



An Examination of Heater Bar Outgassing

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Background



Goal: Limit molecular deposition on Artemis 1 vehicle during Thermal Vacuum/Thermal Balance testing



Ways to Achieve This

- Use appropriate materials for vacuum environment (per NASA RP-1124)
 - Total Mass Loss <1.00%
 - Collected Volatile Condensable Materials <0.1%
- Bake out painted metals and cable sets (per ASTM E 2900, SEC Contamination Control Plan)
 - Vacuum bake-out at 100°C for 100 hours



What about Heater Bars?

- Metal rod with heater element encased with Magnesium Oxide (MgO)
- Some mixed thoughts about use and outgassing among those we talked to



From “Outgassing Characterization of Rod Heaters used for GOES-R Thermal Vacuum Testing” by Brieda et. al. presented at the 2015 Contamination, Coatings, Materials and Planetary Protection Workshop:




Rod Heater Outgassing Characterization

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**



12

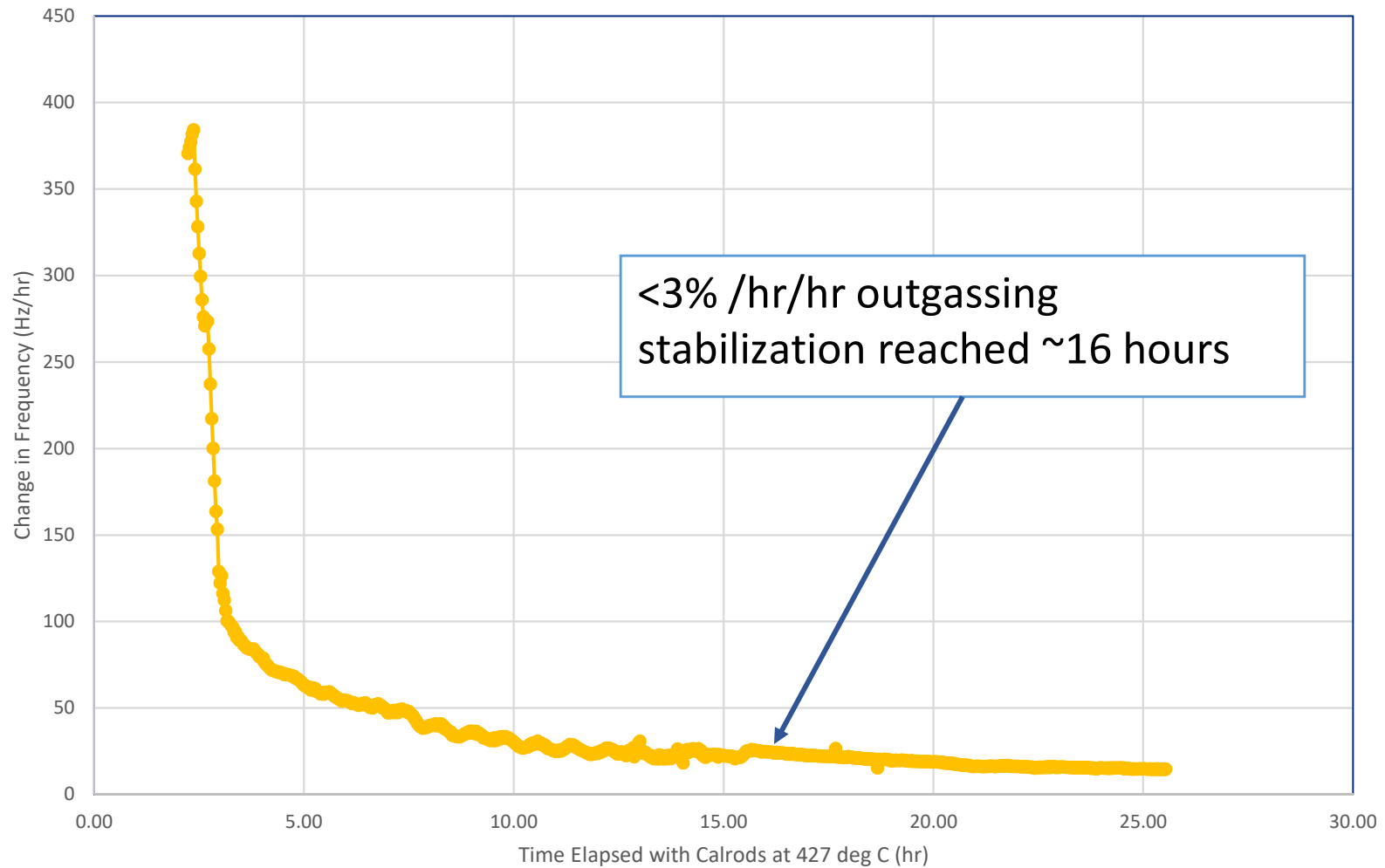


Heater Bar Characterization Test

- Test performed at Goddard Space Flight Center chamber 240 (3' diameter x 3' length, diffusion pumped)
- Test parameters:
 - Operational Temperature of the heater bars: 427C (800F)
 - Shroud Temperature: < -80C
 - 15 Mhz QCM Temperature: -59C
 - Vacuum level: < 5e-5 torr
 - Hold Time at Temperature: 24 hours (to include 8 hour coldfinger)



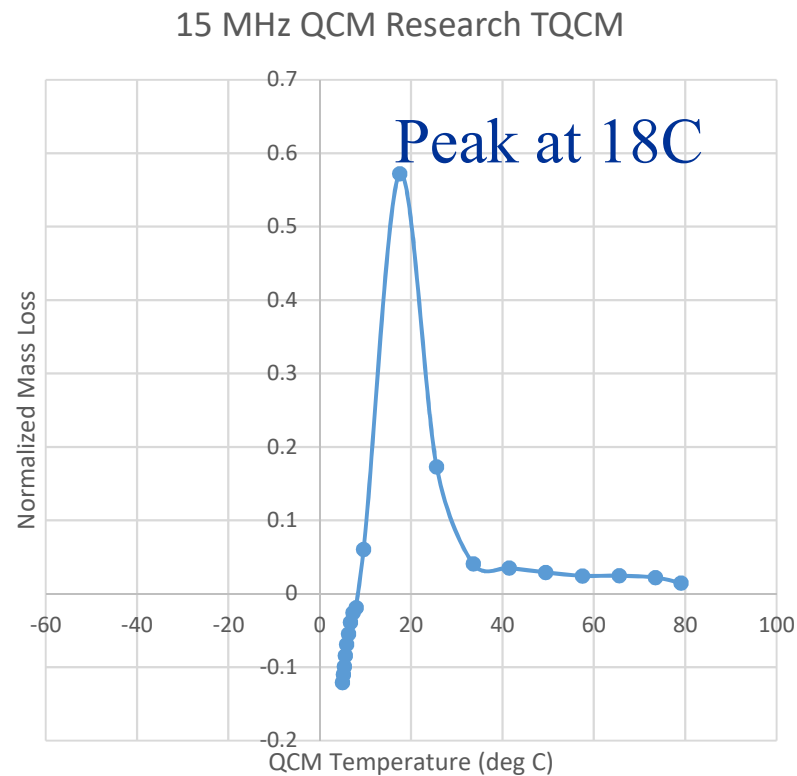
Characterization Test Results: Deposition Rate on TQCM



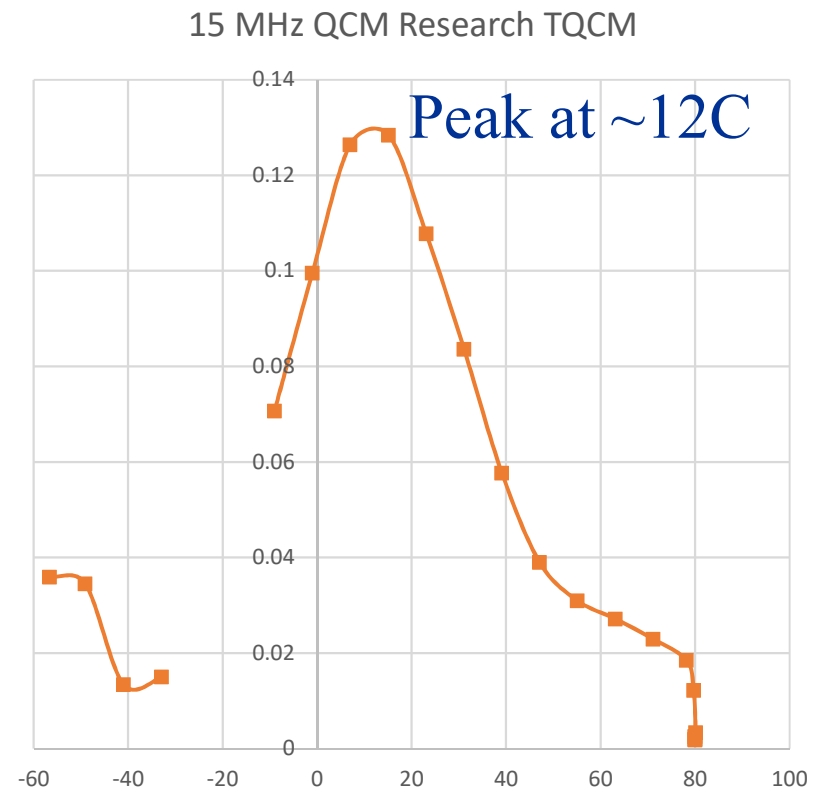


Characterization Test Results: Qualitative Thermo-gravimetric Analysis

Pre-Test (blank chamber)



Post-Test



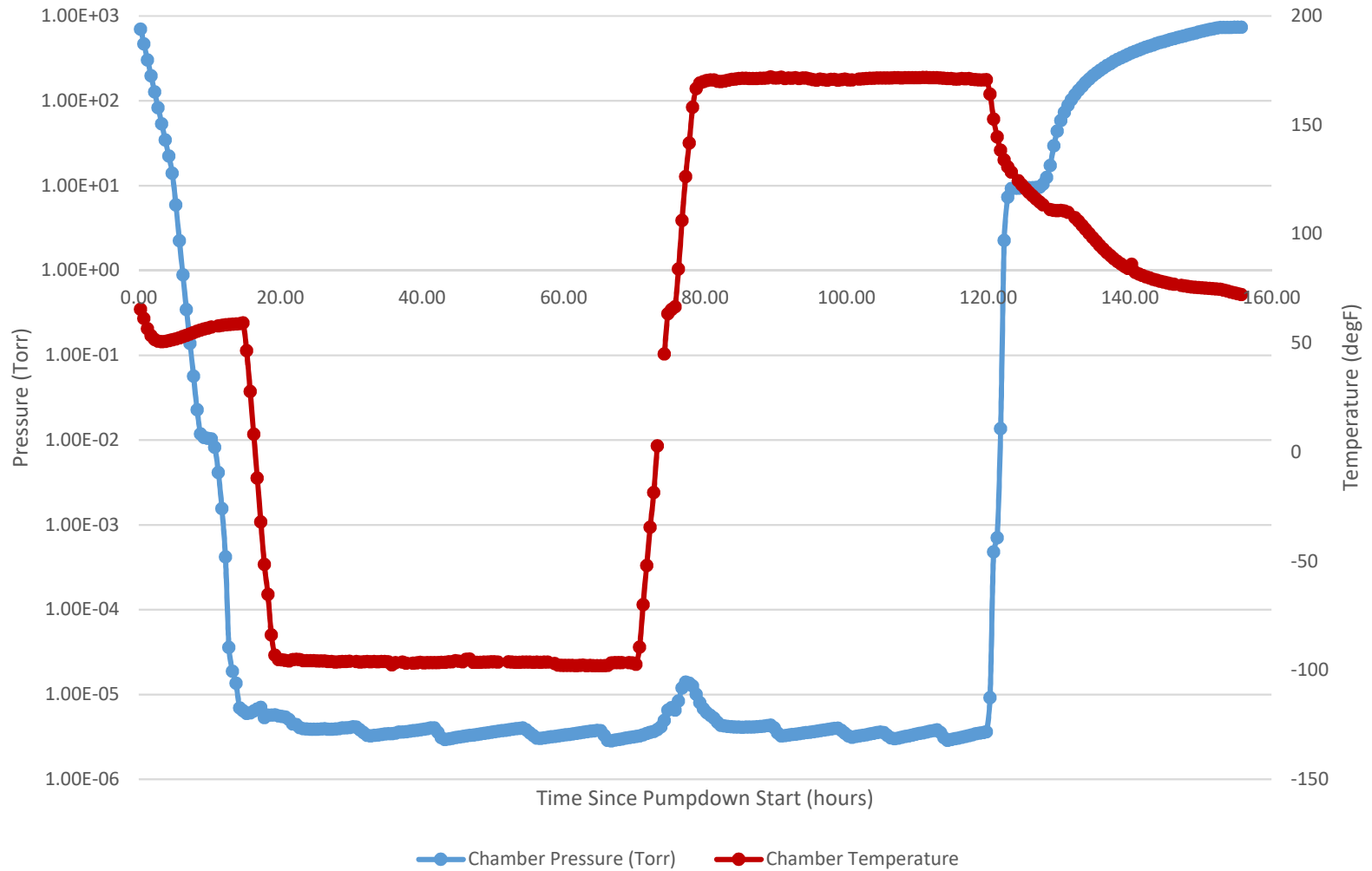


Total Heater Bar Vacuum Bake-out

- Heater Bar Bake-out Parameters:
 - Vacuum: $< 5E-5$ Torr
 - Operating Temp of Heater Bars: $\sim 585F$ ($307C$)
 - Cryoshroud: $-100F$
 - Bakeout Duration: 48 hours
 - QCM Temperature: $-20C$ or $-50C$
- Cryoshroud Bake-out Parameters:
 - Vacuum: $< 5E-5$ Torr
 - Operating Temp of Heater Bars: $320F$ ($160C$)
 - Cryoshroud: $170F$
 - Bakeout Duration: 48 hours
 - QCM Temperature: $-20C$ or $-50C$



Chamber Pressure and Temperature





Heater Bar Bake-out Test Results: Deposition Rates on QCMs



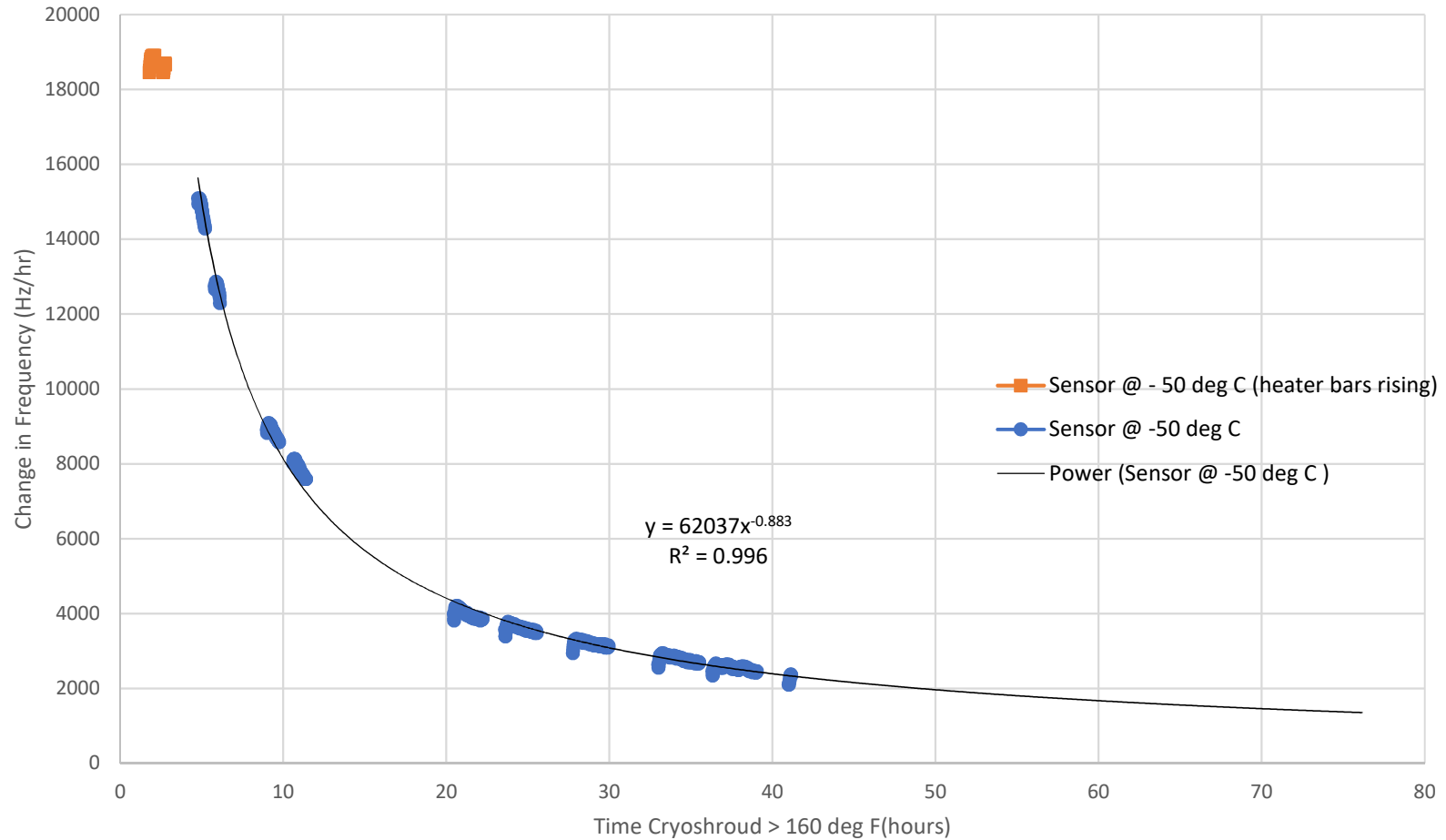
Monitor	Configuration	Direct Data	Date/Time	Elapsed Time	Deposition Rate
TQCM 1	TES = 675F Shroud = -100F	-3.5±10%/hr (4 hr avg)	4/16/19 12:56	49.87 hrs	13 Hz/Hr
TQCM2	TES = 675F Shroud = -100F	-3.6±14%/hr (4 hr avg)	4/16/19 13:07	49.97 hrs	9 Hz/Hr
TQCM1	TES = 200F Shroud = +175F	-2.4±2.4%/hr (1 hr avg)	4/19/19 02:54	39.15 hrs	2490 Hz/Hr
TQCM2	TES = 200F Shroud = +175F	-3.5±1.0%/hr (1 hr avg)	4/19/19 01:41	39.73 hrs	2458 Hz/Hr



Heater Bar Bake-out Test Results: Deposition Rate on QCMs



TQCM 1 Outgassing Rate

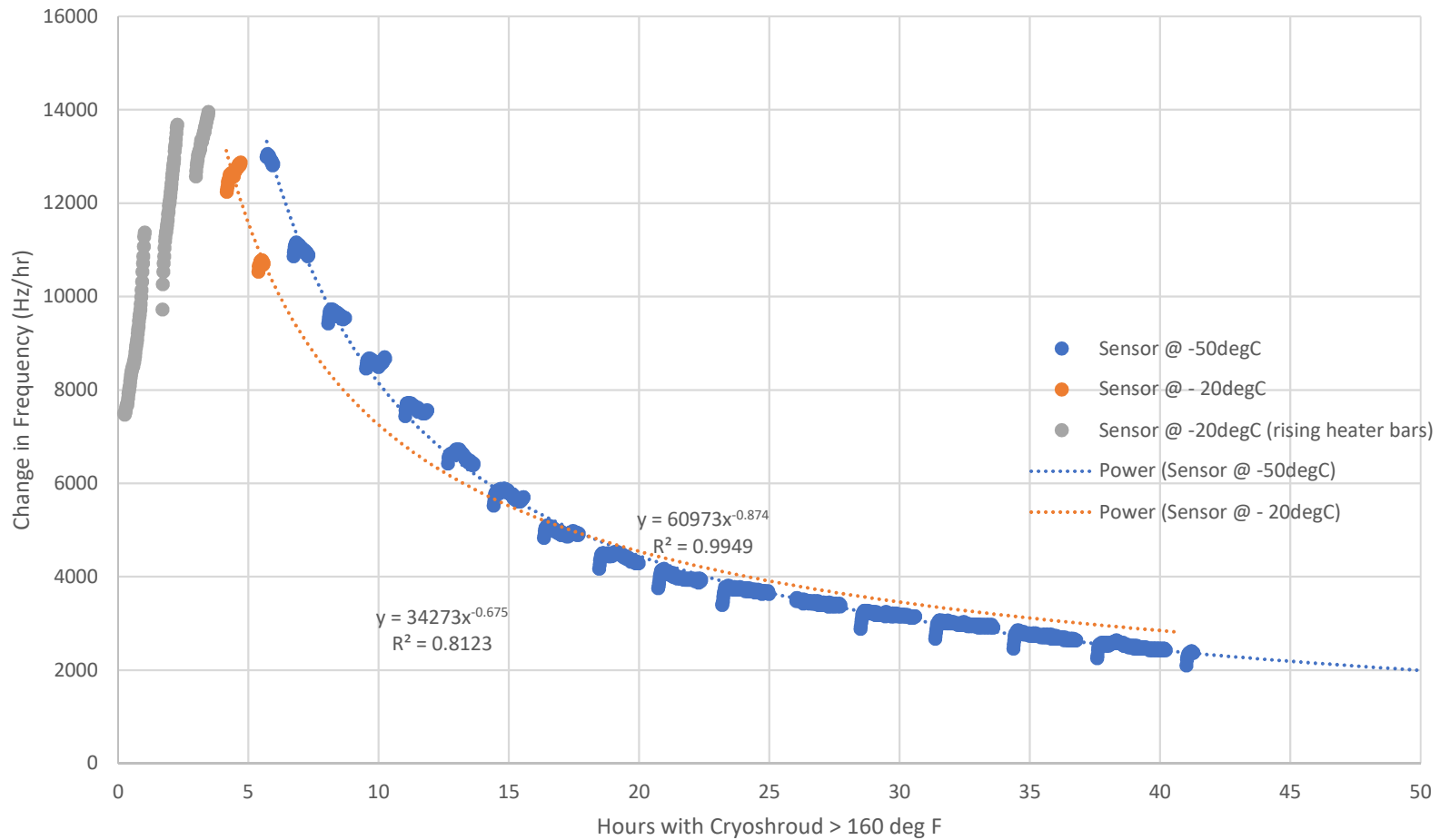




Heater Bar Bake-out Test Results: Deposition Rate on QCMs

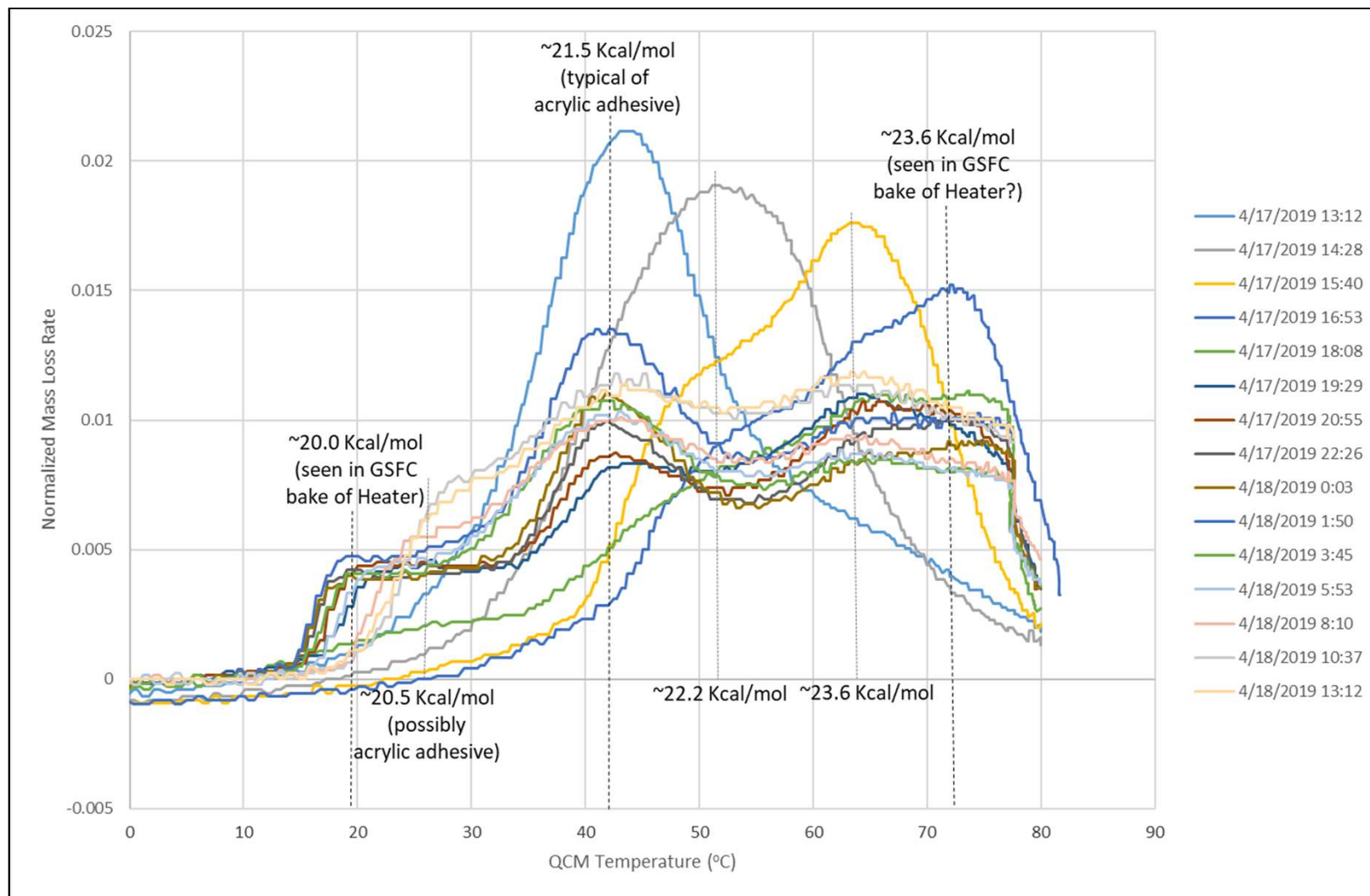


TQCM 2 Outgassing Rate



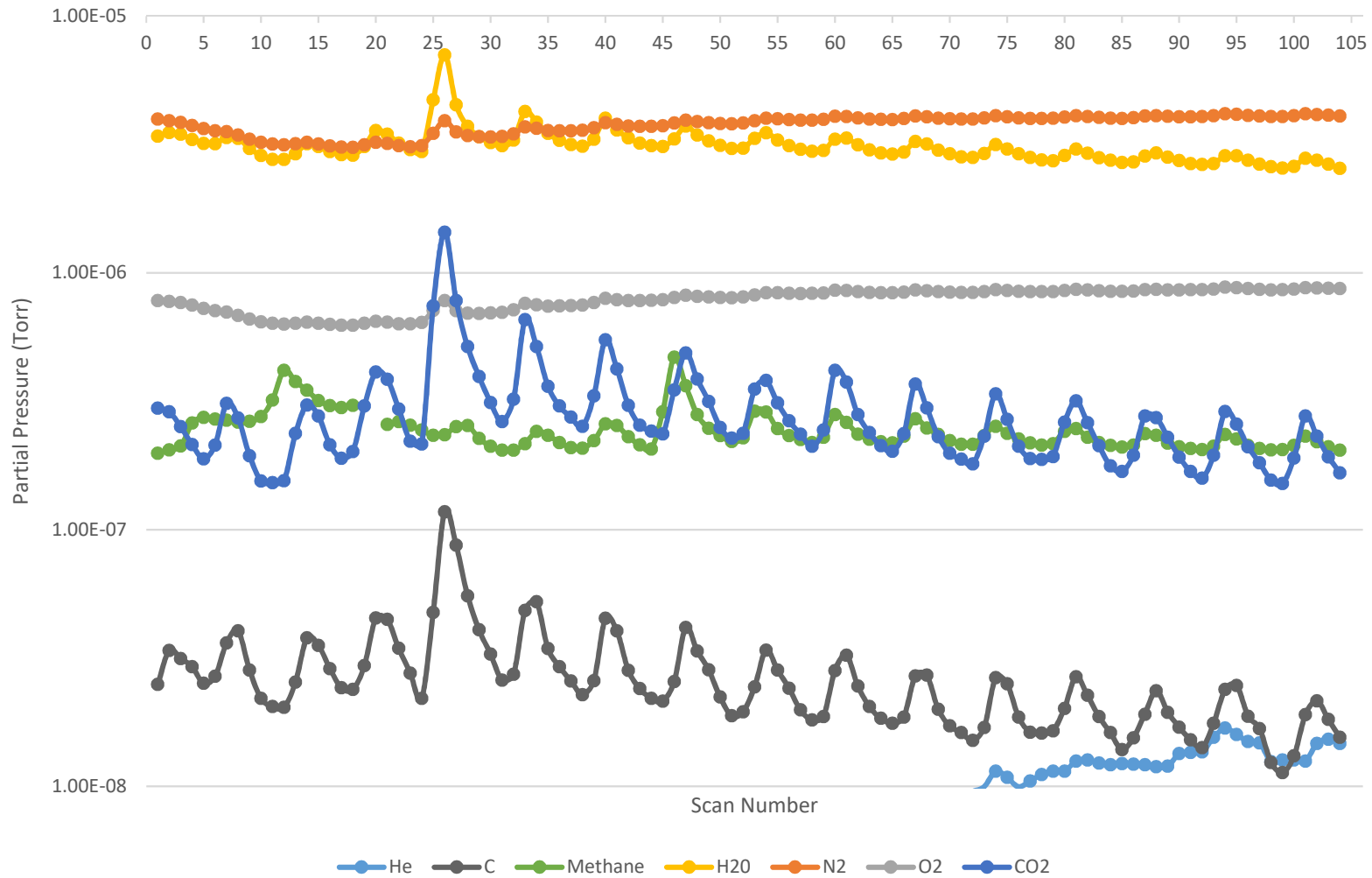


Heater Bar Bake-out Results:



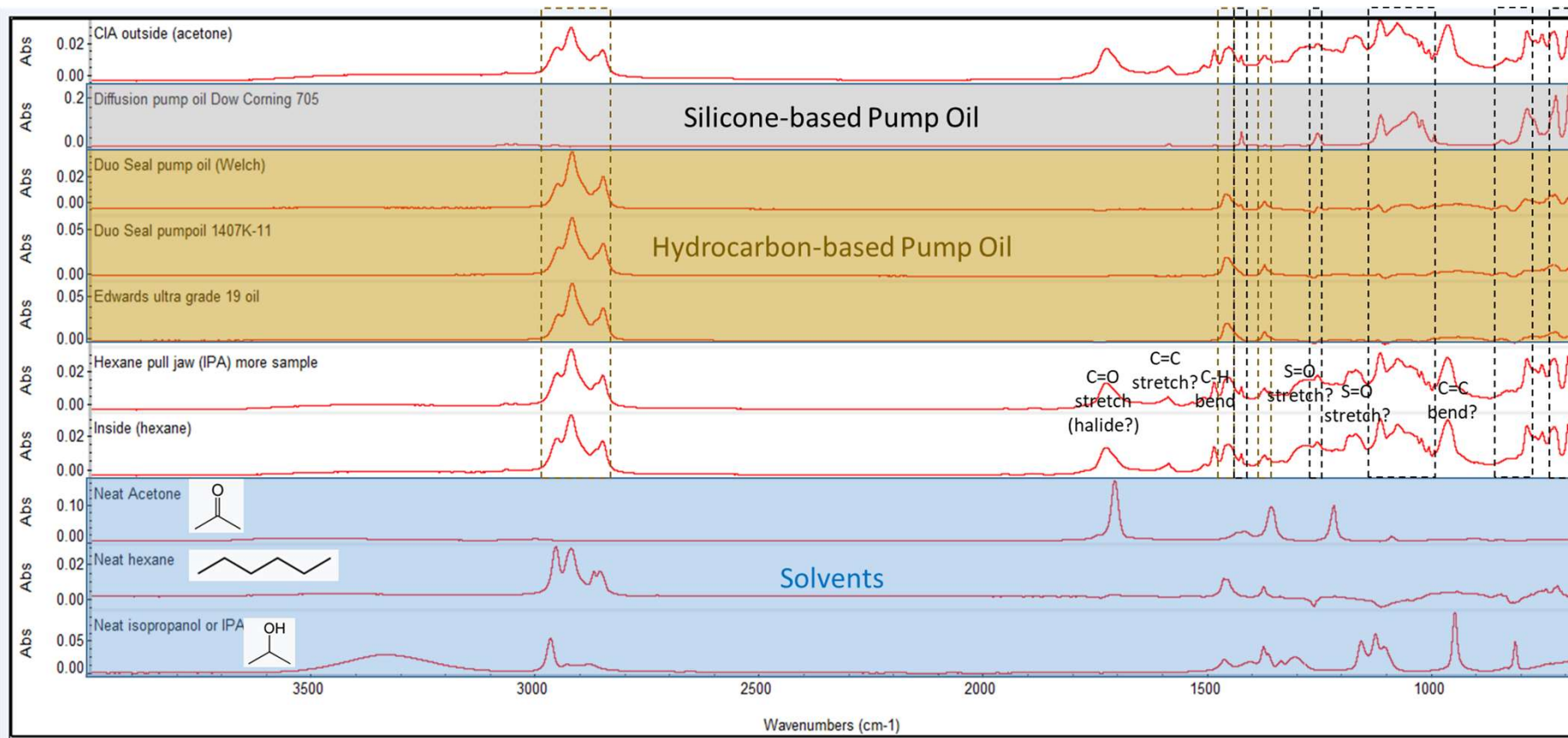


Heater Bar Bake-out Results: Residual Gas Analyzer





Heater Bar Bake-out Results: Scavenger Plate FTIR Analysis





Did It Work?





Integrated Facility System Test

- Heater bars operated at 20F below bake-out operating temperature
- Vacuum: $< 5E-5$ Torr
- Cryoshroud: -250 to -100F
- QCM Temperature: -20C



TQCM Outgassing Results

- TQCM 1: Rates dropped over test period from 410 Hz/hr to ~5 Hz/hr
- TQCM 2: Rates dropped over test period from 325 Hz/hr to 8 Hz/hr
- Passive QCM lost 0.03 mg/ft² over test period



Witness Plates Results



Witness plates are UHV aluminum foils, rinsed with reagent-grade Hexane

Witness Plate	Deposition (mg/ft ²)
TQCM-1 W	<0.01
TQCM-1 NE	<0.01
TQCM-2 NW	<0.01
TQCM-2 SE	<0.01
CQCM SE	<0.01
CQCM NW	<0.01

Deposition on witness plates is undetectable for microbalance.



Summary

- Heater bars pose a risk of contamination
- Baking out heater bars under vacuum did help reduce outgassing and contamination on QCM and witness plates
- Several tools are available to help examine specific contaminants and outgassing



Acknowledgements

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