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(54) **Title**: PERFORATED TRANSPARENT GLAZING FOR HEAT RECOVERY AND SOLAR AIR HEATING

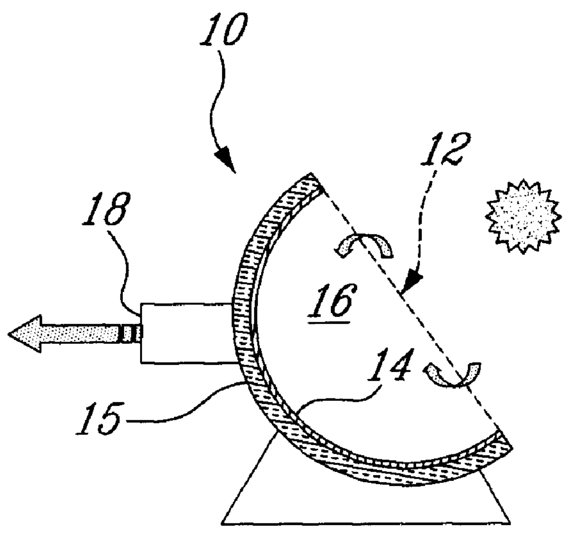

FIG. 1

(57) **Abstract**: A heat collector comprises a transparent glazing (12) exposed to the ambient. The transparent glazing (12) is spaced from a back surface to define a plenum (16) therewith. A plurality of perforations is defined through the transparent glazing (12) for allowing outside air to flow through the transparent glazing (12) into the plenum (16) and substantially maintain the transparent glazing (12) at the ambient temperature, thereby providing for higher thermal efficiency.

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PERFORATED TRANSPARENT GLAZING FOR HEAT RECOVERY AND SOLAR AIR HEATING

TECHNICAL FIELD

The present application generally relates to a device suited for pre-heating fresh outside air by means of free energy, such as solar energy and/or heat recovery.

BACKGROUND ART

Design of traditional glazed solar air heaters generally comprises a glass, polycarbonate or Lexan® transparent cover placed in front of a dark solar absorber. The front transparent cover is provided for minimizing heat losses from the top of the collector. Fresh outside air is traditionally admitted at on end of the collector between the front transparent cover and the solar absorber. The air passes through the collector along fins and absorbs heat from the solar absorber as it travels therealong. Warm or hot air is discharged at the opposite extremity of the collector. As air progresses inside the collector, its temperature rises above ambient. The higher the temperature in the collector is, the higher the heat loss towards the ambient becomes. Heat loss happens through the bottom, the edges and the top (where the glazing is) of the collector. Typically the edges and the bottom are insulated, so that heat loss mostly occurs through the top, that is by convection between the absorber and the glazing and then by conduction through the glazing. When the glazing becomes very warm, the collectors become less efficient.

Various unglazed solar air heaters have also been designed over the years. Current transpired collector designs are such that the solar absorbing surface is located outside facing the sun, unprotected by means of a glazing. The perforated absorber is coupled to a fan which creates a negative pressure between the building (or the bottom of the collector) and the absorber. When the fan is in operation, the air is drawn through the absorber. The air passing through the perforations in the outer opaque absorber breaks the naturally occurring warm film of air on the outside facing side (the boundary layer) of the absorber. This method provides acceptable performances when the flow of air per unit area exceeds 6 cfm per square foot of collector. However, for unitary flow rates below 5 cfm per square foot, the amount of cool air leaching the perforated plate is insufficient to prevent the collector plate from heating up, thereby negatively affecting the overall thermal efficiency of the system. Efficiencies at the rate of 2 cfm per square foot drop to 30% or even less.

SUMMARY

It is therefore an aim to address the above mentioned issues.

Therefore, in accordance with a general aspect of the present application, there is provided a heat collector comprising a transparent glazing exposed to the ambient, the transparent glazing being spaced from a back surface to define a plenum therewith, a plurality of perforations defined through the transparent glazing for allowing outside air to flow through the transparent glazing into the plenum, the perforations being distributed over a surface area of the transparent glazing, the plenum having an outlet, and air moving means to draw heated air from said plenum via said outlet.

In accordance with a further general aspect, the back surface includes a solar radiation absorbing panel.

In accordance with another general aspect, there is provided a device for heating air, the device comprising a perforated transparent surface allowing solar radiations to pass therethrough, a solar radiation absorbing surface located behind the perforated transparent surface for absorbing the solar radiations, and a gap of air defined between the perforated transparent surface and the radiation absorbing surface, the air flowing in the gap absorbing heat from the radiation absorbing surface while fresh ambient air flowing through the perforations of the perforated transparent surface providing for a minimal temperature delta through the transparent surface.

In accordance with still another general aspect, there is provided a transparent and perforated surface exposed to the ambient. The perforated transparent surface is spaced from a back surface so as to define an air gap or plenum therebetween. Fresh outside air is drawn into the plenum through the perforated

transparent surface. The back surface can, for instance, be provided in the form of a bottom of a solar collector, a building wall or roof, an outer surface of a greenhouse, a photovoltaic panel, the ground or any non-porous surface. Between the perforated transparent surface and the back surface, the gap of air is maintained under negative pressure due to mechanical or natural means. An outlet is provided for allowing the air flowing through the plenum to be drawn into a duct or a channel, for use as make-up, ventilation, process or combustion air to a device which consumes or needs thermal energy.

The air in the plenum is heated either by incident solar radiation on the surface of the back panel, which acts as a solar absorber, and/or by heat escaping from the back surface. The device can therefore act as a solar air heater and/or as a heat recovery unit. When used as a solar air heater, the back surface can be of a dark color, so that incident solar radiation passing through the perforated transparent surface is absorbed by the back surface in the form of heat and not reflected back to outer space. However, if the back surface, for any aesthetic reason or other, must be of light color, the solar thermal efficiency remains higher than other conventional unglazed collector design. This is particularly true when the device is used as a heat recovery device, since the back surface can be of any color with no influence on efficiency (it can even be transparent like in the case of a greenhouse), but the lower the thermal resistance (insulation) of the back surface, the greater the heat recovery rate. The device can be simultaneously used for both functions of solar heating and heat recovery.

If necessary, the preheated air leaving the device can have an auxiliary heating device located downstream (e.g. a gas-fired system) to bring its temperature to a given set point.

In accordance with a further aspect, there is provided a method of preheating outside air for a building having a sun-facing surface, the method comprising: providing on the sun-facing surface of the building a perforated transparent surface allowing solar radiations to pass therethrough, a plenum being defined between the perforated transparent surface and the sun-facing surface, drawing outside air through the perforated transparent surface into the plenum, capturing incident solar radiations passing through the perforated transparent surface, heating the air in the plenum using the captured solar radiations, and withdrawing the heated air from the plenum.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic side view of a solar collector including a perforated transparent surface in accordance with an embodiment of the present invention;

Fig. 2 is a schematic side view of another embodiment of a solar collector having a perforated transparent glazing;

Figs. 3 and 4 are schematic side views of ground-mount configurations of solar collectors having perforated transparent glazing in accordance with further embodiments of the present invention;

Fig. 5 is a schematic side view of a wall mounted solar collector having a perforated transparent glazing;

Fig. 6 is a schematic side view of a roof mounted solar collector having a perforated transparent glazing;

Fig. 7 is a schematic view illustrating a perforated transparent glazing surrounding a greenhouse shell for pre-heating cold outside air before being drawn into the greenhouse by a ventilation system; and

Fig. 8 is a graphic comparing the efficiency of perforated glazing collectors vs. unglazed perforated collectors as a function of the quantity of air flowing therethrough.

The term “glazing” is herein intended to broadly refer to any transparent surface allowing the light to pass therethrough.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 shows a solar air heater 10 provided in the form of an elongated conduit-like enclosure mounted on a base and including a sun facing perforated transparent glazing 12 exposed to the ambient and placed in front of a back panel having an arcuate solar radiation absorber plate 14 applied over an insulation layer 15. The back panel is generally provided in the form of a half-pipe wall covered with the perforated transparent glazing 12. The absorber plate 14 can be of a dark color to maximize solar gain. The perforated glazing 12 can be provided in the form of a perforated polycarbonate or transparent UV-resistant plate. Other transparent polymers could be used as well. The glazing 12 can be rigid or flexible. The perforations can be distributed over the entire surface of the glazing or over only a selected surface area thereof. The density of perforations can be uniform or variable over the glazing surface.

The perforated glazing 12 and the solar radiation absorber plate 14 define a plenum 16 therebetween. A fan or other suitable air moving means 17 is operatively connected to an outlet 18 provided at one end of the back panel to draw fresh outside air through the perforated glazing 12 into the plenum 16 before being directed to a ventilation system, such as a building ventilation system. The solar radiations passing through the perforated transparent glazing 12 are absorbed by the absorber plate 14. The air in the plenum 16 picks up the heat absorbed by the absorber plate 14 before being drawn out of the plenum 16. As air travels longitudinally along the plenum 16 between the absorber plate 14 and the perforated glazing 12, additional fresh outside air is drawn through the perforated glazing 12. In this way, the glazing 12 remains at a temperature substantially equal to the ambient temperature. Accordingly, the temperature differential between the incoming air and the ambient is equal to zero or close to zero, so that thermal efficiency remains at the highest possible value. Heat losses through the glazing cover are thus kept to a minimum.

Fig. 2 shows a second embodiment in which like reference characters refer to like components. The solar air heater 10a shown in Fig. 2 essentially differs from the solar air heater 10 shown in Fig. 1 in that the solar air heater 10a has a planar configuration characterized by spaced-apart parallel transparent glazing and back panel. The back panel is provided in the form of a flat absorber plate 14a applied over a planar layer of insulation material 15a. The absorber plate 14a could be corrugated. Sidewalls or supports 19a are provided along the perimeter of the back panel and the perforated transparent glazing 12a in order to create a uniform air gap 16a therebetween. The perforated glazing 12a and the back panel are preferably co-extensive. The back panel 14a can be provided in the form of photovoltaic (PV) panels to provide the double function of air heating and cooling the PV panels, which produce more electricity when their surface is kept at cool temperatures. As shown in Figs. 1 and 2, the perforated transparent glazing 12a is preferably supported at an inclination equal to the latitude of a given location, and facing the equator, depending on use. However, it is understood that the transparent glazing could be oriented and inclined otherwise. For instance, Fig. 4 shows a horizontally oriented perforated transparent glazing, whereas Fig. 5 shows a vertically oriented glazing.

As shown in Figs. 3 and 4, the solar air heater can be mounted directly on the ground, the ground surface forming the back panel of the device. In the embodiment of Fig. 3, wherein like reference characters refer to like components, the plenum 16b is formed by the perforated transparent glazing 12b, a building wall 20b and the ground G. The fresh outside air drawn in the plenum 16b is heated by the solar radiations absorbed by the ground G as well as by the heat escaping from the building through wall 20b. The fresh outside air flowing through the perforations defined in the transparent glazing 12b maintains the temperature delta across the glazing close to zero, thereby ensuring high thermal efficiency. The heated air is drawn out from the plenum 16b and circulated in the building B via the building ventilation system (not shown). As shown in Fig. 4, where like reference characters again refer to like components, the solar air heater can also be provided in the form of an enclosure having a perimeter wall 19c, a closed bottom end formed by the ground, and a top end covered by the perforated transparent glazing 12c. An outlet 18c connected to suitable air moving means is provided for withdrawing the heated air from the enclosure.

As shown in Figs. 5 and 6, the perforated transparent glazing 12d and 12e can be mounted in opposed facing relationship to a building wall 20d or the roof 22e of a building. In the embodiment of Fig. 5, the plenum 16d is formed between the outside surface of the building wall 20d and the adjacent vertically oriented perforated transparent glazing 12d. In the embodiment of Fig. 6, the plenum 16e is formed by the outside surface of the building roof 22e and the perforated transparent glazing 12e. In both embodiments, the heat escaping from the building envelope through the wall 20d or the roof 22e is recovered to heat the air in the plenum 16d and 16e. The roof 22e and the building wall 20d both act as solar radiation absorbers to further heat the ambient air drawn in the plenums 16d and 16e. The solar radiations pass through the perforated transparent glazing and are absorbed by the underlying building wall or roof surfaces and the air in the plenum absorbs the heat from the building wall or roof. As opposed to conventional solar walls or solar roofs wherein solar radiation are directly absorbed by dark panels covering the wall or roof of the buildings, the transparent glazing does not negatively alter the appearance (i.e. change the color of the building wall or roof) of the building. Unlike the prior art, the performance of the system is not influence or restricted by the color of perforated panels installed on the building wall or roof. The perforated glazing 12d and 12e are transparent and thus they do not change the color of the building wall or roof. No compromise has to be done for aesthetic purposes.

Fig. 7 shows a further potential application of the present invention. More particularly, Fig. 7 illustrates a greenhouse B' having a skeleton framework covered with a transparent skin 25f or membrane, as well know in the art. A perforated transparent glazing 12f is mounted to the greenhouse wall and roof to define a double-walled structure including an air gap 16f defined between the perforated transparent glazing 12f and the inner transparent skin 25. In this embodiment, the perforated transparent glazing 12f acts as a second insulation layer for the greenhouse B'. The heat escaping from the greenhouse through the inner skin 25 is recovered in the air gap 16f. A fan or the like can be provided for drawing heated air from the air gap back into the greenhouse B'. The perforated transparent glazing 12f maintains the required transparency required for plant growth.

As can be appreciated from the above embodiments, the device can be used in several applications including:

- Solar thermal air heaters
- Solar fresh air preheater mounted on building walls or roofs
- Hybrid solar air/water heating systems
- Preheating of air-to-air and air-to water heat pumps
- Transparent energy recovery device for greenhouses
- Cooling of photovoltaic panels
- Residential, low-cost solar preheater

Also various apparatus can be provided downstream of the device for further processing the air. For instance, the device could be coupled to the following units:

- Gas-fired make-up air unit
- Air-based heat pump (air-to-air or air-to-water)
- Swimming pool heat pump
- Combustion chamber
- Heat recovery unit

The above described transpired or perforated glazing offers numerous benefits. The incoming air is admitted throughout the glazing surface, either on a large proportion of its surface or over the entire surface. Accordingly, the glazing surface remains cold so that collector top heat loss is substantially prevented. Furthermore, the air temperature inside the collector remains relatively cold, lowering heat losses through the bottom and the edges. The proposed perforated transparent glazing design provides solar efficiencies at least as good as that provided by the perforated plate design at high flow rates. For lower flow rates, however, the solar efficiency remains high and by far exceeds that of opaque perforated collectors, and even exceeds that of glazed collectors, for less than half the cost. That can be readily appreciated from Fig. 8. More particularly, it can be seen that for flow rate between 2 and 6 cfm per square foot of perforated surface, the efficiency of a perforated glazing with a black backing surface is greatly superior to that a conventional black perforated sheet metal solar collector. The difference in performance is even more noticeable for light or white color solar collectors. The perforated glazing with a white color backing surface is up to 100% more efficient than a white perforated sheet metal collector. It can also be appreciated that the difference in performance between conventional unglazed perforated collectors and the above described perforated glazed designs is even more significant at low flow rates of, for instance, 3 or 4 cfm per square foot.

It will be apparent to one skilled in the art that modifications may be made to the illustrated embodiments without departing from the spirit and scope of the invention as hereinafter defined in the claims.

WHAT IS CLAIMED IS:

1. A heat collector comprising a transparent glazing exposed to the ambient, the transparent glazing being spaced from a back surface to define a plenum therewith, a plurality of perforations defined through the transparent glazing for allowing outside air to flow through the transparent glazing into the plenum, the perforations being distributed over a surface area of the transparent glazing, the plenum having an outlet, and air moving means to draw heated air from said plenum via said outlet.

2. The heat collector defined in claim 1, wherein the back surface includes a solar radiation absorbing panel.

3. The heat collector defined in claim 2, wherein said solar radiation absorbing panel overlies a layer of insulation material.

4. The heat collector defined in claim 2, wherein said solar radiation absorbing panel is curved.

5. The heat collector defined in claim 1, wherein the back surface comprises at least one photovoltaic panel.

6. The heat collector defined in claim 1, wherein the back surface is of a light color.

7. The heat collector defined in claim 2, wherein the solar radiation absorbing panel is corrugated.

8. The heat collector defined in claim 1, wherein the back surface has an elongated pipe-like configuration with the perforated glazing running longitudinally along one side thereof.

9. The heat collector defined in claim 1, wherein the plenum is at least partly delimited by a building wall.

10. The heat collector defined in claim 1, wherein the back surface includes a transparent membrane forming part of a building envelope of a greenhouse.

11. The heat collector defined in claim 1, wherein the back surface is at least partly defined by a ground surface.

12. A device for heating air comprising a perforated transparent surface allowing solar radiations to pass therethrough, a solar radiation absorption surface located behind said perforated transparent surface for absorbing the solar radiations, and a gap of air defined between said perforated transparent surface and said radiation absorption surface, the air flowing in the gap absorbing heat from the radiation absorption surface while fresh ambient air flowing through the perforations of the perforated transparent surface provides for a minimal temperature delta through the transparent surface.

13. The device defined in claim 12, wherein air moving means are provided for maintaining said gap under negative pressure.

14. The device defined in claim 13, wherein the perforated transparent surface is mounted to a building surface, the gap of air being defined between the perforated transparent surface and the building surface.

15. The device defined in claim 14, wherein the building surface is a transparent membrane extending over a greenhouse skeleton structure.

16. The device defined in claim 14, wherein the building surface forms part of the solar radiation absorption surface and is of a light color.

17. The device defined in claim 12, wherein the solar radiation absorption surface comprises a collector panel mounted to a building surface, the perforated transparent surface separating the collector panel from the ambient.

18. A method of preheating outside air for a building having a sun-facing surface, the method comprising:

providing on the sun-facing surface of the building a perforated transparent surface allowing solar radiations to pass therethrough, a plenum being defined between the perforated transparent surface and the sun-facing surface,

drawing outside air through the perforated transparent surface into the plenum,

capturing incident solar radiations passing through the perforated transparent surface, heating the air in the plenum using the captured solar radiations, and

withdrawing the heated air from the plenum.

19. The method defined in claim 18, wherein the incident solar radiations are captured by the sun-facing wall of the building.

20. The method defined in claim 18, wherein capturing incident solar radiations comprises mounting a collector panel on the building wall at a distance from the perforated transparent surface, the plenum being defined between the perforated transparent surface and the collector panel.

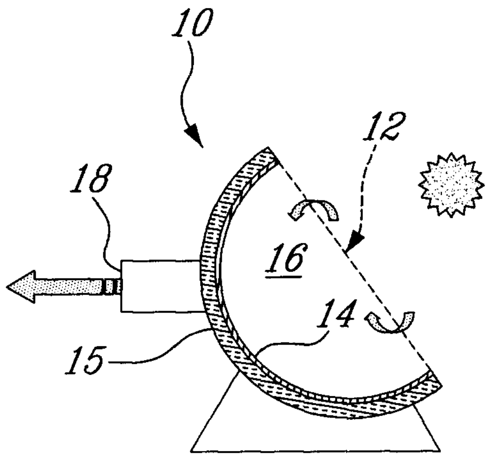


FIG. 1

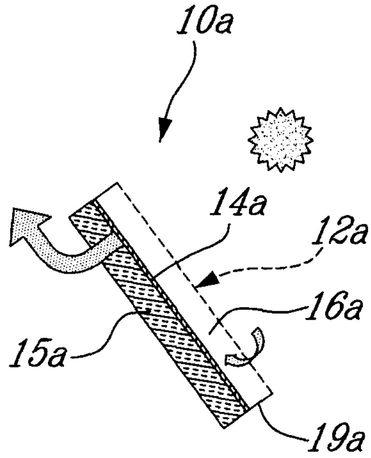


FIG. 2

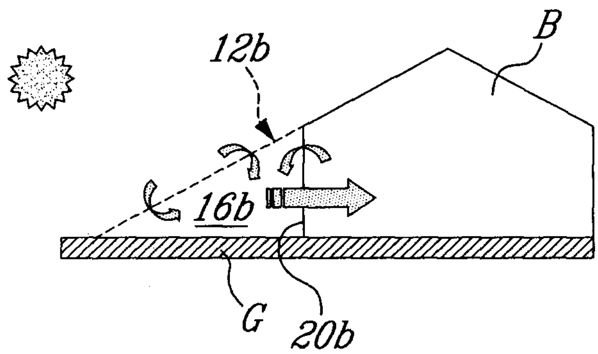


FIG. 3

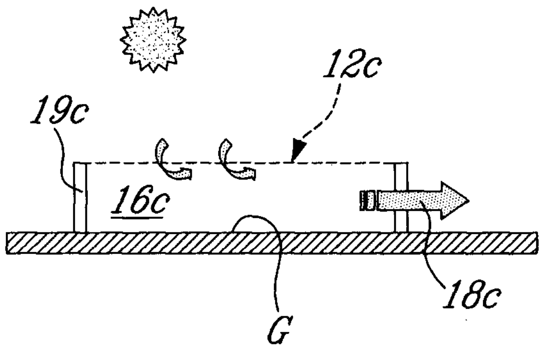


FIG. 4

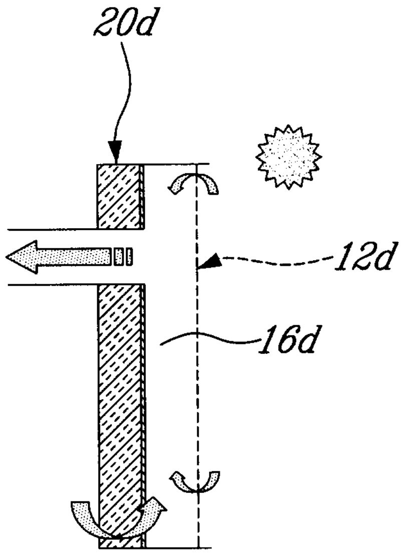


FIG. 5

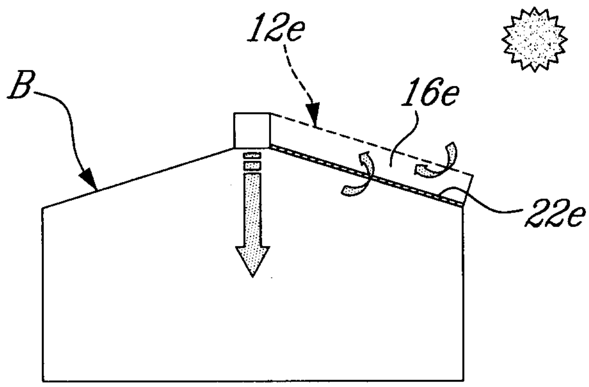


FIG. 6

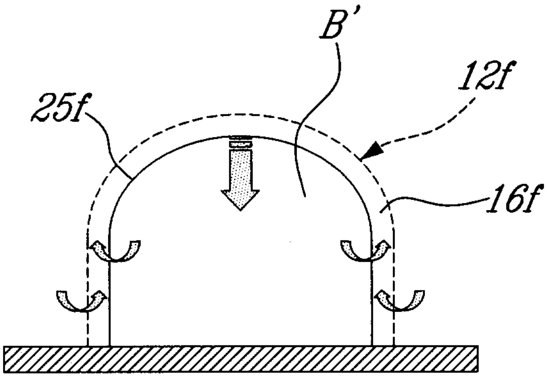
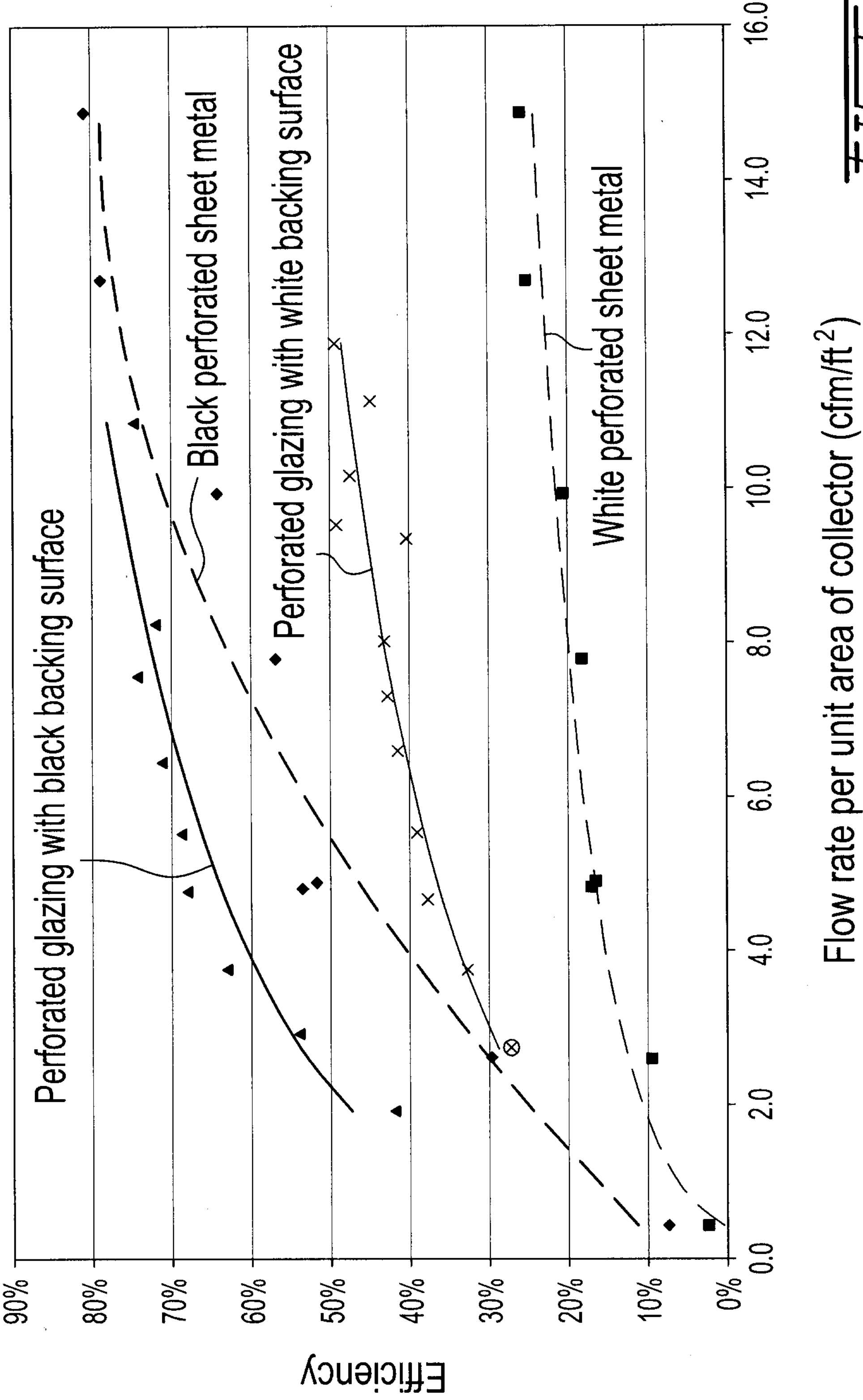


FIG. 7



Efficiency
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Flow rate per unit area of collector (cfm/ft^2)
Perforated glazing with black backing surface
Black perforated sheet metal
Perforated glazing with white backing surface
White perforated sheet metal

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2008/001588

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***F24J 2/20*** (2006.01) , ***F24J 2/05*** (2006.01) , ***F24J 2/50*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (2006.01): F24J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)

Delphion, Questel and Canadian Patents Database
Internet (keywords: solar wall, perforated, hole, solar panel)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,692,491 A (CHRISTENSEN et al.) 2 December 1997 (02-12-1997) *see column 3, lines 18-31 and lines 51-59, column 4, line 33 to column 6, line 56; figures*	1-20
X	US 2008/0139106 A1 (VACHON, CHRISTIAN) 12 June 2008 (12-06-2008) *see paragraphs 14, 18-21 and figures*	1-20
X	National Renewable Energy Laboratory (Produced for the US Department of Energy). Transpired Air Collectors. June 2006 [retrieved on 5 May 2009 (05-05-2009)] Retrieved from the Internet: <URL: http://www.scribd.com/full/2385794?access_key=key-28hb8m87pk2m3jt2ukm4> DOE/GO-102001-1288	1-20
X	US 5,081,982 A (MACKENZIE, JOHN A.) 21 January 1992 (21-01-1992) *see whole document*	1-20
X	WO 03/048655 A1 (CHRISTENSEN, HANS JORGEN) 12 June 2003 (12-06-2003) *see page 8, line 15 to page 11, line 13; figures*	1-20

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
5 May 2009 (05-05-2009)	9 June 2009 (09-06-2009)

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Authorized officer

Kristian MacKenzie 819- 934-4267

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