A Quadrupole Ion Trap Mass Spectrometer for Quantitative Analysis of Nitrogen-Purged Compartments within the Space Shuttle

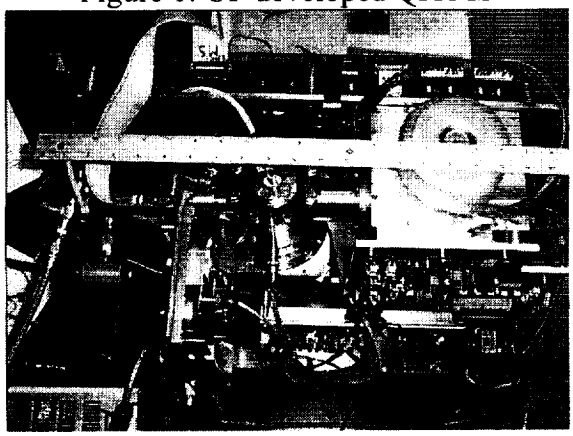
Andrew K. Ottens[1,2], Timothy P. Griffin[2], William R. Helms[3], Richard A. Yost[1]

1. The University of Florida, Department of Chemistry, Gainesville, FL 32611
2. Dynacs Engineering Co., Inc., Kennedy Space Center, FL, 32899
3. NASA, Kennedy Space Center, FL, 32899

To enter orbit the Space Shuttle burns 1.8 million liters of liquid hydrogen combined with 0.8 million liters of liquid oxygen through three rocket engines mounted in the aft. NASA monitors the nitrogen-purged aft compartment for increased levels of hydrogen or oxygen in order to detect and determine the severity of a cryogenic fuel leak[1]. Current monitoring is accomplished with a group of mass spectrometer systems located as much as 400 feet away from the shuttle. It can take up to 45 seconds for gas to reach the mass spectrometer, which precludes monitoring for leaks in the final moments before liftoff (the orbiter engines are started at T–00:06 seconds).

To remedy the situation, NASA is developing a small rugged mass spectrometer to be used as point-sensors around the Space Shuttle. As part of this project, numerous mass analyzer technologies are being investigated[2]. Presented here are the preliminary results for one such technology, quadrupole ion trap mass spectrometry (QITMS). A compact QITMS system (Figure 1) has been developed in-house at The University of Florida for monitoring trace levels of four primary gases: hydrogen, helium, oxygen and argon, all in a nitrogen background. Since commercially available QITMS systems are incapable of mass analysis at m/z 2, the home-built system is preferred for evaluation of QITMS technology.

Figure 1: UF developed QITMS



Key requirements stipulated by NASA for the system are shown in Table 1. Initial results for the system are presented in Table 2. The linear response of the system is illustrated in Figure 2 shown over three concentration decades.

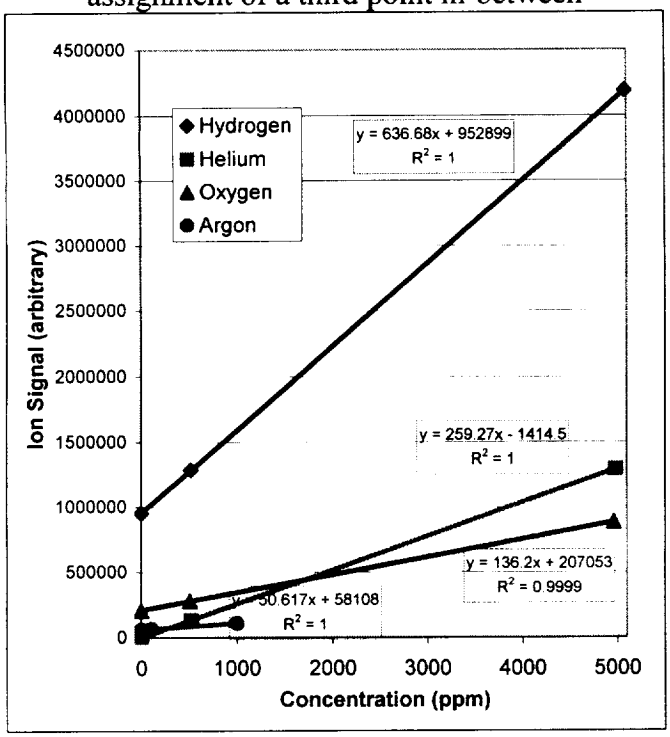
Table 1: Key NASA requirements (Doc. # KSC-MM-4864)

Requirements	Hydrogen	Helium	Oxygen	Argon
LOD (ppm)	25	100	25	10
Accuracy (% Error)	$< \pm 10$ for each in nitrogen			
All requirements are for the specified gas in a nitrogen background				

Table 2: Current performance specifications for UF QITMS

Requirements	Hydrogen	Helium	Oxygen	Argon
LOD (ppm)	26	3.3	32	43
Accuracy (% Error)	1.4	5.4	7.9	3.3
All requirements are for the specified gas in a nitrogen background				

Figure 2: Two-point calibration plot with accurate assignment of a third point in-between



Present data indicate that use of segmented scanning with two or three small mass ranges (e.g., m/z 1 – 5 and m/z 31 – 41) in conjunction with ion source and ion trap parameters optimized for the specific mass ranges provides for optimal performance. Further investigation of such optimal parameter settings based on desired m/z will be investigated.

Additionally, future work will encompass further reduction of total system volume. NASA is requesting a system size of 33,000 cc, and while the present QITMS system is compact it is not considered miniaturized at the present volume of 60,500 cc. Since the majority of the system is comprised of vacuum pumps and RF drive electronics, these two areas will be targeted for miniaturization.

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[1] Griffin, T. P.; Naylor, G. R.; Haskell, W. D. A Fully Redundant On-Line Mass Spectrometric System for the Space Shuttle Used to Monitor Cryogenic Fuel Leaks. *The 2nd Workshop on Harsh-Environment Mass Spectrometry*, St. Petersburg, FL, **2001**.

[2] Arkin, C. R.; Ottens, A. K.; Diaz, J.; Griffin, T. P.; Follistein, D.; Adams, F. Evaluating Mass Analyzers as Candidates for Small, Portable, Rugged Single Point Mass Spectrometers for Analysis of Permanente Gases. *The 49th ASMS Conference On Mass Spectrometry And Allied Topics*, Chicago, IL, **2001**.