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S. L. GENDLER ET AL

2,765,414

METHOD AND APPARATUS FOR UTILIZING ENERGY FROM RADIOACTIVE MATERIAL

Filed Nov. 7, 1950

2 Sheets-Sheet 1

Fig. 1.

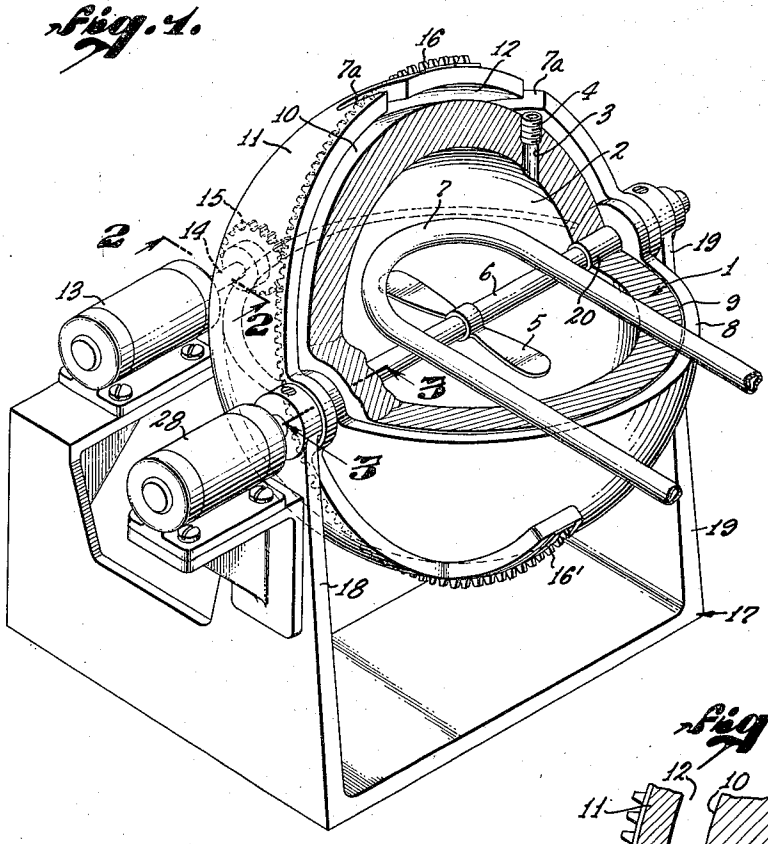


Fig. 2.

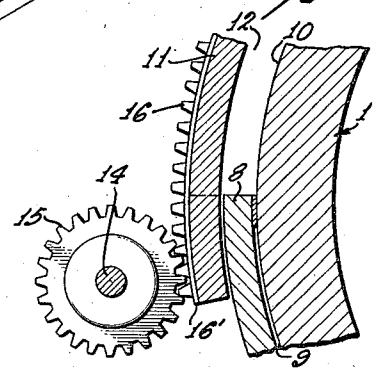
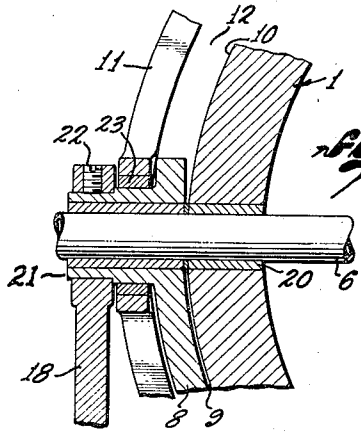


Fig. 3.



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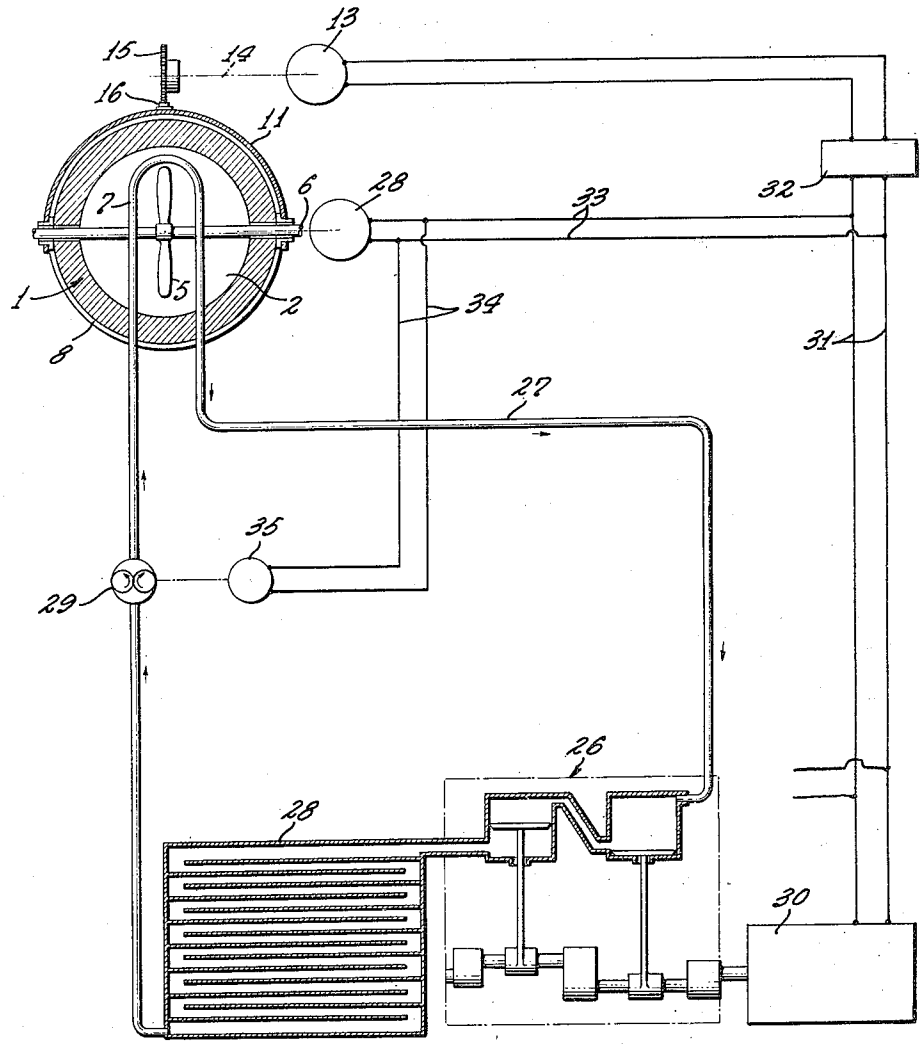


Fig. 4.

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METHOD AND APPARATUS FOR UTILIZING ENERGY FROM RADIOACTIVE MATERIAL

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11 Claims. (Cl. 290—2)

This invention relates to a device and method for converting energy from radioactive material to electrical energy and more particularly for obtaining from radioactive material a regulated, as for example a constant electrical power supply, and still more particularly an electrical power supply at regulated or constant voltage.

As is generally known, power supplied by radioactive material is not constant with time but drops off in accordance with a characteristic activity decay curve. Accordingly, when radioactive material is used as a source of power, the power available is first relatively large and then falls off with time in accordance with the particular characteristic decay curve for the particular material used. For many applications involving the use of radioactive material as a source of power, it is desirable to control the amount of power available as for example at a constant value. When converting to a supply of electrical energy, it is desirable to obtain an electrical power supply at regulated voltage, which for most applications will be at a regulated constant value. Also, for some purposes it is desirable to do this with as little equipment as possible, particularly with as little weight as possible. This is especially true for providing an auxiliary power supply for operating controls and various auxiliary devices of a rocket where both space and weight must be kept low.

In accordance with this invention power from radioactive material is converted to electrical power at a value less than the initial power available from the radioactive material and the excess of power from the radioactive material is dissipated in a manner to maintain the converted electrical power at a regulated value, for example, substantially constant, or more particularly at a regulated voltage which preferably is a regulated constant voltage. This is accomplished by dissipating a sufficient amount, that is, the excess of the energy from the radioactive material to maintain the converted electrical power at the desired regulated value.

In accordance with one embodiment of my invention in a nuclear reaction power source, a quantity of radioactive material is enclosed within a sphere a portion of which is opaque to outward radiation from the sphere and another portion is transparent to or will permit outward radiation of energy and this transparent portion has an adjustable opaque or reflecting cover to adjust the amount of radiation dissipated through the transparent portion by increasing or decreasing its area by moving the opaque cover over a greater or lesser area of the transparent portion. This source of power from radioactive material so controlled is converted to electrical power preferably by means of a mercury vapor system the heating tube for which is placed within the radioactive material and the mercury vapor system used for converting power into electrical power preferably by means of a mercury vapor engine driving an electrical generator. To maintain the supply of electrical power at a controlled or regulated value, the extent to which the opaque cover extends over the transparent area of the sphere is controlled in accordance with the electrical power output. For example, to maintain a controlled electrical power output, the opaque cover position may be adjusted in accordance with the voltage produced by the electrical generator in such a manner that when the voltage goes above a given value the opaque cover is moved to expose more transparent area and when the voltage goes below a given value the opaque cover is moved to cover more of the transparent area to respectively increase or decrease the energy dissipated and to respectively decrease or increase the radioactive power converted to electrical power so that it is thereby adjusted and controlled to the desired constant value of voltage.

My invention will be further illustrated and described in connection with the accompanying drawing in which

Figure 1 is a perspective view of the radioactive heating unit showing a portion of the spherical container or boiler cut away.

Figure 2 is a detailed view on the line 2—2 of Figure 1 showing the mechanical arrangement for moving the opaque cover, with the cover in fully closed position.

Figure 3 is a detailed view on the line 3—3 of Figure 1 showing how the spherical container and adjustable cover are supported.

Figure 4 shows schematically the arrangement for using the radioactive heating device for converting the radioactive power to electrical power and controlling the conversion to maintain a regulated electrical power output.

Referring now particularly to Figure 1, at 1 is shown a spherical container or boiler the interior 2 of which is substantially filled with radioactive material. The radioactive material is omitted from the drawing for a clearer showing of the interior structure and arrangement of the radioactive heating unit inside the spherical container. The radioactive material is a molten liquid which may be put into or removed from the spherical container through opening 3 having removable plug 4. The spherical container 1 is preferably made of beryllium. Beryllium has a surprising combination of properties making it readily suitable for this purpose, particularly including low density, high melting point, it produces very little secondary gamma-radiation (Bremsstrahlung), has high conductivity for conducting excess heat to its outer surface, and provides a surface with a high emissivity. The thickness of the spherical container 1 should be greater than the maximum range of 3 m. e. v. beta particles in beryllium, which is about 8.5 millimeters to shield against beta-radiation. Inside the spherical container 1 is a paddle 5, also preferably made of beryllium, mounted on a rotatable shaft 6 which is preferably hollow and preferably made of ceramic such as carborundum. The paddle 5 is provided to stir the molten liquid containing the radioactive material to avoid development of hot spots in the molten liquid. Also, inside the spherical container within the molten radioactive material is a boiler tube 7 also preferably made of beryllium. This tube 7 conducts the working fluid, preferably mercury vapor, through the molten radioactive material.

Extending over the lower hemisphere of the spherical container 1 is an opaque reflecting cover or shell 8 preferably of steel gold plated on both sides with an air gap 9 between the shell 8 and sphere 1 to reduce heat loss by conduction. This gold plated steel shell 8 provides a fixed cover over the lower hemisphere of the sphere 1 and reflects thermal radiation back to the interior of the sphere. This gold plated steel shell maintains a high infra-red reflectivitity and low emissivity even at high temperature.

The upper hemisphere 10 of sphere 1 has no fixed cover and when uncovered serves as a radiator to radiate ther-

mal energy into space from the beryllium surface. The area of this radiation surface and the extent of such radiation of energy into space is adapted to be varied by adjustable cover **11**. This adjustable cover **11** is also a gold plated steel shell the same as the fixed cover **8**. Adjustable cover **11** is mounted to rotate about an axis as represented by shaft **6** from an extreme open position in which the entire upper hemisphere **10** is uncovered to the other extreme position in which the entire upper hemisphere **10** is covered. Adjustable cover **11** is in the shape of a hemisphere and is adapted to fit over the clear fixed cover **8** so that when drawn over hemisphere **10** an air space **12** is left between the surface of hemisphere **10** and the adjustable cover **11** to reduce heat loss by conduction. Slots **7***a* are provided in cover **11** as shown to fit over tubes **7** when cover **11** is in a fully closed position.

The variation of the position of adjustable cover **11** is preferably mechanically accomplished by means of a motor **13** connected by shaft **14** to pinion **15** which meshes with rack **16** on the periphery of adjustable cover **11**. The gear teeth of rack **16** extend a short distance, as at **16'**, beyond the edge of the adjustable cover **11** so that by means of pinion **15** the adjustable cover **11** may be readily moved to a completely closed position as particularly illustrated in Figure 2.

The whole radioactive heating unit including the sphere **1**, fixed cover **8**, adjustable cover **11** and hollow shaft **6** are conveniently supported on a bracket member shown generally at **17** having two upright supporting members **18** and **19** the upper portions of which are each provided with bearings for supporting the shaft **6** and sphere **1**, fixed cover **8** and adjustable cover **11**. The detail of the supporting arrangement is shown particularly in Figure 3. Hollow shaft **6** is fitted into a ceramic bearing **20**, preferably carborundum. On bearing **20**, sphere **1** and fixed cover **8** are fixed. Extending as part of fixed cover **8** is a protruding bearing member **21** which extends over bearing member **20** and to which the upper portion of upright member **18** is fixed by set screw **22**. Adjustable cover **11** is arranged to rotate about bearing member **21**. For this purpose there is provided an anti-friction annular bearing member **23** between **21** and adjustable cover **11**. The outer end of shaft **6** is connected to motor **28** for turning paddle **5**.

The preferred radioactive material to be filled into spherical container **1** is cerium 144. It is available as a by-product of a pile, and has a half-life of about 275 days. It emits mainly high-energy beta-rays, which are the least dangerous. This radioactive material is preferably diluted at a ratio of 100 diluent to 1 part by weight of cerium 144 with stable nonradioactive cerium 140. This avoids any chemical reaction effects due to heat or radiation because of the use of a single chemical species. This radioactive material emits high energy particles which when slowed down in passing through the cerium 140 diluent produces heat which in turn is supplied to the mercury vapor or other working fluid in tube **7**. Thus it will be seen that the cerium 140 serves not only to convert radioactive energy into heat but serves as well as part of a heat exchanger body to transfer the heat energy to the mercury.

As pointed out above, the radioactive power from the radioactive material is converted into electrical power preferably by means of a mercury vapor system. This is more particularly shown in Figure 4 where at **26** is shown schematically a compound piston engine operated by mercury vapor. The mercury is heated and vaporized in tube **7** immersed in the radioactive material within spherical container **1** and the heated mercury vapor is passed to the engine **26** through tube **27**. The mercury vapor expands in engine **26** and is exhausted to a radiant condenser **28** and mercury is pumped therefrom by pump **29** back to heating tube **7**. The engine **26** is used to drive electrical generator **30** and through leads **31** connects to voltage regulator **32** which in accordance with any desired voltage setting operates as a feedback control to run motor **13** in a direction to close adjustable cover **11** if the voltage drops below the given value, or to open adjustable cover **11** if the voltage goes above the given value. Also, from leads **31** there may be leads **33**, connecting motor **28** and leads **34** for connecting motor **35** which drives pump **29**.

In order to prevent the radioactive heating unit from overheating to a dangerous temperature a temperature sensitive element, not shown on the drawing) such as a thermocouple may be placed in the spherical container **1** and connected to override the voltage regulator **32** to open adjustable cover **11**.

Also, instead of controlling the position of cover **11** by the electrical output voltage, the control may be, in accordance with a modification of my invention, effected by a thermostat having its thermosensitive element within the spherical container **1** electrically connected to a controller (not shown on the drawing) to cause motor **13** to open cover **11** when the temperature in sphere **1** goes above a set value and to close cover **11** when the temperature falls below a set value.

In operation the voltage regulator **32** will be set at the value of voltage which is desired to maintain on the electrical system. With the conversion system in operation, if the voltage at **32** is too high regulator **32** will cause motor **13** to operate in such a direction that adjustable cover **11** will be moved to expose more of radiation surface **10** to allow dissipation of radioactive energy by radiation from surface **10** and to decrease the amount of heat imparted to the mercury vapor in tube **7**. This will slow down the electrical generator until the voltage drops to the desired value. If, on the other hand, the voltage at **32** is too low, regulator **32** will cause motor **13** to operate in the opposite direction to cause a closing of adjustable cover **11** to reduce the exposed portion of radiation surface **10** and thus retain more heat in boiler **1** and increase the heat supply to the mercury vapor in tube **7**. In this manner it will be seen that the energy output from the electrical system can be thus regulated in terms of the voltage. Moreover, since the regulation as here shown is in accordance with the voltage, the electrical power supplied to the power system will be that amount of power required to maintain a constant voltage. It will be understood of course that in any event the regulation here described and contemplated is within the upper and lower limits of the device. Furthermore, in accordance with this arrangement the automatic control will maintain a constant voltage for the electrical power output even though due to the activity decay the power from the radioactive material drops off with time. As the activity of the radioactive material declines with time and the voltage drops below the set value, the cover **11** will automatically be closed to retain sufficient heat in the spherical container or boiler **11** to cause the mercury vapor system to deliver enough power to the generator to maintain the required voltage. This will take place until the cover **11** has been adjusted to its completely closed position.

Although in accordance with my invention harmful radiations have been materially reduced, it will be understood, of course, that in order to eliminate any risk, personnel should be properly shielded especially within the proximity of such a unit, in accordance with known procedures.

The above description and specific embodiments are intended to illustrate my invention and not to limit the scope thereof, and my invention extends to all modifications and variations which fall within the scope of the appended claims.

We claim:

1. In a device for converting energy of radio-active material into a form of energy appearing as an increase in temperature of mercury vapor of a mercury vapor system, the combination comprising a container having walls of beryllium containing cerium 144 as the radio-active

material and relatively a substantially large proportion of cerium 140 as a diluent therefor and as an absorber of radio-active energy therefrom, at least a portion of the beryllium walls of said container covered by an opaque reflecting steel cover plated on both sides with gold with space between the beryllium wall and said cover, and a beryllium tube extending through said wall of beryllium and forming a heat exchange coil within the mixture of cerium 144 and cerium 140 within said container so that heat absorbed by said cerium 140 is transferred to said beryllium tube and to mercury vapor therewithin.

2. In a device as defined in claim 1 having means for varying the portion of said veryllium walls covered by said opaque reflecting cover.

3. The device as defined in claim 2 in which said portion is varied in accordance with a measure of the energy converted.

4. The method of regulating the rate of usable heat energy delivered by a nuclear reaction power source, which comprises the steps of: absorbing in a heat exchanger body, the radioactive emanations from a radioactive body to convert said emanations into heat; conducting a portion of said heat from said heat exchanger body to a heat engine to utilize said portion and radiating the remaining portion of heat from said heat exchanger body; and reflecting a progressively increasing portion of said radiated heat back to said heat exchanger body whereby to compensate for the decreasing heating of said heat exchanger body due to the decay in rate of emanations from said radioactive body, thereby to produce a substantially uniform rate of delivery of heat to said heat engine.

5. The method of regulating the rate of usable heat energy delivered by a nuclear reaction power source which comprises the steps of: absorbing in a heat exchanger body the radioactive emanations from a radioactive body to convert said emanations into heat; conducting a portion of said heat from said heat exchanger body to a heat engine to power the latter; radiating from said heat exchanger body the heat which is not delivered to said heat engine; employing said heat engine as a prime mover to generate electric power; reflecting a variable portion of said radiated heat back to said heat exchanger body whereby to augment the heating thereof; and increasing the portion of heat reflected to said heat exchanger body in inverse proportion to the voltage of said electric power, whereby to maintain a substantially constant rate of delivery of heat to said heat engine.

6. A nuclear reaction power source comprising: a body of radioactive material; a heat exchanger body adjacent said radioactive material and arranged to absorb substantially all of the radioactive emanations therefrom whereby to heat said heat exchanger body; power conversion means positioned in heat transfer relation to said heat exchanger body whereby to convert a first portion of thermal power from said heat exchanger body to another form of power; means surrounding said heat exchanger body to dissipate a second portion of the thermal power from said heat exchanger body; and means operatively associated with said dissipating means to progressively reduce said second portion of power dissipated thereby whereby to compensate for loss of heating due to decay of said radioactive material.

7. A nuclear reaction power source comprising: a body of radioactive material; a heat exchanger body adjacent said radioactive material and arranged to absorb substantially all of the radioactive emanations therefrom whereby to heat said heat exchanger body; power conversion means positioned in heat transfer relation to said heat exchanger body whereby to convert thermal power from said heat exchanger body to another form of power; means surrounding said heat exchanger body to dissipate a portion of the heat from said heat exchanger body; means operatively associated with said dissipating means to vary the portion of heat dissipated thereby; and feedback means coupled between said conversion means and said varying means to adjust the latter in response to the power level of the output of said conversion means whereby to maintain said power level substantially constant over a given period of time during which there is a substantial reduction in radioactive emanations from said radioactive material.

8. A nuclear reaction power source comprising: a body of radioactive material; a heat exchanger body adjacent said radioactive material and arranged to absorb substantially all of the radioactive emanations therefrom whereby to heat said heat exchanger body; heat engine means positioned in heat transfer relation to said heat exchanger body whereby to convert heat in said heat exchanger body to another form of power; means forming a radiator in heat transfer contact with an outer surface of said heat exchanger body to absorb and radiate therefrom, heat in excess of that converted as aforesaid; and an adjustable reflector in the path of heat radiated from heat exchanger body, and arranged to return a variable portion of said radiated heat to heat exchanger body whereby to vary the amount of heat lost by radiation from said heat exchanger body to compensate for loss of thermal power due to decay of said radioactive material.

9. The construction of claim 8 further characterized by having feedback means coupled between said heat engine means and said reflector to adjust the latter in response to the power level of the output of said heat engine means whereby to maintain said power level substantially constant.

10. A nuclear reaction power source comprising: a radioactive body comprised of cerium 144 diluted with cerium 140; a beryllium container completely surrounding said radioactive body, and of sufficient thickness to absorb substantially all of the radioactive emanations from said body and convert the same into heat, said container being in heat transfer contact with said body to heat the same and having a heat radiating exterior surface; a boiler in heat transfer contact with said body; shell means partially surrounding said container and having an inner reflecting surface adapted to returned to said container, a substantial portion of the heat radiated therefrom; and means to adjust said reflector to vary the amount of heat returned as aforesaid whereby to compensate for loss of heating due to decay of said radioactive body.

11. The construction of claim 10 further characterized by having control means responsive to the power level in said boiler and connected to said adjusting means whereby to maintain said power level substantially constant over a given period of time.

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