Establishing Gas and Vapor Cartridge Change-out Schedules

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3M Personal Safety Division
This training material has been prepared by 3M for the purpose of helping you understand applicable OSHA standards, or other safety regulations, workplace hazards, and safe workplace practices.

It is the responsibility of both the employer and employees to comply with safety rules and regulations and to use all safety equipment in accordance with product user instructions, limitations, and warnings. Questions regarding proper use should be directed to the employer or the equipment manufacturer. For 3M products call 3M Technical Service 1-800-243-4630.
Presenter

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Types & Styles of Respirators

Respirators

*Does not include all NIOSH respirator types or styles

“Types”

Air Purifying

Powered Air Purifying

Filtering Facepiece

Elastomeric Half-Mask

Elastomeric Full-Face

Atmosphere Supplying

Air Line

Self Contained

“Styles”
Terminology

Filters
Terminology

Cartridges
Terminology

Filter/Cartridge Combinations

Filter

Cartridge
Respirator Gas/Vapor cartridges

- Many different types
- May be used on reusable half and full face pieces as well as Powered Air Purifying Respirators (PAPRS)
- Most contain activated carbon, or treated active carbon
- Service life will depend on specific gas/vapor, concentration, temperature, relative humidity, and breathing rate
Occupational Safety and Health Administration (OSHA)

- Develops and enforces mandatory job safety and health standards
  - Substance-specific Health Standards: Respirator Programs
- Provides training, education and outreach programs.
- OSHA enforcement actions
  - Voluntary corrections
  - Civil penalties
  - Monetary fines
  - Criminal prosecutions and sentences
Elements of Written Respiratory Protection Program
(OSHA 29 CFR 1910.134)

- Written worksite specific procedures for:
  - Respirator selection
  - Medical evaluations
  - Use of respirators
  - Maintenance and care
  - Assuring adequate air quality
  - Training and fit testing
  - Program evaluations
OSHA Requirement for Change-out Schedules

1910.134(d)(3)(iii)(B)(2) .... if there is no ESLI appropriate for conditions in the employer's workplace, the employer implements a change schedule for canisters and cartridges that is based on objective information or data that will ensure that canisters and cartridges are changed before the end of their service life. The employer shall describe in the respirator program the information and data relied upon and the basis for the canister and cartridge change schedule and the basis for reliance on the data.
Chemical Cartridges

- Acid Gas
- Organic Vapor (OV)
- Ammonia
- Methylamine
- Multi-Gas
Organic Vapor (OV) Cartridges

- Common type of cartridge
- OV cartridges typically contain activated carbon
- Gas & vapor molecules cling to surfaces of carbon
- Capacity of cartridge depends on contaminant and concentration
- OV cartridges do not remove particles
Activated Carbon

- Carbon derived from coconut shells or coal.
- Crushed and conditioned at high temperatures, low oxygen levels.
- Creates extensive network of internal pores and large internal surface areas.
- **Not for filtering particles!**
Cartridges except OV have “treated” carbon to chemically convert vapors (Chemisorption)

Approved for specific chemicals only as listed on cartridge label

Color coding of label required by NIOSH
## Examples of Color Coding for Chemical Cartridges

<table>
<thead>
<tr>
<th>Chemical Type</th>
<th>Color</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Vapor</td>
<td>Black</td>
<td><img src="image" alt="Black Cartridge" /></td>
</tr>
<tr>
<td>Acid Gases</td>
<td>White</td>
<td><img src="image" alt="White Cartridge" /></td>
</tr>
<tr>
<td>Organic Vapor / Acid Gases</td>
<td>Yellow</td>
<td><img src="image" alt="Yellow Cartridge" /></td>
</tr>
<tr>
<td>Ammonia / Methylamine</td>
<td>Green</td>
<td><img src="image" alt="Green Cartridge" /></td>
</tr>
<tr>
<td>Multi-Gas and Vapor</td>
<td>Olive</td>
<td><img src="image" alt="Olive Cartridge" /></td>
</tr>
<tr>
<td>Mercury Vapor / Chlorine Gas</td>
<td>Orange</td>
<td><img src="image" alt="Orange Cartridge" /></td>
</tr>
<tr>
<td>P100 (filter)</td>
<td>Magenta</td>
<td><img src="image" alt="Magenta Cartridge" /></td>
</tr>
</tbody>
</table>
How Long Will My Cartridge Last?
Odor, taste, or irritation not always reliable indicators of end of service life

OSHA states a user must use one of the following methods to determine when to change a cartridge:
- End of service life indicator (ESLI)
- Estimated end of service life based on objective data
- Substance Specific Rules
Why Less Reliance on Chemical Warning Properties for Changing out Cartridges?

- Odor Thresholds
  - Not available for many compounds
  - Quality varies
  - Difficult to locate
  - Usually for single compounds, i.e., not mixtures
  - Personal odor thresholds may spread over 2 orders of magnitude of concentration
  - Approximately 15% of people cannot detect the odor at levels exceeding 4 times the odor threshold.
OSHA Option 1
End of Service Life Indicator (ESLI)

- ESLI are not common

- NIOSH approves ESLI’s if certain conditions are met:
  - May be active or passive
    - Passive require visible line of sight, color, indicator of change
  - Data demonstrating effectiveness
  - Data on safety
  - Must not interfere with respirator function
Cartridge End of Service Life Indicators (ESLI)

- **Goal:** Indicator will give specific cartridge change information for each individual worker as a result of their unique combination of workplace conditions and behavior.
- **Needs:** Respond to the chemicals of interest, and not respond to other chemicals, and work in various temperatures and humidity.
- ESLI have been developed for certain concentrations of certain chemicals (e.g., mercury vapor, carbon monoxide), but in general are rare.
- Most are color change indicators with reference colors for “good” and “finished.”
Cartridge End of Service Life Indicators (ESLI)
Difficulties in Developing ESLI for Organic Vapors

- Thousands of different OV
ts that differ both chemically and physically
- Exposure limits vary greatly
  - ESLI needs to respond rapidly at concentrations that are relevant for each individual exposure limit
  - Exposure limits vary between chemicals and also between countries for the same chemical.
- Best if ESLI is not affected by water vapor, or is affected similarly to how water vapor effects service life for OV
ts
- For US NIOSH regulations, ESLI must show indication while there is at least 10% service life remaining
- OV
ts travel through the cartridge at greatly different rates
- Signal from ESLI inside the cartridge must be transferred to user
OSHA Option 2
Cartridge Replacement Schedule

- Determine or estimate service life
- Replace cartridges before expected breakthrough
- Document objective data in written respiratory protection program
Service life (breakthrough time): The time required for a stated concentration of a chemical to be detected on the downstream side of a cartridge.
Example of a Typical Breakthrough Curve
Definitions (cont’d)

- Change schedule:
  - A time interval after which a used cartridge is replaced with a new one.

- An appropriate change schedule:
  - Assures the cartridge will be changed before the downstream concentration exceeds the exposure limit
  - Is convenient, e.g., 4, 8 or 40 hours
Cartridge Service Life

- Depends on:
  - Carbon characteristics
  - Carbon mass
  - Contaminant species
  - Concentration
  - Airflow (breathing rate)
  - Temperature
  - Relative humidity
  - Presence of other vapors
Specific Issues

- Migration
- Desorption
- Competition
Organic vapors may migrate through carbon during periods of non-use.

“Running clock” for service life estimates.

Not as much of a concern for non-organic vapor cartridges that use a chemical reaction to convert or bind the vapor/gas.
Initial Use

Air flow
Initial Use
Initial Use

Air flow
Storage

No air flow
Storage
Storage
Storage
Reuse
Mixtures

- Chemicals may compete for active sites in the carbon
- Low volatility organics may displace more volatile organics
  - Exit concentration of volatile component may actually be higher than inlet concentration
- Not as much of a concern for non-organic vapor cartridges that use a chemical reaction to convert or bind the vapor/gas
Competition

Toluene
Styrene
Competition

Toluene
Styrene
Competition

Toluene
Styrene
Effects of Relative Humidity on Service Life

- Water takes up space in carbon pores—can be treated as separate contaminates.
- High RH may negatively or positively affect service life depending on the carbon, carbon treatments, and chemical.
Methods for Determining Service Life

- Estimate with rules of thumb
- Test in laboratory using “simulated” workplace
- Calculate using breakthrough equations
- Test cartridge in the workplace
- Test cartridge after use
- Utilize manufacturers or OSHA software

Covered in today’s presentation
Rules of Thumb

- Estimate service life based on criteria such as:
  - Chemical properties (e.g. boiling point)
  - Flow rate (breathing rate)
  - Chemical concentration
  - Relative humidity
  - Carbon properties/mass
Chemical Concentration
- Reduce the concentration by a factor of 10, increase service life by a factor of 5
Most respirator manufacture’s have cartridge change schedule information
- Use on site or download free of charge

OSHA - Respiratory Protection Advisor
(http://www.osha-slc.gov/SLTC/etools/respiratory/change_schedule.html)

- Table of breakthrough times using “default” values for parameters
- “Advisor Genius” software improves accuracy by using specific input values for cartridge you are using
Manufacture supplied calculation (Software) for Chemical Cartridge Service Life

Enter Contaminants and Exposure Concentration

Add Contaminants

<table>
<thead>
<tr>
<th>Add</th>
<th>Contaminant</th>
<th>CAS Number</th>
<th>Exposure Limit</th>
<th>Exposure Limit Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Nitrotoluene</td>
<td>88-72-2</td>
<td>2 ppm</td>
<td>TWA</td>
</tr>
<tr>
<td>+</td>
<td>o-Chlorotoluene</td>
<td>95-49-8</td>
<td>50 ppm</td>
<td>TWA</td>
</tr>
<tr>
<td>+</td>
<td>o-Aminotoluene</td>
<td>95-53-4</td>
<td>2 ppm</td>
<td>TWA</td>
</tr>
<tr>
<td>+</td>
<td>Toluene</td>
<td>108-88-3</td>
<td>20 ppm</td>
<td>TWA</td>
</tr>
<tr>
<td>+</td>
<td>2,4-Toluene diisocyanate</td>
<td>584-84-9</td>
<td>0.005 ppm</td>
<td>TWA</td>
</tr>
</tbody>
</table>

This program estimates the service life for certain gas/vapor cartridges (not particle filters). Please select the gases and vapors in your work environment or CAS number. Next, enter the worker exposure which is often obtained by sampling the air near the worker’s breathing zone. For further information regarding air sampling, please contact 3M at 1-800-243-4630. For organic vapors not in this list, please select “User-Defined Organic Vapor.”

Selected Contaminants

<table>
<thead>
<tr>
<th>Remove</th>
<th>Contaminant</th>
<th>CAS Number</th>
<th>Exposure</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Toluene</td>
<td>108-88-3</td>
<td>50</td>
<td>ppm</td>
</tr>
</tbody>
</table>
Enter Cartridge

Enter Environmental Conditions (relative humidity, atmospheric pressure, temperature)

Enter Work Rate (breathing rate)

Environment Questions

Cartridge: 6001-Organic Vapor Cartridge
Relative Humidity: <65%
Atmospheric Pressure: 1.0
Temperature: 30
Work Rate: Medium

Acceptable range of atmospheric pressure is 0.8 to 1.2 ATM.

Solution

WARNING: These results are estimates only and must be used with caution. Change cartridge earlier if the contaminant is detected.

Estimated Service Life is 53 Hours

until breakthrough to 1/2 of the exposure limit (10 ppm)

Service life calculation based on Toluene at an Exposure = 50.0 ppm
Example
Determine Replacement Schedule

- Utilize the service life estimate to determine a replacement schedule for the cartridge
- A cartridge change schedule is based on a service life estimate and an appropriate margin of safety

Example:

- Software predicts breakthrough time of 21 hours for moderate work rate, low RH. **Daily** replacement schedule established for the following reasons:
  - Convenient
  - Takes into account varying conditions such as breathing rates, relative humidity and chemical concentration
  - Possible storage issues
How long a cartridge will last varies

Do not rely on odor or smell as a means of changing out a cartridge. However, regardless of the change schedule, wearers should leave the area immediately if they taste or smell contaminants.

A cartridge change schedule is based on a service life estimate and an appropriate margin of safety.

Service life for one manufacturer’s cartridge is not the same for another manufacturer’s cartridge.

Need to determine a change-out schedule for each different make and model of cartridge.

Always follow the manufacturer's User Instructions.
Conclusions

- Store cartridges properly when not in use following OSHA and the manufacturer’s guidelines

- The change schedule and the information used in its development must be documented in the written respirator program
CARTRIDGE CHANGE SCHEDULE DOCUMENTATION

Job: __________________________ Location: __________________________
Respirator Model: __________________ Cartridge Model: __________________

Chemical(s)

<table>
<thead>
<tr>
<th>Name</th>
<th>Exposure Limit</th>
<th>Concentration</th>
<th>Odor Threshold</th>
<th>Boiling Point*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

*Chemicals with boiling points less than 65° C (149° F) may be readily desorbed from activated carbon during periods of non-use.

Patterns of Use:
Number of shifts per week: _______ Hours cartridge used during shift: _______
Estimated work rate: □ Light □ Moderate □ Heavy

Environmental Data:
Maximum Expected Temperature: _____°C Maximum Expected Relative Humidity: ___%

Basis for Service Life Estimate:
□ Rule(s) of thumb: Specify: __________________________

□ Laboratory data (Attach Data Used):
□ Mathematical Model (Identify Model Used and Attach Result)
□ Workplace Cartridge Testing (Attach Description of Method and Results)
□ Cartridge Testing After Use (Attach Description of Method and Results)
□ OSHA Method for Mixtures (Attach Calculation Worksheet)

Cartridge Change Schedule:
□ Every ___ Hours
□ After Each Shift
□ After One Week
□ Other (Specify): __________________________

Logic Used in Setting Change Schedule:
Thank you