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MAGNETOHYDRODYNAMIC GENERATORS
Filed March 25, 1964

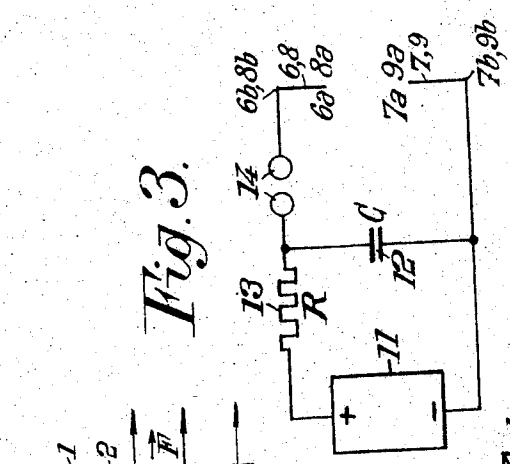


Fig. 3.

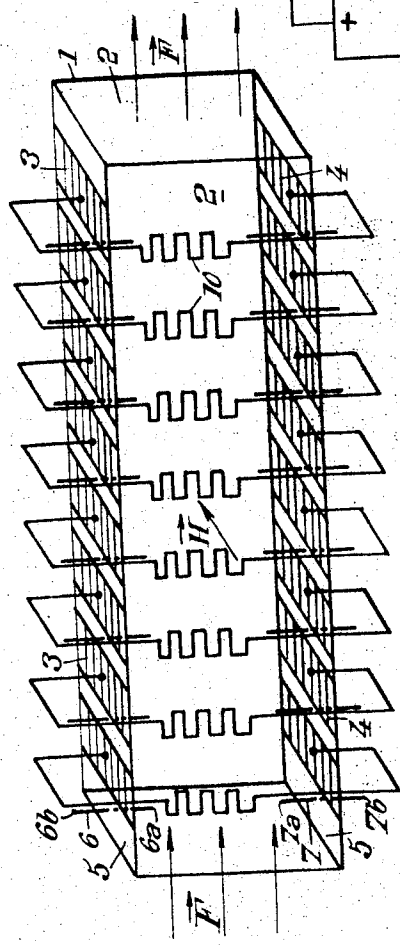


Fig. 1.

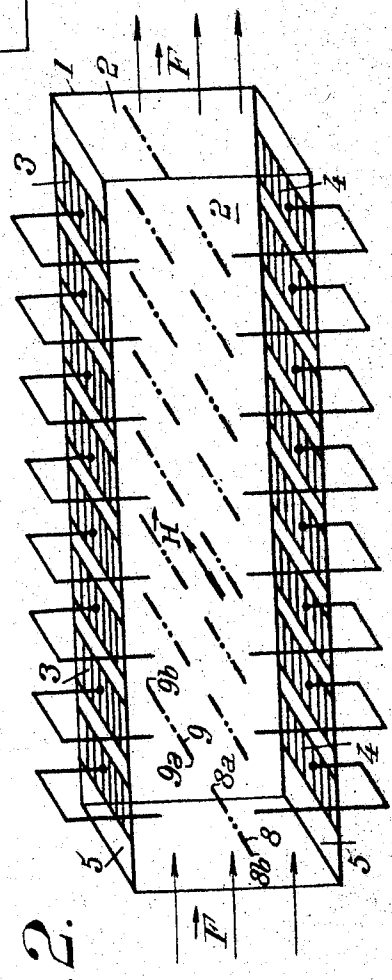


Fig. 2.

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MAGNETOHYDRODYNAMIC GENERATORS

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The present invention relates to methods and devices for producing a strongly ionized gaseous stream and in particular an ionized gaseous stream intended to produce available electric current in a generator of the magnetohydrodynamic type.

The chief object of the present invention is to improve the efficiency and uniformity of ionization in a magnetohydrodynamic generator.

The invention is concerned with a method of producing or increasing the ionization of a gaseous stream, by the application of a succession of luminescent discharges or arcs, of relatively short duration in several localized zones of said gaseous stream.

For producing or increasing the ionization of a gaseous stream flowing through a conduit of a magnetohydrodynamic generator, we provide in said conduit, in combination, a series of pairs of ionization electrodes carried by the walls of said conduit and disposed in such manner that the discharge ends of every pair are located opposite each other inside said conduit in said gaseous stream, and means for applying between the feed ends of every pair, which are disposed outside said conduit, voltage pulses, having a sufficient amplitude to start discharges or arcs between the corresponding discharge ends.

In a preferred embodiment the ionization electrodes are disposed in such manner that the straight lines defined by the couples of discharge ends of every pair of said electrodes are substantially parallel to the direction of the magnetic field, generally provided in a magnetohydrodynamic generator, thereby providing for a given quantity of ionizing energy, a higher degree of ionization than when these straight lines make a substantial angle with said direction.

Preferred embodiments of our invention will be hereinafter described with reference to the appended drawings, given merely by way of example, and in which:

FIG. 1 diagrammatically shows in perspective view an embodiment of a conduit, belonging to a magnetohydrodynamic generator, through which flows a gaseous stream, this conduit being made according to our invention;

FIG. 2 is a view similar to FIG. 1 corresponding to another embodiment of the invention;

FIG. 3 shows an example of means for applying voltage pulses.

In FIGS. 1 and 2, it will be supposed that a gaseous, preferably hot, stream $\vec{F}$ flows at high speed through a conduit **1** (for instance of square or rectangular cross section) made of an insulating material (for instance glass). This conduit belongs to a magnetohydrodynamic generator and is located in a substantially uniform magnetic field $\vec{H}$ (for instance perpendicular to the side walls **2** of conduit **1**). This conduit carries a series of pairs of collecting electrodes **3**, **4** for collecting positive and negative electric charges, these electrodes being disposed with their faces parallel to the magnetic field $\vec{H}$ and to the direction

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of the gaseous stream $\vec{F}$, for instance on the side walls **5** of conduit **1**. The electric voltage thus created is to be used in load resistors **10** shown in FIG. 1, but not shown in FIG. 2 in order to simplify it.

According to the present invention, ionization of gaseous stream $\vec{F}$ as it flows in conduit **1** is obtained or increased by producing a series of luminescent discharges or arcs, of relatively short duration, in several localized zones of said gaseous stream (conduit **1**).

The discharges or arcs ionize the gaseous stream inside conduit **1** by producing on the one hand negative electrons and on the other hand positive ions. These electrons and ions diffuse through the fluid stream and tend to be distributed therein in a substantially uniform manner if said localized zones are sufficiently close to one another. After some milliseconds, the negative electrons and the positive ions recombine; however if the discharges or arcs are sufficiently frequent (for instance if the frequency of repetition is higher than 1000 cycles per second), it is possible to obtain a substantially statistic equilibrium, the number of ion-electron pairs in a given volume remaining substantially constant inside a given volume, during the operation of generator.

Furthermore, if the gaseous stream contains an easily ionizable substance, in particular an alkaline metal such as cesium, in the powdery or vapor state for instance, the discharges or arcs ionize not only the gas of the gaseous stream but also said substance, thereby producing or increasing the ionization of the whole body of the gaseous stream with a satisfactory efficiency.

According to the present invention, said arcs are produced by means of voltage pulses having a sufficient amplitude to produce discharges or arcs between the discharge ends **6***a*, **7***a*, or **8***a*, **9***a* of a series of pairs of ionization electrodes **6**, **7** (FIGURE 1) or **8**, **9** (FIGURE 2) which are distinct from the collecting electrodes **3**, **4** and carried by the side walls **5** (in the embodiment of FIGURE 1) or **2** (in the embodiment of FIGURE 2) of conduit **1**. Said discharge ends of every pair of ionization electrodes are located opposite each other in the gaseous stream inside conduit **1**. Said voltage pulses are applied (means not shown) between every pair of input ends **6***b*, **7***b*, or **8***b*, **9***b* located outside conduit **1**.

The distance between the ionization electrodes of every pair is advantageously substantially equal to the distance between the walls of conduit **1** that carry said electrodes, whereby these electrodes do not protrude substantially inside conduit **1**. If these electrodes protruded substantially they would be eroded by the generally hot gas flowing through said conduit.

The frequency of repetition of the arcs is chosen in accordance with the speed of recombination of ions and electrons. It may for instance average 1000 cycles per second.

Preferably, as illustrated in FIG. 2, the ionization electrodes **8** and **9** are disposed in such manner that the straight lines defined by the couple of discharge ends **8***a*, **9***a* of every pair are substantially parallel to the direction of the magnetic field $\vec{H}$, thereby producing for a given ionizing energy, a more intensive ionization than when these lines make a substantial angle with said direction, because the passage of the ionizing electric current is easier in a direction parallel to the magnetic field than transversely to said direction.

The means for applying the voltage pulses may consist of systems analogous to those serving to produce shock waves. Electronic units, for instance comprising thyratrons, may be brought into play for applying the voltage pulses generated by said systems to the different ionization electrodes, either simultaneously or successively. We may also use, for every pair of ionization electrodes the device for producing shock waves, of a type known per se, illustrated in FIG. 3. Such a device comprises:

(a) a first circuit, or charging circuit, consisting of a high voltage source **11** (advantageously common to all the circuits for the different pairs of ionization electrodes), a capacitor **12** and a resistor **13**, capacitor **12** being gradually charged by source **11** through resistor **13** during a first phase; and

(b) a second circuit, or discharge circuit, comprising, in addition to capacitor **12**, a spark gap **14**, this second circuit serving to feed the ends **6***b*, **7***b* or **8***b*, **9***b* of a pair of ionization electrodes **6**, **7**, or **8**, **9**, respectively. The ionized gaseous stream that flows between the discharge ends **6***a*, **7***a* or **8***a*, **9***a* of the electrodes closes the electric circuit between these discharge ends. When capacitor **12** has been charged, at the end of the first phase of operation, to a sufficiently high potential difference, a spark is produced in spark gap **14** and a discharge takes place between the ends **6***a*, **7***a* or **8***a*, **9***a*. This is the second phase of operation, which constitutes, with the first phase, a cycle of operation of the device.

A new cycle (charging of capacitor **12** by the first circuit and discharging of said capacitor **12** by the second circuit with prodution of discharges at **6***a*, **7***a* or **8***a*, **9***a*) starts then again and so on, the capacitance C of capacitor **12** determining the duration of the discharges in the gaseous stream between the ionization electrodes, whereas the product CR (R being the resistance of resistor **13**) determines the frequency of the discharges.

If it is desired to obtain an ionization which is substantially uniform in space and in time inside conduit **1**, i.e., a constant density of ionization in each small volume of the fluid stream during operation, then the successive pairs of ionization electrodes should be located sufficiently close to one another and the voltage pulses should be produced with a frequency of repetition sufficiently great to obtain a substantially homogeneous and constant statistic distribution of the electrons and of the ions inside the conduit during operation.

It is thus possible to bring the electric conductivity of a gaseous stream intended to supply electric current in a magnetohydrodynamic machine (said stream consisting for instance of argon with 0.1% of potassium, under atmospheric pressure at a temperature of 2000° K.) to a value ranging from about ten to several hundreds of mhos per meter, for instance equal to about fifty mhos per meter.

The present invention permits the production or increase of the ionization of a gaseous stream.

We may also apply the invention to varying the mean conductivity of a gaseous stream. In order to obtain such a variation, the frequency of repetition of the discharges of arcs is varied by varying the frequency of repetition of the voltage pulses applied to the feed or input ends **6***b*, **7***b* or **8***b*, **9***b* of the ionization electrodes **6**, **7** or **8**, **9**.

It is even possible to modulate the mean conductivity of a gaseous stream, by modulating the frequency of repetition of the discharges or arcs.

The present invention has, over prior methods and devices, many advantages in particular as follows:

First it permits the ionization of a gaseous stream in a simple and efficient manner.

It permits the varying of the conductivity of a gaseous stream by varying the degree of ionization.

The ionization method and means according to the present invention are therefore quite different from the prior methods and means, in particular from that disclosed in the U.S. Patent No. 3,080,515 issued on March 5, 1963, to Edward Charles Kehoe according to which there is created, by means of a single arc, a single conductor localized at a given time and which is displaced along a conduit. On the contrary, according to the present invention, we produce an ionization distributed in the whole volume of gas, in particular in the whole of the conduit **1** of a magnetohydrodynamic generator.

It follows that, in the method and device disclosed by said U.S. Patent No. 3,080,515, the electrodynamic forces are exterted on a thin slice of gas whereas, according to the present invention, the electrodynamic forces are distributed throughout the gaseous volume, in particular conduit **1**. As a consequence, for a given flow rate and for a given extracted power, the length of a magnetohydrodynamic generator according to the present invention may be shorter than that of a generator made according to the U.S. Patent No. 3,080,515. The reduction of length of the conduit and the other advantages of a ionization distributed in a substantially uniform manner throughout the volume owing to the present invention are very important from a technical point of view, in particular the heat losses along the walls are reduced when the length of the conduit is shorter.

In a general manner, while we have, in the above description, disclosed what we deem to be practical and efficient embodiments of our invention, it should be well understood that we do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of our invention as comprehended within the scope of the appended claims.

What we claim is:

1. In a magnetohydrodynamic generator:

an elongated conduit made of an electrically insulating material and adapted to be traversed by a hot gaseous stream containing constituents ionizable in positively and negatively charged fragments;

means for producing inside said conduit a substantially uniform magnetic field substantially perpendicular to the longitudinal direction of said elongated conduit;

a plurality of pairs of substantially flat collecting electrodes secured against the inside wall of said conduit, the two collecting electrodes of each pair being disposed in a confronting position with the flat surfaces thereof substantially parallel to the longitudinal direction of said elongated conduit and to said magnetic field, and being connected, outside said conduit, through a utilization load;

a plurality of pairs of substantially elongated ionization electrodes carried by and traversing the wall of said conduit, and electrically insulated from said collecting electrodes, each of said ionization electrodes having a discharge end located inside said conduit and a feed end located outside said conduit, the discharge ends of the two ionization electrodes of each pair being disposed in a confronting position, with the direction of the straight line connecting said discharge ends of the two ionization electrodes being substantially perpendicular to the longitudinal direction of said elongated conduit;

and means for applying in operation, between the feed ends of the two ionization electrodes of each pair, voltage pulses having a sufficient amplitude to produce arcs between the discharge ends of said two electrodes through said gaseous stream flowing in operation through said conduit in the longitudinal direction thereof.

2. A magnetohydrodynamic generator as claimed in claim **1**, wherein the straight line connecting the discharge ends of the two ionization electrodes of each pair is substantially parallel to said magnetic field.

3. A magnetohydrodynamic generator as claimed in claim **1**, wherein said discharge ends of said ionization

electrodes are substantially flush with the inside wall of said conduit.

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