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Reply to Comment by J. E. Borovsky on Paper Entitled Double Layers are not Particle Accelerators

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ABSTRACT

A paper by J E Borovsky disputing the conclusion that electrostatic double layers are not particle accelerators appears to be based on a concept inconsistent with Poisson's equation. Claims made in the paper that measurements of auroral particles and magnetospheric electric fields are consistent with the potential-difference theory of auroral electron acceleration are shown to be unjustified.

Borovsky's reluctance [1] to accept the conclusion [2] that static, localized regions of space charge, of which double layers are an example, are unable to cause a net change in the kinetic or potential energy of a charged particle, and therefore cannot be considered particle accelerators, may stem from his definition of double layers as "strong electrostatic fields". This definition, which echoes the earlier "small localized regions of a single electric field polarity"[3], is clearly inadequate for representing two (or any number) of space charge layers[4], since it does not incorporate the opposing fields necessary to satisfy Poisson's equation and so ensure that equipotential surfaces are closed. The line integral of the electric field, taken along any route between any two points separated by more than a few characteristic dimensions of a double-layer is essentially zero. The vanishing line integral establishes that there is no net potential difference across any finite, static space charge configuration. The only effect on a charged particle of the local perturbation of potential is a temporary redistribution of potential and kinetic energy. This basic problem [5] cannot be circumvented by departing, as Borovsky does, from the double layer concept and invoking a large-scale region of space charge in the terrestrial magnetosphere from which charged particles are accelerated, since any kinetic energy gained (at the expense of potential) on exit will have been lost (to potential) on entry.

In resorting to circumstantial evidence in an attempt to overcome fundamental difficulties, Borovsky makes a statement that could be seriously misleading about the equivalence of potential differences derived from auroral particle energies and line integrals of measured electric fields. The reader may gain the impression that the particles in question are the precipitating electrons of the present discussion. This would be incorrect. The geometry of the potential difference model [6] is such that measured electron energies depend on potential

differences between the observation point and the interior of the potential well (ie ABOVE the observer) while the measured electric fields relate to potential differences between the satellite trajectory and the outer limit of the potential well (ie BELOW the observer). They are therefore not comparable quantities, so even the circumstantial evidence disappears. It is important to note, too, when considering comparisons with upward flowing particles, which would, in this model, cross the relevant equipotentials, that the estimates of potential differences below the spacecraft are strongly qualified in the references cited by Borovsky by the declarations that "Experimental problems such as electric field saturation effects, threshold limitations, and sensitivity difficulties make this conclusion [the estimate of potential difference] tentative at best"[7], and "...it is to be expected that the energy of maximum ion flux would be only a rough indicator of the potential difference below the satellite"[8]. Reservations have been expressed, too, about the quality of fit between observed and predicted velocity space density contours of electrons flowing upward in the so-called widened loss cone [9,10].

Another cause of serious misunderstanding in the circumstantial evidence is the claim that "the DIRECT evidence for substantial (multi-kV) electrostatic potential structures in the auroral zone is plentiful." This is incorrect. These substantial potential differences are not measured DIRECTLY; they are INFERRED from much smaller potential differences measured by probes spanning much smaller distances and from particle distributions interpreted in terms of the potential difference theory. Assumptions are made in both cases about the stability of the electric fields over particle, and indeed satellite, transit times. Again, even the circumstantial evidence is seen to have no foundation.

The fact that a theory of auroral electron acceleration by electrostatic waves has been

advanced [11, 12] was not intended to be an integral part of the argument [2,13] against double layers as accelerators. While it is certainly true that realization of the latter was the spur for the former, the inability of double layers, or any other static, finite soace-charge configuration, to have a net effect on particles traversing them is obviously unconnected with the validity or otherwise of any other theory.

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