

## Experiment 2. Pumping Speed

When designing a vacuum system, one of the most basic considerations is the time required to evacuate a vessel to a given pressure. This time typically ranges from a few minutes to hours but can, on occasion take a few days. If the pump is assumed to be operating at constant speed and efficiency then the pressure vs. time behavior exhibited by a system is given by:

$$P = P_0 e^{-\left(\frac{s}{v}\right)t}$$

where  $P_0$  is the initial pressure at zero time  $t$ ,  $P$  is the instantaneous pressure at any time  $t$  greater than zero,  $v$  is the volume of the chamber (in liters), and  $s$  is the pumping speed of the pump in liters/sec. The quantity  $v/s$  is known as the time constant of the system and is defined as the time it takes to pump the system to a pressure of  $P_0/e$  or 37% of its initial value.

The pumping speed of the pump and the time constant of the vacuum system can be obtained by observing the pressure vs. time characteristics during the pumpdown cycle. There are two main objectives of the following exercise: to experimentally determine the pumping speed of the pump and the time constant of the vacuum system, and to use these values to understand some of the problems inherent in the design of vacuum systems.

- Set the vacuum system for a pumpdown cycle, switch on the pump and record the pressure every two or three seconds. You might want to repeat the experiment two or three times to obtain average values thereby eliminating some uncertainty in the values. Record data until the pressure is at the lower limit of the gauge.
- Plot the pressure readings vs. time in seconds. Note that the pressure has fallen  $1/e$  (ca. 37 %) of its original value in about 10 seconds,  $1/e^2$  after 20 seconds and so on. Does it ever get to zero? Determine the pumping speed and time constant of the system?
- Plot the  $\ln$  pressure vs. time for the same data. It should be a straight line whose reciprocal slope is equal to the time constant of the system. Recalculate the pumping speed using  $v/s$  from the  $\ln$  plot.

$$\ln P = -(s/v)t + \ln P_0$$

- Compare the time constant and pumping speed obtained from the raw data and the  $\ln P$  vs. *time* plots. Explain differences.

