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THE NONEXISTENCE OF DC STATES IN LOW PRESSURE THERMIONIC CONVERTERS

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A low pressure thermionic converter consists ideally of an evacuated space between two infinitely extended parallel plates. One of these plates is at a high temperature and is capable of emitting both ions and electrons with half-Maxwellian velocity distributions. The other plate acts as a collector. A constant potential difference is applied across the emitter and collector plates. It is assumed that collisions do not occur between particles of either species, and both plates are transparent to incoming particles.

The possible dc states of such a system were analyzed by Auer,[1] McIntyre,[2] and by C. Warner.[3] These authors assumed that a time-independent solution has developed in the system and proceeded to calculate the potential distributions of such solutions between the emitter and collector plates. Although these dc states are mathematically correct, physically they are of questionable value because it is possible that for some choice of the diode parameters the behavior of this converter can be described only by time-varying fields. We will show that at least for the case of large currents through the converter, dc states do not exist at all and the state of the diode has large amplitude oscillations at all times.

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In order to show the large signal time-dependent behavior of the converter, we have simulated its operation on an IBM 7090 computer. Similar computer calculations have been conducted by Buneman[4], Birdsall and Bridges[5], and the same method was applied to a finite thermionic plasma diode by Burger[6]. These computer calculations, or computer experiments, are based on computing the trajectories of a large number (10,000) of electron and ion sheets acted upon by the electrical fields they experience in the one-dimensional space of the thermionic converter. The thermionic emitters of our model are simulated by giving the charged sheets that are injected into the space of the converter random velocities distributed by the half-Maxwellian distribution law. This procedure is similar to what is known as the Monte-Carlo method[7].

Our earlier work (see Ref. 6) clearly demonstrates that the computer simulated diode finds the theoretically calculated dc states rapidly if these dc states are stable under rf perturbations. This work also showed us that the computer simulated diode displays large amplitude changes or oscillations in the diode if its initial state is unstable. We have now applied the computer model to the low pressure thermionic converter. In Fig. 1 the computed current through the diode is plotted as a function of normalized time for two cases which are covered by McIntyre's dc analysis. The current is normalized to the saturation current of the electrons, the solid line showing the currents predicted by McIntyre's dc solution.

The time unit is approximately one-ninth of an electron plasma oscillation period referred to the close neighborhood of the emitter. For Fig. 1 it takes 25 units of time for an average electron to traverse the diode at its initial speed (50 for Fig. 2 which shows results for another case). The average transit time of an ion is m_i/m_e times the average transit time of the electrons. For computational reasons m_i/m_e cannot be chosen very large--but according to the results of our earlier work with this computer model, the value $m_i/m_e = 64$ already shows the essential characteristics of diode behavior. The reduced parameters shown on the diagram have the following definitions (these definitions agree with McIntyre's): $\alpha = (J_{si}/J_{se})\sqrt{m_e/m_i}$, where J_{si} and J_{se} are the ion and electron saturation current densities respectively; $\eta = (eV/kT)$, $\xi = (d/\lambda_{Db})$, where d is the plate separation distance in the diode and V is the potential applied across it. The debye length λ_{Db} is calculated from the number density of the electrons near the emitter.

Figure 2 shows the computed current through the diode for parameters closely approximating the experimental diode of Cutler[8]. Two values of the mass ratio (16, 64) were studied in order to show the effect of changing the mass ratio on the behavior of the diode. It can be observed that the current through the diode has large amplitude fluctuations with two distinguishable periods. One is connected to the average electron transit time (50 normalized time units), the other to the average ion transit time ($50\sqrt{m_i/m_e}$ normalized time units). This result is in close agreement with experiments conducted by Cutler (Ref. 8).

The results of these computer calculations establish the fact that the low pressure thermionic converter does not have a dc state for large electron currents through the diode, and we cannot expect that dc or small signal analysis could describe the state of this device.

REFERENCES

1. Auer, P. L., J. Appl. Phys. 31, 2096 (1960).
2. McIntyre, R. C., J. Appl. Phys. 33, No. 8, 2485 (1962).
3. Warner, C., Advanced Energy Conversion 2, 459-463 (1962).
4. Buneman, O., Phys. Rev. 115, No. 3, 503 (1959).
5. Birdsall, C. K. and Bridges, W. B., J. Appl. Phys. 32, No. 12, 2611 (1961).
6. Burger, P., "The Opposite Stream Diode," Technical Report No. 0254-1, Stanford Electronics Laboratories, Stanford, Calif. (1964).
7. Tien, P. K. and Moshman, J., J. Appl. Phys. 27, 1067 (1956).
8. Cutler, W. H., J. Appl. Phys. Letters, (February 1964).

FIGURE HEADINGS

Fig. 1: The normalized diode current in the computer simulated converter for two cases that were included in McIntyre's dc analysis. The normalized current of value 1.0 is the expected dc current for both cases.

Fig. 2: Fluctuations of the current in the computer simulated diode that approximates an experimental cesium diode (Ref. 8). Comparison of the two curves shows the effect of the mass ratio m_i/m_e on the fluctuations. A normalized current of value 1.0 is again the expected dc current in the diode.

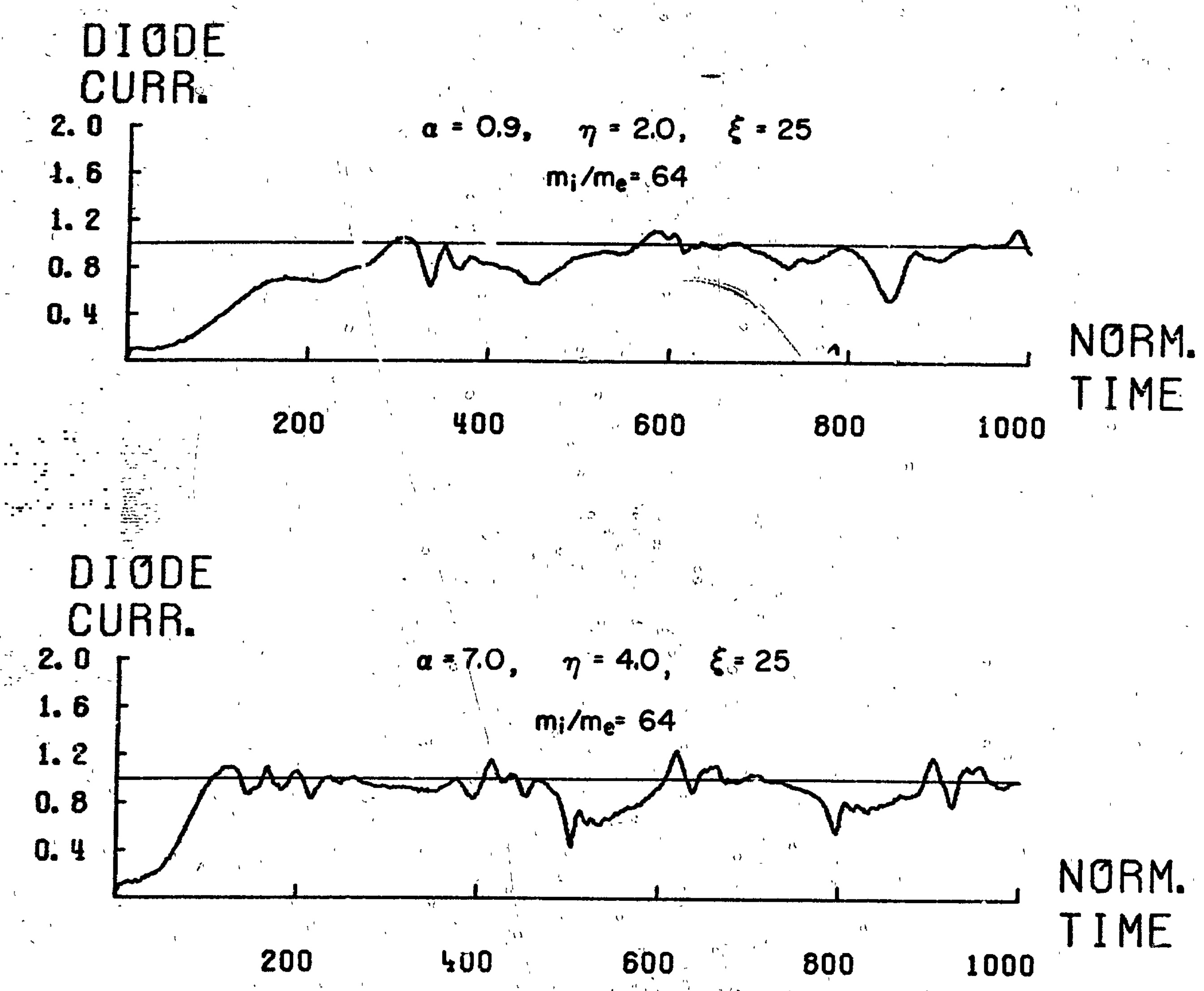
DIØDE
CURR.
2.0
1.6
1.2
0.8
0.4
α = 0.9, η = 2.0, ξ = 25
m_i/m_e = 64
NØRM.
TIME
200
400
600
800
1000
DIØDE
CURR.
2.0
1.6
1.2
0.8
0.4
α = 7.0, η = 4.0, ξ = 25
m_i/m_e = 64
NØRM.
TIME
200
400
600
800
1000

FIG. 1

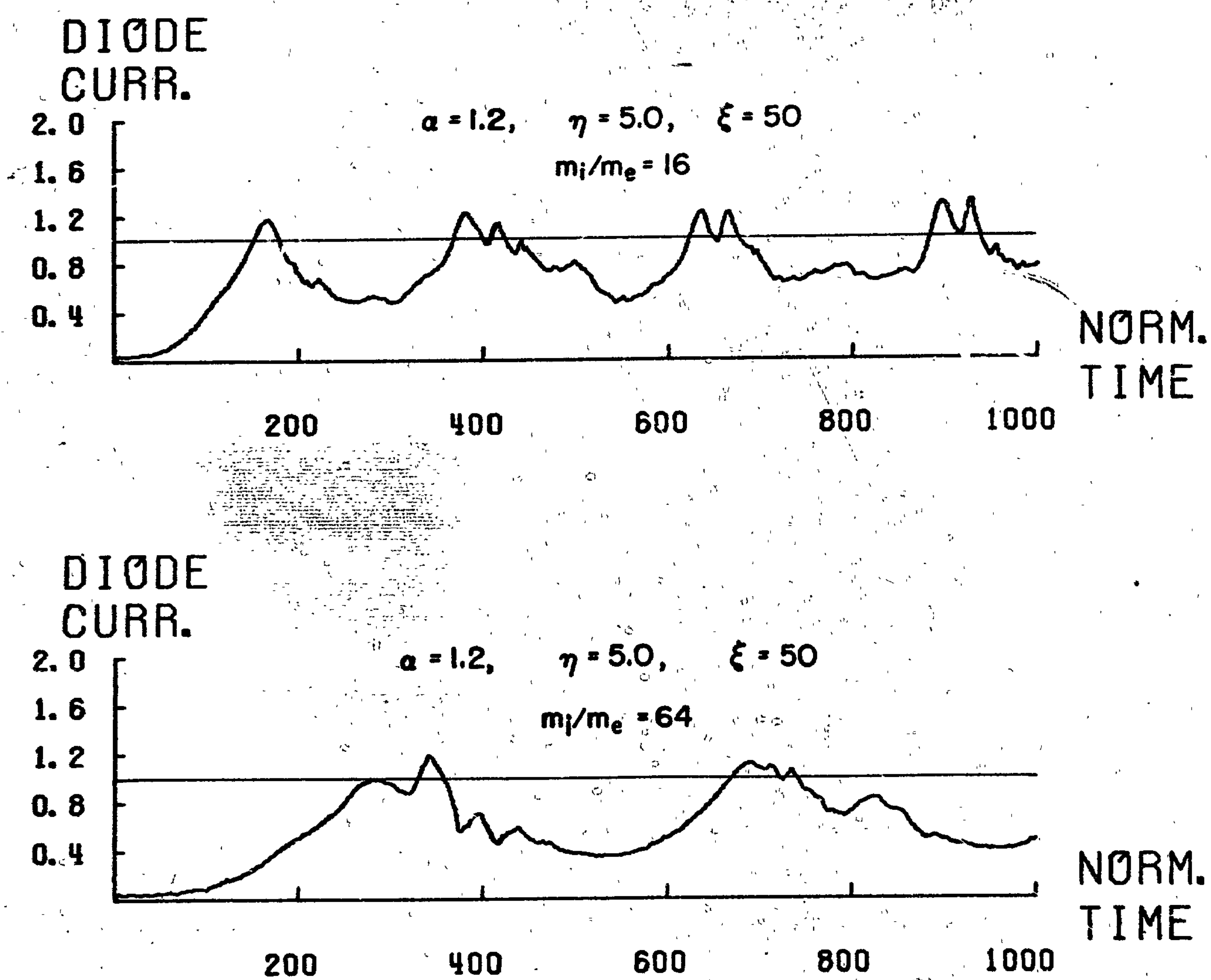
DIØDE
CURR.
$\alpha = 1.2$, $\eta = 5.0$, $\xi = 50$
$m_i/m_e = 16$
2.0
1.6
1.2
0.8
0.4
200
400
600
800
1000
NØRM.
TIME
DIØDE
CURR.
$\alpha = 1.2$, $\eta = 5.0$, $\xi = 50$
$m_i/m_e = 64$
2.0
1.6
1.2
0.8
0.4
200
400
600
800
1000
NØRM.
TIME

FIG.2.