INNOVATIONS IN PUMPED AIR SAMPLING

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MilliporeSigma

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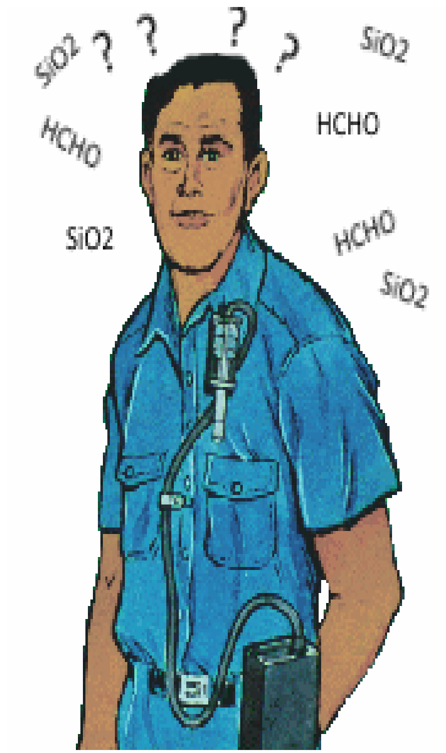
Innovations in Pumped Air Sampling

- The Big Picture
- What do we need?
- How do we collect a volume of air?
- How does this pulsation impact air sampling?
- Current pump designs
- Progress in design

Innovations in Pumped Air Sampling
The big picture

- Personal Sampling
- Area sampling
- Exposure Limit Regulations



Innovations in Pumped Air Sampling
What do we need?

$$\text{Concentration} = \frac{\text{Mass of Pollutant}}{\text{Volume of Air}}$$

$$\text{Volume of Air} = \text{Length of Time} \;\; x \;\; \text{Flow Rate}$$

Innovations in Pumped Air Sampling
How do we collect a volume of air?

Preparation/calibration → Calibration device → Sampling media → Pump

Sample acquisition → Sampling media → Pump

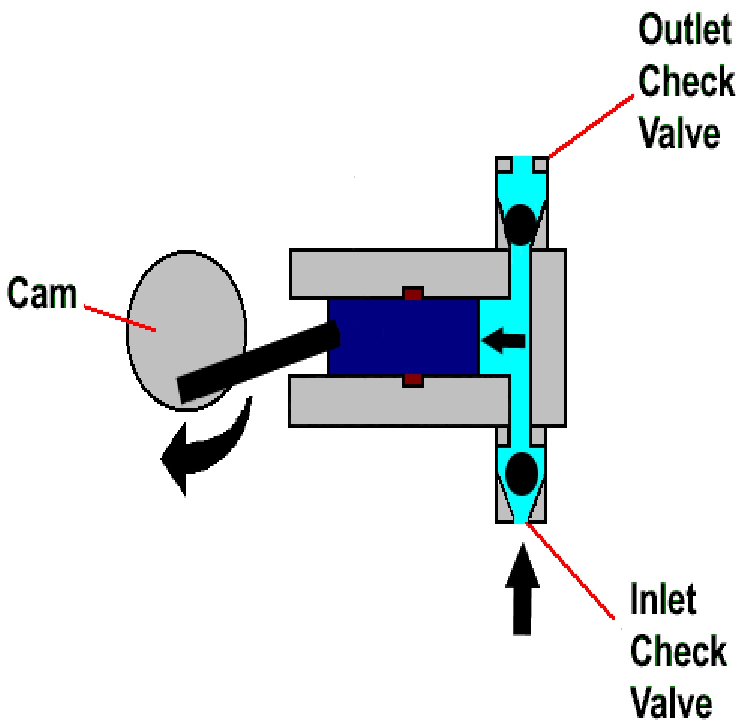
Post acquisition/calibration → Calibration device → Sampling media → Pump

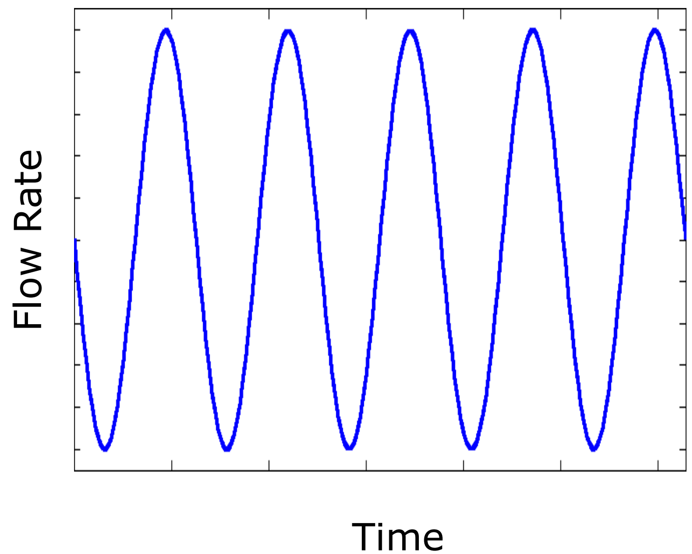
Innovations in Pumped Air Sampling
Pump Calibration Today

Personal sampling pumps are essential equipment for sampling airborne contaminants. Determining airborne concentrations requires accurate knowledge of the *volume* of air sampled. Constancy of *flow rate* and equipment reliability are two important factors that affect air volume.

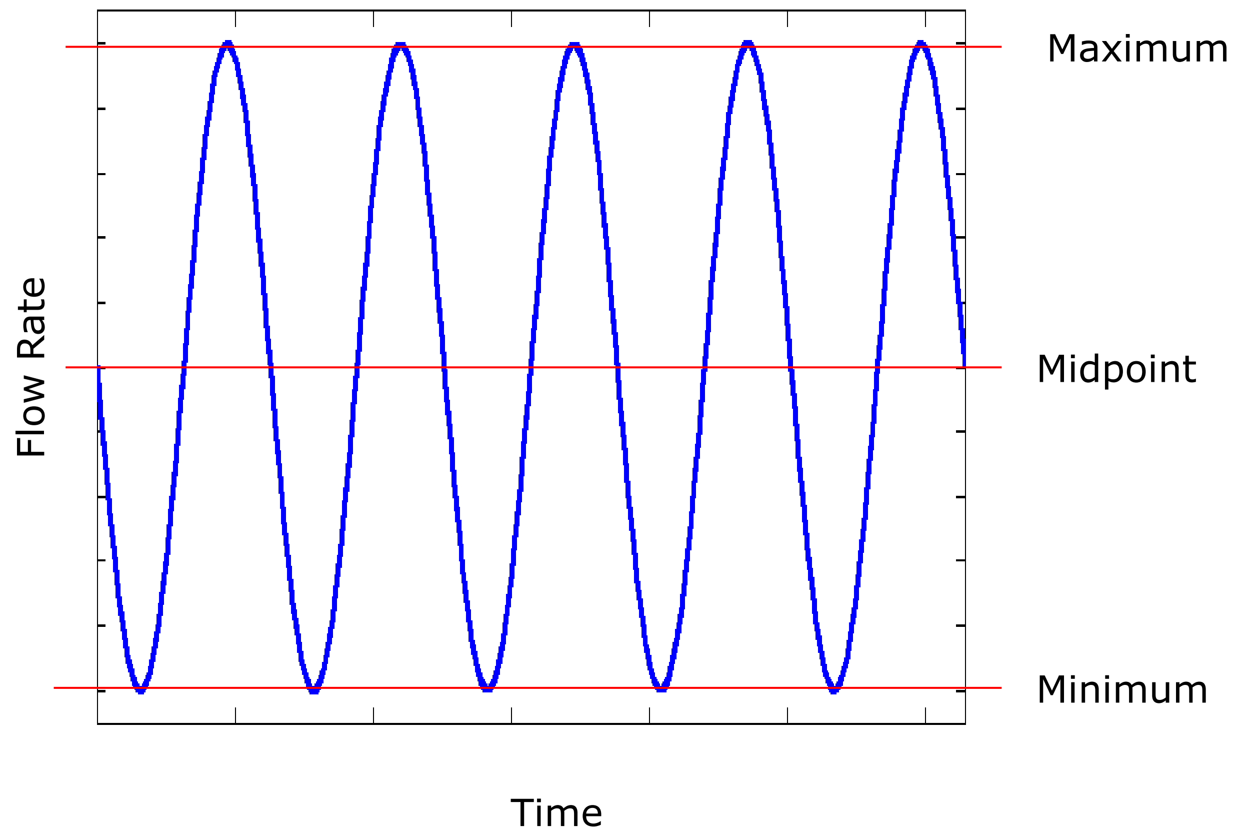
Innovations in Pumped Air Sampling
How do we collect a volume of air?

Basic Piston Pump





Innovations in Pumped Air Sampling
How do we collect a volume of air?



Flow Rate= Midpoint?

Innovations in Pumped Air Sampling
How do we collect a volume of air?

ISO 13137:2013(E) Workplace atmospheres – Pumps for personal sampling of chemical and biological agents – Requirements and test methods First Edition 2013-10-15

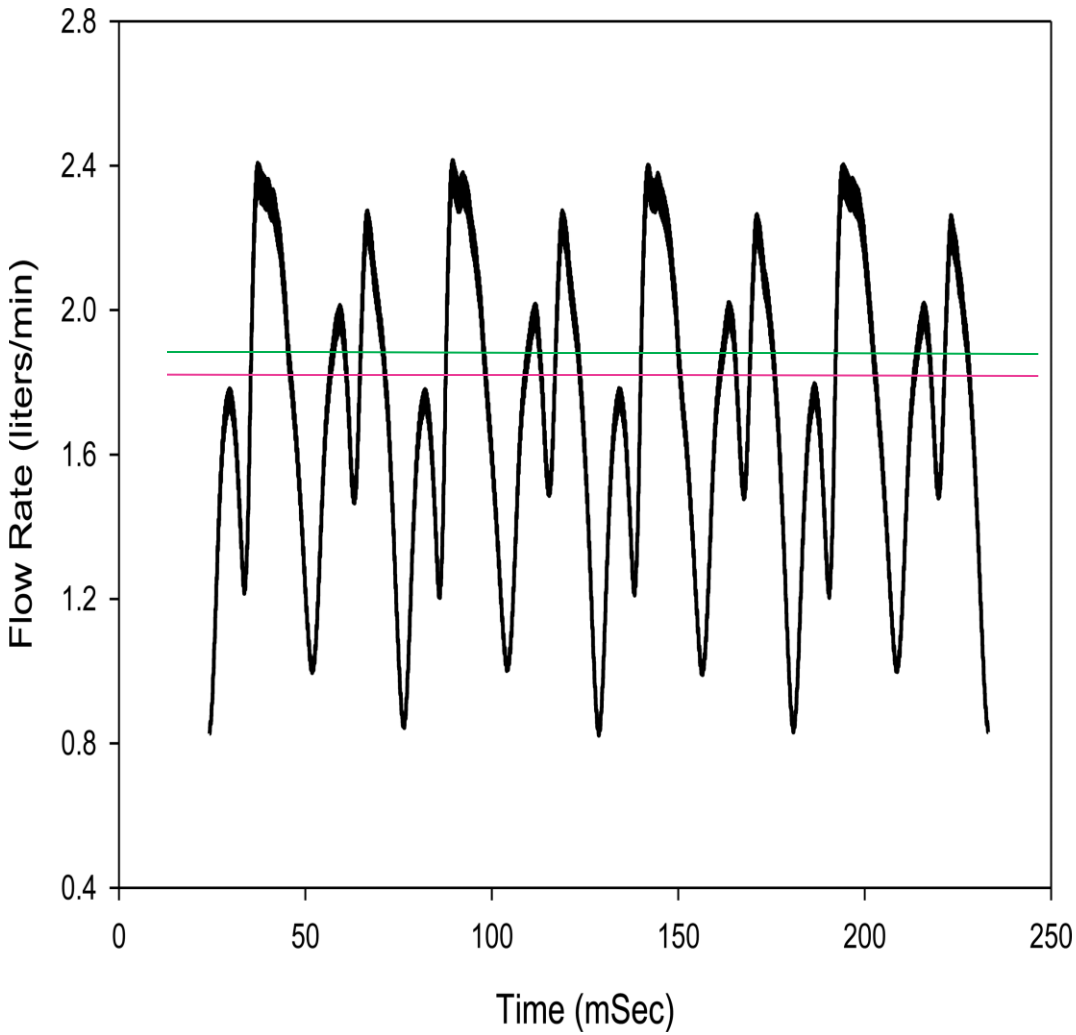
$$\%\ Pump\ pulsation = \frac{\sqrt{\frac{1}{T}\int_0^T [f(t) - \overline{f}]^2\,dt}}{\bar{f}}\ x\ 100$$

Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

- Variation of flow with respect to pulsation
- Remember the average (midpoint)
- Where does this not work?

Target Flow Rate	*Unit*	*Flow Extremes*	*+/- 1% Pulsation*	*+/- 5% Pulsation*	*+/- 10% Pulsation*	*+/- 15% Pulsation*	*+/- 20% Pulsation*	*+/- 25% Pulsation*
0.10	LPM	Max	0.101	0.105	0.110	0.115	0.120	0.125
		Min	0.099	0.095	0.090	0.085	0.080	0.075
0.20	LPM	Max	0.202	0.210	0.220	0.230	0.240	0.250
		Min	0.198	0.190	0.180	0.170	0.160	0.150
0.50	LPM	Max	0.505	0.525	0.550	0.575	0.600	0.625
		Min	0.495	0.475	0.450	0.425	0.400	0.375
1.00	LPM	Max	1.010	1.050	1.100	1.150	1.200	1.250
		Min	0.990	0.950	0.900	0.850	0.800	0.750
1.50	LPM	Max	1.515	1.575	1.650	1.725	1.800	1.875
		Min	1.485	1.425	1.350	1.275	1.200	1.125
1.70	LPM	Max	1.717	1.785	1.870	1.955	2.040	2.125
		Min	1.683	1.615	1.530	1.445	1.360	1.275
2.00	LPM	Max	2.020	2.100	2.200	2.300	2.400	2.500
		Min	1.980	1.900	1.800	1.700	1.600	1.500
2.20	LPM	Max	2.222	2.310	2.420	2.530	2.640	2.750
		Min	2.178	2.090	1.980	1.870	1.760	1.650
2.50	LPM	Max	2.525	2.625	2.750	2.875	3.000	3.125
		Min	2.475	2.375	2.250	2.125	2.000	1.875
3.00	LPM	Max	3.030	3.150	3.300	3.450	3.600	3.750
		Min	2.970	2.850	2.700	2.550	2.400	2.250

Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?



Wave Function mean (1.68)

Amplitude mean (1.60)

COMPARISON OF PUMP PULSATIONS

Innovations in Pumped Air Sampling
Comparison of Pump Pulsations

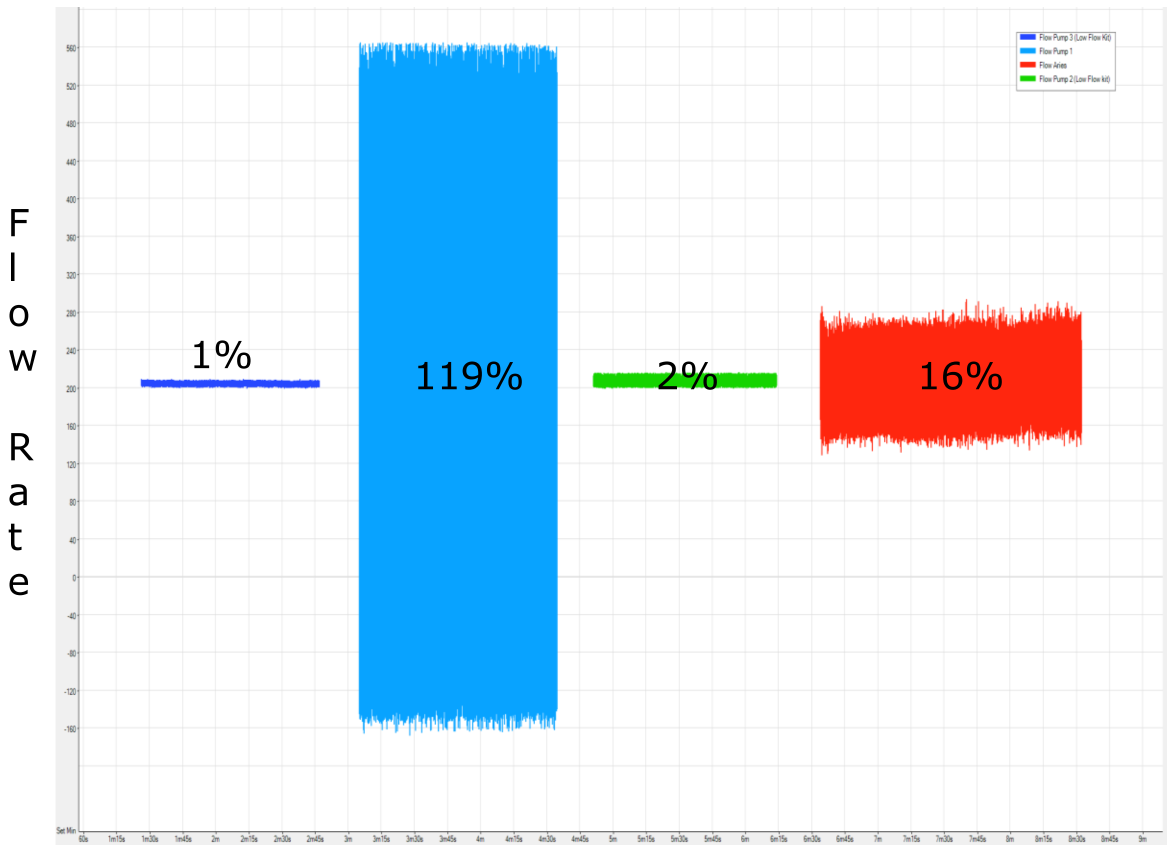
- Low Flow rate and pump pulsation with current pumps, how is this achieved?
  - Low flow adapter or switch

- Sampling two devices on 1 pump
  - Manifold set-up
  - Setting flow using a bypass system – the pump can't measure that flow directly
  - Dual sampling pump
    - No low flow kit required
    - Measures flow of 2 devices
    - Combined flow rate

Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Flow Pulsation

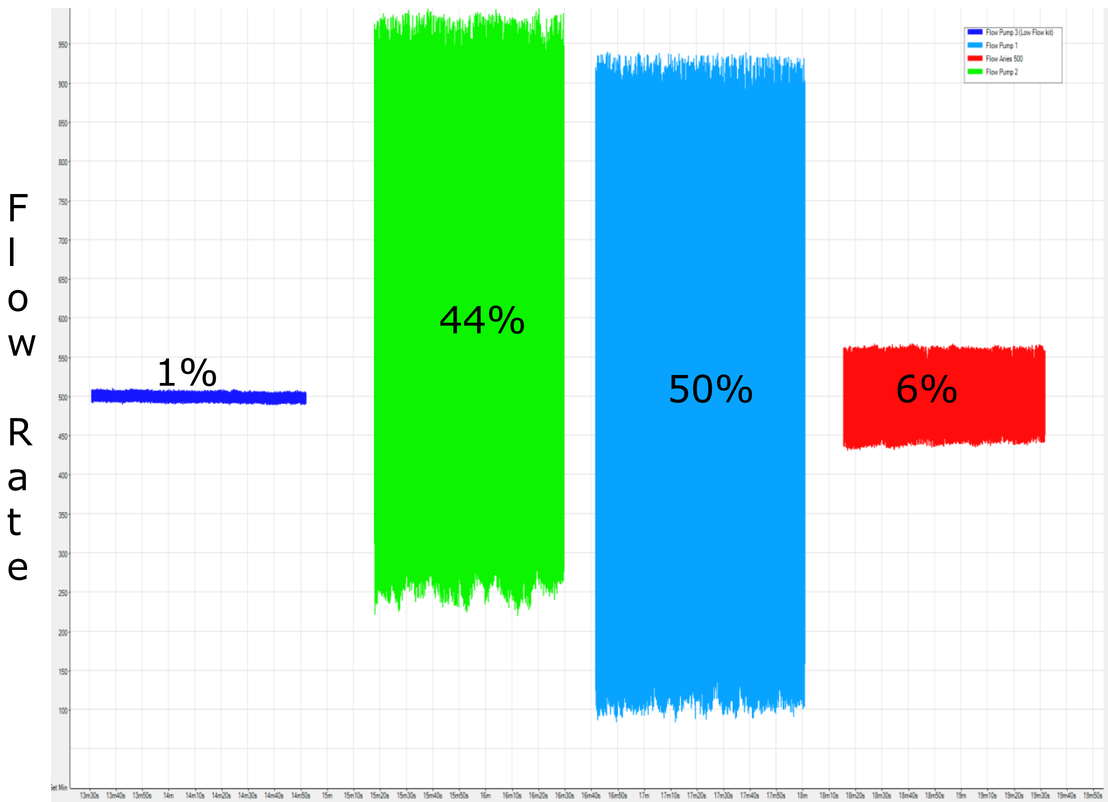
Flow Rate: 200 mL/min



Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Flow Pulsation

Flow Rate: 500ml/min

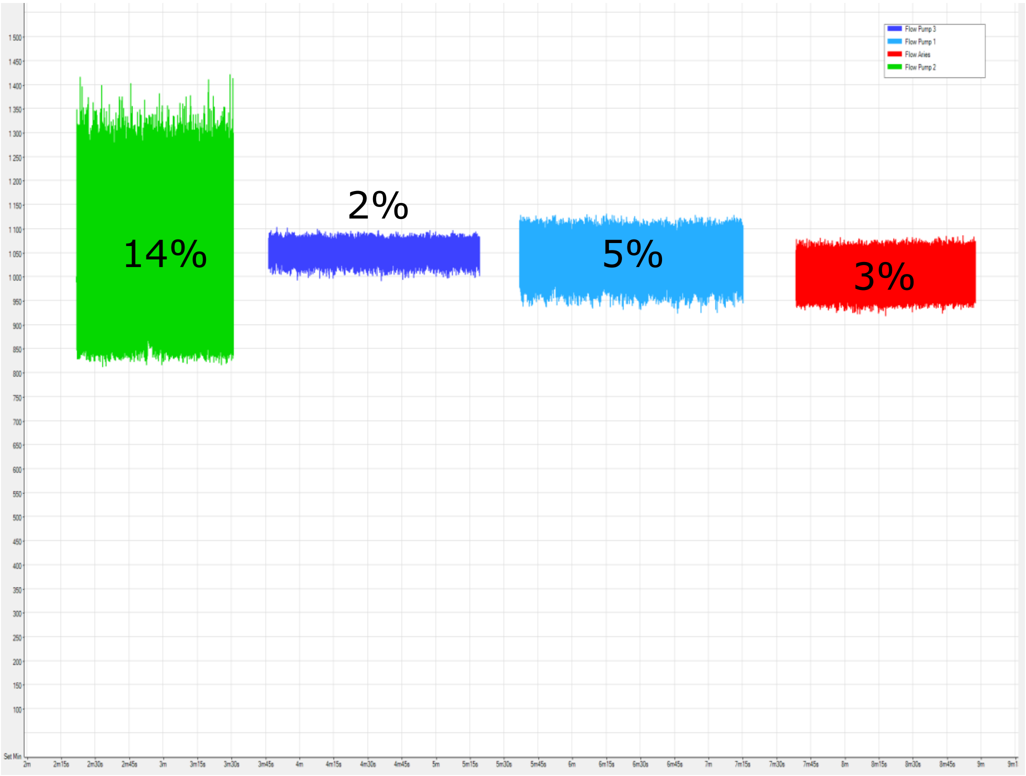


Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Flow Pulsation

Flow Rate: 1,000 mL/min

Flow Rate

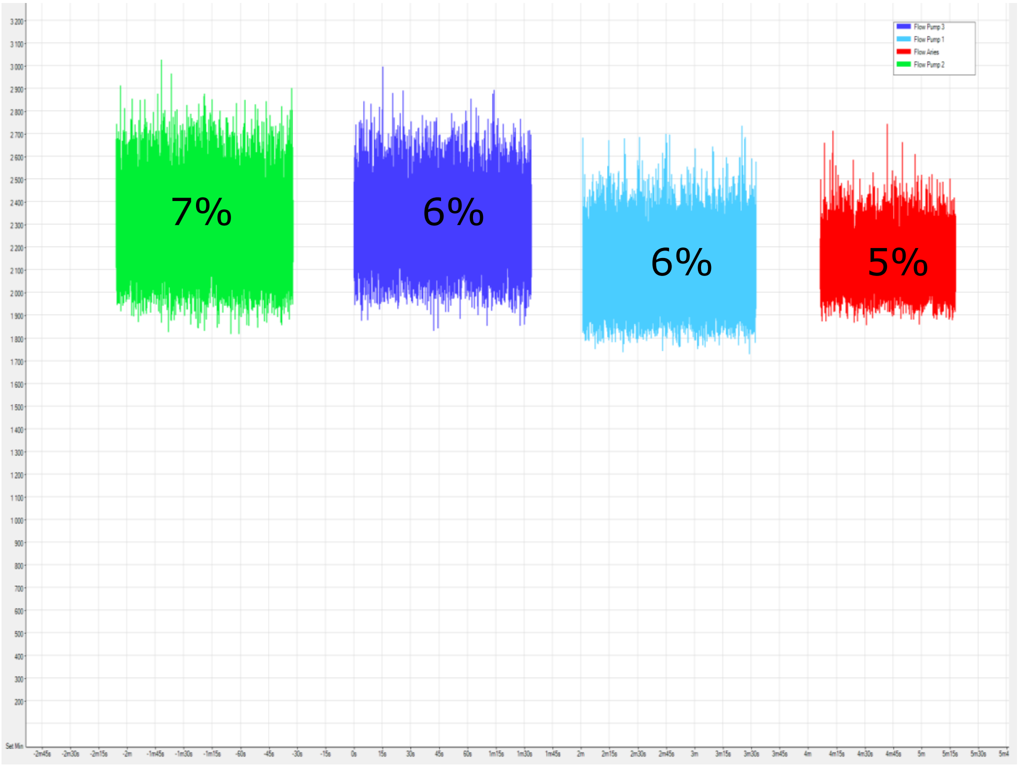


Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Flow Pulsation

Flow Rate: 2,000 mL/min

Flow Rate



Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Particulate Sampling

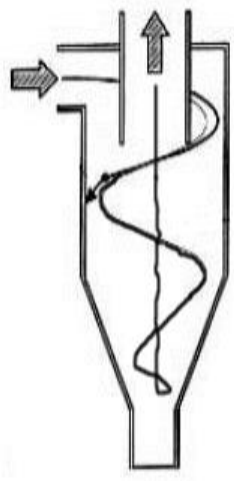
- Filter (as a barrier) – little to no impact – used for total values

- Cyclone samplers – provide a way for some size based differentiation

- Impactors – also provide a way for some size based differentiation created by a different design

Innovations in Pumped Air Sampling
How does this pulsation impact air sampling?

Effects of flow rate variation on particulate sampling



- *Cyclones* function on centrifugal force generated according to aerodynamic diameter.

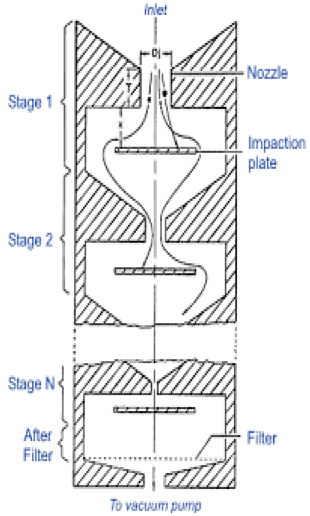
$$F_c=mv^2/r$$

F_c=centrifugal force, m=mass, v=speed, and r=radius

- *Impactors* function on particle momentum generated by air velocity

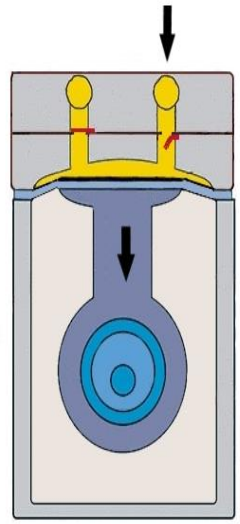
$$P=mv$$

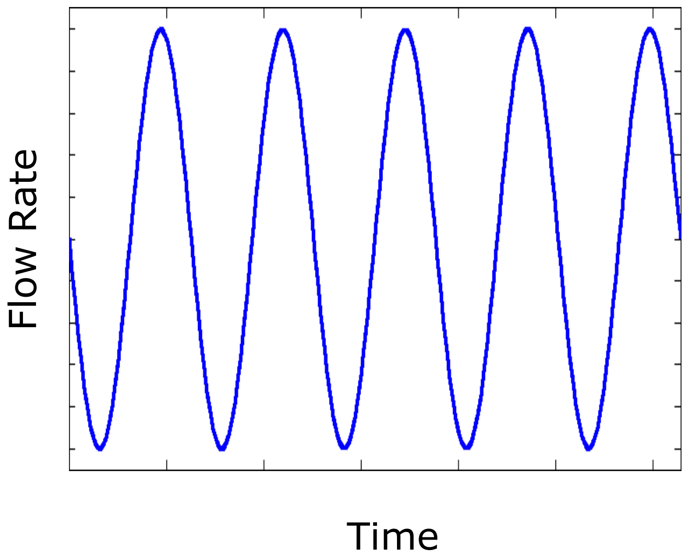
P=momentum, m=mass, and v=velocity



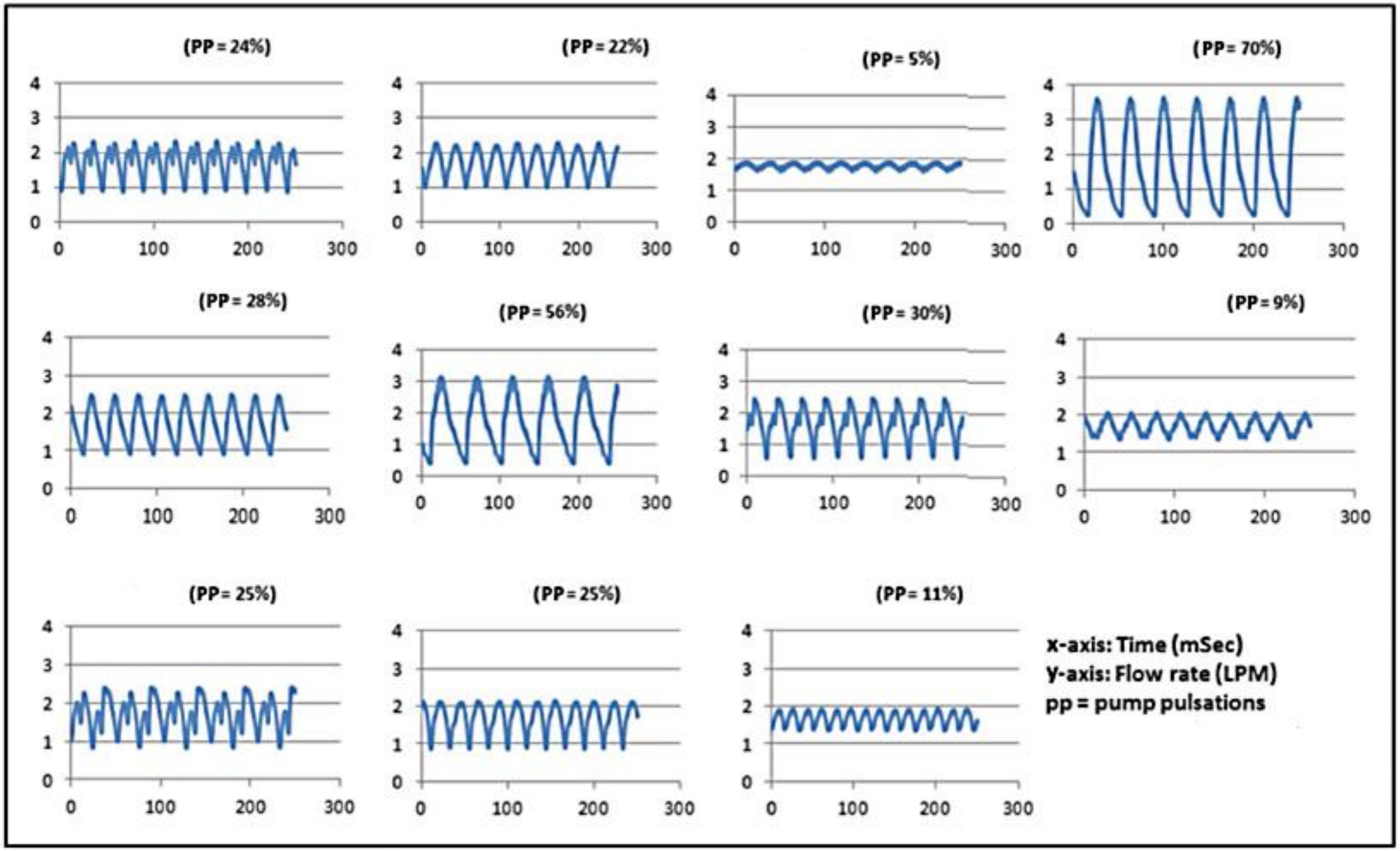
Innovations in Pumped Air Sampling
Current pump design

Pump Pulsation – basic diaphragm cross section





Innovations in Pumped Air Sampling
Current pump design



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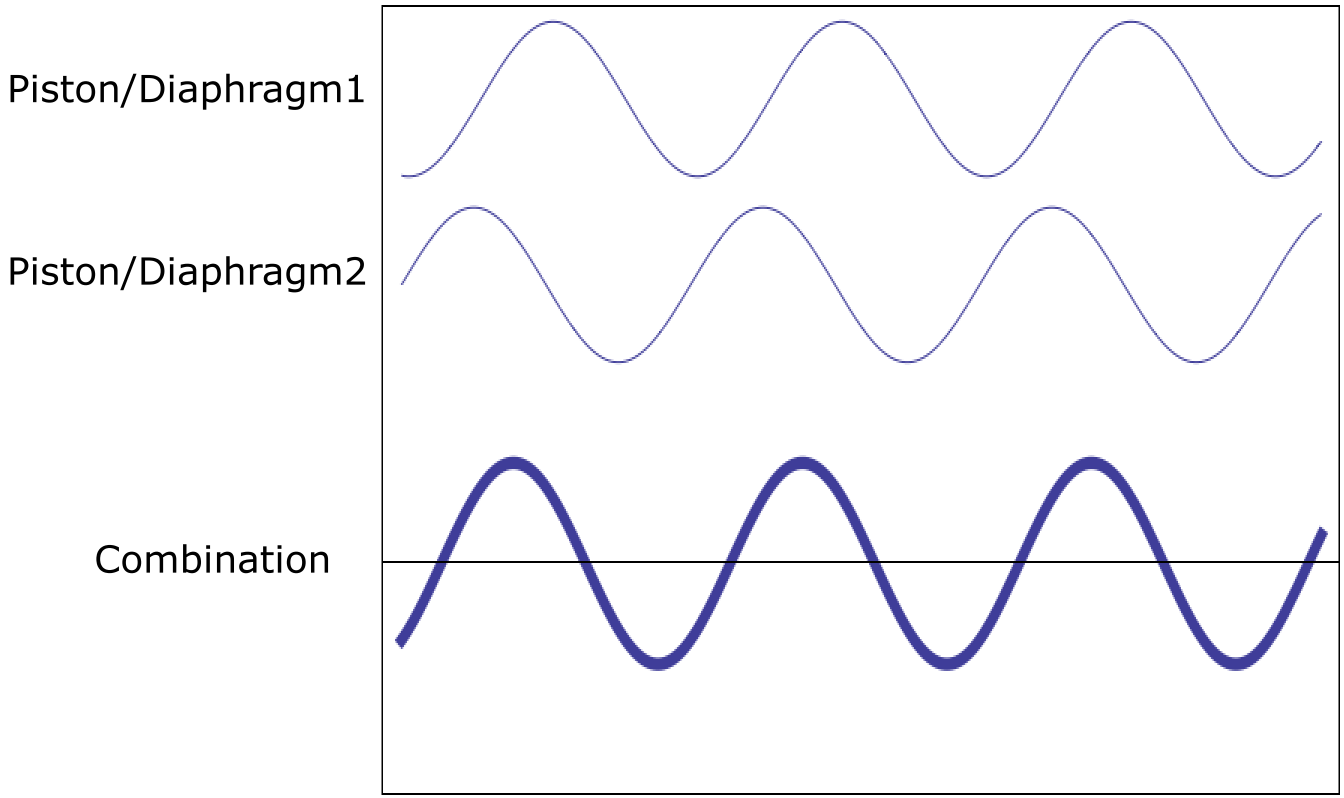
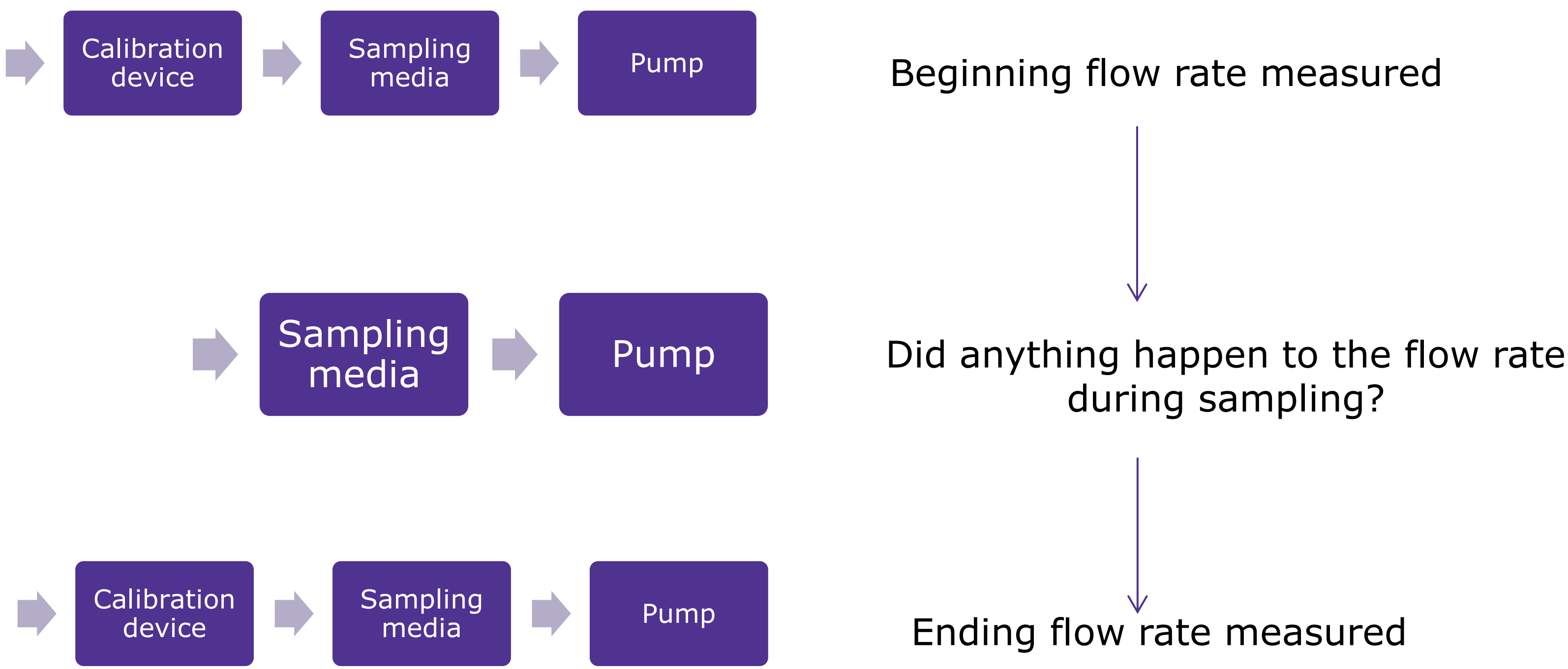
Innovations in Pumped Air Sampling
Current pump design

Dual Piston/Diaphragm pump



Innovations in Pumped Air Sampling
Progress in design - Calibration

What is the advantage?

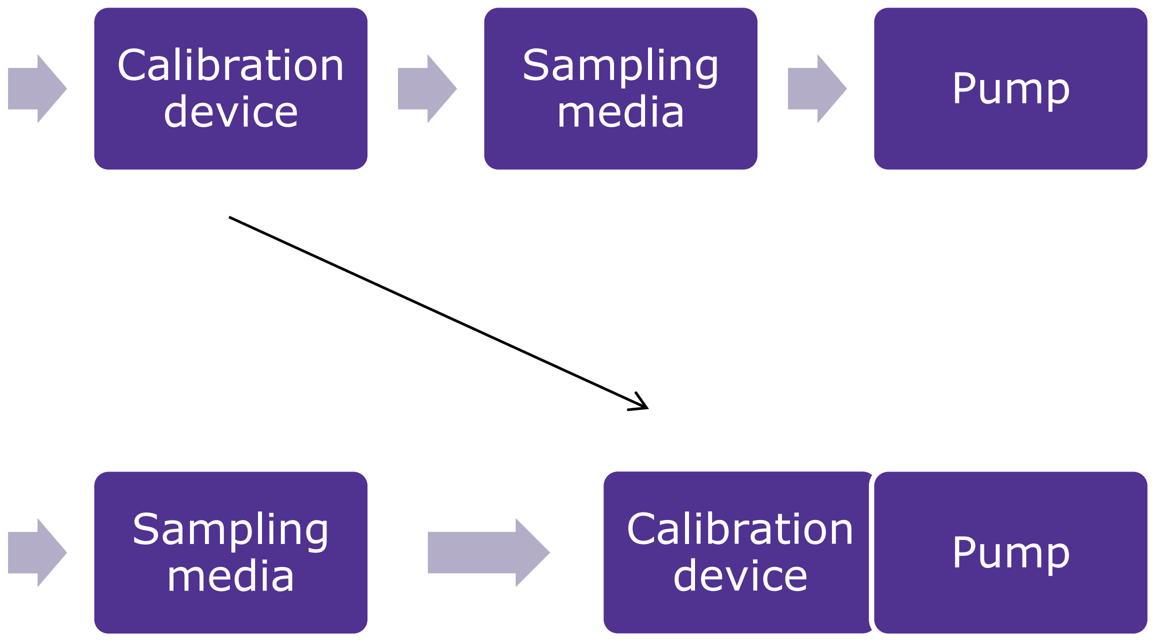


Innovations in Pumped Air Sampling
Progress in design - Calibration

Current

Pre & Post acquisition

New Approach



Innovations in Pumped Air Sampling
Progress in Design - Calibration

What is the advantage?

Sampling media → Calibration device | Pump

Beginning flow rate measured

↓

Did anything happen to the flow rate during sampling?

← Recorded flow rate over sampling period

↓

Sampling media → Calibration device | Pump

Ending flow rate measured

Innovations in Pumped Air Sampling
Progress in design - Calibration

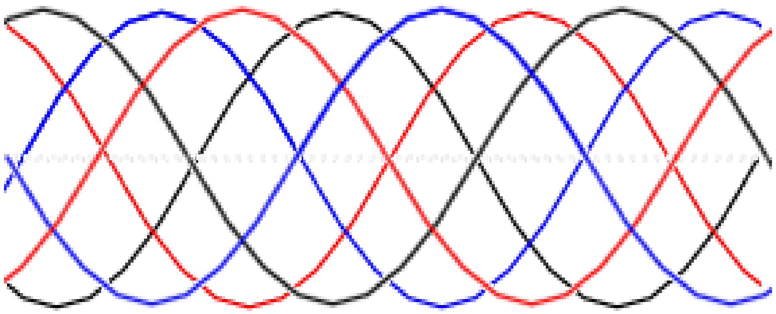
Calibration made easy

- Integrated calibration
  - Mass flow based
  - Traceable to a NIST standard
  - Annual recalibration required

- No sampling train calibration required

Innovations in Pumped Air Sampling
Progress in Design – Pump mechanism

Multiple diaphragm design



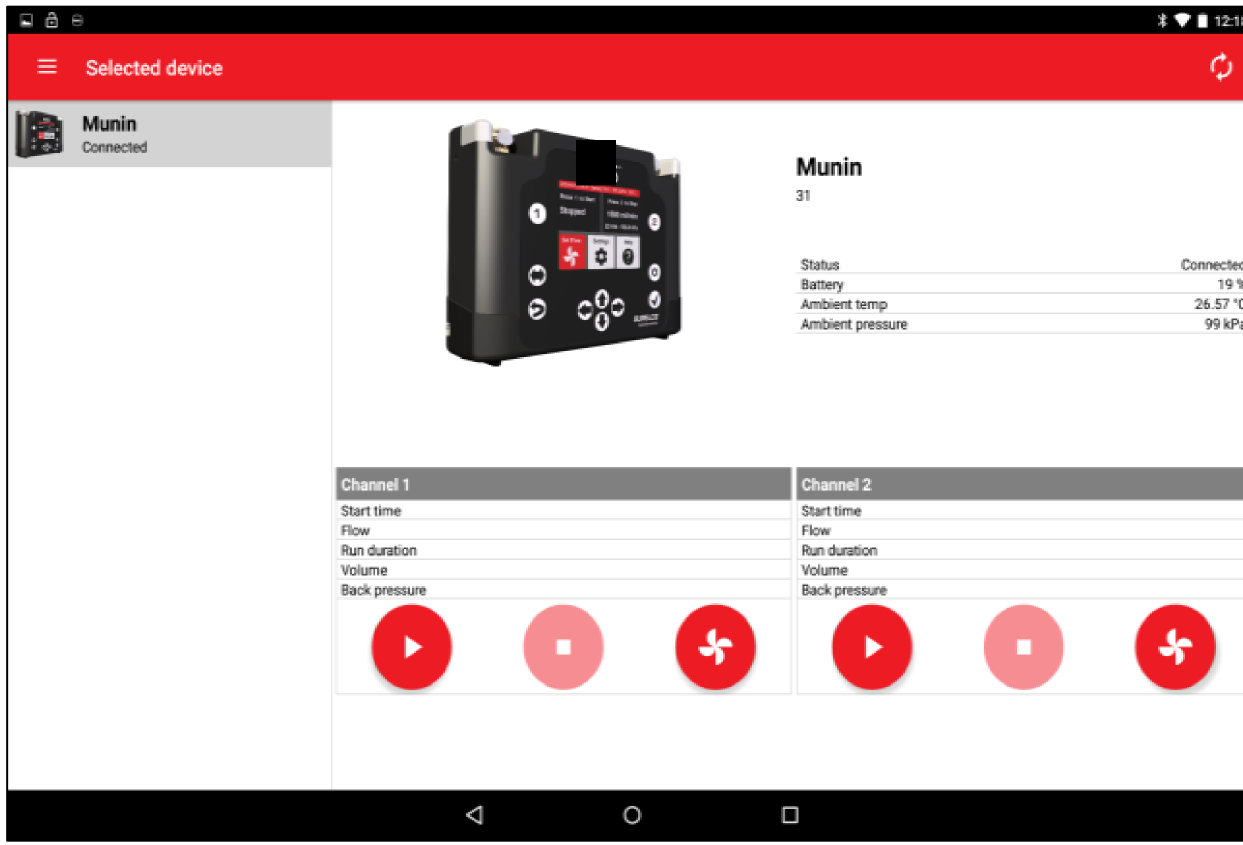
- Minimize flow pulsation
  - Multiple out of phase pairs
  - Reduce torque resistance

Innovations in Pumped Air Sampling
Progress in Design – Electronic Integration

Electronic Integration through Bluetooth®
Connectivity and Android™ application

Control

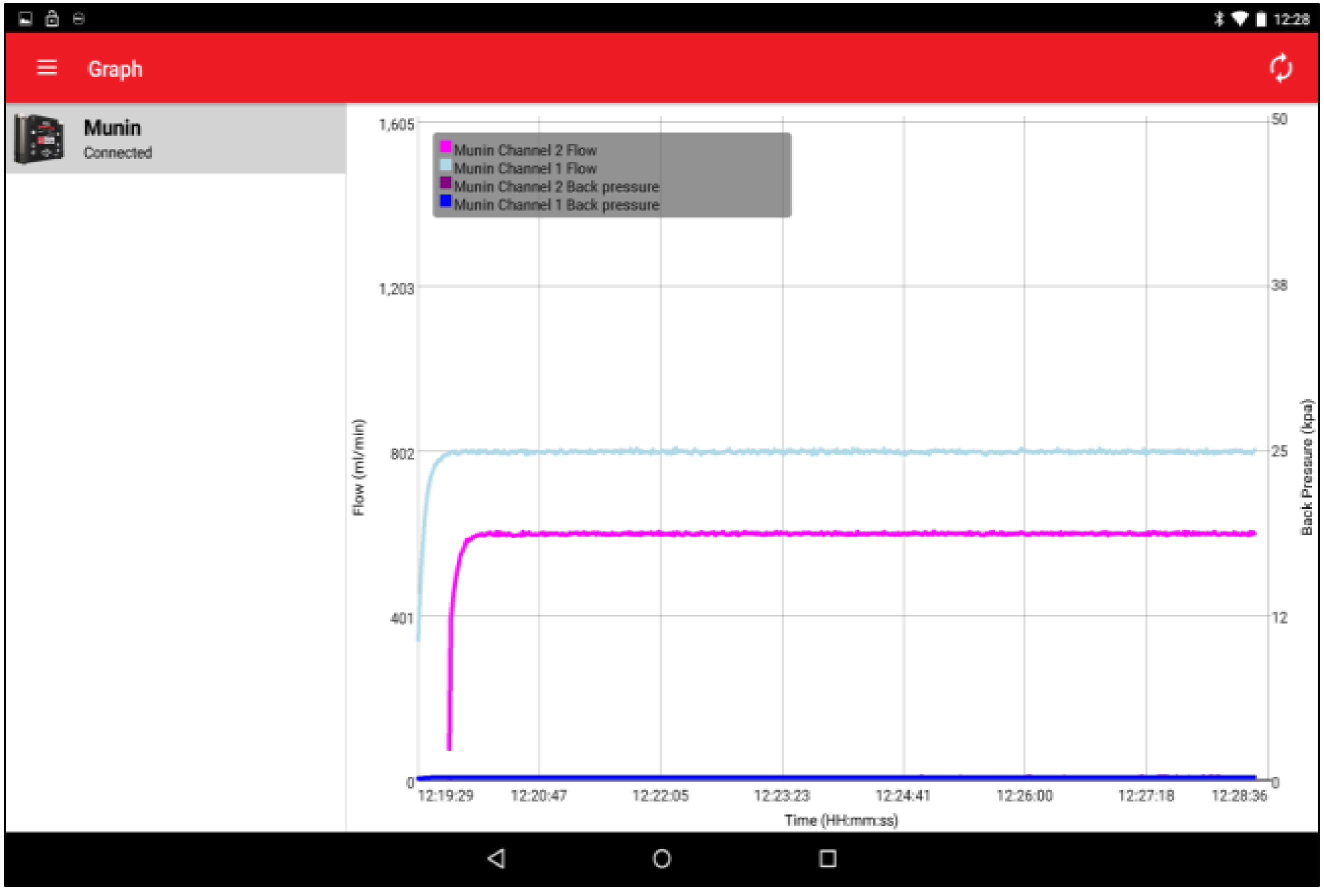
- Remote operation
  - Start/Stop
  - Set Flow



Innovations in Pumped Air Sampling
Progress in Design – Electronic Integration

Monitoring

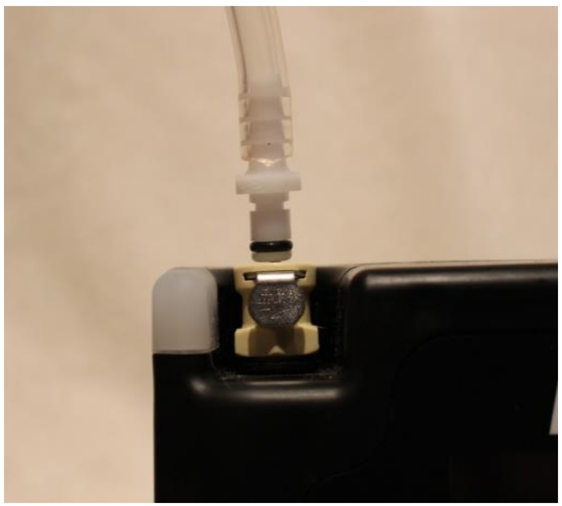
- Multiple Pumps
- Flow Rate
- Backpressure

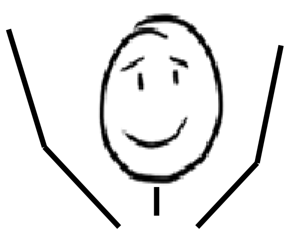


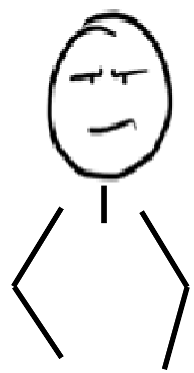
Innovations in Pumped Air Sampling
Progress in design – Quick Connect Fittings

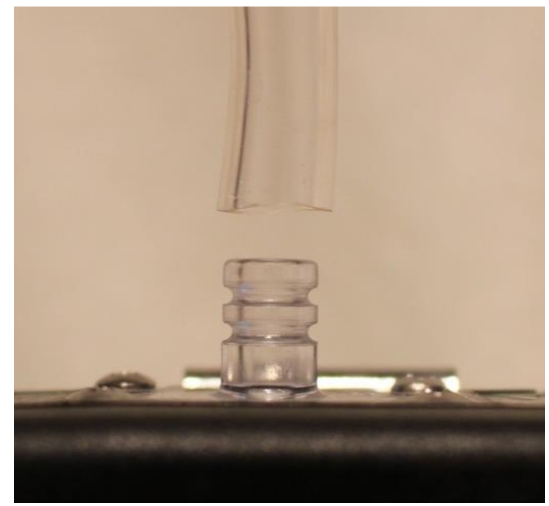
Easy connection via…

- Quick connect fittings



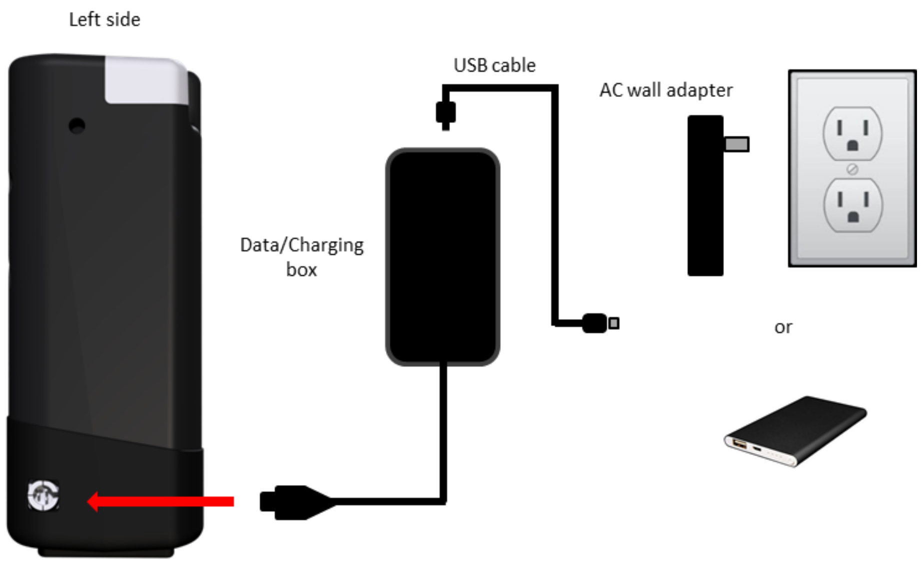






Innovations in Pumped Air Sampling
Progress in Design - Charging

- Standard charging via wall adapter
- Also capable of charging by USB connection
- Charging in remote locations (non-Ex environments)



Innovations in Pumped Air Sampling
Conclusion

- Accurate measurement of air sampled
- Included calibration of sampling train
- Record/History of flow rate for sampling period
- Minimize flow pulsation
- Bluetooth® capable / Android™ application
- USB Charging

Innovations in Pumped Air Sampling
References

Lee, E.G.; Lee, L.; Mohlmann, C.; Flemmer, M.; Kashon, M.; and Harper, M. "Evaluation of Pump Pulsation in Respirable Size-Selective Sampling: Part I. Pulsation Measurements" *Ann. Occup. Hyg.*, 2014, Vol. 58, No. 1, 60–73 doi:10.1093/annhyg/met047 Advance Access publication 24 September 2013

Lee, E.G.; Lee, T.; Kim, S.W.; Lee, L.; Flemmer, M.; and Harper, M. "Evaluation of Pump Pulsation in Respirable Size-Selective Sampling: Part II. Changes in Sampling Efficiency" *Ann. Occup. Hyg.*, 2014, Vol. 58, No. 1, 74–84 doi:10.1093/annhyg/met048 Advance Access publication 24 September 2013

ISO 13137:2013(E), Workplace atmospheres – Pumps for personal sampling of chemical and biological agents – Requirements and test methods

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Thank You!

Questions?

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