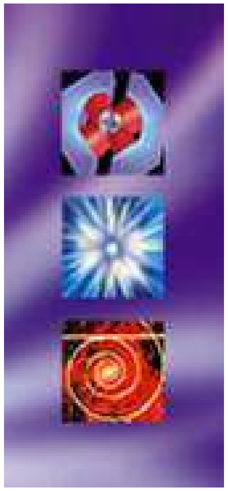
Cleaning for UHV/XHV at Daresbury Laboratory



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Outline

- Cleaning – Why?
- Brief Review of Cleaning Methods Available
- Development of Cleaning Processes at Daresbury Laboratory
- Latest Results of Recent Investigation
- Current and Future Challenges – eXtreme High Vacuum (XHV)

Cleaning – Why?

- **It's all about the end product, what do we want to achieve….**
  - **Particles to pass through accelerator WITHOUT scattering**
    - Maintain Satisfactory Lifetime Stored Electron Beam
- **Electron Scatter ∝ Atomic Number²**

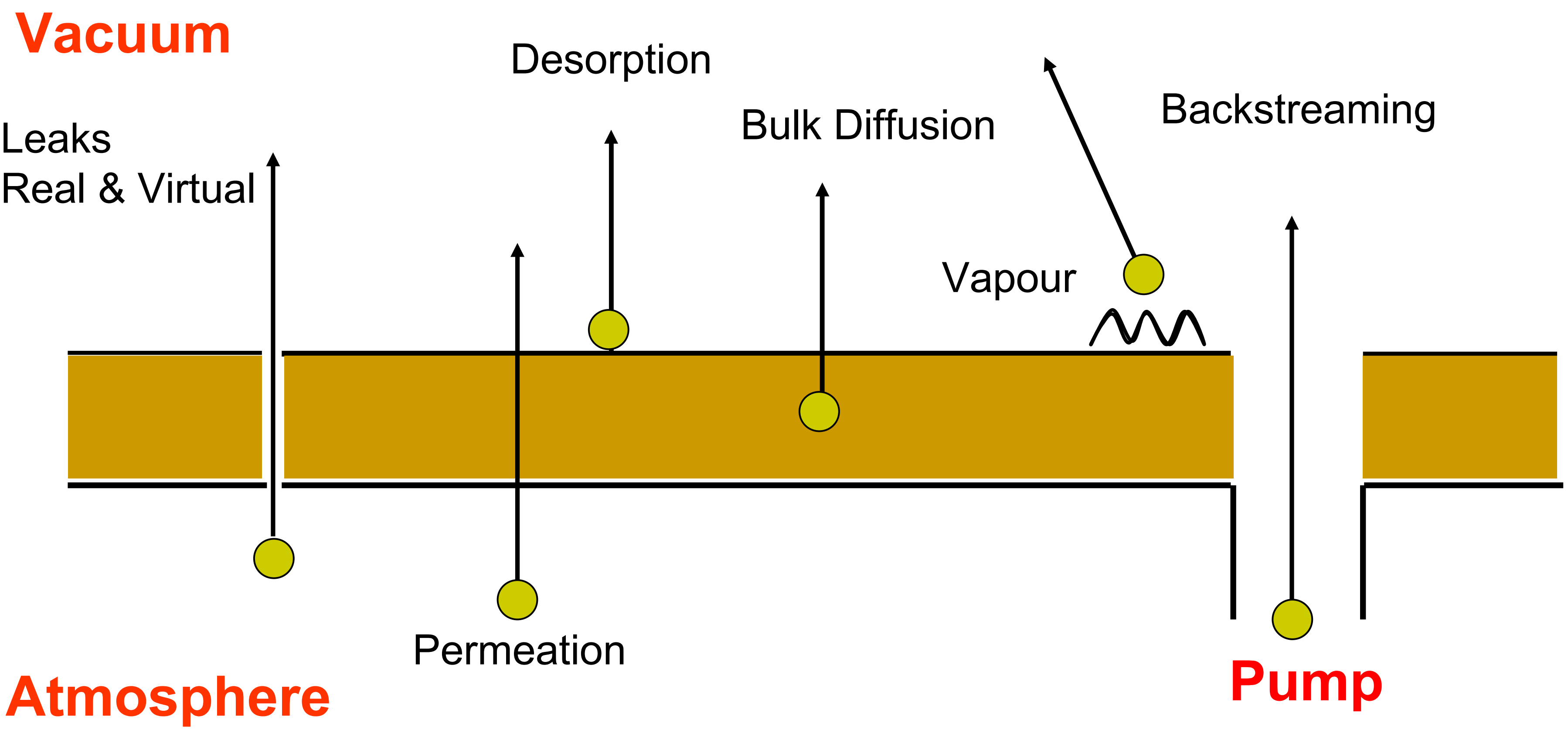
- **Reduce Outgassing Rates - Low Presence of High Mass Species**
  - Hydrocarbons < 0.1%   Pump Lubricants < 0.01%

- **Stimulated desorption – Usually the MAJOR Gas Load**
    - Photon Stimulated **Desorption** (PSD)
    - Electron Stimulated **Desorption** (ESD)
    - Ion Impact **Desorption**
    - Increased Thermal **Desorption**

- **Maintain Clean In-Vacuum Surfaces**
  - Coating Deposition
  - Prevent Particle Target Poisoning
  - Maintain Efficient Optical Properties for EM Radiation Transport

☞ **Cleanliness is an 'Essential Step' in achieving this**

Sources of Residual Gas



So to Reduce Residual Gas, we must Inhibit or Reduce these processes

Broad Range of Methods Available

Chemical	**Thermal Treatment**	**Polishing**	**In-Situ Treatment**	**Others…**
Wash – Detergent or Solvent	Vacuum **Bakeout**	**Electro-Polish**	Vacuum **Bakeout**	**Bead Blasting**
Ultrasonic – Aqueous or Solvent	**Vacuum Fire** (typical ~950C for STST)	**Diamond Paste** Machine/Manual	**UV Lamps**	**CO2 Snow**
Vapour Clean– Solvent	**Air Bake** (up to ~ 400C)	**Plasma Etch**	**Glow Discharge**	
ACID Etch – Pickling or Passivation	**Vacuum Remelt**	**Diamond Turning**	**Chemical**	
Power Wash – Water Jet		**BCP-Buffered Chemical Polishing**		

Selecting A Cleaning Method

- Can be difficult….
  - Conflicting views
  - Legislation varies country to country
  - Cost
- So what often happens?

A. **Copy** an **existing proven method** from elsewhere.

B. **Develop a cleaning recipe** that is Practical & Economic but **Conservative** (Belt and Braces)

- When a cleaning process works it's usually **'Set In Stone'** , sometimes for many years without investigation!

Daresbury Cleaning History

Orginally

- **CERN UHV Procedures Sufficient** (Ultrasonic and Vapour Cleaning)
  - Trichloroethane
  - CFC113 (Freon)
- **Alkaline Degreasing** (Almeco/CERN)
- **Glow Discharge** (added following research at Liverpool University)

1990's

- Research Study to find alternative solution due to Environmental Protection Legislation (e.g. Kyoto Protocol)
  - Restricted use of Ozone depleting chemicals
  - Restriction then Ban of Trichloroethane and CFC113

Research Summary

✓ **Trichloroethylene** selected (comparable to Trichloroethane)

✗ **Aqueous** cleaners NOT SUFFICIENT alone but OK in combination with solvent.

✓ **Glow Discharge** – Dropped

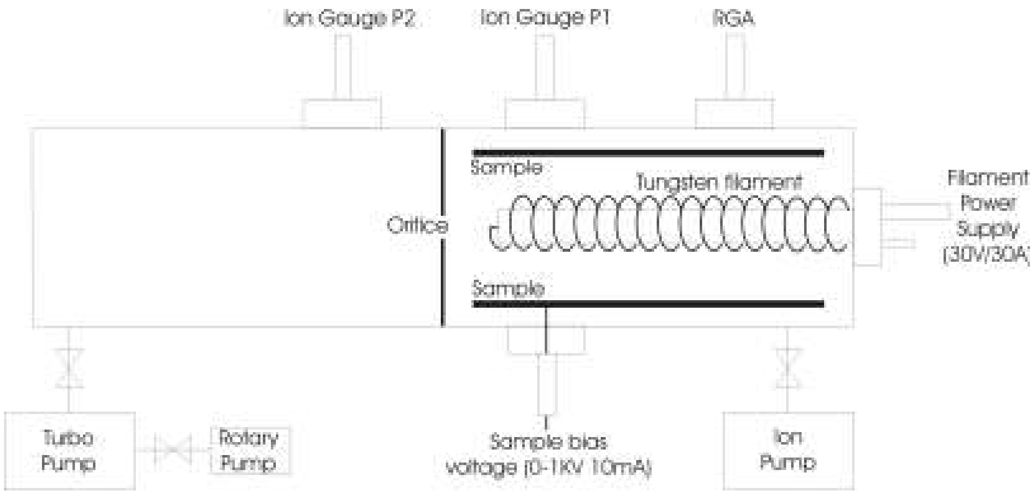
Daresbury Cleaning History

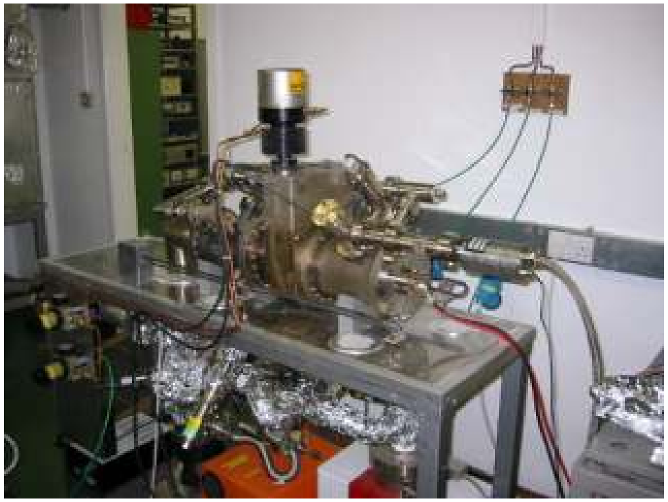
2000’s

- Tighter Environmental Protection **Legislation** and New H&S Legislation for VOC’s, SED and COSHH
  - ☹ Restricted Use & Emissions for all VOC’s under SED
    - ☹ Trichloroethylene re-classified as a Class 2 carcinogen.
    - ☹ Tighter Restrictions on use of Trichloroethylene!
- New research programme started to find suitable alternative

Replacement of Trichloroethylene

- What is important to us? - **Thermal outgassing and Stimulated Desorption**





$$Q = \frac{P1 - P2}{A} \cdot C$$

- Comparative Tests - existing procedure proven for 20 years

A Selection of Cleaning Agents Tested

- n-propyl bromide - LEKSOL
- n-propyl bromide - LENIUM

Bromine Based

- Hydrofluoroether – **HFE-72 DE** (>20 test runs)

HFE

- Isopropyl Alcohol

Alcohol

- Aqueous Cleaner 1 - MICRO 90
- Aqueous Cleaner 2 - LANCERCLEAN
- Aqueous Cleaner 3 - BANNERCLEAN

Aqueous

- Methylene Chloride

Stable Chlorinated

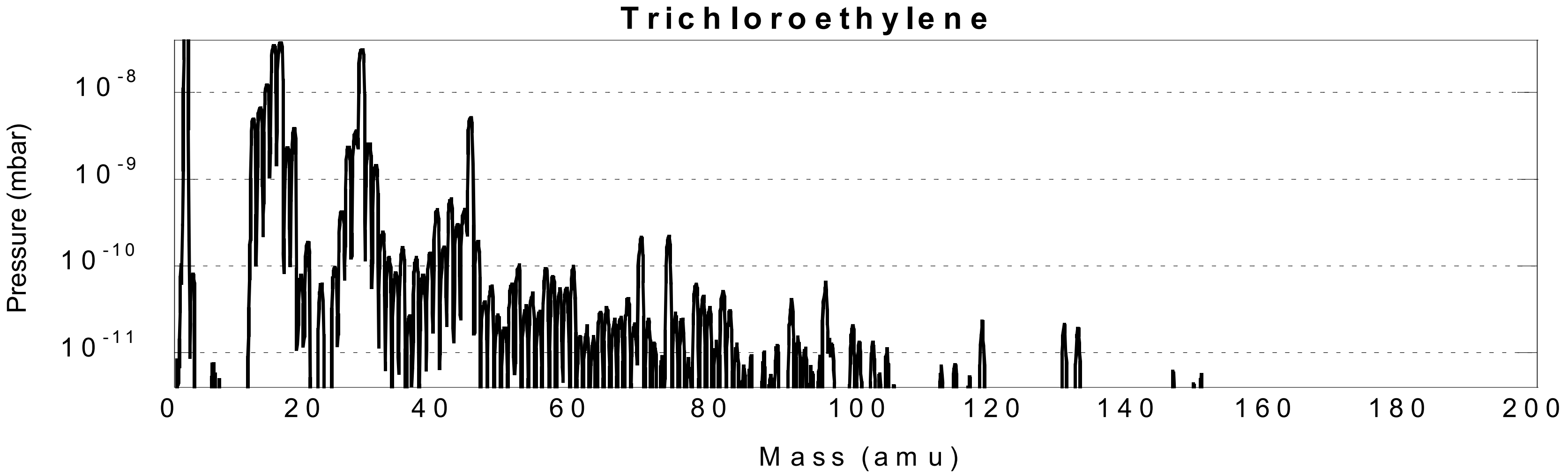
- Co-Solvent (HFE71 + 1,2 trans-dichloroethylene) -
- Co-Solvent (HFE71 + Isopropyl alcohol)

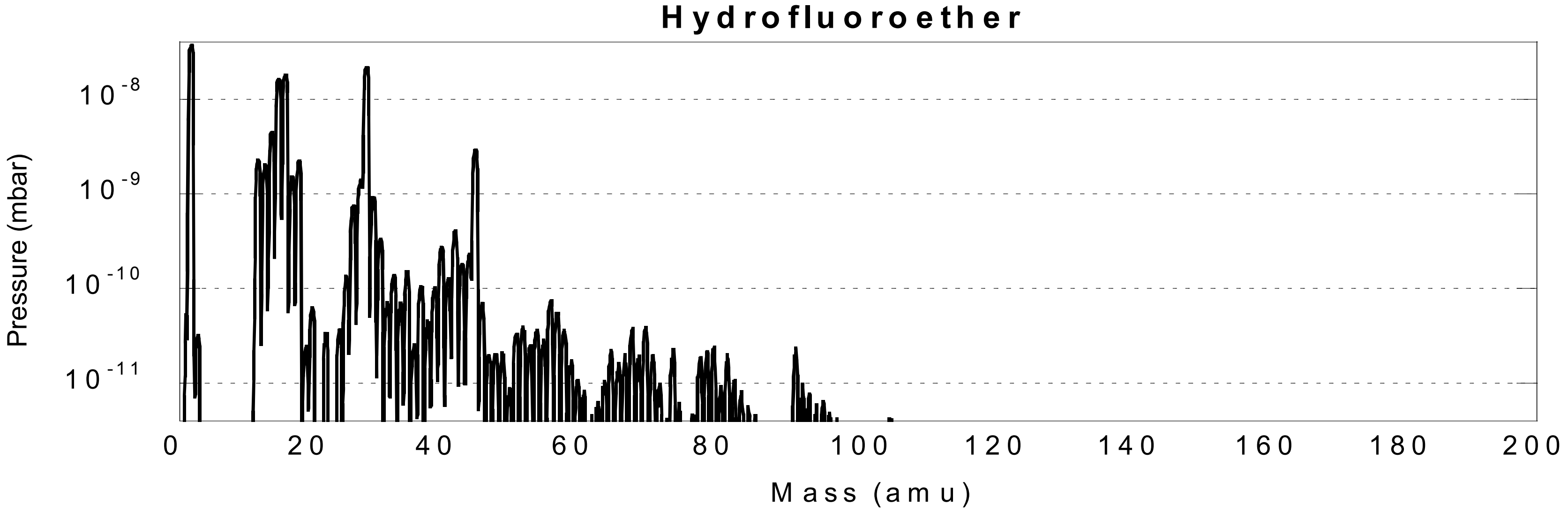
Co-Solvent

Cleaning Project Results

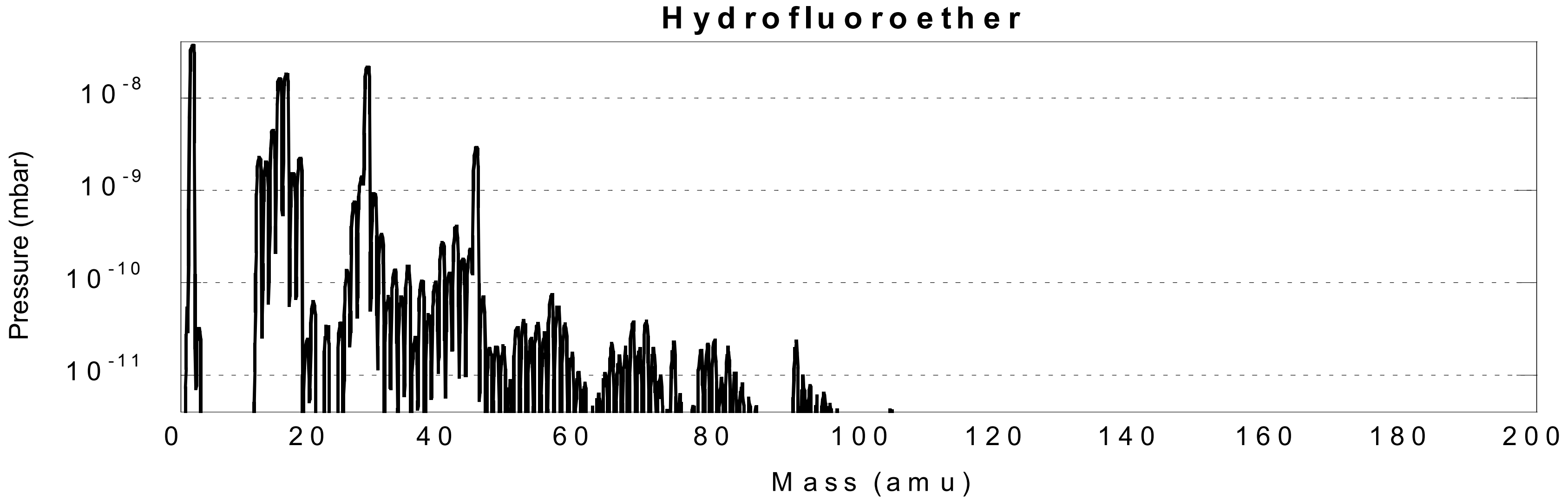
Cleaning Agent	Net thermal outgassing rate due to residual contaminants (mbar l s^{-1} cm^{-2})	Hydrocarbon contamination (%)	Ratio of Mass 69 to Mass 28	Pressure rise from ESD (mbar)	Desorption Yield (molecules/electron)
Blank Run (No sample)	8.2 x 10^{-13} ± 5.8 x 10^{-13}	0.46	1.8 x 10^{-4}	-	-
Trichloroethylene (No contamination)	<2 x 10^{-12}	0.58	3.2 x 10^{-4}	-	-
Trichloroethylene (No contamination)	<2 x 10^{-12}	0.53	8.3 x 10^{-4}	-	-
Trichloroethylene (Full contamination)	<2 x 10^{-12}	0.90	8.5 x 10^{-4}	6.3 x 10^{-6}	**0.055**
Trichloroethylene (Full contamination)	<2 x 10^{-12}	0.92	5.8 x 10^{-4}	-	-
n-propyl bromide 1 – Manufacturer 1	<2 x 10^{-12}	1.34	6.1 x 10^{-4}	3.6 x 10^{-6}	0.29
n-propyl bromide 2 – Manufacturer 2	6 x 10^{-12} ± 2 x 10^{-12}	2.52	1.9 x 10^{-2}	2.7 x 10^{-5}	2.19
Hydrofluoroether – Experiment 1	<2 x 10^{-12}	0.52	4.3 x 10^{-4}	2.1 x 10^{-7}	**0.017**
Hydrofluoroether – Experiment 2	<2 x 10^{-12}	0.86	2.7 x 10^{-4}	-	-
Isopropyl alcohol	<2 x 10^{-12}	0.93	1.0 x 10^{-3}	4.3 x 10^{-6}	0.35
Aqueous cleaner 1	<2 x 10^{-12}	2.86	1.6 x 10^{-3}	5.5 x 10^{-5}	4.46
Aqueous cleaner 2	1.2 x 10^{-11} ± 2 x 10^{-12}	2.03	1.93 x 10^{-3}	3.7 x 10^{-5}	2.99
Aqueous cleaner 3	<2 x 10^{-12}	2.70	2.2 x 10^{-3}	2.6 x 10^{-5}	2.12

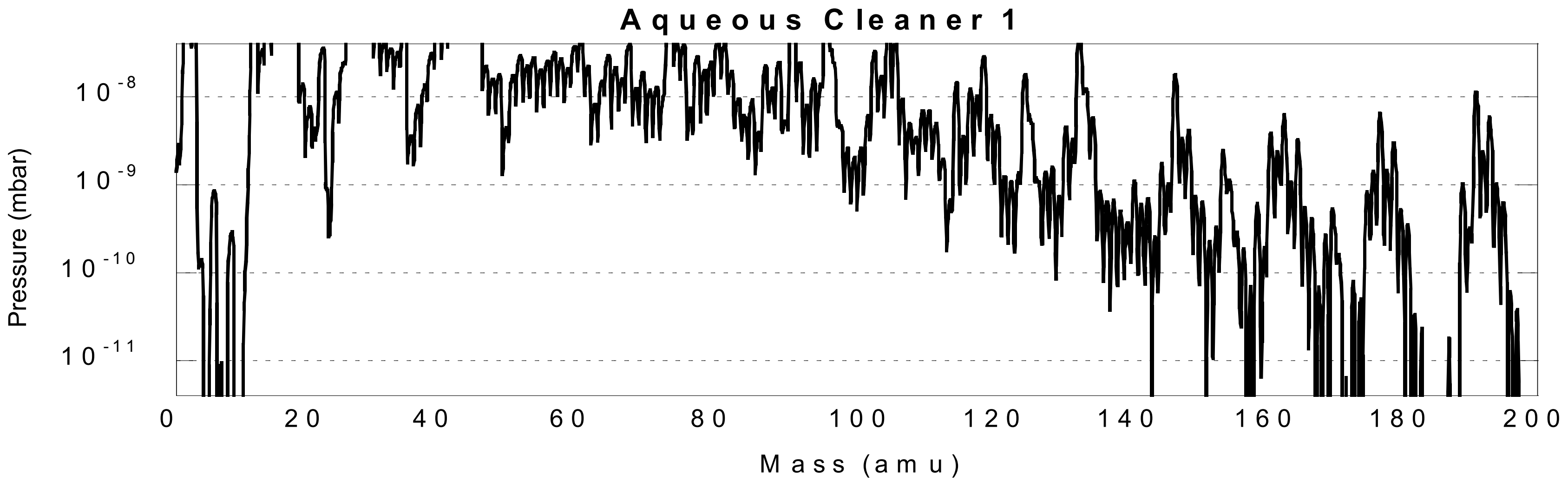
ESD RGA data for HFE and Trike



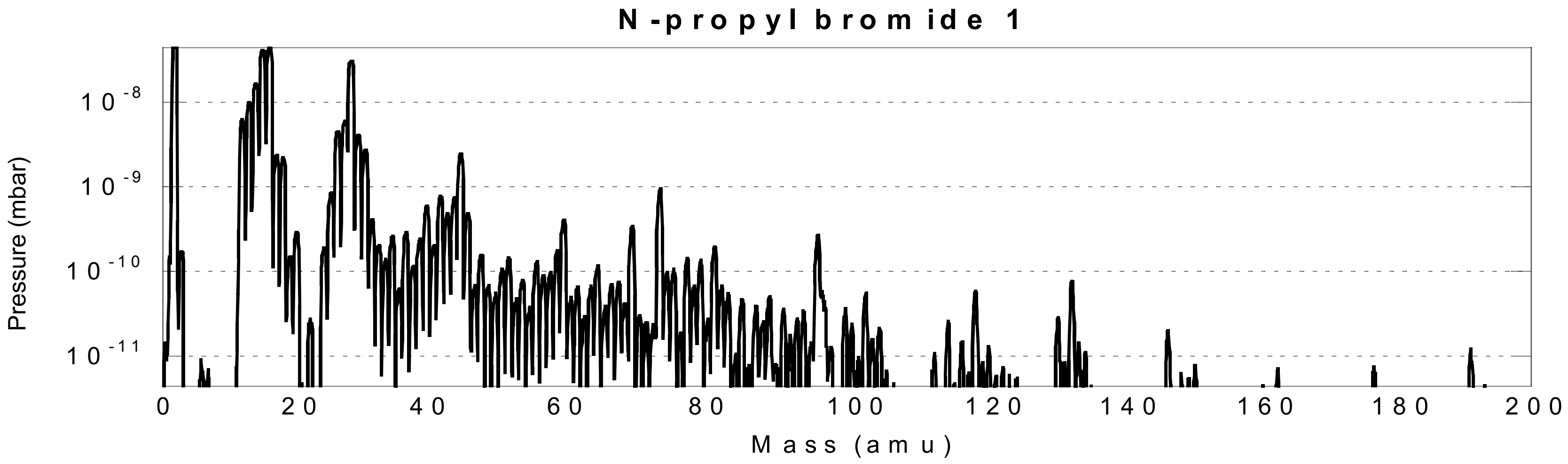


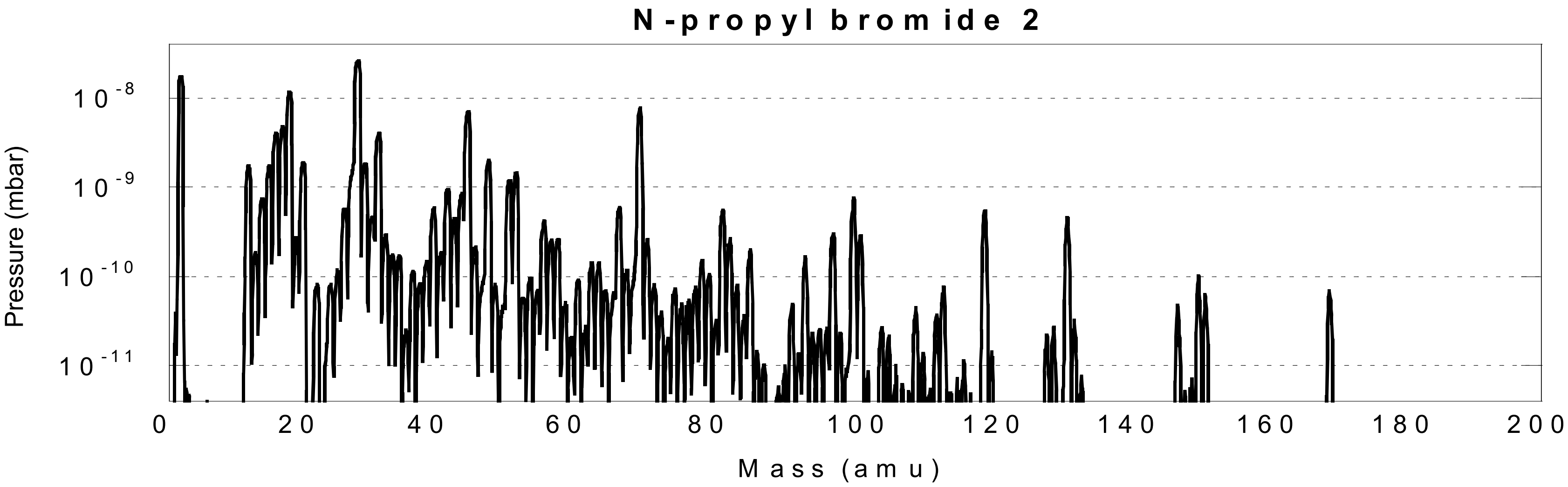
ESD RGA data for Aqueous and Solvent (HFE)



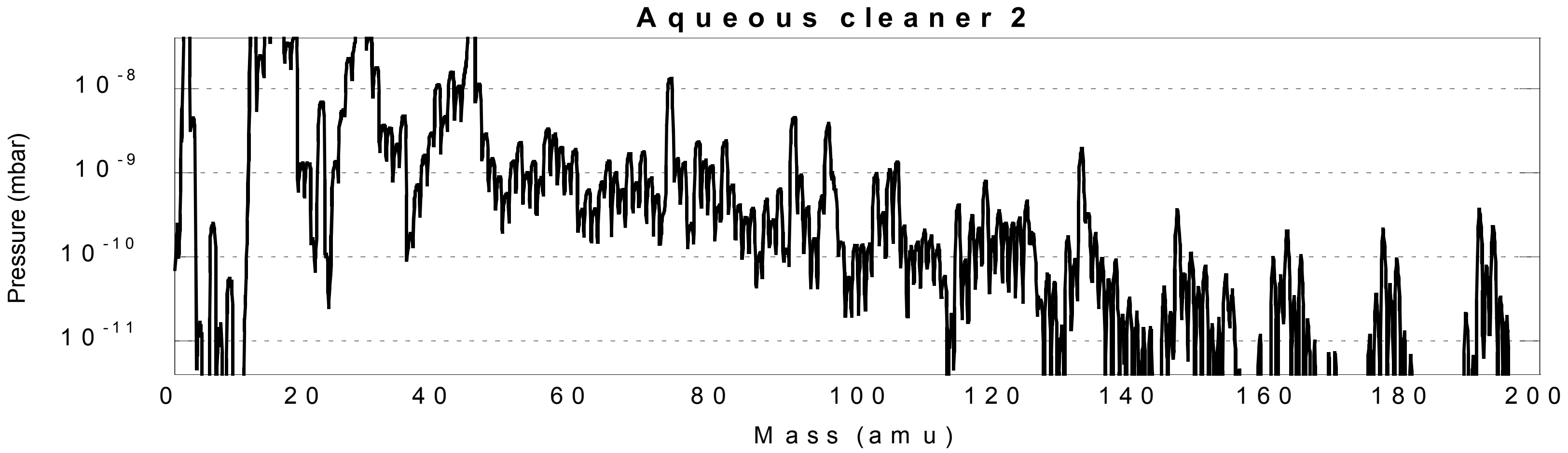


Cleaning Project ESD Results – N-propyl bromides

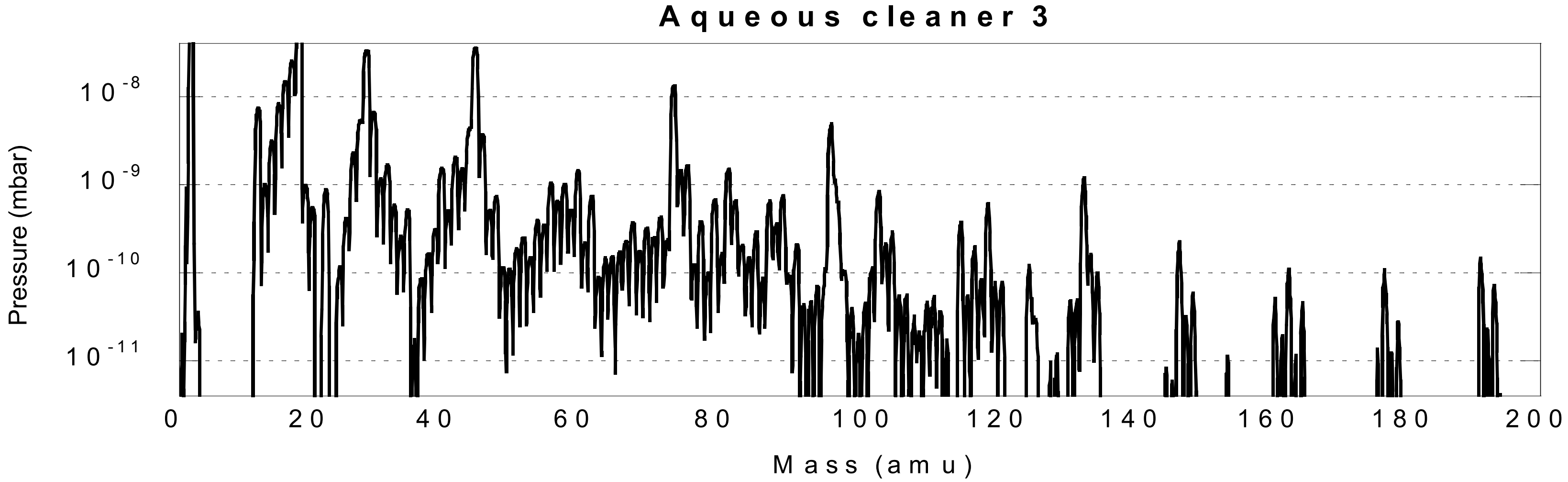




Cleaning Project ESD Results – Aqueous Cleaners



Aqueous cleaner 2



Aqueous cleaner 3

Summary of Findings

- Some Modern **Aqueous Cleaners** clean as well as solvents when considering Room Temperature Outgassing

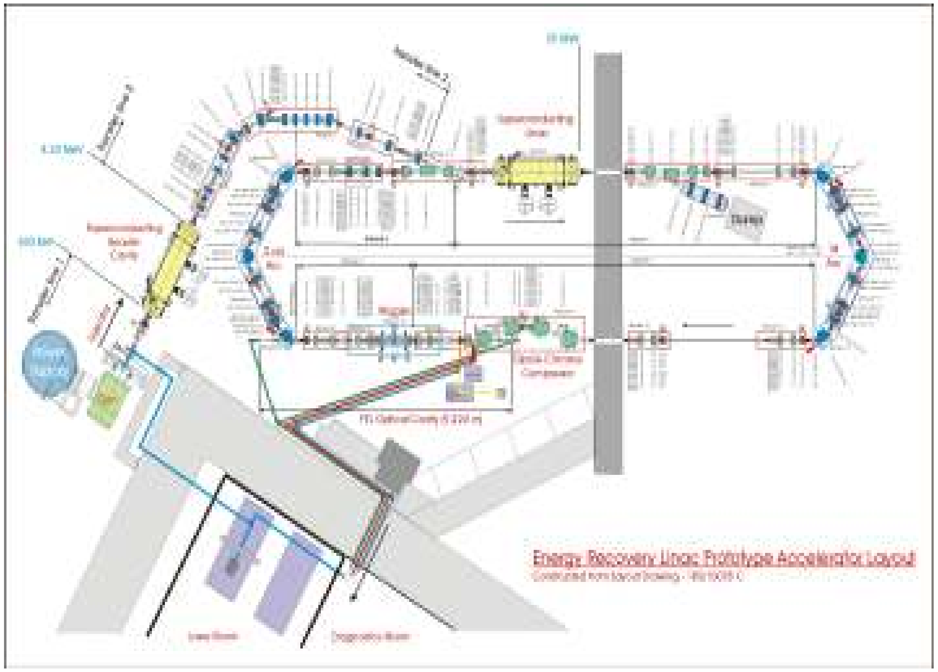
- **ESD Data** – Solvents Much Better

- **HFE** (Hydrofluoroether – 3M™ Novec™) – Preferred Trike replacement

- Reference:- Phase 1 – **Vacuum 81 (2007) 793-798** *
  Phase 2 – In Print

Current and Future Challenges

- Currently Developing XHV and Low Particle Processing Techniques
  - Use of SRF (**$P_T<10^{-10}$ mbar**, low levels of particles and surface contaminants)
  - Requirements for High Average Current Photoinjectors (**$P_T<10^{-11}$ mbar**, **$P_{O2}<10^{-14}$ mbar**, low levels of particles and surface contaminants)
  - **Reduce gas density in region of photo-injector**
  - E.g. To reduce **ion back bombardment** on photocathode material and to prevent **cathode poisoning**. May lead to reduced QE.



Particle Control

CLEANROOM TECHNOLOGY

CLEANROOM DISCIPLINES

ENTRY AND EXIT OF PERSONNEL

Particle Control

- Systems of flushing and counting particles
- Use of Clean Hoods and Clean Rooms
- Careful Design to Minimize Particle Sources or Position Them Safely away from Beam.
- Careful Selection of in-vacuum components
- Use of gas filters during let up
- Controlled gas flow (pump down/letup speed)
- **Good Cleaning Procedures (HFE)**

Summary

- Why cleaning is so important for UHV/XHV
- Historical look at cleaning here at Daresbury
- Results of recent studies show solvents are a much better solution than aqueous cleaners for our application.
- Introduced particle control procedures.
- XHV requirements for a GaAs photocathode.
- Particle control for superconducting cavities.