicating with one passage 8, 10, in use, one conducts a heat exchange fluid to the passage and the other conducts it from the passage.

[0034] Fig. 3 illustrates schematically embodiments of a system 30 for electroless nickel plating an assembled heat exchanger. An assembled spiral plate heat exchanger 20 is illustrated in Fig. 3 but an assembled plate heat exchanger or other type of assembled heat exchanger may equally well be electroless nickel plated in the system 30. The system 30 comprises a conduit system with conduits 32 (schematically illustrated). The conduit system further comprises a pump 34, a releasable connection 36 for connecting an assembled heat exchanger 20 to the conduit system, a pre-treatment liquid storage 38, a solution container 40 for a solution containing nickel ions and to be used for the electroless nickel plating. The conduit system further comprises a valve arrangement 42 comprising several valves. The system 30 may be utilized for a method of coating an internal surface of an assembled heat exchanger according to embodiments.

[0035] Fig. 4 illustrates embodiments of a method of coating an internal surface of an assembled heat exchanger. Reference is made in the following to Figs. 3 and 4.

[0036] The pump 34 circulates pre-treatment liquid from the pre-treatment liquid storage 38 through a first passage of the heat exchanger 20 and back to the pre-treatment liquid storage 38. Also, the pump 34 circulates the solution from solution container 40 through the first passage of the heat exchanger 20 and back the solution container 40. The valve arrangement 42 is used for connecting either the pre-treatment liquid storage 38 or the solution container 40 to the pump 34, and the heat exchanger 20. Accordingly, pre-treating 410 a first surface of a heat exchange element of the heat exchanger 20 is performed by circulating the pre-treatment liquid through a first passage of the heat exchanger 20 and the pre-treatment liquid storage 38, and electroless nickel plating 420 the first surface in the heat exchanger 20 is performed by circulating the solution through the first pas-

sage and the solution container 40. Known solutions containing Ni ions may be used for the electroless nickel plating, such as e.g. disclosed in US2006/0024514, US 6066406, US2009/123777, and US 5019163. Pre-treatment liquids as such are known, such as e.g. discussed in US 2009/123777 and US 5019163.

[0037] Fig. 5 illustrates embodiments of a method of coating an internal surface of an assembled heat exchanger. Reference is made in the following to Figs. 3 and 5.

[0038] The pre-treatment liquid storage 38 according to embodiments comprises three containers 44, 46, 48. A water container 44 is connected to the conduits 32 by means of two valves 50, 52. Pre-treatment liquid in the form of water may thus be circulated in the system 30 by means of the pump 34 when the valves 50, 52 are open, as represented by the circulating water step 510 in Fig. 5. A container 46 containing a solvent is connected to the conduits 32 by means of two valves 54, 56. The solvent may be water with an added detergent, a hydrocarbon based solvent, or a different solvent. Pre-treatment liquid in the form of solvent may thus be circulated in the system 30 by means of the pump 34 when the valves 54, 56 are open, as represented by the circulating solvent step 520 in Fig. 5. A container 48 for activating liquid, such as an acid, is connected to the conduits 32 by means of two valves 58, 60. Pre-treatment liquid in the form of activating liquid may thus be circulated in the system 30 by means of the pump 34 when the valves 58, 60 are open, as represented by the surface activating step 530 in Fig. 5. Activating liquids as such are known, such as e.g. discussed in US 2009/123777.

[0039] The solution container 40 is connected to the conduits 32 by means of two valves 62, 64. The solution comprising nickel ions may thus be circulated in the system 30 by means of the pump 34 when the valves 62, 64 are open, as represented by the electroless nickel plating step 540 in Fig. 5.

[0040] The step 510 may be repeated after one or more of the steps circulating solvent step 520, circulating activating liquid step 530, and circulating solution comprising nickel ions of the electroless nickel plating step 540. In this manner the heat exchanger 20 may be rinsed with water to remove a previously used liquid or solution.

[0041] Alternatively, the circulating water step 510 may be replaced or complement with a directing water step 550, in which water from a water source, such a water tap, is directed through the first passage of the heat exchanger 20.

[0042] The method may include a preceding step of connecting 560 a heat exchanger 20 to the releasable connection 36 such that the liquids and solution may be directed through the first passage of the heat exchanger 20. In case the heat exchanger 20 comprises a nickel plating on the first surface, for instance if the heat exchanger 20 is a used heat exchanger which is to be re-plated with a nickel plating, the method may include a removing step 570, in which the nickel plating is removed

by means of a removing liquid being circulated through the first passage and a container for removing liquid by means of the pump 34. Removing liquids as such are known, such as e.g. discussed in US4554049. A removing liquid may also be known as a stripping solution/liquid. The removing step 570 may not be required in some embodiments, wherein the heat exchanger instead is subjected only to one or more of the pre-treatment steps 510 - 530 before the electroless nickel plating step 540. Fig. 6 illustrates a container 70 for removing liquid and two valves 72, 74 connected via conduits to the container 70 for removing liquid. This container 70 and these valves 72, 74 may be connected to the conduits 32 of the system 30 illustrated in Fig. 3 to permit the removing liquid to be circulated by the pump 34 through the heat exchanger 20 and the container 70 for removing liquid.

[0043] The valves 50 - 64 of the valve system 42 and the pump 34 may be manually operated or automatically controlled by a schematically disclosed control system 66. As schematically illustrated, the control system 66 may be connected to the pump 34 and all of the valves 50 - 64. To perform a method of electroless nickel plating of a first surface of a heat exchanger according to embodiments illustrated in Figs 4 and 5, the control system 66 may manipulate pump 34 and the valve arrangement 42 such that the valves 50 - 64 are opened two at a time to allow a relevant liquid or solution to be circulated by the pump 34 through the first passage of the heat exchanger 20 and a relevant container 40, 44 - 48 for a certain period of time.

[0044] Some or all of the containers 40, 44 - 48 may be provided with heating elements 80 - 86 for heating a respective liquid or solution contained therein. Also one or more of the containers 40, 44 - 48 may be provided with stirring elements 90 - 94 for stirring a respective liquid or solution contained therein. The heating elements 80 - 86 and the stirring elements 90 - 94 may be controlled by the control system 66. The temperature of a liquid or solution may for instance be kept at a temperature of 1 - 50 degrees Celsius below a boiling temperature of the relevant liquid or solution by means of a relevant heating element controlled by the control system 66. Further suitable temperatures for the solution comprising nickel ions are known, e.g. from previously mentioned prior art documents. A temperature sensor (not shown) is suitably arranged in each of the containers 40, 44 - 48. Each temperature sensor is connected to the control system 66 to permit controlling of the respective heating elements 80 - 86. Each stirring element 90 - 94 may be controlled to stir a relevant liquid or solution at least while the liquid or solution is circulated through the first passage and the relevant container 40, 44 - 48.

[0045] Heating the solution in the solution container 40 is performed by the heating element 86 in the solution container 40, as represented by the solution heating step 580 in Fig. 5, and the solution heating step 440 in Fig. 4.

[0046] Heating the pre-treatment liquid in the pre-treatment liquid storage 38 is performed by a heating element

80 - 84 in the pre-treatment liquid storage 38, as represented by the pre-treatment liquid heating step 450 in Fig. 4. The pre-treatment liquid heating step may be performed by one or more separate steps in which a respective of the pre-treatment liquids is heated. A water heating step 582 (Fig. 5) may be performed by a water heating element 80 in the water container 44. A solvent heating step 584 (Fig. 5) may be performed by a solvent heating element 82 in the container 46 containing a solvent. An activating liquid heating step 586 (Fig. 5) may be performed by an activating liquid heating element 84 in the container 48 for activating liquid.

[0047] Stirring the solution in the solution container 40 is performed by the stirring element 94 in the solution container 40, as represented by the solution stirring step 590 in Fig. 5, and the solution stirring step 460 in Fig. 4.

[0048] Stirring the pre-treatment liquid in the pre-treatment liquid storage 38 is performed by a stirring element 90, 92 in the pre-treatment liquid storage 38, as represented by the pre-treatment stirring step 470 in Fig. 4. The pre-treatment stirring step may be performed by one or more separate steps in which a respective of the pre-treatment liquids is stirred. A water stirring step 592 (Fig. 5) may be performed by a water stirring element (not shown) in the water container 44. A solvent stirring step 594 (Fig. 5) may be performed by a solvent stirring element 90 in the container 46 containing a solvent. An activating liquid stirring step 596 (Fig. 5) may be performed by an activating liquid stirring element 92 in the container 48 for activating liquid.

[0049] It may be noted that: increasing the circulation time for the solution comprising nickel ions will yield a thicker coating (up to a certain thickness); a higher temperature may promote reaction - resulting in an increased coating speed; different substrate material, i.e. material of the heat transfer elements, will result in different coating speeds; different solutions for electroless electroless nickel plating, e.g. for Ni-B plating, Ni-diamond plating, etc will result in different coating speeds. These relationships are well known to a person skilled in the art.

[0050] Example embodiments described above may be combined as understood by a person skilled in the art. It is also understood by those skilled in the art that nickel plating may be performed simultaneously in several heat exchangers connected in parallel or series to the system 30 illustrated in Fig. 3. Accordingly, the method may comprise nickel plating more than one heat exchanger at a time.

[0051] A connection to a drain may be provided in the embodiment system 30 of Fig. 3. More than one pump 34 may be used in the system 30. For example, one pump for each liquid/solution may be arranged in the conduit system of the system 30. The concentration of substances in the liquids and solutions may be measured. The control system 66 may provide a warning if a relevant concentration value is over, or below, a threshold value. The concentration of substances in the liquids and solutions may be corrected by means of the exchanging a

liquid or solution or by adding concentrates of a relevant substance. A heating element and a stirring element may be used in the container 70 for removing liquid.

[0052] The second surface of a heat transfer element may also be nickel plated in accordance with the method. This may be performed at the same time as the first surface is nickel plated. Alternatively, it may be performed in a separate process. The nickel platings on the first and second surfaces may be of the same kind or of different kinds, e.g. nickel/boron plating on one surface and nickel/polymer plating on the other surface.

[0053] Therefore, it is to be understood that the foregoing is illustrative of various example embodiments and the invention is not to be limited to the specific embodiments disclosed and that modifications to the disclosed embodiments, combinations of features of disclosed embodiments as well as other embodiments are intended to be included within the scope of the appended claims.

[0054] As used herein, the term "comprising" or "comprises" is open-ended, and includes one or more stated features, elements, steps, components or functions but does not preclude the presence or addition of one or more other features, elements, steps, components, functions or groups thereof.

[0055] As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0056] As used herein, the common abbreviation "e.g.", which derives from the Latin phrase "exempli gratia," may be used to introduce or specify a general example or examples of a previously mentioned item, and is not intended to be limiting of such item. If used herein, the common abbreviation "i.e.", which derives from the Latin phrase "id est," may be used to specify a particular item from a more general recitation.

[0057] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0058] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0059] It will be understood that when an element is referred to as being "on", "coupled" or "connected" to another element, it can be directly on, coupled or connected to the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on", "directly coupled" or "directly connected" to another element, there are no intervening

elements present.

[0060] It will be understood that although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another element, component, region, layer or section. Thus, a first element, component, region, layer or section discussed herein could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

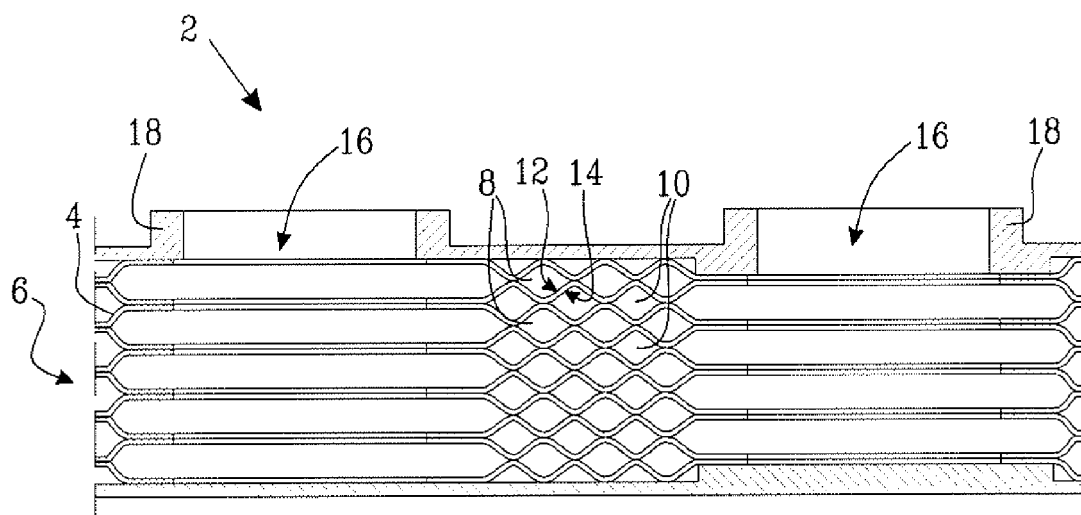
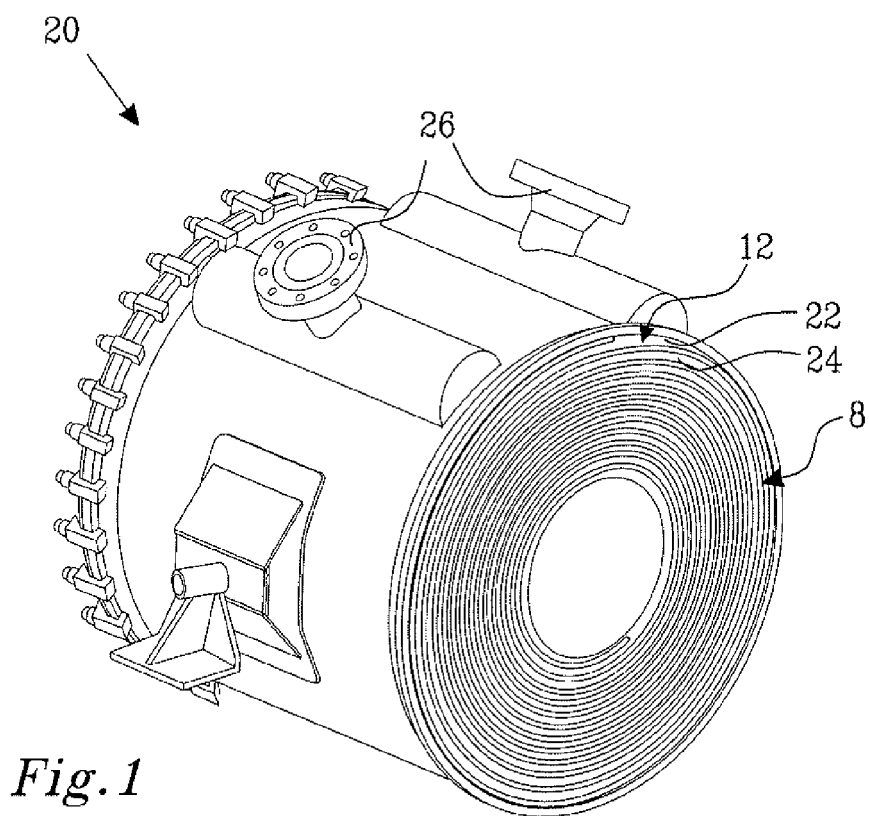
[0061] Spatially relative terms, such as "beneath", "below", "bottom", "lower", "above", "top", "upper" and the like, may be used herein for ease of description to describe one element's or feature's relationship to other element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Also, as used herein, "lateral" refers to a direction that is substantially orthogonal to a vertical direction.

[0062] Example embodiments of the present invention have been described herein with reference to cross-section illustrations that are schematic illustrations of idealized embodiments (and intermediate structures) of the invention. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances are to be expected. Thus, embodiments of the present invention should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shape that result, for example, from manufacturing.

Claims

1. A method of coating an internal surface of an assembled heat exchanger (2, 20), the heat exchanger comprising a first passage (8) for a first heat exchange fluid, and a second passage (10) for a second heat exchange fluid, the first and second passages (8, 10) being separated by at least one heat transfer element, the heat transfer element having a first surface (12) facing the first passage (8) and a second surface (14) facing the second passage (10), wherein the method comprises; pre-treating the first surface by circulating at least one pre-treatment liquid through the first passage (8) of the heat exchanger.

- er and a pre-treatment liquid storage (38) separate from the heat exchanger, and electroless nickel plating (420, 540) the first surface (12) by circulating a solution comprising nickel ions through the first passage (8) of the heat exchanger and a solution container (40) separate from the heat exchanger.
2. The method according to claim 1, wherein the pre-treating comprises;
circulating one of a pre-treatment liquid in the form of water, a solvent, an acid, or a liquid comprising solid particles through the first passage (8).
 3. The method according to any one of claims 1 - 2, wherein the pre-treating comprises;
circulating water (510) through the first passage (8) and a water container (44), or by directing water (550) from a water source through the first passage, and
cleaning the first surface (12) by circulating a solvent, or a liquid which comprises solid particles, through the first passage (8) and a container (46) for the solvent, or a container for the liquid which contains solid particles.
 4. The method according to any one of the preceding claims, wherein pre-treating comprises;
a surface activating step (530) for activating the first surface (12) before the electroless nickel plating by circulating an activating liquid through the first passage (8) and a container (48) for the activating liquid.
 5. The method according to any one of the preceding claims, wherein circulating the pre-treatment liquid and circulating the solution is performed by one or more pumps (34) forming part of a conduit system, the conduit system further comprising a releasable connection (36) to the heat exchanger, the pre-treatment liquid storage (38), the solution container (40), and a valve arrangement (42) for directing either the pre-treatment liquid, or the solution, through the pump (34) and the heat exchanger.
 6. The method according to any one of the preceding claims, wherein the solution is an aqueous solution comprising nickel ions, a chemical reducing agent, and a catalyst.
 7. The method according to any one of the preceding claims, wherein the method comprises heating the solution in the solution container (40) by means of a heating element (86).
 8. The method according to any one of the preceding claims, wherein the method comprises heating the pre-treatment liquid in the pre-treatment liquid storage (38) by means of a heating element (82, 84).
 9. The method according to any one of the preceding claims, wherein the method comprises stirring the solution in the solution container (40) by means of a stirring element (94).
 10. The method according to any one of the preceding claims, wherein the method comprises stirring the pre-treatment liquid in the pre-treatment liquid storage (38) by means of a stirring element (90, 92).
 11. The method according to any one of the preceding claims, wherein the method comprises;
removing (570) an old nickel plating layer from the first surface (12) by circulating a removing liquid through the first passage (8) of the heat exchanger and a container (70) for the removing liquid, before the pre-treating is performed.
 12. The method according to any one of the preceding claims, wherein the heat exchanger comprises at least two permanently joined heat transfer elements, the first and second passages being separated by at least a first heat transfer element of the at least two permanently joined heat transfer elements.
 13. A heat exchanger (2, 20) comprising a first passage (8) for a first heat exchange fluid, and a second passage (10) for a second heat exchange fluid, the first and second passages (8,10) being separated by at least one heat transfer element, the heat transfer element having a first surface (12) facing the first passage (8), the first surface (12) having a nickel plating applied in accordance with the method according to any one of claims 1-12.
 14. The heat exchanger (2, 20) according to claim 13, wherein the heat transfer element is welded to a further heat transfer element having a first surface (12) facing the first passage (8), at least part of the first passage (8) being formed between the heat transfer element and the further heat transfer element.
 15. The heat exchanger according to claim 13, wherein the heat transfer element is brazed to a further heat transfer element having a first surface (12) facing the first passage (8), at least part of the first passage (8) being formed between the heat transfer element and the further heat transfer element.



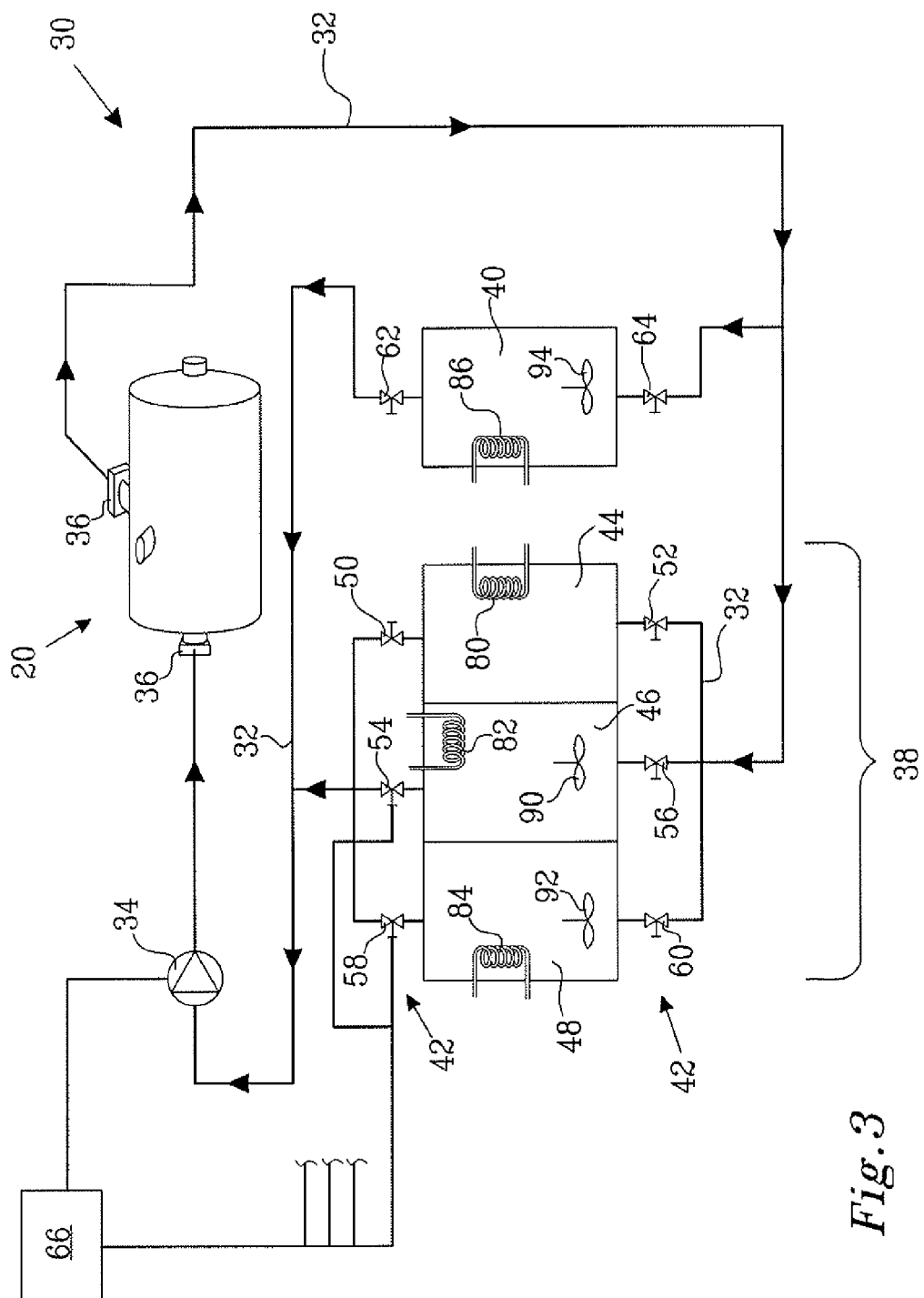


Fig. 3

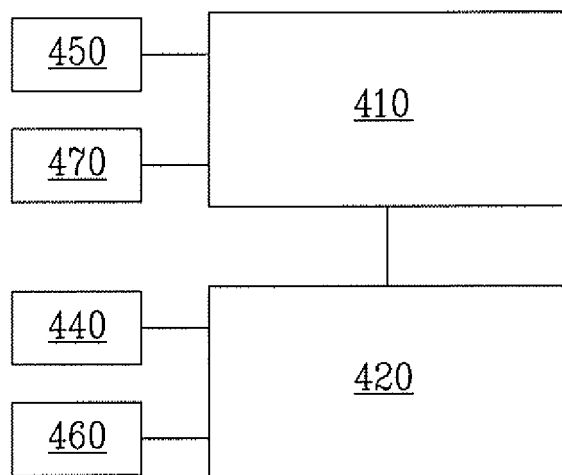


Fig. 4

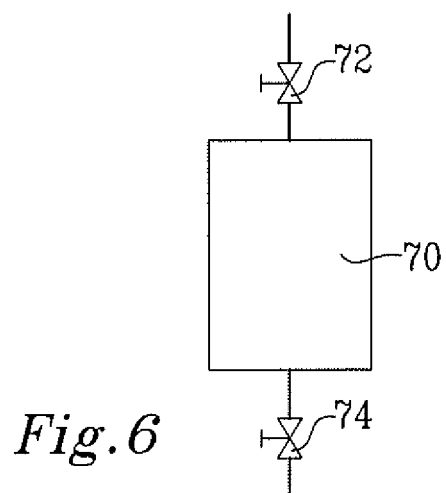


Fig. 6

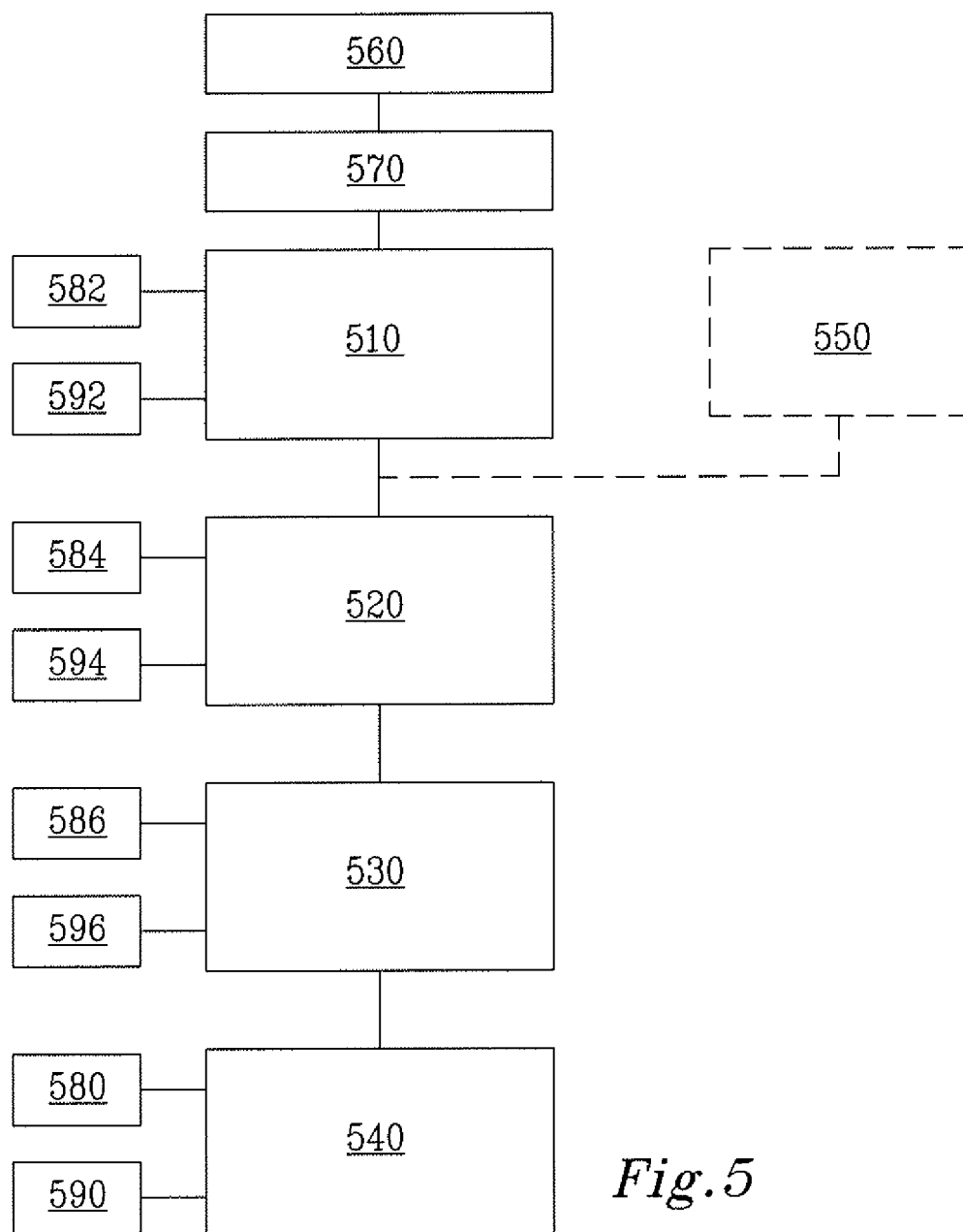


Fig.5

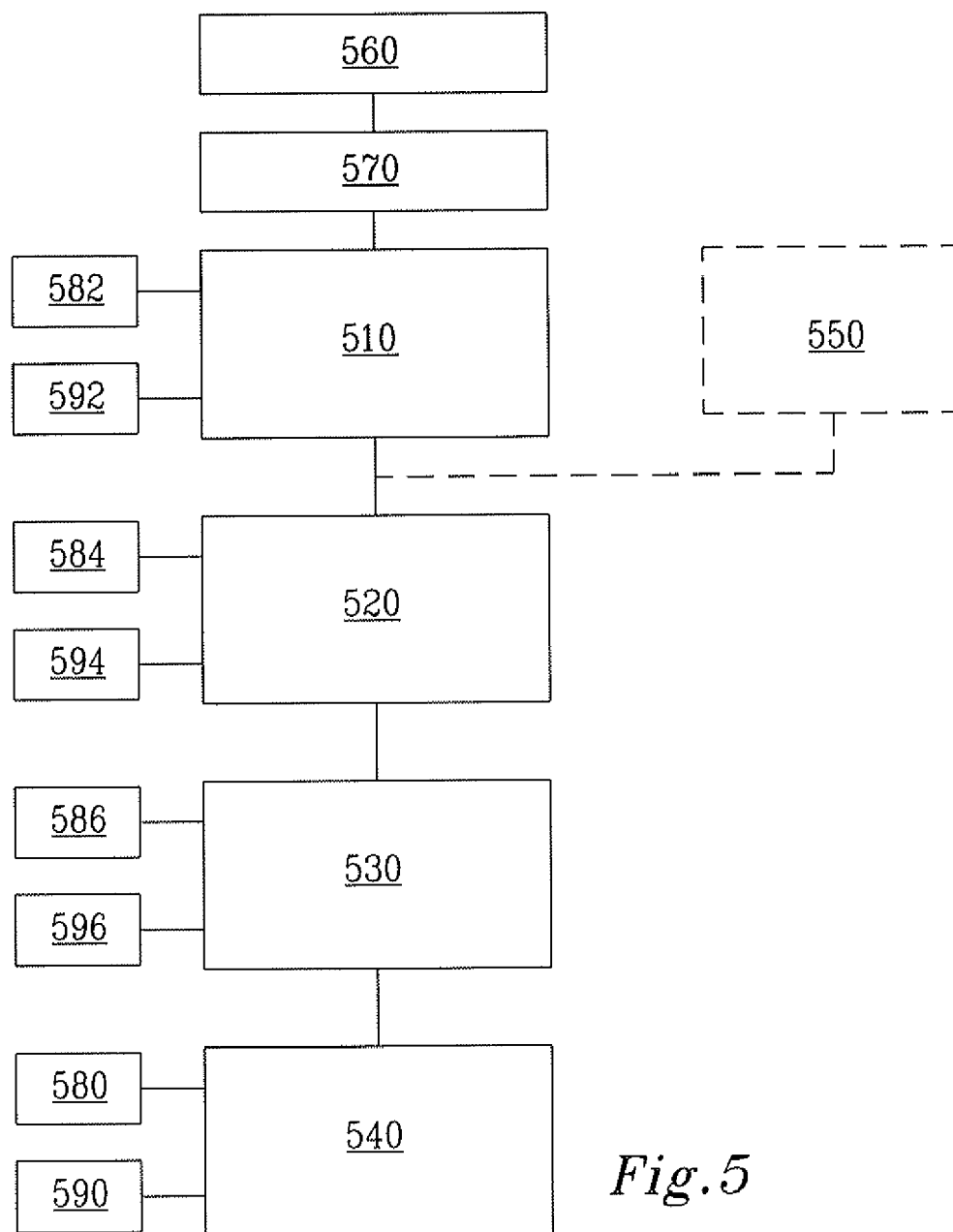


Fig. 5



EUROPEAN SEARCH REPORT

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