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Puriri

(54) FREE-CONVECTION, PASSIVE, SOLAR-COLLECTION, CONTROL APPARATUS AND METHOD

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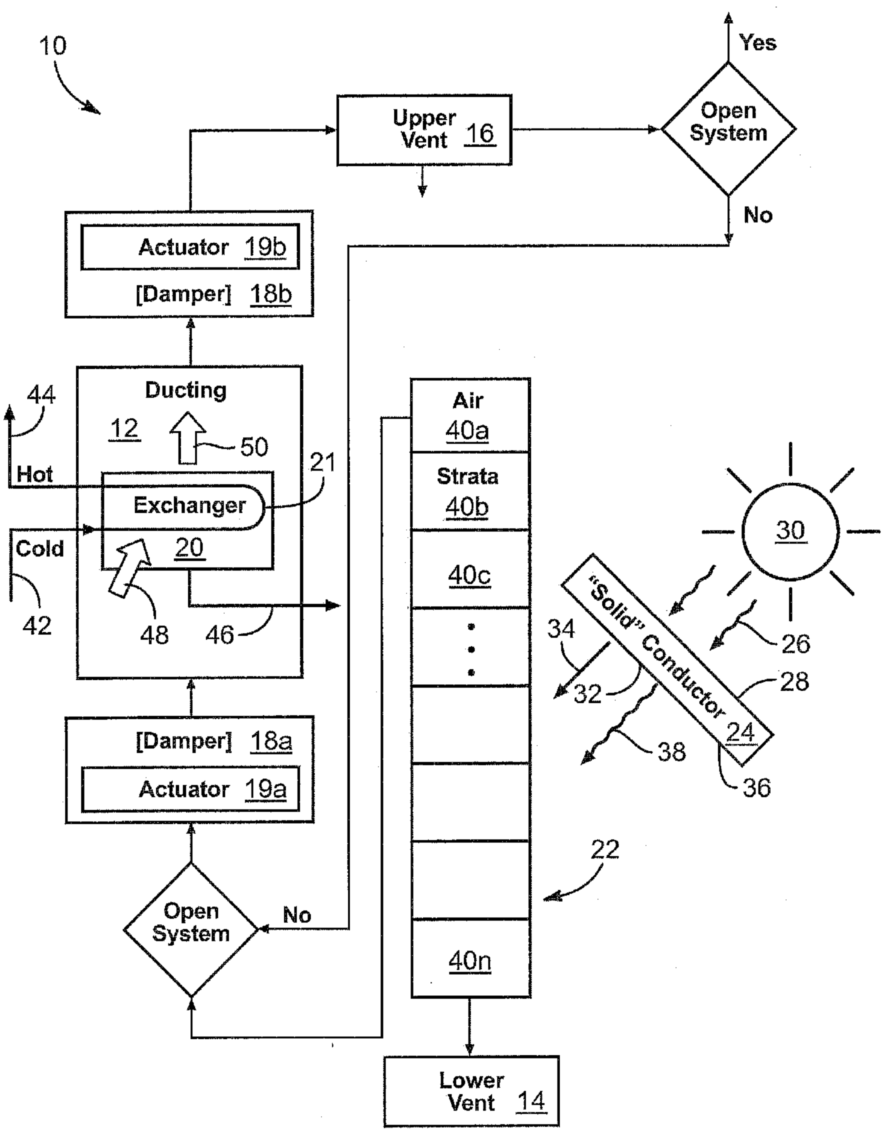
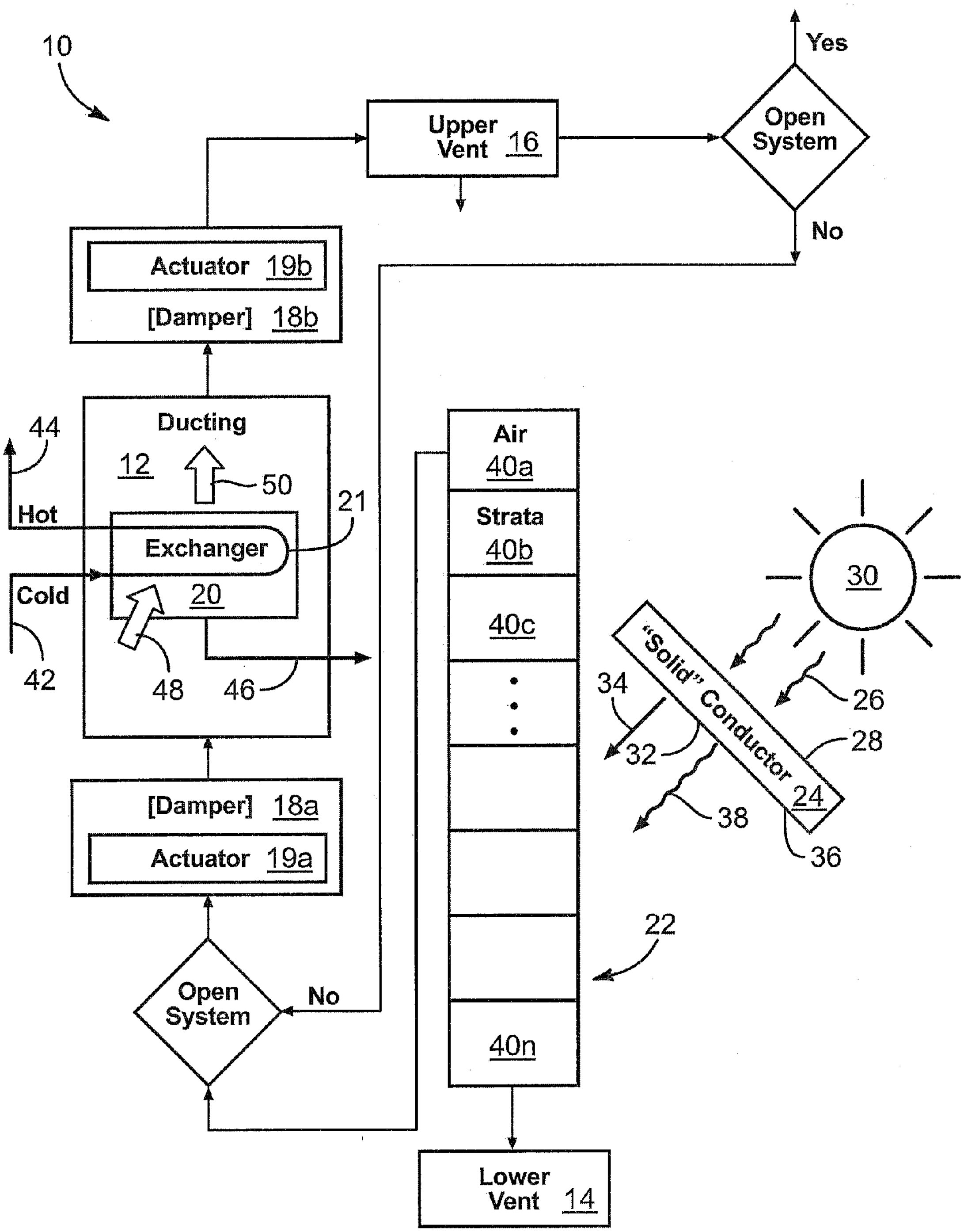
(57) **ABSTRACT**

A structure and method of solar energy collection use a building roof acting as a heat collector, conductor, and convector passing thermal energy to air in a volume below. The air may stratify according to temperature, with flow controls maximizing temperatures by operating dampers, valves, or both in the air and a liquid working fluid, respectively. A finned heat exchanger may be a hydronic baseboard-type heating unit operating to transfer heat in the opposite direction, into water inside the central pipe. A thermo-mechanical actuator, such as a wax motor may provide passive control, and heat may be collected in an open circuit of culinary water, a closed loop, or a double loop system. Ducting aids stratification, temperature maximization, and heat exchange to enforce pre-selected temperatures in the air and water working fluids.





10
Upper Vent 16
Open System
Yes
No
Actuator 19b
[Damper] 18b
Ducting
12
50
21
44
Hot
Exchanger
Cold
20
42
48
46
Air
40a
Strata
40b
40c
30
"Solid" Conductor 24
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32
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28
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[Damper] 18a
Actuator 19a
22
Open System
No
40n
Lower Vent 14

FIG. 1

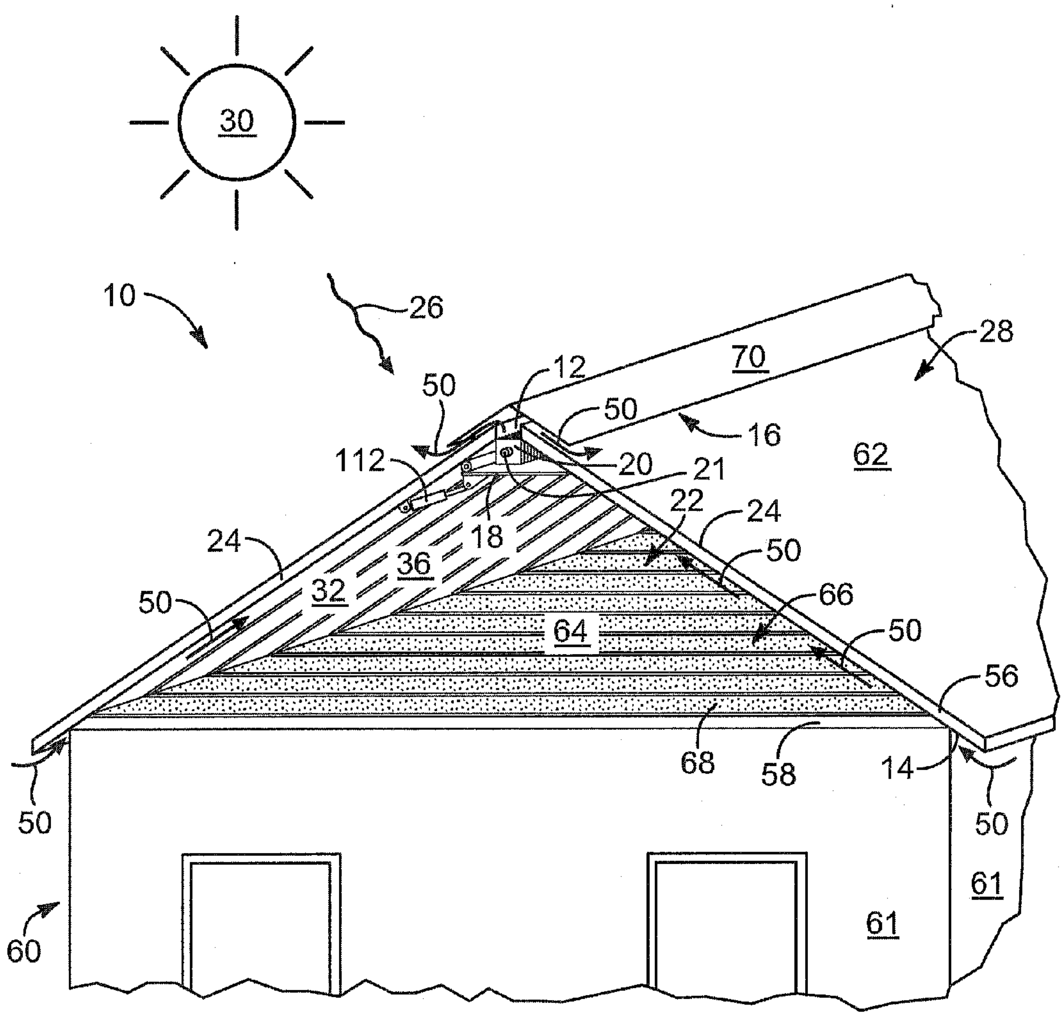
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FIG. 2

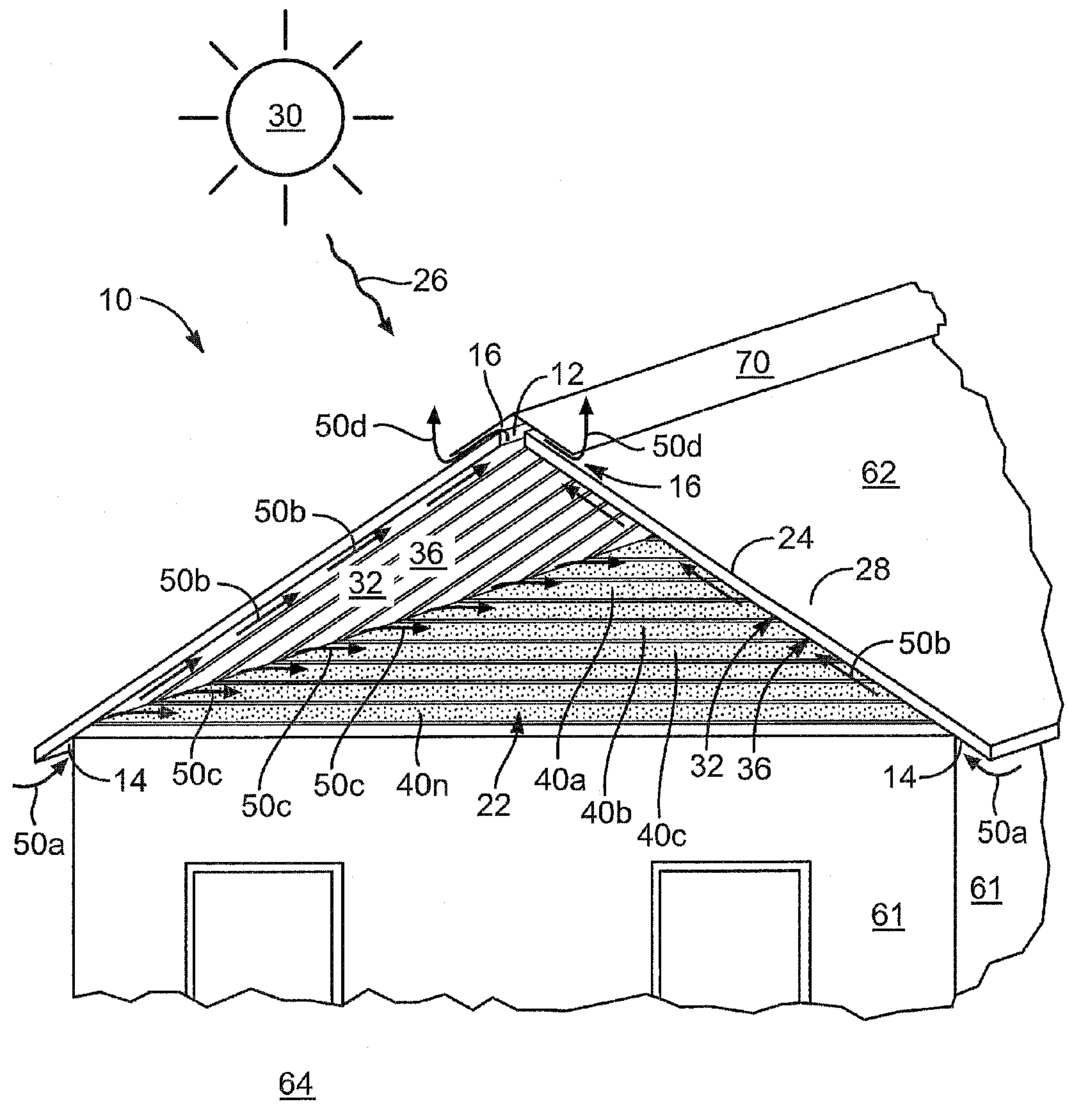
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FIG. 3

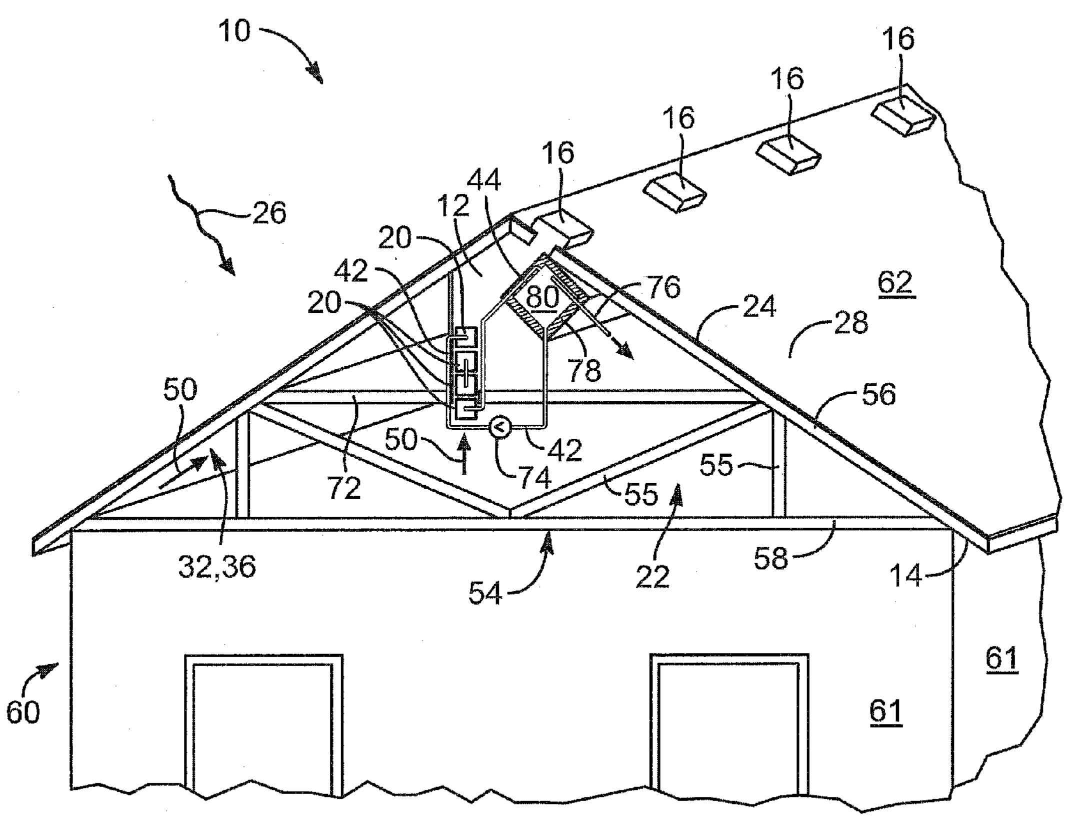
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FIG. 4

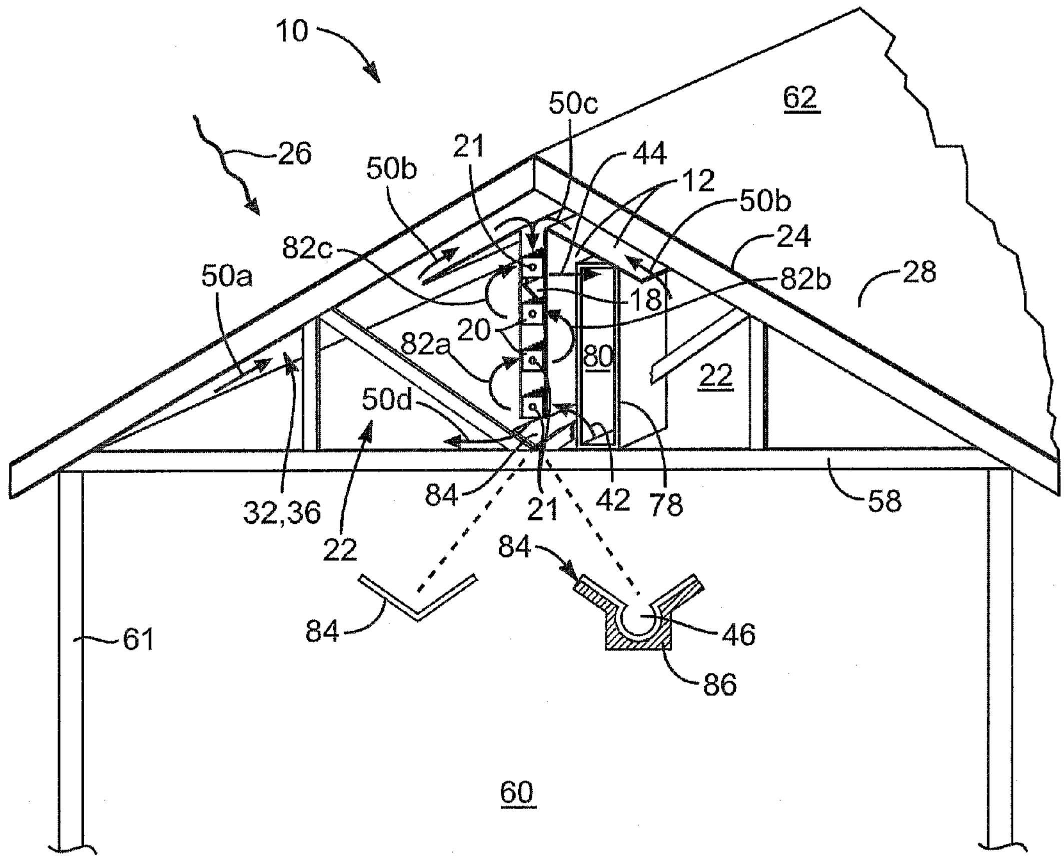
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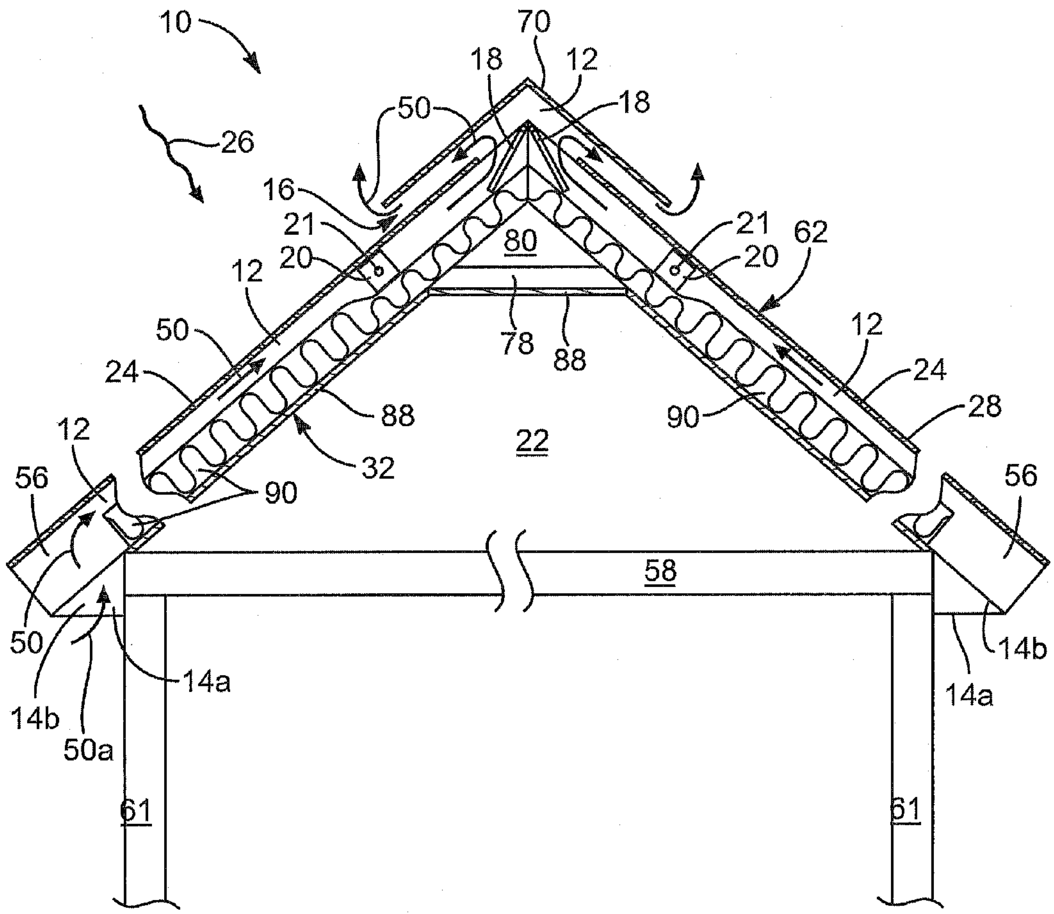
FIG. 5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50a
61
61

FIG. 6

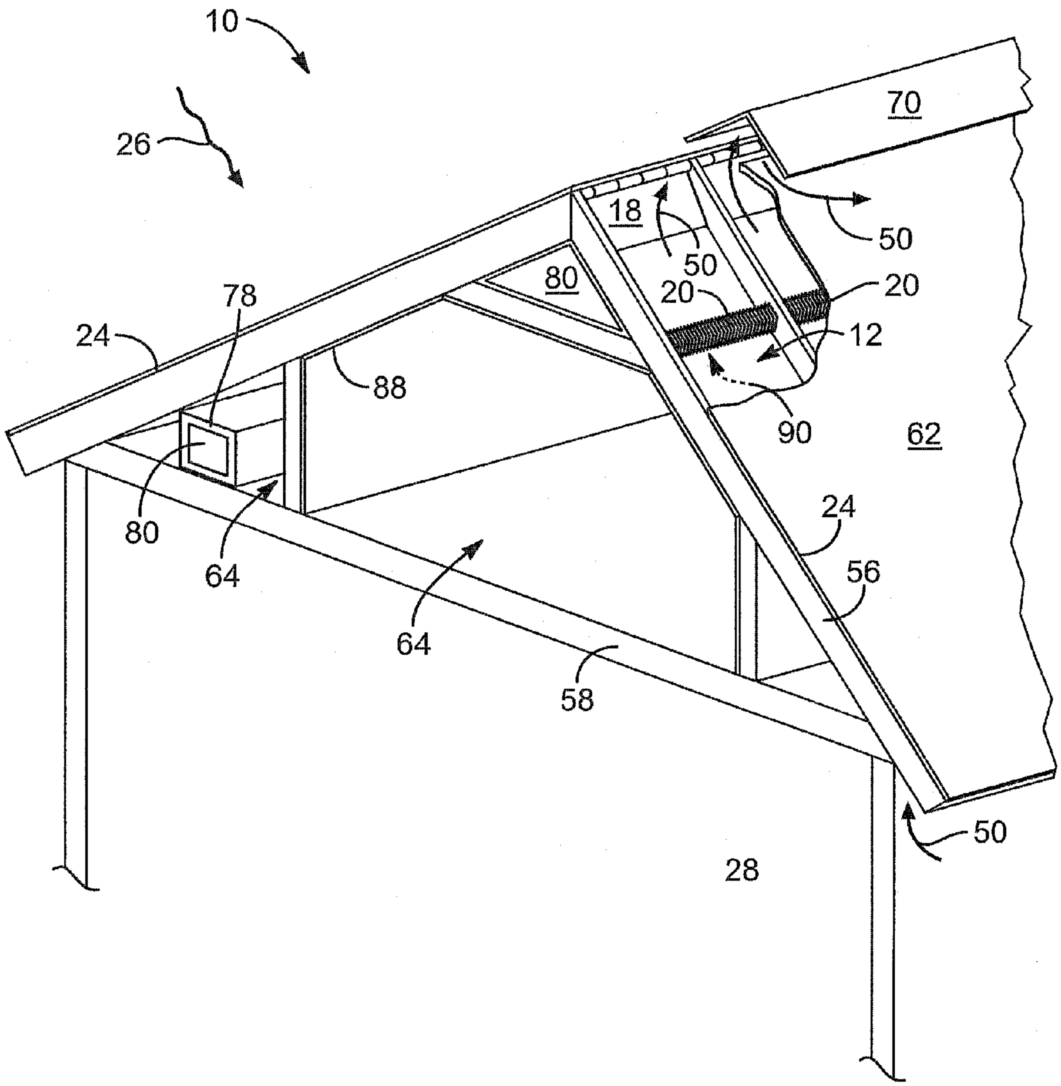

FIG. 7

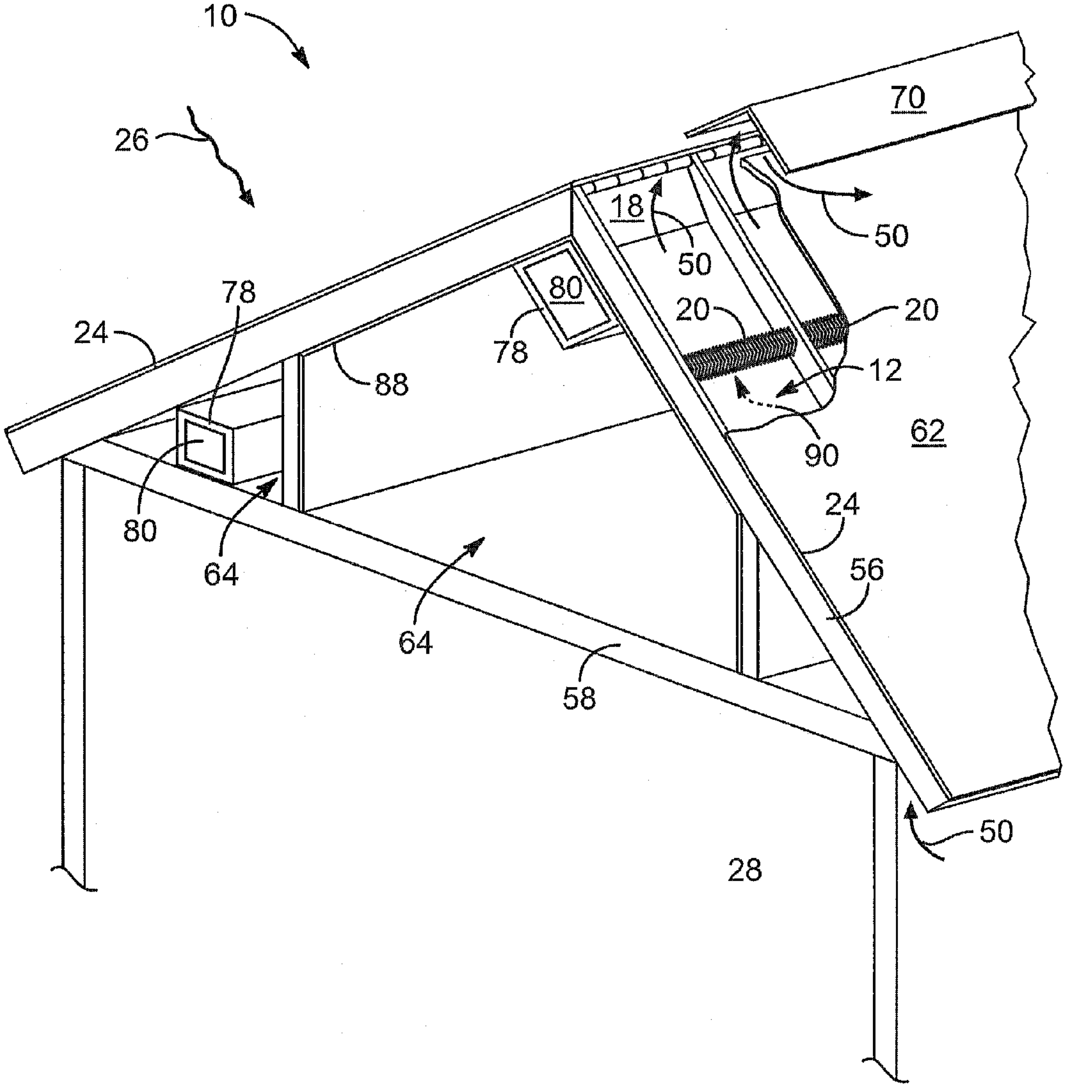

FIG. 8

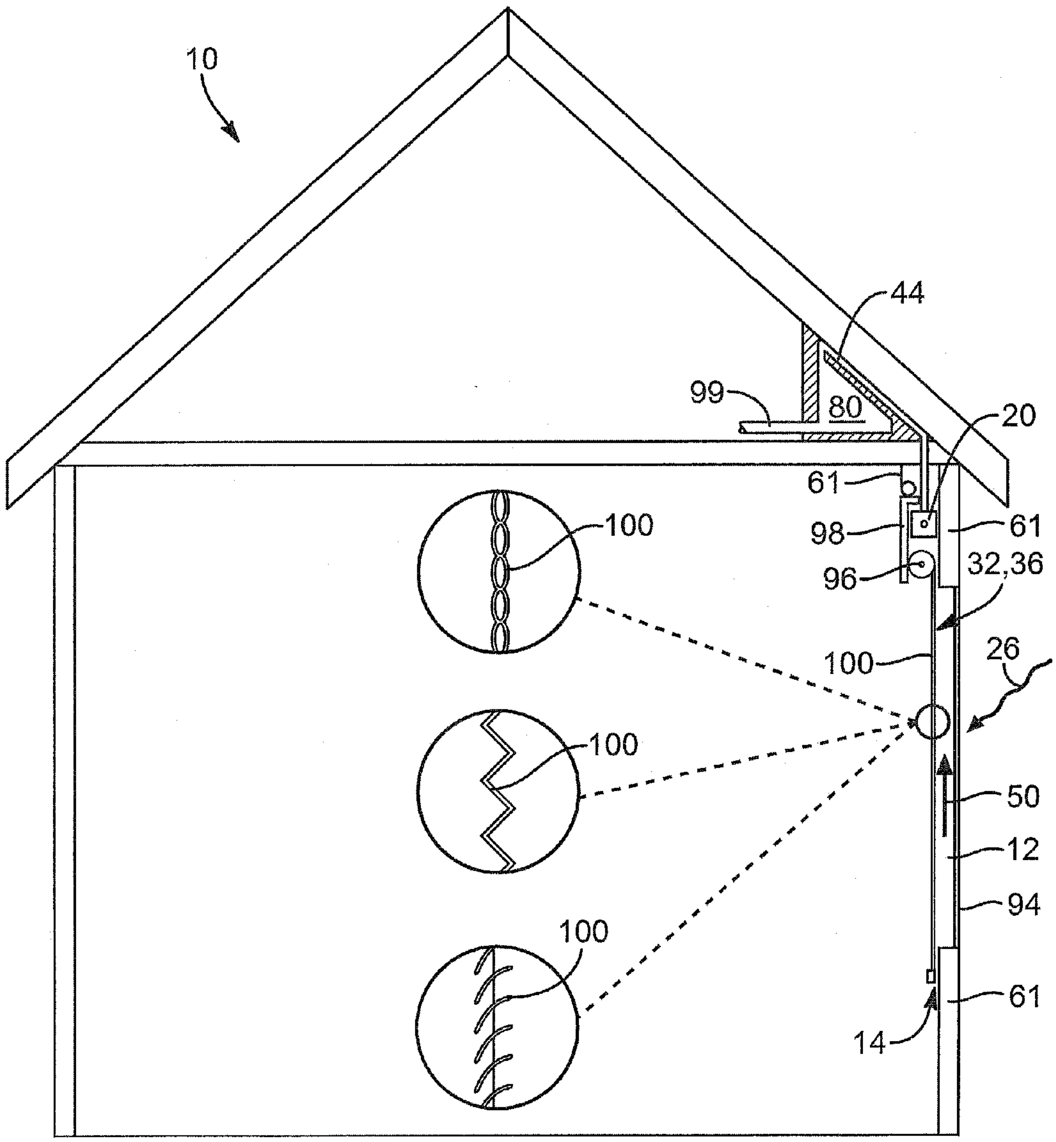

FIG. 9

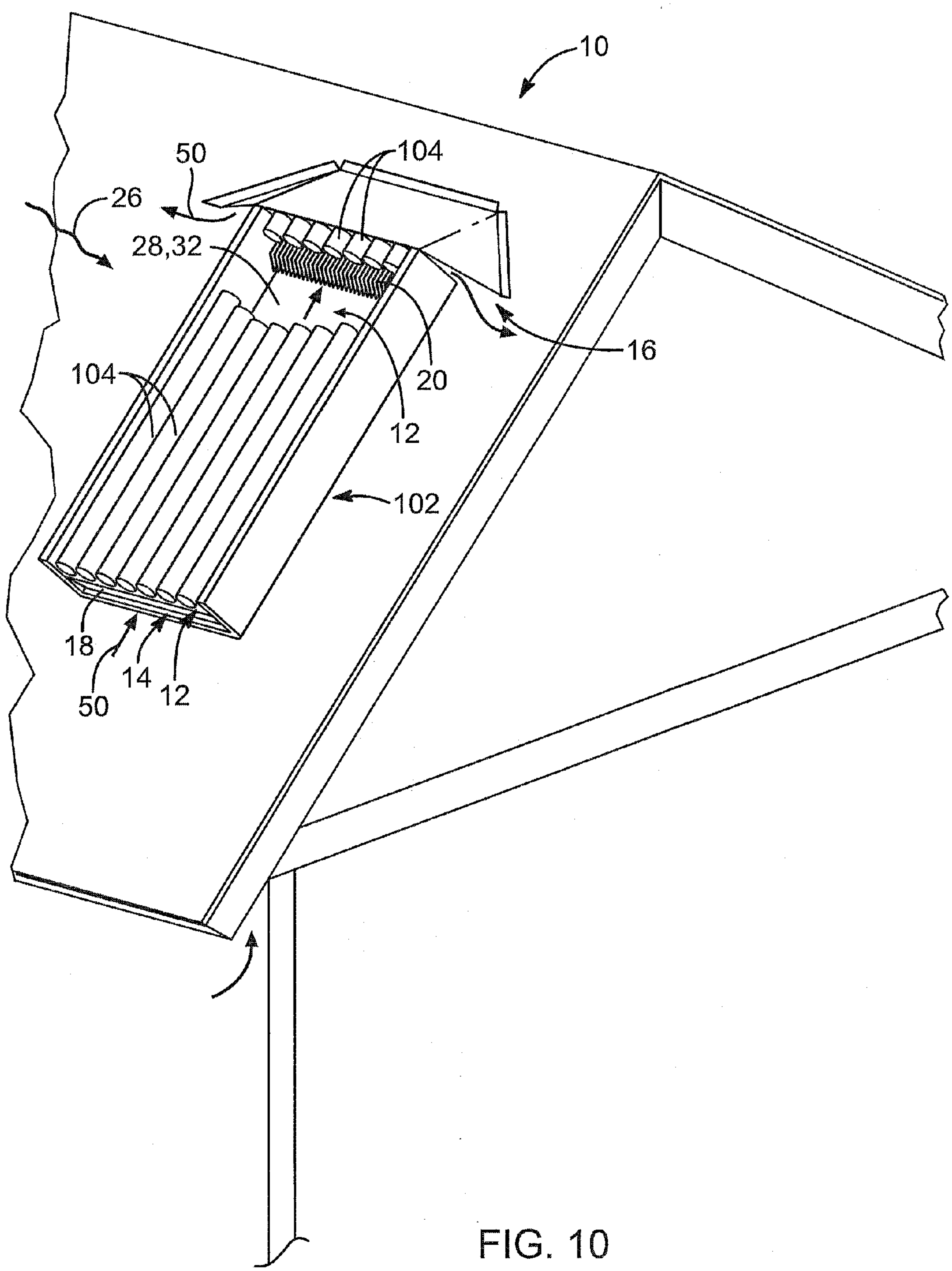

FIG. 10

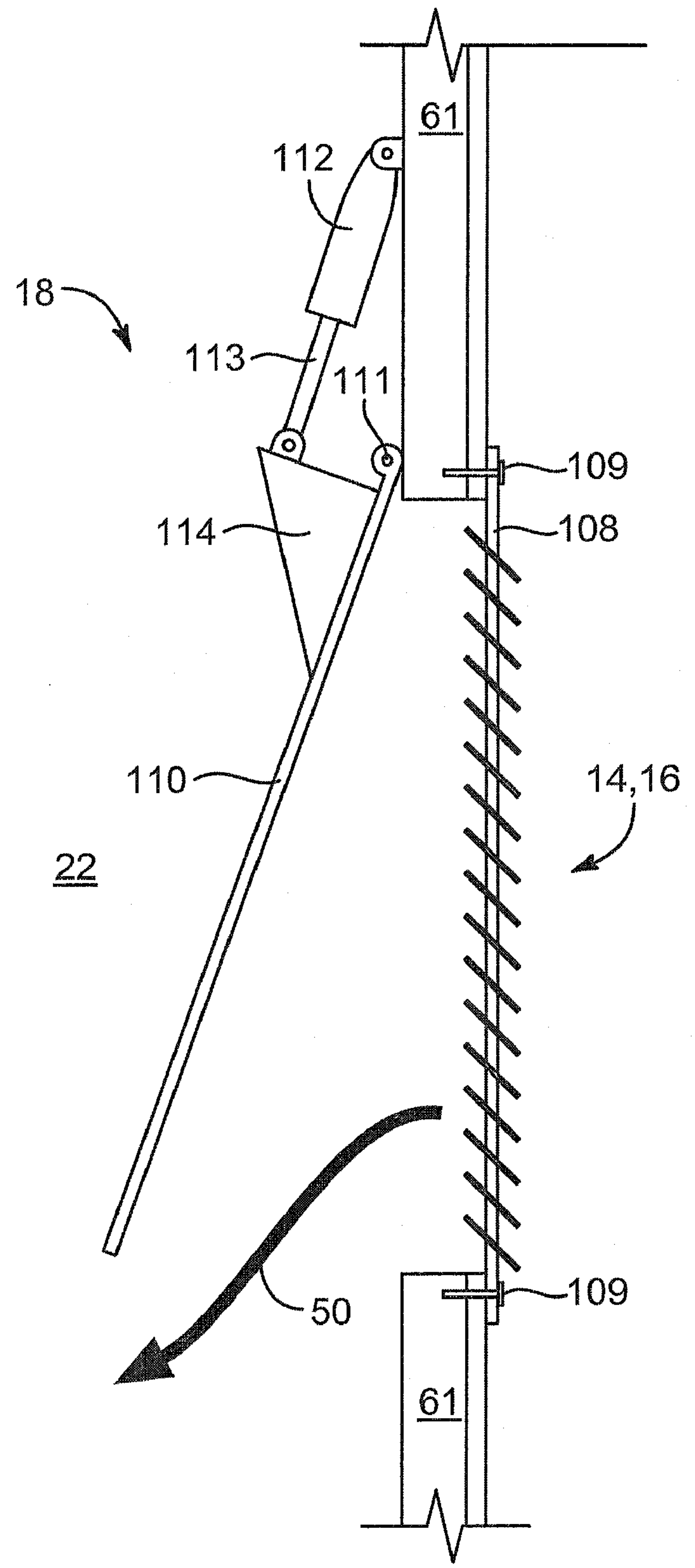

FIG. 11

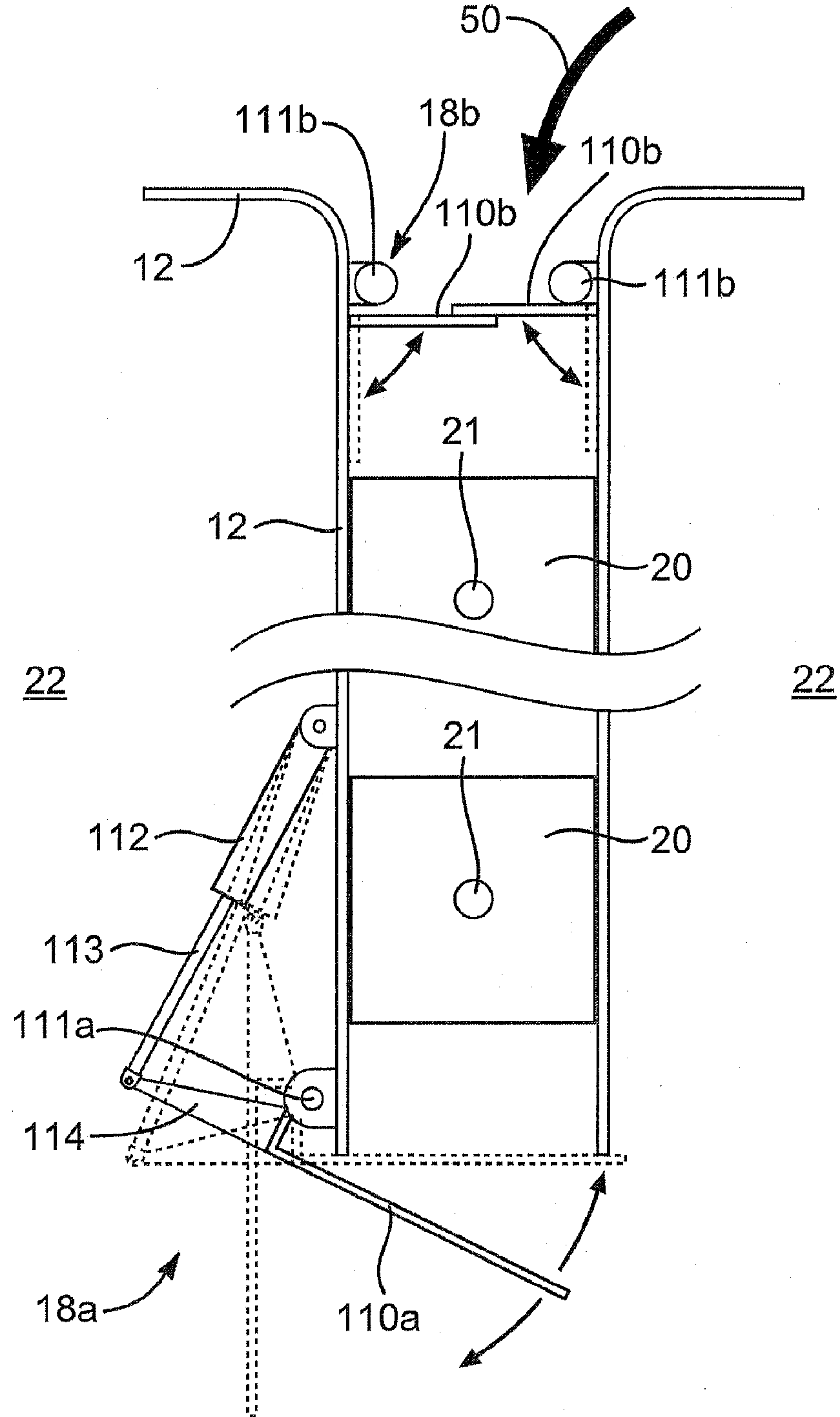
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FIG. 12

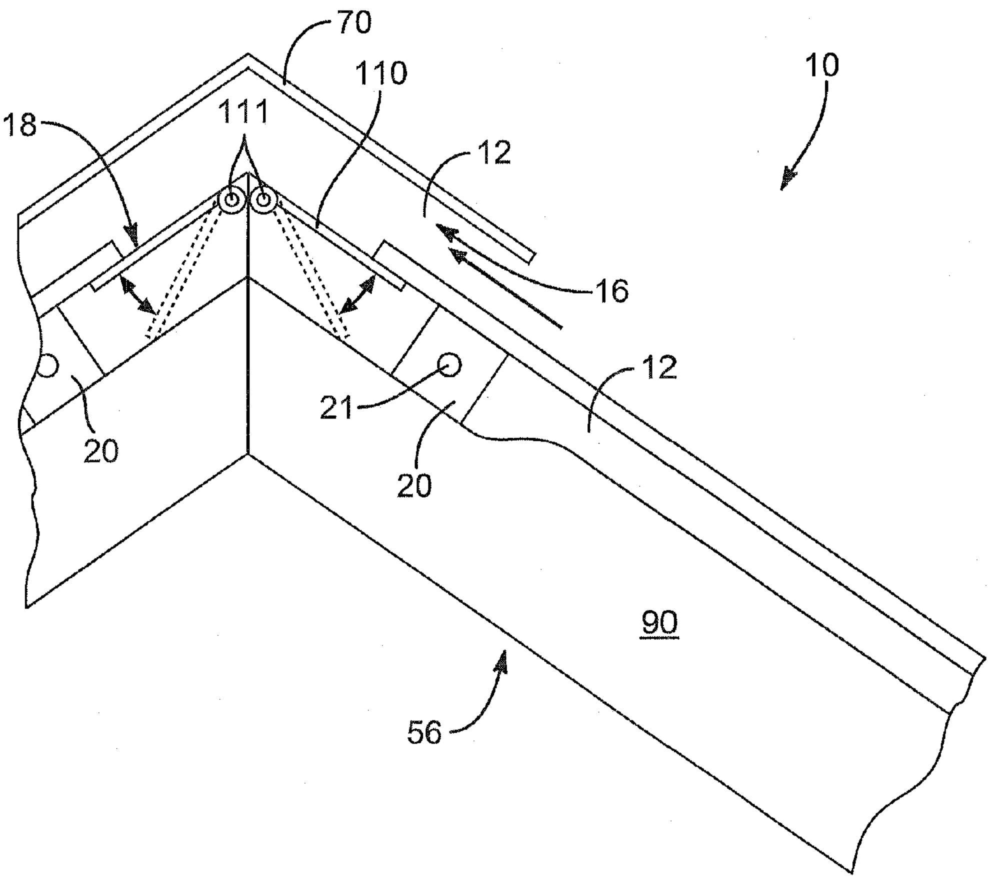

FIG. 13

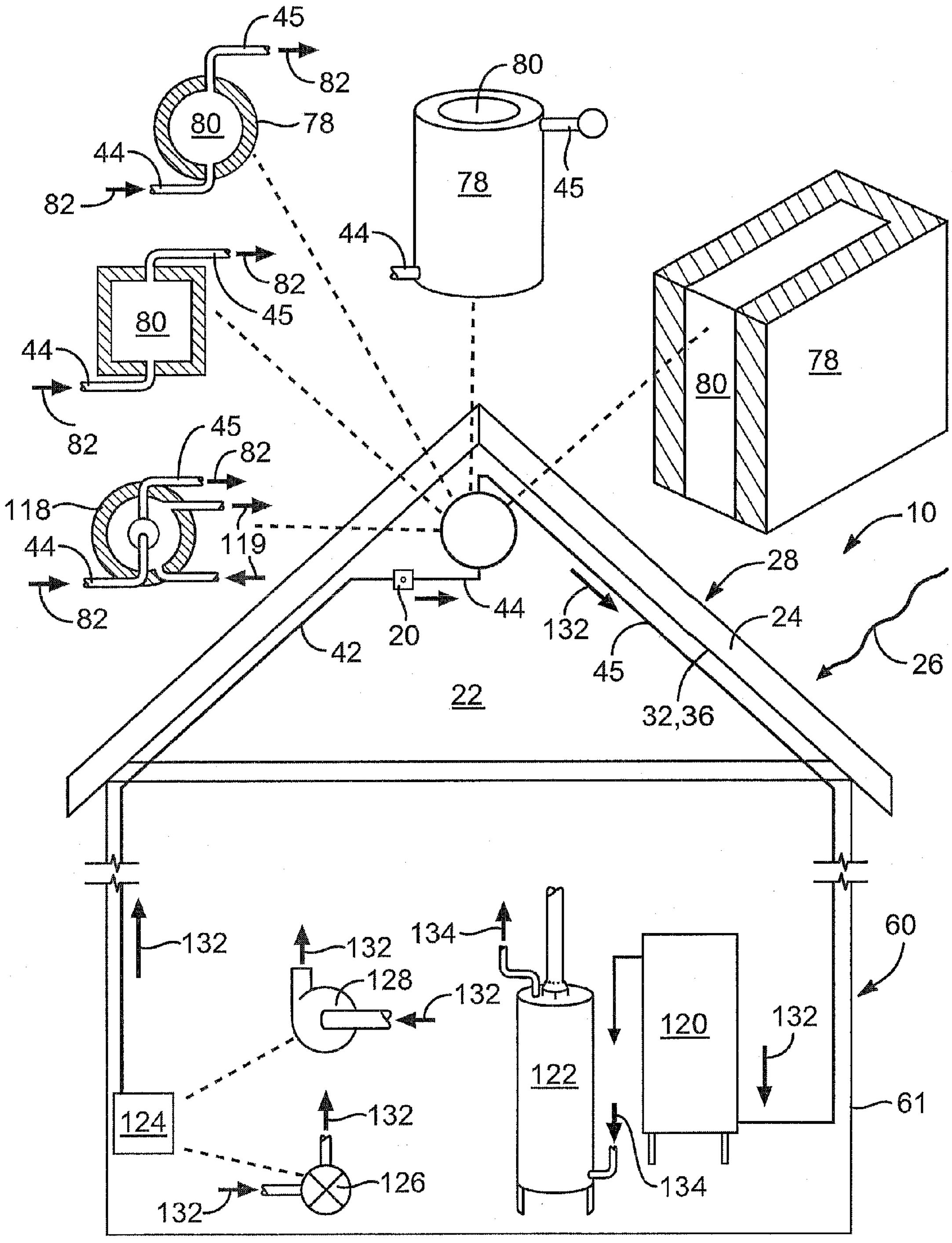
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FIG. 14

FREE-CONVECTION, PASSIVE, SOLAR-COLLECTION, CONTROL APPARATUS AND METHOD

RELATED APPLICATIONS

[0001] This application claims the benefit of co-pending U.S. Provisional Patent Application Ser. No. 61/295,062, filed on Jan. 14, 2010 for FREE-CONVECTION, PASSIVE, SOLAR-COLLECTION, CONTROL APPARATUS AND METHOD.

BACKGROUND

[0002] 1. The Field of the Invention

[0003] This invention relates to heat exchange and, more particularly, to novel systems and methods for passive solar energy collection.

[0004] 2. The Background Art

[0005] Attic and roof structures are struck by solar energy as radiation, largely as a nuisance, damaging roofs, overheating attics, and generally achieving little good. Solar collectors from the 1970s found support on rooftops, at some considerable capital expense, ongoing maintenance costs, reliability problems, unsightly structures, and hard-earned tax credit with a headache. Solar radiation occurs in greatest concentrations in places that need the least space heating. Mainly attic ventilation is about passing enough air through an attic to keep moisture evaporated, while encouraging ambient air to cool the attic to about ambient temperature through small openings and screens designed to keep out birds and insects.

[0006] What is needed is an apparatus and method to modify roof structures to improve heat transfer, protect solar heat collection devices inside the roof structure instead of on top thereof, maximize the temperature of working fluids in heat transfer, and minimize costs while improving reliability with minimum maintenance. Minimizing risk by simplifying the fluid handling systems and using well adapted, readily available hardware would be a plus.

BRIEF SUMMARY OF THE INVENTION

[0007] In view of the foregoing, in accordance with the invention as embodied and broadly described herein, a method and apparatus are disclosed in one embodiment of the present invention as including a structure and method of solar energy collection using a building. A roof acting as a heat conductor has a top surface converting solar radiation to thermal energy, which is then conducted down through to the bottom surface. The bottom surface of the roofing buildup convects thermal energy to air in a volume below.

[0008] The air may be stratified within the volume of an attic or other space according to a temperature thereof. Controlling a maximum temperature in the air by operating a damper relies on controlling a rate of a flow of air in the volume. The air flow passes through an exchanger extracting heat from the flow at substantially the maximum temperature.

[0009] The heat exchanger uses a fluid cooler than the maximum temperature of the air, and may use an open cycle of culinary water, a closed loop of any suitable fluid, or the like. The heat exchanger may comprise fins extending into the air flow, including a hydronic baseboard-type heating unit operating to transfer heat in the opposite direction, into water inside the central pipe.

[0010] A damper may operate by any suitable means, such as a thermostat, and may use a wax actuator dependent on local temperature near the heat exchanger or under the roof layer to control air flow heating water in the heat exchanger. A thermo-mechanical actuator, such as a wax motor provides passive control, but may be replaced by conventional controls if desired.

[0011] Suitable collectors may evacuate condensate from the heat exchanger as water is condensed from the humidity in the air being cooled. The condensate may be conducted in a channel, pipe, or the like to a location outside the volume used as the solar heat collection region so as to not increase humidity by re-evaporation, which could also present heat loss for the collection process otherwise.

[0012] Air in the volume (e.g., attic, ducts, ventilation spaces, etc.) may be freely movable therewithin by free convection, and may be substantially unobstructed in at least one direction. Ducting or some other director may be positioned in the volume to conduct air through at least a portion of the lower and upper ends, directing the heated air through the exchanger or banks of exchangers in series, parallel, or both. A channel may substantially enclose a heat exchanger against substantial escape of air, except in the direction of flow. The flow may transfer heat in the air flow, collected from the roof's under surface, through the heat exchanger, which extracts the heat from the air into a transfer fluid in the heat exchanger.

[0013] A damper controlling the flow of air, and valving controlling the flow of water may both be passive or active, or one of each. In any event, the controls may support limiting air flow to obtain maximum temperature in the air from the roof, and maximum temperature in the water from the air. Air and water flows may be restricted to maximize temperatures, and thus, the thermodynamic availability of the heat collected. Contrary to much of solar collection technology, solar radiation need not be concentrated to raise the thermodynamic availability of the fluid stream collecting the heat.

[0014] An actuator, such as a wax actuator or wax motor may operate as a thermostat to selectively open and close the dampers, valves, and the like to enforce pre-selected temperatures in the air and water working fluids.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The foregoing features of the present invention will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only typical embodiments of the invention and are, therefore, not to be considered limiting of its scope, the invention will be described with additional specificity and detail through use of the accompanying drawings in which:

[0016] FIG. **1** is a schematic block diagram of a passive solar heat exchange system in accordance with the invention, controlling temperature rise for increased thermodynamic availability by promoting stratification and restricting air flow;

[0017] FIG. **2** is an end view of one embodiment of a dampered, stratified, solar collection system under a roof, using the roof for solar energy absorption;

[0018] FIG. **3** is a schematic diagram of the air flows associated with stratified heating within an attic space of a building such as a house;

[0019] FIG. **4** is an end view of a heat recovery system in accordance with the invention installed in a trussed attic space;

[0020] FIG. **5** is an end view of a trussed attic space containing a substantially closed circulation system down drafting cooled air in accordance with the invention;

[0021] FIG. **6** is a partial, cutaway, end view of the system of FIG. **5** showing the open air path through the soffits and lower vents, along the underside of the roofing materials, through the heat exchange elements, and ultimately through the top damper and exiting out the ducting created by a vent cap;

[0022] FIG. **7** is a perspective view of the apparatus of FIGS. **5** and **6**, illustrating alternative locations for storage tanks, one high and suitable for free convection heating, and the other set low and thus remaining cooler than the exchanger absent forced convection;

[0023] FIG. **8** is an end view of the apparatus of FIG. **7**, relying on a larger tank located principally above the heat exchangers in order to maintain maximum temperature by free convection of the liquid, heat-exchanging fluid;

[0024] FIG. **9** is an end view of one embodiment of an alternative heating system relying on passive solar collection through windows provided with curtains as absorbent receptors of solar radiation and directors of (e.g., effectively ducting) heated air toward the heat exchange element in accordance with the invention;

[0025] FIG. **10** is a perspective view of one embodiment of a dry, rooftop, solar collector relying on transparent, insulating cover over a duct provided with an absorbent top surface to collect heat without requiring large expanses of conventional, liquid, carrier lines;

[0026] FIG. **11** is a side elevation view of one embodiment of a damper controlling horizontal or vertical flows, depending on orientation of the wall element, of incoming or outgoing air heated in accordance with the invention;

[0027] FIG. **12** is a side, cutaway, elevation view of a duct, illustrating various alternative embodiments of dampers to control the flow of air through the heat exchange elements thereof;

[0028] FIG. **13** is a partial, cutaway, end view of a heat recovery system collecting passive solar energy from a roof, where the insulation is placed between the rafters in the roof, rather then at the base of the attic; and

[0029] FIG. **14** is a schematic end elevation view of a building containing various alternative embodiments of elements including controls, storage tanks, pre-heaters, water heaters, and connecting lines, illustrating various alternative embodiments for maintaining free and forced convection of heating fluids such as water passing through heat exchangers implemented in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] It will be readily understood that the components of the present invention, as generally described and illustrated in the drawings herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the system and method of the present invention, as represented in the drawings, is not intended to limit the scope of the invention, as claimed, but is merely representative of various embodiments of the invention. The illustrated embodiments of the invention will be best understood by reference to the drawings, wherein like parts are designated by like numerals throughout.

[0031] Referring to FIG. **1**, a system **10**, apparatus **10**, or method **10** in accordance with the invention may include ducting forming a wall defining a channel. It may be appropriate to talk about ducts **12** or ducting **12**, meaning the channel, and the walls, respectively, formed as ducts **12**. In general, the ducting **12** is responsible to conduct air, and need not be closed completely imperviously. For example, conventional heating, ventilating, and air-conditioning (HVAC) technology includes plastic, metal, and sometimes wooden chambers and conduits that effectively act as ducting **12**. Similarly, the entire structure of a room or attic may act as a plenum as part of a circuit (closed or open) of air flow.

[0032] Typically, controlling the restriction on the flow of air, and thus the flow of air through ducting **12**, through one or more vents **14**, **16** may obstruct the flow and control temperatures. Since temperature is a direct function of mass flow rate of air, for a particular amount of heat available, temperatures may be maintained at higher values (within temperature and transfer limits of a heat source) by restricting the amount of air available to receive the heat transferred into the air. Thus, a vent **14** may be placed low in the air flow system, high (e.g., as upper vent **16**) in the air flow system, or both may be employed.

[0033] Typically, the vents **14**, **16** may be completely open at all times. In other situations, the vents **14**, **16** may be provided with dampers **18** to selectively open and close flows, such as by closing the vents or opening them. In yet other alternative embodiments, the vents **14**, **16** may be open at any or all times, while the dampers **18** are placed elsewhere in the flow. Regardless of the location of a damper **18**, so long as it is within a single path of ducting **12**, it may partially or completely obstruct the flow through that ducting and thus through any vents **14**, **16** in the direct path of the air flow through that ducting **12**.

[0034] Dampers **18** may be placed as lower dampers **18*a*** or upper dampers **18*b*** in the flow. However, a damper **18** may not be placed at a high or low position, but may be placed anywhere within ducting **12** to provide the required obstruction. It is proposed in several embodiments that actuators **19*a*, 19*b*** associated with dampers **18*a*, 18*b*** operate based on temperature.

[0035] For example, in one embodiment, an actuator **19** may be a wax actuator having an operating material of a blend of wax that expands with temperature. The wax operates on a piston to expand or contract the overall length of the actuator **19** by extension of a piston thereof. Thus, in one embodiment, the dampers **18** may be controlled by actuators **19**, which are themselves responsive to temperature.

[0036] For example, in one embodiment, an actuator **19** on one damper **18** may act to seal the system **10** off in cold weather. By the same token, another damper **18** may be controlled by an actuator **19** that will restrict airflow to achieve a particular temperature at a particular location in the system **10**, such as near the exchanger **20** to maintain an air temperature sufficiently high to ensure a proper temperature of liquid in the heat exchanger **20**.

[0037] For example, high thermodynamic availability is a direct function of temperature differential. Accordingly, in order to provide a good supply of sufficiently hot water, from the heat exchanger **20**, it may be advisable to restrict the flow of air through the heat exchanger **20**, assuring a higher temperature. Thus, a particular actuator **19** operating on a corresponding damper **18**, may be engineered, designed, or otherwise set to restrict the flow through a damper **18** or past a damper **18** whenever the temperature of the consequent air flow is not at a sufficiently high air temperature, such as one for which the system is designed or desired to operate.

[0038] In general, a line **21** may pass through a heat exchanger carrying a fluid such as water. In certain embodiments, an exchanger **20** may actually be transferring heat into another heat exchange system in a "double loop" arrangement. In such circumstances, the fluid in the line **21** need not be potable water. For example, a water providing with a certain amount of alcohol, glycol, or other antifreeze agent, and may even include salt, as a mechanism to maintain the line **20** free flowing and without any freezing. In other embodiments, the line **21** may carry a once-through pass of culinary water that is simply pre-heated to whatever extent it can be before being sent off to other systems such as a water heater for final heating.

[0039] In one embodiment of an apparatus in accordance with the invention, the line **21** carries water while an array of fins intimately bonded to the line **21** exchanges heat between the passing air and the line **21**. Thus, a comparatively larger area exposed to air may accommodate the reduced heat transfer coefficient in air, while the comparatively smaller area of the line **21** corresponds to the comparatively higher heat transfer coefficient of water.

[0040] In general, a volume **22** such as the enclosed body of an attic **22** may host the ducting **12** and the exchanger **20**. In typical embodiments, a solid conductor **24** basically comprises the roofing. Typically, the conductor is a composite of various materials. For example, tiles, shingles, membranes, and other roofing materials on top of wooden substrates such as plywood, composition board, concrete, steel, or the like may form the conductor **24**. The conductor **24** is typically solid, although it may contain spaces, gaps, air, or the like.

[0041] The conductor **24** may also include insulated spaces. However, in many embodiments of an apparatus in accordance with the invention, the enclosed volume **22** is not interior to insulated spaces. For example, if rafters pitched along the angle of a roof are themselves insulated, then ventilation will typically be provided along the rafters above the insulation, and below the roofing materials that form the conductor **24**.

[0042] Meanwhile, in an uninsulated attic, the enclosed volume **22** of space or air typically sits above insulated joists or horizontal members of truss work. Here, the angled portions of a roof are called rafters. The horizontal portions of roof trusses are called joists here, although people sometimes refer to them as rafters also. Nevertheless, in certain roof structures, insulation is placed exclusively over the ceilings of lower floors, and the attic remains unused. This is typical when truss work fills the attic such that it is not habitable space not readily accessible space for living storage.

[0043] Typically, radiation **26** from the sun **30** may strike an absorber **28**. The absorber **28** is typically an upper surface of the same material that forms the conductor **24**. For example, the stone surface of an asphalt shingle, the surface of a ceramic, clay, concrete, or other tile, or the like may form or define the absorber surface **28**. Accordingly, radiation **26** from the sun **30** strikes the absorber **28** and is converted from its short wavelength, high frequency wave form to thermal energy that may then be transmitted by conduction through the conductor **24**. Of course, a certain amount of the absorbed energy found in the absorber **28** may be convected away by ambient air.

[0044] Opposite the absorber **28** or absorber surface **28** of the conductor **24** is the convector **32** or convector surface **32**. Typically, the convector **32** engages in two types of heat transfer. That is, convection **34** involves conduction of heat from the convector **32** to adjacent air, followed by a net flow or bulk flow of the air as it moves, e.g., as it heats and rises in free convection. Thus, convection **34** is a combination of conduction and bulk air flow.

[0045] Meanwhile, the same surface that operates as a convector **32** may also serve as a radiator **36**. For example, radiator surface **36** maintains a temperature that may be substantially higher than other portions or surfaces within the space **22**. Accordingly, energy may radiate from the radiator **36** as infrared radiation **38**. Infrared radiation is not as effective as solar radiation. For example, typically, radiation **38** transfers between a comparatively warmer surface to a comparatively cooler surface only at about the same rate that energy convects away from a heat transfer service by convection **34**.

[0046] Heat transfer controls many aspects of a temperature within the space **22**. To the extent that a heater exists completely below a particular point in a freely flowing, inviscid fluid of any state (liquid, gas, vapor) the entire process of convection **34** will usually dominate. The heated space **22** has little temperature gradient above the source of heat. Typically, where convection is unobstructed inside, and only free convection cooling is available outside, any type of a heating element in a free pool of fluid will heat all of the fluid above the heating element to some stable temperature. Only a very slight gradient, typically a few degrees will exist between the top of the pool of fluid and the top of the heating element.

[0047] By contrast, throughout the depth of the heating element, a temperature gradient will exist. Below the heating element, the temperature will have a steep gradient or be an almost uniform temperature, depending on whether any significant heat source is below, often having only the gradient imposed by conduction downward.

[0048] Thus, where a conductor **24** is made of the roof of a building, such as a slanted roof, heat is added all the way along the length of the roof. Thus, heat is added at the lowest levels, heat is added at the highest levels, and heat is added at intermediate levels. Accordingly, the enclosed volume **22**, space **22**, or attic **22** will typically stratify, providing strata **40** at different temperatures.

[0049] The air strata **40** may have some maximum temperature stratum **40***a* at the top, with subsequently cooler strata **40***b*, **40***c*, etc. down to the lowest stratum **40***m*, and temperature may vary continuously.

[0050] The strata **40** exist exactly because heat is added along substantially the entire height of the space **22** or the volume **22**. In any system where heat is added in one location and extracted from another, a gradient will exist. Nevertheless, it has been found that wherever water or air is free to move, the entire temperature gradient between a heat source and the upper level of the tank or containment vessel holding the fluid is typically only a matter of a degree or two unless some very significant (e.g., liquid or forced convection) is occurring to take heat away from the containment region.

[0051] Otherwise, so long as free convection in air is the only mechanism for removing heat from a volume, across the wall, the temperature gradient above a heating element is comparatively insignificant. Likewise, where a heating element provides substantially constant heat at all levels over the height of a contained mass of fluid, such as water or air, it has been found that a gradient will be established at a very significant slope. The temperature typically will vary substantially linearly from top to bottom between the maximum temperature at the top and the coolest temperature in the contained reservoir or volume at the bottom.

[0052] Typically, an input line **42** connects to or is a part of the line **21** through the exchanger **20**. In certain embodiments, the ducting **12** conducts hot air, while the line **21** is fed water through the inlet line **42**. Typically, the inlet line **42** is cold, comparatively speaking, while the outlet line **44** also connected to the line **21** and the exchanger **20** is comparatively hot.

[0053] When warm air from the normal environment is cooled, its capacity to hold moisture is reduced. To the extent that humidity may be high, cooling of air in an exchanger **20** with comparatively cooler water passing through a line **21** in the exchanger **20** will result in condensate **46** exiting out a condensate line **46** from the exchanger **20**. The condensate line **46** is not carrying away water from the line **21**, or from the inside of the line **21**. The condensate line **46** carries away humidity that has been chilled out, like the sweat on a cold drink container on a hot, humid day.

[0054] As heat **46** is transferred from the air into the water or other fluid in the line **21** of the exchanger **20**, the cooled air resulting may condense out moisture that was previously carried as vapor in the humidity of the air. Accordingly, a condensate line **46** may feed condensed moisture out of the ducting **12** or from regions thereabout for disposal elsewhere. Otherwise, the moisture may cause other problems.

[0055] In general, a flow **50** of air passing through ducting **12** inside or connected to the volume **22** may pass through an exchanger **20**, giving up heat **48** into the fueled line **21** on the exchanger **20**, while condensing out any excess humidity as liquid through the condensate line **46**.

[0056] Referring to FIG. **2**, while referring generally to FIGS. **1-14**, a system **10** is shown in one embodiment. Rafters **56** and joists **58** (sometimes called rafters, but referred to as joists simply to distinguish horizontal members **58** from the angled rafters **56**) together support a building **60** by tying together the walls **61**, and supporting the roof **62**.

[0057] Typically, an attic **64** may define the contained volume **22** of air below the roof **62** and heated thereby.

[0058] Typically, in an attic **64** as illustrated in FIGS. **2-3**, the bottom **66** of the attic **64** may have insulation **68** to insulate the occupied space of the house **60** or building **60** therebelow. Meanwhile, in such a configuration, the roof **62** is typically uninsulated and vented. Therefore, the flow **50** of ambient air flows up through soffits or vents under the eaves of the roof **62**, and along the undersurface **32** thereof. Typically, the space **22** is completely filled with air, and thus the flow **50**, rises and stays closest to the convector **32** and radiator **36** surfaces of the roof **62**. Accordingly, the absorber **28** of the roof **62** receives radiation **26** from the sun **30** which then heats the conductor **24** or roofing material **24**. Thereupon, the convector **32** and radiator **36** proceed to convect heat into the flow **50**, further heating it, as well as radiating, respectively, to the bottom **66** of the attic **64**. Accordingly, some warming of the bottom **66** of the attic **64** may occur with consequent heating of air thereabove.

[0059] Nevertheless, the majority of heat in the attic **64** will be received by the convector **32** convecting heat into the flow **50** rising along the underside of the roof **62**. Typically, attics will have some type of a venting system. In certain embodiments of an apparatus and method in accordance with the invention, a damper **18** may limit the ability of air to vent through ducts **12**, vents **16**, or both.

[0060] For example, typical construction may include placing vents **16** in roof structures. Vents may be formed as ridge vents, such as the duct **12** feeding air out of the attic **64** under a ridge cap or cap **70** that forms the upper vent **16**. Meanwhile, soffits of eaves may be provided with lower vents **14**. Typically, in a system in accordance with the invention, cooler air enters a lower vent **14**, and is ducted out through one or more openings higher in the attic **64**.

[0061] Some attics may be vented by cross flow of breezes through vents in the gable of the attic. In other situations, a vent cap **70** or ridge cap **70** covers an opening or openings near the ridge of the roof **62** protecting against entry of weather such as rain and snow, while still providing exit of the flow **50** of air through the attic **64**. Thus, the flow **50** may pick up much of the heat impinging on the roof **62** as radiation **26** absorbed therein and carry it out by convection through the upper vent **16**.

[0062] In an apparatus and method in accordance with the invention, maximum thermodynamic availability is desired for obtaining most efficient heat transfer into the exchanger **20** and maximum temperature. Higher thermodynamic availability results in and from higher temperatures at the highest points in the space **22** of the attic **64**, thus providing maximum temperature in the line **21** of the exchanger **20**.

[0063] In the illustrated embodiment, one or more dampers **18** form, control, or both the ducting **12** directing air from the flow **50** through the exchanger **20**. For example, the damper **18** may be placed below, above, or in both places with respect to the exchanger **20** in order to restrict the flow **50** of air. If the flow **50** is left unrestricted then the temperature in the exchanger is left largely to chance.

[0064] In certain embodiments, the exchanger **20** may operate in the absence of a damper **18**. However, in order to provide flows by free convection, substantially exclusively, it may be preferable to rely on the damper **18** to limit the free convection flows **50** of air. This helps maintain the thermodynamic availability of heat in the flow **50** by limiting the net mass flow rate thereof.

[0065] Referring to FIG. **3**, in particular, while continuing to refer generally to FIGS. **1-14**, a system **10** in accordance with the invention may take advantage of the strata **40** formed by virtue of the flows **50** of air entering into and rising through the space **22** below a roof **62** of a building **60**. As illustrated, each of the individuals **50***a* into the lower vent **14** of the attic space **22** of a building **60** may rise along the convector surface **32** and radiation surface **36** of the conductor **24**. Typically, if the upper vent **16** is open, then the flows **50** will progress as directly as permitted toward the upper vent **16** to exit the space **22**.

[0066] However, to the extent that the flows **50***b* are heated faster by the convector **32** then they can rise above all the strata **40** then the air may stratify. For example, if a flow **50***b* is rising along a convector **32** and picking up heat, it may come to the point that it exceeds in temperature the surrounding strata **40***a*, **40***b*, **40***c* and so forth to stratum **40***n*. However, alternatively, if the ducting **12** is restricted, artificially, by design, or simply as a result of the built in floor resistance from either vent **14**, **16** then a flow **50***b* may find that a particular stratum **40** is already hotter than the flow **50***b*. Thus, the flow **50***b* may spread out as a flow **50***c* at a particular level of a stratum.

[0067] For example, a flow **50***b* may rise along a convector **32**, picking up heat. However, as soon as the net temperature of the convector **32** can no longer effectively heat the flow **50***b* (which is cooling down by entraining fluid from the space **22**) hotter then a stratum above it, say, for example, the stratum **40***b,* then the flow **50***c* must flow laterally under the stratum **40***b,* and become the stratum **40***c*.

[0068] Each of the flows **50***b* will continue to draw into it from each of the strata **40** as the flow **50***b* passes by. For example, as the flow **50** traverses upward along the convector **32**, it continues to pick up additional mass. One may think of this entrainment as the flow **50***b* growing larger, extending further away from the convector **32** and carrying more net mass flow with it. Thus, a certain degree of mixing occurs between the flow **50***b,* and the strata **40** of air in the space **22**.

[0069] Nevertheless, no particular flow **50***b* can rise above a stratum **40** hotter than flow **50***b* is itself. Thus, air in the stratum **40***a* has received heat from all layers below. However, air in the stratum **40***n* receives heat only from the lowest portion of the roof **62**, because the flow **50***b* entrains air from the strata **40**, it exchanges not only momentum but heat energy. Therefore, the net temperature or net average temperature of the flow **50***b* is increasing as the result of additional heat added by the convector **32**, but decreasing as a result of mixing with the various strata **40** in passing. Thus, one may think of the flow **50***b* as being involved in a balancing act between the net temperature gained from the convector **32** balanced against the net temperature loss caused by mixing with the strata **40**. Thus, one can readily see how the flow **50***b* may top out at a particular stratum **40** short of the top stratum **40***a* in the space **22**.

[0070] Ultimately, heated air in the space **22** will arise through the duct **12** and exit out the vent **16**, driven by the net effective density of the air outside the building **60** compared to the net density of the air in the space **22** within. One may thus think of the flow between the vents **14**, **16** as a chimney-like effect as the more dense column of air outside the building **60** displaces, through the vent **14**, the lighter density air in the space **22**. Accordingly, air incoming through the vent **14**, may actually flow immediately into the bottom stratum **40***n* as hot air from the uppermost stratum **40***a* is rising through the duct **12** and exiting through the vent **16**.

[0071] Referring to FIGS. **4-8**, specifically, while continuing to refer generally to FIGS. **1-14**, a system **10** in accordance with the invention may include some type of a barrier **72** restricting air in the space **22** from rising, except through duct work **12**. In the embodiment of FIG. **4**, for example, flow from the vent **14** into the space **22** may fill the space surrounding the various trusses **54**, including braces **55**, rafters **56**, and joists **58**. As discussed above, the term joist **58** is used even though a roof structure **62** may not have a floor thereabove. Since typically, the horizontal and angled members of the perimeter of a truss may both be called rafters we will refer to the angled member of a truss **54** as the rafter, and the lower member, extending horizontally as the joist **58**. In the illustrated embodiment, a flow **50** rising from a vent **14** may be heated by the roof **28**. Meanwhile, ducting **12** provides the only escape for the flow **50**.

[0072] Accordingly, with exchangers **20** located in the duct work **12**, the flow **50** must pass through one or more exchangers **20** delivering heat into the lines **20** therethrough. Thus, the incoming line **42** provides a substantially and comparatively cooler stream of liquid, such as water, into the exchangers **20**. In the illustrated embodiment, the cooler water from the inlet line **42** goes first to the top exchanger **20**. This is not necessary. In certain embodiments, the inlet line **42** may go first to the bottom exchanger **20**, and then pass into subsequently higher exchangers **20**. In fact, such an arrangement will flow much more readily and naturally without the need for a check valve **74**. A check valve **74** may be placed in the line **42** in order to assure that fluid (water) is always passing only in one direction through the exchangers **20**.

[0073] Also, the water passing through the exchangers **20** may or may not be the same water as is drawn off for use by an independent draw line **76** or draw **76**. For example, insulation **78** around a tank **80** may provide a reservoir of hot water received from the outlet line **44** of the exchangers **20**. Thus, the maximum temperature in the tank **80** is at the top thereof where the inlet line **44** delivers hot water. Meanwhile, the coldest water in the tank **80** is at the bottom thereof and is fed into the inlet line **42** to the exchangers **20**.

[0074] In certain embodiments, the inlet line **42** may simply be connected to the building water supply. Thus, the line **42** may feed directly into the exchangers, and thus provide pressure, flow, and a water supply to be heated by the exchangers **20**. In such an event, the outlet for the tank **80** may simply be in the draw **76**. Alternatively, the line **42** may be thought of as two lines, one serving the building **60** out of the tank **80**, and the other feeding from the building water supply into the exchangers **20**, to provide the outbound outlet line **44**.

[0075] In the illustrated embodiment of FIG. **4**, the duct **12** exits the roof **62** through a vent **16**. The illustrated vents, sometimes called turtle vents **16**, at particular locations may permit exit of the flow **50** only after that flow **50** has passed through the exchangers **20**. In other embodiments, a ridge vent, or even an end vent may be ducted to dispose of or to conduct out of the space **22**, the hot air being released to ambient air.

[0076] Check valves **74** may assure that water can only flow in one direction into the exchangers **20**. If the highest exchanger **20** is provided the coldest flow of incoming water from the line **42**, then the density in the line **42** is higher and the water column therein is heavier than the column in the exchangers **20** themselves. With the buoyancy effect of hot water against cool water, cool water will tend to drop, thus drawing water backwards out through the line **42**. To assure that this did not occur, the line **21** of the top exchanger **20** may be placed below the lowest point of the tank **40**. Thus, the weight of the column of water in the exit line **44** may be lighter than the column within the tank **80** and the line **42** feeding into the exchangers **20**. Any transient circumstances otherwise may be cured by the check valve **74** prohibiting flow backwards through the line **42**.

[0077] One reason for placement of the feed line **42** feeding water first into the topmost exchanger **20** is to assure that the hottest air from the space **22** strike the bottom exchanger **20** first, and that the bottom exchanger **20** be the last unit to heat the water thus heating water to its maximum possible temperature before being discharged into the tank **80**.

[0078] Alternatively, the free convection flow through the lines **42**, exchangers **20**, and line **44** may be best served by feeding the cool water from the line **42** into the bottom exchanger **20** first. However, this tends to reduce the driving temperature difference heating water in the upper exchangers **20**, driven by the hot water below, already heated by the comparatively hottest air passing through the bottom exchanger **23**.

[0079] Referring to FIG. **5**, while continuing to refer generally to FIGS. **1-14**, certain embodiments in the space **22** may be comparatively closed. For example, in the illustrated embodiment, a flow **50***a* is rising along the convector **32** in the space **22**. The flow **50***a* may stratify, mix, or otherwise fill the space **22**. Ultimately, however, from the space **22**, a flow **50***b* may be ducted upward through the ducting **12**. The flow **50***b* may then turn down through the array of exchangers **20**.

[0080] Again, the chilling effect of water in the line **21** is operating to push the colder flow down through the exchangers **20**. Each exchanger **20** chills the flow **50***c*, with the upper exchanger **20** receiving the hottest air available. As the air cools, it drops down through the ducting **12** to the next lowest exchanger **20**. Ultimately, the coolest air drops down past the bottom exchanger **20** and exits as the flow **50***d* back into the bottom of the enclosed space **22**.

[0081] Meanwhile, the tank **80** with its insulation **78** in the illustrated embodiment may feed a flow **42** into the bottom exchanger, from whence the flow **82***a* feeds to the next exchanger **20**, followed by the flow **82***b* to the next exchanger, and so forth until the flow **82***c* feeds the last exchanger **20** at the top of the duct **12**. Finally, the last exchanger **20** provides a flow **44** into the top of the tank **80**. Thus, the air flow **50***c* drops down through the ducting **12**, while the heated water flow rises through the various exchangers **20** and ducting **12**.

[0082] To ensure that maximum temperatures are reached, a thermally activated damper **18** may restrict the ducting **12** at any appropriate location. The damper **18** may be located within the ducting **12** near the exchangers **20**, at the bottom thereof, at the entrance of the air flow **50***b* into the ducting **12**, or the like.

[0083] As a result of the extensive cooling that a flow of cool liquid such as water may cause in the flow **50***c*, in humid environments, a tray **84** may collect water or condensate from the airflow **50***c* for disposal. In certain embodiments, a condensate line **46** imbedded in the tray structure **84** may even be insulated **86** to limit re-evaporation thereof. Thus, the insulation **86** may keep the tray **84**, condensate line **46**, and the condensed water therein somewhat isolated from the heat of the attic space **22**. The condensate line **46** may drain into an appropriate location, such as a household drain, outdoor drain, or the like, limiting humidification of the space **22** that might tend to inhibit operation of the system **10** or damage the structure of the building **60**.

[0084] In addition to the system **10** of FIG. **5**, additional roof vents may be provided as free vents. For example, certain small vents **16** may be provided that will provide only minimal venting of the space **22**. Thus, the system **10** operates primarily as a ducted system, as far as the air is concerned. However, in order to flush or bleed off moisture in the air and provide a small amount of makeup air, a lower vent **14** and upper vent **16** of comparatively restrictive smaller size may be provided. For clarity, the illustration of FIG. **5** does not include vents, but the system may be comprised of vents such as those shown in the other FIGS. **1-14**.

[0085] Referring to FIGS. **6-8** some attic space **22** may be living space. Even when the attic **64** is constructed in a way to provide only storage or vacant space, the attic **64** may be cooled. For example, in the illustrated embodiment, the vent **14***a* may feed the flow **50***a* into a vent **14***b* extending up between the rafters **56** of a roof **62**. In the illustrated embodiment, a closure **88**, such as sheet rock or other finished material may enclose a living space **22**. The living space **22** may actually be separated completely from the ducting **12**. Instead, the embodiment of FIG. **6**, air through the vents **14***a*, **14***b* may pass into ducting **12** lying above the insulation **90**. The insulation **90** may be separated by a vapor barrier and other material as part of the closure **88**. In typical construction, sheet rock backed by a vapor-liquid-impervious layer may form the closure **88** sealing the heated space **22** away from the exterior space. The ducting **12** above the insulation **90** may conduct the flow **50** upward toward an exchanger **20**.

[0086] Passing through the exchanger **20**, the flow **50** gives up heat into the line **21** for exiting out through the upper vents **16**. A tank **80** (all parts and systems may be plural) may be fixed high among the rafters **56**. In one presently contemplated embodiment, the exchangers **50** may be at or below the lowest point in the tank **80**. Meanwhile, the tank **80** may be insulated **78** by or between the structures holding it. The tank **80** may be accessed by a simple plumbing system as discussed hereinabove, or as described in other art, such as U.S. Pat. No. 5,014,770 to Palmer, incorporated herein by reference.

[0087] In the embodiment of FIG. **6**, dampers **18** may be placed over the vents **14***a*, **14***b*, or ducts **12**, as illustrated. Likewise, the damper **18** may be fixed across or within a vent **16**. In certain embodiments, dampers may be placed in more than one location. For example, in one embodiment, the damper **18** may be placed to trigger on cold weather, thus shutting off the system when temperatures are so low outside that the system **10** will not operate properly. Meanwhile, those or other dampers **18**, such as dampers high in the system **10** may be configured to operate only when temperatures are sufficiently high to provide suitably high water temperatures. In certain embodiments, a damper **18** such as the damper **18** of FIG. **6** may be positioned high in the system **10**, such that only the existence of suitable temperatures to provide predetermined water temperatures within the lines **21** of the exchangers **20** will open the damper **18** to allow the flow **50** to exit the vent **16**. At all temperatures lower, the vent **16** may have substantially zero flow.

[0088] In certain situations, such as systems **10** that receive culinary water destined for use from a water heater, in the "off season" of winter conditions, one may take the exchangers **20** out of service valves by passing them with the culinary water and draining them. Thus, ventilation may continue past them in winter time without fear of freezing pipes or condensation within the ducting **12**. In substantially all embodiments, condensation should be considered, inasmuch as humidity is increased whenever a flow **50** of air is cooled, reducing its capacity to hold moisture.

[0089] Referring to FIG. **7**, alternative locations for the tank **80** may be not only above the exchangers **20**, but sometimes below, elsewhere in the attic **64**, or even on floors below the attic **64** or in a cellar or basement. However, to the extent that the tank **80** is positioned below the exchangers **20**, flow will not be naturally (freely) convected from the lines **21** into the tank **80**. Water will have to be pumped against the density gradient.

[0090] Palmer, incorporated hereinabove by reference, discusses many systems for manipulating the flow of water by forced convection. Such may be incorporated into an apparatus **10** in accordance with the invention. Nevertheless, such systems are not the principal point of an apparatus and method in accordance with the invention. In contrast to Palmer, an apparatus and method in accordance with the instant invention may rely primarily or completely on passive, convective flows of both air and water. To the extent that a water line from a building may be connected through the tank **80** in a secondary heat exchange loop or path, or directly as a primary fluid in the line **21** of the exchanger **20**, water flow may occur by forced convection.

[0091] Referring to FIG. **8**, the tank **80** may be formed to be of any arbitrary shape for which space exists. For some roofs, the pitch angle is sufficiently large with respect to horizontal that a large (e.g., narrow triangular or otherwise) space is available, and substantially unusable for living space. Thus, a rectangular or circular tank **80** may be suspended, supported by braces, or otherwise fixed within the structure of the rafters **56**.

[0092] Accordingly, it is contemplated that structural changes to the internal structure of an attic **64**, including selecting, moving, designing, attaching to, or passing around braces **55**, rafters **56**, joists **58**, and other truss members **54** may be done in order to install initially during construction, or as an after-construction modification to a building **60**, such a system **10**.

[0093] Referring to FIG. **9**, an apparatus and method **10** in accordance with the invention may also be implemented in spaces other than an attic **64**. For example, in the embodiment of FIG. **9** a wall **61** may support a window **94** having one or more panes through which solar radiation **26** may pass. Glass, for example, provides a window **94** that will pass solar radiation, but will not effectively transmit infrared radiation back from a heated object inside the building **60** of the window **94**.

[0094] In the illustrated embodiment, an exchanger **20** may be located above, behind, or near a driver **96** and may be hidden by a valance **98** in front of a curtain **100**, or by the curtain **100** alone. The curtain **100** may be of any suitable type. When solar radiation **26** is available, and particularly when undesirable to allow it into the space **22**, due to excessive lighting or heating effects, the curtain **100** may itself become the convector **32** and radiator **36**. The radiator **36** may radiate heat back to the window **94**, which heat cannot readily escape.

[0095] Thus, the flow **50** may be heated by the window **94** and convector **32** (outer surface of the curtain **100**) as the flow **50** rises. The curtain **100** and window **94** form ducting **12** or a duct **12** through which the flow **50** may rise. The curtain **100** may be of any suitable material and may be colored or treated to readily absorb solar radiation.

[0096] For example, the insets show various embodiments including a series of tubes such as reeds, bamboo, plastic, or the like forming a substantially continuous curtain **100**. Likewise, certain expandable (e.g., folded) panels made of paper, polymer fabric, or the like may be extended or drawn up.

[0097] Likewise, Venetian-type curtains **100** having a series of louvers may also operate successfully whether in a substantially open or closed visual configuration. For example, even if the louvers are not in their most nearly vertical orientation, then they still tend to absorb heat, and convect heat back into the flow **50**.

[0098] An exchanger **20** located in the duct **12** formed by the curtain **100**, window **94**, and valance **98** may receive the flow **50** and extract heat therefrom into the contained fluid (e.g., water, etc.) heated and delivered into the tank **80**. In the illustrated embodiment, the line **42** may be the water inlet line to the exchanger **20**.

[0099] In an alternative embodiment, the inlet line **42** may be provided directly to the exchanger **20** from the household water supply. In such an event, the line **99** may actually feed out to some other appliance, such as a water heater, space heater, other energy storage or manipulation system, or the like. For example, in some embodiments, the heat in the water of the tank **80** may actually be used to run a refrigeration cycle. In one embodiment, the energy provided by the heat in the tank **80** may be run through a cycle, such as, for example, the Servel cycle used in natural gas or propane refrigerators.

[0100] Thus, homes **60** in hotter climates where solar energy **26** or solar radiation **26** is most abundant may benefit by a source of energy for driving refrigeration systems. In the Servel cycle, for example heat from the tank **80** may heat a boiler boiling a vapor out of a solution (an absorbed or condensed gas out of the solution). The gas or vapor and liquid may then be cooled at a location cooler than the tank **80**, such as the outdoor ambient. Though the outdoor ambient itself may be uncomfortably warm it is still cooler than the tank **80**. Subsequently, the chemical reaction of absorption of the vapor back into the solution is a net endothermic reaction, cooling the fluids now a solution. The combined, cooled solution may pass through a heat exchanger to cool an enclosed space such as a room or refrigerated space to be cooled. The fluid, now warmed by the exchanged heat, may be run through the entire cycle again.

[0101] In alternative embodiments, the tank **80** may be filled at some location other than its highest point, operating as a pre-heater. As a pre-heater, the tank **80** may provide an initial quantity of energy to a flow, which flow will then be heated further by another auxiliary or principal means. By any of these methods, the net energy gained from the tank **80** resulting in the solar radiation **26** may be used to provide useful work or heating energy.

[0102] Referring to FIG. **10**, various solar collectors **102** or solar units **102** may also benefit from an apparatus and method **10** in accordance with the invention. For example, a solar unit **102** may have a cover **104** such as a flat plate, various tubes, or the like forming a convective barrier resisting loss of collected heat while providing transmission of light therethrough. Thus, the cover **104** may transmit light to a layer or surface **32** below, acting as a convector **32**. The convector layer **32** may heat up as a result of absorbing solar radiation, thus acting as both a surface absorber **28** and a convector **32**.

[0103] A damper **18** may operate anywhere in a duct **12** to limit the flow of air through the apparatus **102**. Accordingly, the damper **18** controls flow through the duct **12** between the convector **32** and the cover **104**. As air enters the lower vent **14**, a flow **50** passes along between the convector **32** (e.g., absorber **28** acting also as a convector **32**) and the cover **104**.

[0104] The damper **18** controls the flow to assure that the temperature of the air flow **50** at the exchanger **20** is suitably hot to provide the desired thermodynamic availability of energy. For this reason, one of the simplest configurations may involve placing the damper **14** above or below the exchanger **20** and very close thereto. In this way, when the temperature at the exchanger **20** is at the proper temperature, then a simple wax actuator, for example, may operate to open and close the damper **18** exactly at the temperature required by the design.

[0105] The upper vent **16** may be covered by a shield **106** or flashing **106**. The flashing **106** may assure a suitable degree of weather protection to prevent damage or cooling by precipitation such as rain, snow, ice, or the like.

[0106] As the convector **32** heats air in the duct system **12**, below the cover layer **104** and above the convector surface **32**, the heated air rises along the angle of the roof toward the exchanger **20**. Notwithstanding the flow **50** will be cooled substantially by one or more exchangers **20** in the path of the flow **50**, the long column of hot air in the duct **12** provides sufficient buoyancy to drive the flow **50** out of the upper vent **16**.

[0107] Referring to FIG. **11**, while continuing to refer generally to FIGS. **1-14**, a damper system **18** may include more than simply the necessary means to substantially close or obstruct a passage in a duct **12**. For example, in certain ventilation systems, a cover **108**, often having louvered slats therein, and therefore often referred to as a louver **108**, may be secured by fasteners **109** to a wall **61** or other portion of a building **60**.

[0108] The cover **108** may be replaced in the illustrated embodiment by any suitable ventilation port or vent **14**, **16**. For example, in certain embodiments, the wall **61** illustrated may actually be a soffit under the eave of a house. In other embodiments, the walls **61** may be at the end wall of a gable. In still other embodiments, the wall **61** may actually be a rafter **56** and the cover **108** may be replaced by any suitable type of cover such as a wind turbine, a turtle vent, a ridge vent, or the like.

[0109] In general, a damper system **18** may operate to selectively open and close any a particular vent **14**, **16** desired. In many embodiments, a damper system **18** may include a closure **110**, such as a vane **110** or panel **110** effectively closing a duct **12** or an opening of a vent **14**, **16**.

[0110] In one embodiment, a panel **110** or closure **110** may pivot on a hinge **111** or other pivot mechanism **111** between an open and closed position. An actuator **112** may be of any suitable type, including electrical, hydraulic, thermal, or any other type. In response to temperature, the actuator **12** may provide an infinitely variable, continuous range of positions for the panel **110** between fully open and fully closed.

[0111] In one presently contemplated embodiment, the actuator **112** may be a wax actuator (e.g., wax motor), relying on the volumetric change in the wax with temperature. Contained within the apparatus **112**, expansion and contraction of the wax drive a piston **113**. Upon heating, the wax expands pushing the piston **113** in one direction. Upon cooling, the wax drives the piston in the other.

[0112] The actuator **112** may be designed so the piston **113** retracts into the housing upon a rise in temperature or extends out of the housing upon a rise in temperature. This may be done by placing the thermally expanding material either in front of the piston face or behind it with respect to the direction of motion. In the illustrated embodiment, the piston **113** draws into the actuator assembly **112** as temperature increases, thus drawing the piston **113** to reduce in length, drawing the bracket **114** toward the actuator **112**, and opening the panel **110** or closure **110** of the damper system **18**. As the damper system **18** is opened, the flow **50** may enter into the enclosed space **22**. As temperature changes the volume of the wax adjusts to a new equilibrium value, acting as a thermostat.

[0113] Referring to FIG. **12**, the actuators **112** are not shown, in some instances for purposes of clarity. However, a panel **110***a* may cover a duct **12** by pivoting about a pivot **111***a* in response to operation of an actuator **112** against a bracket **114**. Likewise, as an alternative, or in addition, panels **110***b* may operate between open and closed positions by direct operation of actuators **112**. Whenever the duct **12** is closed off by any amount by any panel **110** of a damper system **18**, the flow of air is restricted. From the contained space **22** or volume **22** of an attic **64** or other heated space, the flow **50** is continuously regulated between maximum flow and substantially stopped. All heat is concentrated into the amount of the airflow **50** permitted to pass, heated from the sun and cooled by the exchangers **20**. Likewise, the comparatively cooler liquid (e.g., water) passing through the lines **21** may be restricted to obtain the maximum temperature rise available in it.

[0114] Referring to FIG. **13**, in certain embodiments of an apparatus and method in accordance with the invention, a damper system **18** may be positioned within a soffit, or over some upper vent **16**. For example, in the illustrated embodiment, a panel **110** of a damper system **18** may pivot about a hinge **111** or other pivot **111** between an open and closed position ventilating a rafter duct **12** above the insulation **90** thereof.

[0115] In the illustrated embodiment, the exchanger **20** may be idled until such time as the panel **110** is opened. Meanwhile, by a proportional actuator **112**, the panel **110** may be positioned to limit flow through the duct **12** and out the vent **16**, maintaining a proper temperature in the air flow in the duct **12**. Maximum temperature differences provide maximum thermodynamic availability of heat to the air flow **50**, the exchanger **20**, and ultimately to the liquid flowing in the line **21** therein. The damper system **18** may be installed near the upper vent **16**, lower vent **14**, or elsewhere in a duct **12**.

[0116] Referring to FIG. **14**, various arrangements of storage and use of liquid, such as water, from the exchangers **20** and tank **80** may be implemented. In certain embodiments, a tank **80** may be located high in the attic space **24** of a building **60**. In the schematic diagram of FIG. **14**, the tank **80** may be disposed in any suitable manner. Typically, the tank **80** will be configured to be above the exchangers **20**. Absent some forced convection imposed on the input line **42**, the exchanger **20** is best located below the top of the tank **80**. To heat the entire tank to the maximum uniform temperature the exchanger **20** is best located entirely below the bottom of the tank **80**.

[0117] Meanwhile, the exchanger **20** may feed the heat transfer fluid flow **82** from the exchanger **20** through the outlet line **44** into the tank **80**, and out the exit line **45** of the tank. As illustrated, various configurations of tanks **80** may be implemented in accordance with the invention. If the tank **80** is in the direct flow of incoming water for the building **60** such as a house **60**, the flow **82** may actually be driven from the city water supply. Accordingly, such an exchanger **20** and tank **80** must accommodate the line pressure of the building **60**.

[0118] In other embodiments, the line **44** incoming into the tank **80** may simply pass heat on to another heat exchanger **118** in the tank **80**, thus heating the water in the tank **80**, before exiting out a line **45**. In such a configuration the flow **119** into and out of the tank **80** is effectively operating in a secondary loop. Thus, the flow **119** may come from the building water supply, while the flow **82** in such a configuration may actually operate in a closed loop with the exchanger **20**. In such a configuration, the flow **82** may be treated with antifreeze, of any chemical variety from salt to glycol to alcohol, and need not even include water. For example, oil, alcohol, and the like may serve well year round. The exchanger **118** provides heat exchange between the heated flow **82** from the exchanger **20** and another fluid such as culinary water or other energy destination.

[0119] In certain embodiments, an auxiliary container such as an extra tank **120** may be used to accumulate heated or preheated water. The tank **120** may be a water heater **122** or may be a reservoir **120** located upstream of the water heater **122** itself. Thus, any amount of heat already captured in the tank **120** may be passed to the water heater **122**, thus reducing the amount of heat the water heater **122** must add.

[0120] In one embodiment, a unit **124** may control the flow **132**. Typically, a unit **124** may include a valve **126** if the flow **132** is coming from the water supply for the house **60** or building **60**. Accordingly, the unit **124** may simply be a valve providing access to water flow **132**.

[0121] In other embodiments, the exchanger **20** may be located other than above the tank **80**. For example, where the exchanger **20** may be high in the space **22**, while the tank **80** is simply replaced by the tank **120** therebelow, forced convection would require a pump **128** in a closed system, or a valve **126** in a system open to regularly receive water from the water supply of the building **60**.

[0122] In the illustrated embodiment, the flow **132** flows up through the input line **42** to the exchanger **20** to be heated. The exchanger **20** then provides the flow **132** out through the exit line **44** into the tank **80**, if present, or directly to a tank **120**. With or without a secondary heat exchanger **118** in the tank **80**, flow through the exit line **45** from the tank **80** may provide a source of hot water, or water as a preheated liquid into a storage tank **120**. Thereafter, the flow **132** may transfer directly to the water heater **122** as the flow **134** therethrough. The flow **134** may be the regular supply of water for the use of the building **60** such as a house **60**.

[0123] In one simple embodiment, the household of water supply may pass through an inlet line **42** to an exchanger **20**. The exchanger may be located in ducting **12** receiving heat collected through and from the conductor **24**. Heat may be passed therethrough by the convector **32** into the air flow **50**.

[0124] In one of the simplest systems to maintain, the exchanger **20** may operate in a closed loop through the tank **80**, and thus rely on a closed loop flow protected against freezing, and therefore never needing to be emptied. In such an embodiment, the flow **82** through an exchanger **118** may exchange water with the tank **80**. The tank **80** may be the tank **120** or feed it. So long as all the lines are properly insulated, the flows **119** from the water supply of the house may run year round. The flow **82** from the closed loop heat exchange cycle need not operate except when effective to augment or supply the heat needed by the tank **80**.

[0125] It may be seen that an apparatus **10** in accordance with the invention and a method **10** in accordance with the invention may operate to constrict flows operating by free convection involving air in a volume **22** receiving heat through a roof **62** of a building **60**. Accordingly, the roof **62** itself may become a passive solar collector and heat exchanger transferring heat from an absorber surface **28** through a conductor **24** constituted by the roofing materials. The convector **32** surface of the roof eventually convects heat out therebelow.

[0126] A flow **50** of air may be substantially enclosed, or may be open to the outdoor environment. By proper use of a damper system **18**, the flow **50** may be constricted to optimize the thermodynamic availability of heat, increasing the temperature in the highest strata of the stratified air in the space **22**.

[0127] By recognizing the appropriate heat transfer mechanisms within the space **22** heated by the conductor **24** and convector **32** (and to a lesser extent by the radiator **36**), provides substantially improved heat transfer, higher temperatures, and higher thermodynamic availability.

[0128] In certain embodiments, the flows through the system **10** may actually operate in parallel to feed hot water when available and to cease operation when neither sufficient nor economical. Nevertheless, in most embodiments, an apparatus **10** and method **10** in accordance with the invention may typically provide substantial additional energy even if only preheating domestic hot water prior to entry into a water heater **122**. So long as the energy input from the convector **32** into the flow **50** is sufficient to heat a water flow **132** coming into a building **60**, economical preheat may be received into the flow **132**.

[0129] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed and desired to be secured by United States Letters Patent is:

1. A method of solar energy collection comprising:

providing a building having a structure comprising a thermal conductor positioned to define a first space and comprising a first surface exposed to solar radiation and a second surface exposed to the first space;

converting into thermal energy, by the first surface, solar radiation incident thereon;

convecting; by the second surface thermal energy to air in a volume defined by the conductor, and a substantially solid region conducting heat between the first surface and the second surface;

stratifying the air within the volume in accordance with a temperature profile of the air in the volume;

controlling a maximum temperature in the air by operating a damper controlling a rate of a flow of air in the volume;

receiving the flow through an exchanger extracting heat from the flow at substantially the maximum temperature of the temperature profile and into a fluid cooler than the maximum temperature;

transporting the fluid to a location outside the exchanger; and

passing the heat away from the exchanger for use outside the volume.

2. The method of claim **1**, wherein the exchanger comprises fins extending into the flow.

3. The method of claim **1**, wherein the exchanger is a hydronic heating element operating in reverse to heat water passing therethrough.

4. The method of claim **1**, wherein the flow of air is further passing through the volume.

5. The method of claim **1**, wherein the flow of air is further substantially contained and circulating within the volume.

7. The method of claim **6**, further comprising operating the damper in accordance with the maximum temperature by a thermo-mechanical actuator.

8. The method of claim **7**, wherein the thermo-mechanical actuator comprises a wax motor.

9. The method of claim **7**, wherein:

the exchanger is a hydronic heating element operating in reverse by extending fins thereof into the flow to extract heat therefrom into a stream of water contained in a conduit intimately connected to extract heat from the fins into the water.

10. The method of claim **9**, further comprising evacuating condensate from the exchanger to a location outside the volume.

11. A method comprising:

providing a building having a roof comprising upper and lower surfaces, the upper surface exposed to solar radiation incident thereupon;

providing the building having a cavity enclosing a first volume below the lower surface and containing a quantity of air movable therewithin substantially unobstructed in at least one direction;

locating a director positioned in the first volume and having upper and lower ends, separated in the at least one direction, and a channel substantially enclosed to extend between the upper and the lower end;

positioning a heat exchanger in the channel exposed to the air;

heating the upper surface by the solar radiation;

heating the lower surface by the upper surface;

heating the air by the lower surface in contact therewith;

transferring heat from the air into a transfer fluid in the heat exchanger;

transferring heat from the transfer fluid into a second volume to be heated.

12. A method comprising:

providing a building having a roof comprising upper and lower surfaces, the upper surface exposed to solar radiation incident thereupon;

providing the building having a cavity enclosing a first volume below the lower surface and containing a quantity of air movable therewithin substantially unobstructed in at least one direction;

modifying the structure of the building with ducting directing a flow of air in the cavity to flow through the ducting;

providing an exchanger within the ducting and receiving heat from the flow

providing a damper controlling the flow of air; and

providing an actuator operable to selectively open and close the damper.

13. The method of claim **12**, further comprising

positioning a director positioned in the first volume and having upper and lower ends, separated in the at least one direction, and a channel substantially enclosed to extend between the upper and the lower end;

positioning a heat exchanger in the channel exposed to the air;

heating the upper surface by the solar radiation;

heating the lower surface by the upper surface;

heating the air by the lower surface in contact therewith;

transferring heat from the air into a transfer fluid in the heat exchanger;

transferring heat from the transfer fluid into a second volume to be heated;

the transferring, further comprising providing dampers controlled by temperature in the heat exchanger;

the transferring, further comprising providing vents controlling the flow of air through the heat exchanger; and

the transferring, further comprising providing ducting directing the air through the heat exchangers.

14. The method of claim **13**, further comprising providing vents extending between rafters and extending to the ridge, and passing the air out through a vent in the ridge.

15. The method of claim **12**, further comprising:

providing a cooler remove the heat from the air;

providing a condenser within the volume condensing water from the air upon cooling of the air; and

circulating the air within the volume to remove the heat into the cooler and water to a location outside the volume.

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