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Laundry dryer including a heat pump system

(57) The present invention relates to a laundry dryer including:

- a casing (2) rotatably supporting a drum (3), said casing (2) including a basement (24) defining a basement plane (X,Y) and in which a first longitudinal half (24 first half) and a second longitudinal half (24 second half) of the basement are identifiable by means of a first plane (P1) perpendicular to said basement plane (X,Y) and passing through a rotational axis (R) of the drum (3);

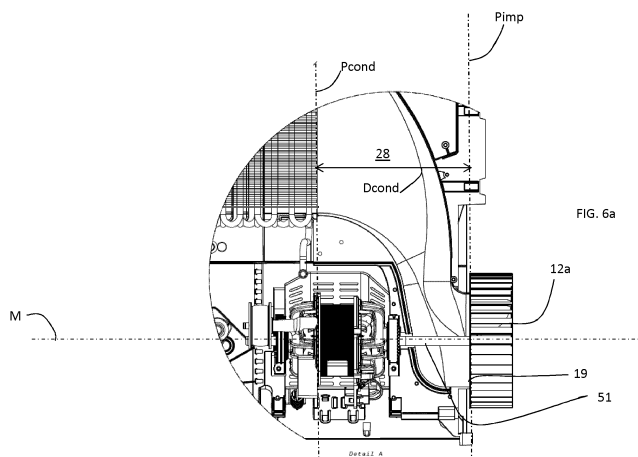
- A heat pump system (30) including a first heat exchanger (31), and a second heat exchanger (32); said first and/or second heat exchanger being arranged in a process air conduit (18) within said first longitudinal half (24 first half) of said basement (24) for the majority of their

respective volumes;

- Said process air conduit including a basement process air duct formed in said basement, comprising a basement process air duct portion (28) channeling said process air between a process air exit (28in) where process air exits from said first heat exchanger (31) and a basement process air outlet (19) where process air exits said basement;

- A main fan (12) including an impeller (12a), said main fan (12) being located in proximity of the basement process air outlet (19) and having an impeller process air inlet, wherein a impeller inlet plane (Pimp) is defined;

- Wherein a distance (Dcond) between any point of the first heat exchanger (31) and said impeller inlet plane (Pimp) is longer or equal to 12cm.



DescriptionTechnical field

5 **[0001]** The present invention relates to a laundry dryer including a heat pump system having an improved air flow within the basement of the laundry dryer.

Background of the invention

10 **[0002]** The heat pump technology in a laundry dryer is at present the most efficient way to dry clothes in terms of energy consumption. In a heat pump system of the laundry dryer a process air stream flows in a closed process air stream circuit. Further, the heat pump system includes a closed refrigerant circuit. The process air stream is moved by a main fan, passes through a laundry chamber, which is preferably formed as a rotatable laundry drum, and removes there water from wet clothes. Then, the process air stream is cooled down and dehumidified in an evaporator, heated
15 up in a condenser and re-inserted into the laundry drum again.

[0003] The refrigerant is compressed by a compressor, condensed in the condenser, expanded in an expansion device and then vaporized in the evaporator.

[0004] Thus, the condenser and the evaporator are components of the process air stream circuit as well as of the refrigerant circuit. The condenser and the evaporator are heat exchangers between the process air stream circuit and
20 the refrigerant circuit.

[0005] Usually, the components of the heat pump system are placed in a basement of the laundry dryer. The basement of a laundry dryer is part of a casing, which includes in addition to the basement also walls, substantially vertically supported from the basement, such as for instance a front wall and a rear wall, and lateral walls. In the casing, a drum, where the laundry is introduced in order to dry the same, is rotatably supported. In particular, the compressor, the
25 evaporator and the condenser are arranged in said basement below the laundry drum. An air duct of the process air stream circuit has to pass the basement of the dryer, bringing the humid air to the evaporator and reintroducing the dry air from the condenser in the drum. The duct in the basement can be formed in an advantageous embodiment by joining together two shells, an upper shell portion and a lower shell portion, which form the basement.

[0006] FIG 7 illustrates a top view of the open basement of a laundry dryer including a heat pump system according to the prior art. The compressor 140, the evaporator 160, the condenser 180, the main fan 200 and the motor 220 are
30 arranged in the lower portion 100 of the basement. The evaporator 160 and the condenser 180 are placed in parallel in a straight basement process air duct. Furthermore, the flow of air exiting the condenser 180 has to perform two substantially 90° turns in order to reach the outlet of the basement process air duct in the basement where the main fan is located, the two 90° turns being connected again by a straight basement process air duct.

35 **[0007]** Such angles in the process air stream circuit cause pressure drops and turbulences increasing the energy consumption and the noise. Indeed, such a basement process air duct is far away from the best aerodynamic shape, this latter being the shape reducing air resistance considerably during the flow.

[0008] However, in order to have a basement process air duct in which sharp turns and angles are avoided, the heat exchangers have to be re-positioned inside the basement. In other words, the basement process air duct, wherein the
40 process air is flowing from the heat exchangers to the main fan, needs "more space" so that it can gently bend avoiding sharp 90° corners.

[0009] It is an object of the present invention to provide a laundry dryer with a heat pump system, wherein the flow of the process air stream is improved, with particular reference to the process air stream flow within the basement of the laundry dryer.

45 **[0010]** Applicant has realized via numerous experiments that a threshold distance can be defined, i.e. a distance "usable" by the basement process air duct to channel process air from the heat exchangers to the main fan of the basement process air conduit, above which a "gentle" curve of the process air process duct can be formed.

[0011] The core of the present invention is the combination of the arrangement of the evaporator and the condenser of the heat pump system inside said the basement on one hand and the fact that at least a given distance (called in the
50 following threshold distance) to be kept between the heat exchangers and the fan is to be present on the other hand. It is possible to have this "larger than usual" given distance in the basement because a more aerodynamically shaped process air duct improves the overall efficiency of the heat pump system and thus the dimensions of the evaporator and condenser, i.e. the surface in which heat exchange takes place, may be reduced. The process air flow from the condenser to the basement outlet is improved by keeping at least this aforementioned threshold distance. The heat exchange
55 between the refrigerant circuit and the process air stream circuit increases.

[0012] In addition, the energy consumption of the motors for the compressor and the main fan is reduced. Further, the noise of the laundry dryer is reduced, too.

[0013] According to an aspect, the invention relates to a laundry dryer including:

- a casing rotatably supporting a drum for receiving a load to be dried, said drum being apt to rotate around a rotational axis, said casing including
 - o a basement defining a basement plane and in which a first longitudinal half and a second longitudinal half of the basement are identifiable by means of a first plane perpendicular to said basement plane and passing through said rotational axis of the drum;
- A process air conduit in fluid communication with the drum where a process air stream is apt to flow;
- A heat pump system having a heat pump circuit in which a refrigerant can flow, said heat pump circuit including a first heat exchanger where the refrigerant is cooled off and the process air is heated up, and a second heat exchanger where the refrigerant is heated up and the process air is cooled off; said first heat exchanger and/or said second heat exchanger being arranged in the process air conduit within said first longitudinal half of said basement for the majority of their respective volumes in order to perform heat exchange between said refrigerant flowing in said heat pump circuit and said process air;
- Said process air conduit including a basement process air duct formed in said basement, said basement process air duct comprising a basement process air duct portion channeling said process air between a process air exit where process air exits from said first heat exchanger and a basement process air outlet where process air exits said basement;
- A main fan including an impeller to blow process air in said process air conduit, said main fan being located in proximity of the basement process air outlet and having an impeller air inlet, wherein a impeller inlet plane is defined;
- Wherein a distance between any point of the first heat exchanger and said impeller inlet plane is longer or equal to 12 cm.

[0014] In the following, with the term "dryer" both drying machines which dry only as well as combined washer-dryers capable of performing washing and drying cycles are meant.

[0015] The dryer of the invention includes a drying chamber, such as a drum, in which the load, e.g. clothes or laundry, to be dried is placed. The drum is part of an air process circuit which includes an air conduit for channeling a stream of air to dry the load. The process air circuit is connected with its two opposite ends to the drum. More specifically, hot dry air is fed into the drum, flowing over the laundry, and the resulting humid (and cooler) air exits the same. The humid air stream rich in water vapor is then fed to an evaporator (or second heat exchanger) of a heat pump, where the moist warm process air is cooled and the humidity present therein condenses. The resulting cool dry air is then heated up before entering again in the drying chamber by means a condenser (or first heat exchanger) of the heat pump, and the whole loop is repeated till the end of the drying cycle.

[0016] The dryer furthermore includes a casing or bearing structure, comprising preferably a basement, a front wall and a rear wall. The front wall is advantageously provided with a through opening, at which a door is mounted to access the drum in order to locate or remove the laundry. Preferably, a rim of the rear end of the drum abuts against the rear wall of the cabinet and even more preferably a gasket is interposed therein between; as well as a rim of the front end of the drum abuts against the front wall with also preferably a gasket therein between.

[0017] Within the casing, the drum is rotatably mounted for rotating according to a horizontal, or at least substantially horizontal, or tilted rotational axis. Support element(s) for rotatably supporting the drum are provided for within the casing. The drum is rotated preferably by means of a motor which defines a motor axis, for example which corresponds to the axis of a motor shaft.

[0018] In an advantageous embodiment, said drum support element includes a shaft, said shaft passing through said back wall, said shaft defining said axis of rotation of said drum. Alternatively or in addition, said drum support element includes a roller, the axis of the roller being substantially parallel to the drum axis of rotation.

[0019] The basement of the dryer of the invention includes a portion of the process air circuit, called basement air conduit, which includes substantially a duct formed in the basement. Within said basement air conduit both heat exchangers of the heat pump system are located. Furthermore, the basement air conduit channels the process air exiting the condenser to an outlet of the basement. From the outlet of the basement, the process air - dried by the condenser - is fed, for example via an additional portion of the process air conduit realized preferably in the rear wall of the cabinet, to the drum so as to dry the laundry therein. The portion of basement air conduit comprised between an exit of the condenser, i.e. a location in which the process air exits the condenser, and the outlet of the basement where the process air exits from the basement is called basement air duct portion.

[0020] Preferably, process air passes through the second and then the first heat exchanger in a direction towards said

rear wall of the casing.

[0021] The basement air duct portion includes one or more lateral walls depending on its geometry. If the geometry of the duct is substantially cylindrical or of a cylindroid form, the duct portion includes a single lateral wall having substantially circular cross section, which may change in diameter depending on the position in which the cross section is measured. Alternatively, two opposite lateral walls can be present, for example one substantially parallel to the other and defining substantially parallel planes.

[0022] In a standard operative position, the basement of the dryer is positioned on a floor or other substrate on which the dryer performs its standard operations (e.g. drying and/or washing and/or spinning cycles). Such positioning defines a horizontal or at least substantially horizontal plane, which is called the basement plane (X, Y). Planes parallel to the basement plane are therefore substantially horizontal planes.

[0023] In this standard operative position, also other terms are well defined: "front" or "rear" (or "back"), "top" or "bottom", "upper" or "lower" are always referred to the normal standard configuration of a dryer with the basement positioned on a floor. The front wall of the dryer is defined by the wall in which the door from which the drum is accessed is positioned. Given the horizontal plane on which the laundry is located, "top" and "bottom" - as their normal common meaning - refer to the position of an object along a vertical axis.

[0024] Preferably, on the basement of the dryer, the rear wall and the front wall are mounted. Even more preferably, the casing includes further walls, e.g. lateral walls and a top wall.

[0025] In a top view of the dryer, the basement can be considered as "divided" in two longitudinal halves by the axis of rotation of the drum (or the projection of said axis onto the basement plane). Whether the axis is horizontal (thus parallel to the basement plane (X,Y)) or tilted with respect to the latter, on a top view of the basement, the projection of the drum axis divides the basement in two halves, a first or left longitudinal half and a second or right longitudinal half. In other words, taking a plane which is perpendicular to the basement plane and which passes through the rotational axis of the drum, which generally coincides with the centerline of the basement, this plane virtually sections the basement in two longitudinal halves. This plane, called first plane, when sectioned by a plane parallel to the (X, Y) plane defines a line of division of the basement in two in a top view.

[0026] The two halves do not need to be identical. In other words with a first and a second half, a "right" and a "left" portion of the basement with respect of the above mentioned plane (first plane) passing through the rotational axis of the drum and perpendicular to the basement plane are meant. The projection on the basement of such rotational axis can be thus shifted from the centerline of the basement. Preferably, the centerline and the projection of the rotational axis of the drum coincide.

[0027] The layout of the heat pump system located in the basement of the dryer of the invention is the following.

[0028] The first heat exchanger and the second heat exchanger are located within the basement air conduit and extend for the majority of their volume within the first longitudinal half of the basement, e.g. they are substantially located for the majority of their volume to the left of the rotational axis of the drum. The heat exchangers can be completely contained within the first longitudinal half of the basement or part of their volume, the minority, can also extend within the second longitudinal half of the basement. Also, the exit of process air from the condenser is located within the first longitudinal half of the basement, at least for most of its area.

[0029] On the other end, the outlet of process air from the basement is located within the second longitudinal half of the basement, i.e. on the half of the basement right of the rotational axis of the drum. Preferably, the basement outlet is realized in the rear part of the basement, i.e. facing the rear wall of the cabinet. Thus, in order to channel the process air outside the basement, the basement duct portion extends from the exit of the condenser to the outlet of the basement starting from the first longitudinal half of the basement and reaching the second longitudinal half of the basement. Due to this geometry and layout, which is forced by the positioning of the various elements of the heat pump system in the basement, although the best aerodynamic solution for a duct channeling air would be a straight duct, the duct portion includes at least one "bend" or "turn".

[0030] In front or in proximity of the basement process air outlet, a main fan apt to blow the process air in the process air circuit, for example from the basement to the drum, is located. The main fan includes an impeller, which rotates to move the process air. The impeller defines an inlet section and an outlet section, which are the surfaces which substantially "touch" the impeller blades at the inlet and at the outlet of the air, respectively. The inlet section defines in turn an impeller inlet plane, said impeller inlet plane being the plane that contains the inlet section. The impeller inlet plane might be perpendicular to the basement plane, in case the impeller is mounted substantially vertically, or tilted with respect to the latter, depending on the chosen configuration of the impeller.

[0031] For example, in case the impeller is contained in a housing inside the rear wall of the casing, the impeller inlet plane can be parallel to the rear wall of the casing.

[0032] According to a preferred embodiment of the invention, the distance between the first heat exchanger, which is the condenser, e.g. the last heat exchanger the process air flows through, and the impeller inlet plane is of at least 12 cm. This means that the minimum distance between any point of the first heat exchanger and the impeller inlet plane is equal to at least 12 cm (≥ 12 cm). The minimum distance is the distance between the point at the first heat exchanger

which is closest to the impeller inlet plane and the impeller inlet plane.

[0033] The minimum distance can be obtained as a single distance, in other words the minimum distance is obtained only between a single specific point of the first heat exchanger and the impeller inlet plane, or many "minimum distances" are obtained, for example the distances between a plurality of points and the impeller inlet plane are all equal to each other and also equal to such minimum distance. For example, in case the condenser is parallel with its exit to the impeller inlet plane, all the points belonging to the whole surface which defines the exit of the condenser have as a distance to the impeller inlet plane the minimum distance. In case the condenser is angled with respect to the impeller inlet plane, i.e. the exit surface is tilted with respect to the impeller inlet plane, the points belonging to an edge of the condenser (i.e. a straight or curved line of points) all have a distance equal to the minimum distance with the impeller inlet plane.

[0034] The distance between any point of the condenser and the impeller inlet plane is calculated in a standard manner:

The distance, d , from a point, P , having coordinates x_0 , y_0 and z_0 , to a plane, π , defined by the equation $Ax + By + Cz = 0$, is the smallest distance from the point to one of the infinite points on the plane.

[0035] This distance corresponds to the perpendicular line from the point to the plane.

$$P = (x_0, y_0, z_0) \quad \pi \equiv Ax + By + Cz + D = 0$$

$$d(P, \pi) = \frac{|Ax_0 + By_0 + Cz_0 + D|}{\sqrt{A^2 + B^2 + C^2}}$$

[0036] Applicant has observed that a distance of at least 12 cm allows the realization of a smoother duct forming the basement process air duct portion which channels air from the condenser to the main fan located outside the basement. Indeed, this distance allows a realization in the ducts of bends which have a radius of curvature wide enough to minimize turbulences in the process air flow.

[0037] Tests of the Applicant has shown that the dryer having such a basement process air duct portion has a flow of process air considerably improved, increasing the overall efficiency of both the heat pump system and of the main fan which moves air within the process air conduit.

[0038] According to this aspect, the invention may include, alternatively or in combination, any of the following characteristics.

[0039] Preferably, said casing includes a rear wall and a front wall, an aperture being realized on said front wall to access said drum and wherein said main fan is located at said rear wall of the casing.

[0040] As already mentioned, the casing has preferably two opposite walls, a front wall where the door is hinged and a rear wall. In this embodiment, the basement process air outlet and the main fan are located at the rear wall of the casing.

[0041] Advantageously, said rear wall of the casing includes an impeller housing to house said impeller of said main fan.

[0042] In order to reduce the number of components in the casing, so that the cost and the assembly time for the mounting of the laundry dryer are reduced, the rear wall of the casing is part of a housing of the impeller or it forms the whole housing of the impeller.

[0043] In an embodiment, the laundry dryer includes a motor having a shaft to rotate said drum, wherein said shaft of said motor also drives said impeller of said main fan.

[0044] Again, in order to minimize components and costs, a single motor to rotate both the drum, for example via a belt, and the main fan is used. Therefore, preferably impeller and motor are located one close to the other.

[0045] Advantageously, said shaft of said motor defines a motor axis, said motor axis being parallel to said first plane mentioned further above.

[0046] The motor is thus located in one half of the basement and reduces the space it occupies.

[0047] In a configuration, said motor axis is parallel to said rotational axis of the drum.

[0048] Preferably, said casing includes a rear wall and wherein in said basement a first quarter, a second quarter, a third quarter and a fourth quarter are identifiable by means of the intersection between said first plane and a second plane perpendicular to said first plane passing through a center line of the basement substantially parallel to said front wall of the casing; said basement process air outlet being realized in said second quarter, said second quarter being the quarter of the second longitudinal half of the basement closest to the rear wall of said casing, and said basement process air duct portion extending in said second longitudinal half of said basement within said second quarter only.

[0049] As mentioned, the basement can be considered as virtually divided in two by the first plane, and in a top view

of the basement, such a first plane is a line. The basement can also be considered to be divided in "quarters" by the first plane and a second plane perpendicular to it and passing through a center line of the basement parallel to the front (or rear) wall of the casing. The quarters could be indicated as the first quarter, the second quarter the third quarter and the fourth quarter in a clockwise manner. The first quarter is the rearmost quarter of the first longitudinal half of the basement, the second quarter is the rearmost quarter of the second longitudinal half of the basement and so on.

[0050] The basement process air duct portion has a part which extends in the first longitudinal half, starting from the process air exit of the condenser, and a part extending in the second longitudinal half of the condenser, reaching the process air outlet of the basement. In this second longitudinal half, the extension of the basement process air duct portion is limited to the second quarter, i.e. there is no basement process air duct portion in the third quarter.

[0051] More preferably, said casing includes a front wall and said first heat exchanger and said second heat exchanger are located within said fourth quarter of said basement for the majority of their respective volumes, said fourth quarter being the quarter of the first longitudinal half of said basement closest to said front wall of the casing.

[0052] Due to the size of the heat exchangers, normally the process air exit of the condenser is located within the first quarter, so the basement process air duct portion extends only within the first quarter and the second quarter.

[0053] Preferably, said basement includes an upper shell portion and a lower shell portion, said basement process air duct portion being formed by the connection between said upper shell portion and said lower shell portion.

[0054] The basement process air duct portion in the basement can be realized for example in an easy and reliable manner joining together two shell portions so as to form the lateral wall of the basement process air duct portion.

[0055] Advantageously, said basement is realized in plastic material and said basement process air duct portion is realized integral to said basement.

[0056] It should be observed that, in the present description and in the attached claims, the terms "plastic material" and the like, are used to indicate any plastic or synthetic material, or based on plastic or synthetic material, possibly added with fillers suitable to improve the functional and robustness characteristics thereof, such as minerals, textile synthetic fillers and so on and so forth.

[0057] The fact that the basement is realized in plastic allows a reduction of the numbers of elements included in the dryer of the invention. Indeed, with a single producing process, for example with the same molding process, the basement can be realized including a plurality of additional functional elements for the dryer that do not have to be realized separately and then assembled, such as the basement process air duct portion or others for example the seats for the heat exchangers.

[0058] Furthermore, plastic material can be used in the present dryer of the invention because a heat pump system is present. Heat pump dryers generate temperatures lower than dryers including electrical or gas powered air heating devices. Therefore, any possible melting of the basement due to higher local temperatures at which different hot drying air generators may work is avoided.

[0059] In a preferred embodiment said first heat exchanger (or condenser) defines an exit surface, where process air exits said first heat exchanger, said exit surface being substantially parallel to said impeller inlet plane.

[0060] The exit of the condenser and the impeller inlet plane are one parallel to the other. This can be due to the fact that both the first heat exchanger (or condenser) and the impeller are substantially perpendicular to the basement plane and preferably also parallel to the rear wall of the casing, or they are both tilted of substantially the same angle with respect to the rear wall of the casing. Alternatively, only the exit surface of the first heat exchanger (or condenser) and the impeller inlet plane could be both tilted with respect to the basement plane and the rear wall. Preferably, said first heat exchanger defines an exit surface, where process air exits said first heat exchanger, and a closest point of said first heat exchanger to said impeller inlet plane belongs to said exit surface.

[0061] The condenser is oriented, in the direction of process air flow, towards the same side of the laundry dryer where the basement process air outlet is located. Preferably, the basement process air outlet is located facing the rear wall of the casing and the condenser is also oriented so that its process air exit is facing the rear wall of the casing.

[0062] Preferably, said basement outlet and said impeller air inlet are separated by a gap.

[0063] In other words, a channel is present between the outlet of the basement and the impeller.

Brief description of the drawings

[0064] Further advantages of the present invention will be better understood with non-limiting reference to the appended drawings, where:

- Fig. 1 is a perspective view of a laundry dryer realized according to the present invention;
- Fig. 2 is a perspective view of the laundry dryer of Fig. 1 with an element of the casing removed for showing some internal components;

- Fig. 3 is a perspective view, in a disassembled configuration, of the basement of the dryer of Fig. 1 or Fig. 2;
- Fig. 4 is a perspective view of the basement of Fig. 3 with all elements removed;
- 5 - Fig. 5 is a top view of the basement of Figs. 3-4;
- Fig. 6 and Fig. 6a are a top view of the basement of Fig. 3 and of a detail thereof, respectively;
- Fig. 7 is a top view of a basement of a laundry dryer according to the prior art;
- 10 - Fig. 8 is a perspective view in an exploded configuration of a portion of the laundry dryer of Fig. 1 or Fig. 2; and
- Figs. 9a and 9b are two schematic representations of two further embodiments of the invention.

15 Detailed description of one or more embodiments of the invention

[0065] With initial reference to Figs. 1 and 2, a laundry dryer realized according to the present invention is globally indicated with 1.

20 **[0066]** Laundry dryer 1 comprises an outer box or casing 2, preferably but not necessarily parallelepiped-shaped, and a drying chamber, such as a drum 3, for example having the shape of a hollow cylinder, for housing the laundry and in general the clothes and garments to be dried. The drum 3 is preferably rotatably fixed to the cabinet 2, so that it can rotate around a preferably horizontal axis R (in alternative embodiments, rotation axis may be tilted). Access to the drum 3 is achieved for example via a door 4, preferably hinged to cabinet 2, which can open and close an opening 4a realized on the cabinet itself.

25 **[0067]** More in detail, casing 2 generally includes a front wall 20, a rear wall 21 and two sidewalls 25, all mounted on a basement 24. Preferably, the basement 24 is realized in plastic material. Preferably, basement 24 is molded via an injection molding process. Preferably, on the front wall 20, the door 4 is hinged so as to access the drum. The cabinet, with its walls, defines the volume of the laundry dryer 1. Advantageously, basement 24 includes an upper and a lower shell portion 24a, 24b (visible in Figures 3 and 6 detailed below).

30 **[0068]** The dryer 1, and in particular basement 24, defines an horizontal plane (X,Y) which is substantially the plane of the ground on which the dryer 1 is situated, thus it is considered to be substantially horizontal, and a vertical direction Z perpendicular to the plane (X,Y).

[0069] Laundry dryer 1 also preferably comprises an electrical motor assembly 50 for rotating, on command, revolving drum 3 along its axis inside cabinet 2. Motor 50 includes a shaft 51 which defines a motor axis of rotation M.

35 **[0070]** Further, laundry dryer 1 may include an electronic central control unit (not shown) which controls both the electrical motor assembly 50 and other components of the dryer 1 to perform, on command, one of the user-selectable drying cycles preferably stored in the same central control unit. The programs as well other parameters of the laundry dryer 1, or alarm and warning functions can be set and/or visualized in a control panel 11, preferably realized in a top portion of the dryer 1, such as above door 4.

40 **[0071]** With reference to Figure 2, the rotatable drum 3 includes a mantle, having preferably a substantially cylindrical, tubular body 3c, which is preferably made of metal material and is arranged inside the cabinet 2 and apt to rotate around the general rotational axis R which can be - as said - horizontal, i.e. parallel to the (X,Y) plane, or tilted with respect to the latter. The mantle 3c defines a first end 3a and a second end 3b and the drum 3 is so arranged that the first end 3a of the mantle 3c is faced to the laundry loading/unloading opening realized on the front wall 20 of the cabinet 2 and the door 4, while the second end 3b faces the rear wall 21.

45 **[0072]** Drum 3 may be an open drum, i.e. both ends 3a and 3b are opened, or it may include a back wall (not shown in the appended drawings) fixedly connected to the mantle and rotating with the latter.

[0073] In order to rotate, support elements for the rotation of the drum are provided as well in the laundry of the invention. Such support elements might include rollers at the front and/or at the back of the drum, as well as or alternatively a shaft connected to the rear end of the drum (shaft is not depicted in the appended drawings). In Fig. 2, for example, a roller 10 connected to the basement via a boss 101 is depicted. Any support element for the rotation of the drum around axis R is encompassed by the present invention.

50 **[0074]** Dryer 1 additionally includes a process air circuit which comprises the drum 3 and an air process conduit 18, depicted as a plurality of arrows showing the path flow of a process air stream through the dryer 1 (see Figures 3 and 4). In the basement 24, a portion of the air process conduit 18 is formed by the connection of the upper shell 24a and the lower shell 24b. Air process conduit 18 is preferably connected with its opposite ends to the two opposite sides of drum 3, i.e. first and second rear end 3a, 3b of mantle 3c. Process air circuit also includes a fan or blower 12 having an impeller 12a (shown in Fig. 3).

[0075] With now reference to Fig. 8, in the depicted laundry dryer 1, the rear wall 21 of the cabinet 2 forms a rear bulkhead 60 which faces the drum 3. Preferably, the rear wall 21 of the cabinet 2 includes also a fan housing 150, covered by a lid 610 which is attached, in a detachable manner, to the rear bulkhead 60. Thus a fan aperture 61a is formed in the bulkhead 60 which is closed by the lid 610, fan aperture used to access the fan 12, and in particular the impeller 12a of the same. The aperture 61a is located substantially below the location of the drum and faces the interior of the casing 2, in this example, the basement 24 and more preferably an outlet 19 of the air from the basement 24. The configuration of the remaining of the rear bulkhead 60 and the rear wall 21 is not relevant in the present invention.

[0076] The aperture 61a, when the rear wall 21 of the cabinet 2 is assembled, is closed by the lid 610.

[0077] Furthermore, as illustrated in the above example, the whole fan housing 150 is realized within the rear wall 21 and it is composed by a first cup-shaped portion 142 (which belongs to the rear bulkhead 60) and the lid 610.

[0078] The first cup-shaped face 142 is provided with a through opening 150in, in the example shown circular, for housing the relevant shaft (not shown) of the fan 12. Of course, the impeller 12a is housed in the housing 150 when the rear wall 21 is assembled. The same opening 150in is also used for the inlet air to the fan 12. Therefore, in the process air conduit 18, air exits the basement from outlet 19, where it has been heated and/or dried by a heat pump system 30, and enters into the fan housing 150. From the fan housing 150, which is a closed element being the fan aperture 61a closed by lid 610, a conduit portion formed by the rear bulkhead 60 and the lid 610 channels air into the drum 3.

[0079] The dryer 1 of the invention additionally comprises the heat pump system 30 including a first heat exchanger (called also condenser) 31 and a second heat exchanger (called also evaporator) 32 (see figure 3). Heat pump 30 also includes a refrigerant closed circuit (partly depicted) in which a refrigerant fluid flows, when the dryer 1 is in operation, cools off and may condense in correspondence of the condenser 31, releasing heat, and warms up, in correspondence of the second heat exchanger (evaporator) 32, absorbing heat. A compressor receives refrigerant in a gaseous state from the evaporator 32 and supplies the condenser 31, thereby closing the refrigerant cycle. In the following the heat exchangers are named either condenser and evaporator or first and second heat exchanger, respectively. More in detail, the heat pump circuit connects via piping 35 (see Fig. 3) the second heat exchanger (evaporator) 32 via a compressor 33 to the condenser 31. The outlet of condenser 31 is connected to the inlet of the evaporator 32 via an expansion device (not visible), such as a choke, a valve or a capillary tube.

[0080] Preferably, in correspondence of evaporator 32, the laundry dryer 1 of the invention may include a condensed-water canister (also not visible) which collects the condensed water produced, when the dryer 1 is in operation, inside evaporator 32 by condensation of the surplus moisture in the process air stream arriving from the drying chamber (i.e. drum) 3. The canister is located at the bottom of the evaporator 32. Preferably, through a connecting pipe and a pump (not shown in the drawings), the collected water is sent in a reservoir located in correspondence of the highest portion of the dryer 1 so as to facilitate a comfortable manual discharge of the water by the user of the dryer 1.

[0081] The condenser 31 and the evaporator 32 of the heat pump 30 are located in correspondence of the process air conduit 18 formed in the basement 24 (see figure 3).

[0082] In case of a condense-type dryer - as depicted in the appended figures - where the air process circuit is a closed loop circuit, the condenser 31 is located downstream of the evaporator 32. The air exiting the drum 3 enters the conduit 18 and reaches the evaporator 32 which cools down and dehumidifies the process air. The dry cool process air continues to flow through the conduit 18 till it enters the condenser 31, where it is warmed up by the heat pump 30 before re-entering the drum 3.

[0083] It is to be understood that in the dryer 1 of the invention, an air heater, such as an electrical heater, can also be present, in addition to the heat pump 30. In this case, heat pump 30 and heater can also work together to speed up the heating process (and thus reducing the drying cycle time). In the latter case, preferably condenser 31 of heat pump 30 is located upstream the heater. Appropriate measures should be provided to avoid the electric heater to fuse plastic components of the dryer 1.

[0084] Further, with now reference to Figures 4 and 5, in the basement, the process air conduit 18 includes a duct formed by the upper and the lower shells 24a, 24b, having an inlet 19in from which process air is received from the drum 3 and the outlet 19 to channel process air out of the basement 24, back to the drum via the rear wall 21 as described above with reference to Fig. 8. Between inlet 19in and outlet 19, the duct is formed, preferably as two single pieces joined together and belonging to the upper and lower shell 24a, 24b, and including a first and a second portion 28 and 29. In the first portion 29 of this duct, seats 29s are formed for locating the first and the second heat exchangers 31, 32. Preferably, first and second heat exchanger 31, 32 are placed one after the other, the first heat exchanger 31 being downstream in the direction of flow of the process air the second heat exchanger 32. Further, the second portion 28, called basement air duct portion 28, channels the process air exiting from the first heat exchanger 31 towards the basement outlet 19.

[0085] The second portion 28 thus starts at the location of the exit 28in of the first heat exchanger 31, considered as the location of a plane sectioning the duct portion 28 and substantially in front or in contact with a surface of the first heat exchanger 31 from which process air exits.

[0086] Furthermore, preferably also the outlet 19, defined as the area at which the air exits the basement, defines in

turn a plane substantially perpendicular to the basement plane, e.g. a vertical plane.

[0087] Considering now a first plane P1 (see Fig. 4) perpendicular to the basement plane (X,Y) and embedding the rotational axis R of the drum 3, this first plane P1 divides the basement 24 in two halves, called, with now reference to figure 6, basement first or right half 24 first half and basement second or left half 24 second half. These two halves 24 first half and 24 second half need not to be identical in dimension (i.e. they are not mathematical halves), however in the present depicted embodiment P1 also embeds a first - longitudinal - centerline H1 of the basement. Furthermore, still in the depicted embodiment, P1 is a vertical plane.

[0088] On the first half of the basement, 24 first half, the portion 29 of the duct is positioned, where also the first and the second heat exchanger 31, 32 of heat pump 30 are located. The heat exchanger can be completely contained within the first half of the basement 24 first half or they can also extend beyond the limit defined by the first plane P1. If a portion of the first and/or second heat exchanger 31, 32 is also located within the second half of the basement 24 second half, this portion is the minority of the whole volume occupied by the first and/or second heat exchanger 31, 32.

[0089] On the second half of the basement 24 second half, preferably the compressor 33 is located. More preferably, also the motor 50 is located in this second half.

[0090] Preferably, motor 50 including shaft 51 defining motor axis M has the motor axis substantially parallel to the first plane P1 (see Figures 5a or 6).

[0091] Again with reference to Figs. 4 and 5, considering now a second plane P2, perpendicular to P1 and to the basement plane (X,Y) and passing through a second centerline H2 of the basement, the basement 24 is divided, by a combination of the first and the second plane P1, P2, in four quarters Q1 - Q4. The quarters are numbered in a clockwise manner, the first quarter Q1 being the rearmost quarter of the first half of the basement 24 (e.g. the quarter facing the rear wall 21), the second quarter Q2 being the rearmost quarter of the second half of the basement 24, the third quarter Q3 the foremost quarter (e.g. the quarter facing the front wall 20) of the second half of the basement and the last fourth quarter Q4 the foremost quarter of the first half of the basement 24.

[0092] It can be therefore seen that the heat exchangers 31, 32 and the duct portion 29 are substantially contained for the majority of their volume within the fourth quarter Q4, the second heat exchanger closer to the front wall 20 than the first heat exchanger 31; preferably compressor 33 is contained within the third quarter Q3, and the outlet 19 of basement 19 is located in the second quarter Q2, preferably facing rear wall 21 of casing 2.

[0093] Motor 50 is preferably contained within the second quarter Q2 as well and its shaft 51 extends in such a way that it sticks out from the outlet 19, i.e. it exits the basement 24 with one of its ends through the basement outlet 19. Preferably, motor shaft 51 is also the shaft of fan 12, which is located in proximity of outlet 19, preferably facing the latter. Fan 12 blows the process air exiting the basement 24 through outlet 19 into the drum 3, preferably through a passage, not shown, part of the process air circuit 18, formed within the rear wall 21.

[0094] The duct portion 28 extends from the air exit, 28in, of the condenser which is located within the first quarter Q1 preferably close to the boundary with the fourth quarter Q4, i.e. close to centerline H2, to the outlet 19 of the basement, located in the second quarter Q4.

[0095] Preferably, but not necessarily, the planes containing the exit 28in and the outlet 19 are substantially parallel to each other and even more preferably they are both parallel to P2.

[0096] The duct portion 28 therefore comprises at least one curve or bend in order to extend from the first to the second quarter. Furthermore, duct portion 28 includes walls 28w which form and delimit the duct portion itself. Any embodiment of the geometrical configuration of walls 28w is encompassed in the present invention. In order to obtain a "gentle" curve or bend, enough space is preferably available within the basement, as detailed below.

[0097] With now reference to Figs. 6 and 6a, the impeller 12a defines an inlet and an outlet for the air passing therethrough. The inlet in turn defines an impeller inlet plane Pimp which is the plane that passes through the impeller air inlet, e.g. it "touches" the blades of the impeller from the inlet side. This plane is depicted as a dot-dashed curve in Figs. 6 and 6a because in the depicted embodiment this plane is substantially perpendicular to the basement plane (X, Y), however different configuration where the plane Pimp is not perpendicular to the basement plane (X, Y) can be considered.

[0098] The impeller inlet plane Pimp is located in front of the outlet 19 of the basement, however it is not necessarily parallel to the latter (see for example the embodiment of Fig. 9b). In the preferred embodiment of Figs. 6 and 6a a plane passing through the outlet 19 is substantially parallel to the impeller air inlet plane Pimp. In the embodiment schematically depicted in Fig. 9b, the plane passing through the outlet 19 and the impeller inlet plane Pimp are not parallel.

[0099] In order to guarantee a "free volume" for the duct 28 in the basement to "smoothly" channels air from the first heat exchanger 31 to the outlet 19, forming a curve having a wide radius of curvature, preferably the distance between any point of the first heat exchanger 31 and the impeller inlet plane Pimp is of at least 12 cm. The distance is depicted as an arrow in the figures and named Dcond.

[0100] For each point of the condenser this distance Dcond is calculated. The distance is calculated as standard, i.e. using the following formula:

$$P = (x_P, y_P, z_P)$$

5 is the point on the heat exchanger 31,

$$ax + by + cz + d = 0$$

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is the Cartesian equation defining the impeller inlet plane Pimp, then the distance between P and Pimp is given by

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$$D_{cond}(P, P_{imp}) = \frac{|ax_P + by_P + cz_P + d|}{\sqrt{a^2 + b^2 + c^2}}.$$

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[0101] This distance Dcond is calculated for all points belonging to the condenser 31 and all these distances are, according to the invention, ≥ 12 cm. In other words the minimum distance between the condenser and the impeller inlet plane is of at least 12 cm.

[0102] As depicted in Figs. 6 and 6a, all points belonging to the exit surface of the condenser 31 have in this depicted embodiment the minimum distance to the impeller inlet plane. In this embodiment, a plane passing through the exit surface of the condenser and the impeller inlet plane Pimp are substantially parallel.

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[0103] In the additional embodiment of Fig. 9a, all points belonging to the rightmost top edge of the exit surface of the condenser 31 have the minimum distance with the impeller inlet plane Pimp. In this embodiment, a plane passing through the exit surface of the condenser and the impeller inlet plane are not parallel, although they are both substantially vertical planes.

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[0104] In the embodiment of Fig. 9b, the rightmost lower edge of the exit surface of the condenser 31 have the minimum distance with the impeller inlet plane Pimp. In this embodiment, a plane passing through the exit surface of the condenser and the impeller inlet plane are not parallel, although they are both substantially vertical planes.

[0105] Preferably, the outlet 19 of the basement and Pimp are separated by a gap. Such gap is visible in Fig. 9a and may be provided for avoiding interference between impeller 12a and basement and/or cabinet walls .

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Claims

1. A laundry dryer (1) including:

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- a casing (2) rotatably supporting a drum (3) for receiving a load to be dried, said drum (3) being apt to rotate around a rotational axis (R), said casing (2) including

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o a basement (24) defining a basement plane (X, Y) and in which a first longitudinal half (24 first half) and a second longitudinal half (24 second half) of the basement (24) are identifiable by means of a first plane (P1) perpendicular to said basement plane (X, Y) and passing through said rotational axis (R) of the drum (3);

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- A process air conduit (18) in fluid communication with the drum (3) where a process air stream is apt to flow;
- A heat pump system (30) having a heat pump circuit in which a refrigerant can flow, said heat pump circuit including a first heat exchanger (31) where the refrigerant is cooled off and the process air is heated up, and a second heat exchanger (32) where the refrigerant is heated up and the process air is cooled off; said first heat exchanger (31) and/or said second heat exchanger (32) being arranged in the process air conduit (18) within said first longitudinal half (24 first half) of said basement (24) for the majority of their respective volumes in order to perform heat exchange between said refrigerant flowing in said heat pump circuit and said process air;

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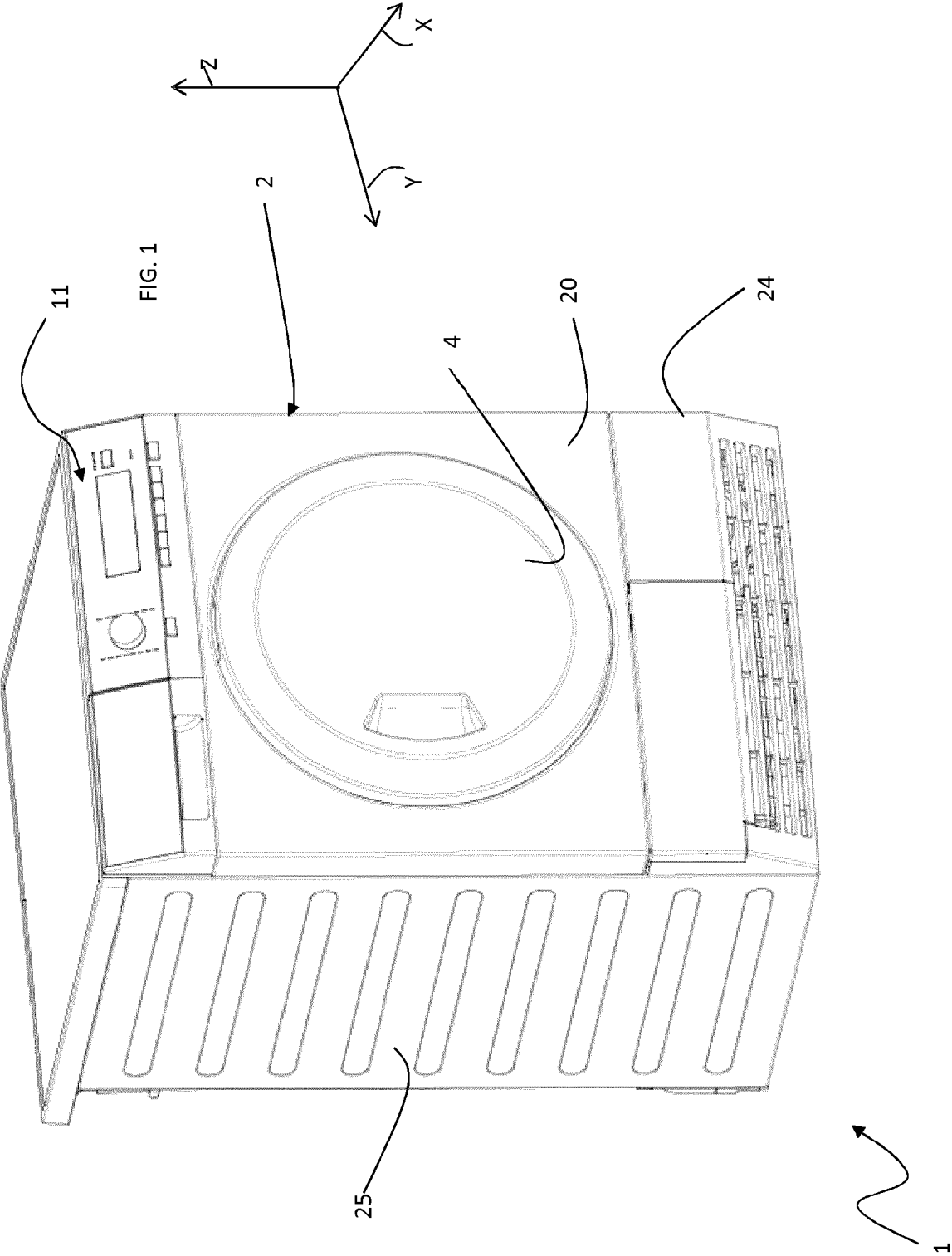
- Said process air conduit (18) including a basement process air duct formed in said basement (24), said basement process air duct comprising a basement process air duct portion (28) channeling said process air between a process air exit (28in) where process air exits from said first heat exchanger (31) and a basement process air outlet (19) where process air exits said basement (24);

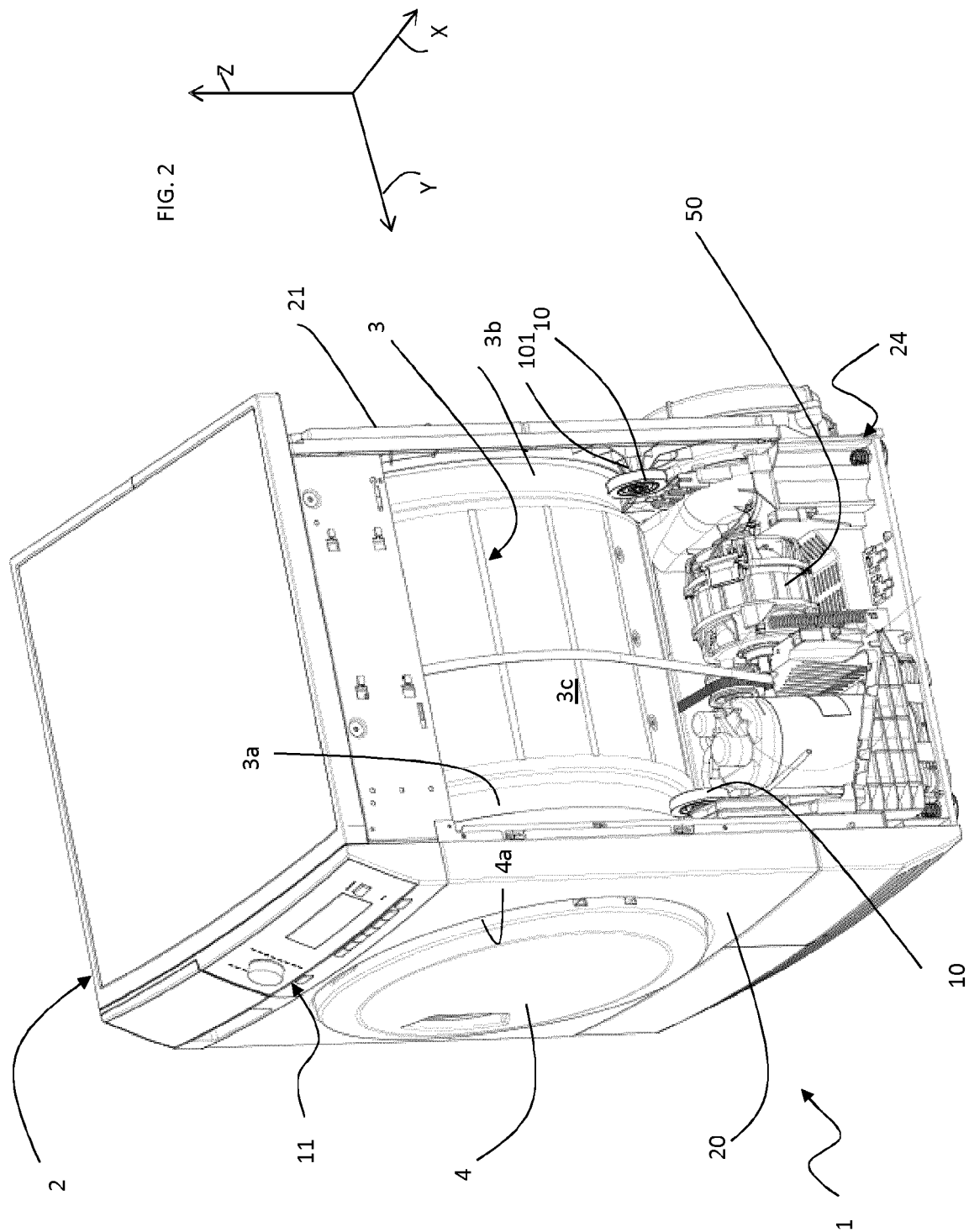
- A main fan (12) including an impeller (12a) to blow process air in said process air conduit (18), said main fan

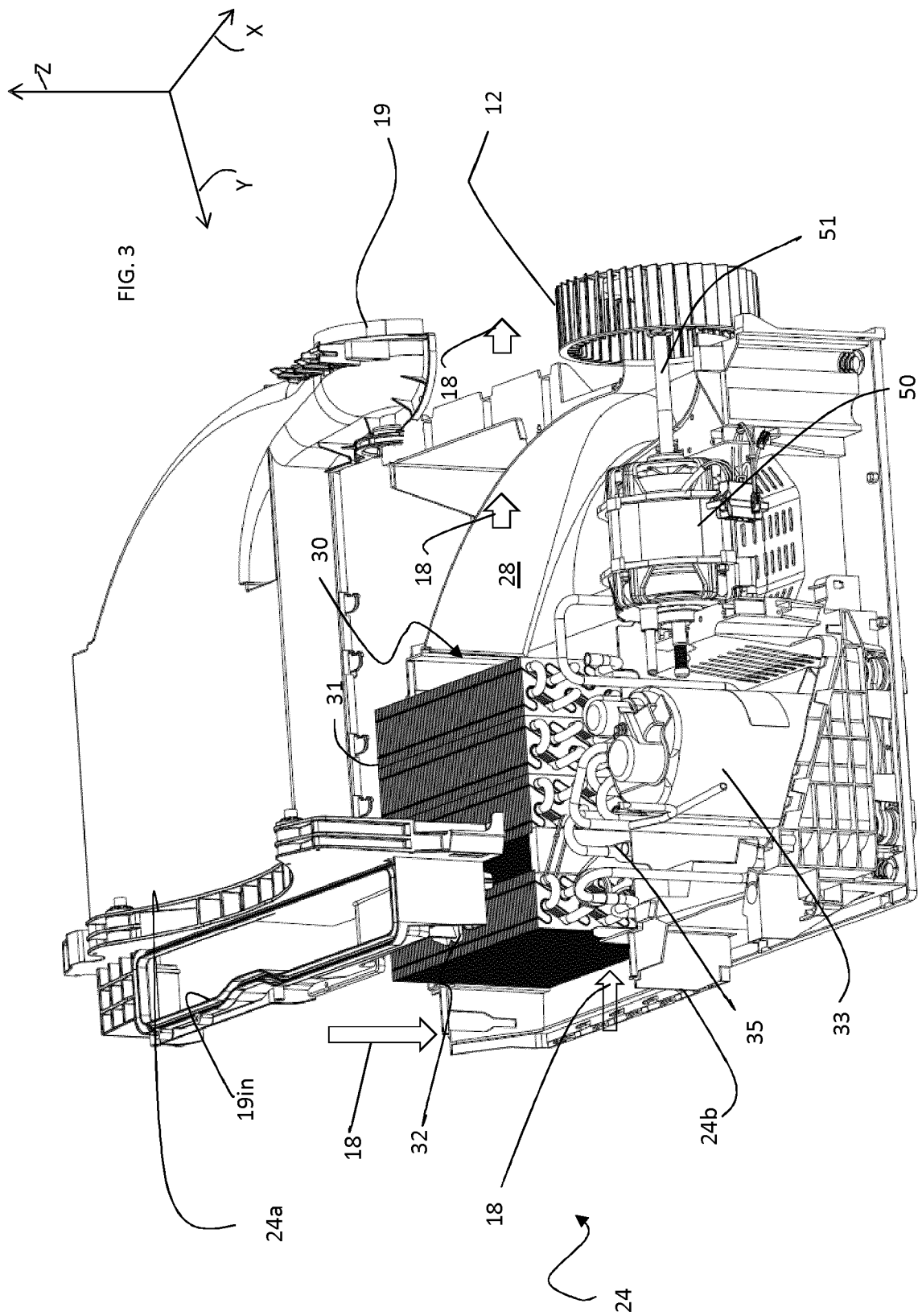
(12) being located in proximity of the basement process air outlet (19) and having an impeller process air inlet, wherein a impeller inlet plane (Pimp) is defined;

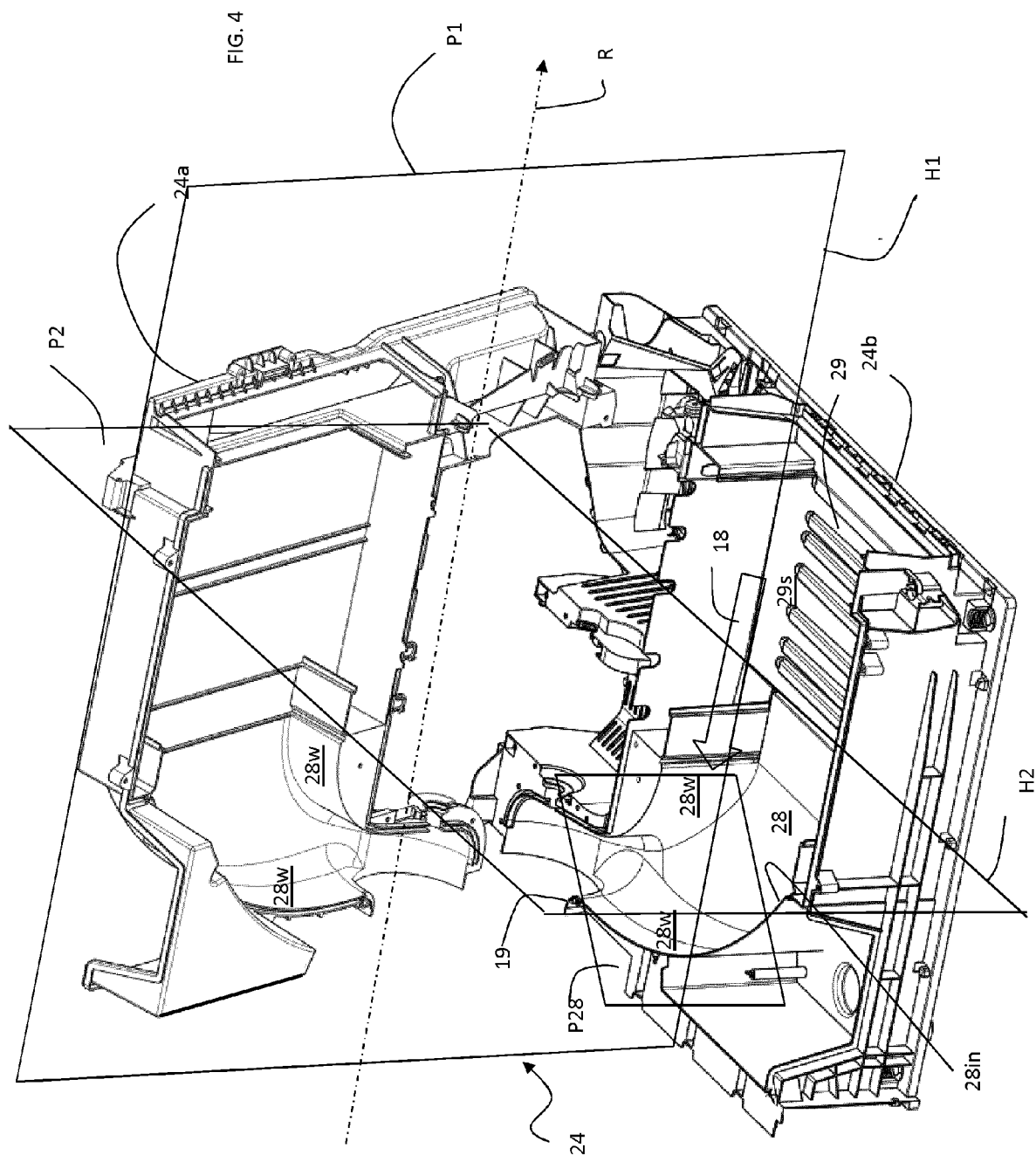
- Wherein a distance (Dcond) between any point of the first heat exchanger (31) and said impeller inlet plane (Pimp) is longer or equal to 12 cm.

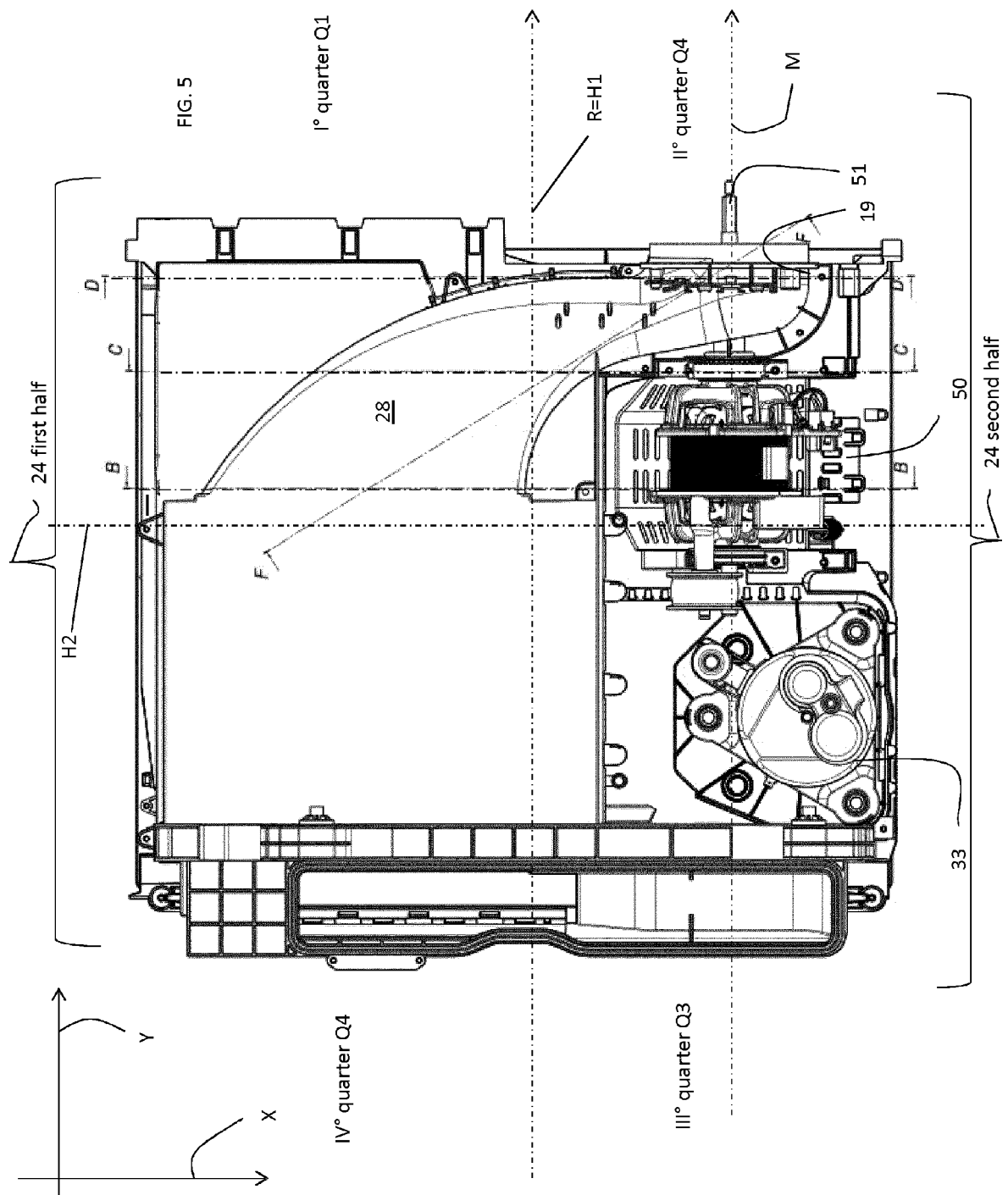
2. A laundry dryer (1) according to claim 1, wherein said casing (2) includes a rear wall (21) and a front wall (20), an aperture (4a) being realized on said front wall (20) of the casing (2) to access said drum (3) and wherein said main fan (12) is located at said rear wall (21) of the casing (2).
3. A laundry dryer (1) according to claim 1, wherein said rear wall (21) includes an impeller housing (150) to house said impeller (12a) of said main fan (12).
4. A laundry dryer according to any of the preceding claims, including a motor (50) having a shaft (51) to rotate said drum (3), wherein said shaft (51) of said motor (50) also drives said impeller (12a) of said main fan (12).
5. A laundry dryer (1) according to claim 4, wherein said shaft (51) of said motor (50) defines a motor axis (M), said motor axis being parallel to said first plane (P1).
6. A laundry dryer (1) according to claim 5, wherein said motor axis (M) is parallel to said rotational axis (R) of the drum (3).
7. A laundry dryer (1) according to any of the preceding claims, wherein said casing (2) includes a rear wall (21) and wherein in said basement (24) a first quarter, a second quarter, a third quarter and a fourth quarter are identifiable by means of the intersection between said first plane (P1) and a second plane (P2) perpendicular to said first plane (P1) passing through a center line (H2) of the basement (24) substantially parallel to said front wall (20) of the casing (2); said basement process air outlet (19) being realized in said second quarter, said second quarter being the quarter of the second longitudinal half (24 second half) of the basement (24) closest to the rear wall (21) of said casing (2), and said basement process air duct portion (28) extending in said second longitudinal half (24 second half) of said basement (24) within said second quarter only.
8. The laundry dryer (1) according to claim 7, wherein said casing (2) includes a front wall (20) and wherein said first heat exchanger (31) and said second heat exchanger (32) are located within said fourth quarter of said basement (24) for the majority of their respective volumes, said fourth quarter being the quarter of the first longitudinal half (24 first half) of said basement (24) closest to said front wall (20) of the casing (2).
9. The laundry dryer (1) according to any of the preceding claims, wherein said basement (24) includes an upper shell portion (24a) and a lower shell portion (24b), said basement process air duct portion (28) being formed by the connection between said upper shell portion (24a) and said lower shell portion (24b).
10. The laundry dryer (1) according to any of the preceding claims, wherein said basement (24) is realized in plastic material and said basement process air duct portion (28) is formed integrally to said basement (24).
11. The laundry dryer (1) according to any of the preceding claims, wherein said first heat exchanger (31) defines an exit surface, where process air exits said first heat exchanger (31), said exit surface being substantially parallel to said impeller inlet plane (Pimp).
12. The laundry dryer (1) according to any of the preceding claims, wherein said basement outlet (19) and said impeller air inlet (150in) are separated by a gap.
13. The laundry dryer (1) according to any of the preceding claims, wherein said first heat exchanger (31) defines an exit surface, where process air exits said first heat exchanger (31), and the closest point of said first heat exchanger (31) to said impeller inlet plane (Pimp) belongs to said exit surface.

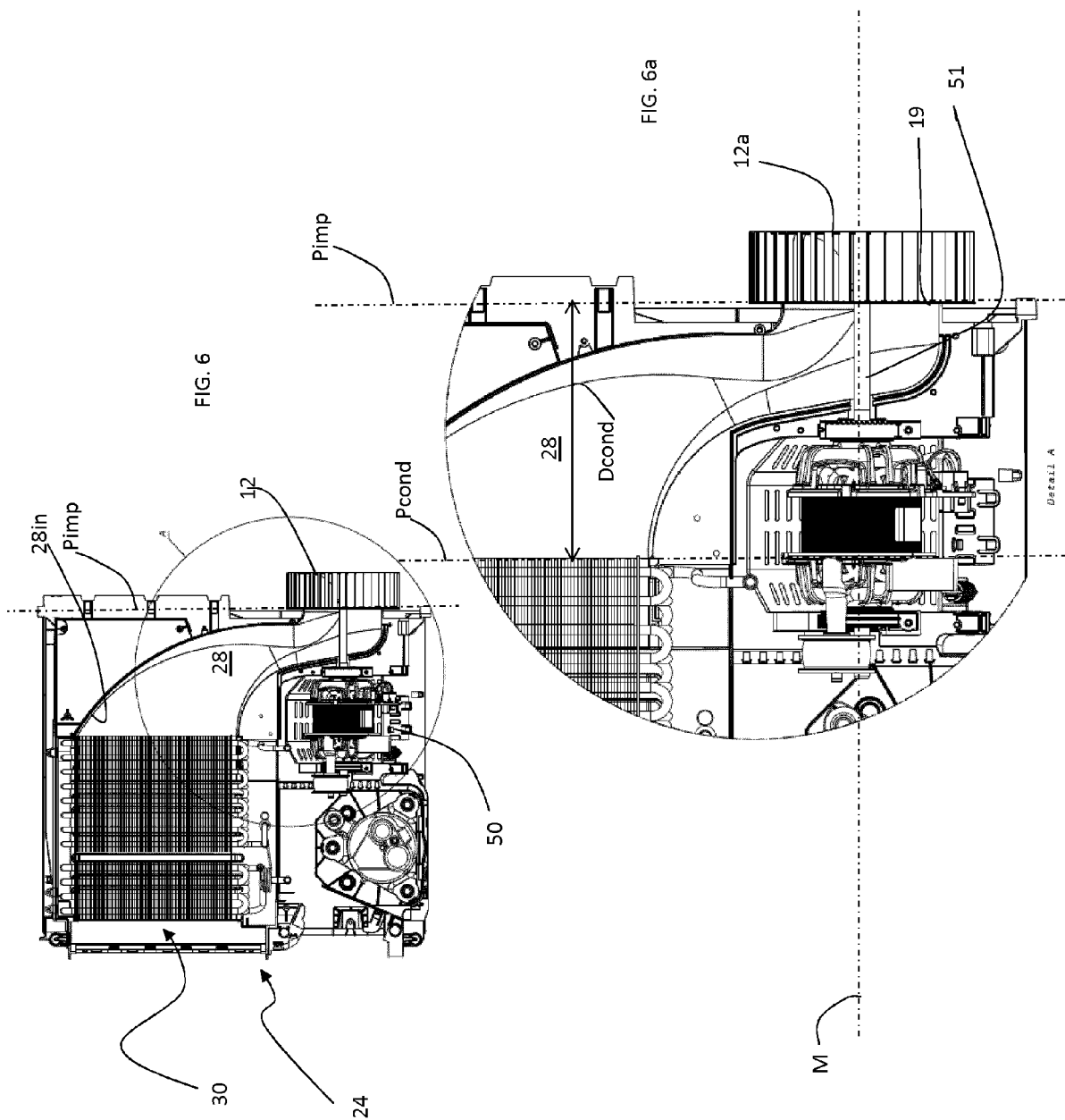












PRIOR ART

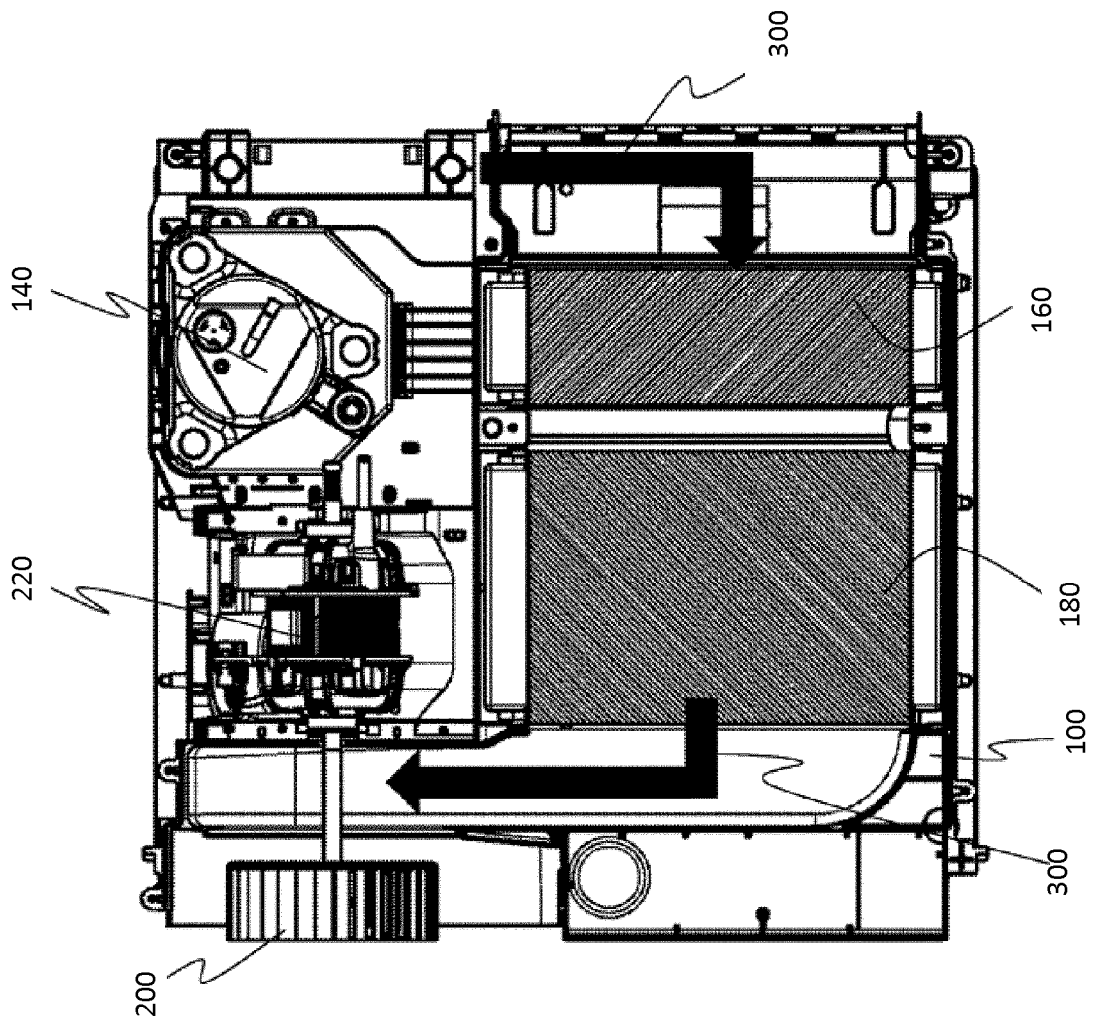


FIG. 7

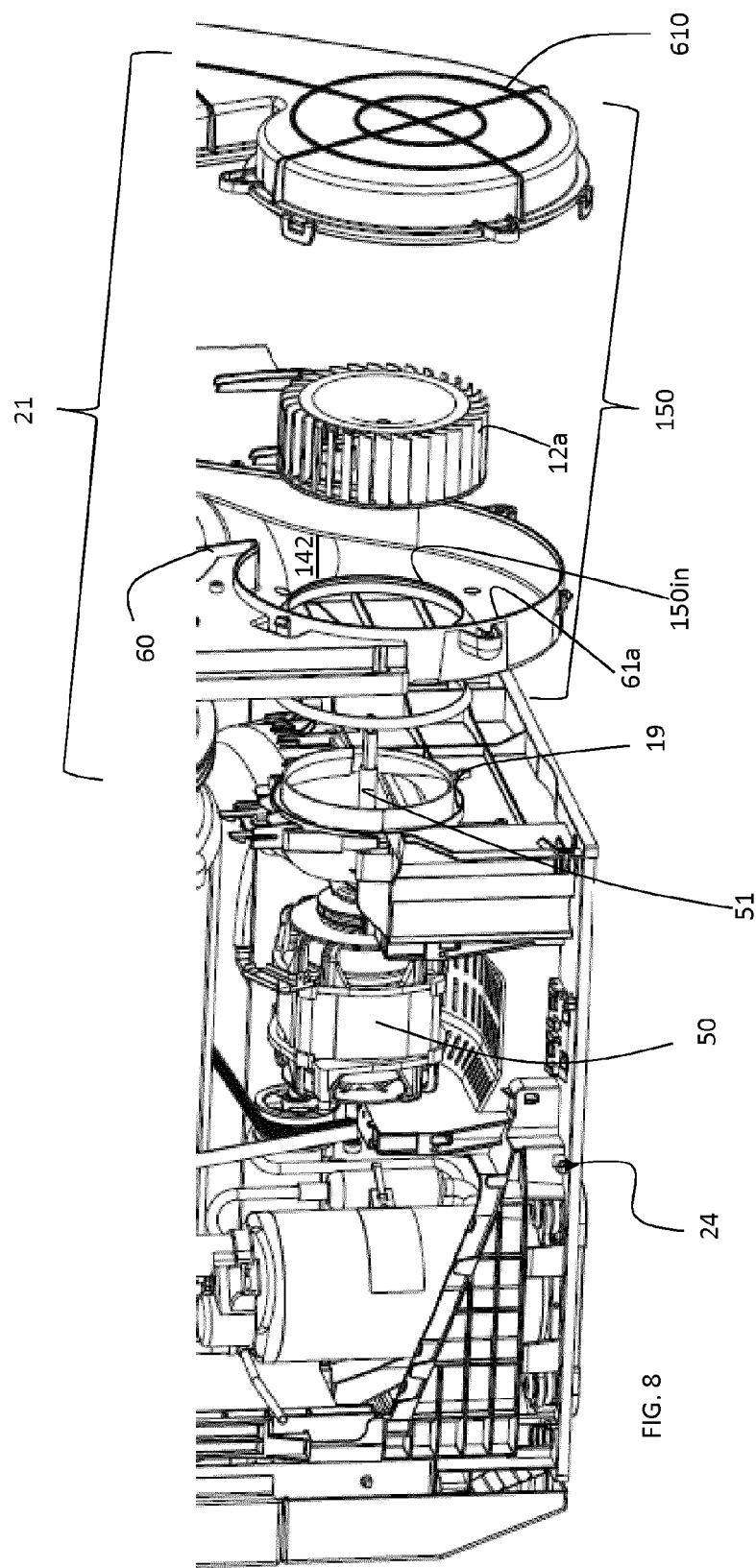


FIG. 8

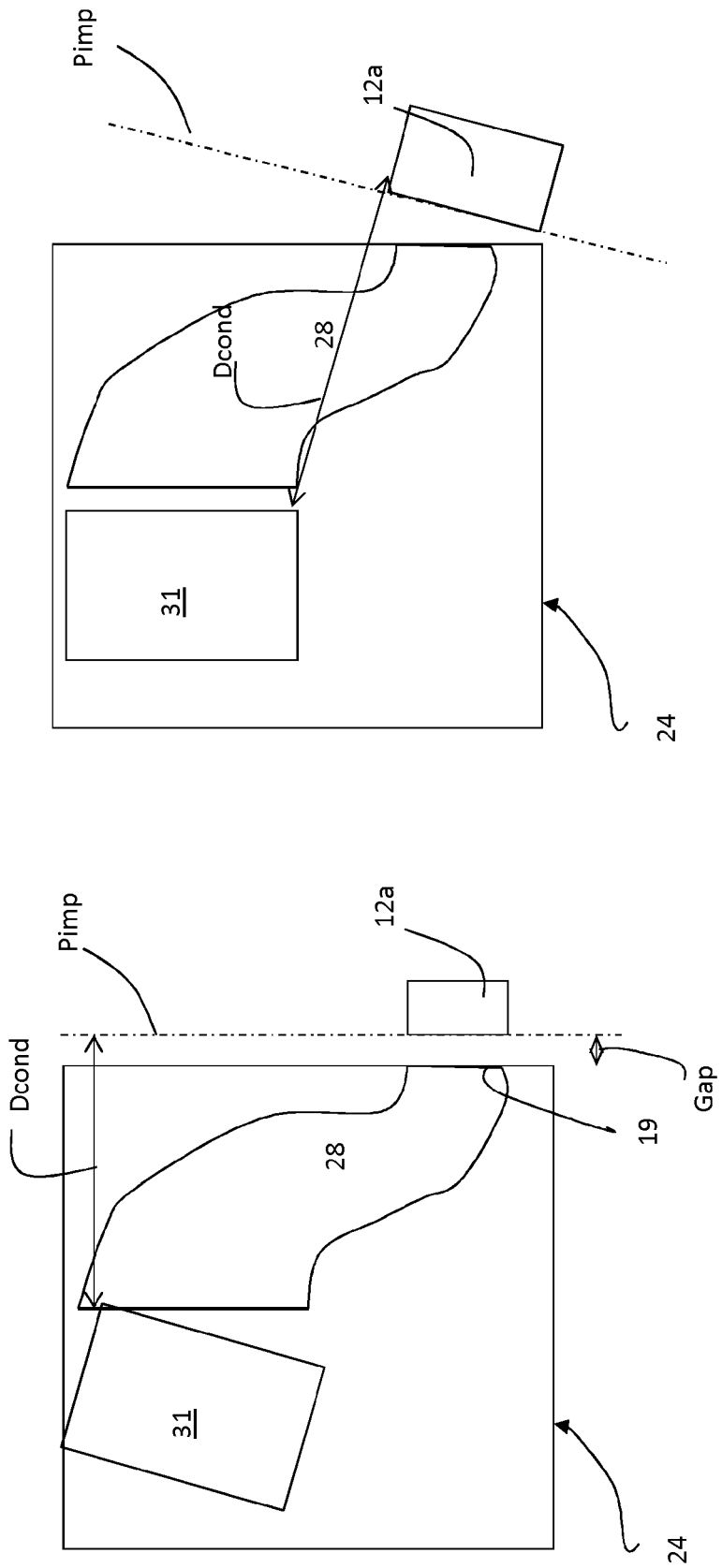


FIG. 9b

FIG. 9a



EUROPEAN SEARCH REPORT

Application Number
EP 14 18 2930

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 628 845 A1 (ELECTROLUX HOME PROD CORP [BE]) 21 August 2013 (2013-08-21) * paragraph [0004] * * paragraph [0008] - paragraph [0010] * * paragraphs [0012], [0015] * * paragraph [0021] - paragraph [0023] * * paragraph [0028] - paragraph [0034] * * claims 1, 7 * * figures 1-13 * -----	1-13	INV. D06F58/02 D06F58/20
A	EP 2 527 527 A1 (ELECTROLUX HOME PROD CORP [BE]) 28 November 2012 (2012-11-28) * paragraph [0005] - paragraph [0011] * * paragraph [0014] - paragraph [0015] * * paragraphs [0020], [0022] * * paragraph [0032] - paragraph [0041] * * paragraph [0046] - paragraph [0052] * * paragraph [0070] - paragraph [0080] * * figures 1-4 * -----	1	TECHNICAL FIELDS SEARCHED (IPC) D06F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		9 March 2015	Bermejo Pasetti, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 14 18 2930

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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09-03-2015

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2628845	A1	21-08-2013	NONE

EP 2527527	A1	28-11-2012	NONE

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82