Enhancing Microelectronics Reliability Through Comprehensive Outgassing

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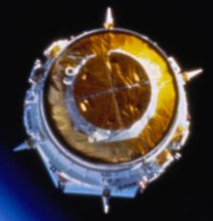

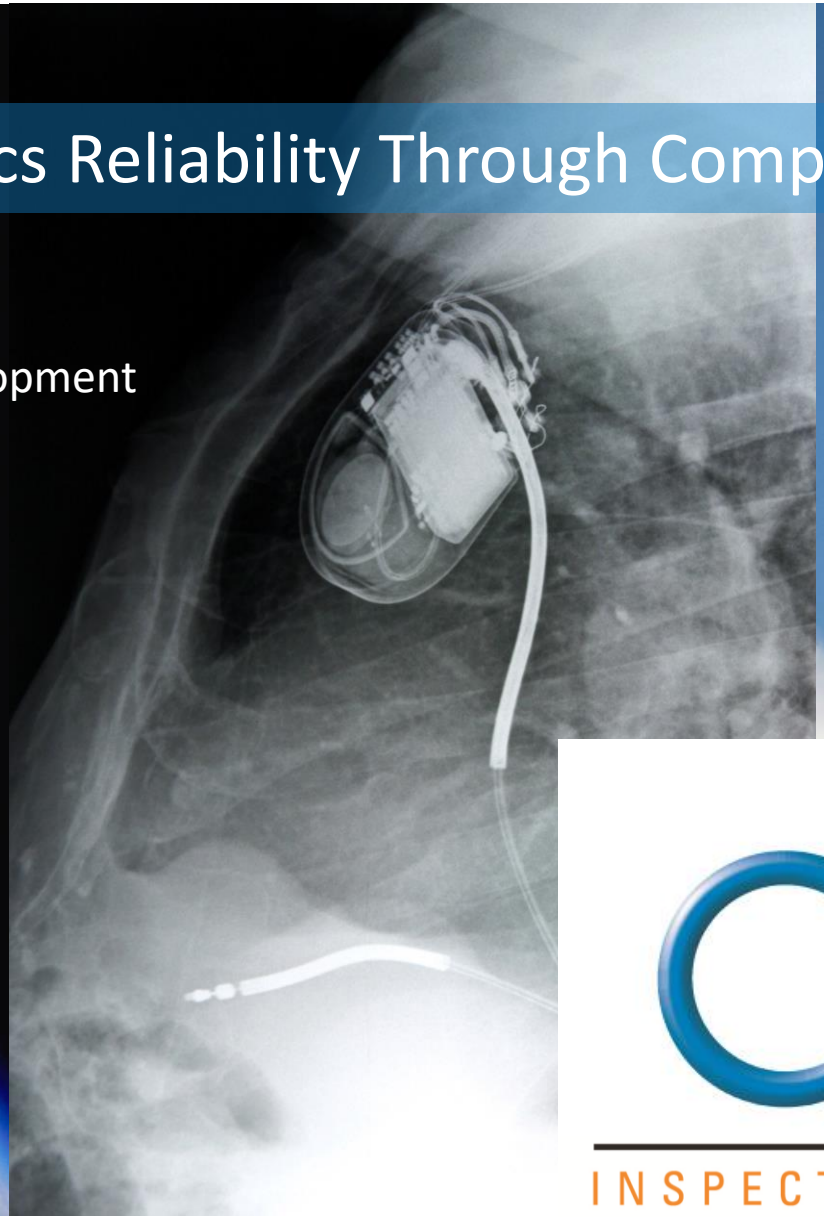

5/1/2025 CMSE 2025

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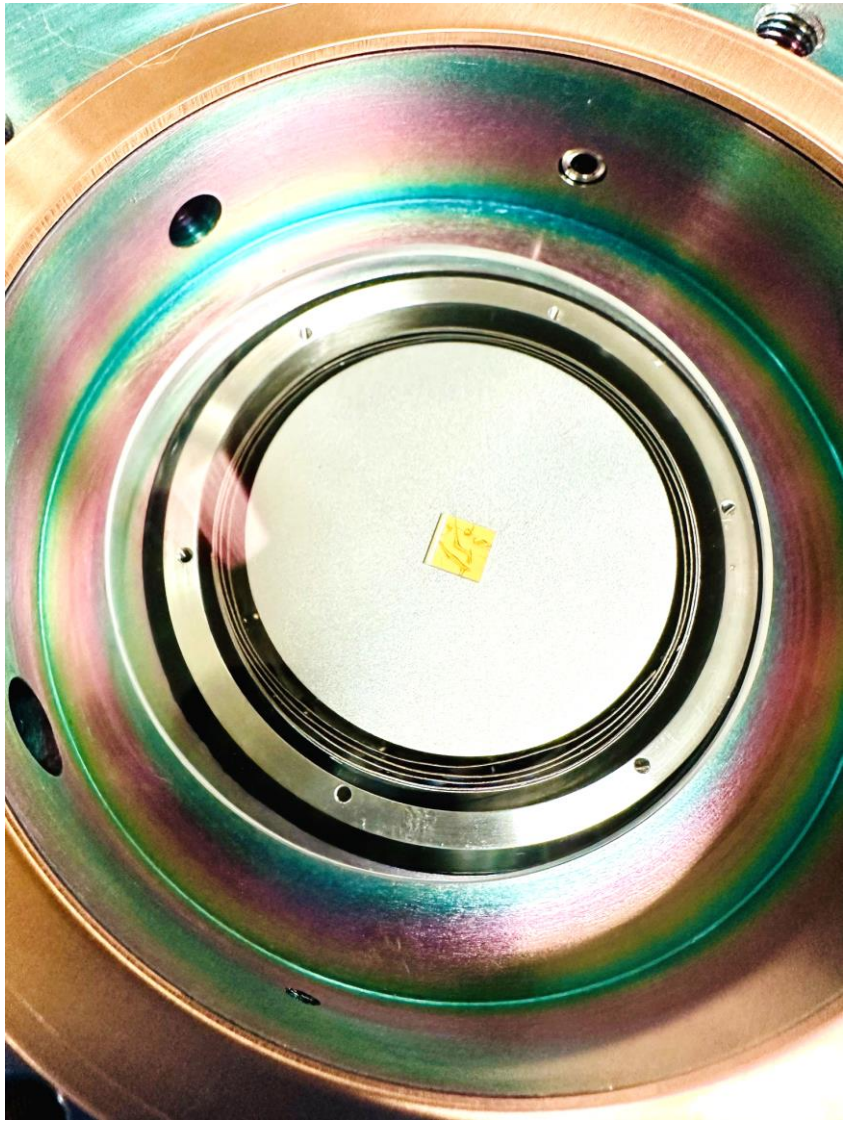
INSPECTION • ANALYSIS • TESTING

Plan of presentation

- Comprehensive outgassing capabilities at ORS
- What is Ultra-High Vacuum Evolved Gas Analyzer (UHV-EGA)?
- Case study
  - Failure analysis for hermetic packages that failed MIL-STD 883, TM 1018
- What is next: Standard Test Method



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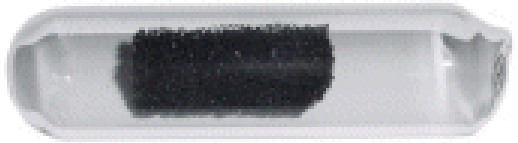
Outgassing Capabilities

- Material outgassing study
- ASTM E595
- TGA-MS
- UHV-EGA

Material Outgassing Study

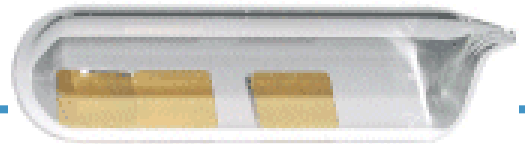


- The sample is hermetically sealed in a clean and dry glass ampoule under controlled atmosphere (e.g. dry N2 or 5%He/Bal N2, or rough vacuum).

- A thermal stress is then applied and the sample outgasses in the hermetic ampoule (up to 450°C). (Quartz to 1100C)

- Finally, an IVA® and/or GC/MS test is performed on the ampoule.
- The test results give the full gas picture (sealing atmosphere + outgassed substances).

- A large range of organic and inorganic substances can be provided by performing both IVA® and GC/MS testing.



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ASTM E595: A screening technique to determine volatile content of materials when exposed to vacuum environment

Designation: E595 – 15 (Reapproved 2021)

Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment[1]

Test conditions: 125°C at less than 5×10^{-5} (Torr) for 24 h

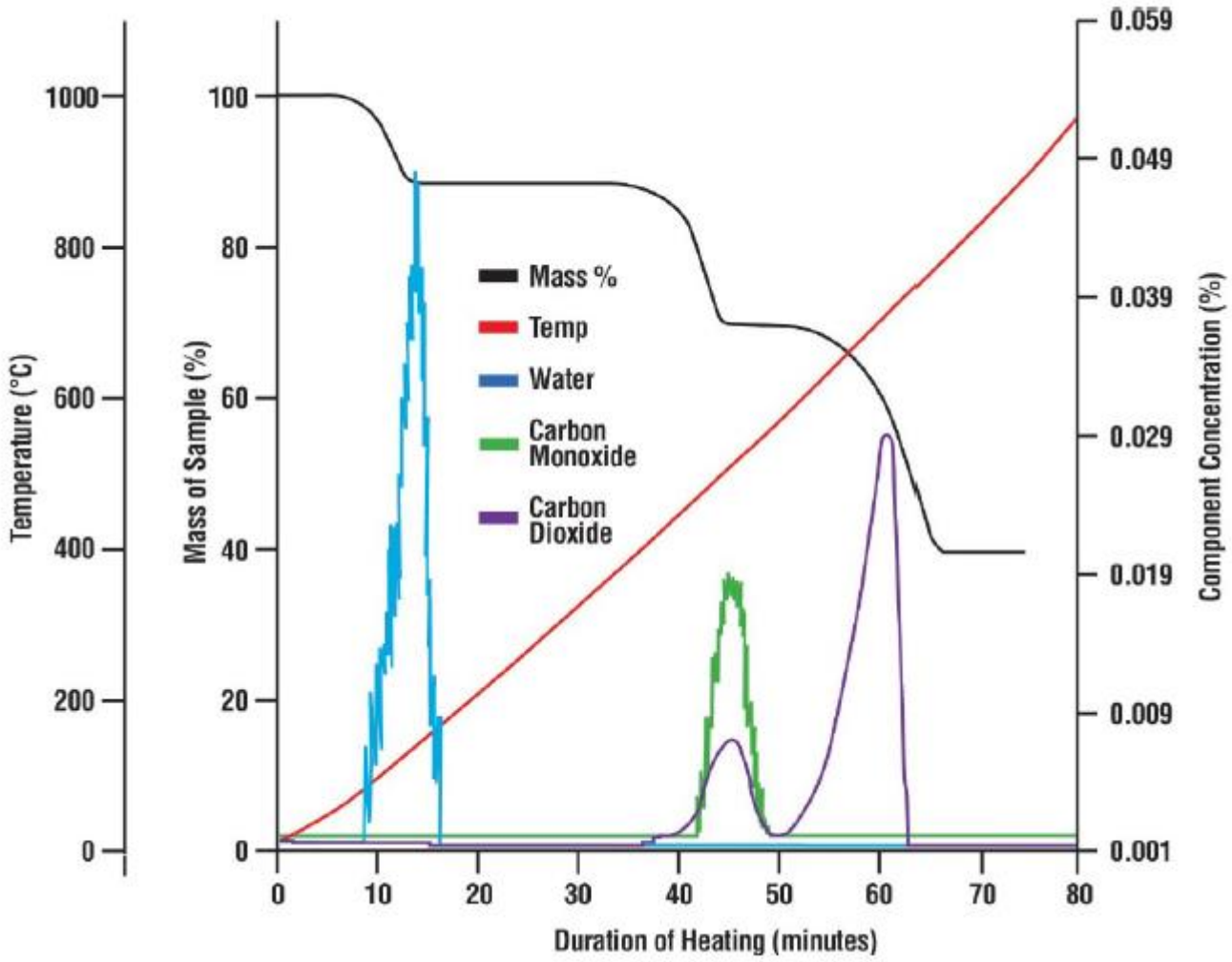
Sample: Organic, polymeric and inorganic materials
(e.g., Polymer potting compounds, foams, elastomers, films, tapes, insulations, Shrink tubing, adhesives, coatings, fabrics, tie cords and lubricants)

Determination: Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCM)
(e.g., TML of 1.00% and CVCM of 0.10% as screening levels for rejection of spacecraft materials.)

Thermogravimetric mass spectrometer analysis (TGA-MS)

Thermal stability per MIL-STD-883J, Method 5011 (sect. 3.5.2 & 3.8.5), originated from ASTM D3850-12

- TGA-MS is an important tool used for material characterization across industries.
- Samples are placed in a Nitrogen atmosphere (5-30mL/min flow). They begin at room temperature (25°C) and then get heated 2°C-10°C/min up to a final temperature of 200°C (max 1000°C). During this test, the weight of the samples is continuously measured.
- A material passes this standard if the weight loss at 200°C is less than or equal to 1.0% of the cured material weight. Three samples are tested and the average value of the three must meet or exceed the minimum requirements.



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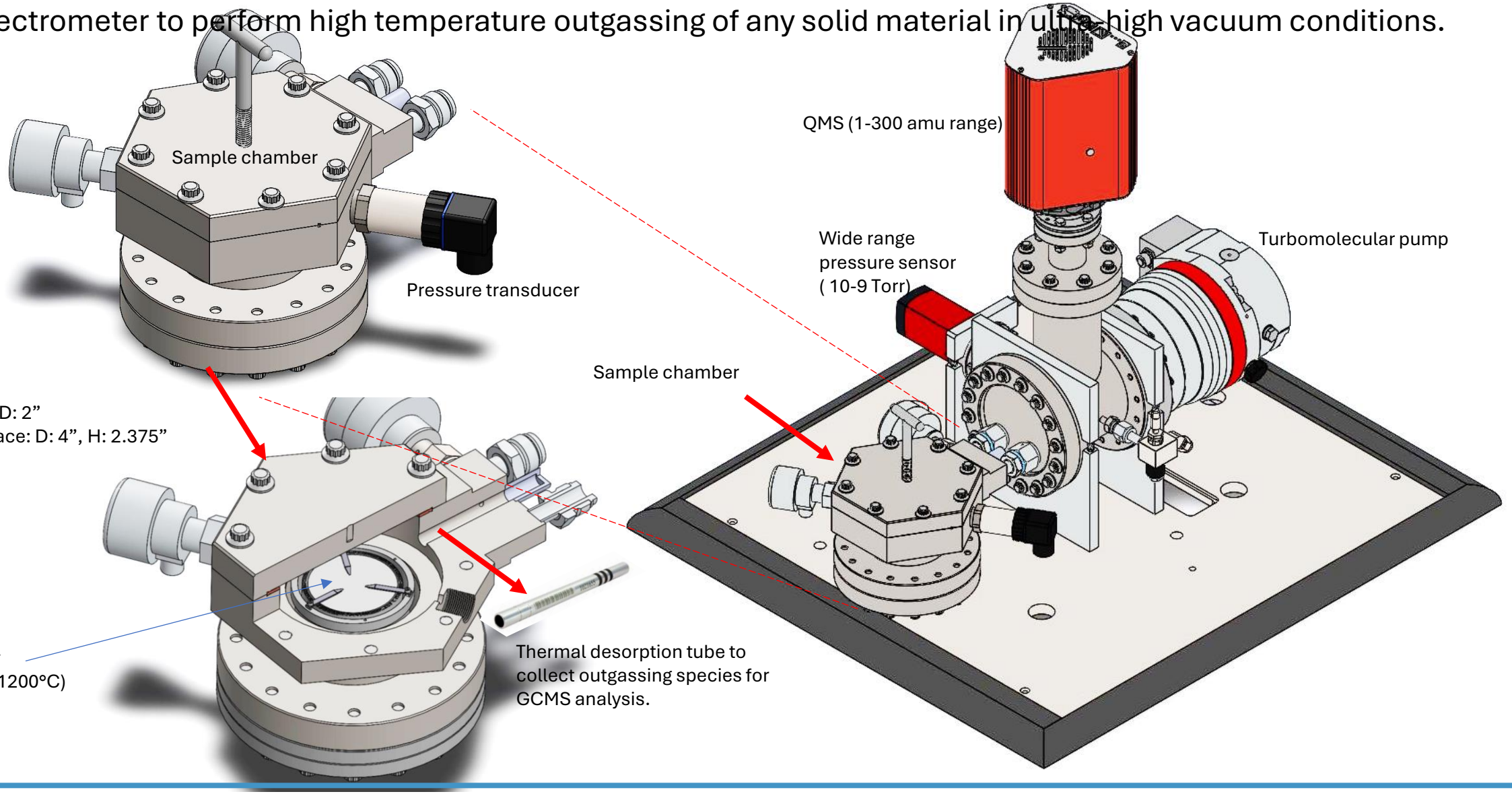
Ultra-High Vacuum Evolved Gas Analysis (UHV-EGA)

Mass spectrometer to perform high temperature outgassing of any solid material in ultra-high vacuum conditions.



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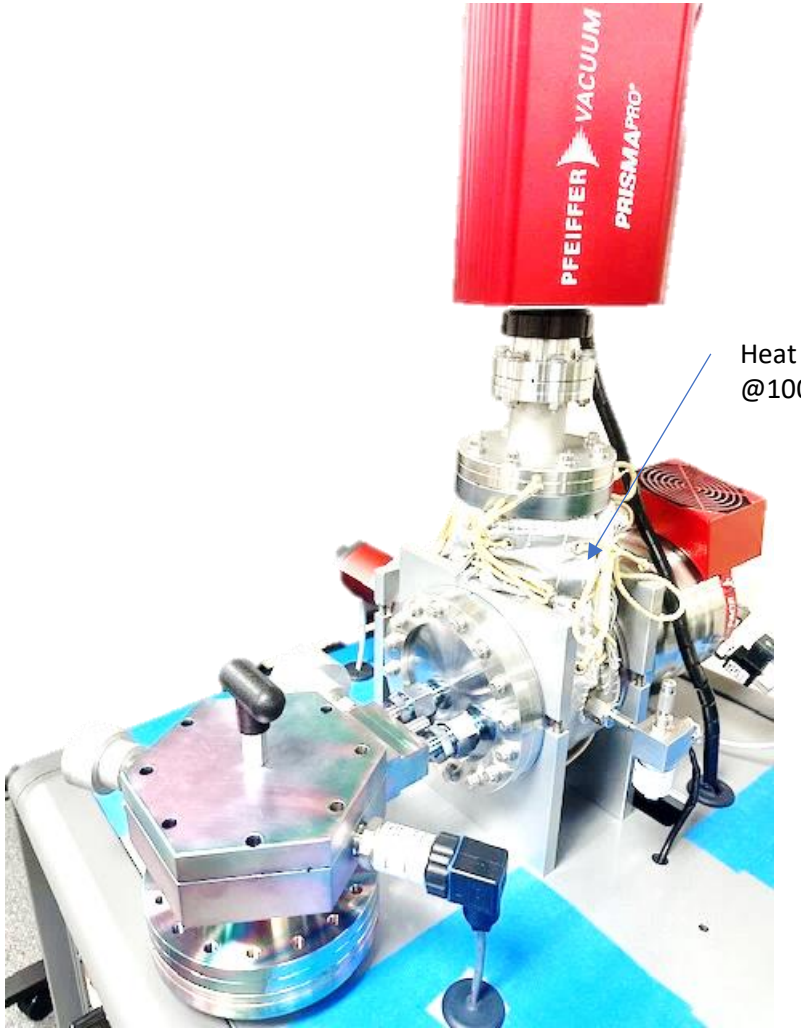
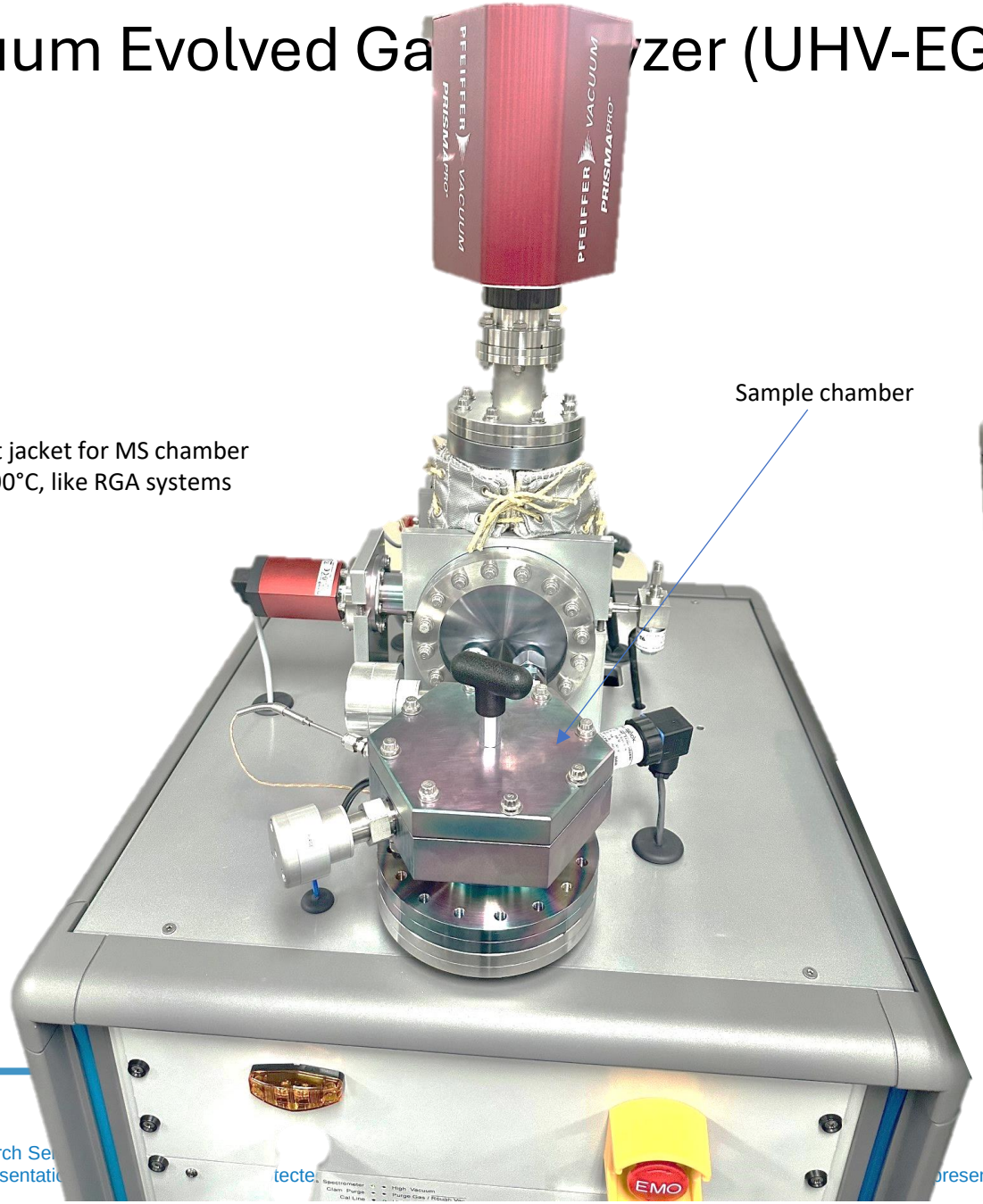
What is Ultra-High Vacuum Evolved Ga[illegible]yzer (UHV-EGA)?



Heat jacket for MS chamber
@100°C, like RGA systems

Sample chamber



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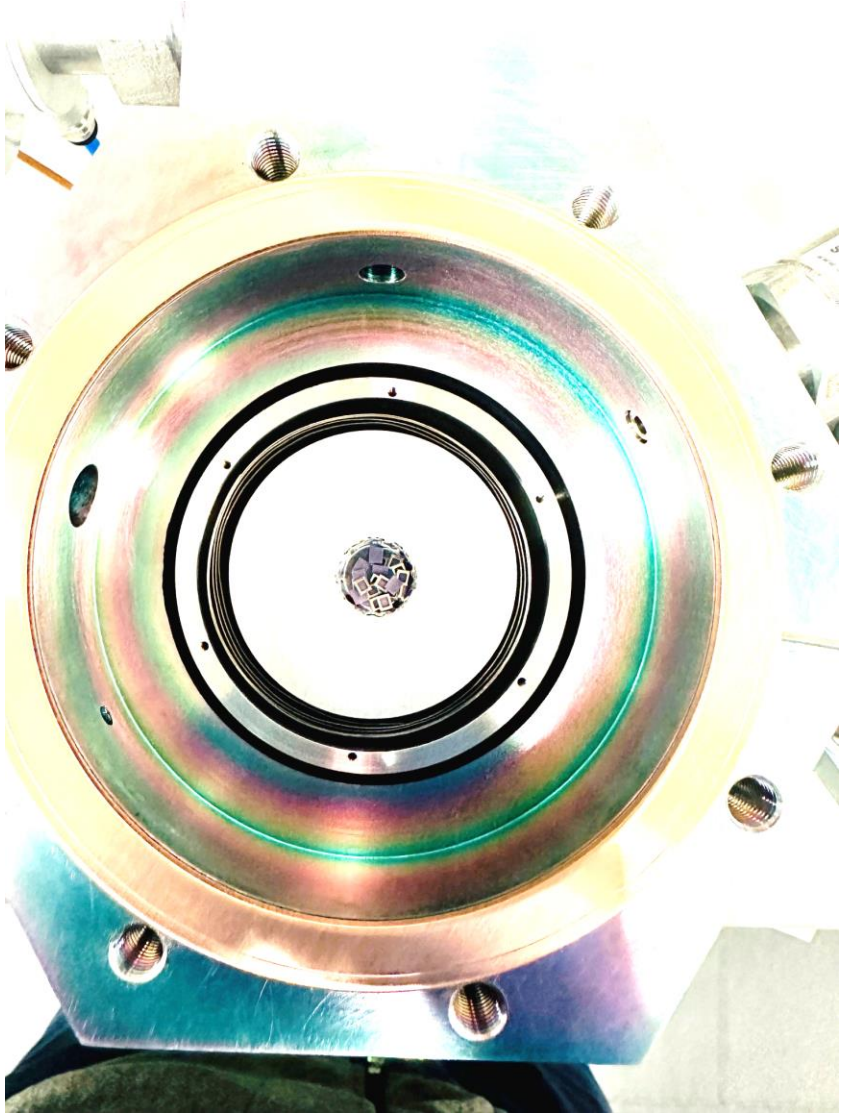
Technical specifications of UHV-EGA

- Outgassing from room temperature to 1200°C
- Heating rates 0.2°C/min to 15°C/min
- Vacuum as low as <5E-8 Torr
- Mass range: 1 to 300 amu
- Scan speed: scan per 10 seconds
- Ion current range: 1E-6 to 1E-11 Amp
- Provision for identification of organic compounds using GCMS



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Applications of UHV-EGA

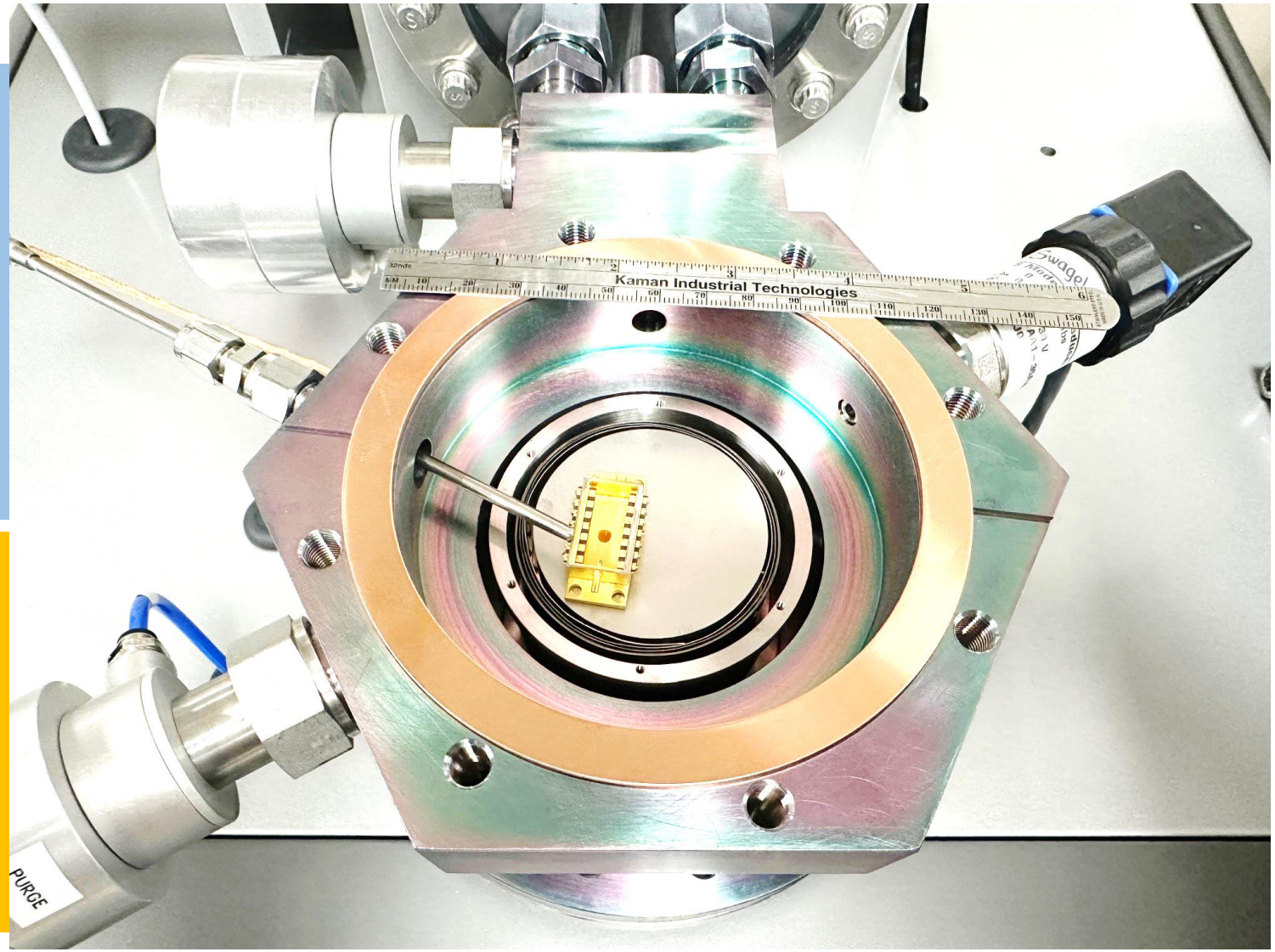
Samples:

Type: Solids

- Wafers
- Ceramics (high temperature electronics)
- Battery raw materials
- Electronics packages & their components
- Metals & Alloys
- Polymers, adhesives

Processes:

- Simulating baking and sealing processes
- Annealing
- Adhesive curing process
- Optimization of baking duration
- Outgassing rates (e.g, moles/g/sec)
- Component level failure analysis



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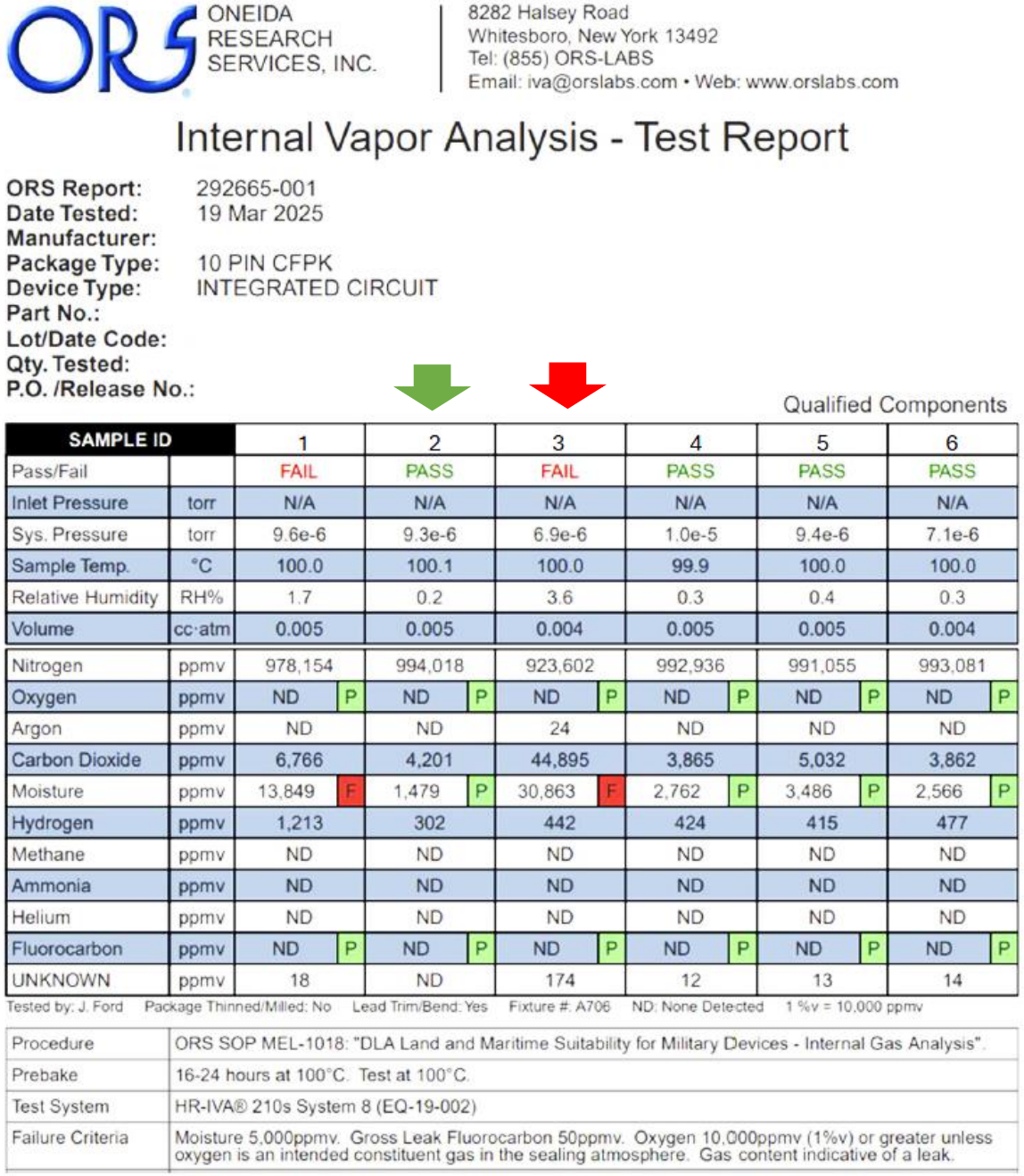
Case study with UHV-EGA

Identifying Root Cause of Moisture Failures in Hermetic Packages with UHV-EGA

Moisture concentration (ppmv)

Sample 2: 1479
Sample 3: 30,863

Sample 2 cannot be a leaker as no oxygen detected.



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Internal Vapor Analysis - Test Report

ORS Report: 292665-001
Date Tested: 19 Mar 2025
Manufacturer:
Package Type: 10 PIN CFPK
Device Type: INTEGRATED CIRCUIT
Part No.:
Lot/Date Code:
Qty. Tested:
P.O. /Release No.:

Qualified Components

SAMPLE ID		1	2	3	4	5	6
Pass/Fail		FAIL	PASS	FAIL	PASS	PASS	PASS
Inlet Pressure	torr	N/A	N/A	N/A	N/A	N/A	N/A
Sys. Pressure	torr	9.6e-6	9.3e-6	6.9e-6	1.0e-5	9.4e-6	7.1e-6
Sample Temp.	°C	100.0	100.1	100.0	99.9	100.0	100.0
Relative Humidity	RH%	1.7	0.2	3.6	0.3	0.4	0.3
Volume	cc·atm	0.005	0.005	0.004	0.005	0.005	0.004
Nitrogen	ppmv	978,154	994,018	923,602	992,936	991,055	993,081
Oxygen	ppmv	ND P	ND P	ND P	ND P	ND P	ND P
Argon	ppmv	ND	ND	24	ND	ND	ND
Carbon Dioxide	ppmv	6,766	4,201	44,895	3,865	5,032	3,862
Moisture	ppmv	13,849 F	1,479 P	30,863 F	2,762 P	3,486 P	2,566 P
Hydrogen	ppmv	1,213	302	442	424	415	477
Methane	ppmv	ND	ND	ND	ND	ND	ND
Ammonia	ppmv	ND	ND	ND	ND	ND	ND
Helium	ppmv	ND	ND	ND	ND	ND	ND
Fluorocarbon	ppmv	ND P	ND P	ND P	ND P	ND P	ND P
UNKNOWN	ppmv	18	ND	174	12	13	14

Tested by: J. Ford Package Thinned/Milled: No Lead Trim/Bend: Yes Fixture #: A706 ND: None Detected 1 %v = 10,000 ppmv

Procedure	ORS SOP MEL-1018: "DLA Land and Maritime Suitability for Military Devices - Internal Gas Analysis".
Prebake	16-24 hours at 100°C. Test at 100°C.
Test System	HR-IVA® 210s System 8 (EQ-19-002)
Failure Criteria	Moisture 5,000ppmv. Gross Leak Fluorocarbon 50ppmv. Oxygen 10,000ppmv (1%v) or greater unless oxygen is an intended constituent gas in the sealing atmosphere. Gas content indicative of a leak.

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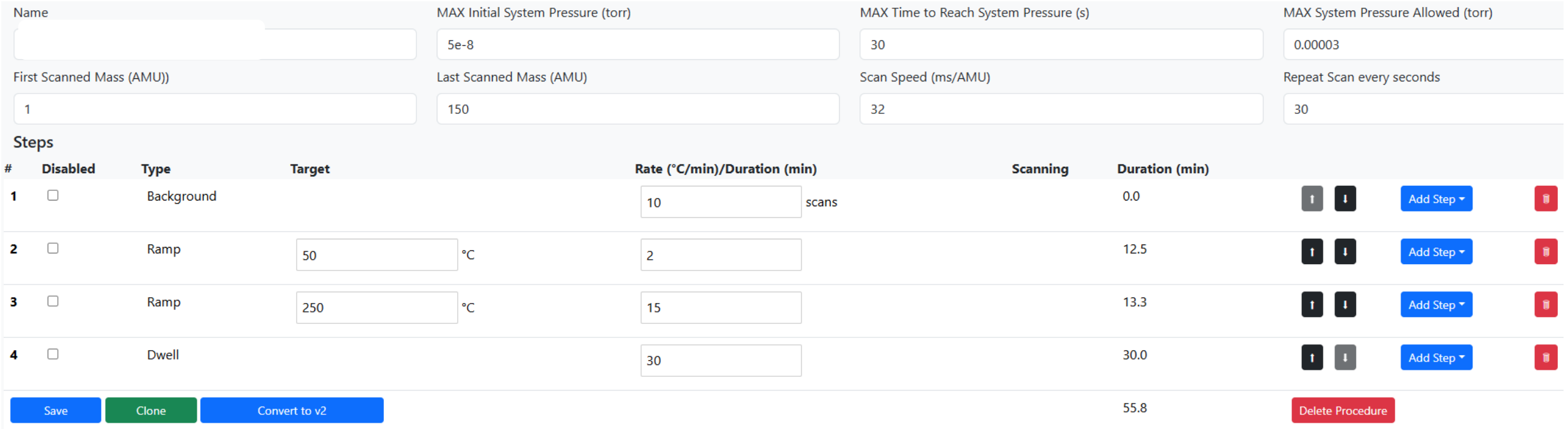
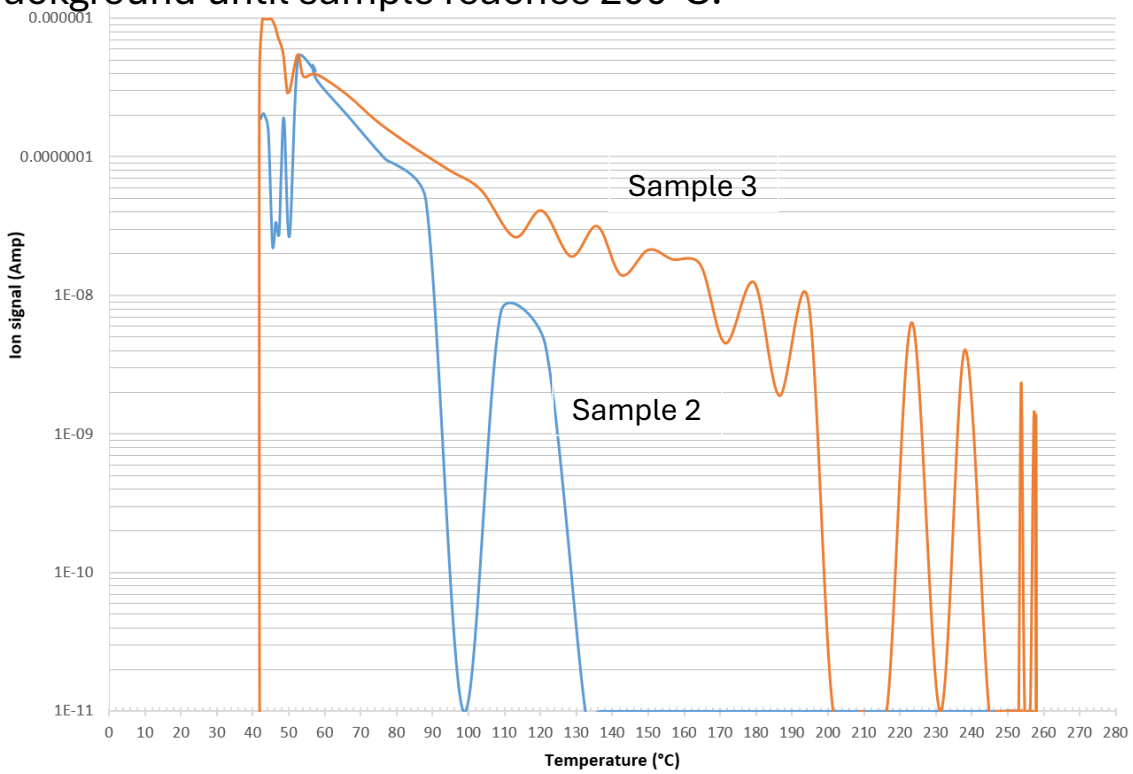
Outgassing protocol



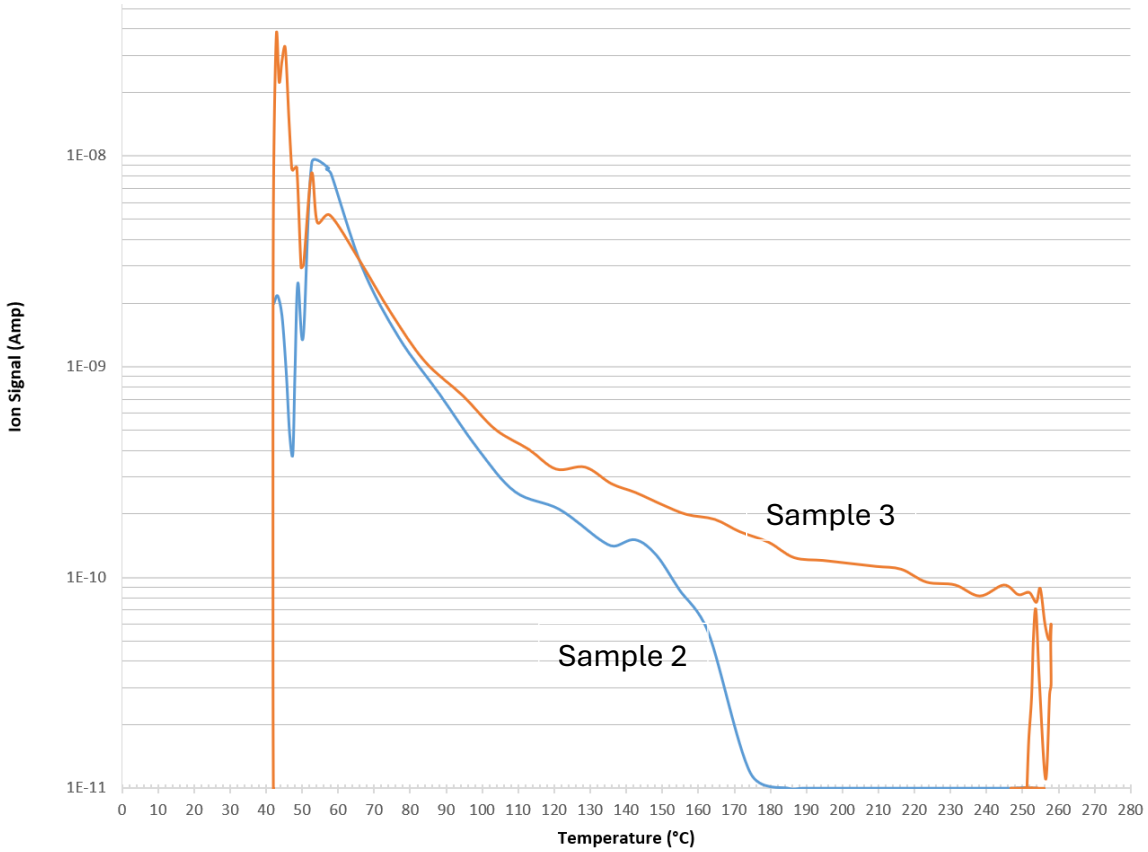
A screen capture of the UI in EVACS™ used to define heating protocol for the IC samples.

Results

Outgassing of moisture in sample 2 reaches background at ~130°C, for sample 3 moisture outgassing does not reach background until sample reaches 200°C.



As observed for moisture, sample 2 reaches background at ~180°C, for sample 3, outgassing for mass 19 continues until reaches 250°C.



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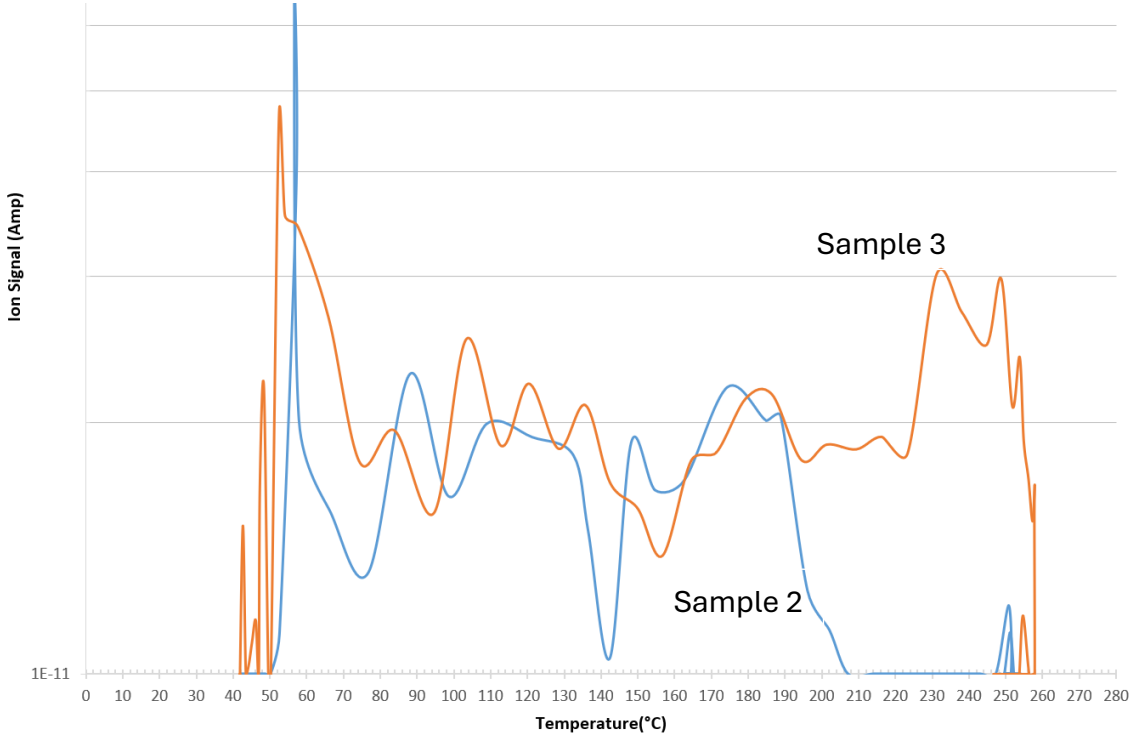
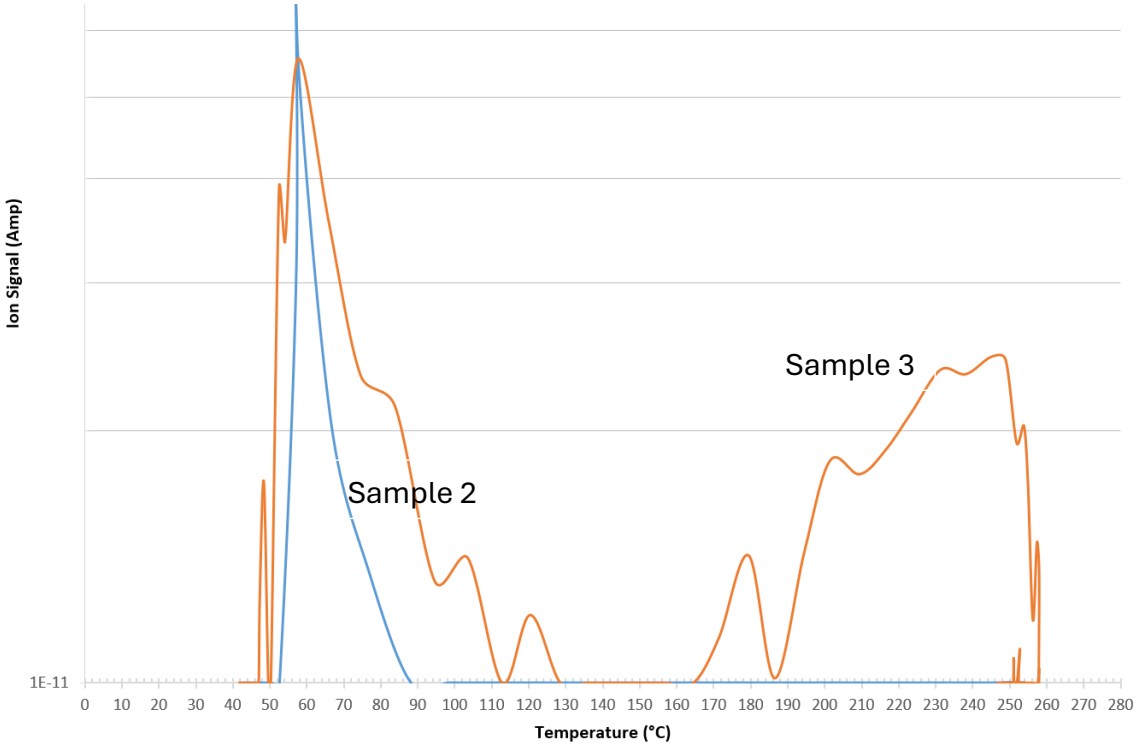
Results

Different outgassing for mass 69 at higher temperature (>130°C -200°C), Outgassing reaches background for sample 2 at 210°C, while sample 3 continue to outgas until 250°C



Both the samples show the mismatch of outgassing for mass 91 (commonly observed for adhesive material), sample 2 has marginal outgassing at 65°C, whereas sample 3 has outgassing in two stages (1) at same temperature observed for sample 2, and later at higher temperature (>190°C).



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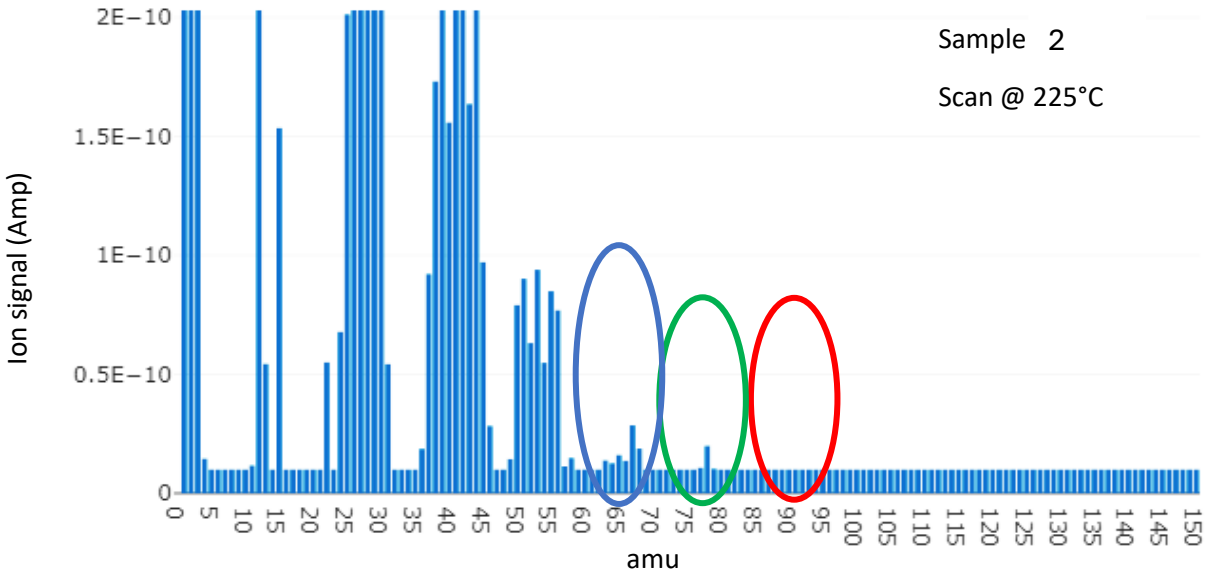
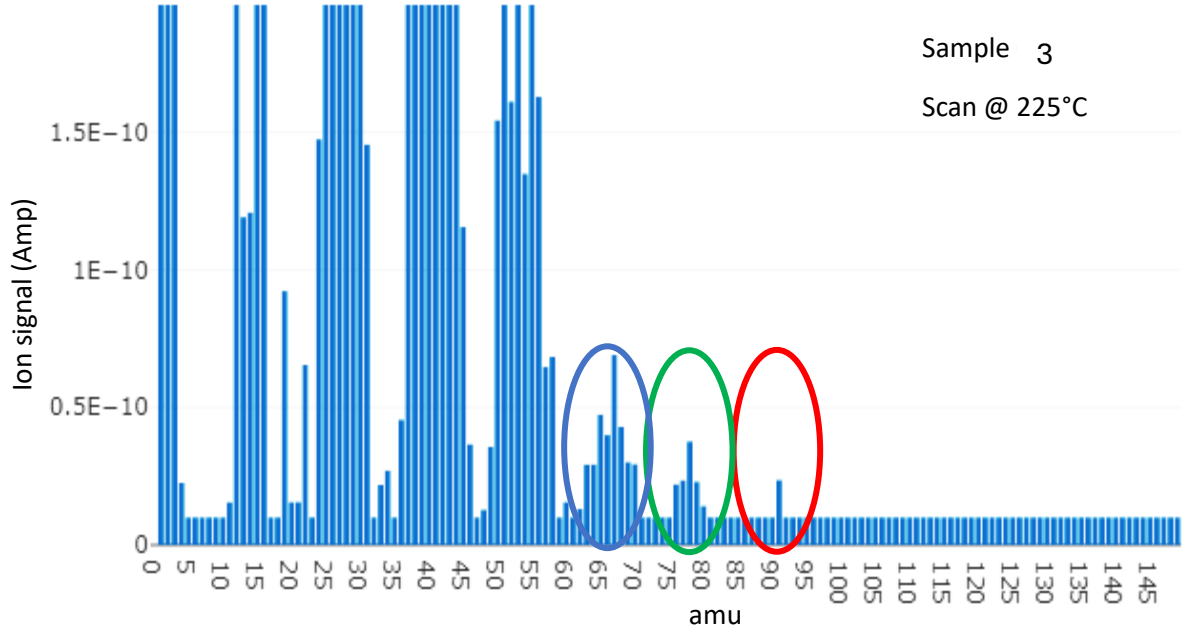
Results





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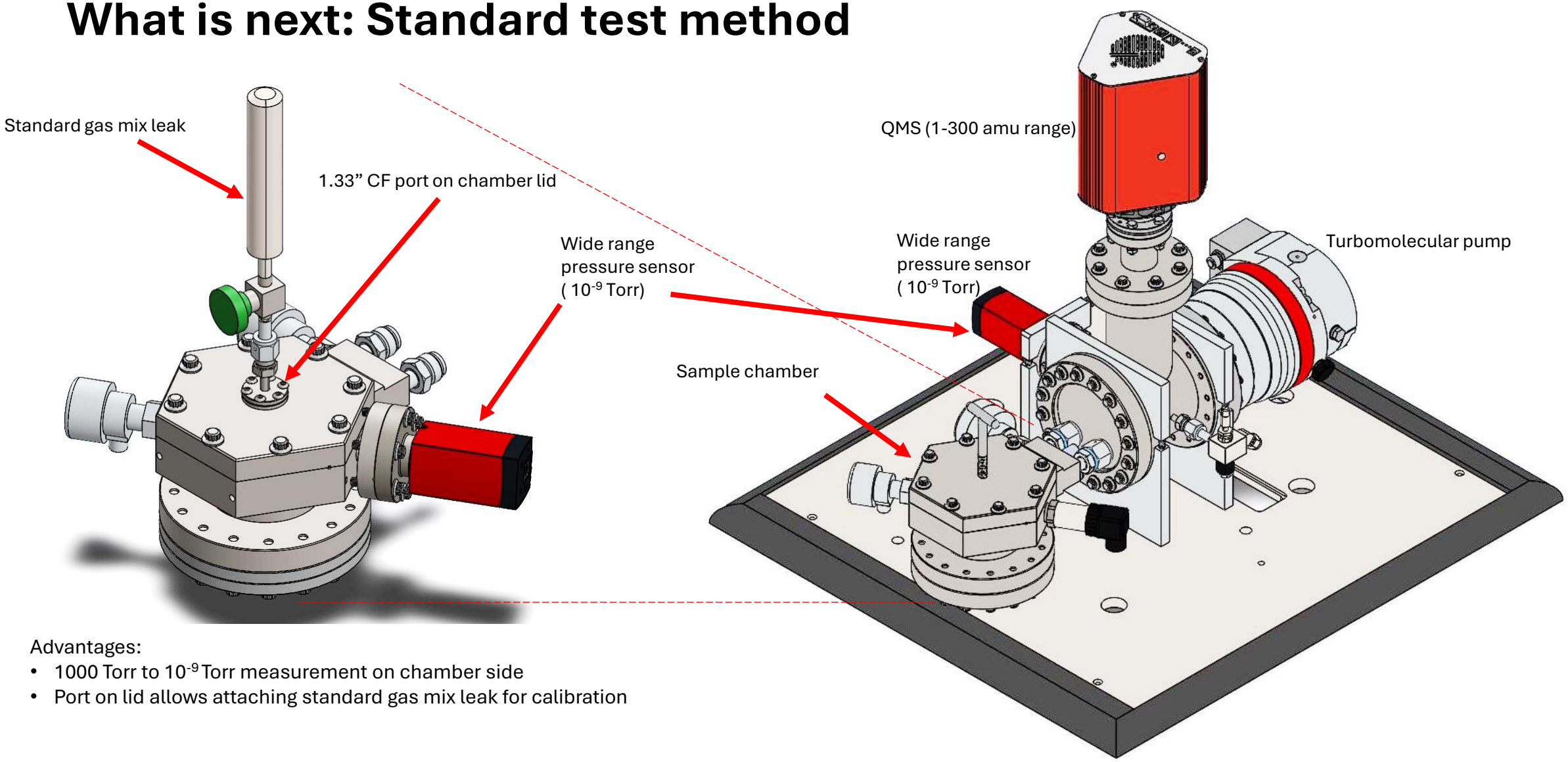
What is next: Standard test method



Advantages:

- 1000 Torr to 10^{-9} Torr measurement on chamber side
- Port on lid allows attaching standard gas mix leak for calibration

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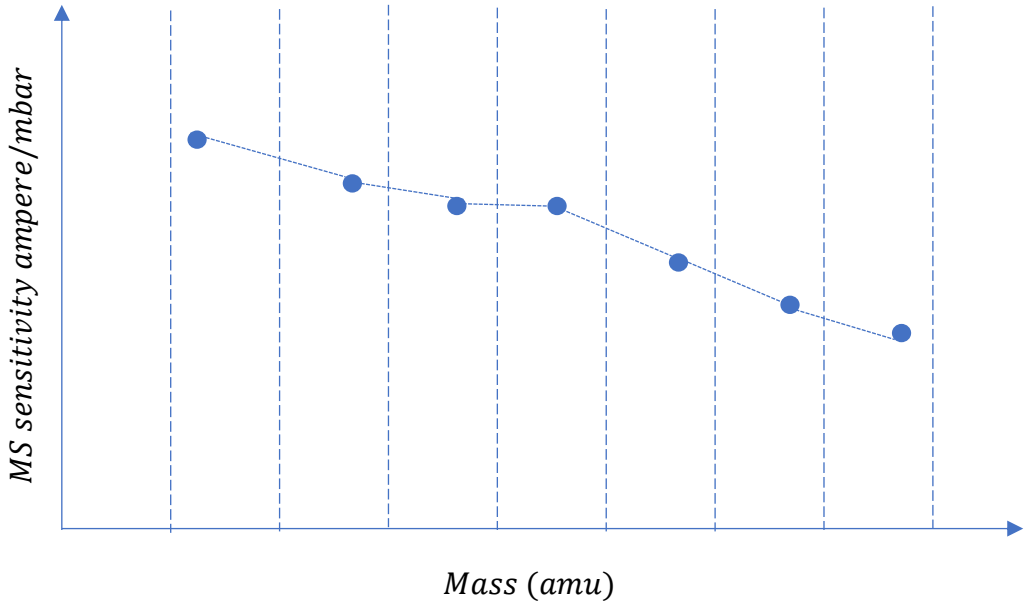
Determination of outgassing rates

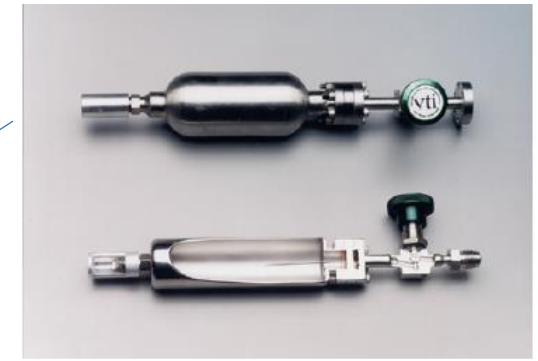
$$Q = P \cdot S_{eff}$$

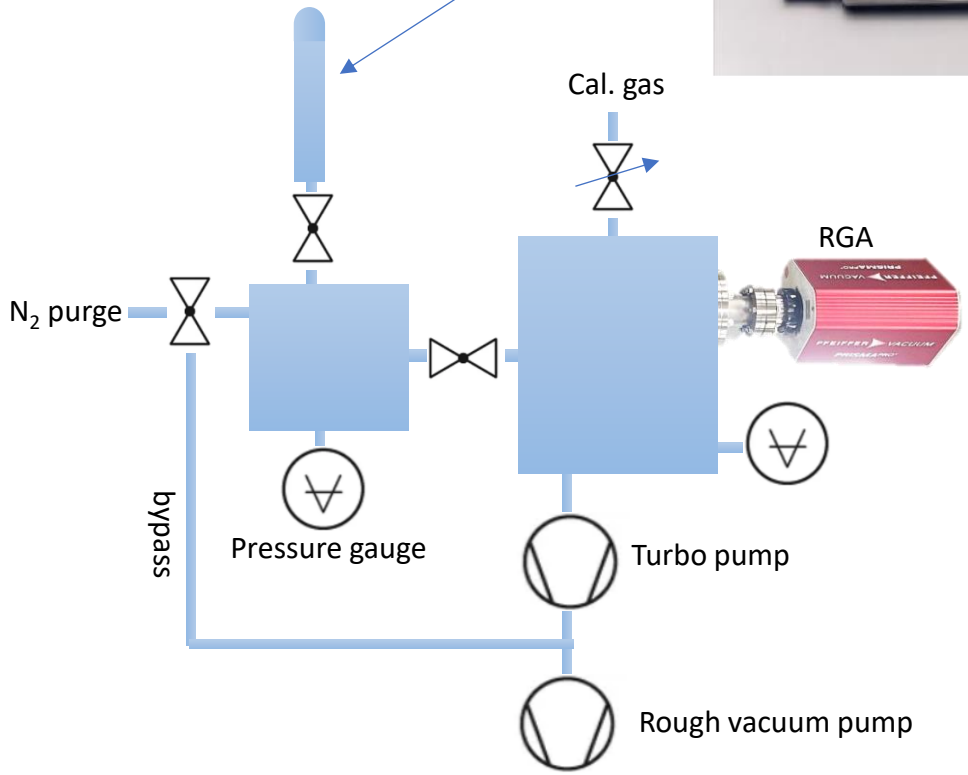
$Q = Outgassing\ rate\ (mbar * liter * S^{-1})$

$P = pressure\ (mbar)$

S_{eff} = effective pumping speed







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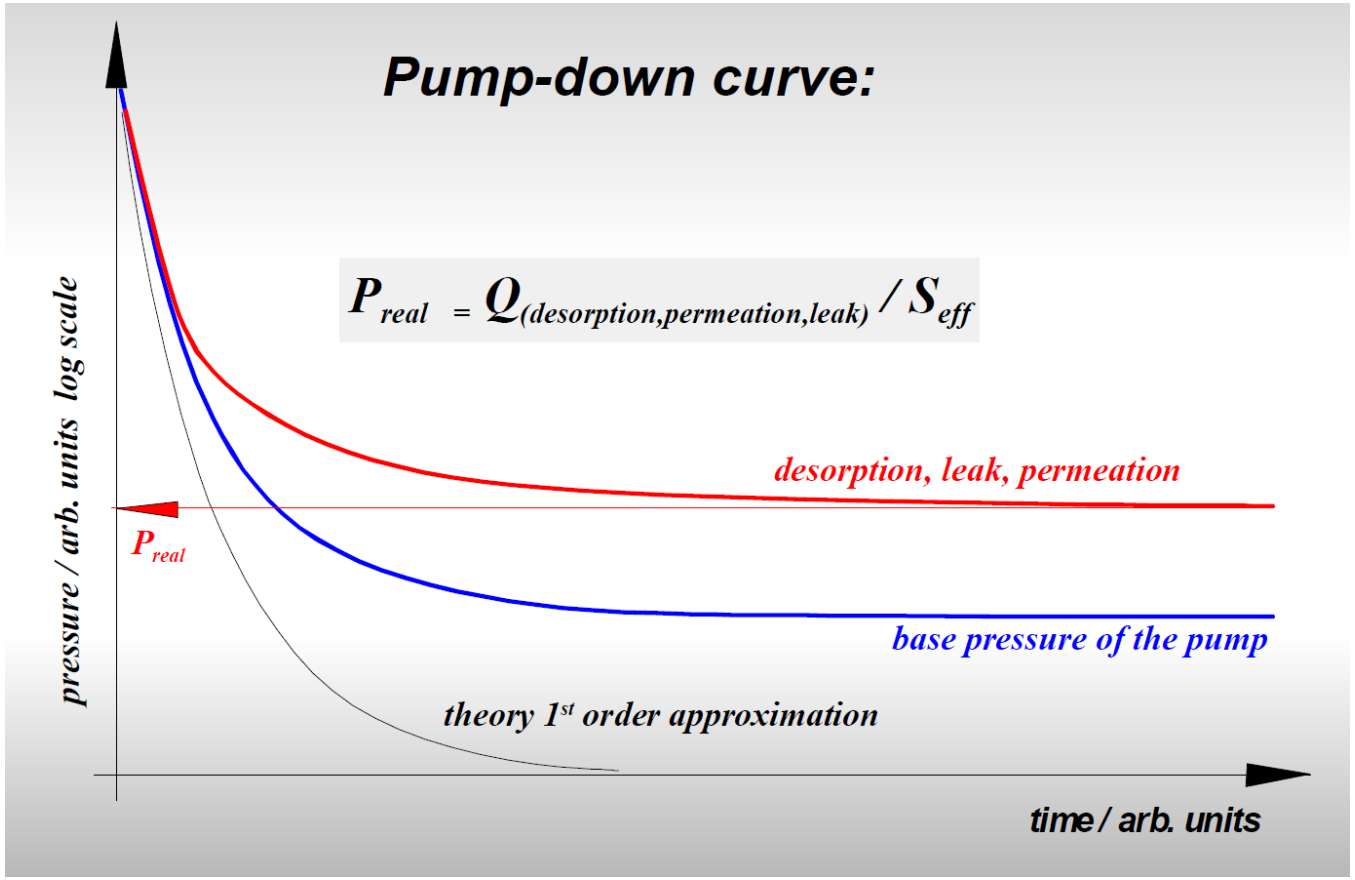
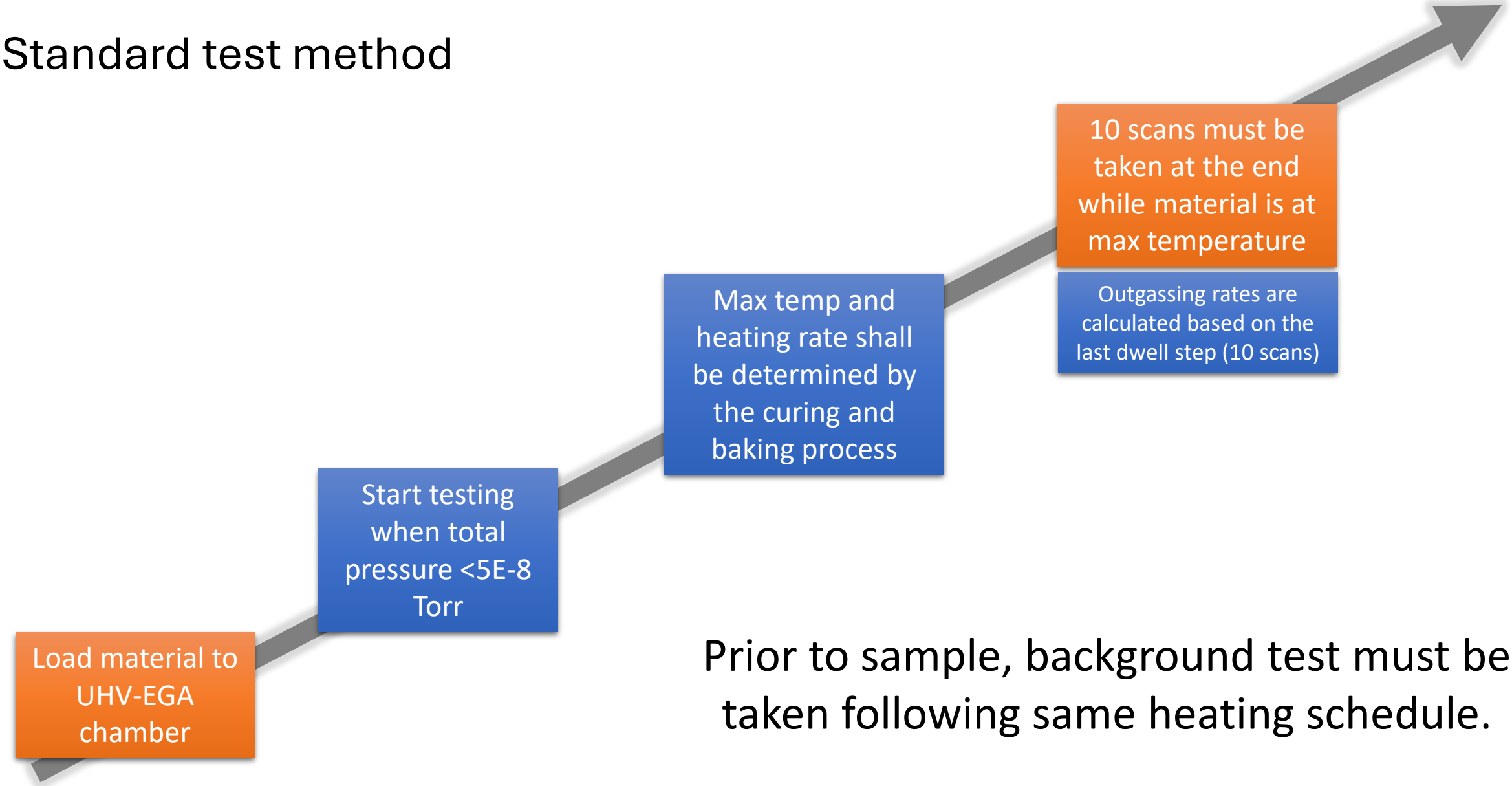


Standard test method



Prior to sample, background test must be taken following same heating schedule.

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Standard test method

Moisture outgassing rate should be calculated using following equation:

$$Q_{H_2O} = I_{H_2O} * S_{eff}$$

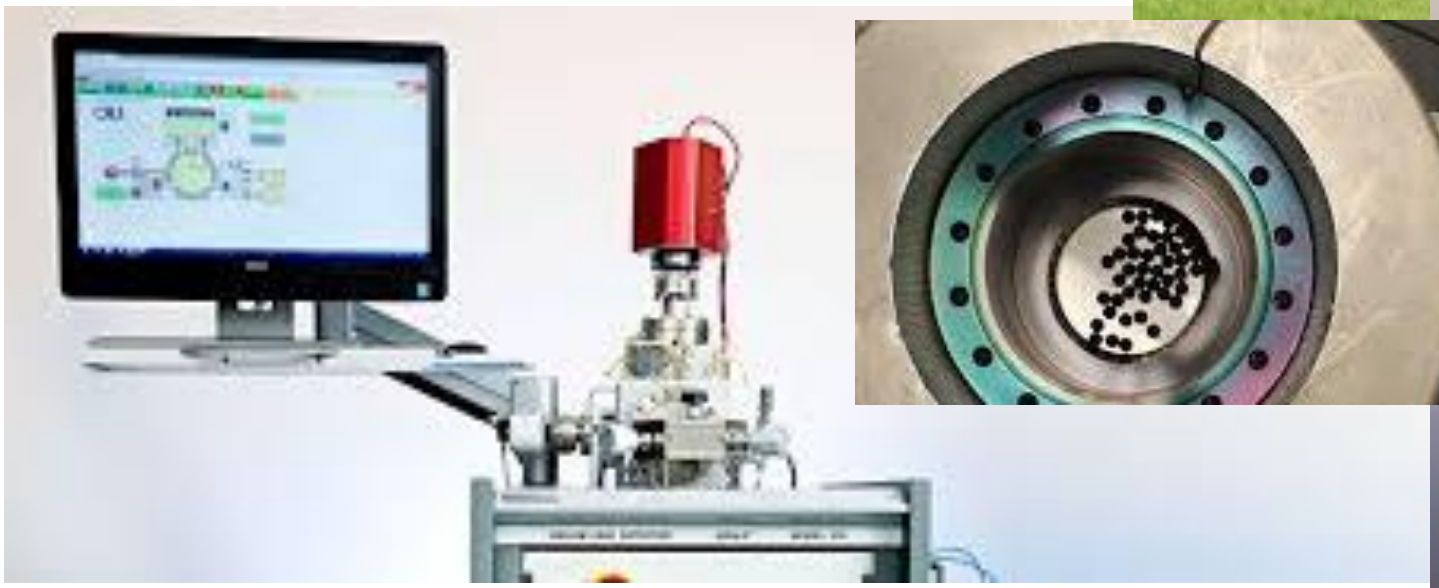
$$Q_{H_2O} = Outgassing\ rate\ of\ moisture\ in\ torr.l/s$$

$$I_{H_2O} = Average\ ion\ current\ at\ mass\ 18\ for\ the\ 10\ scans\ in\ the\ last\ dwell\ step$$

$$S_{eff} = Effective\ pumping\ speed$$

The outgassing rate for moisture should be less than **2×10^{-10} torr/s per gram** of adhesive material (either direct or as component of a package). This outgassing rate will release less than 5000 ppmv of moisture if **one gram of adhesive** is sealed in **one cubic centimeter package** in period of **one year**. The validation criteria should be updated based on the actual amount of adhesive, volume of the package and desired time of operation.

Thank you.



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