March 5, 1963 E. C. KEHOE 3,080,515

METHODS AND APPARATUS FOR GENERATING ELECTRICITY

Filed March 28, 1960

2 Sheets-Sheet 1

Fig. 1.

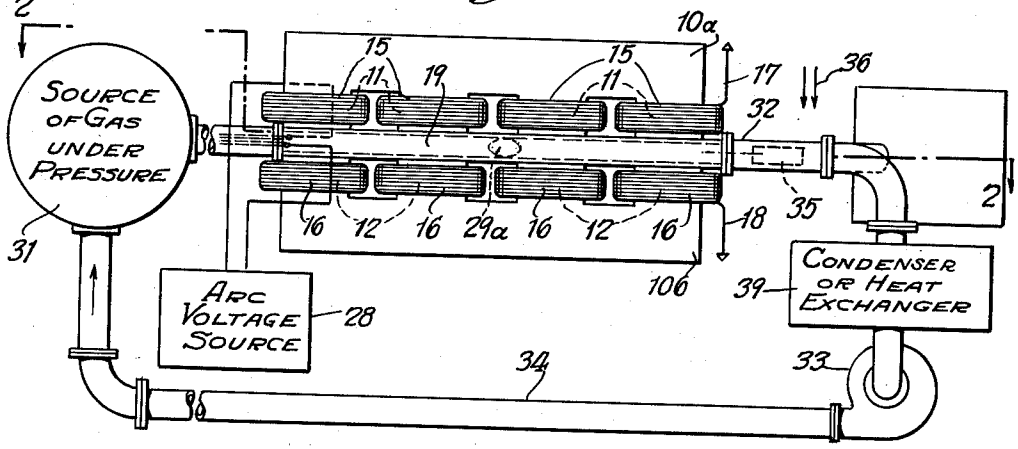
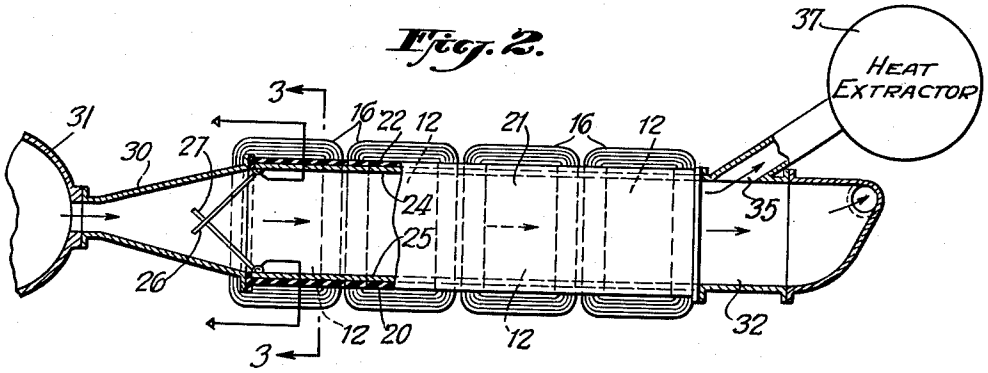


Fig. 2.



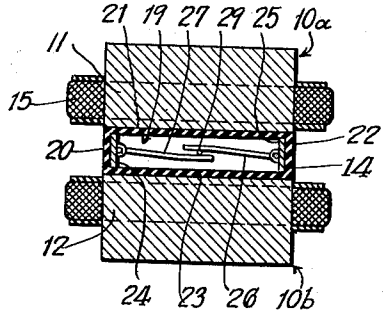


Fig. 3.

INVENTOR.
EDWARD CHARLES KEHOE.
BY

Ward, Neal, Haselton, Ormet & McElhannon
ATTORNEYS.

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2 Sheets-Sheet 2

Fig. 4.

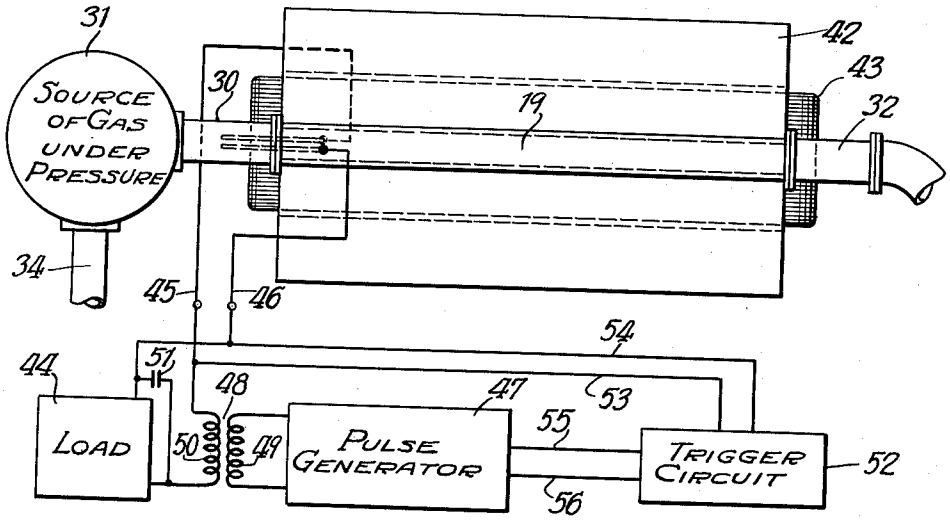
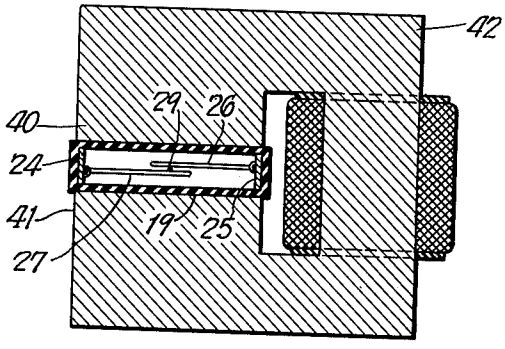


Fig. 5.



INVENTOR.
EDWARD CHARLES KEHOE.
BY
Ward, Neal, Haselton, Ormer & McElhannon
ATTORNEYS.

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METHODS AND APPARATUS FOR GENERATING ELECTRICITY

Edward Charles Kehoe, 11 Hillcrest Place, North Caldwell, N.J.

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12 Claims. (Cl. 322—2)

This invention relates to electrical generators and particularly to apparatus and methods for developing electrical energy by means of a gas driven electric arc.

It has heretofore been proposed to generate electricity by passing ionized gas through a magnetic field and abstracting electrical energy by means of electrodes disposed adjacent the flowing gas and spaced in a direction extending transversely to the magnetic field and the direction of movement of the gas. In the devices proposed, the ionization of the gas has been produced by raising the temperature of the gas to a relatively high temperature, such as by heating in a furnace or boiler, and in some such cases, additional ionization has been caused by means of an electric field between electrodes ahead of the generator electrodes. However, in such devices, the space between the generator electrodes has been completely filled with the ionized gas so that there is a sheet of ionized gas extending from one end of the electrodes to the other, the gas leaving at the exit end of the electrodes being continuously replaced by ionized gas at the entrance end of the electrodes.

The foregoing prior art methods and devices place severe requirements on the materials from which the generator must be made if any practical efficiency is to be obtained. The gases constituting the working fluid and conductor must be ionized and in a conducting state in order to be useful in generating power and developing output current. Most gases are not good conductors unless at temperatures in the order of 3500° to 4000° F. The addition of low ionizing atoms such as potassium, sodium and others can aid in attaining these temperatures of ionization. As these are the lowest conducting temperatures, the exhaust gases of the prior art devices are at this temperature and the inlet gases must be at higher levels in order to extract net energy. For instance, with 3500° F. exhaust temperature, a temperature of approximately 7500° F. at the inlet is required to approach 50% thermal availability. Thus, the materials from which the generator is made must be able to withstand temperature of their magnitude continuously. Obviously, this increases the cost of the generator, and with known materials limits the usable upper temperature and efficiency obtainable.

Furthermore, the above-menttioned prior art devices produce direct current, rather than alternating current, which must be inverted, with a further loss of efficiency, for commercial use and transmission in the conventional manner.

In accordance with my invention, an electric arc, which is a high temperature, confined, stream or rod of ionized gas of relatively small cross section, is produced and is subjected to a flow of gas so as to cause it to move in a predetermined direction, electrical energy being abstracted from the moving arc. Because the ionized gas is confined and of relatively small cross section, the high temperature problems are simplified since the generator components are subjected to the high temperature gas only periodically.

In the preferred embodiment of the invention in which alternating current is produced, the arc is pushed by a non-ionized gas under pressure along a pair of electrodes between which the arc is initially struck at one end thereof, the arc being maintained between said electrodes during movement therealong by an external voltage source.

In moving along the electrodes, the arc passes successively across the faces of poles of magnetic material and induces a changing magnetic flux therein. The poles have windings thereon which produce voltage from the changing flux. This voltage is used to provide useful output power from the device.

In another embodiment of the invention in which direct current is produced, the arc is pushed by a nonionized gas under pressure along a pair of electrodes between which the arc is initially struck at one end thereof, the arc being maintained between said electrodes during movement therealong by an external magnetic field arranged to induce voltage in the arc sufficient to maintain the arc and to supply energy to an external load connected to the electrodes. Preferably, the means for producing the magnetic field comprises a pair of pole pieces with a direct current energized winding thereon, the arc passing between the pole pieces.

It is one object of the invention to provide methods and apparatus for generating electricity without the use of moving mechanical parts and which do not have the disadvantages of the prior art methods and devices described above.

It is a further object of the invention to provide methods and apparatus for generating alternating electrical current without the use of moving mechanical parts and which do not have the above-described disadvantages.

Other objects of the invention will be apparent from the following detailed description of preferred embodiments of the invention illustrating the manner in which I now prefer to practice the invention, which description should be considered in conjunction with the accompanying drawings in which:

FIG. 1 is a partly schematic, side elevation view of the preferred embodiment of the invention;

FIG. 2 is a fragmentary, cross sectional, top elevation view of the embodiment shown in FIG. 1 and is taken along the line 2—2 indicated in FIG. 1;

FIG. 3 is an end elevation view, partly in cross section, of a portion of the embodiment shown in the preceding figures and is taken along line 3—3 as indicated in FIG. 2;

FIG. 4 is a partly schematic, side elevation view of a further embodiment of the invention; and

FIG. 5 is a cross sectional, end elevation view of a portion of the embodiment shown in FIG. 4.

The generator illustrated in FIG. 1 comprises cores 10*a* and 10*b* of laminated magnetic material, such as transformer steel, having a plurality of poles 11 and 12 extending therefrom. As indicated in FIG. 3, the faces 13 and 14 of the poles 11 and 12, respectively, are spaced from but relatively close to each other. The poles 11 are surrounded by coils or windings 15 of wire and the poles 12 are surrounded by coils or windings 16 of wire. The windings 15 and 16 may be connected in series with each other and are provided with output leads 17 and 18 which may be connected to a suitable load. The useful output of the generator is supplied to the load by way of the leads 17 and 18, but of course it will be understood that the windings 15 and 16 may be connected in other conventional manners. Also, it will be understood by those skilled in the art that the laminated cores 10*a* and 10*b* may have other known configurations and the windings 15 and 16 may be wound or disposed in conventional patterns employed in alternating current generators.

Mounted between the poles 11 and 12 is an arc chute 19 which comprises (FIG. 3) insulating walls 20—23 and a pair of plate like electrodes 24 and 25 mounted against the insulating walls 20 and 22. The walls 20—23 form a gas tight enclosure or chute 19 between the poles 11 and 12, and the electrodes 24 and 25 preferably extend the length of the chute and hence the length of the cores 10*a* and 10*b*.

A pair of arc striking electrodes 26 and 27 are mounted at one end of the chute 19 and are electrically connected to the electrodes 24 and 25. A conventional voltage source 28, such as a conventional direct current source, is electrically connected to the electrodes 24 and 25 and hence to the arc striking electrodes 26 and 27. The voltage and capacity of the source 28 are sufficient to produce an arc, such as the arc 29 (FIG. 3), between the close portions of the electrodes 26 and 27 and to maintain the arc between the electrodes 24 and 25 during the operation of the generator. In addition, the capacity and characteristics of the source 28 are sufficient to produce an arc current between the electrodes 24 and 25 of a magnitude which will produce the desired output voltage and current at the leads 17 and 18.

The left hand end of the chute 19 as viewed in FIG. 1 is connected by a gas tight duct 30 to a source of gas under pressure 31. The gas supplied by the source 31 may be air, but if desired, it may alternatively be an alkali metal gas, such as sodium, which has a lower ionization potential. The pressure of the gas supplied by the source 31 is dependent upon the desired frequency of the voltage supplied at the output of the generator and the magnitude of the arc current as will be explained hereinafter.

The right hand end of the chute 19 as viewed in FIG. 1 is connected to a gas tight duct 32 which in turn may be connected to a condenser or heat extractor 39 and to a pump 33. The gas enters the left hand end of the chute 19 at relatively high pressure and temperature and is removed from the right hand end of the chute 19 at a relatively low pressure and temperature. The duct 32 and the pump 33 are provided to permit recirculation of the gas which is supplied from the pump 33 to the source 31 by way of a duct or pipe 34.

The duct 32 has a slot 35 in one wall thereof which permits separation of the relatively hot ionized gas of the arc from the cooler gas supplied by the source 31. For this purpose a magnetic field indicated by the arrows 36 may be provided by any conventional means so as to deflect the hot ionized gases through the slot 35. The hot ionized gas flows from the slot to a heat extractor 37 which may be, for example, a heat exchanger or may be other apparatus which may be operated by the hot gases, such as a turbine.

The recirculation system illustrated in FIGS. 1 and 2 is important primarily when gases other than air are employed, and if air is employed, the pump 33 and the return pipe or duct 34 may be omitted, the gas reaching the duct 32 passing into the atmosphere or being otherwise used. Similarly, if it is not desired to recover the hot ionized gases of the arc, the slot 35 and the heat extractor 37 are unnecessary.

In the operation of the embodiment illustrated in FIGS. 1–3 an arc is struck as between the electrodes 26 and 27 by virtue of the connection of the voltage source 22 thereto. As used herein, the term "arc" refers to a high density electric current flow in an ionized gas which is at least partly surrounded by cooler, non-ionized gas and which is relatively small in cross section as compared to the distance through which it is moved as described hereinafter. Preferably, the magnitude of the arc current is such that the arc substantially fills the cross section of the chute 19, that is, fills the space between the electrodes 24 and 25 and the walls 21 and 23. Preferably, also, the magnitude of the arc current is sufficient to cause the arc to more than fill the cross section of the chute 19 so that the arc is elliptical in a cross section taken transversely of the length of the arc between the electrodes 24 and 25 as illustrated at 29*a* in FIG. 1. In this way, the arc acts as a piston within the arc chute 19 and is driven by the gas from the source 31 from the left hand of the chute 19 as viewed in FIG. 1 to the right hand thereof.

It will be noted that the electrodes 24 and 25 terminate at the right hand of the chute 19 as viewed in FIGS. 1 and 2, and hence substantially at the right end of the cores 10*a* and 10*b*. When the arc is driven by the gas of the source 31 to the right hand ends of the electrodes 24 and 25 and beyond, the arc is extinguished because either the voltage of the source 28 is insufficient to maintain the arc between the electrodes 24 and 25, the arc being bowed or extended to the right because of the gas flowing through the arc chute 19 from the source 31 or because the ionized gas of the arc is cooled sufficiently to prevent further maintenance of the arc, or both.

It is apparent to those skilled in the art that the gas within the arc is at a relatively high temperature and may for example be at a temperature exceeding 5000° F. However, the arc constitutes a small percentage of the gas flowing through the chute and is in contact with any portions of the walls 21 and 23 and the electrodes 24 and 25 for only short intervals of time, the arc passing rapidly from one end of the chute 19 to the other depending upon the pressure of the gas supplied by the source 31. The velocity of the arc through the chute 19 may, for example, be at the rate of several hundred or more feet per second.

When the arc is extinguished just beyond the right hand end of the chute 19, a new arc is immediately thereafter struck between the electrodes 26 and 27 because of the continuous connection of the voltage source 28 thereto, and a new arc repeats the cycle described above.

The gas supplied from the source 31 is not ionized, neglecting incidental ionization, and may even be at room temperature. However, if desired, the gas of the source 31 may be heated to a temperature of several hundred degrees F. but below the ionizing temperature of the gas to assist in producing an arc between the electrodes 26 and 27, to aid in the production of the desired gas pressure, and to make it easier to maintain the arc between the electrodes 24 and 25. However, it is unnecessary to raise the temperature of gas from the source 31 to the relatively high temperatures employed in prior art devices because it is not necessary to completely fill the chute 19 with ionized gas. Accordingly, the components of the generator are not continuously subjected to the relatively high temperatures of the prior art devices, and the components are subjected to cooler gases during the relatively long intervals between the passing of successive arcs. For these reasons, a wider selection of materials is available and the cooling problems are simplified. Furthermore, higher ionized gas temperatures (in the arc) may be employed resulting in greater efficiency as a conductor.

It will be apparent to those skilled in the art that the arc between the electrodes 24 and 25 acts in the same manner as a current carrying conductor, and therefore, as it moves down the length of the chute 19, it induces an alternating voltage in the windings 15 and 16 because of the magnetic field associated with the arc in the same manner that an alternating voltage is induced in the stator windings of an alternator when the energized rotor thereof is rotated. Accordingly, the frequency of the output voltage of the generator is dependent upon the velocity at which the arc moves through the chute 19 and the spacing between successive poles in the direction of movement of the arc, whereas the magnitude of the output voltage of the generator is dependent upon the velocity at which the arc moves through the chute 19 and the magnitude of the arc current. It will be apparent also from a consideration of the foregoing that in order to produce an alternating voltage in the windings 15 and 16, the width of the arc between the electrodes 24 and 25 in the direction of movement of the arc should be less than the distance between corresponding points on a pair of adjacent poles 11 or 12, and preferably, the width of the arc in the direction of the movement thereof is substantially less than the width of the face of poles 11 or 12, for example, less than one-quarter of the distance

across the face of poles 11 or 12 in the direction of movement of the arc.

Although I have illustrated four poles 11 on one side of the arc chute 19 and four poles 12 on the opposite side of the arc chute 19, it will be apparent to those skilled in the art that a greater or lesser number, preferably an even number, of poles and associated windings may be employed. Also, each pair of opposed poles 11 and 12 may have only a single winding associated therewith, windings 16, for example, being omitted.

The arc striking electrodes 26 and 27 having portions relatively close to each other, have been provided to reduce the magnitude of the voltage required to strike an arc initially, and to cause the arc to strike initially near the entrance end of the chute 19. It is well known to those skilled in the art that the voltage required to initially strike an arc is substantially greater than the voltage necessary to maintain the arc after it has been struck. For this reason, the spacing between the electrodes 24 and 25 may be substantially greater than the spacing of the portions of the electrodes 26 and 27 between which the arc is initially developed. However, it will be understood that if desired, the spacing between the relatively close portions of the arc striking electrodes 26 and 27 may closely approach the spacing between the electrodes 24 and 25, a higher voltage being required to strike the arc initially.

The embodiment illustrated in FIGS. 4 and 5 utilizes an arc to develop direct current as opposed to a sheet of ionized gas as in prior art. The device bears resemblance to the device of FIGS. 1–3 in that an arc is driven through a chute but a different method of energizing the arc and abstracting energy from the arc is employed. In the embodiment illustrated in FIGS. 4 and 5 the arc passes between the faces of the poles 40 and 41 of a magnetic core 42 having an energizing winding 43 on one leg thereof. The winding 43 is energized from a direct current source (not shown) so as to produce a magnetic field extending between the faces of the poles 40 and 41. Preferably, the core 42 is energized by means of the winding 43 so as to produce a relatively high magnetic field flux density between the faces of the poles 40 and 41, but it will be understood that, in some cases, the core 42 may be permanently magnetized and therefore the winding 43 may be omitted.

An arc chute 19 which may be the same as the arc chute 19 described above is mounted between the faces of the poles 40 and 41 and includes electrodes 24 and 25. Arc striking electrodes 26 and 27 are also provided at the entrance end of the chute 19 for the purposes of striking an arc as hereinafter described. The useful output of the generator is supplied to a load 44 by way of leads 45 and 46 connected to the electrodes 24 and 25.

The output of a conventional pulse generator 47 is coupled in series with the load 44 and to the electrodes 24 and 25 by transformer 48 having its primary winding 49 connected to the output of the pulse generator 47 and having its secondary winding 50 connected at one end to the load 44 and connected at the other end to the electrode 25 by way of the lead 45. Preferably, the load 44 presents a low impedance to the pulse generated by the pulse generator 47, but if the load 44 does not have such an impedance, it may be by-passed by a capacitor, such as the capacitor 51.

The magnitude of the pulse supplied to the electrodes 26 and 27 by the pulse generator 47 through the transformer 48 is sufficient to strike an arc between the electrodes 26 and 27. The pulse generator 47 is triggered or synchronized by a conventional trigger circuit 52 whose input is connected to the electrodes 24 and 25 by way of the leads 53, 54, 45 and 46 and whose output is connected to the input of the pulse generator by the leads 55 and 56. The trigger circuit 52 provides a triggering pulse to the pulse generator 47 when the voltage between the electrodes 24 and 25 decreases below a predetermined

value which is less than the magnitude of the voltage required to maintain an arc between the electrodes 24 and 25, and the trigger circuit 52 may be either amplitude sensitive or sensitive to rates of change of voltage greater than a predetermined rate.

In operation, an arc is initially struck between the closest portions of the arc striking electrodes 26 and 27 and then the arc is forced to the right as viewed in FIG. 4 by the gas supplied from the source 31. When the arc then enters the entrance end of the chute 19, it enters the magnetic field between the poles 40 and 41 and then continues along to the chute 19 to the exit end thereof where it extinguishes in a manner described in connection with FIGS. 1–3. The polarity of the magnetic field between the faces of the poles 40 and 41 is such as to induce a voltage in the arc by generator action when it is between the faces of the poles 40 and 41, and the velocity of the arc along the length of the chute 19 as well as the strength of the magnetic field is such that the voltage produced in the moving arc by the magnetic field is more than adequate to maintain the arc between the electrodes 24 and 25.

The time duration of the pulse supplied by the pulse generator 47 is substantially equal to the length of time required for the arc to move from the point between the electrodes 26 and 27 at which the arc is initially struck to a point within the magnetic field between the poles 40 and 41 at the entrance end of the chute 19. Accordingly, the pulse supplied by the pulse generator 47 maintains the arc until it is within the magnetic field where the voltage induced in the arc is sufficient to maintain the arc between the electrodes 24 and 25 even though the pulse supplied by the generator 47 has terminated. As mentioned above, the trigger circuit 52 is insensitive to the initiation or termination of the pulse by the pulse generator 47 but is operated when the voltage between the electrodes 24 and 25 drops due to extinguishment of the arc between the electrodes 24 and 25 at the exit end of the chute 19. Accordingly, immediately after the arc is extinguished at the exit end of the chute 19, the trigger circuit 52 causes the generation of a further pulse by the pulse generator 47 and, hence, causes a new arc to be struck between the electrodes 26 and 27.

Because of the movement of the arc through the chute 19 and hence through the magnetic field of the poles 40 and 41 electrically charged ions of the arc will flow along the length of the arc and between the electrodes 24 and 25 in a manner well known to those skilled in the art. Similarly, while the arc is moving along the length of the chute 19, current will be supplied to a load, such as the load 44, connected to the electrodes 24 and 25. However, the current will be a direct current interrupted for short intervals between the time that one arc becomes extinguished and a new succeeding arc enters the magnetic field between the poles 40 and 41.

In other respects the operation of the embodiment shown in FIGS. 4 and 5 is similar to the operation of the embodiment shown in FIGS. 1 and 3. In particular, it will be noted that the components of the generator are not subject continuously to relatively high temperatures, the components being subjected to the hot ionized gas of the electric arc for only short periods of time and being cooled for relatively long intervals of time by the gas supplied by the source 31. Accordingly, only relatively small portions of the generator need be made of materials able to withstand relatively high temperatures and even these portions need not withstand relatively high temperatures continuously.

Having thus described my invention with particular reference to the preferred form thereof and having shown and described certain modifications, it will be obvious to those skilled in the art to which the invention pertains, after understanding my invention, that various changes and other modifications may be made therein without

departing from the spirit and the scope of my invention, as defined by the claims appended thereto.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method for converting mechanical energy into electrical energy comprising generating an electrical arc, forcing said arc along a predetermined path by subjecting said arc to a flowing gas and abstracting electrical energy from said arc as it moves along said path.

2. A method for converting mechanical energy into electrical energy comprising generating an electrical arc, forcing said arc through a magnetic field and along a predetermined path extending transversely to said field by subjecting said arc to a flowing gas and removing electrical energy from opposite ends of said arc as it moves along said path.

3. A method for converting mechanical energy into electrical energy comprising generating an electrical arc, forcing said arc along a predetermined path by subjecting said arc to a flowing gas and abstracting energy from the magnetic field of said arc as it moves along said path.

4. An electrical generator comprising a pole having a face, a pair of spaced electrodes mounted adjacent said face of said pole, said electrodes extending across said face and being spaced with respect to each other in a direction extending substantially parallel to said face, means connected to said electrodes for producing an electric arc between predetermined portions of said electrodes and means for moving said arc along said electrodes comprising means for forcing a gas along said electrodes and therebetween.

5. An electrical generator comprising means for producing a magnetic field including a pole having a face, said magnetic field extending outwardly from said face, a pair of spaced electrodes mounted adjacent said face of said pole, said electrodes extending across said face and transversely to said field and being spaced with respect to each other in a direction extending transversely to said field, means connected to said electrodes for producing an electric arc between predetermined portions of said electrodes and means for moving said arc along said electrodes comprising means for forcing a gas along said electrodes and therebetween.

6. An electrical generator comprising a pole having a face, a load winding around said pole, a pair of spaced electrodes mounted adjacent said face of said pole, said electrodes extending across said face and being spaced with respect to each other in a direction extending substantially parallel to said face, means connected to said electrodes for producing an electric arc between predetermined portions of said electrodes and means for moving said arc along said electrodes comprising means for forcing a gas along said electrodes and therebetween.

7. An electrical generator comprising a pair of poles each having a face and mounted with said faces adjacent but spaced from each other, a load winding around at least one of said poles, a pair of spaced electrodes mounted between said faces of said poles, said electrodes being spaced with respect to each other in a direction extending parallel to at least one of said faces, means connected to said electrodes for producing an electric arc between predetermined portions of said electrodes and means for moving said arc along said electrodes comprising means for forcing a gas along said electrodes and between said electrodes and said faces.

8. An electrical generator comprising a pair of adjacent electrodes spaced apart in a predetermined direction, means for producing an electric arc between adjacent ends of said electrodes, gas means for blowing said arc along said electrodes from said ends thereof toward the opposite ends thereof, magnetic core means having a pair of poles on opposite sides of the space between said electrodes, said poles being aligned with each other and being spaced from each other in a direction extending transversely to the direction of spacing of said electrodes, and a winding encircling said core means.

9. An electrical generator comprising magnetic core means having a plurality of aligned pairs of opposed poles, the faces of each pair of opposed poles being separated by a predetermined distance, a winding encircling at least one of each of said pairs of poles, an arc chute mounted between said faces, a pair of electrodes mounted in said chute and spaced from each other on opposite sides of the centers of said opposed and aligned poles, means for striking an electric arc between said electrodes at one end of said chute, said arc having a cross section taken substantially parallel to said electrodes substantially equal to said distance but less than the dimension of a pole face in a direction parallel to a pole face, and means for forcing said arc along said chute comprising means for blowing a gas along said chute from said one end thereof toward the opposite end thereof.

10. An electrical generator comprising magnetic core means having a plurality of aligned pairs of opposed poles, the faces of each pair of opposed poles being separated by a predetermined distance, windings encircling said poles, a gas tight arc chute mounted between said faces, a pair of electrodes mounted in said chute and spaced from each other on opposite sides of the centers of said opposed and aligned poles, said electrodes extending adjacent the faces of all said poles, means including a voltage source connected to said electrodes for striking an electric arc between said electrodes at one end of said chute, said arc having a cross section taken substantially parallel to said electrodes at least equal to said distance but less than the dimension of a pole face in a direction parallel to a pole face, and means for forcing said arc along said chute comprising means for blowing a gas along said chute from said one end thereof toward the opposite end thereof.

11. An electrical generator comprising a pair of adjacent electrodes spaced apart in a predetermined direction, means for producing an electric arc between adjacent ends of said electrodes comprising a pulse generator having its output coupled to said electrodes, and trigger circuit means having its input connected to said electrodes and responsive to a voltage less than a predetermined value between said electrodes for generating a trigger voltage, means supplying said trigger voltage to said pulse generator, said pulse generator being responsive to said trigger voltage for supplying an output pulse to said electrodes, gas means for blowing said arc along said electrodes from said ends thereof toward the opposite ends thereof, and magnetic core means having a pair of poles on opposite sides of the space between said electrodes and having means for producing a magnetic field between said poles, said poles being aligned with each other and being spaced from each other in a direction extending transversely to the direction of spacing of said electrodes.

12. An electrical generator comprising a pair of adjacent electrodes spaced apart in a predetermined direction, means for producing an electric arc between adjacent ends of said electrodes including a source of voltage connected to said electrodes, gas means for blowing said arc along said electrodes from said ends thereof toward the opposite ends thereof, and magnetic core means having a pair of poles on opposite sides of the space between said electrodes and having means for producing a magnetic field between said poles, said poles being aligned with each other and being spaced from each other in a direction extending transversely to the direction of spacing of said electrodes.

No references cited.