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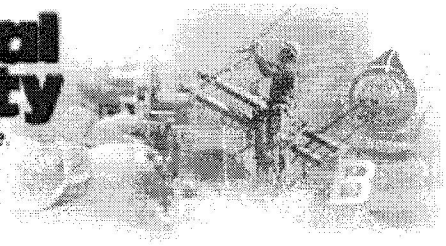
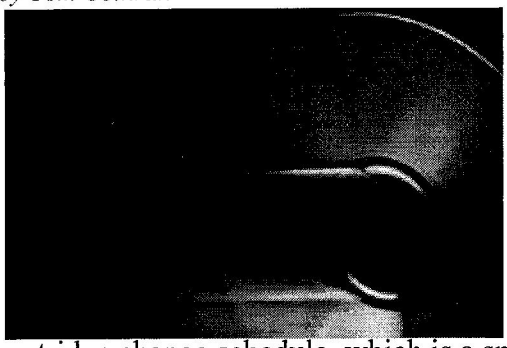


Service Life Software for Organic Vapor Cartridges

Manufacturers' software programs help end users calculate the service life of these respirator cartridges, as OSHA's new standard requires.

by Tom Cothran



Computer software is becoming a major tool to help health and safety professionals determine the service life of respirator cartridges used to protect workers against airborne gas and vapor hazards.

Service life is the measured or estimated period of time before "breakthrough" of a gas or vapor contaminant for a specific chemical cartridge under specified conditions of the test or estimate. A service life estimate can be helpful in establishing a cartridge change schedule, which is a specified time period after which the chemical cartridge should be replaced.

An appropriate cartridge change schedule is one that is both convenient and assures that the concentration of the chemical downstream does not exceed the exposure limit. For example, a cartridge may have a breakthrough time of 15 hours for a given vapor. Changing cartridges at the end of a normal work shift is convenient, and this period of use is conservatively less than the breakthrough time.

The Occupational Safety and Health Administration believes chemical odor breakthrough is no longer an adequate, sufficient indicator for when workers should change chemical cartridges. Therefore, OSHA's 1998 revision to its respiratory protection standard, 29 CFR 1910.134, requires users of chemical cartridge respirators to implement a cartridge change schedule based on "objective information or data." In this way, used cartridges would be replaced before the chemical breaks through the cartridge at a level that could result in worker overexposure.

It's important for respirator program administrators to know the limitations and understand the results of whichever software program they elect to use. Most of the programs are similar, providing the user with input boxes to select a specific value or enter data on a chemical, its concentration in the workplace, the cartridge type, breakthrough concentration, temperature, humidity, and work rate. The better programs also require the user to input data on atmospheric pressure and select a safety factor.

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These software programs are largely based on research and formulas developed by G.O. Wood and published in the January 1994 issue of the *American Industrial Hygiene Association Journal*, and by G.O. Nelson and A.N. Correia, writing in the same publication in 1976.

It's important to recognize that each manufacturer's software applies specifically to its own cartridges or canisters and their unique carbon properties. Because these software programs cannot know each workplace situation, they can provide only estimates--not exact predictions--with an accuracy range of plus-or-minus 25 percent to plus-or-minus 50 percent. User estimates of work rates and measurements of contaminant concentrations, as well as temperature and humidity, can further affect accuracy.

Service Life Software

The first software program available was 3M's Respirator Service Life Software, released soon after OSHA revised its respirator standard. It calculates service life based on workplace conditions such as contaminant concentration, temperature, work rate, and atmospheric pressure. Based on the Wood model, it has had two upgrades and can be downloaded at no charge from 3M's Web site (www.3m.com/occsafety).

This software is logically organized in a series of screens: Introduction, Contaminants, Cartridge, Environment and Results. After reviewing the introductory warnings, the user clicks on the Contaminants screen to bring up a listing of materials either alphabetically or by CAS number. The software calculates for chemical mixtures (organic or inorganic) to provide an estimate of a mixture's breakthrough time.

The user can add data for materials not included in the database, such as correction factors to account for uncertainties and user-entered contaminants. Once the user selects the chemical and an exposure concentration, a specific cartridge is chosen on the Cartridge screen. Then the user enters data on work rate, humidity, temperature, atmospheric pressure, and the desired breakthrough concentration on the Environment screen. Clicking on the Results screen provides an estimated breakthrough time.

OSHA's "Advisor Genius" also is based on the Wood model. It is available at the agency's site (www.osha-slc.gov/SLTC/respiratory_advisor/mainpage.html). Advisor Genius also permits the user to enter information on a series of screens. The software contains data for 120 chemicals. If a chemical is not listed, the user may enter the molecular weight, liquid density, vapor pressure and molar polarization of the contaminant to obtain an estimate.

The software includes default values for cartridge and carbon characteristics, or users can enter their own values based on information obtained from the respirator manufacturer. Using the manufacturer's data results in a more accurate breakthrough estimate. Then the user inputs work site-specific data such as concentration.

AO Safety's "Merlin" software program is a spreadsheet available free on the AO Web site (www.aosafety.com). This software program calculates breakthrough times for either inorganic gases or organic vapors based on the Wood model. It uses a single screen for both data entry and results and provides a list of chemicals. If the user's applications include a chemical not on Merlin's list, the software cannot be used. It also offers no correction for atmospheric pressure. Merlin's single page format makes it easy to see how changes (e.g., concentration) to any value will affect the calculated breakthrough time.

North Safety's "esLife" software is available on a CD only. It operates with a series of screens, allowing the user to select chemicals from a list either by name or by CAS number. The software's database maintenance function allows the user to add any chemical not included on its list as long as the user can input data on vapor pressure, molecular weight, density, and boiling point. The next screen is used to enter work site information (e.g., work rate), which may be selected from a list or entered as specific values. An optional screen allows the user to enter a job and workplace description, thus providing a printed record of the breakthrough calculation.

If OSHA's standards dictate the frequency of cartridge change depending on the substance, most programs do not calculate a breakthrough time.

Willson's service life program, also available on CD only, is a spreadsheet based on the mathematical model by Nelson. The user enters data on a single page and selects chemicals from a list of 265 materials, not including acid gases. There is no provision for adding other materials. The user enters the contaminant concentration, relative humidity, and temperature onto the spreadsheet, using up to three materials to perform a mixture calculation. Then, a work rate is selected from five ranges--from 20 to 60 liters per

minute (lpm)--and a margin of safety from 20 percent to 100 percent. If a margin of safety of 100 percent is selected, no breakthrough time is given. With the single-page format, it is easy to see how changes to any value affect the calculated breakthrough time.

The MSA "Cartridge Life Expectancy Calculator" is available on a CD or on MSA's Web site (www.msanet.com). MSA's software calculates breakthrough times based on extensive data for 17 materials that is extrapolated to other materials. It provides a list of chemicals but has no provision for adding additional chemicals. The user may select data from lists or by entering information onto a single, scrolling page. The software calculates breakthrough times for organic vapors only, but the Web site offers a listing of breakthrough times for many materials, including inorganic vapors.

Survivair's "Air Purifying Respirator Cartridge Service Life Estimation" program is available free on the Survivair Web site (www.survivair.com). It works for both organic vapors and inorganic gases, using Nelson's model for the organic vapors. The program uses a series of four screens for data entry. A scrolling list provides a selection of chemicals. There is no provision to add additional chemicals or to correct for atmospheric pressure, although the software provides for a safety factor. There is an optional screen to enter workplace information and provide a printed record of the breakthrough calculation.

Programs' Idiosyncrasies

Users should be aware of the idiosyncrasies of the program they use. For example, finding a chemical can be a challenge in some of the programs. Methyl ethyl ketone and MEK are common synonyms for 2-butanone. Searching for MEK in the North and 3M software programs will bring up this material. In the other programs, common names and synonyms are not listed in the search mechanism, making a CAS number search a better option.

The programs differ in the air flow value used to make a calculation for work rates, which could mean a difference in the breakthrough time of up to 50 percent. For low work rate, the 3M and Willson software use a 20 lpm value. Survivair uses 30 lpm. OSHA, North, and MSA default to 30 lpm but allow any value to be entered. Similar differences are found at other work rates.

High relative humidity shortens service life for organic vapor cartridges. OSHA's software warns that when the humidity exceeds 50 percent, the estimated breakthrough time should be cut in half. The 3M software provides a graph that allows the user to set a specific correction factor for higher humidity values. The correction factor varies by chemical volatility and concentration.

Other programs allow the user to enter the relative humidity using set levels (such as 65 to 80 percent) or any value up to 100 percent. When the humidity is very high, the user should be even more conservative, because there is not yet enough research to provide an accurate estimate of the effect of humidity on breakthrough time.

All of the software programs discussed here warn about the potential for desorption or stipulate not to use a cartridge for more than one work shift. Until more research is complete, these warnings are good advice.

Each program may handle specific issues differently, requiring caution on the part of the user. For example, if OSHA's standards dictate the frequency of cartridge change depending on the substance, such as benzene. For this reason, most of the programs do not calculate a breakthrough time or alert the user to the presence of a standard. Using a cartridge longer than allowed by an OSHA standard can result in a citation.

Air purifying respirators should not be used at concentrations that are immediately dangerous to life or health (IDLH). Most programs will issue a warning and refuse to calculate a breakthrough time if user enters a concentration greater than the IDLH. The OSHA and AO programs provide no warning and allow a breakthrough time to be calculated. The 3M program provides a warning that the concentration is above the IDLH value but allows a calculated service time to be displayed.

The most commonly used values for materials considered IDLH are listed in the National Institute for Occupational Safety and Health pocket guide to chemical hazards. NIOSH revised the IDLH values in 1994, substantially lowering many of them. For example, the IDLH for acetic acid was revised from

1,000 ppm to 50 ppm.

OSHA subsequently stated that it will enforce the values listed in the NIOSH Pocket Guide to Chemical Hazards for 1990 (NIOSH Publication NO. 90-117), since the revised values were interim recommendations. The North, Survivair, and MSA programs use the 1994 values.

Organic Vapor Migration and Mixtures

The programs also differ in how they address problems arising during the use of respirator cartridges. For example, organic vapors absorbed on an organic vapor cartridge can migrate through the carbon bed without airflow. Also, previously absorbed materials may be released from a cartridge when the cartridge is reused after a short period without use (for example, overnight). This process is known as desorption.

All of the software programs discussed here warn about the potential for desorption or stipulate not to use a cartridge for more than one work shift. Until more research is complete, these warnings are good advice. Workers who use their respirators intermittently and perhaps in different environments, such as a maintenance worker or inspector, should never reuse organic vapor cartridges.

Employers also must develop and document a change schedule for cartridges used for inorganic gases, such as ammonia. The 3M, North, AO Safety, and Survivair programs will calculate breakthrough times for these materials. It's not unusual to find more than one airborne contaminant in many workplaces. 3M and Willson software provide an estimate of the breakthrough time for mixtures. Both use the recommendation from OSHA's compliance directive (CPL2.120 "Inspection Procedures for the Respiratory Protection Standard"). Willson's program will calculate a breakthrough time for mixtures of up to three materials. 3M's software has no limit and will calculate a breakthrough time for a mixture containing both organic and inorganic contaminants.

Other software programs require the user to calculate the times. First, the user must determine the breakthrough time of each material at the measured concentration. Assuming that some of the materials have a lower breakthrough time than others, the entire mixture is treated as if the material with the shortest breakthrough time makes up the entire mixture. A breakthrough time for the entire mixture is then calculated.

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2. Nelson, G.O.: and A.N. Correia: Respirator Cartridge Efficiency Studies: VII, Summary and Conclusions, *American Industrial Hygiene Association Journal* 37, 197, pp. 514-525 (1976).

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