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[54] **METHOD AND APPARATUS FOR PRODUCING A TEMPERATURE GRADIENT IN A SUBSTANCE CAPABLE OF CARRYING THERMAL ENERGY**

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[51] **Int. Cl.** **F28d 11/08**

[58] **Field of Search** 165/6, 7, 105, 106, 86, 165/88, 1

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[57] **ABSTRACT**

A rotor is mounted for high-speed rotation. At its center is located a source of thermal energy whereas at its periphery there is located a heat exchanger. Chambers are provided, accommodating a gaseous material which, depending upon its position in the chambers, can receive heat from the source of thermal energy or yield heat to the heat exchanger.

The gas is subjected to a very high acceleration and is moved from the region of the source of thermal energy to the region of the heat exchanger; as a result of this high acceleration a thermal or temperature gradient will be established so that the gas will have a higher temperature on contacting the heat exchanger to which it can then yield heat.

15 Claims, 7 Drawing Figures

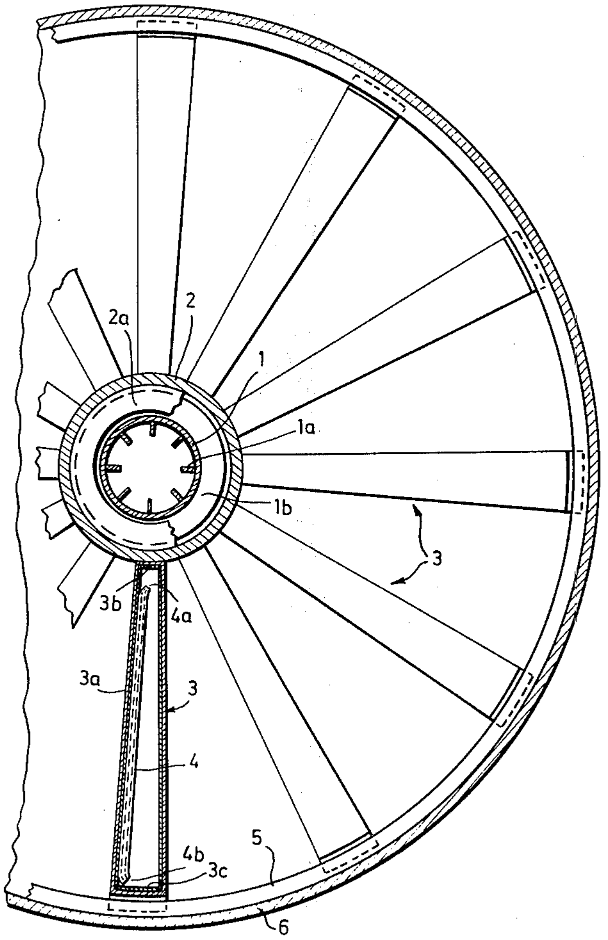


FIG.1

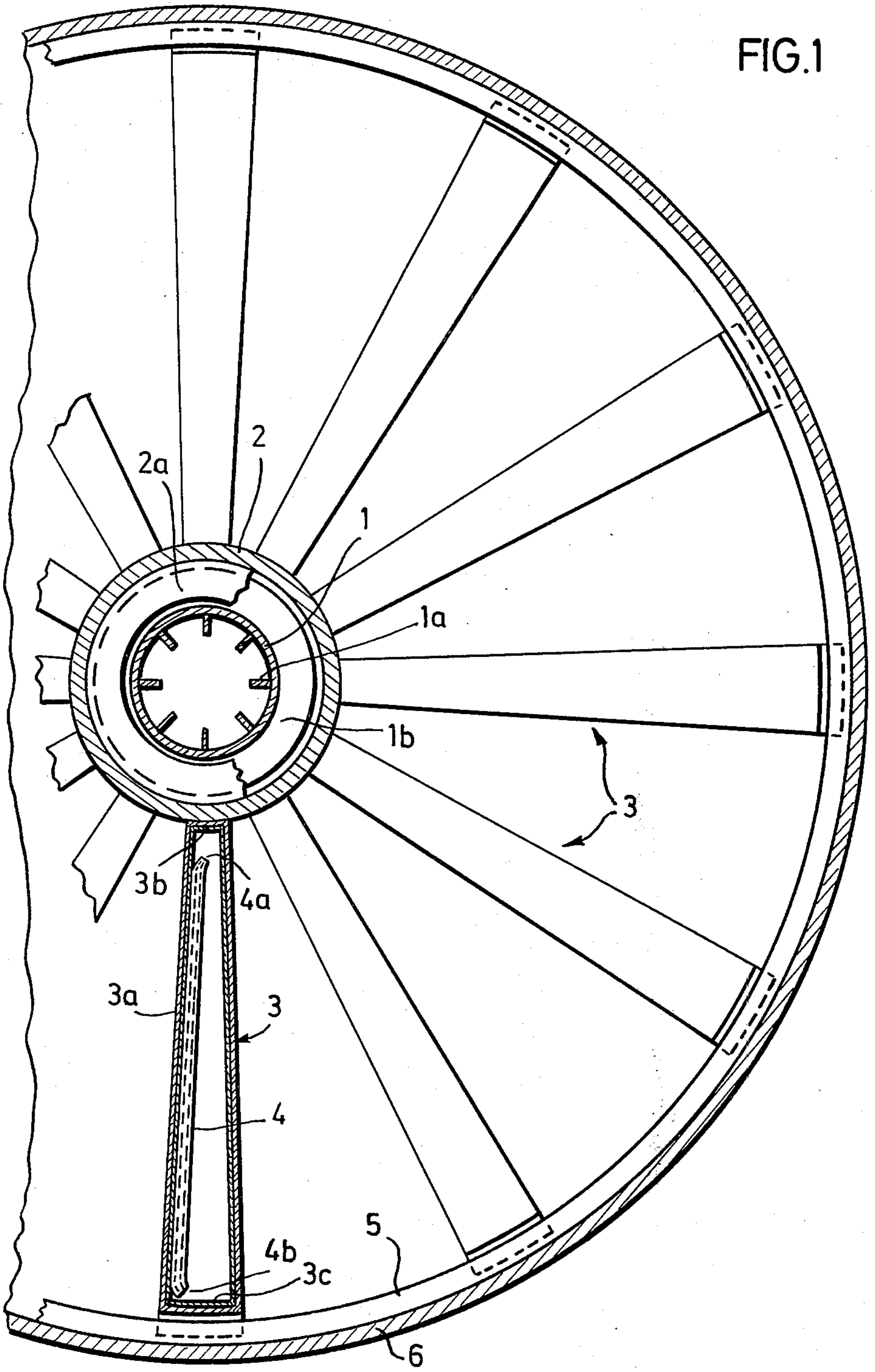


FIG.2

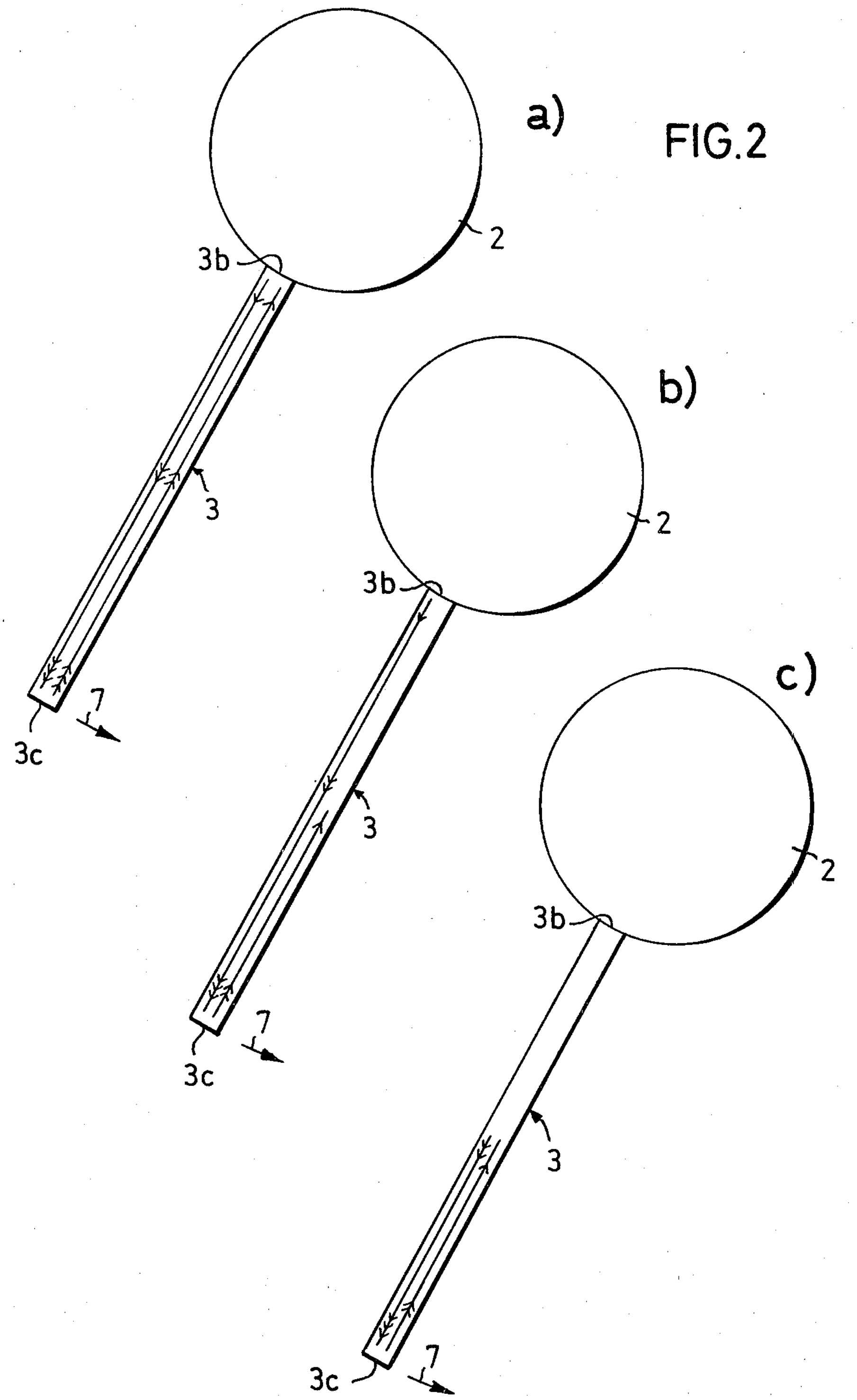


FIG.3

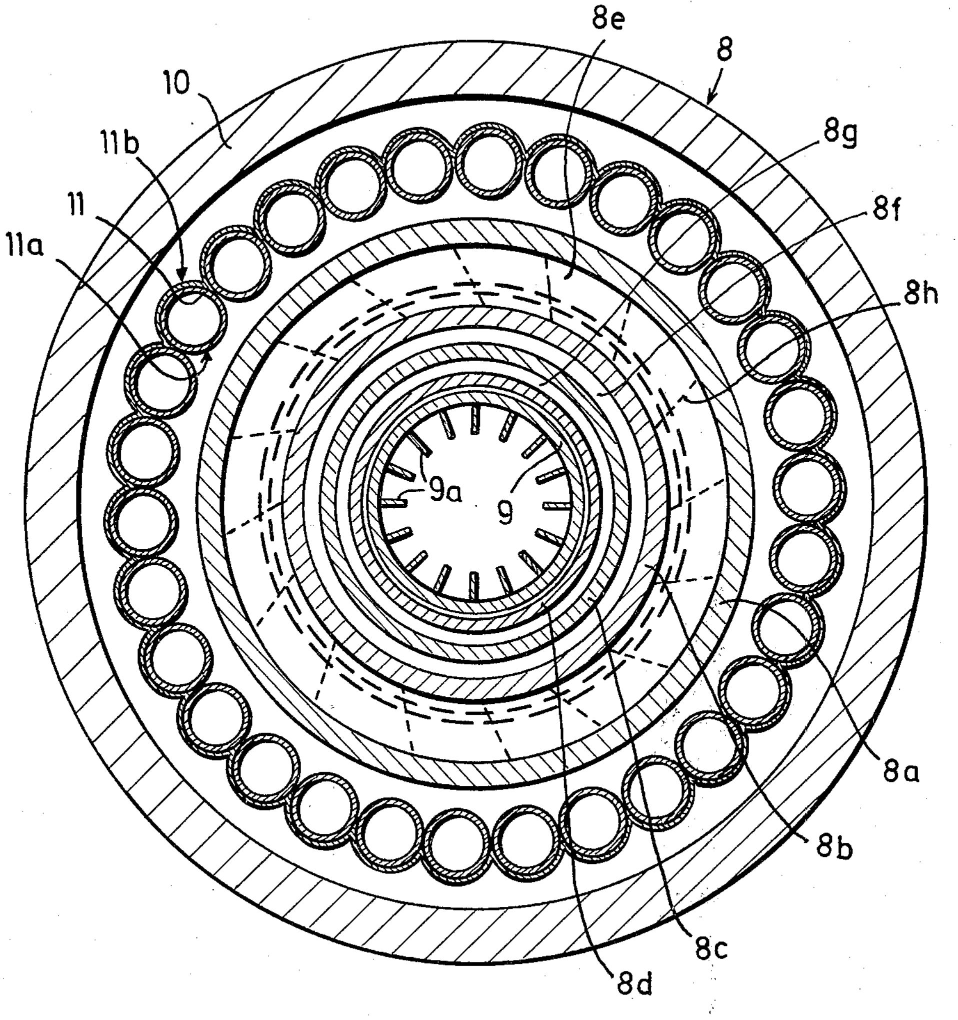


FIG. 4

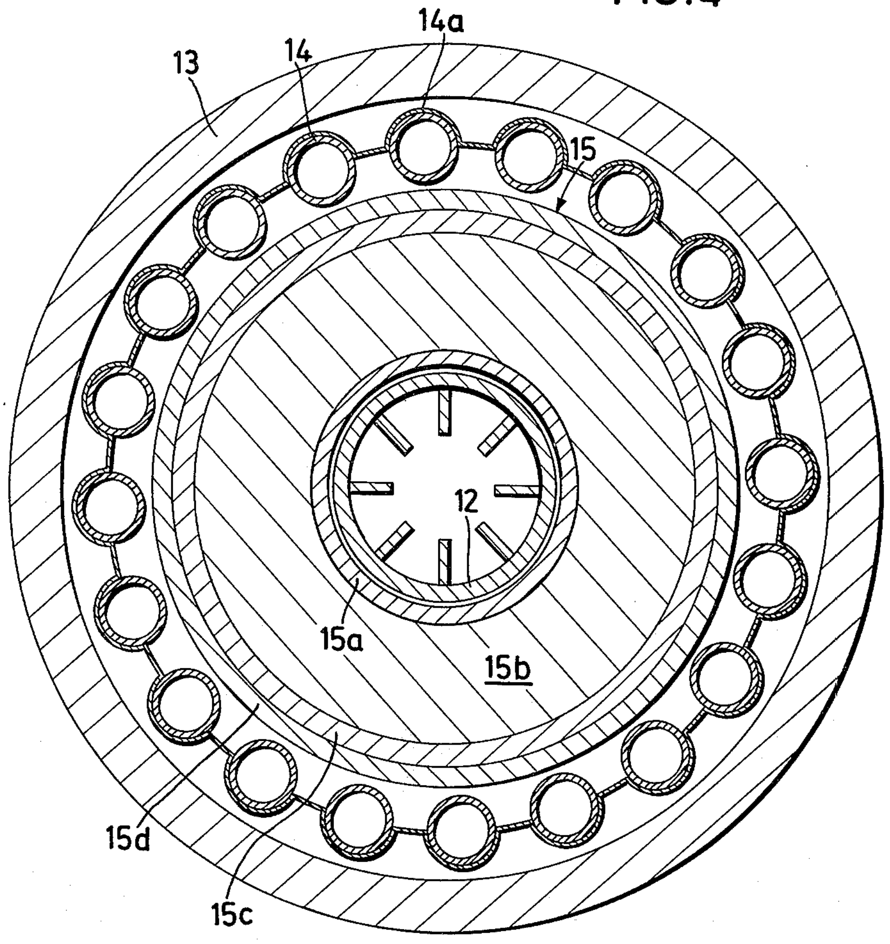
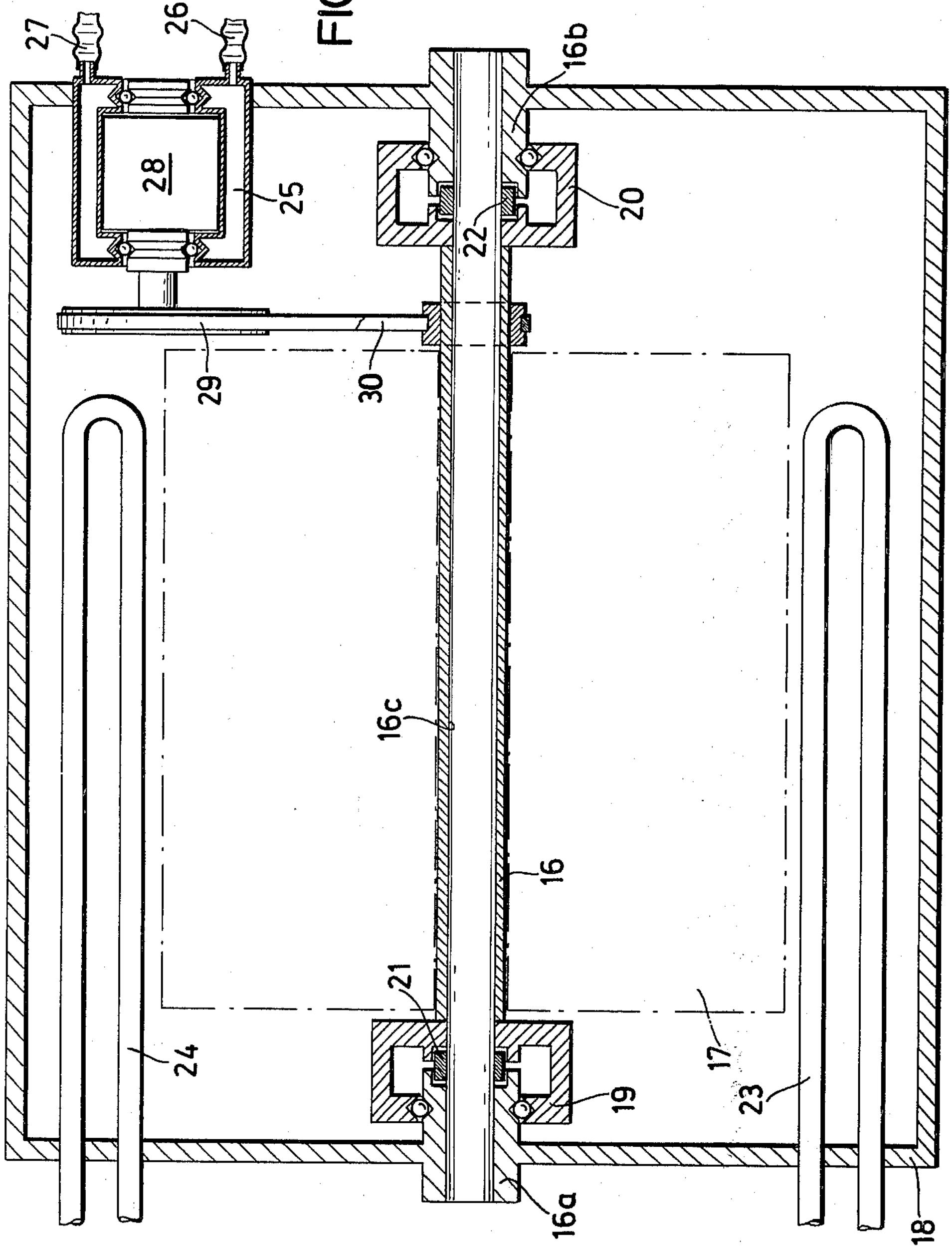


FIG. 5



METHOD AND APPARATUS FOR PRODUCING A TEMPERATURE GRADIENT IN A SUBSTANCE CAPABLE OF CARRYING THERMAL ENERGY

BACKGROUND OF THE INVENTION

The present invention relates to the production of a temperature gradient in a substance capable of carrying thermal energy, and more particularly to a method and apparatus for carrying this into effect.

The present invention is based on the realization that it is impossible to economically extract energy from a medium, for example water, which has a high thermal storage capacity, if the medium is at a relatively low temperature. On the other hand, it is possible to economically exploit the energy in such a medium if the latter is available at a high temperature. Generally speaking, the energy exploitation is the more advantageous, the greater the temperature differential which is available.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to make it possible to produce in a substance capable of carrying thermal energy, hereafter called an energy carrier, a temperature differential, in order to obtain a sufficiently large thermal capacity which can be economically utilized.

Another object of the invention is to provide for the establishment of such a temperature gradient which can be utilized in a user of heat, or in a producer of coolness.

In keeping with these objects, and others which will become apparent hereafter, one feature of the invention resides in a method of producing a temperature gradient in a substance capable of carrying thermal energy, such method comprising the steps of providing a source of thermal energy, providing a heat exchanger to which thermal energy is to be transferred, and establishing a path between the source and the heat exchanger. A substance capable of carrying thermal energy is confined in this path for transmission of such energy from the source to the substance, and the latter is then subjected to a very high acceleration whereby to effect movement of the substance in the path, contact of the substance with the heat exchanger, and simultaneously establish an upward temperature gradient in the substance during movement of the same towards the heat exchanger.

The acceleration is obtained by rotation, that is it is centrifugal acceleration, and normally the rotation will be at uniform speed. However, it is also possible to so regulate the rotation that a strong but pulsing acceleration field is obtained.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additonal objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a fragmentary section through an apparatus for carrying out the present invention;

FIGS. **2***a*, **2***b* and **2***c* are three diagrammatic sketches illustrating the operation of the apparatus of FIG. **1**;

FIG. **3** is a view analogous to FIG. **2** but illustrating a further embodiment of the invention;

FIG. **4** is similar to FIG. **3** illustrating an additional embodiment of the invention; and

FIG. **5** is an axial section through still another embodiment of the invention.

THEORETICAL CONSIDERATIONS BEHIND THE PRESENT INVENTION

Before discussing the drawing in detail, it is believed advisable to first discuss the theoretical considerations which are behind the present invention. The invention is based upon the realization that it is possible to obtain economically utilizable thermal energy by exploiting the temperature gradient which is called into being in solids, liquids and gases capable of carrying thermal energy, hereafter identified as energy carriers, when they are subjected to strong acceleration.

For explanation it will be assumed that a gas is accommodated in a completely thermally insulated vertical tube, which can be maintained in thermal equilibrium and at constant temperature by a thermostat which is advantageously located at the lower end of the tube. It will further be assumed that a source of thermal energy is arranged at the lower end of the tube and controlled by the thermostat.

It will be apparent that gas molecules of the gas in the tube will progressively lose energy of motion the farther they move upwardly away from the source of thermal energy, because due to the influence of gravitation they are forced to expend some of their energy in moving away from the center of the gravitational field. On the other hand, if a gas particle moves in opposite direction, that is follows the direction of gravitational attraction, then it undergoes an acceleration, that is an increase in its speed. The development of an equilibrium in such an arrangement is a very slow process, because gases are poor thermal conductors. The average molecular speed v in gases having a mass M per gas molecule can be calculated at a certain temperature T in accordance with the following formula which is found in Euckenwicke, "Grundriss der physikalischen Chemie", **1959**, page **28:**

$$\sqrt{v \cdot v} = 157.90\sqrt{\frac{T}{M}}\ M/\mathrm{sec}$$

A gas molecule, which in principle is a freely moving body, would completely lose its speed within v/g sec., as it moves vertically upwardly in the aforementioned tube. The height to which is rises is designated with s and can be derived as follows:

$$s = \frac{g}{2} \quad \frac{v \cdot v}{g \cdot g} = \frac{v \cdot v}{2g}$$

During this distance s the gas molecule passes through a temperature range from T–O and s/T is that distance over which the gas molecule (considered with reference to the mean) loses a degree of temperature, because the temperature is proportional to the internal energy of the gas. It must be taken into account that a gas can be and must be considered as a three-dimensional structure, and that a noble gas has three energy-carrying degrees of freedom. Nevertheless, no other formula for the temperature decrease exists because all gas molecules are subjected to gravitational force. If a molecule is considered which has received a horizontal impulse, then it will be seen that it will move in a path which is downwardly curved under the influence of gravitation, that is a path having a downward component of movement, as a result of which a downward impulse is transmitted for instance to an adjacent rising molecule. In the end result the sum of the kinetic energy and the positional energy is maintained on average. Thus, for gases having more than three degrees of freedom greater heights of rise will be found, and it will be found that their molecules rise over longer distances per degree of temperature loss. If the number of degrees of freedom is designated with F, then a formula is obtained for the rising distance x per degree of temperature:

$$x = \frac{S}{T} \cdot \frac{F}{3}$$

From the above formula it is possible to determine that a utilization of the gravitational field for energy production is impossible, because the temperature gradient caused by the gravitational field would be established very slowly and a device for exploiting this would have to be extremely large.

The circumstances are different, however, where strong acceleration fields act, for instance acceleration which has been caused by high-speed centrifuges, where the establishment of a temperature gradient can be effected in small or very small spaces. It can be calculated that with the noble gas Xenon, for instance, it is possible to obtain over a distance of only 1 cm. a temperature gradient of 506°C. if it is assumed that a centrifugal acceleration of 500,000 g can be obtained. Of course, the question arises whether this temperature differential, that is this temperature gradient thus obtained, is not obtained at the expense of exteriorly supplied energy. Naturally, energy must be employed in order to start up the centrifuge. However, this requires only a single expenditure of energy on the whole, if it is assured that during the operation a minimum of frictional energy loss will occur, for instance if the centrifuge is accommodated in a vacuum chamber. Despite the high temperature gradient which will develop, no heat transportation occurs if the gas space in question is thermally insulated, as soon as an equilibrium has been obtain.

If one considers a gas molecule in this equilibrium condition, which molecule movws upwardly and downwardly while travelling radially in a radial tube, then this gas molecule will on the average rise by a distance equal to a distance to which it has previously descended. If heat is axially supplied, that is if energy is applied in the form of heat, and if radial cooling is effected, meaning that thermal energy is withdrawn, then the molecule will no longer rise as high as it had previously descended and it will therefore not fully yield the previously accepted energy. This means that in order to reestablish the desired equilibrium, energy must be supplied from the exterior of the system. If, however, sufficient heat is supplied axially to compensate for the amount of heat removed at the outer circumference of the centrifuge by heat exchanger, then in effect a quasi-stationary condition will develop. If, under such circumstances, one follows the motion of molecule which is moving in radially outward direction, then it will be seen that the molecule will find the same temperature at the radially outer end of its path which has caused it to rise. Thus, the molecule will always reach the same height. However, it will have arrived at the radially outer end of its path with a speed which is sufficient for a greater rise than the one it has achieved, resulting from the axially supplied thermal energy. The excess of speed will, however, be reduced again by heat exchange at the outer circumference if the centrifuge, that is at the outer end of the molecule path.

If one now considers the formula initially given for the calculation of the average molecular speed v of gases having a mass T per gas molecule, it will be seen that T can be calculated as follows:

$$T = \frac{M \cdot v^2}{157.9^2}$$

The speed v after a descent through a distance of one centimeter at an acceleration of 5 million m/sec. can be calculated and will be found to be 316.23 m/sec. Thus, T = **4.0109**M. Actually, this is true only for single-atom gases, such as noble gases and metal vapors.

Because the temperature is directly proportional to the energy of movement, the value of T must be reduced in accordance with the number of degrees of freedom to which the energy produced by the descent is distributed. This is obtained by multiplying with the factor 3/F, wherein F designates the number of degrees of freedom. Because the heat capacity C_v of a gas can be considered to be directly proportional to the number of degrees of freedom of the gas, this can be written as follows:

$$T = \frac{3 \cdot 4.0108 \cdot M}{C_v} = \frac{12.0327\ M}{C_v}$$

This also takes abnormalities into account, namely if C_v is not equal to the number of degrees of freedom. The value of 2.98 is indicative of the heat capacity C_v for argon and helium. Because a gas at least three degrees of freedom, it is possible to replace the factor 3 with the factor 2.98 and the resulting formula will be:

$$T = \frac{11.952 \cdot M}{C_v}$$

In this connection it is pointed out that it is permissible, as done in the present instance, to use the speed increase beginning from rest position as a measure of temperature increase, because proportionality with the energy content exists. Furthermore, on descent the energy increase is dependent upon the distance of descent, independently of the speed at which the body, for instance the gas molecule, travels over this distance.

Thus, the following values can be calculated:

Xenon	$M = 131.3$	$C_p = 2.98$	Temperature	Increase	526.6°K (Kelvin)
Krypton	$M = 83.8$	$C_p = 2.98$	"	"	336.1°K
Argon	$M = 39.948$	$C_p = 2.98$	"	"	160° K
Neon	$M = 20.183$	$C_p = 2.98$	"	"	80.95°K
Helium	$M = 4.0026$	$C_p = 2.98$	"	"	16.05°K
Chlorine	$M = 70.906$	$C_p = 6.216$	"	"	136.3°K
Oxygen	$M = 31.998$	$C_p = 5.034$	"	"	76.15°K
Air	$M = 28.96$	$C_p = 4.966$	"	"	69.26°K
Nitrogen	$M = 28.0134$	$C_p = 4.971$	"	"	67.36°K
Carbon Dioxide	$M = 28.01$	$C_p = 6.938$	"	"	48.25°K
Hydrogen	$M = 2.0159$	$C_p = 4.905$	"	"	4.91°K
Electron	$M = 1/1200$		"	"	0.00334°K

The above table gives information for gases, but analogous considerations obtain with respect to liquids and solids.

It is still necessary to point out that adiabatic increases and descents will lead to quasi-stationary conditions, even with intended heat throughput, in which a mean distribution condition of the gas masses in radial direction is obtained. This is not only unavoidable, but in fact even desired, because such conditions make possible a much more substantial heat transport than in gas masses which are known as excellent thermal insulators. Thus, measures should be taken to favor the rises and descents of this type, or otherwise to assure movement of the gases.

If one now considers an energy carrier, that is a carrier of thermal energy, be it in a form of a one-atomic or multi-atomic gases, a liquid or a solid, then the atoms or molecules will perform a microscopic movement. The amount of such movements is a measure for the temperature of the energy carrier. If on these irregular movements a radially directed strong acceleration is superimposed, then all radially outwardly directed components of movement will correspondingly strengthen and by influencing one another there will be a corresponding temperature increase in radial direction. This condition can now have superimposed a heat flow, also in radial direction from inwardly towards outwardly, because at the point of the high temperature heat can be withdrawn.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Having thus discussed the theoretical considerations, reference will now be made to the drawing in general, and in particular to the embodiment illustrated in FIGS. **1** and **2**.

The embodiment in FIGS. **1** and **2** serves to produce a radial temperature gradient, a temperature increase, by producing a strong acceleration field in form of centrifugal force. In the interior of a rotor which will subsequently be discussed in detail, there is provided a stationary tube **1** which is coaxial with the axis of rotation of the rotor and is provided at its ends with connections for the inflow and outflow of a medium flowing through the tube **1** and providing a source of thermal energy. This medium may be river water or ocean water, by way of example. The inner circumferential surface of the tube is provided for purposes of improved heat exchange with radial fins **1**a. The outer wall of the tube **1** is provided with a plurality of discs **1**b which extend radial and normal to the axis of rotation of the rotor and are spaced on the tube axially distanced from one another at equal dimensions. Additional discs or lamellas **2***b* always extend between two adjacent ones of the discs **1**b without, however, contacting them; the discs **2***b* are mounted on the inner circumferential surface of an inner tube **2** of the rotor itself. The inner tube is turnably journaled at is opposite axial ends and carries on its outer periphery a plurality of gas compartments which are of strong material and extend radially outwardly. It will be appreciated that these gas compartments must be so arranged that during rotation the rotor will be in dynamic equilibrium. The number of compartments **3** should be as great as possible and their radially extending side walls **3***a* are of material which has good thermally insulating properties. The inner and outer part-cylindrical walls **3***b* and **3***c* are of material which has good heat-conductive properties.

To obtain gas circulation in the region of the colder portion of the respective compartment **3**, that is the one closer to the tube **2**, an insulating tube **4** may be provided which communicates with a nozzle **4***a* and is provided at its other end with insulation **14**. The compartments **3** are surrounded at the exterior of the rotor by a heat exchanger, for instance in form of fins **5** which serve to withdraw heat at high temperature. Advantageously, the rotor will be mounted in a stationary vacuum chamber **6** in which a high vacuum is produced. However, although the vacuum chamber encloses the entire rotor it leaves the interior of the tube **1** free, that is the interior of the tube **1** will not be under vacuum.

Heat exchange can be effected via radiation to the lamellas or fins, and from there via non-illustrated cooling elements through which a heat exchange liquid can flow. However, it is also possible to provide at the outer circumference of the rotor solder connections of a large number of thermal elements which rotate with the rotor, and the latter can then be configurated with the housing as a collector-less direct current motor. In any case, it is advantageous that for the hot components of the thermal elements to be provided with thermal insulation in outward direction, and for the cold components and solder connections of the thermal elements to be located in the radially inner end portions of the compartments **3**.

The table given earlier indicates clearly that it is advisable to use as the energy carrier in the chambers **3** a heavy noble gas or gas mixture. Because heavy noble gases have poor thermally conductive properties, especially at the low temperatures which are desired in the region towards the tube **2**, it is advisable to compensate for this by a strong pressure increase, that is by strongly pressurizing the compartments **3**. In addition, it is possible to provide agitating devices which agitate the cold gas layers in order to prevent the strongly heat-insulating effect exerted by stationary cold gas layers.

The supply of heat at the inner portion of the rotor and the removal heat at the outer portion thereof, as well as the various dimensions must be so accommodated to one another that no unacceptable stresses will be obtained. If, instance, the rotor is to provide an acceleration of approximately 500,000 g and the rotor has a radius of **6** cm., with xenon being the energy-carrying gas, then between the inner and outer ends of each compartment **3** there will be established a temperature differential (at equilibrium) of 3000° Kelvin. In other words, a temperature differential or gradient of this magnitude will be produced, and it will be advantageous for example to have the temperature of the gas be at 150°K at the inner end of the compartment and at 3150°K at the outer end. If at the inner end heat is supplied by the source of heat to increase the temperature of the gas from 150° to 200°K, and if heat is removed at the outer end of the chamber to decrease from 3150° to 800°K, then this would result in a deviation from equilibrium by 2400°K, meaning that for each centimeter of radial length of the compartment 3,400°K will be available for exploitation.

These conditions are obtained if the gas used as the energy carrier is xenon. Of course, it is possible to use gas mixtures instead of xenon, for instance a mixture of a heavier gas and a ligher gas. In this case the lighter gas provides for a better contact with the colder end of the compartment **3** and also has advantages because of its higher thermal conductivity in this region. This makes it possible to reduce the pressure at which the compartments **3** must be kept.

If the construction is such that thermal transference is obtained by radiation, then in the appropriate temperature region it is possible to transmit a very high amount of thermal energy in a very advantageous manner. If radiation from a square meter of surface takes place at a temperature of 300°K to a similarly dimensioned surface at a temperature of 250°K, an amount of thermal energy is transmitted which corresponds approximately to 1.6 kilowatt of energy. Furthermore, one square meter of metal surface can extract from a liquid whose temperature is higher by 50°K, an amount of thermal energy corresponding to approximately 60 kilowatt. A further increase at identical surface area and temperature difference, employing the condensation of vapors, can produce heat transfer equal to approximately 210 kilowatt of energy. Even low-boiling liquids such as ammonia or ethane have strong heat of vaporization.

In FIGS. **2***a*, **2***b* and **2***c* I have illustrated the behavior of a gas molecule in one of the chambers **3** of the embodiment in FIG. **1**. The direction of rotation of chamber **3** with the tube **2** is indicated by the arrow **7**.

FIG. **2***a* illustrates the behavior of a gas molecule when the final speed of rotation has been reached, that is when the rotor has come up to speed. In the narrow compartment **3** the molecule is accelerated in radially outward direction by the wall **3***b*, impinges upon the wall **3***c* and during a rise returns at the same speed to the original height, that is the starting position.

FIG. **2** shows how the molecule behaves when it begins to cool at the wall **3***c* of the compartment **3**. It will be seen that due to the cooling it loses speed and can no longer reach its starting position. Therefore, it cannot fully yield the energy which it has received during the fall in outward direction, it is during the accelerated movement from the wall **3***b* towards the wall **3***c*, and thus energy must be supplied.

FIG. **2***c* illustrates a quasi-stationary condition after an equilibrium between the supply of energy at the inner end of the chambers **3** rear the wall **3***b*, and cooling at the outer wall **3***c* has been achieved. The gas molecule arrives at the wall **3***c* at an increased speed from the starting position which is lowered or decreased with respect to FIG. **2***a*, but because of the cooling at the wall **3***c* it will reach only its previous position. The force received is higher during the accelerated movement outwardly due to the higher speed, but lasts for a correspondingly shorter time, so that the two impulses in the two successive directions of movement will be equal and opposite.

Coming now to the embodiment of FIG. **3** it will be seen that here the rotor is designated with reference numeral **8**, surrounding a stationary tube **9** having radially inwardly extending fins **9***a*. The tube **9** corresponds to the tube **1** of FIG. **1** and serves the same purpose.

The rotor **8** is accommodated in a vacuum chamber **10** which is also stationary and connected at least at one side with the tube **9** rigidly. The rotor **8** in this embodiment is composed of a plurality of concentrically arranged pressure-tight tubes **8***a*, 8*b*, 8*c* and **8***d* the ends of which are closed by thermally insulating material and connected with one another. The tube **9** extends through opposite walls of the chamber **10** and a heat-supplying medium, for instance ambient air, ocean water or river water, can be circulated through this tube which has good thermally conductive properties, and especially has a good heat-radiating outer surface.

To obtain the maximum benefit of thermal transmission the inner surface of the inner tube **8***d* of the rotor is blackened, as well as the outer surface of the outer tube **8***a*. Intermediate of the tubes **8***a*, **8***b*, 8*c* and **8***d* are obtained completely closed annular gas compartments **8***e*, 8*f* and **8***g* of which the inner chamber or compartment **8***g* can be pressurized very high whereas the successively outer compartments may be subjected to lesser internal gas pressure. The compartments, which contain a gas as the energy carrier, may also be provided interiorly with thin silvered foils or sheet **8***h*, which have many pores so that they do not have to withstand gas pressure during rotation.

Between the rotor **8** and the chamber **10** there are provided many stationary tubes **11** extending in axial parallelism with the rotor and connected together to form a system through which a heat exchange medium can flow. Each of the tubes **11** is advantageously blackened on its inwardly directed semi-cylindrical outer surface portion **11***a*, whereas on the other outwardly directed semi-cylindrical surface portion **11***b* it will advantageously be silvered.

The operation of the device in FIG. **3** will be already understood. When the rotor **8** is rotated at high speed, then a strong temperature gradient will develop in the compartments **8***e*, 8*f* and **8***g*, which on the one hand will be dependent upon the speed of rotation and on the other hand dependent upon the type of gas enclosed in the compartments. Thermal energy is withdrawn from the tube **9** by radiation and is yielded from the outer surface of the tube **8** again by radiation to the tubes **8** which are connected with the user, for instance a steam engine, a steam turbine or a gas turbine. The working medium which circulates through the tubes **11** can advantageously be pre-cooled after it leaves the respective user, the cooling being effected by contact with the medium passing through the inner tube **9** before the latter enters into the tube **9**. Thus, the thermal differential which cannot be utilized in the user itself, can be exploited and recovered. A transmission by radiation is substantially faster than the development of a thermal gradient, and the purpose of the mirrored surfaces mentioned earlier, which may also be provided at other appropriate locations, are intended to prevent a deterioration of the thermal gradient.

In FIG. **4** I have illustrated still another embodiment of the apparatus which is reminiscent with the apparatus of FIG. **3**. The inner tube **12** corresponds to the tube 9 of FIG. **3**, the vacuum chamber **13** corresponds to the vacuum chamber **10** of FIG. **3** and the tubes **14** correspond to the tubes **11** of FIG. **3**.

In FIG. **4** the rotor **15** is provided with a turnably journalled driven hollow shaft **15***a* the inner surface of which is blackened. Exteriorly the shaft **15***a* is surrounded by a ring **15***b* which is fixedly connected with it and constituted with electrically non-conductive material. It is held together exteriorly by a metal ring **15***c* and reinforced by one or more shrink-fitted metal rings **15***d*. The outer metal ring **15***d* is also blackened on its outer surface, as well as the inwardly facing semi-cylindrical outer surface portions of the tubes **14**. The outwardly facing semi-cylindrical outer surface portions of the tubes **14** are provided with a layer **14***a* of insulating material and the metal rings of the rotor are advantageously insulated.

FIG. **5**, finally, is an axial section through a further embodiment of the invention which is essentially analogous to FIGS. **3** and **4**. The rotor is designated with reference numeral **17** and is illustrated only diagrammatically because of its likeness to FIGS. **3** and **4**. It surrounds the stationary inner tube **16** and is in turn mounted in a vacuum chamber **18** which has at opposite sides openings for inflow and outflow of the heat-supplying medium for the tube **16**. The center portion of the tube **16** is fixedly connected with the rotor **17** and turns with the same, bearings **19** and **20** (preferrably ball bearings) being provided for journalling it with respect to the adjacent laterally stationary tubular portions **16***a* and **16***b*. Intermediate the portions **16** and **16***a*, and **16** and **16***b*, there are provided sealing rings **21** and **22**. The inner surface **16***c* of the tube **16** is advantageously provided with a thin coating, for instance of teflon or the like. Tubes **23** and **24** for circulating a heat-exchanging medium are provided between the rotor **17** and the wall of the chamber **18**.

A motor housing **25** is mounted in the chamber **18**, being hollow and receiving a cooling material which flows in and out via the conduits **26** and **27**. The motor **28** drives a pulley **29** which in turn drives the rotor **17** via belts **30**.

In the illustrated embodiments the inner tubes **1**, **9** or **12** are so configurated that it is possible to directly pass through them a heat-yielding medium, for instance water. If a very large amount of heat is to be supplied, the tubes can also be replaced with massive shafts of material having good thermally conductive properties, and these may be connected at one or both outer ends with appropriately dimensioned heat exchangers through which heat is supplied into the material of the shafts to be yielded from the same to the respective rotors. It is also possible to use heat of vaporization or heat of condensation for heat exchange purposes with such constructions.

It will be understood that it is also possible to provide a closed circulation of a medium, for instance a medium other than water, with which heat is supplied to the center of the rotor. Such a medium may for instance be a low-boiling liquid such as ammonia or ethane whose boiling temperature can be adjusted in wide limits by changing the pressure to which it is subjected. If a heat exchanger is provided exteriorly of the rotor housing, the vapor of such a medium can be supplied, for instance via a pump, into the inner tube **1** or the like of the rotor, and this inner tube is provided with fins or other means for increasing its surface in order to provide for a maximum heat exchange efficiency. The steam has heat removed from it by transference to the rotor as this was disclosed before, to such an extent that the steam becomes converted into condensate. This condensate is conducted externally of the rotor by the centrifugal speed of the rotor into an annular heat exchanger which is located externally of the rotor and turns with the same. Such a heat exchanger will also have a very large surface area and by operation of the rotor there will develop a strong heating of the condensate and thus the formation of hot steam which can be introduced into a user, for instance a turbine. Such a turbine can then be used for driving other users. The turbine rotor itself can, however, also be coupled with the rotor of the apparatus according to the present invention, in which latter case the arrangement can advantageously be used as a refrigerant apparatus. The cooled steam leaving the apparatus, for instance a turbine, is again condensed in a separate condensor or by recirculating it to a second heat exchanger system with large surface area in the interior of the tube **1** or the like. From here the condensate returns to the initially described heat exchanger which can serve as a refrigerant-producing device in such a manner that it receives heat from the exterior, that is from the areas to be cooled, which serves to convert the condensate in the interior of the heat exchanger into steam so that the steam can again be recirculated.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of constructions differing from the types described above.

While the invention has been illustrated and described as embodied in an apparatus for producing a thermal gradient, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended:

1. In an apparatus for producing energy by establishing a temperature gradient in a substance capable of carrying thermal energy, a combination comprising a rotor having an outer circumference and being mounted for rotation about an axis at speeds capable of providing an acceleration of up to 500,000 g; a stationary member for providing a source of thermal energy in the region of said axis; a heat exchanger in the region of said outer circumference for extracting useful heat energy from said apparatus; a substance capable of carrying thermal energy; and means defining in said rotor a path in which said substance is confined and which extends from said source to said heat exchanger whereby when said substance, having received an initial thermal energy from said source, travels under the influence of centrifugal force in said path to said heat exchanger, an upward thermal gradient is established so that said substance can yield thermal energy to said heat exchanger that is significantly greater than said initial thermal energy.

2. A combination as defined in claim **1**, wherein said stationary member is a tube coaxial with said axis.

3. A combination as defined in claim **1**, wherein said substance comprises a noble gas.

4. A combination as defined in claim **1**, said rotor having edge faces having general planes which extend substantially normal to said axis; and further comprising thermally insulating means at said edge faces.

5. A combination as defined in claim **1**, wherein said heat exchanger is a radiant-heat exchanger.

6. A combination as defined in claim **1**, further comprising stationary evacuated chamber means surrounding said rotor, source and heat exchanger; and conduit means connecting said source and said heat exchanger with the exterior of said chamber means.

7. A combination as defined in claim **1**, said rotor having a central hollow hub coaxial with said axis and provided with an inner circumferential surface; further comprising a plurality of annular heat exchange fins provided on said surface; said means comprising wall means forming a plurality of hollow radial spokes extending from said hub to said outer circumference; and wherein said substance is a gas accommodated in said spokes.

8. A combination as defined in claim **7**, wherein said gas is Xenon.

9. A combination as defined in claim **1**, said means comprising a plurality of pressure-resistant gas-tight tubes arranged concentrically and with spacing from one another, said tubes having respective ends which are sealed with thermally insulating material; said substance being a gas accommodated under pressure in said tubes; and wherein said heat exchanger comprises a plurality of pipes surrounding said rotor.

10. A combination as defined in claim **1**, said rotor comprising an inner and an outer cylindrical rotor portion, and an annular rotor portion interspersed between said inner and outer rotor portions and being composed of material having at most poor electrical conductivity characteristics.

11. A combination as defined in claim **1**, wherein said source is a heat exchanger, and heat exchange fluid circulates through the same.

12. A combination as defined in claim **1**, wherein said substance has in liquid state good thermal but at most poor electrical conductivity characteristics.

13. A combination as defined in claim **1**, wherein said substance has in gaseous state good thermal but at most poor electrical conductivity characteristics.

14. A combination as defined in claim **1**, wherein said substance has in solid state good thermal but at most poor electrical conductivity characteristics.

15. A combination as defined in claim **1**, said rotor having opposite axial ends; and further comprising thermally insulating means provided at said opposite axial ends.

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