Service Life Assessment by Measuring Residual Capacity

(end-user's perspective)

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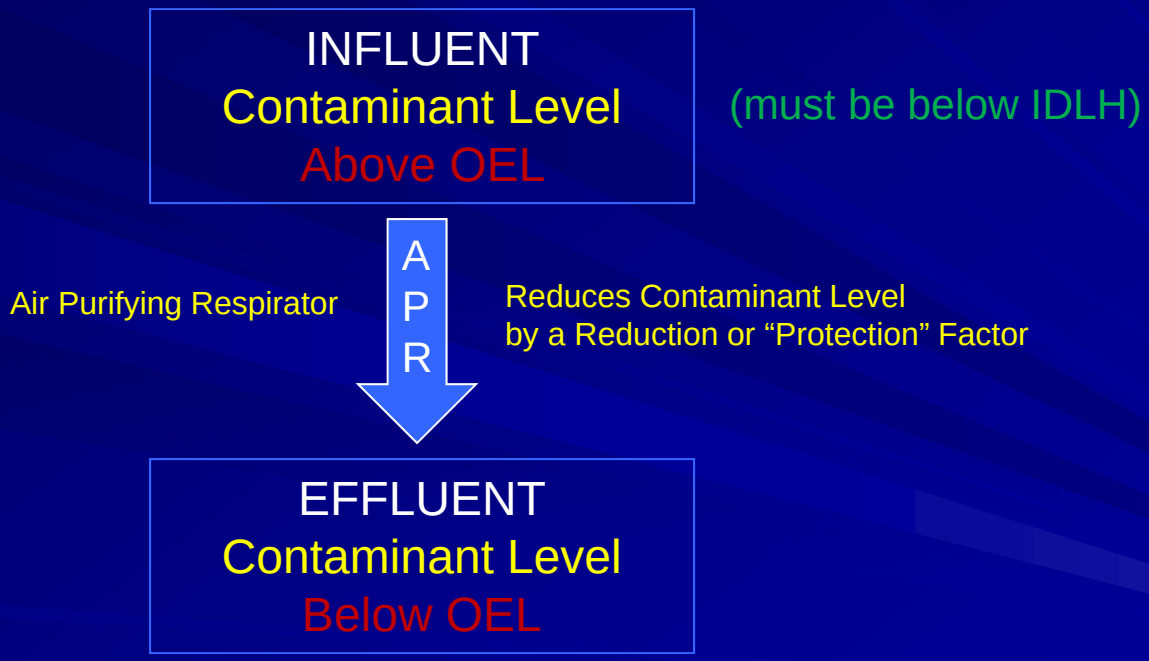
Acknowledgement
(Mentors)

- Gary O. Nelson
  - Experimental service life studies
- Gerry O. Wood
  - Service life theory

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



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

Service Life (hypothetical)

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

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

i.e., Service Life is relative to the Challenge applied by environmental conditions

OSHA (USA) Suggestions for Service Life Estimation

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

Real-World Service Life

End-User usually estimates by combining …

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

Caveat: When you combine operations, the overall system error is a summation of errors in each operation.

Real-World Service Life
(error estimate)

- ERROR (Lab Determination)

+

- ERROR (Math Model)

+

- ERROR (Input Data including Environmental Conditions)

Summation to get Overall System Error

Factors Entered into Model

Average contaminant concentrations (ppm)
Work Rate (breathing rate in L/min)

Plus …

- Expected temperature
- Expected humidity
- Expected wearing time
- Quantity and Nature of Sorbent in Cartridge

more Factors Entered into Model

If you don't select "typical cartridge" the Multi-Vapor Model will ask you for 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

more Factors Entered into Model

If your contaminant is not known by the NIOSH Multi-Vapor Model, you will be asked for the following:

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

Accurate Service Life Estimates
(for setting Change Schedules)

- Available to more sophisticated end-users
- Others Rely on Respirator Mfr recommendations
  - Often guessing at environmental challenge conditions
  - For some conditions, Mfr has no recommendation

End of Service Life Indicators (ESLI)

(*the 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 (ESL)

… is the moment when
Effluent Contaminant Level
approaches the OEL

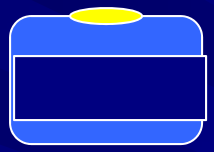
OUR OBJECTIVE:

To provide an alternate method for an END-USER to detect the ESL

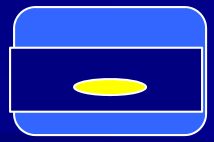
End of Service Life Indicators

(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

(Current Designs Have Limitations)

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

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?

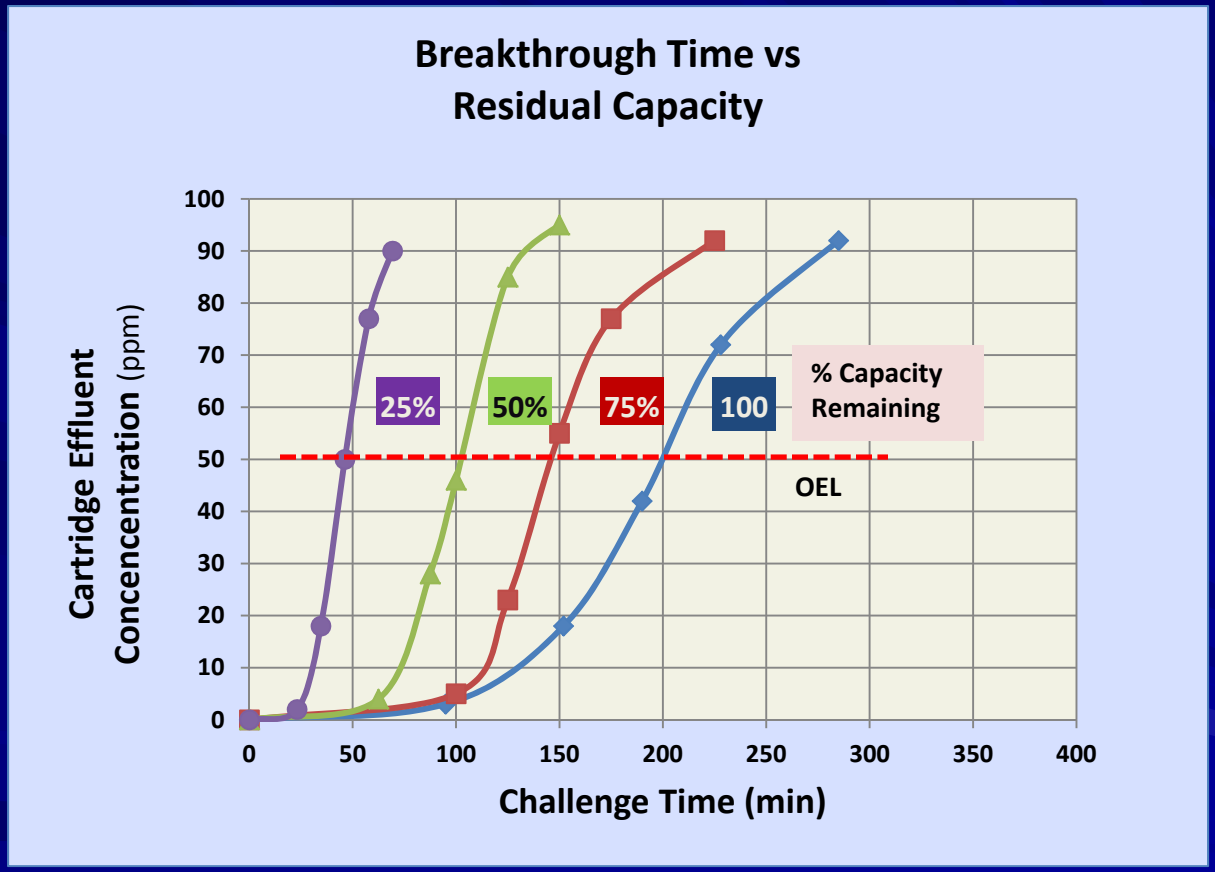
Measure the "Residual Capacity"

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

Method “A”
Lab Verifies Existing Change Schedule

- Perform a Destructive Test on a “used” Cartridge
  - **Wear the respirators & use the cartridges**
    - Follow an established change schedule
    - Select cartridges used within each “similar exposure group”
    - Immediately send used cartridges to Lab for Challenge Test
  - Run a single NIOSH Lab Test
  - If cartridges have retained > 10% of capacity,
    - Change Schedule has been validated

Breakthrough Time (Service Life)
decreases as Capacity is consumed



Cost of Method A

(Destructive Test of “used” Cartridges)

- Single (SEG) Similar Exposure Group $1,000 (USD) for testing 3 used cartridges in Lab
- Three (SEGs) Similar Exposure Groups $2,500 (USD) for testing 9 used cartridges in Lab

Method “B”
On-Site Verification of Existing Change Schedule

- Non-Destructive Test on a “used” Cartridge
  - **Wear the respirators & use the cartridges**
    - Follow an established change schedule
    - Select cartridges used within each “similar exposure group”
    - Immediately send used cartridges to Lab for Challenge Test
  - Run an ON-SITE Adsorption Test
  - If cartridges have retained > 10% of capacity,
    - Change Schedule has been validated

Method B

Non-Destructive Test of “used” Cartridges

- Inject Pulse of Weakly Adsorbed 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

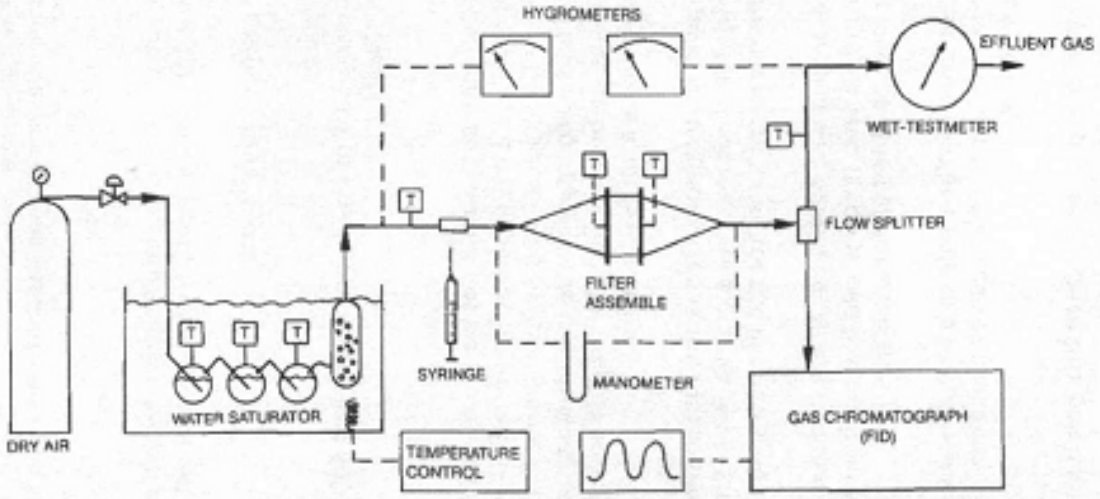
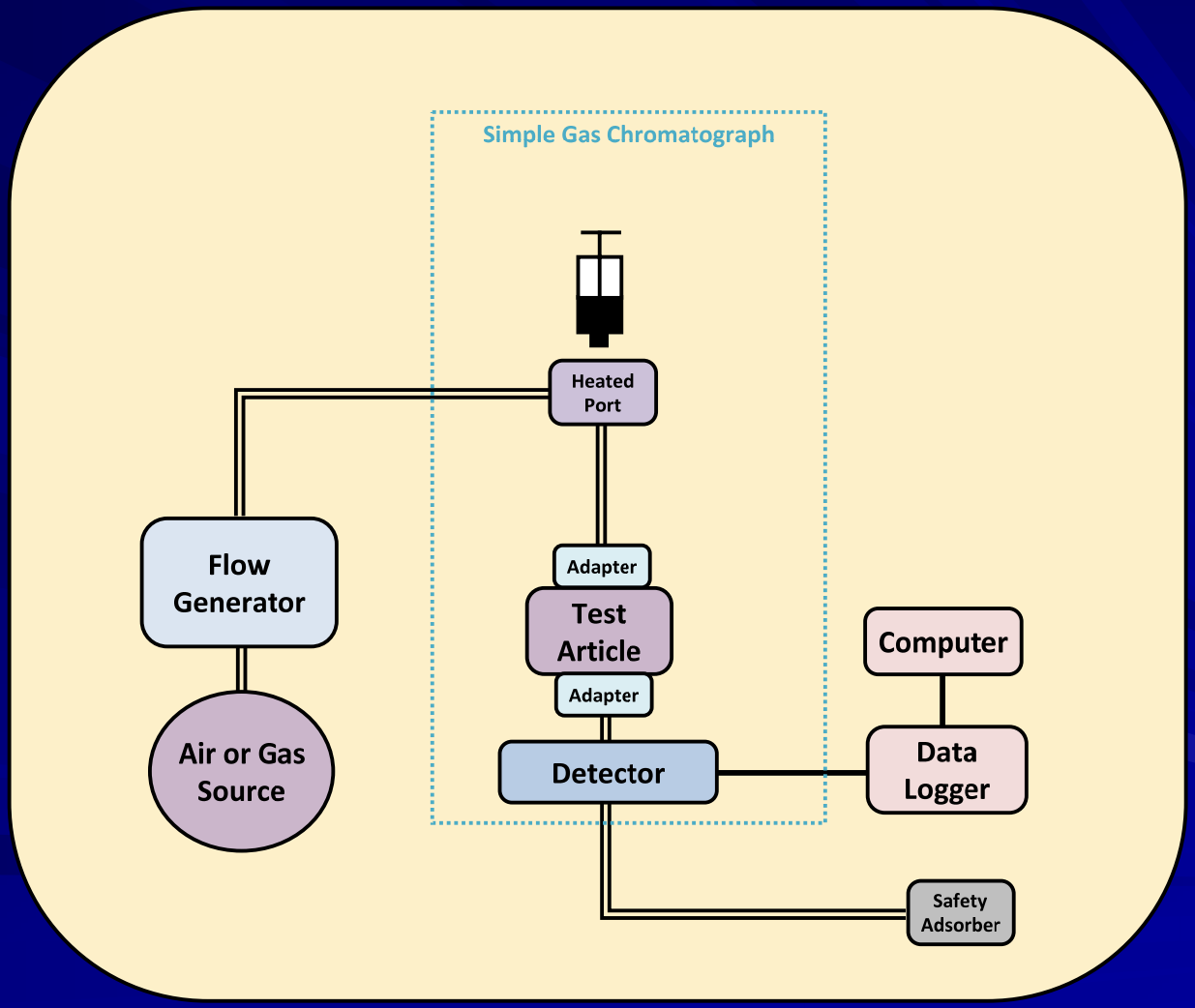


FIGURE 1 Schematic of the test apparatus.

On-Site Test
for Residual Capacity



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

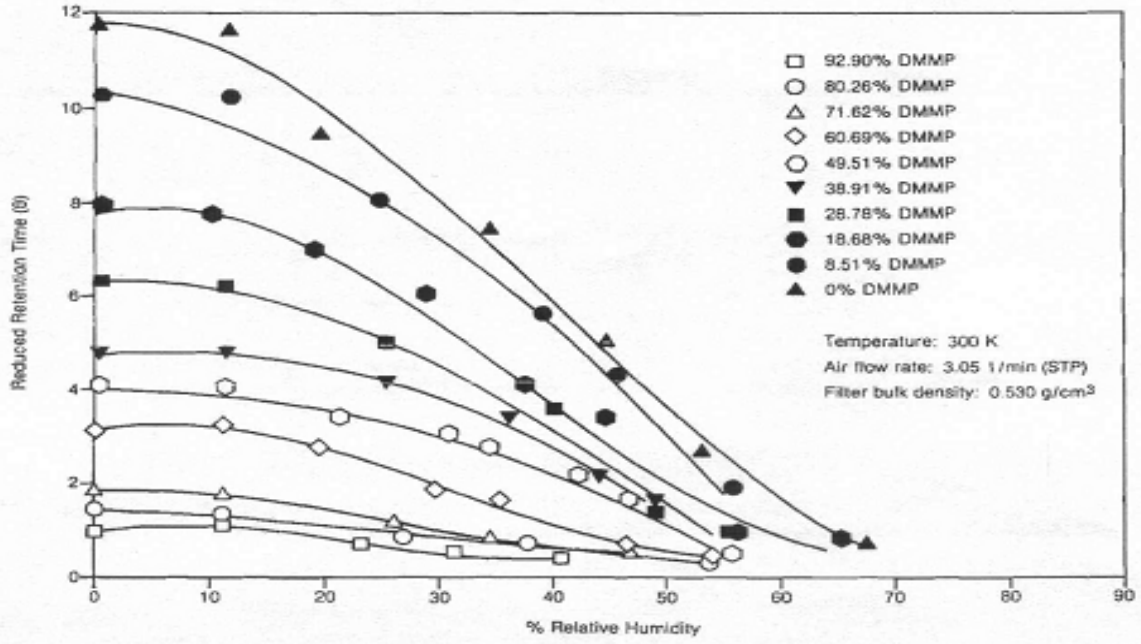
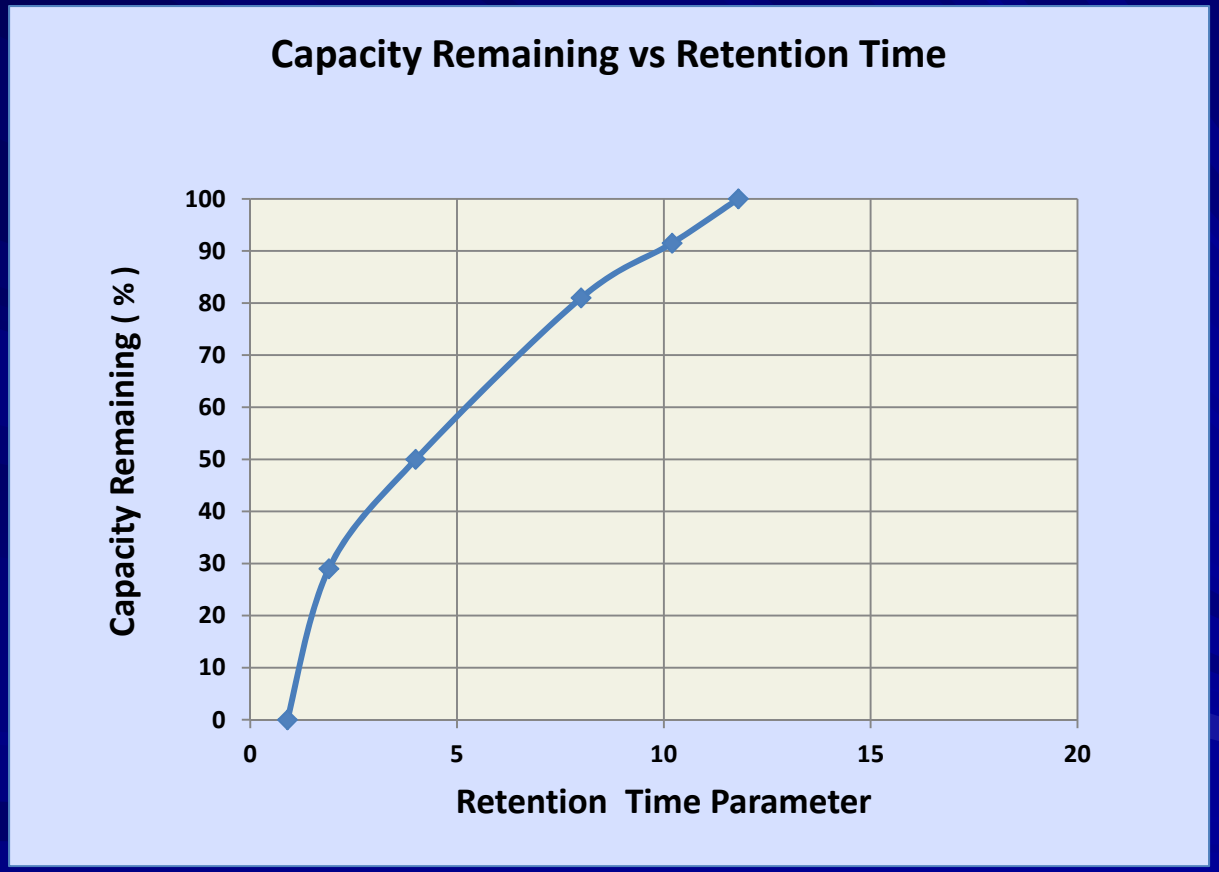


FIGURE 2 Correlation between the reduced retention time of CH_4 and the percent relative humidity. (Filters at equilibrium water loadings.)

Capacity (Service Life)
as a function of Reduced Retention Time



Conclusions

- In the “real world”, error is generated because users lack accurate data to input into models to generate Service Life and Change Schedules.
- End of Service Life Indicators have advantage of not requiring end-users to know very much about environmental conditions or respirators.
- Among the approaches to detecting End of Service Life, measuring Residual Capacity has two advantages:
  - **Applicable to a wide variety of real-world situations**
  - **No need to modify respirator by installing exotic sensors.**
- Residual Capacity testing of “used” cartridges may currently be conducted in a Lab; On-Site Residual Capacity Test under development.

AT Respirator and Filter Chemical Challenge Test Lab

Assay Technology Facility

(Livermore, California)