Sept. 2, 1969 O. P. BREAUX 3,465,187
HOMOPOLAR GENERATOR HAVING PARALLEL POSITIONED
FARADAY DISK STRUCTURES
Filed June 5, 1967 7 Sheets-Sheet 1

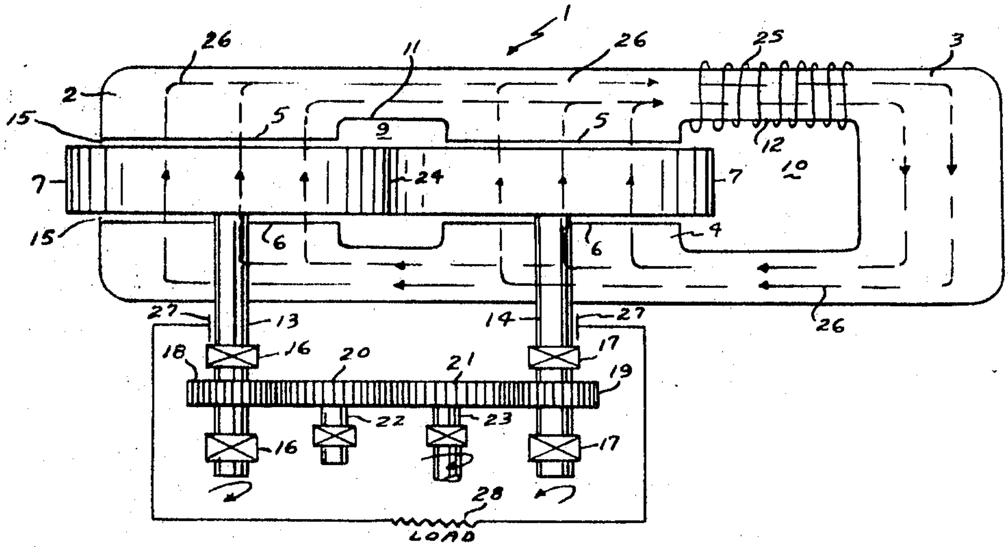

Fig-1

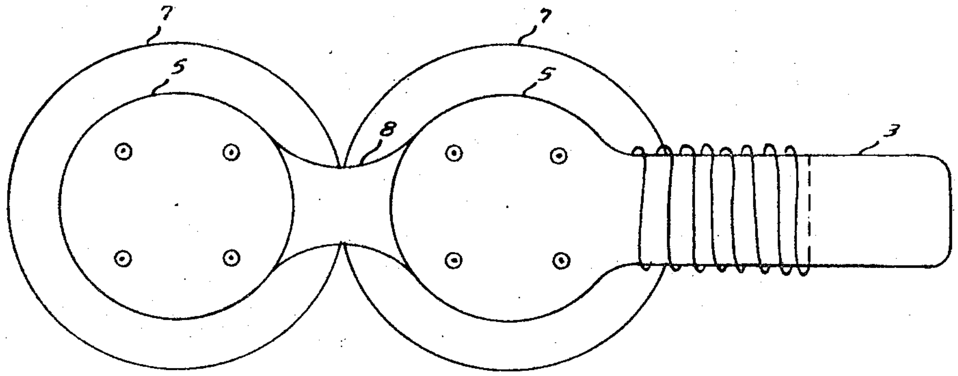

Fig-2

INVENTOR.
ONEZIME P. BREAUX
BY Harry A. Herbert Jr. and
Herbert H. Brown
ATTORNEYS

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HOMOPOLAR GENERATOR HAVING PARALLEL POSITIONED FARADAY DISK STRUCTURES

Filed June 5, 1967 7 Sheets-Sheet 2

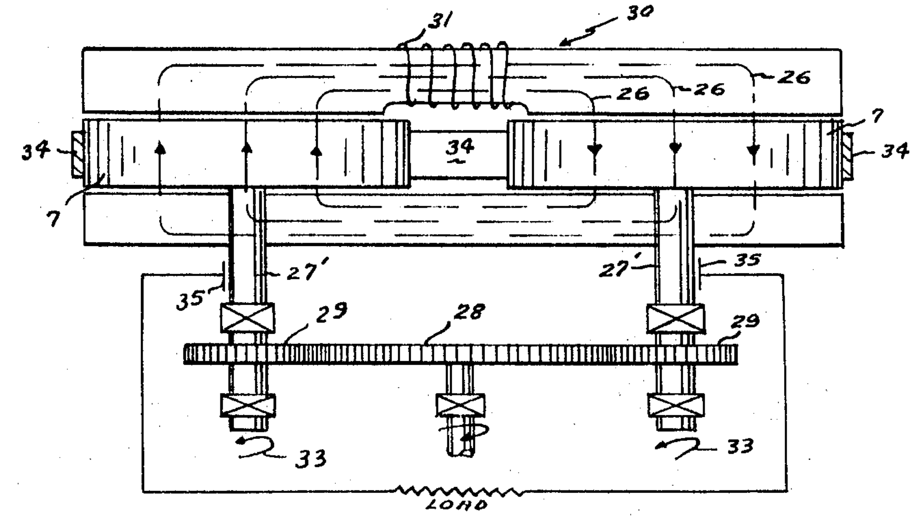

Fig-3

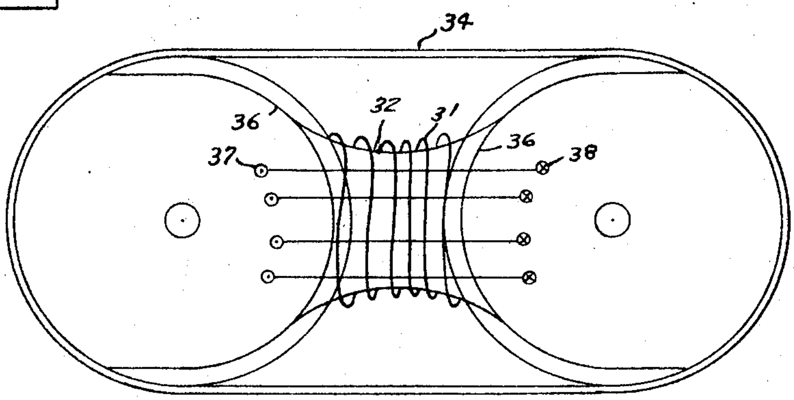

Fig-4

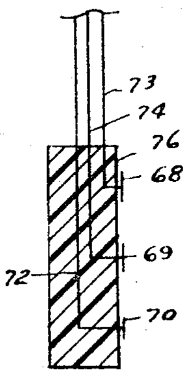

Fig-7

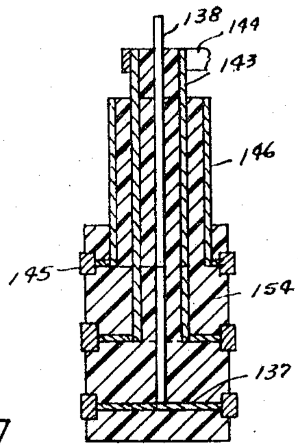

Fig-14

INVENTOR.
ONEZIME P. BREAUX

BY Harry A. Herbert Jr. and Herbert H. Brown

ATTORNEYS

Sept. 2, 1969 O. P. BREAUX 3,465,187

HOMOPOLAR GENERATOR HAVING PARALLEL POSITIONED FARADAY DISK STRUCTURES

Filed June 5, 1967 7 Sheets-Sheet 3

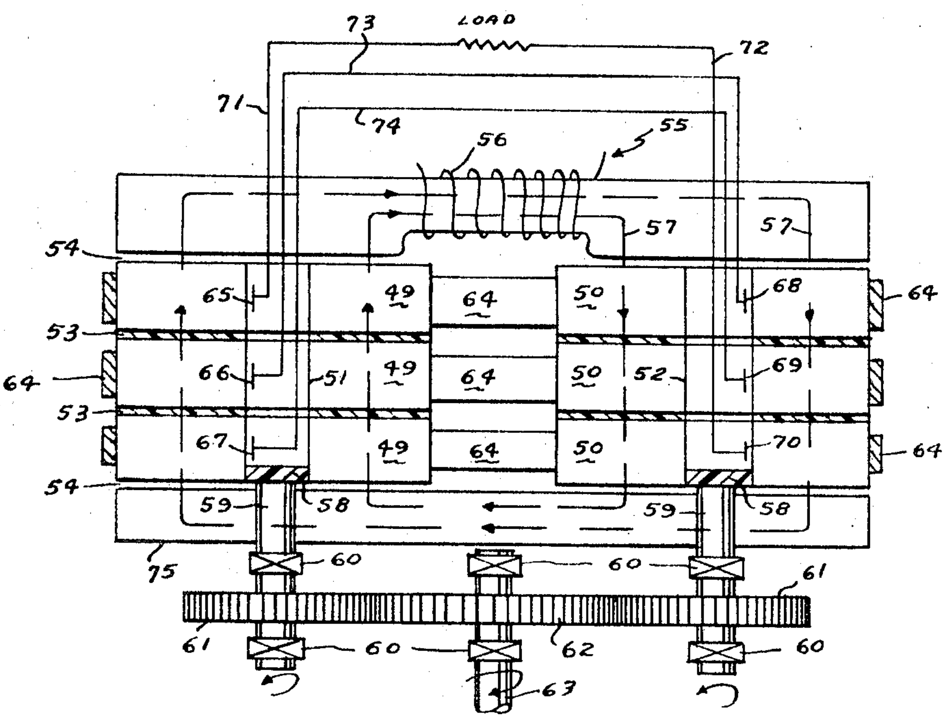

Fig 5

INVENTOR.
ONEZIME P. BREAUX

BY Harry A. Herbert Jr
Herbert D. Brown and
ATTORNEYS

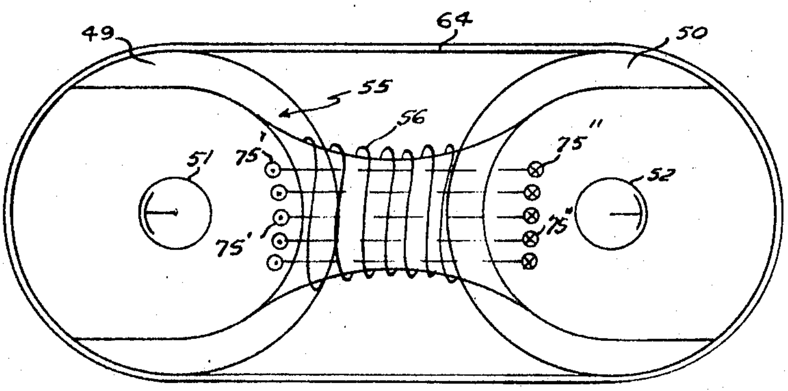

Fig-6

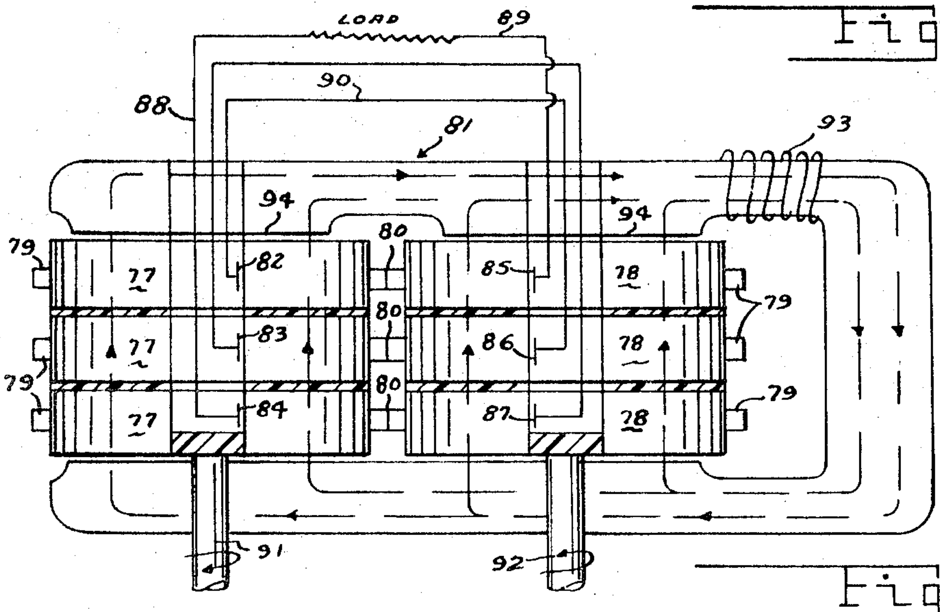

Fig-8

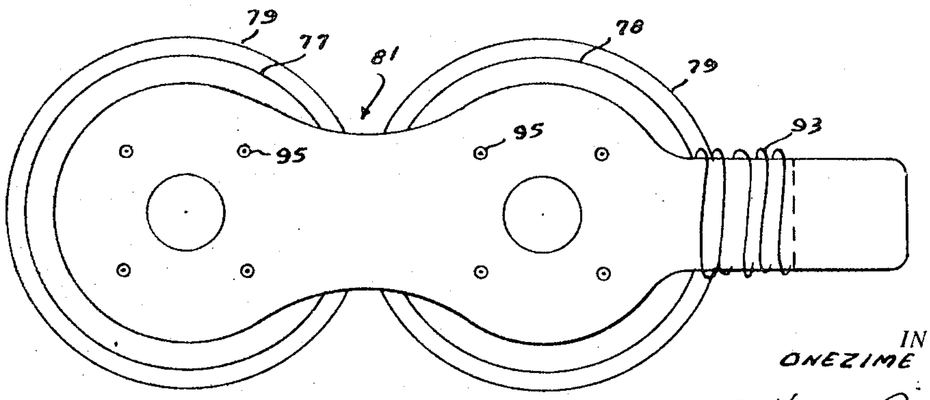

Fig-9

INVENTOR.
ONEZIME P. BREAUX
BY Harry A. Herbert Jr
and Herbert S. Braun
ATTORNEYS

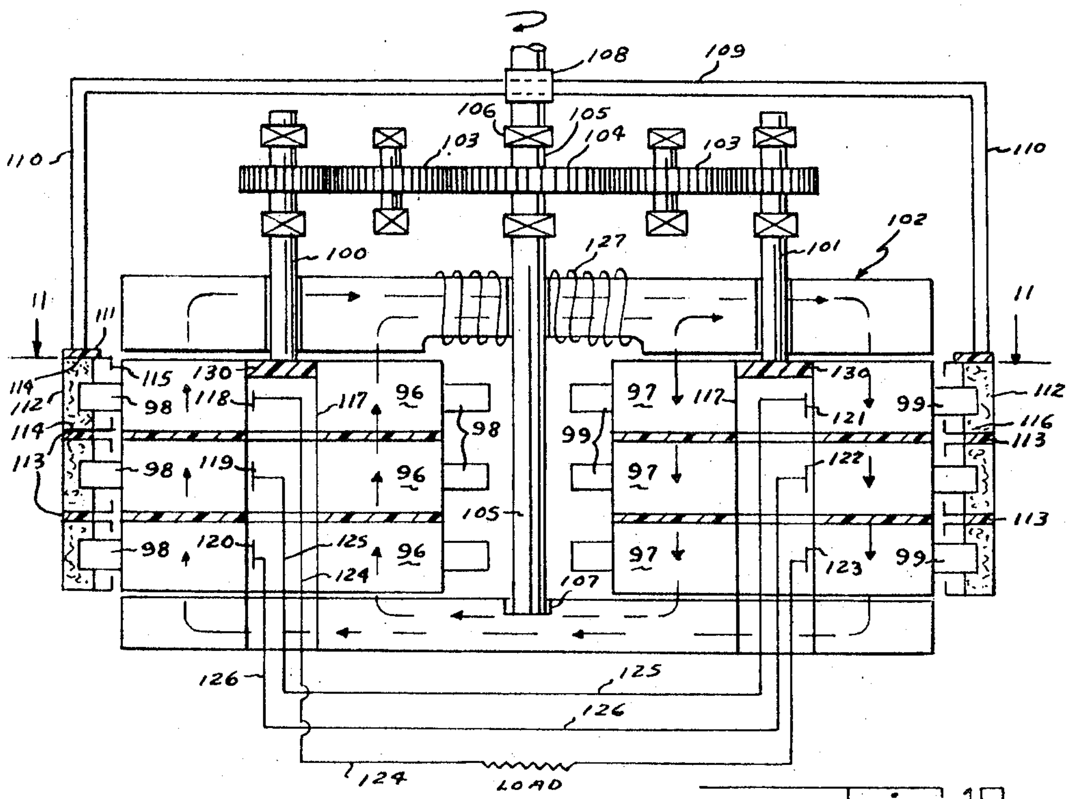

Fig-10

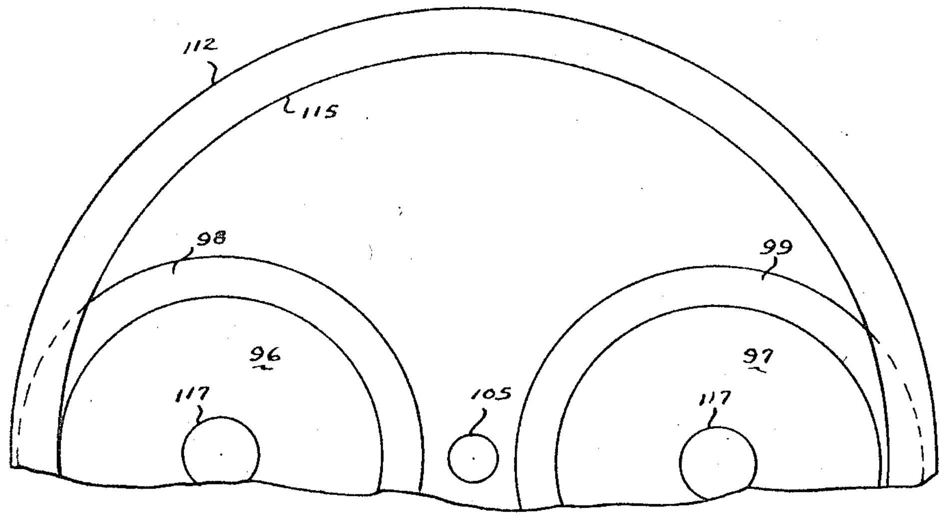

Fig-11

INVENTOR.
ONEZIME P. BREAUX

BY Harry A. Herbert Jr. and Herbert H. Brown

ATTORNEYS

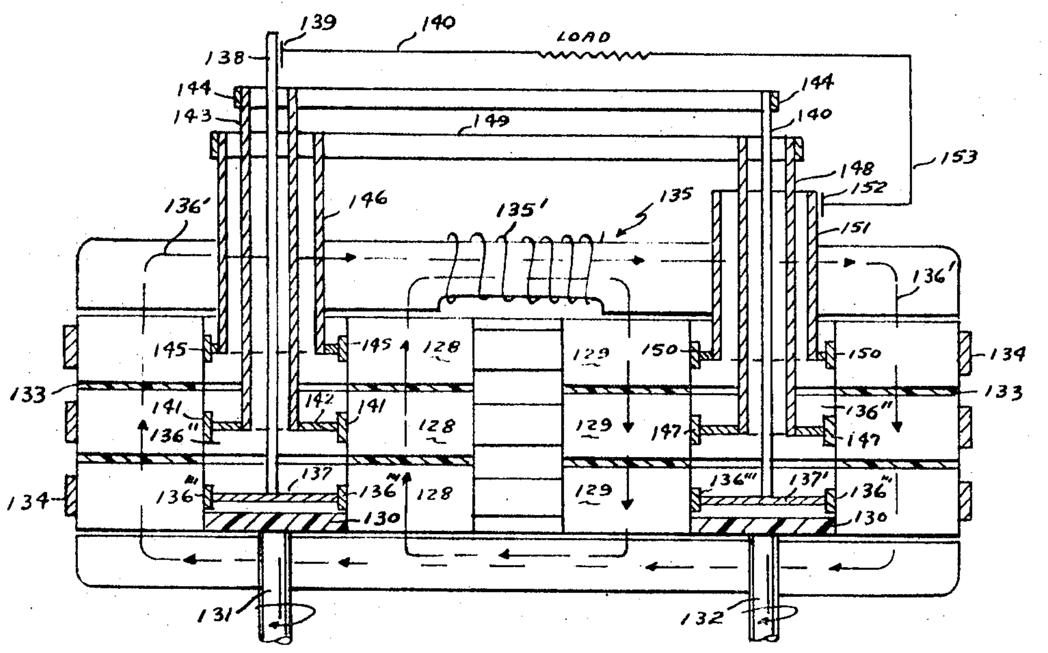

Fig 12

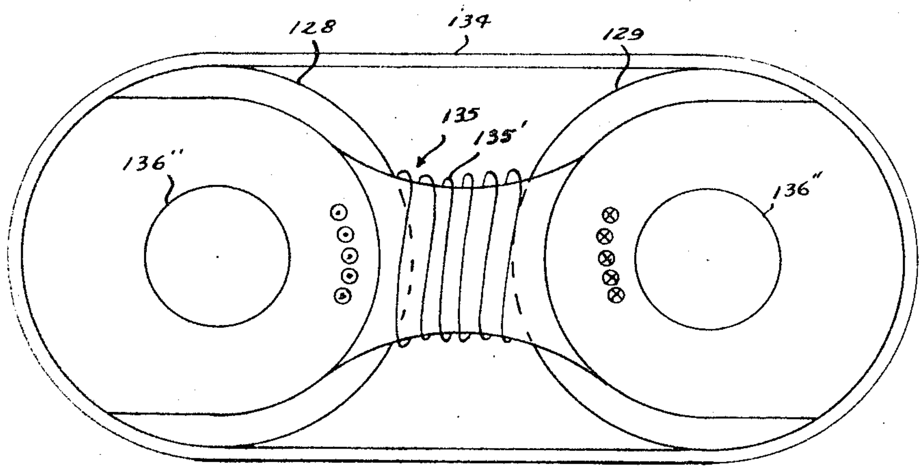

Fig 13

INVENTOR.
ONEZIME P. BREAUX
BY Harry A. Herbert Jr. and Herbert H. Brown
ATTORNEYS

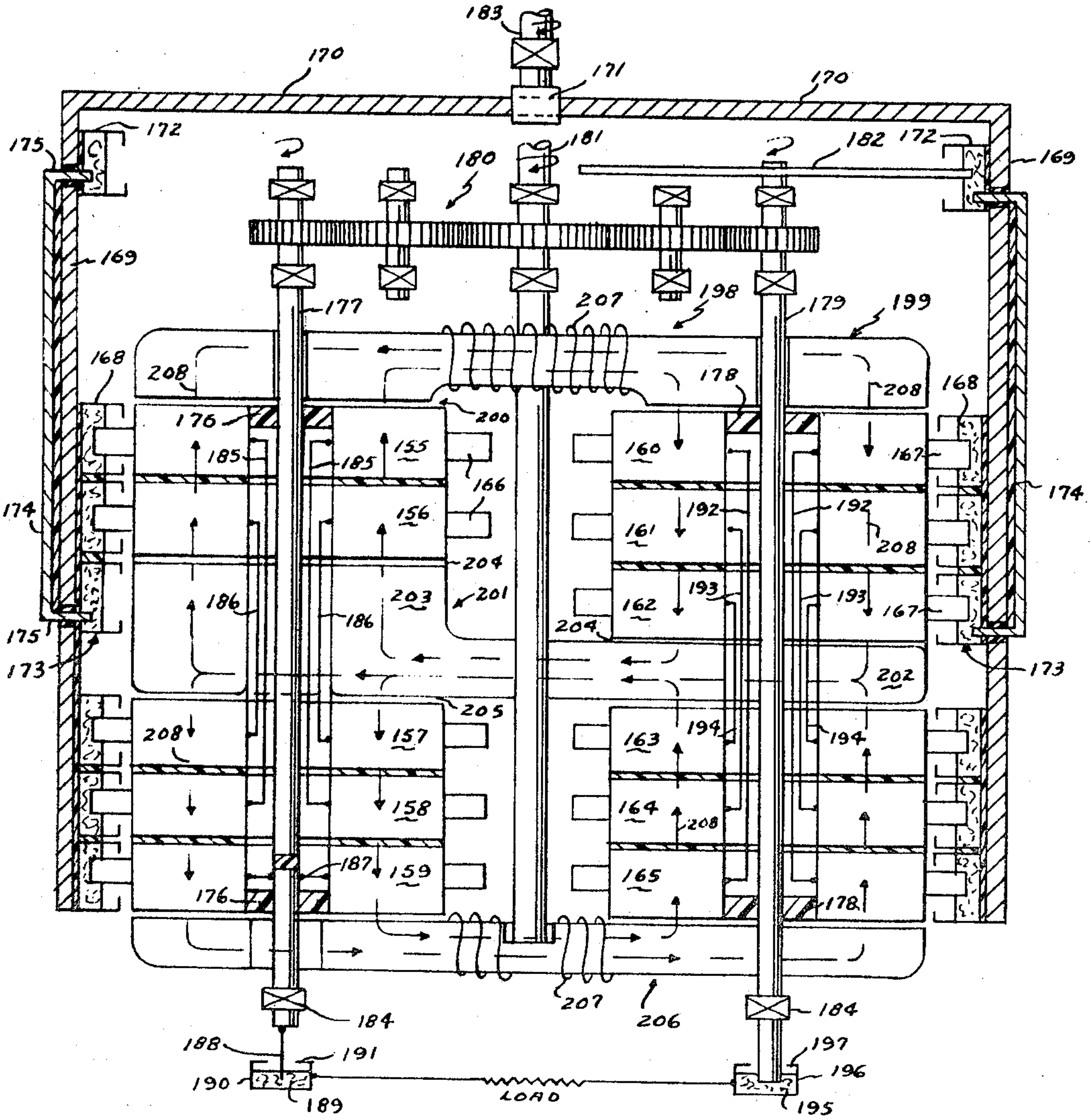

Fig-15

INVENTOR.
ONEZIME P. BREAUX
BY Harry A. Herbert Jr
Herbert H. Brown and
ATTORNEYS

United States Patent Office

3,465,187
Patented Sept. 2, 1969

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3,465,187

HOMOPOLAR GENERATOR HAVING PARALLEL POSITIONED FARADAY DISK STRUCTURES

Onezime Philip Breaux, 104 E. 3rd St., Dayton, Ohio 45402

Filed June 5, 1967, Ser. No. 644,456
Int. Cl. H02k *31/00*
U.S. Cl. 310—178 12 Claims

ABSTRACT OF THE DISCLOSURE

A homopolar generator having parallel positioned Faraday disks rotated in a magnetic field. The disks operate at a high speed and the current takeoff point on each periphery employs a circular confined column of mercury which moves at the same velocity as the peripheral speed of the disk. Each disk is also provided with a central opening of relatively small size, the periphery of which is employed as a low speed current takeoff point. The disks are presented edgewise toward one another by being mounted on the parallel shafts and are separated from each other along the shafts by thin layers of insulation material. Thus, the combined mass of each bank of disks is extremely compact and the magnetic field which passes through the banks of disks is used most efficiently. The disks are electrically connected either by physical contact at their peripheries or by the use of conducting belts in order to complete the electrical circuit.

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

Disk generators as originally conceived represent a single stage, radial homopolar machine employing a solid but annular metal cylinder, rotating at high speed in a strong magnetic field. The generator voltage is taken off by solid state frictional electrical contacts such as brushes. The electromotive force V is generated between the inner radius r_1 (meters) and the outer radius r_0 (meters) of the disk as it is rotated at an angular velocity $\dot{\theta}$ (radians/second) in a uniform magnetic field of flux density B (webers/meter^2) whose direction is parallel to that of the axes of rotation. This electromotive force V (volts) can be expressed by:

$$V=B\dot{\theta}=\left(\frac{r_0^2-r_1^2}{2}\right)$$

It may also be expressed in terms of the area A (meters^2) between the disk radii and the frequency f (cycles/sec.):

$$V=BAf$$

A Faraday disk generator producing electrical power which has unidirectional electromotive force is inherently a device for generating low electromotive force but with a tremendous ampere load capacity. The chief drawback is due to the high speeds that are necessary when employing a magnetomotive force of practical value, to induce even a meager voltage, even though the wattage output is consistently high. As for example, a generator having an armature diameter of about 20 inches, running at 3000 r.p.m. and employing a magnetic field of practical strength would give less than 10 volts but with a large current output. It is apparent that the peripheral speed of the outer surface of the armature would be so as to cause tremendous loss in friction and voltage drop at the current take-off point or points as well as loss in the material of the contacts due to the rubbing effect. The same losses

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but perhaps in different degree are present should several unipolar generators be connected in series to increase the total output voltage or to reduce the voltage output per machine for a required overall voltage of a multi-unit device and thereby permit a reduction in speed of each machine. Consequently, the field of application of the Faraday disk type of generator is quite limited and it has been supplanted to a large extent by the coil wound generators. However, the latter is far more complicated in design and definitely more expensive to make because the disk type generator comprises little more than a solid piece of metal, such as high permeability iron rotating in a magnetic field.

SUMMARY OF THE INVENTION

An object of the invention is to provide an improved form of voltage take-off for a Faraday single disk unit or a multi-unit commercial form of a unipolar generator providing relatively high voltage and/or high current.

Another object is to provide an improved system for coupling any number of unipolar machines together, both electrically and magnetically, into a compact, rugged structure which utilizes the magnetic field to the optimum extent.

Still another object is to provide a multi-homopolar generator in which the multi-units are carried on a common shaft, separated from one another by the minimum amount of insulation material and utilizing the minimum air space clearance with respect to a stationary magnetic enclosure.

A further object is to provide a rugged current takeoff adapted to accommodate a large current generated by a considerable number of high-speed Faraday disk units connected in series and in which the voltage drop due to the current load and the loss of contact material brought about by the high peripheral speed are reduced to a minimum.

These objects are carried out, in brief, by mounting the disks with the minimum insulation therebetween on a common hollow shaft for carrying the electrical connections and providing direct or indirect velocity-matched electrical contacts for picking off the current from the surfaces traveling at high peripheral speed.

In another aspect my invention contemplates the use of Faraday disks arranged on parallel shafts and providing a line contact between the fast-moving peripheries of the disks to effect the necessary velocity-matched electrical contact.

The invention will be better understood when reference is made to the following description and the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 represents diagrammatically an improved multi-stage generator utilizing two disks coupled together in accordance with the principles of my invention and employing a velocity-matched electrical contact;

FIG. 2 is a plan view of the apparatus shown in FIG. 1 but without the gearing;

FIG. 3 is a plan view of a modified form of an improved double stage generator but employing a metal belt or band to obtain the velocity-matching effect at the area of electrical contact;

FIG. 4 represents a plan view of the apparatus shown in FIG. 3 but without the gearing;

FIG. 5 depicts a machine in which a dual bank of disks are employed in series relation and the contacts at the high peripheral speed surfaces are velocity-matched;

FIG. 6 represents a plan view of the machine illustrated in FIG. 5 but by way of diagram and without a showing of the gearing;

FIG. 7 is a vertical section view of a multiconductor plug with exposed contacts, found useful in making connection with the interior surface of the disk shown in FIG. 5;

FIG. 8 shows by way of diagram a dual stack of disks in which the velocity-matching effect at the contacting surface is obtained in a different manner from that shown in FIG. 5;

FIG. 9 represents a diagrammatic plan view of the structure shown in FIG. 8 but without the electrical circuits;

FIG. 10 shows in elevation and by way of diagram a still further modification of the velocity-matching effect at the contact making areas;

FIG. 11 represents a diagrammatic plan view of the structure depicted in FIG. 10 but without the showing of the gearing or the magnetic field. This view is taken at about line 11—11 in FIG. 10;

FIG. 12 illustrates a multistage disk structure in which the contacts within the interior surface and the exterior surface of the disks are velocity-matched;

FIG. 13 represents a plan view in diagram of the structure depicted in FIG. 12 but with the interior contacts and band connecting members not shown;

FIG. 14 is a vertical section of the plug adapted to be inserted in the disk assembly of FIG. 12 for readily making contact with the interior surface of the disks; and

FIG. 15 represents two banks of five and six disks, respectively, all connected in series and the contacts at the peripheries of the disks being velocity-matched to avoid friction and excessive voltage drop at the high peripheral speed surfaces.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, reference character **1** generally designates a magnetic core of high permeability iron and having end pieces **2, 3** and a central section **4**. The latter and the end piece **2** terminate in a pair of relatively large juxtaposed bosses **5, 6** ground to a close dimension and absolutely flat and smooth. These bosses are separated from one another and are of circular configuration as seen in FIG. 2, somewhat smaller than the diameter of the disks **7** to which reference will be made later. The connecting portion between the circular bosses may be necked down as indicated at **8** (FIG. 2) and the end piece **3** is of approximately the same width as the portion **8**. Extended openings **9** and **10** are provided along the center portion of the core to leave portions **11, 12** of restricted width. The end piece **3** is of solid material in which two disks **7**, preferably of good conductive and magnetic material such as iron, are mounted on vertical shafts **13, 14** which pass loosely through openings (not shown) in the core **1** with as little friction as possible and at positions corresponding to the center of the circular bosses **5**. These disks are of such thickness and so carefully positioned on the shafts **13** and **14** that only the smallest necessary amount of clearance indicated at **15** is provided with respect to the bosses **5** of the core. As in the case of the bosses, the disks are ground to close dimension and are absolutely flat and smooth on both sides.

The shafts **13, 14** are journalled at **16, 17**, preferably through ball bearings (not shown). The shafts carry gears **18, 19** which are driven by gears **20, 21**. The latter are mounted on shafts **22, 23**, respectively, and suitably journalled. Assuming that the shaft **23** is driven by an electric motor (not shown) the gearing arrangement is such that the disks **7** will rotate in opposite directions. The diameters of the disks are so chosen that they will lightly contact at their outer peripheries indicated at **24** forming a line contact as to rotate in the manner described. A thin copper band (not shown) may be placed around the disks in order to obtain better current flow along the periphery of the disks.

A coil **25** of insulated wire or cable is wrapped around the constricted magnetic portion **12**, and when energized by direct current (not shown), provides powerful lines of magneto-motive force indicated by the dot-dash arrowed lines **26** which pass through the entire core including the end portions **2, 3**. These lines of force also pass upwardly (depending on the magnetic polarity of the coil **25**) through the disks **7** as is also indicated. Assuming that the magnetomotive force is of sufficient intensity as it is cut by the rotating disks and the latter turns at considerable speed, while still touching one another at **24**, an electromotive force will develop between the center of each disk and its outer surface.

In accordance with the equation set forth hereinbefore, the voltage derived from one disk can be added to the voltage derived from the other disk (due to the fact that they are rotating in opposite directions) and the combined voltage may be taken off from the shafts **13, 14** since the series relation is established through the contact at **24**. Brush contacts **27**, of any suitable and well-known character, are established with the shafts and a load **28** connected between the contacts. Inasmuch as the peripheral speed at the shafts **13, 14** is relatively low, very little, if any, friction or voltage drop is encountered at this position. However, at the place where the peripheral speed is extremely high, i.e. at the outside boundary of the disks, the disks are traveling at the same relative speed, assuming that the gears **18, 20, 21, 19** have the proper teeth ratio. There is no slippage at the contact area **24**. Moreover, if desired, spring-loaded rings (not shown) may be provided about the peripheries of the disks to provide the required area of electrical contact and to take up wear. There is therefore no relative friction loss or IR drop in carrying this series connection from one disk to the other.

While I have shown only two disks traveling in opposite directions and making a light line contact at places where the peripheral speed is quite high, it is obvious that another pair of disks could be added to the planar arrangement with suitable modification of the portion **3** of the magnetic core **1** to accommodate the additional pair, provided the strength of the magnetomotive force passing through the disks is duly increased, and their output were serially connected together by extraneous circuits in order to add the voltage to those of the original disks.

It is desirable that the lower surface of the bosses **5** and the upper surfaces of the bosses **6** of the magnetic core should be positioned at a distance no greater than is necessary to provide mechanical clearance between the rotating disks **7** and the core. For this purpose, it may be desirable that the boss surfaces be milled and ground quite smooth to extremely close tolerance in order not to provide any greater clearance space than is necessary. It is evident that a machine of the type described is extremely rugged since all of the parts may be of substantial thickness, and if desired, a slight adjustment may be provided in the well-known manner for bringing the shafts **13, 14** slightly closer together so as to regulate the pressure at the contact line **24** and also to take up for any unusual wear that may have been caused.

In FIG. 3 there is shown a modified form of the generator and in which the disks **7** are moved apart and no longer touch one another. These disks are carried on the shafts **27′**, which in this case are caused to rotate in the same direction (as indicated) by means of a large driving gear **28** and two smaller gears **29**. The output circuit is taken off from the shafts **27′** in the same manner as in FIG. 1. However, the source of the magnetomotive force indicated generally at **30** is different from that shown in FIG. 1 in that the coil **31** which supplies the magnetic lines of force is now wound on a restricted width portion of the core, preferably at a position about midway of the length of the core and specifically at the position of the necked down portion **32** (FIG. 4). These lines of force extend upwardly through the left-hand disks **7** and downwardly through the right-hand disks 7. As stated hereinbefore, these disks rotate at the same speed (assuming proper gear teeth ratios) and also in the same direction as indicated by the arrows 33 at the bottom of FIG. 3. In view of the manner in which the disks are separated and for circuit reasons, it is necessary that the peripheries shall be in electrical contact with one another. A fairly thin metal belt or band 34 is passed around the peripheries of the two disks.

The circuit can be traced from one side of the load through the brush contact 35 to the shaft 27', then toward the center and thence outwardly to the periphery of the left-hand disk, and from there is taken by the belt or band 34 to the periphery of the right-hand disk 7. From there the circuit continues through the right-hand shaft 27' to the brush contact 35 to the other side of the load.

As in the case of FIG. 1, the magnetic core in FIG. 4 has inwardly curved surfaces indicated at 36 which are of smaller radius than that of the disk. This tends to facilitate the making of the necked down portion 32 which receives the coil 31. The small circles 37 shown in FIG. 4 containing dots or points and the small circles 38 containing crosses indicate the direction of the magnetic field passing through the disk 7 in accordance with well-known practice. It will be understood that these circles and the indications would actually extend over the entire area of each of the disks.

The band 34 may be comprised of closed strands of wire or thin strips of any suitable conductive material mounted tight or with any suitable lengthwise adjustment, since the band is not relied upon to provide any driving effect to either of the disks. As in the case of FIG. 1, the dot-dash lines 26 in FIG. 3 indicate broadly the direction of movement of the magnetic field induced by the presence of the coil 31. It will be noted that in the machine shown in FIG. 3, it will become necessary to transfer current or at least make a connection between the peripheries of the disks 7 which are moving at an extremely high peripheral speed. However, the band 34 takes care of the continuation of the circuit since it moves at the same linear speed as the peripheral speed of the two disks. The other points where the current is removed from the rotating parts is at the surface of the shafts 27' where the peripheral speed is relatively low and thus does not incure either any abnormally high IR drop, notwithstanding the considerable current involved, nor excessive friction which might otherwise tend to wear out the brushes. The electromotive forces developed in each of the disks 7 are added together in the same manner as was explained in connection with FIG. 1.

It is apparent that a machine operating in accordance with the description given in FIGS. 3 and 4 may be expanded to include more than two disks provided the shape of the core and strength of the magnetomotive force are increased to develop the extra electromotive force required.

In FIGURES 5 and 6, there is shown two banks of three Faraday disks arranged on vertical axes parallel to one another, and as in the case of FIG. 3, separated from one another. The circular disks 49 and 50 of the respective banks are provided with central openings 51, 52 and are insulated from one another in each bank by means of a thin layer 53 of any suitable and well-known insulation material such as plastic, oiled paper, fiber glass, etc. The thickness of insulation can be quite small. The disks and interleaved layers of insulation material can constitute a solid mass and form this standpoint represent a rugged object. The uppermost and the lowermost disks 49, 50 are provided with a small clearance space 54 with respect to the core indicated generally at 55. A coil 56 is wound about the central necked down portion of the core 55 so as to supply magnetomotive force so that magnetic lines of force pass upwardly through the left-hand bank of disks and downwardly through the right-hand bank as indicated by the dot-dash arrowed

lines 57. In order to rotate these disks in view of their hollow character, it is necessary to provide a round plug 58 of insulating material and fitted tightly within the holes of the lower disks. The plug is connected to a shaft 59 which is journalled at 60 and carries a gear 61.

There is an intermediate driving gear 62, preferably of a larger size than the gear 61, and this intermediate gear is power-driven through a shaft 63. Thus when the latter is rotated, the shaft 59 and the disks are turned at high speeds in the same direction. It is therefore possible, as in the case of FIG. 3, to apply a band 64 of good conducting material across each adjacent pair of disks 49, 50. In order to complete the connections, brush contacts 65, 66, 67 are taken from the inner peripheries of the disks 49 and brush contacts 68, 69, 70 are taken from the disks 50. Conductor 71 connects the brush contact 65 with one side of the load and the other side is connected through conductor 72 to the brush contact 70. A conductor 73 is taken from the brush contact 66 to the brush contact 68 of the adjacent disks 50. A conductor 74 is connected between the brush contact 67 and the brush contact 69.

In operation, the disks 49, 50 are rotated at the same fast speed in the manner described hereinbefore so that the bands 64 travel with their respective disks. As in the case of previous figures, the air gap 54 are kept as small as possible to give only the required clearance with the adjacent surfaces of the magnetic core. It will also be noted that the core is preferably made narrow at the position encircled by the coil 56 but the ends of the core in this case conform closely to the circular configuration of the disks 49, 50. When the disks are turned in the manner stated, a circuit can be traced from the brush contact 65 through the conductor 71, thence through the load, conductor 72 to the brush contact 70. The circuit then follows through the radial width of the lowermost disk 50 to the band 64, then passes through this band to the outer periphery of the lowermost disk 49, thence through the contact brush 67 to the conductor 74 into the contact brush 69 of the middle disk 50, thence through the radial width of the disk to the outside band 64. The current passes through this band to the outside periphery of the middle disk 49, thence through the radial width of the disk to the brush contact 66, thence through the conductor 73 to the brush contact 68, then through the radial width of the uppermost disk 50 to the band 64 and then through the radial width of the upper disk 49 to the lead 71 to complete the circuit. Thus there are six disks, all combining their generated electromotive force together, to energize a load which may require commercial voltages perhaps of 110 volts D.C. and considerably higher and requiring perhaps considerable current.

As in the case of the previous figures, the bands 64 make their respective connections with the disks of each bank without the slightest friction because the bands are traveling at the same speed as the disks. The central openings 51, 52 in the disks can effectively be used not only to accommodate the contact brushes but also to carry out all the various leads. It is obvious that these conductors must be well insulated within the openings and as will be explained hereinafter, the latter can be separated from one another by being molded within a plastic plug. It should be added that the lower portion of the core indicated at 75 may be provided with the necessary openings to receive the shafts 59. The lower portion of the core is mechanically secured to the upper core portion in any suitable manner (not shown) so as not to interfere with the rotation of the disks. Inasmuch as the peripheral speed of the disk surfaces within the openings 51, 52 are relatively low, very little IR drop or friction at the brush contacts 65 through 70, inclusive, would be encountered, as it has been explained that the intolerable losses apply almost entirely to peripheral surfaces that are traveling at extremely high speeds. These losses are eliminated by the flexible velocity-matching effect between the outside peripheries of the respective disks and the band conductors **64**.

FIG. 6 diagrammatically indicates the direction of the magnetic lines of force passing through the core **55**, also through the lower portion **75**, as well as the disks **49, 50**. The point in each circle **75'** shown to the left of the figure indicates an upward direction of the magnetic lines while the crosses in the circles **75''** indicate a downward direction. This figure also shows the tangential position of the bands **64** about the disks **49, 50**.

FIG. 7 shows in a fragmentary manner a vertical section through a plug **76** which has an outer diameter according to the central opening in the six disks shown and described in connection with FIG. 5. This plug may be made of moldable plastic and contains the brush contacts **68, 69, 70** connected through the various conductors **73, 74, 72**. It will be understood that these conductors are only diagrammatically indicated in FIG. 7 but would normally be sufficiently large to carry considerable current. The moldable material **76** serves to sepaarte and insulate the conductors from one another and are readily inserted into the openings in the various disks **50** for connection to the exterior circuits. The plug for the other opening **51** in the disk **49** would be made similiarly to that shown and described in FIG. 7 but with the contacts moved to the opposite side of the plug. It will be understood that the brushes can be springloaded, if desired.

FIG. 8 depicts still another modification of connecting two banks or stacks of three disks, all in a series manner in order to add the electromotive forces developed by the individual disks to a useful value. In this figure the two banks of disks **77, 78** are made similar to those described in connection with FIG. 5 and these disks are hollow and are rotated in substantially the same manner as described in connection with FIG. 5, so that the gearing and the necessary driving parts have not been shown. However, the disks **77, 78** are each provided with an annular and centrally located flange, indicated at **79**; these flanges being of a thickness and the disks so located that the flanges contact one another as indicated at **80** in the center of the machine. These flanges may also be spring-loaded as was described in connection with FIG. 1. Thus, in this case, there is no need for providing the bands surrounding the disks so that these flanges, in touching one another at the inner portions of their peripheries, operate in a manner similar to that shown and described in connection with FIG. 1. The magnetic structure **81** is similar to that described in connection with FIG. 1 in that the magnetic lines of force pass through the disks **77, 78** in the same direction. However, this modification differs from the earlier described figure in that two sets of three disks have centrally disposed openings in which contact is made to the various outgoing conductors. It is obvious that the plug arrangement shown and described in connection with FIG. 7 could also be used to make these low peripheral speed connections.

A circuit can be traced, beginning at the brush contact **84**, and passing upwardly through the lead **88** and through the load, thence through lead **89** to the contact **85**. The circuit continues through the upper disk **78** to the flange **79** which then makes contact at **80** with the flange **79** of the upper disk **77**, thence through the brush contact **82** through the lead **90** to the contact brush **86**, then radially widthwise to the flange **79** of the middle disk **78** and from there the circuit continues at the line contact **80** to the flange **79** of the middle disk **77** and thence through the brush contact **83** to the brush contact **87**, then outwardly through the lower disk **78** to the flange **79** over to the flange of the lower disk **77** and thence through the contact brush **84** to the lead **88**. It is obvious that a gearing arrangement may be used in connection with the shafts **91, 92**, as was described in connection with FIG. 1. The coil **93** encompasses that portion of the magnetic circuit which is to the right beyond the position of the bosses **94** so that the magnetic lines of force will pass upwardly through both banks of disks in the same manner as was described in FIG. 1, in connection with the single disk structure.

In FIG. 9 the points in the center of the circles **95** represent the magnetic lines of force passing upwardly through the two banks of disks. The spring-loaded surface contact **80** between the rings provided about the disks permit an exact velocity match between the fast moving peripheral surfaces of any one disk and the point where the current is being withdrawn or collected. Thus, in FIG. 8 there is no slippage at the point of **80**, and yet current is readily transferred from one disk **78** to the other disk **77**, notwithstanding the fact that the surfaces at the peripheries of these disks are traveling at extremely fast speeds. There is therefore no appreciable IR drop occasioned by this transfer of current at this point nor any induced friction which would wear the surface of a stationary contact.

FIGS. 10 and 11 diagrammatically show the liquid form of velocity-matching the contacts with the peripheral speed of the disks at the point of contact. The disks **96, 97** are provided with integral centrally located flanges **98, 99**. Each bank of disks is formed with a hollow bore and the shafts **100, 101** are preferably taken out through the top of the magnetic core generally indicated at **102** and connected to the disks by means of the plugs **130**. The shafts **100, 101** are carried through intermediate gears **103**, suitably journalled as indicated, to a large drive gear **104**. The latter is mounted on a central shaft **105** journalled at **106** at the top and within a suitable recess **107** at the bottom of the magnetic core. On the shaft **105** there is a fairly large connecting plate **108** which has horizontal holes therethrough for receiving the rod **109**. This rod extends vertically downward as indicated at **110** at both sides of the figure and connects with a heavy block of insulation **111** which is secured to a series of metal rings **112** at each side. These rings are shown as being insulatedly separated from one another as indicated at **113**. The latter are of circular configuration as seen in FIG. 11 and have side strips of metal **114** which are bent inwardly to leave a lip **115**.

Each of the rings **112** and the companion inwardly extending strips **114**, together with the lips **115**, constitute an annular chamber for receiving a quantity of liquid metal, such as mercury **116**. The mercury may be poured into the lower part of each of these annular ring compartments and when the latter are rotated at a high speed, as explained hereinafter, the mercury will move upwardly and outwardly to distribute itself against the inner surface of the ring portion **112** as seen on the drawing. The flanges **98, 99** located on the outside periphery of the disks **96, 97**, respectively, extend for a short distance into these annular vertically positioned rings of mercury upon rotation of the disk structure in order to make contact at these points. As each bank of disks **96, 97** are rotated through the gearing described hereinbefore, each in turn is driven by the drive shaft **105** and its gear **104**. The horizontal rod structure **109** is rotated at the same angular velocity as the driving shaft so that the annular ring-like compartments **112** are rotated as a group. The gear ratios are so calculated that the compartments **112** will have a peripheral speed approximately the same as the peripheral speed of the flanges **98, 99** in order that there will be no slippage between these two elements.

The disks **96, 97** are hollow as indicated at **117** in order to accommodate the three brush contacts **118, 119, 120** (within disk **96**) and their respective leads **124, 125, 126**, respectively, so that a circuit can be established beginning at one side of the load through lead **124**, brush contact **118**, thence outwardly radially to the flange **98** of the uppermost disk **96** to the body of mercury, thence around the annular ring compartments containing the mercury and through a semicircular path to the flange **99** of the upper disk **97**. From there the circuit may be traced as passing through the upper disk toward the center to the brush contact **121**, through the conductor **125** to the brush contact 119, thence through the middle disk 96 to the outer portion of the flange 98 where it contacts with the body of mercury in the second ring-like compartment. The circuit continues through the semicircular body of mercury and solid-state conductor of the ring to the flange 99 of the middle disk 97 thence through the disk to the brush contact 122 and through the conductor 126 to the brush contact 120, then out to the flange 98 of the lowermost disk 96, thence through the semicircular body of mercury and solid-state conductor of the ring to the flange 99 of the lower-most disk 97 to the brush contact 123 and thus to the other side of the load. Sufficient magnetomotive force is supplied to the core 102 by the coil 127 such that when the entire structure including the rods 109, 110 are rotated and each bank of disks 96, 97 are given the proper speed of rotation through the gear ratios, each disk will generate its quota of the required electromotive force, and inasmuch as the individual disks are effectively connected in series as explained hereinbefore, an appreciable output voltage from the two banks of disks is entirely possible. Obviously, instead of employing only three disks in each bank, this number may be increased so that an electromotive force of any practical value may be obtained from the group of Faraday disks.

FIGS. 12 and 13 show still another form that the dual bank of disks could take in order to add their electromotive force together and run at fast speed without any intolerable IR drop or friction at the brush contact points. In these figures, there are two banks of three Faraday disks designated 128, 129, supported on the usual circular plugs 130 of insulating material and driven by the shafts 131, 132. The gearing is shown in this figure and the gears are so related that the shafts are rotated in the same direction at a relatively high speed. The disks are insulated from one another by any suitable and well-known insulating material generally indicated at 133. As stated hereinbefore, this material may be quite thin and, in some cases, could take on the form of an insulating oxide. There are bands of conducting material 134 encompassing the outer halves of each set of disks, the purpose of which is to complete the series circuit between the disks as will be explained hereinafter. The core is indicated generally at 135, magnetically excited by a coil 135′ which provides the necessary magnetomotive force passing through the upper portion of the core, thence down through the right-hand bank of disks, then through the lower portion of the core and then through the left-hand bank of disks 128 as indicated by the arrowed dot-dash lines 136′. As explained hereinbefore, the purpose of the bands 134 is to serve to provide a velocity-matched contact between the outer peripheries of the disks and the conductor or conductors which carry the generated electromotive force on through the rest of the disk system.

The disks are hollow as indicated at 136″ and the series circuit is completed through a number of ring contacts which are attached to the inner peripheries of the disks and are connected through a series of metal tubing which extend through each of the openings 136″. The lowermost disk 128 is provided with ring contact 136‴ joined to a disk 137 to which a rigid rod upright 138 is attached. At the top of the rod 138 there is provided a stationary brush contact 139 having a conductor 140 which leads to one side of the load. The lowermost disk 129 is provided with a similar ring contact and connecting disk 137′ to which an upright rod 140 extends. The middle disk 128 has ring contact 141 together with a connecting disk 142 which connects with an upright metal cylinder 143. A band 144 of conducting material extends around this cylinder and also around the rod 140 so that the ring contact 141 of the intermediate disk 128 is electrically connected to the ring contact of the lowermost disk 129 through the afroementioned band. The uppermost disk 128 is provided with ring contact 145 having a radially extending rod which supports an upright cylinder 146 of metal. The intermediate disk 129

is provided with ring contact 147 which supports an upright cylinder 148 of metal. A metallic band 149 passes around the cylinders 146 and 148 so that the ring contact 145 is in electrical communication with the ring contact 147 of the intermediate disk 129.

The uppermost disk 129 is provided with ring contact 150 which supports an upright cylinder 151 of metal. A brush contact 152 is taken from this cylinder 151 and through a conductor 153 to one side of the load.

A series circuit can be established frm the other side of the load through the ring contacts and the radial paths through the disks, the current being carried from one set of disk banks to the other set in series by means of bands 144 and 149. Thus, here again, at any place where there is generally high peripheral speed among the parts forming part of the series circuit, velocity-matching contacts are provided at the bands 144 and 149 in order to reduce any considerable IR drop or excessive friction. In this way, considerable current can be passed through the battery of disks, all of which add their electromotive force to provide a voltage of commercial value or any other desired amount.

It is obvious that, if desired, and in order to facilitate the assembly of the various sleeves 143, 146 and the center rod 138 within the openings 136″ (FIG. 12) the parts may be cast within a plastic material as shown in FIG. 14. Thus the rod conductor 138 and the sleeve 143 also the sleeve 146, can be securely held within a solid casting of material 154. The solid insert would also serve to space the various conductors and cylinders from one another. It is necessary merely to insert the entire plug into the opening 136″ of the disk 128, or a corresponding plug into the opening 136″ of the disk 129 and make the necessary band connections described hereinbefore; the entire plug being rigidly affixed to the bank of disks. Moreover, in this manner the ring contacts 145 through 150 can be accurately spaced with respect to one another.

FIG. 15 represents a form of the invention which, while it incorporates some of the features of FIG. 10, nevertheless has additional elements. This figure is adapted to a large multistage construction, for example, as shown, there are eleven disk units, five on the left and six on the right, whereas in FIG. 10 there are shown only six units. The left-hand bank of disks carry the reference characters 155, 156, 157, 158 and 159 whereas the right-hand bank of disks are designated 160, 161, 162, 163, 164, and 165. As in the case of FIG. 10, the disks are provided with peripheries formed by the flanges 166 on the left-hand bank and by flanges 167 on the right-hand bank of disks. These flanges extend into the mercury or other liquid metal compartments 168 which take on a circular configuration as in the case of FIG. 10, the purpose of these compartments being to provide a conducting path between the disks of one bank to the disks of the other bank. Thus, there are six annular rings 168 and each contain a flange 166 or 167 of the various disks. These flanges are immersed in a quantity of mercury, or other liquid metal form of contact. The ring-like compartments 168 are held in alignment by being insulatedly supported from rods 169 (shown as being vertical), which are of substantial rigidity and extend through transverse portions 170 to a thick plate member 171. In addition to the ring-like compartments 168, the rods 169 support an extra circular ring-like compartment 172, which also contains a liquid metal contact material and the purpose of which will be described hereinafter. There is one ring compartment indicated at 173, which, even though supported by the left-hand rod element 169, does not receive any part of a disk for reasons which will also be mentioned hereinafter. As has been pointed out, the mercury or other liquid metal in all of these ring-like compartments tends to move outwardly and is held in position by centripetal force during the rotation of the various parts of the machine. There is a wide metal band 174 having inwardly extending lips 175 which enters the mercury of the ring compartments **173**. The purpose of this band is to complete the series circiut to which all of the eleven Faraday disks add their individual electromotive force.

The disks **155** to **165**, inclusive, have hollow interiors for receiving the various electrical conductors and this necessitates the use of circular plugs **176** of insulating material which tightly fit within the disks **155** through **159** and are connected to a shaft **177**. The other bank of disks are provided with circular plugs **178** which tightly fit within the disks **160** through **165** and are connected to a shaft **179**. These shafts are rotated in the same direction by means of the gearing indicated generally at **180** which receives power from the shaft **181**. The shaft **179** at the right-hand bank of disks is extended through its gearing and bearings to provide the support for a flat metal disk **182**, the purpose of which will be apparent when the circuit for the entire machine is set forth in more detail.

The plate **171** to which the rods **170** are connected is driven by a shaft **183**. The general arrangement is such that the shaft **183** which causes the rods **169** and the wide band **174** to describe a large circular movement is so correlated with the gear ratio of the gearing **180** that the compartments **168** which travel with the rods **169** have the same circumferential speed as the peripheral speed of the disks **155** through **165**, inclusive. Consequently there is no slippage between the flange members **166**, **167** and the ring-like circular compartments **168** to which reference will also be made hereinafter.

The shafts **177** and **179** are preferably carried through the hollow interior of the banks of disks and supported at each end by suitably positioned plugs **176** and **178**. The shafts are journalled at the bottom as indicated at **184**. Conductors **185** are taken from the uppermost disk **155** down to the inner periphery of the disk **158**. Conductors **186** are carried between the inner peripheries of the second disk **156** of the left bank down to the inner peripheries of the disk **157**. Finally, conductors **187** are taken from the inner peripheries of the lowermost disk **159** of the left-hand bank and joined together by a conductor **188** which is received by the mercury or other liquid metal **189** of a round and stationary compartment **190** having the inner lips **191** to prevent leakage of the liquid metal.

Similarly, conductors **192** are taken from the inner peripheries of the uppermost disk **160** of the right-hand bank and then through the hollow disks down to the lowermost disk **165** of that bank. Conductors **193** are joined between the inner peripheries of the disk **161** of the right-hand bank to the interior of the disk **164**. Similarly conductors **194** are connected between the inner peripheries of the disk **162** and the disk **163**. It is apparent that these various conductors at both banks of disks are made for the purpose of maintaining a series circuit from one disk to the other. The shaft **179** is extended beyond its bearing **184** and is received by the mercury or other liquid metal **195** of a small and stationary circular compartment **196** having an internal lip **197**. The load circuit is connected between the metal compartments **190** and **196**.

For supplying the necessary mangetomotive force to pass up through the disks of both banks, a core generally indicated at **198**, but made up of three parts of high permeability iron, is employed. The first part which is specifically designated **199** passes along the tops of the uppermost disks **155**, **160** with as little clearance as possible between the core and each uppermost disk. The clearance is indicated at **200**. There is a middle portion of the core indicated generally at **201** which conforms to a narrow portion **202** where it underlies the disk **162** and then becomes thicker as indicated at **203** at the left-hand bank of disks. There is a clearance for mechanical reasons indicated at **204** between the thicker portion of the core **203** and the lower surface of the disk **156**, also between the narrow portion of the core **202** and the disk **162**. The lower surface of this intermediate core member **201** is flat over its entire length and is provided with a small clearance **205** with respect to the upper surface of the disks **157** and **163**.

The third portion of the core is indicated generally at **206** and except for the openings to receive the shafts **177**, **179** is perfectly flat and a mechanical clearance is provided with respect to the lower surfaces of the disks **159** and **165**. These three portions **199**, **201** and **206** of the core can be bolted (not shown) or otherwise secured together in such a way as not to interfere with the rotating disks. When sufficient ampere-turns, indicated by the coils **207**, are introduced into the three portions of the core to provide a magnetic field, electromotive force will be developed in each of disks **155** to **165**, and these electromotive forces will all add serially within other circuits which have been set forth hereinbefore.

The magnetic lines of force developed by the coil **207** travel in the manner set forth by the dot-dash arrowed lines **208**, and it will be found that the rotation of these disks **155** to **165** within the magnetic fields, as indicated, will cause the electromotive force generated by each of the disks to be added to one another and thus obtain an output voltage at the load which is quite considerable in addition to the large amperage which characterizes the nature of the Faraday disks.

It is believed unnecessary to trace the rather lengthy series circuit except that it should be pointed out that the wide band **147** is necessarily included in that circuit in conducting current from the flange **617** of the disk **162** to the mercury compartment **172** and thence through the rotating disk **182** to the shaft **179** and through the mercury compartment **195** to one side of the load. As in the case of the other constructions described hereinbefore, any contact which has to be made at a surface traveling at high speeds involves no appreciable IR drop or excessive friction losses on account of the fact that the transfer of energy at the contact point is accepted without any slippage between the contacting parts. In other words, there is a strict velocity matching provided at places of high surface speed between the contacts, and it is further noted that by employing mercury or other liquid conductor in the various rotating compartments **172** and **168**, there will be not the slightest slippage at these points.

A generator of the type described would be capable of generating high electromotive force and would still retain its high current handling capability.

From the foregoing it is evident that I have disclosed a double bank form of a generator employing serially connected Faraday disks in any number in each bank and all insulated from one another, with the minimum mechanical clearance between the end disks on each stack and the electromagnetic core. The contacts at the high speed peripheral surfaces are velocity matched so as to minimize the IR drop and contact wear at those points where the current is taken off. The banks, when formed and assembled are extremely rugged since the parts are rigidly held together as a solid mass. The bank can accommodate a greater or lesser number of electromotive force generating disks depending on the ouput voltage desired. The electrical wiring is simplified by providing the disks with an opening at the center through which the conductors can be taken and, if desired, held in a plug form of matrix to provide the necessary pressure at the contact points on the interior of the disks.

In the event that the multi-unit generator is being employed to provide high load current in addition to high voltage, and in this connection, the structures shown in FIGS. 10 and 15, which employ liquid contacts at the peripheries of the disks are particularly well adapted, there might appear extraneous magnetic fields as the result of this high load current. These fields, especially those that are present about the peripheries of the disks as the load current flows to the collection points, could distort the original magnetic field, i.e. the magnetic field which produces the electromotive force. In this case the load current may be directed in return paths by stationary conductors to set up magnetic fields to compensate for the extraneous fields originally brought about by the load current.

While a certain specific embodiment has been described, it is obvious that numerous changes may be made without departing from the general principles and scope of the invention.

I claim:

1. A homopolar generator comprising a plurality of Faraday disk structures mounted respectively on parallel shafts, means including a core of high permeability material and a coil for producing magnetic lines of force which pass through said disk structures, a mechanical clearance space between the end surfaces of said disk structures and the core, said structures being electrically connected together so as to add their respective voltages when the structures are caused to cut the magnetic lines of force upon rotation of said shafts, and means effective at the disk surfaces which run at the highest peripheral speed for completing the electrical connection and producing negligible IR drop and contact wear.

2. A homopolar generator comprising a plurality of pairs of Faraday disk structures, a plurality of shafts parallel to one another, one disk structure of each pair being mounted on one of said shafts, the other disk structure of the air being mounted on another shaft, said pairs of disk structures being presented edgewise to one another, a magnetic core for producing magnetic lines for force which pass through said disk structures, a mechanical clearance space between the end surfaces of the disk surfaces and the core, the structures on each shaft being separated by thin layers of insulating material, and said structures being connected in series to add the generated voltages together when the structures are caused to cut the magnetic lines of force upon rotation of said shafts, and means contacting the disk surfaces which run at the highest peripheral speed for completing the electrical connections.

3. A homopolar generator according to claim 2 and in which said last-mentioned means includes a device which contacts the periphery of one of said structures and travels at the same speed as the periphery of said one structure.

4. A homopolar generator according to claim 2 and in which said last-mentioned means includes a movable band conductor connected between the disk structures and travelling at the same speed as said structure.

5. A homopolar generator according to claim 2 and in which the clearance space is positioned between the extreme end surfaces of each bank of disks and the adjacent surface of the core.

6. A homopolar generator according to claim 2 and in which the metal disks of one of said banks are in planar alignment with the disks of the adjacent bank and the means by which the voltages of the disks are added together is constituted, at least in part, of metal conductive bands which pass around the peripheries of the adjacently disposed disks of the banks.

7. A homopolar generator according to claim 2 and in which the disk structures are hollow and the series connections for adding the respective voltages together are taken from the inside surfaces of the disk structures and also from velocity-matched contacts positioned at the outside surfaces of the disk structures where the peripheral speed is maximum.

8. A homopolar generator according to claim 7 and in which said velocity-matched contacts are constituted of a confined body of a liquid metal.

9. A homopolar generator according to claim 7 and in which said velocity-matched contacts are constituted of a body of a liquid metal which body is caused to move at a rate equal to that of the outside surface of the disk structures.

10. A homopolar generator comprising a plurality of banks of disks of metal, each arranged in stack form, said banks being separated from one another and mounted on parallel shafts, said disks having a bore therethrough, means including a coil and contained core positioned along the top and bottom surfaces of the banks for producing magnetic lines of force which pass through one bank in a given direction and through the other bank in the opposite direction, metallic bands embracing the outer peripheries of the adjacent disks of the two banks, and electrical connections which contact the interior peripheries of the disks and include said metallic bands about the exterior peripheries thereof for connecting the disks electrically in series to add the generated voltages of the disks notwithstanding the difference in direction of the lines of magnetomotive force as they thread through the two banks of disks.

11. A homopolar generator comprising a plurality of bored circular disks of metal arranged flat-wise and spaced from one another by insulating material to form a solid body, said body being mounted on a shaft which is adapted to be driven at high speed, means including a core of high magnetic permeability and a surrounding coil for producing magnetic lines of force which pass through the disks and their insulating partitions, a clearance space between the end surfaces of said body and said core, means for connecting the output of said disks in series in order to add the voltages generated by said disks when cutting the magnetic lines of force, and means for taking off the current from the fast-moving periphery of the solid body of disks and the bores thereof with negligible attendant IR drop and contact wear.

12. A homopolar generator comprising a plurality of pairs of Faraday disk structures, a plurality of shafts parallel to one another, one disk structure of each pair being mounted on one of said shafts, the other disk structure of the pair being mounted on another shaft, said pairs of disk structures being presented edgewise to one another, a magnetic core for producing magnetic lines of force which pass through said disk structures, a mechanical clearance space between the end surfaces of the disk surfaces and the core, the structures on each shaft being separated by thin layers of insulating material, and said structures being connected in series to add the generated voltages together when the structures are caused to cut the magnetic lines of force upon rotation of said shafts.

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MILTON O. HIRSHFIELD, Primary Examiner

R. SKUDY, Assistant Examiner