March 11, 1969 JEAN-LOUIS CHEVALLEY 3,432,692

MAGNETO-HYDRODYNAMIC GENERATORS

Filed Aug. 19, 1966

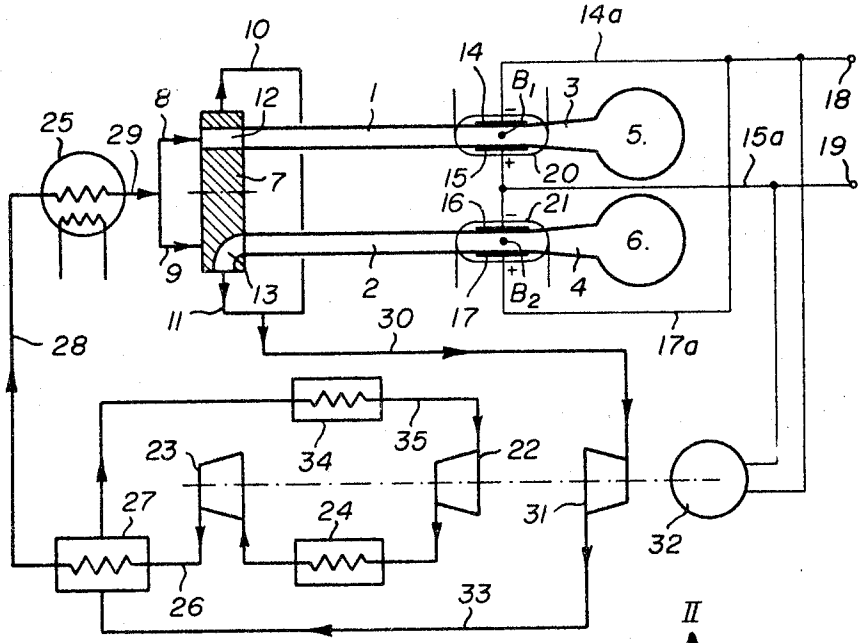


FIG. 1

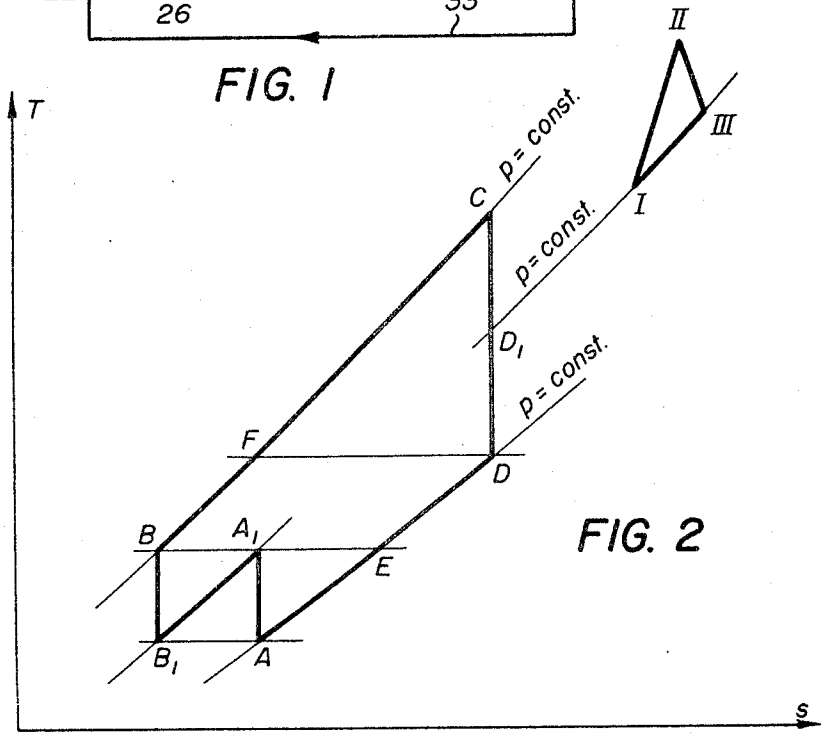


FIG. 2

United States Patent Office 3,432,692
Patented Mar. 11, 1969

3,432,692

MAGNETO-HYDRODYNAMIC GENERATORS

Jean-Louis Chevalley, Carouge, Geneva, Switzerland, assignor to Eric Brocher, Chenebougerie, Geneva, Switzerland

Filed Aug. 19, 1966, Ser. No. 573,662
Claims priority, application Switzerland, Aug. 26, 1965, 12,015/65
U.S. Cl. 310—11 4 Claims
Int. Cl. H02k 45/00

ABSTRACT OF THE DISCLOSURE

A magneto-hydrodynamic generator comprising at least one pair of shock tubes is provided, there being a reservoir of working fluid communicating with each tube at one end, a source of heated and compressed auxiliary fluid connected to the other end of the tubes via a cyclically controlled distributor, at least one pair of parallel electrodes arranged within each tube on oppositely arranged wall portions of its inner surface, adjacent the end communicating with the reservoir of working fluid, and means producing in each tube a transverse magnetic field parallel to said electrodes. The distributor is adapted to introduce the auxiliary fluid alternately into the tubes of the pair and to discharge said fluid after a predetermined lapse of time. The electrodes are connected to output terminals so as to obtain an alternating voltage whose period is formed by two alternations each produced by one tube of the pair.

The present invention relates to a magneto-hydrodynamic generator.

As is known, the efficiency of a magneto-hydrodynamic generator depends on the conductivity of its work fluid, which conductivity depends in particular on temperature. The method and apparatus disclosed in copending application Ser. No. 359,874 of Eric Brocher and Walter Dallenbach, filed Apr. 15, 1964, and on which Patent No. 3,350,584 since has issued, have the great advantage of enabling the use of an economic source of heat to heat a compressed auxiliary fluid and the work fluid of the generator, and of raising the temperature of the work fluid, through shock wave compression, to a working temperature which is substantially greater than that of conventional heat sources.

This, however, involves the use of cyclically controlled distributors to control the introduction and discharge of the fluids so as to produce shock wave compressions in order to yield trains of ionised work fluid pulses. Clearly, the production of alternating electric energy by means of these pulse trains will thus necessitate distributors whose opening cycle is repeated at a frequency corresponding to that of the alternating current being produced. Multi-way rotary distributors are well suited for this purpose. As is known, movable mechanical elements are far more liable to damage caused by high temperature than stationary elements.

An object of the present invention is to provide a magneto-hydrodynamic generator capable of operating at temperatures far exceeding those of conventional heat sources, in which the number of movable mechanical elements that are exposed to such temperatures is reduced to a minimum.

The generator according to the present invention is intended to enable constant load operation at temperatures of about or greater than 3000° C., and comprises at least one pair of shock tubes each communicating at one of its ends with a reservoir adapted to contain the work fluid of said generator, a source of heated and compessed auxiliary fluid connected to the other end of said tubes via a cyclically controlled distributor, said distributor being adapted to introduce the auxiliary fluid alternately into the tubes of said pair and to discharge said fluid after a predetermined lapse of time, each of said tubes being provided, near the end thereof connected to the work fluid reservoir, with at least two parallel electrodes so disposed as to form two opposite faces of its inner wall and with means for producing a magnetic field parallel to the electrodes and transverse to the tube, the electrodes of said one pair of tubes being connected to the output terminals of the generator so as to obtain thereat an alternating voltage whose period is formed by two alternations which are each produced by one tube of said one pair.

In the accompanying drawings:

FIGURE 1 is a schematic representation of an embodiment of the invention generator operating in a closed cycle; and

FIGURE 2 shows, by means of an entropy diagram indicating absolute temperature T and pressure p as a function of entropy S, the thermodynamic cycles of the work fluid and of the auxiliary fluid in the generator of FIGURE 1.

The generator shown in FIGURE 1 comprises a pair of parallel shock tubes **1** and **2** connected at one end by diffusers **3** and **4** to reservoirs **5** and **6** each containing an equal amount of work fluid. The temperature and pressure of this fluid may have any suitable initial value. At the other end of tubes **1** and **2**, i.e., at their input, a rotary distributor **7** is provided for alternately and cyclically connecting these tubes with one of a pair of conduits **8** and **9** for introducing a heated and compressed auxiliary fluid and with one of a pair of conduits **10** and **11** for discharging the expanded auxiliary fluid.

The distributor **7** consists here of a disc which is disposed symmetrically opposite the inlets of tubes **1** and **2** and which cooperates with drive means (not shown) for rotating it at a predetermined speed about an axis which is contained in a plane common to the axes of tubes **1** and **2** and parallel thereto. The disc **7** is formed with two passages **12** and **13**, passage **12** serving to establish communication successively between tube **1** and conduit **8** and bewteen tube **2** and passage **9** and passage serving to establish communication successively between tube **2** and conduit **11** and between tube **1** and conduit **10** for the introduction and discharge of the auxiliary fluid. In the position illustrated in this figure, passage **12** lies between the inlet conduit **8** and tube **1** to enable the inflow of compressed and heated auxiliary fluid into the latter. At the same time passage **13** lies between the outlet conduit **11** and tube **2** to enable the outflow of expanded auxiliary fluid from the latter. When the distributor has rotated through 180° in relation to the position illustrated in FIGURE 1, tube **2** will communicate via passage **12** with inlet conduit **9** and tube **1** will communicate via passage **13** with discharge conduit **10**. The disc **7** thus performs a cyclic operation which comprises for each tube the following phases:closure, introduction of auxiliary gas, closure, and discharge of auxiliary gas. The duration of the auxiliary gas introduction and discharge phases will of course depend on the peripheral width of the cross-sections of passages **12** and **13** and on the rotational speed of the disc **7**. It would thus be of advantage to provide means (not shown) for accurately adjusting said duration, for example means for varying the peripheral limits of said cross-sections, in order that the closure and through-flow phases can be adjusted to the various working conditions that are envisaged. Moreover, the rotational speed of the disc **7** is so chosen, for reasons given below, that it may carry out one revolution per cycle of the alternating current to be produced by the generator.

The tubes **1** and **2** are each provided, near the diffusers **3** and **4**, with two electrodes, respectively identified by

numerals **14, 15** and **16, 17**, which are disposed opposite one another and parallel to the tube axis. The electrodes **14, 15** and **16, 17** are mounted so as to be electrically insulated from the associated tube and so as to have their inner surfaces washed by the fluid flowing through this tube. Electrodes **14** and **17** are connected by leads **14***a* and **17***a* to the output terminal **18** of the generator and electrodes **15** and **16** are connected by leads **15***a* and **16***a* to the other output terminal **19** of the generator.

The tubes are further provided with electro-magnets whose windings **20** and **21** serve to produce magnetic fields B1 and B2 each of which is transverse to the axis of the associated tube and passes between the electrodes. The electro-magnets are so arranged that the two fields may be parallel—in the present instance at right angles to the plane of the drawing—and extend over the entire length of the electrodes.

The generator illustrated in FIGURE 1 comprises moreover two compressors **22** and **23**, with an intermediate cooler **24**, and a heat generator **25** for heating the compressed auxiliary fluid to a temperature of 1000 to 2000° C. A conduit **26** conveys the compressed auxiliary fluid from the compressor **23** to a recuperator **27** whence it is conveyed by a conduit **28** to the heat generator **25**. The heated and compressed auxiliary fluid then flows through conduit **29** into input conduits **8** and **9** and is alternately introduced, by the rotary disc **7**, as described above, into tubes **1** and **2**. The discharge conduits **10** and **11**, respectively associated with tubes **1** and **2**, open into a recycling conduit **30** leading to the inlet of an expansion turbine **31** driving compressors **22** and **23**. An electric motor **32** which, in the present instance, is supplied by the generator, serves to provide the additional energy required to drive these compressors. The auxiliary fluid flows from the turbine **31**, via a conduit **33**, the recuperator **27** and a cooler **34**, into the suction conduit **35** of compressor **22**.

The thermodynamic cycles carried out by the two fluids during operation of the above described generator are schematically represented in the entropy diagram of FIGURE 2.

The auxiliary fluid cycle comprises the following stages:

A–A_1: first compression in compressor **22**.
A_1–B_1: intermediate cooling in cooler **24**.
B_1–B: second compression in compressor **23**.
B–F: preheating in recuperator **27**.
F–C: heating in heat generator **25**.
C–D_1: first expansion in shock tubes **1** and **2**.
D_1–D: second expansion in turbine **31**.
D–E: first cooling in recuperator **27**.
E–A: second cooling in exchanger **34**.

The work fluid cycle comprises the following stages:

I–II: compression (and superheating) by shock wave in tubes **1** and **2**.
II–III: expansion by flowing between the generator electrodes **14, 15** and **16, 17**.
III–I: cooling due to heat losses through the walls of shock tubes **1** and **2**.

It should be noted that the cycles represented in FIGURE 2 are theoretical cycles and do not take into account the efficiencies of the compressors, of the turbine and of the exchangers. It will be observed that the temperature of the work fluid at point I is greater than that of the heat source **25**, i.e. than that of the auxiliary fluid at point C. This is due to the fact that cycle I, II, III shown in FIGURE 2 is that carried out under constant load conditions of the generator.

When starting the generator, the work fluid contained in reservoirs **5** and **6** and in tubes **1** and **2**, whose inlets are closed off by the disc **7**, can either be preheated by an external source, possibly indirectly by the heat generator **25**, or have any temperature, even ambient temperature. In the latter instance, the generator can be started under no load conditions in order to subject the fluid to a succession of compressions each followed by expansion so that it may gradually be heated up by the losses due to the irreversible nature of these two operations. Once the work fluid has reached the desired preheating temperature, the generator is loaded and the fluid begins to carry out working cycles with its temperature increasing at each cycle, until reaching a point at which this cyclic operation stabilizes itself under constant lead conditions as shown by points I, II, III in FIGURE 2. The stabilization level of this cyclic operation will depend on the cooling effect (III–I) that is obtained on the walls of the shock tubes. Although it is advantageous to carry out the work cycle at temperature levels which are as high as possible in order to improve the efficiency and the specific power of the generator, the problem of the resistance of materials to high temperature will require in certain cases the use of additional means for cooling the shock tubes in order that they may withstand very high temperatures better and in order to stabilize the work fluid cycle under constant load conditions at a temperature level which is very close to the limit imposed by the refractory materials being used.

I claim:

1. A magneto-hydrodynamic generator which comprises at least one pair of shock tubes each communicating at one of its ends with a reservoir adapted to contain the work fluid of said generator, a source of heated and compressed auxiliary fluid connected to the other end of said tubes via a cyclically controlled distributor, said distributor being adapted to introduce the auxiliary fluid alternately into the tubes of said pair and to discharge said fluid after a predetermined lapse of time, each of said tubes being provided, near the end thereof connected to the work fluid reservoir, with at least two parallel electrodes so disposed as to form two opposite faces of its inner wall and with means for producing a magnetic field parallel to the electrodes and transverse to the tube, the electrodes of said one pair of tubes being connected to the output terminals of the generator so as to obtain thereat an alternating voltage whose period is formed by two alternations which are each produced by one tube of said one pair.

2. A generator according to claim **1** wherein said distributor includes a rotary closure member comprising two passages which successively and cyclically connect one of the tubes of said one pair to an auxiliary fluid input conduit and the other tube of said one pair to a discharge conduit for said fluid.

3. A generator according to claim **1**, further comprising means for regulating the introduction and discharge time for the auxiliary fluid through said distributor.

4. A generator according to claim **1**, further comprising a recycling conduit for collecting the auxiliary fluid discharged from said tubes and for returning it to said source.

References Cited

UNITED STATES PATENTS

3,161,789 12/1964 Nagamatsu et al. ------ 310—11

DAVID X. SLINEY, *Primary Examiner.*