PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 3 : F24J 3/02

A1

(11) International Publication Number: WO 85/ 00212

(43) International Publication Date: 17 January 1985 (17.01.85)

(21) International Application Number: PCT/US84/01005

(22) International Filing Date: 27 June 1984 (27.06.84)

(31) Priority Application Number: 508,130

(32) Priority Date: 27 June 1983 (27.06.83)

(33) Priority Country: US

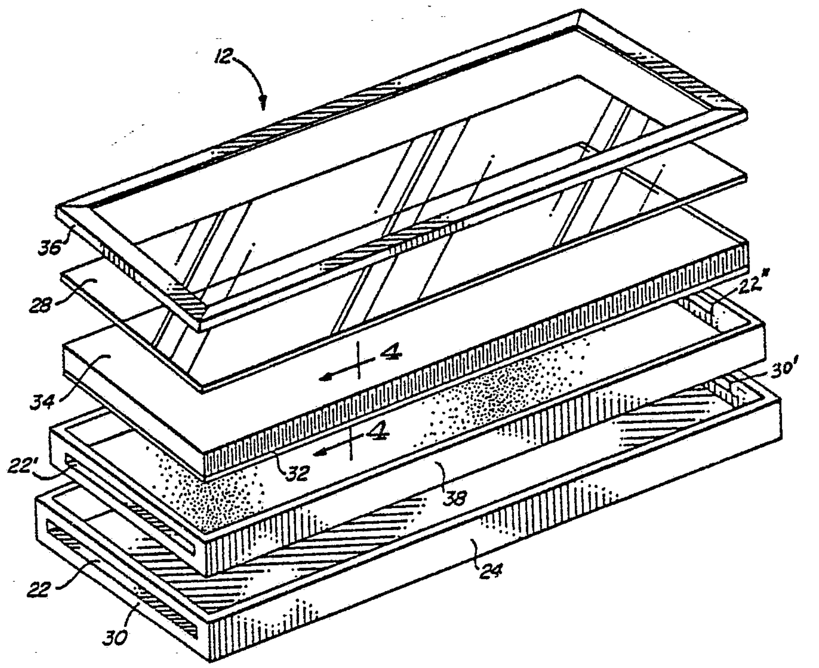
(71)(72) Applicant and Inventor: STEIN, Charles [US/US]; Post Office Box 9233, Albuquerque, NM 87119 (US).

(74) Agents: HINDS, William, R. et al.; Law Offices of William R. Hinds, 727 Twenty-Third Street South, Arlington, VA 22202 (US).

(81) Designated States: AT (European patent), AU, BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: SOLAR AIR HEATING SYSTEM



(57) Abstract

A solar air heating system (10) especially adapted for residences where nighttime heating is important. Solar air heating systems have relatively low efficiency, especially when designed to store energy. The parent invention is an improvement to this type of system. The system comprises a solar heat collector plate (43, 60, or 76), an energy storage medium in a subdivided chamber (34) or a structure (64), and a heat exchange means consisting of fins (33, or 44) or walls (65). The fins or walls extend from the chamber or structure wall into the storage medium to subdivide the chamber or the structure to improve the heat exchange relationships of the storage material with its surroundings. The panel is adapted to be incorporated into existing house air heating systems. Air from an enclosure (14) to be heated is drawn through the collector panel (12) by a fan or by natural convection where it extracts heat from the collector plate (43, 60 or 76) and the energy storage medium. The heated air then flows back to the enclosure. High solar collector efficiency is realized because of the unique design of the panel which thermally ties the temperature of a solar collector plate directly to a large thermal mass of energy storage medium. High system efficiency is also realized since an air blower motor is not required to transfer the energy from the collector to the storage volume. Low summer time stagnation temperatures are realized due to the collector plate/energy storage volume relationship.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	KR	Republic of Corea
AU	Australia	LI	Liechtenstein
BE	Belgium	LK	Sri Lanka
BG	Bulgaria	LU	Luxembourg
BR	Brazil	MC	Monaco
CF	Central African Republic	MG	Madagascar
CG	Congo	MR	Mauritania
CH	Switzerland	MW	Malawi
CM	Cameroon	NL	Netherlands
DE	Germany, Federal Republic of	NO	Norway
DK	Denmark	RO	Romania
FI	Finland	SD	Sudan
FR	France	SE	Sweden
GA	Gabon	SN	Senegal
GB	United Kingdom	SU	Soviet Union
HU	Hungary	TD	Chad
JP	Japan	TG	Togo
KP	Democratic People's Republic of Korea	US	United States of America

SOLAR AIR HEATING SYSTEM

Technical Field and Background

Phase-change media for solar energy storage have been studied for almost twenty-five years. Sodium sulfate decahydrate (Glauber's Salt) was first used in an experimentally heated house by Telkes because (a), its phase-change is accompanied by a relatively high heat of fusion; (b), it is cheap and available in abundant quantities; (c), it is nontoxic and non-flammable; and (d), the phase-change takes place within a desirable temperature range near 89°F. However, certain adversities encountered in the use of sodium sulfate decahydrate have been known for some time. In the first place, the decahydrate upon incongruently melting, separates into sodium sulfate and a saturated solution, whereupon the former, because of its higher density, precipitates out of solution and is therefore unavailable for further cycling. Second, the phase-change which occurs on cooling the liquid sulfate, which is responsible for the evolution of almost 100 Btu/pound of solution, is subjected to severe undercooling due to a nucleation problem. Lastly, the nature of the solidification process requires that heat be extracted from the liquid undergoing solidification through a layer of solid material. Since the container walls are usually a distance away from where the phase-transformation reaction is taking place, the poor thermal conductivity of the solution means that achievement of thermal equilibrium is a rather difficult process. The converse is also true on melting the decahydrate, since poor thermal conductivity will minimize the amount of phase-change medium undergoing transformation during the short solar hours of the winter. In the recited U. S. patent to Telkes No. 2,677,367, several, although not all of these adverse characteristics of the sodium sulfate decahydrate reaction, have been addressed. The problem of heat transfer to and from the salt solution remains, while the problems of nucleation, leading to supercooling as well as settling out of the sulfate have been overcome by additions of extremely fine silica and thickening agents to the liquid, respectively. A successful sodium sulfate decahydrate phase-change product, licensed by Telkes to Valmont Energy Systems, Inc. has been on the market for a few years now. A calcium chloride hexahydrate version of this patent is presently marketed by Holiday Energy Products.

In the present collector, heat exchanger, energy storage volume concept, hereinafter sometime referred to as CHE, sodium sulfate decahydrate or a paraffin wax is used as a phase-transformation medium. In the case sodium sulfate decohydrate, the problems of supercooling, phase precipitation and thermal conductivity were solved by the present invention by the use of aluminum honeycomb construction as well as rippled strips of aluminum sheet which subdivides the storage volume into small separate compartments. Good thermal conductivity, on a suitably fine scale, close to the reaction sites is thereby achieved for the wax as well as the Glauber's salt while the large surface area and the cell-like nature of the honeycomb and ripple sheet structure prevent supercooling of the sodium sulfate decahydrate and phase separation, respectively.

This storage concept has been carried out on sodium sulfate decahydrate using various metallic "wools" as the subidividing, cell containers. It has been found that this phase-change medium in steel "wool" experienced little undercooling prior to solidification at 80°F, while the "control" sample of sodium sulfate decahydrate undercooled by as much as 20°F below the transformation temperature before the phase-change took place.

The problem of precipitation of the sulfate from solution has been solved by the present invention which avoids any major change in the isothermal duration of the arrest time of the phase-change reaction using steel "wool". While experiments have shown success in alleviating problems associated with the use of the decahydrate, its potential as a storage medium is deemed inferior to the waxes because of the low transformation temperature of the former. Hot air obtainable at distribution registers, if it could be provided there without any heat losses from the phase-change temperature of about 89°F, would feel cool to the skin due to its flowing condition. On the other hand, waxes are available with transformation temperatures between 110°F and 155°F. These two extreme phase-change temperatures have been successfully tried using the present invention.

Disclosure of Invention

A solar air heating system which includes a collector, a heat exchanger, and an energy storage volume, all arranged onto a unitized panel and sometime hereinafter referred to as CHE unit. A phase-change medium is isolated within the energy storage volume, and a solar heat collector is arranged in heat transfer relationship respectively to the energy storage volume. The solar collector is oriented to receive solar energy from the sun. The heat exchanger comprises apparatus by which relatively cool air is forced to flow by natural convection or by a fan in heat exchange relationship respective to the energy storage volume as well as the collector plate so that heated air emerges from the unit.

A number of units can be connected in either series or parallel relationship and integrated or retrofitted into a prior art air conditioning or furnace ducting system, thereby minimizing the initial cost of the entire system. In addition, several units can be mounted on outside walls of the residence and collect, store and transfer solar energy directly to the enclosure in a passive manner.

In the preferred embodiment of the invention, a hermatically sealed subdivided chamber is filled with wax. A top absorber plate is affixed to the top of the subdivisions and provides the means by which solar energy is transferred directly from the collector into the energy storage volume.

The opposed ends of the subdivided chamber are attached in heat transfer relationship to a heat exchanger, thereby allowing heat exchange to occur between the cells and the exchanger. Air is circulated through the heat exchanger, thereby providing means by which heat energy is transferred from the energy storage volume or the collector plate into the air which circulates through the enclosure to be heated.

The solar panels can operate in three distinct modes: Collector to house, collector to energy storage, and energy storage to house. The present collector system employs a phase change wax which is directly in contact with an absorber plate. The wax, when heated to its phase change temperature, stores all of its latent heat of fusion without any further increase in absorber plate temperature. This is due to the absorber plate temperature being held invarient because of the thermodynamics of a single component system (the wax) existing simultaneously in both the solid and liquid phases.

A primary object of the present invention is the provision of improvements in solar air heating systems.

Another object of the present invention is to provide a retrofittable, active as well as passive solar air heating system which uses a phase-change medium in which latent heat of fusion is made available for heating air.

A further object of the present invention is the provision of an integrated collector, heat exchanger, and energy storage volume combined into a single, inexpensive, compact unit.

Still another object of the present invention is the provision of a combination collector, heat exchanger, and energy storage volume combined into a unit and mounted on the roof of an enclosure to be heated, or mounted vertically against a south facing wall of an enclosure to be heated.

An additional object of this invention is the provision of a unitized collector, heat exchanger, and energy storage volume which comprises an active as well as a passive solar heating apparatus which greatly increases the efficiency of operation, is inexpensive to fabricate, and is relatively small in space requirements as compared to prior art solar heating systems with energy storage provisions.

Another object of the invention is the provision of a CHE comprising a hermetically sealed subdivided chamber filled with wax, with a top absorber plate affixed to the top of the subdivided chamber to provide means by which solar energy is transferred directly from a solar collector into an energy storage volume. In one embodiment of the invention the subdivided chamber is made of individual honeycomb cells or a series of rippled metallic sheets. In another embodiment both the energy storage volume as well as the heat exchanger are made of porous metallic or graphite cells.

An additional object of the invention is the provision of a solar heating system wherein solar energy is simultaneously transferred into an energy storage volume and into an airduct so that solar heat is immediately used for heating an enclosure, while at the same time the residual solar energy is stored for later use.

A further object of the present invention is the provision of a solar panel which operates in three distinct modes: collector to load; collector to energy storage; and, energy storage to load.

These and other objects and advantages of the invention will become readily apparent to those skilled in the art upon reading the following detailed description and claims and by referring to the accompanying drawings.

The above objects are attained in accordance with the present invention by the provision of a method for use with apparatus fabricated in a manner substantially as described in the abstract and summary.

Brief Description of the Drawings

Figure 1 is a fragmentary, perspective, part diagrammatical, illustration of a solar air heating system made in accordance with the present invention;

Figure 2 is an enlarged, perspective view of part of the apparatus disclosed in Figure 1, with some parts thereof being broken away therefrom in order to disclose the interior thereof;

Figure 3 is an enlarged, exploded, perspective view of the apparatus disclosed in Figure 2;

Figure 4 is an enlarged, fragmentary, cross-sectional view taken along line 4-4 of Figure 3;

Figure 5 is an enlarged, fragmentary, part cross-sectional, detailed view of an alternate embodiment such as may be taken along line 5-5 of Figure 1;

Figure 6 is a longitudinal, fragmentary, part cross-sectional, schematical representation of another embodiment of the present invention;

Figure 7 is a lateral, enlarged, cross-sectional view as may be taken along line 7-7 of Figure 1, which discloses another embodiment of the present invention;

Figure 8 is a broken, perspective bottom view which discloses some of the details of Figure 7, with some parts thereof being broken away therefrom in order to disclose the interior thereof;

Figure 9 is a fragmentary, perspective top view of the apparatus disclosed in Figure 7, with some parts being broken away therefrom in order to more clearly disclose the interior thereof;

Figure 10 is an enlarged, cross-sectional view of an alternate embodiment of the invention such as may be taken along line 5-5 of Figure 1;

Figure 11 is a cross-sectional view which sets forth a further modification of Figure 6; and

Figure 12 is an enlarged, cross-sectional detailed fragmented view taken along line 12-12 of Figure 11.

Modes for Carrying Out the Invention

In Figure 1, there is disclosed a solar heating system 10 made in accordance with the present invention. A plurality of solar panels, also referred to as solar collectors, are arranged on the roof of an enclosure 14, as for example, a residence located in the southwestern geographical area of the United States. Heated air emerges at 16 from the panels, and is conducted through a suitable passageway to a furnace 20, which preferably is a gas furnace of conventional design. Air from the furnace is conducted through a suitable duct, as indicated by numeral 21, which can be the present air conditioning or heating ducts, and into the enclosure 14 where the air is heated, as may be desired. Return air from the heated enclosure enters the panel at inlet 22.

As seen in Figure 2, together with other figures of the drawings, the panel 12 includes an outlet end 23, opposed sides 24 and 25, a bottom 26 (Figure 1), a top 28 which is opposed to the bottom, and an inlet end 30 opposed to the outlet end 23. The outlet end can be made identical to the inlet end. The top 28 in the embodiment of Figure 2 comprises one or a plurality of sheets of glass suitably supported in the illustrated position by means of a support frame 36 which sealingly engages the entire peripheral edge of both the glass and the upper edge of the walls of the panel.

In Figures 3 and 4, a plurality of downwardly directed heat transfer fins 32 are connected in heat transfer relationship respective to a subdivided chamber, preferably in the form of the illustrated structure 34. The fins extend into an air chamber formed between the housing of the panel and the lower surface of the finned structure. Insulation 38 preferably is rectangular in form and presents an upwardly opening, box-like container within which the finned structure is received. In Figure 4, the energy storage structure 34 is seen to be comprised of a series of coacting baffles 33, 35 arranged in interlocking spaced relationship respective to one another. Fins 32 are a continuation of the baffle structure 33, while the roof 40 is a continuation of the baffle structure 35. A subdivided chamber comprised of a wax receiving multiplicity of communicating chambers 42 is formed by the structure of Figure 4.

Figure 5 sets forth another embodiment of the invention, wherein there is disclosed a solar collector having a chamber divided into spaces 45 which underlie a collector roof 43. Inverted, U-shaped heat transfer elements 44 have a medial portion thereof connected to roof 43, and thereby rapidly and directly transfer heat from the collector roof 43, into the small chambers 45. An upright U-shaped heat transfer element 46 has a medial portion thereof connected to a floor 48, so that the heat energy contained within the cells 45 is rapidly transferred directly into the floor 48, and then into the fins 32. The fins are an integral part of the floor.

Number 47 indicates that a pair of adjacent cells are in communication with one another at the lower end of one leg of the inverted U, while numeral 49 indicates that the upper end of a pair of adjacent cells are placed in communication with one another by one leg of the upright U 46.

Roof 40 and floor 48 are joined together at 50 to hermetically seal the interior 42 of the collector, thereby preventing contamination of the heat transfer medium located therewithin. Foam at 52 and 53 provides insulation at critical locations about the solar collector apparatus, and prevents significant loss of energy to the ambient.

As seen disclosed in Figures 1, 3, and 5, air passageway connector 54 interconnects the outlet 22", 30' of one solar panel with the inlet 22, 22' of an adjacent solar panel, when the collectors are placed in series relationship. Insulation 57 provides suitable insulation at the bottom of the air passageway 55.

Figure 6 discloses another embodiment 212 of the panel of the present invention. A collector plate 60, similar in many respects to the structure 40 of Figure 5, forms an air space 62 in conjunction with glass 28.

The subdivided chamber of Figure 6 is in the form of an aluminum honeycomb structure 64 which is filled with a phase-change substance, such as wax, and the wax is maintained isolated within the honeycomb structure in a manner similar to some of the previously disclosed embodiments. A heat exchange member 65 made of metallic honeycomb, or of a finned construction, exchanges heat between structure 64 and an air passageway 66, which is formed between the honeycomb structure and insulation 68.

Connecting framework 70 reinforces the entire structure and provides support structure for the glass 28. Metal covering 72 encloses the structure and provides a suitable housing therefor. Throughbolt 74 maintains the structure properly connected together. Sheet metal screws additionally interlock one sheet metal member with another.

Figures 7-9 illustrate another embodiment of the present invention. In Figures 7 and 9, a collector plate 76 is directly affixed in efficient heat transfer relationship to a honeycomb heat exchanger structure 78. Heat transfer assembly 80 is directly connected to efficiently transfer heat from the lower face of the honeycomb structure 78 into the wax receiving honeycomb structure 82 comprising the energy storage volume within which wax is stored. Housings 84 and 86, seen in Figures 8 and 9, respectively, enclose the heat exchanger 78 and energy storage volume 82, respectively.

The upper surface 88 of the collector plate 76 is preferably insulated from ambient with a suitable barrier, such as glass panes or sheets of treated clear plastic, to minimize convective and radiation losses. The lower face 90 of the collector plate 76 is connected in heat transfer relationship respective to the air passageway which forms the heat exchanger 78. The lower surface of the heat exchanger 78 is connected in heat transfer relationship to the upper face 92 of the energy storage volume 82. Accordingly, cool air flowing through cold air return passageway 96 receives energy from the energy storage volume 86, or directly from the collector plate 76.

In cold winter months, as solar energy is received at 88, the solar energy during the day can be directly transferred into the return passageway 96, while at the same time excessive solar energy is transferred into the energy storage volume 82, or, if the competing driving forces of the heat flow mechanism so demands, heat can simultaneously be extracted from the collector plate 88 and the energy storage volume 82 by the air flowing through the return passage 96.

Figure 10 is a lateral cross-sectional view similar to Figure 5 which illustrates another embodiment of the present invention. Water pipes 100 are provided with a plurality of fins 101 attached thereto. The pipes and fins are imbedded in the phase change medium 102. The fins 101 are in thermal heat transfer relationship respective to the U shaped heat transfer elements 44 and 46. Accordingly, thermal energy received at the collector plate 43 is transferred to the energy sub-divided cells 45 and stored for later preheating of water or, alternatively, the energy can be made immediately available to preheat domestic hot water through the pipe and fin assembly 100 and 101, respectively.

Figures 11 and 12 disclose a further embodiment of the invention which is a modification of Figure 6, wherein the collector plate 60 forms the roof of the enclosure 103. Enclosure 103 is comprised of porous metal cells or porous graphite cells 61 which surround and subdivide a phase change medium. Solar energy impinging on the collector 60 is thereby rapidly transferred directly to an energy storage medium contained within the cells 61 of enclosure 103.

In Figures 11 and 12, the floor 105 of enclosure 103 forms the roof of the heat exchanger passage 104 while the floor of said heat exchanger passageway forms the top of the enclosure containing the insulation 68. The heat exchanger 104 is comprised of metallic or graphite cells 107 whose communicating chambers are in heat transfer relationship to the energy storage medium contained within the enclosure 103 by means of the communicating chambers 61 and the thermally conducting floor 105. The heat exchanger passageway 104 is also in direct heat transfer with the collector plate 60 thereby permitting solar energy to be made immediately available to heat the house during cold winter days.

Operational Modes of the System.

The solar panels can operate in three distinct modes: separately or in combination with one another: collector-to-load, collector-to-energy storage, and energy storage-to-load. Each of these modes is described further below.

Collector-To-Energy Storage Mode:

In this mode, the CHE unit acts in a passive manner and transfers converted solar energy directly to the phase-change medium via aluminum honeycomb or other metallic conductors. The aluminum honeycomb, which is in direct contact with the absorber plate, uniformly distributes the solar energy throughout the storage volume. The total energy stored in the CHE unit is manifested in three ways: The sensible heat of the phase-change wax; the heat of fusion of the wax; and the sensible heat of the aluminum honeycomb or other metallic conductors.

Collector-To-Load Mode:

Solar energy absorbed by the collector system of the CHE unit can be sent directly to the load during the daytime. In this mode of operation, "cold" air from the return duct enters the CHE unit and, in one embodiment of the present invention, is passed directly below the heat storage units and back into the house by use of the blower. In a variation of this design, "cold" air from the house is also passed directly over the hot absorber plate, in addition to its being baffled through the channel below the heat storage unit.

Energy Storage-To-Load Mode:

In the "active" embodiment of this invention, when the temperature in the residence drops below a preset value, the furnace blower is turned on, which drives "cold" return air from the house through the CHE unit, where it absorbs the energy stored during the daytime in the energy storage volume. The temperature of the energy storage medium will drop until all of the sensible heat above the phase-change temperature is removed. Further energy extraction will result in solidification of the wax, which occurs at the constant phase-transformation temperatures, with a concomitant release of approximately 95 BTU/lb. Further energy needs can be supplied by the sensible heat of the wax and the aluminum honeycomb below the phase-change temperature of the wax, down to approximately 70°F, before the furnace burner is turned on. In the "passive" embodiment of this invention, natural thermal convection is used to drive the energy, stored in the phase change medium, out of the vertically mounted solar panel and directly into the attached enclosure.

<u>Solar Selective Surface Enhancement</u>.

Solar collector efficiencies are increased by the use of selective surface absorbers. In an application, it is desirable to increase the absorptivity, a, while making the infrared emissivity, E, as low as possible. Unfortunately, this combined effect is often very difficult to achieve in an operational surface since, generally, both parameters tend to change in the same direction. Recently, Collier (R. K. Collier, "A Simplified Technique For Comparing the Effectiveness of Collector Absorber Coatings," Solar Energy, 23, 1979, p. 455.) has discussed a simplified method of comparing solar absorber selective surfaces whose graphic presentation permits a determination of the ease or difficulty of increasing the thermal performance of the absorber. Collier shows that the lower the absorber temperature, T_S, the lower is the function B, for a given reradiating glazing temperature, T_C. The function B is the ratio of the change in absorptivity, a, to the change in emissivity, E. The lower this ratio is, the greater is the possibility of changing one of these parameters and still improving the thermal performance of the absorber, despite the fact that the second parameter is changing in the same direction.

When the present invention was tested in an early summer environment, the absorber plate did not exceed 15°F above that of the phase-transformation temperature of the wax (110°F) during its melting time. Consequently, it is not expected that the absorber plate would reach temperatures in excess of 125°F during solar collection/storage in the winter months, while most hot air collectors are reported to operate above the range of 200°F. If the average January insolation for Albuquerque, New Mexico, of 1133 BTU/ft^2/day is chosen with an assumed reradiating glazing temperature of 10°C, (Collier's Figure 1), B would be about 0.4 for the present absorber, while it would be about 1.25 for a hot air absorber plate which reached 225°F while operating under similar ambient conditions. That is, the latter plate would require an increase in the absorptivity greater than 1.25 times the concomitant increase in the emissivity in order to improve the thermal performance of a typical hot air absorber operating with a selective surface. On the other hand, because the collector plate in the present invention is forced to operate at a lower temperature due to the invariance of the phase change medium while it is melting, an increase of the absorptivity of only 0.4 times the increase in the emissivity is required in order to achieve an increase in the performance of the absorber; a reasonably easy objective to achieve.

The forte of the present solar heating system is to combine the solar collection, heat exchanger, and energy storage functions into a single, compact unit (CHE unit) which is light enough to be retrofitted onto the roof of existing residences. This unique synergism of several active as well as passive operational features permits higher efficiency as well as greater cost reductions to be realized, which are unattainable with other contemporary systems.

The overall system is simplified and contains fewer individual subsystems compared to conventional systems performing the same operational functions. For example, during solar collection, the CHE units act in a passive mode and therefore do not require a fan motor to circulate the air past the absorber plate. In addition, due to the novel component arrangement, wherein the absorber plate is directly connected to the thermal storage volume, the requirement for ducting to transport the heated air to the usual rock-bed storage or water storage heat exchanger is eliminated.

Another unique feature of the present collector system is the employment of a phase change medium which is directly in contact with the absorber plate. Consequently, once the medium reaches its phase change temperature, it will store all of its latent heat of fusion without any further increase in absorber plate temperature, thus avoiding further degradation in absorber efficiency. This unique feature of the invention is realized because the absorber plate temperature is held invariant due to the thermodynamics of a single component system wherein the phase change medium exists simultaneously in two physical states (solid and liquid). In contrast to this phenomenon, the average temperature of a conventional air-type absorber continues to rise continuously up to the maximum heating portion of the day. Operation of absorber plates at elevated temperatures results in a decrease in collector efficiency, with greater heat losses occuring through the insulation and a more rapid thermal degradation of the collector materials.

An additional desirable and novel feature of the present invention is the achievement of a maximum summertime stagnation temperature, which is about 150°F below that of many conventional collectors. The stagnation temperature remains so low because of the unique design of the collector which directly connects the absorber plate to the large thermal mass of phase-change medium held in the solar energy storage core.

Since the phase change medium's temperature remains constant until the entire mass melts, requiring approximately 100 Btu/lb of wax and aluminum honeycomb, the collector remains rather cool and only increases its temperature beyond this point by the further absorption of sensible heat. Here again, since the combined specific heats of the wax and the aluminum are about 0.78 Btu per pound, large temperature increases are mitigated.

Another unique feature of this invention is its capability to provide domestic hot water after solar insolation has ceased. As illustrated in Figure 10, domestic hot water heating can be provided through pipes imbedded in the energy storage volume. Consequently, energy provided directly by the collectors in day time or by the latent heat of fusion of the phase change medium in the early morning or evening can be used to preheat water for domestic use when sunshine is absent. Passage of water through these pipes in the summertime will provide an additional advantage in that it will further help to lower the stagnation temperature of the collector in addition to the effect achieved by the phase change medium itself.

I CLAIM:

Claim 1. Solar air heating panel having an air inlet, an air outlet; means forming a collector, a heat exchanger, and an energy storage volume within said panel;

said energy storage volume includes a phase change medium in which the latent heat of fusion thereof is made available; means directly connecting said energy storage volume in heat transfer relationship respective to said collector and said heat exchanger, whereby air flow through said panel occurs across said heat exchanger, thereby extracting heat therefrom; and, solar energy directed onto said collector causes heat to be stored within said energy storage volume.

Claim 2. The solar heating panel of Claim 1 wherein said collector is placed above said energy storage volume and said heat exchanger is placed below said energy storage volume.

Claim 3. The solar heating panel of Claim 2 wherein said energy storage volume comprises a plurality of subdivided chambers filled with said phase change medium;

said collector includes an absorber plate affixed to the upper extremity of said subdivided chambers so that solar energy is directly transferred into the phase change medium.

Claim 4. The solar heating panel of Claim 3 wherein said heat exchanger underlies said subdivided chambers and is directly connected thereto so that air can flow from said inlet, through said heat exchanger, and through said outlet.

Claim 5. The solar heating panel of Claim 1 wherein said energy storage volume is an enclosure which is subdivided into a multiplicity of small chambers, there being a phase change medium stored within the small chambers, the upper end of said energy storage volume being closed by said collector, the lower end of said energy storage volume being closed by said heat exchanger;

means connecting said collector, energy storage volume, and heat exchanger together in heat transfer relationship respective to one another;

whereby solar energy received by said collector is directly transferred into said phase change medium and from said energy storage volume directly to said heat exchanger;

means connecting said heat exchanger respective to said inlet and outlet so that air flows in heat exchange relationship through the heat exchanger.

Claim 6. The panel of Claim 5 wherein said upper closure member is a metallic plate member affixed in spaced relationship to a transparent member;

said heat exchanger includes a chamber to which said inlet and outlet are connected, the upper wall of the chamber is a metallic plate member which forms the lower closure member for said energy storage volume; said heat exchanger further includes heat transfer fins extending from attached relationship respective to said lower plate member and into the air chamber.

Claim 7. A packaged active solar heater device comprising:

a collector, a heat exchanger, and an energy storage volume;

said energy storage volume is at least partially filled with a phase change medium which is isolated within said energy storage volume;

said collector is in heat transfer relationship respective to said phase change medium, said collector is adapted to be oriented to receive solar energy from the sun;

said heat exchanger is placed in heat transfer relationship respective to said phase change medium, and further includes an inlet and outlet by which air flows in heat exchange relationship through the heat exchanger.

Claim 8. The device of Claim 7 wherein said collector is placed above said energy storage volume and said heat exchanger is placed below said energy storage volume.

Claim 9. The device of Claim 7 wherein said energy storage volume comprises a plurality of subdivided chambers filled with said phase change medium;

said collector includes an absorber plate affixed to the upper extremity of said subdivided chambers so that solar energy is directly transferred into the phase change medium and into the heat exchanger.

Claim 10. The device of Claim 7 wherein said heat exchanger underlies said subdivided chambers and is directly connected thereto so that air flows from said inlet, through said heat exchanger, and through said outlet.

Claim 11. The device of Claim 7 wherein said energy storage volume is an enclosure which is subdivided into a multiplicity of small chambers, there being a phase change medium stored within each of the small chambers, the upper end of said energy storage volume being closed by said collector, the lower end of said energy storage volume being closed by said heat exchanger,

said collector, energy storage volume, and heat exchanger being connected together in heat transfer relationship respective to one another;

whereby solar energy received by said collector is directly transferred into said phase change medium and to said heat exchanger;

means connecting said heat exchanger respective to said inlet and outlet so that air flows in heat exchange relationship through the heat exchanger.

Claim 12. The device of Claim 7 wherein said energy storage volume includes an upper closure member in the form of a metallic plate member affixed in spaced relationship to a transparent member;

said heat exchanger includes a chamber to which said inlet and outlet are connected, the upper wall of the chamber is a metallic plate member which forms a lower closure member for said energy storage volume; and heat transfer fins extending from attached relationship respective to said lower plate member and into contact with any air which may be flowing through the heat exchanger.

Claim 13. The device of Claim 7 wherein said heat exchanger is positioned between the collector and the energy storage volume, so that solar energy directly heats the heat exchanger; and, energy can be extracted from the energy storage volume when solar energy is unavailable.

Claim 14. The device of Claim 7 wherein a water conduit is placed in heat transfer relationship respective to the phase change medium so that water contained within said water conduit is heated whenever the temperature of said energy storage volume is above the water temperature.

Claim 15. The device of Claim 7 wherein a porous graphite body is used for the energy storage volume and the heat transfer enclosure.

Claim 16. The device of Claim 7 wherein a porous metal is used for the energy storage volume and the heat transfer enclosure.

Claim 17. Method of transferring heat from a solar collector into a heat exchanger comprising the steps of:

(1) isolating a quantity of material which changes from a liquid phase into a solid phase at a temperature of 80-155°F;

(2) using a solar collector as a closure member at the top of the isolated material;

(3) using a heat exchanger as a closure member at the bottom of the isolated material;

(4) orienting the collector to receive solar energy from the sun, and directly heating the phase change medium with the collector;

(5) flowing air through the heat exchanger to thereby elevate the temperature of the air.

Claim 18. The method of Claim 17 wherein said collector is placed above said energy storage volume and said heat exchanger is placed below said energy storage volume.

Claim 19. The method of Claim 17 and further including the step of subdividing said energy storage volume into a plurality of small chambers and filling said small chambers with said phase change medium;

providing said collector with an absorber plate and affixing said plate to the upper extremity of said subdivided chambers so that solar energy is directly transferred into the phase change medium and into the heat exchanger.

Claim 20. The method of Claim 17 and further including the step of arranging said heat exchanger in attached relationship below said subdivided chambers, and directly connecting said heat exchanger to the lower end of the energy storage volume so that air flows from said inlet through said heat exchanger, and through said outlet.

Claim 21. The method of Claim 17 and further including the step of subdividing said energy storage volume into a multiplicity of small chambers; storing a phase change medium which changes phase at a temperature between 80°F and 155°F within the small chambers; closing the upper end of said energy storage volume by said collector; closing the lower end of said energy storage volume by said heat exchanger;

connecting said collector, energy storage volume, and heat exchanger together in heat transfer relationship respective to one another;

whereby solar energy received by said collector is directly transferred into said phase change medium and to said heat exchanger.

Claim 22. The method of Claim 17 and further including the step of positioning said heat exchanger between the collector surface and the energy storage volume.

Claim 23. The method of Claim 17 and further including the step of heating water whenever the temperature of said energy storage volume is above the temperature of the water by positioning water conduits in heat transfer relationship respective to the phase change medium.

Claim 24. The method of Claim 17 and further including the step of using porous graphite for the energy storage volume and the heat transfer enclosure.

Claim 25. The method of Claim 17 and further including the step of using porous mètal for the energy storage volume and the heat transfer enclosure.

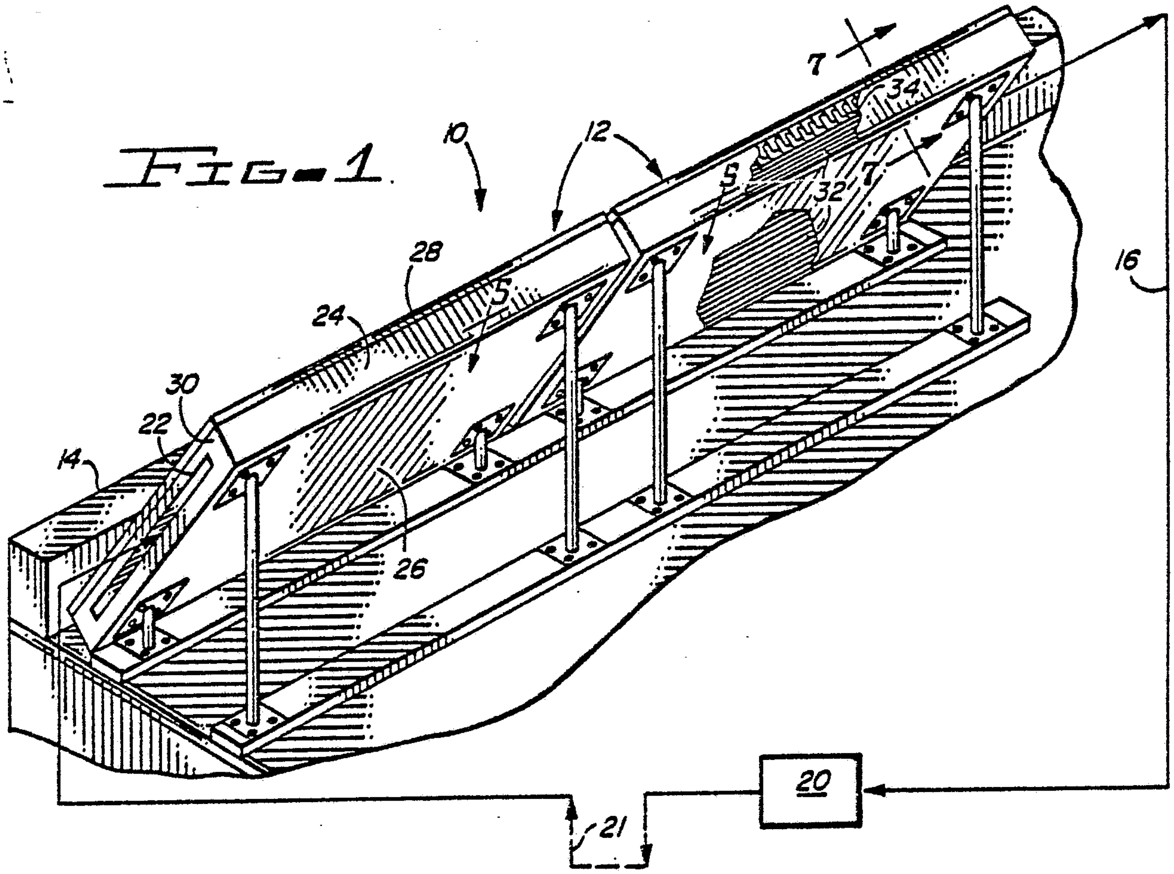


FIG-1

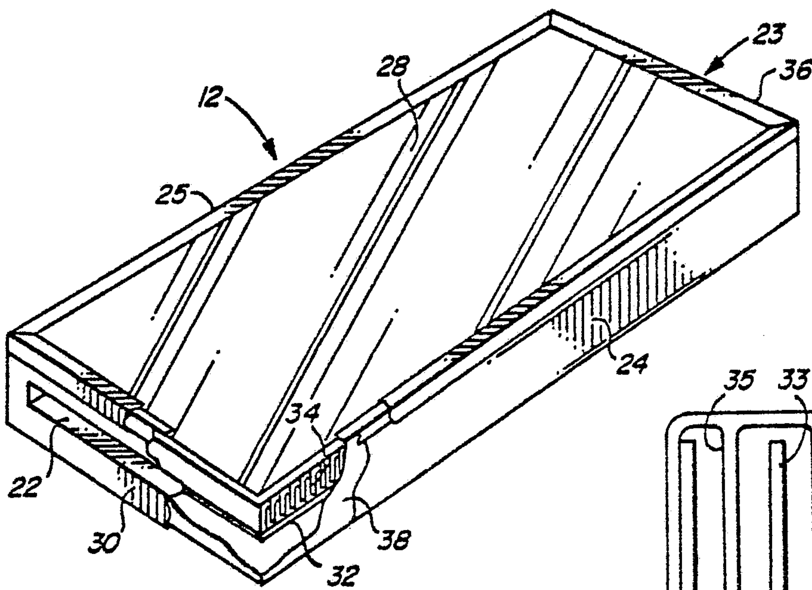


FIG-2

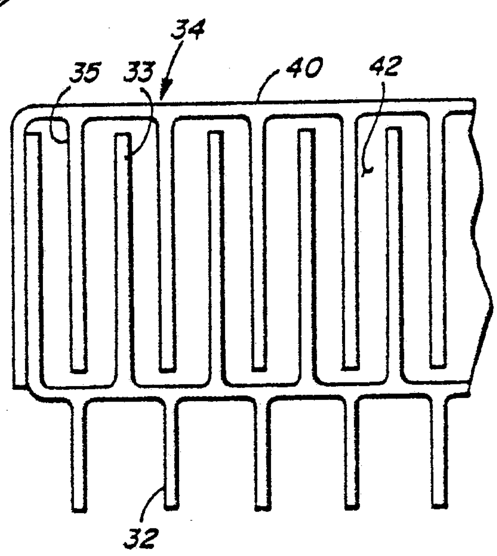
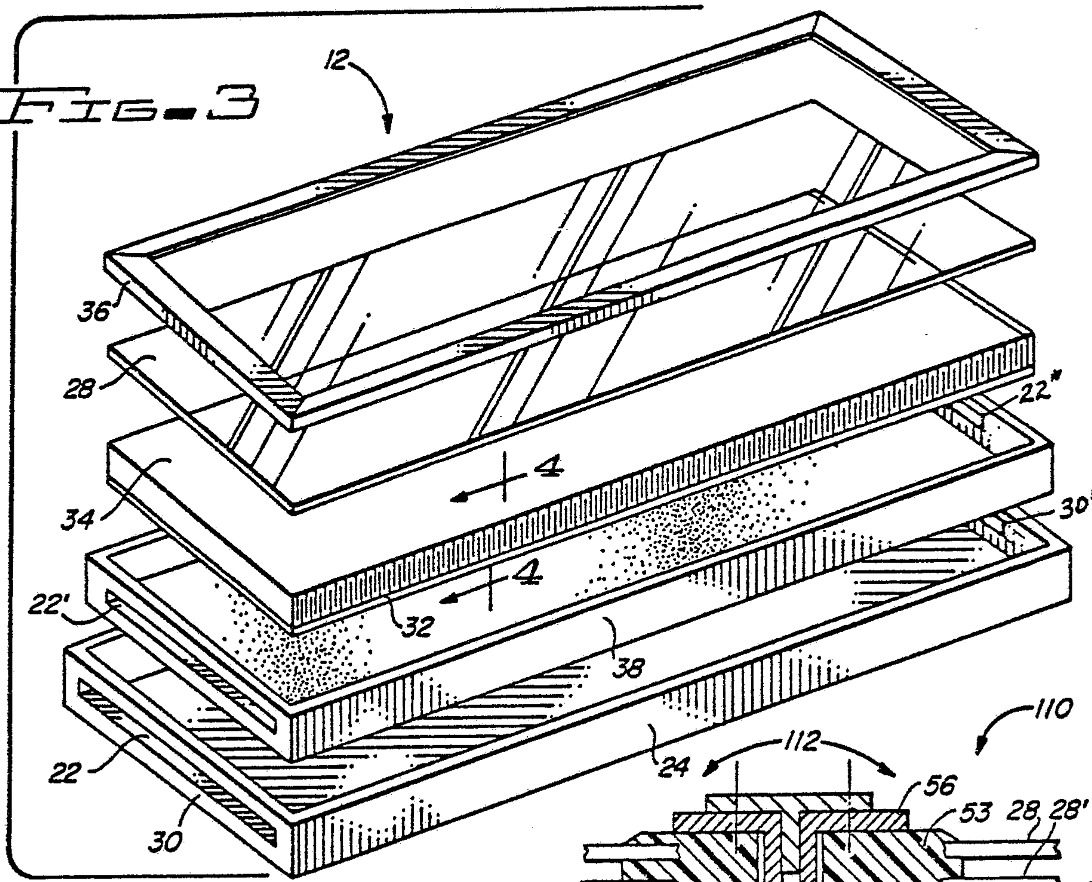


FIG-4

FIG. 3



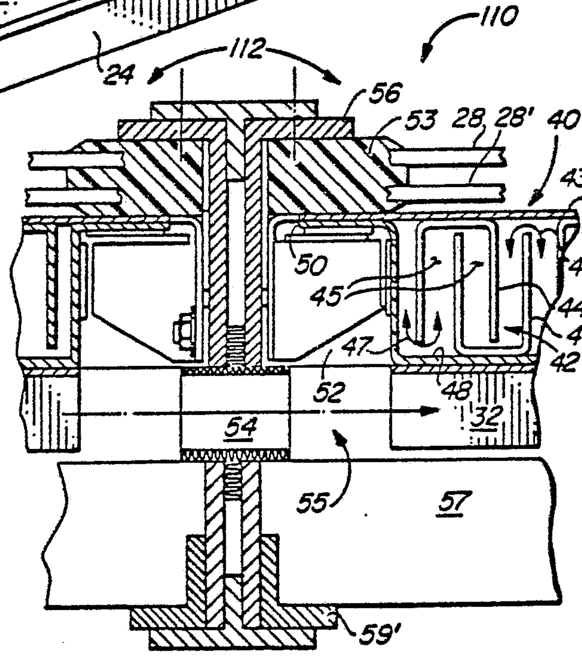


FIG. 5

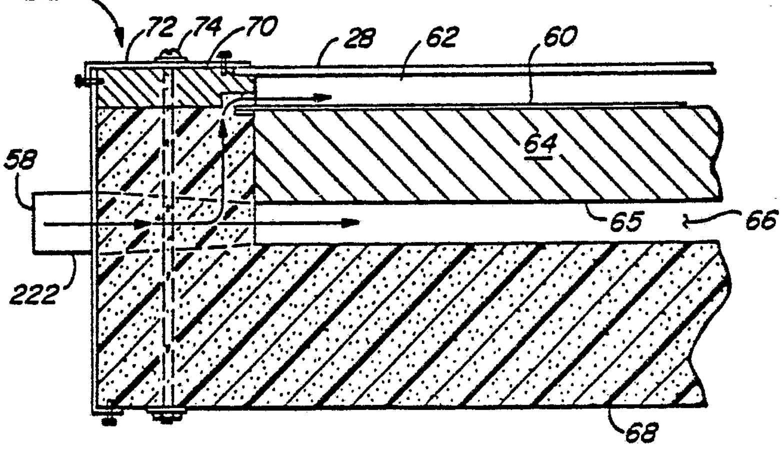


FIG. 6

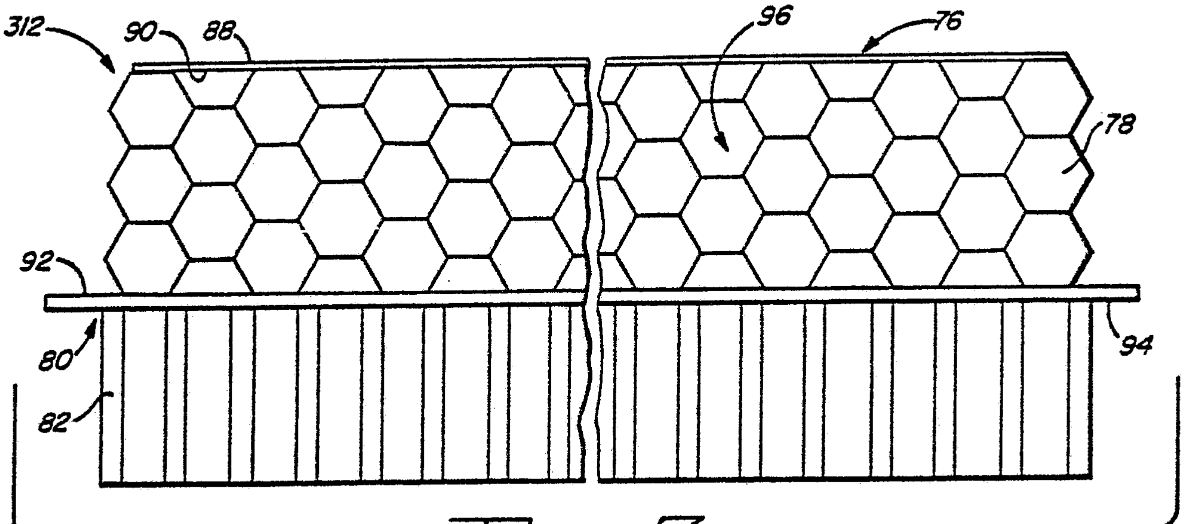
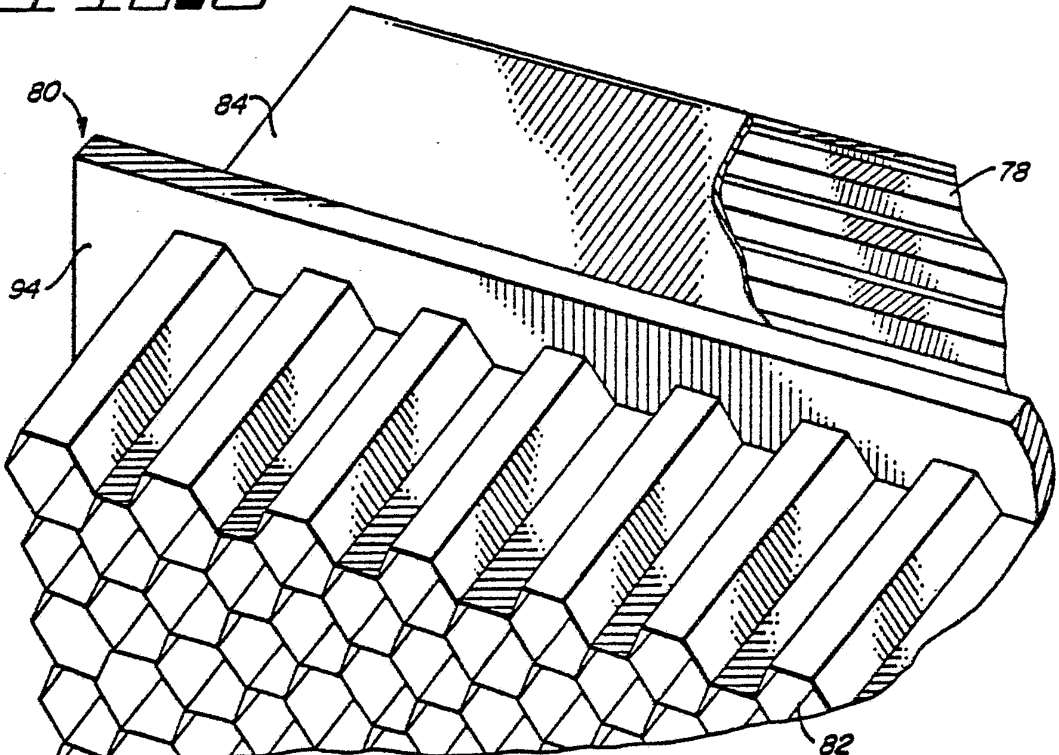


FIG. 7

FIG. 8



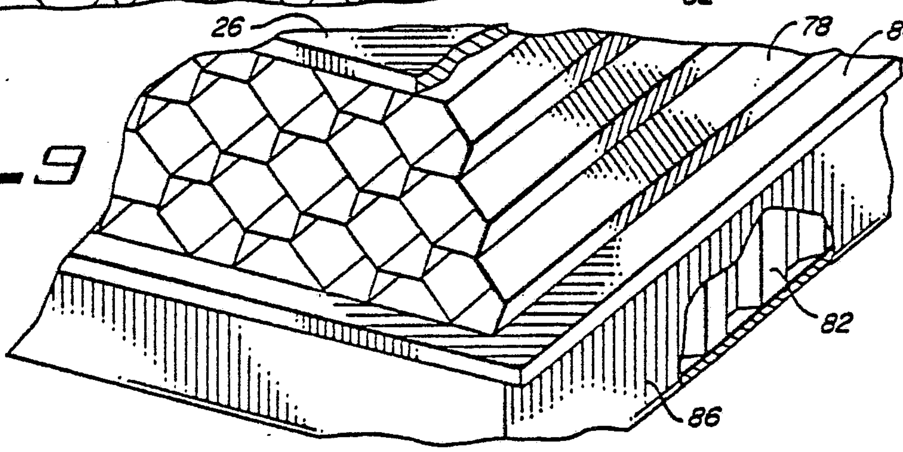


FIG. 9

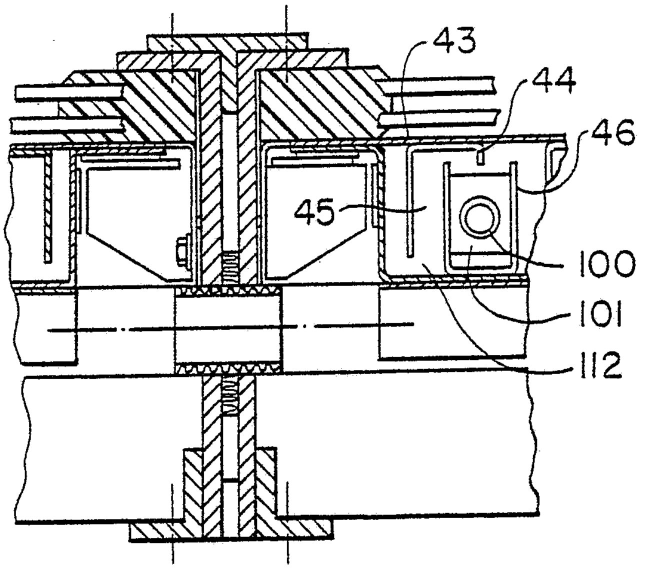


FIG. 10

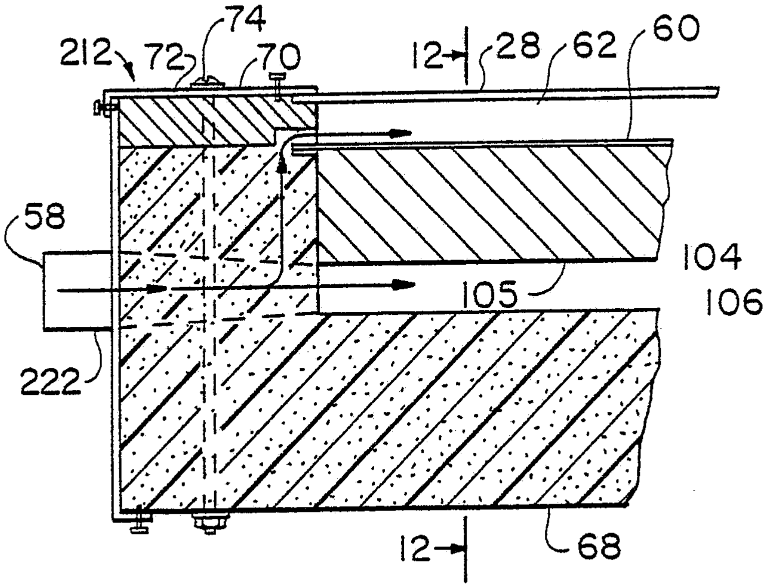


FIG. 11

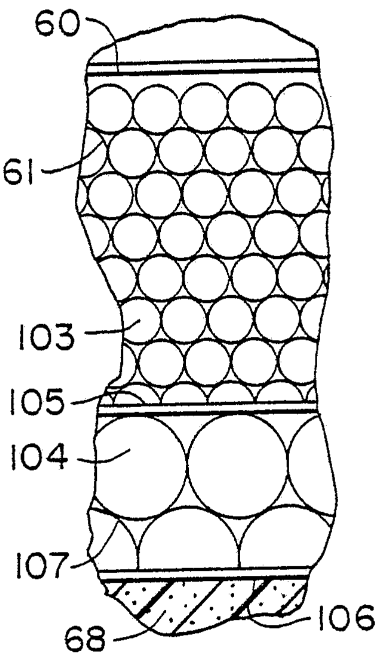


FIG. 12

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 84/01005

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.3 F24J 3/02

U.S. CL. 126/447; 165/10

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	126/400, 436, 446, 447, 452 165/10, 10A, 1, 104.12, Dig. 4, Dig. 10

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A 4,389,533 21 June 1983 (21.06.83) Ames	1, 2, 7, 8, 17, 18, 22
X	US, A, 2,911,513 03 Nov. 1959 (03.11.59) MacCracken	3-5, 9-11, 19, 21
Y	US, A, 3,996,919 14 Dec. 1976 (14.12.76) Hepp	6, 12, 17-21
Y	US, A, 4,384,569 24 May 1983 (24.05.83) Clearman	13, 14, 23
A	US, A, 4,250,871 17 Feb. 1981 (17.01.81) Milburn	----
Y	US, A, 4,068,652 17 Jan. 1978 (17.01.78) Worthington	1, 5-7, 9, 12, 13

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
September 7, 1984	13 SEP 1984
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	GERALD ANDERSON

Form PCT/ISA/210 (second sheet) (October 1981)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No [18]
A	JP, A,57-35,293 25 Feb. 1982 (25.02.82)	
Y	US, A, 4,268,558 19 May 1981 (19.05.81) Boardman	15, 16, 24, 25
Y	US, A, 4,332,690 01 June 1982 (01.06.82) Kimura et al	15, 16, 24, 25

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ **OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE** [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ...., because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☒ **OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING** [11]

This International Searching Authority found multiple inventions in this international application as follows:

I. Claims 1-16 drawn to the apparatus of a solar collector.

II. Claims 17-25 drawn to a method of heat exchange.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☒ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.