A field-portable thermal desorption time-of-flight mass spectrometer

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Overview

- TOF-MS for field applications
- Kore Technology MS200
  - direct vapour sampling dual membrane inlet TOF
  - performance
- Modifications for rapid detection of semi-VOCs
  - Trap-Evacuate-Desorb (TED)
  - novel thin membrane
  - high temperature valve
- Prototype system
  - performance
- Summary

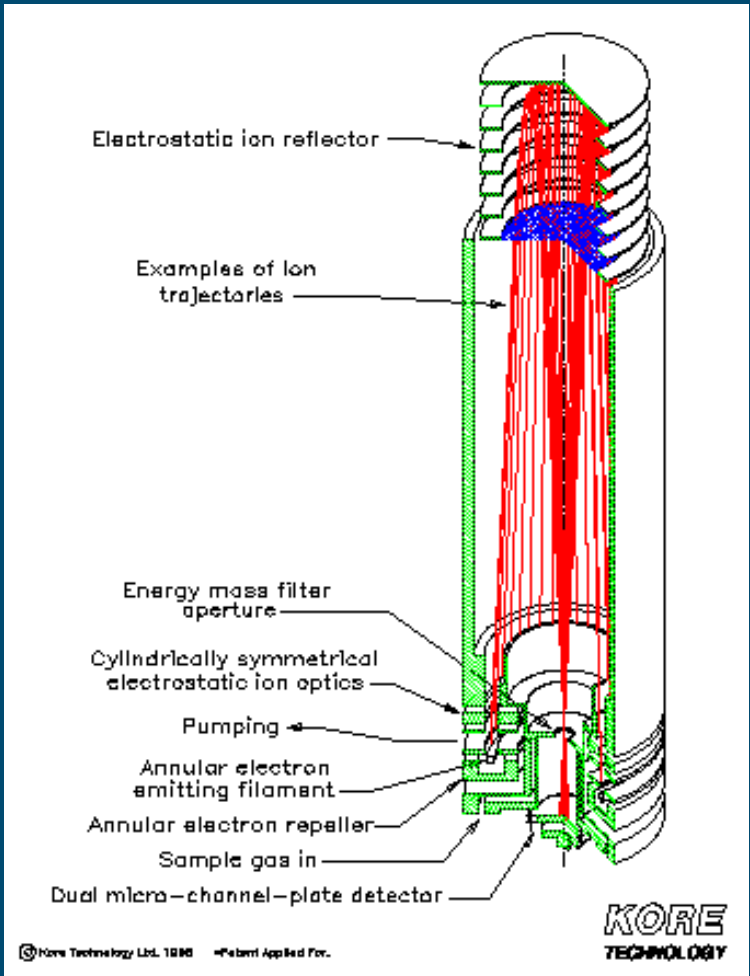
TOF-MS for field applications

- Advantages
  - all masses sampled in parallel
  - high duty cycle
    - sensitive
  - capable of high resolution
  - unlimited mass range
  - simple
    - rugged
- Disadvantages
  - high vacuum required
    - more power required
  - ionisation mechanisms restricted
    - less adaptable
  - not capable of MS/MS
    - less selective

Kore MS200

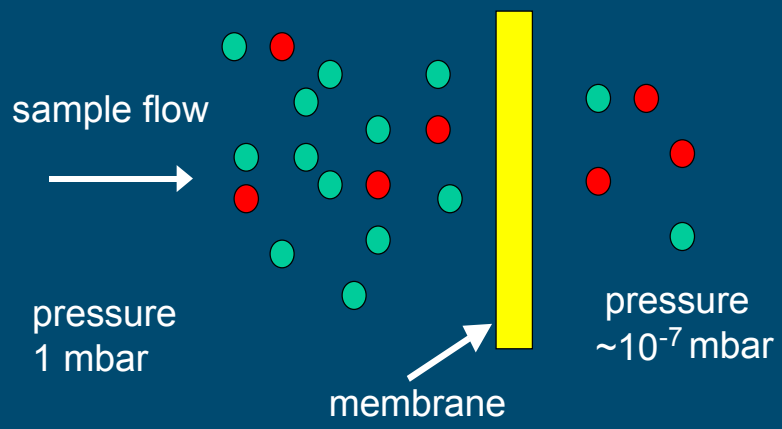
- Field-portable membrane inlet TOF-MS
  - sealed system
  - ion/ getter pumps
  - no consumables
  - battery powered
  - weight ~ 20 kg
  - library matching of unknowns
  - low ppb sensitivity
  - relatively low cost ~ £30K
  - VOC detection

Converging annular reflectron TOF



- Annular 70 eV EI filament source
  - more ions created than in point source
  - retains focussing benefits of point source
- 10^{-7}mbar operating pressure
  - 10^{-9} mbar base pressure
  - ion pump only requires low power
- Complete spectrum generated each analysis cycle
  - 50000 cycles per second
- High efficiency of analyser results in very high sensitivity

Membrane inlet

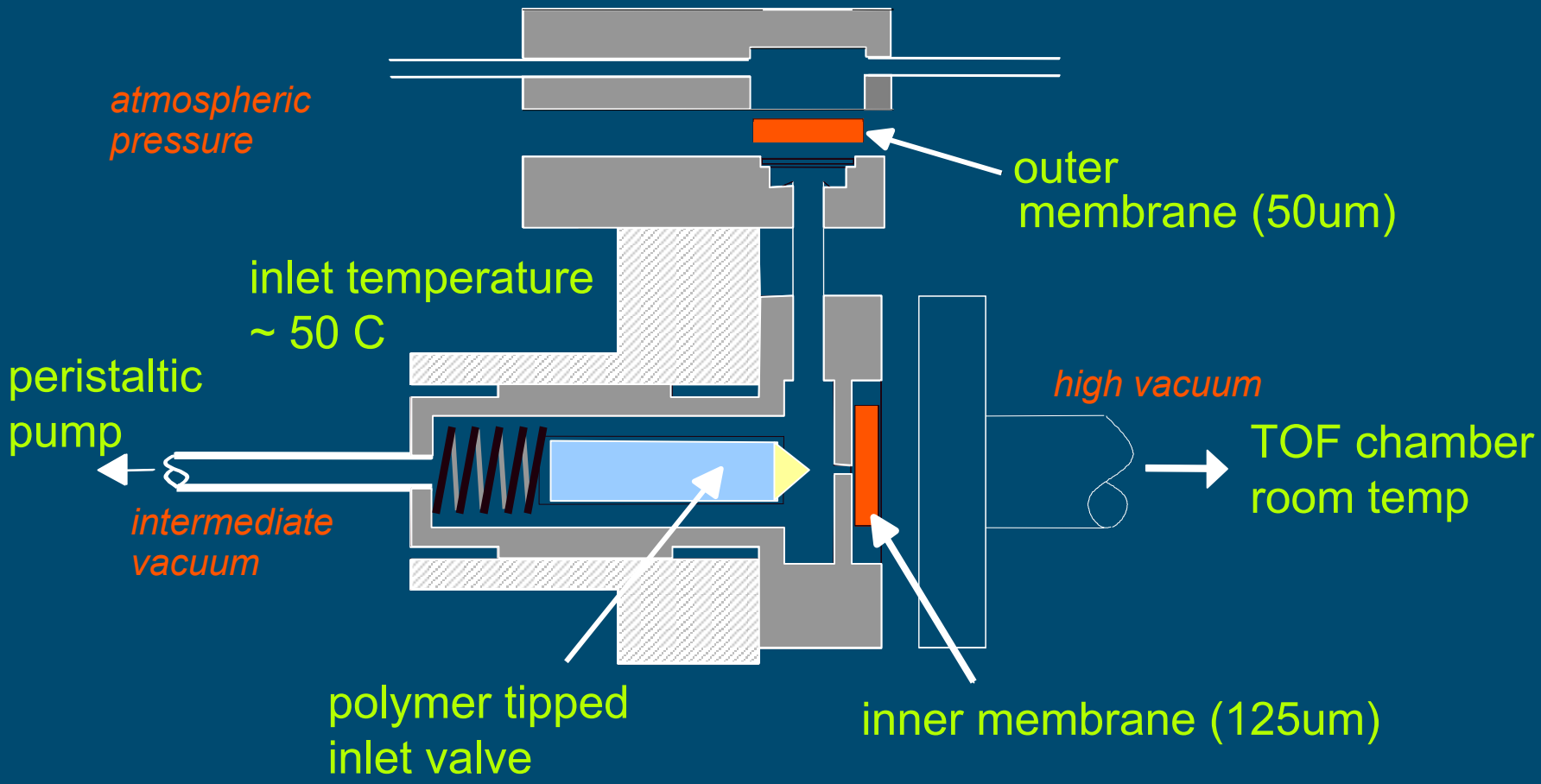


Membrane selectivity causes more of the analyte (red) to pass than the background (green).

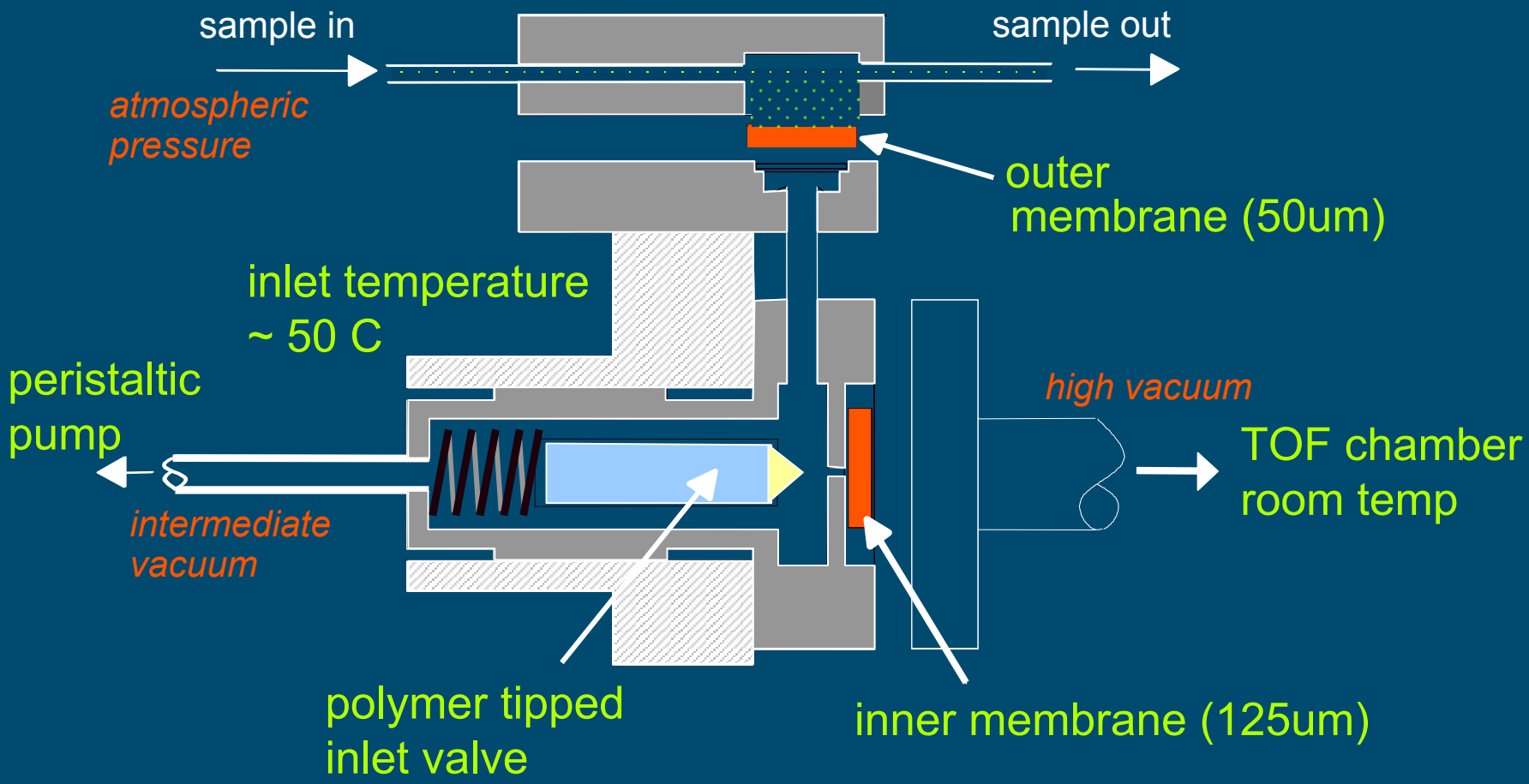
The concentration of analyte compared to the background is increased, although total pressure is much lower.

- Rate of permeation depends on:
  - membrane material
  - chemical and physical properties of analyte
  - temperature
  - partial pressure of the analyte on the two sides of the membrane
- Results in much improved sensitivity

MS200 standard inlet



MS200 standard inlet



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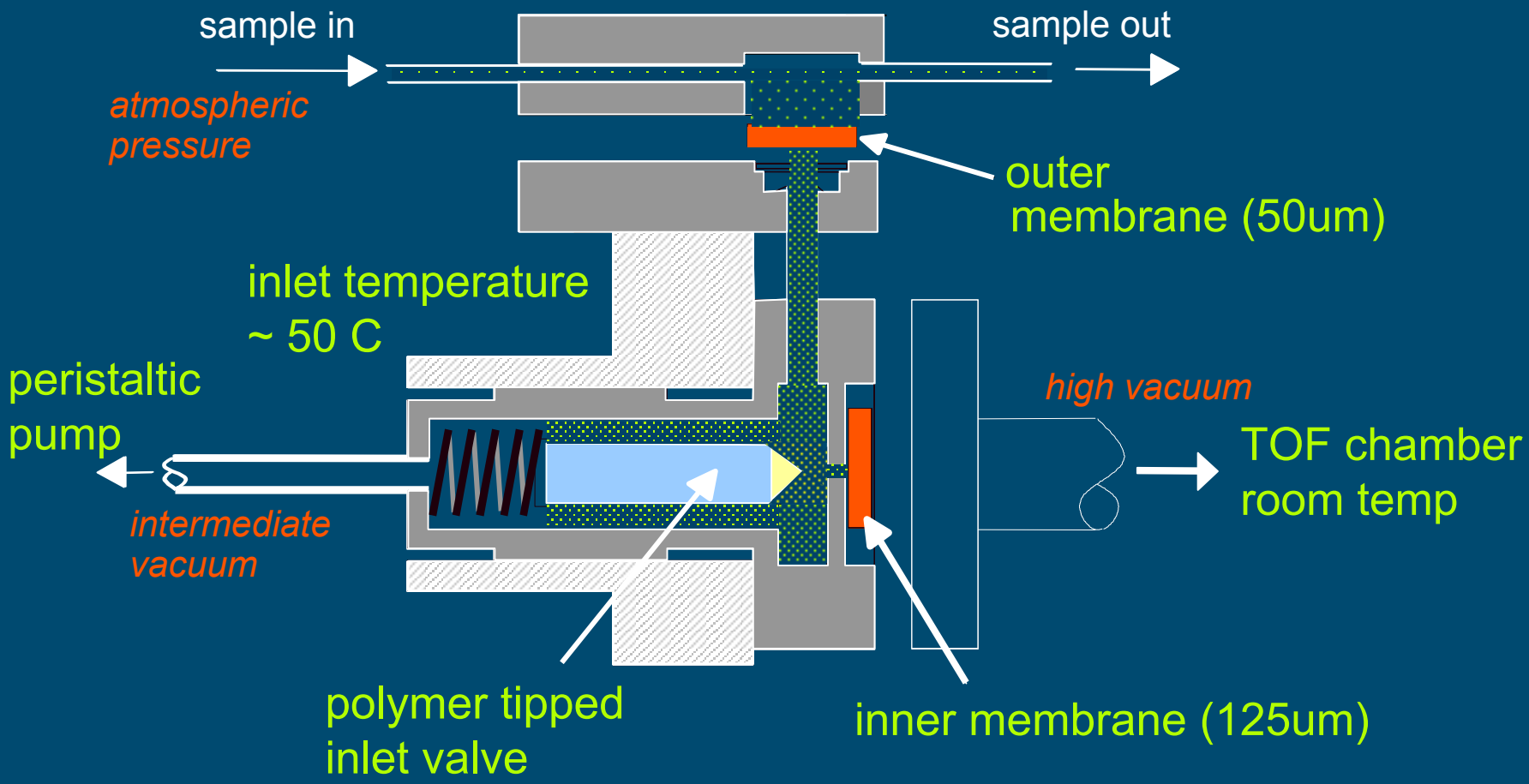
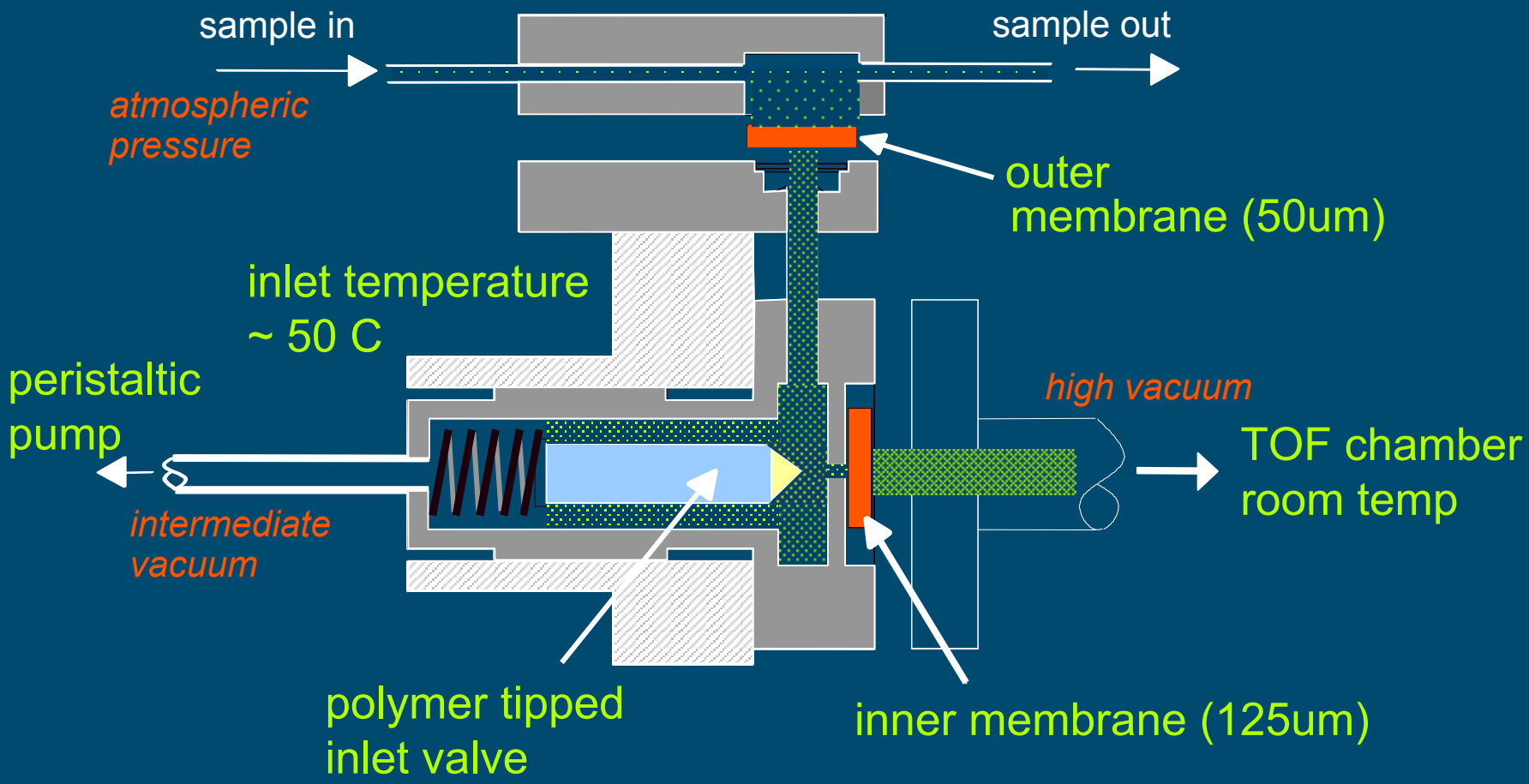
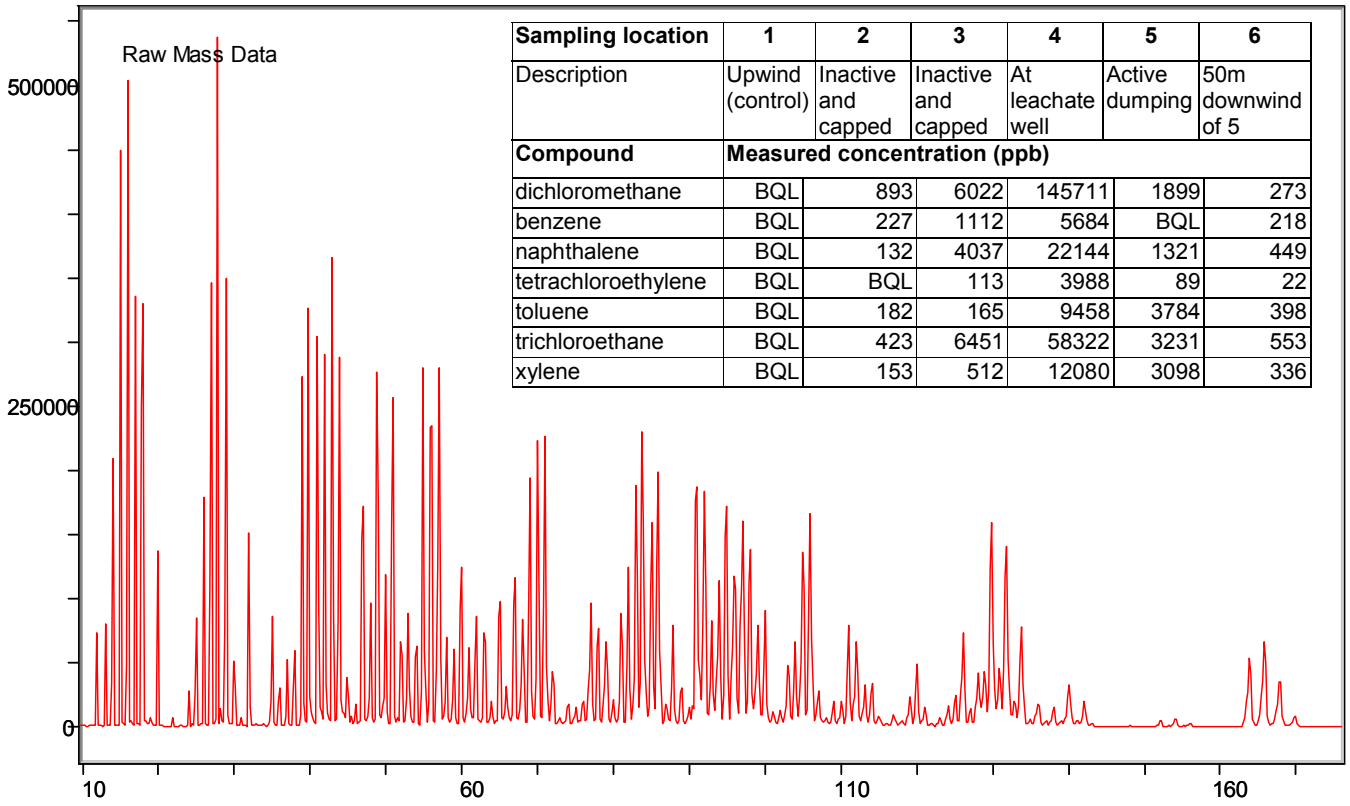


MS200 standard inlet



Mass spectrum- landfill site



Sampling location	1	2	3	4	5	6
Description	Upwind (control)	Inactive and capped	Inactive and capped	At leachate well	Active dumping	50m downwind of 5
Compound	**Measured concentration (ppb)**					
dichloromethane	BQL	893	6022	145711	1899	273
benzene	BQL	227	1112	5684	BQL	218
naphthalene	BQL	132	4037	22144	1321	449
tetrachloroethylene	BQL	BQL	113	3988	89	22
toluene	BQL	182	165	9458	3784	398
trichloroethane	BQL	423	6451	58322	3231	553
xylene	BQL	153	512	12080	3098	336

Requirements for semi-VOC analysis

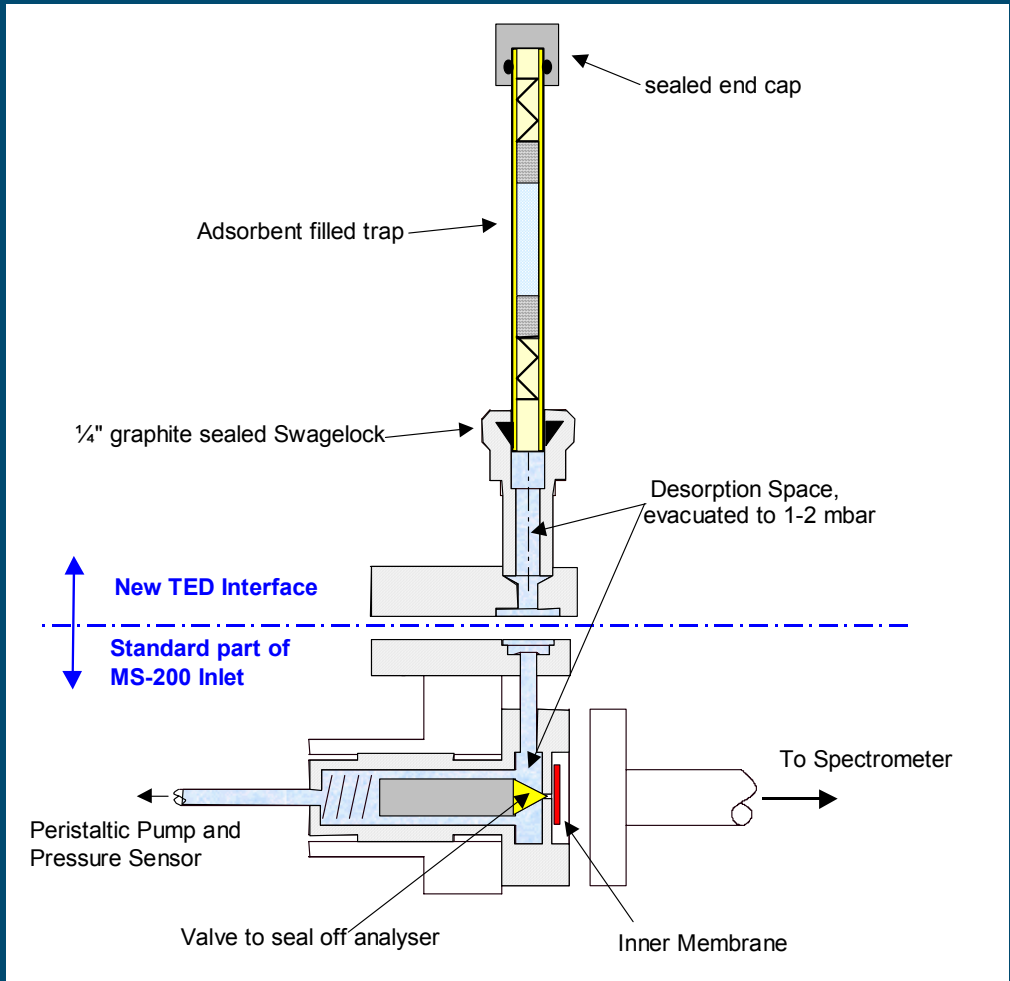
- Pre-concentrate sample
- Higher temperature operation
  - inlet valve critical
- Increase speed of analysis cycle
  - thinner membrane
  - faster pump-down

Pre-concentration & sampling

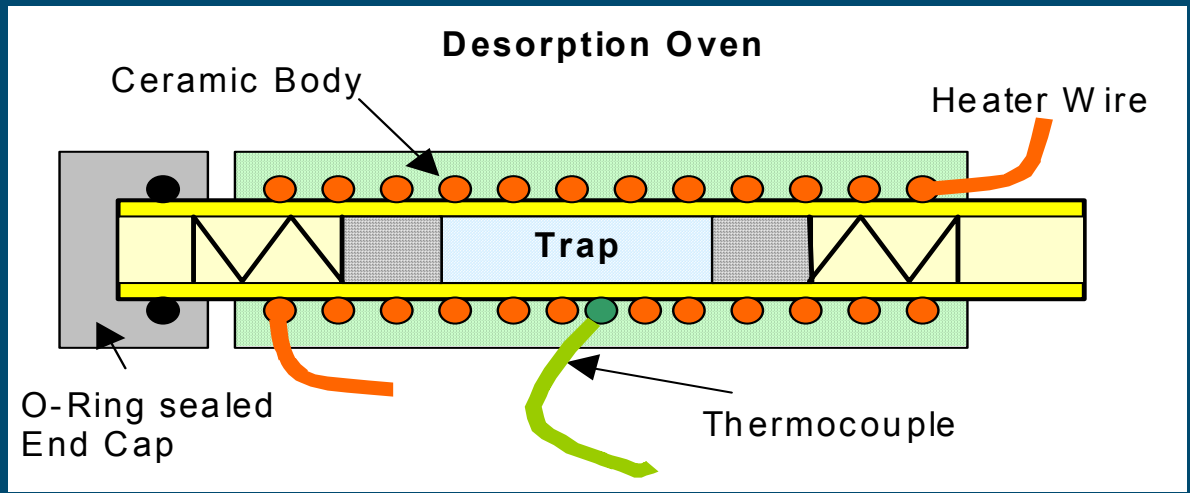
- Utilise Tenax tube (2 L/min sampling)
  - Tenax causes significant background
    - reduces selectivity and sensitivity
    - long sample release time
- Alternative pre-concentrator materials tested
  - polymer coated nickel foams
    - similar background problems
    - uncoated foams better (but lower capture efficiencies)
- Background subtraction important

Hand-held sampling unit

Single membrane with tenax trap

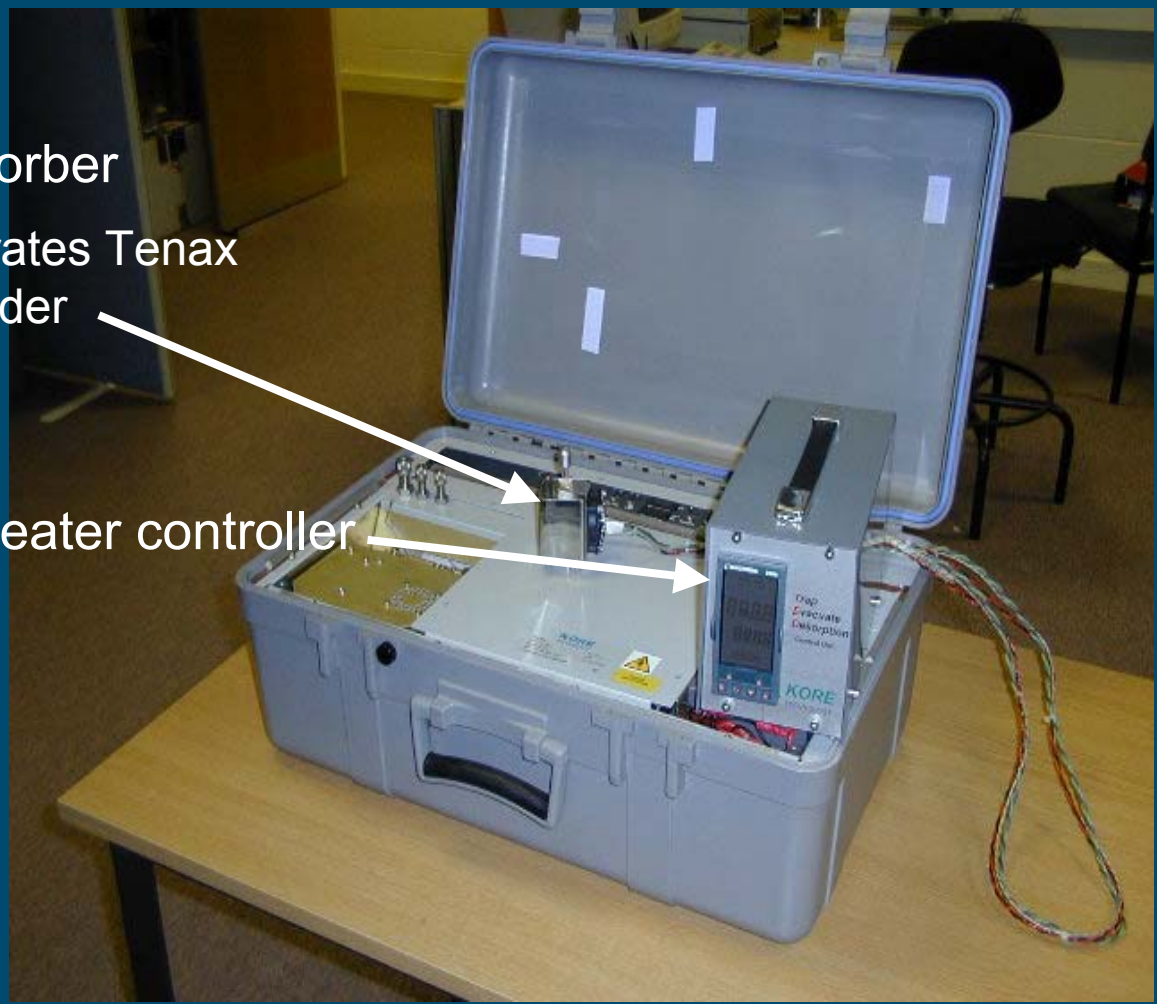


Desorb heater unit



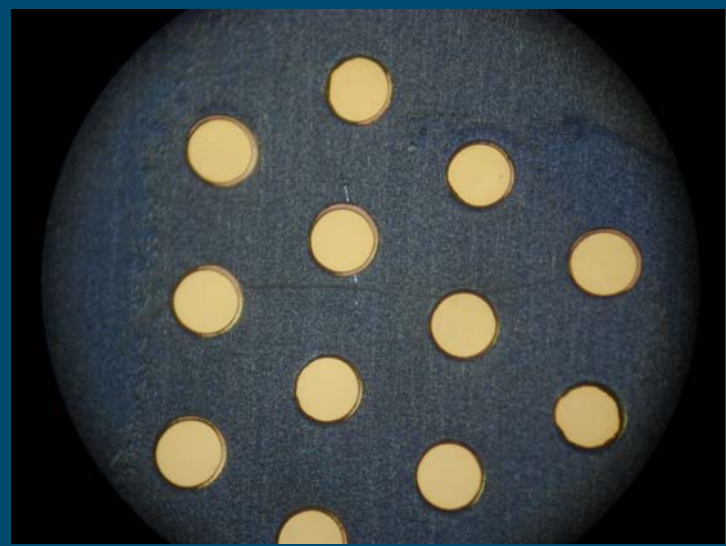
Retro-fit MS200 unit

- Bolt on desorber
  - incorporates Tenax tube holder
- Additional heater controller

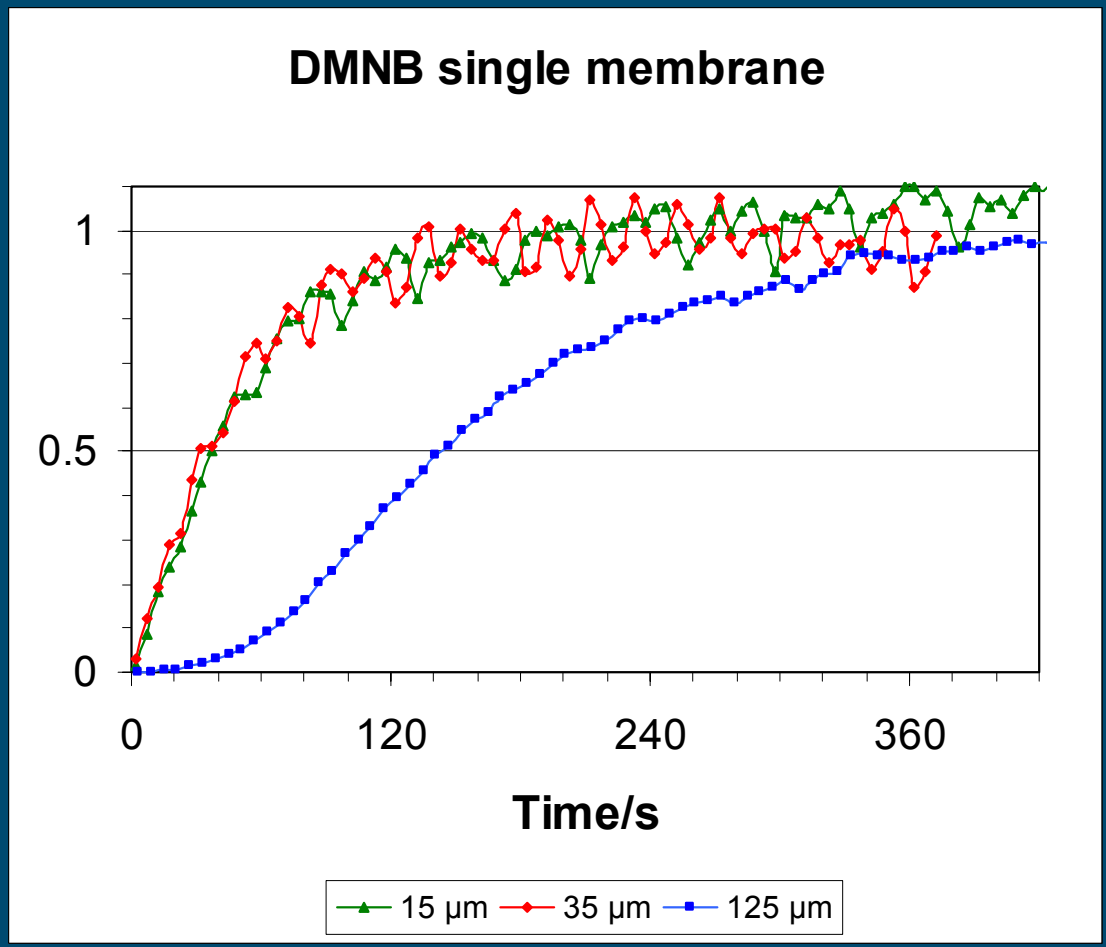


Thinner membrane

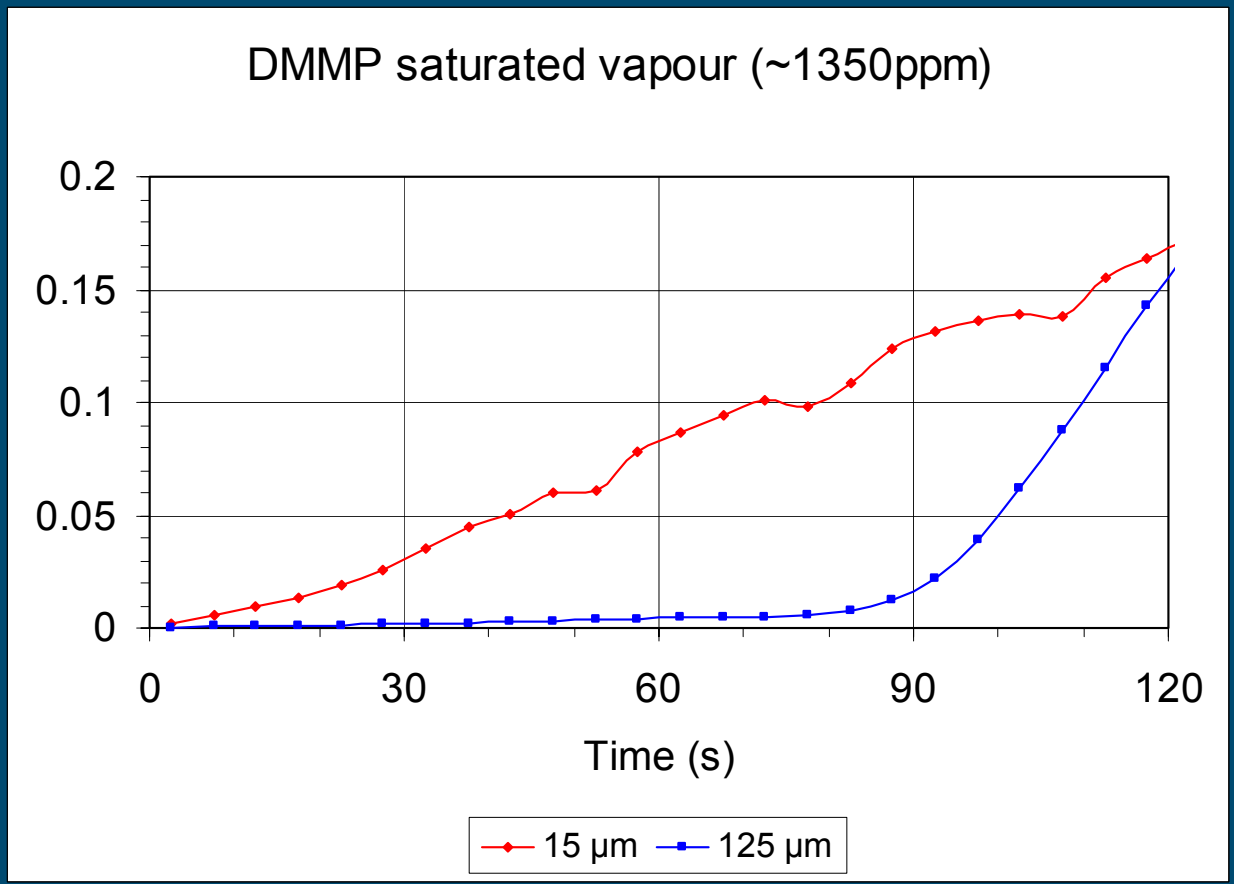
- Must be robust to withstand pressure differential
- Use mechanical support
- Maintain conductance and concentrating power
- Reduce equilibration time
- thickness ϕ n
  - 125 2mm 4
  - 50 800μm 10
  - 25 400μm 20
  - 2.5 40μm 200



Response time – DMNB (ICAO taggant)

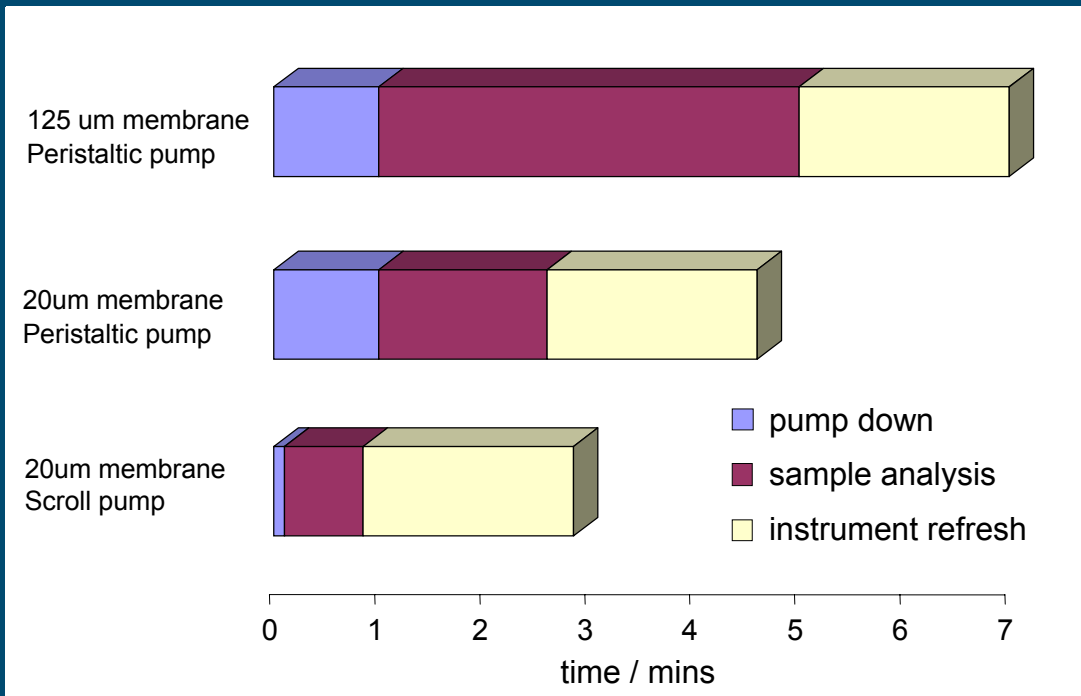


Response time – DMMP (CW simulant)



Analysis time

- Analysis time significantly reduced
  - incorporated new miniature scroll pump (Air Squared)
  - pump down to < 0.1 mbar in < 5 sec (previously 1 min)



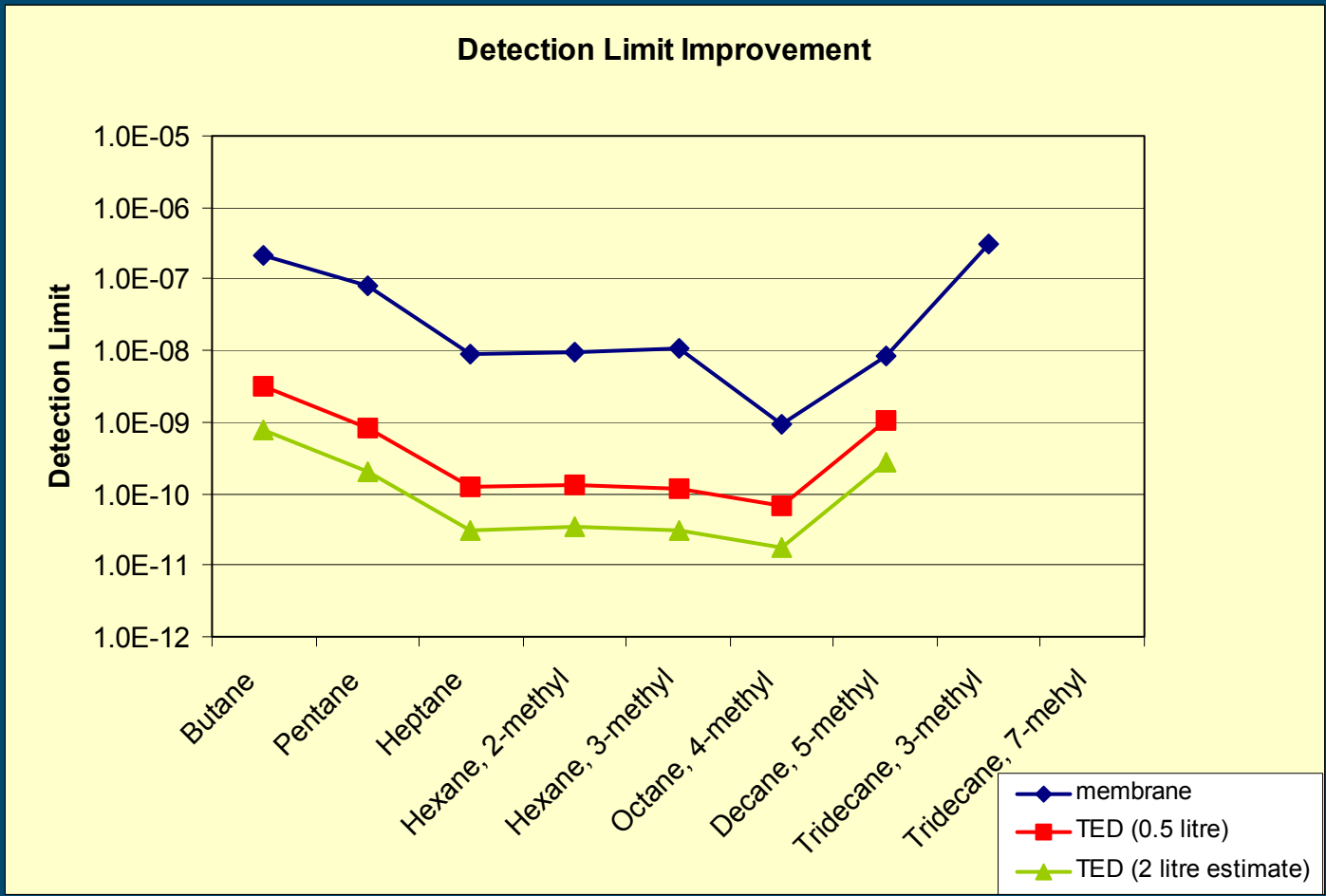
High temperature inlet valve

- To enable higher temperature operation
  - original valve has polymer tip (limited to 75 °C)
    - acts as sponge for analytes
    - deforms if baked under load
- Approach #1: Novel sapphire on copper sealed valve
  - lacked robustness
- Approach #2: Stainless steel on copper sealed valve
  - leak and robustness tested
  - retro-fitted to instrument

Prototype unit

Desorber

Detection limit improvement



Summary

- MS200 is a robust field-portable dual membrane inlet TOF-MS
  - VOC detection and identification
- Significant instrument improvements
  - Trap-Evacuate-Desorb (TED) unit
  - thin membrane for fast response time
  - high temperature valve for heated inlet region
  - scroll pump for rapid sample pump-down
  - 2 orders of magnitude sensitivity improvement (sub-ppb)
- Increased range of detectable compounds
  - semi-VOC detection and identification
- Selectivity limits instrument capability for more complex mixtures
  - signal processing and rapid separation techniques under development
- Field trials underway

Acknowledgements

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Questions