STAIRCASE ELECTRODE-WALL CONFIGURATION FOR MHD GENERATORS

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References Cited

U.S. PATENT DOCUMENTS

2,558,816 7/1951 Bruynes
2,618,903 7/1955 Keating, Jr
3,428,835 2/1969 Diung
3,660,701 5/1972 Blattman et al.
3,854,061 12/1974 Rosa

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ABSTRACT

A staircase electrode-wall configuration for a MHD generator which uses fluid dynamic means to protect the electrodes from substantial damage due to arcing and chemical attack. The electrode walls of a MHD generator duct have periodic conductor/insulator elements where channel divergence or convergence is accomplished in a stepwise fashion. The electrode is situated within the insulator of each element to be back-ward-facing so as not to be directly exposed to the hot gas flow. The turbulence which exists at the backward-facing electrode moves the arc spot about the surface to prevent severe local damage. Chemical attack is inhibited by a laminated electrode surface of a low corrosive material and the turbulence which aids in cooling the electrode face. Additional cooling may be obtained by a purge jet at the electrode face.

9 Claims, 2 Drawing Figures
CATHODE ELECTRODES INSULATOR

HOT FLOW

MHD DUCT

FIG. 1 (PRIOR ART)

CATHODE WALL (TOP)

ANODE WALL (BOTTOM)

FIG. 2

(PURGE GAS)
STAIRCASE ELECTRODE-WALL CONFIGURATION FOR MHD GENERATORS

BACKGROUND OF THE INVENTION

1. Field of the Invention
The present invention relates to magnetohydrodynamic (MHD) generators, and more particularly to a staircase electrode-wall configuration for MHD generators.

2. Description of the Prior Art
MHD power generation is of interest for the production of large amounts of electricity. However, MHD generators have a limited lifetime due to electrode-wall erosion which hampers their practical application. The electrodes function in a high temperature, corrosive environment, resulting in chemical reactions, erosion, etc. which erode and otherwise cause failure to the electrodes. This necessity to prolong electrode and insulator lifetimes in the MHD generator has resulted in a variety of electrode-wall designs (see for example Heywood and Womak, Open-Cycle MHD Power Generation, Chapter 7, Pergamon Press, Oxford, 1969).

A typical electrode-wall configuration is shown in FIG. 1 where the electrodes alternate with insulators, with the electrode face flush with the inner wall of the MHD duct. The current, J, flows from the anode to the cathode in the presence of the magnetic field, B, and the hot gas flow. The current causes arc spots at the anode, particularly, and together with the turbulent hot gas flow this results in chemical reactions at the electrode/insulator interface which erode the electrodes. Also, the hot plasma may deposit seed or slag which disrupts the electrode function.

SUMMARY OF THE INVENTION
Accordingly, the present invention provides a staircase electrode-wall configuration for MHD generators which uses fluid dynamic means to protect the electrodes from substantial damage due to arcing, seed deposition, and chemical attack. The electrode walls of a MHD generator duct have periodic conductor/insulator elements where duct divergence or convergence is attained in a stepwise fashion. The backward-facing step element contains the electrode within the insulator so the electrode is not directly exposed to the hot gas flow. The electrode is water-cooled copper with a laminated stainless steel face. A purge jet may be introduced at the electrode face between conductor/insulator elements.

Therefore, it is an object of the present invention to provide an electrode configuration for a MHD generator which has a practical lifetime for high power applications.

Another object of the present invention is to substantially reduce arc spot damage to the electrode face.

Yet another object of the present invention is to provide increased resistance to the electrodes to chemical attack.

Other objects, advantages and novel features of the present invention will be apparent from the following detailed description when read in conjunction with the appended claims and attached drawings.
vent or delay seed permeation from shorting out the axial electric field. Also, non-porous ceramics which resist chemical attack and thermal shock may be used. The electrode portion 21, which is typically water-cooled copper, may have a laminated stainless steel face 22 for additional chemical stability. The stainless steel face 22, being harder than copper, also resists arc spot damage, but the thickness must not be such as to significantly affect the current flow between cathode and anode and the plasma.

The step height, $h$, is a function of the dimension, $L$, of the electrode element 17 in the flow direction. These dimensions are arrived at from considerations of the electrode segmentation required, the boundary layer thickness, etc. The electrodes may also be offset in the diagonal wall duct.

Thus, the present invention provide a geometrical arrangement between the hot gas flow, the magnetic field and the electrode configuration which provides a cooler electrode with the cold surface not directly exposed to the hot gas flow and with more insulator between electrodes to reduce chemical attack, and which provides a recirculation area which constantly moves the arc spot on the electrode surface to prevent severe local damage.

What is claimed is:

1. An electrode configuration for an MHD generator in which a hot plasma flows along a duct having opposing electrode walls, said hot plasma being subjected to a strong magnetic field, comprising a plurality of periodic electrode elements forming said electrode walls, each of said electrode elements being in the form of a backward-facing step having an insulator portion and an electrode portion, said electrode portion being situated so as not to be directly exposed to said hot plasma and so as to have the electric field generated coact with said magnetic field to essentially balance the convection force at the exposed surface of said electrode portion, and each of successive ones of said electrode elements along the axis of said hot plasma flow being offset to form a steplike divergence for said duct.

2. An electrode configuration as recited in claim 1 wherein each of said electrode elements comprises:
   (a) an insulator portion having a slope portion and a backward-facing step portion; and
   (b) an electrode portion being situated in said backward-facing step portion so as not to be directly exposed to said hot plasma.

3. An electrode configuration as recited in claim 2 wherein said electrode portion comprises:
   (a) a highly electrically conductive portion having a cooling duct passing therethrough; and
   (b) a laminate of a high strength non-corrosive material to form the face of said electrode, the thickness of said laminate being such as to not significantly impede the flow of current between said opposing electrode walls.

4. An electrode configuration as recited in claim 3 further comprising means for introducing a purge jet of inert gas at said electrode face without disturbing the recirculation area formed by said hot plasma flow at said backward-facing step.

5. In an MHD generator of the type in which a hot plasma flows along a duct having opposing electrode walls through a strong magnetic field, an improved electrode arrangement for forming said walls, which comprises:
   (a) a plurality of periodic electrode elements with each electrode element being in the form of a backward-facing step and having an insulator portion and a conductor portion;
   (b) said conductor portion being embedded in said insulator portion so that only a single surface of said conductor portion is uninsulated and uncovered, said uncovered surface being on the downstream end of said element, facing downstream, and oriented normal to the longitudinal axis of said duct;
   (c) said insulator portion having an upward sloping surface extending from the upstream end of said element to a surface parallel to the longitudinal axis of the duct, said parallel surface extending to the downstream end of said electrode element;
   (d) said electrode elements being arranged to provide a step-depression from the backward-facing surface of the upstream electrode element to the upward sloping surface of the downstream electrode element; and
   (e) said arrangement thereby providing that said conductor portion is not directly exposed to said hot gas flow and also providing a turbulent region of three-dimensional flow and a recirculation region two-dimensional flow formed by said hot gas flow downstream of the step-depression.

6. The electrode arrangement as recited in claim 5 wherein successive electrode elements are offset to form steplike changes in the opposing electrode walls.

7. The electrode arrangement as recited in claim 5 wherein successive electrode elements are offset to form a steplike divergence in said opposing electrode walls.

8. An electrode arrangement as recited in claim 5 wherein said conductor portion includes:
   (a) a cooling duct passing therethrough; and
   (b) a laminate of a high strength non-corrosive material to form the face of said electrode, the thickness of said laminate being such as to not significantly impede the flow of current between said opposing electrode walls.

9. An electrode arrangement as recited in claims 5 or 7 further including means for introducing a purge jet of inert gas at said conductor surface without disturbing the recirculation region formed downstream of the step-depression.