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Gas Leak Measurement of TRT Barrel Module

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1. Introduction

One of the requirements for the TRT module acceptance is the gas tightness. The present leak specification for the barrel module is 0.1 mbar/bar/min. The leak rate is calculated by pressurizing the module with argon and measuring the pressure drop as a function of time. In order to reach the required sensitivity, the measurement takes several hours. Although the temperature, pressure and humidity in the room vary enough to distort the measurement during this period, the leak rate can be calculated by measuring the absolute room pressure and the temperature and making the necessary corrections.

However, it is not clear if the measurement using this technique reflects the true leak rate from the module when the module is filled with the ionization gas ($Xe/CF_4/CO_2$-70/20/10 mixture). In order to understand the correlation, we have constructed a gas tight box with space to put a module inside. The box is connected to a GC (gas chromatograph) to determine the gas composition in the box. The basic principle is to fill the box and the purging volume with CO_2 and to fill the straws with Xe. The purging volume is the volume inside the shell other than straws. The pressure inside the straws is kept higher than the box pressure. Periodically, the gas inside the box is sampled in order to measure Xe content inside the box. By knowing the volume of the box and the module, and the Xe concentration in the box (from the GC), the Xe leak rate can be calculated.

Another interesting measurement is the CO_2 permeation rate. It is well known that CO_2 permeates through kapton much better than other gases. Since straws are surrounded with CO_2, the permeation process could affect the ionization gas composition and change the operating characteristics of the detector. This rate can be easily measured using our setup.

In this paper, we report on two measurements. One is the leak rate measured using two techniques (pressure drop method, and using the box with GC), and the other is the CO_2 permeation rate through straws.

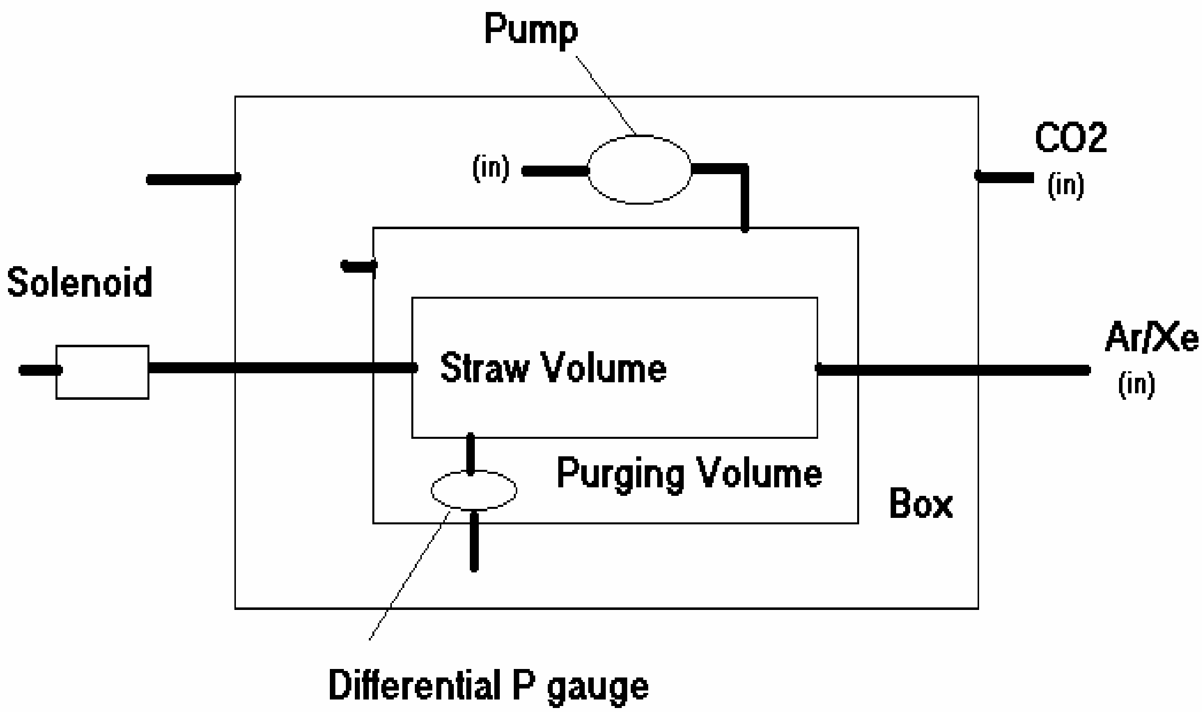
2. Setup

For this study, we have chosen module 2.06 because this module exhibits some leak. The measurement using the pressure drop shows that the leak rate for the module is 0.3 mbar/bar/min. The operating principle for the pressure drop measurement is fairly simple and won't be described here.

For the setup using the box with GC, a picture of the setup is shown below.

The dimension of the box (made of aluminum and sitting on the long table in the picture above) are 30 cm x 30 cm x 170 cm. The box was designed to accommodate the largest module (type III). For type II, about 1/3 of the space inside is filled with ballast material to reduce the overall volume. The GC (red color) is sitting on the top of the rack in the picture.

The following is a schematic of the operation. 'in' in the figure indicates the input gas direction.

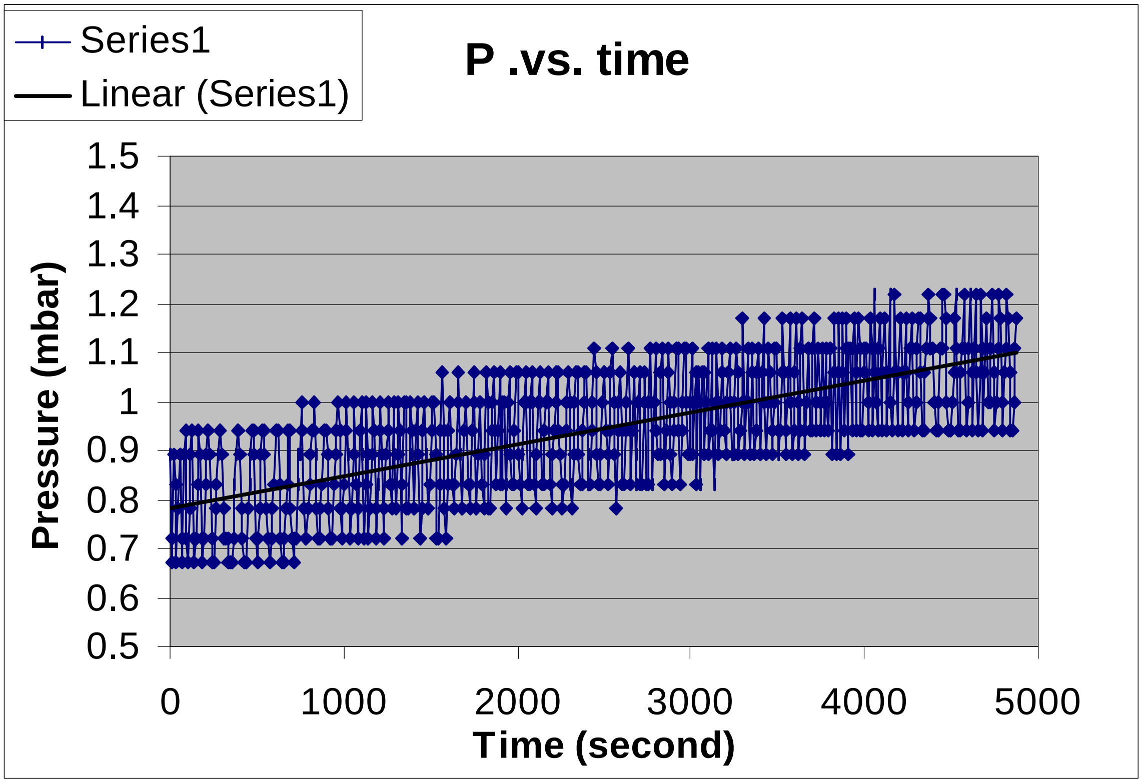


3. Data taking and analysis

a) CO_2 permeation rate

One of the interesting quantities is the CO_2 permeation through straws. We have previously measured the permeation rate using the first prototype module (type I) and the result was 5×10^{-5} cc/cm of straw/min, or 0.0075 cc/min/barrel straw. With the new straws, it is expected that the permeation rate is not to be as large as the old straws used in the prototype.

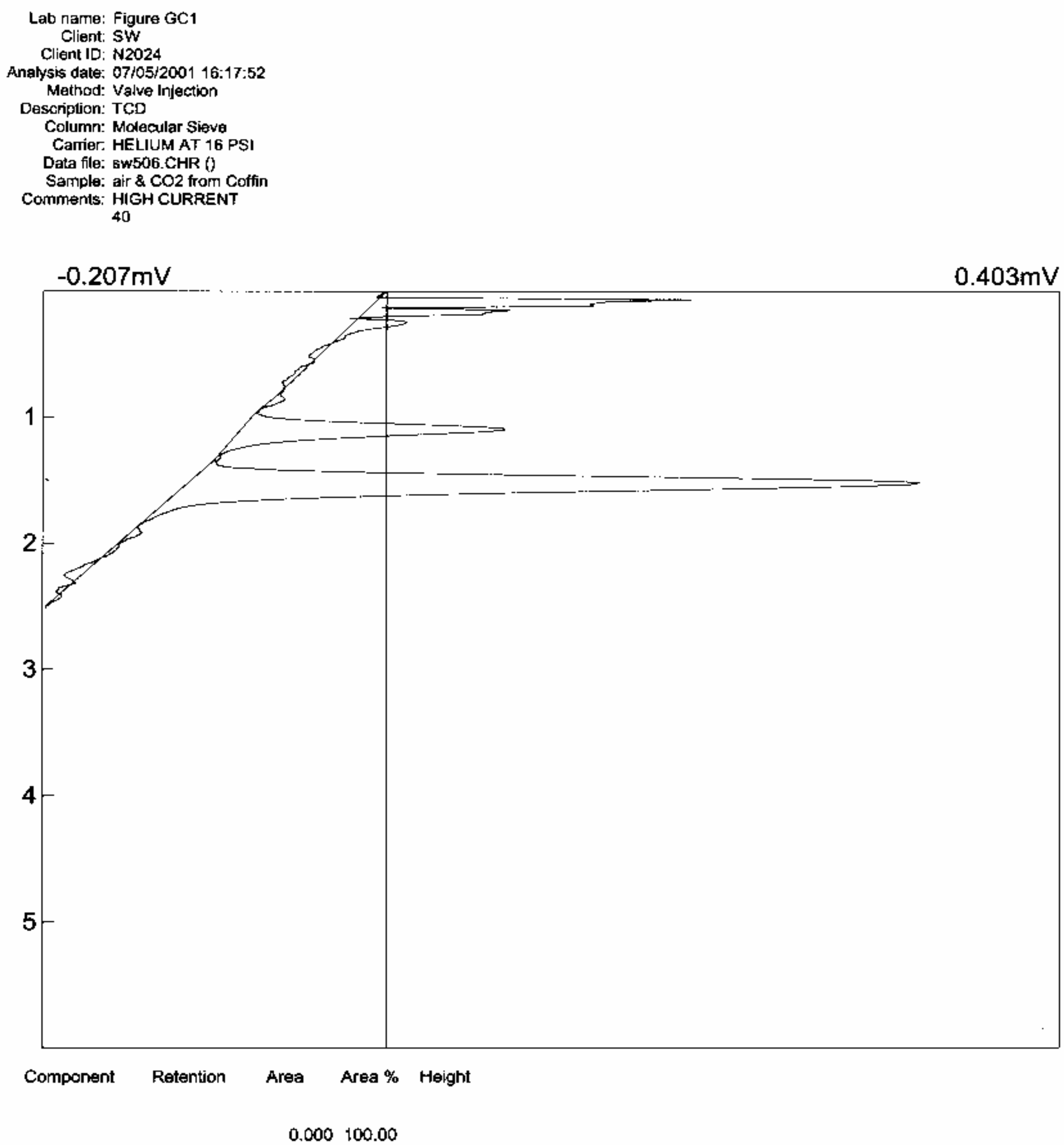
This permeation rate is measured by filling the box and the purging volume with CO_2 and the straws with Xe. The purging volume inside the shell is flushed with CO_2 by a small aquarium pump operated between the purging volume and the box. The pressure inside the straws with respect to the box is measured as a function of time using a differential pressure gauge. For this measurement, the pressure inside straws is maintained slightly above the box pressure by ~1 mbar. Figure below shows the measurement. The x-axis is the time in second and the y-axis is the pressure inside straws in mbar. (We assume that the argon permeation and the leak rate (Δp ~1 mbar) are small compared to the CO_2 permeation rate.) The oscillation shown in the data is due to the characteristic of the differential pressure gauge. From the figure, the permeation rate of about ~0.04 cc/min for the type II module or 0.05×10^{-5} cc/min/(cm of straw) is obtained, which is about a factor of ~100 less than the result from the old straws. The rate corresponds to about extra ~5 cc/min of CO_2 in the ionization gas for the entire barrel TRT.



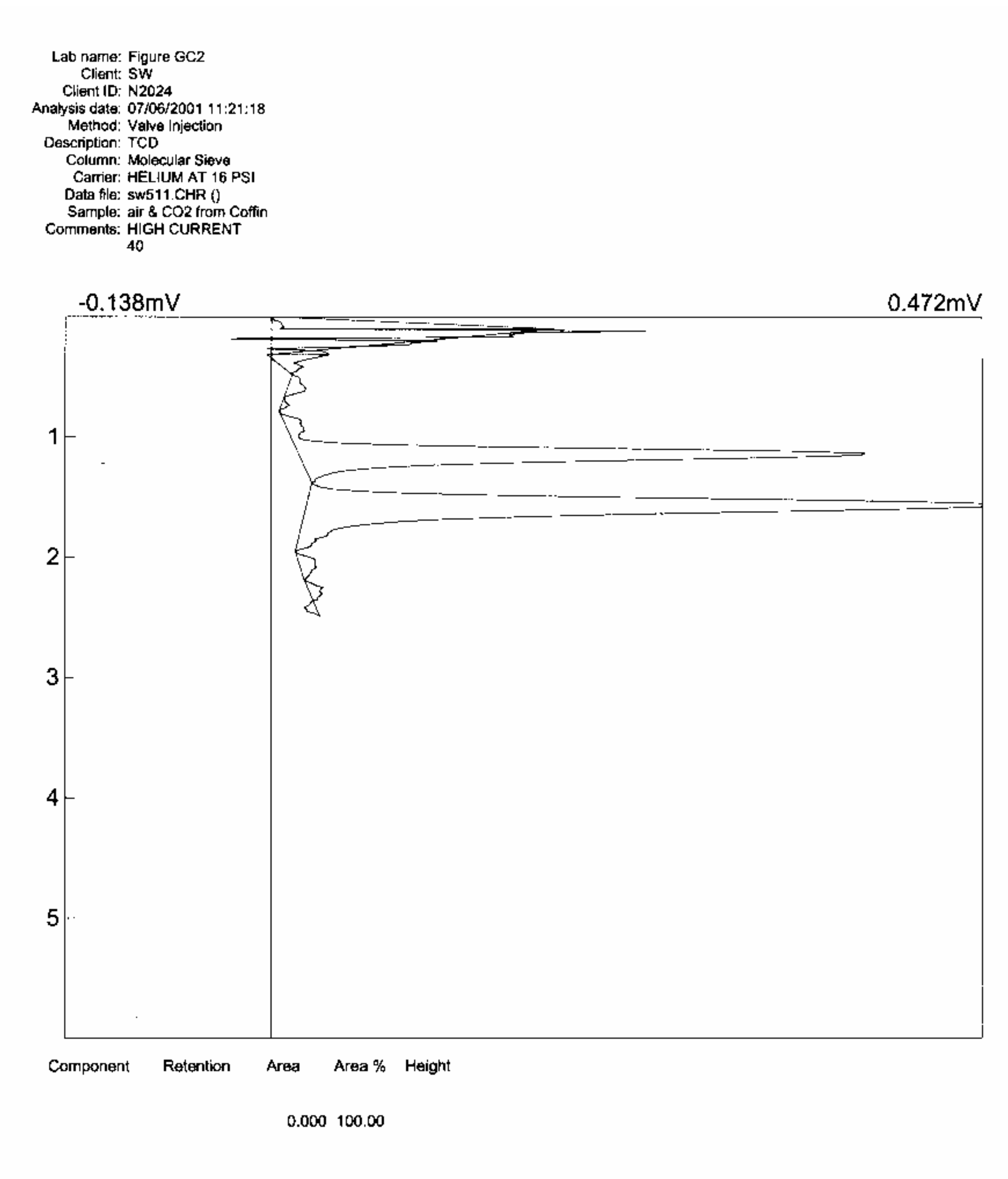
b) Ar/Xe leak rate

The next was to measure the Xe leak rate. Because of the cost, the argon leak rate is measured first to debug the system. As in the permeation measurement, the straws are filled with argon and the box and the purging volume are filled with CO_2 (see the schematic shown above). The straws are over pressurized (20 mbar) compared to the box. This is accomplished with a computer-controlled solenoid valve attached to the gas outlet. The pressure difference between the straws and the box is measured (using the differential pressure gauge) and the solenoid valve is opened or closed depending on the pressure difference. We note that 5-10 cc/min of argon (or Xe later) is flowed continuously through the module for this test.

Figure below (Figure GC1, the figure number is on the top of the figure) shows the GC analysis of the gas from the box at the beginning. The first peak is oxygen (t~1.2min) and the second peak is nitrogen (t~1.5 min). The peaks at the beginning are due to the gas injection. The vertical axis is what we call retention time. This measures the time in minutes that a particular gas takes to pass through a GC column. The integrated area below a peak is proportional to the gas concentration. The conversion of the area to the concentration requires a calibration and it is done by injecting a known amount of the gas into the column (typically 1cc). In this GC column (molecular sieve column), unfortunately, the argon peak overlaps with the oxygen peak.



The next figure (Figure GC2) shows the same but after one day of running. As shown in the figure, the nitrogen peak has increased very slightly while the argon/oxygen peak increased by a factor of ~2. The increase of the nitrogen peak tells us that the box is not completely gas tight. Although the argon and oxygen peak overlap, the leak rate can be calculated from the peaks in two plots since the ratio of the oxygen to nitrogen is known (we assume that air leakage to the box preserves the ratio). The argon leak rate from the module is calculated to be 0.04 cc/min, which correspond to 0.2 mb/bar/min. We again note that the pressure difference of 20 mbar was maintained between the straws and the box. This is somewhat lower than 0.3 mb/bar/min measured using the pressure drop method.



The last step was to measure the Xe leak rate. The setup is identical to the argon leak rate measurement except argon was replaced with Xe. Figure GC3 shows the first measurement (time=0). Similar to the earlier plots, there are two small peaks corresponding to oxygen/argon and nitrogen respectively. Thus is after flushing the box with CO_2 to purge air and argon left from the previous argon leak measurement. Calibration with Xe gas shows that the Xe peak should appear at a retention time of 8 minutes, thus Xe peak identification is not a problem

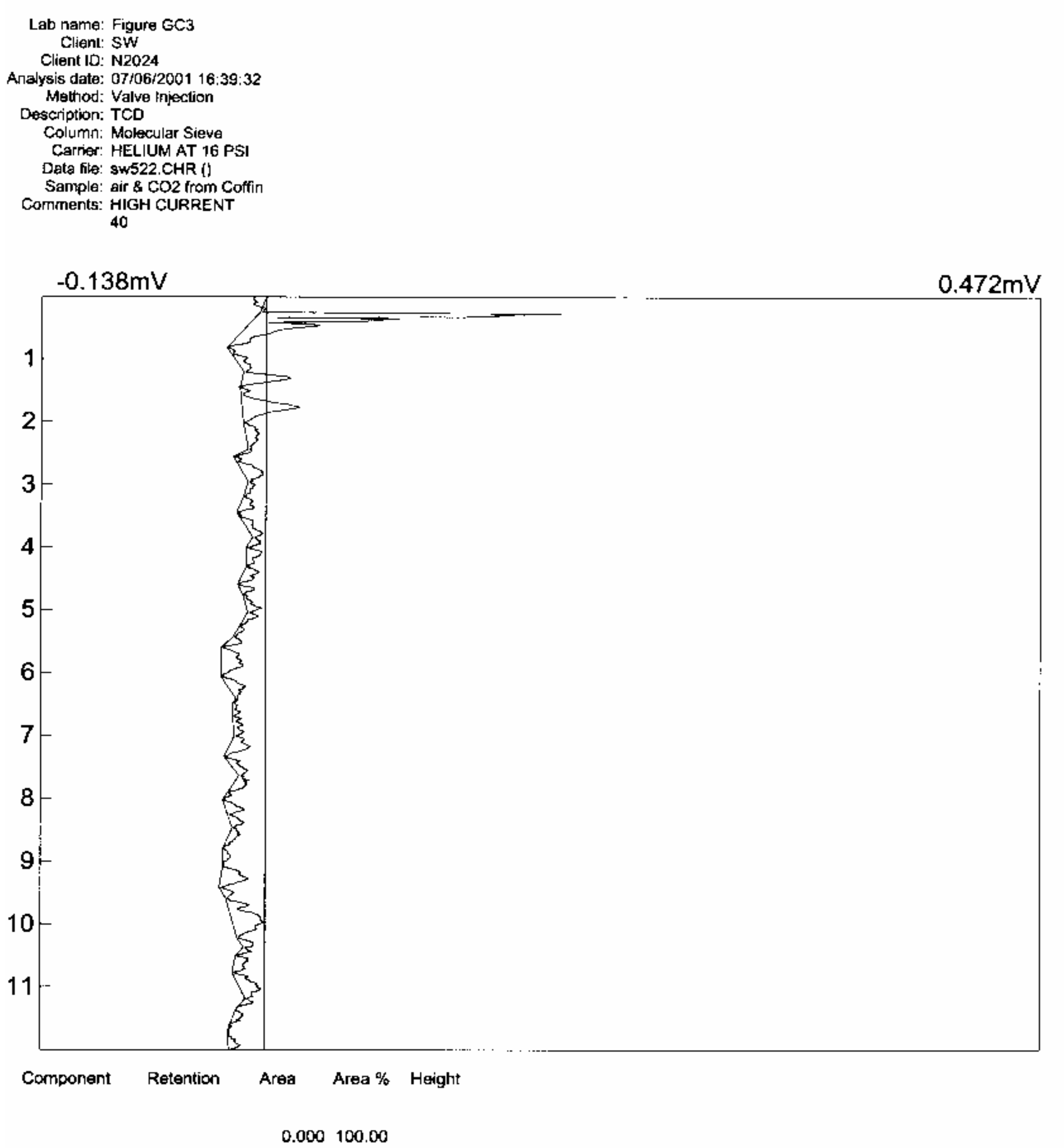
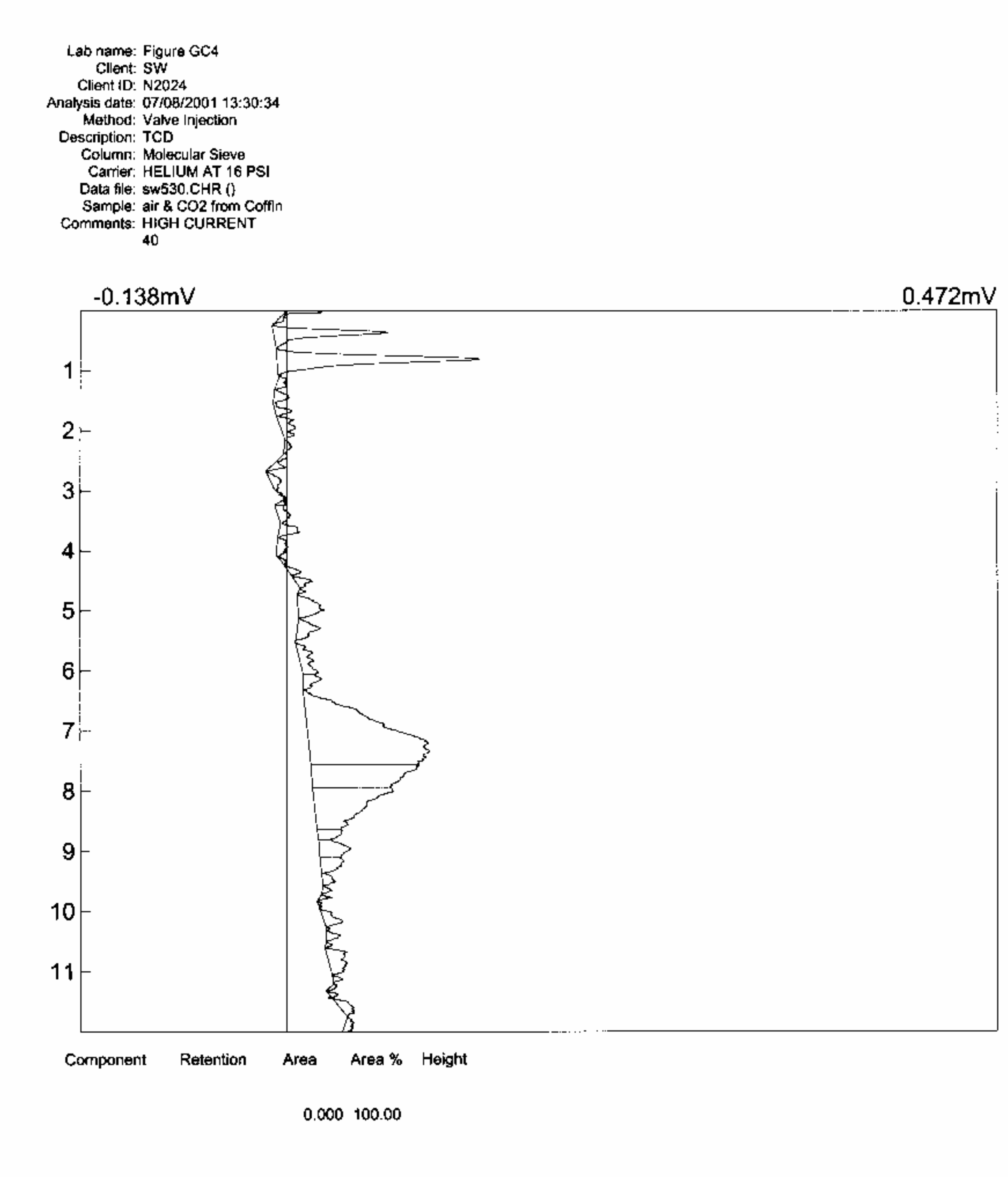


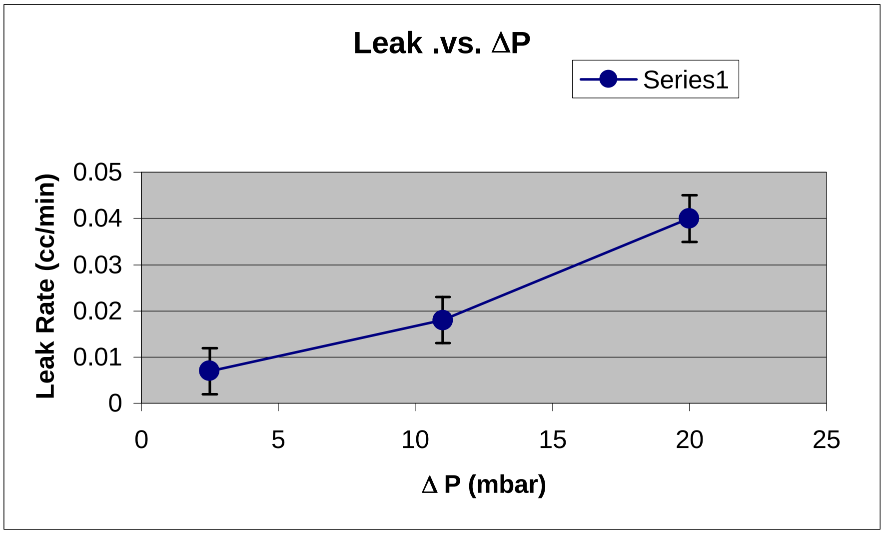
Figure GC4 below show the GC measurement after two days. As shown in the figures, there is evident Xe peak. From the figures, the leak rate of 0.04 cc/min is obtained and it corresponds to 0.2 mb/bar/min leak rate. This is consistent with the argon leak rate.



The table below summarizes the leak test results.

Module Type	Leak (P method)	Leak (with GC) Argon	Leak (with GC) Xe
2.06	~0.3 mb/bar/min	~0.2 mb/bar/min	~0.2 mb/bar/min

The Xe leak rate is measured for two other pressure differences between the straws and the box in order to estimated the Xe permeation rate. The figure below shows the leak rate as a function of the pressure difference. Extrapolating the curve to $\Delta p = 0$, we obtain less than 0.01 cc/min for the Xe permeation rate for a type II module.



4. Summary

We have measured the CO_2 and Xe permeation rate and Ar and Xe leak rate using production module 2.06. The CO_2 permeation rate is 0.04 cc/min for the type II module (or ~10^{-4} cc/min for a barrel straw or ~5 x 10^{-7} cc/(cm of straw)/min). This corresponds to an extra ~5 cc/min of CO_2 in the ionization gas for the barrel TRT. We also measured the Xe permeation rate and it is less then 0.01cc/min for the type II module.

The Ar/Xe leak rate was measured using two methods. One measures the pressure drop due to the leak in the straws and the other measures the leaked out Ar/Xe in the box using GC. The results from both methods are reasonably consistent with each other. Using our measurement, the leak rate specification 0.1 mb/bar/min corresponds to the leak rate of ~0.015 cc/min for the type II module, when the pressure difference is 20 mbar.