Ionospheric Neutral Mass Spectroscopy Instrumentation

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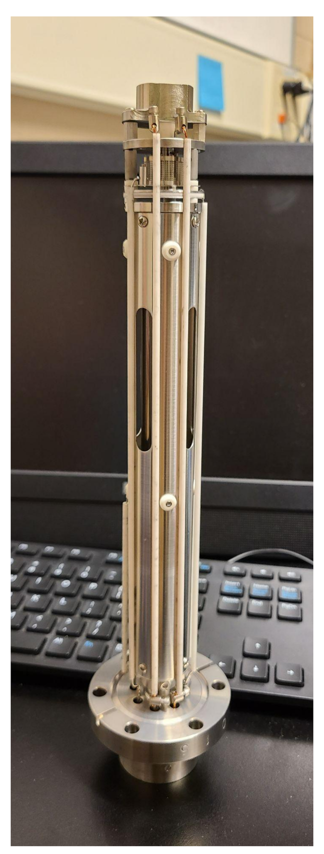
Introduction

Motivation: Understanding neutral masses in the ionosphere, especially in the E- and D-regions, is a very challenging endeavor. This is due to the high density of neutral masses at this height and the speed at which sounding rockets travel. These factors limit the ability to understand the quantity and quality of neutral masses in these regions; the density of these masses and the percentage of different masses present is not well resolved. Therefore, there exists a need to further investigate neutral mass in the ionosphere.



Here the use of a residual gas analyzer (RGA) as a neutral mass spectrometer for application within the E- and D-region ionosphere was tested. The RGA in use is the Partial Pressure Transducer Quadrupole RGA produced by MKS Instruments. This device utilizes quadrupole mass spectrometry in order to process gas analysis and filtering in order to detect distinct constituents surrounding the device. The device was set to detect N2 as this was readily available and leaked into the system for testing.

Project Objectives: Determine the device's accuracy and rate of collection over different modes and input configurations

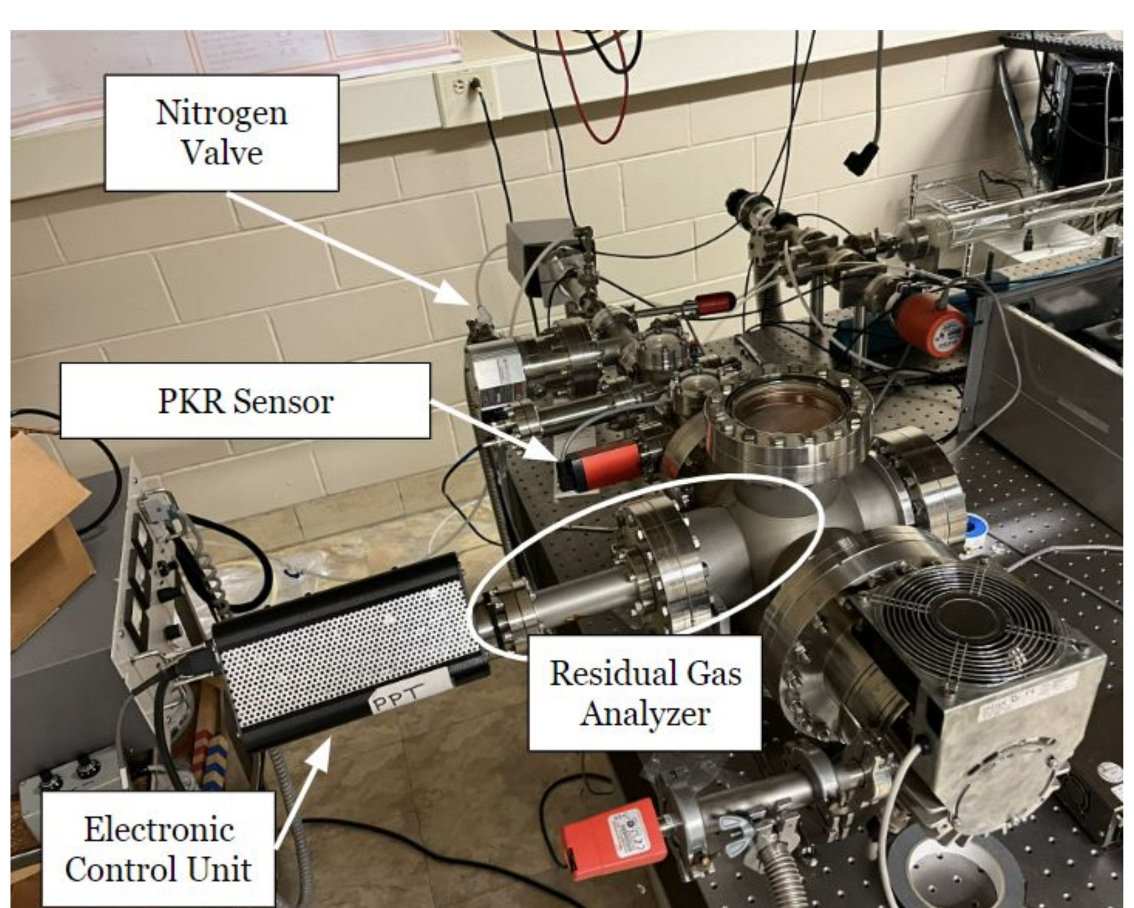


Figure 1. The experimental configuration with the RGA placed within a vacuum chamber created by a roughing and turbo pump.

Methods and Results

Experiments were conducted using the device in its Primary Mode and its Secondary Electron Multiplier (SEM) Mode using the configuration displayed in ***Figure 1***. The device's software allowed for different inputs for the Dwell variable, which was an integration factor in addition to a predetermined one set in the software's code.

Additional Scan Time = (Dwell × 20 ms) + 10 ms per channel

Primary Mode Results

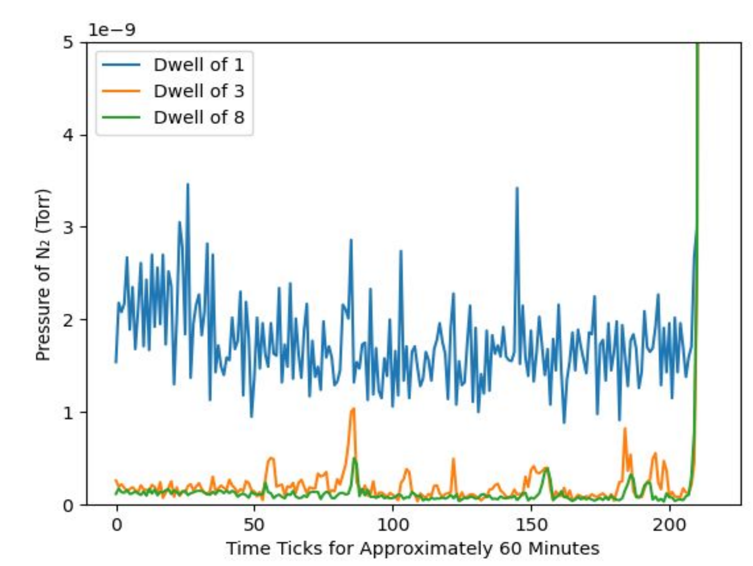


Figure 2. Three channels were run with a Dwell of 1, 3, and 8. Both the turbo pump and roughing pump were turned off at approximately the 40 and 200 time tick marks respectively. The higher Dwell values experienced less noise and reported lower values for the pressure of N2. Since these were expected to be more accurate, it is possible that most of the readings using Dwell 1 were noise until the pressure of N2 was high enough.

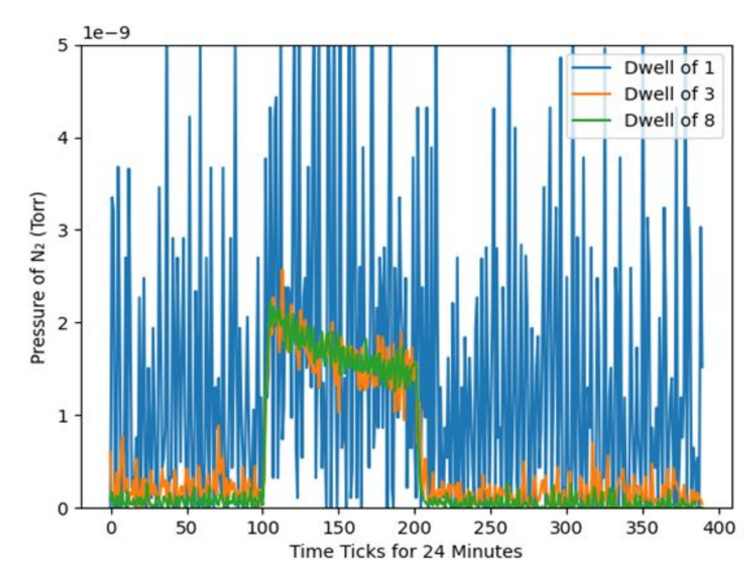


Figure 3. Three channels were run with a Dwell of 1, 3, and 8. Between the 100 to 200 time ticks, the N2 valve was opened to 62% and then closed afterwards. Here the Dwell 1 time was much noisier than the higher Dwell valued channels, however the Dwell 3 channel was not much noisier than the Dwell 8 channel.

SEM Mode Results

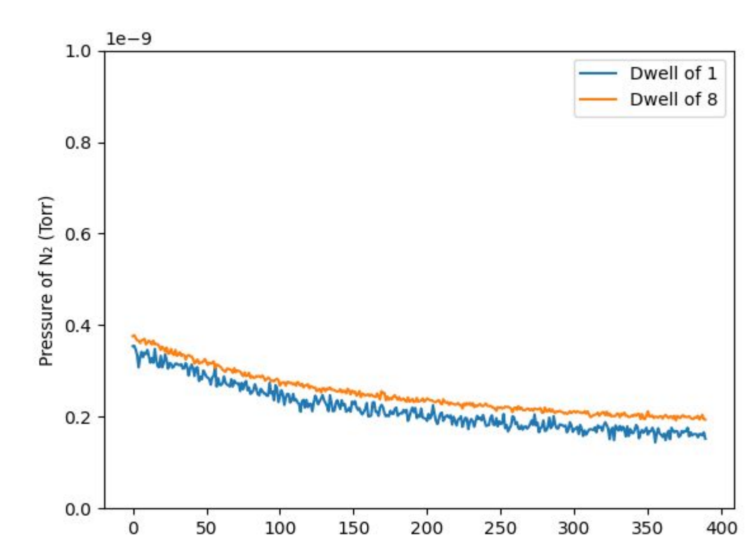


Figure 4. Two channels were run with a Dwell of 1 and 8 at 1000 volts. For both of the channels at the two Dwell values the data was much more consistent compared to the data collected in Primary Mode. A downward trend was observed due to the vacuum chamber lowering the pressure again after the RGA was turned on.

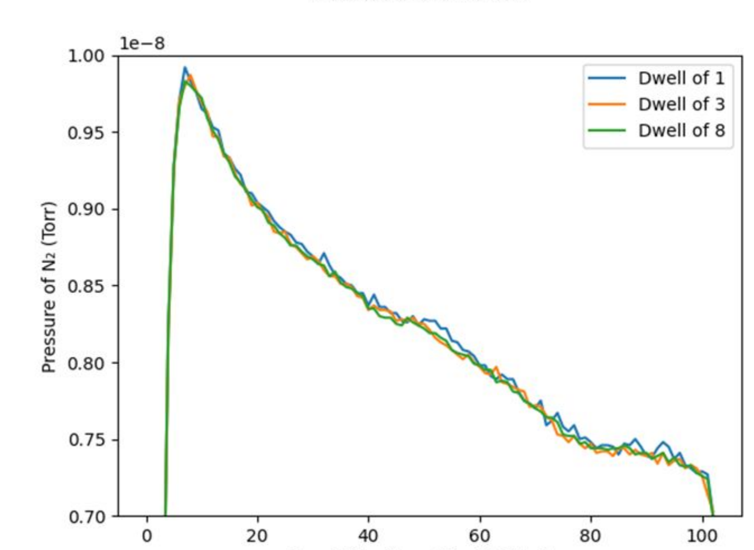


Figure 5. Three channels were run with a Dwell of 1, 3, and 8 at 1000 volts. The N2 valve was opened to 62% just after the experiment began and was closed at the 100 time tick mark. All three channels at the different Dwell values were less noisy and more consistent with one another when compared to the data collected in the Primary Mode.

Discussion and Conclusion

1.) Device Accuracy

When operated in Primary Mode, the device was found to have an operating range of 10^{-4} to 10^{-9} Torr while in SEM Mode it was 10^{-4} to 10^{-12} Torr. Since a majority of the experiments conducted were at approximately 10^{-9} to 10^{-8} Torr this was near the lower limit of operation for Primary Mode. However all of the experiments were still within the operating ranges of both modes and the Primary Mode data was much less consistent than the SEM Mode data.

In addition, the device was more accurate when a larger Dwell value was used. However, it was clear from the results that when the device was in SEM Mode, it was less noisy across all Dwell values and therefore using a lower Dwell value to achieve a higher rate of collection was more feasible. Early testing of the device also found that operating the SEM Mode at 1000 volts presented more accurate results compared to 500 or 2000 volts.

2.) Device Rate of Collection

The fastest rate of collection achieved by the device operating only one channel using Dwell 1 was 1 data point per 0.9 seconds. Assuming a sounding rocket was roughly traveling 1 km per sec, this would achieve a resolution of 900 meters per data point which would not provide useful information of the E- and D-regions.

However, the main constraining factor on the speed of the device was found not to be the Dwell value, but the predetermined integration done within the software of the device. Therefore, it is advised that changes are made to its code in order to allow for integration only from the Dwell factor.

Conclusion: Given the current MKS-PPT software limitations, the RGA device would not currently be viable for flight on a sounding rocket, but changes to how the data is integrated would allow for flight. It is therefore advised that the code behind the MKS-PPT software be edited to decrease integration time, and that the device is then further tested.

Acknowledgements

I would like to thank Dr. Stephen Kaeppler for his help and planning of the project. In addition, I would like to thank the SC Space Grant Consortium for funding and support.