Material Outgassing Kinetics: The Development of a Testing Capability

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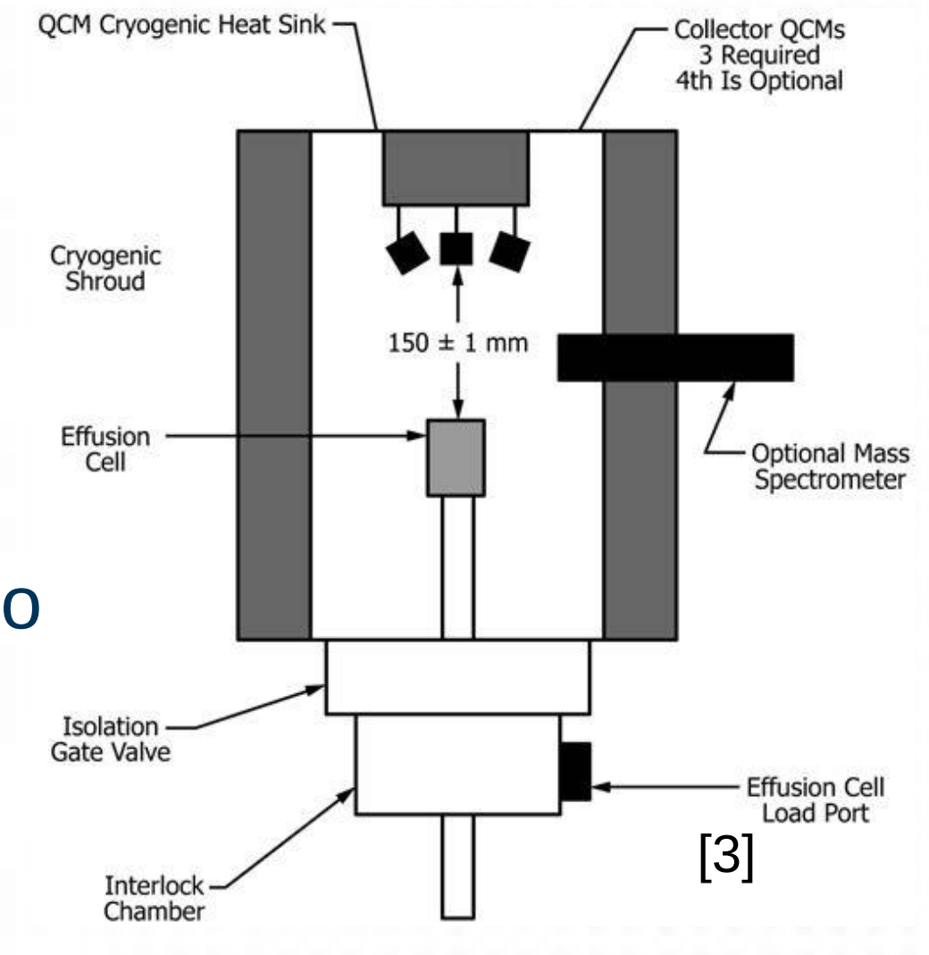
Materials must be well understood and well characterized to be allowed in most space applications. Testing requirements for materials to go to the International Space Station or to fly on unmanned spacecraft are rigorous. SDL needed to develop the testing capability to understand these materials better. The American Society for Testing and Materials (ASTM) E1559 standard is used to determine the outgassing kinetics of materials and the corresponding rates of contaminant deposition on nearby surfaces at various temperatures. [1] The objective is to upgrade existing hardware to develop a state-of-the-art ASTM E1559 compliant test chamber. This will allow SDL to evaluate and space-qualify new aerospace materials to be used in critical on-orbit applications.

What is the ASTM E1559 standard?

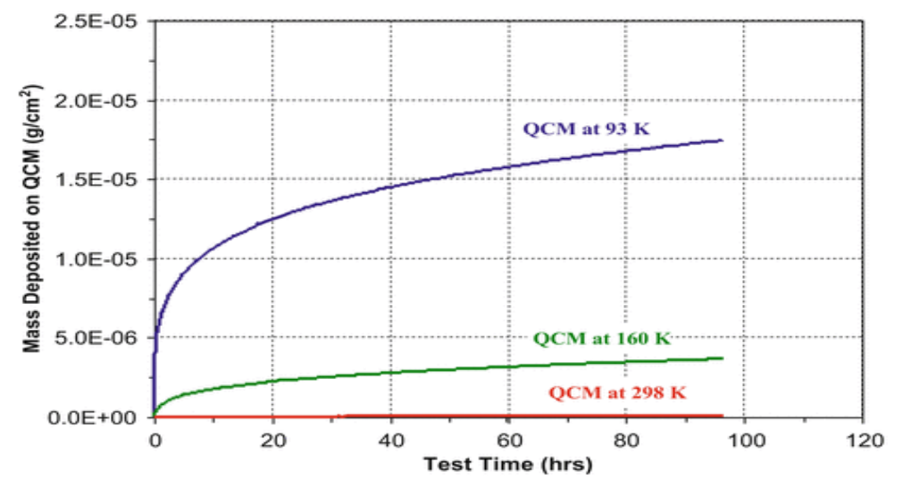
The ASTM E1559 standard specifies there must be four main components for the test chamber. Fig. 1

- Vacuum chamber – A outgassing test chamber with a cryogenic shroud connected to a sample introduction "load lock" chamber. Each chamber is independently pumped using a turbo pump backed by a oil-free scroll pump.
- Internal configuration – Three quartz crystal microbalances (QCMs), an effusion cell, a cryogenic heatsink, and a Residual Gas Analyzer (RGA).
- QCM – Measures material deposition rates by monitoring the frequency change of a quartz crystal oscillator as mass is accumulated. Deposition rates can be measured at various temperatures.
- RGA – Quadruple mass spectrometer used to identify chemical composition of outgassing vapors. It is used to identify QCM contaminants by warming the crystal to re-evaporate accumulated deposits.
- Data acquisition – Used to measure frequencies of QCMs, temperature of QCMs, temperature of effusion cell, and times of data collection at specified intervals. Data is stored for later retrieval for further analysis.
- Temperature control system – Able to maintain temperatures of effusion cell and QCMs independently. QCMs have their own internal heaters and are cold-biased by being mounted on the cryogenic heatsink.[2].



[3]

Fig. 1



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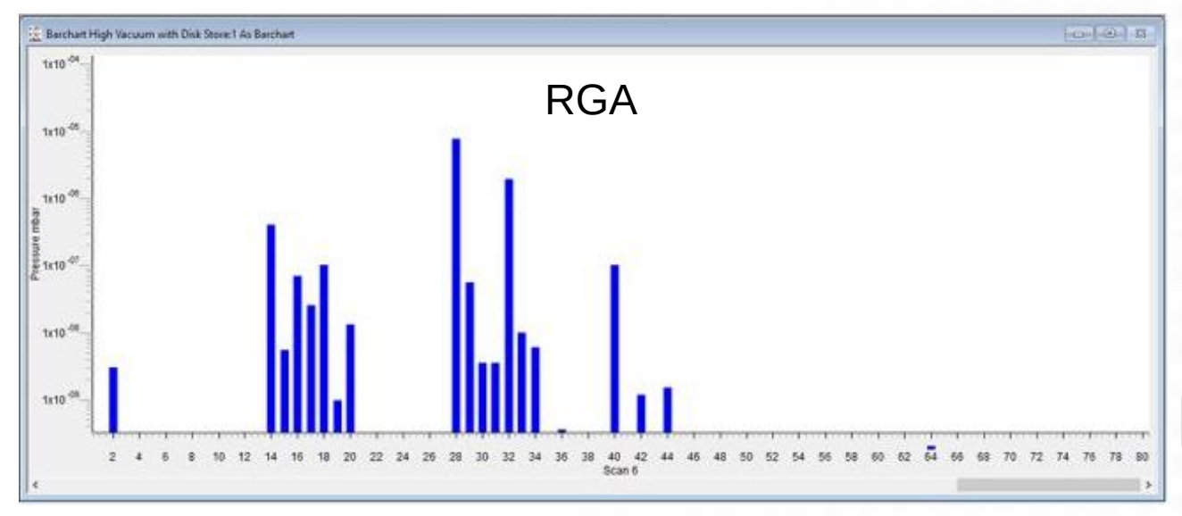
QCM Deposition Rate vs Time & Crystal Temp



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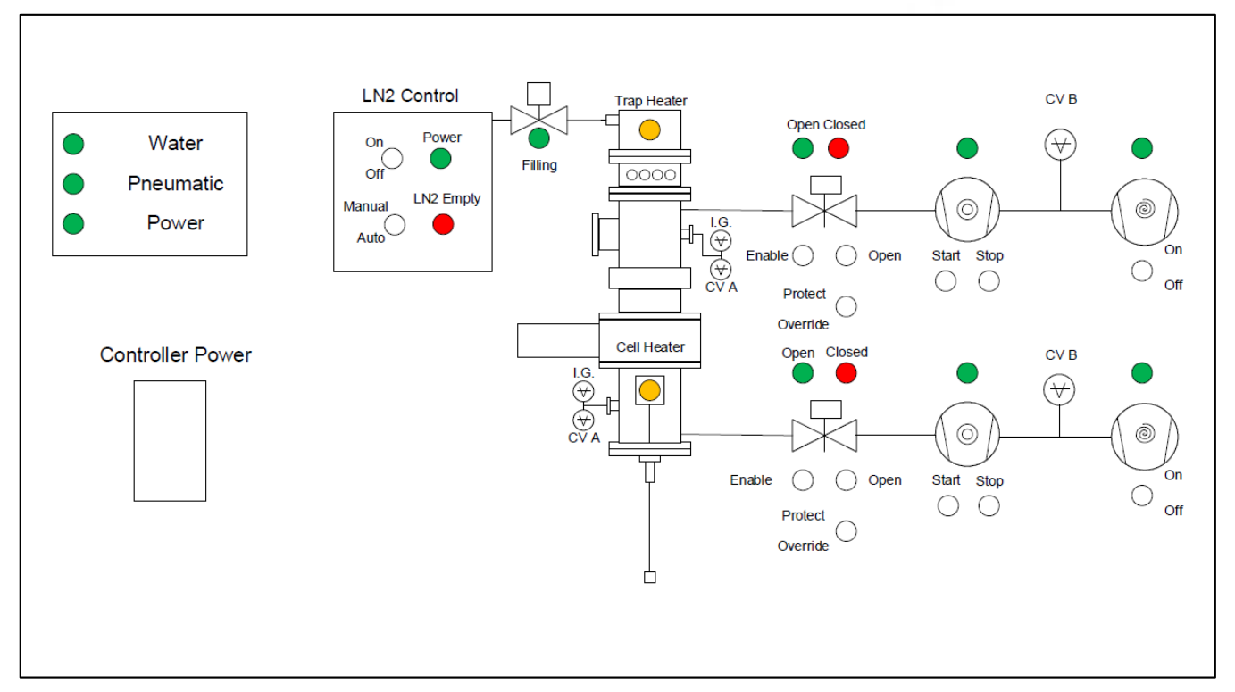
Mass Spectrum of Residual Gas in Analysis Chamber

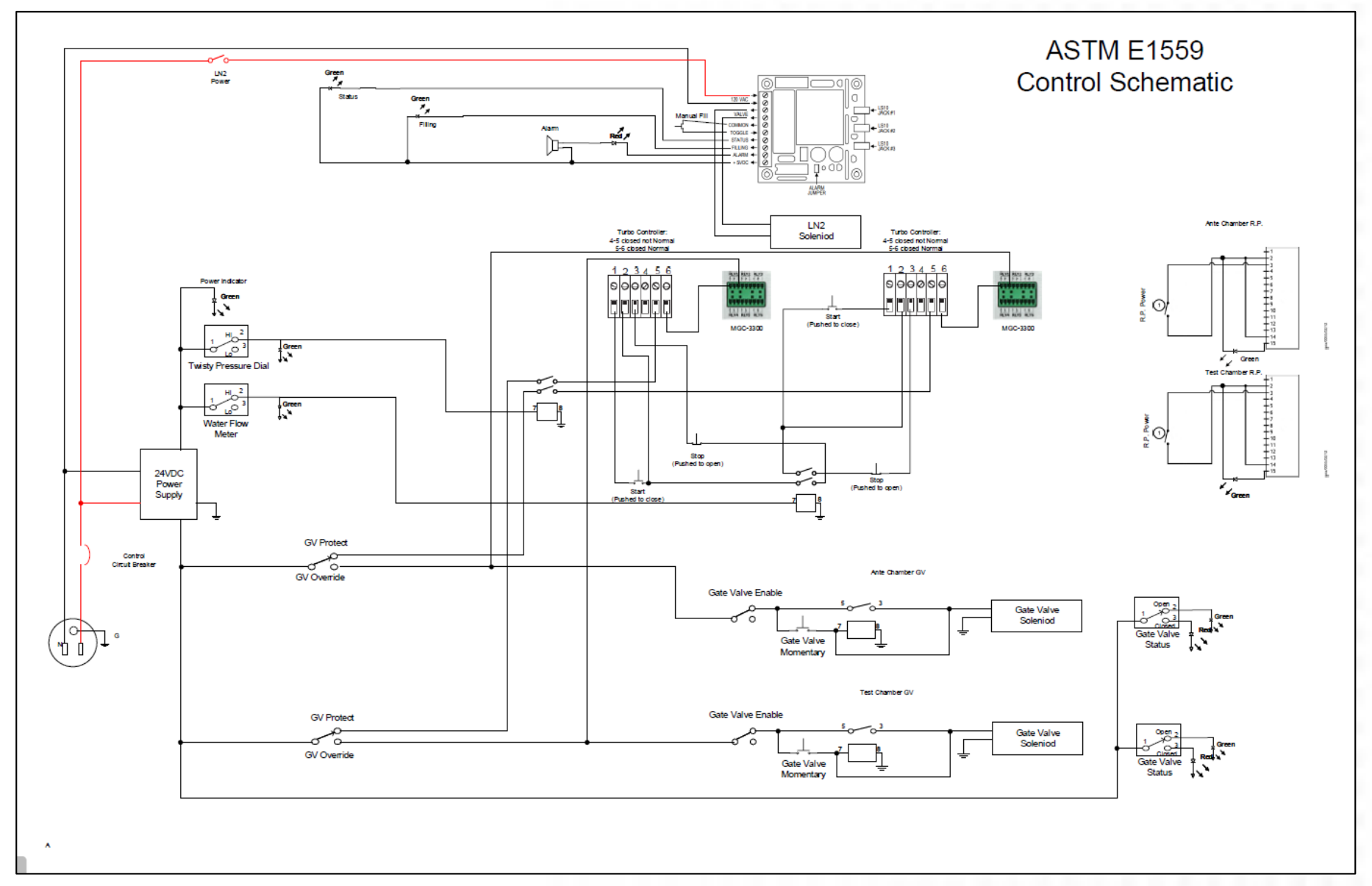
Design of Electromechanical Controller

An instrumentation chassis was designed to integrate the vacuum gauge controllers, the vacuum pump control panel, the heater control panel, QCM controller, turbo pump controllers, power distribution system, Agilent data acquisition unit, and computer. A vacuum system controller was designed to turn on and off the pumps, open and close the pneumatic gate valves, and manage the liquid nitrogen level controller. Easy to see indicator lights show the status of gate valves, scroll and turbo pumps, LN2 controller, water flow, and pneumatic air. The pneumatic gate valves are interlocked to protect the turbo pumps. For a gate valve to remain open there must be sufficient water flow for cooling, turbo must be operating normally, chamber pressure sufficiently low, and enough air pressure to operate the gate valve. If any of these criteria fail, the gate valves will close automatically and protect the pumps.

Vacuum System Control Panel



Vacuum System Wiring Schematic



Mechanical Design

Solid Edge was used to model all existing hardware so that it could be integrated into an efficient test stand. The hardware was adapted to a vertical configuration, as shown in Fig. 2 and 3, to improve the cryogenic performance.

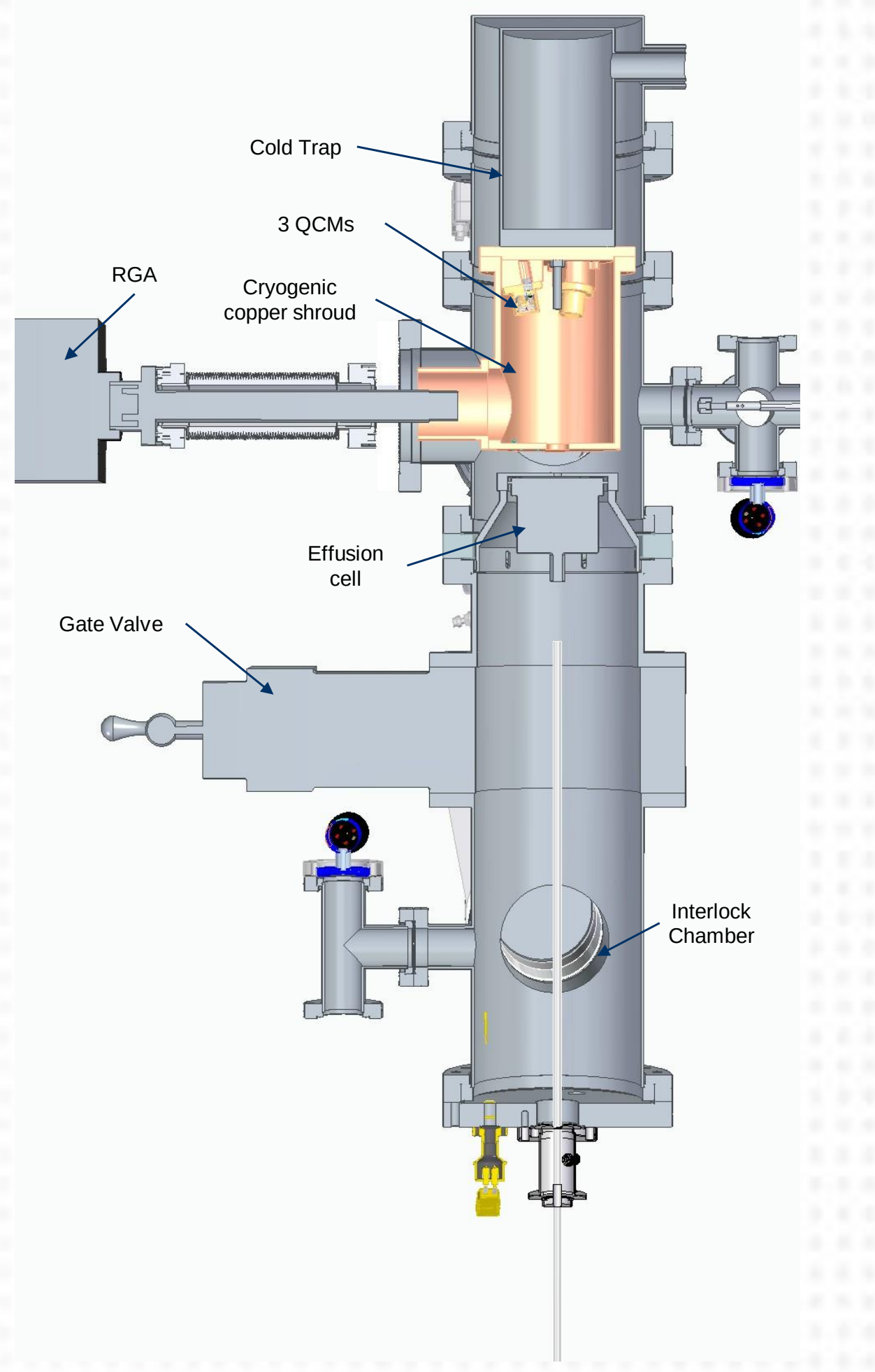


Fig. 2

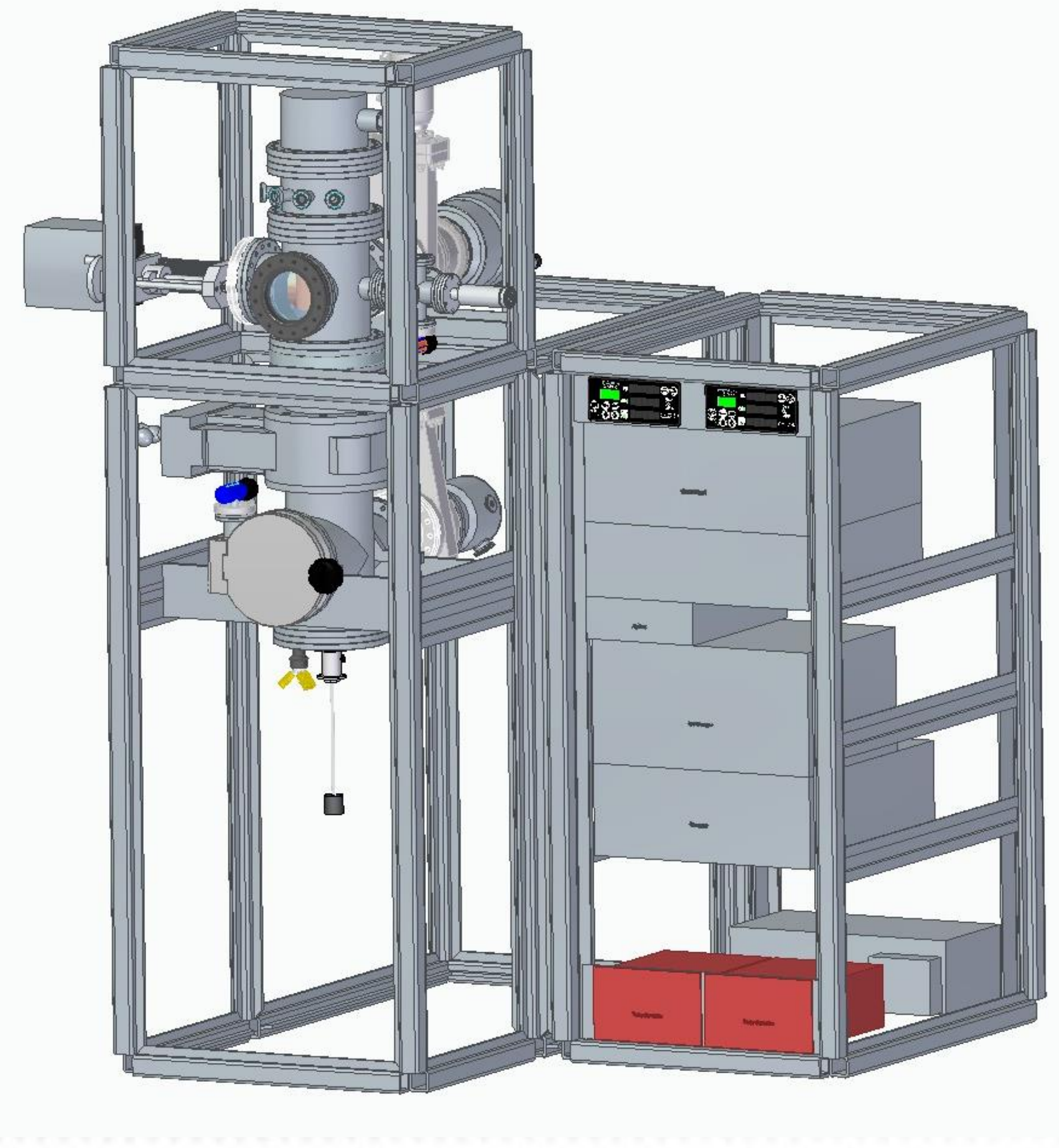
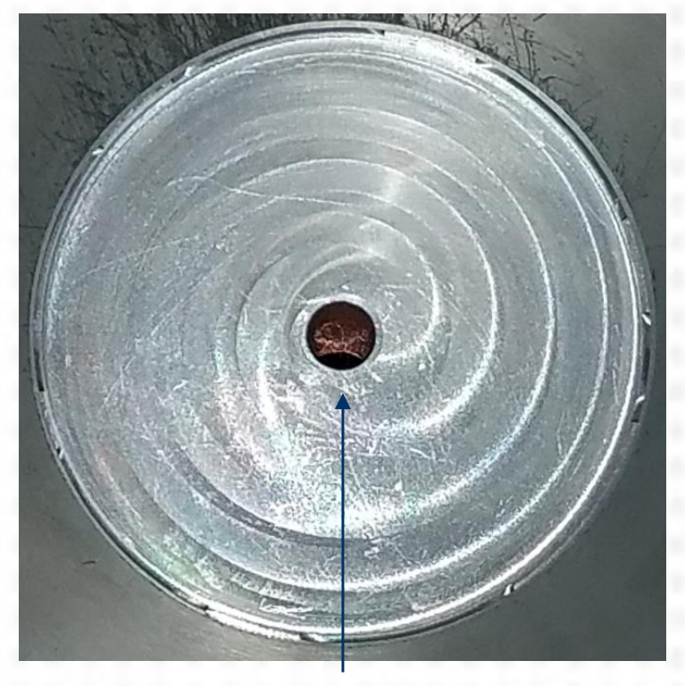


Fig. 3

Assembly

After finishing the design and ordering all needed parts, assembly was started. Putting the frame together was straight forward, it was designed to go together easily (A). Once the frame was assembled, the cross braces and saddles were mounted for the chamber (B). This involved drilling, lining up, and tapping all the holes. The upper cross brace and saddle were able to be attached once the vacuum chamber was in the frame to help line it up.

Next was getting the vacuum chamber placed in the frame. All vacuum chamber components were removed from existing frame (C), disassembled, and precision cleaned. The interlock chamber was placed first in the bottom saddles (D) and built up to the test vacuum chamber, including the copper shroud (E). Unfortunately, the copper shroud was eclipsing the effusion cell (see below). The cold trap had sagged from originally being mounted in a horizontal position and the QCM mounting plate was slightly angled. This would impede the QCMs' line of sight, which would invalidate test results. We were able to bend the cold trap to align with the centerline of the chamber, and we machined the QCM mounting plate to remove the tilt.



Misalignment of cryogenic shroud initially eclipsed apertures

No of eclipsing of apertures after significant rework of target chamber

Assembly (Cont.)

Additionally, the data rack needed assembly. Four data rails were mounted inside of the supporting hardware frame. This was done by drilling and tapping holes in the frame. Once the data rails were mounted, it was a simple matter of mounting the vacuum gauge controllers, turbo controllers, and a shelf for the computer and QCM controller. The front panels for the control box and heater control were mounted for aesthetics.

(A)

(B)

(C)

(D)

(E)

Work still to do

With the data rack and vacuum chamber fully assembled work can start on installation of the internal configuration. This will involve mounting the QCMs, RGA, and installing the effusion cell. Now that we have all of the electrical components, wiring of the control box can begin. Once this is complete we can begin connecting everything together to get ready to do a test on the chamber. The initial testing will compare SDL measurements of common aerospace materials to previously published reference data.

References

[1] ASTM International. Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials. 2016; section 1.1
[2] ASTM International. Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials. 2016; section 5.1
[3] ASTM International. Standard Test Method for Contamination Outgassing Characteristics of Spacecraft Materials. 2016; section 1.1 FIG.2
[4] Vitali Issoupov, Sergey Horodetsky, Jacob Kleiman. 17 May 2017. ASTM E1559 Comparative Testing of Low-Outgassing Silicone-Based MAP Thermal Control Coatings.
[5] MKS. https://www.mksinst.com/f/vision-2000-p-xd-process-monitor