

Predicting the effect of high relative humidity on organic vapor cartridge performance

By Erik Johnson, CIH

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Introduction

OSHA regulations for use of chemical cartridges require the establishment of change schedules based on objective information. One of the most commonly used mathematical models for estimating the service life of organic vapor (OV) cartridges was developed by Wood.⁽¹⁾ However, this model does not account for the potential effect of relative humidity (RH) above 50% on service life. The effect of RH on service life of OV cartridges depends on the relative humidity level, the chemical concentration, volatility of the chemical and the chemical's miscibility (ability to dissolve) in water.

The degree of the effect of high RH on the performance of OV cartridges is often underestimated. Early work by Nelson demonstrated that OV cartridges preconditioned and tested at 90% RH had only about half the service life of cartridges preconditioned

and tested at 50% RH.⁽²⁾ However, these tests were conducted at a challenge concentration of 1000 ppm. Nelson's observation that humidity may have an even greater effect on cartridge performance at lower concentrations commonly seen in workplaces has not been widely recognized.

A paper presented by Johnson at the 2001 AICHE described the effect of RH on OV cartridges at workplace concentrations (5-1000 ppm).⁽³⁾ Correction factors were measured for several organic solvents representing a wide range of volatility including n-hexane, benzene, toluene, and styrene (see Table 1).

Cartridges were tested without preconditioning to mimic the dynamic competition of water and solvent vapor for active sites on fresh cartridges. Testing was done at a flow rate of 32 L/min per cartridge (equivalent to 64 L/min for a pair of cartridges) to 1% breakthrough.

Discussion

Figures 1-3 illustrate the correction factors necessary to adjust a service life estimate calculated at 50% RH for each solvent at various challenge

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Table 1. Vapor pressure at 20° C and boiling point for five solvents.

Solvent	Vapor Pressure, mmHg	Boiling Point, °C
n-Hexane	124	69
Benzene	75	80
Toluene	21	110.6
Styrene	5	145-146

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Performance

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concentrations and higher RH. Note that the RH effect is greatest for volatile chemicals such as n-hexane at low concentrations. For chemicals with low volatility such as styrene, the effect of high relative humidity is small at any concentration.

In practice, a 50% RH service life estimate should be divided by the correction factor on the y-axis to determine the predicted service life at 75, 85 or 90% RH. For example, 25 ppm toluene at 85% RH would require a correction factor of about 4. For solvents not shown on the figures, the compound with the closest vapor pressure or boiling point could be used as a surrogate. Methyl ethyl ketone has a boiling point of 79.5° C and a saturation vapor pressure of about 75 mm Hg at 20° C. Therefore, the correction factors for benzene may be used.

Figure 1. Correction factors versus solvent concentration at 75% relative humidity and 1% breakthrough.

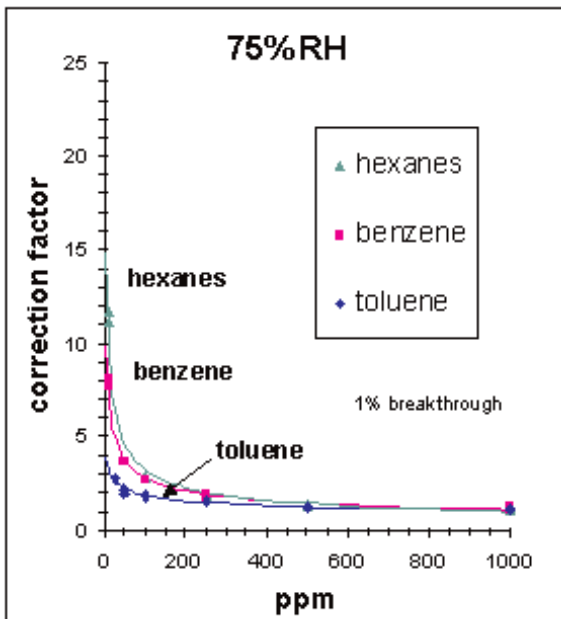


Figure 2. Correction factors versus solvent concentration at 85% relative humidity and 1% breakthrough.

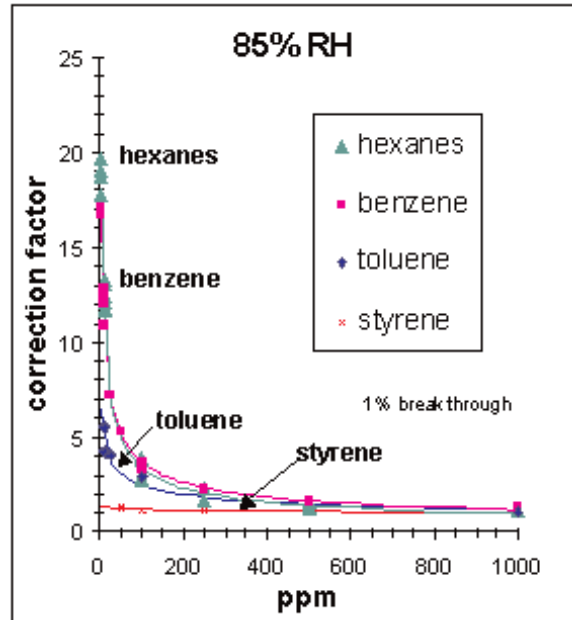
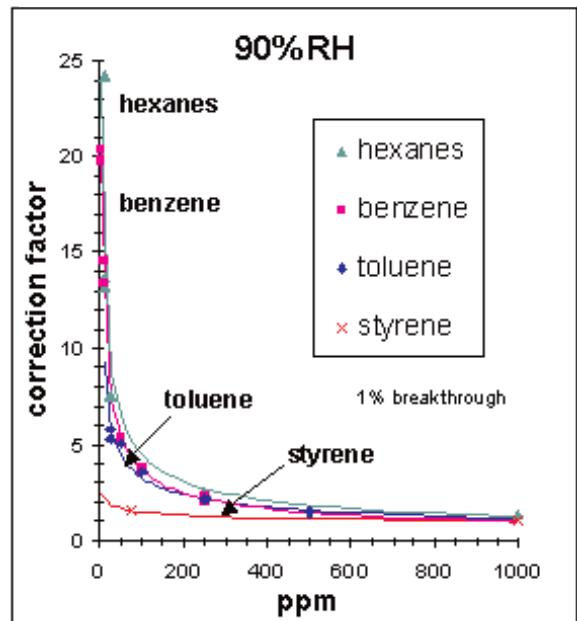


Figure 3. Correction factors versus solvent concentration at 90% relative humidity and 1% breakthrough.



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Service life testing was also done at 65% RH. Compared to the tests done at higher RH, the effects were very limited. Correction factors for the most volatile solvent in this study, n-hexane, ranged from 1.9 at 25 ppm to 1.0 (no correction at all) at 1000 ppm.

The tests in this study were done with water immiscible (insoluble) solvents to demonstrate worst-case RH effects. Water miscible solvents are less strongly affected by RH.⁽⁴⁾ At room temperature, 85% RH is equivalent to about 27,000 ppm water. Under these conditions, a significant amount of water will be adsorbed into the carbon pores. This allows increased loading of water miscible compounds or even compounds that are normally considered only slightly soluble in water. For example, ethylene dichloride and methyl ethyl ketone were less strongly affected by high RH than non-miscible compounds with the same chemical properties and adsorption capacity.

It should be noted that unlike OV performance, service life for cartridges designed to remove acid gases and bases may actually improve at high RH. Water vapor may improve interaction between the chemical treatment on the carbon and the acid or base contaminant. Testing of these compounds for Service Life Software™ was done at 50% RH to represent a challenging environment.

Conclusion

These experiments illustrate the potential impact of relative humidity on OV cartridge service life depending on the contaminant involved. Nelson's widely quoted observation that high humidity reduces service time by half holds true only at high contaminant concentrations. The impact of high RH must be considered when establishing cartridge change schedules. Service life estimates calculated at low RH should be divided by the appropriate safety factor when high

RH is present in the workplace. Professional judgment should be used, and the user may also wish to conduct testing on the performance of OV cartridges in their work environment.

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Workplace protection factor study: 3M™ Hood Assembly H-422 supplied air respirator.

Introduction

An assigned protection factor (APF) is an estimate of the level of protection provided by a properly functioning respirator or class of respirators to a large percentage of properly fitted and trained users. Respirators are assigned protection factors by a number of organizations. These include the Occupational Safety and Health

Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH) and the American National Standards Institute (ANSI). The APF values published by these organizations do not always agree with one another. For example, OSHA lists several different APF values for supplied air helmets and hoods in various substance specific standards. OSHA's APFs range from >10 to 2000 for these devices.^(1, 2) NIOSH lists an APF of 25, and 1000 is listed in the ANSI Z88.2 (1992) respiratory protection standard.^(3, 4)

A recent article reported on the workplace performance of the 3M™ Hood Assembly H-422.⁽⁵⁾ Personnel at Tinker Air Force Base used a supplied air hood during aircraft sanding and painting activities. In 1994, the U. S. Air Force incorporated the NIOSH APF of 25 into its respiratory protection program.⁽⁶⁾ Feasible administrative, work process, and engineering controls were not able to control worker exposure to less than 25 times the occupational exposure limit (OEL) for strontium chromate, the contaminant with the highest exposure. This prompted the Air Force to change respiratory protection required during these activities.

Personnel were required to stop wearing supplied air hoods and start wearing full-facepiece pressure demand supplied air respirators to comply with AFOSH Standard 48-1. AFOSH 48-1 uses an APF of 1000 for this device. The change adversely affected personnel by increasing the potential for heat stress, fatigue and other ergonomic issues. The full facepieces also limited workers' field of vision and reduced their ability to communicate with one another. Additional costs were incurred for the purchase of the new respirators and for workers' medical evaluations and respirator fit tests.

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For these reasons, the Air Force decided to perform a study to assess the performance of the H-422 hoods. The study's objective was to measure the workplace protection factors (WPFs) of the hoods during sanding and painting operations on several types of aircraft. Based on the data collected and other studies of supplied air hood performance, it was felt that an appropriate APF could be assigned for the sanding and painting activities.

Workplace Testing

WPF measurements were made while employees performed their normal work duties during sanding and spray application of a primer on aircraft. Metals in the primer and sanding dust were the air contaminants measured. The primary metal of concern was strontium.

The employees wore 3M Hood Assembly H-422. The assembly consisted of the hood H-420, hardhat W-3258, suspension W-2878, and a clamp to attach the breathing tube to the hood. The breathing tube used was the W-5114. The respirator was equipped with either the vortex cooling assembly W-2862 or the vortex heater assembly W-2863. The respirators' pressure was regulated from 60 to 80 psi. (Note: correct operating pressure ranges are 60-75 psi for the W-2862 and 65-75 psi for the W-2863 with 50 feet of W9435 hose).

Samples were collected inside (C_i) and outside (C_o) the respirator while employees performed their normal work activities. The cassettes were attached to sample lines and personal sampling pumps. The pumps were started after the employee's respirator was connected to the breathing air supply. Sample times were approximately 2 hours for sanding and about 90 minutes for priming (the time it took to apply a single coat). Care was taken to prevent contamination of the samples.

Filter manufacturer blanks (MB)

were taken to identify any contamination that may have occurred during filter manufacture. An unused cassette was randomly chosen, marked, and stored with the other samples and sent in for analysis without ever being opened.

Field blanks (FB) were taken to identify potential contamination due to handling, field storage and shipment. The blanks were treated in the same manner as the C_o and C_i samples except no air was drawn through them. The cassette plugs were removed and replaced. The sealed cassette was then hung on the employee. At the end of the sample period, the FB cassette was again opened and closed, stored with the other samples and sent in for analysis.

A system blank (SB) sample was taken in one building to determine if any contamination could be present in the breathing air supply. The cassette was mounted in a hood as the other C_i samples and attached to an air pump set to flow rate of approximately 2 L/min. The hood was hung from scaffolding away from the work area. Air flow was started into the hood. After one minute the cassette inlet plug was removed and the sampling pump started. After two hours, the pump was stopped and the cassette plugged and removed from the hood.

Results

The C_o concentrations of strontium ranged from none detected to 29 $\mu\text{g}/\text{m}^3$ during sanding. Half the C_o samples collected during sanding did not contain any strontium on the filter. The average level of strontium was only 30 times the mean detection level. For painting, the ambient concentrations of strontium ranged from 340 to 24,500 $\mu\text{g}/\text{m}^3$.

There was no strontium detected on any C_i sample. All blank samples were also free of measurable strontium. Because no strontium was detected on any C_i sample, an estimate of the WPF could not be directly

made. A WPF calculation requires that a measurable amount of material be found inside the respirator.

The WPFs for painting were estimated using the detection limit of the analytical method to represent C_i . Only C_o samples with a strontium mass at least 1000 times the detection limit for the C_i samples were used. The WPFs were estimated to be greater than 1200 for these samples.

Discussion

The WPFs from this study are consistent with WPFs or simulated workplace protection factors (SWPFs) found by other researchers. Johnston conducted a WPF study on a helmet type supplied air respirator during sand blasting of a barge.⁽⁷⁾ When C_o samples with mean loadings greater than 1000 times the mean blank loading were used, 95% of the WPFs were greater than 1040.

Colton measured WPFs of a supplied air hood during a furnace tear-down and rebuilding.⁽⁸⁾ The mean WPF was 9532, and 95% of the WPFs were greater than 2200. Skaggs measured SWPFs for a supplied air hood.⁽⁹⁾ The mean SWPF for the various conditions tested ranged from 7500 to 20,000.

A powered air purifying respirator (PAPR) with a hood or helmet is similar to a supplied air respirator with the same type of inlet covering. The minimum permissible air flow rate is the same for both types. Keys *et. al.* reported on the performance of one helmet and two hooded PAPRs in a pharmaceutical manufacturing facility.⁽¹⁰⁾ They found that 95% of WPFs were greater than 1500.

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Conclusion

Employees using the 3M Hood Assembly H-422 during aircraft sanding and painting operations were not overexposed to strontium. The respirator provided more than adequate protection. This study is consistent with other WPF and SWPF studies in that the ANSI Z88.2 APF of 1000 is supported.

Based on the results of this study and other available information, the Air Force has allowed employees engaged in aircraft sanding and painting operations to resume use of supplied air hoods for respiratory protection.

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ANSI Standard Z88.10: Respirator Fit Testing Methods

By Thomas J. Nelson, CIH

Tom Nelson is a consultant specializing in respiratory protection. He was secretary of the Z88.10 committee from 1995-2000.

The American Industrial Hygiene Association recently announced the availability of a new American National Standard Institute (ANSI) standard on fit test methods, designated ANSI/AIHA Z88.10-2001.

This standard took more than 17 years to develop.

The standard contains:

- Suggested qualifications of people who will perform fit testing;
- Specific quantitative and qualitative test procedures;
- Recommendations for record keeping; and
- Recommendations for program elements such as medical evaluations, evaluation of possible conditions that may interfere with fit, and maintenance of fit test respirators.

The fit test procedures are similar to those published by OSHA in its respiratory protection regulation 29 CFR 1910.134, with some differences in specific details. For example, the OSHA regulation requires specific, 60-second exercises. The ANSI standard recommends different test exercises, each 30 seconds long. In the U.S., people who conduct fit tests must follow the OSHA requirements; Z88.10 is an advisory standard rather than a regulation.

The ANSI standard contains the same qualitative and quantitative fit tests that are found in Appendix A of the OSHA regulation. Qualitative fit tests include isoamyl acetate, saccharin, Bitrex™ and irritant smoke. Generated aerosol, ambient aerosol and controlled negative pressure quantitative fit test procedures are described. The ANSI standard notes that the current irritant smoke fit test does not meet the suggested validation criteria listed in the standard. Therefore, it recommends that the irritant smoke test not be used after three years unless validation data is developed to demonstrate the fit test is capable of identifying inadequate fits.

The standard states that the respirator program administrator is

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responsible for evaluating and verifying the training and qualifications of the people who perform fit tests. Those who conduct fit tests must be adequately trained and demonstrate proficiency in the fit test method they will use. The standard acknowledges that there is no recognized certification for persons who conduct respirator fit testing. General criteria for qualifications of those who conduct fit testing are outlined. A checklist to document fit tester training is included as an annex to the standard.

Suggested records to document fit test results are similar to the record-keeping requirement in the OSHA respiratory protection standard. Two other records not contained in the OSHA standard are also suggested:

1. An equipment maintenance record, and
2. A record documenting the fit tester's ability to conduct a fit test.

Like the OSHA regulation, Z88.10 advises that a fit test should not be performed if a person has facial hair that comes between the sealing surface of the facepiece and the face, or if facial hair interferes with valve or respirator function. It goes on to state that a fit test should be performed with protective equipment that could interfere with respirator fit. This normally means that protective eyewear should be worn during fit testing.

Another important aspect of the ANSI standard is the location of sampling probes used to obtain in-facepiece samples for quantitative fit tests that use an aerosol challenge. Research has shown that aerosol quantitative fit tests have an average sampling bias of -20% with a possible error of $\pm 98\%$. To minimize these errors, the sample should be drawn at a point midway between the nose and mouth. The sample probe should extend into the facepiece cavity (i.e. not be flush with the inside surface), but should not touch

the face. If a nose cup is used with a full-facepiece, the sample point should be inside the nose cup.

Seventeen years is a long time to develop a standard. The time it took to write this standard reflects the differences in opinion that exists among people who are knowledgeable about fit testing. For example, extensive debate was held regarding which fit tests should be considered acceptable. Some committee members favored quantitative fit testing only. Others did not believe that the controlled negative pressure test was acceptable since test exercises cannot be done during the test. After much discussion, the committee realized that each fit test measures something different. Based on workplace and simulated workplace performance studies, each fit test provides an acceptable level of performance.

Heat Stress

Warmer summer temperatures increase the risk of heat-related illnesses. The Federal Occupational Safety and Health Administration (OSHA) does not have heat stress regulations. However, it has recently developed a "heat stress card" to help employers and employees recognize warning signs, symptoms and early treatment of heat-related conditions. For a copy of the card and accompanying trade news release, visit OSHA's website at www.osha.gov/media/oshnews/may02/trade-20020528.html.

3M OH&ESD offers respiratory protection training courses

Since 1995, 3M has offered two professional development courses that provide valuable information to individuals involved in respiratory protection programs. The courses are based on the technical and regulatory aspects of a sound respirator program rather than specific products. A large equipment display from a number of respirator manufacturers is used to supplement the classroom and workshop presentations. These courses emphasize the important practical aspects of a successful program, including selection principles, cartridge change schedules, and testing breathing air quality. Both courses carry CEUs, American Board of Industrial Hygiene Certification Maintenance points, and other professional development credits.

Respiratory Protection is a comprehensive 4 ½ day course intended for anyone involved with managing all or part of a respiratory protection program. All respirator types and each element of a respirator program are thoroughly discussed. Workshop sessions are used extensively to reinforce the course material.

Current Topics in Respiratory Protection is a two day course designed to provide the latest in technical and regulatory information to experienced program managers. This course is offered on request.

The 2002/2003 schedule of course locations and dates is listed here. To find out more about these courses, please do one of the following:

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- Visit our Web site at www.3M.com/occsafety;
- 3M Fax On Demand system at 1-800-646-1655.

Respiratory Protection

Dates	Locations
<u>2002</u>	
September 9-13	Seattle, WA
October 7-11	Denver, CO
<u>2003</u>	
January 20-24	Phoenix, AZ
February 24-28	San Diego, CA
March 31 - April 4	New Orleans, LA
July 14-18	Minneapolis, MN
September 8-12	Portland, OR
October 20-24,	Charleston, SC

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