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SHOCK TUBE STUDIES OF MAGNETICALLY INDUCED IONIZATION MHD GENERATOR VOLTAGE-CURRENT CHARACTERISTICS

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An experimental investigation was performed of the electrical characteristics of various segmented electrode MHD generators, operating under conditions where magnetically induced ionization occurred. The study was conducted in a high purity shock tube, the details of which are described elsewhere[1]. The differences between the electrode assemblies were: the ratio of the electrodes pitch to channel height, which varied from .08 to .9; the ratio of electrode segment width to electrode pitch, which varied from .04 to .79; and the mounting of the electrodes. For the larger ratios the electrodes were flush mounted with the channel wall; whereas for the smaller ratios, the electrodes consisted of .020" wires mounted 1/4" away from the wall and parallel to the wall and magnetic field direction. The test gas used in the experiments was Xenon. Initial gas conditions behind the shock wave were as follows: Gas temperatures from 3,000°K to 9,500°K; equilibrium electron densities, n_e, 10^9/cc to 5×10^{16}cc; equilibrium electrical conductivity, σ, .01 mhos/meter to 4,000 mhos/meter, and $\omega_e \tau_e$, .01 to 100.

It has been previously reported[1] that conductivity and ionization increases were observed in the MHD generator for initial Xenon gas temperatures above 5000°K. In the upper end of the Xenon gas temperature range, 7000° to 9500°K, the relative conductivity increase observed could be well explained by Lorentz force compressional heating. In the 5000 to 7000°K temperature range the relative conductivity increase in the generator was in many cases of the order of magnitude of 10. However, due to the low initial ionization rate, behind the shock wave, the electron density of the gas entering the generator was far less than equilibrium value corresponding to the gas temperatures. Thus the final electrical conductivity of the gas leaving the generator as measured by various probes corresponded in most cases to the equilibrium value at the gas temperature. However, the conductivity deduced from the generator voltage-current characteristics was always lower than the conductivity measured by conductivity probes even at the higher gas temperatures. This descrepancy widened as the Xenon gas temperature was lowered. Thus a better understanding was needed of the operating characteristics of the segmented electrode voltage generator over a wide range of conductivities and electron densities and $\omega\tau$'s. This study was performed using six different generator geometries, having the previously mentioned electrode configurations. In addition, to the measurements of the Faraday voltages, Hall voltages, and the current at the electrodes, the voltage potentials inside the generator were measured by means of floating probes.

The results obtained can be divided into 3 regions which depend upon the electron density in the MHD generator. The regions are: 10^{15} electrons/ cc and above; 10^{12} to 10^{15} electrons/ cc; and less than 10^{12} electrons/ cc. Above 10^{15} electrons/cc, the current flow mechanism to the electrodes was the cold cathode arc. The potential drop of the cathode was in the vicinity of 10 volts and the anode voltage drop was a few volts higher than this. An induced Faraday potential greater than 25 volts was necessary for operating the generator in this particular current mode. The electron density region of 10^{12}/cc to 10^{15}/cc was a transition region. For small applied Faraday potentials, almost the whole Faraday potential appeared as a cathode voltage drop. However, raising the Faraday potential to 150 - 200 volts or applying a battery voltage of 50 volts in the induced Faraday field direction, produced a transition to the arc mode operation. It is in this electron density range that the largest relative ionization increases were observed. Below 10^{12} electrons/cc, it was not possible with induced Faraday fields of 200 volts to break down the cathode resistance. However, with applied voltages above 100 volts either alone or in combination with the Faraday voltage, it was possible to break down the cathode resistance and obtain very large conductivity increases.

On comparing the measured fields and currents with the finite segmented electrode theory[2], one obtains the following results. Above an electron density of 10^{12}/cc, the open circuit Faraday voltage, UBL, agrees within 80 per cent of the theoretical value. However, at very high fields (20-30 K gauss) the measured value of UBL decreases to 50 per cent. However, the discrepancies can be accounted for by considering flow and field non-uniformities. Below 10^{12} electrons/cc the measured Faraday voltage is over a factor of 10 lower than the theoretical value. This discrepancy is due to the finite impedance of the measuring probes which at low electron densities can severly load down the electrode circuit. The measured currents agreed fairly well with the theory of the segmented electrode generator[2] provided the sheath voltages are subtracted from the induced Faraday potential. It has been verified from the current measurements, that at high $\omega_e \tau_e$ the electrodes act as one continuous electrode if the ratio of electrodes width to electrode pitch is greater than .75. The agreement between the theoretical and experimental values of the Hall potential is far from satisfactory. The following results have been obtained. Above 10^{14} electrons/cc electrodes mounted flush with the wall produced higher Hall potentials than those mounted in the body of the stream.

The latter electrodes are probably shorting in the conducting plasma between the electrodes and the wall. For flush mounted electrodes, the adjacent electrode potential is only a factor of 2 lower than the theory[2] compared to the factor of 10 discrepancies for the total Hall potential. This discrepancy was not observed for the wire electrodes. It is thus apparent that shorting of the plasma to the metal part of the shock tube downstream or upstream of the MHD channel reduced the Hall potential. Below 10^{14} electrons/cc the low Hall voltage observed can be attributed to the large electrode sheath resistance. The major conclusions of the electrode study are:

(a) The electrode boundary layer resistance at low electron densities is the controlling parameter which limits non-thermal ionization. The low Hall voltage is a consequence of this boundary layer resistance.

(b) If this boundary layer resistance is overcome by large enough fields, large magnetically induced ionization increases occur despite the low Hall voltages.

(c) With the exception of the Hall voltages, the finite segmented electrode generator theory agrees reasonably well with experiments.

References

1. Zauderer, B., Paper No. 27, Proceedings of the 2nd International Symposium on MHD Power Generation, Paris, July 6-11, 1964; to be published.

2. H. Hurwitz, Jr. R. W. Kilb, and G. W. Sutton, J. of App. Physics <u>32</u>, 205-216 (1961).