AEDC
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12V Electric Propulsion Test Facility

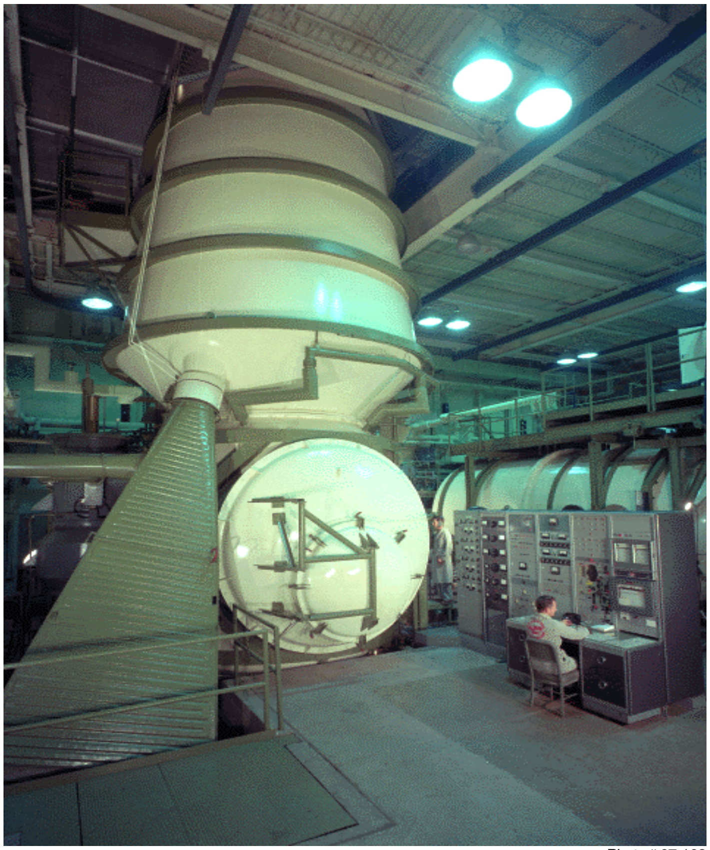
AEDC's 12V Chamber is a two-section, 12-ft-diameter by 35-ft-high thermal vacuum test facility originally designed and constructed for thermal balance testing of small vehicles and components and with solar simulation capability. The facility contains a full liquid nitrogen (LN_2) thermal shroud and has an optional gaseous helium (GHe) inner liner that can be cooled down to 10 degrees Kelvin. The chamber can be pumped to a pressure of less than 1x 10^{-7} torr in 30 hours allowing time for three nitrogen sweeps to remove any water vapor.

The chamber's lower section is enclosed by a LN_2-cooled liner and LN_2-cooled floor made of an extended surface material providing high absorptivity. The upper section of the chamber is lined with D-tube paneling cooled to LN_2 temperatures and expands to a maximum 17 ft diameter. The solar simulator is an off-axis system with xenon (Xe) arc lamps using integrating lens assemblies to collimate a uniform, one- solar constant beam, over an 8-ft-diameter by 8-ft-high test volume.

Recent facility modifications enable the chamber to facilitate testing of Electric Propulsion (EP) thrusters at the lowest possible vacuum levels and can also be configured for EP thruster plume analysis and integration effects testing. These modifications include baffling to direct the plume, large internal GHe cryopumps, thruster fuel feed and power systems and chamber/thruster data systems.

Operators control thruster power and Xe flow from a remote control room at the base of the chamber. Throughout a typical EP test, a test engineer and a technician continuously operate chamber system systems from a separate control console. Customers have the option to operate and/or monitor the thruster themselves or allow AEDC test engineers to conduct the test.

Chamber 12V's vacuum pumping system consist of a 650- cubic-ft/min (CFM), a 130-CFM and a 50-CFM roughing pumps, a 700-CFM lobe-type blower, a 52,000-L/sec (LPS) diffusion pump with a LN_2 baffle, and two



AEDC Chamber 12V Photo # 67-163

1,500 LPS turbomolecular pumps backed by a 23-CFM foreline pump. AEDC-fabricated helium upper and lower internal cryopumps pump Xe to the chamber as needed with a total pumping speed in excess of 2,000,000 LPS. The lower cryopump surface area is 742 square feet, and the six upper cryopumps comprise a total surface area of 150 square feet. A 3 kW helium refrigerator supplies the cold gas. Recent testing of a 4.5 kW Hall Current Thruster (HCT) in 12V demonstrated the ability to pump Xe in excess of 2,000,000 LPS.

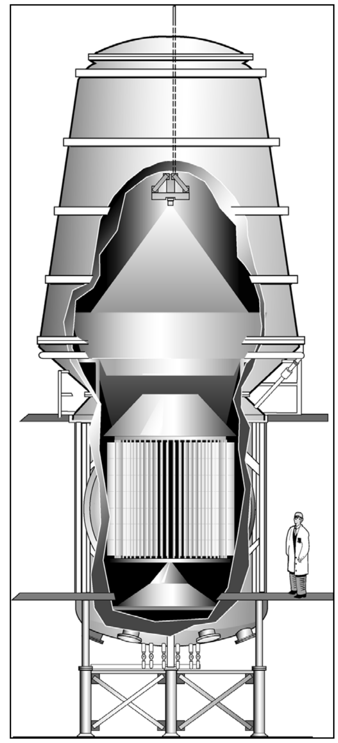
A wide variety of test configurations are possible within the chamber. To accommodate radio frequency (RF) measurements of the thruster plume, a thruster is suspended in the upper chamber section and fires downward. The thruster is translated using an AEDC- designed HCT positioning system. Positions of the thruster in both X and Y are recorded in the test log along with relevant HCT power settings and Xe flow rates. Vertical movement is accomplished using a mechanical rod type feed thru allowing for up to 1 meter of travel. The horizontal travel is accomplished using a 33-inch cryogenic rated ball-screw translator attached to the vertical feed thru rod. Control and monitoring of the 33-inch stage is accomplished with a PC using Labview programming. Moving the thruster and leaving the instrumentation fixed assures alignment and decreases the total time under vacuum conditions by 50 percent. This subsequently reduces costs for our customer.

AEDC also developed a novel hydrogen abatement system to trap hydrogen produced when the HCT fires. The system allows AEDC to reduce the partial pressure of hydrogen by several decades. A mass spectrometer is utilized to monitor hydrogen levels and the abatement system is employed to maintain the lowest total pressure possible.

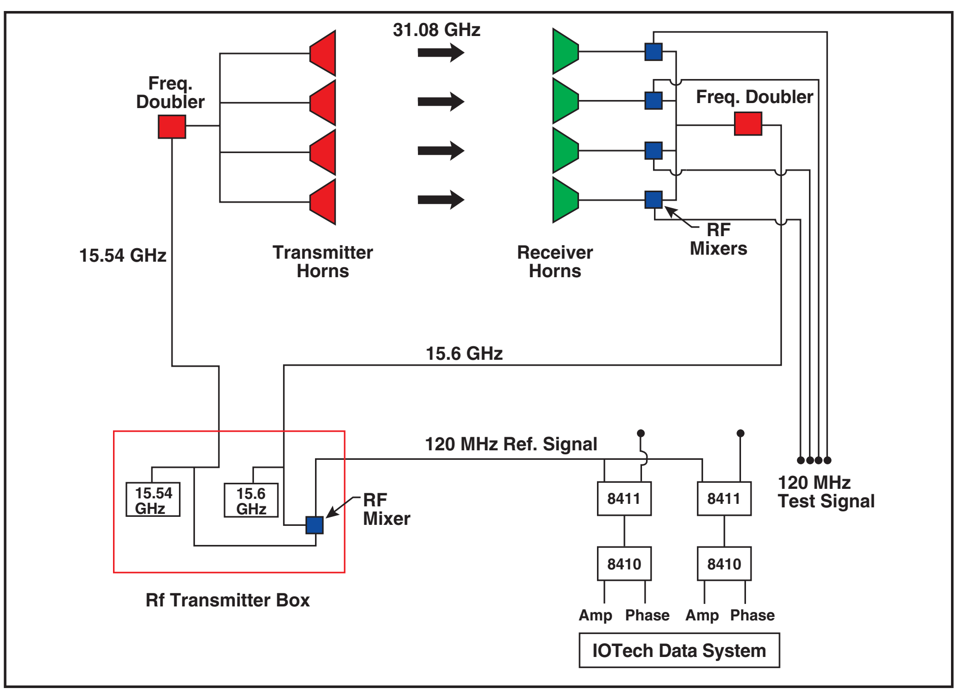
Radio Frequency Characterization of an HCT Plume

AEDC has been heavily involved for the last 5 years with the development of plasma diagnostic tools and continues development and application of various existing and new disciplines in this area. Inquiries made to the EP community indicated a strong need for a facility with very high pumping capacity and a large test volume to allow plume investigations at the most realistic conditions negating chamber effects as much as possible.

Recent test requirements focused on plume characterization and the use of RF equipment to analyze the phase shift, amplitude change and modulation of a microwave beam transmitted through the plasma plume of the HCT. To increase test efficiency, four pairs of horns simultaneously measure these quantities at multiple points in the plume. The AEDC 31-GHz RF system is shown in Figure below. The microwave beam is obtained by generating two 15-GHz high -power signals (30 dBm) that are transmitted into the test chamber using Teflon RF cable.



A typical thruster installation with access to the thruster through a manhole at the top of the chamber where existing built-in panels fold down to provide a working platform. Existing Xe supply and HCT cabling also enter through the top.



Typical 31-GHz RF Test Setup for 12V

The signals are then doubled from 15 GHz to 31 GHz using active doublers.

Wave-guide directional bridges and splitters carry the two 31-GHz signals to the horns and mixers. These signals are separated by 120 MHz in frequency. Mixing the signals results in a 120-MHz test output signal that contains the Amplitude and Phase information acquired from passing through the Hall Thruster Plume. The reference 120-MHz signal is generated outside the chamber from the two 15-GHz source signals. An HP 8410 Network Analyzer compares the two 120-MHz test signals to the reference 120 MHz and measures the relative Amplitude and Phase. The analog output signals from the Network Analyzers are then digitized using an *IOTECH Wavebook® 516* Data System and a *Gateway®* Laptop (900 MHz Pentium). A total of four signals are simultaneously digitized measuring the Amplitude and Phase from two sets of horns. Frequencies of up to 10 kHz (digitizing at The reference 120-MHz signal is generated outside the chamber from the two 15-GHz source signals. An HP 8410 Network Analyzer compares the two 120-MHz test signals to the reference 120 MHz and measures the relative Amplitude and Phase. The analog output signals from the Network Analyzers are then digitized using an *IOTECH Wavebook® 516* Data System and a *Gateway®* Laptop (900 MHz Pentium). A total of four signals are simultaneously digitized measuring the Amplitude and Phase from two sets of horns. Frequencies of up to 10 kHz (digitizing at 20 kHz) can be measured with this system on all four channels with 16-bit resolution.

Chamber Data Systems

The AEDC housekeeping data system is a PC-based HP3852 that records 100 channels of temperature and pressure data at a scan rate of 15 seconds. Liquid nitrogen panel temps, GHe cryopump temps, chamber pressures, Xe and CO_2 line temps, HCT and HCT mount temps are all monitored by AEDC and record to the hard drive at two-minute intervals. The system also monitors the temperature of critical RF equipment. This system serves as the master time clock, and other AEDC data systems are synchronized to it as required.

AEDC uses two quadrapole residual gas analyzers. *Stanford Research* RGA 200's in the upper and lower chamber (1-200 amu scan range) are monitored and data recorded as required.

Langmuir Probe Measurements

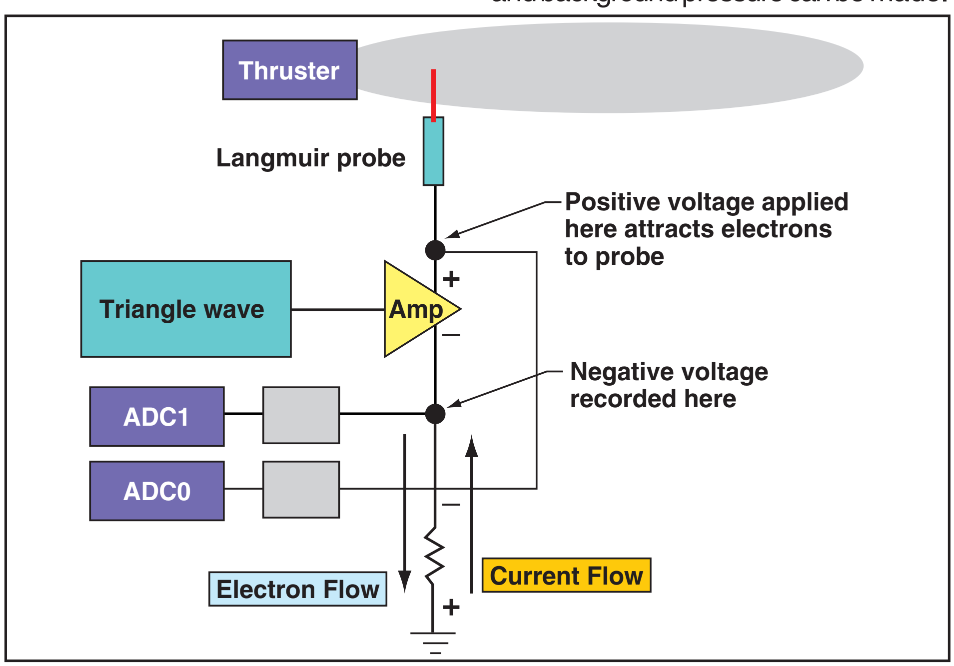
AEDC has enlisted the assistance of the University of Tennessee Space Institute (UTSI) to develop and apply improved Langmuir Probe diagnostic capabilities for the 12V. A recent test involved positioning two Langmuir probes in the plume of the HCT. Each probe consisted of a 9.25mm length of 0.10 mm diameter tungsten wire mounted in ceramic holder. The HCT was mounted on a motion system that moved it with respect to the probes.

The probes were driven by a linear ramp voltage that sweeps from approximately -5 to 30 volts at a 2 Hz rate. The probe current was determined by measuring the voltage developed by the probe current across a 1,000-ohm resistor. Four simultaneously triggered analog-to-digital converters (ADC) recorded the two probe voltages and current. Langmuir probe data were acquired by measuring the current-voltage (I-V) characteristic of the probe. The probe current and excitation voltage were recorded as the excitation voltage was swept from its minimum to maximum values. The sample frequency for each ADC was 4,096 Hz.

Future Diagnostic Capabilities

AEDC made initial attempts to utilize AEDC-designed and fabricated Faraday Cups and associated electronics and performed additional evaluation into use of Quartz Crystal Monitors (QCM's) and witness cubes. Two collimated sensors from QCM research (MK9-1 & MK9-2) can be mounted in the Chamber 12V. The MK9-2 includes a motorized flipper for blocking the direct particle flux while transmitting thermal flux. Beveled witness cubes with vapor deposited aluminum samples can be mounted to avoid interfering with the other instruments.

Laser-induced fluorescence (LIF) can be used to measure the relative number density and the velocity vector of neutral molybdenum (Mo) as a function of position and operating point. Transverse and axial velocity components are determined from Doppler shifts measured from the corresponding laser beams. The beams and collection optics are fixed while the thruster is translated to record fluorescence signal as a function of position. A movable Mo target is placed temporarily in the plume for initial tune-up. Relative density of Mo is measured at a number of positions in the range of 5 to 50 cm axial and 0 to 50 cm radial. A sufficient number of points can be sampled to allow a normalization of the relative density distribution to the assumed total efflux of Mo. Signals recorded with the Mo target in the plume may provide an absolute calibration based on known sputter yield. Sensitivity of the LIF signal to thruster power level, discharge potential, propellant utilization and background pressure can be made.



A typical experimental Langmuir setup used in the 12V.

AEDC has two laser systems capable of generating the required frequency of 345 nm required for LIF of Mo to determine relative number density along with transverse and axial velocity. One system consists of a Continuum NY82S-10 Nd:YAG Laser-second harmonic output (532 nm) that can pump a tunable Continuum ND60 dye laser (Rh690 dye in MeOH). The resulting output would be frequency-doubled via a BBO crystal and angle-tuned synchronously with the dye laser to yield 345nm at a maximum output of ~500 mJ. Another consideration for the laser system is the use of AEDC's Lambda Physik LPX130i (308 nm) Excimer, which can pump the tunable Lambda Physik LPD3002 dye laser (PTP dye in p-Dioxane) directly yielding the 345nm output; i.e., no doubling required. Maximum output at 345nm of ~ 8 mJ is much higher than the Nd:YAG. The dye laser has an optional etalon for narrow line width demands (~0.2 cm^{-1}).

The AEDC Acton .275-m spectrometer configured with the Princeton Instruments ICCD could serve as a "tunable band pass filter" for the actual fluorescence detection. In this configuration, the Laser energy could be routed to the test cell area via vacuum rated fiber-optic feedthrus. With spatial information being obtained via thruster rotation/translation it may be possible to collect the LIF Mo fluorescence yield with a fiber-optic collection system with output directed to an ICCD camera.

An added feature of 12V is the solar simulator that is incorporated into the chamber. The green triangular apparatus seen in the photograph on page one is the lower end of the simulator. Lamp radiation is generated at the base of the segment and transmitted into the 12V vacuum cell to an 8-ft diameter mirror located at the top of the chamber. This mirror is used to bathe the test article in a simulated solar environment. Presently the mirror has been removed to avoid contamination.

Chamber 12V Specifications

Thermal Control	Chamber is completely lined with a liquid nitrogen shroud that can provide thermal conditions down to 77°K. Optional 10°K GHe liner available upon request.
Vacuum Range	£ 1x10^{-8} Torr (with gaseous helium shroud) to local atmospheric pressure.
Working Volume	12 ft dia. x 35 ft tall.
Support Structure	N/A
Pumping System	Mechanical roughing pumps, blowers, turbopumps, 36-in. diffusion pump, all with cryogenic traps. Large Internal GHe Cryopump with H2 abatement. Upgrade to oil-free vacuum pumps in progress.
Loading	Horizontal – 6-ft manway. Vertical – 10-ft cap at top of chamber.
Cold Wall	Full liquid nitrogen cryogenic shroud. Optional 10°K GHe liner available upon request.
Special Features	Quartz xenon arc lamp solar simulator system.
Data	All facility data time tagged and archived.
Work Areas	Test customer offices available. Hardware storage` available.
Solar Simulation	Off-axis system with xenon arc lamps that use an integrating lens assembly to collimate a uniform, 1 solar constant beam over an 8 ft diameter by 8 ft high test volume.
Electric Propulsion	In the EP configuration, the cell pressure during thruster operation can be maintained at or below 10^{-6} Torr, with a Xe pumping speed exceeding 2,000,000 liters/sec. Plume Diagnostics with Langmuir Probes

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