Principles, Practices, and Equipment for Performance Evaluation of Personal Monitoring Badges

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Personal Sampling

has arisen …

In response to the

Occupational Safety and Health Act of 1970 OSHA Rules 29CFR1910.1000 & later

placed limits on time-averaged

chemical concentrations

within employees personal breathing zones

Two types of Samplers: Active & Diffusive

- **Active Sampling**
  - Tubes
  - Pump Delivers Analyte to Sorbent
  - Less work to validate (4 tests)
- **Diffusive Sampling**
  - Badges
  - Diffusion Delivers Analyte to Sorbent
  - More work to validate (7 tests)

Published Protocols

Described Evaluation Parameters for Diffusive Samplers

- **NIOSH Draft Protocol**
- **CEN EN 838 (Europe)**
- **ANSI/ISEA 104-2009**
- **ASTM D6246**
- **MDHS 27 (UK)**

Personal Sampler
Evaluation Parameters

- Analytical Recovery & Blank
- Sampling (uptake) Rate
- Reverse Diffusion
  - Breakthrough
- Velocity/Orientation Effects
- Humidity Effects
- Temperature Effects
- Storage Stability

Analytical Recovery & Blank
(Desorption Efficiency)

- **Add Analyte to each Sampler**
- **Add Analyte to Extraction Fluid**

}

- 5x replicates
- 3 concentrations: low, medium, high
- Blank

- **Analyze Samplers & Calculate Recovery**

$$\textbf{\% Recovery = DE =} \frac{\text{(Qty Found, Sampler)} - \text{(Blank)}}{\text{(Qty Found, Fluid)}}$$

Personal Sampler Evaluation Parameters

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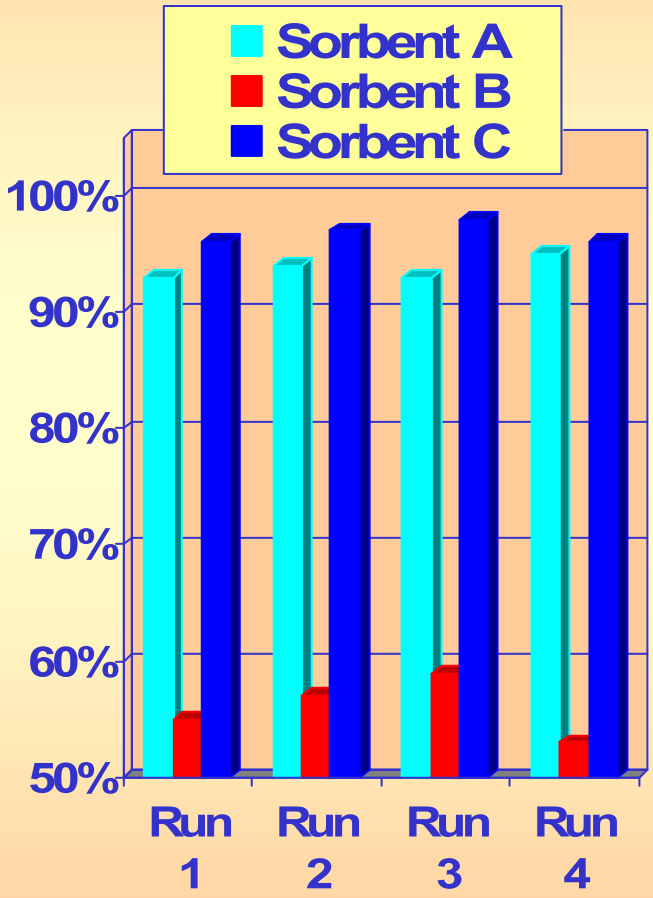
Analytical Recovery & Blank
(Desorption Efficiency)

Possible Causes of Low DE

- Weakly attracted to sorbent
Re-evaporation

- Strongly Held on Sorbent
Incomplete Recovery

- Decomposition



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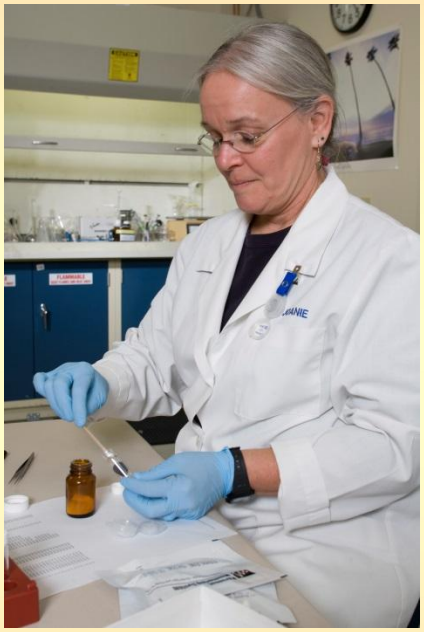
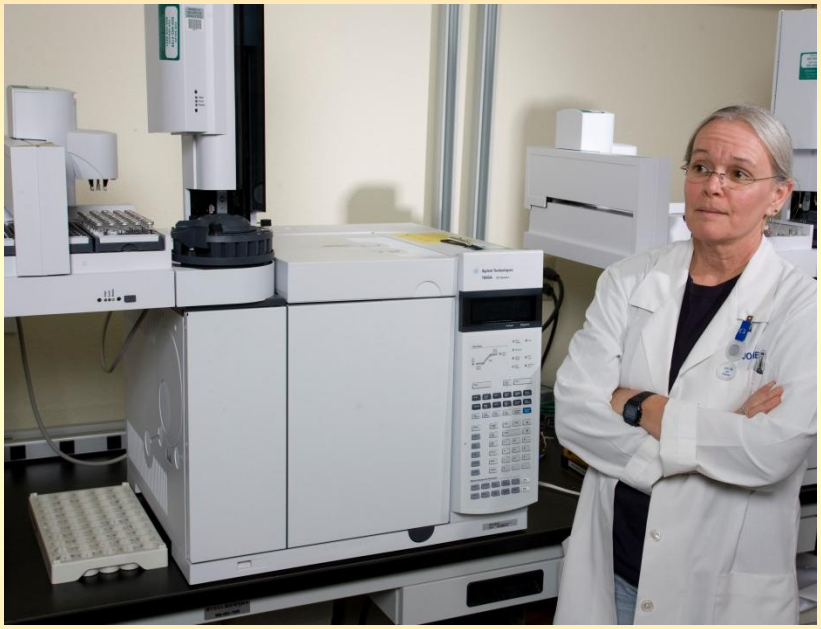
Analytical Recovery & Blank

Equipment Needed





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Sampling Rate Test

- **In a dynamic (flowing) exposure chamber:**
  - Generate Analyte
    - **Constant concentration**
  - Expose Diffusive & Active Samplers
    - **Active sampler is reference method**
    - **Set period of time**
  - Analyze Samplers
    - **Qty found on each sampler**
  - Sampling Rate =

$$\frac{\textbf{Qty Found (diffusive) x Sample Volume (active)}}{\textbf{Qty Found (active) x Sampling Time}} = \frac{\textbf{mL}}{\textbf{min}}$$

Personal Sampler Evaluation Parameters

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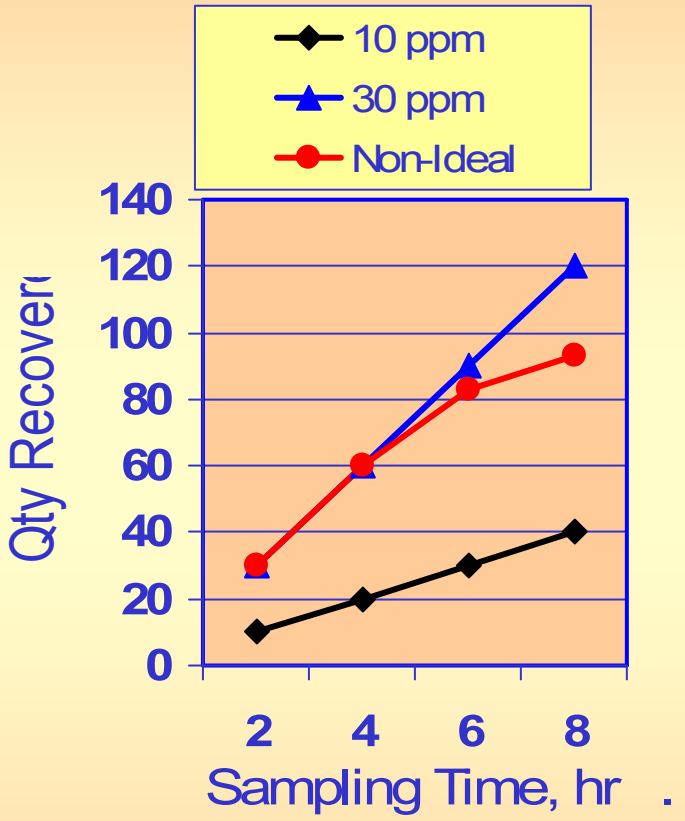
Sampling Rate Test

Analyte Uptake:

- **Linear**
  - Time
  - Concentration
- **Slope ~ Sampling Rate**



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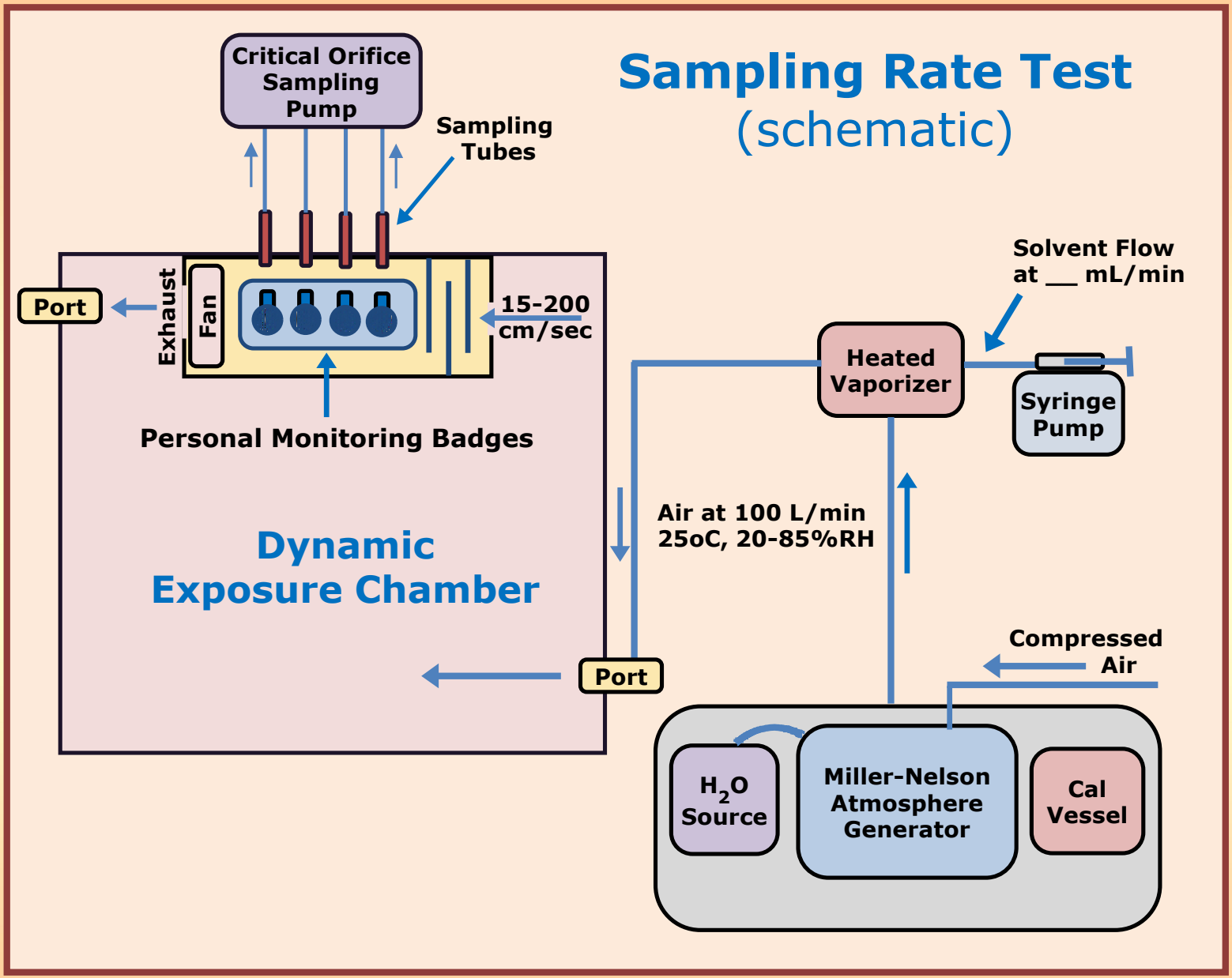
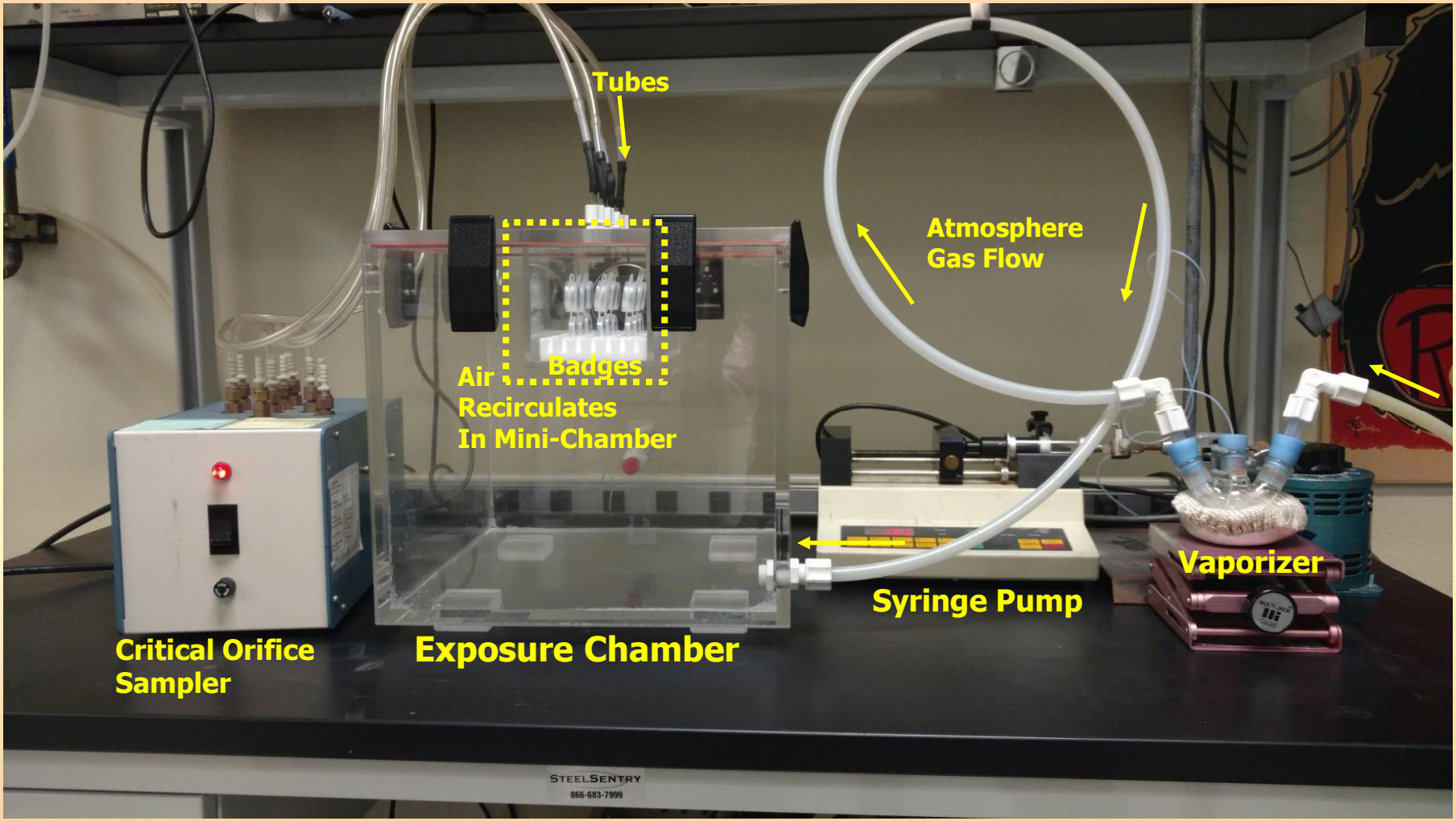
Sampling Rate Test
(schematic)



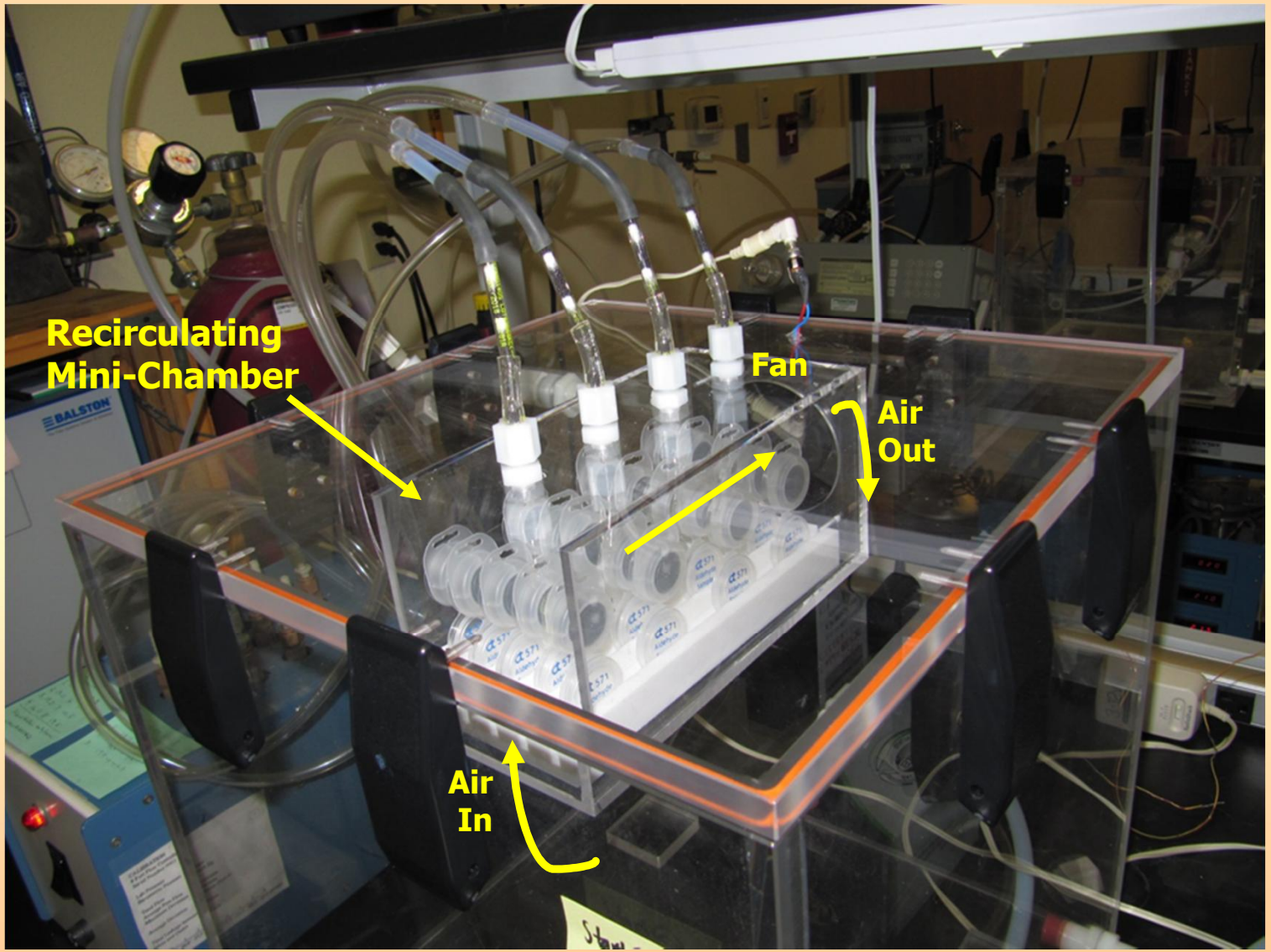
Sampling Rate Test Set-Up

Photo



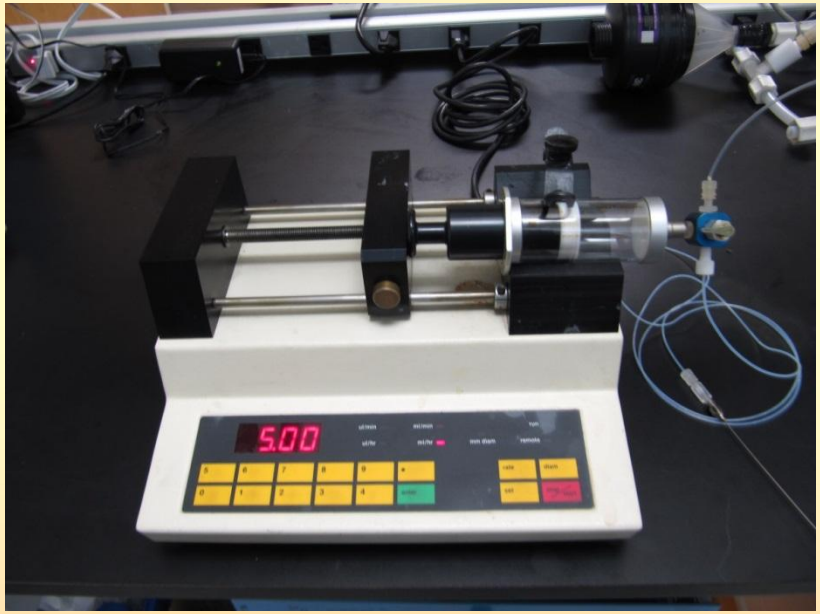
Sampling Rate Test Set-Up

Close-up showing tubes and badges

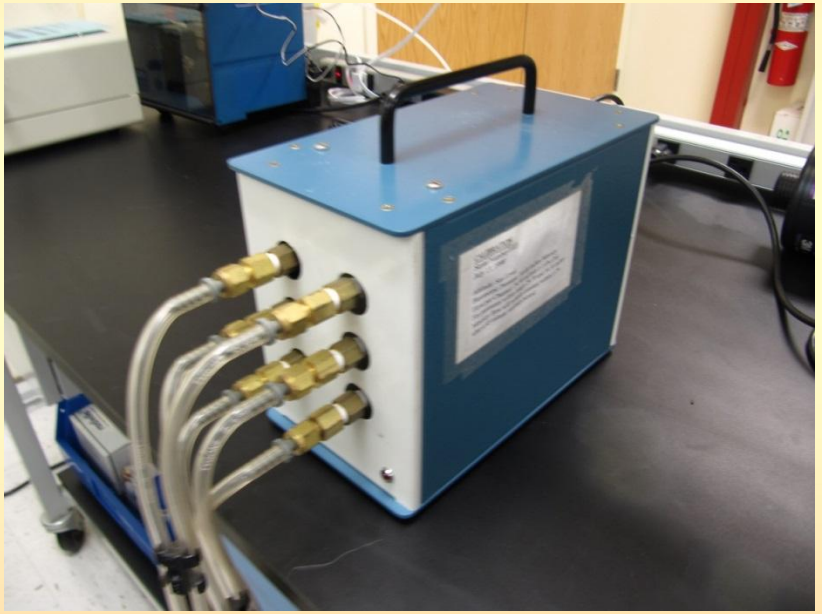


Miller-Nelson Atmosphere Conditioner

Syringe Pump



Critical Orifice Sampler



Reverse Diffusion Test

(evaporative loss during/after sampling)

- **Expose 10 Diffusive Samplers**
  - **Highest Expected Concentration for short time**
- **Remove & Cap 5 Samplers (A)**
  - **Store Cold & Analyze Later**
- **Leave 5 Samplers Open (B)**
  - **Expose to Zero Air (several hours)**
- **Analyze All Samplers Together**
  - **Compare:** $\frac{\text{Analyte Found (B)}}{\text{Analyte Found (A)}}$

Difference (A – B) due to Reverse Diffusion

Personal Sampler Evaluation Parameters

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- **Reverse Diffusion**
  - Breakthrough
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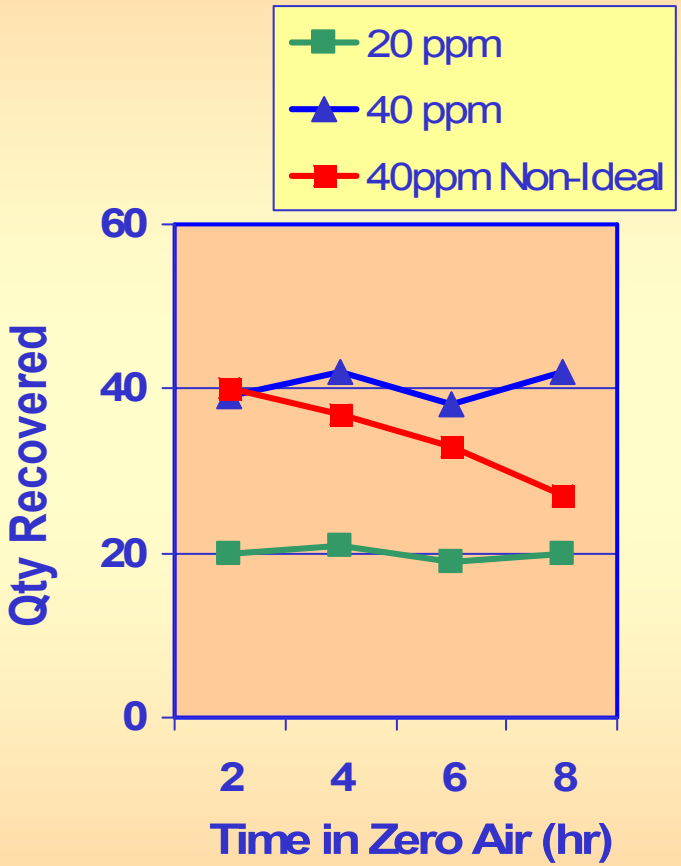
Reverse Diffusion Test

(evaporative loss during/after sampling)

Reverse Diffusion

- Causes:
  - Exceeding Capacity of Sorbent
  - Weak association between analyte and media
- This test determines the Maximum Sampling Time (MST) for each Analyte



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Air Velocity Test

- **Expose 5 Samplers @ V = 15 cm/sec** (30 ft/min)
- **@ V = 50 cm/sec**
- **@ V = 100 cm/sec**

} Fixed %RH, Time, Concentration

- **Compare Analyte recovered on all Samplers for different air velocities**
- **Sampling Rate should be unaffected by air velocity when V ≥ minimum required air velocity**

Air Velocity Test Looks for Differences

at 15 cm/sec vs higher flows

(15 cm/sec = 30 ft/min … lowest typical air velocity in workplaces)

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- Humidity Effects
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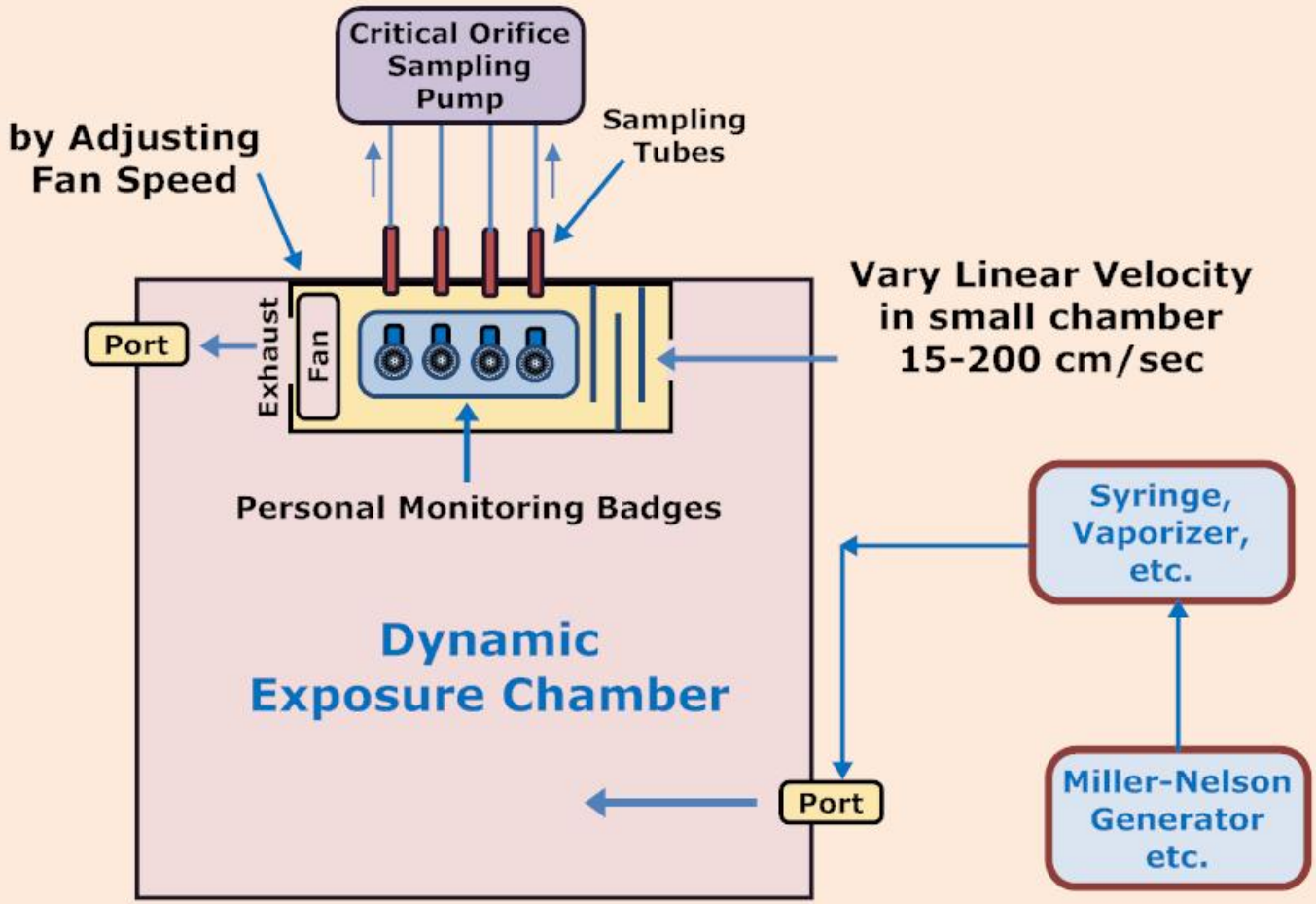
Air Velocity Test Set-Up



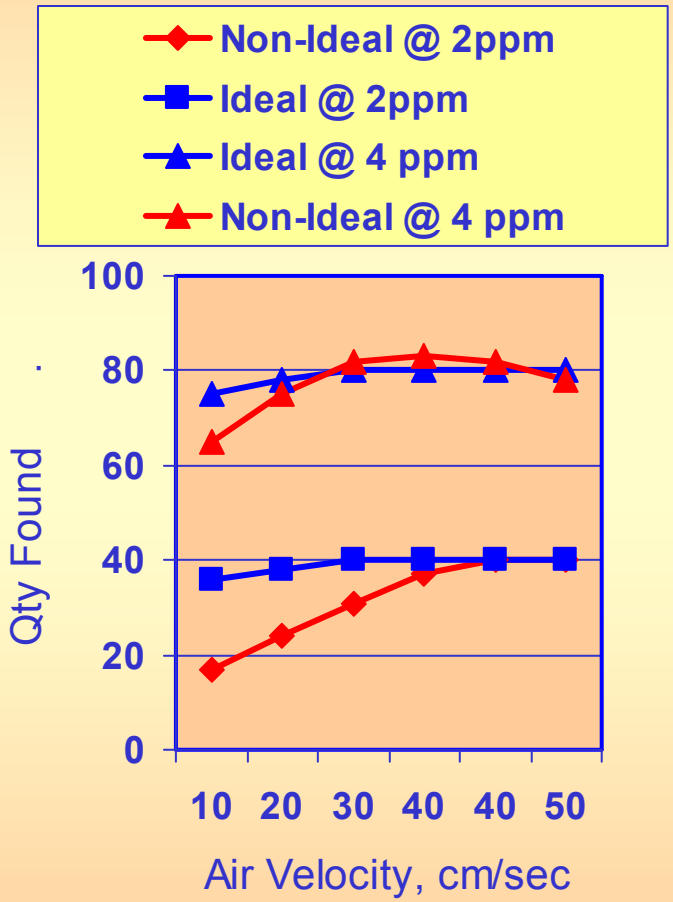
Air Velocity Effects

Air Velocity Effects

At some air velocity, Sampling Rate will begin to decrease

With proper design, Sampler "works" down to 15 cm/sec

Results for a particular Sampler will be similar for many analytes



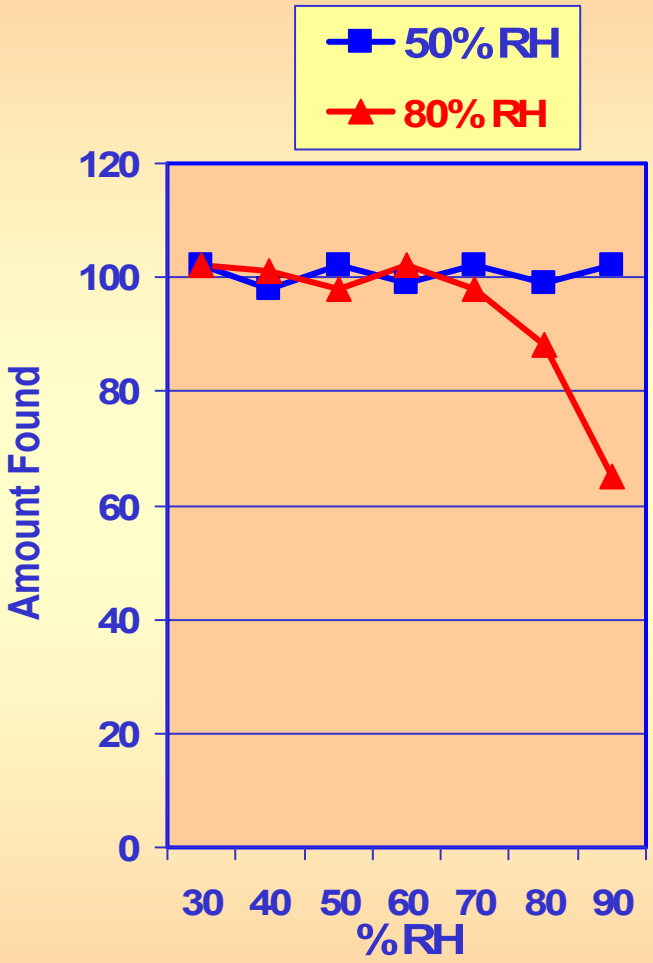
Personal Sampler Evaluation Parameters

- Analytical Recovery & Blank
- Sampling (uptake) Rate
- Reverse Diffusion
  - Breakthrough
- **Velocity/Orientation Effects**
- Humidity Effects
- Temp Effects
- Storage Stability

Humidity Effects

(typical experiment)

- **Expose 15 Samplers at Fixed Concentration, Temp, Time**
  - **5 at 20% RH**
  - **5 at 50% RH**
  - **5 at 80% RH**
- **Analyze All Samplers**
- **Compare Amt Found for Different Humidity Exposures**
  - **Difference Due to Evaporative Loss Arising from Moisture Taking Up Sorbent Capacity**



Personal Sampler Evaluation Parameters

- Analytical Recovery & Blank
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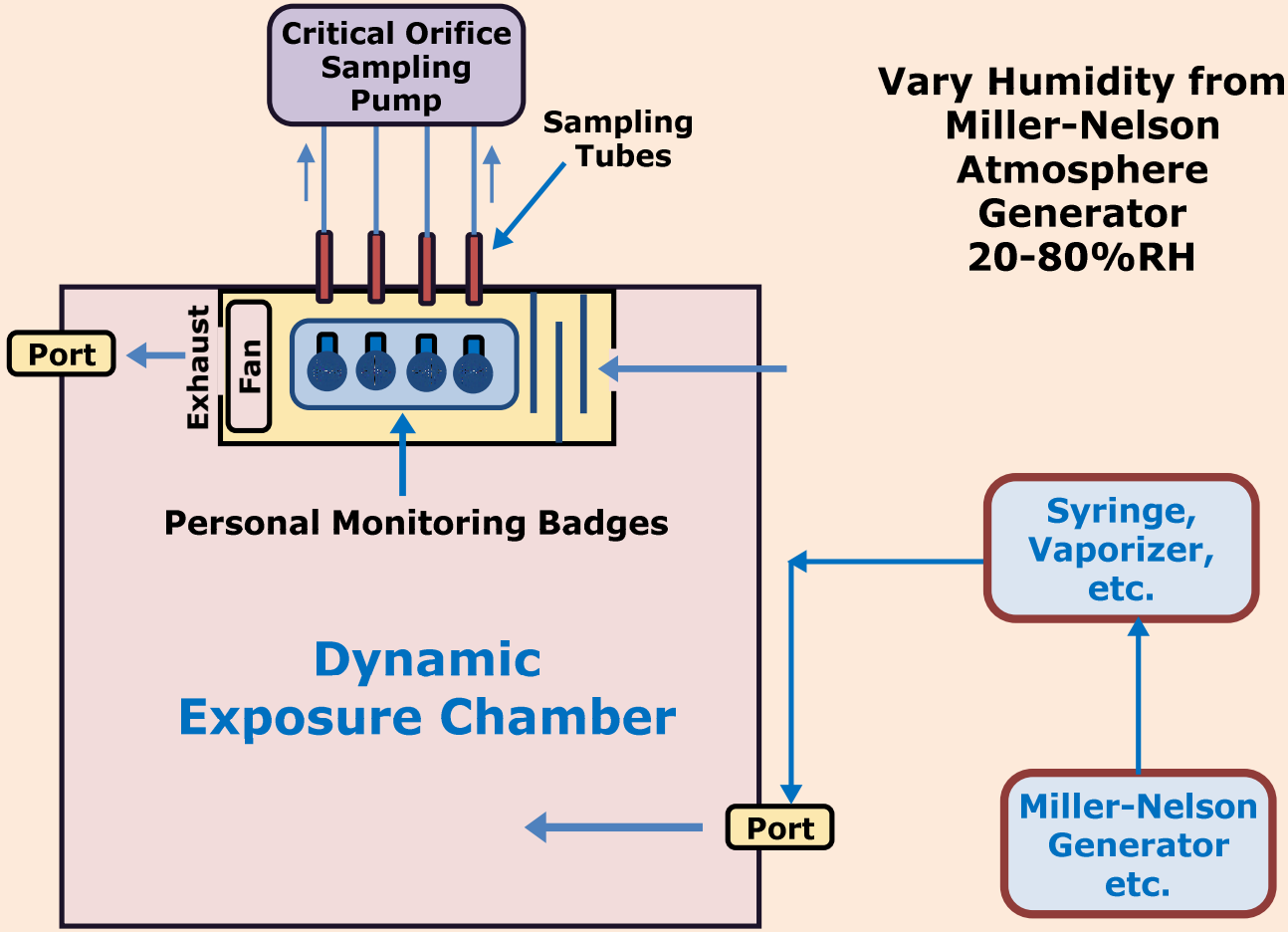
- Velocity/Orientation Effects
- **Humidity Effects**
- Temp Effects
- Storage Stability

Humidity Test Set-Up



Miller-Nelson Atmosphere Conditioner

Supplies air at controlled flow, temp, and %RH

Personal Sampler Evaluation Parameters

- Analytical Recovery & Blank
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  - Breakthrough
- Velocity/Orientation Effects
- **Humidity Effects**
- Temp Effects
- Storage Stability

Temperature Effect Test

(Sampling Rate increases with Temp)

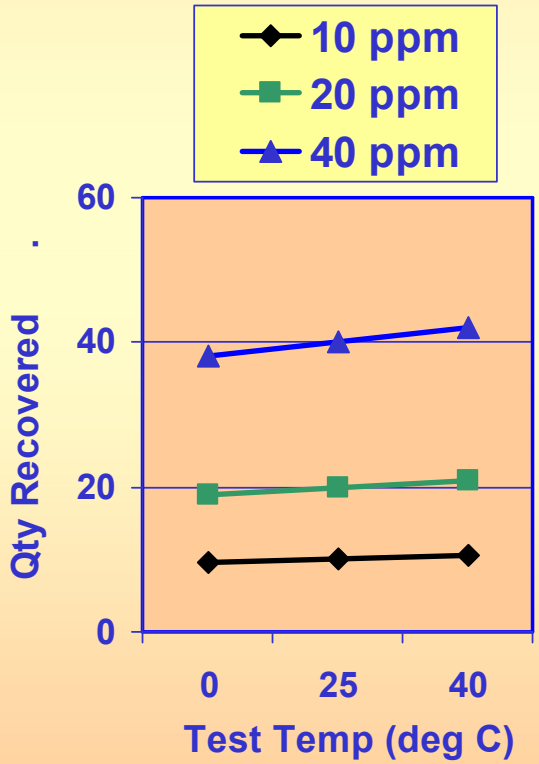
- Expose 5 Samplers at **0 °C**
- **25 °C**
- **40 °C**

} Fixed %RH, Time, Concentration

- Compare Analyte Recovery on All Samplers

Typical S.R. Increase:

3% per 10 °C



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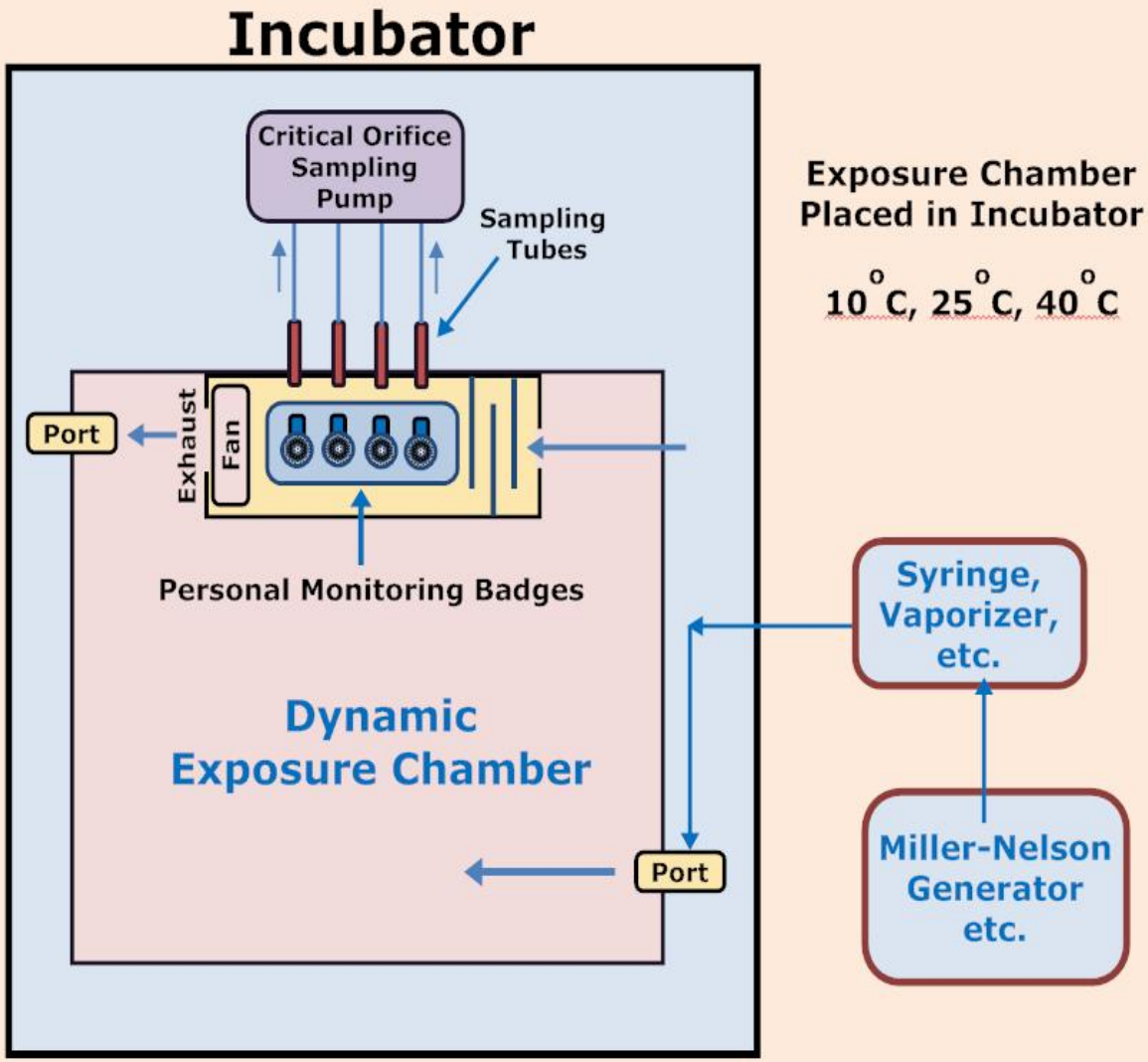
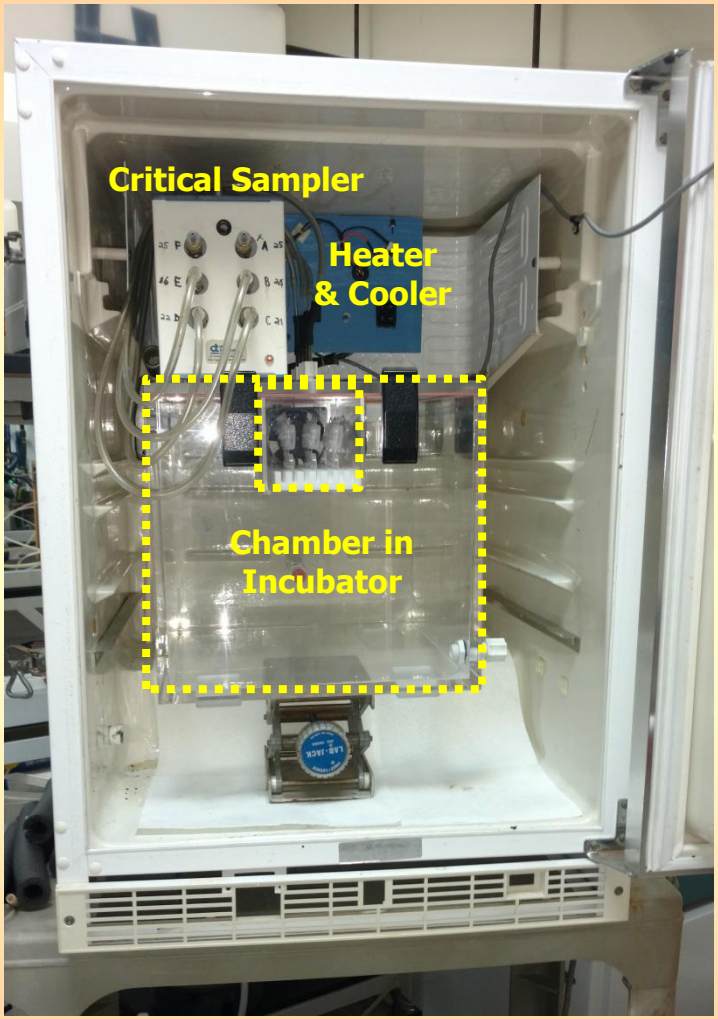
- Storage Stability

Temp Test Set-Up



Temperature Test



Personal Sampler
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- Humidity Effects
- **Temp Effects**
- Storage Stability

Storage Stability Test

(analyte loss on storage)

- Expose 30 Diffusive Samplers
  - **At Fixed Concentration, Temp, Time**
- Remove & Cap 10 Samplers
  - **Store at Room Temp (25°C)**
- Remove & Cap 10 Samplers
  - **Store In Freezer (-20°C)**
- Remove & Cap 10 Samplers
  - **Store in Refrigerator (2-8°C)**

Analyze Stored Samplers:

- 15 after 1 week storage

- 15 after 2 week storage

Personal Sampler Evaluation Parameters

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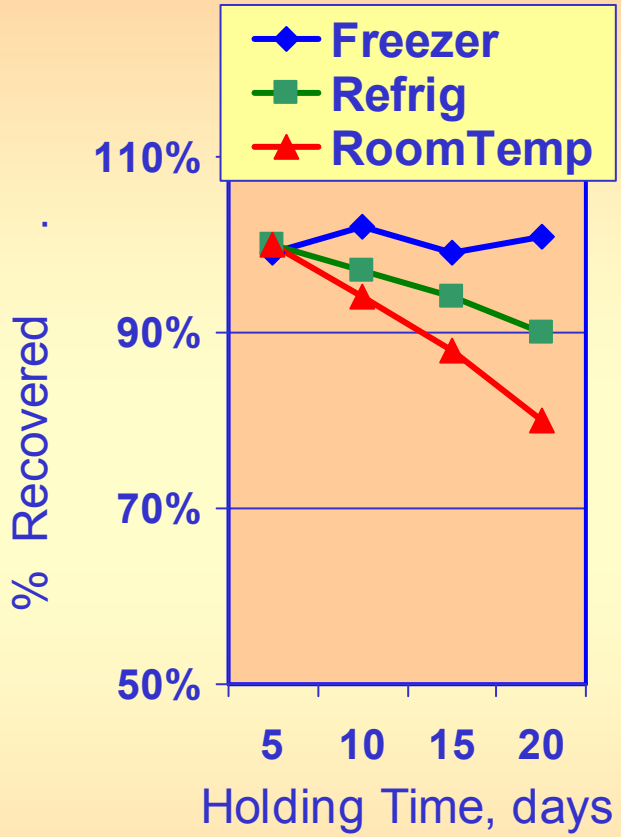
- Velocity/Orientation Effects
- Humidity Effects
- Temp Effects
- **Storage Stability**

Storage Stability Test

(analyte loss on storage)

Causes for decreased storage stability

- Analyte Loss
  - Evaporation
  - Migrates into packaging
- by Decomposition



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- **Storage Stability**

Evaluation Criteria

- **Several OSHA Rules & most NIOSH criteria suggest an overall uncertainty of ± 25% is acceptable for personal monitoring tests.**
- **Taking a 25% accuracy criterion, you would accept evaluation results as validation of a sampler provided test variation stay within ± 25% overall system variation.**
- **In some cases in conformance with accuracy requirements, you may place procedural limits on (for example):**
  - **(a) Allowed %RH or Temperature Range in which Sampler is used**
  - **(b) Allowed Holding Time or Storage Conditions after sampling**
  - **(c) Allowed Sampling Time (< 8 hr)**

Summary

- **Diffusive Samplers are easy to use, but difficult to evaluate.**
- **7 types of tests are needed to evaluate a Personal Monitoring Badge (Diffusive Sampler).**
- **Complex Sampling Rate evaluations for Badges replace use of the Sampling Pump. (Sampling Rates can be predicated with some accuracy.)**
- **Desorption efficiency (DE) tests, humidity effects, and sample stability tests are similar for both Diffusive or Active samplers.**
- **Diffusive Samplers can suffer evaporative losses (Reverse Diffusion) if maximum sampling time is exceeded, but MST is large for most analytes.**
- **Temperature & Air Velocity affects are simple and similar for many analytes, so they need be performed only 1 time per each type of Sampler.**

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