(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 206 551 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
05.07.2023 Bulletin 2023/27

(21) Application number: **22217296.7**

(22) Date of filing: **30.12.2022**

(51) International Patent Classification (IPC):
F24F 11/74 *(2018.01)* ***F24F 11/80*** *(2018.01)*
F24F 12/00 *(2006.01)* *F24F 110/10* *(2018.01)*
F24F 110/20 *(2018.01)*

(52) Cooperative Patent Classification (CPC):
F24F 12/006; F24F 11/74; F24F 11/80;
F24F 12/003; F24F 2012/007; F24F 2110/10;
F24F 2110/20; F24F 2221/08

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **04.01.2022 IT 202200000068**

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(54) APPARATUS FOR TREATING AIR IN ARENAS AND RELATED METHOD OF USE

(57) The present invention discloses an apparatus (10) for treating air in arenas (100) comprising air movement means (11a, 11b), detector devices (12) of environmental parameters, a heat exchanger (26), at least one air thermal treatment device (27) and a control unit. The invention also describes a method for using an apparatus (10) for air treatment.

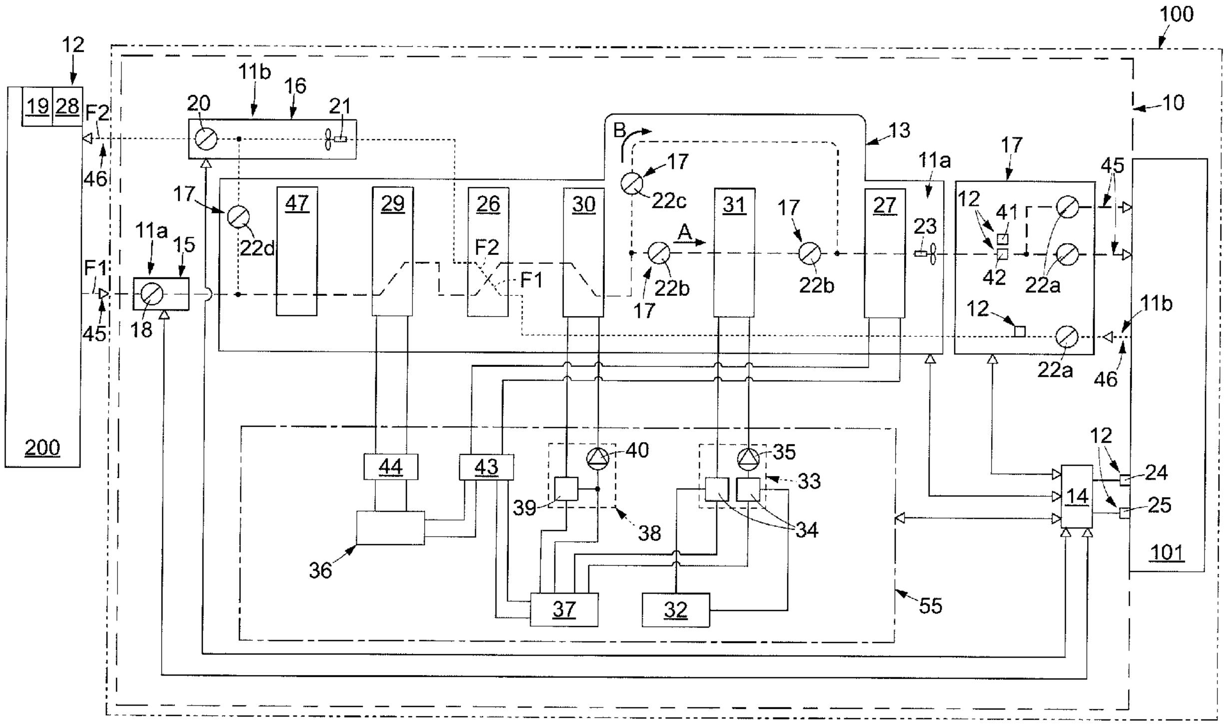

fig. 1

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Description

FIELD OF APPLICATION

[0001] The present invention relates to an apparatus for treating air and the related method of use.

[0002] The invention is applicable to arenas, preferably to sports or recreational arenas, by way of example but not limited to sports facilities such as swimming pools or preferably ice arenas, where it is necessary to ensure a controlled temperature while avoiding the formation of condensation or fog and ensuring a certain flow rate of external air exchange.

BACKGROUND ART

[0003] It is known that in arenas, for example in sports halls such as swimming pools, ice arenas or the like, it is usually required to maintain predetermined thermo-hygrometric conditions. For example, inside an ice arena, or ice rink, the ideal thermo-hygrometric conditions which are usually required envisage a temperature of about 10/12°C and a relative humidity of about 45%.

[0004] It is also known that it is preferable to avoid the formation of condensation or fog in the internal space of the arena; for example, this can occur in correspondence with the ice rink of an ice arena in certain external climatic conditions or also due to the number of people inside.

[0005] In addition to this, an extremely high humidity rate (close to 100%), in addition to being a source of discomfort for users, also causes the degradation of the arena structures and electrical and sound systems. In addition, moisture, by condensing, creates continuous drippings making the activity areas less performing.

[0006] The guarantee of a certain exchange of the internal air is also usually required in arenas.

[0007] The most common system for resolving the formation of condensation or surface fog, for example inside ice arenas, is that which uses an adsorption dehumidifier which operates with a completely separate process air circuit and regeneration air circuit. In the process air circuit, the dehumidifier sucks in the humid air inside the ice arena, conveys it to a rotor, comprising hygroscopic material on which the moisture remains trapped, and returns the dried air inside the ice arena. The humidity bound to the rotor passes through a second separate treatment stage, called "regeneration", where it is released by exploiting the external air - sucked and suitably heated - and is then conveyed, to the outside. To raise the outside air temperature to the temperature necessary for the evaporation of water, electrical resistors are normally used and thus the electrical power required is extremely high since the consumption of an electrical kW corresponds to a power of a thermal kW. And this represents a first drawback of these known systems.

[0008] A further disadvantage of these systems is that their operation usually does not take into account the external thermo-hygrometric conditions, as they are operated continuously and independently of the external-thermo-hygrometric conditions.

[0009] Furthermore, said systems work in a closed circuit, as there is no exchange of air between the internal and external spaces. Indoor ice arenas, for example, which require an air exchange rate of approximately 25 m3/hour per person according to regulations, must therefore have a separate air exchange system.

[0010] EP3499140A1 describes an air treatment and drying apparatus for air recirculation in a pool or similar spaces, in which there is a generally high temperature and is thus unsuitable for recirculating high flows of cold air in ice arenas or similar arenas. Furthermore, the apparatus described in EP3499140A1 does not allow to perform a control of the vapor quality during heating.

[0011] EP3438561A1 discloses an apparatus for treating air in a domestic space, in which the relative temperatures and humidity at play are very different from those of an ice arena or the like.

[0012] WO2019/078774A1 discloses a flow control device for a ventilation apparatus of a Heating, Ventilation and Air Conditioning (HVAC) system for living spaces.

[0013] There is therefore a need to improve an apparatus for treating air which can overcome at least one of the drawbacks of the prior art.

[0014] In particular, an object of the present invention is to make an apparatus for the treatment of air, and to develop a relative method of use, suitable both to keep the required thermo-hygrometric conditions in the internal space of the arena, and to ensure a correct air exchange, in particular avoiding the formation of condensation or fog during the entire period of activity.

[0015] Another object of the invention is to make an air treatment apparatus and related method of use which is efficient and allows to adapt to the external thermo-hygrometric conditions to dehumidify the internal space of the arena and achieve energy savings.

[0016] An object is also to make an air treatment apparatus which is suitable for preventing the formation of moisture from condensation inside the space even during periods of inactivity, consequently reducing the maintenance time and costs of the arena.

[0017] Another object of the invention is to make an apparatus and a method for air treatment which allow air to be exchanged and recirculated effectively both in arenas hosting swimming pools, in which medium high temperatures and high humidity are envisaged, and in ice arenas, in which the thermo-hygrometric conditions envisage a temperature of about 10/12°C and a relative humidity of about 45%, regardless of the external temperature.

[0018] The Applicant has studied, tested and realized the present invention to overcome the drawbacks of the prior art, and to obtain the above as well as further objects and benefits.

DISCLOSURE OF THE INVENTION

[0019] The present invention is expressed and characterized in the independent claims. The dependent claims show other features of the present invention or variants of the main solution proposed.

[0020] In accordance with the aforesaid purposes and to solve the aforesaid technical problem in a new and original manner, also obtaining considerable advantages with respect to the prior art, an apparatus for the treatment of air in an arena according to the present invention comprises first and second air movement means configured to generate an incoming air flow and an outgoing air flow.

[0021] Said apparatus further comprises at least one heat exchanger crossed between said air flows and at least one device for the thermal treatment of said incoming air flow, in which said at least one exchanger and said at least one device are able to manage the exchange of air between an external space and an internal space of said arena.

[0022] The apparatus further comprises at least one cooling device disposed between said exchanger and said thermal treatment device along the path of the incoming air flow.

[0023] A control unit comprised in said apparatus is configured to determine at least the flow rates of said air flows and the operating temperatures of said at least one exchanger and said at least one thermal treatment device, so as to maintain the internal temperature and the vapor quality in the internal space within a range of predefined values.

[0024] The control unit is also configured to adjust the operation and possibly the operating temperatures of the at least one cooling device in a coordinated manner with those of the heat exchanger and the thermal treatment device.

[0025] According to an aspect of the invention, the at least one cooling device can be selectively activated by the control unit as a function of the internal temperature and the external temperature of the arena. That is, the cooling device can be selectively activated and deactivated as a function of needs.

[0026] The presence and the possibility of selectively activating the at least one cooling device make the apparatus according to the invention versatile and adaptable to use both in different types of arenas and in different climatic conditions, so as to ensure the maintenance of the desired hygrometric characteristics and the desired vapor quality within the arena in each season.

[0027] In particular, said control unit can be configured to control said air movement means, said heat exchanger, and said at least one thermal treatment device, in order to manage the exchange of air between the external space and the internal space in relation to environmental parameters detected by detector devices, determining said flow rates of incoming and outgoing air flows and operating temperatures.

[0028] Said apparatus further comprises environmental parameter detector devices comprising at least one detector of said internal temperature and a detector of said vapor quality.

[0029] According to an aspect of the invention, the detector devices also comprise an external temperature detector, suitable for detecting at least the temperature of the space outside the arena.

[0030] In doing so, the advantage is obtained of maintaining the ideal thermo-hygrometric conditions in the internal space of the arena, combining the exchange of air with the action of dehumidification and temperature control, as well as significant savings in terms of energy consumption, and it is not necessary to install special equipment for the exchange of air.

[0031] In particular, the use of the internal temperature and the vapor quality as setting values on which to base the adjustment of the ventilation means and the operating temperatures allows to have an absolute reference value which is suitable for any environmental condition. Said absolute reference allows the system to self-regulate, modifying the internal temperature so as to always set the conditions so as to respect the set vapor quality value. As a result, unlike the known systems, which envisage the use of temperature and relative humidity as setting values, it is no longer necessary to change the reference values in relation to the operating conditions.

[0032] Furthermore, advantageously, the apparatus according to the invention allows the air to be introduced into the arena under the thermo-hygrometric conditions suitable for maintaining the established conditions.

[0033] The apparatus according to the invention allows to exploit the external thermo-hygrometric conditions to de-humidify the internal space almost free of charge, without using adsorption systems which are expensive.

[0034] According to another aspect of the present invention, said treatment apparatus comprises at least one further thermal treatment device of the air, selected from a heating or cooling device, selectively activatable by said control unit as a function of internal and external temperatures.

[0035] According to embodiments, the at least one further thermal treatment device is configured to only treat the incoming air flow and does not interfere with the outgoing air flow.

[0036] It is thus possible to optimize temperature control, reducing the time to reach the desired thermo-hygrometric parameters.

[0037] Furthermore, the apparatus comprises at least one heating device positioned upstream of said heat exchanger and configured to heat the incoming air flow. It is thereby possible to prevent the freezing of parts of the heat exchanger, with incoming air flow at a temperature lower than or equal to about 2°C.

[0038] According to another aspect of the invention, the apparatus comprises the at least one cooling device disposed between the heat exchanger and the air thermal treatment device, selectively activatable at least when the external temperature is higher than the desired internal temperature. It is thereby possible to effectively reduce any moisture contained therein and allow the easier maintenance of the vapor quality in the desired range of values.

[0039] In accordance with another aspect of the present invention, said at least one cooling device can be deactivated and, when deactivated, can be selectively associated with defrosting means: it is thus possible to bring the temperature of the incoming air flow around or below 0°C, allowing an effective and rapid reduction of any moisture contained therein while avoiding the blockage of the cooling device itself, due to the formation of ice in its parts.

[0040] The apparatus according to the invention can comprise two cooling devices disposed in cascade to each other, and in which the second has lower operating temperatures than the first cooling device; in this case the defrosting means can be associated with the second defrosting device and can also be operated automatically at predefined intervals.

[0041] In accordance with another aspect of the present invention, said second air movement means can comprise a perimeter recovery channel of the internal space of the arena. Advantageously, the perimeter recovery channel, for example a perimeter recovery channel of an ice rink, can be configured to prevent, with its suction action, the formation of fog.

ILLUSTRATION OF THE DRAWINGS

[0042] These and other aspects, features and advantages of the present invention will become clear from the disclosure of some embodiments, provided by way of nonlimiting example, with reference to the accompanying drawings in which:

- fig. 1 is a schematic depiction of an apparatus for the treatment of air, according to the present invention;
- fig. 2 is a schematic view of the apparatus of fig. 1 applied to an ice arena;
- figs. 3, 4 are schematic depictions of an air treatment apparatus, according to further embodiments which allow further energy recovery.

[0043] It should be noted that, in the present disclosure, the phraseology and terminology used, as well as the figures in the accompanying drawings, even as disclosed, have the sole purpose of illustrating and explaining the present invention, since their function is illustrative and not limited to the invention itself, the scope of protection thereof being defined by the claims.

[0044] To facilitate understanding, identical reference numbers have been used, where possible, to identify identical common elements in the figures. It should be noted that elements and features of an embodiment can be conveniently combined or incorporated into other embodiments without further clarification.

DESCRIPTION OF SOME EMBODIMENTS OF THE PRESENT INVENTION

[0045] With reference to fig. 1, an apparatus 10 for treating air in an arena according to the present invention comprises at least first and second air movement means 11a, 11b, environmental parameter detector devices 12, a thermal treatment assembly 13 and a control unit 14.

[0046] In the present text, the example case of the application of the apparatus 10 to an ice arena 100 will be described. The apparatus 10 is in any case intended to be applicable to any arena, for example preferably to a sports or recreational arena, for which a controlled temperature is to be ensured, to avoid the formation of condensation or surface fog in the internal space and to ensure a certain flow rate of external air exchange.

[0047] The first air movement means 11a can be configured to generate an incoming air flow F1. They can comprise air suction means 15, configured to suck air from the outside and send it to the thermal treatment assembly 13, provided with air flow rate regulation elements 18 and/or air movement elements 23 and at least one delivery channel 45.

[0048] The air movement elements 23 can be positioned downstream of a thermal treatment device 27 of the thermal treatment assembly 13. Advantageously, the downstream positioning of the thermal treatment device 27 allows a greater uniformity of the air flow into the internal space 101, for example of the ice rink as depicted in fig. 2. In particular, in figs. 1, 3 and 4, the air movement elements 23 are positioned inside the thermal treatment assembly 13 and downstream of a thermal treatment device 27.

[0049] The second air movement means 11b can be configured to generate an outgoing air flow F2. They can comprise air expulsion means 16, configured to expel air from the thermal treatment assembly 13 outside the ice arena 100, provided with air flow rate regulation elements 20 and/or air movement elements 21 and at least one recovery channel 46.

[0050] The air movement elements 21 can be positioned downstream of a heat exchanger 26 of the thermal treatment assembly 13. Advantageously, the positioning of the air movement elements 21 downstream of the heat exchanger 26 allows to optimize the operation of the heat exchanger 26.

[0051] The apparatus 10 can further comprise internal movement means 17, configured to move air inside the thermal treatment assembly 13 and to and from the internal space 101 of the ice arena 100. Internal space 101 of the ice arena 100 is intended as the space comprising the ice rink 102, bleachers, stairs, and the like, where athletes and the public can be found.

[0052] The internal movement means 17 can comprise air flow rate adjustment elements 22a, 22b, 22c, 22d. In particular, the air flow rate adjustment elements 22b, 22c, 22d can be positioned inside the thermal treatment assembly 13.

[0053] The air flow rate adjustment elements 18, 20, 22a, 22b, 22c, 22d can be valves, gates, dampers, configured for continuous adjustment or for on/off-type adjustment or the like.

[0054] The air movement elements 21, 23 can be motor fans, fans, aspirators, or the like.

[0055] Said delivery channel 45 and recovery channel 46 can be pipes, conduits, ducts, or the like, able to create a circulation circuit for the air flow, as depicted in fig. 2. The delivery channel 45 can comprise nozzles 50 for the exit of air. The recovery channel 46 can comprise an upper recovery channel 48 and a perimeter recovery channel 49, comprising air suction inlets 51, 52.

[0056] The inlets 52 of the perimeter recovery channel 49 can be positioned in correspondence with the ice rink 102, in particular positioned at a height from the rink 102 which is as low as possible, as a function of on structural conditions, regulations and the like. For example, the inlets 52 can be positioned at a height of less than 2 meters, preferably less than 1.5 meters, even more preferably 1 meter, even more preferably less than 50 cm. In the case of different arenas, the inlets 52 can in any case be provided in the proximity of the floor.

[0057] The environmental parameter detector devices 12 can be sensors or detection devices of environmental parameters such as temperature, humidity, vapor quality, and the like.

[0058] In particular, the detector devices 12 can comprise at least one detector 24 of internal temperature Ti and a detector 25 of relative humidity and/or vapor quality TdVi of the internal space 101. The value of the vapor quality TdVi can be calculated based on the internal temperature Ti and the relative humidity detected.

[0059] The detector devices 12 can also comprise external parameter detectors, such as a detector 28 of the external temperature Te and/or a detector 19 of relative external humidity and/or a detector of external vapor quality TdVe. The value of the vapor quality TdVe can be calculated based on the external temperature Te and the external relative humidity.

[0060] The apparatus 10 can further comprise non-environmental parameter detector devices, such as sensors for flow, flow rate, fog, the number of people or the like, not depicted in the figures.

[0061] The thermal treatment assembly 13 can comprise at least the aforesaid heat exchanger 26 and air thermal treatment device 27.

[0062] The exchanger 26 can be of the cross-flow type, configured for heat exchange between the incoming F1 and outgoing F2 air flows, for the pre-treatment or treatment of the incoming air flow F1 for energy saving purposes.

[0063] For example, if the external temperature Te is lower than a desired temperature Ti_set in the internal space 101, the heat exchanger 26 can heat the incoming air flow F1; on the other hand, if the external temperature Te is higher than that desired in the internal space 101, the heat exchanger 26 can cool it.

[0064] The predefined value Ti_set of the internal temperature Ti is the temperature which is desired to be kept in the internal space 101 of the ice arena 100. For example, the value Ti set can be comprised between 10 and 12 °C.

[0065] The air thermal treatment device 27 can be configured to bring the air to the desired temperature in the space 101. The thermal treatment device 27 can be able to heat and possibly cool the air, preferably to heat it.

[0066] According to embodiments, the thermal treatment device 27 can be associated with heating means 36 and/or with cooling means 37, allowing a selective activation of one or the other by acting on fluid flow control means 43.

[0067] That is, as a function of the application of the apparatus 10, i.e., the type of arena in which it is to be installed, the thermal treatment device 27 can comprise only heating means 36 or cooling means 37, or both.

[0068] The control unit 14 can be a microprocessor, a computer, a server, a PLC, an electronic platform, or the like. The control unit 14 can comprise, in a known manner, at least one memory module and the processing module, configured respectively to store and execute control algorithms of the apparatus 10, and interface elements with an operator for setting at least the desired values of temperature Ti_set and vapor quality TdVi_set.

[0069] The processing module can be one or more processors of any type of local or remote processor, able to execute the aforesaid program. The memory module can be one or more of those commercially available, such as random access memory (RAM), read-only memory (ROM), floppy disk, hard disk, mass memory, or any other form of digital storage, local or remote.

[0070] Said control algorithms can be configured to receive in input, or calculate, environmental parameters or non-environmental parameters, such as internal temperature Ti, external temperature Te, internal vapor quality TdVi, external vapor quality TdVe, flow, flow rate, presence of fog on the rink 102, number of people inside the ice arena 100 and the like, and to process them for controlling at least said air movement means 11a, 11b and the thermal treatment assembly 13.

[0071] For example, in thermo-hygrometric conditions in which the external vapor quality TdVe is lower than a required internal vapor quality TdVi_set, the latent moisture load to be neutralized is formed only by the water vapor produced by the people present in the ice arena 100: the air flow rate necessary to neutralize it will be automatically managed by the control unit 14 as a function of the number of people.

[0072] The required internal vapor quality TdVi_set can be less than 5 g/kg dry air (d.a.), preferably less than 4 g/kg d.a., even more preferably substantially equal to or less than 3.77 g/kg d.a.

[0073] Below are two tables (tab. 1 and 2) exemplifying the correlation between internal vapor quality TdVi, internal temperature Ti and relative humidity, for a vapor quality TdVi of 3.72 g/kg d.a.

Table 1

Temperature	12.00	°C	Relative humidity	43.00	%
Saturation pressure	1,402.59	Pa	Vapor pressure	603.11	Pa
Vapor quality	**3.72**	**gr/Kg d.a.**	Enthalpy	21.47	KJ/Kg
Density:	1.23	Kg/m3	Dew temperature	-0.16	°C
Pressure	101,325.00	Pa	Wet bulb temperature	6.51	°C

Table 2

Temperature	10.00	°C	Relative humidity	49.11	%
Saturation pressure	1,228.00	Pa	Vapor pressure	601.72	Pa
Vapor quality	**3.72**	**gr/Kg d.a.**	Enthalpy	21.47	KJ/Kg
Density:	1.24	Kg/m3	Dew temperature	-0.19	°C
Pressure	101,325.00	Pa	Wet bulb temperature	5.48	°C

[0074] In particular, said control unit 14 is configured at least to regulate the air flow rate of the air movement means 11a, 11b and the heat exchange temperatures of said exchanger 26 and said at least one air thermal treatment device 27 to keep the vapor quality TdVi in the internal space 101 at the desired value TdVi_set or in near thereto.

[0075] The apparatus 10 can comprise at least one further air thermal treatment device 29, 30, 31, which can be selectively activated by the control unit 14, as a function of the internal temperature Ti and the internal vapor quality TdVi and, where appropriate, the external temperature Te and the external vapor quality TdVe.

[0076] The thermal treatment device 29, 30, 31 can be able to heat and/or cool the air. In particular, the at least one further thermal treatment device can be chosen from a heating device 29 or a cooling device 30, 31.

[0077] For example, the apparatus 10 can comprise a heating device 29 disposed upstream of said exchanger 26. The heating device 29 can be associated with heating means 36 by fluid flow control means 44.

[0078] According to an aspect of the invention, the apparatus 10 can comprise at least one cooling device 30, 31 disposed between said exchanger 26 and said thermal treatment device 27.

[0079] According to embodiments, the apparatus 10 comprises at least one heating device 29 disposed upstream of the at least one exchanger 26 and at least one cooling device 30, 31 disposed between the at least one exchanger 26 and the thermal treatment device 27.

[0080] In such a case, the control unit 14 can also be configured to regulate the operation and possibly the operating temperatures of the at least one cooling device 30, 31 and/or the heating device 29, if present, in a manner coordinated with those of the heat exchanger 26 and the thermal treatment device 27.

[0081] The cooling device 31 can be deactivatable and a bypass path B outside said cooling device 31 can be provided, able to allow the passage of said incoming air flow F1 when the cooling device 31 is deactivated.

[0082] In particular, said cooling device 31 can be deactivated by the operation of respective adjustment means 22b, 22c which deviate the flow towards the bypass path B, excluding the path A.

[0083] When deactivated, the cooling device 31 is connectable to defrosting means 32; when activated, the cooling device 31 is connectable to cooling means 37.

[0084] The apparatus can comprise fluid flow control means 33, such as valves 34 and circulation pumps 35, for selectively associating the cooling device 31 with defrosting means 32 or with cooling means 37; said control means 33 can be configured as switching means.

[0085] According to embodiments, a second cooling device 31 is located in cascade to a first cooling device 30 and is configured to operate at lower temperatures with respect thereto. In such a case, the defrosting means 32 can be connected to only the second cooling device 31.

[0086] According to possible variations, it can also be envisaged that the defrosting means 32 are connectable to both of the cooling devices 30, 31.

[0087] The apparatus 10 can comprise fluid flow control means 38, such as valves 39 and circulation pumps 40, configured to associate the cooling device 30 with cooling means 37.

[0088] The apparatus 10 can comprise a filtering battery 47, for the filtration of incoming air for the elimination of impurities and dust.

[0089] In the present text, the thermal treatment devices 29 can be heating devices or heat exchangers configured to cooperate with heating means 36 or the like; the thermal treatment devices 30, 31 can be a heat exchanger configured to cooperate with cooling means 37 and/or with defrosting means 32 or the like.

[0090] In the present text, the cooling means 37 can be or comprise in a known manner a refrigeration assembly - or chiller - or a multi-purpose chiller or the like.

[0091] In the present text, the heating means 36 and the defrosting means 32 can be or comprise in a known manner one or more of heat pumps, boilers, multi-purpose chillers, total heat recovery systems of cooling means 37 or heat storage tanks fed in turn by air treatment means 55 comprising one or more of heat pumps 54, boilers, multi-purpose chillers, total heat recovery systems, storage tanks and/or the like. Advantageously, the efficiency of the apparatus 10 is greater with respect to the known adsorption dehumidification systems. Even more advantageously, if the apparatus 10 allows total heat recovery, the evaporation of moisture does not require further energy consumption.

[0092] In embodiments, the defrosting means 32 can coincide with the heating means 36.

[0093] The operation of the apparatus 10 for the treatment of air in arenas 100 described so far, which corresponds to the method according to the present invention, comprises the steps described below.

[0094] The method of use envisages providing an apparatus 10 for air treatment comprising air movement means 11a, 11b, environmental parameter detector devices 12, a thermal treatment assembly 13 and a control unit 14.

[0095] The method of use provides to:

- set respective desired values of temperature Ti_set and vapor quality TdVi_set to be maintained in an internal space 101 of said arena 100;
- detect the vapor quality TdVi in the internal space 101;
- regulate the air flow rate of said air movement means 11a, 11b for the recirculation and exchange of air between the internal space 101 and the external space 200, selectively activating at least one cooling device 30, 31 as a function of said internal temperature Ti and an external temperature Te and regulate the operating temperatures of said exchanger 26, said at least one air thermal treatment device 27 and possibly of said at least one cooling device (30, 31), so as to keep the internal temperature Ti and the vapor quality TdVi within a range of predefined values Ti_set, TdVi_set.

[0096] The method can further provide to detect the vapor quality TdVe in the external space 200.

[0097] The method can generally provide to use at least one further air thermal treatment device 29, 30, 31, selected from a heating device 29 or cooling devices 30, 31 and selectively activatable as a function of the environmental conditions.

[0098] Advantageously, it is thereby possible to reach the desired vapor quality TdVi_set more easily.

[0099] The method can provide to activate the cooling device 31 for dehumidification when the vapor quality TdVe in the external space 200 is higher than the internal vapor quality TdVi.

[0100] Advantageously, the cooling device 31 can be activated only when necessary, it being possible to perform the dehumidification free of charge when the vapor quality TdVe in the external space 200 is lower than the internal vapor quality TdVi, as described below.

[0101] The method can provide at least two different operating modes: a first mode in conditions of external temperature Te lower than a predefined value Ti_set of the internal temperature Ti and a second mode in conditions of external temperature Te higher than the predefined value Ti_set.

[0102] The first operating mode can be for example during the winter period, in which the external temperatures Te can assume values up to -10 °C, or less, and in which the external vapor quality TdVe is lower than the required internal vapor quality TdVi set.

[0103] In such a first operating mode, the dehumidification can simply occur by the input of external air: the incoming air flow F1 of dry air, coming into contact with the humid air in an internal space 101, is saturated and is expelled by the outgoing air flow F2 with a higher vapor quality; thereby there is a continuous transport of matter (water vapor) between the incoming and outgoing air, resulting in the dehumidification of the area inside the arena.

[0104] In this thermo hygrometric condition, the need for air exchange coincides with the dehumidification of the air inside the arena 100, which occurs without the use of other dehumidification means and, therefore, with significant savings of energy and economic resources.

[0105] In the first operating mode, the exchanger 26 can act as a condenser, because the temperature of the incoming air flow F1 is lower than that of the outgoing air flow F2 coming from inside the arena 100.

[0106] The method can then provide to heat the incoming air flow F1 by the heat exchanger 26 and/or the thermal treatment device 27. In particular, it can provide to pre-heat the incoming air flow F1 by means of said exchanger 26 and further heat it by means of the thermal treatment device 27.

[0107] The method can provide to pre-heat the external air, for example at temperatures comprised between about 0 and 2°C or higher, by means of a heating device 29 positioned upstream of said exchanger 26. Thereby, a possible formation of frost in correspondence with the exchanger 26 is avoided.

[0108] The second operating can may be implemented during the summer period, in which the external temperatures Te can assume values up to 20 °C or more and in which the external vapor quality TdVe is higher than the required internal vapor quality TdVi_set.

[0109] During operation in the second operating mode, the method can provide to cool the external air by means of the exchanger 26. It can further provide to further cool the air by means of the at least one cooling device 30, 31, if present.

[0110] The method can provide to dehumidify the incoming air flow F1 to about 2/3 of the desired total dehumidification by means of the first cooling device 30.

[0111] The method can provide to feed the cooling device 30 by means of a cooling fluid having a temperature comprised between -1 and 4°C, preferably below 0°C, preferably substantially -1°C.

[0112] The method can provide to send the air in output from the first cooling device 30 to the second cooling device 31, when this is activated, or to the at least one thermal treatment device 27, when the cooling device 31 is deactivated.

[0113] The method can provide to feed the second cooling device 31 with a cooling fluid having a temperature comprised between 0 and -5°C, preferably below 0°C, still more preferably substantially -5°C.

[0114] The method can provide to perform an automatic defrosting procedure, in particular of the second cooling device 31 when two or more cooling devices 30, 31 are provided.

[0115] For this purpose, the method can provide to activate or deactivate said cooling device 31, closing the path A by means of adjustment elements 22b and diverting the incoming air flow F1 towards the bypass path B.

[0116] When deactivated, the cooling device 31 can be connected to defrosting means 32, while when activated, it can be connected to cooling means 37.

[0117] The cooling means 37 can be controlled by the control unit 14, based on the temperature and vapor pressure levels of the air in input to the internal space 101 of the ice arena 100. The aforesaid temperature and vapor pressure levels of the air in input can be detected by temperature probes 41 and vapor pressure probes 42.

[0118] When the external vapor quality TdVe is greater than the vapor quality TdVi_set required in the internal space 101, the essential condition for reaching the required vapor quality TdVi_set is to have a cooling fluid circulating within the cooling device 31 with a fluid temperature below 0°C. This condition inevitably causes frost to form on the surface of the cooling device 31 itself. Advantageously, the aforesaid defrosting method allows to repair such a criticality.

[0119] The defrosting method can be activated autonomously, at regular cycles, for example every 2 or 3 hours. According to alternative embodiments, the control unit 14 can manage the defrosting method, for example by detecting the presence of frost or ice, by means of detectors not depicted in the figures.

[0120] In particular, and by way of example, the defrosting method can provide at least part of the following steps:

- closing air flow rate adjustment elements 22b and opening air flow rate adjustment elements 22c: this allows the air to bypass the cooling device 31 (path B);
- blocking the flow of cooling fluid to the cooling device 31 and feeding heating fluid from defrosting means 32 to the cooling device 31, acting on fluid flow control means 33;
- actuating a circulating pump 35 with a predetermined flow rate of heating fluid until the cooling device 31 is defrosted, thanks to the raising of the temperature in the cooling device 31;
- detecting having reached a defrost temperature and sending a stop signal to the circulation pump 35;
- keeping the cooling device 31 in the inactive condition for a defined time, to allow the draining of the coil itself;
- feeding cooling fluid to the cooling device 31, acting on said control means 33;
- when in correspondence with the cooling device 31 the temperature reaches values around 0°C, for example -1°C, the reopening of air flow rate adjustment elements 22b and the re-closure of air flow rate adjustment elements 22c, for restoring the normal operating conditions of the cooling device 31 (path A).

[0121] The process can provide air movement elements 21, 23 to maintain a predetermined and constant flow rate even during the defrosting method.

[0122] The method can provide at least some of the following operating conditions:

- start-up;

- maintenance with control of the internal temperature Ti and the vapor quality TdVi, by means of a temperature detector 24 and calculating the vapor quality TdVi based on the internal temperature Ti and the relative humidity detected by a detector 25;
- exchange with all external air;
- mixed exchange of external air and modular recirculation of internal air.

[0123] The start-up operating condition can provide only the recirculation of internal air.

[0124] The start-up operating condition can provide to operate in said first mode with external temperature conditions Te lower than a predefined value Ti_set or in said second mode with external temperature conditions Te higher than the predefined value Ti set.

[0125] In general, in recirculation, the air suction means 15 and the air expulsion means 16 can be controlled, in a known manner, to withdraw the air from the recovery channel 46, closing the access to the external air.

[0126] In the start-up operating condition, the apparatus 10 can be started, in internal recirculation, to increase or decrease the internal temperature Ti up to the value Ti_set, depending on the external temperature conditions Te. The air movement elements 21, 23 can keep a predetermined and constant flow rate during the start-up phase.

[0127] The maintenance operating condition can provide only for internal recirculation and maintenance of the internal temperature Ti and the vapor quality TdVi. If the vapor quality TdVi is higher than the set critical condition, the cooling device 31 and, possibly, the cooling device 30 can be activated in the maintenance operating condition. The defrosting method can then be activated.

[0128] The exchange operating condition with all external air can provide for operation with only external air, excluding internal recirculation, and the maintenance of the internal temperature Ti and the vapor quality TdVi. The operation of the apparatus 10 during the exchange operating condition with all external air is substantially the same as the maintenance operating condition.

[0129] During the exchange operating condition with all external air, the flow rate of the air movement elements 21, 23 can be modulated, for example on the basis of the number of spectators present.

[0130] The modular internal air recirculation and external air exchange mixed operating condition can provide to control the air suction means 15 and the air exhaust means 16 so as to modulate the internal air recirculation and external air exchange flow rate, with varying and otherwise settable percentages, from 0% external air exchange and 100% internal air recirculation, to 100% external air exchange and 0% internal air recirculation.

[0131] The operation of the apparatus 10 during the modular mixed external air exchange and internal air recirculation operating condition is substantially the same as the maintenance operating condition.

[0132] The method can provide, in order to optimize consumption, to increase the efficiency and/or yield of the heating, to activate one or more of the aforesaid heat pumps, boilers, multi-purpose chillers, total heat recovery systems of the thermal treatment assembly 13, in particular of the cooling means 37, or of the air treatment means 55.

[0133] By way of example, an activation sequence of heat sources of air treatment means 55 can provide:

- the activation of a boiler where the use of the heat pump 54 is not efficient: with a particularly low external temperature Te, (for example -5°C or -10°C) the control unit 14 sends a start signal to the boiler only;
- the activation of the heat pump 54 and the simultaneous deactivation of the boiler when the external conditions are such as to ensure a good degree of efficiency of the heat pump 54;
- total heat recovery of the chiller: activation of the chiller causes the heat pump 54 to stop; total heat recovery of the chiller is activated when the chiller is in operation and when the temperature in a hot water storage tank is lower than a preset value.

[0134] In particular, the energy recovered in the form of heat from the total recuperator during the operation of a chiller is greater than the refrigeration effect by about 30%; therefore, when the chiller is active, the recovered heat makes the entire system self-sufficient, cancelling the cost necessary to heat the carrier fluid by means of the boiler or the heat pump 54.

[0135] According to an embodiment, the method can provide to increase the efficiency of the apparatus 10 by sending the outgoing air flow F2, prior to emission into the external space 200, to a heat pump 54 (fig. 3), to increase the temperature of the incoming air to its evaporating coil: the increase in the COP (Coefficient Of Performance) of a heat pump is directly proportional to the increase in the temperature of the incoming air to its evaporating coil.

[0136] According to a further embodiment, the method can provide to increase the efficiency of the apparatus 10 by sending the air withdrawn from the space 200 to the evaporating coil of a heat pump 54 and subsequently to the thermal treatment assembly 13, in particular to the heat exchanger 26: the vapor quality of the air in output from the evaporator is always lower than that in the space 200, since the passage of the air through the exchange surface of the evaporator, which is at a lower temperature than the ambient temperature Te, determines the dehumidification thereof (fig. 4).

[0137] The aforesaid heat pump can for example be the heat pump 54 of air treatment means 55 or a heat pump comprised in the thermal treatment assembly 13.

[0138] For example, considering an exchange air flow rate of 40,000 m3/h, with the sending to the thermal treatment assembly 13 of air sucked directly from the space 200, the total power required in cooling and dehumidification can substantially correspond to 190 kW, in heating to 286 kW, for a vapor quality TdVi of about 2.49; with the sending to the thermal treatment assembly 13 of air through the heat pump 54, the total power required in cooling and dehumidification can substantially correspond to 0 W, in heating to 180 kW, for the same vapor quality TdVi.

[0139] The method can provide to suck air from the internal space 101 only through a perimeter recovery channel 49 of the rink 102, closing an upper recovery channel 48. Thereby, damp air, and possibly fog, present on the rink 102 can be drawn by means of suction through air suction inlets in correspondence with the rink 102.

[0140] In general and by way of example, in winter the only latent heat is that produced by the people present inside the ice arena. Hypothesizing a presence of 1800 people and an air exchange of 40,000 m3/h, the total amount of water vapor to be condensed is 82.93 kg/h.

[0141] With an external temperature Te of -5°C, a relative humidity of 100% and an external vapor pressure TdVe of 2.48, the apparatus 10 according to the present invention has a consumption of about electric 130 kW.

[0142] The known adsorption dehumidification system - under the same conditions - has a consumption of about electric 226 kW.

[0143] The advantage is relevant because the apparatus 10 according to the present invention, unlike the known adsorption system, also performs, with a consumption of slightly more than half, two other functions: the exchange of the internal air and the heating of that which withdraws from the outside.

[0144] In summer, the latent load, already highlighted in winter, must be added to that related to the humidity present in the external air. Keeping the number of people and the exchange rate equal, with an external temperature Te of 15°C, a relative humidity of 75% and an external vapor pressure TdVe of 7.95, the total amount of water vapor to be condensed is equal to 218.92 kg/h.

[0145] The apparatus 10 - under suitable internal conditions to avoid the formation of fog and/or condensation and for an internal vapor pressure TdVi of 3.46 - has a consumption of about electric 170 kW.

[0146] The known adsorption dehumidification system - under the same conditions - consumes about 430 kw to condense the required amount of water.

[0147] In particular, in winter the known adsorption dehumidification system has an electrical consumption which is not proportional to that of summer, as the relative humidity conditions of the internal space are not the same. This is due to the fact that the absolute humidity in winter is lower than that in summer.

[0148] It is clear that modifications and/or additions of parts may be made to the apparatus 10 and to the method disclosed herein, without departing from the scope of the present invention as defined by the claims.

[0149] It is also clear that, although the present invention has been described with reference to some specific examples, a person skilled in the art will be able to make many other equivalent forms of apparatus 10 for the treatment of air and related method of use, having the features expressed in the claims and therefore all of which falling within the scope of protection defined thereby.

[0150] In the following claims, the references in parentheses have the sole purpose of facilitating reading and must not be considered as limiting factors of the scope of protection defined by the claims themselves.

Claims

1. Apparatus (10) for treating air in arenas (100) comprising first and second air movement means (11a, 11b) configured to generate an incoming air flow (F1) and an outgoing air flow (F2), at least one heat exchanger (26) between said air flows (F1, F2), at least one device (27) for the thermal treatment of said incoming air flow (F1), wherein said at least one exchanger (26) and said at least one device (27) are able to manage the exchange of air between an external space (200) and an internal space (101) of said arena (100), **characterized in that** said apparatus (10) comprises at least one cooling device (30, 31) disposed between said exchanger (26) and said thermal treatment device (27) along a path of said incoming air flow (F1) and a control unit (14) configured to determine at least the flow rates of said air flows (F1, F2) and the operating temperatures of said at least one exchanger (26), said at least one device (27) for thermal treatment and said at least one cooling device (30, 31) so as to keep the internal temperature (Ti) and the internal vapor quality (TdVi), which are detected by detector devices (24, 25), or calculated on the basis of data detected by the latter, within a range of predefined values (Ti_set, TdVi_set), wherein said at least one cooling device (30, 31) can be selectively activated by said control unit (14) as a function of said internal temperature (Ti) and an external temperature (Te).

2. Apparatus (10) as in claim 1, **characterized in that** it comprises at least one further device (29, 30, 31) for the thermal treatment of the air, chosen from a heating device (29) disposed upstream of said at least one exchanger

(26) or a cooling device (30, 31) disposed between said at least one exchanger (26) and said thermal treatment device (27), that can be selectively activated by said control unit (14) as a function of said internal temperature (Ti) and said external temperature (Te).

3. Apparatus (10) as in any one of claims 1 or 2, **characterized in that** said cooling device (30, 31) can be deactivated and a bypass path (B) is provided outside said cooling device (30, 31) able to allow the passage of said incoming air flow (F1) when said cooling device (30, 31) is deactivated.

4. Apparatus (10) as in any one of the preceding claims, **characterized in that** said cooling device (30, 31) can be selectively connected to defrosting means (32).

5. Apparatus (10) as in any one of the preceding claims, **characterized in that** it comprises a first (30) and a second (31) cooling device, which is located in cascade to said first cooling device (30) and configured to operate at lower temperatures with respect thereto, adjustment means (22b, 22c) configured to selectively connect/disconnect said first and second (30, 31) cooling device or said thermal treatment device (27) by means of said bypass path (B).

6. Apparatus (10) as in claims 4 and 5, **characterized in that** it comprises means (33) for controlling the flow of fluid flow able to connect, alternatively, said second cooling device (31) to said defrosting means (32), when deactivated, and to cooling means (37), when activated.

7. Apparatus (10) as in any one of the preceding claims, **characterized in that** said air movement means (11b) comprise a perimeter recovery channel (49) of the rink (102) **and in that** said perimeter recovery channel (49) comprises inlets (51) positioned in correspondence with the rink (102).

8. Method of using an apparatus (10) for the treatment of air of an arena (100) as in any one of the preceding claims, **characterized in that** it provides to:

   - set respective desired values of temperature (Ti_set) and vapor quality (TdVi_set) to be maintained in an internal space (101) of said arena (100);
   - detect the internal temperature (Ti) in said internal space (101) and determine the vapor quality (TdVi);
   - regulate the air flow rate of said air movement means (11a, 11b) for the recirculation and exchange of air with a space (200) outside said arena (100), selectively activating at least one cooling device (30, 31) as a function of said internal temperature (Ti) and an external temperature (Te) and regulate the operating temperatures of at least one heat exchanger (26), at least one air thermal treatment device (27) and possibly of said at least one cooling device (30, 31), so as to keep said internal temperature (Ti) and said internal vapor quality (TdVi) within a range of said predefined values (Ti_set, TdVi_set).

9. Method as in claim 8, **characterized in that** it provides to verify whether said external temperature (Te) is lower, higher or equal to said predefined value (Ti_set) and, during operation in conditions of external temperature (Te) lower than said desired value (Ti_set), it provides to heat said incoming air flow (F1) by means of said at least one exchanger (26) and/or by means of said thermal treatment device (27) and, during operation under conditions of external temperature (Te) higher than said desired value (TiD), it provides to cool said incoming air flow (F1) by means of said at least one exchanger (26).

10. Method as in claim 8 or 9, **characterized in that** it provides to verify whether said external temperature (Te) is lower, higher or equal to said predefined value (Ti_set) and during operation in conditions of external temperature (Te) lower than said desired value (Ti_set), it provides to heat said incoming air flow (F1) by means of a heating device (29) disposed upstream of said at least one exchanger (26) at least up to a temperature above zero and during operation in conditions of external temperature (Te) higher than said desired value (Ti_set) it provides to cool said incoming air flow (F1) by means of said at least one cooling device (30, 31) disposed between said at least one exchanger (26) and said thermal treatment device (27).

11. Method as in any one of claims 8 to 10, **characterised in that** it provides to detect the vapor quality (TdVe) in the external space (200) and to activate said cooling device (31) when the vapor quality (TdVe) in the external space (200) is higher than the internal vapor quality (TdVi).

12. Method as in any one of claims 8 to 11, **characterized in that** it provides to perform, at least at predefined intervals, a procedure to automatically defrost said at least one cooling device (30, 31) and to deactivate it by making said

incoming air flow (F1) transit along a bypass path (B) outside said at least one cooling device (30, 31), connecting it to defrosting means (32).

13. Method as in any one of claims 8 to 12, **characterized in that** it provides to draw an outgoing air flow (F2) from the internal space (101) only through a perimeter recovery channel (49) comprising inlets (51) positioned in the proximity of the near the rink (102) or the floor, closing an upper recovery channel (48), said upper recovery channel (48) and said perimeter recovery channel (49) being comprised in the air movement means (11b).

14. Method as in any one of claims 8 to 13, **characterized in that** it provides to send said outgoing air flow (F2) to a heat pump (54), before being released into the external space (200).

15. Method as in any one of claims 8 to 14, **characterized in that** it provides to send said incoming air flow (F1) to the evaporating coil of a heat pump (54) before sending it to said heat exchanger (26).

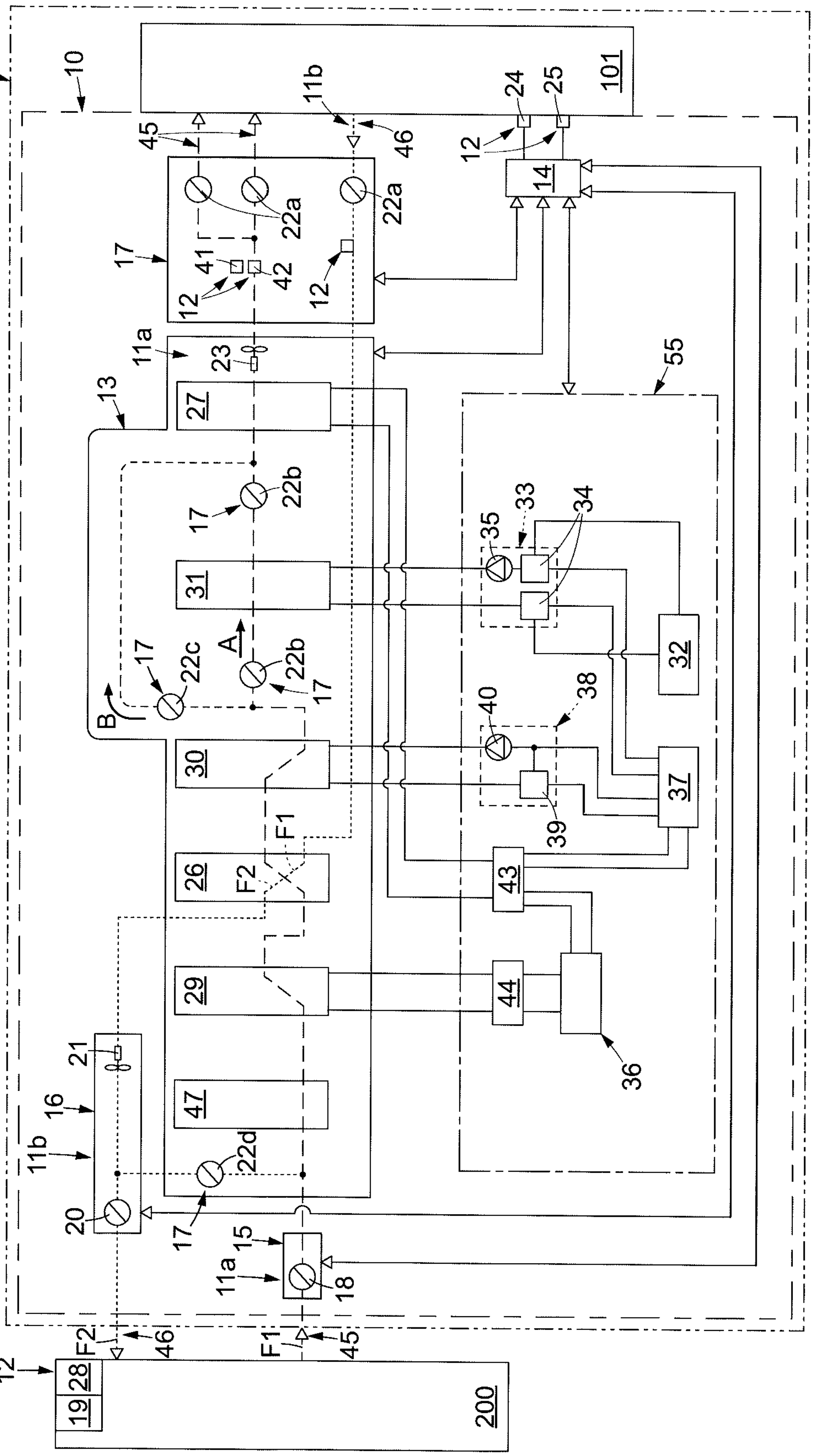
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fig. 1

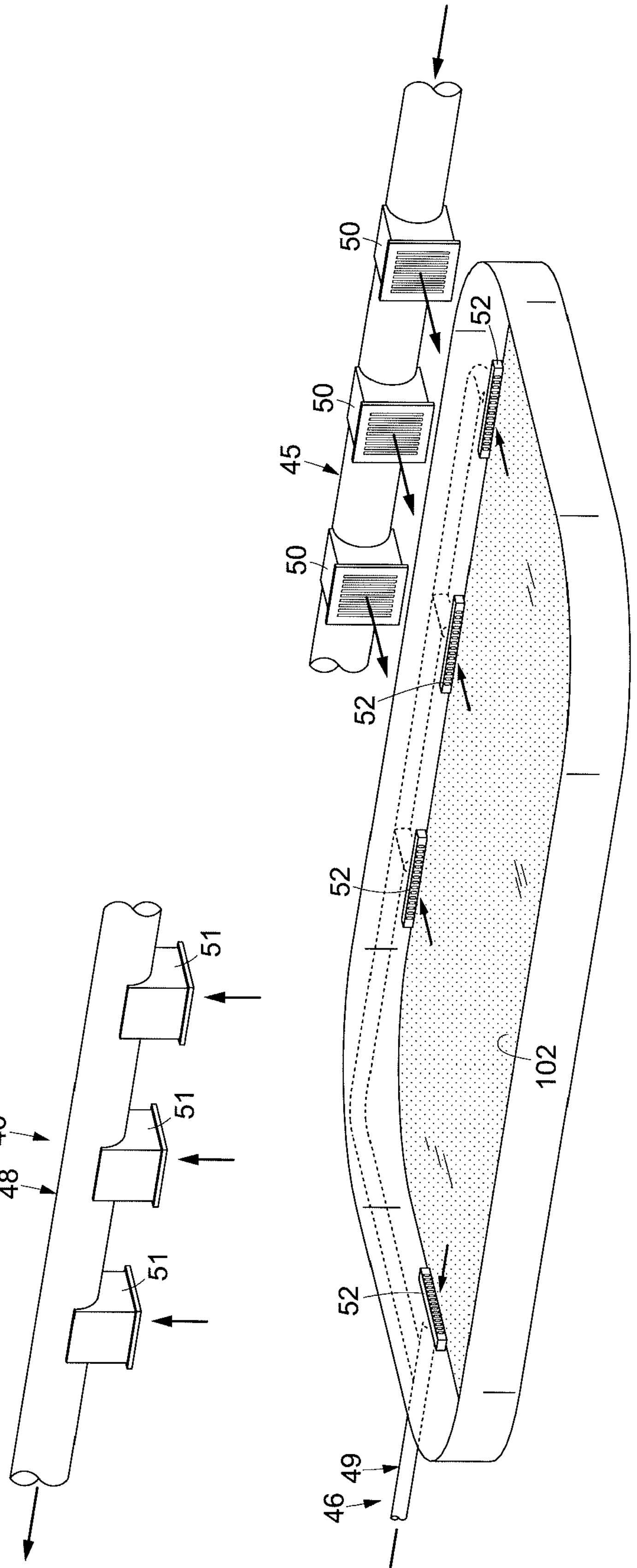

fig. 2

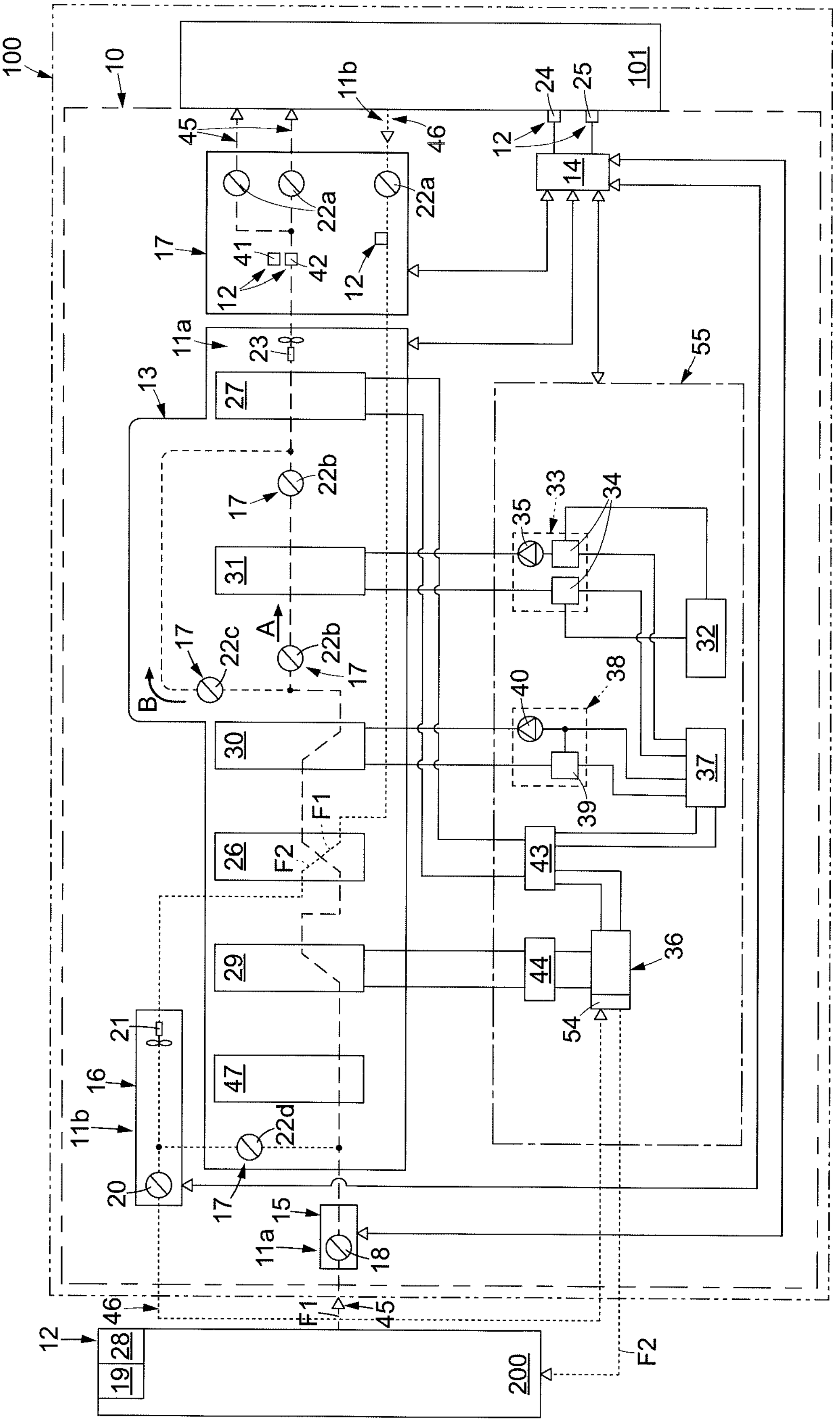

fig. 3

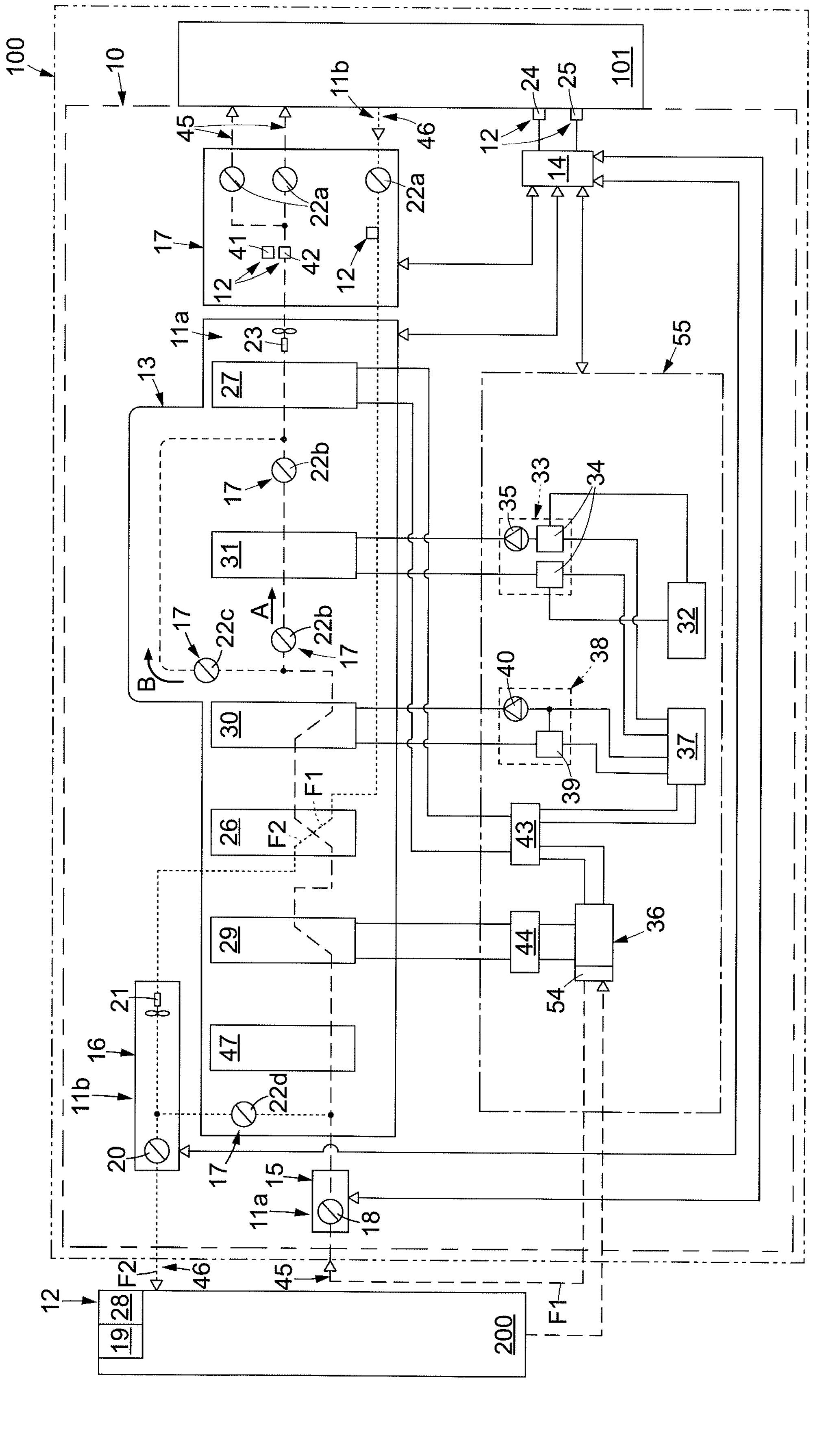
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fig. 4

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
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X : particularly relevant if taken alone
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