Solar air collector

WINTECH PROJECT – KESHAV SUNDAR V

The project

- **Solar air collectors** (SACs) are a type of **solar** thermal **collectors** that use **solar** radiation to actively deliver warm **air** into buildings
- Used in locations experiencing cold climates.
- Alternative to photoelectric heaters
- Very simple system
- Relative low cost
- Can be used to heat other fluids such as water

Problems

- The available air collectors have **low efficiency**.
- It is necessary to invent a higher efficient solar collector, but it shouldn’t increase the WDC & complexity

Restrictions

- The landed price less than 300 USD
- Weight less than 25 kg
- Dimension constraints 1mx2mx0.25m

Features

EXISTING MODELS

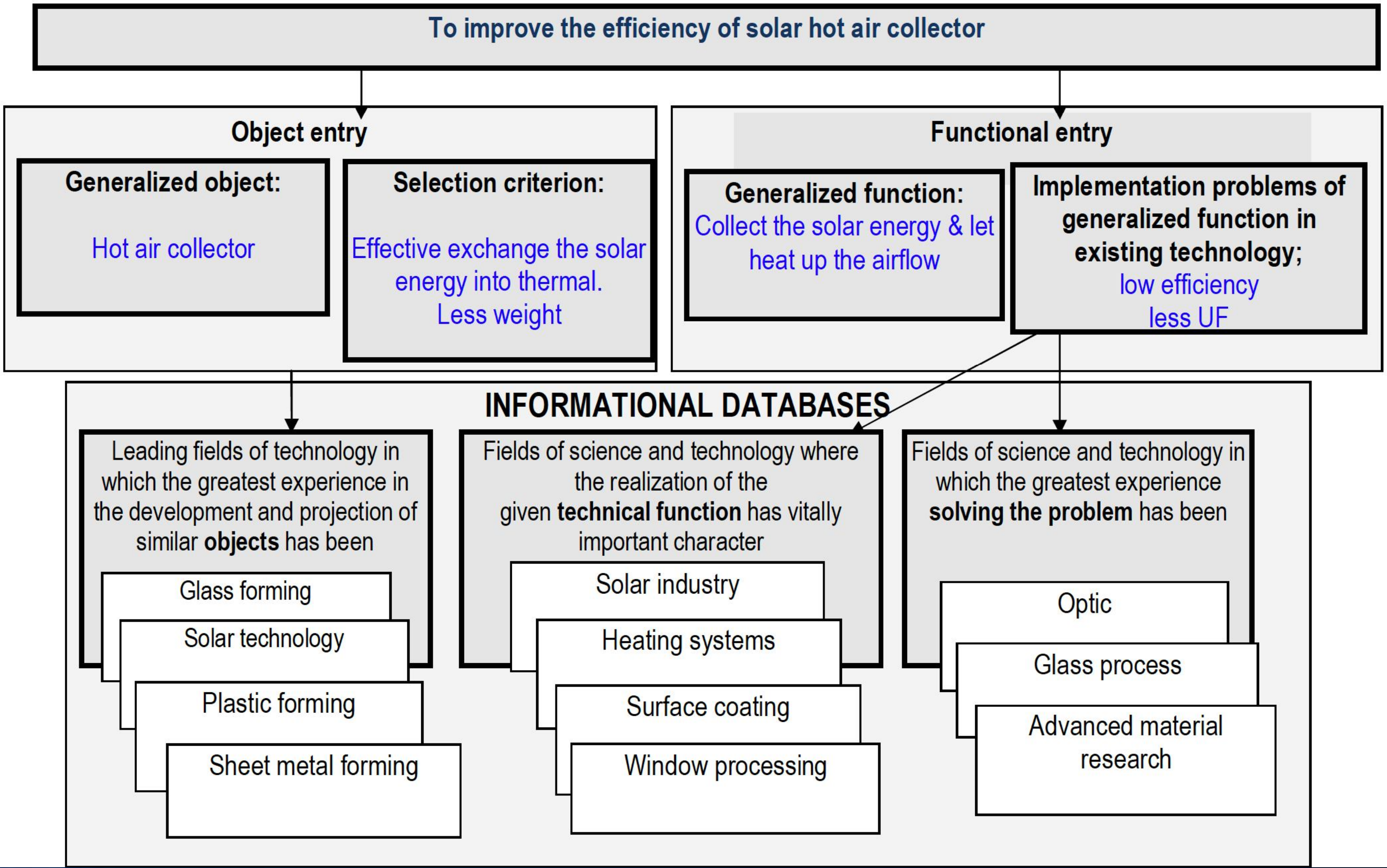
nformation Stage

Component	Config
op Cover Material	Glass
leat Trap Material on the top	None (Air)
bsorber medium Material: hape:	Copper Plain sheet
urrounding Insulation	Rock Wool
hassis	Plastic

lame of lement	Purpose	Materials	UF	Negative effects	Is it possible to change the element	Physical limit of function fulfilling	Gray areas
op cover	Cover collector	Glass	Let in Sun rays Trap Heat Reduce heat loss	Not 100% transparent Can break Heavy	Yes Material, shape	Ideal: Zero thickness, 100 % transparent 100% heat trap	No

lame of lement	Purpose	Materials	UF	Negative effects	Is it possible to change the element	Physical limit of function fulfilling	Gray areas
bsorber	Absorb heat	Aluminium/ Copper/ Steel sheet	Sun energy to heat	Low efficiency	Yes Material, Shape	100% absorption	No
hassis	Rigid frame	Al,plastic	Structure	Heavy	Yes	Ultra light, high resistance to external forces	No

Leading engineering branches definition:



Information Stage[contd.]

- Element is supersystem

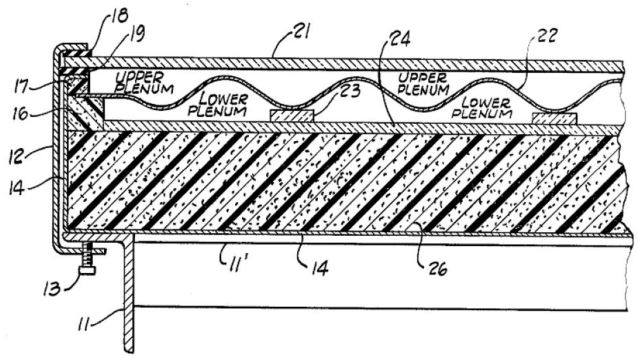
Objects	Forces
• Sun • Wind • Air flow • Buildings, Wall or roof, • City, Town • Earth • Ambient environment, fe grass or concrete • ground (reflection) • Rain & Moisture	• Gravity, • Solar intensity, • Wind intensity, • Radiation angle, • Magnetic field, • Temperature, • Diffusion, • Osmosis • Charged air, lightening bolt

Evolution Of SACs

EXISTING PATENTED DESIGNS

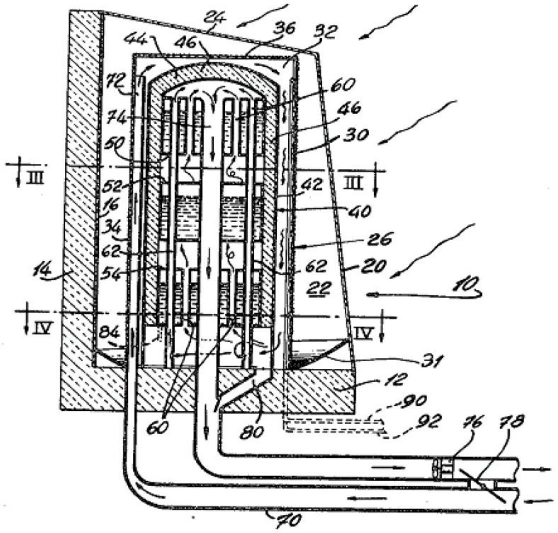
30/03/2021

Patents:
US 4 091 797



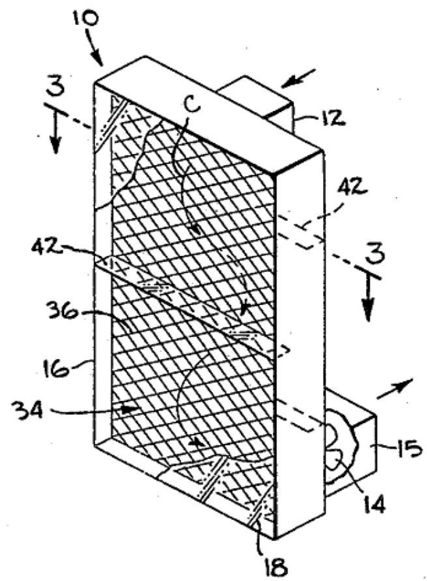
[57] **ABSTRACT**

A solar air heater comprises in array a plurality of structurally rigid, air-canalizing modular ducts communicating in parallel flow with a common header, each duct being about 4–6 meters long, about 1.2 meters wide, and about 100–650 cm² in cross sectional area of its bottom plenum air passageway, and having a top, low velocity air plenum between a transparent cover and a solar heat collector element, and a bottom, higher velocity walled air plenum between said collector element and the base of the duct.



[57] **ABSTRACT**

A solar heating system including a radiant heat collector apparatus made up of an enclosure having glazed panels. The collector provided within the enclosure is upstanding with the enclosure and the collector has heat absorbent flat walls spaced inwardly from the glazed panels. A heat storage core is provided centrally within the collector and spaced from the walls of the collector. The heat storage core includes an insulated housing and a heat retaining member within the insulated housing. Air passageways are formed between the collector walls and the insulated housing for passing input air, and duct members are provided for communicating with a household.



[57] **ABSTRACT**

A fluid-heating solar collector comprises a solar energy absorber with heat conducting and radiation absorbing material arranged to provide a plurality of angularly bent conduits extending therethrough thus to optimize the heat absorption surface at differing sun angles and also to substantially increase the area for convective heat transfer to passing air or other fluid.

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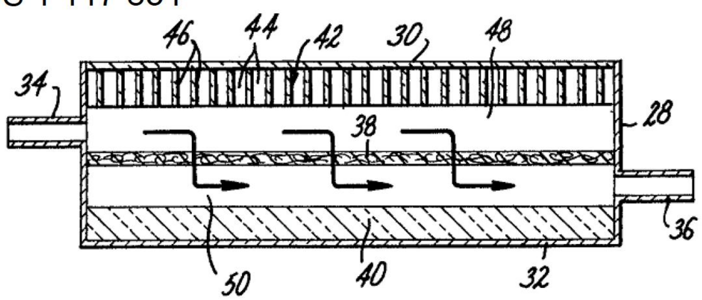
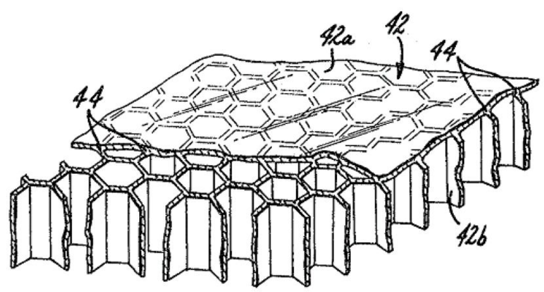
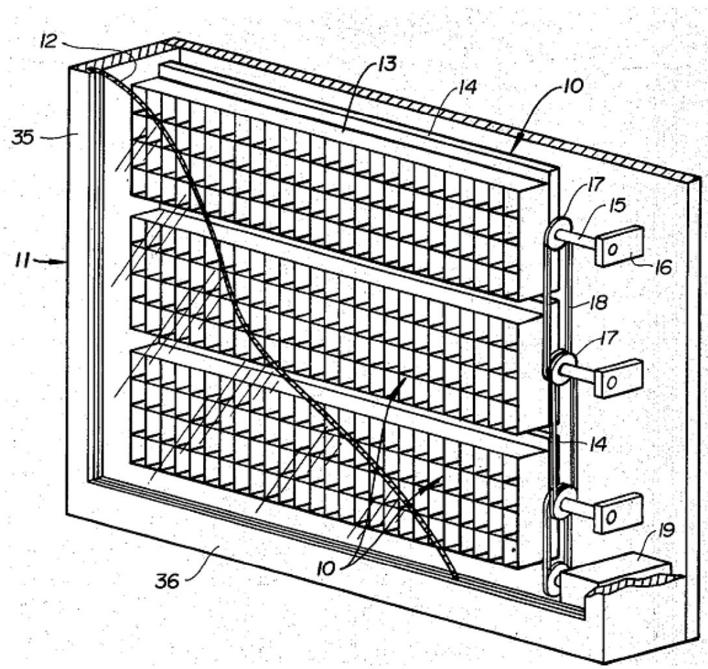




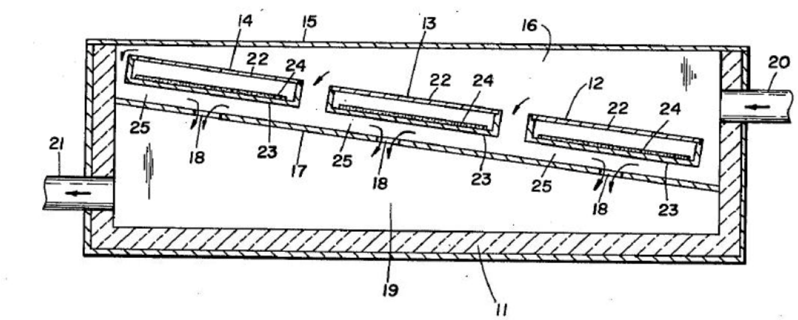
F24J 2/50, F24J 2/26, F24J 2/28, F24J 3/02



[57] **ABSTRACT**

A solar energy heating panel is provided for mounting in a building wall to effect heating of the air in an interior building space. A plurality of the heating panels are mounted in parallel relationship in a supporting structure for angular rotation about horizontal pivot axes to selected position. Each of the heating panels includes a heat-transfer controlling panel and a cellular unit mounted on one surface of the controlling panel, the opposite surface of the controlling panel being reflective of solar radiation. The cellular units are formed with mutually intersecting, longitudinally and transversely extending walls disposed in upstanding relationship to the controlling panel surface and which define a plurality of individual cells that are open at an end remote to the controlling panel surface. The longitudinally extending walls are disposed parallel to the axes of rotation and have a plurality of apertures formed therein to permit airflow transversely through each cell. All wall surfaces of each cell, except one longitudinal wall surface, are coated with a material to enhance absorption of solar radiation, the longitudinally and transversely extending walls being formed from a metal having a relatively high coefficient of thermal conductivity.

US4095997

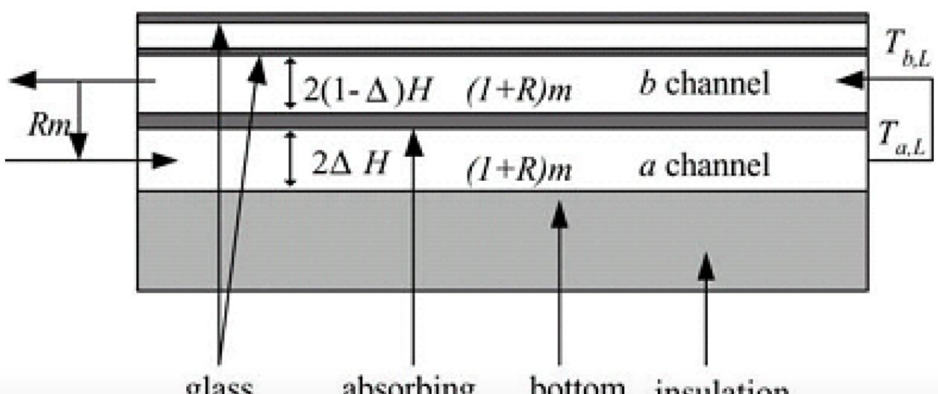


[57] **ABSTRACT**

A solar collector having at least one solar cell, an air retaining plate located parallel to and immediately behind the unlit side of the cell. A plate is spaced from the back of the cell to permit passage of substantially all the air that is to be treated by the cell, the retaining plate being in communication with the portion of the collector through which the air is withdrawn.

22: transparent upper face
23: transparent lower face
24: photovoltatic material (silicon, copper sulphide, cadmium sulphide)

Double glass cover & double pass with air recycle:



Evolution Of Components

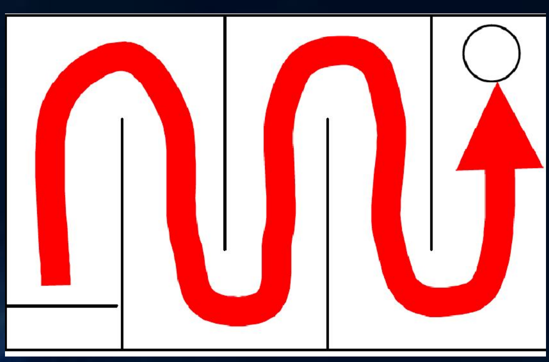
30/03/2021

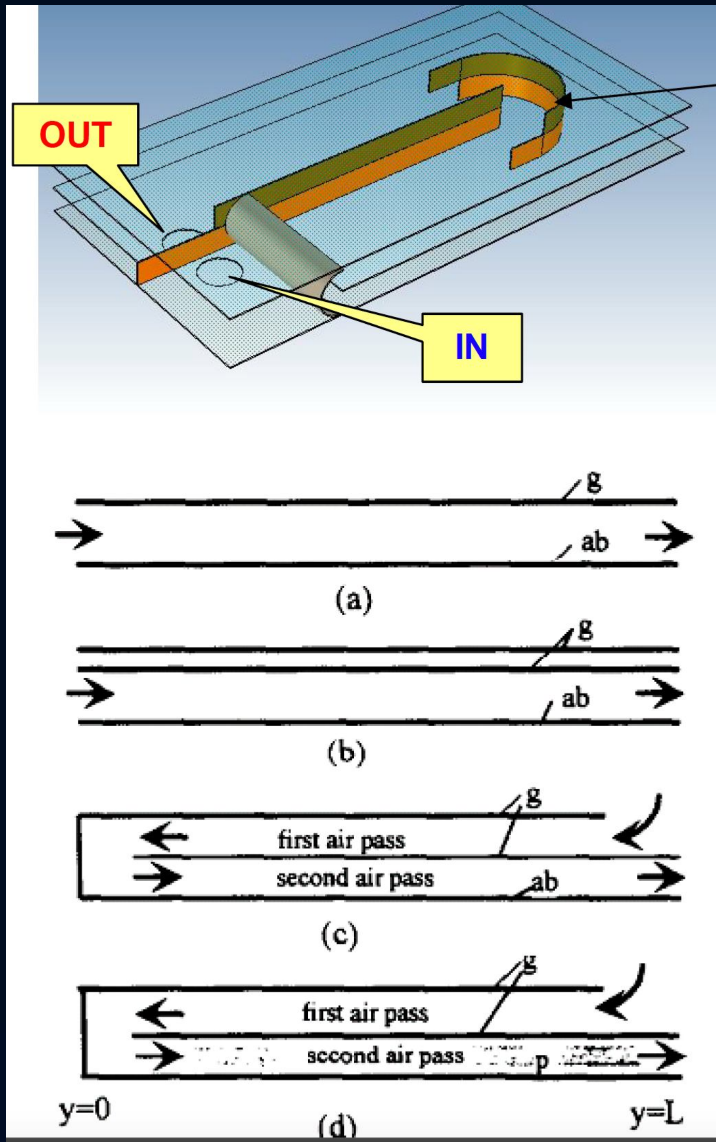
Glass (EXISTING VERSIONS)

- 1 pane
- 2 pane
- 2 pane & sealing
- 3 pane wit argon filling & low emissivity coating
- 2 pane with silica aerogel,
- 2 pane with vacuum
- FRAME:
  - Wood
  - Aluminum
  - Vinyl, internal chambers

Air Passage

- Single pass - 1 layer
- Double pass - 2 layers
- Double pass with 1 curve
- Double pass more curves





Trends of Evolution

IN EXISTING MODELS

30/03/2021

nation Stage: Configuration of the Components after studying the database

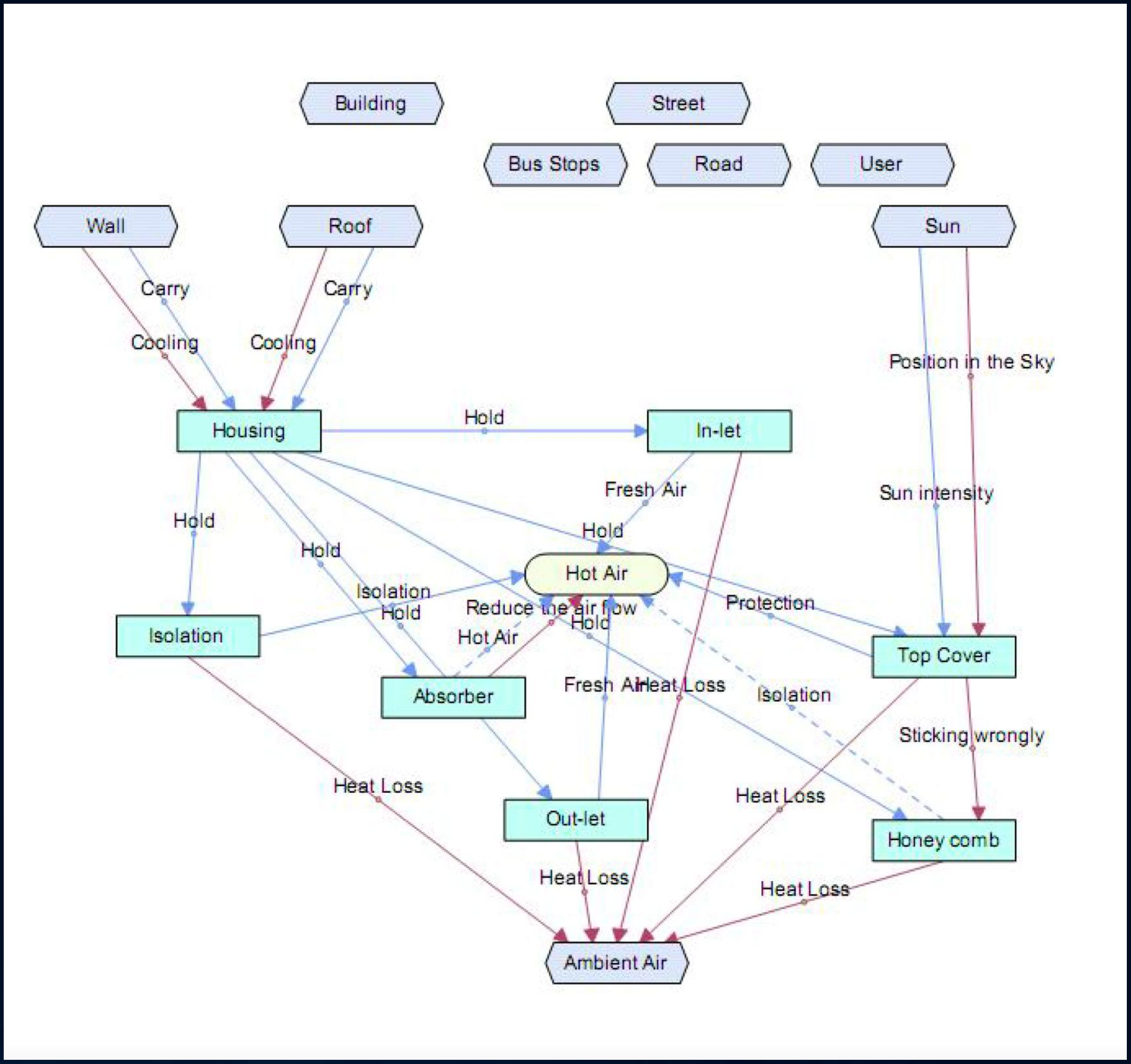
onent	TREND OF EVOLUTION						
ver Material:	Glass	Transparent plastic					
Shape:	Plane	Wavy	Fresnel lens				
rap (top) Material:	Nothing (air)	Glass	Transparent plastic, Acrilyc			Silica aerogel	Vacu
Shape:	---	1 or 2 plain sheets	1 or 2 plain sheets	Fins	Honeycomb with different shapes	Porous	
sage way Pass:	1 pass	Double pass	More pass				
Shape:	Straight	1 curve	2 curves	More curves			
er medium Material:	Aluminum, Copper, Steel					Carbon aerogel	
Shape:	Plain sheet	Fins	Meshes	Fragments	Porous	Porous	Porou Nanotu
tive substance:	Nothing	Black paint	Selective coating				
nding ion	Polystyrene	Polyurethane	Rock Wool	Glass Wool		Silica aerogel	Vacu
s Material:	Aluminum	Plastic	Rubber	Rubber with ferro particles+EM field			
Shape:	Rectangular	Triangle	Trapezium	Dome, Sphere	Deformable		

	Air fan with indoor thermostat & power source	Air fan and only solar cell mounted on the collector	Water pump	Electric charging & discharging system	Diffusion (instead of air fan)		
time	Daylight	Night					
UF)	Only Hot Air	Hot air & Electric	Hot air, Electric & Warm water	--- “ --- & holding (wall & roof)	--- “ --- & Capacitor/Battery (*)	--- “ --- & Cold air	

: new ideas. (*) the carbon aerogel is excellent capacitor as well (quick charge & discharge). If the lightening bolt is coming, than the collectors a
energy for 1 year !

Structural Analysis

30/03/2021

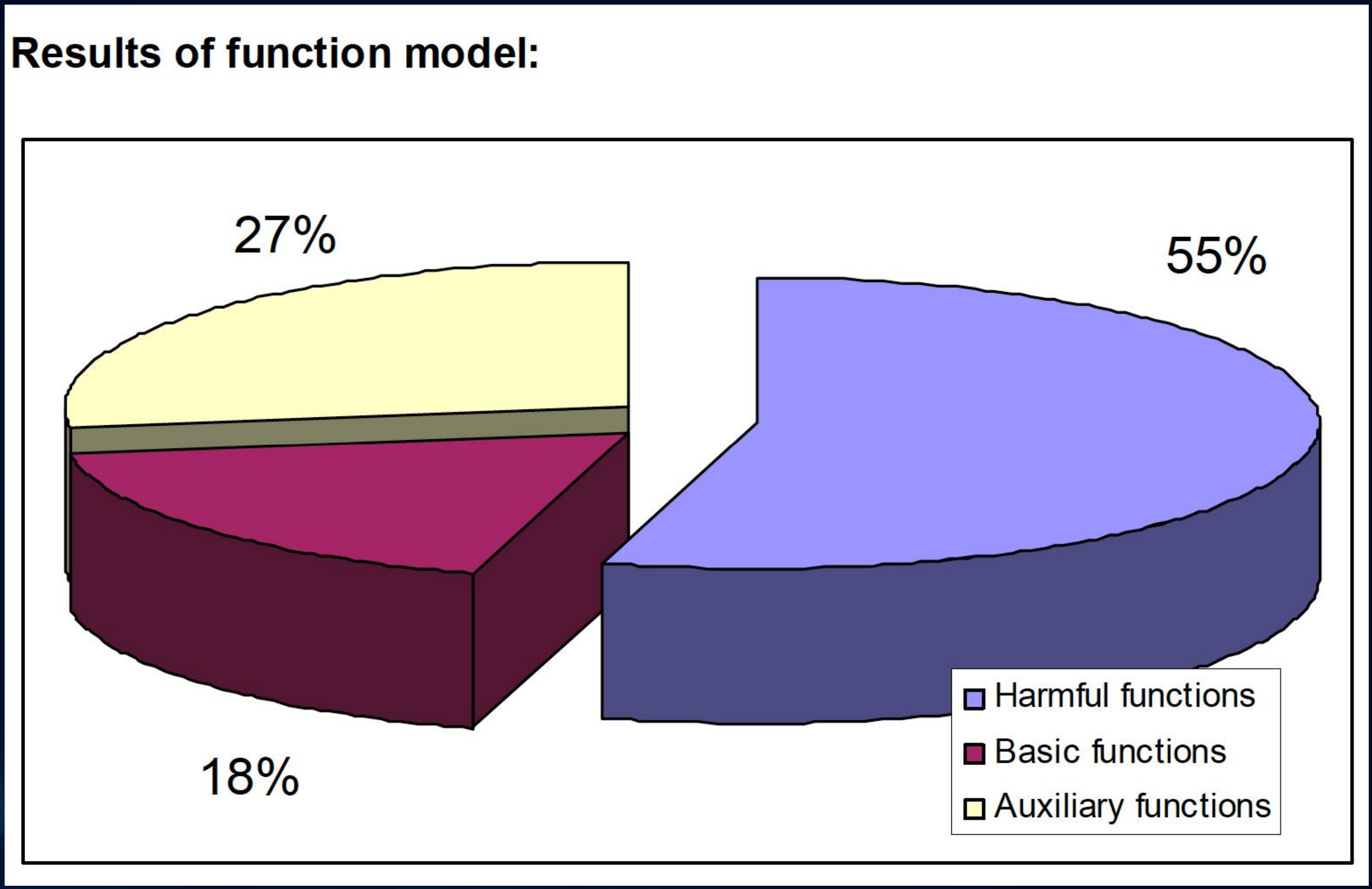


Building
Street
Bus Stops
Road
User
Wall
Roof
Sun
Carry
Carry
Cooling
Cooling
Position in the Sky
Housing
Hold
In-let
Fresh Air
Sun intensity
Hold
Hold
Hold
Hot Air
Isolation
Hold
Reduce the air flow
Hold
Protection
Isolation
Hot Air
Top Cover
Absorber
Fresh Air
Heat Loss
Isolation
Sticking wrongly
Heat Loss
Heat Loss
Out-let
Honey comb
Heat Loss
Heat Loss
Ambient Air

Solar Hot Air Collector	Hot Air	Absorber	Honey comb	Housing	In-let	Isolation	Out-let	Top Cover	Ambient Air	Building	Bus Stops	Road	Roof	Street	Sun	User	Wall
Hot Air		🔵🔴	🔵		🔵	🔵	🔵	🔵									
Absorber	🔵🔴			🔵													
Honey comb	🔵			🔵				🔴	🔴								
Housing		🔵	🔵		🔵	🔵	🔵	🔵					🔵🔴				🔵🔴
In-let	🔵			🔵					🔴								
Isolation	🔵			🔵					🔴								
Out-let	🔵			🔵					🔴								
Top Cover	🔵		🔴	🔵					🔴						🔵🔴		
Ambient Air			🔴		🔴	🔴	🔴	🔴									
Building																	
Bus Stops																	
Road																	
Roof				🔵🔴													
Street																	
Sun								🔵🔴									
User																	
Wall				🔵🔴													

Result

Result


Results of function model:
27%
55%
18%
Harmful functions
Basic functions
Auxiliary functions

Conclusion

PRELIMINARY

30/03/2021

- The share of harmful actions in total amount is 55%. It indicates that the existing Solar Air Collector is imperfect.
- The greatest quantity of harmful functions (12) is connected with heat loss. It is the dominant cause of low efficiency.
- Transition to the new physical principle of solar air collector with greater efficiency coefficient of the heat transfer and less heat loss is required.

Parametric Analysis

- To increase the efficiency we have to:
  - Find & reduce the heat losses (reduce the temperature difference between two areas)
  - Increase the heat convection from the absorber to the air steam

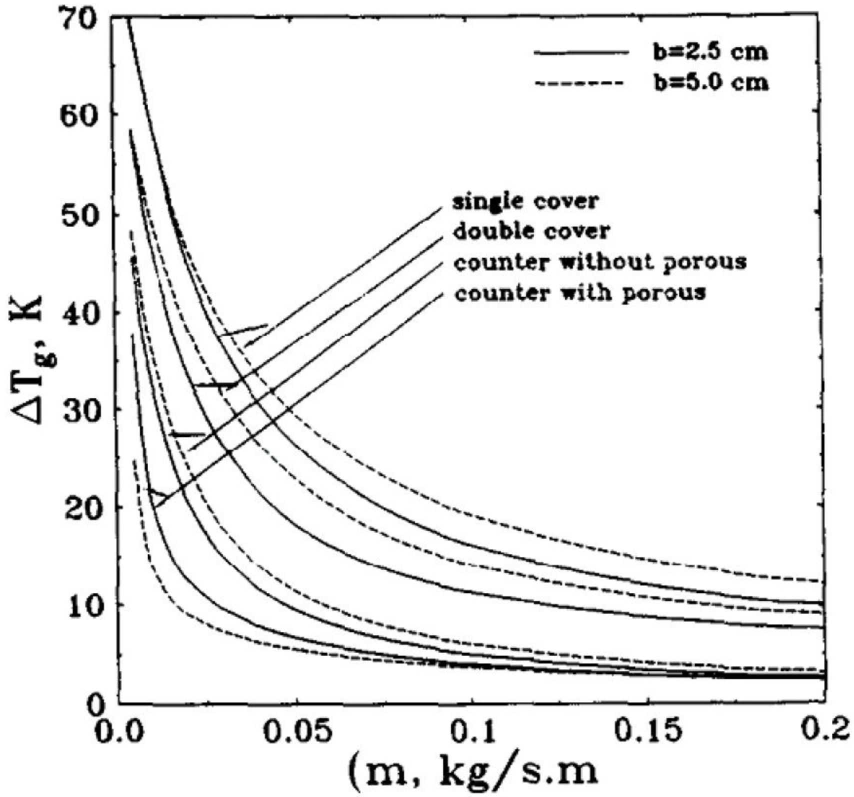


Fig. 3. Maximum temperature difference between the first glass cover and ambient air as a function of air flow rate, for $b = 2.5$ and 5.0 cm.

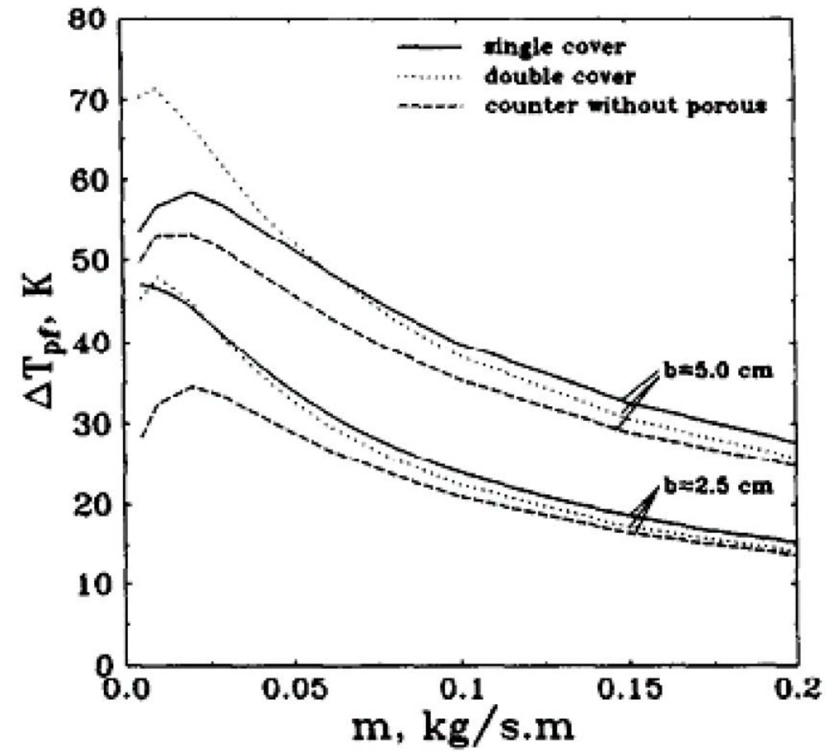


Fig. 4. Maximum temperature difference between absorber and airstream.

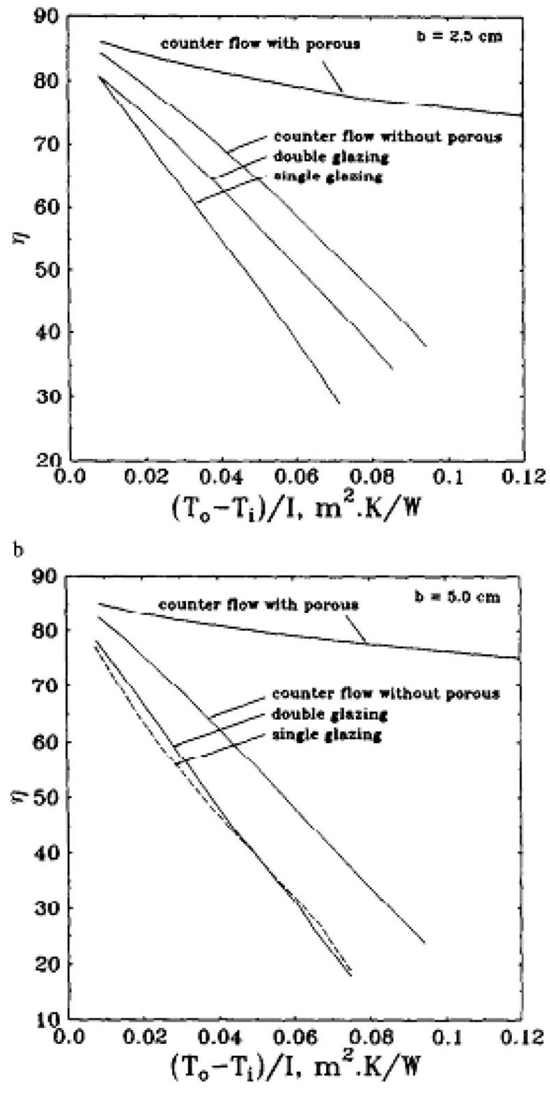


Fig. 5. Performance curves for different types of solar air heaters: (a) $b = 2.5$ cm and (b) $b = 5.0$ cm.

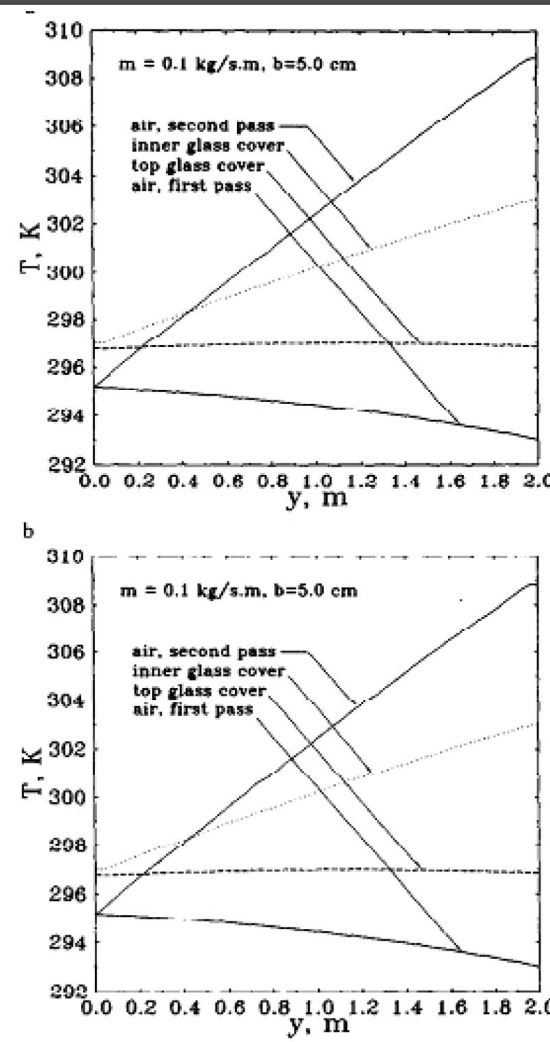


Fig. 6. Temperatures variation along the heater for the glass covers and the airstream for $b = 5.0$ cm: (a) $m = 0.05$ kg/(s m) and (b) $m = 0.1$ kg/(s m).

Conclusion -1

PORIOUS MATRIX

30/03/2021

- The drawbacks of conventional air heaters are identified, which are heat loss to the ambient air through the glass cover and poor heat convection from the absorber to the airstream.
- The performance of counter-flow solar air heater with porous matrix is analyzed and the results are compared with conventional solar are heaters.
- Under normal operating conditions, the analysis indicates that the suggested heater thermal efficiency can exceed 75 %. However the pressure drop (pumping power) is higher for the suggested heater, but this factor is not so significant for low flow rates.

Parametric Analysis [contd.]

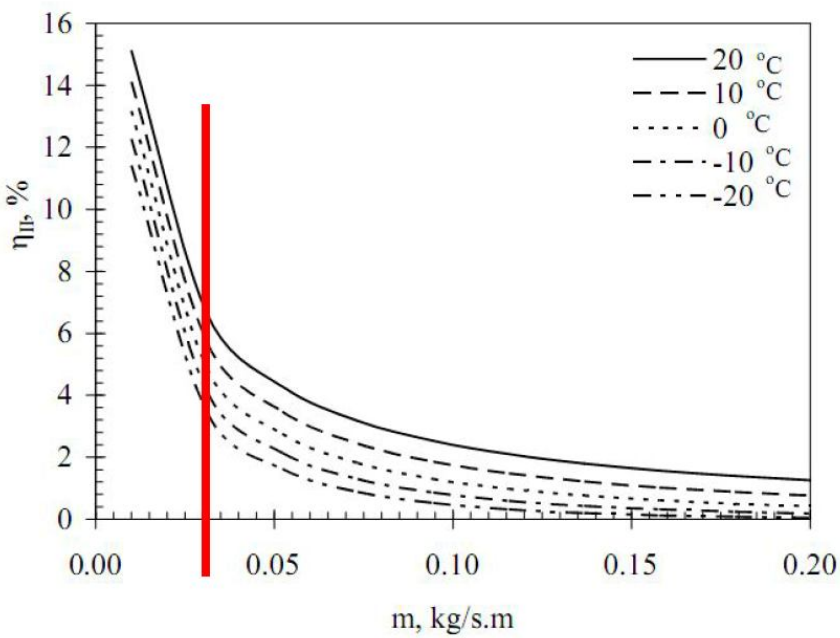


Fig. 4: Effect of air mass flow rate on solar collector thermal efficiency.

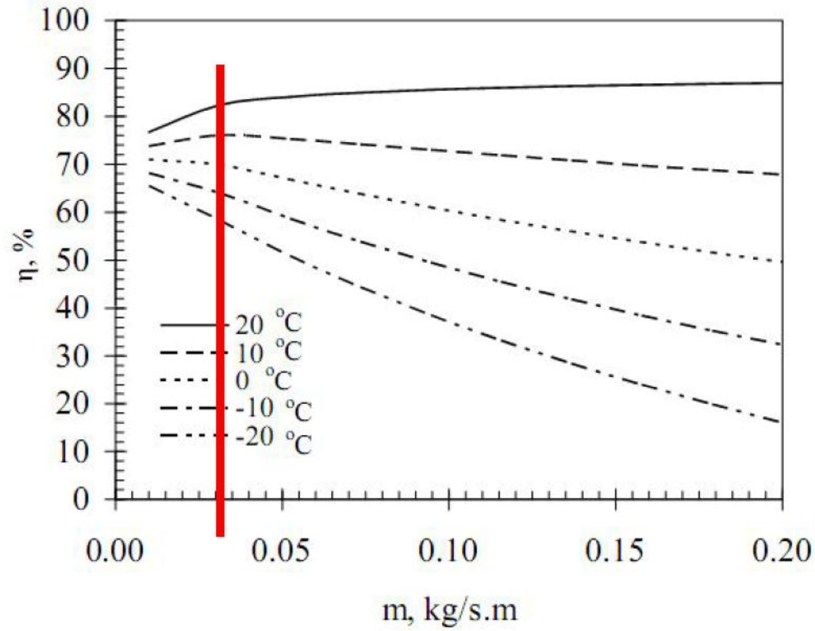


Fig. 5: Effect of air mass flow rate on solar collector exergetic efficiency.

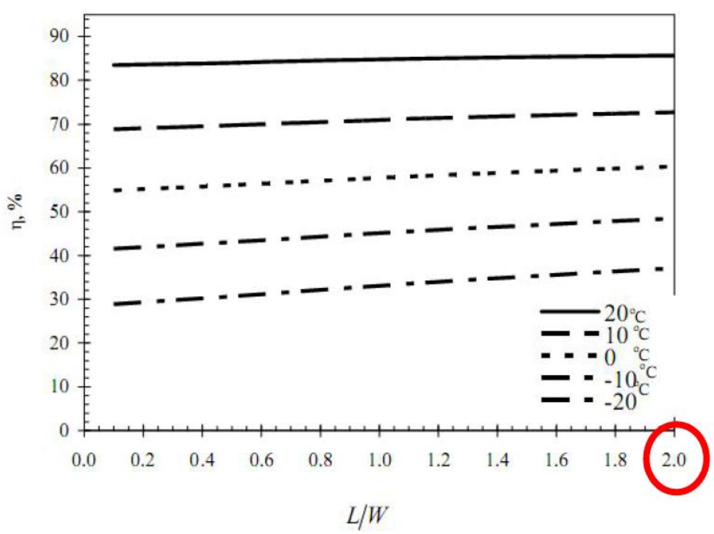


Fig. 8: Efficiency versus length to width ratio

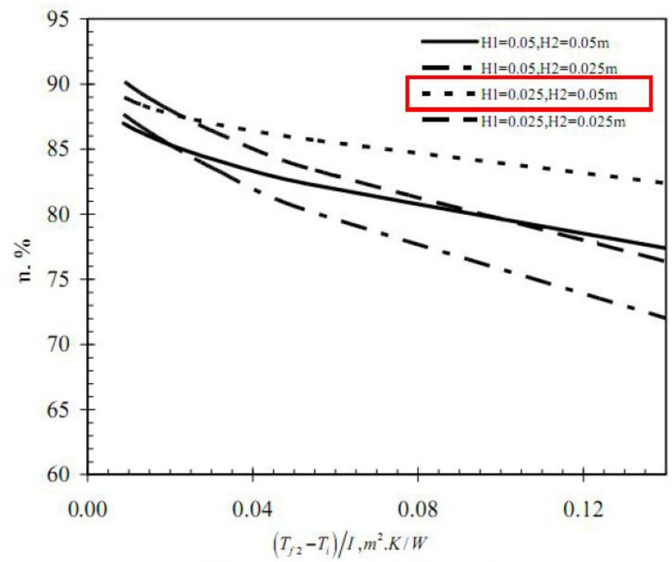


Fig. 10: Efficiency versus gap thickness.

Conclusion

The efficiency of the solar air heater can be improved more:

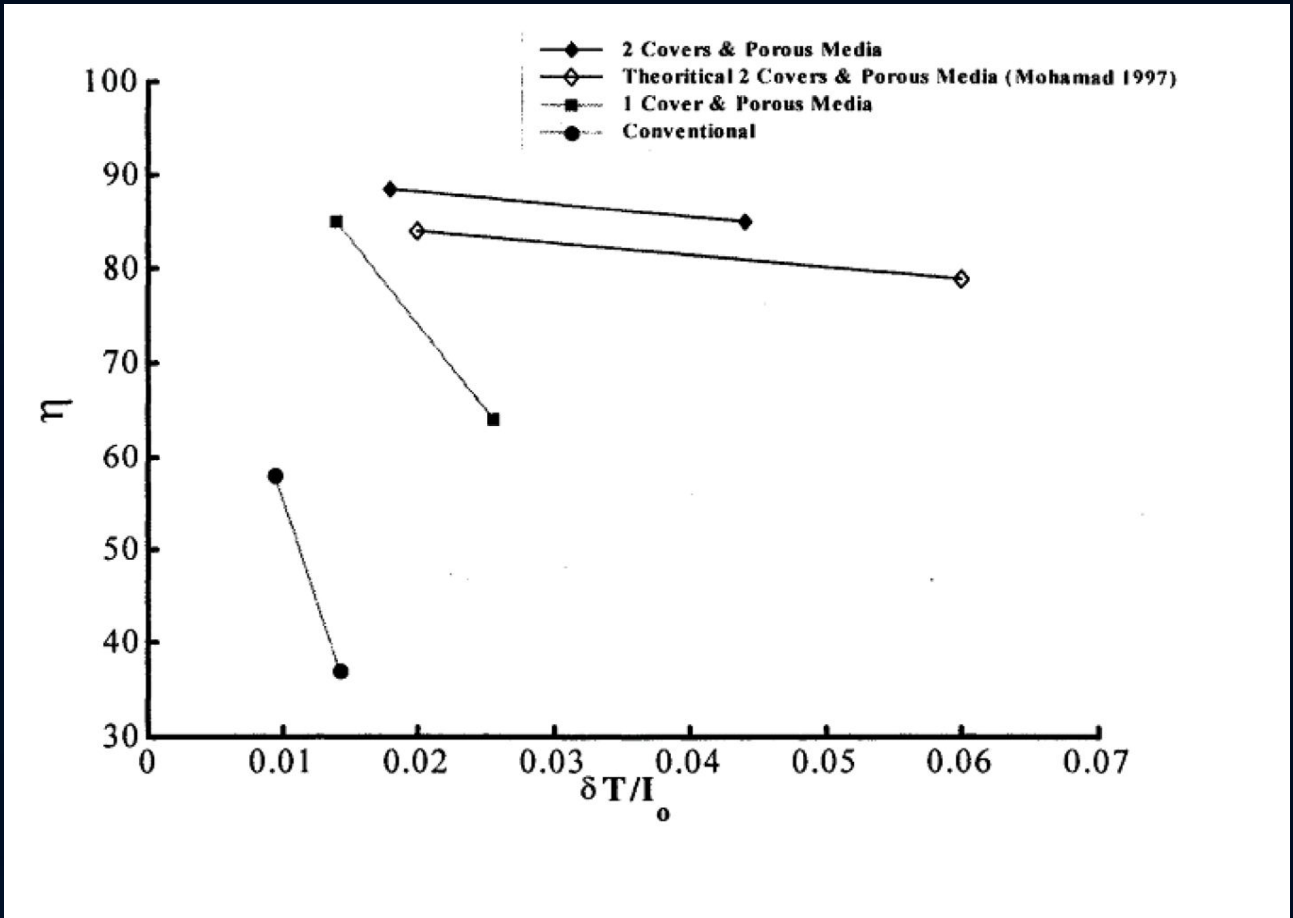
- Flow rate less than: 0,03 m, kg/ s.m
- Length vs. Width of the collector chassis more than: 2
- Gap thickness (height) of the air channels: H_1=2,5 cm, H_2=5 cm

Therefore, the second air pass through the porous media:

$$(5) \qquad \overset{o}{m} C_p \frac{\delta T_{f1}}{\delta x} = k_{eff} \frac{\delta^2 T_{f2}}{\delta x^2} + h_{f2c2}(T_{c2} - T_{f2}) + U_a(T_a - T_{f2}) + I_o \alpha_p \tau_c \tau_c \qquad W/m^2$$

Table 5.3 Comparative Analysis of Various Collectors' Thermal Efficiency

	Thermal Efficiency of Compared Solar Collectors				
Airflow	**Conventional Flat Plate**	**One Pass & Porous Media**	*% Thermal Enhancement**	**Two Pass & Porous Media**	*% Thermal Enhancement**
31.21 L/s	**35%**	**64%**	*82%*	**85%**	*140%*
73.78 L/s	**55%**	**85%**	*54%*	**87%**	*58%*


2 Covers & Porous Media
Theoritical 2 Covers & Porous Media (Mohamad 1997)
1 Cover & Porous Media
Conventional
η
100
90
80
70
60
50
40
30
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
δ T/I
o

Each point is plotted based on, $\frac{(T_{out} - T_{amb})}{I_o}$, and η.

Figure 5.25 clearly shows that the performance of the present solar air heater, with porous media and a two-pass system, provides drastically improved operating capabilities. Whereas the characteristic of the conventional collector is to drop in efficiency significantly as the flow rate decreases (i.e. temperature gradient increases), the present collector has shown to maintain a high thermal efficiency in a variety of operating conditions. The porous media provides superior thermal output from the collector. It is also necessary to consider the other effect of the porous bed being the pressure drop, which the next section will discuss.

Conclusion -2

PASSAGEWAY MODIFICATION

30/03/2021

- From above statistics, it is clear that a two-way air passage system drastically increases efficiency of the system.
- This can be attributed to humongous increase in surface area
- Two passage system combined with a porous matrix for the absorber bed proves to be rewarding.

Conceptual Stage - ABSTRACT

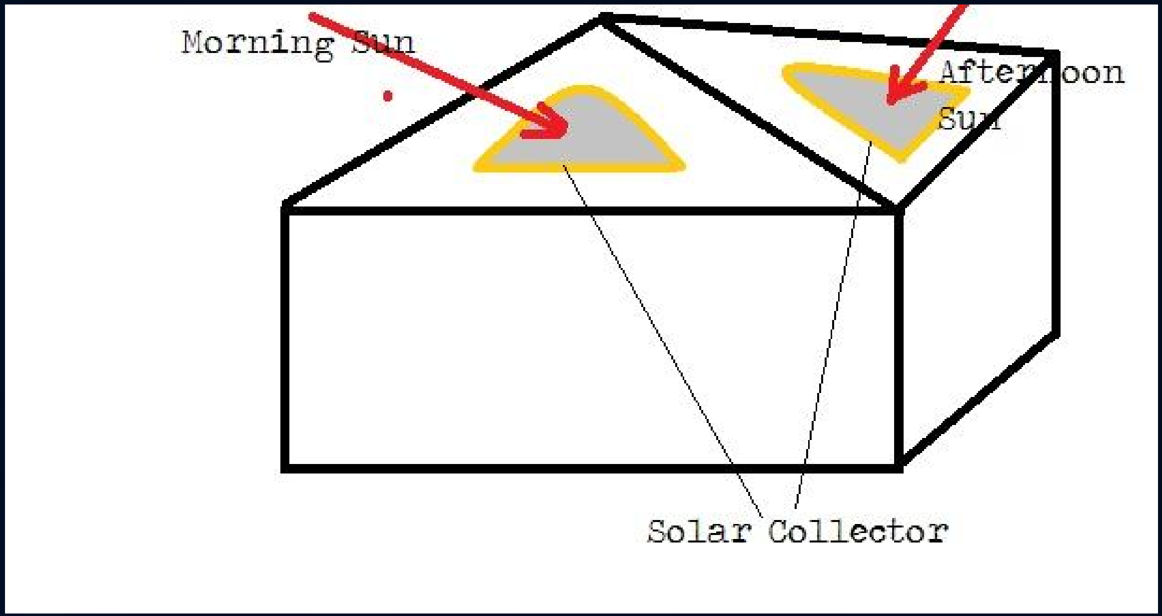
30/03/2021

- As a result of carried out analytical studies the following directions of performance improvement (heat loss reduction) of solar heat air collector are revealed:
  - Direction 1. Reduce heat loss on the top surface.
  - Direction 2. Improve heat conventions of the absorber
  - Direction 3. Reduce heat radiation from the absorber

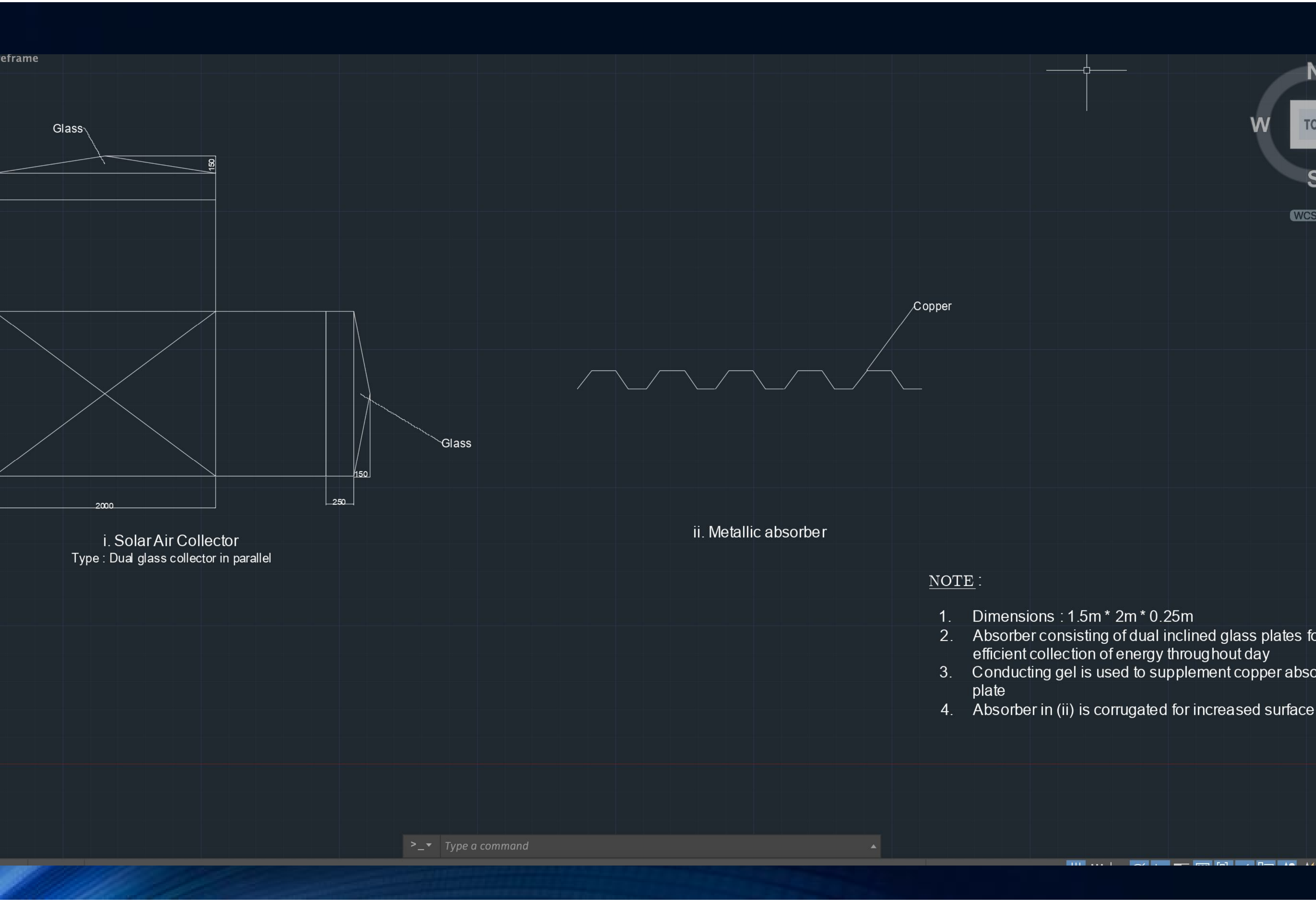
Proposed Solutions

- It is offered for efficient hot air collector with aerogels at any operation mode to use improved material of aerogels.
- To provide inclined glass plates, enabling Sun tracking(absorb morning and evening insolation) throughout the day without any electrical systems (cost effective), for utmost utilisation of Sun's energy.
- Using anti – reflective film coating on top cover.
- The aero gel has several advantages:
  - - very high porosity which can be increased with nano technology(nano tubes)
  - - very good insulation
  - - very high durability, can carry a big weights
  - - very light
  - - carbon aerogel can be used as capacitor

Proposed Model

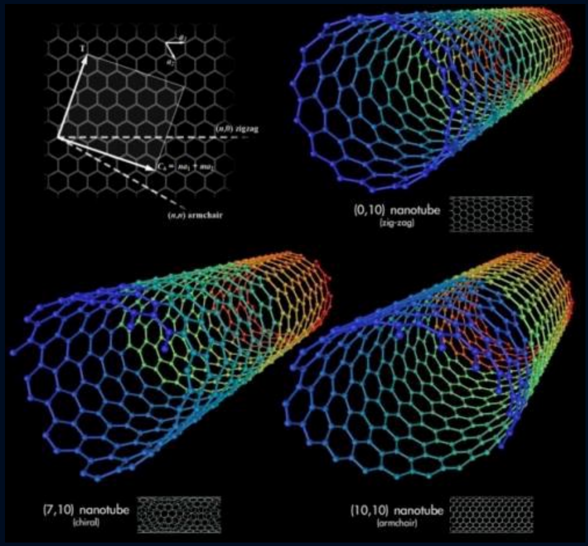


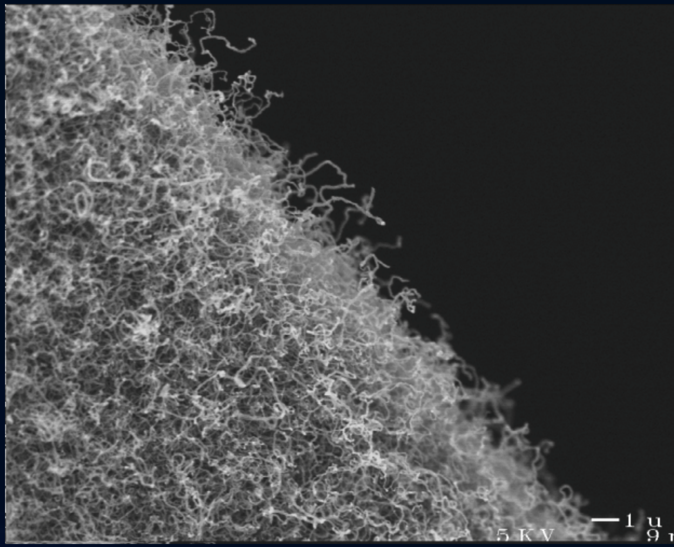
Dual Glass collector in parallel


eframe
Glass
150
Glass
150
2000
250
i. Solar Air Collector
Type : Dual glass collector in parallel
Copper
ii. Metallic absorber
NOTE :
1. Dimensions : 1.5m * 2m * 0.25m
2. Absorber consisting of dual inclined glass plates fo
efficient collection of energy throughout day
3. Conducting gel is used to supplement copper abso
plate
4. Absorber in (ii) is corrugated for increased surface
W
WCS
Type a command

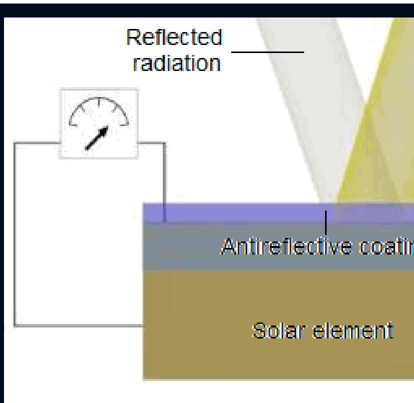
Aerogel

- Non-silicone thermal grease -Diamond Filled
- Electrical Resistivity (ohm-cm) as >1×1013
- Thermal Conductivity(watt/m-°C) as 10.0





Anti – Reflective Film



When an unabsorbing plane-parallel film is applied to the surface of a light-sensitive layer, the radiation is reflected from the outer and inner film surfaces.

Both reflected beams propagate in parallel and interfere.

If the Under certain conditions, the reflected beam interference causes the inter-suppression of radiation reflected from the film upper and lower boundaries.

The condition for this is that the film thickness of $h = m\lambda/4n$ (λ – radiation wave length, n – film refractive index, m = 1, 3, 5,...)

film optical density is greater than those of the first medium but lower than those of the light-sensitive layer.

Interference results in the energy redistribution between the incident and passed radiation.

Causes an increase in the energy penetrating the light-sensitive layer

The design of Solar Hot Air Collector with Aerogels (**SHACA**) contains:

- Top cover (glass) with anti-reflecting film
- Silica aerogel heat trap
- Air passage to warm up the fresh air from the inlet
- Glass separator plate
- Carbon aerogel as absorber medium
- Air passages
- Rock wool
- Insulator on bottom & on the sides
- Inlet air
- Warmed air
- Hot air in the absorber medium

Process

1. fresh air inlet
2. solar energy through the top cover
3. transparent silica aero gel
4. Absorb: carbon aerogel selective coating on top
5. heat convection
6. air is warmed up
7. warmed air leaves: outlet

Advantages

- Improved effectiveness
- SHACA can be convoluted as a brick or complete wall in the house, because silica & carbon aerogels are very strong
- Carbon aerogel can be used as electric capacitor so energy (Lighningbolt) can be stored & discharged.

POTENTIAL NEW PROBLEMS
- Aerogel is expensive

Final Solution

- Through experimentation and statistical study, it has been established that implementation of a porous absorber bed matrix increases thermal efficiency by 75% and that by a two passage air circulation system 140% (under low airflow rates).
- Implementation of above-said modifications along with the aerogel, dual plate top cover and anti-reflective top surface modifications can result in a much better utilisation of the perennial energy of the Sun for human use, and also relaxing the stress on fossil-fuel depletion used by conventional heaters.

THANK YOU