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"Evaluation of Thermal Control Coatings in the Space Environment"

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FACILITY FORM 602

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I. INTRODUCTION

The purpose of this interim report is to provide a description of the AVCO/Tulsa space environment simulation facility and other equipment used for this program, and a discussion of the methods used in the calibration and monitoring of the various parameters.

II. THE TEST EQUIPMENT

A. Space Environment Simulator

1. Van de Graaff Accelerator

The accelerator is capable of accelerating positive ions or electrons in the energy range from about 10 Kev to 500 Kev. The Van de Graaff voltage generator is used from about 500 Kev down to 100 Kev below which point the voltage stability becomes poor. Energies below 100 Kev are provided by disabling the Van de Graaff voltage generator in the accelerator and connecting an auxiliary 0 - 100 kilovolts power supply across the acceleration tube. Positive ions are generated by an R. F. ion source. The accelerator is pumped by a four-inch oil diffusion pump containing Dow Corning 705 diffusion pump oil. A freon cooled baffle prevents migration of oil into the system. Basic pressure in the accelerator is about 10^{-6} torr as measured by a Phillips ionization gauge and pressure during operation is in the 0.6 - 1×10^{-5} torr range.

The accelerator is equipped with an analyzing magnet to provide mass analysis of the ion beams. The analyzed beam which is used is bent at an angle of 45^{o} to the accelerator axis. Beyond the magnet, a transition section and the ultra-high vacuum chamber are shown in Figure 1. The facility actually has two transition sections and two sample chambers each at 45^{o} to the accelerator axis. By reversing the direction of the magnetic field (direction of current flow through the analyzing magnet) the particulate radiation can be aimed into either chamber.

2. Vacuum Chambers

The ultra-high vacuum chambers are depicted schematically in Figure 2. They are approximately 16 inches ID x 18 inches OD x 30 inches high (inside). The chamber walls are constructed from a pair of

1. Ion Source
2. Hydrogen Gas
3. Van de Graaff Accelerator
4. Acceleration Tube
5. Valve
6 Diffusion Pump and Baffle
7. Analyzer Magnet
8. Beam Monitor
9. Bellows
10. Differentially Pumped Orifice
11. Differential Ion Boostivac Pump
12. EUV Source Port
13. UV Beam Port
14. Deflection Plates
15. Mirror
16. Ultra-High Vacuum Chamber
17. Target Holder
18. Insulated Feedthrough

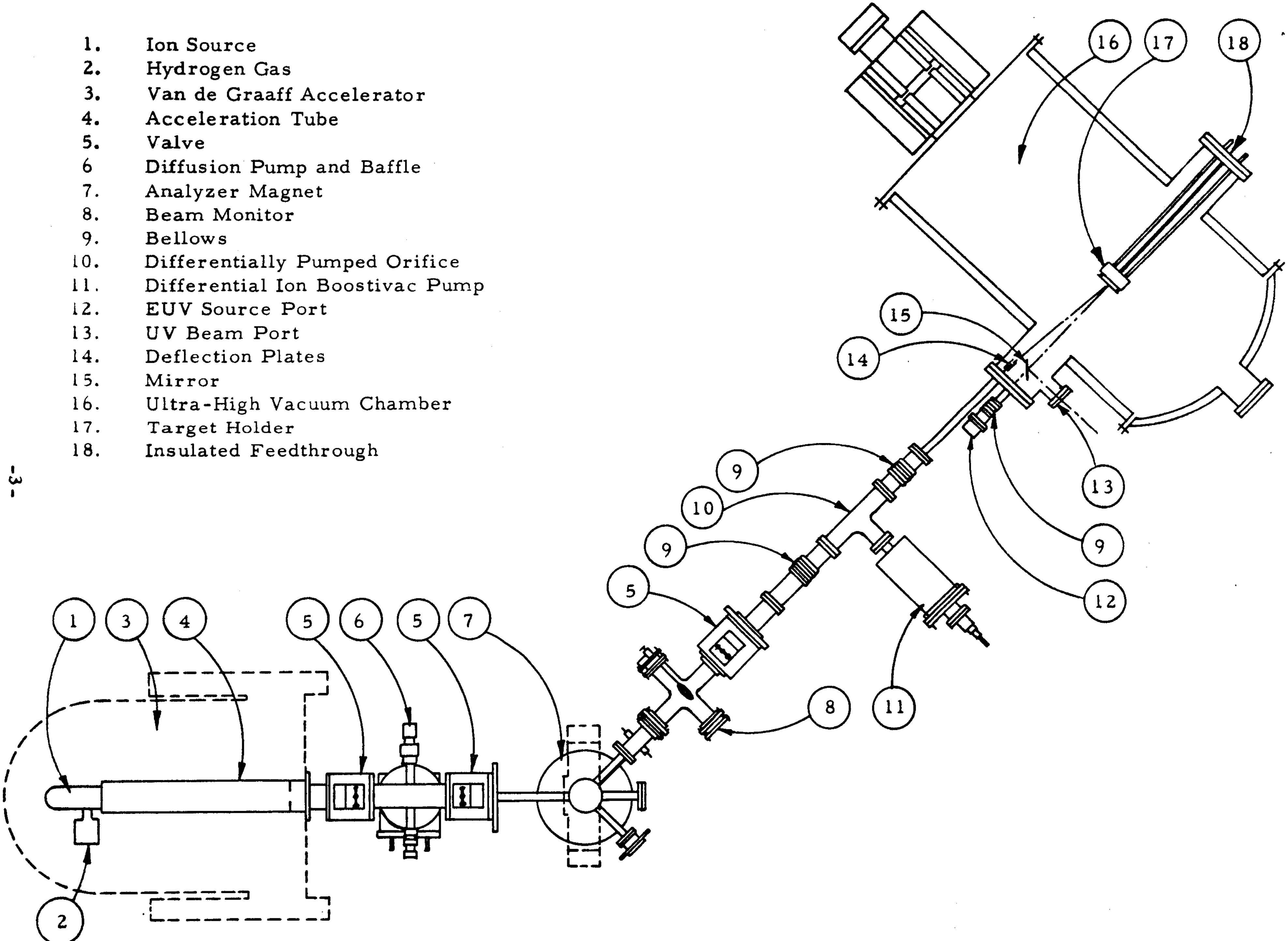

Figure 1 -- SCHEMATIC OF SPACE ENVIRONMENT SIMULATOR

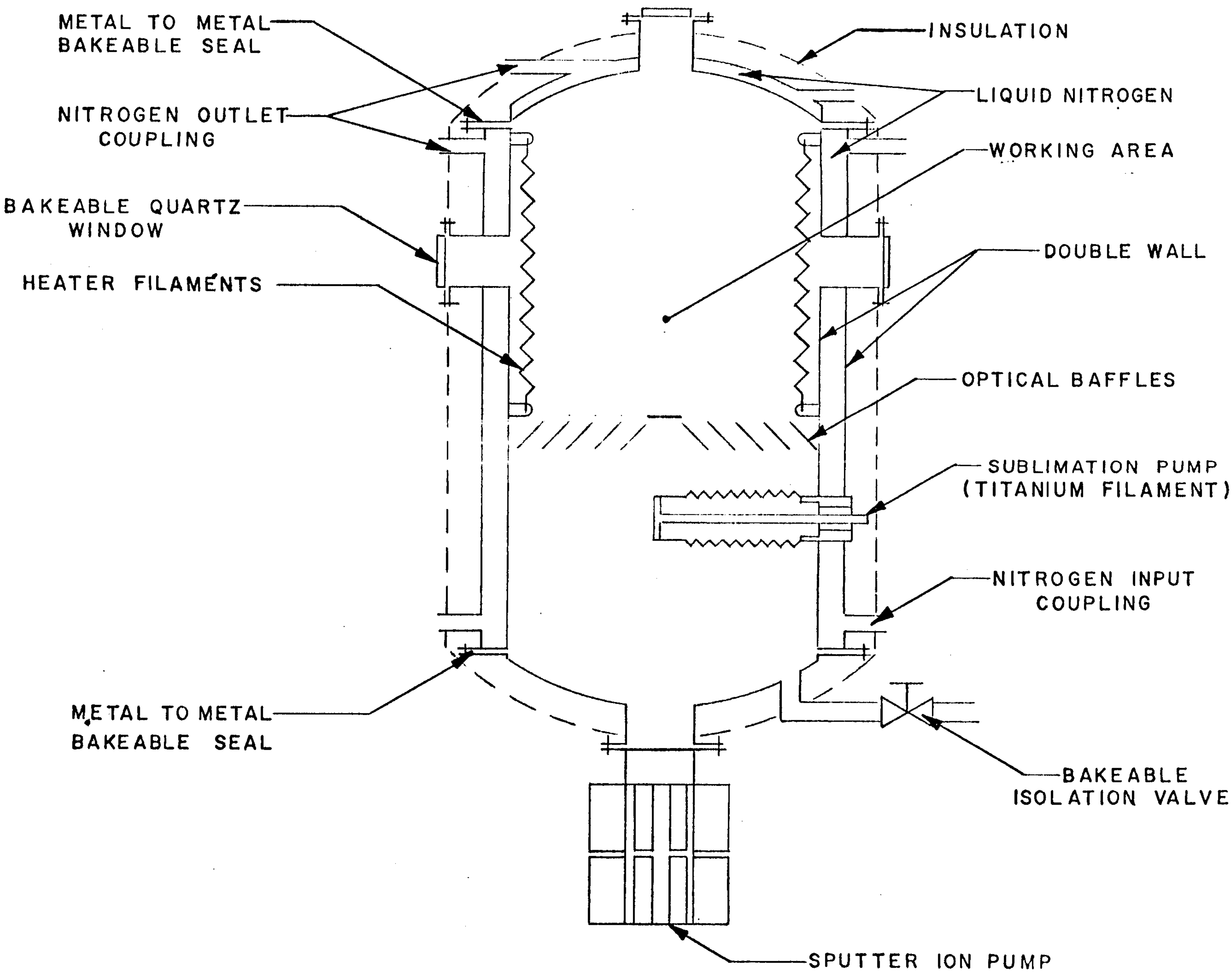

Figure 2 - SCHEMATIC OF ULTRA-HIGH VACUUM SYSTEM

concentric cylinders of type 304 stainless steel. The chambers are capped at both ends with metal-to-metal type high vacuum flanges. The annulus between the cylinders, except in regions taken up by feedthroughs and flanges, serves as a passage for liquid nitrogen or other coolants to provide cold surrounds and some cryogenic pumping as desired.

The chamber is pumped by a 5000 liter per second titanium sublimation pump backed by a 400 liter per second ion pump to provide an exceptionally clean vacuum for the tests. An optical baffle prevents titanium vapor migration into the working area of the chambers. The chambers can be baked out at temperatures up to 400° C by internally mounted tungsten heater elements.

The working section of the chambers is 18 inches in length. Around the mid-periphery of this section, four ports (4 inch nominal on 4-1/2 inch inserts) are located 90° apart. Particulate and electromagnetic radiation are introduced through one of those ports on the side of the chamber and the sample holder is introduced through the port diametrically opposite.

3. Transition Section and Beam Scanner

After leaving the analyzing magnet, the beam passes through a glass cross. Within the cross a monitor, consisting of a Vycor disc covered with a stainless steel screen, can be positioned to intercept the beam. This provides a beam current readout at that point and also a visual observation, since the glass scintillates when the ions or electrons impinge upon it.

The accelerator and chamber are separated by a differentially pumped section to isolate the ultra-high vacuum region of the chamber from the moderately high vacuum region of the accelerator. The differentially pumped section is terminated at either end by rectangular slit orifices which help to limit gas conductance, and also serve to collimate the charged particle beam prior to entrance into the beam scanner. Pressure in the differential section is normally about 1.5 orders of magnitude lower than that in the accelerator. Pressures in the chamber are normally in the 10^{-8} to 10^{-9} torr range during operation.

The beam scanner consists of a pair of electrostatic deflection plates. The collimated beam passes between these plates and is moved to sample center by application of a d. c. bias and then "rastered" across the required area by means of a low frequency sawtooth voltage applied to the plates.

4. Solar Simulator

The solar simulator, designed by Aerospace Controls Corporation and constructed at AVCO/Tulsa, utilizes a 5 kilowatt short-arc lamp, either xenon or xenon-mercury to simulate the solar spectrum. The light from the simulator is beamed through a quartz window in the port (13, Figure 1) and reflected from an aluminized front face mirror onto the samples. The lens system in the simulator provides for focusing the light such that with the end of the simulator barrel about one-fourth inch from the quartz window flange, a uniform three-inch diameter beam is obtained at a distance of 14 inches from the mirror. Total intensity at this point can be in excess of ten solar constants with either type tube. However, it is not possible to achieve ten solar equivalents in the 0.2 - 0.4 micron range with the Xe lamp so that the Xe-Hg lamp was chosen for this study.

5. Lyman-Alpha Source

The vacuum ultraviolet source of AVCO/Tulsa design is essentially a Penning discharge tube with water-cooled anode and cathodes. Light from this source is beamed through a lithium fluoride window onto the samples. The source provides energy in the 0.105 to

0.2 micron range. With hydrogen gas it is essentially a line source with the Lyman-alpha line at 1216 Å as the most prominent. The port for the source is shown in 12, Figure 1.

6. Sample Holder

The sample holder assembly, which was designed and fabricated for the study is shown in Figure 3. Three samples can be clamped in the holder. Two samples face the sources of radiation and one, mounted in the end of the holder, is shielded from these sources. Coolant fluids can be circulated through the sample holder via stainless steel tubing running through an insulated feedthrough which isolates the holder from ground. A cartridge heater is installed in the holder for maintaining higher temperatures. A thermocouple is spring loaded against the back of the sample which is irradiated by both particulate and electromagnetic radiation.

The samples tested are nominally 15/16-inch in diameter. The sample area which is exposed to radiation is 13/16-inch in diameter, since the samples are clamped at the edge. Two plates are mounted on insulating standoffs from the face of the sample holder. The plate farthest from the holder face serves to collimate the particle beam and thus define the area of sample and sample holder which is irradiated. Two 15/16-inch diameter holes in this plate are centered over the samples. The charged particle beam as it is incident on this plate is rectangular, approximately 1-1/8-inches long x 3/16-inch wide. The beam is rastered across the appropriate collimating hole in the plates by the sawtooth voltage applied to the deflection plates. The collimating plate is connected to an insulator in the four-inch vacuum flange and may be grounded or biased as necessary. The purpose of the intermediate plate is to serve as a secondary electron suppressor. The charged particle beam passes through a short section of tubing in this plate. The plate (and tubing) is biased

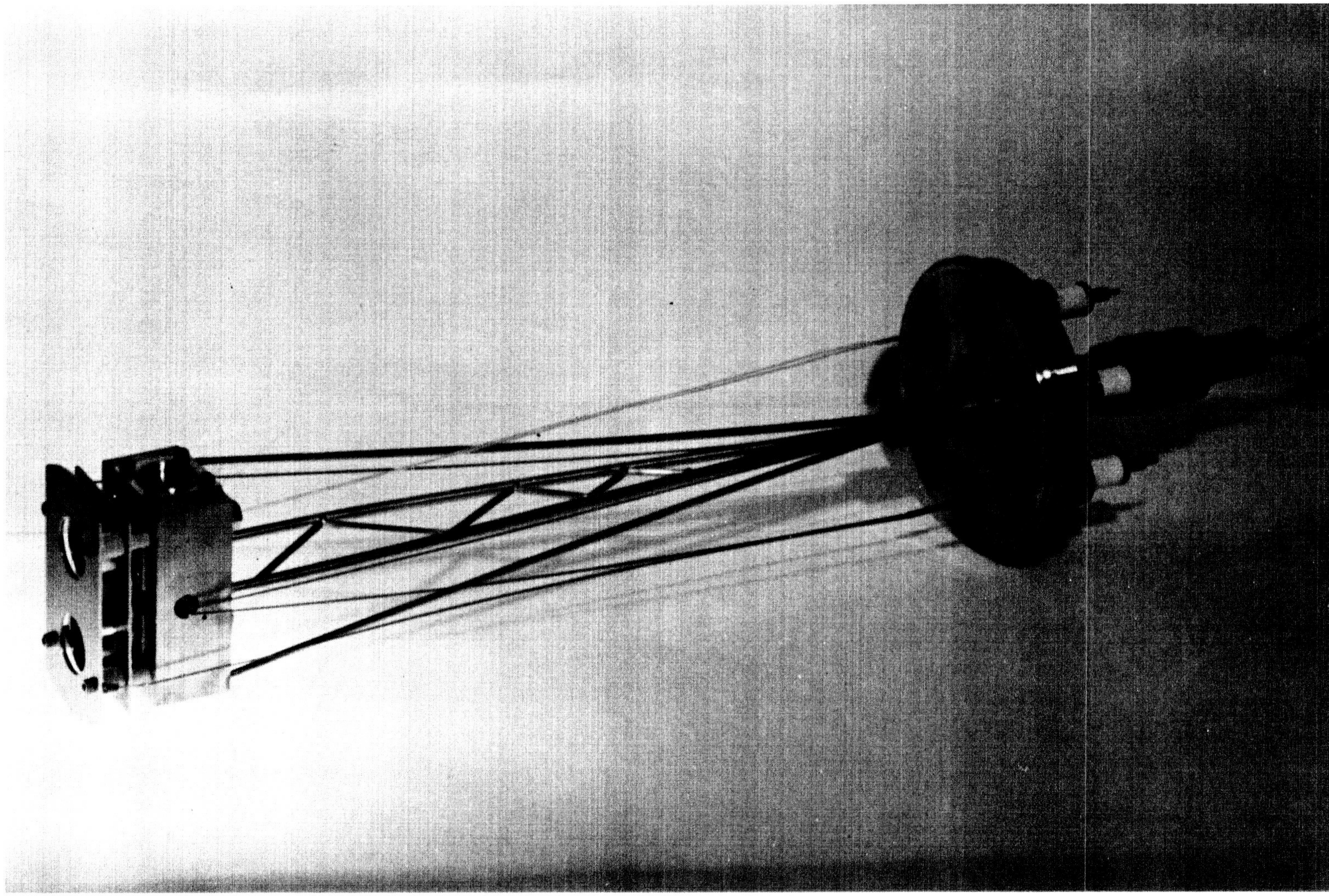

Figure 3 -- SAMPLE HOLDER

negatively with respect to the sample holder and collimating plate to force secondary electrons arising from particle bombardment back to their respective sources. Target current is read directly by connecting a meter to the insulated feedthrough which supports the sample holder. When samples which are good insulators, such as the paints, are being irradiated, a grid consisting of five parallel strands of one mil stainless steel wire is mounted in contact with the sample surface. This grid masks less than one percent of the sample area and serves to prevent the sample surface from becoming electrically charged with consequent "chasing" of the particle beam and inaccurate beam current readings.

B. Reflectance Measuring Apparatus

Reflectance measurements are made with a Perkin-Elmer Model 112-U spectrophotometer attached to a Gier-Dunkle Model AIS-6 integrating sphere coated with MgO. A Pek Model X-75 xenon lamp and Gier-Dunkle Model RXS-1 power supply were obtained to provide sufficient intensity for reflectance measurements below 0.4 microns. A tungsten lamp is used for measurements at longer wavelengths.

It was found necessary to mask off the upper half of both the entrance slit and the exit slit on the monochromator to prevent first-pass (d. c.) light from getting through to the sphere and saturating the photomultiplier tube when attempting to make measurements in the ultraviolet. The method is effective, since the d. c. image of the entrance slit is inverted once and the chopped image is inverted twice in the monochromator. It was possible to focus the light from the xenon lamp on the unmasked half of the entrance slit so that no loss of intensity occurs.

C. <u>Temperature Control</u>

A controller, designed and built at AVCO/Tulsa, utilizes the signal from the thermocouple which monitors sample temperature to maintain sample temperature at any level from -160 to $+300^{\circ}$ C.

III. EQUIPMENT CALIBRATION

A. Particle Energy and Flux Density

Particle energy is essentially determined by the potential drop across the acceleration tube in the accelerator. When the Van de Graaff voltage generator is being used the generating voltmeter on the Van de Graaff has been calibrated to read directly the particle energy. The calibration was performed as follows:

The particle beam from the accelerator after collimation by the orifice slits passes between the electrostatic deflection plates of the beam scanner. The beam was permitted to fall on a Pyrex window and the resultant scintillations marked the position of the beam. By applying a d. c. potential to the deflection plates the beam was moved to a different position. The accelerating potential was determined from the well known equation

$$V_A = \frac{ld\ V_d}{2tx}$$

where V_A is the acceleration voltage, l is the length of the deflection plates, d is the distance from the center of plates to the glass window, V_d is the applied deflection voltage, t is the spacing between the plates, and x is the distance the beam was moved on the window.

The calibration was made at several accelerating potentials to accurately calibrate the readout meter.

When the auxiliary power supply is used, the reading from the meter on its control panel is used to determine the particle energy, i. e., a 10 kilovolt potential produces 10 Kev particles. This is not strictly true in the case of positive ions since in addition to the potential across the acceleration tube, the ions are given an initial acceleration to extract them from the R. F. ion source by application of a relatively low potential to the source probe. However, the total energy of the particles is known to within ten percent.

Flux densities are readily determined due to the geometry of the sample holder. As described in Section II. A. 6, the collimating plate mounted in front of the sample holder defines the area, A, of the sample and sample holder which is irradiated. The average current striking this area is directly measured by connecting a meter from the sample holder to ground. If this current, I, is noted in amperes, the flux density is given by

$$\frac{I}{A} \times 6.25 \times 10^{18}, \quad \text{particles/cm}^2\text{/second}$$

Where a certain flux density is required it is, therefore, simple to determine the required beam current and adjust the Van de Graaff accordingly. The method used in adjusting for the desired current is to adjust for a current on the monitor in the glass cross section which will yield approximately the proper target current and to make final minor corrections after the beam is on target.

The target current is recorded on a strip chart recorder throughout the tests. The current is sufficiently stable that the total integrated flux in particles/cm^2 striking the samples during a test is known within an estimated fifteen percent.

B. Solar Simulator Calibration

The solar simulator was calibrated by setting up the exact vacuum chamber geometry on a bench. Spectral calibrations were made using a monochromator calibrated with an NBS Standard quartz-iodine lamp, thus providing quantitative spectral intensity data. Such calibrations can be carried out at intervals by setting up the monochromator next to the target chamber to analyze the light coming through the sample holder port.

A special ultraviolet calibrator has been constructed such that two pyrheliometers manufactured by Hy-Cal Engineering can be mounted in the chamber at the exact position occupied by the samples when they are irradiated. By mounting various filter combinations (7-54, 0-54, and

RG-2 Schott glass) in front of these detectors a check of the ultraviolet light can be made. Such checks are to be made at the beginning and end of each test.

A radiometer with a 7-54 ultraviolet transmitting filter is mounted in the solar simulator so that intermittent measurements of ultraviolet intensity can be made during the tests.

C. Vacuum Ultraviolet Calibration

The vacuum ultraviolet light calibration was made with one centimeter nickel discs mounted at the sample positions in the sample holder, and with a nitric oxide ionization cell with a lithium fluoride window also at sample position. The nickel discs serve as photoelectric detectors. With a negative bias applied to them, the photoelectrons, which are generated primarily by Lyman-alpha photons, are ejected and the current is proportional to the light intensity. A quantum efficiency of 2.5 percent was assumed for the nickel based on data of Hinteregger and Watanabe(1). The overall quantum efficiency of the NO cell obtained from G. B. L. Associates was not known. Dunkelman(2) states that efficiencies range from 10 to 50% for similar detectors.

A loop of 10 mil nickel wire permanently mounted close to the light source was cross calibrated to provide continuous monitoring of light intensity during the tests.

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(1) Hinteregger, H. E. and K. Watanabe, J. Opt. Soc. Am., 43, 7, pp 604-608 (July, 1953).

(2) Dunkelman, L., J. Quant. Spectrosc. Radiat. Transfer, 2, pp 533-544.