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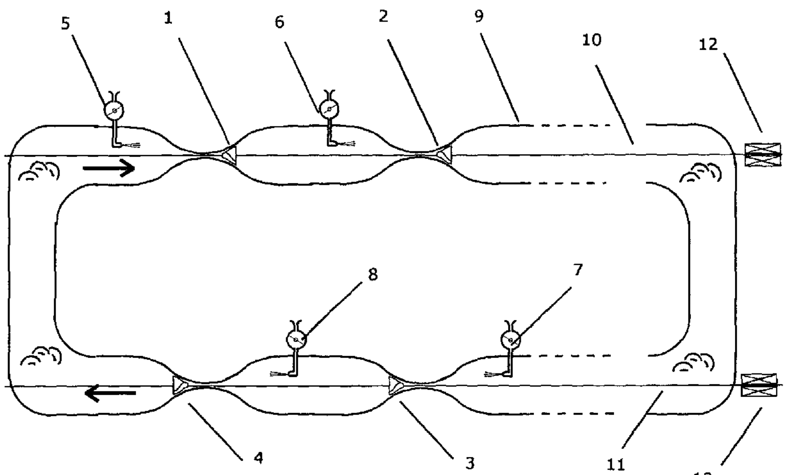

Fig. 2.

(57) Abstract: A power conversion device comprising injecting a first fluid, at a temperature approximate to its phase transition temperature, into a second fluid, and circulating the combined fluid through a heat engine, such as a turbine, wherein the combined fluid cools, and part of it undergoes a phase change, as it passes through and drives the heat engine. Figure 2 depicts an illustrative example of the present invention. Items (1, 2, 3) and (4) are turbines.. Items (5, 6, 7) and (8) are jet pumps used for injecting saturated steam into the largest cross section area parts of the conduit 9, linking the turbines. Each jet pump is fitted with a tap or other means of controlling the rate of steam flow through it. Two shafts (10) and (11) are rigidly attached to the two rows of turbines and rotate with them. Generator armatures (12) and (13) are fined to the ends of the shafts.

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Phase change turbine incorporating carrier fluid

Technical Field

According to the invention, there is provided a power conversion device comprising injecting a first fluid, at a temperature approximate to its phase transition temperature, into a second fluid, and circulating the combined fluid through a heat engine, such as a turbine, wherein the combined fluid cools, and part of it undergoes a phase change, as it passes through and drives the heat engine.

Brief description of the drawings

Figure 1 depicts a device according to the earlier invention.

Figure 2 depicts an illustrative example of the present invention.

Figure 3 depicts a single turbine serviced by two jet pumps.

Figure 4 depicts a steam compression pump servicing an array of jet pumps.

Figure 5 depicts an East to West cross section through part of a version of the invention that exploits solar energy to generate the required steam.

Figure 6 depicts a type of ball cock valve used in the invention.

Figure 7 depicts alternative turbine and jet pump designs according to the invention.

Figure 8 depicts another jet pump design according to the invention.

Figures 9a, 9b and **9c** reveal one design solution for condensation and helical fluid flow problems associated with the invention.

Figure 10 depicts a version of the invention suitable for extracting latent heat from warm moist air.

Figure 11 depicts a version of the invention, suitable for cooling underground railway platforms.

Figure 12 explains how the invention can be used for cooling the walls and roofs of buildings, with the thermal energy absorbed being used to drive the invention and generate electricity.

Figure 13 depicts how a version of the invention, as revealed with reference to **Figure 10** can be used to extract latent heat from warm humid air in tropical rainforests and convert it into electricity.

Figure 14 depicts hot climate glass house according to the invention.

Figure 15 depicts a heat exchange system according to the invention, for extracting latent heat from contaminated, warm, water saturated air.

The prior art

The present inventor, Courtney, has revealed novel forms of steam turbines in patent applications GB 05 11946.6, CT/GB2007/001380 and GB 2459326. A common feature of all these inventions is that they differ from Rankine cycle turbines by deliberately manipulating the thermodynamic conditions in order to harness the latent heat released as saturated steam condenses. In contrast, Rankine cycle turbines delay condensation until as late as possible in the thermodynamic cycle, with the bulk of the latent heat released by condensation being disposed of as low grade waste heat.

According to Courtney's most recent prior art invention as revealed in GB 2459326, external work is done at the expense of the release of latent heat, caused by condensation, as saturated steam flows through a chain of progressively smaller turbines. The turbines decrease in size in order to maintain saturated vapour conditions as vapour condenses out along the chain.

Figure 1 depicts part of a chain of turbines according to GB 2459326. Items **1, 2** and **3** are successive turbines. Typically, saturated steam at about 100°C is injected at 4, but significantly higher or lower temperature saturated steam may also be employed. The turbines are coupled to a generator **5** by a rotating line shaft **6.** A small fraction of the steam condenses out on passing through each turbine. This rejuvenates the steam by releasing latent heat. If each successive turbine is made progressively smaller, to offset the reduced mass rate of steam passing through it, then it is possible to maintain a steady steam temperature along the chain. To maintain a steady flow of steam in the face of opposition from viscous drag and turbulence, impellor pumps such as 7, **8, 9** and **10** are added.

In patent application GB 2459326, Courtney revealed the conditions required to ensure that the work done on the fluid by the impellor pump was only a small fraction of the productive work done by the fluid during the same period. These conditions are relevant to the present invention, so they will be stated again.

The cross sectional area of the conduit in which each successive impellor pump is situated is significantly larger than the cross sectional area of the following turbine nozzle. Consequently the kinetic energy imparted by each pump is significantly less than the kinetic energy possessed by the steam as it passes through the following nozzle. If an unsaturated vapour had been used, it would have cooled as it progressed along the nozzle taper. But, because the steam is saturated, partial condensation and the liberation of latent heat occurs instead of significant cooling. This latent heat is recaptured as the steam slows down and warms up on passing through the flared section following each turbine. But a second release of latent heat as the turbine does external work is permanently lost.

This prior art device is superior to Rankine cycle turbines because it is far more efficient at converting the latent heat stored in steam into useful work. But it has three design weaknesses:

(i) Each successive turbine has o be made progressively smaller.

(ii) The impellor pumps add complexity.

(iii) At some stage the chain has to be terminated on efficiency grounds, because as turbine size decreases, the power output from the turbine also decreases, but there is no proportionate decrease in the work done against turbulence and viscous drag.

Disclosure of the invention

This invention employs some form of fluid, with a fraction of the fluid experiencing a phase change, with the release of latent heat, as it passes through the device. The preferred fluid is a saturated vapour, for example saturated steam or a saturated organic vapour such as pentane or hexane. However the invention is not limited to vapours. The fluid could be for example, water; with small ice particles forming as latent heat of fusion is released. The fluid could alternatively be an emulsion, with the finely dispersed second liquid particles experiencing a phase change that releases latent heat, with the first liquid experiencing no phase change. The fluid could also be a mixture of a vapour which at least partially condenses inside the invention and a gas which experiences no phase change. Unless otherwise stated, in the illustrative examples described below; saturated steam will be assumed as the operating phase change fluid.

The present invention offers several advantages over Courtney's prior art turbine patents. In particular, it overcomes all three weaknesses listed above.

In order to allow successive turbines to be similar in shape and size, additional replenishment or "top-up" steam is injected after the main body of the steam has passed through each turbine. For quantitative analytical purposes, the bulk of the steam which passes through each turbine and the "top-up" steam may be considered as separate fluids. To a first approximation, the bulk of the steam contributes the effective mass, which allows the moving fluid mixture to possess kinetic energy, and the relatively small mass of "top-up" steam provides replacement energy in the form of latent heat release, to compensate for that lost as work, when the moving fluid rotates the turbine blades against a load. It also restores the saturated vapour pressure to its value before entering the prior turbine.

At least some of the replenishment steam is injected using jet pumps that transfer momentum from the injected steam to the more sluggish main body of steam. The jet pumps thus carry out the fluid motivating role of impellor pumps in the earlier invention. The chain of turbines form a closed loop, with the main body of the steam being indefinitely re¬ circulated, for the whole of any period that the turbines are productively rotating. For analytical purposes, this main body of steam can be considered as a carrier of momentum as well as kinetic energy, providing moving mass that impacts on the turbine blades and transfers momentum to the turbines.

Figure 2 depicts an illustrative example of the present invention. Items **1, 2, 3** and **4** are turbines that are similar in size and design. Items **5, 6, 7** and **8** are jet pumps used for injecting saturated steam into the largest cross section area parts of the conduit **9,** linking the turbines. Each jet pump is fitted with a tap or other means of controlling the rate of steam flow through it. In this example, two shafts **10** and **11** are rigidly attached to the two rows of turbines and rotate with them. Generator armatures **12** and **13** are fitted to the ends of the shafts. As in the earlier related inventions by Courtney, the condensed steam has to be drained off at intervals along the chain.

A problem with this design is that the two functions of each jet pump; motivating the sluggish carrier steam and injecting top-up steam cannot be separated out. Changing one of these variables causes a proportionate change in the other. One way of overcoming this problem is to use variable aperture jets. For a given rate of mass flow through a jet, the jet pump effect can be increased by reducing the nozzle aperture and injecting the steam at a higher velocity.

Figure 3 illustrates a second way of overcoming this problem by servicing each turbine with two jet pumps. The first jet pump **1** injects steam into the widest section of the preceding section of the conduit, where the carrier steam is at its most sluggish. Consequently a large fraction of the momentum from the fast moving injected steam is transferred to the slower moving carrier steam. The second jet pump **2** injects top-up steam inside the nozzle taper, where the carrier steam is travelling faster, so the transfer of momentum is less efficient.

Existing steam turbines, as used in power stations, emit low pressure exhaust steam at about 30°C. Typically this is fed into a condenser, where the latent heat is extracted, with the resultant sensible heat then being dumped into the environment. In one version of the present invention, this low pressure exhaust steam is harnessed by injecting it into a chain of turbines according to the invention. The density of saturated steam at 30°C is very low. Consequently, if this was directly injected into carrier steam at about the same temperature and pressure, the turbine blades would need to be very large. A more practical form of the invention would incorporate saturated carrier steam at about 100°C and standard atmospheric pressure.

Figure 4 depicts a steam compression pump 1 servicing a linear array of jet pumps, including jet pumps 2, 3 and 4 shown. This arrangement would be suitable for converting low pressure saturated steam 5, drawn in at about 30°C to high pressure steam 6, suitable for adding to saturated carrier steam at say 100°C. Preferably the system is well lagged, so that the heat of compression is not lost. Work has to be done compressing the steam back to atmospheric pressure, but this is only approximately 20% of the energy which is recoverable from the condensation of the steam. An alternative method for capturing heat of compression will be revealed later with reference to Figure 10. It should be noted that the recompression process is only necessary if the invention is retrofitted to existing steam turbines. For completely new power generation plants, conventional steam turbines can be dispensed with and turbines according to the invention used to exploit all of the energy stored in the steam delivered from the boiler.

Figure 5 depicts an East to West cross section through part of a version of the invention that exploits solar energy to generate the required steam. A large North - South aligned cylindrical Fresnel lens canopy, 1 focuses solar energy on to a North - South array of covered water filled troughs2-9. As the apparent position of the sun in the sky changes throughout the day, different troughs receive the maximum intensity of focused solar energy. The canopy has hanging cylindrical Fresnel lens sidewalls 10 and 11. These refract solar energy down on to the troughs when the sun is low in the sky. Roll up silvered reflectors 12 and 13 are also used to reflect energy on to the troughs when the sun is low. Courtney's prior art inventions included solar versions that look superficially similar to Figure 5, but these earlier inventions operated using a mixture of steam and air above the water in the troughs. The present invention includes new optional features which allow the solar energy to generate pure steam. The water in each trough is held at a pressure very slightly above current atmospheric pressure, for example, by means of a top-up cistern that has a water surface a few centimetres above the highest point inside each trough. When the water inside any trough reaches a temperature that generates steam with a saturated vapour pressure that exceeds current atmospheric plus water head pressure, the water surface inside that trough is depressed, leaving a layer of saturated vapour above it. This vapour is drawn off at regular intervals along the North South axis of the troughs and injected into the main body of the invention. Engineers will be aware of a number of methods for drawing off the saturated steam from above the water. In Figure 5, a variation on the standard ball cock, item 14, is used.

Figure 6 depicts this type of ball cock valve in greater detail. A buoyant ball **1** and a sealing cap **2** are mounted at opposite ends of a semi-circular arm **3** that rotates about a pivot **4.** The associated trough is currently receiving sufficient solar energy to generate a steady flow of steam such that the trough water is depressed to a level **5,** with the steam being vented off via an outlet pipe **6.** If the supply of solar energy is cut off, evaporation ceases, the water level rises and the ball is displaced upwards, in an arc, so that the sealing cap blocks the entrance of the outlet pipe.

If the water in the troughs is sea or brackish water, the invention can also perform the incidental role of desalinating brine, with the condensation being distilled water.

A problem with solar generated electricity is that it is intermittent, varying with the incident solar intensity. In addition to using storage batteries, there are a number of methods for eliminating this problem.

(i) A fraction of the electricity generated can be used to melt a bath of salt, with the bath being thermally insulated and the latent heat released when the salt solidifies being used to generate steam for driving the turbine.

(ii) Using an optical system similar to that depicted in **Figure 5,** a wax, naphthalene, or other low melting point solid can be melted, and then stored in its molten state, ready for generating saturated vapour during low solar intensity periods. In this case, the working fluid may be ethanol or another organic vapour that boils at a temperature below 100°C, at normal atmospheric pressure.

(iii) A fraction of the steam can be stored in a compressed state, in a large well lagged chamber, and then subsequently used to fuel the invention.

(iv) Air from the atmosphere can be compressed during the day, stored in its compressed state, then used to drive conventional turbines at night. The heat of compression can be removed before storage and used to evaporate additional water for exploitation in the invention during the day. At night, the chilling effect caused by the dry air expanding through the conventional turbine(s) can be used to cool external atmospheric air and capture the dew formed as it cools.

(v) If fossil fuel or any other type of combustible material is locally available, this can be burned to supplement the solar energy input.

(vi) Large sealed glass houses can be built adjacent to the solar power stations and high value tropical crops that thrive in a humid atmosphere grown inside. The heat storage capacity of the glasshouses can be increased by adding water troughs, fish farms or pools. A fraction of the humid air can be drawn off at night and its latent heat extracted. A version of the invention for doing this will be revealed below with reference to **Figure 10.**

According to the invention, the use of pure steam is just one of the design options available to engineers. In another version of the invention, a phase-change fluid is injected into a single phase carrier fluid. If the phase-change fluid is steam and the carrier fluid is a gas, this option offers several advantages compared with the versions of the invention revealed above.

(i) In general, the preferred implementation of the invention is both compact and cool running. But for compactness, the working fluid must have a high density. These high fluid density/low temperature preferences cannot be met simultaneously using pure steam because, as the steam density increases, its dew point also increases. This means, high steam densities require high operating temperatures. Dalton's Law of Partial Pressures indicates how the conflict can be resolved using a mixture of steam and a gas such as air. Dalton's law tells us that the total pressure in any region inside the invention is equal to the sum of the partial pressures of the steam and air, if they alone filled that region. Consequently, the dew point can be kept low by using steam at low pressure. Independently, the density of the working fluid can be kept high by adding high pressure air.

(ii) The higher the density of the carrier fluid used, the higher the rate of momentum transfer to the turbine blades, for a given temperature and pressure.

(iii) H_20 water molecules have a molecular weight of 18. However, dry air has an effective mean molecular weight of 28.84, because its approximate formula is 79% N_2 of molecular weight 28 and 21% O_2 having a molecular weight of 32. Consequently, for the same temperature and pressure conditions, dry air is 1.6 times denser than water vapour. Other possible carrier fluids include carbon dioxide, molecular weight 44 and synthesised gases having a high molecular weight.

(iv) Heat losses through the walls of the invention are easier to minimise if its operating temperature can be reduced.

(v) Viscous friction for gases and vapours increases with temperature. So by lowering the operating temperature, viscous friction problems are also reduced.

(vi) Water droplet impact damage to the turbine blades is less at cool temperatures.

(vii) Corrosion damage also falls with operating temperature. This is a particularly useful feature if the invention also serves as a desalination plant.

(viii) A low temperature system is quicker and easier to fire up to its normal operating conditions, compared with a high temperature system.

It is emphasised that according to the invention, the carrier fluid is not restricted to gases. It can also be a liquid, for example water or mercury.

The invention can also be used to improve the net efficiency of conventional gas turbine power generators. Heat is produced when the fuel and air are compressed for injection into the combustion chamber. But, gas turbines run more efficiently if the air and gas are injected cool. The unwanted heat could be removed using a heat exchanger and used to boil water or an organic liquid, to create the vapour required to power the present invention.

To establish the broad scope of the invention, the following characteristics are emphasised:

(i) The essential feature of the invention is that it exploits the latent heat released by a phase change to rejuvenate a carrier fluid passing through one or more turbines that do external work. The phase change is not limited to condensation and the fluids concerned are not limited to saturated vapours.

(ii) The jet pump action described above may not be sufficient for overcoming viscous drag in small versions of the invention. To solve this problem, a fraction of the single phase carrier fluid can be drawn off, and then re-injected, to provide additional jet pump action.

(iii) Instead of using jet pumps, any form of impellor pump can be used to move the carrier fluid.

(iv) It is to be understood that the term "saturated vapour" is used in its broadest sense, to include any gas that has been cooled to below its critical temperature and is circulating within the invention at a partial pressure greater than its critical pressure. This means that the "gas" is actually a vapour and can condense out if heat is removed from it.

(v) It is to be understood that the illustrative depictions of turbines and jet pumps are not intended in any way to limit the scope of the invention. For example, **Figure 7** depicts a turbine 1 that occupies the full width of a parallel sided conduit, with the turbine nozzle effect being created by the addition of a cowling **2.** Item **3** is a set of three jet pumps that can be switched on or off independently of each other.

(vi) **Figure 8** depicts another type of jet pump arrangement with the pump section inside the conduit taking the form of a hollow torus, having forward facing nozzles.

Compared with existing steam turbines, the current invention (in its steam turbine form) poses a number of design problems for the engineer to resolve.

(i) Condensation is essential for the release of latent heat.

(ii) The condensation droplets need to be removed from the carrier fluid passing through the system.

(iii) These droplets may damage the turbine blades if they collide with them at high velocity.

(iv) After passing through a rotating set of turbine blades, the working fluid will rotate and swirl in the opposite sense to the turbine blades. If left unchecked, this would reduce the overall efficiency of the steam turbine.

Figures 9a, 9b and **9c** reveal one solution for these problems. But it is emphasised that this solution is not intended in any way to limit the scope of the invention.

Figure 9a depicts a vertical cross section along a turbine axis. Seven points along a straight line A-B-C-D-E-G-G are highlighted for particular attention.

Figure 9b depicts a horizontal cross section along the turbine axis with the same seven points labelled.

Figure 9c shows sketched working fluid velocity vector diagrams at these seven points.

In **Figures 9a** and **9b** item **1** a steam jet capable of emitting negatively charged steam ions by virtue of the fact that the electrically conducting jet nozzle is connected to the negative terminal of a high voltage, low current power supply. Item **2** is the main turbine shaft which links turbine **3** to a plurality of other turbines. The set of turbine blades for **3** is also connected to the negative terminal of a high voltage, low current power supply. These turbine blades have electrically conducting radial ridges cut into their upstream face. Item 4 is an auxiliary set of turbine blades connected to an auxiliary generator **5.** The auxiliary set turbine blades are connected to earth and rotate independently of the main shaft.

It is convenient to start the explanation of the interaction of these components at B. Here the working fluid is moving relatively slowly and directly towards the first set of turbine blades **3**. At C, the velocity has increased because the fluid has been throttled by the cowling. In travelling from B to C, the fluid has suffered Venturi cooling, resulting in partial condensation and the release of latent heat. The ionised steam molecules originating from the nozzle **1** form the preferred water droplet condensation sites. Thus, the majority of water droplets have a negative charge causing them to be repelled by the negative charge that exists on the ridges of the set of turbine blades **3.** Even if the charged water droplets physically collide with the like charged turbine blades, the electrostatic repulsive force considerably reduces the impact velocity because an inverse square law of repulsion applies. That is, at very small distances, the repulsive force is very large.

Newton's laws of motion and the laws of conservation of energy and momentum apply to the transfer of energy and momentum from the moving fluid to the rotating turbine blades. Vectors D and E may appear to violate these laws, but this not so. It has to be born in mind that the vectors are a summary of information about the macroscopic or bulk movements of the fluids. The changes in random movement at a molecular level are not taken into account but they are not ignored because they show up as changes in fluid temperature and phase changes between the vapour and liquid states.

The velocity vector for the fluid at D is at an angle to the velocity vector at C, but its axial component must be approximately the same as at C because the rate of mass flow, apart from any condensation losses to the side walls, remains constant. The tangential component of this velocity produces an unhelpful swirling movement of the fluid and the increase in kinetic energy occurs at the expense of further condensation. The swirling is reduced by the second set of turbine blades **4,** which absorb a large fraction of the tangential momentum of the fluid, but do not significantly absorb forward momentum. Thus, if the first set of turbine blades is viewed as rotating in an anti¬ clockwise sense, the second set of blades must rotate in a clockwise sense. In this example, the second set of blades is electrically conducting and grounded, so a positive charge is induced on the blades by the approaching negatively charged water droplets. This attracts the droplets towards the blades, with many of them hitting the blades and coming to rest in a hollow radial cavity which extends along the length of each blade. The deposited water is flung towards hollows in the enclosing conduit walls, **6** by a centrifuge effect. Two mechanisms reduce impact pitting damage to the second set of blades: (i) the component of the impact velocity at right angles to the broad surface of the blades is less than its equivalent for the first set of blades, (ii) the droplets impact on the water that has already collected in the blade channels, so hydraulic mechanisms reduce the point loading on the underlying blade surface. As the fluid moves from E to F it slows down and tends to warm up, encouraging the evaporation of water droplets that were not trapped by the second set of blades.

The nozzles **1** and **6** are set at a (variable) angle to the line A-G, so that the freshly injected fluid creates a transverse torque, which neutralises the residual swirling effect.

In another version of the invention, the second set of turbine blades is dispensed with, and grounded parallel plates 7, are used to capture the charged water droplets and provide a partial correction for the swirling motion.

Figure 10 depicts a multiple device version of the invention suitable for extracting latent heat from warm moist air. Items **1, 2** and **3** are single turbine devices according to the invention, and operating out of phase, in three phase mode. As explained below, the three phases are induction, condensation and exhaust.

Moist air **16** is extracted from the environment, compressed and held in an insulated reservoir **4**. The heat generated by compressing the air is used to produce additional water vapour by bubbling the hot compressed air though water inside the reservoir. Valves **5, 6** and 7 are opened successively, to allow compressed air into the turbine chains. The air is compressed in order to increase the partial pressure of the water vapour. If, for example, the air being processed holds water vapour at 2% of atmospheric pressure and is compressed by a factor of ten, then the partial pressure of the water vapour increases to 20% of atmospheric pressure. This raises the dew point from 18.7°C to 61>.4°C.

Item **1** is depicted as being at the induction phase, with valve **5** open and compressed hot air is flowing into the turbine chain. As the hot air passes through the turbine it does external work and cools, so that eventually it drops in temperature to its dew point and condensation begins.

Item **2** is depicted as being at the condensation phase, but with valve **6** closed, so that the jet pump action is no longer promoting air circulation around the chain. Instead, an impellor pump **8** has been switched on to promote circulation. This pump must consume less power than is being simultaneously generated by its conjugate turbine. In order to fulfil this condition, the perpendicular cross sectional are of the conduit in the region of the pump is at least one order of magnitude higher than the perpendicular cross sectional area of the turbine nozzle(s), so the kinetic energy in the region of the nozzles is about two orders of magnitude higher than that imparted by the impellor pump. The condensation water produced during this phase is drained off at **9**.

Item **3** is depicted as being at the exhaust phase, with exit valve **10** open, so that the compressed dehumidified air flows through conventional turbine **11** on its journey back into the environment. As the compressed air expands through the turbine it cools. By some means or other, as discussed below, it absorbs heat so that it ends up at the same temperature as the external air. This generalised temperature restoring process is represented by the heat exchange region **12** in the diagram. For compactness, the heat exchange process preferably includes a phase change process, for example, the freezing of water, or condensation of water vapour from humid air.

Optionally, flap or other types of valves **13** are included to ensure that the air continues to pass through the condensing turbines during the exhaust phase. Also optionally, flywheels may be added to the turbine shafts, to smooth out short term power output variations.

The air compression pump **14** warms up during continuous operation. It is kept cool by immersing it in the water reservoir **15.** External air **16** entering the system has to pass through **15,** so any water vapour produced by evaporation of the reservoir water is captured and its latent heat exploited. The compression pumps are illustrated as being impellor pumps, but other pumps known to engineers may be used instead.

Figure 11 depicts how a version of the invention, as revealed with reference to **Figure** 10 can be used to increase air quality on underground railway station platforms under conditions where warm humid air has a tendency to emerge from the tunnels, onto the platforms. According to the invention, this warm humid air is seen as an energy resource for generating electricity rather than as a problem.

The main stages in the air treatment are as follows:

(i) A fraction of the humid air in the tunnel is diverted through the invention in order to generate electricity. The precise fraction depends on the reduction in relative humidity and temperature drop required.

(ii) When working near maximum capacity, the exhaust air from the invention will be uncomfortably cold but pleasantly dry. In comparison, the unprocessed tunnel air which bypassed the invention wiii be too warm and too humid. In order to blend these two air masses without creating an aerosol of water droplets, it is preferable to temporarily keep them physically apart using a combined heat exchanger and condenser unit. After passing through the heat exchanger/condenser, the cold air has warmed up significantly, because it is dry, but the warm tunnel air has only cooled slightly because it has given up latent heat and moisture.

(iii) In order to ensure that both masses of air travel towards the platform instead of back down the tunnel, the exhaust air is kept in a slightly compressed state and directed towards the platform using jet pumps. During mixing of the two air masses, the exhaust air gives up forward momentum to the tunnel air, so that the combined air mass moves slowly towards the platform.

In **Figure** 11 a fraction of the warm humid air in the tunnel, 1 passes through a humid air version of the invention, 2. The cold, dry exhaust air then passes through a heat exchange unit 3 in the roof of the tunnel, where it picks up heat from the warm humid air that has continued to flow through the main body of the tunnel. An array of jet pumps, 4 surrounds the mouth of the tunnel. At the far end of the platform, a similar array of jet pumps 5 works in reverse, creating a gentle pressure gradient that keeps warm, humid air inside the far tunnel.

In a similar manner, the invention can be used for cooling deep mine workings and nuclear waste repositories. Complete nuclear power plants, cooled according to the invention could be installed deep underground. This would allow nuclear waste to be stored on site while improving security against terrorist attack.

Skilled civil engineers and architects will be able to use the invention for cooling buildings in warm climates. This can be done wholly internally in buildings which have large rooms where moist air can be drawn off in bulk, or partially externally for compartmentalised buildings. The following example relates to a large building compartmentalised into flats, with the thermal energy captured in the cooling process being used to evaporate water, and then generate electricity.

Figure 12 depicts a vertical cross section through part of a single floor and external wall in a multi-storey block of flats. It shows a kitchen area where an insulated pantry or cool room 1 is adjacent to an external wall 2 that is currently facing the direction of incident sunlight 3. The solar exposed walls are all (except the window areas) clad with two layers, 12 and 13, of vertically interconnected cavities through which forced convection air currents flow. The walls of the cavities are made from thermally conducting material, for example galvanised iron but the inner and outer cavities are separated by a thermally insulating barrier 14.

The forced convection loop consists of: (1) upward movement of air, which warms and gathers water vapour as it travels through the outer layer of cavities on the currently sunlit walls, (2) on the rooftop, induction into the invention, in this case, taking the form depicted in Figure 10, (3) severe cooling and dehumidifying of the air as it travels through the invention, (4) partial re-warming of the cold air as it chills a bath of water to 4°C, (5) re-warming as the air travels down through the inner layer cavities on walls that are currently in the shade, (6) horizontal air movement back to the base of the currently sunlit wall.

In order to generate water vapour in the outer sun warmed cavities, their external facing walls, for example 4, are internally doused by fine sprays of water, 5. The spray water originates as condensation inside the roof mounted turbine unit.

The pantry is chilled by the water that has been cooled to 4°C at roof top level. At this temperature, water has its maximum density, so it is more efficient for generating water convention currents than iced water that has been cooled to 0°C. An insulated down pipe 6 carries the chilled water from the roof to the ground floor, but a fraction of the chilled water is dawn off by side pipes such as 7 at the level of each flat, so that it cools the back wall of the pantry 8. After drawing heat from the pantry, the temperature of the water inside the panel increases and its density decreases, so it moves upwards to join the main up-flow of warmed water from other panties in the building **9**.

This method for cooling pantries produces net cooling of the building. In contrast, domestic refrigerators produce net wanning because they are less than 100% efficient and the heat removed from indoor refrigerators is dumped into the atmosphere in the immediate domestic area. A second advantage of this method of pantry cooling is that the rate of cooling increases with rate of electricity generation, which in turn, increases with incident solar energy on the building walls. A thermal contact panel **10** allows a food freezer **11** to be installed inside the pantry and deposit its waste heat into the up-flow water. The freezer can have a different physical location to that depicted and be connected by a heat pump.

In order to extract heat from the warmest air in the rooms at ceiling level, holes, **15,** are left in the outer walls so that air inside the rooms is in thermal contact with the cool down flowing air in the inner cavities.

To enhance cooling and increase the solar energy collection area, the windows can be fitted with canopies which also take the form of hollow evaporation cavities.

Skilled engineers will be able to modify this design in order to produce electricity and pantry cooling for the whole of the twenty four hour cycle. For example, the unused external roof space could be covered with troughs of phase change wax which melt during the day, and then release their latent heat at night, to produce water vapour for use by the invention.

The warm moist cavities are a potential breeding ground for micro-organisms. lingineers and architects skilled in the design of air conditioning systems will be aware of the precautions necessary to eliminate them. These include chemical and/or radiation treatments to sterilise the water and designing the whole system so that it can easily be opened up for inspection and cleaning.

't'his illustrative example does not limit the scope of the invention. *tor* example it could exploit solar energy absorbed from overhanging canopies, such as those found in sports stadiums. It could also be used to extract solar energy falling on canopies covering car parks, with the electricity generated being used to recharge the batteries of the parked cars.

The solar energy collecting cavities can alternatively be covered with glass, so that they trap heat using the greenhouse effect. This option requires higher maintenance, to prevent the build up of micro-organisms and fungi, but has the advantage of transparency, allowing light, but not excessive heat into the building. Glass cavities would be particularly appealing for sports stadiums, because they would permit photosynthesis, allowing grass to be grown in the sports playing area.

Figure 13 depicts how a version of the invention, as revealed with reference to **Figure 10** can be used to extract latent heat from warm humid air in tropical rainforests and convert it into electricity. In this plan view, the main body of the invention, as in **Figure 10** is housed inside a structure **1**. Warm moist air is drawn in from multiple distant induction ports such as **2** and then on to the invention via larger conduits, such as **3**. Cold, de-moisturised air optionally passes through a galvanised iron covered re-warming zone **4,** before re-entering the forest air. The larger cross section conduits can include internal service roads, to minimise human disturbance to the external environment. These larger conduits may have transparent roofs, allowing delicate crops, normally susceptible to heavy tropical rainstorms, to be grown inside them. The arrow **5** indicates the direction of the prevailing wind.

For ecological reasons this version of the invention will preferably be constructed in replanted rather than virgin rainforests. The replanted forest will have a slightly lower mean temperature and humidity than the adjacent virgin forest because heat and moisture has been extracted from the air, but there will be no distinct physical boundaries, so flora and fauna will migrate to their preferred micro climate. This will encourage bio-diversity.

Mid day to night time temperature variations within rain forests are far lower than in deserts at the same latitude because of the latent heat exchanges in their humid air. This means that rain forest installations of the invention will be able to generate electricity continuously throughout the twenty four hour cycle.

Figure 13 is not intended in any way to limit the scope of the invention. It could also be used for example, to marginally cool parkland areas or city streets in humid tropical countries. Using the invention in an attempt to cool very large urban areas to temperate zone temperatures has power generation limitations, because moist air at temperate zone temperatures holds less water vapour.

A similar "trunk and branch" system can be used for collecting moist air from above tropical seas. The floating pipes can either be matt black or have transparent upper sections and be partly filled with sea water, allowing enhanced evaporation inside the conduits. This version will be discussed in further detail below.

Horticultural glass houses are commonly used for growing crops in hot semi-arid climates. Their primary function is to localise moist air around the crops, but in doing so they also risk trapping too much solar thermal energy. To prevent this, the glass is given a translucent white reflecting surface underlay. This wastes solar energy, which according to the invention can be exploited to generate electricity. **Figure 14** depicts hot climate glass house according to the invention. There are no white reflecting surfaces, so the bulk of the solar energy **1** is trapped inside the glass house. The crops are kept cool by dousing them with a fine spray of water **2**. This water evaporates and the moist air is withdrawn at **3** for use inside a version of the invention similar to that depicted in **Figure 10.** Replacement dry air is drawn in at the opposite end of the glass house. In order to generate electricity during the hours of darkness, the glass house can include heat reservoirs. For example, the glass house could include a large tank of brackish or sea water **4** which is isolated from the cropping area and has its moist vapour drawn off during the night. This provides distilled potable water as a by-product. Alternatively, the heat reservoir could take the form of stacked trays **5** filled with water and nutrient, and used for growing algae, for producing bio-fuel. In this example, a simple sun tracking reflector **6** is used to provide side illumination for the troughs. The roofs and walls of heat reservoir type glass houses are preferably double glazed 7, to reduce heat losses at night when they are working to produce water vapour. This version of the invention is not restricted to arid climates. It would be useful, for example, for providing protection for crops and their growing medium in wet climates during the monsoon season. It could also be used for the fractional distillation of alcohol from water, with the tank of **4** being filled with alcohol dissolved in water.

If the invention is used to extract energy from warm, moist, chemically or biologically contaminated air, then it is preferable to extract the energy indirectly, by incorporating a heat exchanger, with the contaminated air passing through simple shaped, easily cleaned conduits. The following illustrative modification of the core invention may be used for example, for extracting latent heat from hot moist air produced by industrial scale cooking processes where the air is contaminated by the inclusion of an aerosol of fine droplets of cooking oil and/or food particles.
Figure 15 depicts a suitable heat exchange system according to the invention. The hot, moist, contaminated air passes through a heat exchange pipe **1** in good thermal contact with water in a plurality of baths **2, 3, 4** and **5.** Clean air from outside the building **6** passes over the baths, warming up and increasing its water vapour content as it moves towards the mouth of the core invention 7, as described with reference to **Figure 10.** To compensate for evaporation, replacement water is fed into the coolest water bath at **8,** and then transferred indirectly to the warmer baths by means of siphons such as **9.** Flap valves such as **10** prevent blow-back, ensuring that the moistened air can only move over the successive baths in the direction the mouth 7. Items **11** and **12** are optional additional heat exchange pipes used for extracting heat from other sources of waste heat inside the factory. Air entering at **11** is cooler than the contaminated air entering at **1,** but warmer than the air entering at **12.** The number of cascading water baths is not restricted to four and the volume and shape of the baths can be varied from that depicted. The whole of the heat exchange unit is lagged to prevent heat losses.

Skilled engineers will be aware of how this heat exchange unit coupled to the invention can be used for recycling water and other resources in manufacturing processes. For example, if the cooking process results in waste consisting of a sludge of water, fats or oils and food particles, the water can be evaporated off for use in the turbines by placing it in a bath ahead of bath 2 and the residual matter after water extraction, can be used as a bio fuel.

The invention can be used to protect coastal settlements in hurricane prone regions, by sapping energy from the hurricanes before they reach land. Versions of the invention similar to those depicted in **Figures 10** and **13** operating in off shore waters would offer three energy sapping mechanisms:

(i) A substantial fraction of the surface level saturated water vapour which fuels hurricanes would be removed from the local air.

(ii) The reduction in vapour pressure would encourage further evaporation and absorption of latent heat from the surface of the sea.

(iii) The cold exhaust air emitted by this version of the invention would be used to chill the adjacent surface water below the critical temperature of 26.5°C. Above this temperature, evaporation provides sufficient latent heat to allow the hurricane to grow.

Under conditions of extreme threat, the invention could also provide the power for pumping cold, deep ocean water to the surface, to provide additional chilling for the surface water.

Hurricanes tend to progress in a horizontal direction in which they can acquire the maximum amount of replacement thermal energy from the underlying sea. Consequently, in addition to sapping energy from hurricanes, this version of the invention will refract threatening hurricanes away from the defended coastal area.

The fresh water from the air condensed out by the invention in this example would have a lower density than sea water, allowing it to be taken to the shore through floating pipes or large collapsible tanks. Fresh water also freezes at a higher temperature than sea water. So, to maximise surface water cooling when the hurricane threat is high, the fresh water is preferably converted to ice and then allowed to melt by floating it into the warmer sea water.

As with any form of geo-engineering, this version of the invention carries potential environmental risks, so it will need to evolve cautiously over many years. After the basic dynamics of dispersed water vapour collection have been mastered, using the rain forest version of the invention, early off-shore versions will be built in regions where deflected hurricanes have negligible risk of moving on to inhabited land.

A similar version of the invention could be used to provide at least part of the energy source for ocean going ships sailing in tropical oceans. In this example, the compressed, dehumidified air could be vented off through submerged nozzles to provide air jet propulsion. Alternatively, it could be used for keeping the cargo cold.
This version of the invention could also be used to provide supplementary electricity for trains operating in tropical climates or warm, humid underground environments. If an air scoop was mounted on the front of the train, the rate of electricity production would increase with train speed.

A very high pressure version of the invention could be used as the basis of a system for stripping carbon dioxide from power station flue gases. Engineers wishing to use the invention for this application should bear the following points in mind:

- **CO_2** has a critical pressure of 73 atmospheres and a critical temperature of 31.1°C. So even if all of the oxygen in the air is converted to **CO_2,** the flue gases will need to be compressed to 365 atmospheres for the partial pressure of the CO_2 to reach its critical pressure.
- If the power station concerned is dedicated to the production of hydrogen by electrolysis of water, the pressure barrier can be lowered by burning the fuel in air richly supplemented by the oxygen also liberated by the electrolysis process.
- If the hydrogen is compressed at source, the heat of compression can be used to fuel the invention.
- Coal burning with carbon capture still creates net carbon pollution because of the CO_2 generated by the mining process, but burning bio-fuel can lead to a net reduction in atmospheric carbon. This is because earlier in the fuel cycle, the bio-fuel extracted CO_2 from the atmosphere during plant growth. So, if a primary aim of the carbon capture process is to meet reduced carbon emission targets, then garbage and other forms of bio-fuel should be burned in preference to coal.
- Garbage and many other forms of bio-fuel have a low calorific value compared with coal because any water that they contain has to evaporate and absorb latent heat during the combustion process. However a carbon capture system constructed according to the invention will also be capable of harnessing this latent heat as the water vapour condenses out of the flue gases.
- Skilled engineers will also be aware of how the present invention could be employed to improve the efficiency of processes for stripping carbon dioxide from flue gases using amine solvents.

Claims

1. A power conversion device comprising injecting a first fluid, at a temperature approximate to its phase transition temperature, into a second fluid, and circulating the combined fluid through a heat engine, such as a turbine, wherein the combined fluid cools, and part of it undergoes a phase change, as it passes through and drives the heat engine.

2. A device according to the first claim, with the first and second fluids being chemically identical.

3. A device according to the first claim, with the first and second fluids being chemically identical vapours.

4. A device according to the first claim, with the first fluid being a vapour that becomes saturated and at least partially condenses out on passing through each turbine or other form of heat engine.

5. A device according to the first claim, with the first fluid being a vapour that becomes saturated and at least partially condenses out on passing through each turbine or other form of heat engine, with the second fluid being a gas having a higher density than the vapour under operating conditions, so that the kinetic energy of the combined fluid is greater than the kinetic energy of pure first fluid circulating under the same pressure and velocity conditions.

6. A device according to the first claim, with the first fluid being a vapour that becomes saturated and at least partially condenses out on passing through each turbine or heat engine with the second fluid being a gas circulating at high pressure, in order to increase the mean density of the fluid passing each turbine.

7. A device according to the first claim, with the fluid being injected through a plurality of fixed or variable nozzle aperture jet pumps, with the high speed fluid jets adding momentum to the combined fluid in order to allow it to continue circulating against the opposition created by friction, turbulence and other forms of damping.

8. A device according to the first claim, including a plurality of impellor or any other type of pump that adds momentum to the combined fluid, in order to allow it to continue circulating against the opposition created by friction, turbulence and other forms of damping.

9. A device according to the first claim with one fluid being a vapour that is compressed prior to being injected into the turbine or heat engine in order to increase its partial pressure and dew point temperature at which it starts to condense out.

10. A device according to the first claim with a fraction of the second, non-phase changing fluid being drawn off at intervals, compressed, then re-injected via jet pumps, to add momentum to sluggishly moving fluid already inside the invention.

11. A device according to the first claim, with each turbine unit including two sets of serially mounted turbine blades coupled to two different loads, with the blades being angled so that the two sets of blades rotate in opposite senses, so that a large fraction of the angular momentum imparted to the fluids as a result of then-interaction with the first set of turbine blades is neutralised by their interaction with the second set of turbine blades.

12. A device according to the first claim, with each turbine unit including two sets of serially mounted turbine blades coupled to two different loads, with the blades being angled so that the two sets of blades rotate in opposite senses, so that a large fraction of the angular momentum imparted to the fluids as a result of their interaction with the first set of turbine blades is neutralised by their interaction with the second set of turbine blades, with the first and second sets of blades possessing opposite electrical charges and some at least of the droplets of condensed fluid also being charged such that they are repelled by the first set of blades and attracted towards the second set of blades.

13. A device according to the first claim, with the fluid being injected through a plurality of fixed or variable nozzle aperture jet pumps, with the high speed fluid jets adding momentum to the combined fluid in order to allow it to continue circulating against the opposition created by friction, turbulence and other forms of damping, with the nozzles being positioned at an angle to the passing fluids, such that they impart an angular momentum to the fluids which tends to neutralise any rotational motion possessed by the fluids, prior to reaching the nozzles.

14. A device according to the first claim operating in three phases, with first and second fluids being compressed and injected into the turbine or heat engine in the first phase, then left to circulate until the bulk of the first fluid has condensed out in the second phase, with the bulk of the second fluid then being removed in the third phase, and then the cycle repeated.

15. A device according to the first claim operating in three phases, with first and second fluids being compressed and injected into the turbine or heat engine in the first phase, then left to circulate until the bulk of the first fluid has condensed out in the second phase, with the bulk of the second fluid then being removed in the third phase, and then the cycle repeated, with the heat of compression being used to lift additional phase change fluid to its higher energy phase, with the additional fluid also being injected into the turbine or heat engine.

16. A device according to the first claim, with the first fluid being water or other volatile liquid that has been evaporated by solar energy, with the vapour being compressed, if necessary, prior to injection into the second fluid.

17. A device according to the first claim, with the latent heat being extracted from a contaminated phase changing fluid, and passed on to a clean phase changing fluid via a heat exchanger, with the clean phase changing fluid being used to power the invention as the clean fluid returns to a lower energy state.

18. A device according to the first claim, with the source of thermal energy being that released as waste heat from carbon dioxide stripping processes such as those using amine solvents.

AMENDED CLAIMS
received by the International Bureau on 08 November 201 1

1. A device for converting latent heat into mechanical work by means of a turbine of other form of heat engine, comprising a closed loop conduit, enclosing a turbine/heat engine, two fluids, difFerentiated because they exhibit different partial pressures when they are in thermal equilibrium at the same temperature and occupying the same volume, with the partial pressure of the first fluid exceeding that of the second fluid, and a circulation pump for driving fluid round the loop against friction, characterised by neither fluid expanding as required for a Rankine cycle and by a fixed mass of the permanently residing first fluid travelling repeatedly round the loop and through the turbine/heat engine without the phase changes required for a Rankine cycle, with the first fluid acting as a carrier fluid that contributes the bulk of the combined fluid mass, with the first fluid having a higher density than the second fluid and the second fluid being a vapour that after diffusion into the first fluid reaches its dew point and then suffers a phase change with the release of latent heat, when the fluids pass through the turbine/heat engine, with the second fluid commonly making a single transit of the turbine/heat engine after being injected into the conduit at a rate sufficient to supply latent heat to compensate for the rate of doing work, with the conduit including a drainage port for the exclusive removal of the second fluid after it has changed phase and given up its latent heat.

2. A device according to the first claim, with the circulation pump being a plurality of impellor pumps in series.

3. A device according to the first claim, with the first fluid having a higher molecular weight than the second fluid so that the combined fluids have a higher kinetic energy when they impact on the turbine blades compared with the second fluid alone impacting on the turbine blades under the same temperature and pressure conditions as the combined fluids.

4. A device according to the first claim, with the first fluid being a gas circulating at high pressure compared with the environmental pressure outside the conduit, in order to increase the mean density of the fluid passing through the turbine/heat engine, compared with the fluid density when its pressure is similar to that in the local environment.

5. A device according to the first claim, with the second fluid being a vapour that has been compressed prior to being injected into the turbine/heat engine.

6. A device according to the first claim, with the circulation pump taking the form of a plurality of jet pumps, with the jet pump action being produced by the second fluid being injected into the first fluid through a plurality of fixed or variable aperture nozzles, with the initially high speed jets of second fluid slowing down, transferring momentum to the circulating first fluid.

7. A device according to the first claim with the circulation pump taking the form of a plurality of jet pumps, with a fraction of the first fluid being drawn off at intervals, compressed, then re-injected via jet pumps, and then, as the injected fluid slows down, transferring momentum to the slower moving fluid inside the conduit that it mixes with.

8. A device according to the first claim, with each turbine unit including two sets of serially mounted turbine blades coupled to two different loads, with the blades being angled so that the two sets of blades rotate in opposite senses, so that a large fraction of the angular momentum imparted to the fluids as a result of their interaction with the first set of turbine blades is neutralised by their interaction with the second set of turbine blades.

9. A device according to the first claim, with each turbine unit including two sets of serially mounted turbine blades coupled to two different loads, with the blades being angled so that the two sets of blades rotate in opposite senses, so that a large fraction of the angular momentum imparted to the fluids as a result of their interaction with the first set of turbine blades is neutralised by their interaction with the second set of turbine blades, with the first and second sets of blades possessing opposite electrical charges and some at least of the droplets of condensed fluid also being charged such that they are repelled by the first set of blades and attracted towards the second set of blades.

10. A device according to the first claim, with the circulation pump taking the form of a plurality of jet pumps, with the jet pump action being produced by the second fluid being injected into the first fluid through a plurality of fixed or variable aperture nozzles, with the initially high speed jets of second fluid slowing down, transferring momentum to the circulating first fluid, with the nozzles being positioned at an angle to the passing fluids, such that the jets impart angular momentum to the fluids which tends to neutralise any angular rotational motion possessed by the circulating fluids, prior to passing the nozzles.

11. A device according to the first claim with the circulation pump taking the form of a plurality of jet pumps, with a fraction of the first fluid being drawn off at intervals, compressed, then re-injected via jet pumps, and then, as the injected fluid slows down, transferring momentum to the slower moving fluid inside the conduit that it mixes with, with the nozzles being positioned at an angle to the passing fluids, such that the jets impart angular momentum to the fluids which tends to neutralise any angular rotational motion possessed by the circulating fluids, prior to passing the nozzles.

12. A device according to the first claim, with the second fluid being water or any other volatile liquid that has been evaporated by solar energy.

13. A device according to the first claim, with the first fluid being water in its liquid state.

14. A device according to the first claim, with the closed loop including a sequential series of devices according to the first claim.

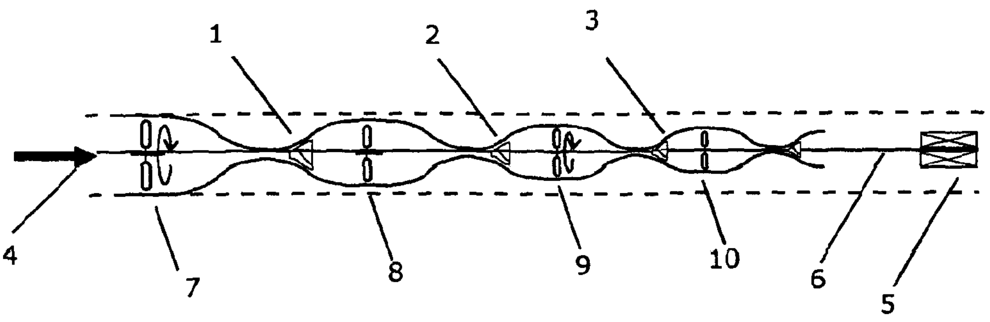

Fig. 1.

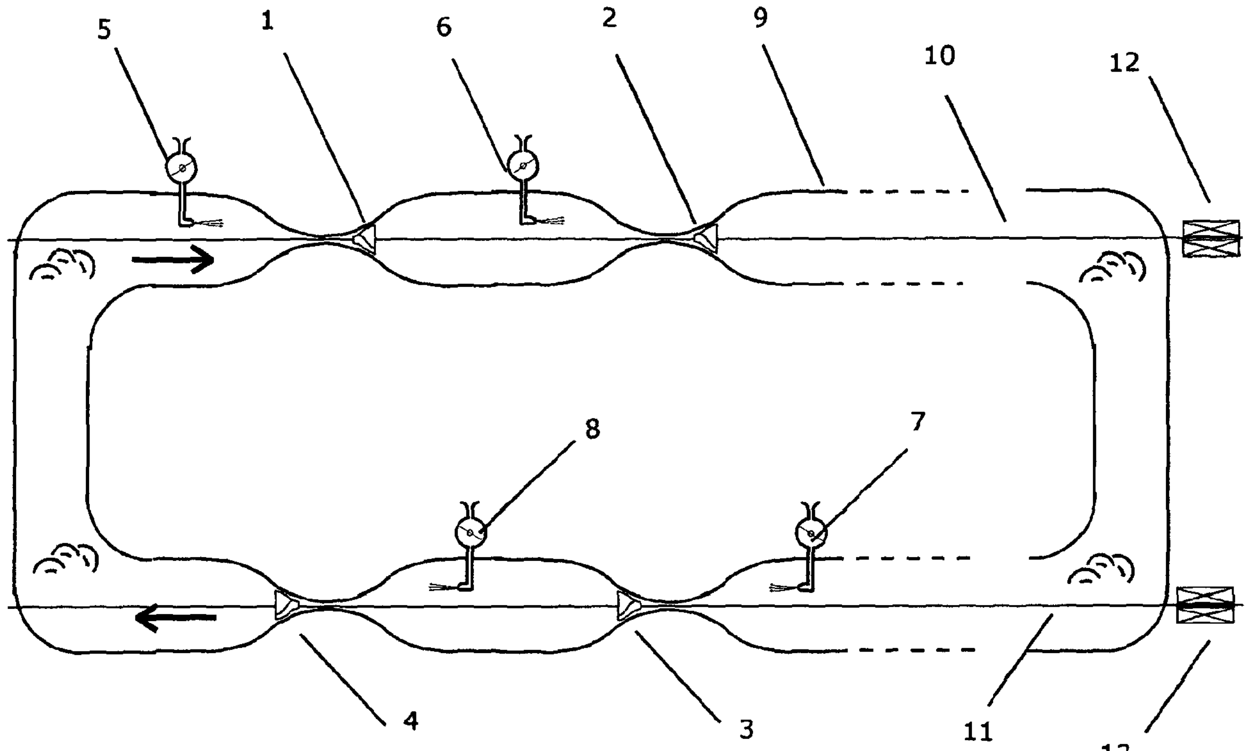

Fig. 2.

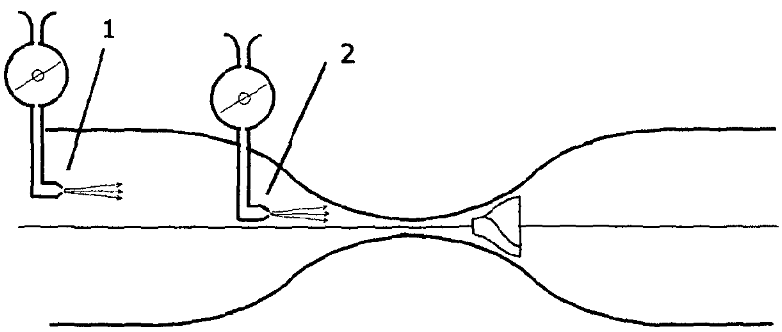

Fig. 3.

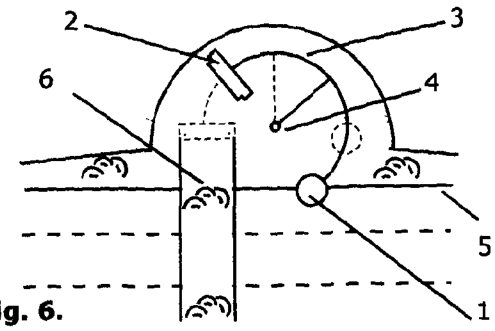

Fig. 6.

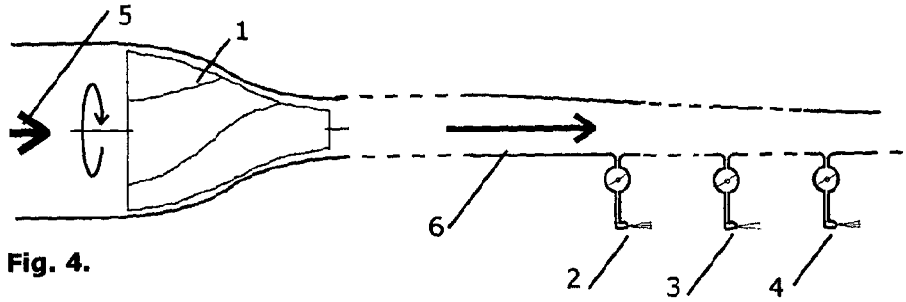

Fig. 4.

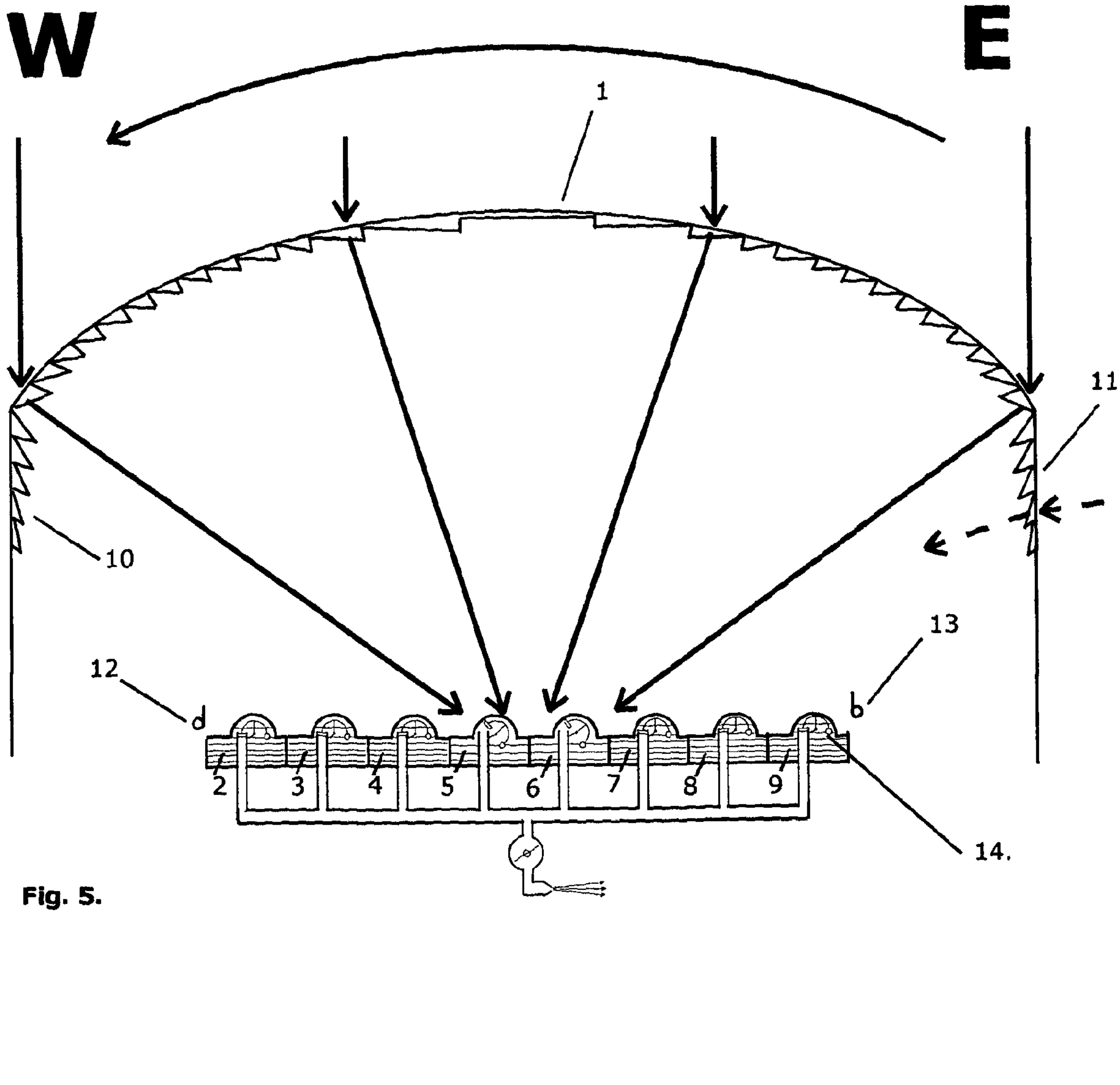

Fig. 5.

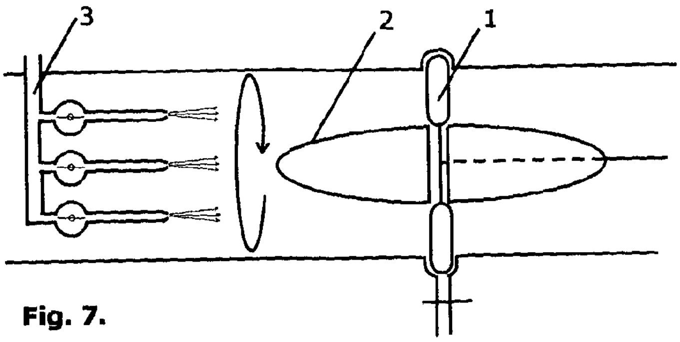

Fig. 7.

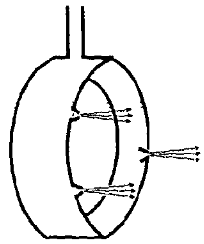

Fig. 8.

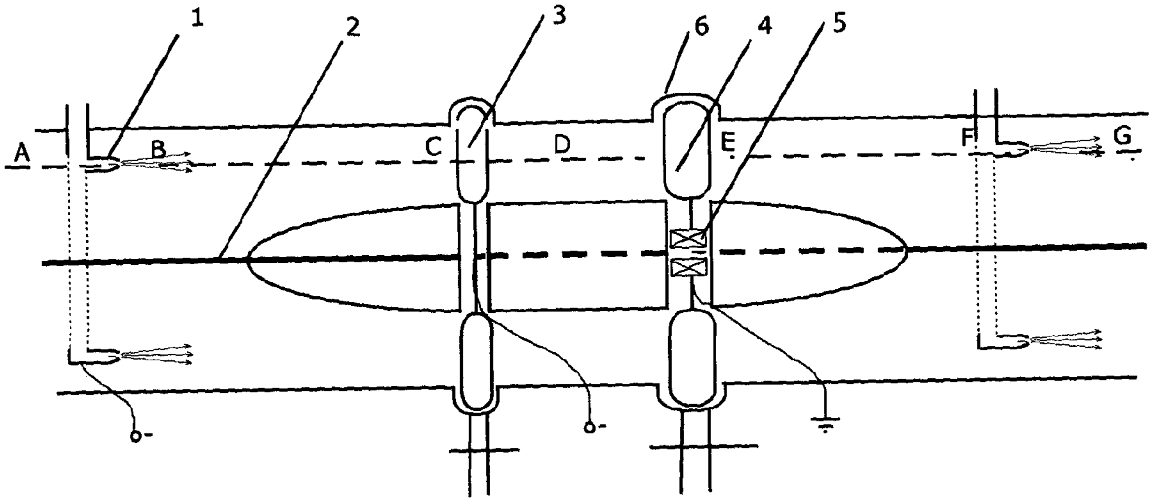

Fig. 9a.

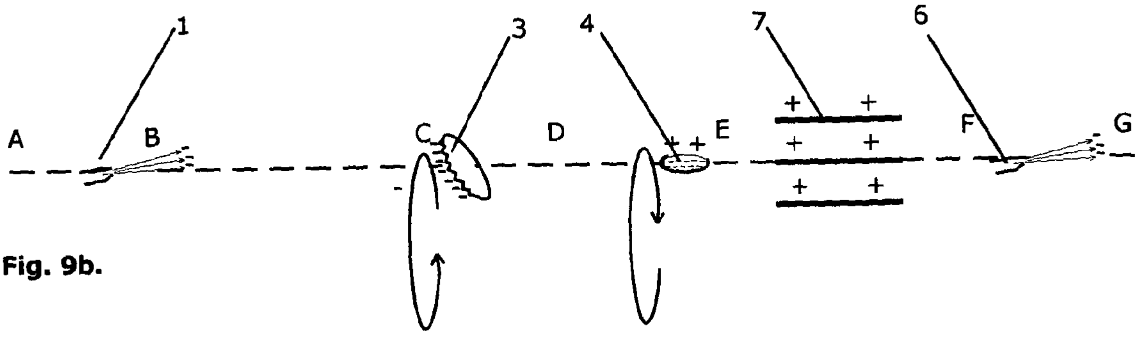

Fig. 9b.

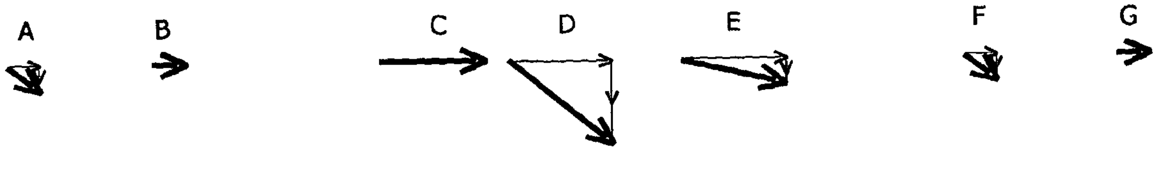

Fig. 9c.

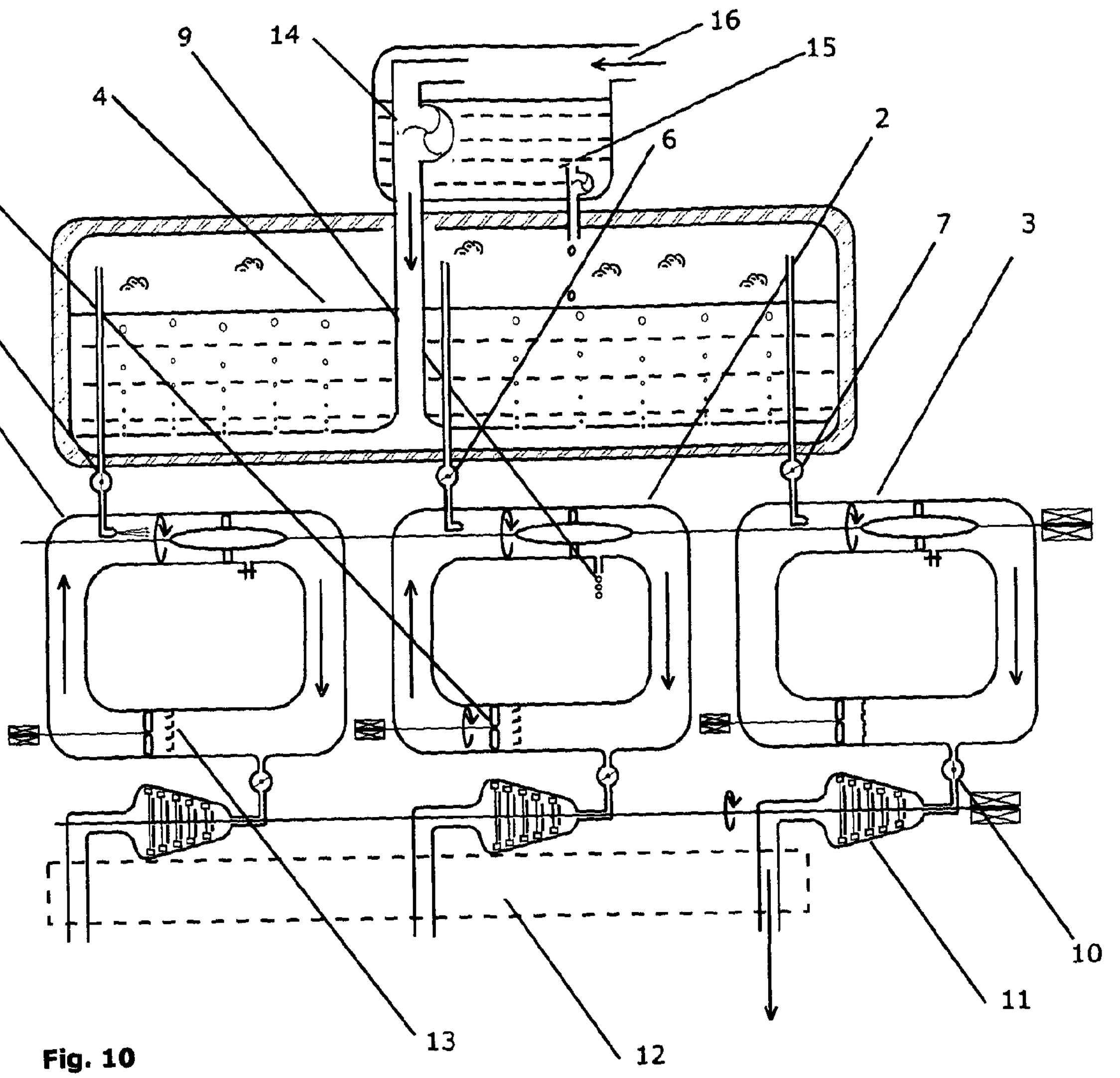

Fig. 10

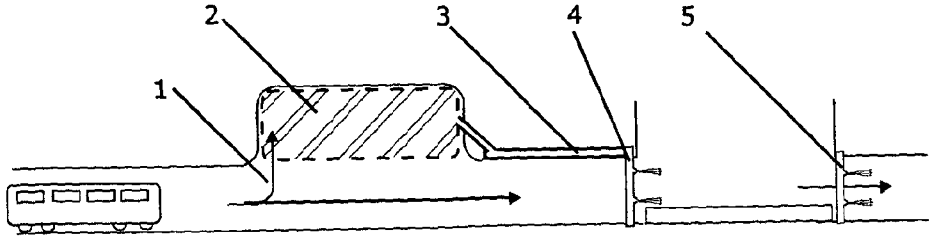

Fig. 11.

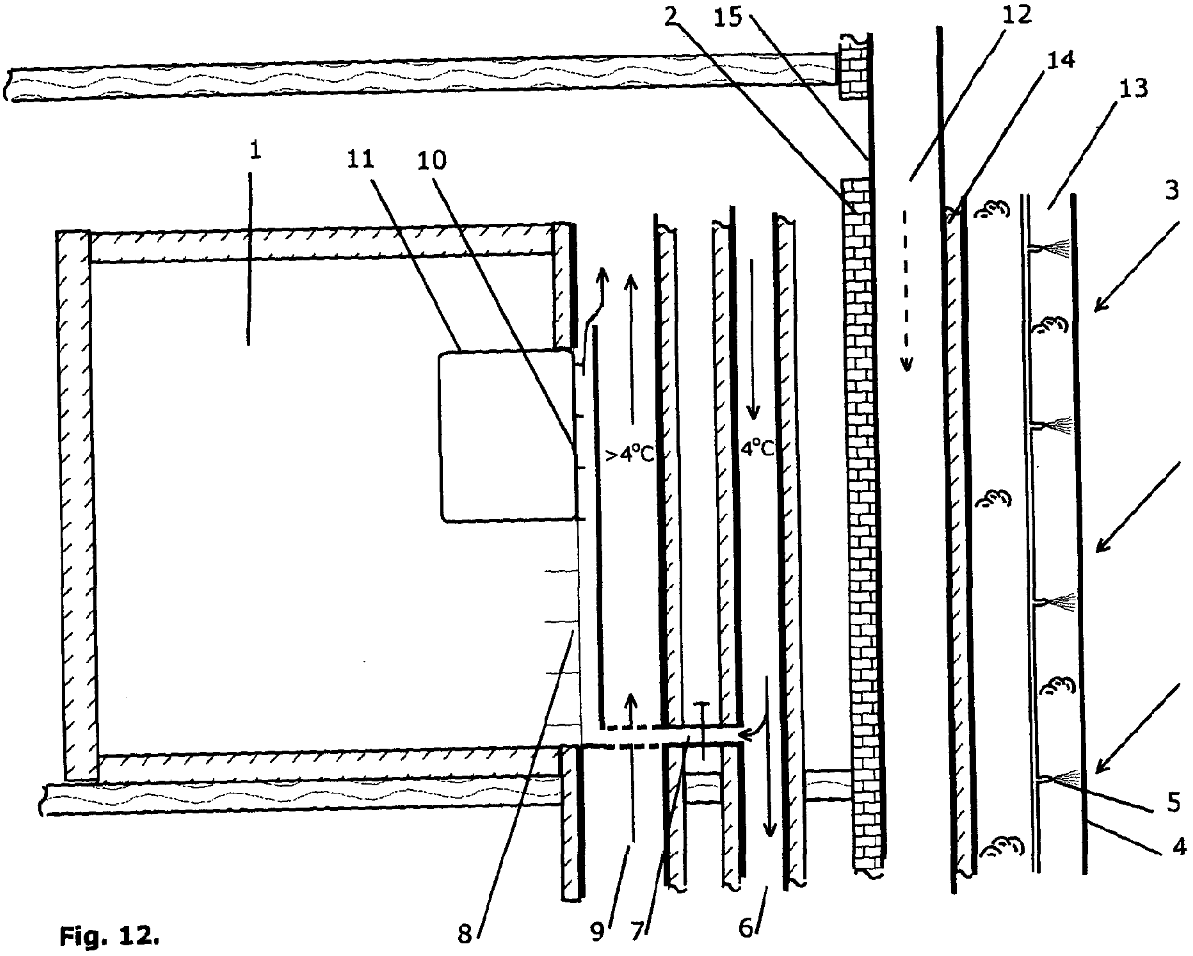

Fig. 12.

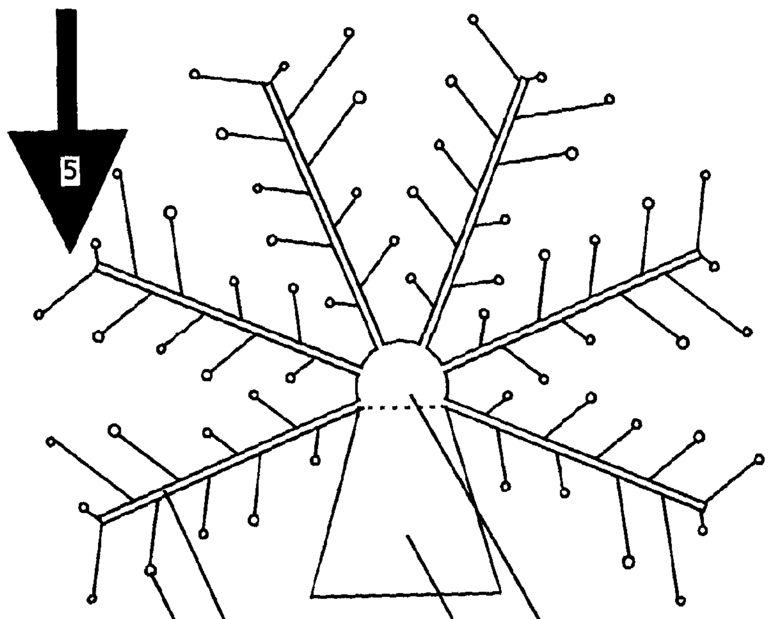

Fig. 13.

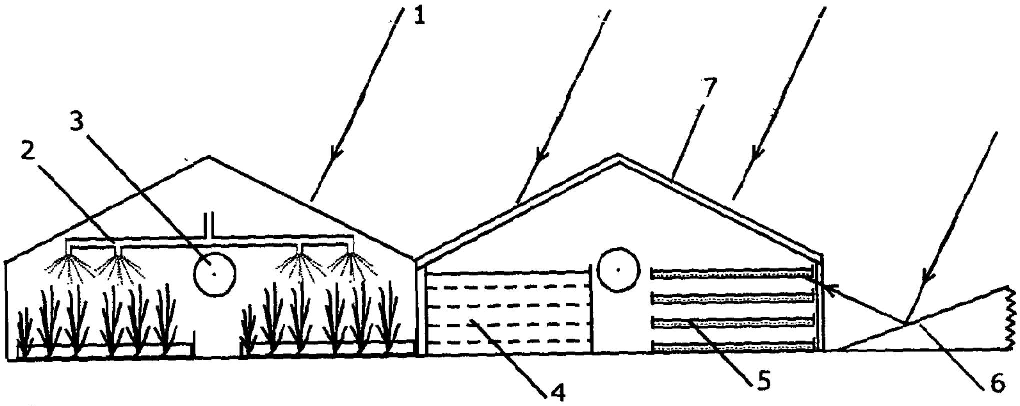

Fig. 14.

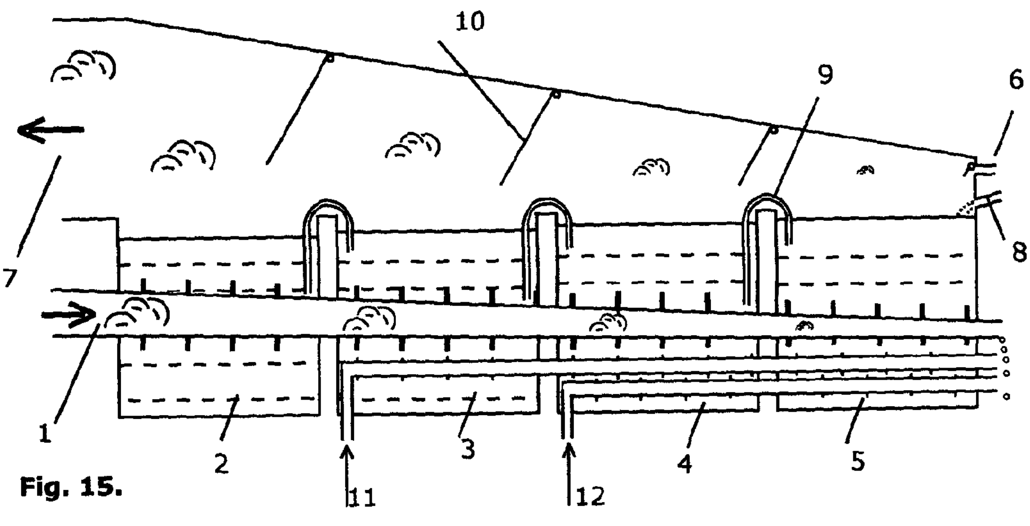

Fig. 15.

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2011/000936

A. CLASSIFICATION OF SUBJECT MATTER
INV. F02C1/00 F01K7/22 F01K21/04 F22B1/00
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)
F02C F01K F22B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 555 731 A (ROSENBLATT JOEL H [US]) 17 September 1996 (1996-09-17) sentence 49 - sentence 53 figure 3 column 7, line 41 - line 52 column 9, line 4 - line 12 -----	1-4,7,9, 11,14, 15,17,18
X	WO 00/60226 Al (STANKOVIC BRANKO [CA]) 12 October 2000 (2000-10-12) figure 2 -----	1-4,14, 15
X	MCCLOSKEY T: "Steam Turbines", 1 May 2003 (2003-05-01), HANDBOOK OF TURBOMACHINERY, MARCEL DEKKER, US, XP002516496, ISBN: 978-0-8247-0995-2 page 19 -----	1-4,9, 14, 15

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"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

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Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2011	06/10/2011

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). 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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Information on patent family members

International application No
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