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(71) Applicant: STANGRECIAK, Malgorzata [PL/PL];
Planty 21, 05-080 Izabelin (PL).

(72) Inventor: JESCHKE, Marius; Planty 21, 05-080 Izabelin
(PL).

(74) Agent: ZEBROWSKA-KUCHARZYK, Agnieszka; No-
woursynowska 162J, 02-776 Warszawa (PL).

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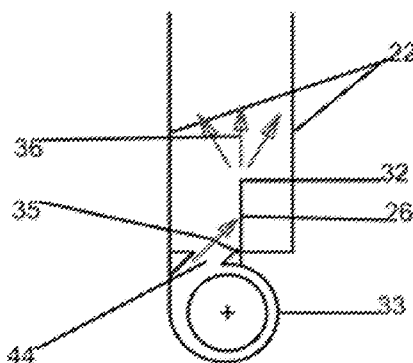


Fig. 4

(57) Abstract: The present invention relates to a solar air system comprising : at least one air duct (A, B, C) for heat transfer, having a cross-sectional area of the air duct, wherein the air duct has a fixed cross-section along its entire length, air inlet duct in fluid connection with air duct to supply air to it for heat transfer purposes, having a cross-section of the inlet duct, and fan system in fluid connection with the inlet duct to supply air to it for heat transfer purposes, wherein the fan system is configured to supply an air stream having a static pressure higher than the static pressure of the axial fan, and the system additionally comprises at least one resonator installed in the air duct to change the air flow from laminar to turbulent, and the inlet duct is configured to supply an air stream to the resonator at an angle to the resonator surface, wherein the cross-section of the inlet duct is less than the cross-section of the air duct of the air system. Present invention provides also a method of heat transfer in the system, where the solar air system according to the invention is used.



5

10 **Solar air system and method of heat transfer using said
solar air system**

Subject of the invention

The present invention relates to a vortex generator for
15 solar air collector, comprising said vortex generator of the
solar system for heating air and to the method of heating the
air using said solar system. According to this solution, it is
possible to provide more effective and extremely simple device
for heating enclosed spaces and for supplying technological
20 heat in an environmentally friendly manner without polluting
the air.

Moreover, due to present solution, it is possible to
supply solar heat of the desired temperature of comfort to
enclosed spaces with a simultaneous reduction of harmful air
25 pollution and the emission of greenhouse gases.

Field of the invention

The development of contemporary civilization is based on
energy obtained mainly from the burning of fossil fuels. The
rapid development of civilization fosters an increasing demand
30 for energy, resulting in an increase in global warming together
with increase in intensive air pollution, leading to a
noticeable increase in diseases related to the cardiovascular
system and diseases of the upper respiratory track. The world-
wide community defines these problems (the Kyoto and Paris

Protocols) and determines the admissible thresholds of the commonly accepted increase in global warming. Moreover, one searches for a solution to this problem by defining the fields related to both ecological production of energy as well as
5 more effective utilization of it, e.g. by reduction of its losses in the construction sector. Simultaneously with the requirements of limiting energy loss in the construction sector, one looks for solutions related to the production of energy from renewable energy sources, i.e. so-called pure,
10 green energy. A natural and primary source of renewable energy is the sun, which provides energy by radiation, which can be converted into electrical and thermal energy. However, full utilization of solar energy in order to cover the human demand for energy without the burning of fossil fuels still faces
15 barriers related to the low efficiency of conversion of solar energy into usable energy, through which the cost of producing green energy from solar radiation is incomparably higher than the cost of producing energy from the burning of fossil fuels.

Thus, new solutions are constantly being developed in
20 order to reduce the costs of producing green energy, consisting of the increase of energy efficiency of solar technology. Especially intensive research related to direct conversion of solar radiation energy into thermal energy contained in the air is performed, due to the fact that a person feels
25 discomfort when he or she dwells at a temperature lower than the temperature of comfort. Developing solar technologies providing maximum conversion of solar radiation energy into utility heat will allow for a drastic reduction of thermal energy production costs, leaving the burning of fossil fuels
30 economically unjustified.

During times of increased global warming, intensified air pollution, resulting, among other things, in the generation of undesired smog, and constantly increasing costs of producing pure energy, one searches for eco-innovative solutions,

including solutions concerning heating devices, which, when provided with sufficient source of utility heat for heating enclosed spaces and thus supplying technological heat, would significantly reduce the emission of harmful gases, chemical substances and dust. It is especially important to provide such systems that would be simple and inexpensive in operation, which in fact would contribute to their universal availability.

In the light of the aforementioned priorities, more and more interest is devoted to systems using solar energy. In this field, there are many differentiated systems using solar energy, used both for private household and industrial applications. However, due to the different degrees of exposure to the sun, which varies based on geographical location or season of the year, there is an on-going research concerning such cost-effective system / circuit / device which would be characterized by increased efficiency with the simultaneous condition of being compact in size, e.g. one proportional to the cubature of the heated room, allowing for its practical applicability.

20 Prior art

Patent application CN 203572053U discloses a two-layer solar air collector, wherein the heated air is forced into the space between the solar glass and the absorber and is returned into the space under the absorber and over the thermal insulation. In order to provide full contact of the air forced through the collector with the absorber surface, the top layer of the collector is fitted with longitudinal crossbars, and the bottom part of the collector is fitted with crosswise crossbars. According to the disclosure, it is preferable to force the air through a single air duct formed by longitudinal and crosswise crossbars determining the route of air flow. The aforementioned solution is aimed at increasing the time the air particles are present in the collector chambers by extending the route of air flow, resulting in a significant

increase in the rise of temperature of the heated air. This solution discards the issue related to energy (heat) transfer efficiency due to significant drawbacks of the solution consisting of even greater heat loss related to the motion of
5 air directly under the collector glass. The increased motion of air, necessary in this solution, increases the heat transfer between the colder glass and the heated air as a result of the heat transfer coefficient, which in the case of glass is significant and is approximately equal to the coefficient
10 typical for water ($W = 0.6 \text{ W/mK}$), leading to a loss of heat received from the absorber surface. Heat loss increases together with the increase in flow rate through the collector, which in this case is a serious drawback, because it limits the volume of air passing through the collector, allowing only
15 for obtaining an increase of air temperature with low efficiency and only at small difference in temperatures and with no movement of air inside the collector.

However, this kind of air flow cannot pick off the near-wall layer of air by the absorber. Although the publication
20 recommends turbulent air flow through the two-layer solar system, the heat transfer in the collector takes place as a result of heat conduction typical for laminar flow. The term "air turbulence" as used in the publication is not justified, because factors necessary to obtain air turbulence, such as,
25 among other things, significant air flow rate, are not provided due to increasing heat losses in the top layer of the collector together with the increasing rate (velocity) of air flow.

Another publication of utility model CN102121799U discloses the option of generating turbulence of fluid passing
30 through the collector; however, in contrast to the aforementioned system, rather focuses on a liquid-type collector. The proposed solution cannot be simply transposed to the utility solutions related to direct heating of gases, because liquids differ from gases in their physical properties,

such as: specific weight 1.2 kg/m³ in the case of air and 1000 kg/m³ in the case of water, heat transfer $W=0.02$ W/mK for air and 0.6 W/mK for water.

Patent publication US 2010020629 discloses a solar
5 system, wherein air is heated in the internal space of the collector by the heated absorber surface as a result of forced convection of air sucked in by the common collector, wherein the air is sucked in from the surface above the absorber through holes made in it. The disclosed system has basic
10 drawbacks, limiting its application only to the ventilation of premises with initially heated air, wherein the thermal energy capacity passing together with air into the internal space of the collector through a perforated absorber surface depends on ambient air temperature and air motion (wind). Air in motion,
15 passing over the absorber surface, leads to its cooling, and thus limits the volume of energy transferred via forced convection in the internal collector space. Another drawback of the disclosed solution is exposure of the absorber surface to direct ambient factors, including air dust, which
20 effectively blocks the route of air flow through the absorber holes. Details of the solution, presented in the figures, wherein the main air flow stream supplying the collector enters through a wide duct to a series of collectors, and part of the air is sucked in from over the absorber surface through holes
25 in the absorber, show that the volume of air supplying the system through the absorber holes is minor and depends on natural air flow outside the collector. The efficiency of heat transfer of the presented system is low, because the heat transfer takes place via convection, and gain of turbulence
30 leading to intensive heat exchange is negligible due to the very low pressure difference between the internal and external space of the collector at the place of perforation due to the negligible resistance of air flow supplying the collector via large side walls of a series of collectors.

Another patent publication DE 10023833 discloses a type of collector, wherein air at a significant rate is forced into an air duct of the meandrically positioned collector, the flow of which at the collector inlet is determined as laminar along
5 the entire duct cross-section. The surface of the air duct has holes, as detailed in the publication, through which air is sucked into the air duct from the air layer between the air duct and solar glass. The air, at atmospheric pressure, penetrates the layer between the solar glass and the air duct
10 and is sucked inside the air duct. The solution according to DE 10023833 can be characterized by a significant increase of temperature of heated air with an efficiency reaching 60%, maintaining the volume of air, defined in the description, entering the collector, together with its detailed
15 quantitative division to air forced into the duct and air sucked through the perforated absorber surface. A significant drawback of the solution is the susceptibility of the collector to ambient conditions, such as ambient temperature or air motion (wind). With a negative ambient temperature and even
20 minor air motion induced by thermal currents or wind, the air motion inside the collector between the solar glass and air duct surface results in an increased negative heat transfer (heat loss) through the solar glass. This results in a cooling of the absorber air duct, and the heat transfer drops far
25 beyond the value stated by the author as the ideal conditions, i.e. 60%. The increase of air flow rate through the air duct results in increased air flow through the duct holes, and thus significantly increases heat losses through the solar glass. The aforementioned reasoning is confirmed by the author,
30 classifying the disclosed solution as a source of heat of high temperature for regeneration of absorber beds in heat accumulators of zeolite and silica gel type.

However, none of the aforementioned documents, neither those known to the Applicant, suggest the existence of such

solar system, which would be highly efficient, thus economically justified and allowing for effective and controllable direct heating of utility premises with air at the temperature of comfort (according to proper standards
5 concerning temperature inside utility premises), regardless of the solar radiation intensity and ambient (external) temperature.

All of the abovementioned solutions are still burdened with numerous imperfections, such as low practical thermal
10 efficiency of devices, reaching a maximum of 60%, or limited practical application, mostly for ventilation with initially heated air (which does not eliminate the necessity to burn fossil fuels in order to reach the temperature of comfort). Moreover, the solutions according to the art depend highly
15 upon the ambient conditions, and the cost of their production is unacceptable from the practical applicability standpoint.

On the other hand, none of the aforementioned documents, neither those known to the Applicant, do not suggest the existence of such solar system which would be highly efficient,
20 cost-effective and allowing for effective and controllable heating of enclosed areas, both in residential buildings and commercial premises, up to the required temperature, especially the temperature of comfort, regardless of any ambient parameters of the heated room, including its location,
25 time of day or season of year.

For this reason, the need exists to search for new, more effective solutions in the area of solar air systems, which would provide for the creation of such solar air systems which could be applied directly to heating as an alternative heating
30 system.

Present inventor unexpectedly found that by designing a new vortex generator that forces air into the air ducts of new generation air collectors of turbulent flow, one may obtain a higher efficiency of heat transfer.

This increase in heat transfer allows for practical application of such collectors for effective heating of both residential buildings and commercial buildings, with full control over the temperature of the air supplied to the premises, regardless of solar radiation intensity.

Moreover, the inventor unexpectedly found that an increased thermal transfer efficiency in the solar collectors is achieved by an inexpensive to produce vortex generator, which is located at the inlet of the straight section of the collector air duct.

Air of turbulent flow generated in the vortex generator, as opposed to air of laminar flow, due to higher energy, and thus a higher rate and differentiated direction of flow in the vortex, can be characterized by the ability of effective picking off the near-wall layer of air representing an insulation barrier. Due to the generated vortices, air particles in the flow are in direct contact with the absorber surface, thus heat transfer in the solar absorber according to the invention takes place first and foremost via thermal conduction.

The method of heating the air developed by the present inventor allows for control of the temperature of heated air by creating a system of three parallel air ducts of a meandrinal pattern, which, prior to the air discharge from the collector, can be returned to the collector inlet in one, two or three ducts, depending on the decrease in solar radiation intensity. Closing three ducts and returning the air to the collector inlet is applied only when starting the collector at an ambient temperature equal or lower than the inside temperature of the heated room in order to prevent a supply of air of lower temperature to heated room. In turn, the system of closing and opening the dampers of ambient air and warm air inside the building allows for effective heating of premises at a negative ambient temperature and low intensity of solar

radiation by introducing warm air from the building into the collector and heating this air. The ambient air damper system, with proper energy supplied from solar radiation, allows for mixing the building air with fresh ambient air with simultaneous ventilation of a room. With full exposure of the sun, at maximum solar radiation intensity, air is drawn in only from outside, providing effective ventilation.

Control and air mixing systems are included in the collector, which promote the use of collector batteries on building walls or roofs, where partial shading of the building has no effect on thermal results, as each of the collectors works individually.

Detailed description of the invention

Present invention relates to a solar air system comprising:

- at least one air duct (A, B, C) for heat transfer, having a cross-sectional area of the air duct, wherein the air duct has a fixed cross-section along its entire length,

- air inlet duct 44 in fluid connection with air duct to supply it with air for heat transfer purposes, having a cross-section of the inlet duct 44, and

- fan system in fluid connection with the inlet duct to supply it with air for heat transfer purposes, wherein

the fan system is configured to supply an air flow stream having a static pressure higher than the static pressure of the axial fan, and

the system additionally comprises at least one resonator installed in the air duct to change the air flow from laminar to turbulent,

while the inlet duct 44 is configured to supply an air flow stream to the resonator at an angle to the resonator surface, wherein the cross-section of the inlet duct 44 is less than the cross-section of the air duct of the air system.

In a preferred embodiment of the invention, the inlet duct 44 is configured to supply an air flow stream to the resonator 26 at an angle of about 30° to about 60° , more preferably about 40° to about 50° , most preferably about 45° .

5 Preferably, the fan system comprises a radial fan 33.

In another preferable embodiment, the fan system is integrated with the inlet duct 44.

According to the preferred embodiment, the ratio of the cross-section of the inlet duct 44 to the cross-section of the
10 air duct is from about 1:2 to about 1:5, preferably about 1:4.

According to the preferred embodiment of the solar air system according to the invention, the air duct comprises at least one baffle 22, which divides the air duct into air subducts A1, A2, A3; wherein the resonator is installed in the
15 baffle 22 at an angle α . More preferably, the air duct has two baffles 22, which divide the air duct into three air subducts A1, A2 A3, and each of the baffles has a separate resonator. In an even more preferable embodiment, the resonators are oriented at an angle in relation to the baffle 22 and wherein,
20 they are positioned at an angle from about 60° to about 120° , more preferably at an angle of 90° , in relation to each other.

According to another preferred embodiment of the solar air system according to the invention, the air duct has at least one baffle 22, which divides the air duct into air
25 subducts A1, A2, A3, and wherein the resonator 26 is installed on the inlet duct 44 at an angle α . More preferably, the air duct has two baffles 22, which divide the air duct into three air subducts A1, A2 A3, and each of the baffles has a separate resonator 26. In an even more preferable embodiment, the
30 resonator 26 is oriented in parallel to the baffle 22.

In yet another preferable embodiment, the fan system includes at least one suction duct to introduce additional volumes of air into the system.

In still another embodiment, the resonator is fitted with a means of angle adjustment in relation to the air flow stream.

Preferably, the solar air system according to the invention comprises at least one meander A1-A2, A2-A3, B1-B2, 5 B2-B3, C1-C2, C2-C3. More preferably, the meander comprises an additional resonator 26, as mentioned above, positioned at the beginning of the rectilinear meander section.

Present invention provides also a method of heat transfer in the system, wherein the solar air system according to the 10 invention is used.

Unless defined otherwise, all technical and/or scientific terms used herein have the same meaning as those commonly understood by a person having ordinary skill in the art, to whom this invention belongs. The terms used in the invention 15 are used to describe individual elements and not to limit the scope of the invention. Any publications, patent applications, patents and other information mentioned herein are incorporated in their entirety by reference. In the event of doubt as to the exact meaning of each of the technical and/or 20 scientific terms used herein, see the references for clarification.

The term "bypass" as used herein means an additional air duct 25 located directly below the three collector air ducts, to which air is returned from one or more, if desirable, namely 25 two or three air ducts before being discharged from the collector 1 after opening the valves 13, 14, 15 separating the collector air ducts from the bypass.

According to the description, "temperature of comfort" means the temperature of a room within a range defined by 30 proper standards concerning the temperature in utility rooms, specifically a temperature between 16°C and 25°C. Exemplary temperatures of comfort, to which the air can be heated using the system according to the invention, cover temperatures

selected from among 16°C, 17°C, 18°C, 19°C, 20°C, 21°C, 22°C, 23°C, 24°C and 25°C.

The term "temperature of stagnation" as used in the description means the temperature to which the air duct is heated with a maximum intensity of solar radiation at stopped air flow.

According to the description, an insulator can be any layer of thermal insulation made, for example, of phenol-formaldehyde foam PF or a layer of insulation made of ceramic paper with silicon-aluminium fibres or silicone foam, as well as a layer of steady air.

As used herein, the term "capacity" means the volume of air produced by the collector.

As used herein, the term "efficiency" means the efficiency of the thermal transfer in the device, including losses.

Whenever in the description term "turbulent flow" is mentioned, this means turbulent flow with vortices oriented crosswise and/or rectilinear, with a chaotic motion and with significant kinematic energy of a particle motion. In the turbulent flow, intensive mixing of fluid layers occurs, preferably a gas such as air.

When the term "laminar flow" is used herein, this means a layered flow, when the fluid, preferably a gas such as air, flows in non-mixing layers.

The term "resonator" as used herein means a resonator, preferable made of a spring plate, more preferably of a steel plate, which is hit by a stream of air at a given angle and rate within the range of 8 to 12 m/s. According to this description, the resonator plate is rigidly fixed at one side, the height of which cannot exceed the height of the air duct, and allows for free motion (plate vibrations without contact with duct walls).

The term "absorber" as used herein means a material able to absorb and release solar radiation, especially in the form

of a coating of air duct from the side of the solar radiation, in the form of a selective layer absorbing solar radiation energy applied on the heat conducting base, especially aluminium or copper sheet.

5 The term "air duct" means any element of the solar collector system that is used to guide air volume. In the preferred embodiment of the invention, the air duct has a form of a tube, more preferably of a rectangular cross-section, made of aluminium sheet with a thickness of 0.4 mm with a
10 galvanized layer absorbing solar radiation energy and with the remaining sides of the rectangle in the shape of the letter "U" made of aluminium sheet with a thickness of 0.5 mm. Preferably, the rectangle representing the cross-section has one side of the rectangle of a length equal to 1/3 of the
15 second side of the rectangle.

The term "generator trailing edge" means the resonator side of a height less than the air duct height, positioned freely inside the air duct.

Unless otherwise stated in the description, the term
20 "about" is used to describe that the stated values are approximate. For example, the term "about", when used in relation to the temperature, means that temperature deviations of 30%, 25%, 20%, 15%, 10% or 5% are included in the temperature value. Similarly, the term "about", when used in relation to
25 the cross-section ratio or an angle or inclination or incidence, means that deviations of such ratio or inclination or incidence angle differing from the stated value by 30%, 25%, 20%, 15%, 10% or 5% are also included in the mentioned values.

30 All aspects of the invention will be more apparent to persons having ordinary skill in the art after reading the detailed description, in light of the practical embodiments presented in the following examples.

Practical embodiments of the invention

The solution according to the invention is described below based on practical embodiments as shown in the following figures:

Fig. 1 presents a top view of the solar collector together with vortex generators A, B, C, each of which comprises a separate fan system connected to the inlet of three collector air subducts (fig. 1a) and with an assembly of vortex generators with a single fan system connected to three air subducts (fig. 1b);

10 Fig. 2 presents a cross-sectional view A-A of the solar collector, in which is shown the location of positioning the assembly of vortex generators A, B, C connected to the inlet of three collector air ducts;

Fig. 3 presents a longitudinal-sectional view B-B of the 15 solar collector, in which is shown the location of positioning the assembly of vortex generators A, B, C connected to the inlet of three collector air ducts;

Fig. 4 presents the solution of the assembly of vortex generator A, B, C;

20 Fig. 5 presents the vortex generator with one common radial fan;

Fig. 6 presents a cross-sectional view of the air duct together with fixed duct walls;

Fig. 7 presents the connection of the top cover of the 25 air duct with the bottom part of the duct;

Fig. 8 presents the temperature increase ΔT_{SAH} achieved in the solar system according to the invention in the function of solar light flux intensity I determined for the solar system at an air flow rate of 110 m³/h for panel a) and 80 m³/h for 30 panel b);

Fig. 9 presents the thermal output of the solar system according to the invention η_A in the function of solar light flux intensity I determined for the solar system at an air flow rate of 110 m³/h for panel a) and 80 m³/h for panel b).

The solar system according to the invention heats the air with solar radiation energy converted into thermal energy with unexpectedly high efficiency.

Practical realizations of the solar system according to 5 the invention are presented in Fig. 1-7. In one aspect, the solar system according to the invention is housed in a casing F of the solar collector. Inside the casing F, two separate sections are provided - an air mixing section and a heat transfer section. The air mixing section 10 adjacently houses 10 the air intake from a building 2 and the air intake from the outside with a filter and valve 3. Next to the air intake, an ambient temperature sensor 4A is located. A crosswise baffle, opposite to the air intake from room 2 and air intake from the outside 3, is fitted with an air inlet to the heat transfer 15 section. In the heat transfer section, the solar collector has a glass coating layer, top layer of the insulator, heat exchanger layer and bottom layer of the insulator. The glass coating is preferably solar glass 24. The top layer of the insulator is preferably a layer of steady ambient air 20, 20 immobilized between the layer of the glass coating and the layer of the heat exchanger. The bottom layer of the insulator is preferably a high-temperature ceramic layer 27 and thermal insulation layer of phenolic foam 30. The heat exchanger layer includes the layer of the absorber 21, 11 coating and of the 25 air duct, limited from the top by the layer with the absorber 21, 11 coating, side walls representing a baffle 22 of the air duct and the layer of the bottom of the air duct 23. Preferably, the absorber 21, 11 coating is an aluminium layer coated by a selective absorbing coating. In the heat exchanger layer, at 30 the air inlet, a resonator(s) 26 is / are provided. In one embodiment, just before air outlet 1, three valves 13, 14, 15 are provided to return air through the valve 7 using a bypass 25 to the air mixing section 10. In another embodiment (not shown), just before the air outlet 1, heat accumulators are

provided, made of, for example, PCN material, to accumulate the surplus of heat.

The air supplying the solar system is fed to the solar system using a stream 6 directly from the atmosphere, a stream 5 of heated air from a room or a stream 9 from the closed circuit in the solar system. In another embodiment of the solar system according to the invention, the supply air is fed in the form of a mixture of streams 5, 6 and 9. In yet another embodiment of the invention, the supply air is fed using a 10 controlled share of streams 5, 6 and 9.

The supply air is sucked into the solar system with the negative pressure of the fan system, especially using the radial fan or system of radial fans A, B, C, located in the air mixing section 10 of the solar system. The air mixing 15 system 10 is separated from the ambient and the thermal transfer section by means on an insulated casing F using thermal insulation 30 and with a cover 29 from the top, made of sheet insulated with insulation 30.

Air sucked from the air mixing section 10 is forced into 20 the air subduct(s) designated as a subduct(s) A-1, B-1, C-1 in the heat transfer section. The air ducts A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 (also referred to as subducts) are placed in a single plane of the collector, together with the fan system, and within the entire collector, they have the 25 same height and width, and thus fixed, constant cross-section. In the solar air system comprising at least on air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3, the air inlet duct 44, fan system consisting of the radial fan(s) 33 and resonator 26, air sucked from the mixing section 10 has a rectilinear 30 rate in the inlet duct 44 from about 6 m/s to about 12 m/s. The air outlet from the radial fan 33, representing the inlet duct 44, is tightly connected with the hole of the air duct A-1, B-1, C-1 and directs the air flow at an angle from about 30° to about 60°, in a preferred embodiment of the invention

from about 40° to about 50° , especially at an angle of 45° to the plane of the resonator 26. In a practical embodiment of the invention, the resonator is represented by a rectangular plate of spring material rigidly fixed in the inlet duct 44.

5 In another practical embodiment of the invention, the resonator is represented by a rectangular plate of spring material rigidly fixed on the baffle 22. The dimension of the longest resonator side is less than twice the height of the resonator 26 plate.

10 The height of the resonator plate is less than the height of the air duct A-1, B-1, C-1 in order to provide space between the resonator plate and the absorber 21 and 11 cover of the air ducts and between the resonator plate and the bottom of the air duct 27. The space between the resonator plate and the
15 absorber 21 and 11 cover and the space between the resonator plate and the bottom of the air duct 27 provides for the absence of physical contact of the resonator with the top and bottom cover of the air duct. The resonator is located in the air duct A-1, B-1, C-1 at a distance equal to $1/3$ of the width
20 of the air duct A-1, B-1, C-1. The stream of air leaving the fan 33 at an angle 45° to the resonator plane incidents on the resonator plane at a distance not more than $1/2$ of the length of the resonator 6. The ratio of the cross-section of the inlet duct 44 to the cross-section of the air duct is about 1:3.
25 However, in another embodiment of the invention, the ratio of the cross-section of the inlet duct 44 to the cross-section of the air duct is about 1:3. In yet another embodiment, the ratio of the cross-section of the inlet duct 44 to the cross-section of the air duct is about 1:4.

30 The stream of air hitting the resonator 26 puts the generator into mechanical vibrations transferring additional kinematic energy to air particles.

As shown in fig. 6 and fig. 7, the air duct A-1, B1, C1 has a cross-section in the shape of a rectangle, the side walls

of which represent baffles 22 of aluminium sheet. The side walls of the air duct are formed of two baffles 22 with a thermal insulation layer 20 provided between them, made of 2 mm thick ceramic paper. To seal the air duct and dampen the vibrations generated by air turbulence generated in the vortex generator, the space created between the baffles 22 forming the air duct side, in their top and bottom part in contact with absorber cover 11, 21 adequately and the bottom of the air duct 27, a layer of glue 39 is applied, such as silicone glue. The top and bottom wall of the air duct are connected to each other using pins 38 with spherical ends, the stem of which, penetrating the thermal insulation layer through a layer of the silicone glue 39 applied in the space between the baffles 22 of the air duct, has a corrugated surface that allows for removing the pin from the place of installation. The pins are positioned along the line of the baffle 22 of the air duct, at a distance that guarantees obtaining a full seal of the air duct.

The air ducts A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 coated, at least partially, with a uniform covering surface of the absorber 21 absorbing the solar radiation, represent a heat exchanger separated with a layer of thermal insulation 20 from the casing F and with a layer of thermal insulation 27 and a layer of thermal insulation 30 of phenolic foam from the bottom, however, from the top the air ducts are insulated from the ambience using a layer of steady air closed with a solar glass.

The air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 covers rectilinear and curved sections in order to create meanders A1-A2, A2-A3, B1-B2, B2-B3, C1-C2, C2-C3. In one of the embodiments, the height and width of the curved section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 is larger than the width of the rectilinear section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 and the height

of the rectilinear duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 by a value that allows for inserting into the curved section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 the ends of the rectilinear section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 to a minimum depth of 100 with the applied layer sealing the connection. Sealing the air duct at the location of changing of the rectilinear section of the air duct of the rectilinear section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 into the curved section of the air duct of the rectilinear section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 can be made using high-temperature silicone. The rectilinear section of the air duct of the rectilinear section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 has a rectangular cross-section and is covered with an absorbing cover made of aluminium sheet covered by a solar radiation absorbing layer, bent to the sides of a length of such a bend that allows for making tabs spaced at a distance from each other not less than 50 mm. The walls of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 along the rectilinear sections are made of aluminium sheet of a thickness of 0.5 mm bent into the shape of the letter "U" and form the baffles and the bottom of the duct 23. The baffle 22 is fitted with recesses 42, the width of which are twice the width of the tab 41. In some embodiments, the recess has the form of a cut out. The distance of the recess 42 in the baffle 22 of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 from its top edge provides an accurate match for the connection between the absorber 21 cover and the baffle 22 by means of a tab 41 entering the recess 42. Such a connection provides adherence of the top edge of the baffle 22 to the bottom part of the absorber 21 cover with simultaneous provision of mobility of the absorber 21 cover in relation to the baffle 22. Thus, the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3, along

the rectilinear section, represents a rigid structure with a moving cover which passes, regardless of the number of meanders, into the flexible sections bent at the curve, wherein the place of connection is sealed. Such an implementation of the air duct allows for full compensation of the rectilinear extension of the air duct, caused by high temperature, especially a temperature of stagnation.

The radius of the curve 16, along which the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 bends, is equal for the outermost of the co-linear air ducts A-1, B1 three-times the width of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3 along a rectilinear section. The internal radius of the air ducts B-1, B-2, C-1, C-2 is reduced accordingly. At the end of the curved section of the air duct A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3, at the curve 16 from the internal side, the layer of the air flow stream adhering to the curve wall hits another resonator 26 at the inlet to the next rectilinear section of the air duct A-2, A-3, B-2, B-3, C-2, C-3. Such resonator has a form of a plate fixed rigidly or by means allowing for control of the angle, which partially covers the cross-section of the duct A-2, A-3, B-2, B-3, C-2, C-3. In one embodiment, the resonator 26, installed at the inlet to another rectilinear section of the air duct A-2, A-3, B-2, B-3, C-2, C-3, is positioned at an angle of 45 degrees in relation to the direction of air flow. In other embodiments, the resonator 26 is positioned at an angle of 30, 40, 50 and 60 degrees in relation to the direction of air flow. The change of the resonator 26 angle affects air flow resistance, affecting the volume of air flowing through the collector air duct, and thus changing the rate of temperature increase and heat transfer efficiency. Each time, the air, after leaving the curved section of the air duct A-1, A-2, B-1, B-2, C-1, C-2 at the curve 16, hits another resonator 26, at the trailing edge 32 of which, a flux of air is picked off and other vortices

generated. After passing the last rectilinear section of the air duct A-3, B-3, C-3, the air moves towards the outlet 1. In one embodiment, upstream the inlet 1 positioned perpendicularly to the air flow in the air duct, the gates of the valves 13, 14, 15 are positioned in the bottom of the air duct A-3, B-3, C-3. The gate of the valve 13, 14, 15, when being opened, closes the air flow to the outlet 1, and the pressure generated with the operation of the fans in the assembly of vortex generators A, B, C sucks heated air back into the bypass 25 through the valve 7 to the air distribution chamber.

When only one valve 13, 14, 15 is open, heated air from this duct heats the air in the mixing section that enters the heat transfer section.

With a fixed increase of temperature, proper for temporary insolation intensity, the temperature of air leaving the collector from the two air ducts operating with closed valves 14 and 15 will be increased by $1/3$.

The solar system for heating the air, as described above, was tested in order to assess its efficiency. Tests were performed for five months at ambient temperatures from $+2^{\circ}\text{C}$ to $+27^{\circ}\text{C}$, with two rates of air flow, i.e. $110\text{ m}^3/\text{h}$ and $80\text{ m}^3/\text{h}$. A panel of the following parameters was used during the tests: width -0.97 m , height -1.67 m , thickness -0.1 m , wherein the collector surface exposed to solar radiation was 1.49 m^2 . In the tested solar system, an aluminium plate covered with a proper coating that provided the absorber plate with a high coefficient of absorption of solar radiation (absorption coefficient = 0.97) was used as an absorber to heat the air. The top layer placed in the fixing profile was provided by a glass coating of a thickness of 3.2 mm . The insulation material, used in the tests of the solar system to heat the air, was phenolic foam, wherein the thickness of the insulation layer was 20 to 50 mm , and thermal conductivity λ was 0.02

W/m/K. The tested solar system was equipped with a vortex generator, as presented in fig. 4 or fig. 5, and with the system controlling the angle of inclination, which allowed for changing the position of the solar panel within the range from 0 to 90 degrees in relation to the surface, on which the solar system according to the invention was fixed. The total area of the panel was 1.7 m^2 , and the area exposed to solar radiation A_A was 1.53 m^2 .

During the tests, the air was sucked in by means of an assembly of radial fans. The rate of flow was set within $50 \text{ m}^3/\text{h}$ to $120 \text{ m}^3/\text{h}$. The air temperature at the inlet and outlet was measured using resistive temperature sensors type PT1000. A multichannel data recorder was used to record and gather test results within one-minute time interval. Meteorological parameters were monitored using an automatic meteorological station integrated with a wireless recorder. The following parameters were measured and recorded within a one-minute interval: air temperature, speed and direction of wind, air humidity and intensity of solar radiation. The tested panel was positioned at a fixed angle of 32 degrees in a southern exposure. During the tests, the following parameters were measured: temperature of air at the inlet and outlet of the solar system, stream of air flow volume, intensity of solar radiation, temperature and humidity of internal air and speed and direction of the wind. The data was recorded within one-minute intervals. Thermographic photos of the external surface of the device were also taken. During the tests, one observed significant fluctuations of both the radiation (from 0 to 1200 W/m^2) and air temperature (from 2 to 27°C), wherein wind speed was mostly stable.

Based on the obtained results, it was possible to determine the thermal efficiency of solar radiation conversion to heat and an increase in air temperature after heating in the solar system according to the invention. As shown in fig.

8, the temperature increase ΔT_{SAH} achieved in the solar air system according to the invention, in the function of solar light flux intensity I determined for the solar system according to the invention, at an air flow rate 110 m³/h (panel 5 a)) and 80 m³/h (panel b)), is basically linear. With a lower air flow rate (panel b)), the maximum increase of temperature exceeds 40 °C. As it is well known, an increase of flow rate causes a reduction of temperature increase; however, the result obtained with a higher air speed, namely close to 30°C, is also very good.

Using a simple dependence:

$$\Delta T_{SAH} = T_{out} - T_{in}.$$

where T_{out} is the temperature of air at the outlet from the solar system, and T_{in} is the temperature of air introduced to the solar system, the coefficients of inclination were calculated, resulting in 0.0293 (panel a)) and 0.0414 (panel b)).

Then, according to the equation

$$q_{SAH} = \frac{V_a \cdot \rho_a \cdot c_a \cdot \Delta T_{SAH}}{A_A},$$

20 where V_a is the air flow rate m³/s, ρ_a is the air density kg/m³, and c_a is the heat capacity of air J*K/kg, the power of the solar system was calculated q_{SAH} .

Based on the equation below, the following was calculated:

$$\eta_A = \frac{V_a \cdot \rho_a \cdot c_a \cdot \Delta T_{SAH}}{I \cdot A_A}$$

25 thermal efficiency of the solar system according to the invention η_A defined as the useful energy produced via conversion of solar radiation into thermal energy in relation to the total radiation absorber is exposed to. The obtained results are presented in fig. 9. An analysis of the obtained dependencies leads to the conclusion that the efficiency of the tested solar system is within the range of 50% to 70%. The energy efficiency of the tested system increases together with the intensity of solar radiation. This dependence is similar

to both tested intensities of air flow. The efficiency of solar energy conversion of the solar system is much higher than the efficiency presented in the prior art for the best available solutions on the market.

5 This invention was described in detail in relation to specific embodiments of its practical implementation. Persons having ordinary skill in the art will notice that various modifications of the presented embodiments are possible without deviating from the general concept of the invention
10 and the scope of protection defined by the enclosed claims. An embodiment other than those disclosed herein will be apparent to persons having ordinary skill in the art, based on the disclosure and general knowledge.

As mentioned above, numerous publications were referenced
15 herein. It is assumed that the content of the referenced documents is included in the description in the form of references, useful not only for a complete definition of the art, but also to provide a more extensive description of the claimed solutions.

20

Number designations used in the description

- 1 air outlet
- 2 air inlet from a building
- 25 3 air inlet from the outside with filter - valve
- 4A ambient air temperature sensor
- 4 I heated air temperature sensor
- 4L light sensor
- 5 air flow stream from a building
- 30 6 air flow stream from outside
- 7 air inlet with bypass - valve
- 8 air flow stream from bypass
- 9 heated air to a building
- 10 air mixing section
- 35 11 flat absorber section
- 12 section of absorber straight ducts
- 13 bypass check valve
- 14 bypass check valve
- 15 bypass check valve
- 40 16 curve (curved guide vane in the absorber)
- A vortex generator assembly
- B vortex generator assembly
- C vortex generator assembly

X vortex generator along curves
17 collector external frame
18 collector back wall
19 collector internal frame
5 20 thermal insulation between ducts
21 air duct absorber coating
22 baffle
23 rectilinear air duct bottom
24 solar glass
10 15 bypass
26 resonator
27 ceramic thermal insulation
28 connection of the absorber air duct
29 sealing of the solar glass
15 30 main sealing of the collector
31 rectilinear air duct of the collector
32 resonator trailing edge
33 radial fan
34 connection of flat absorber with duct absorber
20 35 air sucked in from outside
36 turbulent air
37 suction duct
38 pin with spherical head
39 glue
25 40 air duct of the section with flat absorber
41 duct absorber cover tab
42 duct absorber cover tab hole
44 inlet duct

5

10

Claims

1. Solar air system comprising:

- at least one air duct for heat transfer, having a cross-sectional area of the air duct, wherein the air duct has a
15 fixed cross-section along its entire length,

- air inlet duct in fluid connection with the air duct, to supply air to it, for heat transfer purposes, having a cross-section of the inlet duct, and

- fan system in fluid connection with the inlet duct, to
20 supply air to it, for heat transfer purposes,

characterized in that

the fan system is configured to supply air flow stream having static pressure higher than the static pressure of the axial fan, and

25 the system additionally comprises at least one resonator (26) installed in the air duct to change air flow from laminar to turbulent,

the inlet duct is configured to supply air flow stream to the resonator (26) at an angle, to the resonator (26) surface,

30 wherein the cross-section of the inlet duct (44) is less than the cross-section of the air duct of the air system.

2. Solar air system according to claim 1, characterized in that the inlet duct (44) is configured to supply an air flow stream to the resonator (26) at an angle of about 30° to

about 60°, more preferably about 40° to about 50°, most preferably about 45°.

3. Solar air system according to any of the claims 1 - 2, characterized in that the fan system comprises a radial fan (33).

4. Solar air system according to any of the claims 1 - 3, characterized in that the fan system is integrated with the inlet duct.

5. Solar air system according to any of the claims 1 - 4, characterized in that the ratio of the cross-section of the inlet duct (44) to the cross-section of the air duct is from about 1:2 to about 1:5, preferably about 1:4.

6. Solar air system according to any of the claims 1 - 5, characterized in that the air duct has at least one baffle (22), which divides the air duct into air subducts (A1, A2, A3), and wherein, the resonator (26) is installed on the baffle (22) at an angle α .

7. Solar air system according to claim 6, characterized in that the air duct has two baffles (22), which divide the air duct into three air subducts (A1, A2 A3), and each of the baffles (22) has a separate resonator (26).

8. Solar air system according to claim 7, characterized in that the resonators (26) are oriented at an angle in relation to the baffle (22), wherein they are positioned at angle from about 60° to about 120°, more preferably at an angle of 90°, in relation to each other.

9. Solar air system according to any of the claims 1 - 5, characterized in that the air duct has at least one baffle (22), which divides the air duct into air subducts (A1, A2, A3), and wherein the resonator is installed on the inlet duct at an angle α .

10. Solar air system according to claim 9, characterized in that the air duct has two baffles (22), which divide the

air duct into three air subducts (A1, A2 A3), and each of the baffles (22) has a separate resonator.

11. Solar air system according to claim 10, characterized in that the resonators are oriented in parallel
5 to the baffle (22).

12. Solar air system according to any of the claims 1 - 9, characterized in that the fan system includes at least one suction duct (37) to introduce additional volumes of air into the system.

10 13. Solar air system according to any of the claims 1 - 12, characterized in that the resonator is fitted with means of angle adjustment in relation to the air stream.

14. Solar air system according to any of the claims 1 - 13 characterized in that comprises at least one meander A1-A2,
15 A2-A3, B1-B2, B2-B3, C1-C2, C2-C3.

15. Solar air system according to claim 14, characterized in that the meander comprises additional resonator (26), as mentioned in any of the preceding claims, positioned at the beginning of the rectilinear meander section.

20 16. Method of thermal transfer in the system, characterized in that the solar air system according to any of the preceding claims 1 - 15 is used.

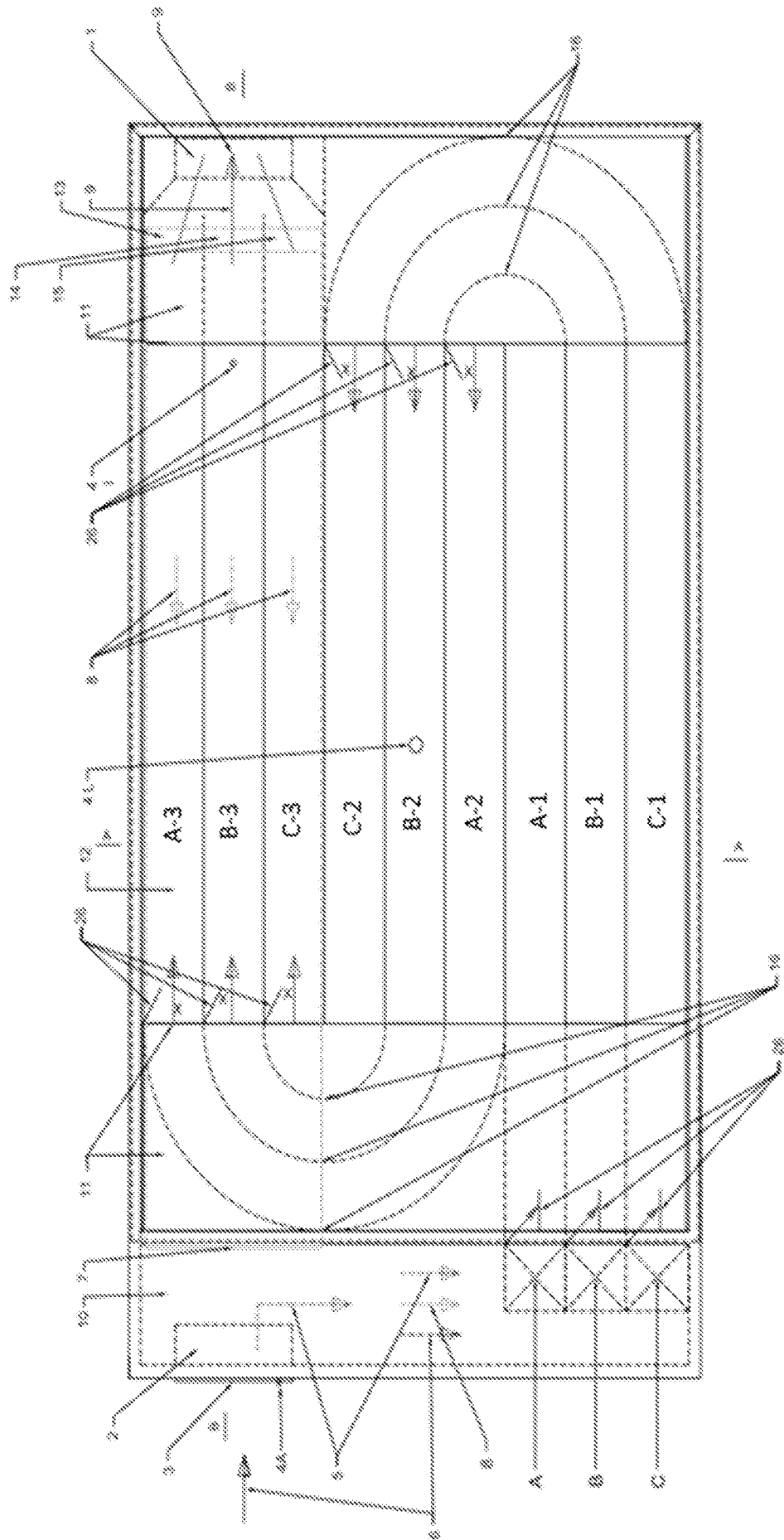


Fig. 1a

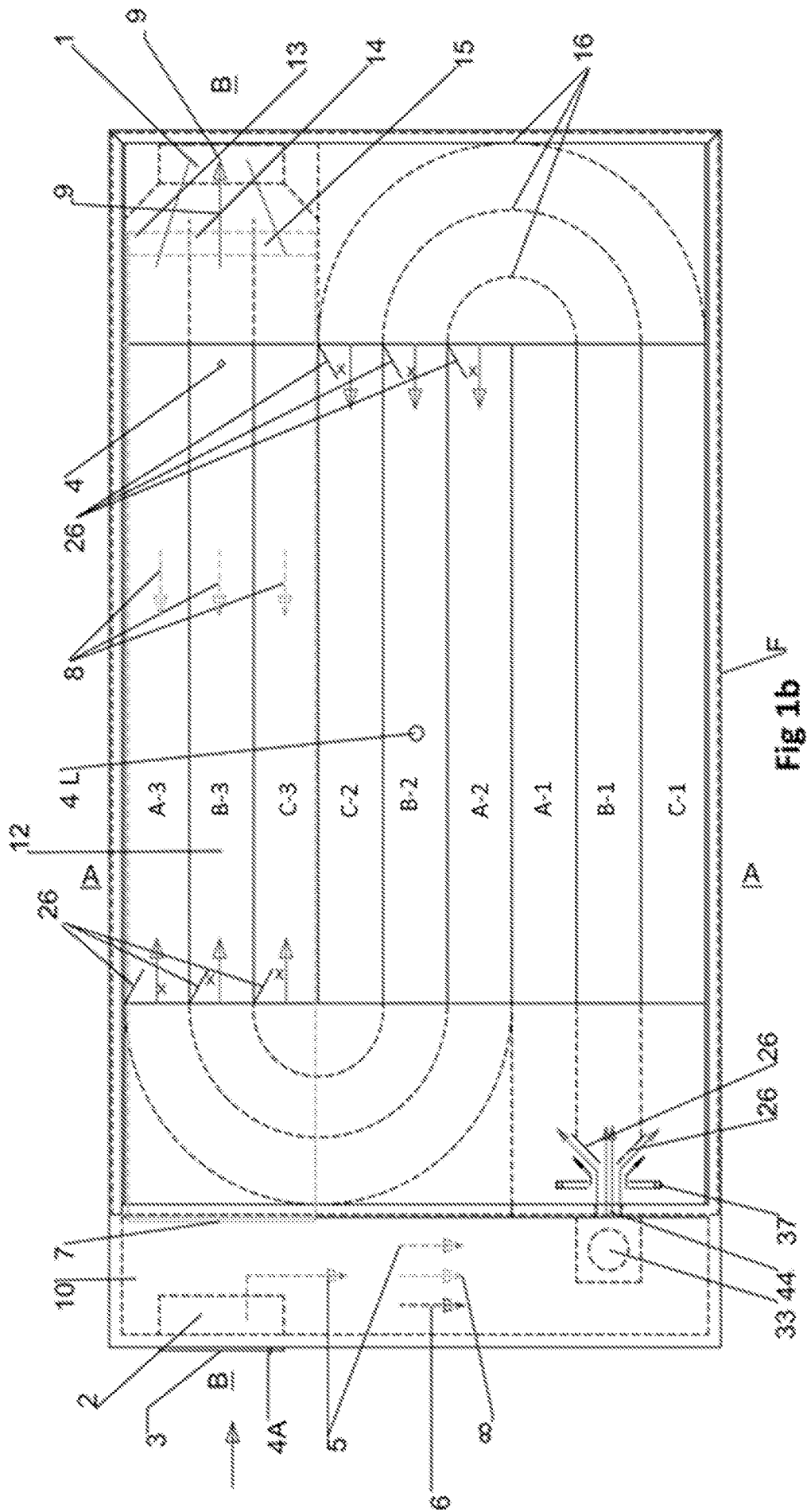
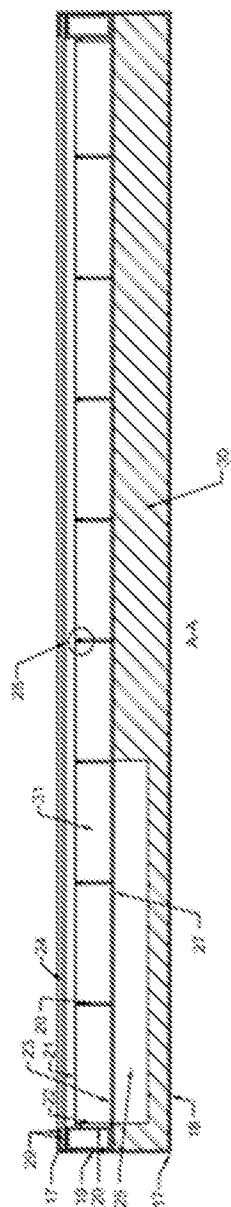
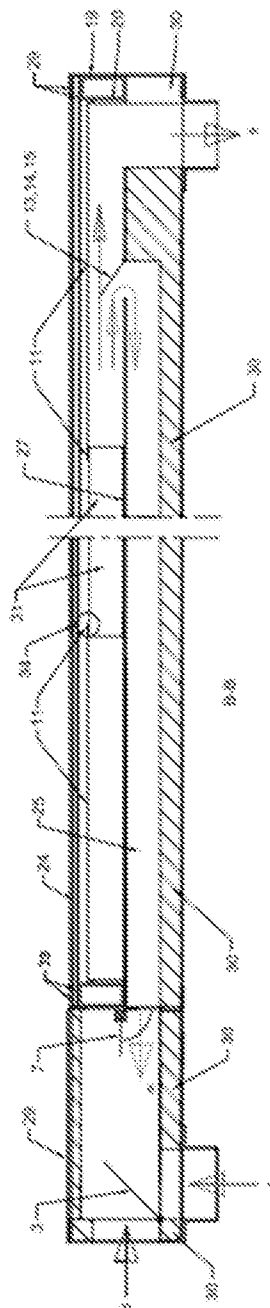


Fig 1b



29



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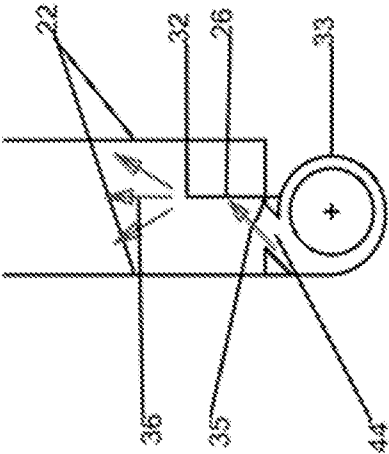
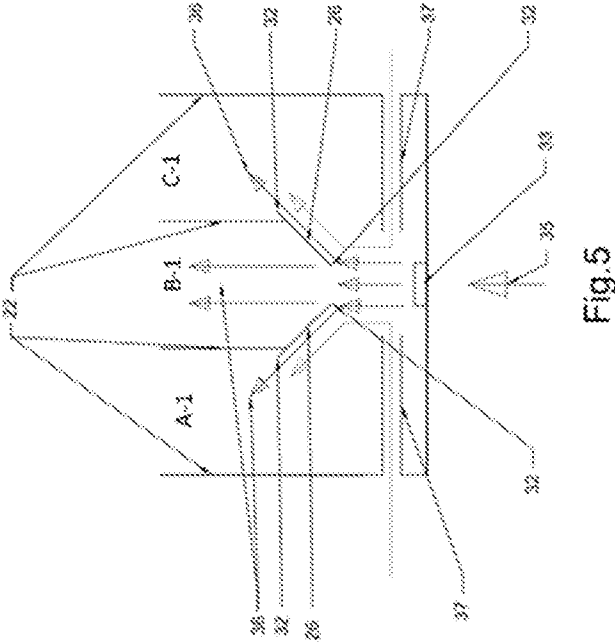


Fig. 4

Fig. 5

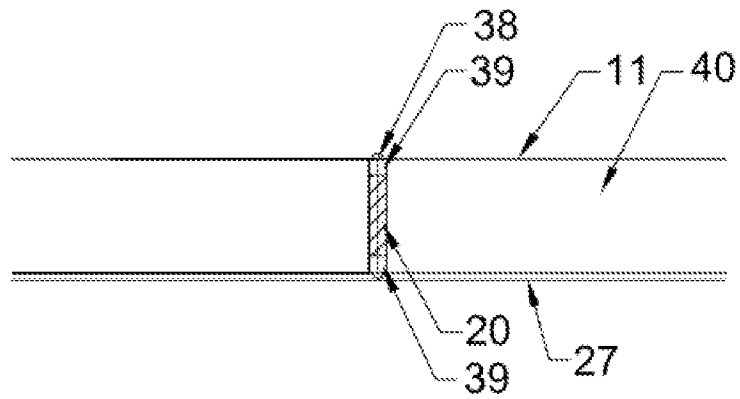


Fig.6

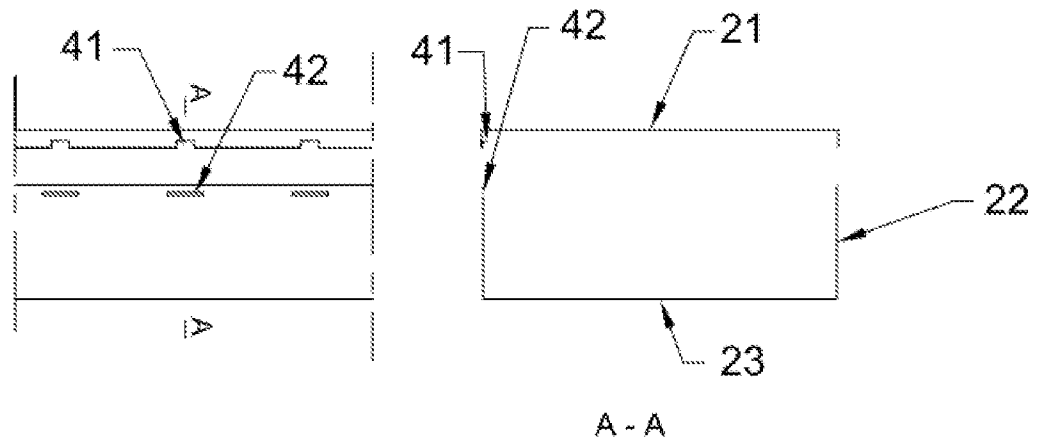


Fig.7

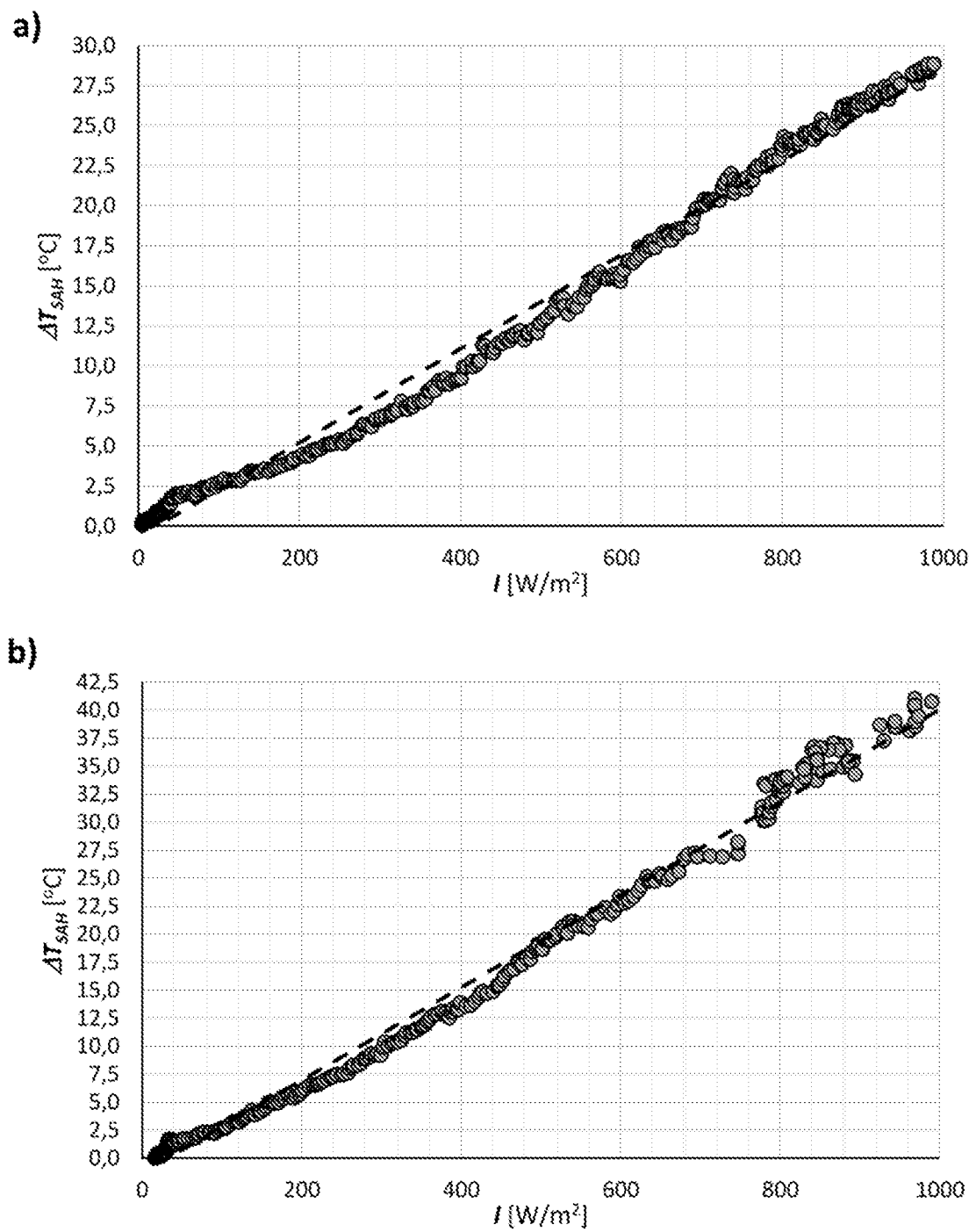


Fig. 8

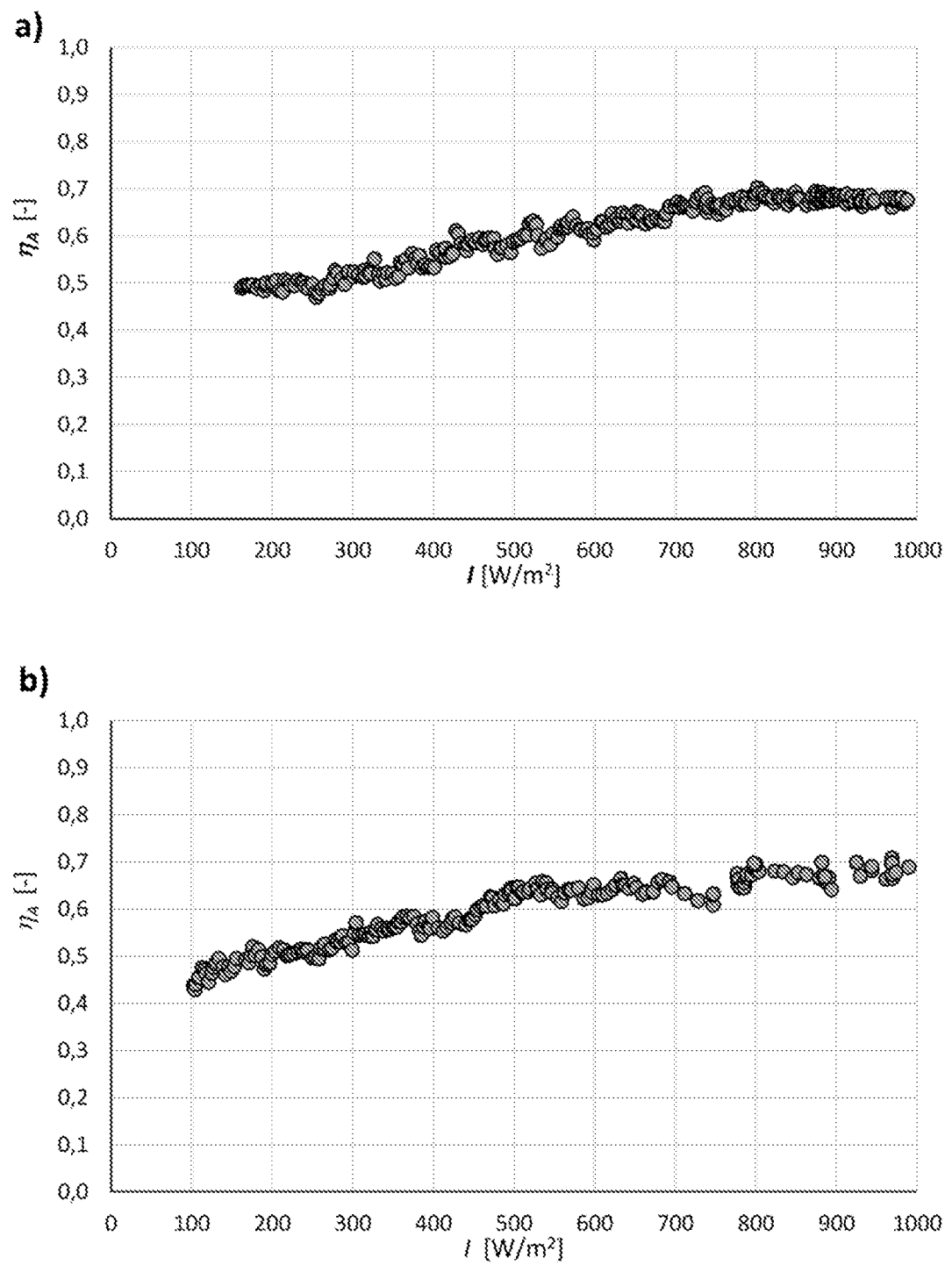


Fig. 9