

Effectiveness of Bakeout on Multi-Layer Insulation

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Contamination Control

12 September 2023



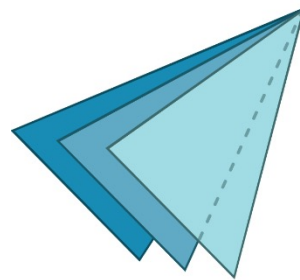
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Contents

- Overview of Experiment
- MLI Bulk Construction
- Testing Facilities
- Data Types
- Results
- Conclusion

- Investigate the outgassing of Multi-Layer Insulation (MLI)
 - Different constructions
 - Bakeout times/temperatures
 - Outgassing rate vs temperature

Special Thanks to Aerothreads for supplying the MLI Samples, and permission to share our results

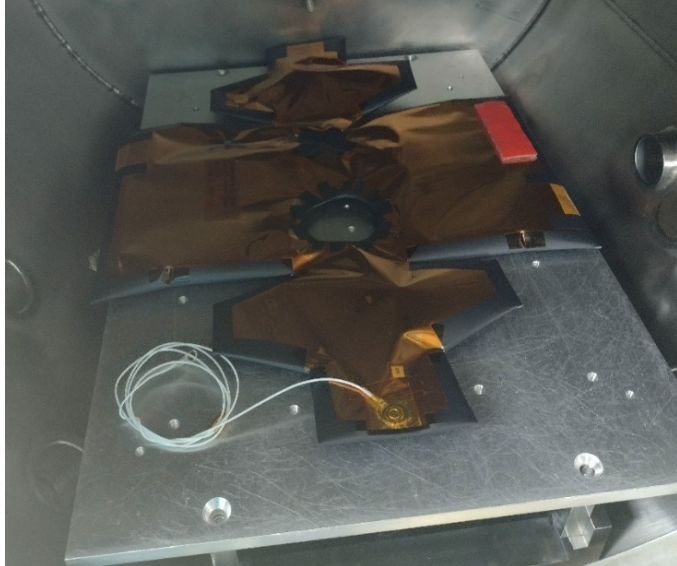


aerothreads

- 4 Different MLI constructions, 11 total samples
 - Different top layers/overlays
 - Black Aluminized Kapton
 - Stamet on Black Kapton
 - Aluminized Kapton
 - Beta cloth overlay

Bulk A:

Layer	Qty	Description
Outer	1	2.75 Mil Black Kapton VDA1
Middle	10	0.25 Mil Mylar VDA2 Perferated
Separator	11	B2A Netting
Inner	1	2 Mil Kapton VDA1 (kapton out)



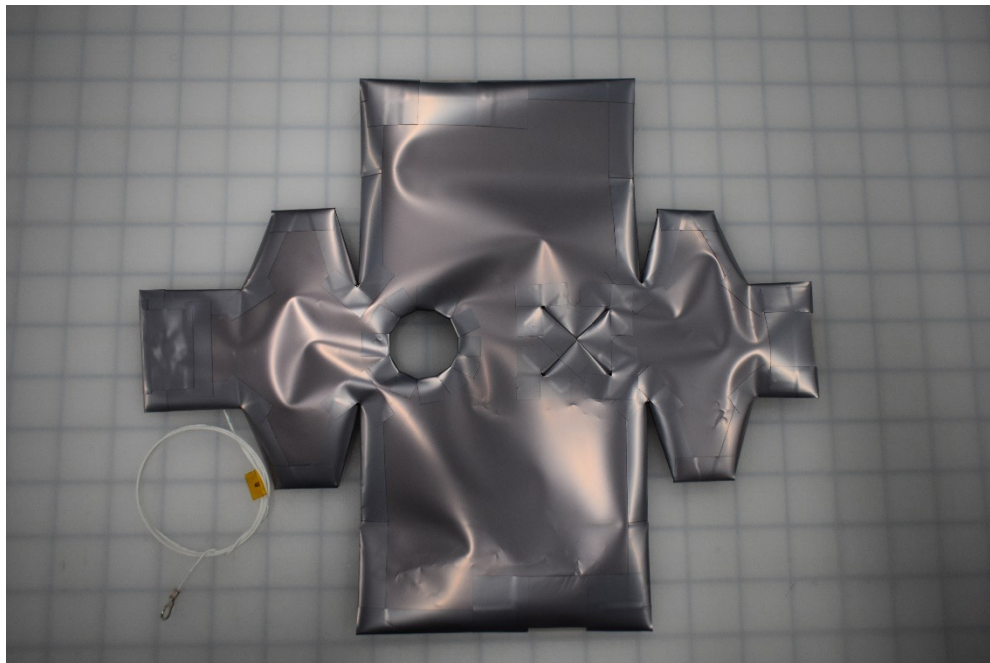
Black Kapton facing down towards platen



Black Kapton bulk

Bulk B:

Layer	Qty	Description
Outer	1	2.75 Mil Stamet Black Kapton XC
Middle	10	0.25 Mil Mylar VDA2
Separator	11	B2A Netting
Inner	1	2 Mil Kapton VDA1 (kapton out)



Stamet-covered MLI sample

Bulk C:

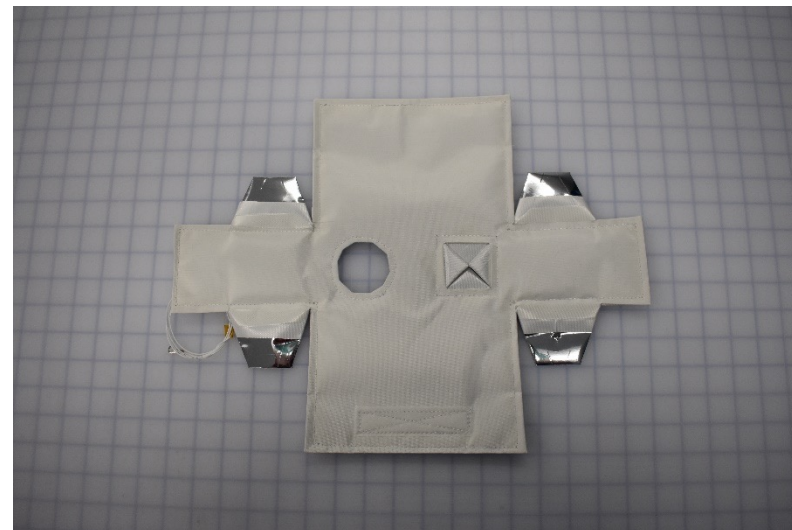
Layer	Qty	Description
Outer	1	2 Mil Kapton VDA1 (Kapton Out)
Middle	14	1 Mil Kapton VDA2
Separator	15	B2A Netting
Inner	1	1 Mil Kapton VDA2



One of the Kapton MLI samples,
In the high vacuum oven

Bulk D:

Layer	Qty	Description
Overlay	1	Beta Cloth
Outer	1	0.25 Mil Mylar VDA2 Perferated
Middle	10	B2A Netting
Separator	11	2 Mil Kapton VDA1 (kapton out)
Inner	1	1 Mil Kapton VDA2 Nomex Scrim

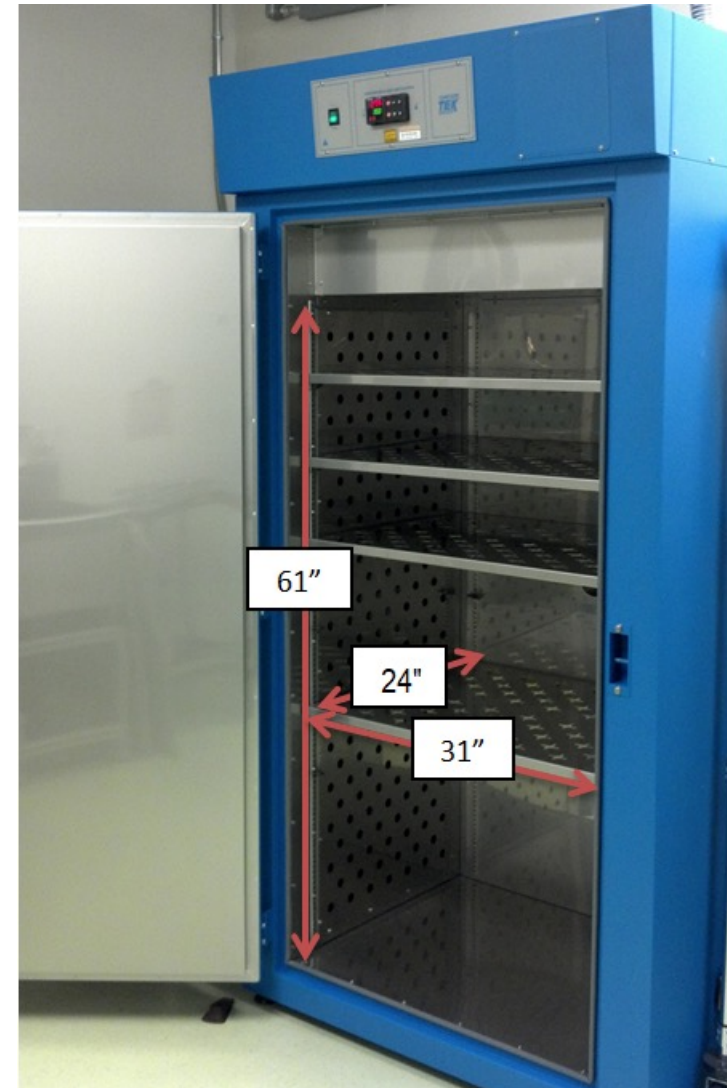


■ Chambers

- Measure outgassing rates in high vacuum oven
 - CQCM
 - RGA
- Do pre-bakeouts in ambient-pressure or low-vacuum ovens

Pre-bake ovens

- Ambient Pressure, purged oven
 - Cascade-Tek TFO-28 forced-air lab oven
 - Run with small nitrogen purge



“TARDIS” Ambient-pressure oven 10

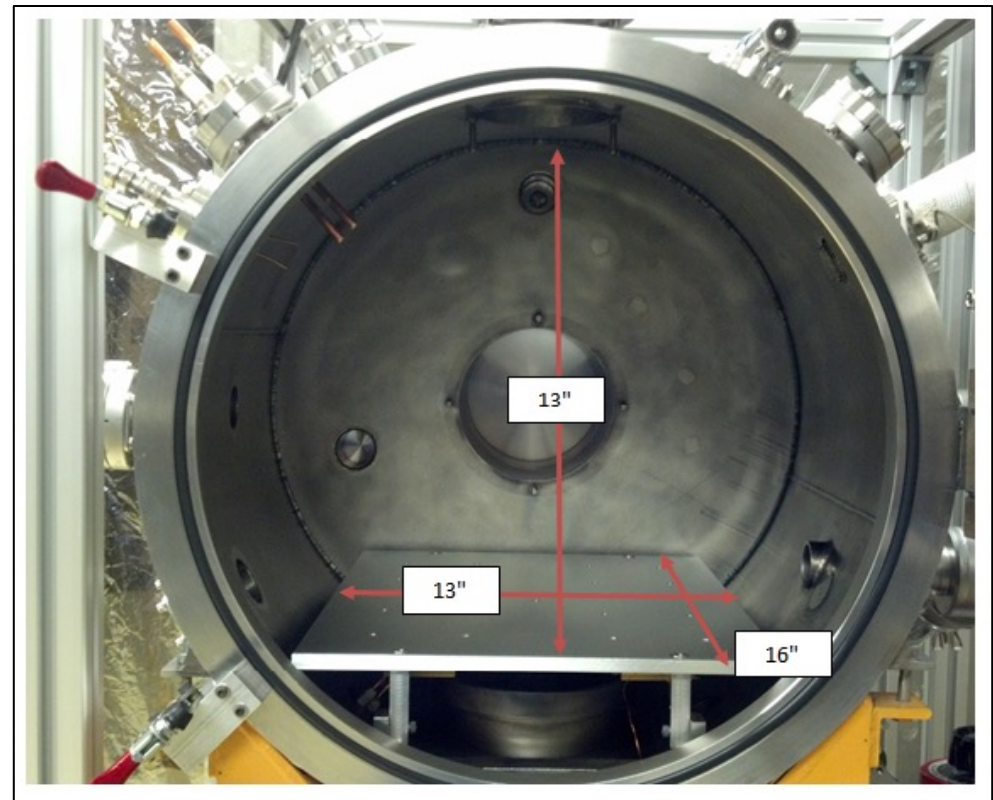
Pre-bake Ovens

- Low vacuum, purged oven
 - Across International AccuTemp 7.5 Cu Ft vacuum oven
 - IDP-7 Scroll pump, 5 CFM
 - Purge with ~ 0.05 SCFM N_2
 - Pressure in the Torr Range

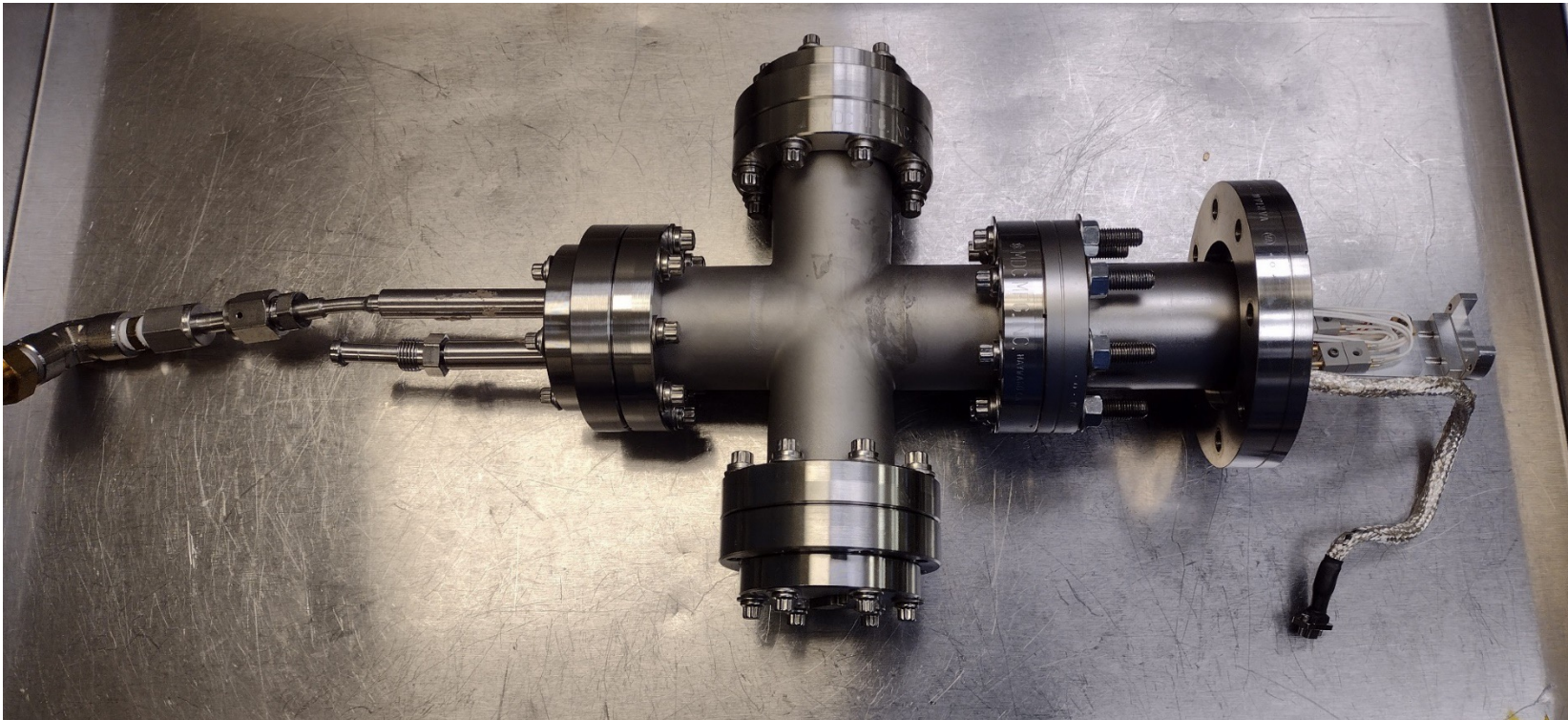


High Vacuum Oven

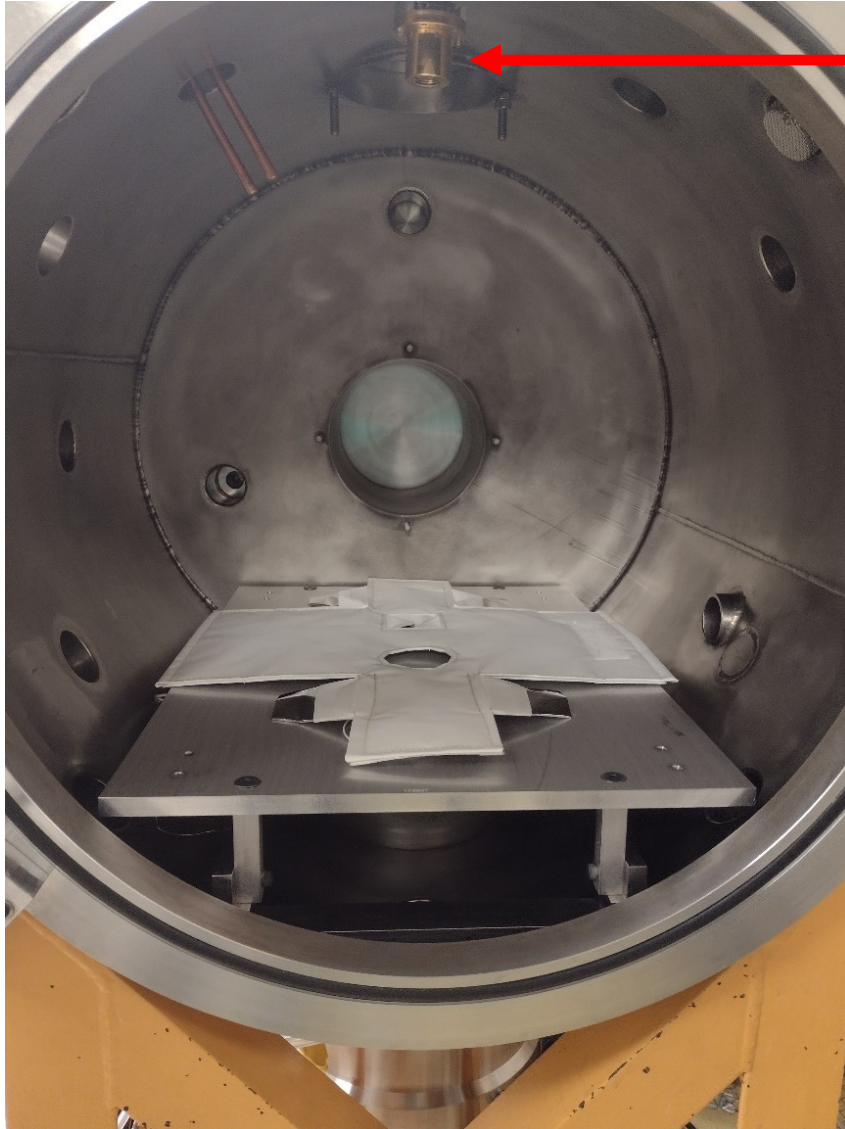
- One of 4 Bake-Out Tanks was used (BOT-III)
 - Heating only from below
 - Agilent TV 551 Turbopump (550 L/s)
 - RGA
 - QCM can be added



- QCM Research Mk 18 CQCM



MLI in High Vacuum Chamber



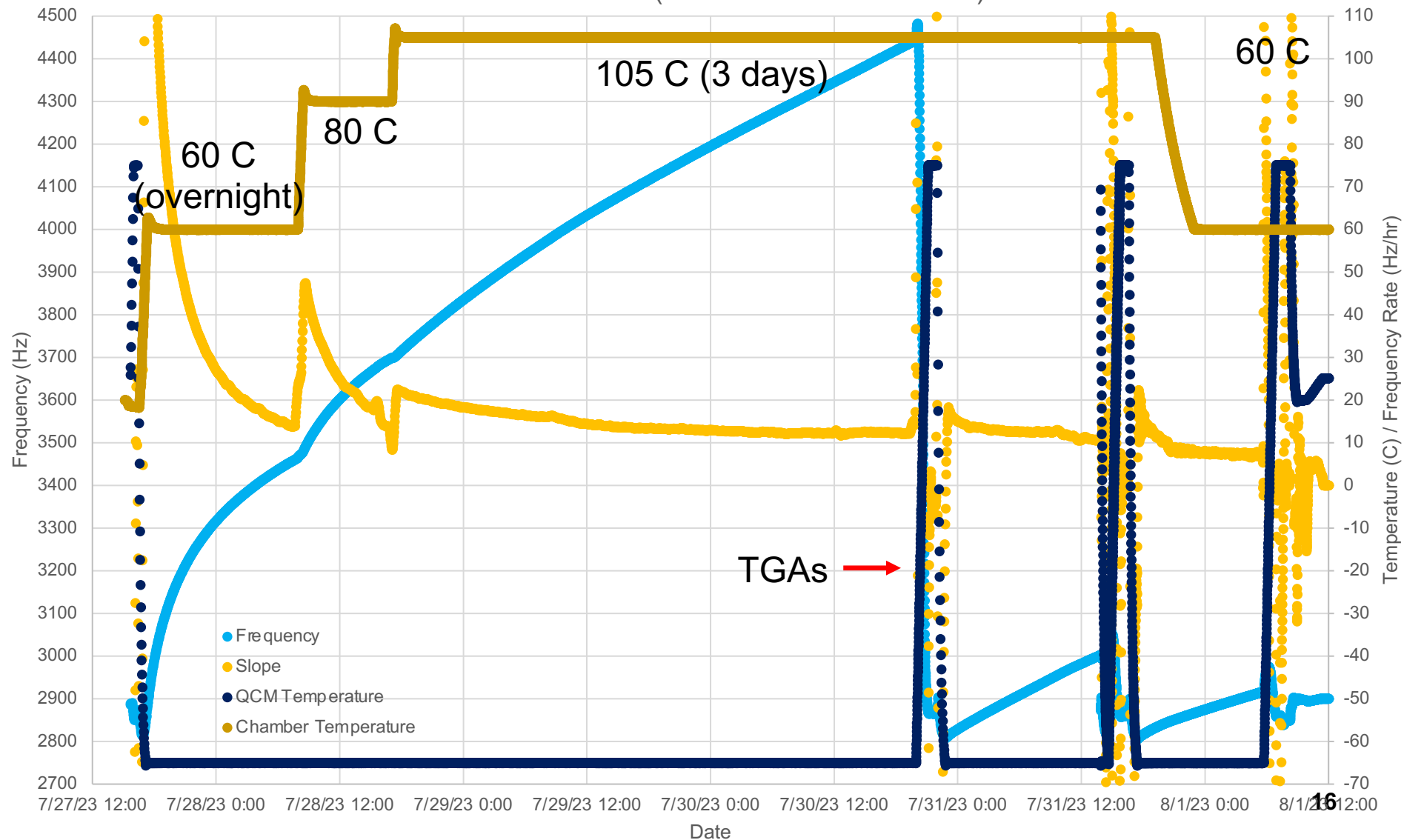
Mk 18 CQCM

- Not a good “hot wall” or “cold wall” test
 - Hard to correlate to a true outgassing rate
 - Assume “hot wall”: $1 \text{ Hz/hr} \approx 6 \times 10^{-11} \text{ g/sec}$

- Prebake in Oven
 - Ambient Pressure or Low Vacuum
 - Up to 110° C
- Bake in HV, with QCM at -65 C
 - Sample at 60, 90, 105 C
 - 3 day bakeout at highest temperature
 - **Final measurement at 60 C**
- Auxiliary measurements
 - Thermogravimetric Analyses (TGA)
 - Residual Gas Analyses (RGA)

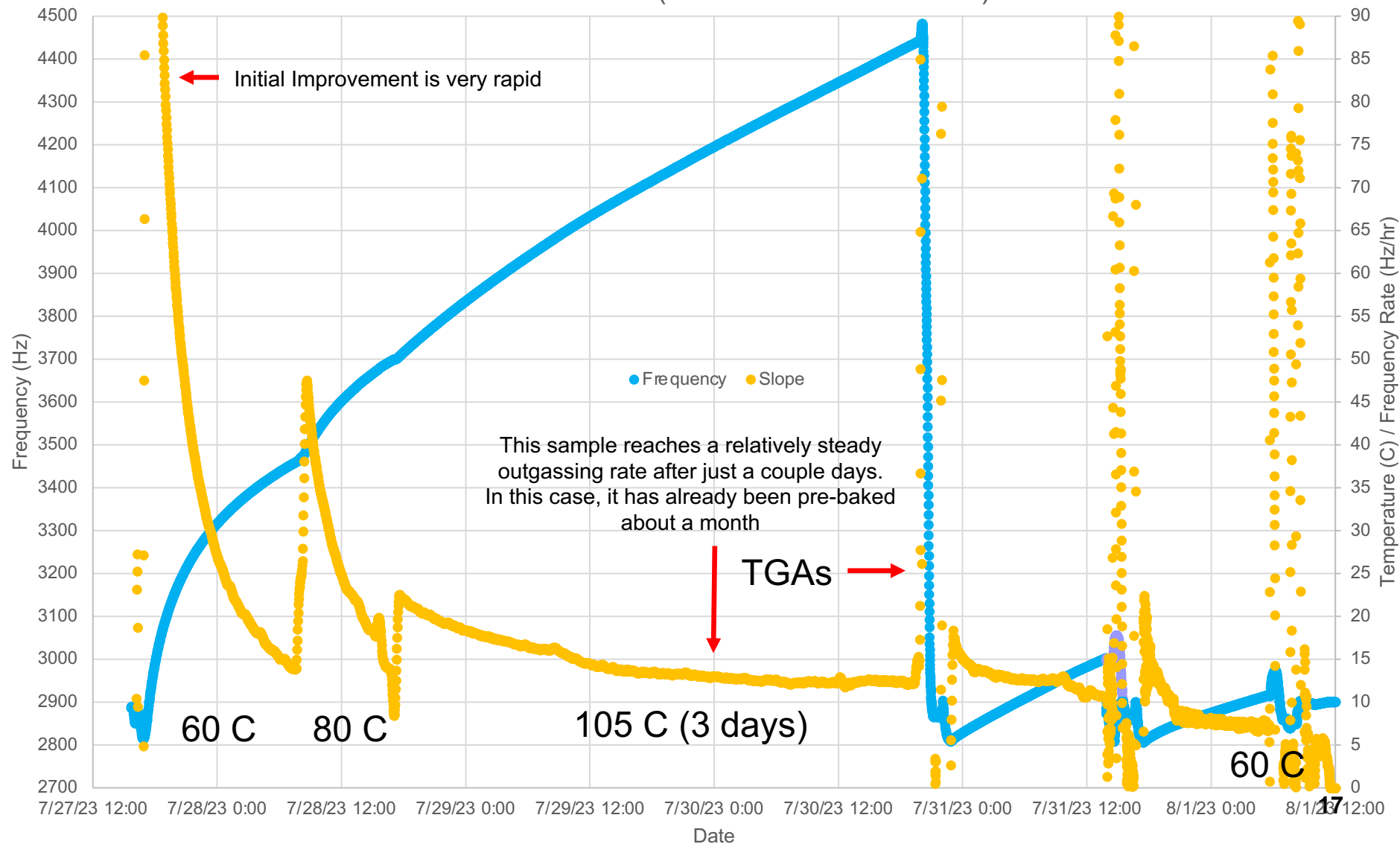
QCM Plots

Bulk D Full Chart (750 hrs at 110 C Prebake)



QCM Plots

Bulk D Full Chart (750 hrs at 110 C Prebake)



Data: Bulk A

- Batch A: Black Kapton Outer Layer
- Independent Variable: Length of bake in Tardis (0, 1, 3 days at 110° C)

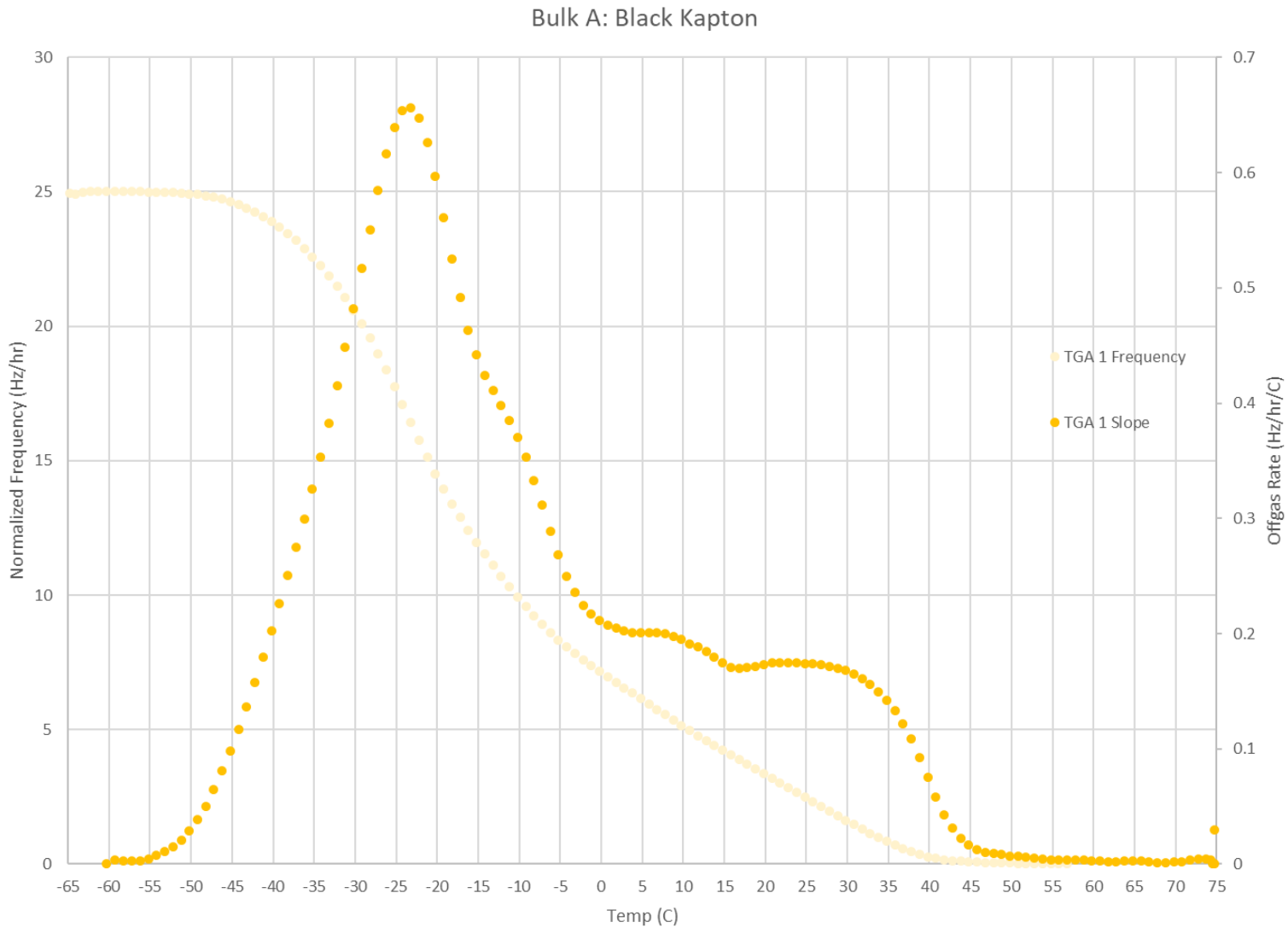
Bulk A	Sample 1 (0 hrs)	Sample 2 (24 hrs)	Sample 3 (72 hrs)
	Normalized /1000 sqcm	Normalized /1000 sqcm	Normalized /1000 sqcm
Sample Number	B_0008-3_00001	B_0008-3_00003	B_0008-3_00005
Area (sq cm)	550	929	915
Edge Lengths (cm)	143.5	179	122
Start Date	9/9/2022	8/19/2022	8/23/2022
End Date	9/14/2022	8/22/2022	8/29/2022
60 C (initial)	158.2	39.8	39.3
60 C (final)	41.8	23.7	24.0
90 C (initial)	200.0	73.2	104.9
90 C (final)	52.7	48.4	48.1
105 C (initial)	130.9	64.6	108.2
105 C (final, 3 days later)	21.8	12.9	16.4
60 C (end)	N/A: Heater failed	2.2	2.2

■ Conclusions:

- 1 day pre-bake helps a lot
- Further days help less

$\approx 1-2 \times 10^{-13} \text{ g/cm}^2/\text{sec}$ at 60 C

TGA: Bulk A



Data: Bulk B

- Batch A: Stamet Outer Layer
- Independent Variable: Temperature in Tardis
 - Also BOT temperature: didn't bake in high vacuum hotter than Tardis

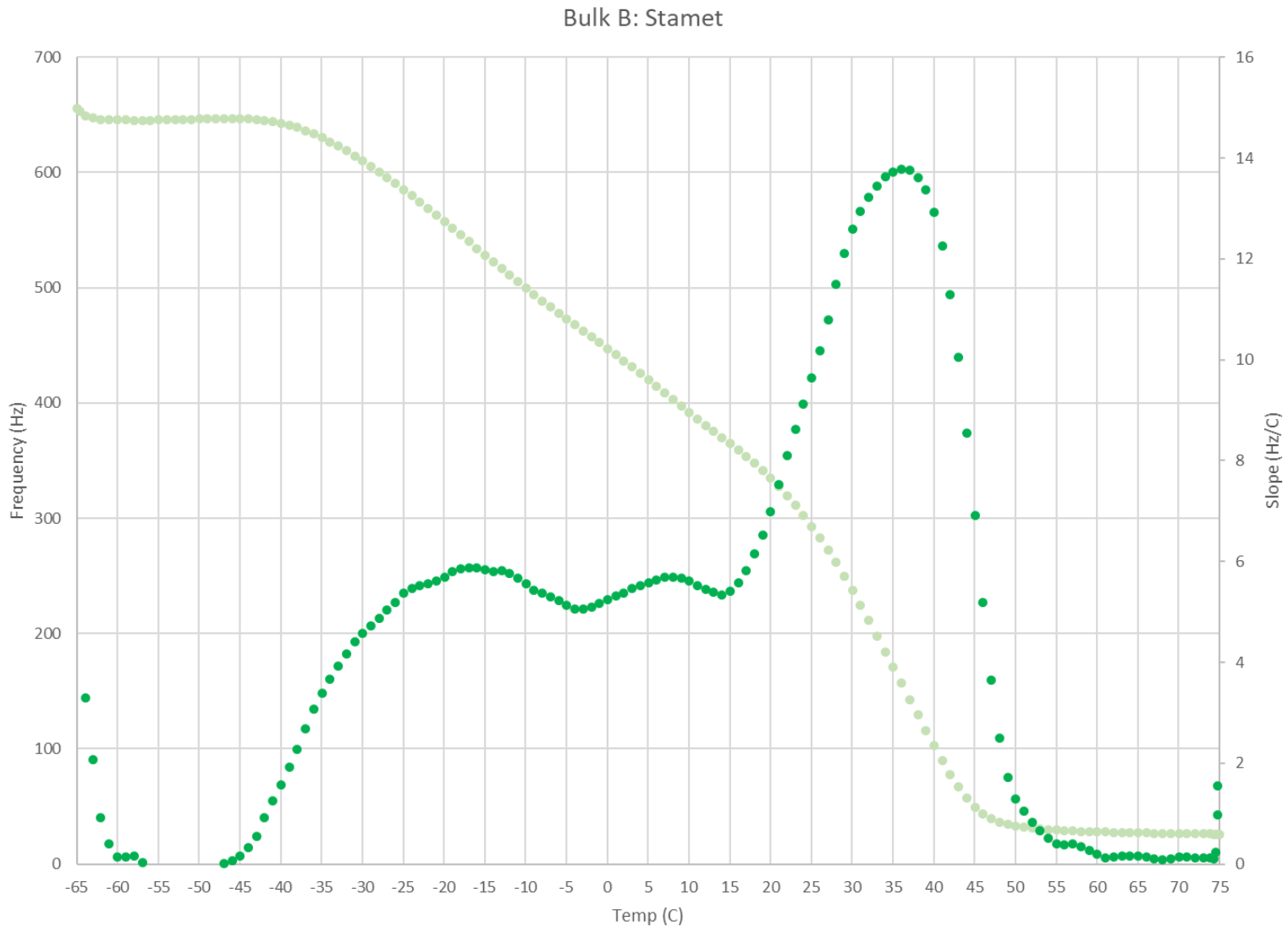
- Conclusions:
 - Higher overall outgassing from Stamet
 - Less clear benefits to hotter pre-bake

$$\approx 5 \times 10^{-13} \text{ g/cm}^2/\text{sec at 60 C}$$

MLI with similar construction was $1.5 \times 10^{-13} \text{ g/cm}^2/\text{sec}$ at 60 C

Bulk B	Sample 1 (110 C in Tardis)	Sample 2 (95 C in Tardis)	Sample 3 (80 C in Tardis)
	Normalized /1000 sqcm	Normalized /1000 sqcm	Normalized /1000 sqcm
Sample Number	B_0008-3_00007	B_0008-3_00009	B_0008-3_00011
Area (sq cm)	550	929	915
Edge Lengths (cm)	144	179	122
Start Date	9/27/2022	11/9/2022	11/15/2022
End Date	10/3/2022	11/15/2022	11/18/2022
60 C (initial)	100.0	107.6	138.8
60 C (final)	25.5	29.1	6.6
90 C (initial)	83.6	254.0	
90 C (final)	38.2	46.3	
105 C (initial)	74.5		
105 C (final, 3 days later)	20.0		
60 C (end)	5.5	8.1	6.6

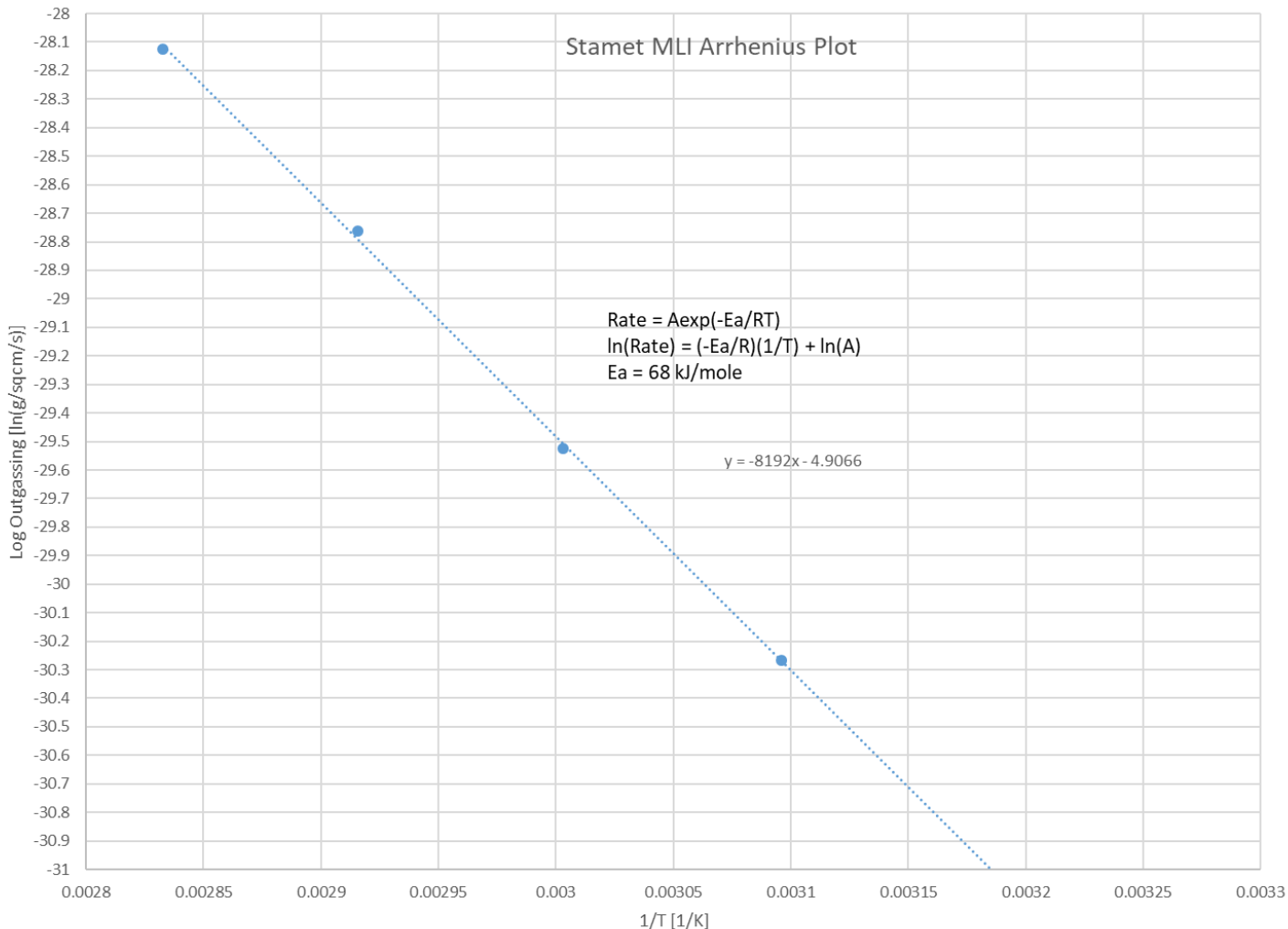
TGA: Bulk B



This was the only good TGA I got from Bulk B

Temperature-Dependence

- Similar Stamet MLI (with no Dacron netting)



50 C: 7.2×10^{-14}
60 C: 1.5×10^{-13}
70 C: 3.2×10^{-13}
80 C: 6.1×10^{-13}
g/cm²/sec

Rule of thumb:
Outgassing
doubles every
10° C

Data: Bulk C

- Batch A: Kapton outer layers
- Independent Variable: Temperature in BOT (60, 90, 105 C)

Bulk C	Sample 1 (60 C)	Sample 2 (90 C)	Sample 3 (105 C)
	Normalized /1000 sqcm	Normalized /1000 sqcm	Normalized /1000 sqcm
Sample Number	B_0008-3_00013	B_0008-3_00015	B_0008-3_00017
Area (sq cm)	550	929	915
Edge Lengths (cm)	143.5	179	122
Start Date	1/12/2023	2/24/2023	2/28/2023
End Date	1/17/2023	2/28/2023	3/4/2023
60 C (initial)	65.5	158.2	17.5
60 C (final)	23.6	32.3	0.0
90 C (initial)	54.5	172.2	0.0
90 C (final)	25.5	39.8	0.0
105 C (initial)	50.9		0.0
105 C (final, 3 days later)	14.5		0.0
60 C (end)	5.5	15.1	4.4

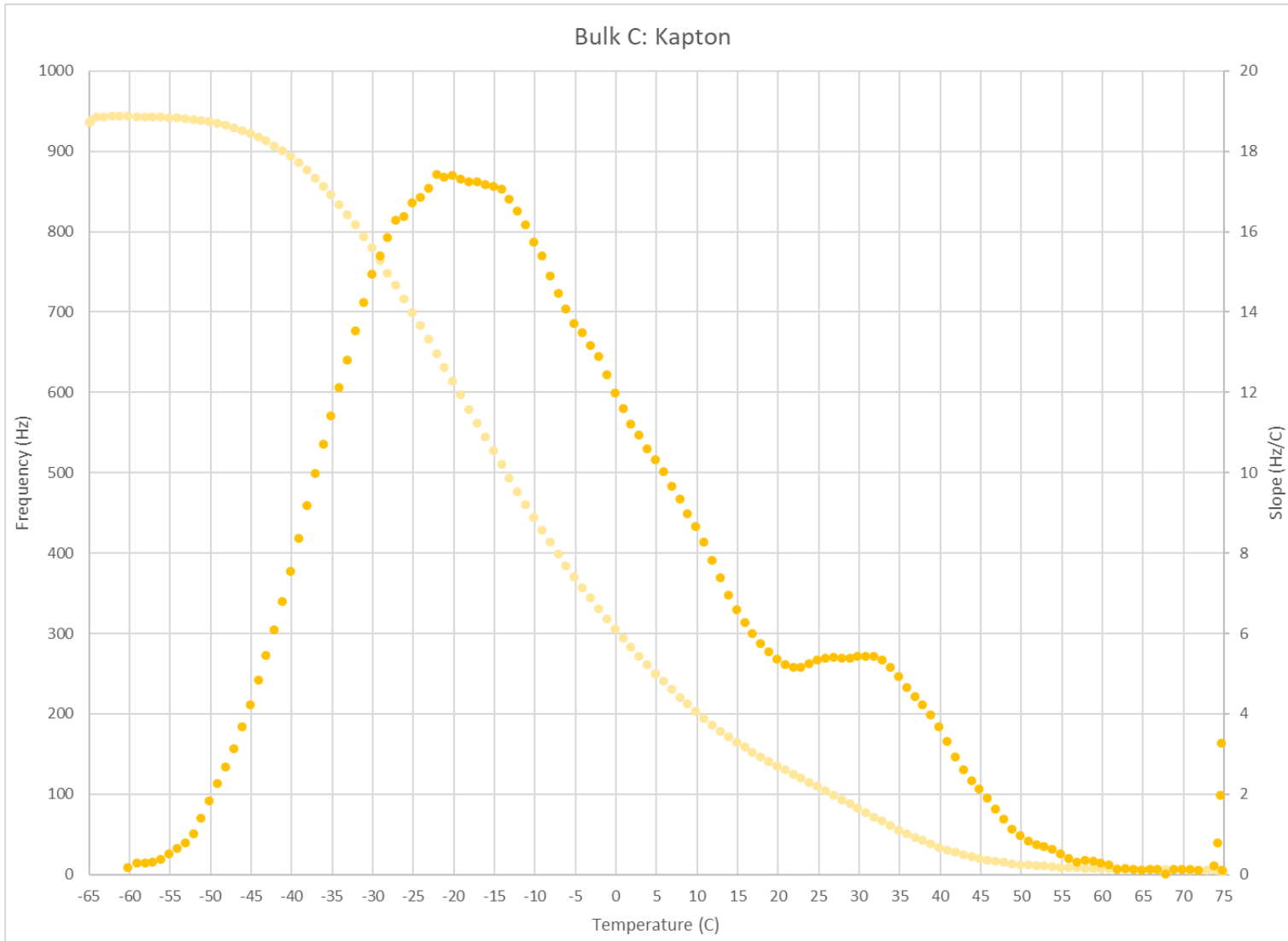


- Conclusions:
 - Hotter temperature prebakes help clean up faster

$\approx 3-10 \times 10^{-13} \text{ g/cm}^2/\text{sec}$ at 60 C

Not sure what's going on with sample 2: Started and stayed worse

TGA: Bulk C



- Batch D: Beta Cloth Overlay
- Independent Variable: Length of prebake (1 day vs 31 days)

Bulk D	Sample 1 (24 hrs)	Sample 2 (750 hrs)
	Normalized /1000 sqcm	Normalized /1000 sqcm
Sample Number	B_0008-3_00019	B_0008-3_00021
Area (sq cm)	550	929
Edge Lengths (cm)	143.5	179
Start Date	3/7/2023	7/27/2023
End Date	3/13/2023	8/1/2023
60 C (initial)	1656.4	214.2
60 C (final)	981.8	15.1
90 C (initial)	2627.3	49.5
90 C (final)	1776.4	19.4
105 C (initial)	2721.8	23.7
105 C (final, 3 days later)	690.9	9.7
60 C (end)	232.7	7.5

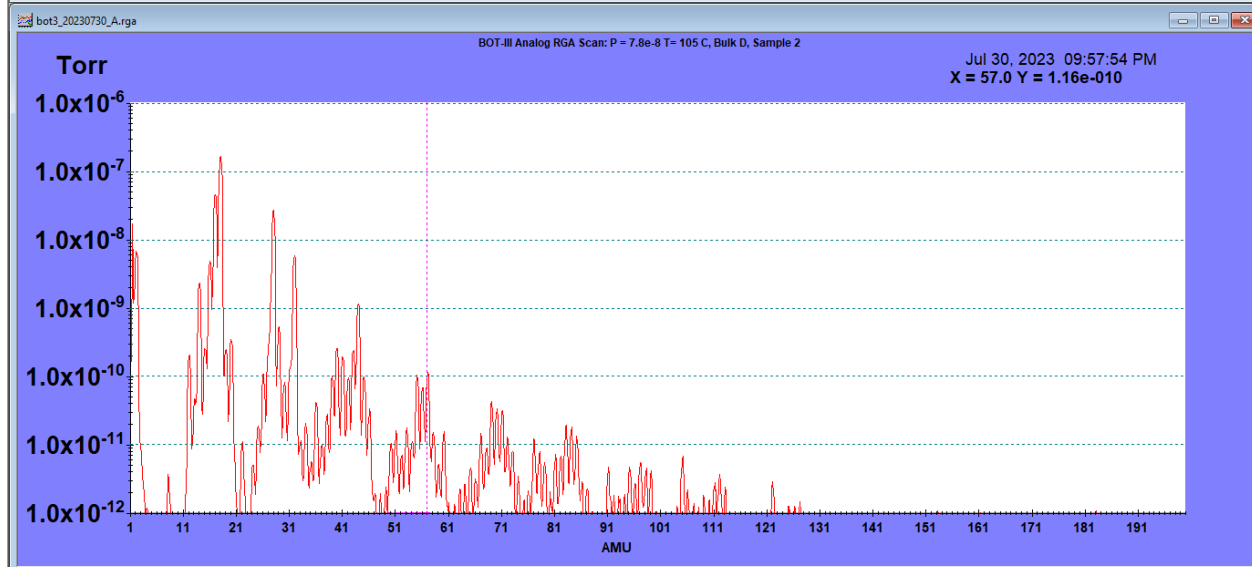
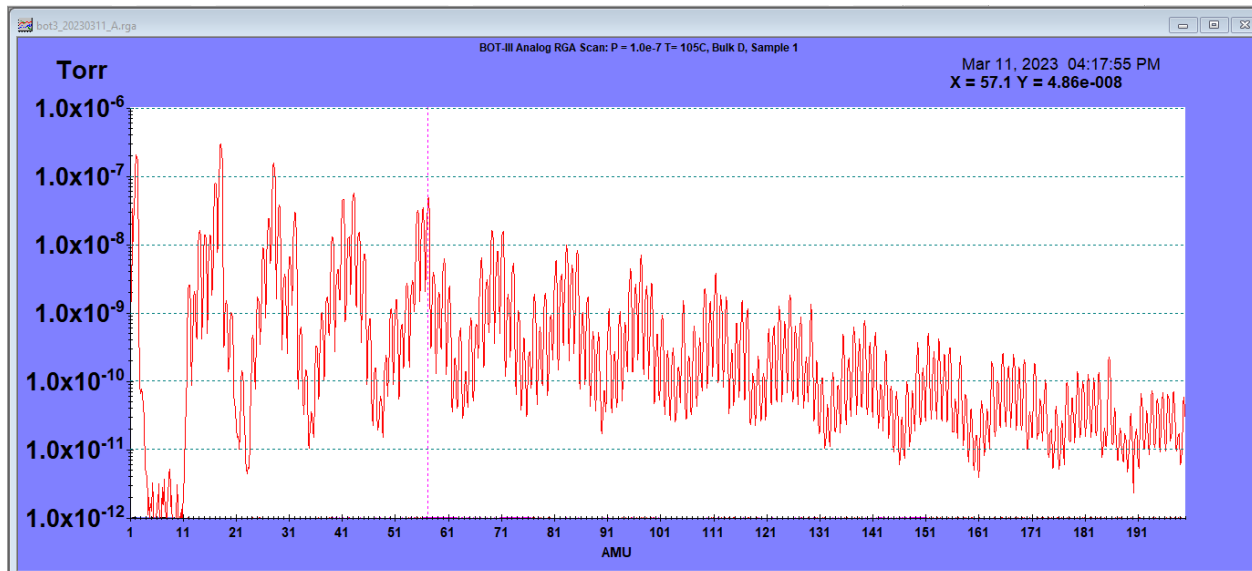
- Conclusions:

- Beta cloth outgasses a lot
- It does improve substantially with vacuum baking

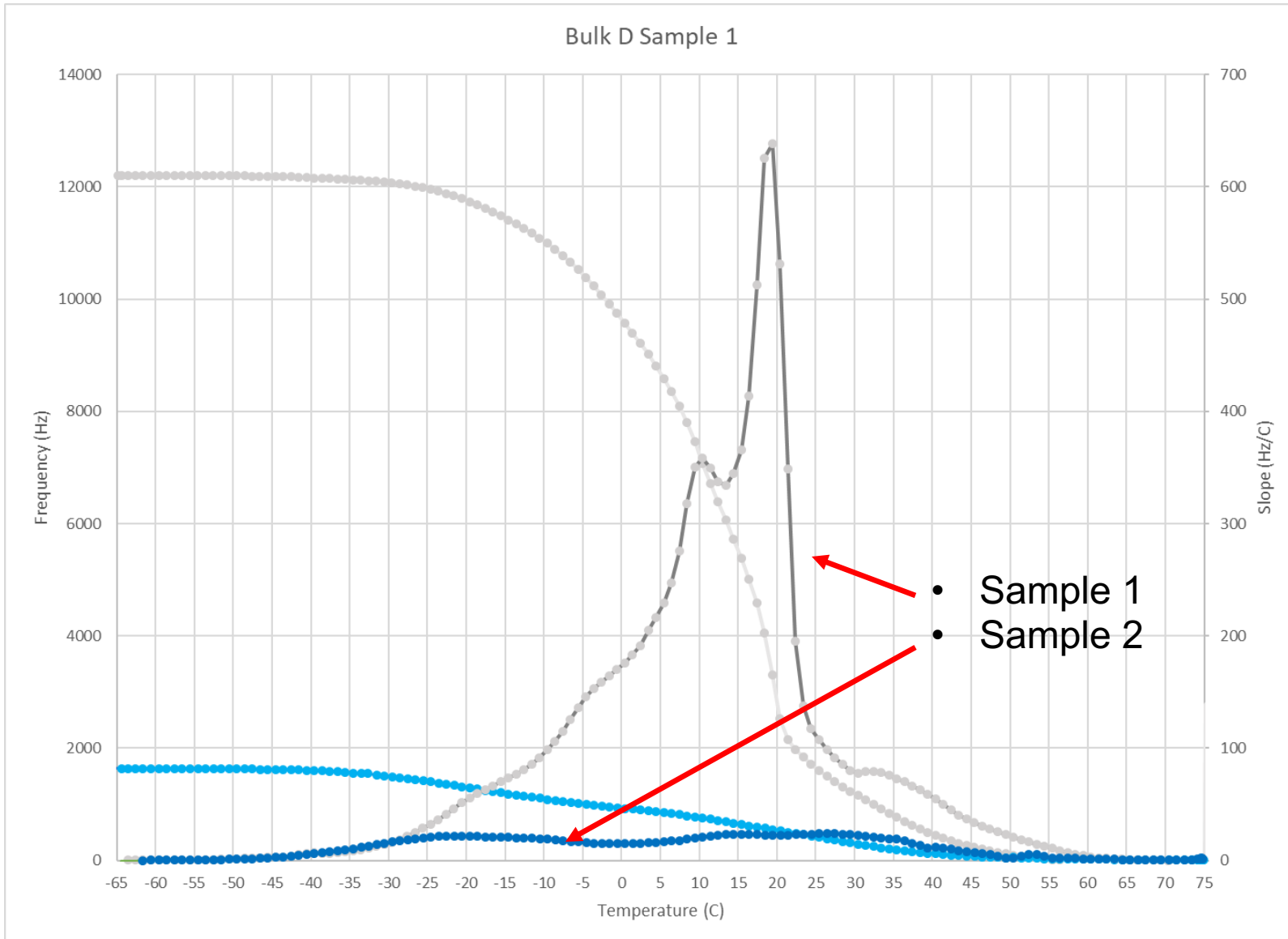
$\approx 5 \times 10^{-13} \text{ g/cm}^2/\text{sec}$ at 60 C

RGA: Bulk D

- RGA shows an oily signature
 - No silicone signature seen



TGA: Bulk D



- MLI can be made reasonably low-outgassing
 - $\sim 1-5 \times 10^{-13}$ g/cm²/sec at 60 C
 - Outgassing roughly doubles every 10 C
- Stamet appears to be modestly higher outgassing than aluminized Kapton
- Beta cloth has a relatively heavy outgassing component, that can be baked out with very long vacuum bakes



Special Thanks to Aerothreads for supplying the MLI Samples

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Questions?