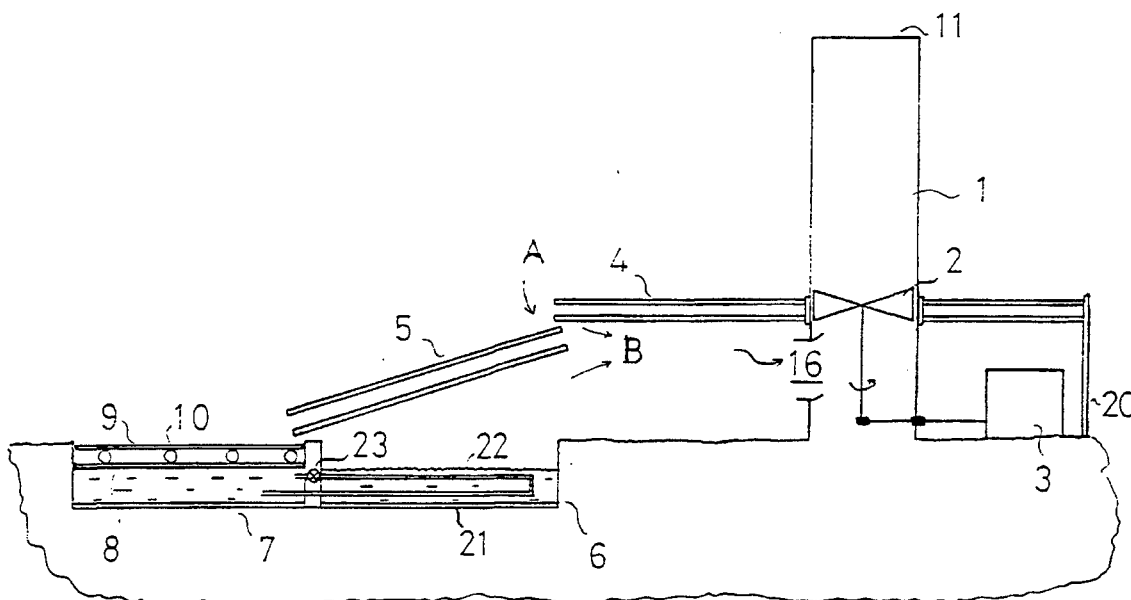


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<p>(21) International Application Number: PCT/IB94/00038 (22) International Filing Date: 11 March 1994 (11.03.94) (30) Priority Data: 10498 11 March 1993 (11.03.93) LK 10613 8 February 1994 (08.02.94) LK (71)(72) Applicant and Inventor: SENANAYAKE, Daya, Ranjit [LK/LK]; 9 Ecrin Place, Colombo 8 (LK). (74) Agent: GEE, David, William; Farmhouse Court, Marston, Sutton Coldfield, West Midlands B76 ODW (GB).</p>		<p>(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, UA, US, UZ, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>

(54) Title: SOLAR CHIMNEY ARRANGEMENT



(57) Abstract

This invention relates to a solar chimney arrangement, and in particular to an arrangement which includes a chimney (11, 31) to receive fluid originating from a solar heat collector (7, 27, 6, 26) and a turbine (2, 32) to be driven by the fluid. The solar heat collector has an evaporative area (6, 26) and a non evaporative area (7, 27), the non-evaporative area acting as heat absorbing area and having a first cover (8, 28) adapted to inhibit evaporation of a heat-absorbing liquid retained therein, the evaporative area having a second cover (4, 24) connected to the chimney and adapted to contain vapour evaporating from a liquid in the said evaporative area, there being means to transfer thermal energy from the liquid of the non-evaporative area to liquid of the evaporative area. The solar heat collector increases the moisture content and the temperature of the air flowing past the turbine.

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SOLAR CHIMNEY ARRANGEMENT

FIELD OF THE INVENTION

5 This invention relates to a solar chimney arrangement.

BACKGROUND TO THE INVENTION

A solar chimney arrangement typically includes a solar
10 chimney having an associated wind turbine, the wind turbine
being energised in response to an updraft of solar-heated
air in the chimney. Such an arrangement can be
environmentally friendly.

15

DESCRIPTION OF THE PRIOR ART

In a known form of solar chimney, the air for use in the
updraft is solar-heated beneath a glass collector roof. To
20 obtain a volume of heated air sufficient to effect
sustained operation of a wind turbine of a size suitable
for the commercial generation of electricity, the collector
roof needs to cover a large land area, and is of a
construction both expensive to erect and costly to
25 maintain.

French patent 2,307,982 shows a chimney carrying a turbine,
the chimney being surrounded by an annular pool which is

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covered by a transparent plastic sheet preventing evaporation. Surrounding the pool is a slab of black-painted concrete. The pool and concrete are covered by a glass canopy. During periods of sunlight the glass canopy
5 permits the concrete slab to heat up, and this in turn heats the air above, which flows into the chimney. The pool serves as a heat sink, storing heat during sunlight hours and giving out this heat during the night.

10 French patent 2,436,268 shows a chimney having a solar panel around its base, to form an air-heating chamber, whereby the air circulates normally i.e by natural in-draught from the outside to the inside of the container, to rise in the chimney stack.

15

US patent 4,452,046 shows a tower, to which is connected at least one separate "hydric hothouse". Each hydric hothouse has a black (thermally absorbent) base covered by a transparent surface providing a membrane sheet over water.
20 The hot air from above the water in each hothouse is sent through a pipe to the chimney installation.

STATEMENT OF THE INVENTION

25

It is the object of this invention to improve upon the efficiency of the known solar collection systems, by

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increasing the temperature and moisture content of the air flowing to the turbine.

From one aspect of the invention we now propose a solar chimney arrangement which includes air heating means comprising a liquid solar-heat absorber.

From another aspect of the invention we propose a solar chimney arrangement in which a solar chimney is associated with a non-evaporative area and an evaporative area, the non-evaporative area having a first cover adapted to inhibit evaporation of heat-absorbing liquid, the evaporative area having a second cover adapted to contain evaporated vapour, and means connecting the second cover with the solar chimney upstream of a wind turbine.

Preferably the evaporating and non-evaporating areas surround the chimney.

Usefully the evaporative areas are provided by ground pans filled with water, and separated into non-evaporating and evaporating areas. The non-evaporating areas are positioned to receive energy from the sun, and this energy is absorbed as heat in the liquid, some or all of that absorbed heat being then transferred to the water in the evaporating area.

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The quantity of heat absorbed by the liquid can be enhanced by supplementing the "direct" absorption of solar energy by the liquid, as by "indirect" absorption. Usefully therefore the liquid is contained in a tank made from one
5 or more heat absorbing materials. In one embodiment a ground pan is constructed by digging an earth trench which is then lined with black polythene sheet, the sheet acting both to contain the liquid e.g. water, and to absorb the sun's rays to become heated thereby.

10

The cover for the non-evaporating area preferably floats on the liquid e.g. water, surface and so is in direct contact therewith. The cover for the evaporating area is positioned above the liquid e.g. water, surface so that
15 there is an evaporation space between the liquid and second cover. In a preferred embodiment the second cover is of a material such as glass, able to permit differential transmission therethrough of radiation whereby to permit the receipt of solar energy by the evaporative liquid but
20 to inhibit loss of the resulting heat energy therethrough; the glazing can be of single thickness or of the multi-pane sealed type.

The second cover will usefully be arranged to extend beyond
25 i.e. overhang the evaporative area whereby to permit air to be indrawn, to replace that flowing to the solar chimney; in an alternative embodiment a pump or similar one-way air

- 5 -

flow means can alternatively be used to provide air to be heated.

The air to be fed for upward flow in the chimney from the evaporation space is thus both hotter than the external air and of reduced density, with enhanced flow characteristics.

The pans can be of large area, and shallow. In a typical installation, the collector roof area or second cover will be positioned completely around the chimney, and the ground pans will be outwardly thereof; though, if space is limited, the ground solar chimney will preferably be positioned away from the centre of the site at a position selected so that the ground pans are between the chimney and the sun's position e.g. at noon on a particular day.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described, by way of example, with reference to the accompanying drawing, in which:-

Fig.1 is a side view, partly in section, of an embodiment of solar chimney arrangement according to the invention;

Fig.2 is a partial side sectional view of an alternative evaporation pan; and

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Fig.3 is a side view, partly in section, of an alternative embodiment.

5

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

A vertical tube or chimney 1 is constructed in the centre of land area. In this embodiment, within the chimney 1 is
10 constructed a wind fan 2, which can be rotated by updraft of air in chimney 1 to operate turbine 3 to produce electricity. In an alternative embodiment, the turbine and electrical generator are themselves located within the base of the chimney.

15

A primary collector roof 4, in this embodiment of glass, but in alternative embodiments of plastic, kevlar, PVC or the like, is constructed around the chimney 1. As drawn, roof 4 is of the double-glazing type, but it can be of the
20 triple-glazed type for extra protection against heat loss.

Roof 4 is mounted on steel struts 20, only one of which is shown, but in an alternative embodiment, of concrete, wooden, or plastic struts, to stand between 0.5m and up to
25 200m above ground level, the height being selected to be less than that of chimney 1.

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The roof 4 closely surrounds chimney 1 in order to prevent the loss of heated air (provided as more fully described below), from between the roof and the chimney. Roof 4 extends outwardly from the chimney for a short distance
5 selected in accordance with the requirements of the project designer, and ground terrain.

In this embodiment a secondary collector roof 5 is also provided, outwards from the periphery of primary roof 4.
10 Second collector roof 5 is constructed at a lower level, in this embodiment being inclined and terminating just below the roof 4, but in another embodiment the second roof is at half the height of roof 4; second collector roof 5 is fitted under roof 4 in order to provide a minimum primary
15 roof overhang necessary to avoid direct outflow of air from under roof 4, in this embodiment of 3m. The second collector roof 5 is similarly constructed of a transparent material, preferably glass but alternatively of kevlar or the like, and is again mounted on struts of a suitable
20 material, such as concrete, wood or steel. The gap between the primary and secondary roofs permits ambient air to be drawn under collector roof 4, as shown by arrow A, thenceforth to pass through opening 16 into the chimney "upstream" of wind fan 2. In a further alternative
25 embodiment the primary roof can be suitably shaped, usefully with openings arranged for the inflow of ambient air.

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Below the second collector roof 5, and in this embodiment slightly below ground level, there is an evaporation pan 6. Whilst in one embodiment pan 6 can be an integral pan of plastics or the like, in a useful embodiment it is provided
5 by shallow trenches cut from the earth, preferably to a depth of 2.5cm - 15cm. Each pan or trench bottom 6 is covered by non-porous material 21 having solar-absorbent properties, in this embodiment black polythene. The pan can be of unitary construction but for ease of manufacture
10 and installation will usually comprise several units, which may be hydraulically interconnected, or independent units.

In use, the polythene 21 in pan 6 is covered with water,
15 which can become heated both by direct absorption of the energy from the sun's rays and indirectly by heat transfer from polythene 21, and can evaporate, to mix at or near position B with the air inflowing under the roof 4 overhang. Thus pan 6 provides an evaporative area and
20 depending upon the solar heat absorption perhaps also a secondary heat absorption area.

As more fully described below, the water in evaporation pan 6 can be pre-heated by water in a pre-heating pan 7, which
25 is the primary, perhaps only, heat absorption area. Pan 7 may be fabricated, and be of unitary (integral) construction though it is preferably assembled from multiple units; usefully however it comprises a series of

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shallow trenches cut from the earth to a depth of 2.5cm - 15cm, with laid sheets of black polythene to prevent water leakage, and filled with water.

5 As compared however with the arrangement for evaporative pan 6, the water in non-evaporative pan 7 is covered by an evaporation inhibiting sheet 8, preferably a sheet which floats directly on top of the water and is in intimate contact therewith; the sheet allows passage of the sun's
10 rays, being in this embodiment a transparent sheet of polythene.

In a preferred embodiment, as disclosed, a second solar transmitting but insulating sheet 9, consisting of a layer
15 of polythene, is held raised above the non-evaporation sheet 8, being separated therefrom by inflated balls 10 which rest on the non-evaporation sheet.

In alternative embodiments, the inflated balls are replaced
20 by rigid foam or styro-foam balls, or the second insulating sheet is otherwise supported, as by struts or ropes, for the same purpose.

Although the water in pan 7 can be heated, because of the
25 covering 8 it cannot evaporate and escape. Excess heat energy of the pan 7 water following solar absorption is, however, transferred to the water in evaporation pan 6, preferably indirectly by heat exchanger tubes 22 utilising

- 10 -

- pump 23; the evaporant is then replaced by fresh water added to pan 6. In an alternative embodiment the pan 7 water heats the pan 6 water directly as by simply being pumped thereinto (with the water level in pan 6 being maintained by the rate of pumping or by the use of a second, return, pump not shown) or being allowed to flow thereinto by gravity; in this second embodiment the evaporant is replaced by fresh water added to pan 7.
- 10 In use, solar energy falls upon the pans and roof, heating the water in evaporation pan 6 and the air under the two roofs. As air from under roof 4 is drawn up chimney 1, it is replaced by ambient air as shown by arrow A, which when under roof 4 becomes heated above the ambient temperature and takes up water vapour evaporated from pan 6, before passing through opening 16 to chimney 1 as vapour-laden low-density heated air, to exit from the chimney top 11 and so driving the fans 2 as it flows therepast.
- 20 The evaporation pans 6 thus permit the transfer of the collected solar heat in non-evaporation pans 7 to the air below roof 4, in the form of heat and vapour; the disposition of the second collector roof 5 relative to primary collector roof 4 permits the mixing of large volumes of ambient air with the heated vapour-laden air rising from evaporation pan or pans 6.
- 25

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It will be understood that the costs of construction of a solar chimney of predetermined output can be substantially reduced, because much of the heat collector area is provided by shallow earth trenches and relatively
5 inexpensive polythene or the like; maintenance costs are also likely to be reduced.

In an alternative embodiment suitable perhaps for locations with strong and varying-direction winds the inflow of
10 replacement air can be supplemented or effected by pumps, preferably driven by electrical energy produced by the turbine/generator.

The turbine and generator will desirably be selected to be
15 of a size to generate electrical power for supply to the national grid, but alternatively can be for local supply as to individual industrial units.

For some installations, with limited available ground area,
20 pan 6 could be positioned wholly or partly under roof 4; secondary roof 5 may then not be provided.

The air inflow can alternatively be drawn under secondary
roof 5, from immediately above pan 7.

25

The pre-heating pan (or pans) 7 and the evaporation pan or
pans 6 combine to provide an increase in the moisture

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content of the air flowing into the chimney 1, preferably by at least 2% over that of the surrounding ambient air.

These pans also combine to provide an increase in the
5 temperature of the air flowing into the chimney 1, preferably by at least 3°C above that of the surrounding ambient air.

In another embodiment the water from pre-heating pan 7 is
10 sprayed into the evaporation area above pan 6. It may be sprayed (atomised) in the direction of flow of the wind (for rapid evaporation);, or into or across the direction of flow, also to assist the vapourisation of the pre-heated water.

15

In the embodiment of Fig.2, pan 26 is of corrugated or wavy configuration, with water-retention canals 29a,29b,29c, of large surface area for enhanced evaporation. Usefully the pan 26 is solid, of pyramid form but with upwardly facing
20 external canals, but in an alternative embodiment (such as that of Fig.3) can have a hollow interior e.g. for housing solar chimney equipment such as pump 30.

Although in this embodiment as installed the canals are
25 horizontal, the pan 26 is angled and with a lower level outer side (than that of the inner canal side) so that heated water transferred from the non-evaporative area 27 can flow by gravity from an upper canal to a lower canal,

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in this embodiment through conduits 28, and thence back to the non-evaporative (primary heat absorbtion) area e.g pan 37 (Fig.3). In an alternative embodiment heated water from the non-evaporative pan or pans is sprayed under pressure
5 (rather than being drip fed) from pipes 22, utilising pump 30. In a further alternative embodiment there is only a single water supply pipe 22, which feeds only the topmost canal 29a, water in this canal overflowing so as to run as a thin film into the next canal 29b, and so on.
10 Evaporation is likely to occur both from the top water film in the canal and whilst as a thin overflowing film.

In an alternative embodiment the canals can be of short length, to face away from one side only of the chimney 11
15 or chimney 31 (Fig.3), but in a further alternative embodiment a single canal but of downwardly spiral form surrounding the chimney is utilised.

In the embodiment of Fig.3, a chimney 31 of standard
20 construction e.g. of brick or concrete, is installed in the centre of the glass collector roof 34. The roof 34 acts as a secondary heat collector, as well as a cover spaced above the evaporation or heat transfer water surface provided by the canals and overflow surfaces. Standard pressure-staged
25 wind turbines 32 (or other types) are installed at the chimney inlet. Solar radiation heats up the water in the primary solar heat absorber pan 37; usefully the pan 37 acts also as a heat reservoir, retaining for a substantial

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period heat energy received during periods of sunlight, though in an alternative but less preferred embodiment the pump 30 or other liquid transfer means (between the pans 37,36) is of a capacity for several water changes in the primary heat absorbtion (non-evaporative) pan 37 each hour.

The solar heat reservoir pan 37 is covered by one or more transparent solar transmitting (polythene or similar material) material sheets 38 adapted to float on the surface of the water, preventing evaporation from the water surface and trapping the transmitted solar hear in the water i.e. manifested as an increase in water temperature. This heated water is pumped into the heat transfer area below roof 34.

15

In the heat transfer area there is not a surface contact sheet, whereby to encourage evaporation and the consequent release of excess heat energy from the water to the air. Air trapped below the glass collector roof 34 becomes heated. The hot air outflows through the chimney 31, to drive the turbine fans 3; the turbines produce electricity, usefully for the national grid, by way of conventional generators.

25

Pan 36 is of generally pyramid form, with external upwardly facing channels, and acts as a heat transfer unit. The pyramid inclination towards the chimney centre acts as an angled flow means again to permit gravity return flow

- 15 -

towards pan 37, outwards from the chimney 31 axis, for water recirculation.

The base of the solar heat reservoir or primary heat absorber 37, as well as the base of heat transfer unit or pan 36 is covered by a black membrane 38, to improve the solar heat absorption and to reduce the heat losses from heated water to the underneath soil or the like. This cover will also prevent leakage of the hot water.

10

In this embodiment pre-heated water from pan 37 circulates through a pipe network (again acting as the transfer means for heated liquid from the non-evaporative area 27) laid on the banks of the circular canals. Hot water drips on to the bank surface through the holes provided in the pipes (or may be sprayed into the air). The increase of water vapour content in the air is believed likely to reduce the air density, for enhance flow past blades 32 to increase the power output.

20

In yet a further embodiment, the non-evaporation sheet 8,38 is replaced by a layer of oil or other liquid, or by a material having the required properties of (i) being less dense than the water in pre-heating pan 7,37; and (ii) being transparent or translucent or being otherwise able to transmit solar heat energy to the water.

25

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In another further embodiment, the invention is carried out on apparatus constructed at sea, or in a lake or other large body of water, using floating troughs and platforms mounted on struts connected to the bed of the sea or other
5 body of water.

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CLAIMS

1. A solar chimney arrangement which includes a chimney (11,31) to receive fluid originating from a solar heat collector (7,27, 6,26) and a turbine (2,32) to be driven by the fluid, characterised in that the solar heat collector has an evaporative area (6,26) and a non evaporative area (7,27), the non-evaporative area having a first cover (8,28) adapted to inhibit evaporation of a heat-absorbing liquid, the evaporative area having a second cover (4,24) connected to the chimney and adapted to contain vapour evaporating from a liquid in the said evaporative area, and means to transfer thermal energy from liquid of the non-evaporative area to liquid of the evaporative area.
2. An arrangement according to claim 1 which includes transfer means (22) to feed heat absorbing liquid from the non-evaporative area into the evaporative area to intermix with the liquid already in the evaporative area.
3. An arrangement according to claim 1 or claim 2 which includes transfer means to feed heat absorbing liquid from the non-evaporative area into the evaporative area at a level above liquid in the non-evaporative area, and angled flow means (26,36) in the evaporative

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area to effect gravity flow of liquid back to the non-evaporative area.

4. An arrangement according to any of claims 1-3 in which the said first cover is adapted to float on top of the liquid in the non-evaporative area, and in which the said first cover is multi-layer, the layers being separated by one of inflated balls, rigid foam and styro-foam balls, and struts, and ropes.
5. An arrangement according to any of claims 1-4 in which the said second cover (4) extends beyond the evaporative area and has a gap adjacent one of its edges for ambient air to inflow, and in which the connection to the chimney is by a chimney inflow opening (16)
6. An arrangement according to any of claim 1-5 in which the evaporative area and the non-evaporative area comprise one of liquid filled pans and trenches dug into the ground.
7. An arrangement according to claim 8 in which the said pans and trenches are between 2.5cm and 15cm deep.
8. An arrangement according to claim 6 or claim 7 in which the said pans and trenches are lined with a heat absorbing material.

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9. An arrangement according to any of claims 1-8 in which the said non-evaporative area and the said evaporative area surround the chimney.

10. An arrangement according to any of claims 1-9, in which the solar heat collector is adapted to increase the moisture content of the air above the evaporative area by at least 2%, and to increase the temperature of the air above the evaporative area by at least 3°C, over that of the surrounding ambient air.

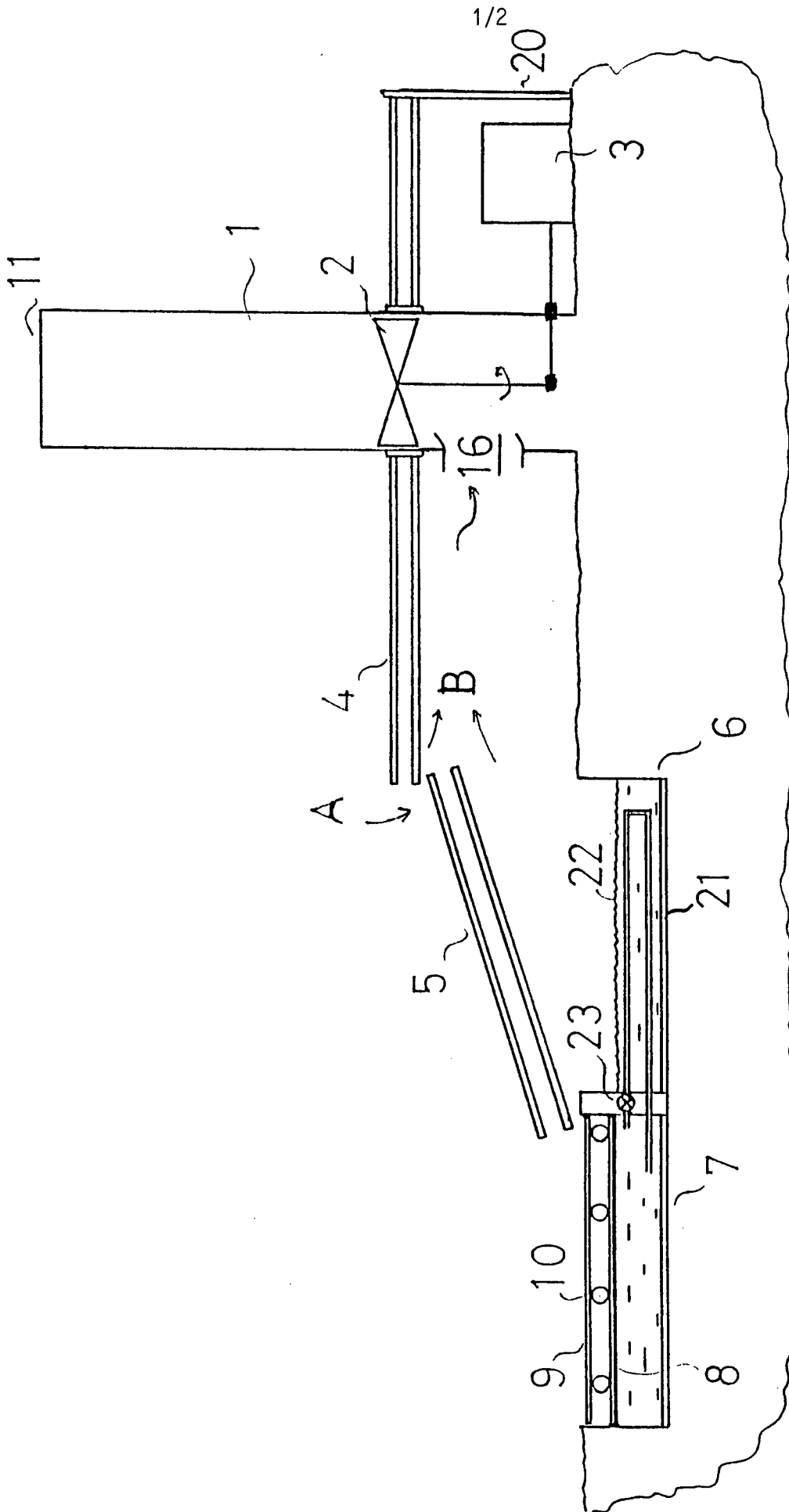
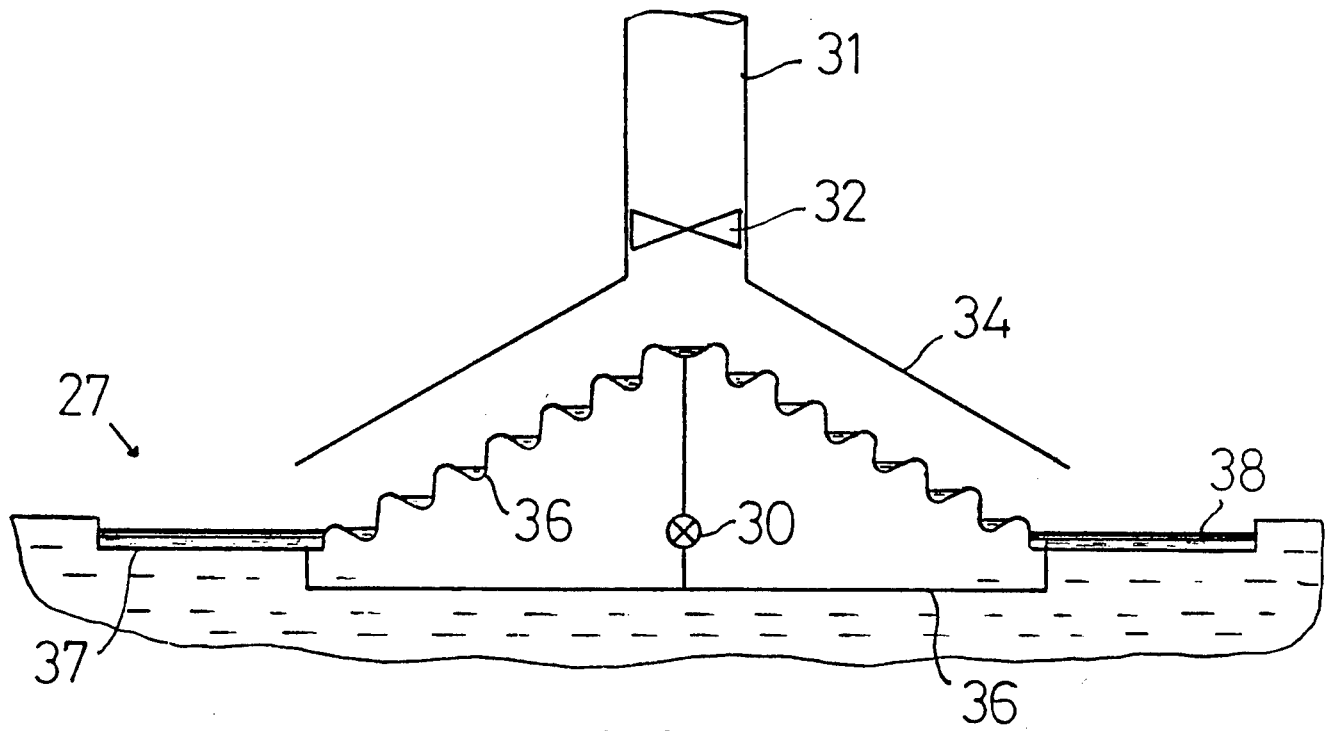
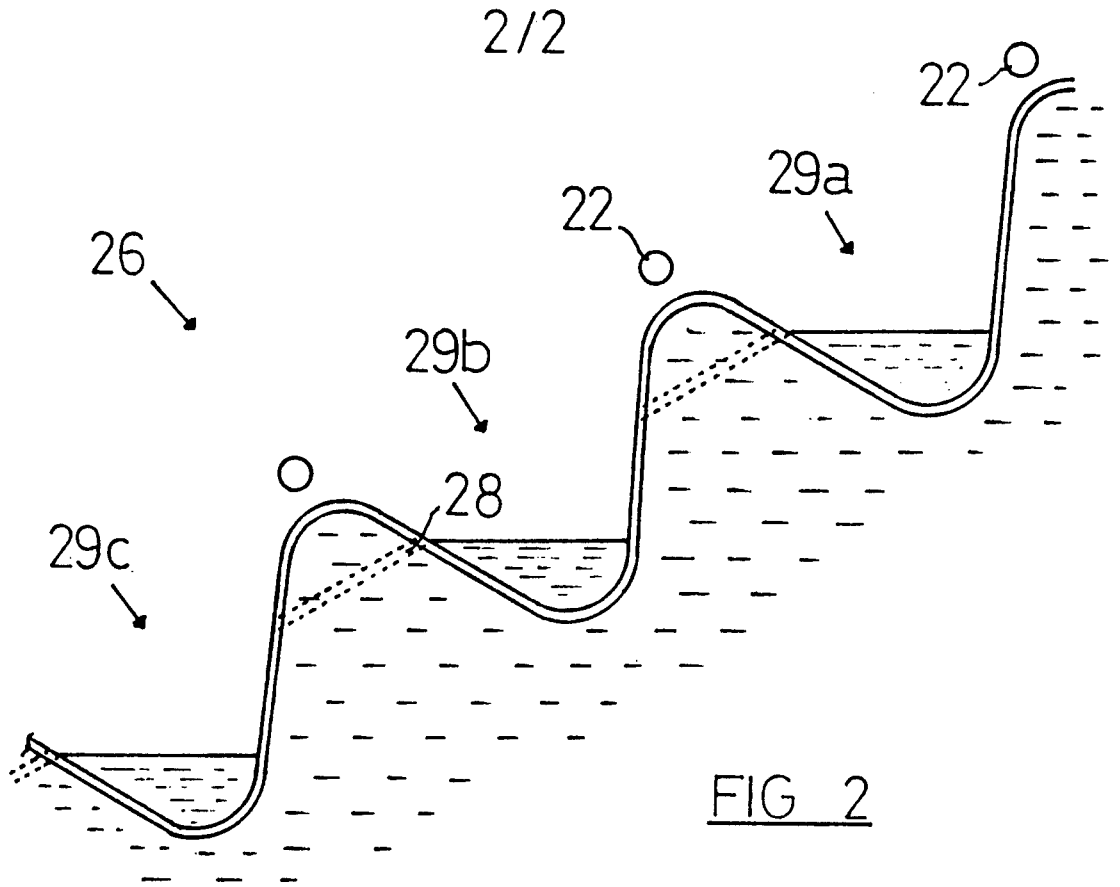


FIG 1



INTERNATIONAL SEARCH REPORT

In: ional Application No
PCT/IB 94/00038

A. CLASSIFICATION OF SUBJECT MATTER IPC 5 F03D9/00		
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 5 F03D C02F B01D		
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)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	DE,A,29 31 349 (H.BEUTEL) 27 May 1981 see page 6, paragraph 5; figure 2 ---	1
A	DE,A,40 36 658 (W.HOLZER) 30 January 1992 see column 3, line 65 - column 4, line 17; figure 2 ---	1
	-/--	
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Date of the actual completion of the international search 10 June 1994		Date of mailing of the international search report 01.07.94
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INTERNATIONAL SEARCH REPORT

International Application No

PCT/IB 94/00038

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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