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[Continued on next page]

(54) Title: THERMAL SOLAR COLLECTOR WITH TAPERED TUBES

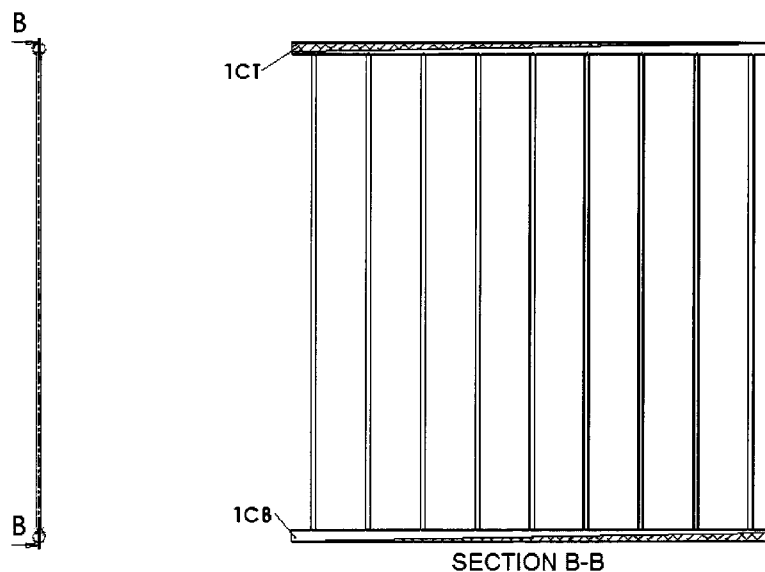


Fig. 5

(57) Abstract: Solar collector for applications with nanofluids or biphasic heat transfer fluids, including both a top pipe (1CT) and a bottom pipe (1CB) wherein at least one of these pipes has a variable cross section in order to avoid sedimentation of nanofluids and other biphasic heat transfer fluids that flow inside the tubes of the solar collector itself.



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- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

Thermal solar collector with tapered tubes

5 DESCRIPTION

This invention consists in a innovative solar collector which can be used with traditional heat transfer fluids and liquid-solid suspensions, as nanofluids.

10 In energy system, thermal conductivity of the heat transfer fluids is a limiting factor, because it is lower than thermal conductivity of the surface of heat exchangers. Therefore, system efficiency and/or their dimensions depend on thermal conductivity of the heat transfer fluids.

To overcome this limit, researchers proposed a new type
15 of heat transfer fluid to improve heat transfer performance, through mixing of traditional heat transfer fluids with solid nanoparticles (<100 nm), the nanofluids. Solid phase causes thermal conductivity enhancement and a convective heat transfer enhancement, through its
20 chemical and physical properties and their interactions with liquid phases. Metal, Cu, Au, Ag, Fe, or metal oxide, CuO, Al₂O₃, ZnO, nanoparticles are used as solid phase. Although nanofluids improves thermal performances of the systems, it is necessary to study new solutions to avoid
25 sedimentation and clogging that could reduce thermal performance of the heat transfer devices and damage the

systems.

Nanofluids can be used in all the systems where it is necessary to transfer thermal energy (e.g. heating system) or when thermal energy has to be carried away through disposal system. Therefore, nanofluids might also be used on solar thermal energy systems in order to produce sanitary hot water, heating and cooling of buildings and thermal energy for industrial processes.

In the double circuit system, water is heated by a heat transfer fluid through an heat exchanger while collector is crossed by heat transfer fluid. Generally in double circuit system, heat transfer fluid, that flows in the collector, must have the better thermal performance and freezing must be avoided. Experts in the sector know that freezing phenomenon can be avoided by using a mixture of heat transfer fluid and antifreeze fluid. In the most cases the thermal conductivity of this mixture is lower than thermal conductivity of water. Besides, heat exchanger introduces a further loss respect to the single circuit system and this influences the global efficiency of the system.

A thermal solar collector is composed of:

- Absorber, which intercepts and adsorbs solar radiation and converts it in heat;
- Transparent cover, that allows solar radiation to pass through but traps infrared radiation emitted by the absorber;

- Frame;
- Insulation material. It is under the absorber and near the sides of the frame;
- Collector composed by riser tubes where heat transfer fluid removes heat from the absorber. Fluid is transported from a bottom pipe to a top pipe that are larger than riser tubes.

In a solar collector, cross section of the tubes is constant and the flow inside is laminar. Therefore fluid flows in parallel layers and velocity profile is parabolic in every cross section, where the minimum value is near tube surface and the maximum value is on the center. Besides velocity has only axial component. As no restrictive example, Figure 1 shows a collector of a traditional solar collector, where A and D are inlet and outlet of the fluid respectively. Along the bottom pipe (1) and top pipe (2) the flow rate varies. In fact, within the bottom pipe flow rate decreases from A to B because fluid is distributed to the riser tubes. Similarly within the top pipe flow rate increases from C to D because fluid come out from the riser tubes. Nanofluids yield sedimentation of the solid phase in a traditional solar collector. Therefore decreases in thermal conductivity and in convective heat transfer and clogging of the tubes can be obtained. Therefore, if nanofluids must be used it is necessary to use a collector with suitable characteristics to avoid these problems. In the patent

literature there are some examples of solar collectors having technical characteristics for specific purpose. U.S. Pat. No. 2007/0084460A1 describes a solar collector for liquid-solid mixture where solar radiation is directly captured by solid phase through transparent system. In the U.S. Pat No. 5413091 is described a solution in order to avoid or mitigate freezing phenomenon within the collector, where riser tubes have a biconical shape and top pipe and bottom pipe are insulated with a fully layer. Avoiding freezing in solar collector is also treated in U.K. Pat.GB 2084312A. In this invention absorber is made with tapered flanges welded on riser tubes, bottom pipe and top pipe to provide a heat dissipating gradient from the wide end to the narrow end. Thus fluid does not freeze at the same time in any point of the tube, therefore ice comes out of the riser tubes instead of bursting them. Besides, a conical bottom pipe can be used to encourage exit of the ice from solar collector. Finally, U.S. 2009/0250051 A1 describes solar collectors used with fluids at high temperature (for example, molten salt), where both top pipe and bottom pipe have a spindle shape or double frustoconical shape or with central area maintained cylindrical and joined to its two frustoconical elements. With this invention it is possible to reduce thermal strain caused by rapid temperature changes due to cloud passage, particularly in the junction with solar absorption tubes. Inlet, or outlet, of

the fluid is in the middle zone of the bottom pipe, or top pipe, and the flow is bidirectional towards both ends of the tubes.

In a generic cross section of the bottom pipe (or top pipe),
5 velocity profile is parabolic and nanoparticles (or more properly clusters) can be subjected to sedimentation, especially near tube surface, where velocity is lower than the center of the cross section. Besides sedimentation depends on particle size (or cluster) and time of
10 permanence on a point. Therefore sedimentation might depend on particle (or cluster) weight and flow rate of the nanofluid. Obviously sedimentation might be higher if mean velocity is low in the cross section. For this reasons, if in the collector in Figure 1 a nanofluid flows, in the
15 bottom pipe and top pipe the amount of precipitated solid phase increases from A to B and from C to D respectively. Besides, some precipitated solid phase slops itself in riser tubes from bottom pipe. Therefore further solid phase will precipitate on the bottom pipe.

20 To avoid these problems flow rate of nanofluids can be increased in the hydraulic system in order to enhance velocity in the solar collector. However, friction losses are directly proportional to the flow rate, therefore an higher power consumption is necessary.

25 Another solution, object of this invention, is a solar collector where it is possible to maintain a constant velocity

along the bottom pipe and top pipe to avoid sedimentation, through variation of the cross section area along them, according to the needs.

As no restrictive example, Figure 2 shows a solution in order to obtain a bottom pipe (or top pipe) with a variable cross section along the tube. The drawing of the traditional bottom pipe (o top pipe), 1A, and the drawing of the suitably shaped element, 1B are shown in this figure. 1B is connected (according to the needs) to 1A to obtain the component shown in Figure 3.

1C is the bottom pipe (or top pipe) with changeable cross section area along the tube and it can be used to make a solar collector. A tridimensional model of 1C is shown in Figure 3. In particulars E and D it is possible to see the difference of the cross section area in the bottom pipe (or top pipe). In the specific and no restrictive case shape of the section is a circular segment.

Another solution can be used to obtain a variable cross section area along the tubes. For illustrative purpose and no restrictive, Figure 4 shows a bottom pipe (or top pipe) with truncated conical shape. On the interrupted section of Figure 4 it is possible to note variation of the bottom pipe diameter (or top pipe diameter)

For illustrative purpose and no restrictive, Figure 5 shows a section view of a collector with top pipe (1CT) and bottom pipe (1CB) with variable cross section. It can have all

dimensions and it can be employed on every thermal solar collector.

Sedimentation of solid phase is avoided by using top pipe and bottom pipe with variable cross section area. Besides
5 in this case additional pressure drop is concentrated in the collector and negligible compared to case of a flow rate increased in hydraulic system. Finally, how it is possible to see in Figure 6, for every cross section, near the edges, the velocity of the flow is higher and its vector has a
10 vertical component, V_b , besides an axial component, V_a . Therefore there is a vertical force that avoids sedimentation.

Generally from this invention is suitable for an efficient use of innovative heat transfer fluids, as biphasic suspension,
15 from thermodynamic and fluid dynamic point of view.

Besides, this invention does not influence the thermodynamic characteristics of thermal solar collector. In fact, differences between this invention and a traditional thermal solar collector do not interest geometry of the
20 absorber, riser tubes and mechanisms of heat transfer between solar radiation and absorber and its riser tubes.

Therefore it is possible to maintain the performance of the traditional thermal solar collector and to enhance their versatility in order to use innovative biphasic heat transfer
25 fluids.

In order to obtain a variable cross section, solid shaped

elements are placed in the tubes with constant cross section, generally employed to make both top pipe and bottom pipe of traditional solar collectors. Thus it is possible to limit the increase of construction costs, that
5 might be significant if variable cross section tubes were made by one element, for example with truncated conical shape.

Tubes of the collector of this invention can be made with any resistant materials to the working temperatures and
10 strains of the systems. Therefore transparent materials can be used and solid phase of the suspensions can directly absorb solar radiation that could enhance performance of the thermal solar collector.

CLAIMS

- 1) Solar collector for applications with nanofluids or biphasic heat transfer fluids, including both a top pipe and a bottom pipe, characterized by the fact that at least one of these tubes has a variable cross section in order to avoid sedimentation of nanofluids and other biphasic heat transfer fluids that flow inside the tubes of the solar collector itself.
- 2) Thermal solar collector according to claim 1 wherein variable cross section is obtained by introducing suitably shaped elements in the tubes.
- 3) Thermal solar collector according to claims 1 and 2 wherein variable cross section determines a radial component of velocity of the flow inside the tubes, near the edges, and therefore a vertical force that avoids sedimentation.

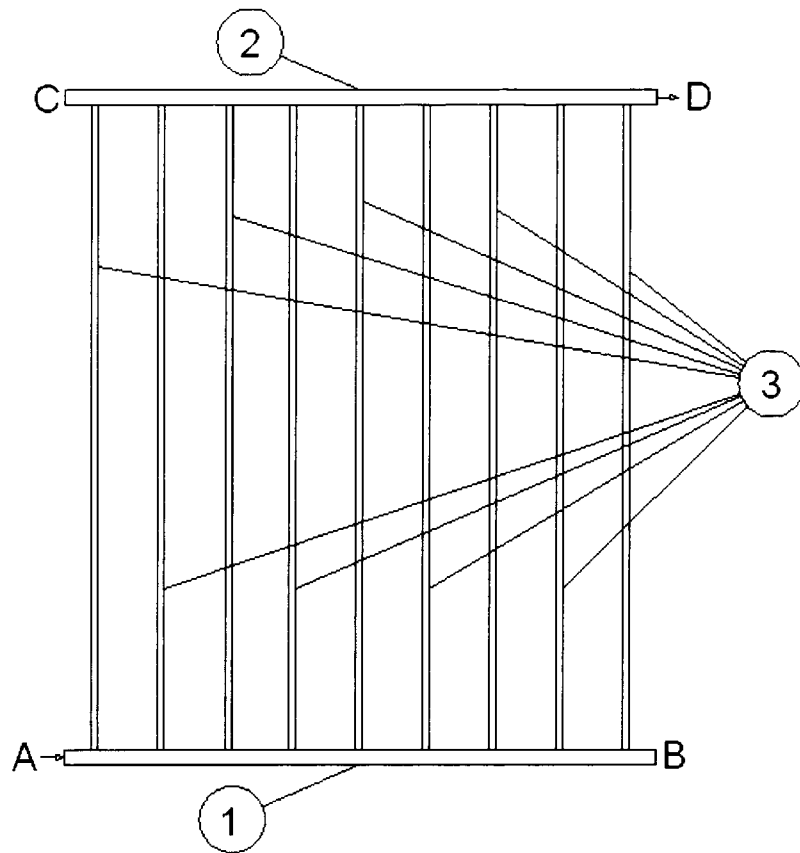


Fig. 1 (prior art)

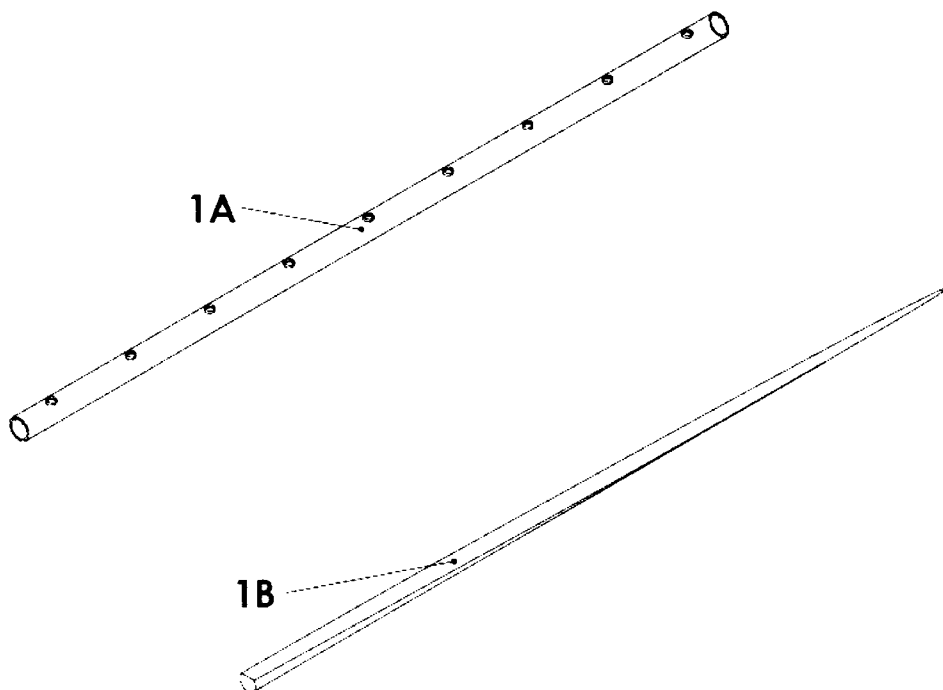


Fig. 2

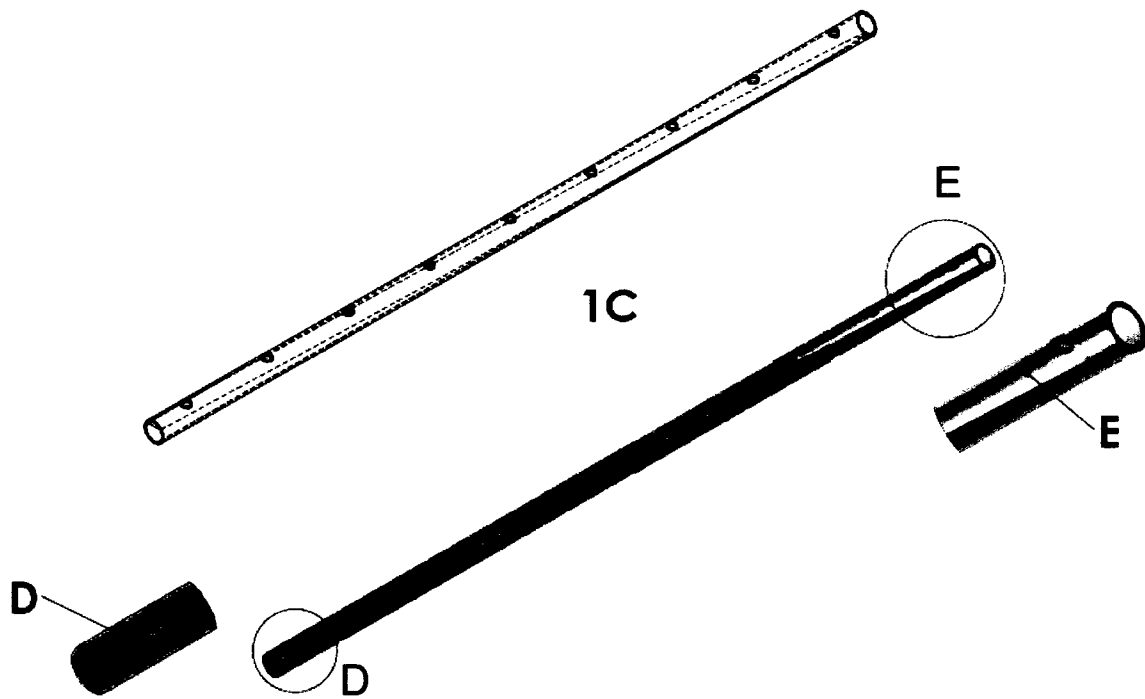


Fig. 3

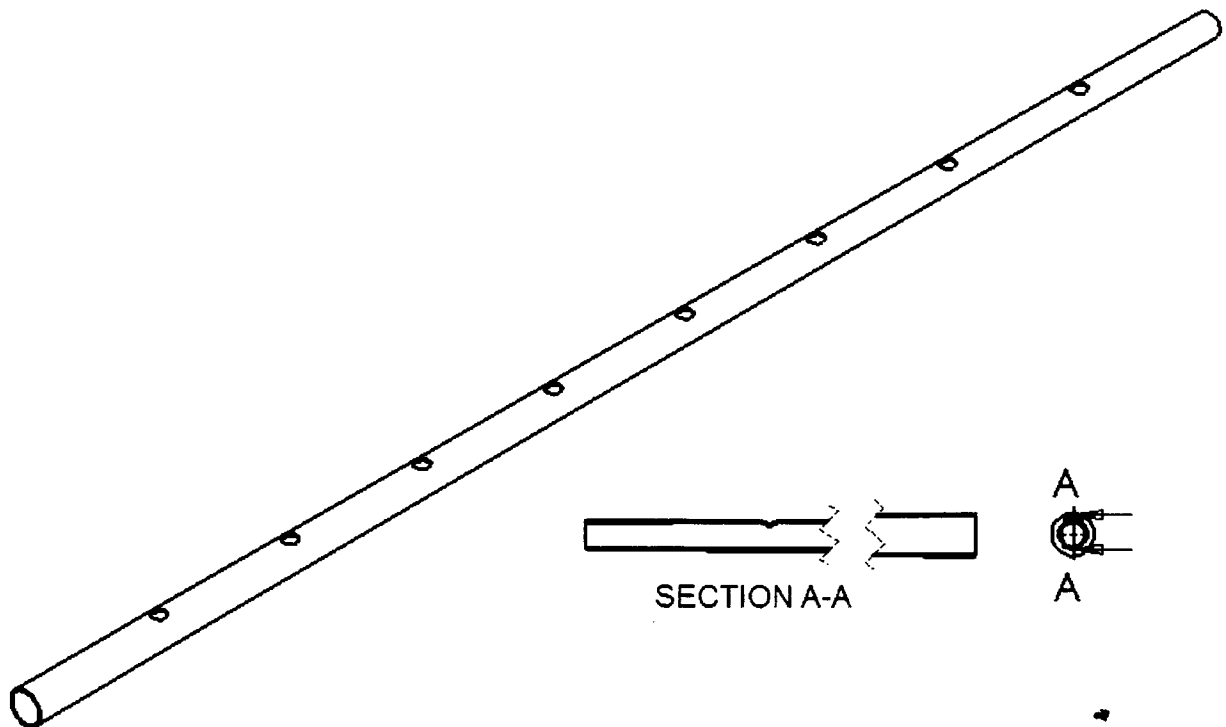


Fig. 4

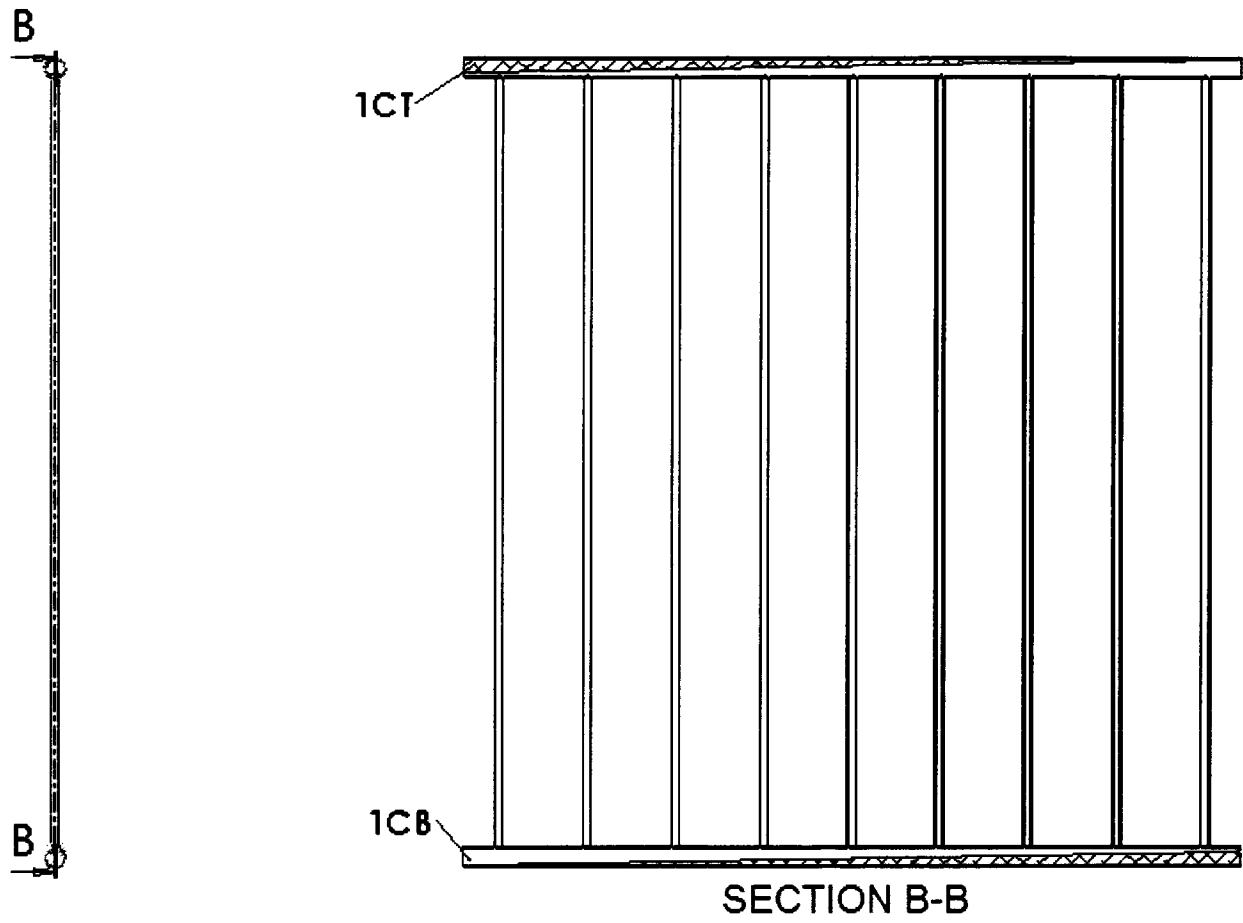


Fig. 5

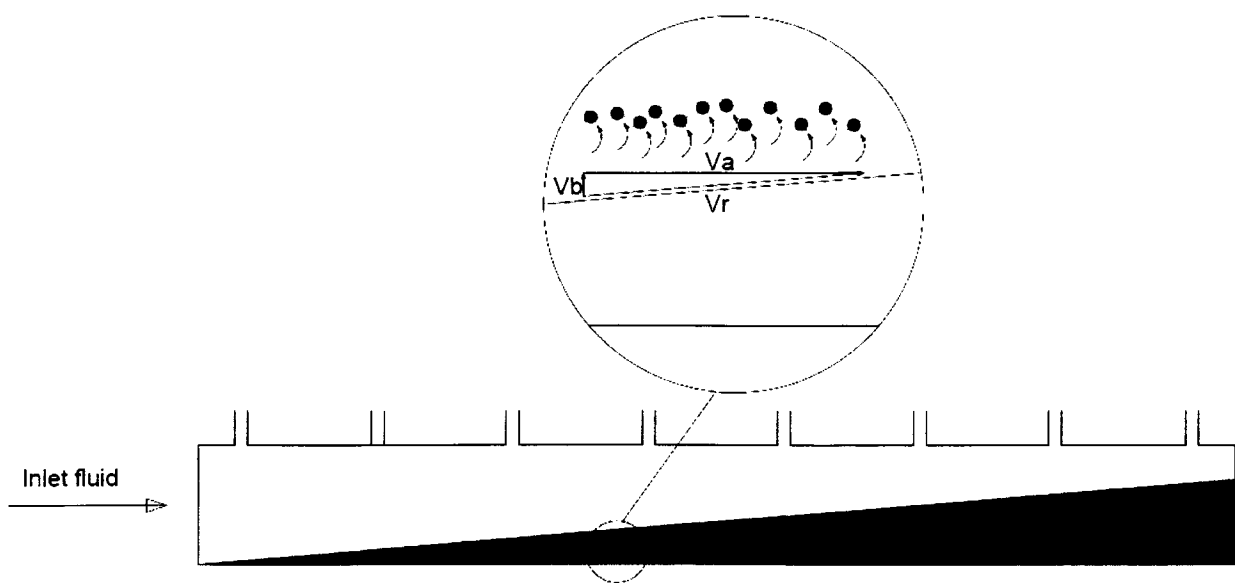


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2011/051988

A. CLASSIFICATION OF SUBJECT MATTER

INV. F24J2/24 F28F13/08
ADD.

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)

F24J F28F

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/250051 A1 (LATA PEREZ JESUS MARIA [ES]) 8 October 2009 (2009-10-08) figures -----	1,3
X	US 4 407 269 A (HOPPER THOMAS P [US]) 4 October 1983 (1983-10-04) column 4, line 34 - line 43 column 4, line 52 - line 64; figures 5-9 -----	1-3
X	GB 2 099 133 A (PIRELLI) 1 December 1982 (1982-12-01) page 2, line 26 - line 33; figures -----	1,3
A	US 3 919 858 A (GARLAND MILTON W ET AL) 18 November 1975 (1975-11-18) column 4, line 21 - line 34; figures -----	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2011/051988

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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