VESPA Experiment: Operating Manual

1. Safety instructions

The power supplies used in the VESPA experiment can supply potentially lethal voltages and currents. It is thus recommended to pay attention and proceed with caution during the experimental operations.

The main rule is the following:

Do not touch any electric component, except for the push buttons and control or the operating knobs of the power supplies, before having verified that all power supplies are switched off.

In particular, any modification to the electric connections must be made when all power supplies are switched off.

2. Safety rules for the experimental device

Summary of the cautions which must be used in order to protect the experimental device:

1) Do not put in operation the turbomolecular pump if pre-vacuum gauge (Pirani) is indicating a pressure level greater than 10^{-1} mbar.
2) Do not switch off the rotary pump if the turbomolecular pump is switched on.
3) When closing the needle valve (used for Argon gas filling), do not take it to its limit.
4) Do not keep the filament on for unnecessarily long periods (i.e. the filament must be switched off when no measurement is performed).

Moreover, the following cares must be taken in order to keep the experimental device in good operative conditions:

5) Switch off the power supplies only after having driven to zero the voltage (or the current).

6) During the switching off of the vacuum pumping system, ventilation must be performed with caution by using the butterfly valve (throttle), immediately after having switched off the rotary pump, so that dangerous oil vapour comeback is prevented.
7) Never drive a current on the filament larger than 7A.
8) Never insert in the vacuum chamber objects which have not been cleaned with extreme care.

3. Hot to put the vacuum system in operation

Here is the sequence of operations to be followed in order to put the vacuum system properly in operation:

1) Close the valve located in between the vacuum chamber and the vacuum pumping system.
2) Switch on the TPW010 (Pirani) and baratron instruments.
3) Switch on the rotary pump with the gas ballast closed.
4) Wait for the rotary pump to become warm and the Pirani to indicate a pressure lower than $5x10^{-2}$ mbar.
5) Open the gas ballast.
6) Open the valve located in between the vacuum chamber and the vacuum pumping system.
7) Wait for the pressure shown by the ionization gauge to reach a constant value.
8) Close the gas ballast;
9) Switch on the turbomolecular pump.

4. How to create plasma

To create plasma, it is necessary at first to wait for a condition characterized by a chamber pressure lower than 10^{-4} mbar. Once such condition is obtained, proceed as follows:

1) Verify with the professor that the Argon filling system is ready.
2) Close with no strength (!) the (lower) needle valve for gas filling.
3) Open (completely) the open/close upper valve of the filling system, located right above the needle valve.
4) If during the previous operation a rapid chamber pressure is observed (due to the small, but not negligible, amount of gas trapped in the valve), wait for the system to get back to its low pressure limit.

5) Smoothly open the needle valve, in order to finely control the chamber pressure and to get the desired operative pressure condition.
6) Switch off the ionization gauge (use the baratron as pressure reference).
7) Switch on the power supply dedicated to the polarization of the filament with respect to the chamber and set the applied voltage to 60V.
8) Verify that the current control knobs of the power supply used to drive the current in the filament are completed rotated towards the left (i.e. set to zero) and that those for the control of the voltage are rotated towards the right (i.e. set to the maximum level). This operation guarantees that the power supply is used in current-control mode, thus preventing the formation of dangerous rapid current spikes which could damage the filament itself.
9) Switch on the power supply and increase the driven current in an extremely smooth way (few minutes, 4-5, must be at least necessary to drive the current up the desired current value, generally around 6.5A). Never overcome 7A.

5. How to switch off the plasma

Once the measurements have been performed, the plasma must be switched off as follows:

1) Smoothly drive down to zero the current flowing in the filament.
2) Drive to zero the voltage on the power supply for the polarization of the filament with respect to the chamber.
3) Switch off the two power supplies.
4) Close the needle valve without reaching its limit, and close the open/close valve located above the needle valve.
5) Switch on the ionization pressure gauge.

6. How to stop the pumping system

Here is the sequence to properly stop the vacuum pumping system:

1) Verify that the open/close valve located above the needle valve is closed.
2) Switch off the ionization pressure gauge.
3) Close the valve located in between the vacuum pumping system and the chamber.
4) Wait for turbomolecular pump deceleration (around 2 minutes).
5) Switch off the rotary pump.

6) Immediately after having switched off the rotary pump, open (slowly) the butterfly valve (throttle) to ventilate the system and to avoid oil vapour comeback towards the chamber.
7) Wait for the turbomolecular pump to be totally stopped (a sound can be heard confirming this to be happened).
8) Close the butterfly valve.
9) Switch off the pressure gauges (expect for the baratron).

Experimental activity

A) Vacuum

In the laboratory:

1) Pump the vacuum chamber until the pressure is lower than $8x10^{-5}$ mbar.
2) Calibrate the baratron by using the 'C' ed 'F' screws.
3) Close the valve located in between the pumping system and the chamber, then measure pressure levels, by means of the ionization gauge, at regular time intervals (10s for the first 3 minutes, then 30s) for a total measurement time of about 10 minutes.
4) Open the valve lo located in between the pumping system and the chamber, then measure the pressure levels, by means of the ionization gauge, at regular time intervals (5s for the first 30 seconds, then 10s for 30s, then 30s) for a total measurement time of about 15 minutes.

Data Analysis

1) Create a graph of the data from the pressure growth phase as a function of time. Such pressure increase is due to a degassing effect from the chamber inner walls and possible vacuum losses.
2) Evaluate a linear fit of the collected data, whose angular coefficient is related to the F_0 flux due to degassing from the walls and vacuum losses.
3) Create a graph of the experimental data collected during the pressure decrease phase.
4) Make a fit of the data with a curve of the type: $p = (pi-p_0)\, e^{-t/\tau} + p_0$.
5) From the τ e p_0 (limit pressure) constants, the effective pumping velocity S of the turbomolecular pump and the F_0 flux can be obtained. Such F_0 value should be compared to the one obtained at the previous point. Compare the effective pumping velocity S deduced from the measurements to the nominal one, 33 l/s. Evaluate the conductivity of the connection between the chamber and the vacuum pumping system.

B) Voltage-current characteristics of the filament

In the laboratory

1) Pump the chamber until a pressure level lower than 8×10^{-5} mbar is obtained.
2) Switch off the ionization gauge; switch on the power supply used to drive the current in the filament in current control mode. Raise the current slowly, collecting couples of voltage-current values (at least 35 values). Never exceed 6.8A.

Data Analysis

1) Create a graph with the collected current values as a function of the voltage.
2) Compared the results with that predicted by the simple model given in section 1.3 of the theoretical part (filament diameter is 0.25 mm, its length is 10cm). Please note that in order to apply such analysis it is necessary two combine the two equations so that the temperature explicitly disappears. In the case strong discrepancies are found, try to modify the given value for the Tungsten effective emissivity, ε .
3) By means of such analysis, create a graph of the estimated filament temperature as a function of the driven current.

C) Voltage-current electric characteristics of the discharge and Paschen curve in DC condition

In the laboratory

1) Pump the chamber until a pressure level lower than 8×10^{-5} mbar is obtained. Smoothly open the needle valve for Argon filling in order to reach a constant in time pressure value of 2×10^{-3} mbar.
2) Electrically connect the grid to ground.
3) Switch off the ionization gauge, then drive slowly the current in the filament up to 6.5A.
4) Switch on the power supply for discharge polarization and slowly increase the applied voltage between the chamber and the filament up to 100V, collecting voltage data and the corresponding current data (measured as potential fall on a $1\ \Omega$ shunt resistor). It is recommended to increase at first the voltage with 1V steps, then 0.5v when the collected

current is above 10mA and then with 2V steps after the plasma has formed (i.e. after the breakdown voltage has been overcome). After 60v, 5V steps are sufficient.

5) Repeat the previous procedure for current filaments equal to 6.1A and 6.8A.
6) Repeat the same procedure (with a current filament of 6.5A) with operative Argon pressure equal to 4×10^{-3} mbar and 8×10^{-3} mbar
7) With a filament current of 6.5A, determine the breakdown voltage by varying the pressure in the range 1×10^{-4} mbar and 1×10^{-2} mbar (it is sufficient to register the breakdown voltage, without collecting the full breakdown curve). In order to determine the Paschen curve, get additional experimental points around the minimum of the curve.

Data Analysis

1) Create a graph with the various breakdown curves (voltage-current characteristics) obtained varying the filament current levels. How does the filament current influence such curves?
2) Compare the discharge current, obtained with a polarization voltage equal to 60V at various filament currents, to those predicted by Richardson law. Discuss the differences.
3) Create a graph with the various breakdown curves (voltage-current characteristics) obtained varying the Argon pressure. How does the pressure influence such curves?
4) Create a graph of the breakdown voltage as a function of the gas filling pressure (Paschen curve), discussing potential differences with the theoretical one and individuating the minimum of the curve.

D) Paschen curve in radiofrequency condition

In the laboratory

1) Using the RF power supply, once obtained a pressure level lower than $8\text{x}10^{-5}$ mbar, individuate the resonance curve (as a function of the frequency) for the circuit, which includes the magnetized electrode for plasma generation.
2) Slowly increase the peak-to-peak voltage applied to the magnetized electrode in order to individuate the breakdown voltage and thus reconstruct the equivalent RF Paschen curve in an Argon pressure range from 10^{-4} to 1 mbar.

Data Analysis

1) Create a graph of the breakdown voltage with RF power supply as a function of the gas filling pressure (Paschen curve), discussing potential differences with the one obtained with DC applied voltage and individuating the minimum of the curve.

E) Measurements of plasma parameters

In the laboratory

1) Pump the chamber until a pressure level lower than 8×10^{-5} mbar is obtained. Smoothly open the needle valve for Argon filling in order to reach a constant in time pressure value close to minimum found for the breakdown voltage with DC polarization. Drive slowly the filament current up to 6.5A.
2) Determine the voltage-current electric characteristics of the Langmuir probes located on both sides with respect to the grid, by using the dedicated LabView program (AIA_6040E_langmuir.vi) for the following values of the discharge polarization voltage: 20V, 30V, 40V, 50V, 60V, also collecting the corresponding plasma discharge current values.
3) Determine the voltage-current electric characteristics of the Langmuir probes with applied 60V of polarization voltage and Argon pressure one order of magnitude larger and one order of magnitude lower than that used at the previous point.
4) Repeat the previous procedure with RF applied voltages for a pressure value close to the minimum of the corresponding RF Paschen curve.

Data Analysis

1) For each Langmuir characteristics, determine the values of electron density, temperature and plasma potential, as described in the section 1.6 of theoretical part, by using the dedicated IDL software.
2) Create graphs of all plasma parameters (density, temperature, plasma potential) as a function of the various operative experimental conditions (plasma current, pressure, DC and RF applied discharge voltages, position in the chamber)

3) Determine, on the basis of the experimentally obtained density values, the ionization fraction, i.e. $f = n/(n+n_0)$, being n the plasma density and n_0 neutral atom gas density , considered at room temperature (suggestion: in order to evaluate $n_{0,}$ the law of ideal gases can be considered).

F) Ion acoustic wave propagation

In the laboratory

1) Set the Argon pressure in the chamber to the value 5×10^{-4} mbar, the current filament to 6.5A and the discharge polarization voltage to 70V. In order to excite a ion sound wave by means of the grid, the latter must be polarized with an oscillating voltage at 20kHz. This is obtained by means of the Kepco power supply, used as 10 x amplifier of the signal coming from a waveform generator. The latter must be set in order to give a sinusoidal output of [0,1.5]V voltage. This induces a density perturbation, which, as described in the theoretical part, propagates in the plasma at the ion sound speed (Cs) and is dumped by collisional effect between charged and neutral particles.
2) The propagation properties of the ion sound wave are determined by means of the Langmuir probes mounted on the manipulator, positively polarized (+50V) in order to collect electron saturation current (measured as potential fall on a 10kΩ resistor), and hence measuring density fluctuations.
3) The phase difference between the measured density fluctuation and the one induced on the grid must be estimated at various distances from the grid itself moving the probe by means of the manipulator.
4) The amplitude of the measured density fluctuation must be estimated at various distances from the grid moving the probe by means of the manipulator.

Data Analysis

1) From the measured phase difference, estimate the propagation velocity and compare it to the ion sound speed deduced from the temperature value given by the Langmuir probe characteristics.
2) From the behavior of the wave amplitude as a function of the distance from the grid, deduce the (exponential) damping length, and estimate the neutral particle density. How does the value compare to the one obtained from the ideal gas law?