Testing Used Respirator Cartridges to Confirm Change Schedules

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Acknowledgement
(Mentors)

- Gary O. Nelson
  - **Experimental service life studies**
- Gerry O. Wood
  - Service life theory
- Jim Johnson
  - **Respirator General Practice**

What is Happening when you wear an Air Purifying Respirator (APR)

INFLUENT
Contaminant Level
Above OEL

(must be below IDLH)

Air Purifying Respirator

A
P
R

Reduces Contaminant Level by “Protection” Factor

EFFLUENT
Contaminant Level
Below OEL

IDLH = immediately dangerous to life & health; OEL = Occupational Exposure Limit

Service Life

Duration of Time a respirator may be worn before contaminant breakthrough exceeds the OEL*

Change Schedule should be based on Hypothetical Service Life plus a safety factor

Hypothetical Service Life is a Projection based on relevant data and theory.

* OEL = Occupational Exposure Limit

Service Life
(hypothetical)

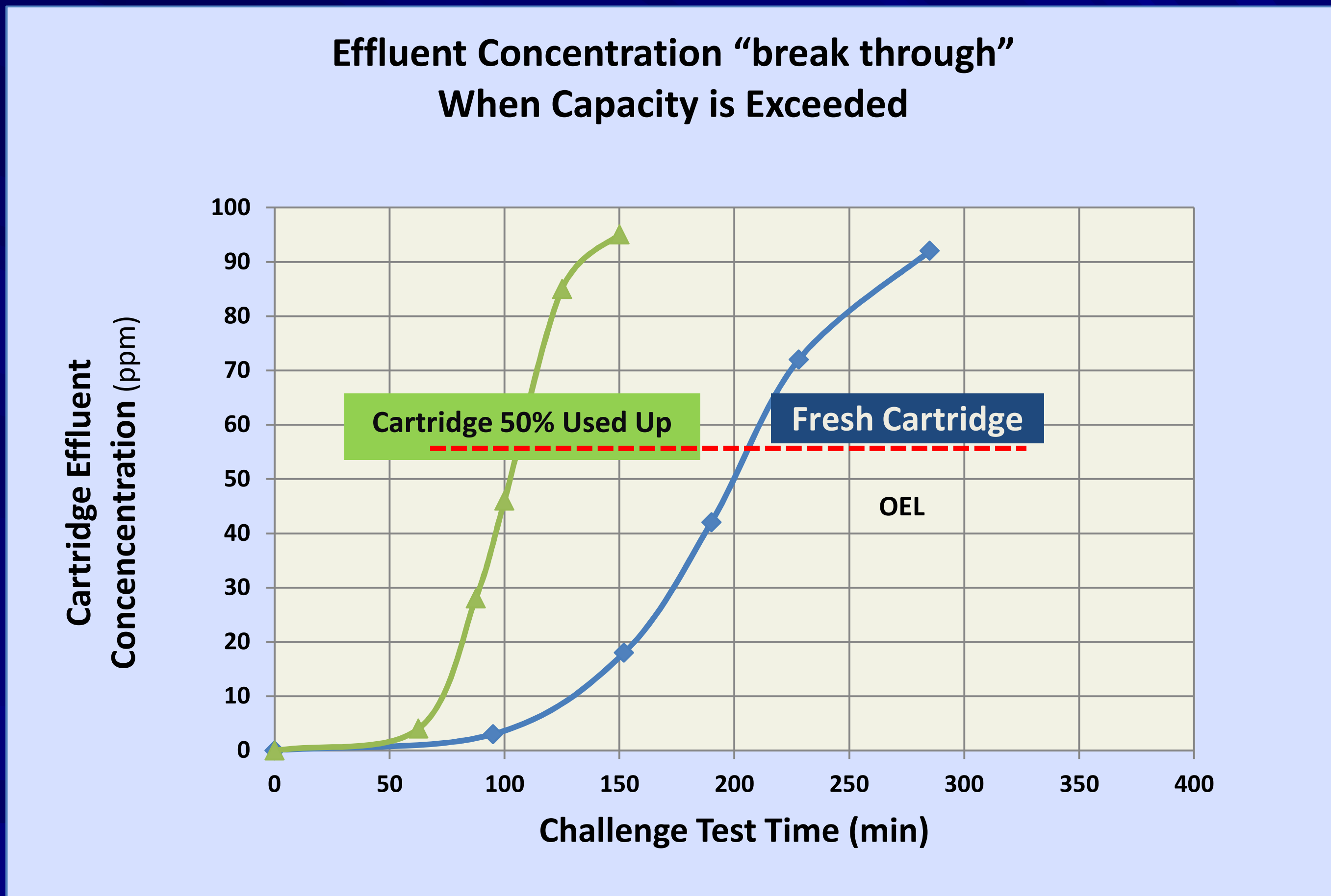
… Can be measured accurately in the Lab under hypothetical environmental conditions, but …

Real-World Service Life depends upon the ***environmental conditions in use***.

i.e., Actual Service Life depends upon actual use

Hypothetical Service Life

as determined in a Lab



OSHA Suggests Options
for Developing a Change Schedule
(OSHA web-site)

- *Measure* Experimentally with Lab Test … in practice, *a model is often used* because influent concentration is low and test time is long
  - *Follow* Manufacturer Recommendation … Mfr Recomendation usually *based on a Model*
    - *Use* a Mathematical Model … NIOSH "Multi-Vapor" is the Most Popular Model

In Actual Practice

You get a hypothetical Service Life by combining …

- Lab Service Life Determinations
- A Mathematical Model
- Estimated Environmental Conditions

Caveat: The overall error of your estimate is a summation of errors in each operation.

Projected Service Life
(estimate of errors)

- Error due to
  - Lab Determination
  - Math Model approximations
  - Data input into the Math Model
    - Capacity Data for Cartridge Used
    - Environmental Challenge Conditions

Factors Entered into Model

expected …

- **Contaminant Concentration (ppm)**
- **Work Rate (breathing rate in L/min)**

Plus expected …

- temperature
- humidity
- wearing time
- Size and Nature of Sorbent in Cartridge

Model → Projected Service Life

Size and Nature of Sorbent in Cartridge

must also be entered into the Model

If you don't select a standard cartridge from the menu, model will need the following information:

- Carbon Bed Diameter & Depth (cm)
- Weight of sorbent in each cartridge (gm)
- The carbon micropore volume (cm3/g)
- Carbon granule size (ave. diameter in cm)
- Carbon's Adsorption Potential for Benzene
- Carbon's Affinity Co-Efficient for Water
- %RH at which Cartridge has been pre-conditioned

Model → Projected Service Life

Factors Related to Contaminant(s)

must be entered into Model

If your contaminant is not on the Menu,
the Model will need the following:

- Molecular weight
- Liquid density (g/cm3)
- Water Solubility Factor
- Vapor Pressure Co-efficients (Antoine co effs)
- Molar polarizability (cm3/ mole)

Model → Projected Service Life

Projected Service Life
(for setting Change Schedule)

- Accurate Projections available to sophisticated organizations
- Most Rely on Respirator Mfr recommendations
  - Approximate fitting to Math Model
  - Many parameters estimated
  - If no data … no recommendation

Projected Service Life

(resulting Change Schedule)

- Competent Leading Company IH Mgr
  - Uses Worst-Case estimates & Safety Factors
    - Safe Employees
    - Discard cartridges with un-used capacity
- Untrained non-Leading Company IH Mgr
  - Not using Worst Case Inputs & Safety Factors
    - Unsafe Employees
    - May use Cartridges after capacity is expended

In the event that you are not completely satisfied with your projected Service Life & Change Schedule …

Are there other ways to get improved confidence in your Respirator Change Schedules?

End of Service Life (ESL)

… is the moment when
Effluent Contaminant Level
approaches the OEL

End of Service Life Indicator (ESLI):
Provides alternate method for an END-USER to detect the ESL

End of Service Life Indicators (ESLI)

(*appeal of*)

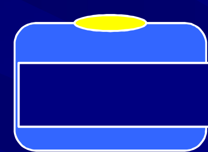
The end-user does not need to:

(a) Know too Much
(b) Think too much
(c) Do too much

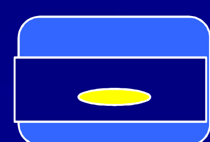
End of Service Life Indicators

(current design approaches)

- A Sensor is placed **ON** the Cartridge
  - **Alarm Based on Time-Weighted Average Exposure**



- A Sensor is placed **INSIDE** the Cartridge
  - **Alarm Based on Instantaneous Concentration**



End of Service Life Indicators

- The Sensor must be inexpensive and selective for all Agents claimed for that cartridge

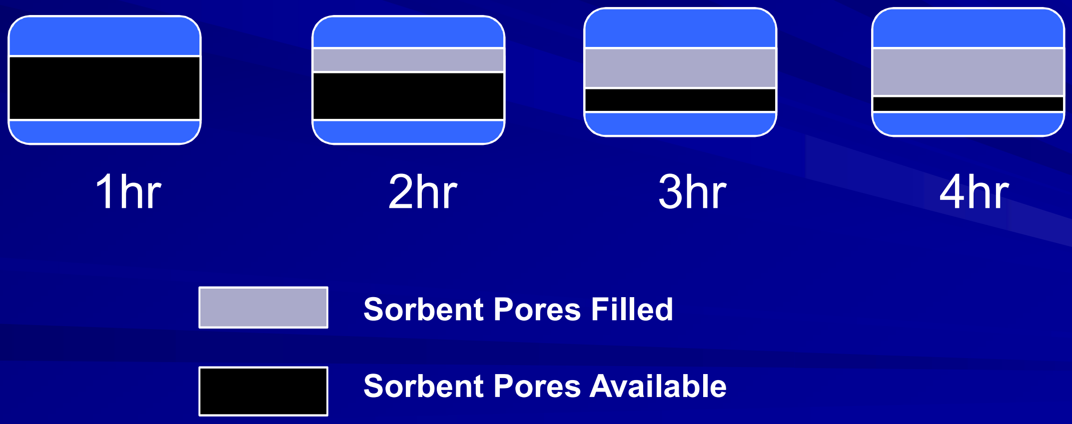
So, ESLI are not yet widely available.

Could There Be Another Approach to Detecting the End of Service Life ?

- Doesn't require detailed knowledge about the use environment and the sorbent.
- Doesn't require a super-selective sensor that is cheap enough to be thrown away with each cartridge use?

Measure the "Residual Capacity" of Cartridge

- Residual Capacity
  - – the adsorptive or chemical capacity remaining after normal respirator use



Laboratory Method A

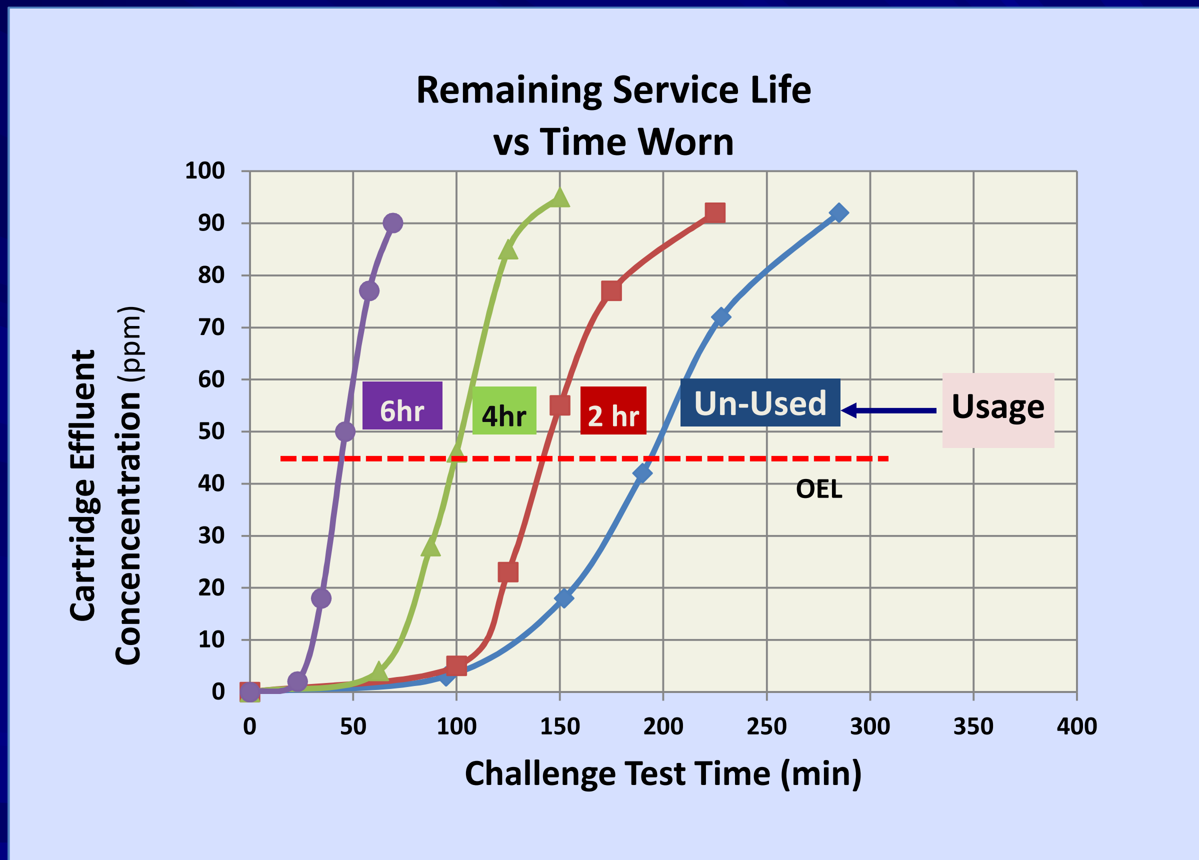
Residual Capacity Test using "suspected" contaminant

- Perform a Destructive Test on a "used" Cartridge
  - **After wearing the respirator**
    - Follow an established change schedule, select cartridges from each "similar exposure group", send "used" cartridges to Lab for Challenge Test

      – Run NIOSH-style Challenge Test on "used" cartridges

      – If cartridges have retained > 10% of capacity,
        - Change Schedule has been confirmed

Effective Service Life
(remaining time to breakthrough)
decreases as Capacity is consumed



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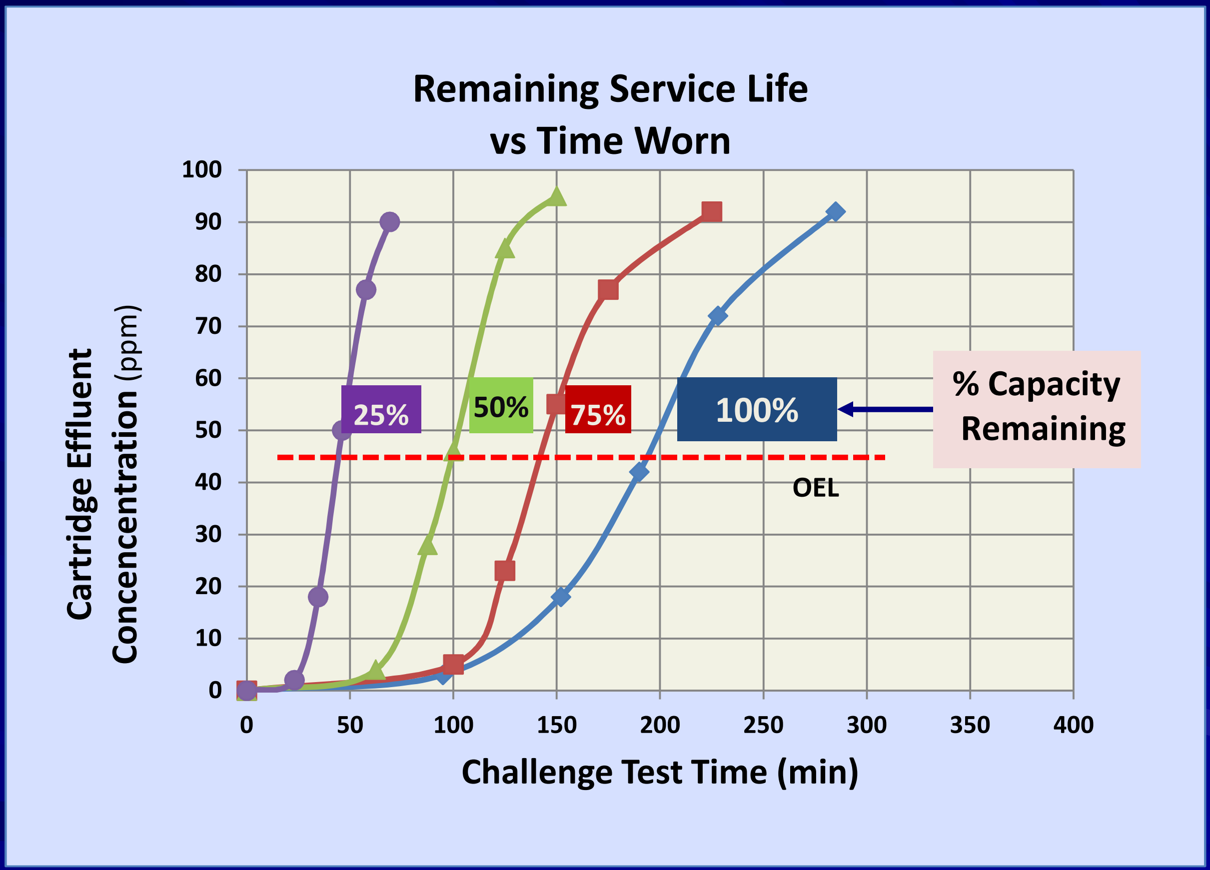


Cost of Lab Method A

(Destructive Test of “used” Cartridges)

- Single (SEG) Similar Exposure Group $950 (USD) for testing 3 used cartridges in Lab
- Three (SEGs) Similar Exposure Groups $1,950 (USD) for testing 9 used cartridges in Lab

Simple Lab Method “B”

Residual Capacity Test using “surrogate” Contaminant

- Non-Destructive Test on a “used” Cartridge
  - **After wearing the respirator**
    - Follow established change schedule, select cartridges from each “similar exposure group”, and send “used” cartridges for Challenge Test
  - Run **non-destructive** Challenge Test
    - Using surrogate agent
    - E.g., Methane or Carbon Dioxide
  - If cartridges have retained > 10% of capacity,
    - Change Schedule has been validated

Simple Lab Method B

Non-Destructive Test using "surrogate" contaminant

- Inject Pulse of Surrogate Agent into "used" Cartridge

- Measure Passage Time thru Cartridge
  - Retention Time Correlates with Residual Capacity

- N. Bac , A. Sacco, & J.L. Hammarstrom, 1983, Measurement of the Adsorption Capacity of Charcoal Filters under Conditions of Variable Humidity Chem. Eng. Comm., 24:4-6, 205-213

N. Bac , A. Sacco, & J.L. Hammarstrom
Experimental Design

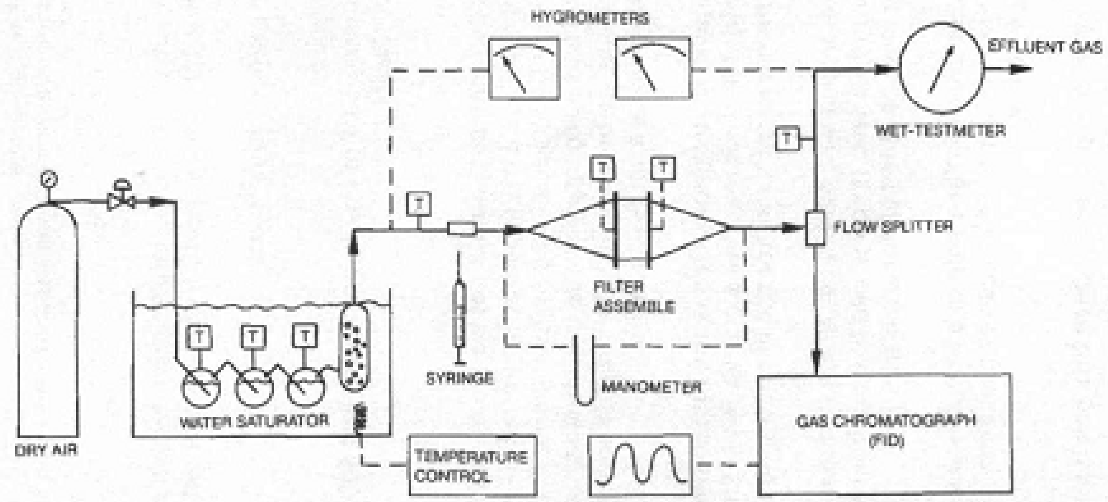
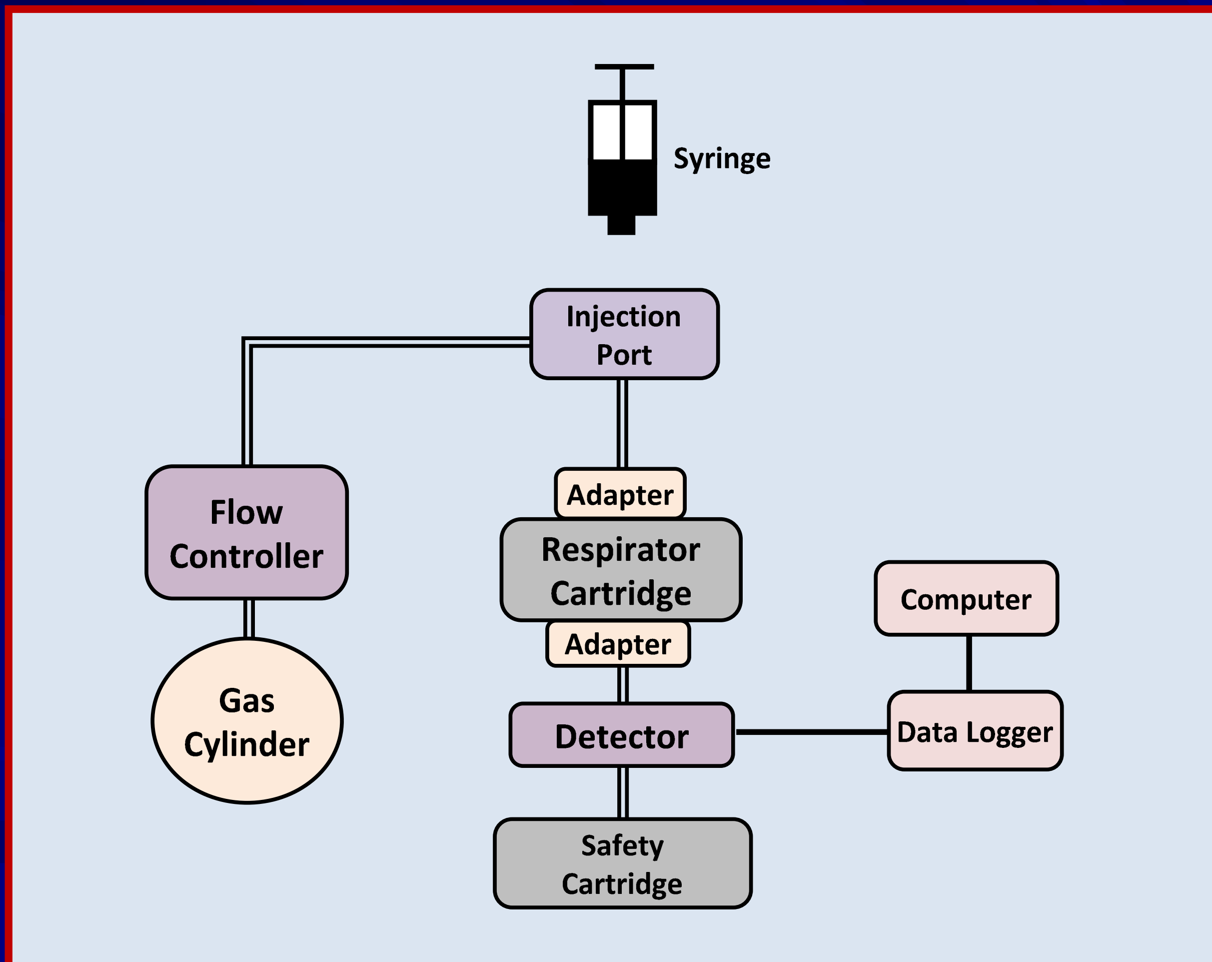


FIGURE 1 Schematic of the test apparatus.

Simple Lab test B
for Residual Capacity



N. Bac , A. Sacco, & J.L. Hammarstrom
Experimental Data

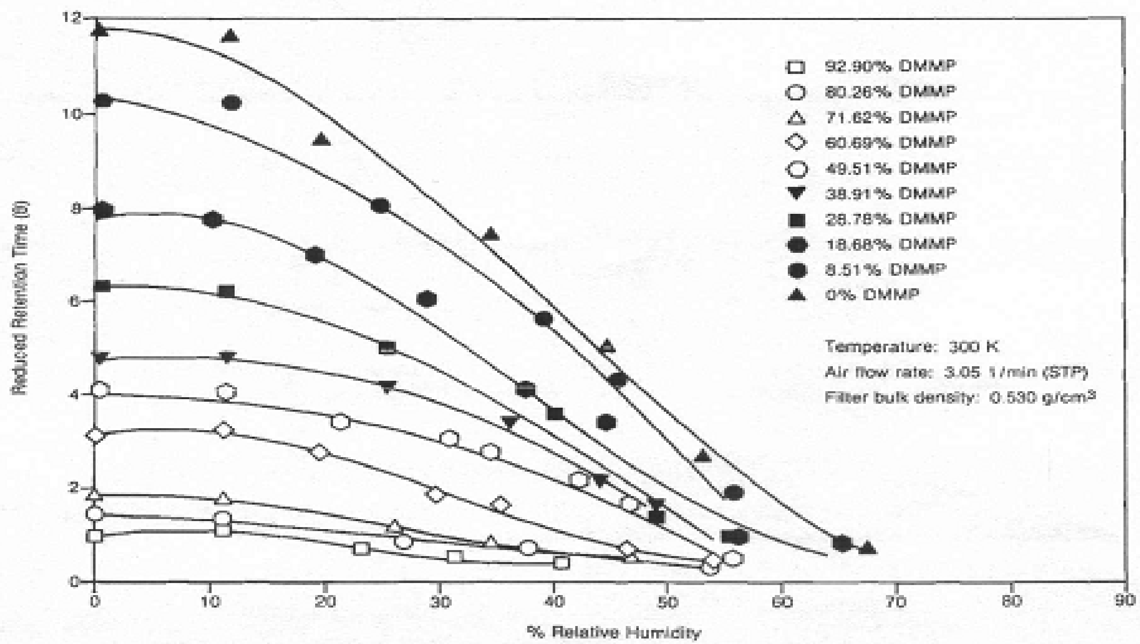
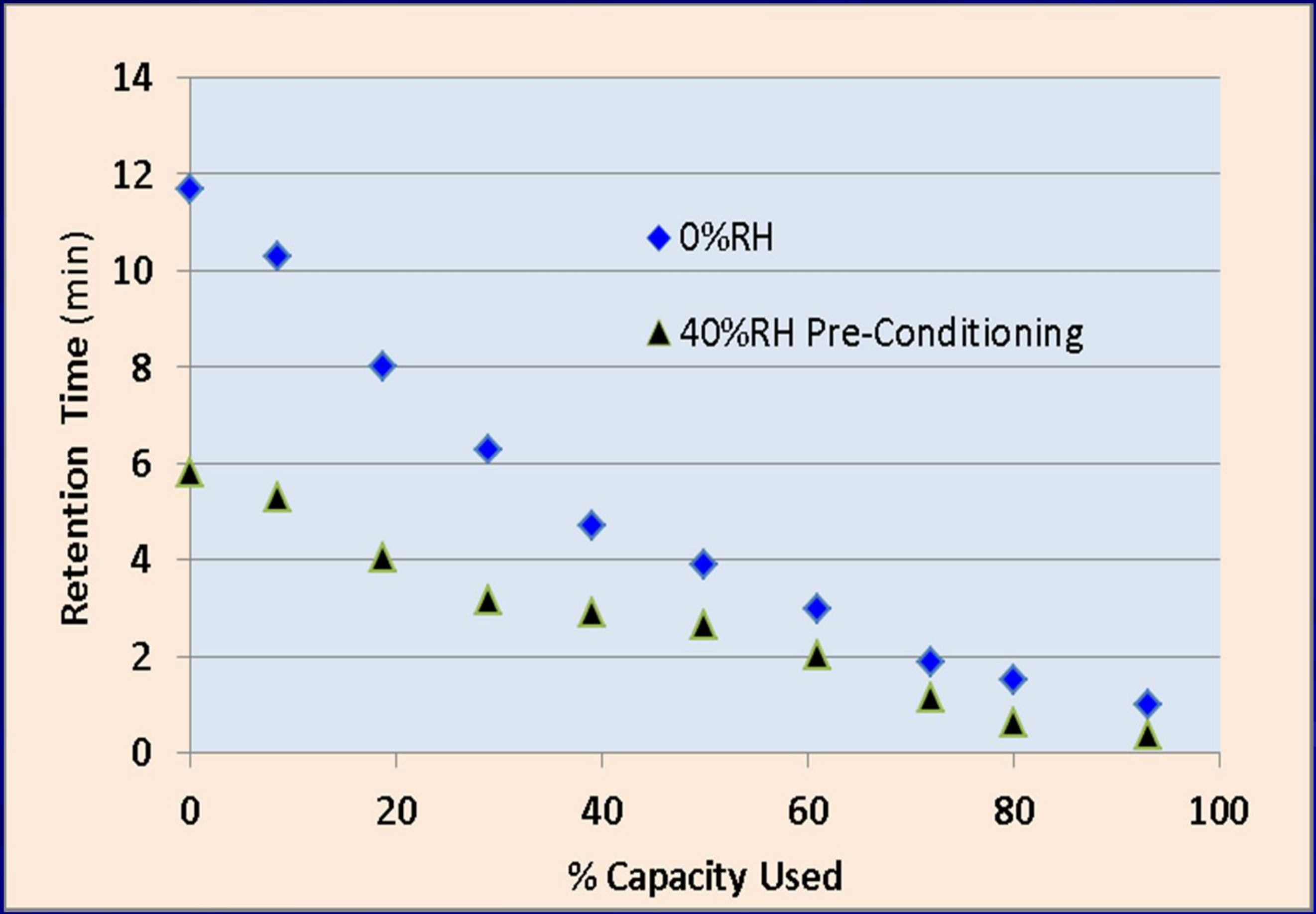


FIGURE 2 Correlation between the reduced retention time of CH_4 and the percent relative humidity. (Filters at equilibrium water loadings.)

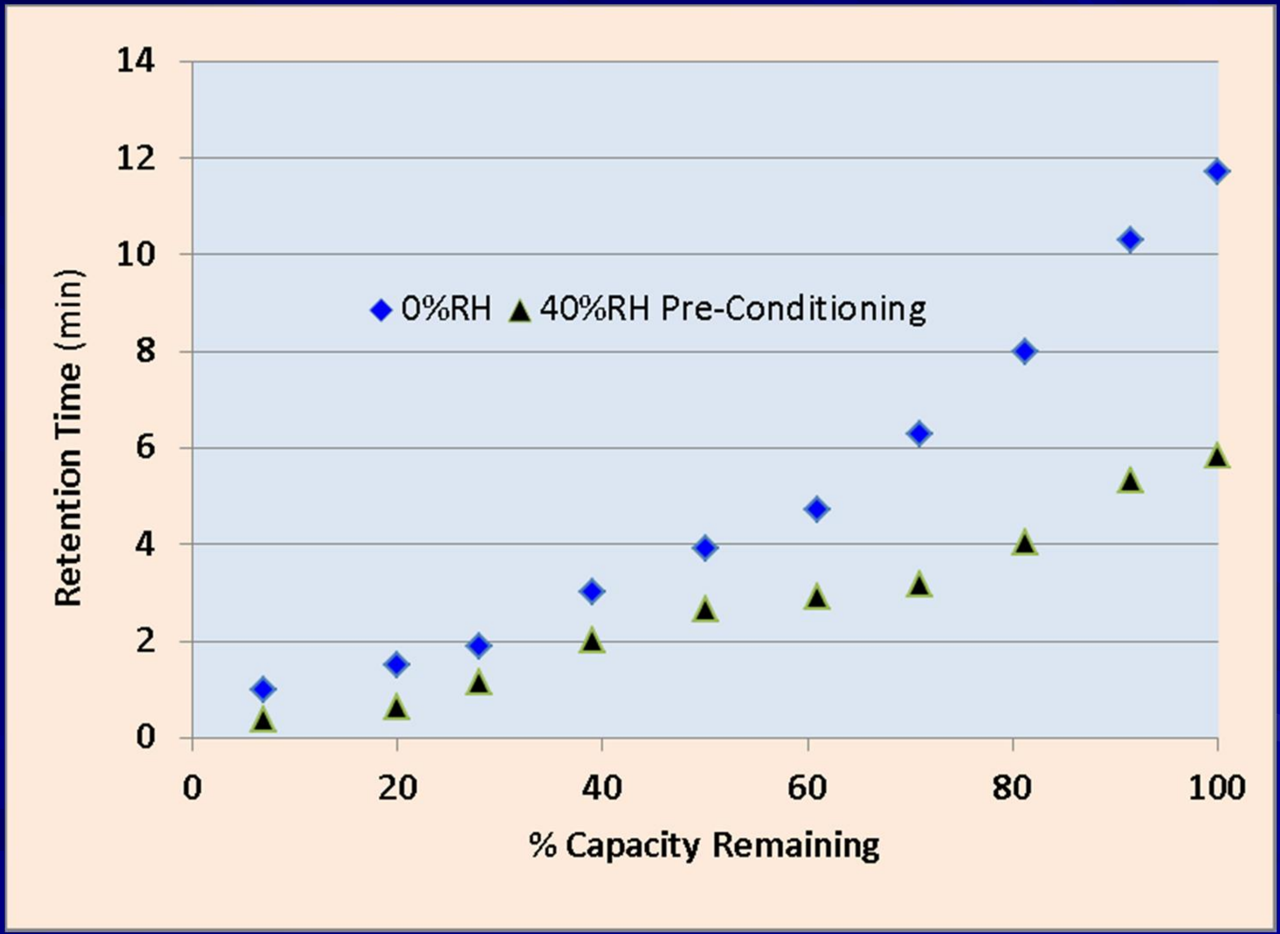
Test Retention Time

correlates with Capacity Used



Test Retention Time

correlates with Capacity Remaining



Conclusions

- Uncertainty in projected Service Life arises when users lack accurate data to input into models to generate Service Life/Change Schedules.

- End of Service Life Indicators have advantage of requiring little input from end-users, but ESLIs are still rare.

- Measuring Residual Capacity to detect End of Service Life, has advantages:
  - **Applicable to a wide variety of real-world situations**
  - **No need to modify respirator by installing exotic sensors.**

- Residual Capacity testing may be conducted using
  - (a) actual expected contaminants (expensive, destructive test)
  - (b) surrogate contaminant (cheap, non-destructive test)

AT Respirator and Filter Chemical Challenge Test Lab

Assay Technology Facility

(Livermore, California)