Experiments in Modern Physics

Introductory Lab: Vacuum Methods

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Goal
Get acquainted with the components of a high-vacuum system.

Introduction

In this lab you will become familiar with the various components of the lab vacuum system and see how good of a vacuum (low pressure) you can achieve. There are many books that contain all necessary information. One of the best is the classic by Roth [1], which is available at the experimental station.

The International System of Units has never become popular among vacuum practitioners. Thus, we shall keep using here the familiar, non-S.I. units (for conversion factors between different units, see [1], p.42 and p.65). Unless otherwise indicated, we will use l (liters = $10^{-3} m^3$) for volume, and Torr (= 133.3 N/m$^2$ (Pascal)) for pressure.

An amount of gas, $M$, is given by $M=pV$ (units: Torr liters). The gas flow $Q$ measures an amount of gas per time $t$, $Q=M/t$ (units: Torr l/s). Gas flow from point A to point B is given by the two pressures $p_A$, $p_B$, and the conductance, $C$, between A and B. The conductance measures how easily gas flows from A to B. It is defined by

$$Q = C(p_A - p_B),$$

and thus, $C$ is measured in l/s. The pumping speed, $S$, of a pump describes the volume that is removed from the system per unit time, and is defined by

$$S(p) = \frac{Q}{p},$$

where $p$ is the pressure at the intake of the pump. Obviously, $S$ is also measured in l/s.

Equipment

Pumping station with various vacuum pumps and gauges.

Preparation

A diagram of the pumping station in the lab is shown in Fig.1. Understand the following components. (See Ref. [1])

Pumps:
Mechanical Fore Pump FP1,2: in our case this is a rotating-vane pump. How does the mechanical pump work? What is the range of intake pressures allowed? What is typically the lowest intake pressure that can be achieved?
**Oil diffusion pump DP.** How does a diffusion pump work? What is the range of intake pressures allowed? What is typically the lowest intake pressure that can be achieved? What are the restrictions on the outlet pressure? Why does the pump need to be cooled?

Gauges:
- **Ionization gauge GI** (uses current of ionized molecules)
- **Thermocouple gauges GTC1,2** (uses thermal conductivity)
- **Convectron gauge GCV** (uses thermal conductivity)
- **Bourdon gauges GB1,2** (uses mechanical deformation). How does each of these gauges work? What are the respective pressure ranges over which they can be operated?

![Figure 1: A diagram of the lab vacuum system](image)

**Task 1: Start-up the system.**
1. Close valves V1, VN, V6 and V4, open V2, VG, and V7.
2. Turn on gauges GCV, GTC1,2.
3. During the whole procedure, record gauges GTC1,2, and GVC vs. time, do NOT turn on the ion gauge GI!
4. Turn on fore pumps FP1, FP2, wait until \( p_1 \) is stable at around 30-100 mTorr.
5. Turn on the diffusion pump cooling water (under sink).
7. Engage heater for the diffusion pump.
8. Wait about ½ hour (GTC1 should now read zero).
9. Turn on the ion gauge GI, record vs time. The pressure \( p_1 \) will decrease slowly for a couple of hours, approaching a base pressure of about \( 10^{-6} \) Torr. If this does not happen, there is a leak and one has to search for it (ask for help).
Record your final pressure value as read by GI. Discuss your results with your instructor.

**Task 2: Investigate pumping speed of diffusion pump.**
1. Open V6 slightly to pump out Volume 3 until GB1 reads ~25 Torr.
2. Open VN slightly to let air into Volume 2 which then passes through a small orifice into Volume 1. Don't let in too much gas of GI will trip. (Keep $p_1$ below ~$1 \times 10^{-4}$ Torr).
3. Close VN quickly and record $p_1$ with time. Estimate the size of Volume 1. Calculate the pumping speed of the diffusion pump. Repeat for Argon and Helium. Compare with quoted values from Ref. [1].

**References**