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Pirc

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[54] **ROTARY CURIE POINT MAGNETIC ENGINE**

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[52] **U.S. Cl.** **310/4**
[51] **Int. Cl.** **H02n 7/00**
[58] **Field of Search** 310/9; 322/2; 318/119; 60/23

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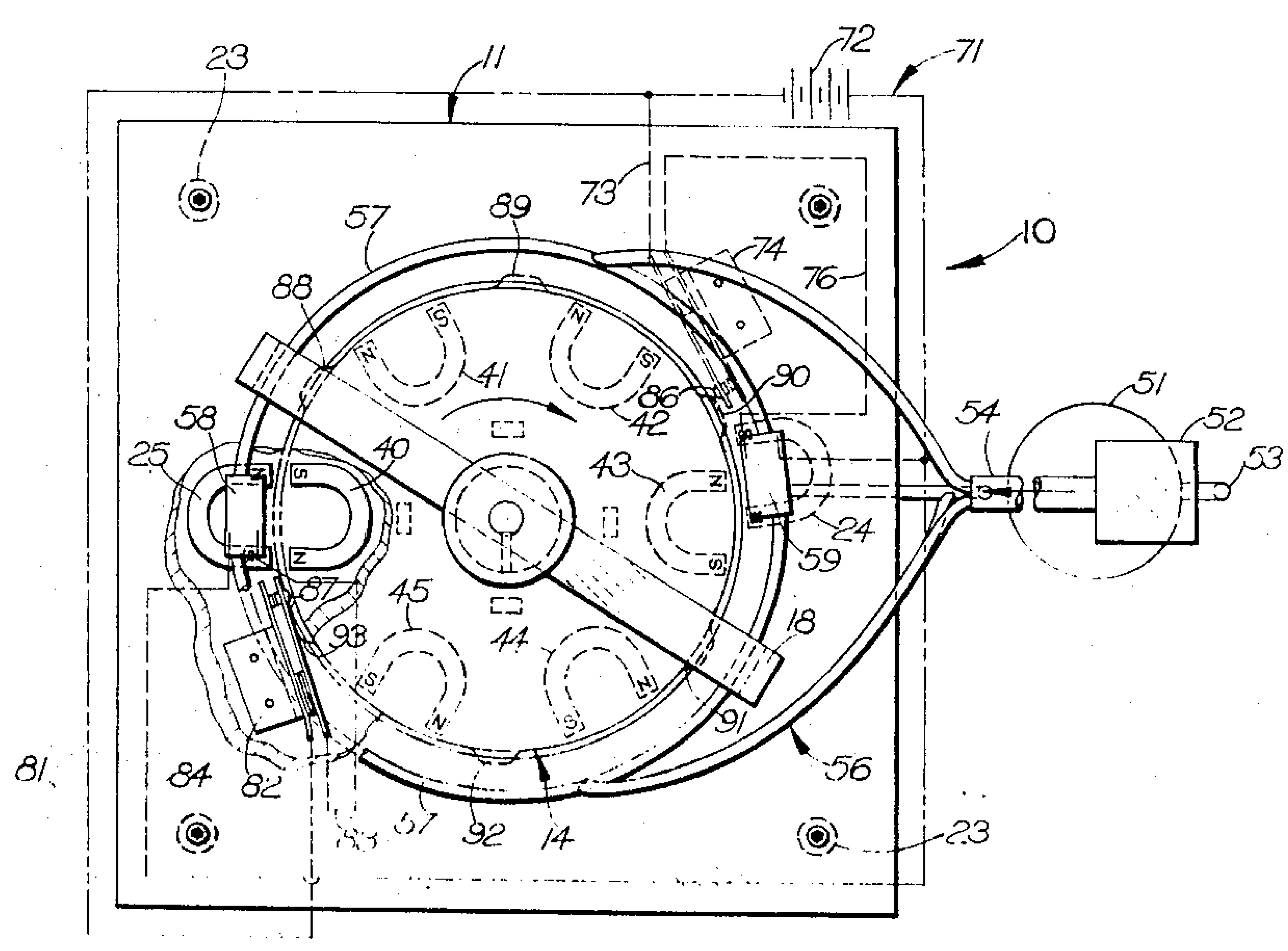
[57] **ABSTRACT**

A rotary magnetic engine in which Gadolinium as a transition material distorts lines of flux in a magnetic field to cause relative movement between a rotor and a stator. Magnets are mounted on the rotor and stator, and the Gadolinium metal is disposed in to form of thin spaced-apart laminae between the poles of certain ones of the magnets with passageways formed between the laminae for directing the flow of a coolant fluid. Circuit means is provided to intermittently direct an electrical current through the laminae responsive to movement of the rotor with respect to the stator. This causes the temperature of the laminae to rise above the Curie point of Gadolinium whereby the lines of flux are released from the laminae to create magnetic attraction between opposed magnets to move the rotor. Thereafter the circuit means is opened to permit the coolant medium to cool the laminae below the Curie point so that the lines of flux are captured by the fluxdistorting means.

10 Claims, 3 Drawing Figures



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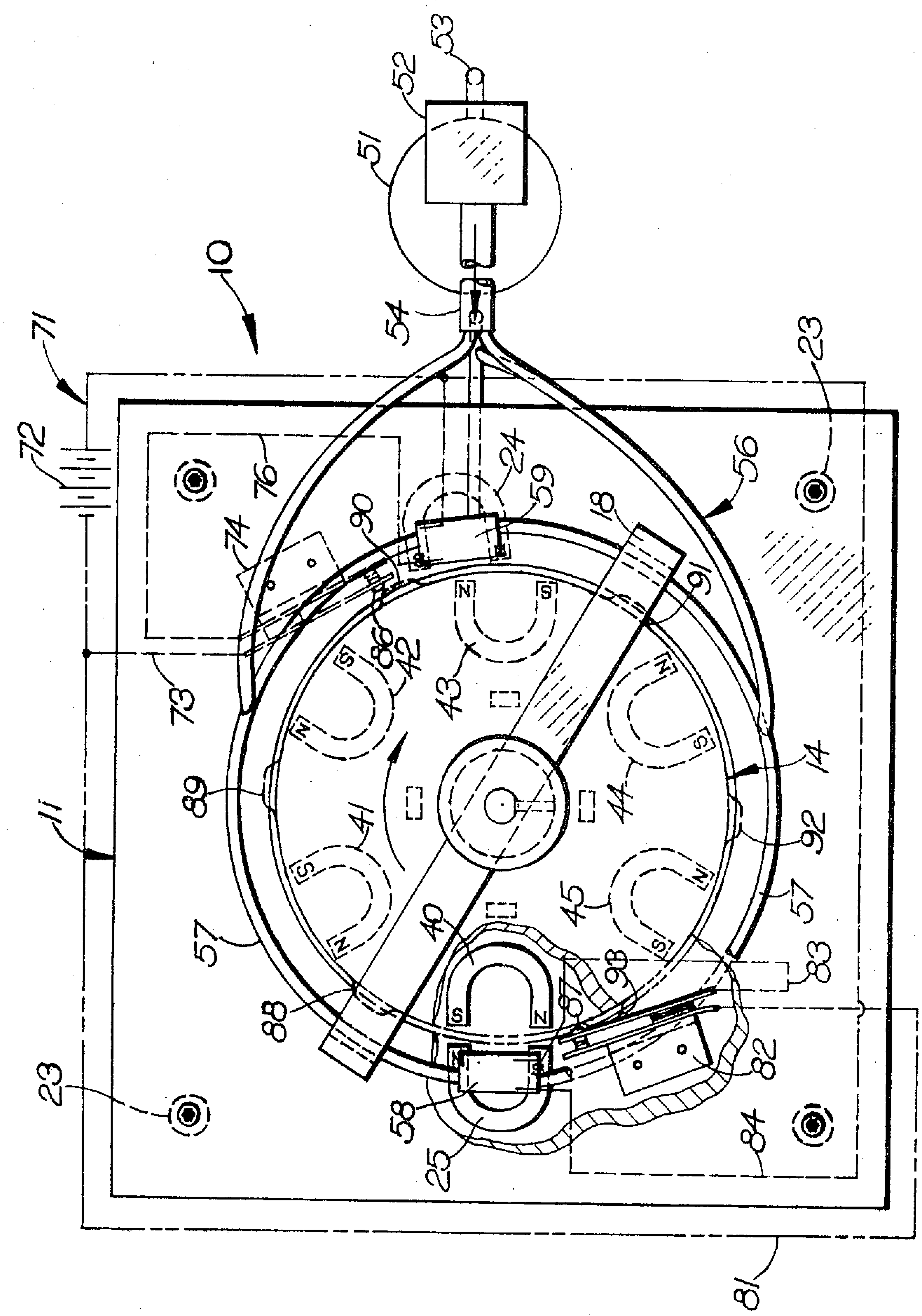

FIG-1

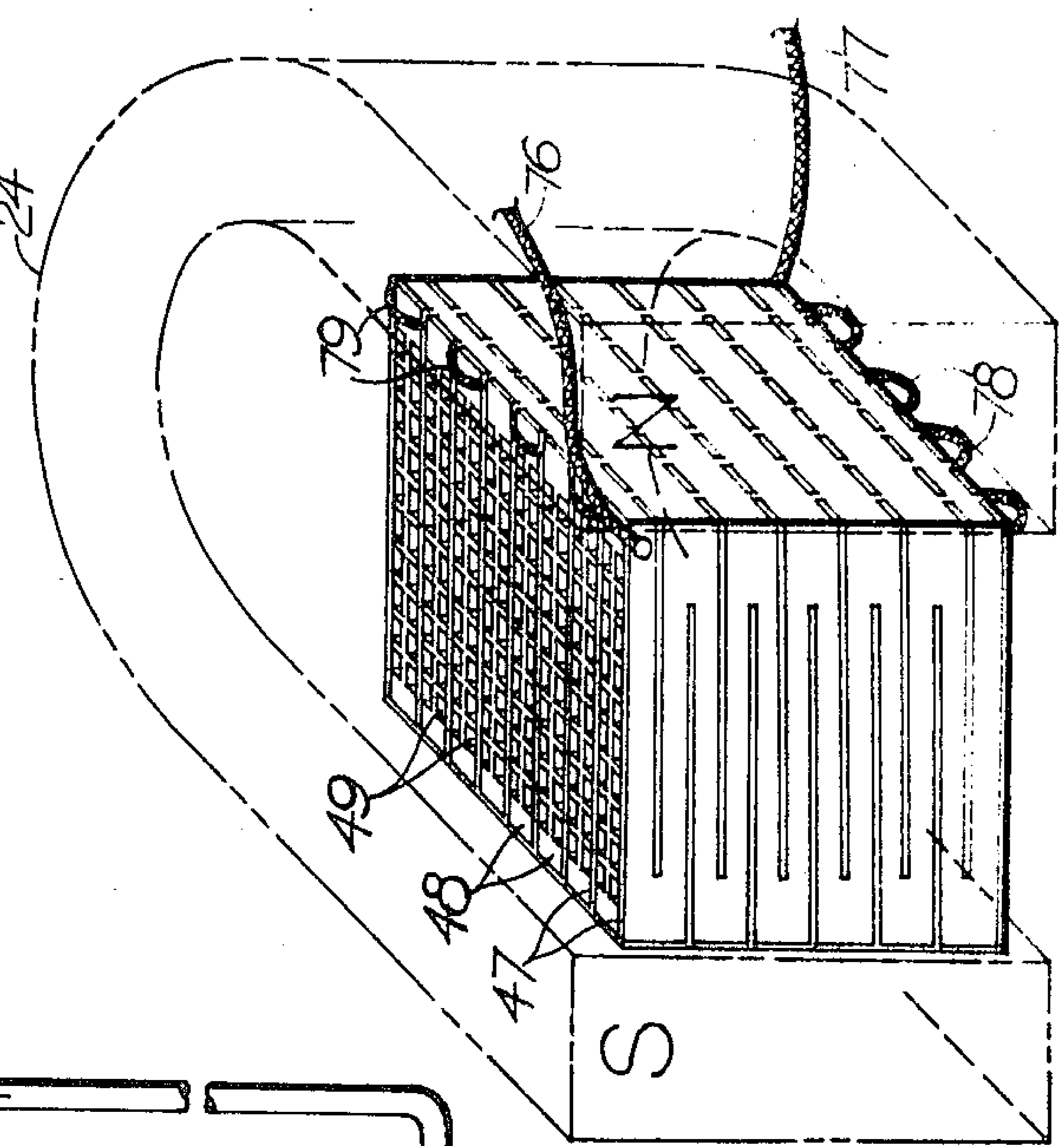
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FIG-3

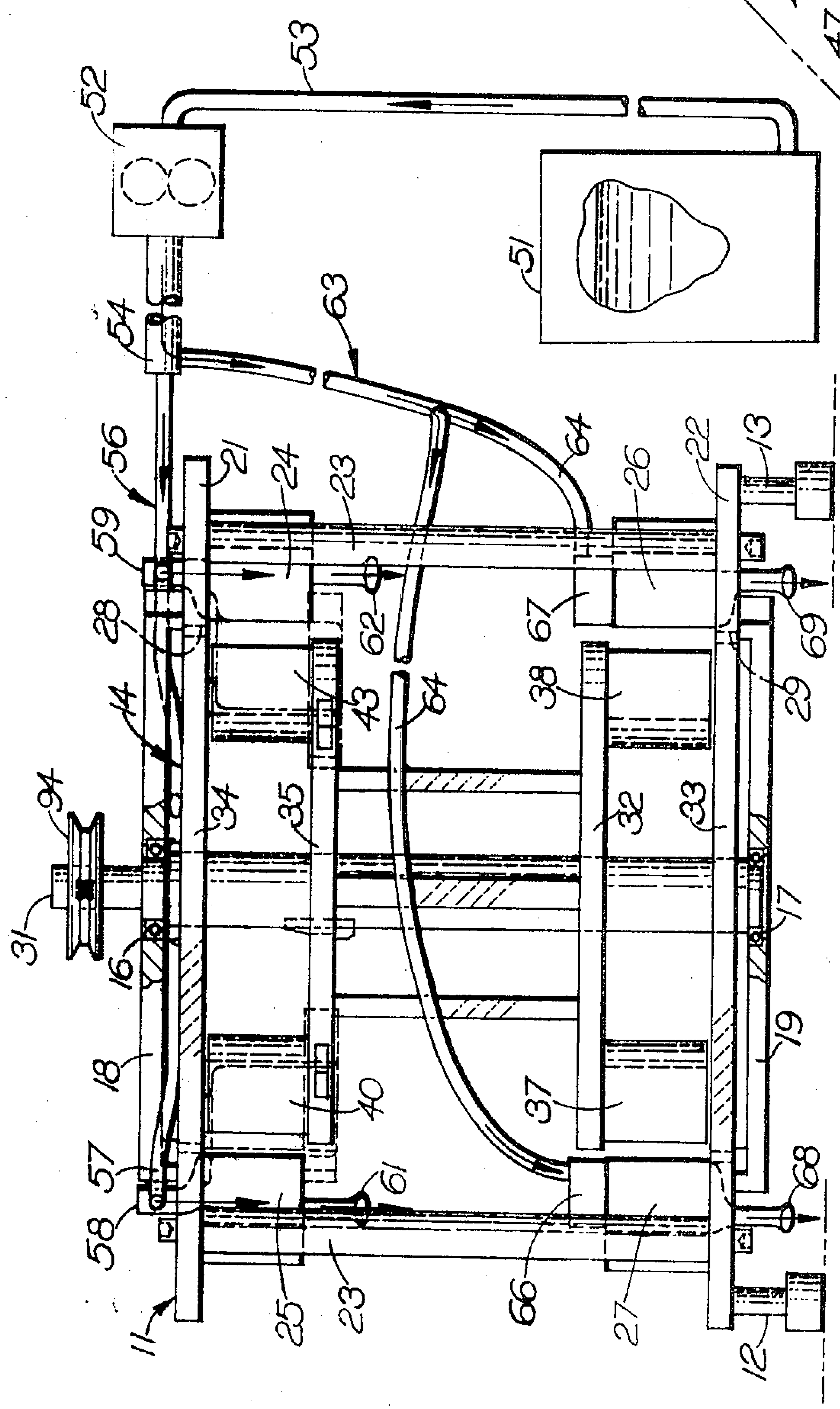
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FIG-2

ROTARY CURIE POINT MAGNETIC ENGINE

BACKGROUND OF INVENTION

This invention relates generally to magnetic engines in which mechanical work is produced by distorting the lines of flux in a magnetic field. More particularly, the invention relates to magnetic engines utilizing transition materials characterized in having a sharp and reversable change in magnetic response in a relatively narrow temperature range, known as the material's Curie point.

Various types of magnetic engines have heretofore been proposed in which the lines of flux in a magnetic field are distorted to create mechanical work by heating and cooling a flux distorting transition material above and below the material's Curie point. These known engines have anumber of limitations and drawbacks and have not been found to be practical. Thus, previous efforts in this field have produced magnetic engines which are extremely limited in torque output in view of the low rotational speeds and weak forces of magnetic attraction which are produced. Furthermore, previous designs are relatively inefficient in view of the high energy transfer to and from the transistion material which is required for cycling the engine, and in adition to the high operating temperatures tend to reduce the intensity of the magnetic field. Accordingly, the need has been recognized for a new and improvied magnetic engine of the type described which is capable of achieving higher torque output, higher rotational speeds, and improved efficiency.

OBJECT AND SUMMARY OF THE INVENTION

It is a general object of the invention to provide a new and improved magnetic engine producing mechanical work by utilizing the properties of a transition material adapted to distort the lines of flux in a magnetic field.

Another object is to provide a magnetic engine of the character described in which a carrier structure is mounted for movement with respect to a stator with means on the stator and carrier structure to create a magnetic field. Magnetic flux distorting means which includes Gadolinium as the transition material is interposed in the magnetic field. Means are provided to sequentially heat and cool the transition material above and below its Curie point to release and capture, respectively, the lines of flux to cause the carrier structure to move relative to the stator.

Another object is to provide a magnetic engine of the character described in which the flux distorting means includes a transition material formed of relatively thin strips of Gadolinium metal disposed in spaced-apart laminae separated by a grid forming coolant flow passagesways. The metal is intermettently heated above its Curie point by an electrical current responsive to the position of the carrier structure with respect to stator, and the metal is cooled below its Curie point by directing a coolant fluid through the passageways.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a magnetic engine incorporating the present invention;

FIG. 2 is an axial section view of the engine of FIG. 1; and,

FIG. 3 is a perspective view to an enlarged scale of one magnet and associated flux distorting means for the magnetic engine of FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2 there is disclosed generally at **10** a magnetic engine including a stator **11** mounted to a suitable foundation by legs **12, 13,** and a carrier structure or rotor **14** mounted for rotation about a vertical axis by suitable ball bearing assemblies **16, 17** which in turn are mounted within respective end brackets **18, 19** secured to the stator.

Stator **11** comprises a pair of end plates **21, 22** vertically spaced-apart by means of four corner posts **23.** Means are provided on the stator to create a stationary magnetic field, and this means includes an upper series of two U-shpaed permanent magnets **24, 25** mounted by suitable fastners below end plate **21** and a lower series of two similar U-shaped magnets **26, 27** mounted by suitable fastners above end plate **22.** Both pairs of magnets **24, 25** and **26, 27** are mounted about the circumference of circular openings **28, 29** formed in respective end plates **21, 22.** Each of these magnets have their north (N) and south (S) poles facing radially inwardly and in like circumferential sequence, as shown in FIG. **1.** The magnets are disposed so that the magnet **24** is circumferentially offset substantially **15°** with respect to a diameter passing through the center of the opposite magnet **25.** Preferably the magnets **26, 27** are of a material providing a strong magnetic flux or coercive force, e.g., Samarium Colbalt material or one of the Alnicol alloys of Aluminum and Nickel. Alternatively, sutiable electromagnets could be used in place of the described permanent magnets.

Rotor **14** comprises a shaft **31** carrying a pair of axially spaced circular plates **32, 33** mounted within lower stator plate opening **29** and a similar pair of axially spaced circular plates **34, 35,** mounted within upper stator opening **28.** The means creating a magnetic field further includes a lower series of U-shaped permanent rotor magnets shown as six magnets **37, 38,** mounted by suitable fasteners between the lower rotor plates **32, 33** and circumferentially spaced so as to turn with the rotor in a path disposed radially inwardly of the two stator magnets **26, 27.** A similar upper series of six U-shaped permanent rotor magnets **40–45** are mounted by suitable fasteners between the upper rotor plates **34, 35** and these magnets are also circumferentially spaced so as to turn with the rotor in a path disposed radially inwardly of the upper stator magnets **24, 25.** The upper and lower series of rotor magnets have their north (N) and south (S) poles facing radially outwardly and in like circumferential sequence, as shown in FIG. **1.** Preferably the rotor magnets are of a material similar to that described for the stator magnets whereby a strong magnetic flux is provided, or alternatively suitable electromagnets could be provided for use as the rotor magnets.

Magnetic flux distorting measn is provided between opposite poles of each of the stator magnets **24, 25, 26, 27.** This flux distorting means includes a transition material characterized in having a sharp and reversable change in magnetic response in a relatively narrow temperature range, known as the material's Curie point. As the transition material is heated and cooled above and below the Curie point the material undergoes a second order transition in magnetization such that the material has, respectively, insubstantial and substantial magnetic response to release and capture lines of magnetic flux.

Applicant's invention utilizes the preferred metal Gadolinium as the transition material in the form of a plurality of relatively thin foil strips **47, 48** disposed in transversly spaced-apart laminae extending between opposite poles of each stator magnet, as best illustrated in FIG. **3** for the typical stator magnet **24**, Gadolinium is characterized in having (with a purity on the order of 99,9%) a favorable Curie point of 16° Celsius together with a relatively high magnetic flux saturization. The metal Thulium has similar favorable properties as a transition material, but Gadolinium is preferred in view of its greatr availability and cost advantages. The use of Gadolinium, or Thulium where such is available, as the transition material in the manner described makes it possible to develop relatively higher rotational speeds and torque for the rotary engine through greater work efficiency. While other transition materials are known, such as Ferromagnetic elements and alloys, these known materials have Curie points which are either too high or too low for practical use, and/or their magnetic saturation properties are so low that strong magnetic fields cannot be employed to achieve the high magnetic attraction forces required for the desired torque output and speed. In addition, a transition material having a relatively high Curie temperature tends to lose its saturation magnetization when heated to its Curie point, e.g. Iron which has a Curie point of 770° Celsius, and in such case work efficiency would be compromised in that objectionable amounts of energy would be lost when heating the material to these high temperatures.

As illustrated in FIG. **3** the Gadolinium laminae are supported in spaced-apart relationship by means of a plurality of grid elements **48** formed of a suitable material such as a synthetic polymer, e.g., epoxy, having a relatively high heat transfer coefficient, Each of the grid elements **48** is formed with a plurlaity of vertically extending channels or grooves **49** which, in cooperation with the surfaces of an adjacent pair of laminae, define coolant fluid passageways. Each grid element comprises a flat, central web portion and a plurality of vertically extending ribs projecting outwardly from opposite sides of the web portion into contact with the laminae. This configuration insures that the coolant fluid flows in direct heat exchange relationship with substantial surface area portions of the foil strips. The coolant passageways which are thereby formed preferably have a cross section configuration which achieves maximum heat transfer for cooling the laminae, e.g., a cross section width of 0.025 inches and height of 0.125 inches with surface-to-surface spacing between adjacent laminae of 0.062 inches.

The means for cooling the laminae below the material's Curie point preferably includes a suitable coolant fluid such as liquid nitrogen, although other coolants such as cold water, or a gas such as Freon **14** (tetrafluoromethane) they also be employed. The liquid nitrogen is stored at approximately 146° Kelvin within suitable tank **51** and is directed through the grid passageways **49** by a suitable pump **52** connected with the tank through conduit **53** and discharging through outlet **54.** An upper manifold **56** directs coolant through piping **57** and into a pair of distributor shrouds **58, 59** mounted above the grids and laminae located between the two upper magnets **24, 25.** Each of the shrouds **58, 59** open downwardly to direct coolant downwardly through the grid passageways for exhaust to the atmosphere through outlets **61,62.** Alternatively, the exhaust nitrogen may be recycled back to tank **51** through a circuit, not shown, incorporating suitable nitrogen liquefaction apparatus. A lower manifold **63** directs a portion of the nitrogen through piping **64** and into a pair of distributed shrouds **66, 67** mounted above the grid and laminae structure located between the two lower magnets **26, 27.** The lower distributor shrouds also open downwardly to direct coolant downwardly through the passageways for exhaust through outlets **68, 69,** or through an alternate circuit for liquefaction and recycle back to tank **51.**

The transition material is sequentially heated above its Curie point preferably by electrical circuit means **71** adapted to intermittently direct a flow of current through the foil strips **47** for resistance heating. Alternatively, other suitable heating means such as radiant energy, electrical induction, or a heat exchange medium such as a suitable high temperature gas may be employed. Resistance heating is perferred in that it achieves relatively fast heating of the laminae with relatively low power requirements to achieve faster cycling and higher speeds at improved efficiency. Each of the foil strips **47** is formed into a sinuous configuration with preferred dimensions having a thickness in the range of 0.001–0.004 inches, a width of each strip leg of 0.120 inches and with spacing between the legs of 0.005 inches. In the illustrated embodiment eight such laminae are assembled in separate stacks for each of the stator magnets.

A suitable source of direct current electrical power **72** is connected through a conductor **73**, a cam operated switch **74** and a conductor **76** with an upper end of a side laminae **47** for the magnet **25**, with the lower end of the opposite side laminae being connected through a conductor **77** with the power source. As best illustrated in FIG. **3** the lower ends of alternate pairs of the laminae are electrically interconnected by short conductors **78** while the upper ends of offset alternate pairs of laminae are similarly interconnected by short conductors **79** so that all laminae for the magnet **25** are in series connection. Similarly, the laminae for the opposite magnet **24** are connected in series with power source **72** through a conductor **81,** a cam operated switch **82** and a conductor **83** leading to an end of one laminae, with the opposite end laminae connected with the power source through conductor **84.** The laminae for the lower pair of stator magnets **26, 27** are connected with power source **72** for intermittent operation through similar circuit means, not shown. The cam operated switches **74, 82** include normally open contacts **86, 87** which are operated to close the respective circuits for heating the associated laminae responsive to movement of six cam lobes **88–93** mounted on rotor plate **35** and projecting radially outwardly therefrom. The cams are positioned with respect to the rotor magnets so that the switches are operated for closing the respective circuits at the predetermined rotor positions where the laminae are to be heated for release of the flux from the stator magnets. The length of the cam lobes is selected so that the switches are closed for a predetermined time interval, as determined from heat transfer and resistance heating calculations, which is sufficient to elevate the temperature of the laminae above its Curie point. As the cams move out of contact with the switch contacts the circuits are again opened so that the continuous flow of coolant fluid begins to reduce the temperature of the laminae. During the time interval at which the temperature is above the Curie point and the magnetic flux is released, like north (N) and south (S) poles of opposing rotor and stator magnets are magnetically attrated to impart torque to the rotor. As the poles of the magnets approach each other the cooling cycle has progressed sufficient to reduce the temperature of the laminae below the Curie point so that the flux is again captured and the magnetic attraction between the magnets becomes insubstantial. This permits the momentum of the moving rotor to carry the rotor magnet past a dead center position with respect to the stator magnet and move the next successive rotor magnet into the influence of the magnetic field of the stator magnet **24.** Continued rotation of the rotor is also assured by the offset angular displacement of the stator magnets such that the centers of one of these magnets lies along a radius disposed substantially at an angle of 15° with respect to the diameter passing through the center of the opposite stator magnet. This configuration provides for one pair of stator and rotor magnets to be in mutual attraction for imparting driving torque while no torque is being developed by the opposite pair of rotor and stator magnets.

The use and operation of the invention is as follows. Assume that a liquid nitrogen coolant is provided within tank **51** at a temperature on the order of 145° Kelvin. The coolant is continuously pumped through the upper and lower manifolds **56, 63** and down through the passageways between the Gadolinium laminae **47** until the metal's temperature is below its Curie point, thereby releasing the magnetic flux from each of the stator magnets **24, 25.** With the rotor turning clockwise, as viewed in FIG. **1**, the rotor magnet **42** moves through an arc of circular travel which carrys its associated cam lobe **89** to a position bearing against and closing contacts **86** of switch **74.** This completes the circuit through the laminae between the poles of magnet **24** to initiate resistance heating. While the Gadolinium is heated above the Curie point magnet **42** is attracted to stator magnet **24** and a driving torque is imparted to the rotor, with power being taken from shaft **31** by suitable means such as a belt seated within pulley **94.** The heating phase continues for a predetermined circular arc of travel until the poles of these two magnets are in substantial registry. At this point cam lobe **89** moves away from switch contacts **86** to open the circuit and terminate heating so that the coolant flow again rapidly cools the laminae associated with stator magnet **24** below the Curie point. This causes the flux of the stator magnet to be captured by the Gadolinium so that the magnetic attraction with magnet **42** becomes insubstantial permitting the rotor to be carried by its momentum through a further arc of travel sufficient to bring the next successive rotor magnet **41** and cam **88** into position for a repetition of the heating phase so that this magnet is similarly attracted to stator magnet **24.** The opposite stator magnet **25** similarly attracts successive rotor magnets, although the operation is out of phase from that of magnet **24** to achieve an overlap in driving torque.

While the embodiments herein are at present considered to be preferred, it will be understood that numerous variations and modifications may be made therein by those skilled in the art, and it is intended to cover

in the appended claims all such variations and modifications as fall within the true spirit and scope of the invention. I claim:

1. A magnetic engine to produce mechanical work comprising the combination of a stator, a carrier structure mounted for movement with respect to the stator, means mounted on the stator and carrier structure to create a magnetic field therebetween, said magnetic field having lines of flux disposed to cause said carrier structure to undergo said movement with respect to said stator, magnetic flux distorting means positioned within said field and including a transition material characterized in having a Curie point above and below which said material has, respectively, insubstantial and substantial magnetic response, said flux distorting means including a plurality of flat laminae disposed in spaced-apart parallel planes lying substantially within said magnetic field, said transition material being substantially comprised of Gadolinium metal, and means to sequentially heat and cool said transition material above and below its Curie point whereby said lines of flux are, respectively, released from and captured by said flux distorting means to create sequential mutual attraction between said carrier structure and said stator, said heating and cooling means including means forming fluid flow passageways between adjacent laminae, and means to direct a coolant medium through said passageways in direct heat exchange relationship with said laminae.

2. A magnetic engine as in claim **1** in which said means creating the magnetic field includes a plurality of magnets each having spaced apart north and south poles between which said lines of flux extend, and said laminae are disposed between the poles of individual magnets.

3. A magnetic engine as in claim **2** in which said heating and cooling means includes means to selectively direct an electrical current through said laminae for resistance heating thereof to a temperature above said Curie point.

4. A magnetic engine as in claim **1** in which said carrier structure comprises a rotor mounted for rotation with respect to said stator, and said means creating the magnetic field includes a first series of magnets mounted on and spaced about the periphery of said rotor, and a second series of magnets mounted on the stator and spaced about said first series of magnets, the poles of individual ones of said second series magnets being arranged to move into radially spaced registry with the poles of individual ones of said first series magnets during rotation of said rotor.

5. A magnetic engine to produce mechanical work comprising the combination of a stator, a carrier structure comprising a rotor mounted for rotation with respect to the stator, means mounted on the rotor and carrier structure to create a magnetic field therebetween including a first series of magnets mounted on and spaced about the periphery of said rotor, and a second series of magnets mounted on the stator and spaced about said first series of magnets, the poles of individual ones of said second series magnets being arranged to move into registry with the poles of individual ones of said first series of magnets during rotation of said rotor, at least a pair of said second series of magnets being mounted at substantially diametrically opposed positions on said rotor, said magnetic field having lines of flux disposed to cause said carrier structure to undergo said movement with respect to said stator, magnetic flux distorting means positioned within said field and including a transition material characterized in having a Curie point above and below which said material has, respectively, insubstantial and substantial magnetic response, means to sequentially heat and cool said transition material above and below its Curie point whereby said lines of flux are, respectively, released from and captured by said flux distorting means to create sequential mutual attraction between said carrier structure and said rotor, said transition material being disposed between the poles of each of said second series magnets whereby the sequential heating and cooling thereof above and below the Curie point creates sequential attraction between the first and second series magnets to turn said rotor.

6. A magnetic engine as in claim **5** is said first series magnets are disposed in equal spaced-apart relationship about the periphery of said rotor, and one of said second series magnets is disposed in circumferential offset relationship with a diameter passing through the center of the other of said second series magnets.

7. A megnetic engine to produce mechanical work comprising the combination of a stator, a carrier structure mounted for movement with respect to the stator, means mounted on the stator and carrier structure to create a magnetic field therebetween including two or more magnets having north and south poles thereof spaced-apart along the path of movement of said carrier structure, said magnetic field having lines of flux disposed to cause said carrier structure to undergo said movement with respect to said stator, magnetic flux distorting means positioned within said field and including a transition material characterized in having a Curie point above and below which said material has, respectively, insubstantial and substantial magnetic response, said flux distorting means comprising a plurality of foil strips disposed in laterally spaced-apart planes extending between associated north and south poles of each magnet, each of said strips being substantially formed of Gadolinium metal as said transition material and having a thickness on the order of 0.001 inches, and means to sequentially heat and cool said transition material above and below its Curie point whereby said lines of flux are, respectively, released from and captured by said flux distorting means to create sequential mutual attraction between said carrier structure and said stator, said heating and cooling means including means to selectively direct an electrical current through said strips to heat the same above the Curie point together with means to direct a coolant fluid in heat exchange relationship with said strips to cool the same below the Curie point.

8. A magnetic engine as in claim **7** in which said flux distorting means includes grid means disposed between adjacent foil strips, and said grid means supports said foil strips in planes which are spaced-apart a distance on the order of 0.03 inches.

9. A magnetic engine as in claim **8** in which said grid means defines in cooperation with said foil strips a plurality of coolant flow passageways adapted to direct said coolant fluid in direct heat exchange contact with substantial surface area portions of the foil strips.

10. A magnetic engine as in claim **1** in which said carrier structure is mounted for rotation with respect to said stator, and said heating and cooling means includes circuit means to direct an electrical current through said laminae to heat the same above the Curie point, said circuit means including switch means operating responsive to the relative position of said carrier structure with respect to said stator to open the circuit means for said cooling and to close the circuit means for said heating, said coolant medium comprising a fluid being directed through said passageways to cool said laminae below the Curie point while said circuit means is open.

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