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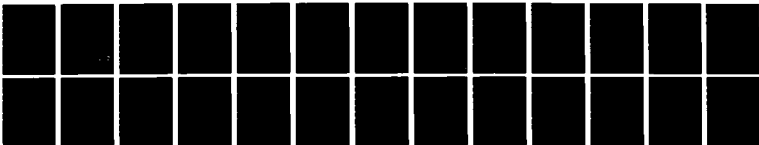
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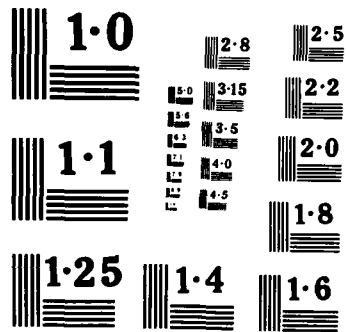
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**THEORY SUPPORT OF PULSED POWER EXPERIMENTS**

**Volume III—E-Beam Chamber Design**

**S-CUBED**

**A Division of Maxwell Laboratories, Inc.**

**P.O. Box 1620**

**La Jolla, CA 92038-1620**

**1 July 1984**

**Technical Report**

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**SECTION 1**  
**E-BEAM TEST CHAMBER DESIGN**

In an SXTF-related effort, the charging of a satellite by multiple electron beams in a test chamber was examined (Appendix A1). The NASCAP 3-D computer model was used to simulate the dynamic charging of the test object for up to ten minutes. The effects of the earth's magnetic field were relatively small in the SXTF test chamber because of its relatively modest dimensions. However, the effects of enhanced backscatter and secondary electrons lead to substantial differential charging and electric field reversal.

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APPENDIX  
MULTIGUN TEST TANK SIMULATION WITH MAGNETIC FIELD  
(TOPICAL REPORT SSS-R-81-5028, JUNE 1981)

A-1 INTRODUCTION

The simulation of spacecraft charging in ground based facilities is of importance both for the study of electrostatic discharges and for precharge enhanced SGEMP. Since it is not possible to recreate the high temperature, low density plasmas of a magnetospheric substorm experimentally, the charging environment usually consists of several electron guns which spray a test satellite with charged particles. Important questions are what charging results from these guns and how does it relate to natural spacecraft charging.

In order to answer these questions we have developed a tank multigun capability for the NASA Charging Analyzer Program. NASCAP has already been shown valid for predicting satellite potentials in space and is now able to model up to ten multi-energy electron or ion guns, each of which may arbitrarily be located and point in an arbitrary direction. Also, the angular width of each beam may be specified. One feature of the NASCAP algorithms is that they account for finite Larmor radius effects on the charged particle beams. The new multigun facility in NASCAP is both flexible and fast running.

We have used NASCAP to model the electron irradiation of SCATSAT, a test object built to examine the charging and electromagnetic response of the SCATHA satellite. Experiments are presently being performed at NASA/LeRC during which four 6 keV electron guns are directed at SCATSAT. In a dark isotropic space environment this object would have charged relatively uniformly. However, during the



laboratory experiments there developed differential potentials of over a thousand volts which led to spontaneous discharges. The NASCAP calculations presented here show clearly what led to the differential charging in these experiments: Electrons obliquely incident on surfaces have high secondary electron yields. This new NASCAP capability may be used to explore questions of optimal beam placement, number and species of particle sources, and photoeffects for optimal design of laboratory simulations of spacecraft charging.

## A-2 RESULTS

The geometry considered is a one meter electrically floating octagonal object in a 3.2 m cubical tank. The object was covered with 0.005 inch thick kapton, and was illuminated by four monoenergetic flood guns. Each gun emitted 5 mA of electrons distributed as  $\cos(\pi\theta/2\theta_0)$ , where  $\theta$  is the angle from the gun axis and  $\theta_0$  was set to 30 degrees. The magnetic field, when applied, was parallel to two of the gun axes and normal to the other two.

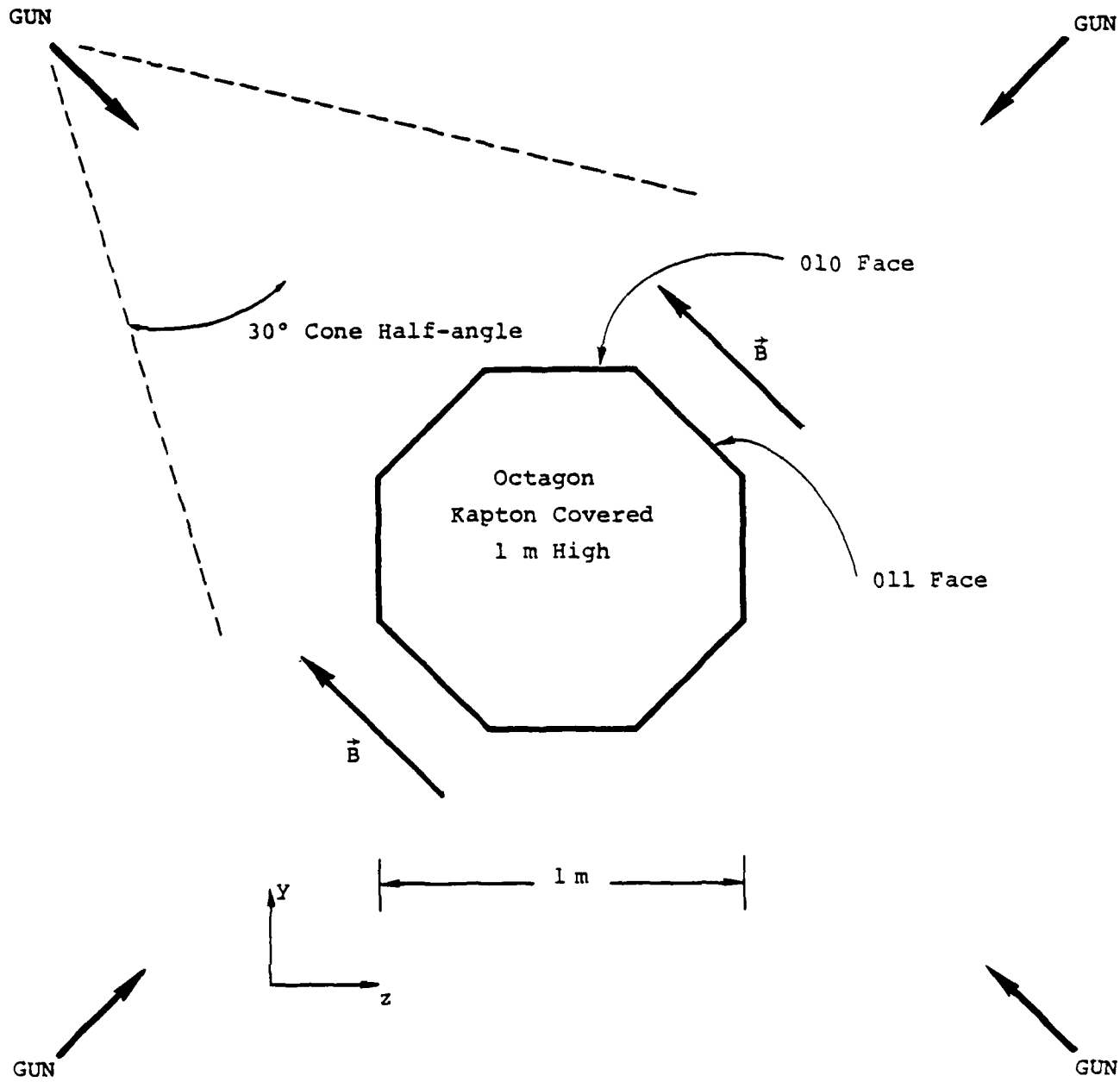


Figure A-1. Geometry of a one meter electrically floating octagonal object in a 3.2 m cubical tank.

Beam Energy	10 keV	10 keV	6 keV
$\vec{B}$ (gauss)	0	(0.,-.3,.3)	(0.,-.3,.3)
Cyclotron Radius	7.9 m	7.9 m	6.2 m
Distance from Gun to Nearest Surface	1.9 m	1.9 m	1.9 m
Peak Potential: 011 Surface	-8540	-8540	-4790
360 sec at x =	0	0	0
Peak Potential: 011 Surface	-8540	-8540	-4700
360 sec at x =	0	0.10	0
Peak Potential: 010 Surface	-6260	-6340	-2920
360 sec at x =	0	0.35	0.45
Minimum Potential: 010 Surface	-6200	-5950	-2580
360 sec at x =	$\pm 0.45$	-0.45	-0.45

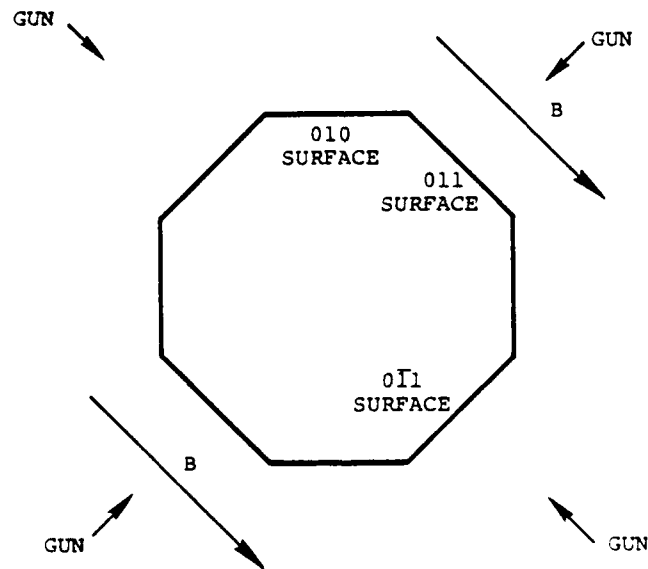


Figure A-2. The three simulations performed were 10 keV beams with and without magnetic field, and 6 keV beams with magnetic field. In all cases, differential charging in excess of 2 kV developed within six minutes. As the gun-object distance was a modest fraction of a cyclotron radius, magnetic field effects, though definitely noticeable, were correspondingly modest.

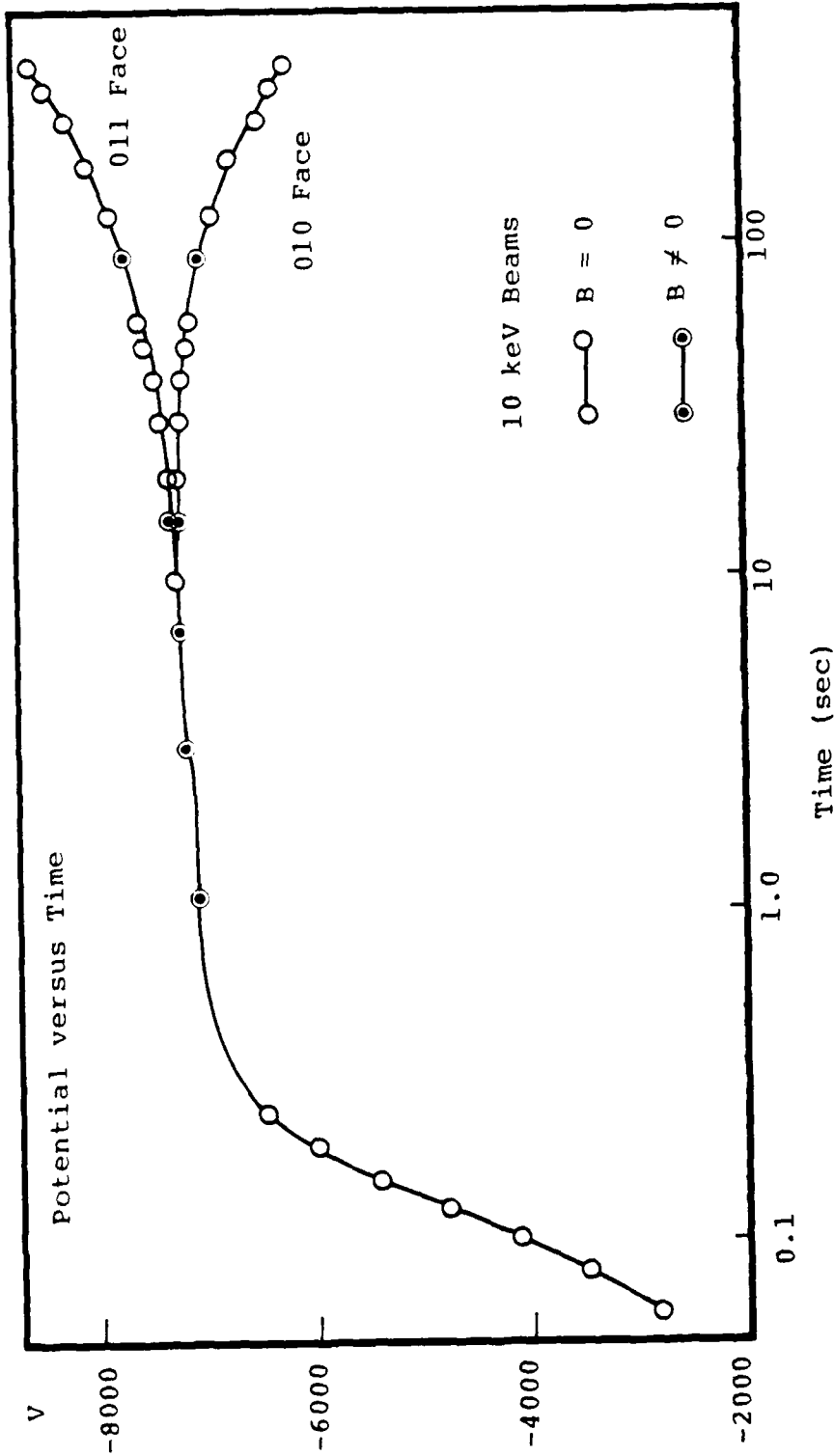


Figure A-3. Potential for two cells near the spacecraft belly, exposed to 10 keV electrons. The object charges uniformly to about -7200 V in about one second. Over the next several minutes the surfaces receiving normally incident electrons continue to charge negatively, while those receiving obliquely incident electrons charge positively due to increased secondary emission. With exposure to 6 keV beams, the plateau voltage was -3600 volts. Magnetic fields, for the strength and geometry considered here, do not greatly alter this behavior.

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NASCAP now has the computational capability for modeling this type of experiment. This capability should be used for facility design, experimental design, and experiment analysis.

### A-3 CONCLUSIONS

Experimental simulation of spacecraft charging in a three-dimensional, multigun facility is an extremely complex process. Even for the relatively simple geometry considered in this report, the combined effects of beam spreading, angular dependence of emission coefficient, magnetic deflection, and potential barrier formation produce effects not anticipated in the experimental design, and require three-dimensional analysis. The added complexities of realistic spacecraft and more elaborate simulation facilities further underline the need for a computational modeling capability.

The magnetic field effects seen in these calculations, though visible, are surprisingly small. This may not be the case in a facility which is an order of magnitude larger, unless the earth's magnetic field is substantially attenuated. However, the reduction by a factor of three or more is probably sufficient, and reduction by an order of magnitude not necessary.

The most dramatic effects seen here are those caused by the anisotropy of the beam environment. When we take into account the enhanced backscatter and secondary electron production for obliquely incident electrons, we see substantial differential charging and large regions of electric field reversal. These conditions will lead to surface flashovers and greatly enhanced SGEMP. While here this charge state is attributable to beam anisotropy, the discharges observed experimentally are similar to those seen on board spacecraft.

POTENTIAL CONTOURS ALONG THE Y-Z PLANE OF X = 9

ZMIN = -4.9958+003 ZMAX = -1.1489+003 DZ = 2.0000+002

CYCLE 23 TIME = 5.86+002

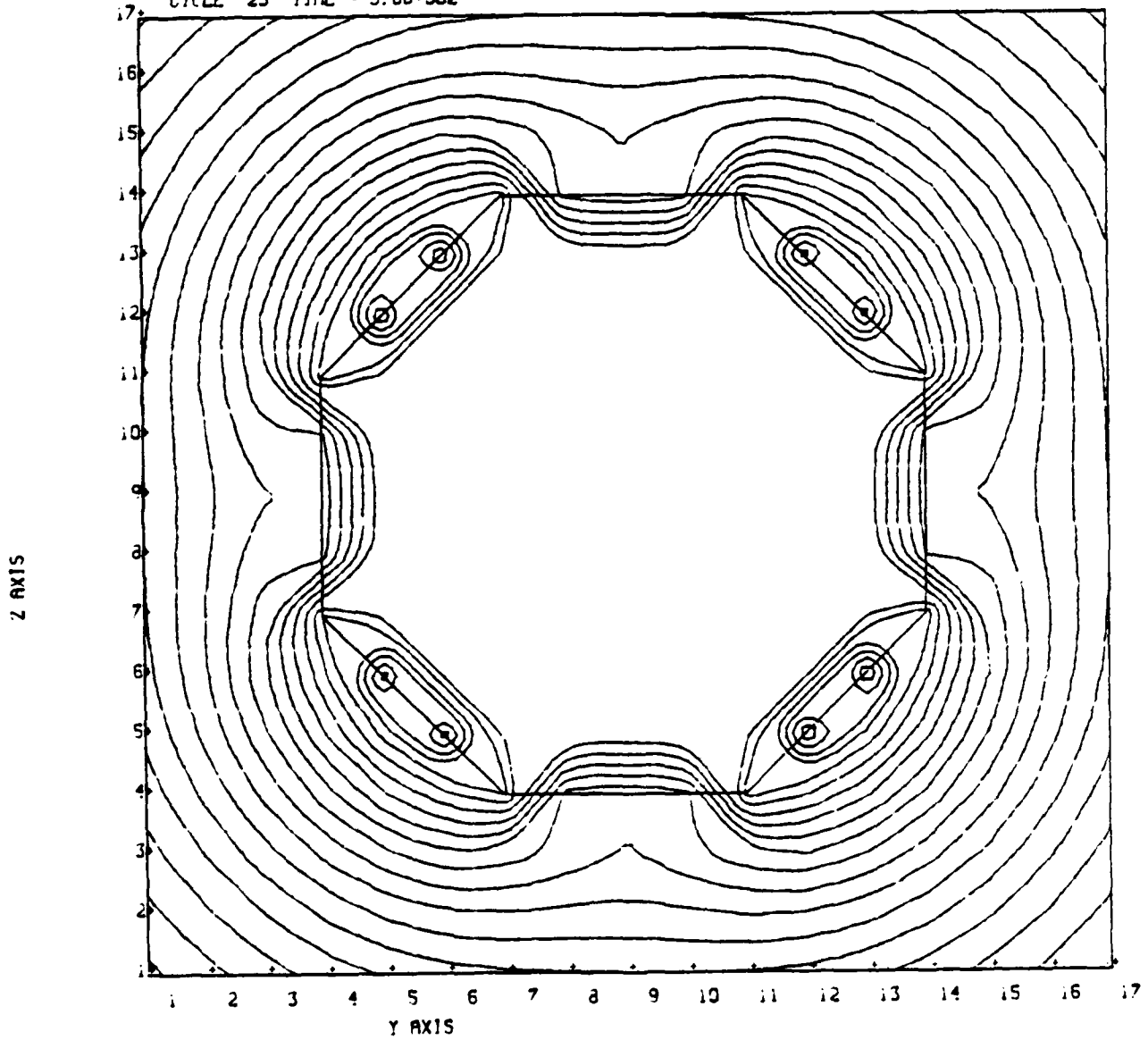


Figure A-13. Potential contours after ten minute exposure to 6 keV beams.

POTENTIAL CONTOURS ALONG THE X-Z PLANE OF Y = 9

ZMIN = -3.7611+003 ZMAX = -1.1940+003 DZ = 2.0000+002

CYCLE 23 TIME = 5.86+002

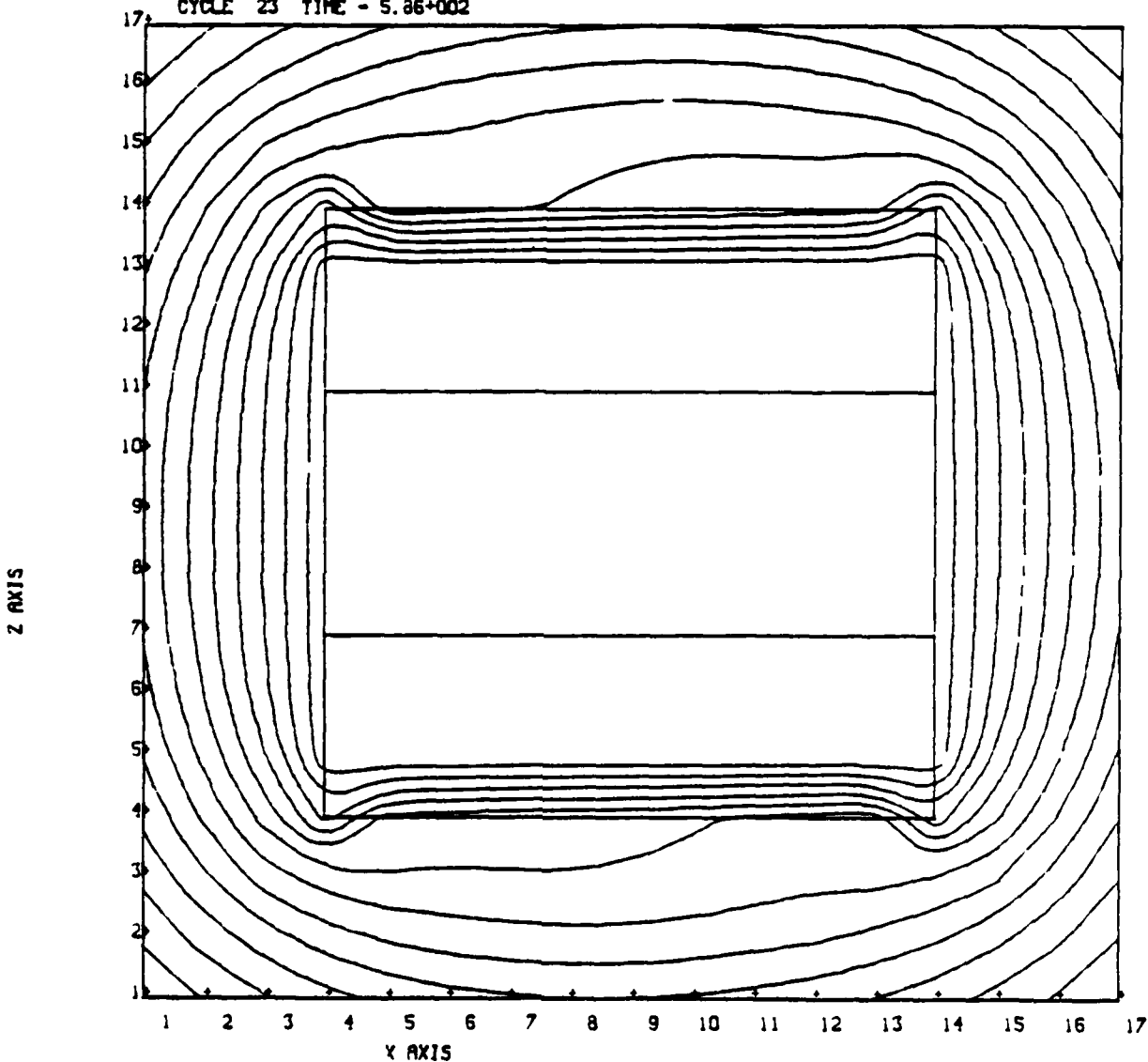


Figure A-12. Potential contours after ten minute exposure to 6 keV beams. Regions of very low external electric field near regions of high differential charging are apparent. An object charged in this manner will exhibit strong SGEMP enhancement with high probability of synergistic surface flashover.

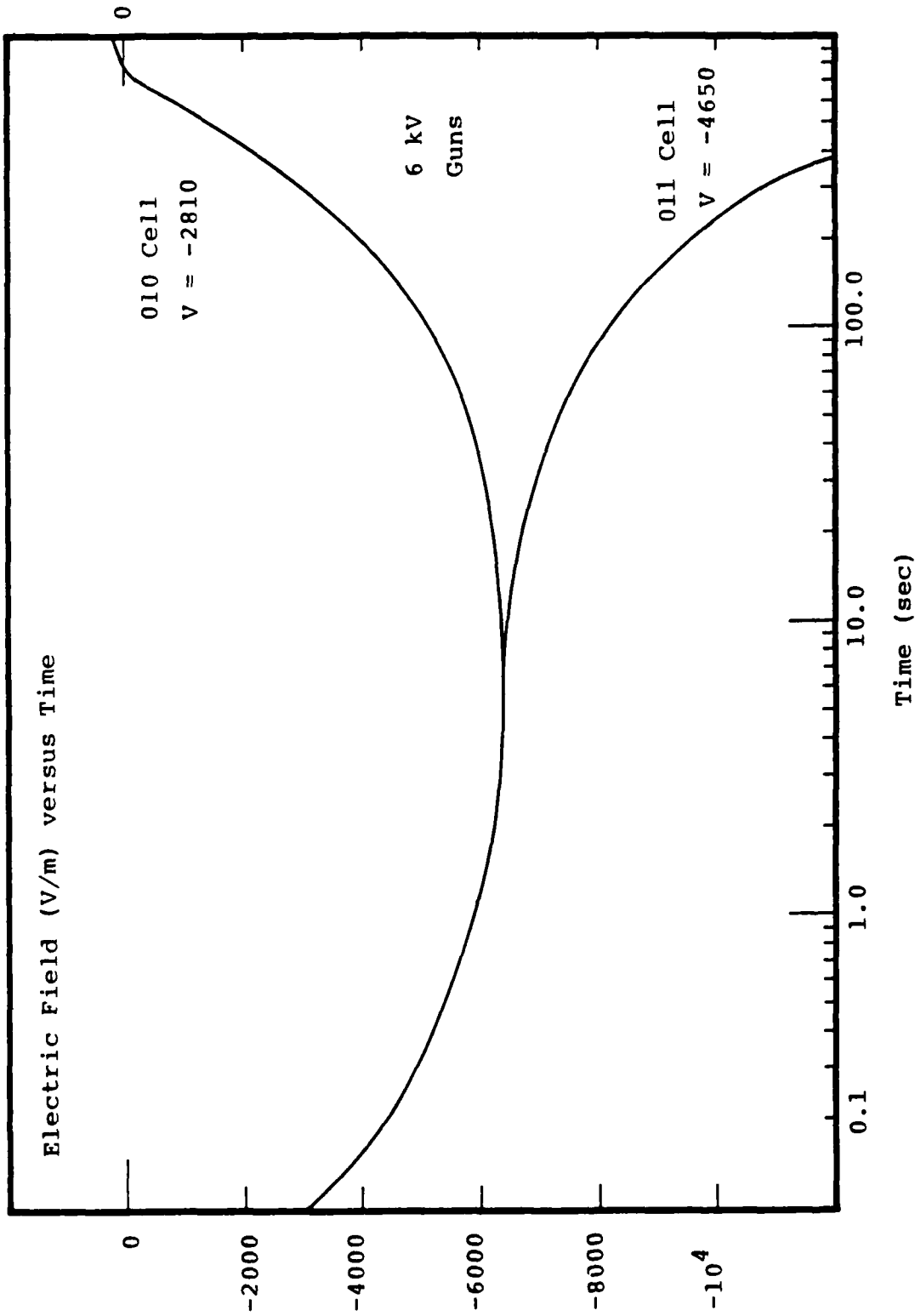


Figure A-11. Electric field for two neighboring cells near the object belly. After six minutes of exposure there is nearly two kilovolts of differential charging, and the electric field near the more positive cell changes sign. Its secondary electrons are now trapped. This is a likely region for a surface flashover discharge, either spontaneous or synergistically to an x-ray burst.

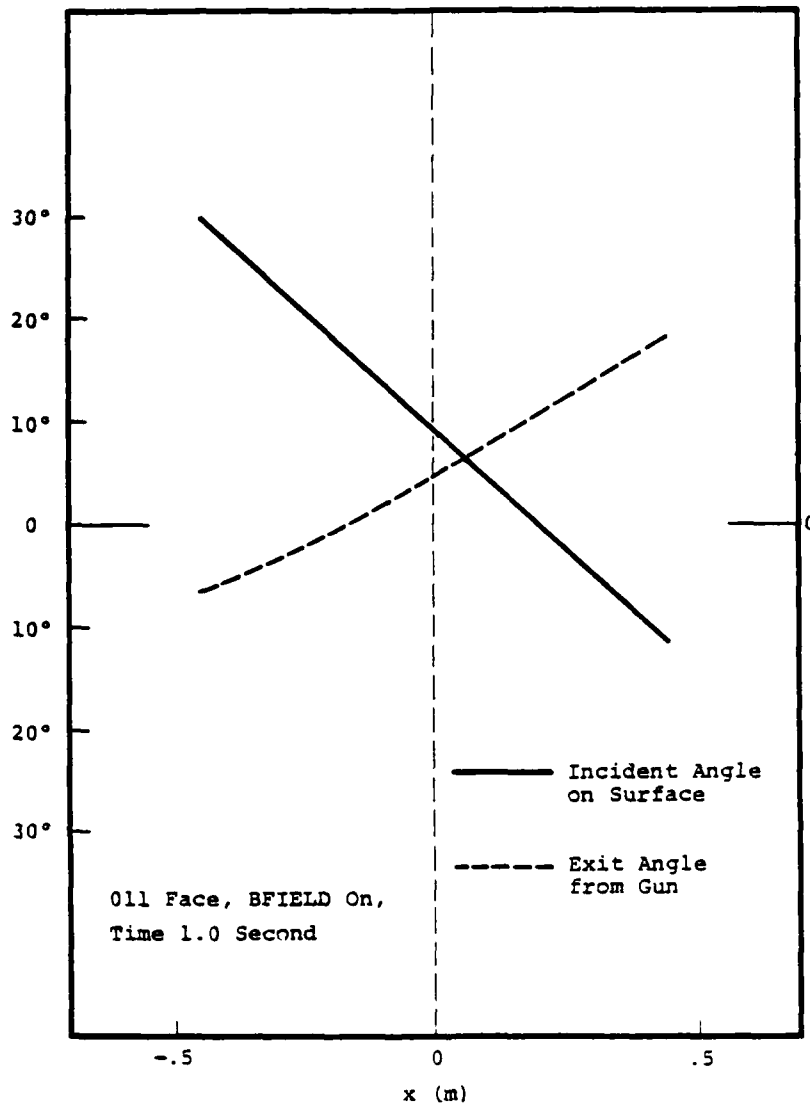


Figure A-10. Resolution of paradox presented in previous figure. The dashed curve presents the angle (relative to gun axis) at which electrons must leave the gun to hit a given point on the object, taking into account magnetic deflection. The node of this curve, representing the densest part of the beam, is at  $x < 0$ . This is the main determinant of the early time flux curve, since secondary emission is fairly small. The solid curve represents the angle of incidence of electrons on the object surface. Its node (at  $x > 0$ ) represents minimum secondary emission. The solid curve is the main determinant of the final fluxes and potentials.

Net Flux at  $t = 0.029$  Seconds

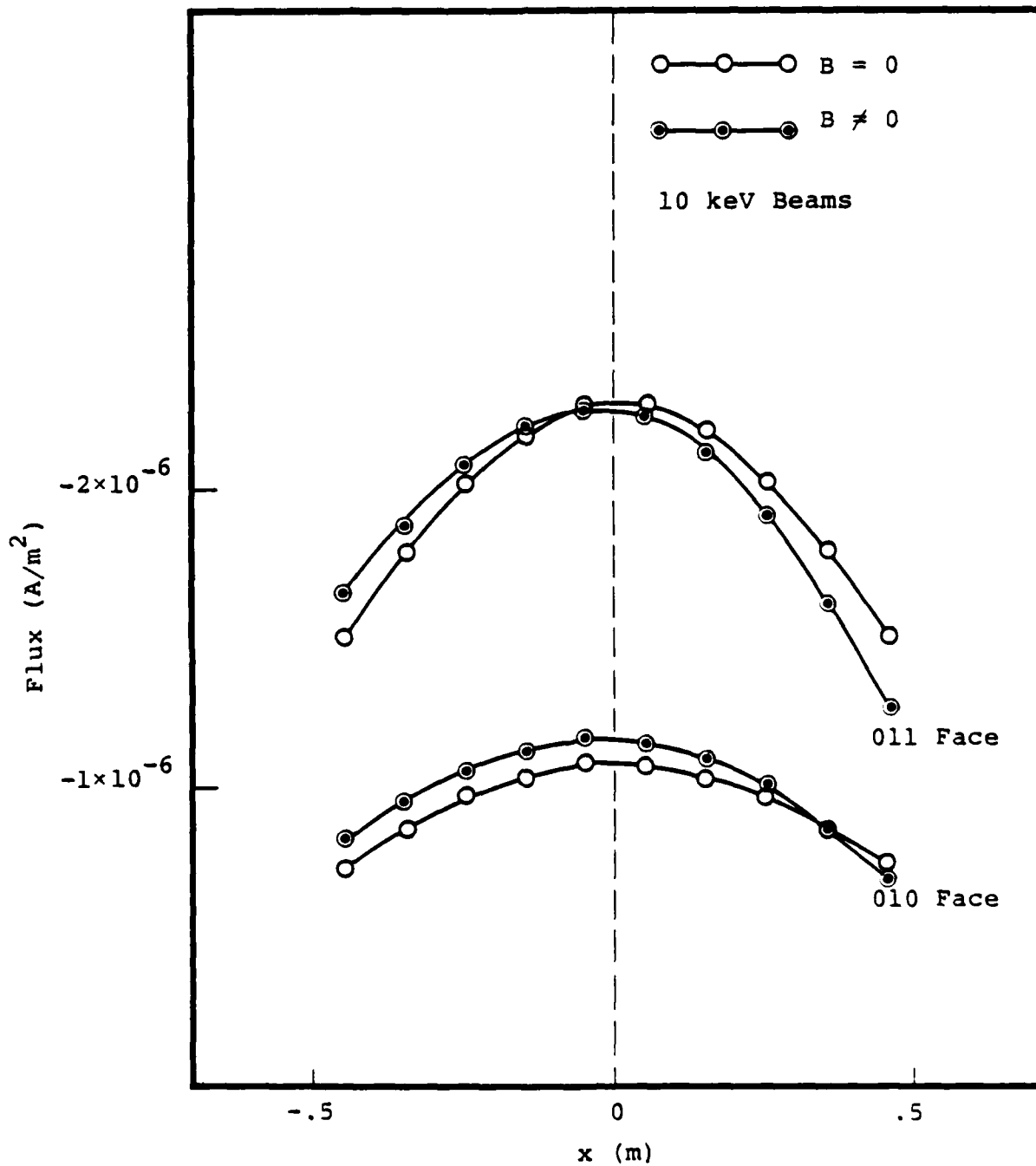


Figure A-9. Fluxes as a function of height for the 10 keV cases at short time. This figure presents an apparent paradox, as the flux anisotropy is in the opposite sense from the final potentials.

POTENTIAL CONTOURS ALONG THE X-Z PLANE OF Y = 9

ZMIN = -3.6871+003 ZMAX = -1.1729+003 DZ = 2.0000+002

CYCLE 19 TIME = 3.61+002

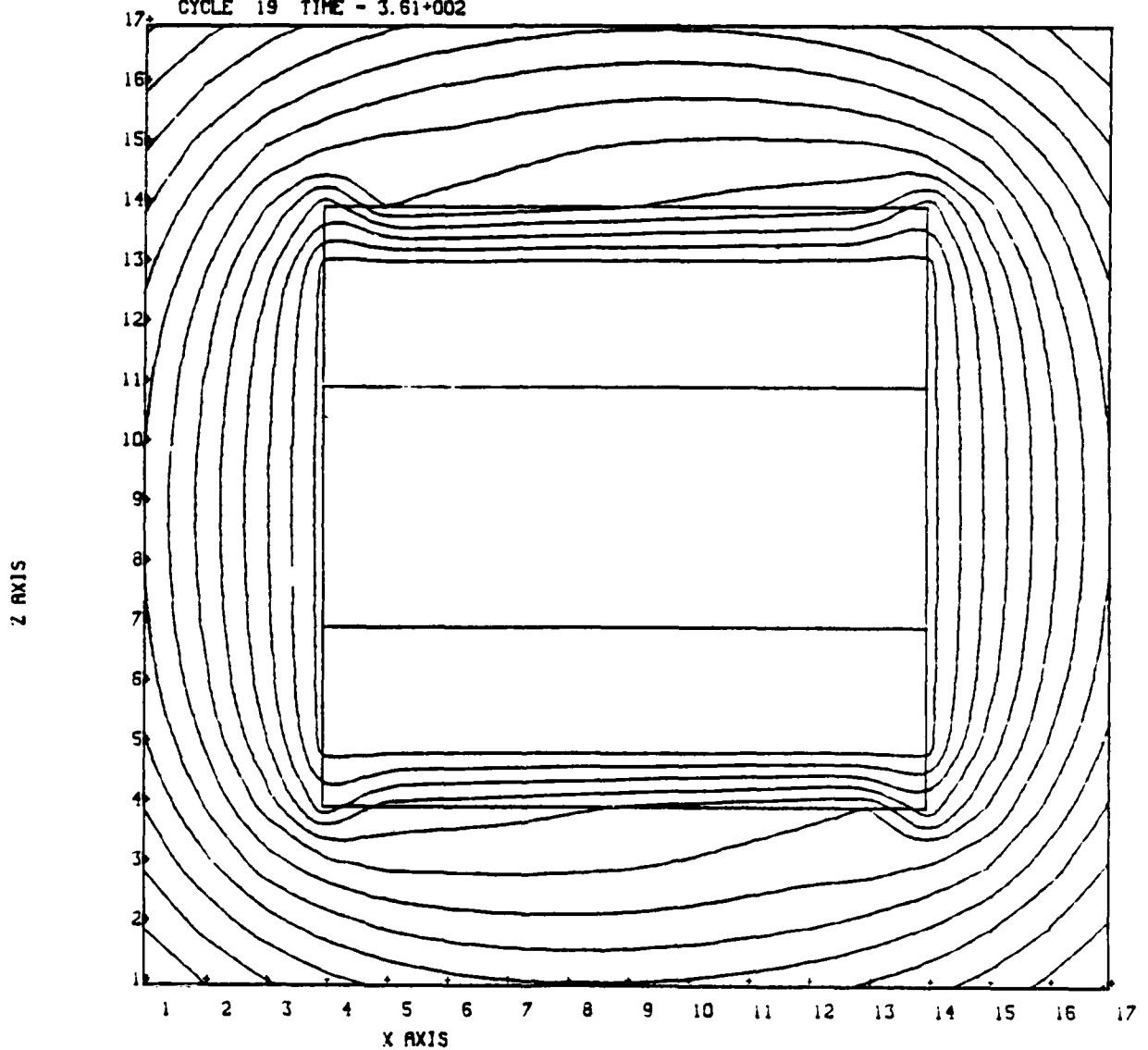


Figure A-8. Side view of potential contours for the 6 keV case. The contours have the symmetry of the magnetic field.



Potentials at 360 Seconds

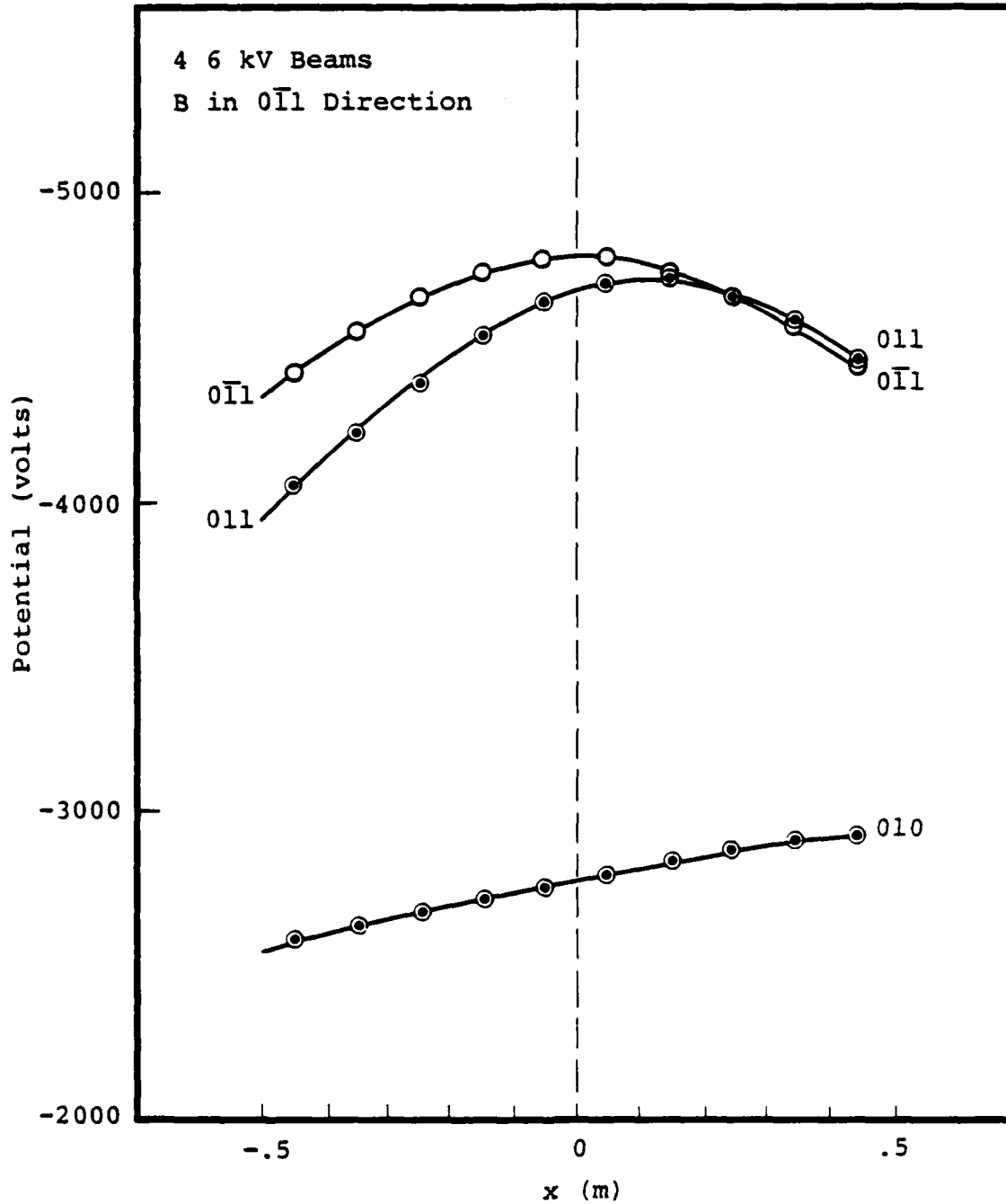


Figure A-7. Final (6 minute exposure) potentials for the 6 keV case. For lower energy the magnetic field has a greater effect.

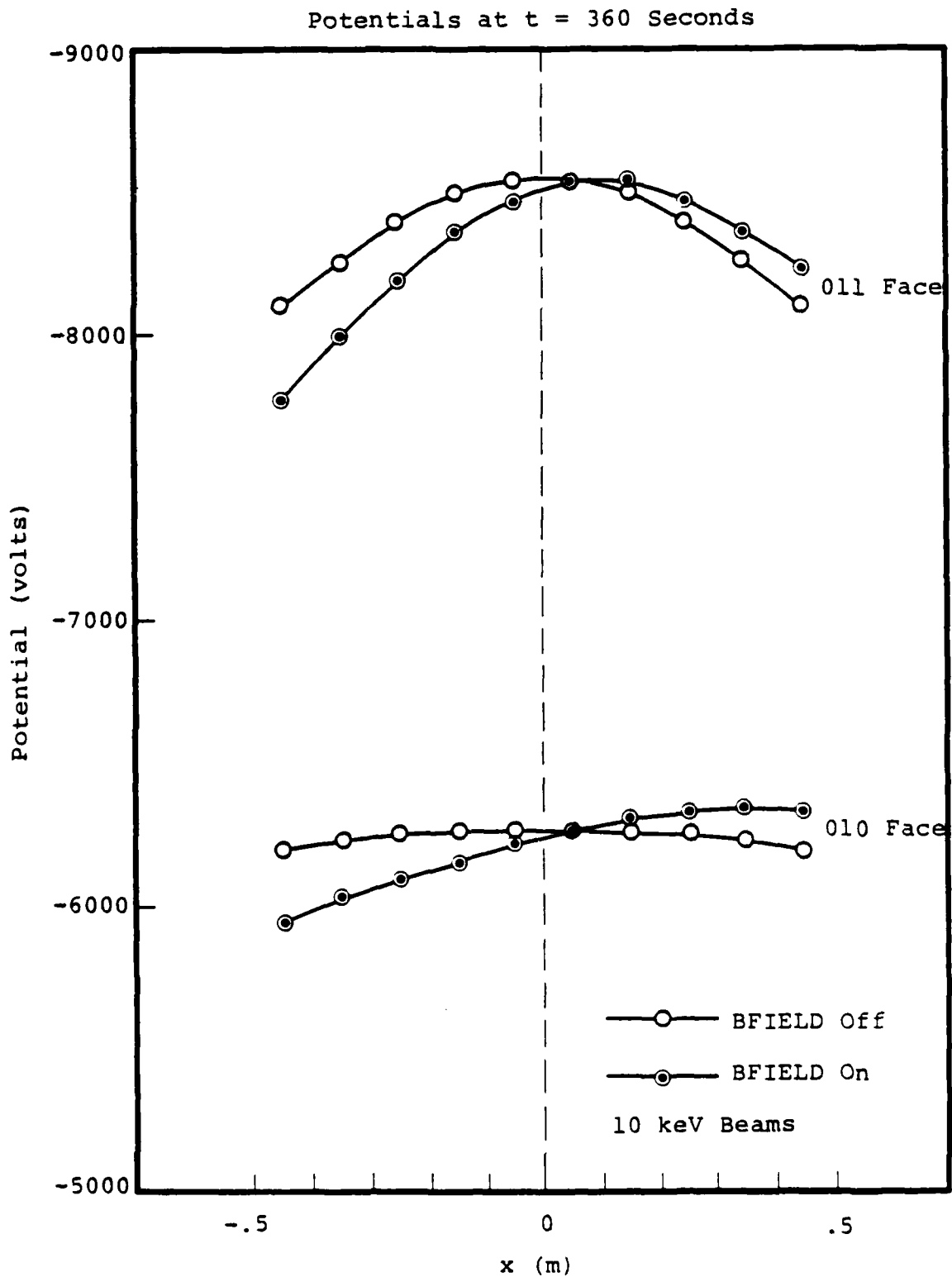


Figure A-6. Final (6 minute exposure) potentials for the 10 keV cases as a function of distance from the plane of the guns. The anisotropy caused by the magnetic field is apparent.

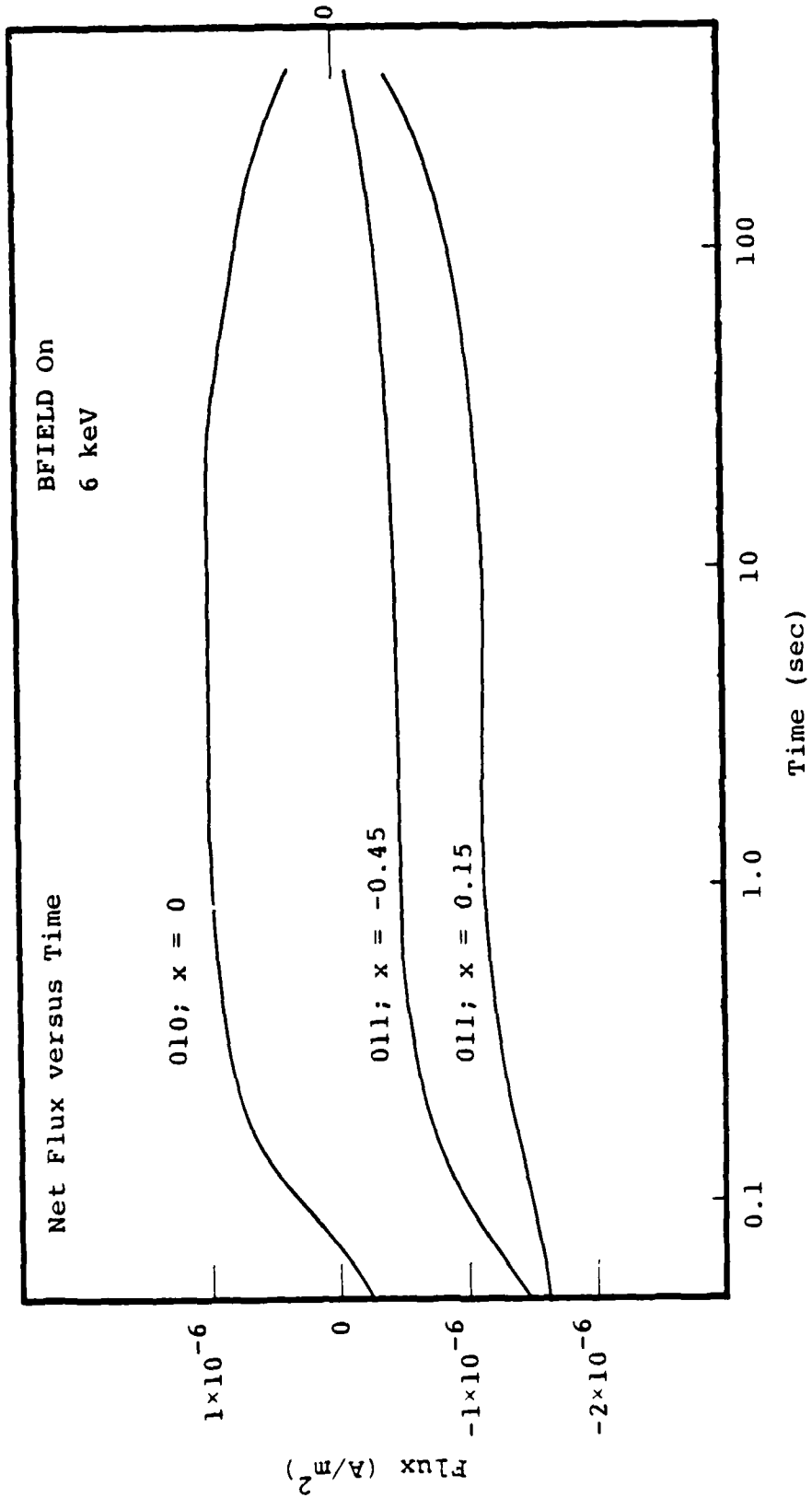


Figure A-5. Same as previous plot, but for the 6 keV case. Here we have drawn two curves to illustrate the range of fluxes on the 011 face.

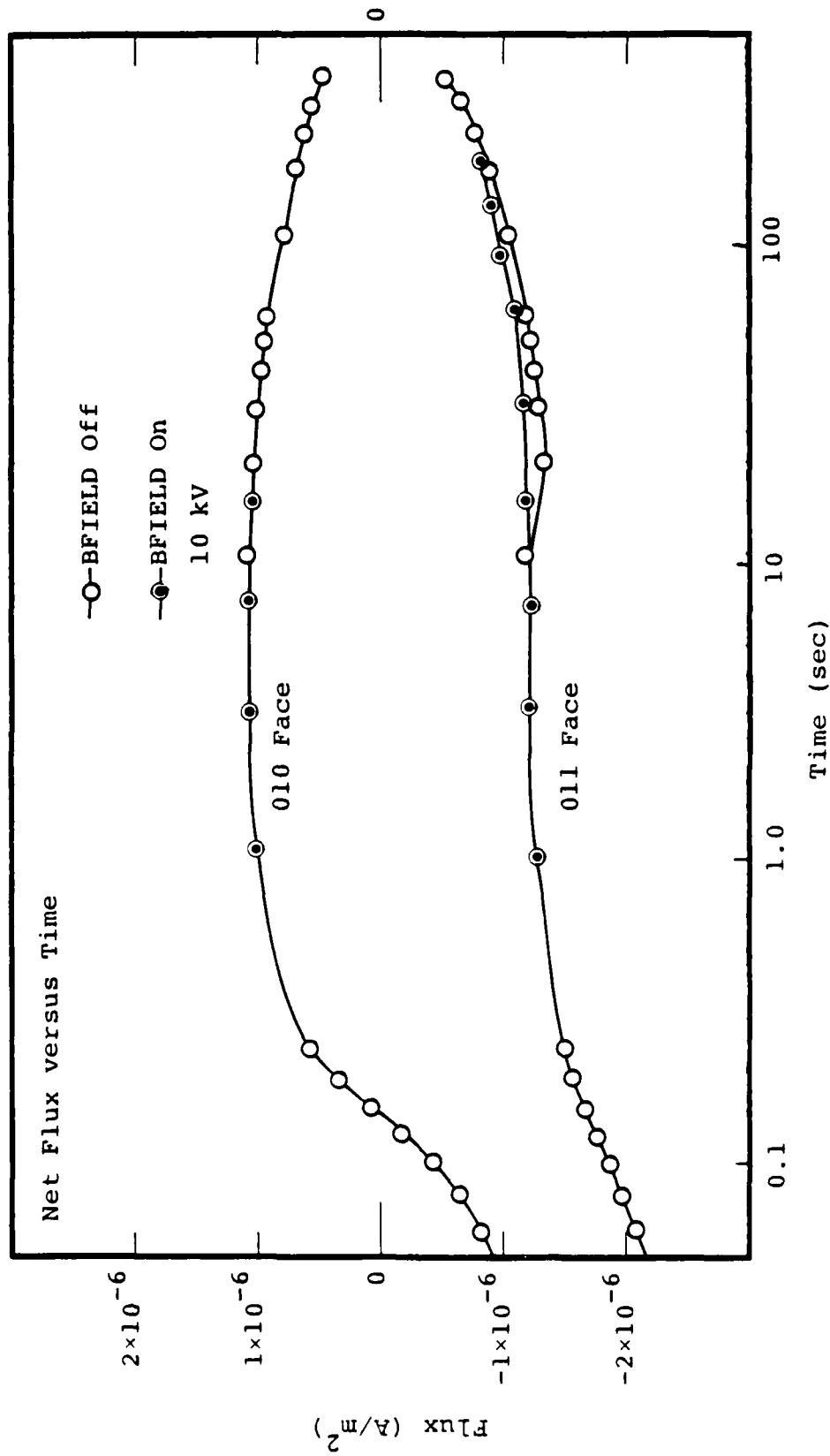


Figure A-4. Net flux to faces indicated versus time for the 10 keV runs, illustrating the same points as the previous potential plot. Note the reduction in differential flux as equilibrium is approached.

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