THE ADVANCED PROPULSION SPACE TEST FACILITIES
AT AEA TECHNOLOGY, CULHAM LABORATORY

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ABSTRACT

This paper describes the space propulsion test facilities in the Space Applications Department of AEA Technology, Culham Laboratory. Two major facilities for the testing of ion thrusters are described in detail, with descriptions of diagnostic equipment installed and data acquisition and control philosophies. Diagnostic effects on the measurement of ion beam current profiles are considered, and preliminary data presented. A method for the accurate determination of the thrust vector is described. Other general space test facilities are briefly described.

1.0 INTRODUCTION

The Advanced Propulsion Space Test Facilities are operated by the Space Applications Department, a part of the AEA Industrial Technology business of AEA Technology.

The expertise of the department has long been involved in spacecraft propulsion, space power and spacecraft environmental analysis. The facilities developed at Culham Laboratory have been provided by internal support and funds. Work is carried out under contract to various customers within the space industry. As discussed below, the majority of work is related to advanced space propulsion systems and the hardware involved in those systems. There is also a significant amount of work performed on plasma interactions in the space environment.

The various facilities are described in turn, the emphasis being placed on their propulsion testing capabilities.

2.0 UK-10 ION THRUSTER LIFETEST FACILITY

The UK-10 ion thruster programme is supported by a large dedicated facility at Culham Laboratory. The details of the facility and the diagnostics installed are described below.

2.1 DESCRIPTION OF THE FACILITY

The facility consists of two chambers, one rectangular 1.5m x 2.5m x 2.5m, the other cylindrical with a diameter of 1.25m and a length of 1.7m. A schematic of the facility is shown in Fig. 1.

The main vessel houses the thruster and its mounting frame, the static diagnostic systems and their supports, and the three dimensional diagnostic positioner. In addition this chamber houses two LN$_2$ shielded liquid helium cryopanels, and a pair of regeneratively cooled cold heads. The latter were recently installed to reduce the running costs of the facility when used instead of the LHe cryopanels. Pumping speed can be increased if the cold heads are used in conjunction with the cryopanels.

The facility is fitted with a 1500 l/s turbo-molecular pump backed by a 670 l/min rotary pump. There is a 4000 l/min rotary pump for roughing. The vacuum systems are controlled by an automatic controller designed to minimise the impact of failures on vacuum integrity. The compressors for the cold heads operate on a Gifford-McMahon cycle, and each has a capability to remove 50 watts from the cold head at a temperature of 50 K, with an input power requirement of 5.4kW.

The calculated pumping speed of each cold head is 7000 l/s of Xenon. If the liquid helium cryopanels are also used, the total facility pumping speed is 28000 l/s of Xenon. The liquid nitrogen shrouds are always used to reduce the loading of the cold heads with volatiles, particularly water vapour.

The smaller chamber is equipped with cooling channels incorporated in its walls and is fitted with a V - shaped aluminium target, which can be cooled to remove the power deposited on it by the ion beam. The shape of the target was chosen to reduce the rate of sputtered material back to the thruster, while maintaining simplicity of construction. A small (25mm) hole in the target allows passage of a laser beam required for accurate thruster alignment.
Figure 1  
Schematic of Lifetest Facility

The flow of propellant to the thruster is controlled by Propellant Supply and Monitoring Equipment (PSME) mounted inside the facility. This controls the flow using a fixed mark/space ratio valve pulse, smoothed by a plenum/orifice combination downstream of the valve. The temperature of the unit is maintained at 30 degrees celsius using a thermally controlled continuous flow water heating system. This also provides temperature stability for the fixed diagnostics described below.

Power for the thruster is provided either by breadboard Power Conditioning and Control Equipment (PCCE) or by laboratory power supplies. Change-over between the two sources is accomplished externally at the vacuum facility feedthroughs.

A centralised interlock control system is available independent of the power source, providing earth dumping facilities for the power supply and personnel protection if covers are removed. It also provides protection for the ion thruster by monitoring the facility pressure, interrupting operation if the pressure rises to an unacceptable level.

2.2 FACILITY DIAGNOSTIC SYSTEMS

A comprehensive range of diagnostics are installed in the facility for sputter measurement, ion profile and plasma potential measurements, and beam ion species ratio determination using a time-of-flight detector.

There are two main types of diagnostic for determining the rate of arrival of sputtered material. These are calibrated solar cells and a Quartz Crystal Microbalance (QCM). Passive silica glass sputter monitors are used to assist in determining the source of the contamination, which can be from either the thruster or the facility depending on the position of the diagnostic.

A collection of solar cells are distributed at known points and facing at known angles with respect to the centre of the thruster extraction grids. The cells are illuminated by two externally mounted tungsten filament lamps incorporating dichroic reflectors to reduce thermal shock to the fused silica windows. Each lamp is rated at 50 watts, and has a half-angle of nominally 26 degrees. The windows are protected from the effects of sputter partially by their location, and also by the inclusion of a 12cm long cylindrical sputter shield. Two lamps are used to provide redundancy, increasing the probability of at least one lamp surviving the entire lifetest period. Both run from DC supplies to reduce
ripple, and are individually switched under computer control.

The I-V characteristic for each solar cell can be acquired automatically under computer control. This is done for each light source individually and both together for redundancy. Two of the cells are positioned and shielded to eliminate sputter from either the thruster or the facility, providing a reference signal to take account of any degradation in the lamp outputs.

The face of each cell is protected by an easily replaceable cover glass of known mass, which collects sputtered material, reducing light transmission through the glass. This has the effect of reducing the light flux on the cell, resulting in a change in the I-V curve. A typical characteristic from this process is shown in Fig. 2. By relating this change to the response of the cell and the total mass collected on the cover glass, the relative rate of arrival of sputtered material at the position can be deduced. The composition of the material collected on the cover glass and the passive sputter monitors can be determined by analysis using x-ray emission spectroscopy; which allows the source of the sputter to be identified. The presence of aluminium implies that the sputter originated from the facility, since the thruster has no components made from this material.

A typical characteristic of the parallel drive strategy is shown in Fig. 2. By relating the change in the I-V curve to the response of the cell and the total mass collected on the cover glass, the relative rate of arrival of sputtered material at the position can be deduced. The composition of the material collected on the cover glass and the passive sputter monitors can be determined by analysis using x-ray emission spectroscopy, which allows the source of the sputter to be identified. The presence of aluminium implies that the sputter originated from the facility, since the thruster has no components made from this material.

Incorporated in the facility is a 3-axis probe positioning unit. This uses a pair of tracks mounted on each side of the facility, co-axially with the thruster axis. 'Trolleys' are movable along the tracks by a stepper motor driven belt on each side. The motors are driven synchronously in opposite directions to achieve parallel movement of the arm joining the two trolleys, positioning it accurately in the X axis or axial distance from the extraction grid plane.

A single stepping motor mounted on this arm drives a belt to position a vertical member on the Y axis, or horizontal component, while a further belt/motor combination positions the probe head in the vertical direction. The gearing gives a resolution of just over 0.1mm on all three axes. The Y & Z axes are equipped with closed loop feedback of their position via digital rotary encoders. This is unnecessary on the X axis due to the improved characteristics of the parallel drive strategy.

Each axis is provided with optical limit switches defining the safe operating limits. A reference position switch is included to provide a calibration point and define the 'safe' position where the entire probe system is behind the thruster and not subject to ion bombardment.

Mounted on the probe head are the ion probe and time-of-flight diagnostics, positioned one above the other on the vertical centre of the carrier. A thermally and electrically isolated aluminium plate is used to protect the diagnostics from direct impingement by the beam, while guard plates on the probe head intercept the majority of the power that would otherwise be deposited on the vertical support member. Apertures in the plate allow the probes to see the thruster over a relatively small area.

A schematic of the ion probe is shown in Fig. 3. It is configured with two grids and a collector, and an aperture with an accurately known area. The case of the probe can be floated, biased or grounded as required. Holes drilled in the insulator and the rear.
of the probe provide sufficient conductance to the facility to prevent the accumulation of neutral Xenon in the device.

![figure 3](image)

**Figure 3** Ion Probe Schematic

In operation, grid 1 is biased to +10 Volts to allow entrance only to ions with an energy of greater than this. The second grid is biased to -22 Volts with respect to facility earth and serves the dual function of suppressing both electrons entering the aperture and secondary electrons induced from the collector. The signal from the collector is conditioned by an operational amplifier to give an output of 1 V/mA.

The time-of-flight ion species analyzer is shown schematically in Fig.4. It comprises a pre-grid flight tube to collimate the ions, with a single grid normally biased at just over the beam potential. This grid is connected capacitively to a thyratron and pulse shaping network which forces the grid periodically to fall to ground for a period of approximately 200 nSec. This allows a 'packet' of ions to enter the flight tube, where the different velocity ions separate in space, and consequently in time once they reach the gridded Faraday cup detector. The collector is biased to +27 volts and connected via an ultra-fast current amplifier to a Digital Signal Adapter (DSA).

![figure 4](image)

**Figure 4** Time-of-Flight Schematic

2.3 DIAGNOSTIC CONTROL AND DATA ACQUISITION

All the active diagnostics installed in the facility are controlled remotely using an IBM PC compatible computer fitted with a pair of stepper motor controller boards, and a combination ADC, DAC and Digital I/O board fitted internally.

The stepper motor control boards provide a simple interface to control the position and speed of up to two channels per board via opto-isolated interface modules.

The ADC board provides 16 multiplexed channels of 12-bit data, 2 12-bit DAC output channels, and 24 digital I/O channels. Data from all the diagnostic sources are buffered by interface modules or 'local' signal conditioning units.

The solar cell characteristics are stored in a comma separated format. This can be imported into a spreadsheet for analysis or printout, or into custom analysis programmes. The three parameters of Open Circuit Voltage, Short Circuit Current and Maximum Power Output are also stored. Acquisition can be done entirely by software, using the features available in the package described below.

Three read-outs from the QCM signal conditioner are read directly by the DAS system. These are Accumulated Mass, Deposition Rate, and QCM temperature.

Data from the ion probe are acquired on a point by point basis, with probe movement in between. Data can be compiled as continuous files, or as individual scans dependant on the macro-language file structure (discussed in greater detail below).

A DSA was chosen to acquire the data for the time-of-flight diagnostic due to its versatility and ease of connection via RS232 serial link to the controlling computer. It has an effective resolution of 0.5 nSec per point for repetitive signals of this type, and allows signal averaging if required for improved signal to noise. The thyatron unit is continuously pulsed, but only on command is the data accepted by the DSA. Acquisition then proceeds without computer supervision until the required number of data cycles are averaged, at which point the data can be down-loaded to the PC across the RS232 link.

The DAS also accepts signals from a pair of photodiodes used in the alignment of the probe carriage.
with respect to the thruster extraction plane. This procedure is described in detail later in this paper.

2.4 DAS SOFTWARE

A software suite has been developed to enable totally remote controlled operation of all facets of the DAS hardware.

A Manual mode allows the user to control the position of the 3D probe carriage and acquisition of data by a simple menu selection or direct keyboard input. The destination coordinates can be entered directly or in relative moves from the current probe location. An algorithm for checking that the movement is within the correct facility envelope, and for determining an optimum path for the move is incorporated. A graphical display of the probe position is provided, and X,Y,Z co-ordinates are continuously updated during probe movement.

To allow unattended operation of the diagnostic systems during a lifetest, the suite incorporates an automatic mode. In this mode, the software is controlled by a 'batch' file of commands in a specially designed macro-language. The macro-language completely emulates operations possible in Manual mode, along with additional commands for data file control. Other commands enhance the ease of implementation of acquisition cycles by providing repeat structures, inclusion of sub-files and time or state control. An RS232 link to the PCCE controller will allow synchronisation of the data acquisition with the cyclic life-test by passing thruster state information to the DAS computer. The batch files undergo an error-check before operation to ensure the file is syntactically correct.

The inherent flexibility of the 'batch' file approach has already proved its worth by allowing unexpected data cycles to be achieved simply by writing a new command file.

2.5 EXAMPLES OF PRELIMINARY DATA

The data described below have been acquired during the proving phase of diagnostic testing, and while derived from an actual T5 ion thruster is not necessarily representative of lifetest results.

Proving tests have been carried out on the DAS as a whole and on the solar cells, the Time-of-Flight diagnostic, the ion probe and the QCM.

The diagnostic from which the greatest amount of data have so far been collected is the ion probe. The use of the auto-control facility and macro language described above has shown it's versatility by allowing automated operation of the probe in areas other than those originally proposed, providing detailed scans in two dimensions as close as 5cm from the thruster extraction plane. The provision of repeat loops simplifies the writing of the macro files.

Several factors have to be considered in the operation of this probe, particularly if used in a quantitative role. When used to determine beam profiles and relate them to the total beam current, the acceptance angle of the probe must be great enough to allow all ions originating from the extraction grids to be collected. Because of the forward-pointing nature of the probe, the defining area of the aperture seen by the detected ions is only circular when the probe A is directly on axis with the thruster i.e. y = 0 , z = 0. For any y,z position other than this, the defining aperture appears as an ellipse, requiring an appropriate correction factor when determining the current density j at that point.

A similar argument can be applied to each of the grids in the probe. The grids each have a nominal wire thickness t and wire separation s giving a nominal transparency T. This reduces with angle to give an effective transparency T_e. The overall transparency of the pair of grids can then be taken as T_e^2. The x, y and z values are the coordinates of the probe aperture related to the probe.

The situation is complicated by the nature of the ion beam streamlines, shown in Fig 5. It can be seen that in the portion of the beam close to the grids, ions are converging, reach a minimum or 'waist' at approximately 12 cm from the grids before diverging into the normal super-beam, dominated by beamlet divergence.

![Figure 5 Ion Beam Streamlines](image)

If the probe is situated well beyond the 'waist' of the ion beam, ions can be considered to originate
from a focal point \( F \) situated at a distance \( x \) from the grids, and consequently the angle of the incident ions with respect to the probe aperture can be determined. Closer to the thruster the ions may originate from areas that are outside of the angular acceptance of the probe. To correct data acquired in this close region would require information about the emittance of the ion source, or the use of a collimated detector and an additional degree of freedom for the probe.

Where the corrections can be applied, they have the form

\[
j = \frac{I}{A \, T_e^2}
\]

where

\[
A = \frac{\pi \, r^2 \, (x + x_f)}{[\sqrt{(x + x_f)^2 + y^2 + z^2}]^2}
\]

\[
T_e = \frac{(t - s_y)(t - s_z)}{s_y \, s_z}
\]

\[
s_y = \frac{s \, (x + x_f)}{[\sqrt{(x + x_f)^2 + y^2}]^2}
\]

\[
s_z = \frac{s \, (x + x_f)}{[\sqrt{(x + x_f)^2 + z^2}]^2}
\]

This is valid for an angle of less than 29° with the current probe geometry, then is subject to vignetting up to an angle of 40°, beyond which no ions can be expected to reach the collector.

Additional correction factors can result from the ion to neutral cross-section if the density of neutral Xenon atoms is high, or if the ion probe lacks a pumping path to the facility.

Data obtained to date are presented in Figures 5 & 6, and show the streamlines of the ion beam, and profiles across the beam at various positions. Correction factors for effective area and grid transparency have been applied to data greater than 25cm from the thruster extraction plane. Closer data are corrected only for nominal grid transparency.

2.6 CORRELATION OF COORDINATE SYSTEMS

To accurately determine the ion beam vector, the coordinate system for the probe must be correlated with the coordinate system defined by the plane and centre of the thruster extraction grids. The shape of the facility results in a flexing of the vessel walls of some 3mm when under vacuum. Since the probe drive is referenced to the facility, this introduces an error in the probe coordinates as referenced to the thruster under atmospheric conditions. This effect is most pronounced in the Y and Z axis, and can be considered negligible in the X axis. To eliminate the error, a laser is used to correlate the two coordinate systems to a high accuracy.

The laser beam passes though a window in the end of the extension tank, though an aperture in the beam dump and strikes perpendicularly on a beam splitter on the thruster mounting plate. A photodiode behind the beam splitter provides an accurate Y,Z position relative to the thruster. The relationship between the beam splitter and the thruster extraction grids is accurately known, as are the coordinates of the photodiode.

A second photodiode moves with the 3D probe, offset from the entrance aperture of the ion probe by the distances \( X_i, Y_i, \) & \( Z_i \). Software routines enable the probe to search for the position of peak intensity of the laser beam at various axial positions. This identifies the \( y,z \) coordinates of the laser beam in probe coordinates for several values of \( x \). Linear interpolation between the known axial positions gives gradients \( m_y, m_z \) and offsets \( c_y, c_z \) for each segment.
If $\alpha$ and $\theta$ are the angles between the X-axis of the two coordinate systems in the Y and Z planes respectively, and $x_0$, $y_0$, $z_0$ are the distances to the photosensor from the origin in the thruster coordinates, then at a distance $x$ from the thruster the coordinates of the laser beam are given by

$$
\begin{align*}
x_t &= x \\
y_t &= y_0 + (x - x_0) \tan \alpha \\
z_t &= z_0 + (x - x_0) \tan \theta
\end{align*}
$$

Probe coordinates can then be mapped to thruster coordinates using

$$
\begin{align*}
y_t &= y_0 + \left[ \frac{(y_p - c_y)}{m_y} + x_0 \right] \tan \alpha \\
z_t &= z_0 + \left[ \frac{(z_p - c_z)}{m_z} + x_0 \right] \tan \theta
\end{align*}
$$

derived since $x$ is the same value in both systems.

Accuracy is anticipated to be less than 0.5 mm for a 6 segment map. The limiting factor is liable to be the physical measurement of the grid plane to reflector plane angles.

### 3.0 THRUSTER TEST FACILITY 1

This facility has been the major general purpose large vacuum test facility since 1985. It is primarily used for testing of the UK-25 large diameter ion thruster and experimental work on plasma interactions with spacecraft.

#### 3.1 DESCRIPTION OF THE FACILITY

The facility comprises a total of three vessels linked by interface flanges. The primary vessel is rectangular 2.5 m x 1.0 m x 1.2 m and mounts four LHe cooled cryopumps with LN$_2$ cooled chevron baffles to reduce the thermal loading to the pump. These cryopanels can be operated individually, or all together to give pumping speeds of up to 250,000 l/s in Hydrogen (30,000 l/s in Xenon). Internally mounted rails are used to guide the supports for the unit under test, and a variety in feedthroughs provide electrical and gas connections into the facility.

Mounted on the primary tank is a cylindrical vessel, 1.2 m long by 1.2 m diameter. This vessel possesses twelve windows equally spaced around its circumference, allowing simple access with optical diagnostics if required.

Attached to the diagnostic tank is a large cylindrical vessel, 2.0 m long by 1.2 m diameter. This vessel provides ports for the non-cryogenic pumping, using a 450 l/sec turbomolecular pump, backed by a 670 l/min rotary pump. A roughing pump of 1440 l/min allows rapid pump down of the facility to pressures of $< 10^4$ Torr. A schematic of the facility is shown in Fig. 7.

The facility is equipped with three ion gauges, one situated in each vessel, a Penning gauge to provide a robust vacuum control head, and numerous Pirani gauges. There are facilities for attachment of a RGA head if required.

Vacuum control is automatic and incorporates recovery from cryopanel dumping. An electrical interlock system provides protection for the operator, and interfaces with the vacuum monitoring to provide load protection in cases where the facility pressure rises to an unacceptable level.

Laboratory power supplies are available for operation of, for example, the UK-25 ion thruster. They are capable of providing discharge currents of up to 50 amps, and beam powers of up to 12.5kW at 2.5kV. Propellant supply is achieved using commercial linear closed loop flow control valves, with additional flow sensors on each of the Main and Cathode lines to provide a check on the flowrate.

This facility does not have a dedicated diagnostics system as the UK-10 facility does. This is in part due to the greater range of operations performed, for which the type of diagnostics would have to be very varied. Instead a number of flexible diagnostics can easily be attached to the facility through its many access ports. These include ion probes and time of flight analyzers of the type.
discussed above, charging probes, plasma wake diagnostics and optical spectrometers.

In addition a probe positioning unit similar to that of the UK-10 facility is currently being commissioned. This will allow a number of diagnostics to be attached for more flexible investigation of thruster beam phenomena and plasma interaction effects.

3.2 ACTIVE BEAM DUMP DESIGN AND TEST

During operation of large diameter ion thrusters, large amounts of power (ie multi-kilowatt levels) are deposited, and the impact of high energy ions sputters material from the target. Traditional strategies for resolving these problems include cooled targets shaped to divert sputter away from the source of the beam.

One possible solution tested in the facility was to use a biased collector, dissipating the power electrically outside of the facility. Grids were placed up-stream of the collector to minimise the effect of collector bias on the extraction optics, and provide suppression from secondary and neutraliser electrons. A schematic of the arrangement is shown in Fig 8.

The singly-charged ions in the beam have an energy of eV, when they reach the target, where
sputter yield of the ions has the form shown in Fig. 9 it can be seen that a very significant reduction could be anticipated.

![Graph](image)

Figure 9  Sputter Yield for Xenon

This technique of active beam dumping, while potentially providing considerable benefits, is only applicable to facilities the low chamber pressure. As a beam traverses from the source to the collector, charge exchange processes take place. The charged current at the collector, I_c, is related to the initial beam current, I_b, by

\[ I_c = I_b e^{-\sigma l} \]

where \( \sigma \) is the charge exchange cross-section, \( n \) is the neutral gas density and \( l \) is the distance from the source to the collector.

As an example, if 95% of the extracted beam is required to be dumped and collected as ions, then the product (\( \sigma n l \)) must be less than 0.05

4.0 INDUCTIVELY COUPLED PLASMA THRUSTER

This is an atmospheric exhausting testbed for an inductively coupled RF plasma torch configured for thrust generation.

4.1 DESCRIPTION OF THE THRUSTER

The thruster is vertically mounted in an RF shielded four legged structure, and exhausts to atmosphere via a tube mounted directly above the nozzle. The thruster consists of a cylindrical fused silica tube into which propellant (typically Argon) is fed tangentially to provide vortex stability of the discharge when operating.

![Diagram](image)

Figure 10  Schematic of RF Thruster

An RF coil wound around the tube is energised at 2 Mhz by an RF generator capable of providing up to 6 kW of power. A discharge is initiated in the gas by the insertion of a thin graphite rod, which heats inductively in the field until it reaches a temperature at which electrons are spontaneously emitted. These 'seed' the gas with ions, causing breakdown into a self sustaining discharge. The carbon rod may then be withdrawn. The propellant is heated by the discharge and subsequently expanded through a nozzle assembly mounted on the top of the tube.

The test-bed is equipped with detailed pressure monitoring as shown in the schematic in Fig. 10, and was constructed to allow direct measurement of the thrust produced using a load cell connecting the thruster mount to the support structure. Since the discharge is highly luminous, a dark glass viewing window was built into the facility and screening provided to protect the operator and others in the vicinity.
5.0 OTHER VACUUM FACILITIES

Other general purpose facilities available in the Department are briefly described below, highlighting their main features.

5.1 THE SMALL STRUCTURE ASSESSMENT FACILITY

This facility consists of a small vacuum chamber 0.5 m x 0.4m x 0.8m in size directly mounted onto a 1000 l/s turbomolecular pump backed by a 670 l/min rotary pump. The direct connection allows the full pumping speed of the turbo without conductance losses, while the small size of the facility minimises outgassing and o-ring diffusion gas loadings. This allows the facility to have a base pressure of better than 10^-7 mbar and an extremely clean vacuum. The facility is equipped with ion gauges and an RGA head to allow accurate analysis of the vacuum. A wide selection of feedthroughs is provided to allow maximum flexibility of use.

The facility has been used to evaluate the suitability of materials and small components for the vacuum environment and propulsion system use, explore breakdown characteristics under varying conditions, and lifetest sub-assemblies under consideration for space use.

The small size, rapid turn-around and versatility of the facility makes it ideal for cost effective material and component evaluation.

5.2 THE LARGE STRUCTURE ASSESSMENT FACILITY

This facility consists of two cylindrical vessels, the larger with a diameter of 0.8 m by 1.1 m in length with a 0.6 m diameter x 0.8 m extension. It is fitted with a 1500 l/sec turbomolecular pump backed by a 500 l/min rotary pump. A LN2 cooled stainless steel shroud can be mounted in the larger vessel if required. A base pressure of 5x10^-7 mbar can be achieved without bake-out of the facility. Ion gauges are used to monitor the facility pressure, and an RGA head can be mounted on the facility if required.

This is a general purpose facility, primarily available for evaluation of structures and sub-assemblies which owing to size are unable to fit in the smaller facility described above.

5.3 OXYGEN EROSION TEST FACILITY

This facility provides a source of low energy oxygen ions, principally to test erosion rates of materials in conditions representative of low Earth orbit.

The facility comprises of a turbo-molecular pumped process chamber approximately 0.8m x 0.5m x 0.4 m. The turbo has a pumping speed of 1000 l/s and is pumped by a dual-stage rotary pump with a speed of 670 l/min. Both pumps were selected to be suitable for pumping of reactive gases. Access to the facility is by 6 large flanges which can be equipped with quartz window, beam diagnostics, sample holders etc. The facility has a base pressure of < 2x10^-4 mbar and a working pressure of 5-10x10^-5 mbar, depending on the gas throughput.

The plasma is generated in a pyrex glass bell jar mounted above the facility by excitation of the gas using a spirally wound RF coil energised by a 6kW RF power generator operating at a frequency of 2 Mhz. Discharge powers of 300-400 watts are normally applied. The bell jar is water cooled by a spiral tube mounted on a cooling hood. The plasma generator is connected to the accelerator section via an electrically insulating flange.

The accelerator section of the facility is housed within a short flanged tube mounted below the plasma source. The two extraction electrodes are mounted via alumina post insulators to this flange. These comprise a pair of dished molybdenum grids, each with 2233 apertures created using a patented process developed at AEA Technology. The grid extraction area is 255 cm², and at the sample plane the beam irradiates an area of 100 cm² with a uniformity of ± 5% The source can provide an ion flux of up to 37 microamps cm⁻² at 20 eV, and can provide ion energies from 20 to 100 eV.

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