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### AIHCE presentations on respiratory protection: A review

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Respiratory protection was a popular topic at the 58th annual American Industrial Hygiene Conference and Exposition (AIHCE) held in Atlanta, Georgia, May 9-15, 1998. Three sessions, including two roundtable sessions and one technical session, were held to address the most current topics in respiratory protection. A brief summary of these activities is presented in this article.

#### Roundtable 221: 42 CFR part 84 respirators: Issues, selection and solutions

On May 12, the roundtable discussion entitled "42 CFR Part 84 Respirators: Issues, Selection and Solutions" provided a forum for representatives of the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the Industrial Safety Equipment Association (ISEA) to share their knowledge and views

on 42 CFR Part 84. The ISEA is a trade association that includes manufacturers of respiratory protection equipment. The session, which was well attended, provided a good summary of the new respirator certification tests, various aspects of the change to new respirators and OSHA's planned enforcement program.

Three procedures for respirator selection were presented. These included the NIOSH User's Guide, the ISEA Use and Selection Guide, and OSHA's view on selecting new filters. None of the groups, however, defined an oil, nor did they define what is meant by the presence of oil aerosols.

Assigned protection factors (APFs) for 42 CFR part 84 respirators were also discussed in these presentations. The ISEA recommends an APF of 20 for full facepiece respirators with 95% efficient filters. This APF may be based on the premise that a 95% filter will allow 5% penetration in the workplace. No data were presented to support this recommendation. OSHA derived APFs by adding filter leakage to an assumed 10% face seal leakage for half facepiece respirators. This recommendation raises questions, however, because OSHA's required fit test methods limit face seal leakage to 1% or less for half facepiece respirators. Further questions could be

posed about ISEA's and OSHA's recommendations for APFs, with respect to filter efficiency, face seal leakage and empirical data on respirator performance.

The elimination of dust/mist filters for powered air purifying respirators (PAPRs) was addressed by M. Cowell of 3M Company. As of July 10, 1998, high efficiency particulate air (HEPA) filters became the only filters available for PAPRs. Dust/mist filters approved under 30 CFR 11 are no longer sold by manufacturers.

#### Roundtable 254: OSHA's revised respiratory protection standard

Attendance was high at the roundtable session held on May 14, which addressed the latest development in respiratory protection regulations, the revision of 29 CFR 1910.134. The session, entitled "OSHA's Revised Respiratory Protection Standard," was chaired by L. Janssen of 3M (see *AIHCE: A review on page 2*)

#### Inside this issue

Volume 16 Number 3 1998

AIHCE presentations on respiratory protection: A review . . . . .	1-4
New 3M Service Life Software available free . . . . .	4
Time use limitations for P-series particulate filters . . . . .	5-7

Company and arranged by T. Nelson of NIHS, Inc. This was one of the first opportunities for OSHA representatives to summarize the new standard and comment on its enforcement. J. Steelnack of OSHA thoroughly summarized the standard using slides developed by the OSHA Office of Training and Education. In addition, several industry representatives addressed aspects of the standard including medical issues, fit testing of positive pressure respirators, and chemical cartridge use time. G. Nelson of Miller-Nelson Research, Inc. discussed the challenges in predicting use time of respirators equipped with chemical cartridges. He mentioned that several manufacturers are providing estimates of service life for single chemicals at given concentrations. He also discussed the difficulty of predicting use time for chemical mixtures.

Many questions still remain regarding enforcement of the new standard. R. Fairfax of OSHA discussed the compliance directive that is being developed to address these questions. The directive is expected this fall.

### Technical session; Papers 280-291

The respiratory protection technical session was held May 14. It began with the presentation of the John White Award, which is given annually to the authors of the article voted best respiratory protection paper published in the American Industrial Hygiene Association Journal. The winners for 1997 were Y. Qian, K. Willeke, S. Grinshpun and J. Donnelly for their article entitled "Performance of N95 Respirators: Reaerosolization of Bacteria and Solid Particles." The article appeared in the December 1997 issue of the AIHA Journal (Volume 58, Number 12).

Following the presentation, twelve papers were given on four general topics: evaluations of respirator fit, workplace performance of respirators, respirator use, and filter and cartridge efficiency.

### Respirator fit

Four papers that addressed aspects of respirator fit testing were presented. The first, by R. McKay and E. Davies of the University of Cincinnati, presented research on qualitative fit testing in health care settings. Subjects were fit tested using both sweet (saccharin) and bitter (Bitrex™) agents. They reported that subjects qualitatively fit tested with Bitrex were more likely to detect leaks in their respirators than those subjects tested with saccharin. However, these results may not be applicable to routine fit testing, because this study employed a stronger concentration of Bitrex than is used in commercially-available fit test kits.

A method for evaluating whether user seal checks (formerly called fit checks) are being performed properly was presented by A. Freeman and R. McKay of the University of Cincinnati. They have developed a system that uses pressure monitors to detect leaks during user seal checks. This system was used to measure the positive and negative pressures achieved during user seal checks and the fit factors of two half facepiece respirator models, including one in which they had induced leaks. Some of the test subjects achieved respirator fits that would be unacceptable for respirators used in the workplace. In 3M's opinion, this makes it more difficult to extrapolate these results to the workplace. Further development and evaluation of this system is necessary. In the future, however, this method may allow laboratory evaluation of user seal check effectiveness.

A new quantitative fit test method from TSI, Inc. was introduced by T. Halvorsen. This commercially-available method was developed for quantitative fit testing of respirators with N95 filters, using either an atmospheric aerosol or a generated aerosol. A particle classifier is used to eliminate particles that may penetrate the filter. Therefore, the in-facepiece sample counts only those particles that enter the respirator through face seal leaks. According to the developers, use of this fit test should be limited to measurement of fit factors of 200 or less, which is sufficient for half facepiece respirators. No data were presented to determine how this method correlates to the DOP procedure; the "gold standard" of quantitative fit testing.

C. Coffey and D. Campbell of NIOSH presented their research on the performance of half facepiece respirators with N95 filters. In the study, properly fit-tested half facepiece respirators reduced exposures 25-50 times. The results of their study reconfirmed the importance of fit testing as a tool for identifying individuals who cannot achieve an acceptable fit with a given respirator model.

### Workplace performance of respirators

Three papers that addressed the topic of workplace performance were presented. C. Coffey and Z. Zhuang of NIOSH quantitatively fit tested workers who wore elastomeric respirators in a variety of workplaces. They then measured the ambient contaminant concentration and the concentration of the contaminant inside the facepiece, then determined the workplace protection factor (WPF), i.e. performance, of the respirator.

(see AIHCE: A review on page 3)

While overall, the fit factors obtained during fit testing did not correlate with the WPFs (which is consistent with studies done by 3M), there was slight correlation when the data were analyzed by workplace and respirator model. The authors suggested that future studies should include low fit factors, (those <100), which may improve the correlation between fit factors and WPFs. 3M agrees that the use of test subjects with fit factors <100 may allow a correlation to be established. However, this would mean that some workers would be wearing poorly-fitting respirators while being overexposed to air contaminants. Since this would be legally and ethically inappropriate, these future studies would be difficult to perform in the workplace.

WPFs were also addressed by the team of Z. Zhuang of NIOSH and W. Meyers of West Virginia University who reviewed WPF studies published over the last thirteen years. They concluded there is a very low probability of overexposure when half facepiece respirators are used correctly, and that the assigned protection factor of 10 is appropriate for half facepiece respirators.

An interesting new method of measuring respirator workplace protection factors for gases and vapors was presented by W. Groves, C. Conrad and S. Reynolds of the University of Iowa. Their method uses pressure differences inside the respirator during inhalation to start the sampling pumps. Therefore, gases and vapors are sampled only during inhalation, with no sampling during exhalation. This design reduces the problems of high humidity and sampling of exhaled air that occur when continuous sampling is used. In addition, the equipment is small enough to be used feasibly in the field. While the preliminary testing in laboratories and livestock facilities showed promising results, the accuracy of

the method was not demonstrated. Without mixing of air, which occurs during exhalation, the bias from probe location may be more significant. The authors did not address this issue.

### Respirator use

Respirator use was the topic of three papers. The ability of test subjects to communicate via telephone was investigated by A. Johnson, W. Scott and C. Lausted of the University of Maryland and D. Caretti of the U.S. Army.

S. Francq and J. Cocalis of NIOSH, E. Mauger of Hershey Medical Center and K. Stricklin of the Mine Safety and Health Administration (MSHA) surveyed respirator use among western Pennsylvania surface miners using questionnaires administered to 664 miners. Although more than 75% of companies provided respirators, more than half of the miners did not use them, 31% had interfering facial hair, and only 28% reported being trained and fit tested for the product. The authors concluded there is a high probability of exposure to silica in this group due to misuse of respiratory protection. This highlights the importance of implementing a respiratory protection program. Both NIOSH and MSHA have responded to the findings of this survey by issuing a silicosis prevention special emphasis program targeting surface miners.

The survival and growth of bacteria on respirator filters was investigated by Z. Wang, T. Reponen, K. Willeke and S. Grinshpun of the University of Cincinnati. They found that none of three test

bacteria were able to grow on loaded N95 filter media, although two bacteria species did survive. The authors suggested that this may have implications for respirator storage and use. The storage conditions in this study (37°C or 28°C and a filter loaded with nutrient broth) were not typical of those found in the workplace.

### Filter and cartridge efficiency

Two papers that evaluated filter or cartridge efficiency were presented. M. Bergman of NIOSH investigated whether an increase in penetration occurred when N95 filters were periodically challenged with an aerosol and stored improperly. Three N95 filters were loaded with a sodium chloride aerosol once per week for 17 weeks and stored uncovered between loadings. This resulted in decreased efficiency over the test period. Breathing resistance levels over the course of the study were either not measured or not reported. Therefore, it is not known if respirators would be used for this length of time or discarded before this point due to increased breathing resistance. Filter efficiency using particles larger than 0.3  $\mu\text{m}$  mass median aerodynamic diameter (MMAD), which would be representative of the workplace, was not measured.

E. Johnson and L. Brey of 3M Company presented results of a study designed to determine if a model developed by Wood can accurately predict respirator cartridge service life for organic vapors at typical workplace concentrations. They generated

(see AIHCE: A review on page 4)

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## AIHCE: A review

(continued from page 3)

breakthrough curves for five organic vapors at three concentrations. These data were utilized to derive parameters for a mathematical model used to predict breakthrough for other compounds. This model was found to be successful and useful in predicting cartridge service life for exposures to single organic vapors. Future work, however, should focus on highly volatile organic vapors and mixtures of vapors. Since the conclusion of AIHCE, 3M has introduced software to determine service life using these data in the Wood model. (See *3M's Service Life Software available free* in this issue of *JobHealth Highlights*.)

## Conclusion

The three respiratory protection sessions at the 1998 AIHCE were very well attended. The roundtable discussions provided both a review of 42 CFR Part 84 filter certification and an introduction to the new 29 CFR 1910.134 respiratory protection standard. The technical discussions added new data and reconfirmed existing knowledge regarding respirators.

## For more information

Abstracts from the AIHCE are available on the American Industrial Hygiene Association home page ([www.aiha.org/abs98/abindx.html](http://www.aiha.org/abs98/abindx.html)).

Information on 29 CFR 1910.134 can be found in 3M's Regulations Update Number 21, March 1998. To obtain a copy call the 3M Tech Line, 1-800-243-4630.

Information on 42 CFR Part 84 certification tests and respirators can be obtained from the 3M OH&ESD Fax On Demand Line, call 1-800-646-1655.

The OSHA slides that summarize 29 CFR 1910.134 can be found on OSHA's home page ([www.osha.gov](http://www.osha.gov)).

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## New 3M Service Life Software available free

3M Service Life Software is available free and may be downloaded from the 3M web site: [www.3M.com/occsafety](http://www.3M.com/occsafety).

### Service life estimate and change schedule

The new software offers an easy method for estimating the service life of 3M organic vapor respirator cartridges. 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 will be replaced.

### Change schedule required by OSHA

The Occupational Safety and Health Administration (OSHA) believes that chemical odor may not serve as a sufficient indicator for all workers to change chemical cartridges. Therefore, the recently revised OSHA 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.

### Approximately 200 organic contaminants

3M Service Life Software is based on a model presented by Wood<sup>1</sup> that requires information about carbon properties, cartridge design, environmental and use conditions, and chemical vapor properties. The model was modified for the characteristics of 3M organic

vapor chemical cartridges and some of the experimentally-determined values were refined.<sup>2</sup> Since the predicted service lives are based on properties of the carbon used in 3M organic vapor cartridges, the software can be used only for 3M cartridges.

The software contains a database of vapor properties for approximately 200 of the organic contaminants listed in the 3M Respirator Selection Guide, as well as a database for several 3M organic vapor cartridges. All contaminants in the database are liquids at ambient temperatures. Organic compounds that have boiling points less than 0°C have been excluded and this model does not consider relative humidity greater than 65% or mixed vapor effects. Since liquid densities are required for service life calculations by the software, materials that are solid at ambient conditions are not included in the database. Gases and vapors for which OSHA has established substance-specific standards are also excluded. For these chemicals, the specific OSHA standards should be consulted.

### Change schedule parameters

A change schedule may be established after consideration of the service life estimate as well as workplace conditions such as contaminant concentration, relative humidity, temperature, work activities, respirator use pattern (e.g., continuous or intermittent use), presence of other materials, potential for contaminant migration/desorption, health effects of the gas or vapor, and the quality of any warning properties.

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# Time use limitations for P-series particulate filters

By Karen Blume, C.I.H.

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*Laboratory testing by NIOSH has revealed that all P-series filters will eventually experience a decrease in filter efficiency when subjected to dioctyl phthalate (DOP) oil testing beyond current NIOSH loading requirements. Since a reduction in filter efficiency may not always be accompanied by an increase in breathing resistance, NIOSH has requested each manufacturer of P-series filters establish service time recommendations. 3M has established a Time Use Limitation for all of its P-series filters based on 1) NIOSH certification test criteria, 2) knowledge of the way oil and non-oil aerosols affect filter performance, and 3) oil aerosols found in the "real world."*

Protection provided by respirators used to reduce worker exposure to particulate contaminants is determined by a combination of wear time, face seal leakage and filter efficiency. Wear time can be maximized through training about the need for proper respirator use and by selecting respirators that are comfortable and easy to breathe through. Face seal leakage can be minimized through training about proper fitting methods and by the use of fit tests. Optimal filter efficiency can be selected based on the contaminants found in the workplace.

Through 42 CFR Part 84, the National Institute for Occupational Safety and Health (NIOSH) has implemented new negative pressure

air purifying particulate filter certification tests that address filter efficiency. This new standard created three new series of particulate respirators: N, R and P. Each series is offered in three efficiency levels: 95%, 99% and 99.97%.<sup>1</sup> By utilizing "worst case" testing parameters, the new test procedures were intended to ensure that filter efficiency in workplace settings would always meet or exceed certified efficiency levels, provided that users followed recommended use instructions.

However, subsequent NIOSH laboratory testing has revealed that all P-series filters can eventually experience at least some decrease in filter efficiency when loaded with sufficient amounts of dioctyl phthalate (DOP) oil. In light of this new information, NIOSH requested that all manufacturers of P-series filters include service time recommendations as part of their use instructions.

## 42 CFR Part 84 certification tests

The "worst case" parameters used in the NIOSH 42 CFR Part 84 filter certification tests are designed to ensure that filters perform at least as well in the workplace as they do in the laboratory. These testing parameters include the use of the most penetrating particle size, challenging test agents and high filter loading requirements.

### Particle size

In the past, NIOSH tested certain classes of filters against typical workplace contaminants, such as silica dust and lead fume. Under 42 CFR Part 84, all filters are challenged with laboratory-generated aerosols that are the most difficult size to capture: particles with approximately 0.3 $\mu$ m mass median aerodynamic diameter (MMAD). Particles both smaller and larger than this size are captured at a higher efficiency and

most aerosols found in the workplace are larger than 0.3 $\mu$ m MMAD.<sup>2</sup> By testing with the most penetrating particle size, it can be reliably predicted that filters will perform at their certified efficiency level (95%, 99% or 99.97%) or better when used against aerosols present in the workplace.

### Test agents

Under 42 CFR Part 84, the test aerosol used depends on the filter classification: the N-series filters are tested with solid sodium chloride (NaCl) particles, and R- and P-series filters with dioctyl phthalate (DOP), an oil. Solid aerosols tend to build up and form a "cake" on the filter which increases both the filter's efficiency and its breathing resistance, thereby indicating when the filter needs to be changed. In contrast, it is thought that DOP oil droplets tend to spread out across the filter fibers or "wet" the fibers. With certain electrostatic filters, this may mask some of the electrostatic charge on the filter fibers and potentially result in a decrease in filter efficiency. The DOP test is made more challenging by the use of a particularly high concentration (100 mg/m<sup>3</sup>) for an oil mist. As a result, from a filter efficiency perspective, the DOP loading test is more discriminating than the NaCl test. Therefore, N-series filters are approved for protection against non-oil aerosols only, and R- and P-series filters are approved for both oil and non-oil aerosols.

### Filter loading requirements

Another important aspect of 42 CFR Part 84 certification testing requires all filters to undergo heavy loading with the NaCl and DOP aerosols. N- and R-series filters must be loaded to 200 mg. Filter performance must exceed the efficiency level desired for certification (95%, 99% or 99.97%) at all times during the test. P-series

*(see P-series filters on page 6)*

## P-series filters

(continued from page 5)

filters are loaded to at least 200 mg. If the efficiency of the filter is decreasing at 200 mg, then the test continues until the filter efficiency stabilizes. At the end of the certification test, the filter efficiency for **all** NIOSH certified P-series filters is stable and exceeds the filter efficiency category.

### NIOSH User's Guide

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In addition to subjecting filters to severe testing requirements, NIOSH has recommended time use restrictions for filters in the "NIOSH Guide to the Selection and Use of Particulate Respirators Certified Under 42 CFR Part 84."<sup>3</sup> In this guide, NIOSH states that "all filters should be replaced whenever they are damaged, soiled, or causing noticeably increased breathing resistance." Additional limitations, specific to the filter series, may also apply. For example, if oil aerosols are present, R-series filters must be changed after 8 hours of use or after being loaded with 200 mg of aerosol.

The User's Guide states that, "Use and reuse of the P-series filters would be subject only to considerations of hygiene, damage, and increased breathing resistance." While the NIOSH test conditions represent "worst case" conditions, subsequent NIOSH laboratory testing has revealed that **all** P-series filters, both electrostatic and mechanical filters, will eventually experience a decrease in filter efficiency when subjected to DOP testing beyond the current NIOSH loading requirements. The mechanism believed to cause a decrease in efficiency for electrostatic filters is discussed above. The mechanism by which filter efficiency decreases for mechanical filters is not known at this time.

NIOSH testing has also indicated that a reduction in filter efficiency may not always be accompanied by an increase in breathing resistance. Given this new information, NIOSH published a *Respirator User Notice*<sup>4</sup> to alert end users that time use restrictions would be recommended for P-series filters. In the *Respirator User Notice*, NIOSH stated that, "This reduction in filter efficiency varies significantly from model to model and NIOSH cannot make a single filter change recommendation that is appropriate for all models. Therefore, NIOSH has requested each manufacturer of P-series filters to establish service time recommendations as part of their instructions."

### P-series time use limitation

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In response to NIOSH's request, the following time use limitation is recommended for all 3M P-series filters:

**If filter becomes damaged, soiled, or breathing becomes difficult, leave the contaminated area and dispose of the filter. If used in environment containing only oil aerosols, dispose of filter after 40 hours of use or 30 days, whichever is first.**

As discussed above, if a filter is used in environments containing non-oil aerosols, solid aerosol particles tend to form a cake on the filter and filter efficiency will increase. This increase in efficiency is accompanied by an increase in breathing resistance that can help signal the wearer to change the filter. Atmospheres that contain both oil and non-oil aerosols will most likely result in filter caking from the non-oil aerosols. Therefore the P-series time use limitation reverts to **dispose of the filter when it becomes damaged,**

**soiled, or difficult to breathe through** if the filter is used in environments that contain no oil aerosols or if the filter is used in environments that contain a mixture of oil and non-oil aerosols. The full time use limitation applies only if a P-series filter is used in an environment that contains exclusively oil aerosols.

### The "real world" perspective

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By creating N-, R- and P-series filters, NIOSH has compelled end users to consider the presence of oil aerosols in the environment when selecting a respirator. The NIOSH User's Guide states that R- or P-series respirators are to be used if oil aerosols are present. (For guidance determining which contaminants may be considered oils, see 3M's Technical Data Bulletin Number 129.)<sup>5</sup> In most atmospheres containing oil aerosols, respirators are worn for protection from contaminants other than oil. For example, in the textile industry, oil aerosols may be generated from looming machines, but respirators may be used to reduce exposures to cotton dust. In foundries, where parting oils are sprayed on molds, respirators are worn to protect workers from silica dust. In the food processing industry, where food grade oils are aerosolized, grain dust may be the primary exposure for which respirators are worn.

All these environments contain oil and, according to NIOSH, would necessitate using an R- or P-series filter. They would also be environments where solid particles are likely to cause filter caking, thereby increasing filter efficiency and breathing resistance, which in

(see P-series filters on page 7)

## P-series filters

(continued from page 6)

turn, would indicate when the filter or respirator should be changed. Following the NIOSH time restrictions, R-series filters should be disposed of if they become damaged, soiled or difficult to breathe through. In addition, they should be changed after no more than 8 hours of use or after 200 mg loading. Based on the 3M P-series time use limitation, P-series filters should be changed when the filter becomes damaged, soiled or difficult to breathe through.

Because oil aerosols are seldom the primary contaminant in the environment, there has been limited documentation of oil concentrations in the workplace. However, recent concern over the health effects of metal-working fluids, many of which would be considered oils, has prompted an extensive survey of oil exposures at three auto parts manufacturing facilities.<sup>6</sup> Each of the facilities had thousands of metal-working machines. Investigators collected 403 personal, 6- to 8-hour time-weighted average samples of workers exposed to metal-working fluids. The mean total exposure was 0.7 mg/m<sup>3</sup> with average particle sizes ranging from 3.6 to 8.2 μm MMAD by operation for exposed workers, significantly larger than the most penetrating particle size of 0.3 μm MMAD.

Based on this survey of metal-working fluids, a typical oil mist exposure is unlikely to exceed 2 mg/m<sup>3</sup>. In contrast, the DOP aerosol concentration of 100 mg/m<sup>3</sup> used by NIOSH would be 50 to 100

times greater than oil mist concentrations typically found in the workplace. Therefore, it is not appropriate to assume that the time a P-series filter lasts under NIOSH laboratory testing conditions will reasonably predict filter service life in the workplace. A more meaningful interpretation would assume a worker is continuously exposed to 2 mg/m<sup>3</sup> of oil while working at a moderate rate. This worker would breathe about 10 m<sup>3</sup> of air over an 8-hour day. Under these circumstances, it would take 10 days of continuous use to reach 200 mg loading of oil, the **minimum** filter loading used by NIOSH in certification tests for P-series filters. By following the 3M time use limitation on P-series filters, the worker would have replaced the filters after no more than 5 days (i.e., 40 hours), which is well before any potential decrease in filter efficiency.

There are few, if any, workplace environments that contain oil aerosols with no other contaminants. Neither 3M nor NIOSH has been able to locate an oil-only environment. Therefore, in most industrial environments, it is expected that non-oil particles will cake the filter and increase filter efficiency, keeping it well above the certified level. In oil-only environments, a potential for a gradual drop in filter efficiency may exist, but filters changed according to the 3M P-series filter time use limitation will perform at or above their certified efficiency.

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## Tech line

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