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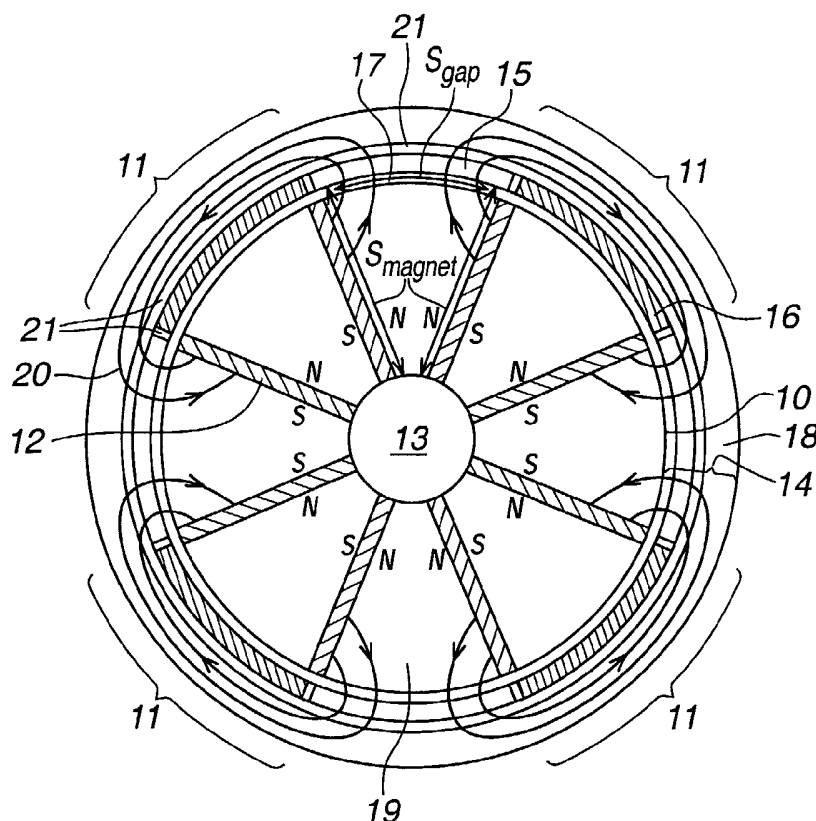
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(54) Title: A FLUID HANDLING SYSTEM



(57) Abstract: A fluid-handling system including a stator (14) and a rotor (10) which are rotatable with respect to each other around a common axis (13) and radially separated by an annular gap (17), where one of said components contains at least one element comprising magnetocaloric material (15, 16) and the other component comprises means to impose a magnetic field on said magnetocaloric material and is adapted to alternately magnetize and demagnetize said material, and means to bring said material into thermal contact with a fluid to change the temperature of that fluid, where the component containing means to impose a magnetic field comprises a plurality of pairs (11) of elongated permanent magnets (12), that are arranged substantially radially around said axis and magnetized so that unlike poles of each magnet pair face each other and like poles of adjacent magnet pairs face each other, in order to provide an intensified magnetic field that extends radially across said annular gap (17).



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A fluid handling system

TECHNICAL FIELD

5 The present invention relates to a fluid-handling system comprising a device to change the temperature of fluid flowing through the system, said device relying on the magnetocaloric effect of magnetic materials to effect temperature changes. More particularly, the present invention concerns the means for imposing a magnetic field on said magnetocaloric material, i.e.
10 magnetic material exhibiting a magnetocaloric effect.

BACKGROUND OF THE INVENTION

One of the functions of fluid-handling systems, such as ventilation/air-
15 conditioning or chemical processing units, is to provide fluid at the right temperature for a particular environment. In order to save energy, regenerative heat exchangers, in which incoming fluid is heated or cooled by thermal contact with material previously heated or cooled by outgoing fluid, are often used in such fluid-handling systems.

20 Refrigeration systems today are based on the gas compression cooling process. The efficiency of these conventional refrigeration systems is only about 40% of the Carnot refrigeration cycle and the refrigerants used in these systems, such as chlorofluorocarbons, hydrofluorocarbons and
25 ammonia, are harmful for the environment. Magnetic refrigeration, which has higher efficiency and is more environmentally friendly, compact and cost-effective, is being considered as an alternative technique to gas compression technology.

30 A process that uses magnetocaloric material as the refrigerant and as the body that stores thermal energy, i.e. the regenerator, is called active

magnetic regeneration (AMR). A device that vents heat released from magnetocaloric material when magnetized at one side and cools a load on another side when the magnetocaloric material is demagnetized, is known as an AMR device and such a device can help to extend the temperature span of a system, which is normally limited by the magnetocaloric effect.

The magnetocaloric effect is the ability of certain materials to heat up in the presence of a magnetic field and cool down when the field is removed. When a magnetic material, such as a ferromagnet or paramagnet, is placed in a magnetic field, the magnetic moments of its atoms become aligned, making the material more ordered and thus decreasing the magnetic entropy of the material. If the magnetic field is applied adiabatically, the total entropy of the material must be conserved, so the material's atoms vibrate more rapidly, consequently raising the lattice entropy of the material and the material's temperature. Conversely when the material is taken out of the magnetic field, it assumes its initial less ordered state, the lattice entropy is transferred back to magnetic entropy and the material returns to its initial temperature. An adiabatic cycle of this type does not produce a net cooling effect. If however, the *magnetized* magnetic material is cooled by exchanging heat with its surroundings, subsequent demagnetization will cool the material to a temperature lower than its initial temperature and in this way a cooling effect is achieved.

To create a magnetic refrigeration cycle magnetocaloric material is magnetized by placing it in a magnetic field, which causes the material to warm up. Heat is removed from the magnetocaloric material while it is in the magnetic field, by bringing the magnetocaloric material into thermal contact with a heat-conducting fluid, for example. The magnetocaloric material cools upon its removal from the magnetic field. Heat can be absorbed from a thermal load by bringing the thermal load into thermal contact with the cooling magnetocaloric material immediately after it is

taken out of the magnetic field. Continuous refrigeration of a thermal load can be achieved by repeating the described refrigeration cycle.

5 The temperature change arising due to the magnetocaloric effect depends on the magnetocaloric material used; it is proportional to the intensity of the applied magnetic field; and it's magnitude decreases with increasing difference between the material's temperature and it's Curie temperature. The magnetocaloric effect reaches its maximum for a ferromagnetic material at the material's Curie temperature, the transition point above
10 which thermally induced disorder overcomes the alignment of magnetic dipole moments of the material's atoms. The magnetocaloric effect is relatively weak in most ferromagnetic materials at room temperature. Gadolinium is an exception as it's Curie temperature is 21°C.

15 Recently new materials have been developed exhibiting an enhanced magnetocaloric effect, two to three times that of pure gadolinium. These new materials include intermetallic alloys comprising lanthanides, such as gadolinium-germanium-silicon alloys, and Al-Ni alloys. An 8 Tesla magnetic field, such as that produced by a superconducting magnet, can produce a
20 magnetocaloric temperature change of up to 15°C in some of these materials.

A common configuration of AMR devices is to incorporate magnetocaloric material into a wheel, ring, piston or the like and cyclically move the
25 magnetocaloric material through a stationary magnetic field to alternately magnetize and demagnetize said material. Rotary devices of this type give rise to the inevitable problem concerning fluid tightness since a heat-conducting fluid has to be brought into thermal contact with a moving body. Although this problem is not insurmountable, the components of the system
30 transporting a heat-conducting fluid to, through and from the moving body have to be manufactured to within very close tolerances to avoid fluid

leakage and thus a decrease in the thermal efficiency of the system. Furthermore, as friction is generated by the means of rotating the magnetocaloric material, the efficiency of such a system used as a refrigerator is lowered.

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One way of avoiding such problems is to cyclically magnetize and demagnetize stationary magnetocaloric material using an electromagnet that can be charged and discharged. However turning a current on and off causes a large ohmic heat loss in the coils, which compromises the efficiency of the system.

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US 4532770 discloses a magnetic refrigerator utilizing a plurality of coils arranged on the outer peripheral surface of a hollow cylindrical rotor. Magnetocaloric material is arranged in a stator around the outer or inner periphery of said rotor and an air gap separates said rotor and stator. A current flows through said coils, to form a distributed magnetic field around the periphery of the rotor and when the rotor rotates a magnetic field is periodically applied to and removed from the magnetocaloric material in the stator, which is magnetized and demagnetized respectively. In a preferred embodiment of the invention superconducting coils are used to increase the intensity of the magnetic field to which said magnetocaloric material is subjected. One disadvantage of this system is that electricity has to be consumed to produce a magnetic field, which increases operational costs. Furthermore if superconducting coils are used they have to be cooled to cryogenic temperatures, for example by immersing said coils in liquid helium, which increases the cost and complexity of the system.

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While it may be apparent for a person skilled in the art to replace the electromagnetic/superconducting coils, in the patented system described above, with permanent magnets, residual magnetic flux density, B_r , would limit the magnetic field which could be obtained. For example if NdFeB

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magnets ($B_r = 1.1$ Tesla) were used in said system, the air gap's magnetic flux density would only reach about 0.8 Tesla. Such a low intensity magnetic field would not produce a large magnetocaloric temperature change in magnetocaloric material.

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US 5182914 describes an AMR refrigerator comprising first and second elongated regenerative beds of magnetocaloric material positioned end to end and within fixed first and second inner dipole magnets respectively. The two inner dipole magnets are connected in opposition so that the field produced by one is in the opposite direction to that of the other. An outer dipole magnet, that rotates around the longitudinal axis on which said regenerative beds are located, surrounds the magnetized regenerative beds. The outer dipole magnet produces a magnetic field of the same magnitude as the inner dipole magnets transverse to its axis of rotation.

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Said beds of magnetocaloric material are magnetized and demagnetized as the vector sums of the magnetic fields of the inner dipole magnets and the outer dipole magnet are added together upon rotation of the outer dipole magnet. When the magnetic fields of the first inner dipole magnet and the outer dipole magnet align, constructive interference increases the intensity of the magnetic field imposed on the first bed of magnetocaloric material positioned within the first inner dipole magnet. At the same time, anti-alignment of the magnetic fields of the outer dipole magnet and the second inner dipole magnet cancel each other out yielding zero intensity. Upon one half rotation of the outer dipole magnet, the field of the first inner dipole magnet is anti-aligned with the magnetic field of the outer dipole magnet which causes the magnetic fields to essentially cancel each other out while the intensity of the magnetic field experienced by the second inner dipole magnet is increased.

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Said regenerative beds are brought into contact with a heat-conducting fluid. In order to achieve a large temperature change of said fluid it is preferable to make the fluid to flow axially along the regenerator beds and to make them as long as possible so as to increase heat transferring time.

5 However such a system housing two beds of magnetocaloric material along a common longitudinal axis would be relatively large. A large outer magnet as well as sufficiently powerful means to rotate said magnet would be required. More importantly, any imbalances in the system would give rise to an uneven rotation of the outer dipole magnet if attraction forces,

10 arising when unlike magnetic poles separate, and repulsion forces, arising when like poles meet, were not overcome. Said imbalances would result in irrecoverable energy losses as the magnets were rotated.

SUMMARY OF THE INVENTION

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It is an object of this invention to provide a fluid-handling system including an efficient AMR device incorporating permanent magnets, for changing the temperature of fluid, i.e. gas or liquid, flowing through the fluid-handling system.

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This and other objects of the invention are achieved by utilizing a device that includes two components in the form of a stator and a rotor, which are rotatable with respect to each other around a common axis and radially separated by an annular gap. One of said components contain at least one

25 element comprising magnetocaloric material. The other component comprises means to impose a magnetic field on said magnetocaloric material and is adapted to alternately magnetize said material contained in the other component in order to increase the material's temperature and demagnetize said material in order to decrease the material's temperature.

30 The device also comprises means to bring said at least one element

comprising magnetocaloric material into direct thermal contact with a fluid to change the temperature of that fluid.

The component containing means to impose a magnetic field comprises a plurality of pairs of elongated permanent magnets, that are arranged substantially radially around said axis and magnetized so that unlike poles of each magnet pair face each other and like poles of adjacent permanent magnet pairs face each other. Since the resultant magnetic field at any point and time is the sum of all individual magnetic fields at that point and time, as the magnetic fields from adjacent magnet pairs are in phase and act in the same direction across said gap, the magnetic fields superimpose constituting constructive interference and thus providing an intensified magnetic field that extends substantially radially across said annular gap.

This arrangement of magnets is a very effective way to increase the magnetic flux density across the gap and in the magnetocaloric material, which consequently increases the magnetocaloric temperature change obtained and the heating/cooling capacity of the temperature-changing device. The use of permanent magnets allows more reliable, simple and portable systems to be constructed. Furthermore, no electricity is consumed to produce a magnetic field leading to savings in operational costs.

In a preferred embodiment of the invention the permanent magnets comprise neodymium-boron-iron, samarium-cobalt or ferrite and the term *substantially radially* is, here and as it stands in claim 1, intended to also include elongated permanent magnets arranged parallel to each other in a pair.

According to preferred embodiments of the invention the magnets are arranged either in the rotor or the stator of said temperature-changing

device. Said rotor revolves either inside or around said stator. Arranging the magnets in the rotor and magnetocaloric material in the stator is however advantageous in that it simplifies the construction of a fluid tight system for the fluid that is brought into thermal contact with the magnetocaloric material.

In another preferred embodiment of the invention the component comprising magnetocaloric material is encased in a magnetically soft material, such as iron, that contains the magnetic flux in a localized area. In a further preferred embodiment of the invention said component comprising magnetocaloric material comprises laminated members, separated by insulating material for example, around said magnetocaloric material to hinder thermal conduction.

According to a preferred embodiment of the invention said stator comprises a substantially cylindrical member containing at least one element comprising magnetocaloric material around its inner or outer periphery, through which said fluid flows axially. According to another preferred embodiment said stator comprises a substantially circular ring-like member containing at least one element comprising magnetocaloric material through which said fluid flows circumferentially i.e. via channels that are substantially parallel to the ring-like member's periphery.

In another preferred embodiment of the invention said stator includes a plurality of elements comprising magnetocaloric material each of which is brought into direct thermal contact with a fluid and said rotor is adapted to impose substantially the same magnetic field on said plurality of elements comprising magnetocaloric material. In another preferred embodiment said rotor is adapted to impose magnetic fields of different magnitudes on said plurality of elements comprising magnetocaloric material. A fluid flows into direct thermal contact with each of said plurality of elements of

magnetocaloric material. The temperature change of the fluid flowing past each element is determined by the choice of magnetocaloric material constituting the element and the intensity of the magnetic field to which said element is exposed. Each element can therefore be used to provide a different amount of heating or cooling to fluids in a plurality of channels simultaneously using the same temperature changing device and thus achieve distributed heating or cooling, for example for different rooms in a building.

10 According to a preferred embodiment of the invention the fluid that is brought into thermal contact with said at least one element of magnetocaloric material is the fluid flowing through the fluid-handling system whose temperature is to be changed. According to another preferred embodiment of the system the fluid that is brought into direct thermal contact with said at least one element of magnetocaloric material is a heat transfer medium that flows through at least one heat exchanger that is in thermal contact with the fluid flowing through the fluid-handling system, said heat transfer medium transferring heat between said at least one element of magnetocaloric material and the fluid whose temperature is to be changed. According to a preferred embodiment of the invention, the heat transfer medium is water that is non-toxic, inexpensive, non-flammable and environmentally friendly. In another preferred embodiment the heat transfer medium is water comprising antifreeze to allow cooling below 0°C.

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According to another preferred embodiment, means are provided to reverse the flow of the heat transfer medium through the system to enable the temperature changing device to change from heating to cooling a fluid flowing through a fluid-handling system or vice versa. In this way the device can act as a heat exchanger and heating device in an air-conditioning system in winter and as a heat exchanger and cooling device in the

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summer and thus provide the option of the device being used to heat or cool the fluid flowing into the fluid-handling system.

5 In order to provide a large heat transfer area between said fluid and magnetocaloric material and thus attain high efficiency, said material constituting said at least one element is porous and has a high specific area per unit volume. According to preferred embodiments of the invention the magnetocaloric material constituting said at least one element is arranged in at least one of the following geometries: hollow tubes, parallel
10 wires, perforated plates, corrugated plates, wire meshes, thin parallel plates, packed individual particles or in the form of solid foam. The geometry of said at least one element is optimized to provide good heat transfer between the magnetocaloric material and fluid in thermal contact with said material while fluid flow resistance giving rise to a pressure drop
15 in the system is minimized. If for example the fluid in contact with said at least one element is air flowing through an air-handling system, a pressure drop means that the fan forcing the air through the system has to consume more energy in order to attain the same airflow through the system.

20 In a preferred embodiment of the invention said at least one element comprises a plurality of magnetocaloric materials having different Curie temperatures that are arranged in layers in order of increasing Curie temperature in the direction of fluid flowing past the element or in order of decreasing Curie temperature in the direction of fluid flowing past the
25 element depending on whether the fluid is to be cooled or heated on passing through the element. This grading of magnetocaloric material along an element is advantageous as the different magnetocaloric materials are arranged to correspond to the temperature profile that arises during the fluid-handling system's operation. This means that the different
30 magnetocaloric materials are maintained at a temperature as near as

possible to their Curie temperature thus optimizing the performance of the element.

According to further preferred embodiments of the invention the magnetocaloric material comprises a rare earth metal such as gadolinium, a rare earth metal-based alloy such as a gadolinium-silicon-germanium alloy or an Al-Ni alloy. In other preferred embodiments the magnetocaloric material is covered with a protective coating which is at least one of the following: hygroscopic, oxidation resistant, chemically resistant, hydrophobic.

The fluid-handling system of the present invention is primarily intended to be used to either increase or decrease the temperature of fluid, such as liquid flowing in a process fluid flow, or gas flowing into an enclosed environment such as a building or a vehicle, particularly, but not exclusively, in the temperature range from -30°C to 25°C .

BRIEF DESCRIPTION OF THE DRAWING

The invention will now be described by way of example and with reference to the accompanying drawing in which:

figure 1 depicts the cross section of a stator and rotor according to a first preferred embodiment of the present invention,

figure 2 shows the cross section of a stator and rotor according to a second preferred embodiment of the present invention,

figure 3 illustrates an AMR device according to a preferred embodiment of the present invention,

figure 4 shows an AMR device according to another preferred embodiment of the present invention,

figure 5 is a chart showing the temperature attained by fluid in thermal contact with magnetocaloric material in the systems shown in figures 3 and 4, and

figure 6 shows an AMR device that is used to achieve distributed heating or cooling according to another preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows the cross-section of a cylindrical rotor 10 comprising four pairs 11 of elongated permanent magnets 12 that are arranged substantially radially around said rotor's axis of rotation 13. The axis of rotation 13 comprises a magnetically hard material. The rotor 10 rotates inside a hollow cylindrical stator 14 that comprises a plurality of elements of magnetocaloric material 15, 16 on its inner peripheral surface. Insulators 21 having a low thermal conductivity divide said elements of magnetocaloric material 15, 16 and insulate said elements from the surrounding stator material 18. Means are provided to bring said magnetocaloric material into direct thermal contact with a fluid via static fluid channels, flowing perpendicular to the plane of figure 1, to change the temperature of that fluid. Fluid to be heated flows through elements 15 upon their magnetization. Fluid to be cooled flows through elements 16 upon their demagnetization. The geometry of the elements is optimized to provide good heat transfer between the magnetocaloric material and fluid flowing through the elements while minimizing fluid flow resistance.

Said rotor 10 and stator 14 are separated by an annular air gap 17. The four permanent magnet pairs 11 are arranged so that unlike poles of each magnet pair face each other and like poles of adjacent magnet pairs face each other in order to provide an intensified magnetic field that extends substantially radially across said annular air gap 17. The magnetic flux density in the gap, B_{gap} , between the rotor and stator can be calculated from the ratio of the area of the magnets, S_{magnet} , to the area of the gap, S_{gap} , and the flux density in the magnets, B_{magnet} , using the following equation:

$$B_{gap} = 2B_{magnet} \frac{S_{magnet}}{S_{gap}} \quad \dots I$$

The magnetic flux density in the gap depends on the parameter S_{magnet}/S_{gap} . If the area of the magnets is equal to area of the gap between said magnets, the magnetic flux density in said gap, B_{gap} , will be two times greater than the magnetic flux density in one magnet, B_{magnet} .

The stator 14 is encased in a magnetically soft material 18, such as iron, that contains the magnetic flux 20 in a localized area around the magnetocaloric material 15,16. The rotor 10 also comprises a magnetically soft material 19 in between the magnets 12.

Figure 2 shows second preferred embodiment of the present invention where the rotor 10, comprising pairs 11 of permanent magnets 12, rotates around a stator 14 that comprises magnetocaloric material 15,16 on its outer peripheral surface. The stator core comprises laminated members that are separated by insulating material 21. An annular gap 17 separates said rotor 10 and stator 14. The stator and rotor comprise a magnetically soft material 18, 19 that contains the magnetic flux 20 in a localized area. The outer periphery of the rotor can be encased in a magnetically hard material.

Figure 3 shows an AMR device including a rotor 10 comprising means to impose a magnetic field on at least one element of magnetocaloric material 15, 16 in a stator 14. Said rotor and stator are separated by an annular gap and the cross-section indicated by line E-E' is that shown in figure 1. As the magnetocaloric material constituting said at least one element is being magnetized a heat transfer medium 31, such as water or any other heat conducting fluid, is brought into thermal contact with the element via a static fluid channel. The heat transfer medium 31 flows axially through said element when it is magnetized and is consequently warmed. The heat transfer medium exiting the element at B has a higher temperature than heat transfer medium entering the element at A. A temperature profile is established along the element where the material nearer side A is colder than material nearer side B. Magnetocaloric materials having different Curie temperatures are arranged in order of Curie temperature so that material with the highest Curie temperature is nearest to B and material having the lowest temperature is nearest to A to optimize the performance of the element by maintaining the magnetocaloric materials as near to their Curie temperature as possible.

The layers or sections of different magnetocaloric materials are not necessarily of the same thickness, as their thickness will depend upon the temperature profile along the element. The element comprises, for example, layers of porous gadolinium-silicon-germanium alloys of different compositions. By adjusting the alloys' compositions, their Curie temperatures can be controlled. The higher the germanium content of the alloy in a layer, the lower it's Curie temperature. Through suitable choice of magnetocaloric material and applied magnetic field, an element can be tuned to a specific operating temperature range. In order to achieve a different operating temperature range, the intensity of the applied magnetic field can be changed or the magnetocaloric material constituting an

element can be replaced without having to redesign the whole fluid-handling system.

5 In another preferred embodiment of the present invention the magnetocaloric material is coated with a protective coating that is chemically resistant to some component of the fluid flowing through the system. In a preferred embodiment of the invention the coating removes moisture from humid gas passing through a gas-handling system.

10 On exiting said at least one element of magnetocaloric material at B, the heat transfer medium 31 is then driven through a heat exchanger 32 where it dissipates heat, Q_{out} . On having passed through the heat exchanger 32, the heat transfer medium is then brought into thermal contact with demagnetized magnetocaloric material 16 via a second static fluid channel
15 33. The heat transfer medium is cooled as it flows axially through said material from C to D. It is then driven through a heat exchanger 34 where it absorbs heat, Q_{in} . The heat transfer medium 31 is in thermal contact with fluid flowing through a fluid-handling system via the heat exchangers 32 and 34. If the fluid flowing into the fluid-handling system is to be heated it is
20 directed to flow past heat exchanger 32, as indicated by arrow 35, where it is heated by heat transfer medium flowing through heat exchanger 32. If the fluid flowing into the fluid-handling system is to be cooled it is directed to flow past heat exchanger 34, as indicated by arrow 36, where it is cooled by heat transfer medium flowing through heat exchanger 34.

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In a preferred embodiment of the invention, means 37 are provided to pump the heat exchange medium around the system and such means can also be used to reverse the flow of heat transfer medium 31 through the system to enable the temperature changing device to change from heating
30 to cooling a fluid flowing through a fluid-handling system or vice versa.

- Figure 4 shows an AMR device comprising a stator 14 comprising at least one element of magnetocaloric material located at the rim of a ring-like member. In the first half of the cycle, shown in figure 4a, a rotor (not shown) provides a magnetic field 40 in the vicinity of magnetocaloric material at the top of said ring-like member. As the magnetocaloric material constituting said at least one element is being magnetized, a heat transfer fluid 31 is brought into thermal contact with the element via a first fixed channel. The fluid 31 flows circumferentially with respect to the ring-like member via channels that are substantially parallel to the plane of the ring-like member's circular surfaces through the magnetized magnetocaloric material whereby it is consequently warmed as it flows from A to B. Said heat transfer fluid is then passed through a heat exchanger 32 where it dissipates heat, Q_{out} .
- In the second half of the cycle, shown in figure 4b a pump 37 reverses flow direction of the heat transfer fluid and the rotor imposes a magnetic field on at least one element of magnetocaloric material located in the lower part of the ring-like member. The heat transfer fluid is brought into thermal contact with demagnetized magnetocaloric material, via a first fixed channel 31 and flows circumferentially with respect to the ring-like member through the demagnetized magnetocaloric material from B to A whereby it is cooled and transferred to a heat exchanger 34 where it absorbs heat Q_{in} from fluid flowing through the fluid handling system.
- The systems shown in figures 3 and 4 can of course be adapted so that the rotor contains magnetocaloric material and the stator contains means for providing a magnetic field. There are also many forms that the stator can take which would be obvious to a person with ordinary skill in the art.
- Figure 5 shows the how the temperature of fluid in thermal contact with magnetocaloric material in the systems shown in figures 3 and 4 changes

as said fluid flows between the points labeled A, B, C and D. If fluid flows from A to B as magnetocaloric material located between those points is magnetized, said fluid is heated. The fluid dissipates this heat, Q_{out} when it loses contact with the magnetocaloric material. When the fluid flows past demagnetized material located between points C and D, the temperature of said fluid decreases. The fluid absorbs heat Q_{in} once it loses contact with the magnetocaloric material. The longer the distance (A to B or C to D) in the flow direction of the magnetocaloric material, the longer the heat transferring time and the larger the fluid temperature change achieved.

Figure 6 shows a stator including a plurality of elements 61, 62, 63, comprising magnetocaloric material 15,16. The rotor 10 is adapted to impose magnetic fields on each of said plurality of elements. A fluid 31 flows into direct thermal contact with each of said elements 61, 62, 63. The temperature change of the fluid flowing past each element is determined by the choice of magnetocaloric material constituting said element and the intensity of the magnetic field to which said material is exposed. Each element 61, 62, 63 can therefore be used to provide a different amount of heating or cooling to fluid 31 flowing in a plurality of channels. For example said system is used to heat two fluids 64, 65 and to cool a fluid 66 simultaneously. These fluids could for example be air used to heat two rooms 64, 65 in a house and to cool a third 66.

While only certain preferred features of the present invention have been illustrated and described, many modifications and changes will be apparent to those skilled in the art. It is therefore to be understood that all such modifications and changes of the present invention fall within the scope of the claims.

CLAIMS

1. A fluid-handling system comprising a device to change the temperature of the fluid flowing through the system which includes two components in the form of a stator (14) and a rotor (10) which are rotatable with respect to each other around a common axis (13) and radially separated by an annular gap (17), where one of said components contain at least one element comprising magnetocaloric material (15,16) and the other component comprises means to impose a magnetic field on said magnetocaloric material and is adapted to alternately magnetize said magnetocaloric material contained in the other component in order to increase the material's temperature and demagnetize said magnetocaloric material in order to decrease the material's temperature, and means to bring said at least one element comprising magnetocaloric material into direct thermal contact with a fluid to change the temperature of that fluid, **characterized** in that said component containing means to impose a magnetic field comprises a plurality of pairs (11) of elongated permanent magnets (12), that are arranged substantially radially around said axis of rotation and magnetized so that unlike poles of each magnet pair face each other and like poles of adjacent permanent magnet pairs face each other, in order to provide an intensified magnetic field that extends substantially radially across said annular gap (17).
2. A system according to claim 1, **characterized** in that the rotor (10) comprises means to impose a magnetic field on magnetocaloric material located in the stator (14).
3. A system according to claim 1, **characterized** in that the stator (14) comprises means to impose a magnetic field on magnetocaloric material located in the rotor (10).

4. A system according to any preceding claims, **characterized** in that said rotor (10) revolves inside said stator (14).
5. A system according to any of claims 1-3, **characterized** in that the rotor (10) revolves around said stator (14).
6. A system according to any preceding claims, **characterized** in that the component comprising magnetocaloric material (15,16) is encased in a magnetically soft material (18) that contains the magnetic flux in a localized area.
7. A system according to any preceding claims, **characterized** in that the component containing magnetocaloric material (15,16) comprises laminated members.
8. A system according to claim 7, **characterized** in that said laminated members are separated by insulating material (21).
9. A system according to any of preceding claims apart from claim 3, **characterized** in that said stator (14) comprises a substantially cylindrical member, containing at least one element comprising magnetocaloric material (15, 16) around its periphery, through which said fluid (31, 33) flows axially.
10. A system according to any preceding claims apart from 3 and 9, **characterized** in that said stator (14) comprises a substantially circular ring-like member containing at least one element comprising magnetocaloric material through which said fluid flows via channels that are substantially parallel to the ring-like member's periphery.

11. A system according to any preceding claims apart from 3, 9 and 10, **characterized** in that said stator includes a plurality of elements comprising magnetocaloric material each of which is brought into direct thermal contact with a fluid.

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12. A system according to claim 11, **characterized** in that said rotor (10) is adapted to impose substantially the same magnetic field on said plurality of elements comprising magnetocaloric material.

10 13. A system according to claim 11, **characterized** in that said rotor (10) is adapted to impose magnetic fields of different magnitudes on said plurality of elements comprising magnetocaloric material.

14. A system according to any preceding claims, **characterized** in that the fluid that is brought into thermal contact with said at least one element of magnetocaloric material (15, 16) is the fluid flowing through the fluid-handling system whose temperature is to be changed.

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15. A system according to any of claims 1-13, **characterized** in that fluid that is brought into direct thermal contact with said at least one element of magnetocaloric material (15, 16) is a heat transfer medium that flows through at least one heat exchanger (32, 34) that is in thermal contact with the fluid flowing through the fluid-handling system, said heat transfer medium transferring heat between said at least one element of magnetocaloric material and the fluid whose temperature is to be changed.

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16. A system according to claim 15, **characterized** in that the heat transfer medium is water.

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- 17.A system according to claim 16, **characterized** in that the water comprises antifreeze.
- 18.A system according to any preceding claims, **characterized** in that
5 means (37) are provided to reverse the flow of the heat transfer medium through the system to enable the device to change from heating to cooling a fluid flowing through a fluid-handling system or vice versa.
- 19.A system according to any of the previous claims, **characterized** in that
10 the magnetocaloric material constituting said at least one element (15, 16) is arranged in at least one of the following geometries: hollow tubes, parallel wires, perforated plates, corrugated plates, wire meshes, thin parallel plates, packed individual particles.
- 15 20.A system according to any of claims 1-19, **characterized** in that the magnetocaloric material constituting said at least one element (15,16) is in the form of solid foam.
- 20 21.A system according to any of the previous claims, **characterized** in that said at least one element (15, 16) comprises a plurality of magnetocaloric materials having different Curie temperatures.
- 22.A system according to claim 21, **characterized** in that said plurality of magnetocaloric materials constituting said at least one element are
25 arranged in layers in order of increasing Curie temperature in the direction of fluid flowing past the element.
- 23.A system according to claim 21, **characterized** in that said plurality of magnetocaloric materials constituting said at least one element are
30 arranged in layers in order of decreasing Curie temperature in the direction of fluid flowing past the element.

24. A system according to any of the previous claims, **characterized** in that said magnetocaloric material comprises at least one of the following: a rare earth metal, gadolinium, a rare earth metal-based alloy, a gadolinium alloy, gadolinium-silicon-germanium alloy, an Al-Ni alloy.

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25. A system according to any of the previous claims, **characterized** in that said magnetocaloric material is covered with a protective coating.

26. A system according to claim 25, **characterized** in that the protective coating is at least one of the following: hygroscopic, oxidation resistant, chemically resistant, hydrophobic.

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27. A system according to any of the previous claims, **characterized** in that the device which changes the temperature of the fluid is adapted to provide the option of being used to heat or cool the fluid flowing into the fluid-handling system.

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28. A system according to any of the previous claims, **characterized** in that the fluid flowing through the fluid-handling system is a gas.

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29. A fluid-handling system according to any of claims 1-27 **characterized** in that the fluid flowing through the fluid-handling system is a liquid.

30. Use of a rotor (10) comprising a plurality of elongated permanent magnets (12), that are arranged radially around said rotor's axis of rotation (13) and magnetized so that like poles of adjacent permanent magnets face each other, for imposing the required magnetic field on at least one element comprising magnetocaloric material (15, 16) in a fluid handling system according to any of the previous claims.

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31. Use of a stator (14) comprising a plurality of elongated permanent magnets (12), that are arranged radially around said rotor's axis of rotation (13) and magnetized so that like poles of adjacent permanent magnets face each other, for imposing the required magnetic field on at least one element in a fluid handling system according to any of the previous claims.

32. Use of a fluid-handling system according to any of claims 1-29 to cool a fluid.

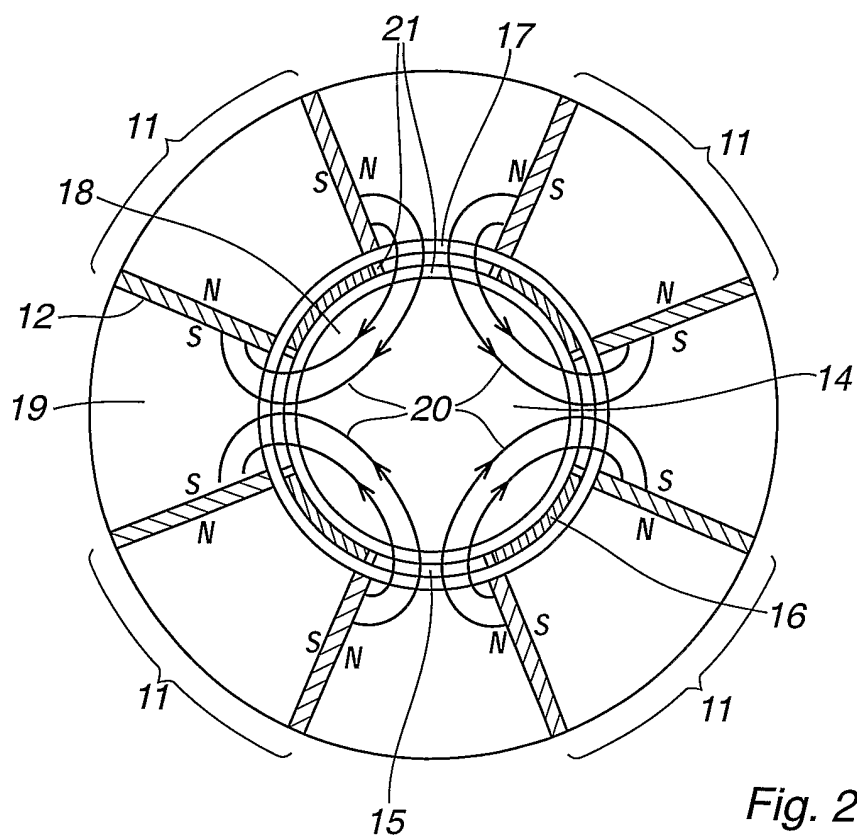
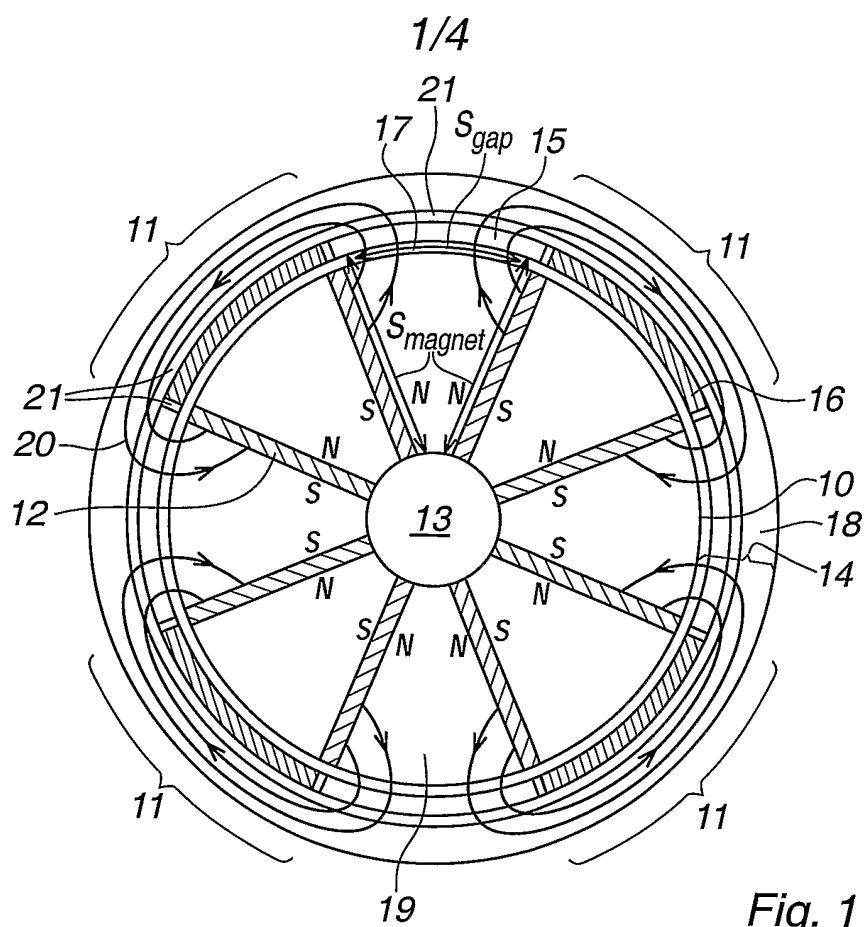
33. Use of a fluid-handling system according to any of claims 1-29 to heat a fluid.

34. Use of a fluid-handling system according to any of claims 1-29 for the
ventilation of a building.

35. Use of a fluid-handling system according to any of claims 1-29 for the ventilation of a vehicle.

20 36. Use of a fluid handling system according to any of claims 11-13 to change the temperature of fluid flowing in a plurality of channels simultaneously to achieve distributed heating or cooling.

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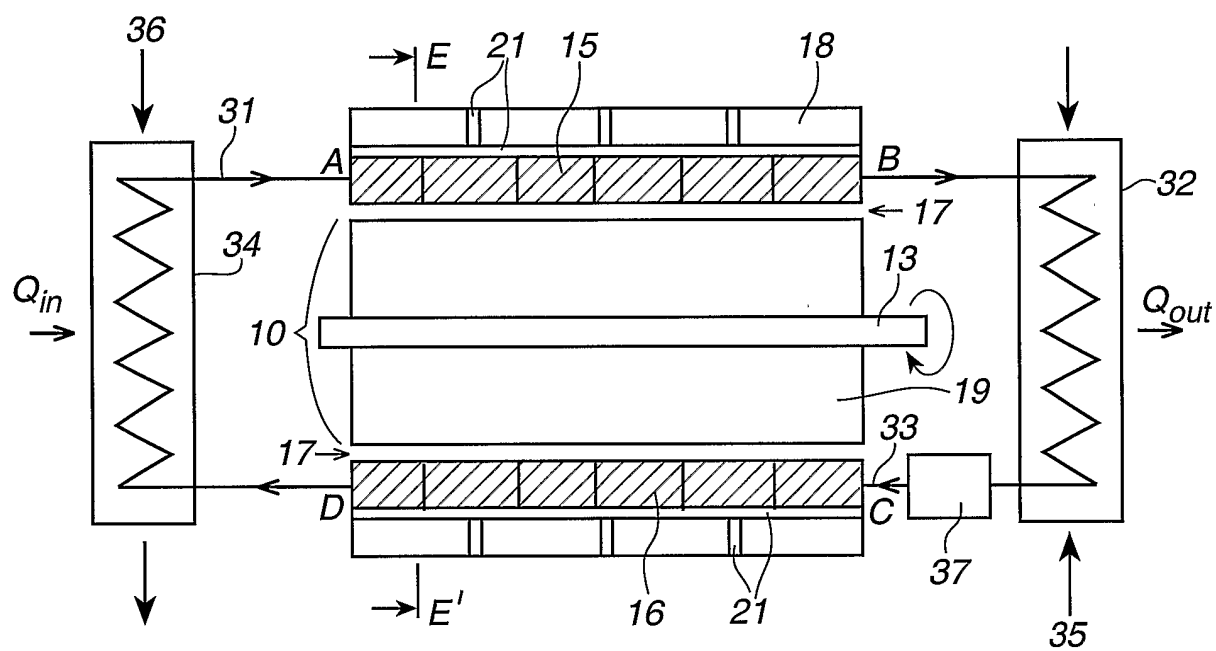


Fig. 3

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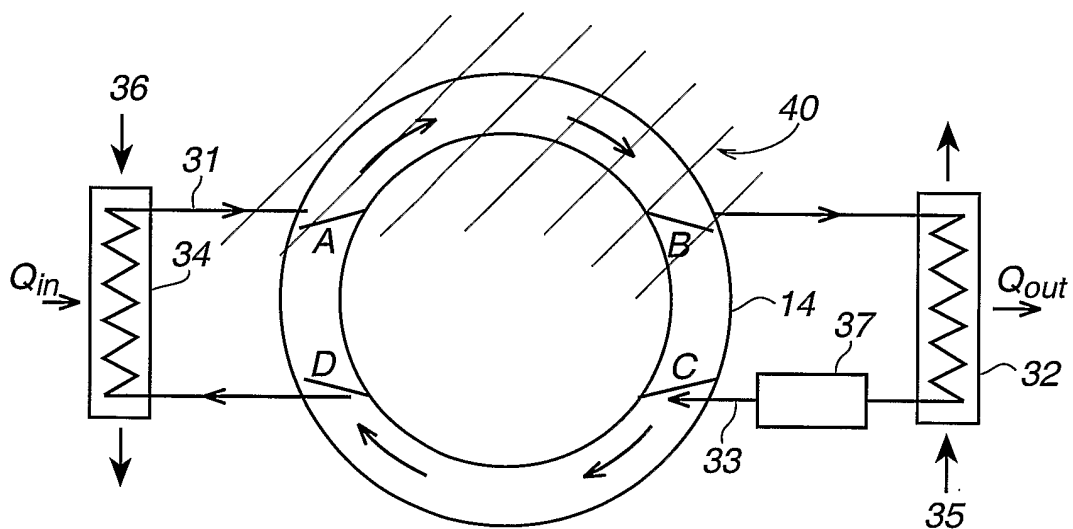


Fig. 4a

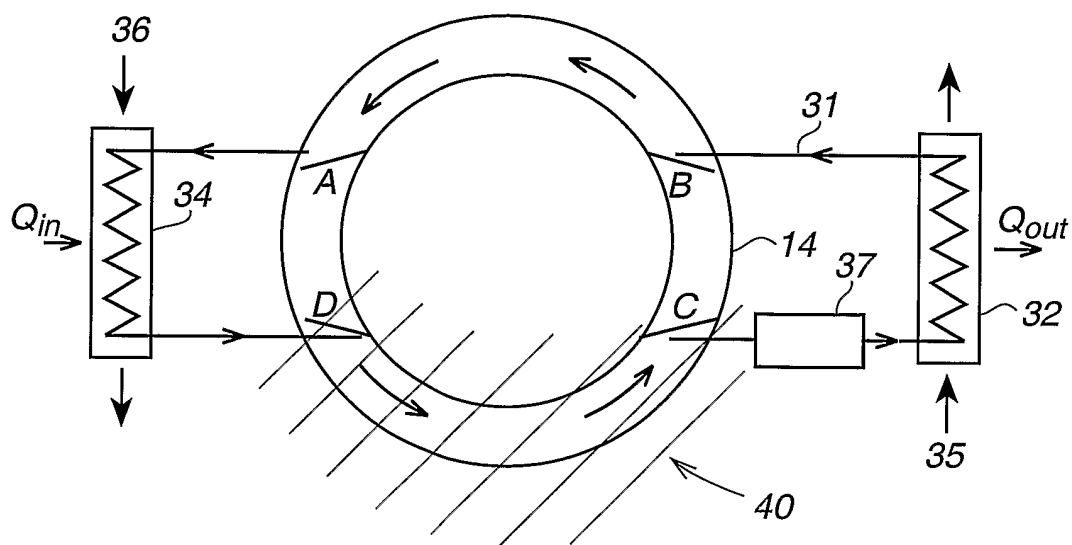


Fig. 4b

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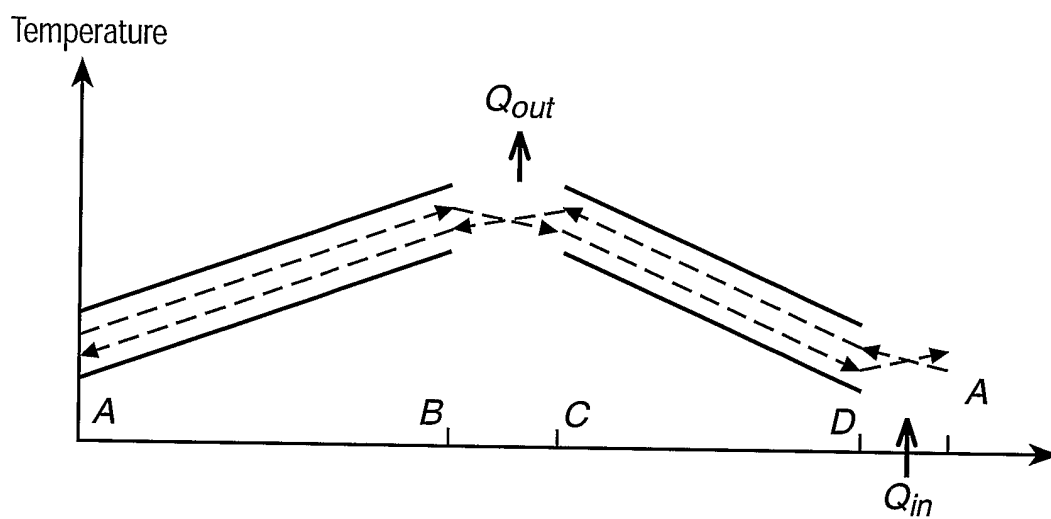


Fig. 5

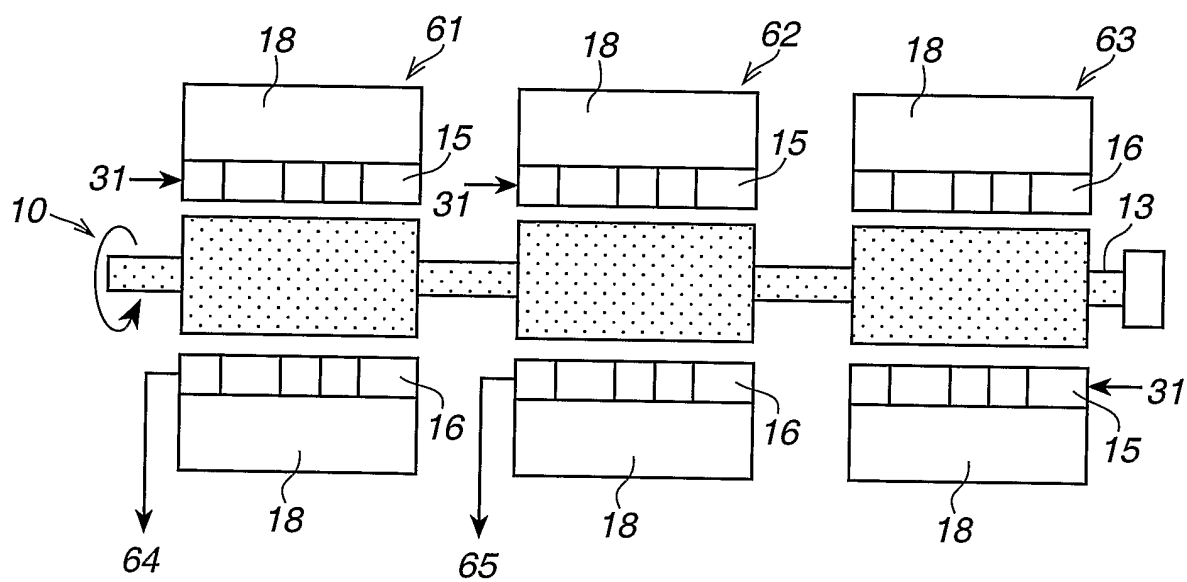


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 02/00634

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F25B 21/00

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)

IPC7: F25B

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5091361 A (HED), 25 February 1992 (25.02.92), Fig. 11 and adherent text --	1-36
A	US 4441325 A (BON-MARDION ET AL), 10 April 1984 (10.04.84), Fig. 5 and adherent text --	1-36
A	WO 0133145 A1 (ABB AB), 10 May 2001 (10.05.01), the whole document --	1-36
A	SU 1719816 A1 (..), 15 March 1992 (15.03.92) --	1-36

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

18 June 2002

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 02/00634

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU 1651055 A1 (...), 23 May 1991 (23.05.91) --	1-36
A	Derwent's abstract, No 92-347364/42, week 9242, ABSTRACT OF SU, 4628265 (KARAGUSOV V I et al), 30 August 1991 (30.08.91) -- -----	1-36

INTERNATIONAL SEARCH REPORT

information on patent family members

01/05/02

International application No.

PCT/SE 02/00634

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US	4441325	A	10/04/84	DE 3275584 D EP 0081411 A,B FR 2517415 A,B JP 58108370 A	00/00/00 15/06/83 03/06/83 28/06/83
WO	0133145	A1	10/05/01	AU 1185901 A NO 312262 B NO 995354 A	14/05/01 15/04/02 03/05/01
SU	1719816	A1	15/03/92	NONE	
SU	1651055	A1	23/05/91	NONE	