Low-Power Atmospheric Gas Sampling System Based on ART MS Sensor and NEG-Ion Pump

Sept 22, 2011

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Less is More ...

- The Workshop on Harsh-Environment Mass Spectrometry (HEMS) was created in 1999 as a means of encouraging interaction among people involved in deploying mass spectrometers outside of the typical laboratory setting.
- These environments are diverse, ranging from volcanoes and battlefields, to ocean depths, outer space and other rugged locales.
- Building mass spectrometers to withstand the rigors of such harsh and remote environments places a unique burden on engineering design and science objective planning, where operational requirements for power, size and durability must be met while achieving the goals of the scientific mission.

Source: http://www.hems-workshop.org/aboutus.html

Win some. Loose the rest!

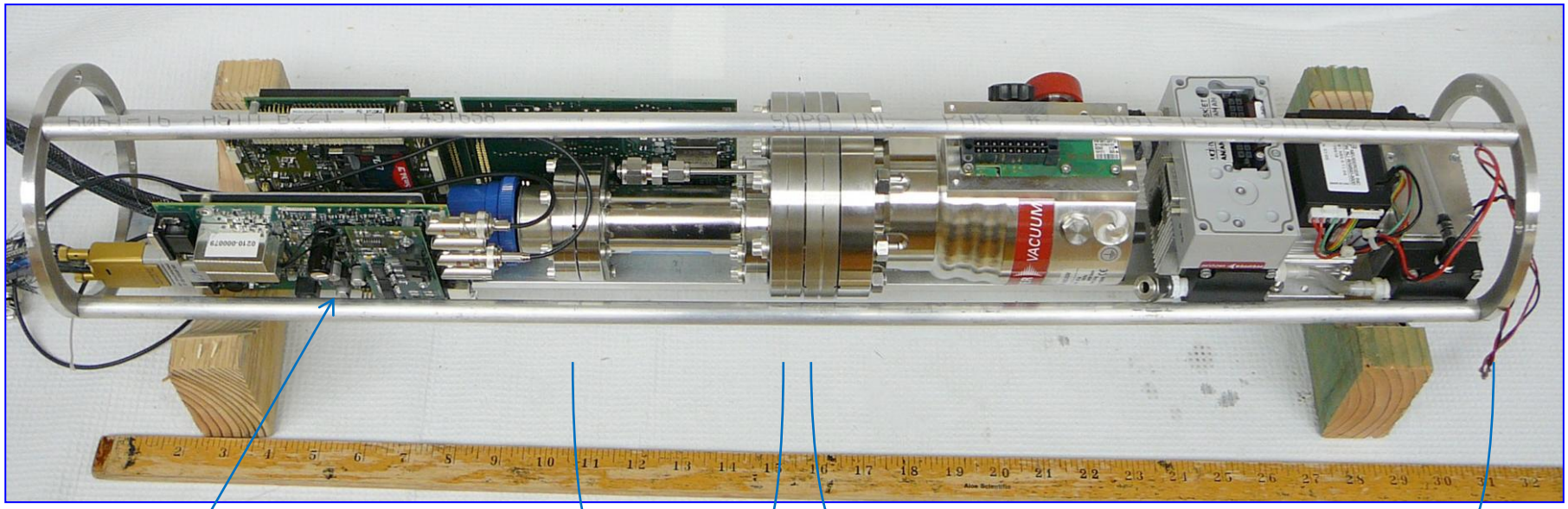
ART MS Sensors are characterized by their excellent sensitivity, fast scan rates, rugged design but particularly by their small size (scalable) and low power requirements.

Mass spectrometers must operate under high vacuum - Vacuum pumps are required system components for atmospheric gas samplers relying on ART MS sensors.

Vacuum pump stations are generally bigger and/or require more power than the ART MS sensor itself.

There is a need to identify/develop high vacuum pumps that match or beat the size and power requirements of ART MS sensors.

The Power/Size Conundrum…..



ART MS Single Board Controller

VQM 830 Sensor **(7.5W)**

Turbo Pump Station **(50W)**

Courtesy: Gary McMurtry, Pace Tech, Hawaii

High Vacuum Pump for ART MS

- High Pumping Speed >5L/s
- Low Power
- Small size
- Light Weight
- Large Gas Capacity
- Inert Gas Pumping (for air sampling)
- Low base pressure (for low background)
- Species Independent Pumping Speed

High Vacuum Pump Technologies

Three basic technologies considered:

- Turbo Pump
- Ion Pump
- Non-evaporable Getter Pump

High Vacuum Pump Technologies

Pump	Speed	Power	Size	Weight	Capacity	Back Pump	Species independence	Inert Gas
Turbo	>40							
Ion	>5			30Lb @ 60L/s				
NEG	>100						CH_4	
NEG + ION								

Do we need to build the NEG-Ion pumping system?

NEXTorr® - NEG–Ion Pump – SAES® Getters

NEG = Non-Evaporable Getter – Sorption Pump

NEXTorr D 100-5

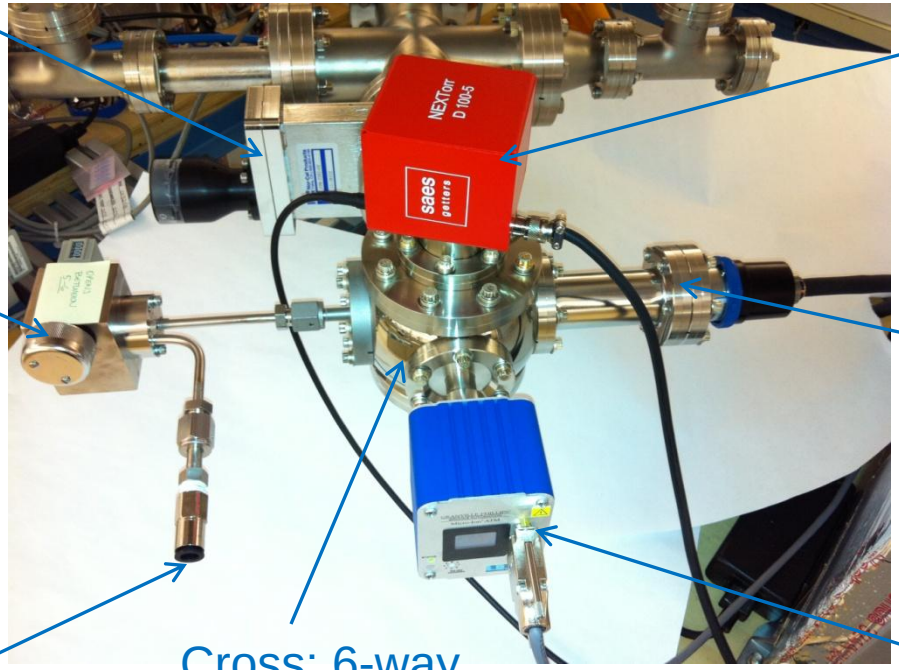
- High Pumping Speed for all active gases: NEG 10-100L/s
- Adequate pumping speed for Inert gases and methane: Noble ION >6L/s
- Adequate capacity (gas and pressure dependence)
- Minimal Power requirement during operation (5KV, mW)
- Extremely compact and light (0.5L, 2.2Kg)
- UHV ultimate pressure limit (E-9 Torr)
- Available controller provides automated NEG activation (500ºC, 1 hour) and independent ion pump control.
- Multiple Reactivations (>50)
- Total Pressure measurement

(NEXTorr – VQM 830) Gas Analyzer

Single-Stage Atmospheric Gas Sampling System

Gate Valve
(to TP system)

Variable Leak Valve
G-P Series 203



NEG-Ion Pump
NEXTorr D 100-5

ART MS Sensor
VQM 830

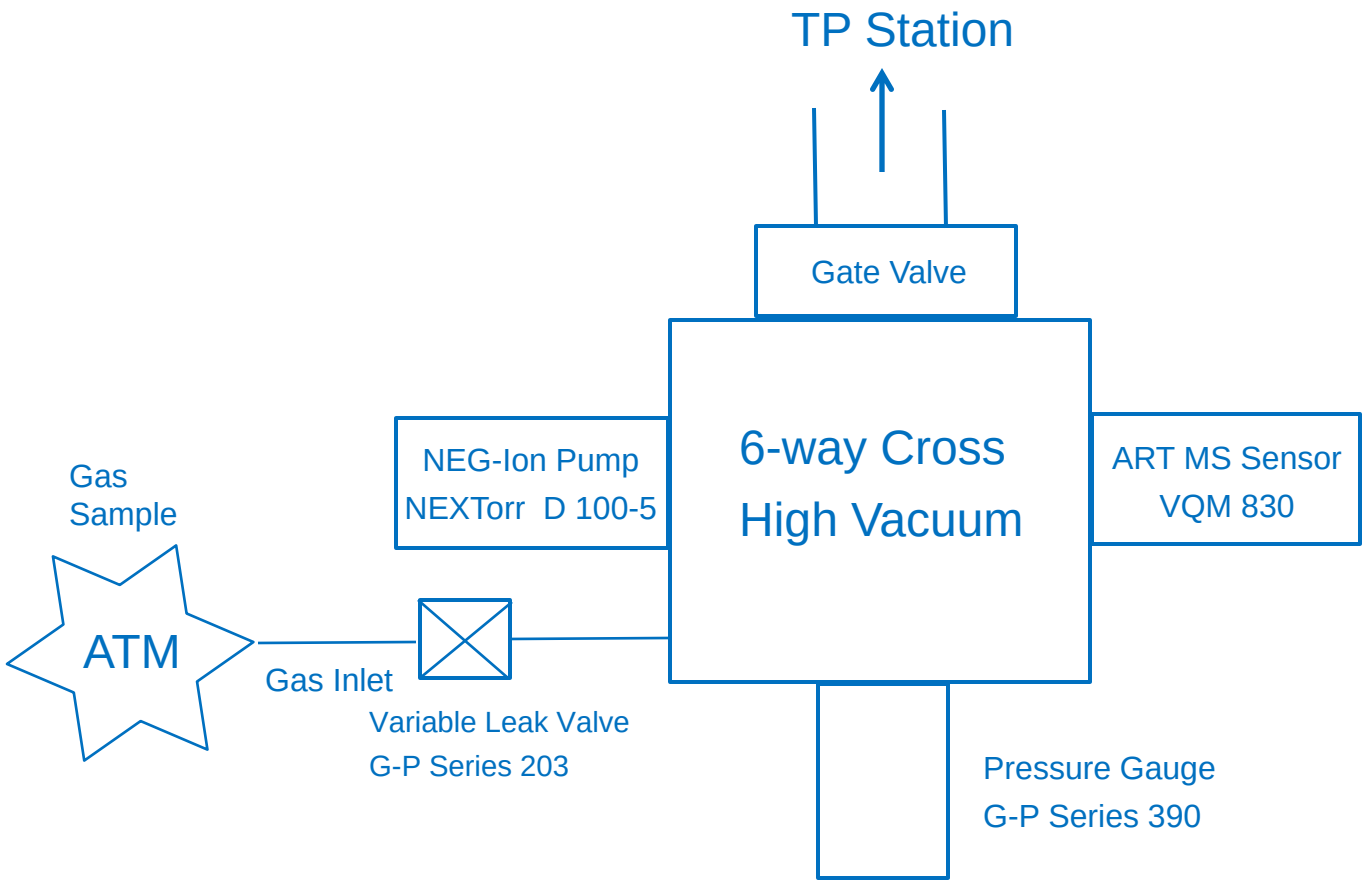
Full Range
Pressure Gauge
G-P Series 390

Cross: 6-way

Gas Inlet

(NEXTorr – VQM 830) Gas Analyzer

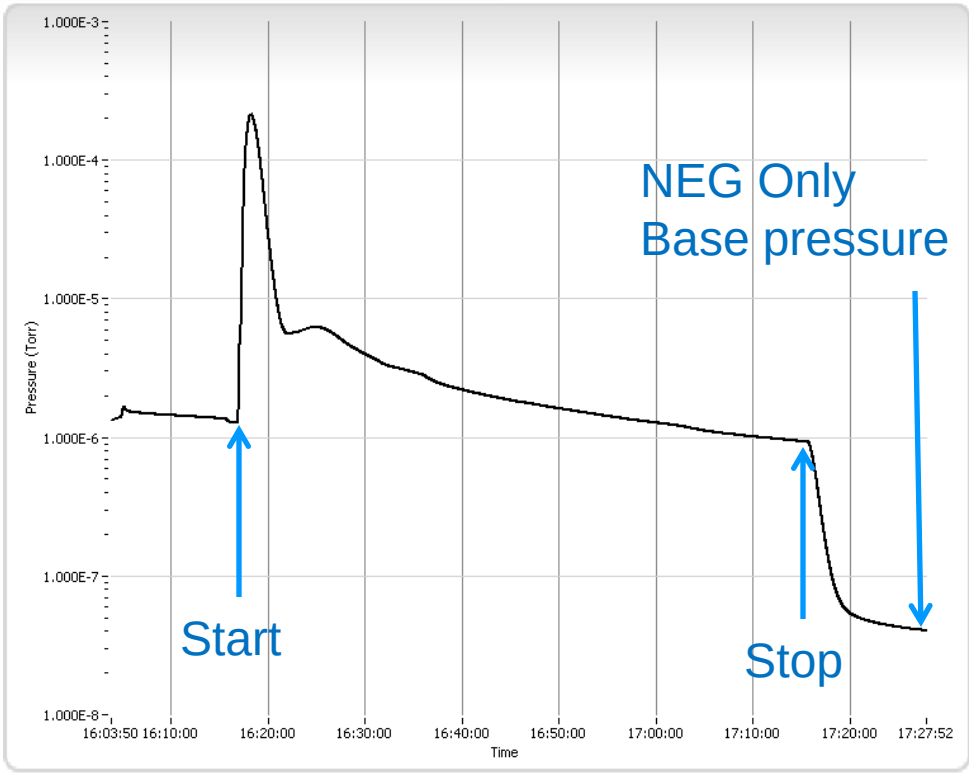
Single-Stage Atmospheric Gas Sampling System



NEXTorr Activation

NEXTorr's NEG must be activated in order to provide full pumping speed and capacity:

- Gate Valve open, Leak Valve closed
- Ion Pump Off
- SAES NIOPS-02 Power Supply automates Activation (9V, 5A, 1 hour)
- Built in heating element (500ºC)
- TP provides High Vacuum conditions
- Close Gate Valve at end of activation
- Turn ION Pump on at end of activation
- NEXTorr is ready!

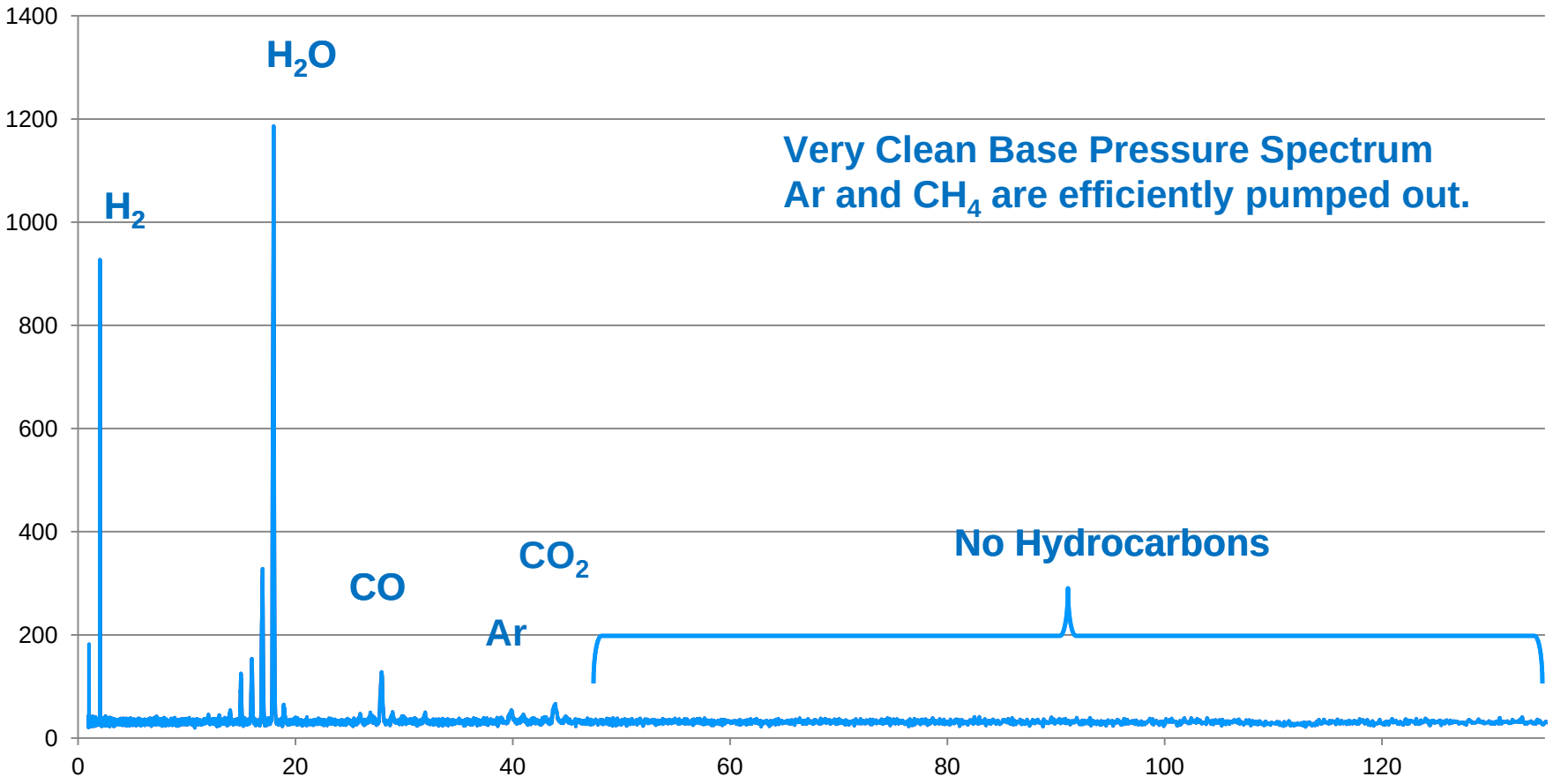


NEXTorr	
NEG Only	5e-8 Torr
NEG+ION	6.5E-9 Torr

Base Pressure – NEXTorr

Post Activation Base Pressure Spectrum

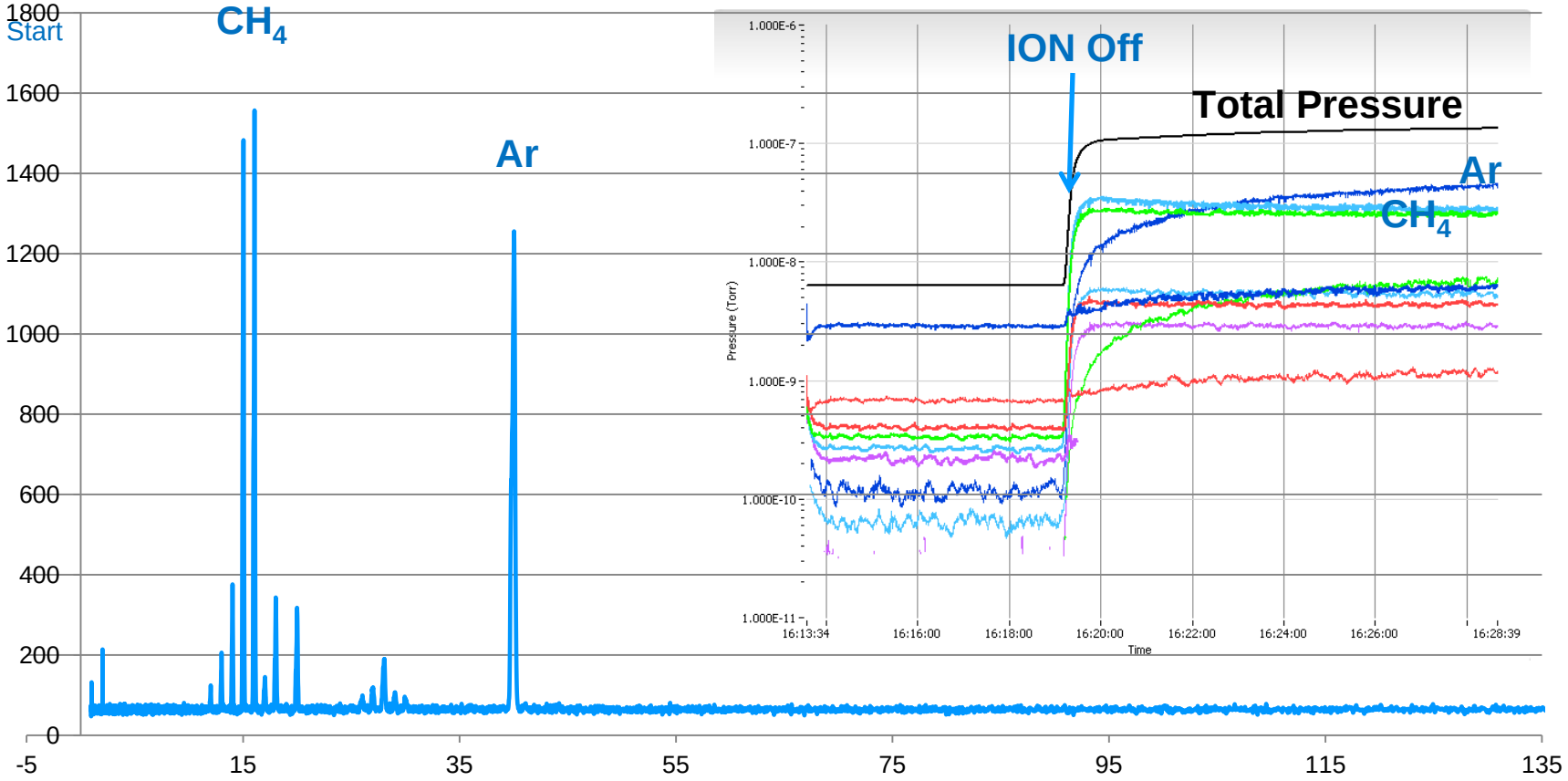
NEXTorr (700μW) - P= 6.5e-9 Torr



NEXTorr - NEG Only Operation = No Power

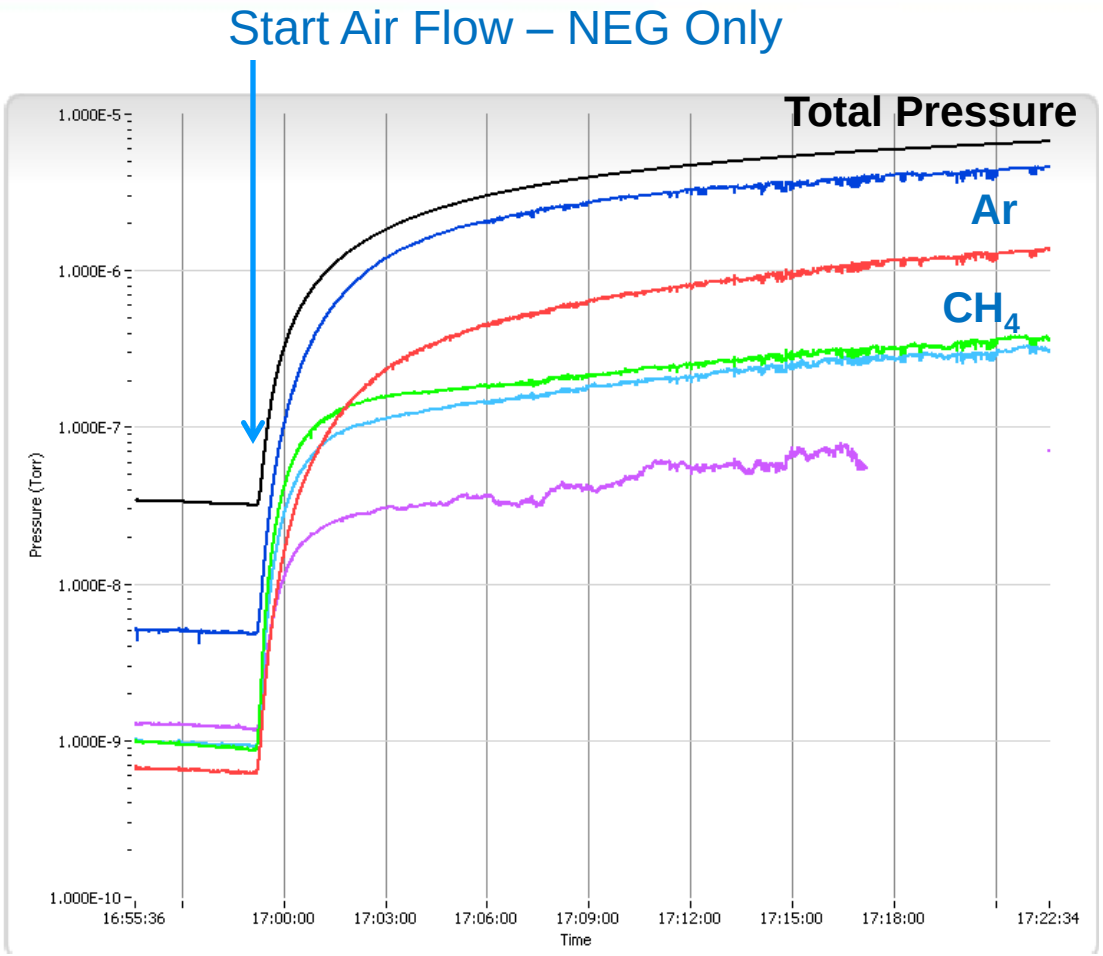
Post Activation Base Pressure Spectrum

NEXTorr NEG Only – P= 1.3E-7 Torr



NEXTorr - NEG Only Operation

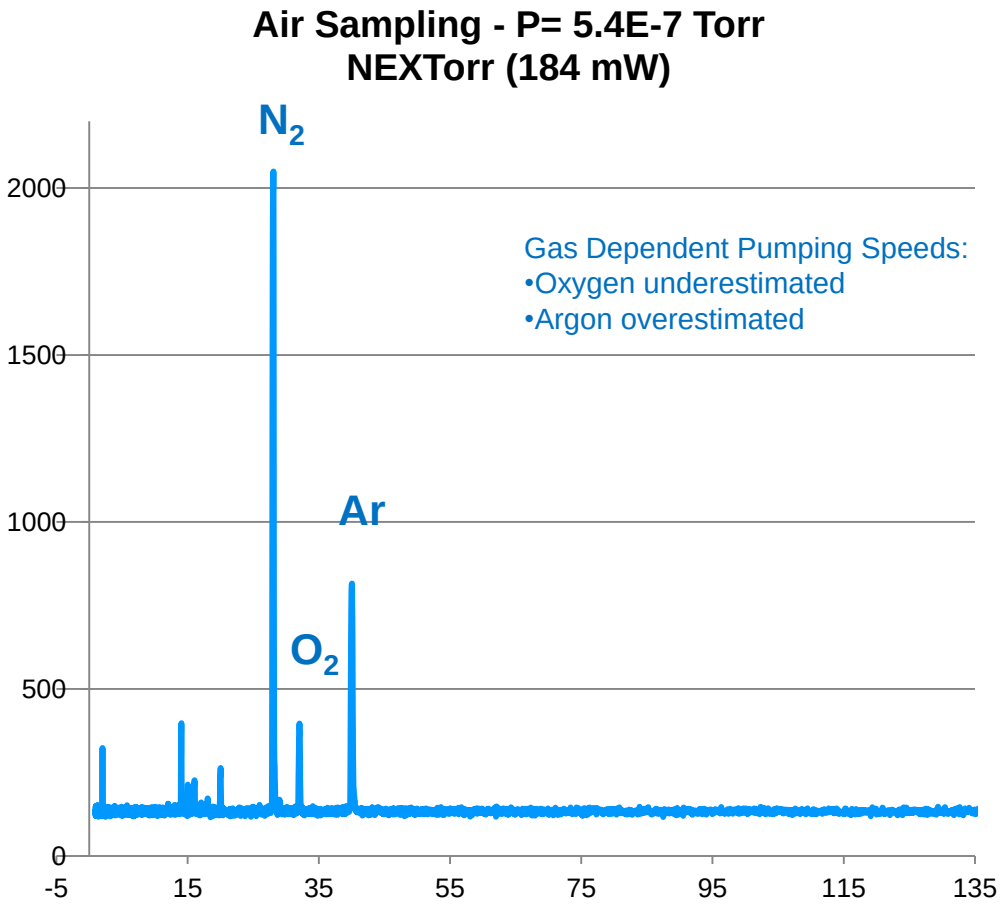
- NEXTorr NEG Only Operation requires no external power but provides no pumping speed for inert gases and reduced speed for methane.
- NEXTorr NEG Only operation not recommended for Air sampling- Ar and methane build up in the chamber-overpressure.



Air Sampling- Gas-Dependent Pump Speed

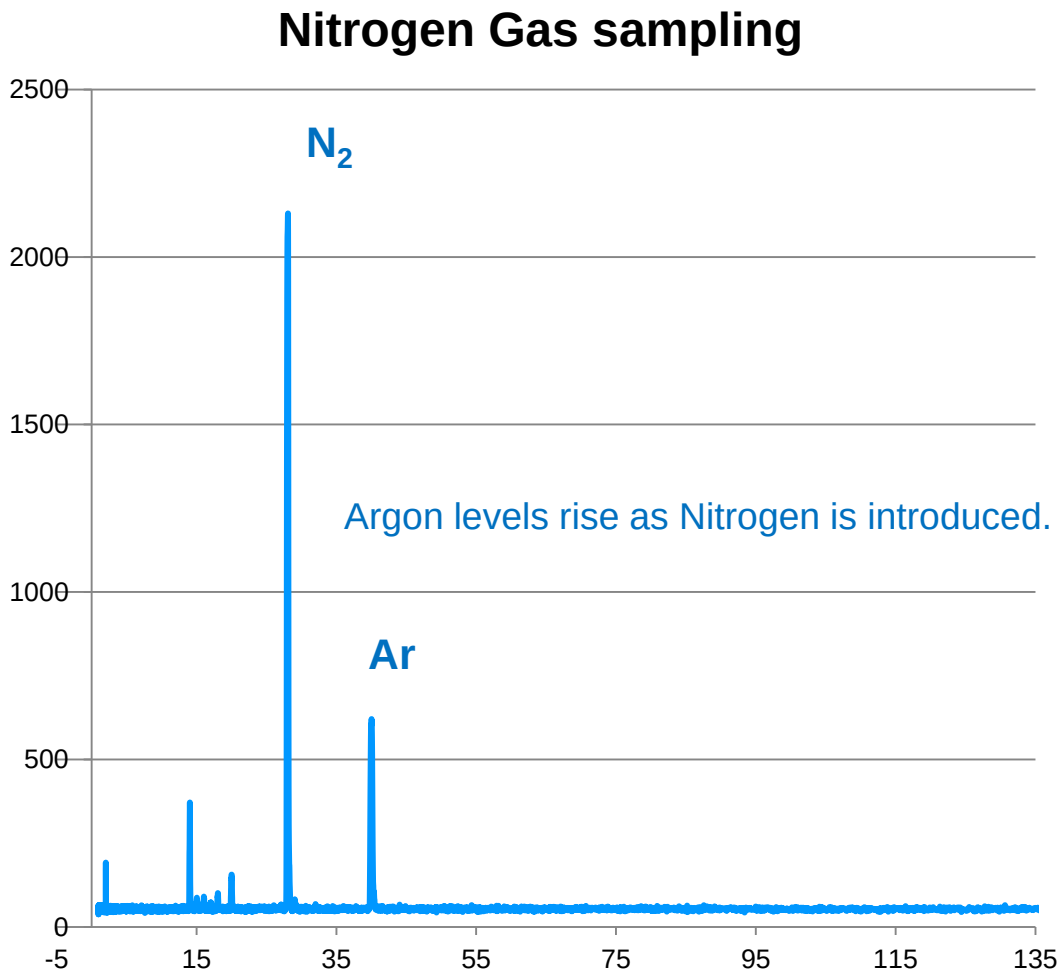
- Air sampling not recommended with NEXTorr NEG Only Operation- Ar buildup.
- Air Sampling is possible with NEXTorr.
- Gas dependency of pumping speeds must be considered for gas compositional analysis

Gas	Speed (L/s)
Oxygen	140
Nitrogen	40
Ar	6



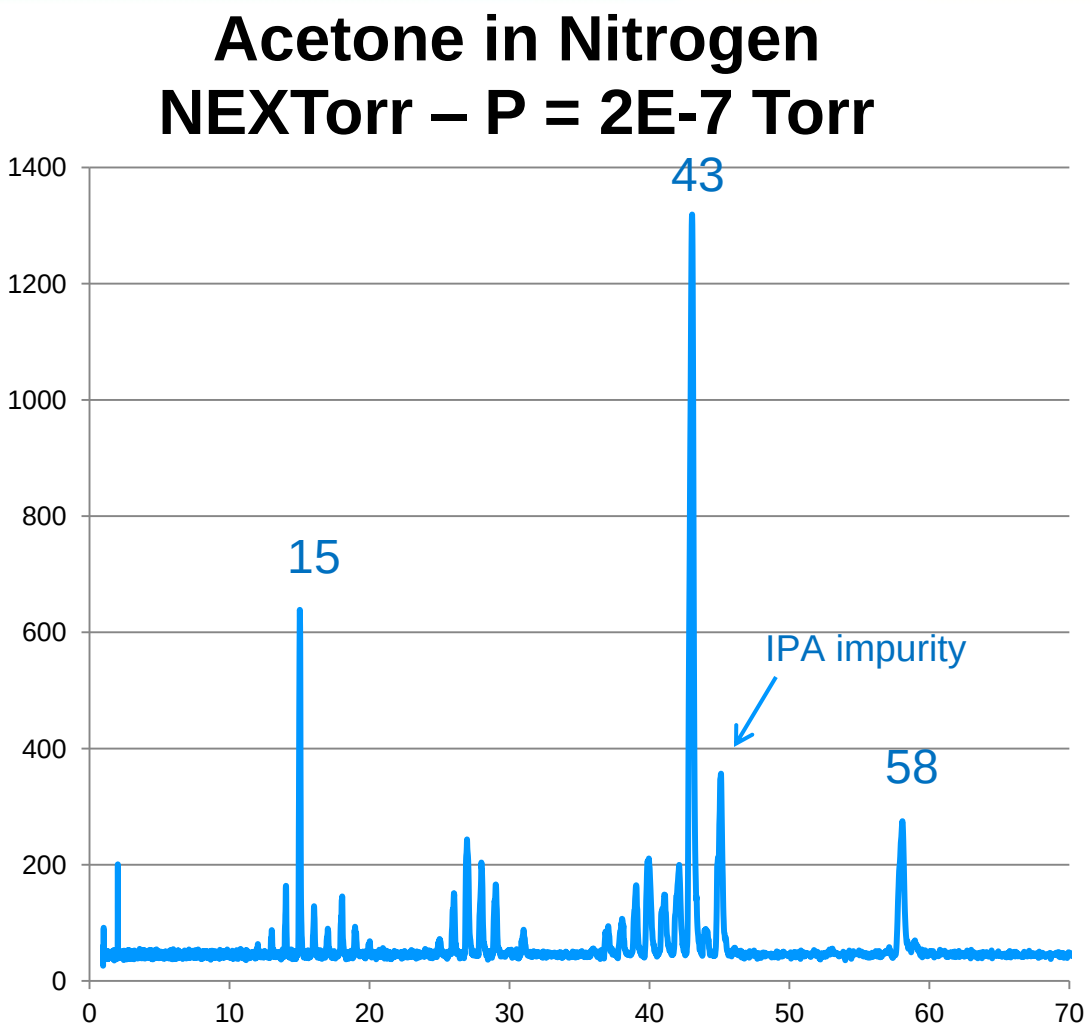
Direct Sampling Mass Spectrometry

- NEXTorr /ART MS combination can be used for direct sampling Mass Spectrometry.
- The buffer/carrier gas must be chosen carefully- i.e. no Argon! Choose high pumping speed and high capacity gas.
- Changes in background gas composition must be expected



Organic Gas Sampling – Acetone in N_2

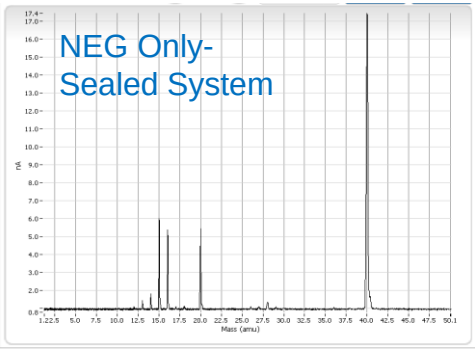
- Volatile organic compounds can be sampled.
- Fragmentation patterns do not suggest any cracking at Ion Pump's high energy discharge.
- Need to understand species dependence of capacity, differential pumping speed and # reactivation cycles.

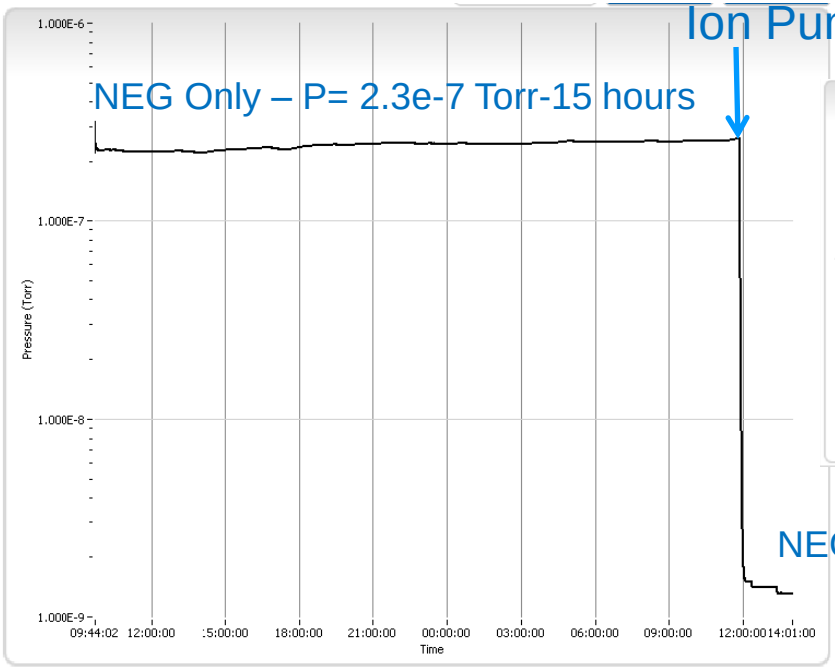


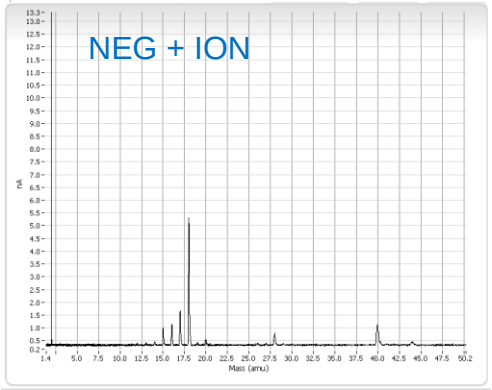
Transportation under High Vacuum

A “sealed” High Vacuum system with an activated NEXTorr will remain at HV for an extended period of time with Ion Pump off (Tested, 10 days): 1. Activate NEG – 2. Seal the vacuum system- 3. Ship - 4. Turn on ion pump.

15 hour trend: sealed sampling system with NEG Only- Total Pressure holds steady at 2.3e-7 Torr.







Build or Buy?

	Build	Buy
Price		
Synergy (*)		
Size		
Magnetic Field		
Flexibility		
Connectivity (vacuum and electrical)		
Control		

(*) Getter pump must intercept impurities from Ion Pump.

Final Comments/Recommendations

- NEXTorr Pump viable for MS Gas Sampling- pumping speed, capacity and reactivation.
- NEXTorr Pump matches size, power and weight of ART MS sensors.
- NEXTorr pump provides continuous “power free” pumping during transportation.
- Gas specific pumping speeds and capacities must be considered/understood.
- Choose carrier gas wisely (pumping speed and capacity)
- NEXTorr NEG Only Operation incompatible with Air sampling.
- NEG temperature provides additional variable to control gas species pumping speed.

Questions?

Visit the adjacent Brooks Automation or SAES Getters booths for a live demo of Low-Power Atmospheric Gas Sampling System Based on VQM 830 (ART MS) Sensor and NEXTorr (NEG+Ion) Pump.

Technology [pumping speed]	Pro	Cons
Turbo Pump [40-100L /s]	High Pumping speeds High Compression ratios Throughput pump w/out capacity limits Large flow Shrinking product Rugged (dual bearings) Fairly species independent Large pressure range	Large dimensions Heavy High power consumption (>10W) Require backing pump (more power, 35-50W) Light gas problems (H2 and He) Exhaust problems
Ion Pump [5 -60 L/s]	Low power [??W] No exhaust Decent pumping speed UHV base pressure Vibration free Does not require Backing pump Good for H2 Bakeable Rugged	Heavy @ high pump speed (30Lb for 60L/s) Bulky @high pump speed Magnetic fields High Voltage Discharge Capacity limitation Requires HV to start (primer pump) Species dependent Inert gases require noble design ($$) Gas cracking UHV pumps Low flows
Non Evaporable Getter (NEG) [100 -1000's L/s]	**No power requirement after activation** High pumping speed Small size Light Dose not require backing pump	Requires activation under HV UHV pump Limited capacity Species dependent Low pumping speed for Inert gases and methane Capacity limit