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Final Report

to the

National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

for a research program titled

Neutralizer and Sample Chamber for the Atomic Oxygen Simulation System (AOSS)

NASA Contract: NAS8 - 37748

[Research Period: November 1, 1989 through April 30, 1991]

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Introduction

NASA Contract NAS8-37748 supported the development of a neutralizer system capable of converting a beam of oxygen ions (O^+ or O_2^+) into a beam of low-energy neutral oxygen atoms (O). The neutralizer system is to be designed to be compatible with the Atomic Oxygen Simulation System (AOSS) located in the Physical Sciences Branch of The Marshall Space Flight Center. The Center for Molecular and Atomic Studies at Surfaces (CMASS) at Vanderbilt University has met these objectives by developing a system that neutralizes the ions through electron transfer during a grazing-incidence reflection of an ion beam from a smooth nickel surface. The purpose of this final report is to describe the system, provide schematic representations of the system, and to discuss the use of the system in relation to the AOSS at the Physical Sciences Branch of NASA Marshall.

Grazing-Incidence Neutralization

Our studies[1] [2] [3] of the neutralization of ion beams at metal surfaces show that many beams, including those of O^+ and N_2^+ , can be transformed into neutral beams for use in space-related research. These investigations resulted in the development of a practical grazing-incidnce neutralizer for which a US patent was issued in 1988[4]. In other contexts charge neutralization at metallic surfaces has been studied by researchers at Bell Laboratories[5], at the University of Osnabrück[6] [7], and at the University of Münster[8]. The eight references listed here provide a background of information related to the neutralizer and to the neutralization process.

The Grazing Incidence Neutralizer

The system which we have developed is shown in Figures 1 through 5. Figure 1 is a three-dimensional schematic drawing of the neutralizer. Figure 2 shows the neutralizer positioned within the NASA AOSS facility. Figure 3 is a two-dimensional drawing that specifies dimensions and electric potentials. Figure 4 is a top view that shows the relation of the unit to the impinging ion beam and Figure 5 depicts details of the deflecting magnet.

Since the creation, focusing, mass selection and energy selection of the ion beam is best accomplished at energies much greater than the final energy (5 to 100 eV) of the neutral beam, the system is designed to accept an ion beam of several hundred electron volts and to decelerate the beam to its final energy just prior to neutralization. In the present configuration, the face of the AOSS beam tube is covered with a 90% transmitting conducting mesh (Mesh #1, Figures 3 and 4) which provides a sharp boundary for the beam potential and which helps create a uniform electrostatic decelerating field between Mesh #1 and Mesh #2. The potential of Mesh #2 is adjusted to decelerate the beam to the desired final energy. Following the deceleration, the beam impinges at grazing incidence on a macroscopically smooth nickel surface where it is neutralized by electron pickup. Mesh #4 is held at a potential significantly above the beam potential in order to reject un-neutralized ions. Mesh #3, adjusted to the same potential as Mesh #2, serves to maintain at a constant potential the neutralizer plate and its surroundings.

Electrons, but not the the more massive ions nor the charge-neutral atoms, are deflected by a high-field (~800 gauss) magnet whose poles are positioned just above and just below the beamline immediately in front of the sample. The positioning of the magnet is illustrated in Figure 3 and the details of the magnet construction are depicted in Figure 5.

The spatial extent of a 5000-eV hydrogen beam neutralized by reflection from a single plate of nickel was measured by scanning a thin wire detector across the beam path downstream from the neutralizing plate. The contribution of the grazing-incidence reflection to the angular spread of the beam was found to be of the order of ± 5 degrees. Since very-low energy beams will be further spread by the deceleration process, the flux striking the sample will depend upon the sample-to-neutralizer-plate distance, which is therefore minimized.

The Colutron ion source used in the AOSS and the Vanderbilt apparatus ionizes the source gas by accelerating electrons between a hot filament and an anode held 100 to 300 volts above the filament potential. Ions swept through an aperture in the anode (which forms one end of the cylindrical chamber) are accelerated by an electrostatic field and become the primary ion beam. Since the potential within the source chamber varies with the distance from the anode, the final energy of a particular ion will depend upon its point of origin. The source chamber has been engineered so that ions are accepted from only a small volume within the chamber and, hence, the energies of the ions of the primary beam differ from one another by no more than about one electron volt. Upon interaction with the nickel plate ions can lose energy through inelastic scattering; however at grazing angles this loss will be no more than approximately 3% of the incident energy. The energy spread of the primary beam and the energy spread introduced by the scattering process lead to a total uncertainty in the neutral-beam energy of less than one and one half electron volts.

We determined the efficiency of the neutralization process by measuring the intensity of the fluorescence of MgF_2 under both N_2^+ and N_2^o bombardment at 200 eV. For the same primary beam current the fluorescence induced by the neutralized beam was 40% that induced by the primary ion beam. At this relatively high bombarding energy of 200 eV the ions and the neutrals are approximately equally effective in producing fluorescence, thus we conclude that the neutral beam was ~40% as intense as the ion beam and that the efficiency of neutralization under these conditions is ~40%.

Installation and Usage

The neutralizer unit consists of three distinct entities: the neutralizer plate, the system of meshes, and the deflecting-magnet assembly. The mesh system and the magnet assembly are mounted on short pedestals attached to the floor of the AOSS vacuum chamber. The mounting bolts pass through slots so that when the bolts are loosened one can slide the units to vary the neutralizer-target distance. The meshes that define the electrostatic fields must be positioned normal to the beam direction to within a few degrees, since final beam energy and spatial focusing is dependent upon this orientation.

The neutralizer plate is attached to the arm of a manipulator with both translational and rotational degrees of freedom so that one can make positional and angular adjustments even when the system is under vacuum. The manipulator can be used to alternatively insert and remove the neutralizer plate so that one can experimentally differentiates the effects of neutral beams from the effects of ion beams. A top-mounted manipulator is preferred, possibly with the addition of a nipple to accommodate a manipulator with a throw of several inches. The manipulator could be side-mounted on one of the existing vacuum ports; however this arrangement has limited flexibility and presents a problem of alignment since the ports are not located directly opposite the position of the neutralizer unit (see Figure 2).

The neutralizer can be used to neutralize not only oxygen ions and nitrogen ions but also a wide variety of other ionic species. Because of the difficulty of producing beams of oxygen ions and because of the corrosive effects of oxygen on the source-chamber filament, setup procedures are accomplished with N_2^+ beams, with a switch to O^+ or O_2^+ occurring after the setup is complete.

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Grazing Incidence Neutralization Apparatus

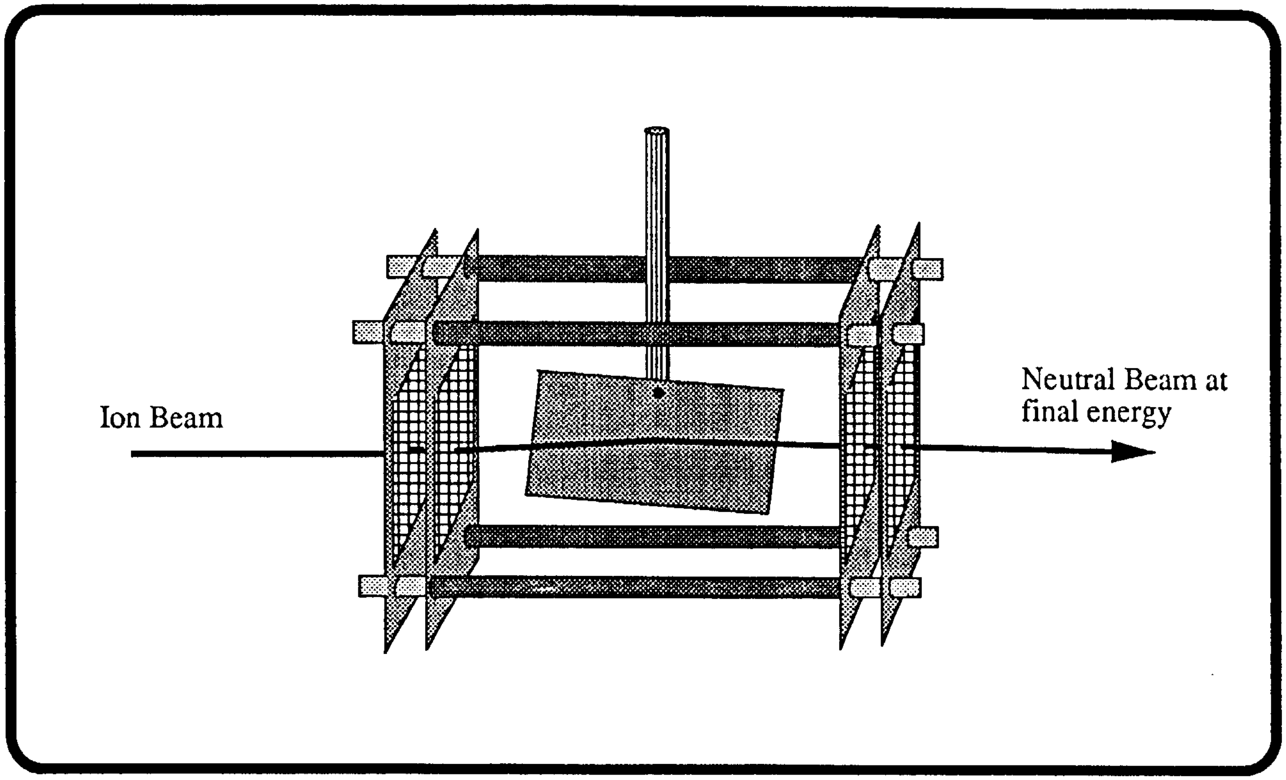


Figure 1

Top View of AOSS Sample Chamber

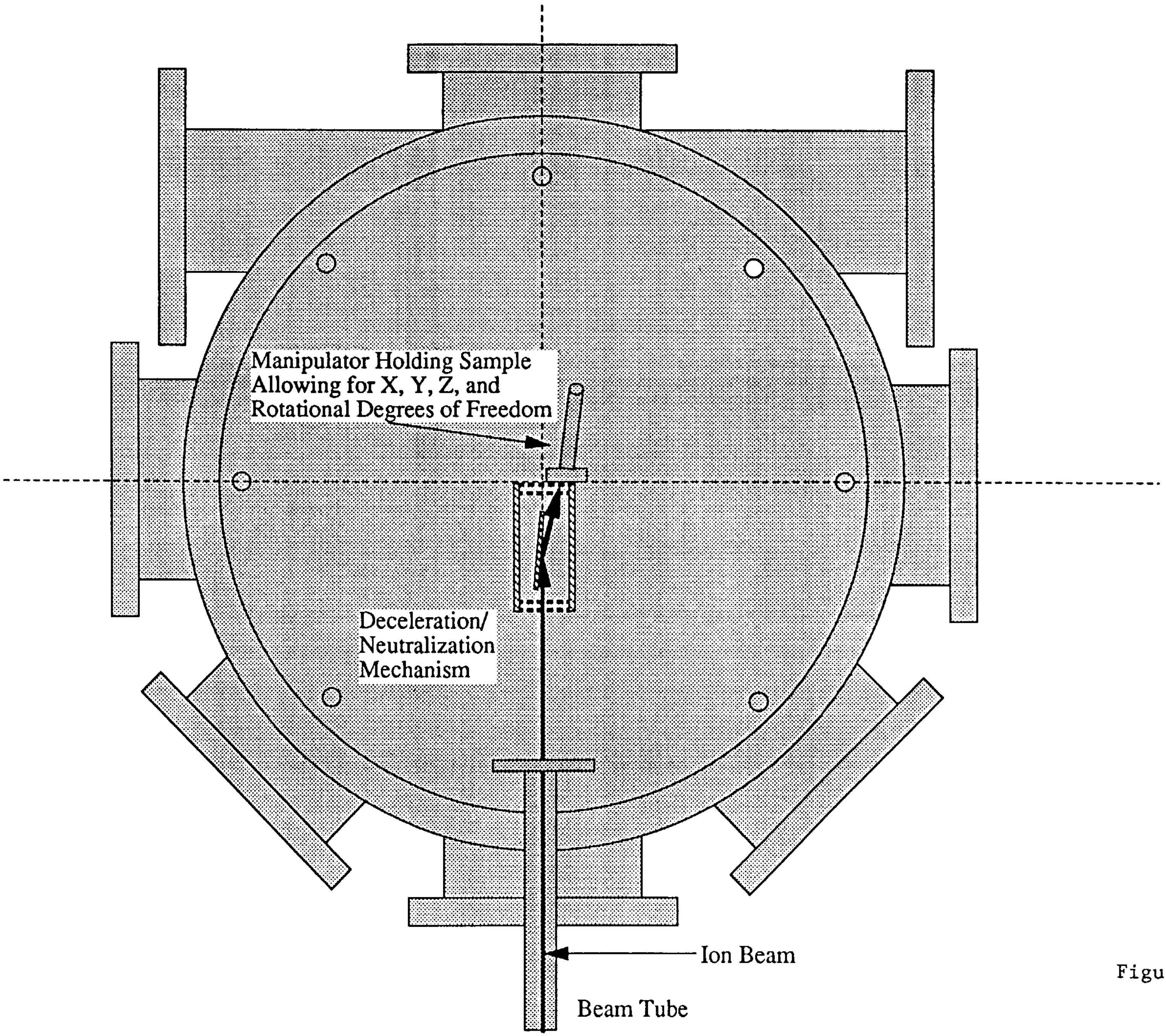


Figure 2

Side View of Grazing Incidence Neutralization Apparatus

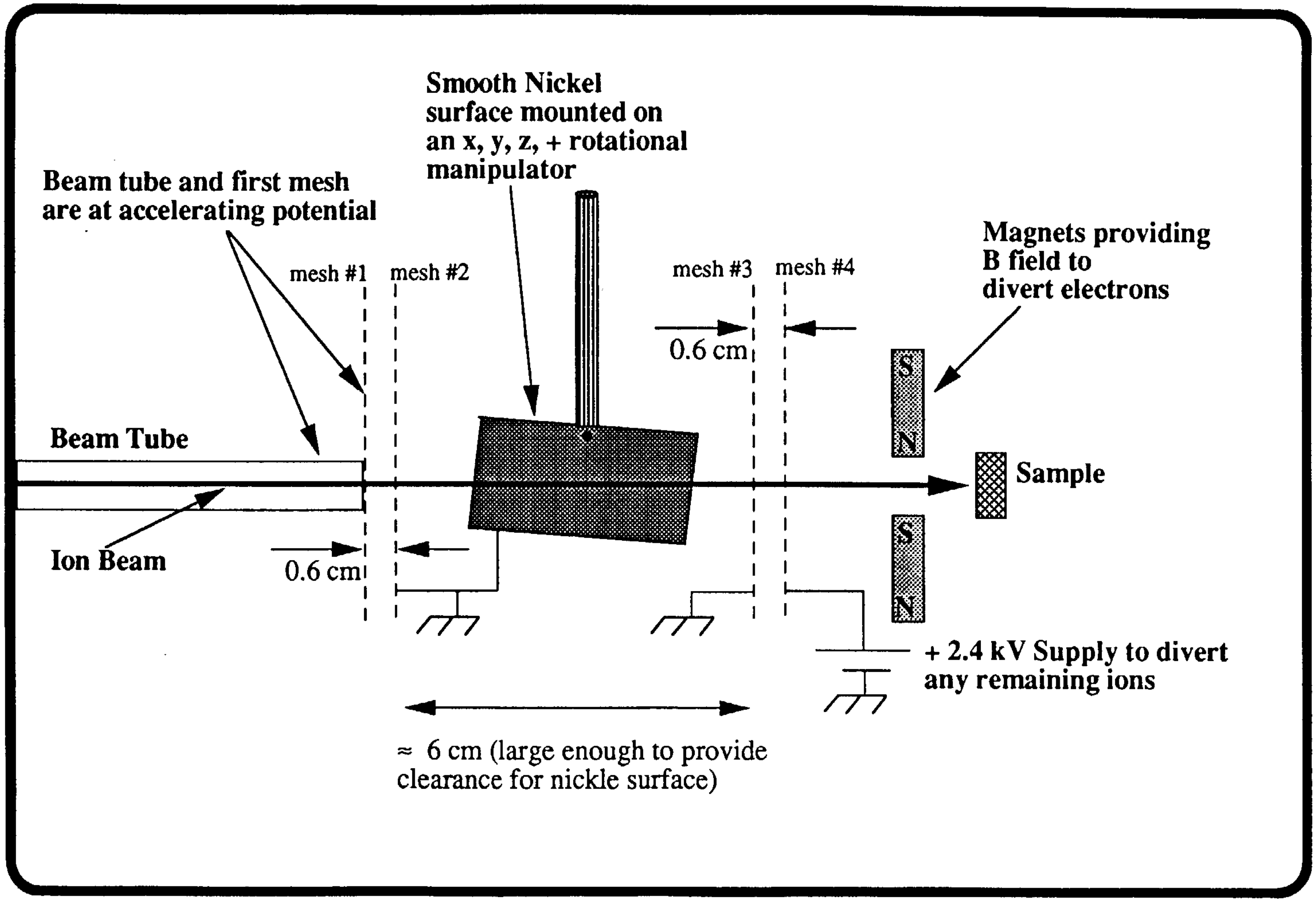


Figure 3

Top View of Grazing Incidence Neutralization Apparatus

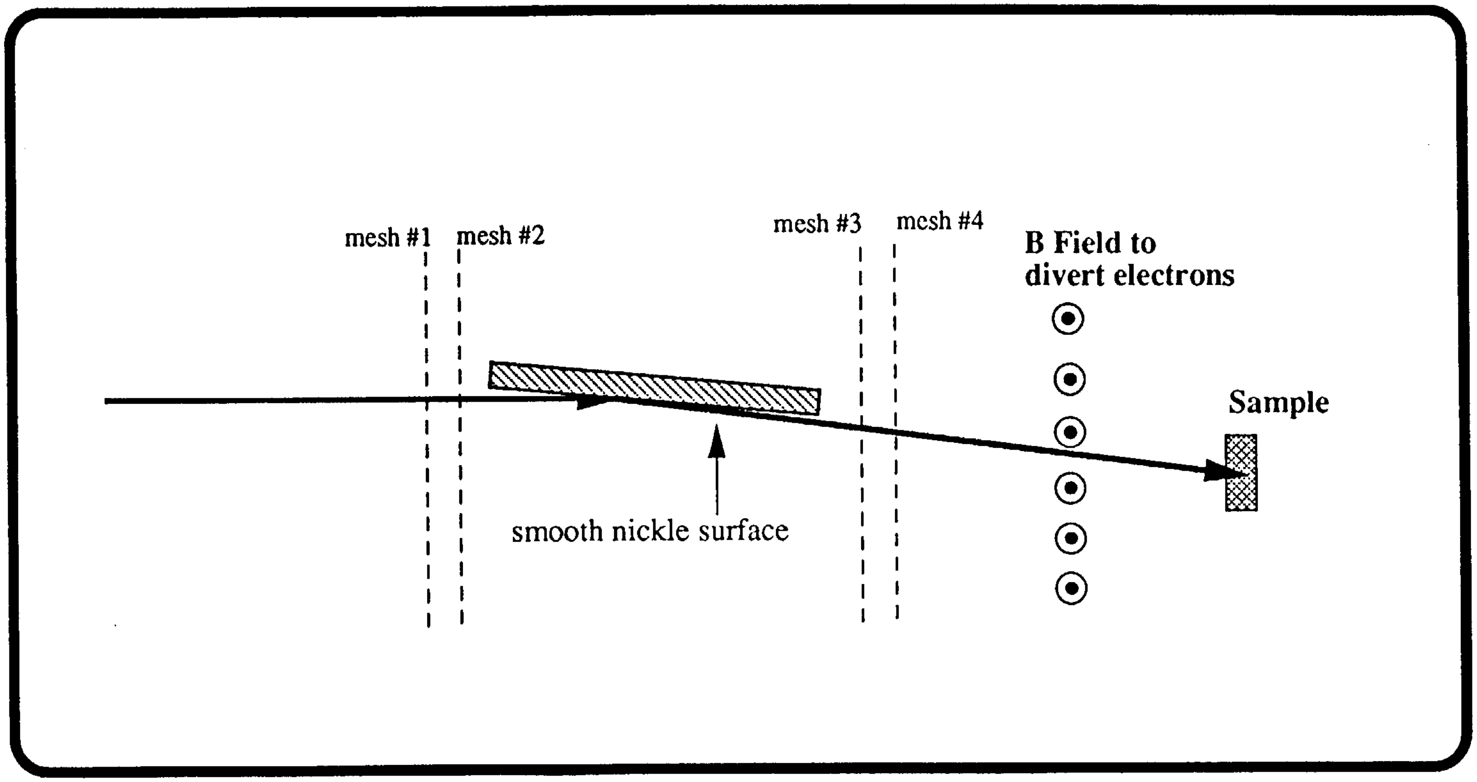
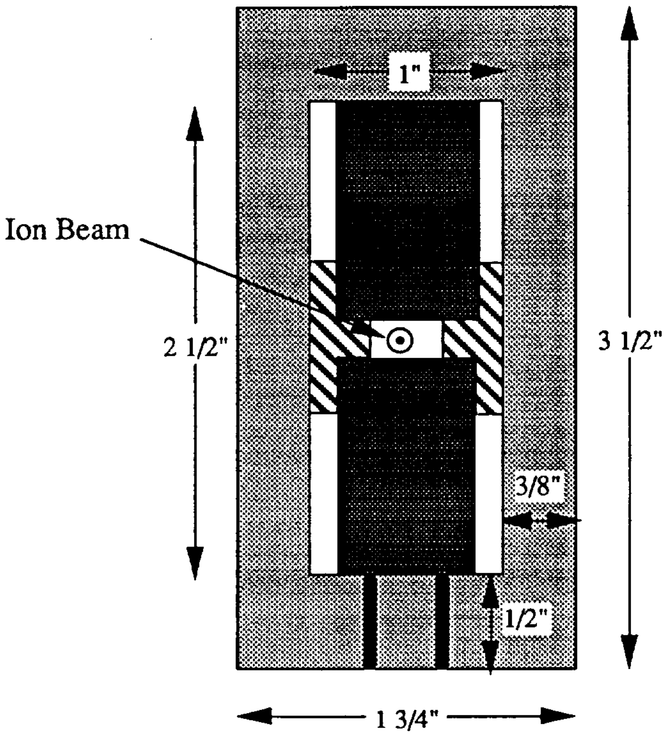


Figure 4

Front View of Magnet Holder with Magnets



MATERIAL LEGEND:

▒ → Soft Iron

▨ → Aluminum

■ → Alnico permanent manets with magnetic field parallel to longest dimension

Figure 5