Outgassing Characterization of Rod Heaters used for GOES-R Thermal Vacuum Testing

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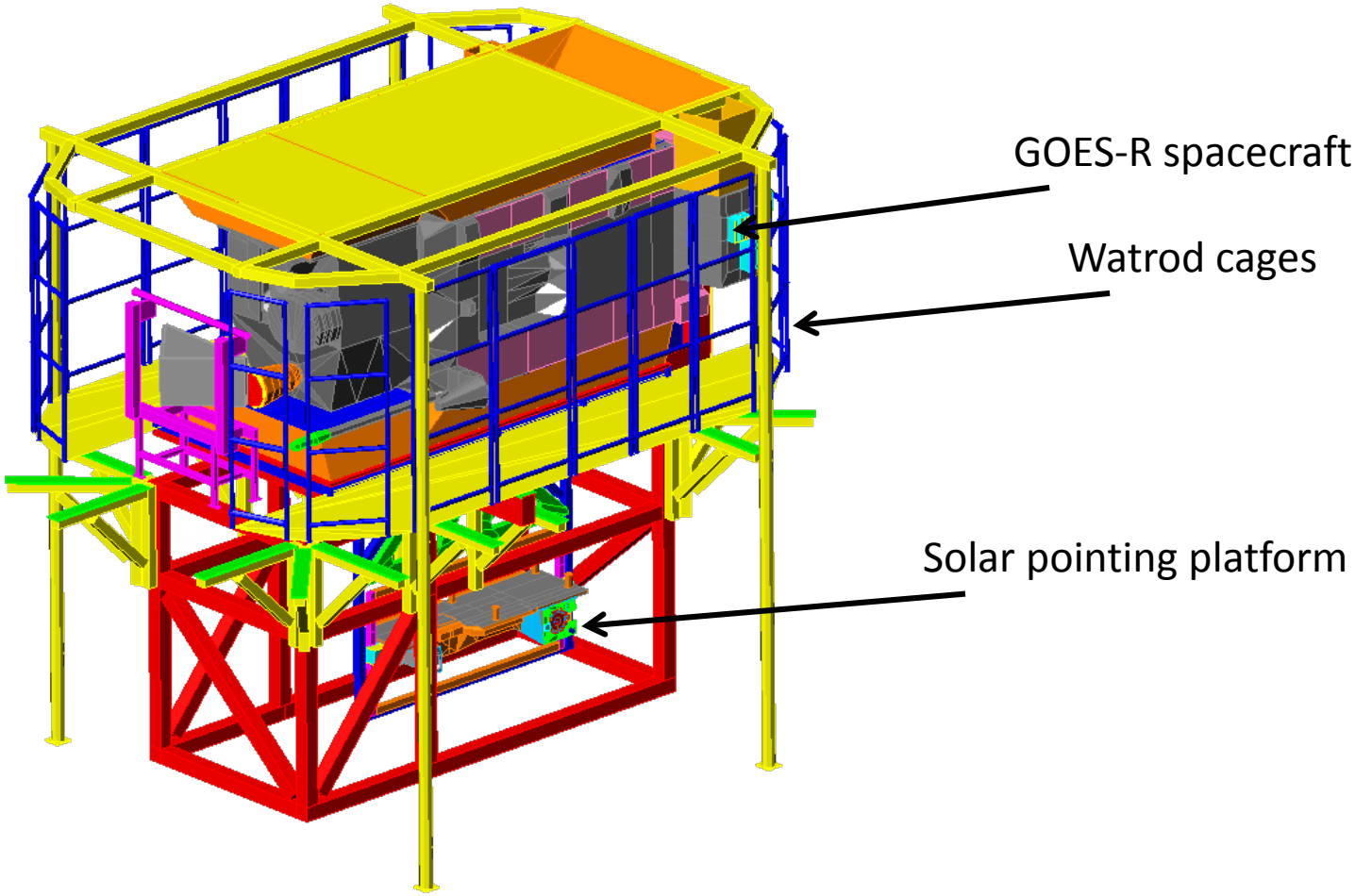
Summary

- Past experiences of Code 546 Contamination Engineers indicated that rod heaters (e.g. calrods or watrods) may be a source of molecular contamination
  - For instance, SDO chamber required over 100 hours of bakeoff
  - However, has been used on other projects (LADEE, etc..) without issues
- GOES-R TVAC configuration uses such heaters (Watlow watrod)
  - GOES-R is highly contamination sensitive – needed to verify these heaters will not contaminate the flight hardware, chamber, or MGSE
- This presentation summarizes the outgassing characterization effort and the subsequent bakeout

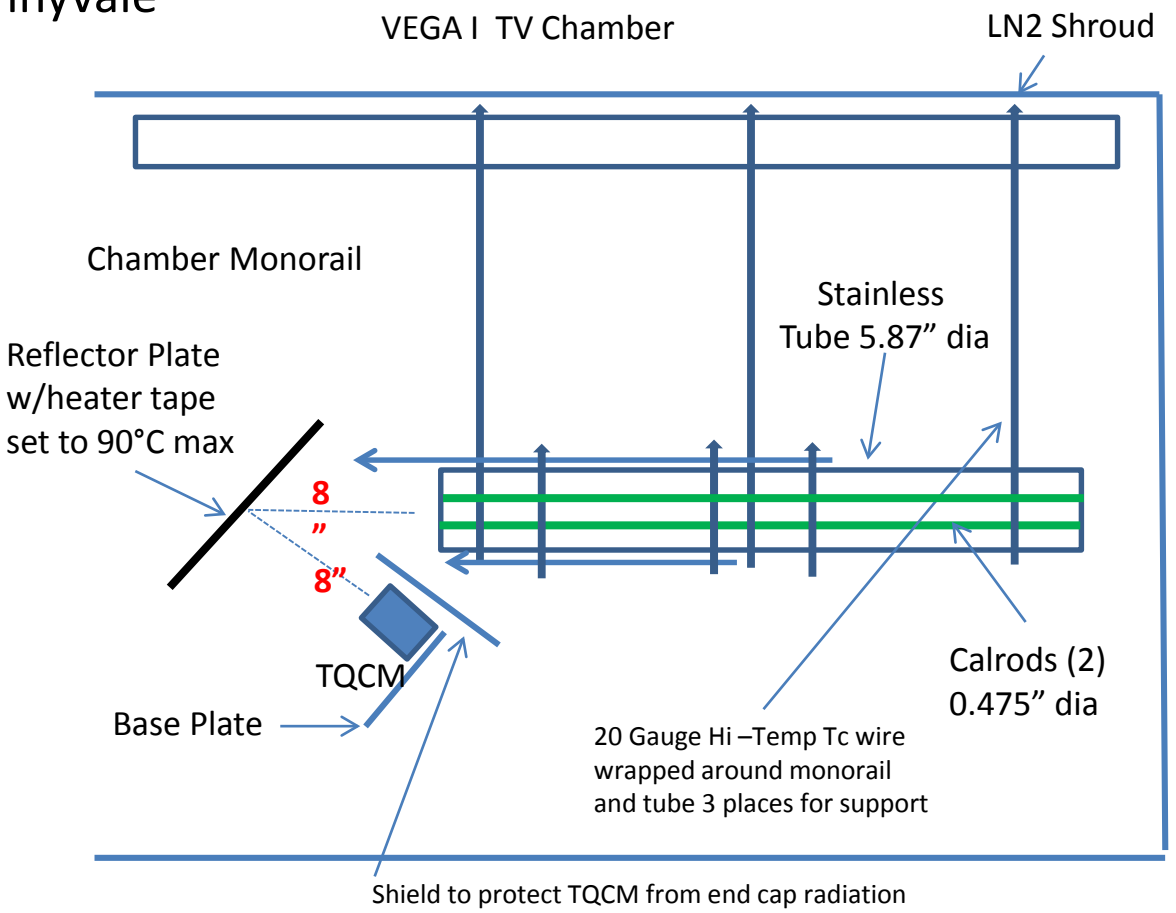
GOES-R TVAC Configuration

- Cold walls used for the entirety of the test
- Spacecraft enclosed in an MGSE watrod cage
  - Some sections use heater plates instead of watrods

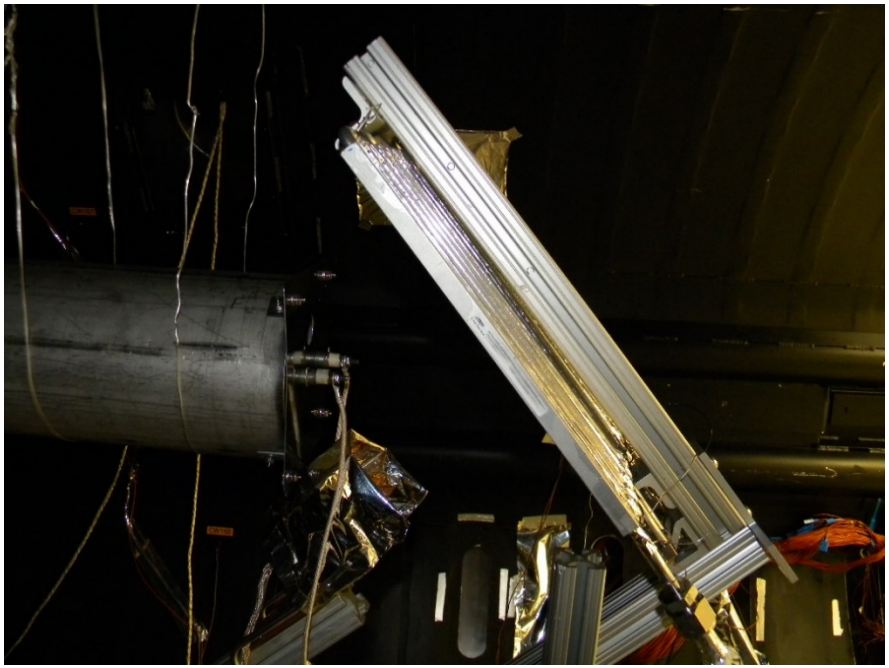


Outgassing Characterization

- Objective was to characterize outgassing from a virgin, un-baked watrod
  - Two rods placed in a stainless steel cylinder with opening on one end, facing reflector
  - 450°C nominal temperature during TVAC per thermal model, but margin up to 600°C
- Used a 90°C reflector plate to protect TQCM crystal, LN2 chamber shroud
- Testing performed at LM Sunnyvale



Experimental Setup

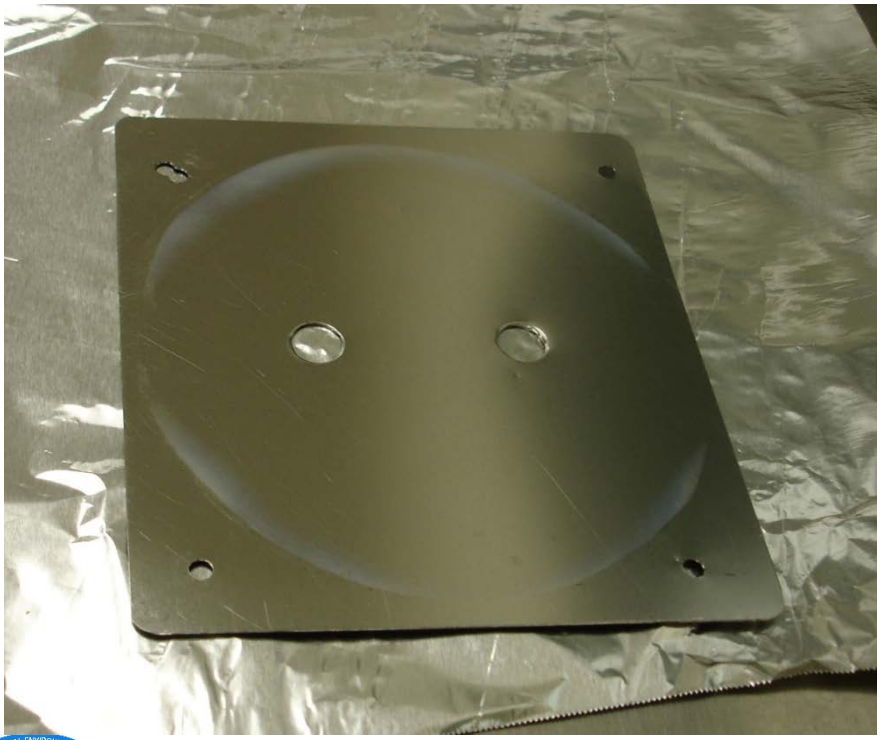


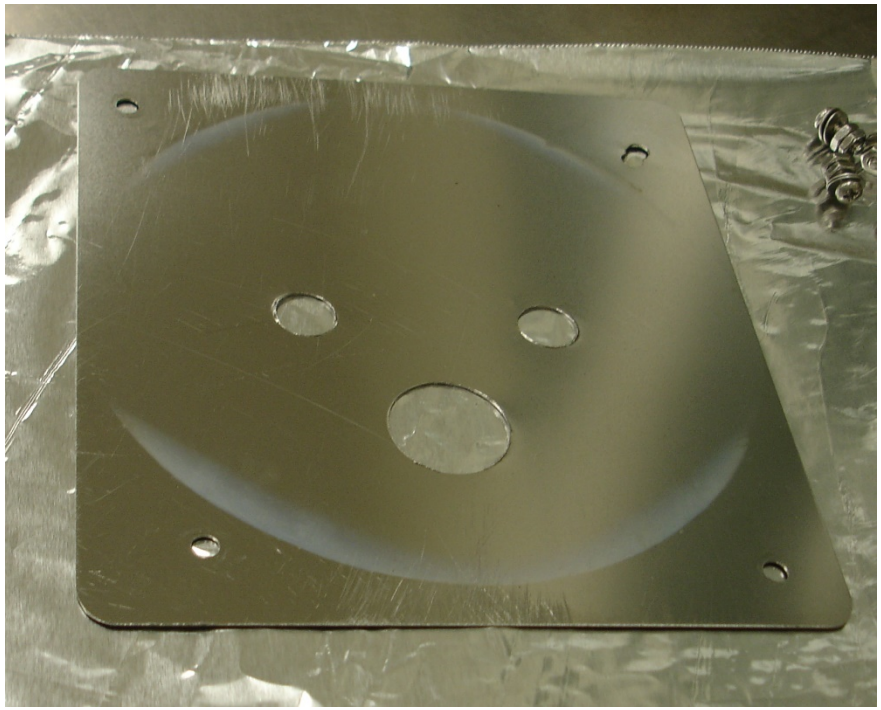
Thermocouples

- The two watrods were instrumented with thermocouples

Post-test observations

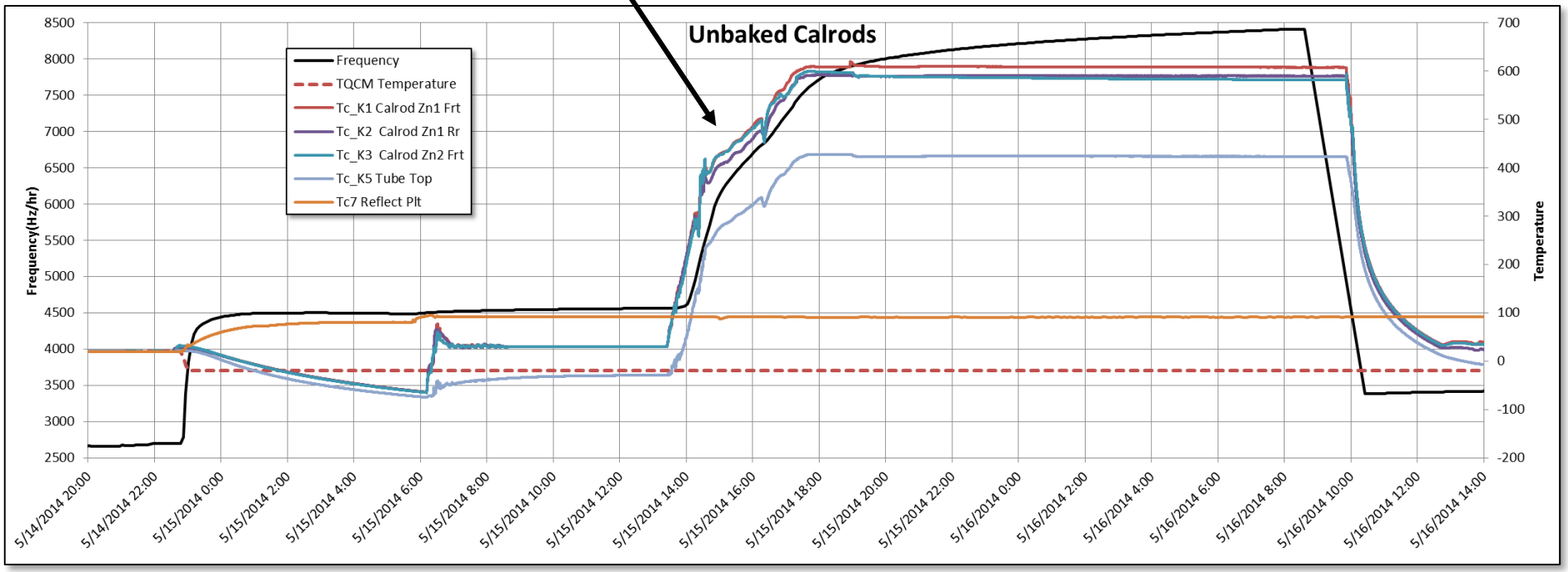
- Molecular deposition was observed on both endplates





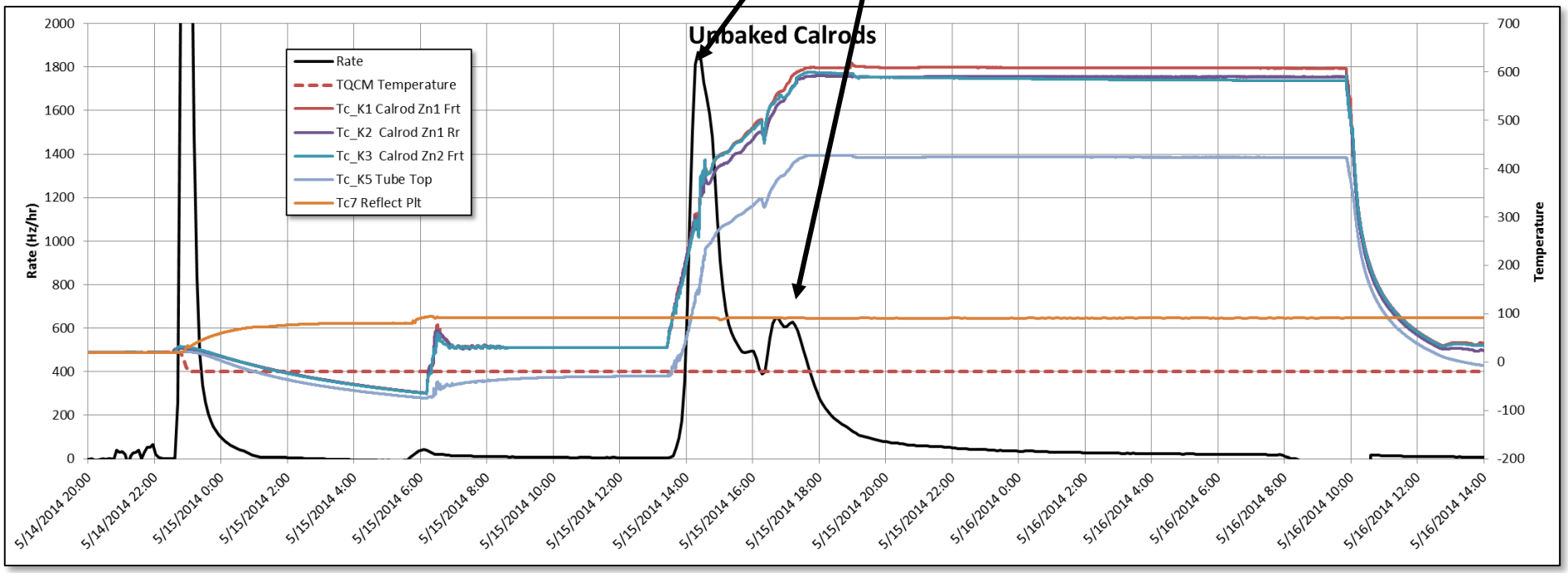
Test Results

- Figure below shows the TQCM frequency and thermocouple data over the test duration
  - Temperature rise non-linear due to controller issues (power instead of temperature control)



Frequency Rate

- Frequency rate indicates spike around 400°C and a secondary spike around 550°C



This spike corresponds to the expected temperature during TVAC!

Outgassing Rate

- The setup was modeled in Thermal Desktop
  - Obtained 3.66×10^{-4} viewfactor between QCM crystal and the aperture
- Rod outgassing rate can be obtained from mass balance

$$\Gamma_{wr} A_{wr} f_v = \Gamma_{QCM} A_{QCM}$$

  - Note, this rate only includes the fraction condensable below 90°C
- Using ½" QCM crystal diameter, and 2x 48"x0.475" diameter watrods we obtain 1 Hz/hr$|_{qcm}$ = 3.74 Hz/hr$|_{wr}$
  - Use 1.96× 10^{-9} g/cm²/hz QCM sensitivity to convert
- At peak observed deposition rate of 1869 Hz/hr, watrod outgassing was 3.82×10^{-9} g/cm²/sec = $\mathbf{1.38 \times 10^{-5}}$ **g/cm²/hr**
  - At the end, watrods outgassing at 18 Hz/hr, corresponds to 1.32×10^{-7} g/cm²/hr

GIRD801 requirement:

GSE hardware used in vacuum testing shall outgas less than **1x10^{-8} g/cm²-hr** at 10°C above the maximum survival temperature of the flight hardware that they are tested with when measured with a QCM held at -65°C (208 K).

During the test, the QCM was held only at -20°C

Observations

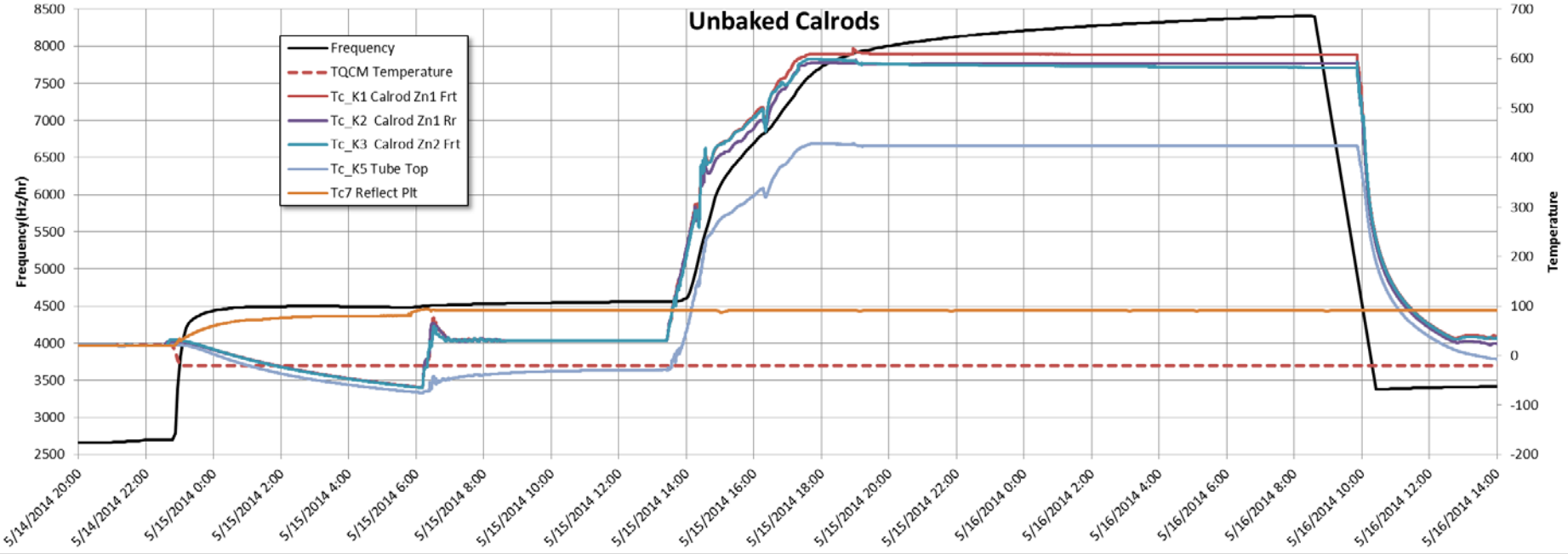
- The spacecraft thermal vacuum test (SCTV) will utilize approximately 1123 linear feet of watrods, .475” diameter
- Rods vary in overall length from ~28” to ~153”
- 600C maximum surface temperature
- 4.1×10^{-5} g/cm^2 measured outgassing source fluence
- 449 Angstroms calculated deposition on external spacecraft surfaces if left as-received
- Not possible to remove majority of deposition by subsequent baking due to high source temperature
- Removal from spacecraft surfaces not practical by other means (solvents, scrubbing, etc.)
- **Conclusion: Some outgas mitigation must be performed on watrods prior to use in SCTV**

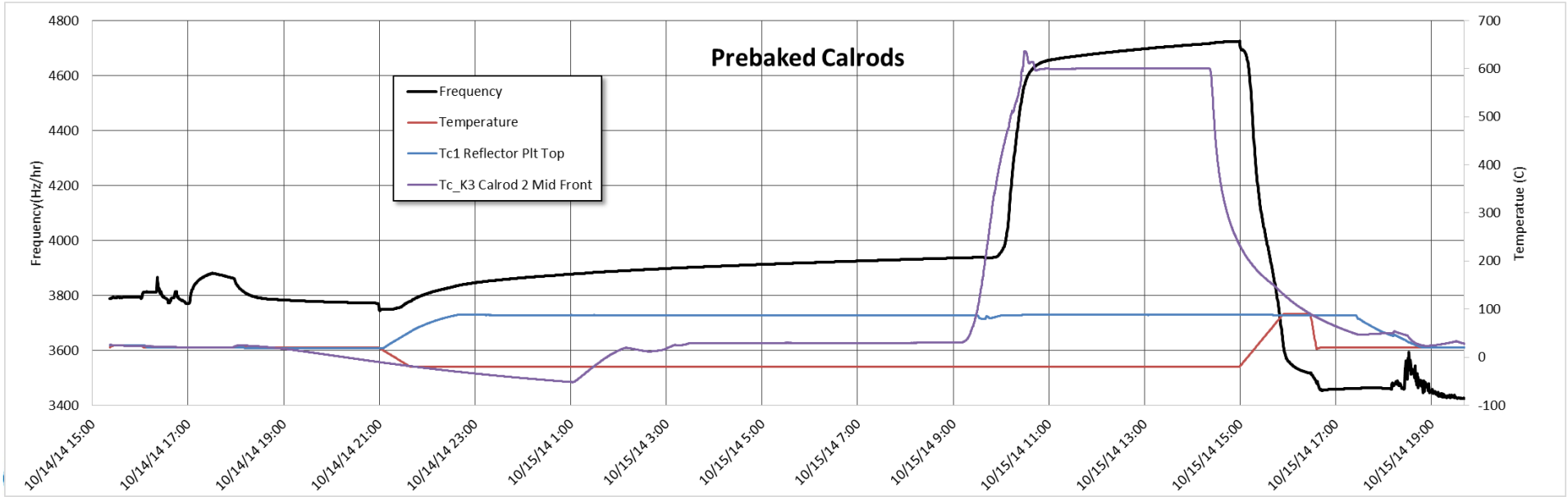
Mitigation Options

1. Pre-bake watrods in vacuum chamber
   - Need a vacuum chamber where high-temp deposition to chamber is acceptable
   - Needs to be batched due to power requirements and chamber dissipation
2. Pre-bake watrods in ambient atmosphere
   - Test was performed to determine that this outgassing method achieved acceptable results
   - Results in minimal deposition on GSE during chamber certification
3. Bake virgin watrods during GSE Bakeout / Chamber Certification
   - TQCMs must be covered or removed for watrod bake to avoid contamination – implies 2-phase bakeout and break of chamber in the middle
   - High-temp deposition would occur on chamber shrouds and GSE, thickness estimated at 100 to ~600 Angstroms
   - Mechanical stability of the deposit is unknown, although observations point to it being stable; i.e. won't flake off during SCTV
   - Likely not an acceptable solution to facility owners

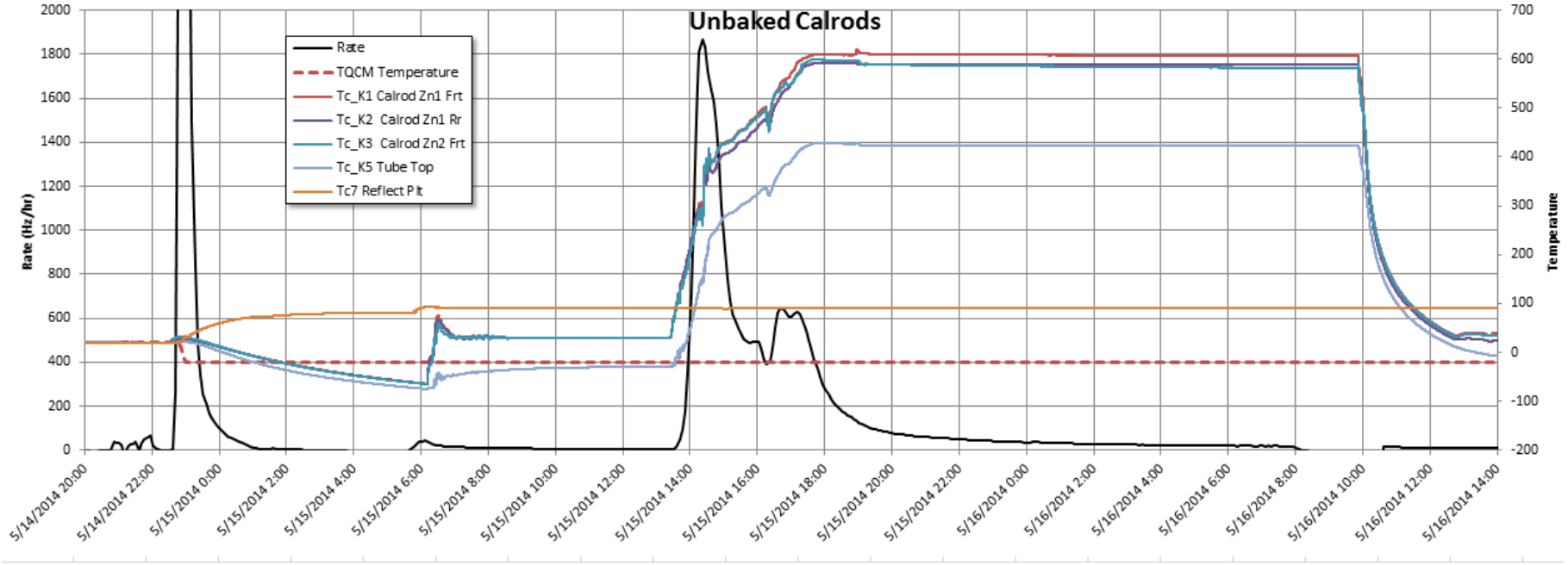
Option 2 most practical – thenew watrods pre-baked in ambient pressure for 16 hours

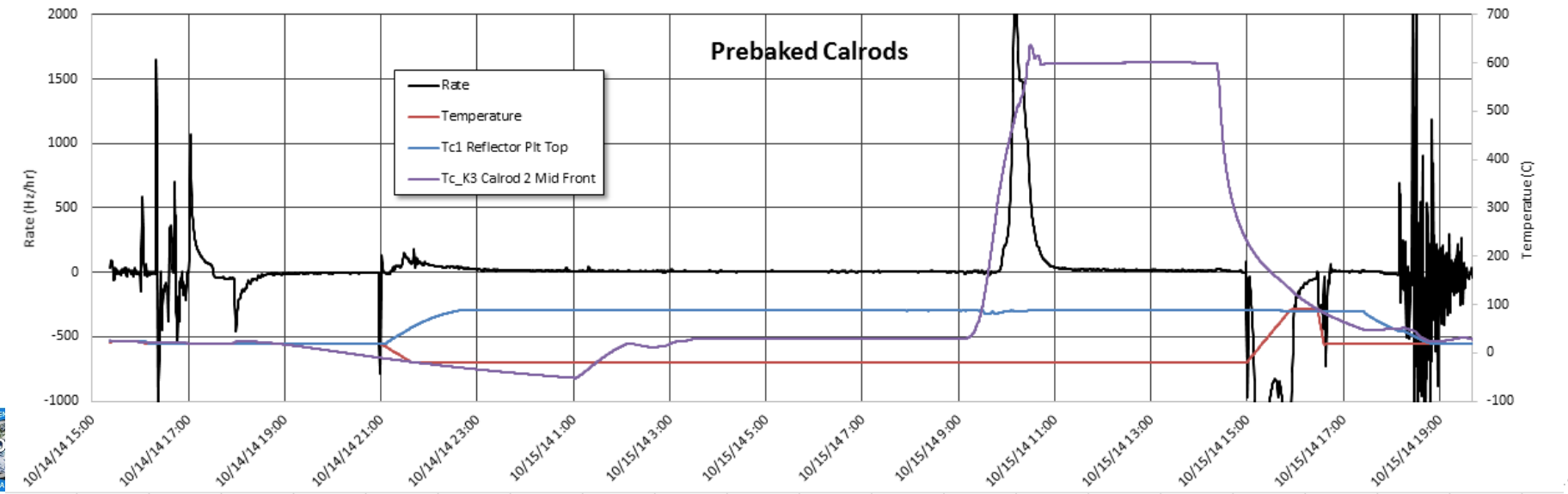
Un- and pre-baked comparison, frequency





Un- and pre-baked comparison, frequency rate

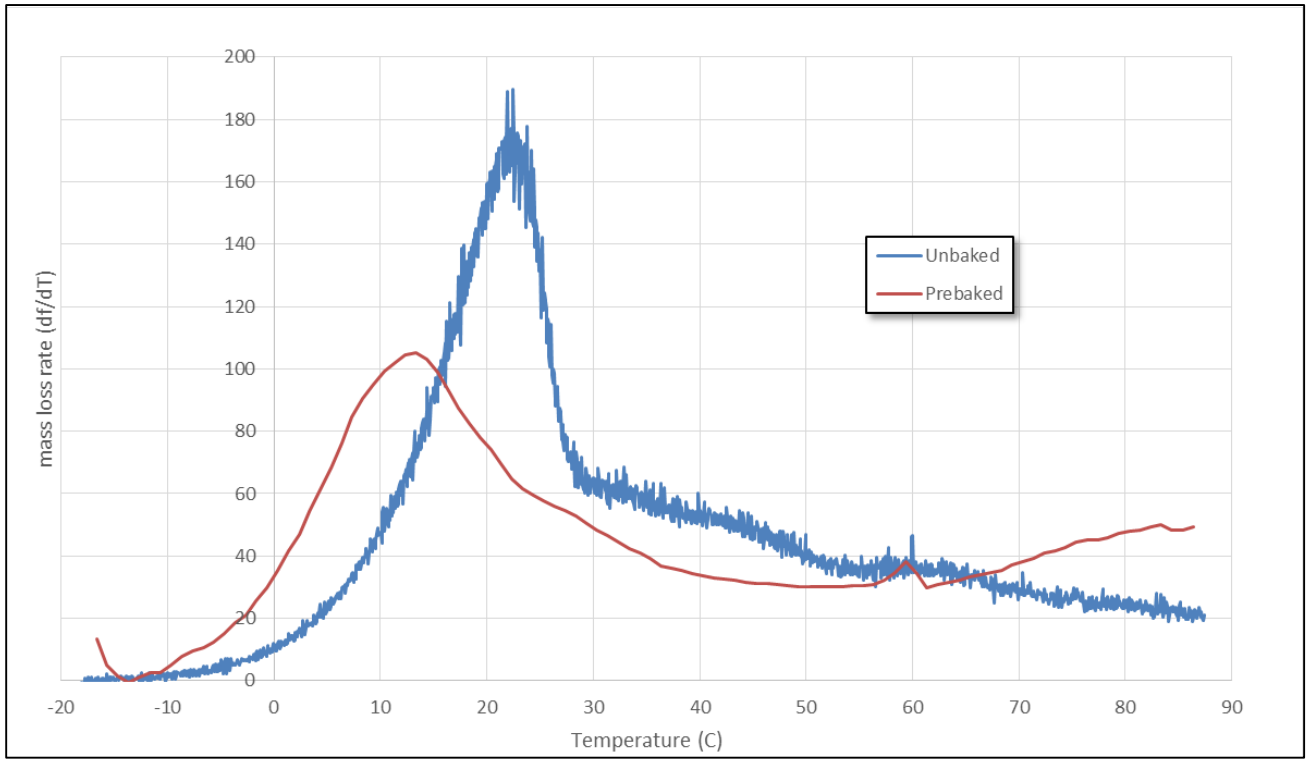




Un- and Pre-baked comparison

- Unbaked watrods: 4560 to 8404 Hz, 3844 Hz mass loss
- Pre-baked watrods: 3942 to 4711 Hz, 769 Hz mass loss
  - **Pre-baking reduced outgassed mass by a factor of 4**
  - This calculation took into account difference of view factors, 0.000292 vs 0.000366

- TGA also indicates that pre-baking reduces high temperature constituent

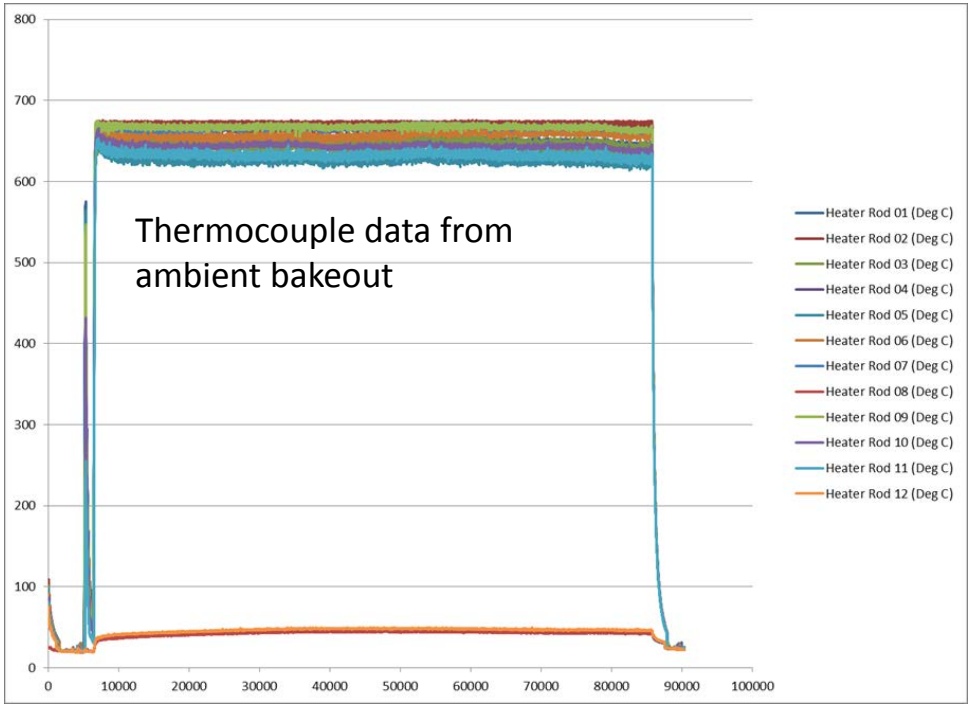


Mass on Reemission Plate

- The mass collected on the reemission plate represents the mass condensable above 90°C.
  - During the first test the mass collected indicated a source fluence from the cal rods of 1.31×10^{-5} g/cm². This is 47% of the total mass compared to 53% that was condensable below 90°C.
  - During the second test of the pre-conditioned watrods, the mass collected indicated a source fluence from the watrods of 8.1×10^{-7} g/cm². This is 9% of the total mass compared to 91% that was condensable below 90C.
- The conclusion is that the pre-bakeout reduced the watrod outgassing (mass condensable above 90°C) by 94%.

Ambient Bakeout

- GOES-R watrods were subsequently prebaked in an ambient air facility at Lockheed Martin
  - 16 hours at 600C, baked in batches per power constraints (about 50kW per batch)
- **Watrods were then activated during MGSE bake out**
  - **Did not observer any significant deposition on the TQCMs**



Conclusion

- We designed and executed a test to determine the outgassing rate of unbaked watrods
- The test indicated that virgin watrods can be a source of contamination
- Pre-baking in air reduces outgassing of mass condensable below 90^{o}C by a factor of 4
- Performed ambient air bakeout of all watrods used in GOES-R TVAC
- MGSE bakeout was successful with acceptable outgassing rates

- **Questions?**