

Changes in filter testing and certification

By Craig Colton, C.I.H.

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The National Institute for Occupational Safety and Health (NIOSH) has been testing and certifying respirators since the 1970's. However, some of their test methods were originally developed in the 1930's while others have evolved over a period of years.

Old tests; recognized weaknesses

Some of the older tests, such as the silica dust, lead fume and paint mist tests, were used to evaluate particulate filters. These tests were conducted in exposure chambers. During the procedure, air containing the test aerosol was drawn through a filter and the total mass of material that passed through the filter was determined.

There were several recognized weaknesses with these tests. First, they were hard to control and did not easily lend themselves to precise calibration. The lead fume test, for instance, used a torch flame impinging on a lead block to generate lead fume. It was very difficult to develop techniques to calibrate the flame and the rate

of fume generation, as well as to control the particle size of the test aerosol.

The dust, mist, fume and paint spray tests measured total penetration through a filter. However, the overall efficiency of some filters depended on their ability to develop a "filter cake" to increase filter efficiency. Consequently, during initial filter loading, before the "cake" developed, higher penetration of an aerosol could occur.

Finally, these tests were not designed to determine filter efficiency on an instantaneous basis. Only the dioctyl phthalate (DOP) test measured filter efficiency continuously, but this procedure was used only for high efficiency particulate air (HEPA) filters.

These limitations do not mean that filters certified by NIOSH under 30 CFR part 11 were defective. Numerous workplace protection factor studies have shown that respirators equipped with 30 CFR part 11 approved filters perform as intended. With the development of new and better-controlled methods for filter testing, it has been suggested for many years that changes to the NIOSH testing and certification system were needed.

A new rule

In 1995, NIOSH published a final rule, 42 CFR part 84, that revised the testing and certification procedures for particulate filters used in negative pressure respirators. Other portions of the certification requirements from 30 CFR part 11 were carried over to 42 CFR part 84 without modifications, except to allow HEPA filters to be certified for powered air purifying respirators. Over the next several years, NIOSH will be updating the other parts of the regulation and publishing them in a series of modules.

Nine filter classes

The new rule's filter classification system provides for nine classes of filters with three categories of oil resistance and three filter efficiency levels (95%, 99% and 99.97%) as shown in Table 1.1.

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Changes in filter testing

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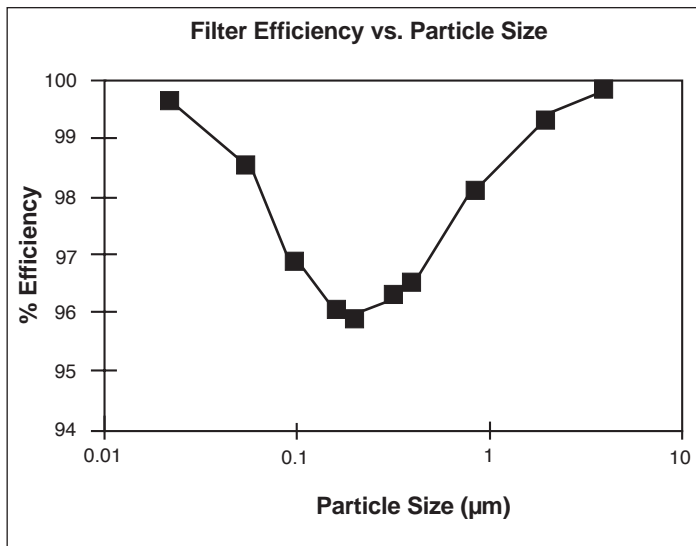


Figure 1.1 Under 42 CFR part 84, a mass median particle diameter close to 0.3 µm was selected as a “worst-case” condition because, for filters, it is in the most penetrating particle size range.

The three levels of oil resistance are categorized as “N,” “R” and “P.” These letters were chosen so that the limitations on filter use could be easily remembered. According to NIOSH, “N” stands for Not resistant to oil, “R” for Resistant to oil and “P” for oil Proof.

Filter efficiency is the percentage of the test aerosol trapped by the filter. It is determined by using an aerosol in the most penetrating particle size range and measuring continuously until a 200 mg loading with the test aerosol is reached. P series filters, however, may be subjected to more loading at this point if their filter efficiency is decreasing. Filter efficiency must never be less than the test criteria of 95%, 99% or 99.97%.

Testing N, R and P filters

Under 42 CFR part 84, NIOSH has updated filter testing, using modern equipment to measure filter penetration and addressing some of the concerns about older testing methods discussed above. For example, in the new tests, penetration of the test aerosol through the filter is measured continuously, thereby eliminating the concern about high initial penetration.

Two types of challenge aerosol are used in the new filter tests. (See Table 1.1.) These are either a mildly degrading solid particle (sodium chloride), or a degrading oil, dioctyl phthalate (DOP) mist. (See Sidebar.) In this context, “degradation” does not mean physical damage to the filter media, but refers to a reduction of filter efficiency for the test particles as aerosol is loaded onto the filter.

N filters are tested with the sodium chloride aerosol and should only be used for particles from solids, water-based liquids or other non-oil liquids.

Filters tested with DOP are recognized as highly resistant to filter efficiency reduction caused by oil loading and are considered appropriate for use with all workplace aerosols. Respirators with R filters are tested until a 200 mg DOP loading is reached. However, since these filters are tested only to this point, no information about their continued effectiveness past this point is available. Therefore, NIOSH recommends their use be limited to 8 hours or to an estimated 200 mg loading, when used in the presence of oil aerosols. They may need to be replaced sooner, however, due to filter damage or excessive breathing resistance or for hygienic reasons.

Respirators with P filters are tested until their filter efficiency is stable or increasing after a minimum loading of 200 mg of DOP. However, if filter efficiency is decreasing at this stage, additional aerosol may be loaded until filter efficiency becomes stable. While P filters should be more resistant to oil than R filters, NIOSH has requested respirator

Filter efficiency degradation or What does the term “degrading” mean?

Some aerosols (especially oil mists) have been shown to reduce filter efficiency as the filter is exposed to the aerosol. To guard against this effect, the new 42 CFR part 84 filter tests use either a mildly “degrading” particle (sodium chloride) or a severely degrading oil (DOP) as challenge aerosols. In this context, the term “degrading” does not imply physical damage to the filter, but a reduction in filter efficiency for the test aerosol. It is more correct to talk about “filter efficiency degradation.” The National Institute for Occupational Safety and Health (NIOSH) selected DOP (dioctyl phthalate) as a test aerosol because it is known that DOP has one of the most severe effects on filter efficiency. The effect on filter efficiency by most workplace aerosols should be less severe than that caused by DOP.

The exact mechanism for reducing filter efficiency is not known. It may be different for different types of filters. For electrostatic filters, the electrical charge imbedded on the fibers may be masked or blocked as the aerosol builds up on the fibers. For fiberglass filters, the aerosol may have an effect on the binder in the filter paper. Because the R and P filters are tested against DOP, these filters should be selected when oil aerosols are present. Since even the efficiency of P filters can be reduced by long-term use in the presence of oil aerosols, NIOSH has recommended time-use limitations for both R and P filters.

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Changes in filter testing

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Table 1.1 Filter classifications, efficiencies, oil resistances and challenge agents specified under 42 CFR part 84

42 CFR part 84	Oil Resistance Categories		
Minimum Efficiency	N Non-oil Aerosols	R Includes Oil Aerosols*	P Includes Oil Aerosols**
95%	N95	R95	P95
99%	N99	R99	P99
99.97%	N100	R100	P100

* May have a time use restriction on this filter series when oil aerosols are present.

** Use according to manufacturer's time use restrictions when oil aerosols are present.

manufacturers establish service time recommendations for all P filters. NIOSH has indicated P filters should be used and reused in accordance with the manufacturer's time-use limitation recommendations when oil aerosols are present. If oil aerosols are not present, P filters should be used and reused subject only to considerations of hygiene, damage and increased breathing resistance.

Worst-case criteria

In the new test requirements, several parameters have been adjusted to reflect "worst-case" conditions. The following worst-case criteria have been specified: a mass median aerodynamic diameter (MMAD) particle of about 0.3 μm ; an airflow rate of 85 liters per minute (lpm); a charge-

neutralized test aerosol; and, for N series filters, preconditioning at 85% relative humidity (RH) and 38°C for 24 hours before testing.

The 0.3 μm particle diameter was selected because, for filters, it lies within the most penetrating particle size range. Smaller and larger particles will be trapped in the filter at higher rates due to the physics of filtration. (See Figure 1.1.) By using this most penetrating particle size, particulate filters certified under these new procedures can be used without regard to aerosol size.¹ Filter efficiency is affected by the flow rate of air through the filter. Higher flow rates tend to reduce filter efficiency measurements. The specified flow rate of 85 lpm represents a very high work rate, equivalent to the breathing rate of an individual running at 10 miles

per hour. The requirements for preconditioning and use of a charge-neutralized aerosol are other variables that can affect filter efficiency. In addition, storage of some filters in high temperature and relative humidity conditions have been shown to reduce filter efficiency.

New expectations

There are several advantages that will be realized when the new 42 CFR part 84 filters are used on respirators. Because filter testing is done with the most penetrating particle size, the size of the aerosol in the workplace is no longer a concern for filter selection. According to NIOSH, "all filters certified under the new procedures will be effective against any size aerosol," thereby simplifying respirator selection.¹

In addition, because NIOSH selected worst-case test conditions, it can be expected respirator filters will always perform better in actual use than they do during certification testing. This adds assurance that respirator filters will provide high levels of respiratory protection.

Reference

1. "Respiratory Protective Devices; Final Rules and Notice," *Federal Register*, 60:110 (8 June 1995), pp. 30336-30398.

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Information on 3M OH&ESD products as well as on current issues in respiratory protection can be obtained by visiting our web site.

Our address is: <http://www.mmm.com/occsafety>

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To reach 3M's Technical Service staff with questions regarding our products, you can call 1-800-243-4630.

If you wish to contact your local sales representative, you can leave a message by calling 1-800-896-4223.

Relating 42 CFR part 84 filters to those currently in use

By Craig Colton, C.I.H.

Under the new respirator certification standard, 42 CFR part 84, the National Institute for Occupational Safety and Health (NIOSH) has designated nine particulate filter classes for negative pressure air purifying respirators. The new filters can have three levels of efficiency (95%, 99% or 99.97%) and three levels of oil resistance (N, R or P). In contrast, under the earlier standard, 30 CFR part 11, filters were divided into “hazard” categories, such as dust/mist, dust/fume/mist, paint spray and pesticide. **There is no direct comparison between the filters being certified by NIOSH under 42 CFR part 84 and those that were certified under 30 CFR part 11.**

The test conditions specified under 42 CFR part 84 differ from those specified under 30 CFR part 11. Consequently, a dust/mist filter will not perform in exactly the same manner as an N95 particulate filter, nor will a dust/fume/mist filter perform in the same way as an N99 filter. As a result, manufacturers have had to design and produce many new types of filters. In fact, NIOSH, in describing the results of the new standard, considered it “technologically forcing,” implying it would necessitate the development of new materials and filter media.¹

Electrostatic and mechanical filters

In designing filters, the scientist can vary physical parameters of the filter media to produce filters that not only meet the 42 CFR part 84 test criteria but also affect breathing resistance, comfort and durability. Some of these parameters are fiber

diameter, basis weight (the weight of filter medium per unit area), filter thickness and, to some extent, filter surface area.

Filters remove particles as air passes through them. There are two fundamental types of particulate filters for respirators: “mechanical” filters and “electrostatic” filters. In turn, electrostatic filters can be divided into subtypes: resin wool filters and electret filters.

The efficiency of mechanical filters is determined by mechanical features such as the diameter, orientation and arrangement of the fibers that comprise the filter. Electrostatic filters function by means of mechanical filtration, but they have an electrical charge on their fibers to enhance their attraction and retention of particles. This electrical charge enhances filter efficiency so an electrostatic filter generally offers lower breathing resistance than a mechanical filter with the same initial efficiency. This is because fewer fibers are needed in an electrostatic filter to achieve the same level of efficiency as a mechanical filter. However, the efficiency of some electrostatic filters may be reduced by exposure to certain aerosols, while mechanical filters are generally more resistant to changes in filter efficiency due to the properties of aerosols.

The tests described in 42 CFR part 84 take this into account. The sodium chloride aerosol used in the test for N filters is described by NIOSH as a mildly degrading aerosol, while the dioctyl phthalate (DOP) used in the R and P tests is, according to NIOSH, more severely

degrading to filter efficiency. (See Sidebar.) So regardless of the type of filter mechanism being used, (pure mechanical or mechanical with electrostatic enhancement), a filter certified by NIOSH as an R or P filter has been shown not to be affected by DOP under the certification test conditions.

A comparison of filter tests

To compare the filter tests described in 30 CFR part 11 with those of 42 CFR part 84, 3M scientists determined the thickness of various filter media needed to satisfy the filtration requirements for some of the filter types described in the two standards. Common filter media, including mechanical and electrostatic media, were evaluated. Comparison of the dust/mist and N95 filter certification tests indicated the N95 test is significantly more stringent than the dust/mist tests. As Table 2.1 shows, all filter media satisfying the dust/mist test criteria required an increased thickness (of 2.0 to 3.5 times) in order to pass the N95 test. The increased stringency of the new tests may provide more consistency in filter efficiency but does not necessarily translate into better protection. Respirators certified by NIOSH under 30 CFR part 11 have been shown to be effective in actual workplace testing.

A comparison between the HEPA and R100 filter tests showed that the R100 test is equivalent to or more stringent than the HEPA test,

(see *Relating 42 CFR part 84 filters on page 5*)

Table 2.1 Comparison of filter types in dust/mist and N95 filter tests

Filter Type	Thickness of Filter Media (mm) Required to Pass the Test	
	Dust/Mist	N95
Large Fiber Electrostatic	3.7	13.3
Small Fiber Electrostatic	0.7	1.4
Fiberglass	0.3	0.6

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Table 2.2 Comparison of filter types in HEPA and R100 filter tests

Filter Type	Thickness of Filter Media (mm) Required to Pass the Test	
	HEPA	R100
Large Fiber Electrostatic	14.8	23.5
Small Fiber Electrostatic	4.2	5.3
Fiberglass	1.82	1.88

Table 2.3 Breathing resistance for equal area, equal penetration for several types of filter media

Filter Medium	Breathing Resistance
Large Fiber– Charged	↑
Small Fiber– Charged	↑↑
New Fiber– Charged	↑↑↑
Fiberglass– Uncharged	↑↑↑↑

depending on the type of filter medium evaluated. (See Table 2.2.) A mechanical filter medium (fiberglass) required no increase in thickness to pass the R100 test versus the HEPA test. However, one of the electrostatic filter media required more thickness to pass the R100 test versus the HEPA test. This indicates the loading of DOP aerosol interferes with particle capture by electrostatic mechanisms for these two filter media tested.

Breathing resistance

In another study, 3M scientists determined how several different types of filter media performed, examining not only filter efficiency but breathing resistance.

Breathing resistance is a very important design consideration for several reasons. First, higher breathing resistance may increase leakage at the face seal of the respirator. Second, respirators with lower breathing resistance are

generally more comfortable and more acceptable to wearers. If respirators are uncomfortable to wear, workers are less inclined to use them as often as they should. Third, high breathing resistance can be an unacceptable physiological burden on some workers. For a worker with impaired pulmonary or cardiovascular function, high breathing resistance may make respirator use impossible.

In the 3M study, it was found that for the same filter surface area, media without an electrostatic charge had higher breathing resistance than media that included an electrostatic charge. (See Table 2.3.) For this reason, purely mechanical filter media, such as fiberglass, generally must be pleated in order to extend its surface area and lower breathing resistance.

Of two types of electrostatic media tested, a smaller fiber electrostatic medium had an initial breathing resistance lower than uncharged medium, but generally

not as low as that of a larger fiber medium. In smaller fiber electrostatic media, solid aerosols can form a filter cake, causing penetration to decrease, while airflow resistance increases with loading. Upon exposure to oily liquid aerosols, performance of smaller fiber electrostatic media is similar to that of large fiber media, where penetration increases while airflow resistance remains constant, however, the increase in penetration is less dramatic.

A new electrostatic technology

3M has developed a new electrostatically charged filter technology that is unique among filter media. This medium has improved resistance to oily liquid aerosols as well as greater levels of electrostatic charge, thereby enhancing filtration. These two improvements result in filters with much lower breathing resistance than that found in fiberglass filters with equal penetration. Airflow resistance is comparable with the best large fiber media, yet the new medium is thinner and lighter weight.

Conclusion

These studies show that significant differences exist among electrostatic filters, some media being better suited for respirators than others. While generalizations cannot be made about the fundamental type as a whole, resin type electrostatic media may suffer a loss in efficiency upon extended exposure to certain aerosols, especially oily mists such as dioctyl phthalate. However, newer electret media which have a higher level of electrostatic charge and oily mist resistance exhibit improved overall filter efficiency while eliminating decreased filter efficiency due to

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aerosol loading. By taking advantage of this advancement in filter technology, respirators may be designed with media optimized for all NIOSH certification classes and types of aerosol challenges.

Reference

1. "Respiratory Protective Devices; Final Rules and Notice," *Federal Register*, 60:110 (8 June 1995), pp. 30336-30398.

Professional and technical development program on respiratory protection

3M is offering a 4 1/2-day course that will provide the information to design, implement, maintain and evaluate a comprehensive respiratory protection program. Break-out workshops within the course will provide hands-on reinforcement of lecture subjects.

Topics will include the new **OSHA Respiratory Protection Standard 29 CFR 1910.134**, ANSI requirements, respirator capabilities and limitations, respirator selection, 42 CFR part 84 filters, medical evaluations, fit testing, breathing air quality for supplied air respirators, air quality testing and self-contained breathing apparatus.

To register or obtain more information, call 1-800-659-0151, ext. 275.

1998 Locations and Dates

Denver, CO	April 20-24
Minneapolis, MN.....	July 13-17
Portland, OR	September 14-18
Phoenix, AZ	October 19-23

42 CFR part 84: Steps for transition

By Craig Colton, C.I.H.

The principal change in the new certification standard, 42 CFR part 84, involves the testing and certification of particulate filters for non-powered air purifying respirators. These "N," "R," and "P" filters with efficiencies of 95%, 99% and 99.97% differ from the dust/mist, dust/fume/mist and high efficiency particulate air (HEPA) filters that have been used for many years. Therefore, new ways of thinking about respirator selection are required, along with preparations for the changeover to the new respirators and filters.

In the new standard, the National Institute for Occupational Safety and Health (NIOSH) gave respirator manufacturers three years to stop selling respirator filters certified under 30 CFR part 11. This means that after July 10, 1998, respirator manufacturers will not be able to sell any filters certified under this standard.

It should be noted that the Occupational Health and Safety Administration (OSHA) has indicated distributors who have purchased 30 CFR part 11 respirators and filters prior to July 10, 1998 will be able to sell them until their inventories have been depleted. In addition, end-users who purchase these particulate filters and respirators from the distributors will be able to use them until the inventories they purchase have been depleted or until the shelf life or service life for these products expires.¹

In order to make a smooth transition to the new filters, you must assess your workplace needs, evaluate new respirators, then plan and implement your changeover.

Step 1. Workplace assessment

Workplace assessment for the new respirators involves determining exposure levels, including the presence of oil mists (if this has not previously been done), assessing environmental conditions and evaluating workplace conditions. All three can be factors in choosing a specific respirator.

Begin the transition process by assembling information on the workplace exposures that require the use of respirators. Prepare a list of the workstations and tasks (such as welding, painting or grinding) in which respirators are worn. For each workstation and task, list the contaminants present and classify them as oil or non-oil. An oil aerosol is any mineral, vegetable or synthetic substance, or animal or vegetable fat that is slippery, combustible, viscous, liquid at room temperature and soluble in various organic solvents (such as ether) but not in water. The specific 42 CFR part 84 filter you select will depend on the presence of oil aerosol. For example, if an oil mist is present, an R or P filter must be used. In this case, the presence of oil is important for its effect on the filter, not its health effect. The presence of oil must be considered even when the levels of oil aerosol are below health limits.

Once the contaminants have been identified, measure the exposure levels. Next, determine whether OSHA has a specific substance standard governing respirator selection for your situation. If an OSHA substance specific standard requires high efficiency particulate air (HEPA) filters (as do the standards for asbestos, cadmium and lead), 99.97% efficient filters must be used as a replacement.

The calculation of a hazard ratio will determine the type of respirator that must be used. A hazard ratio is the concentration of a contaminant

(see *Steps for transition on page 7*)

Steps for transition

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divided by the exposure limit. When selecting a respirator, the assigned protection factor (APF) must be greater than the hazard ratio. For example, 3M recommends an APF of 10 for a half facepiece respirator and an APF of 50 for a full facepiece air purifying respirator. If the hazard ratio is greater than 10, the half facepiece respirator cannot be used.

Within a given respirator class, there can be many variations in design and some respirators offer features for specific environmental situations. This enables you to choose the respirator that best suits your needs.

As you evaluate the environment in which respirators will be used, determine whether sparks or flames are present. If so, you will want to consider respirators or filters that are resistant to spark burn-through. In areas where heat and humidity are high, a respirator equipped with an exhalation valve that permits the escape of hot humid air can increase worker comfort and wear time. If odors are a problem, a filter with an odor-removing medium may be desirable. If limited eye protection is needed, a full facepiece respirator may be the best choice.

In this portion of your evaluation, you will want to consider the number of respirators and filters used in your workplace, the duration of their use and their maintenance. When selecting new respirators, you may want to consider maintenance-free respirators. For example, if a respirator is used infrequently, then maintaining spare parts, a cleaning facility and someone trained to do the necessary cleaning, repairs and inspection may not be cost effective. Instead, a maintenance-free respirator may be a better solution.

If you find you will need several types of filters (i.e. N, R or P), it may make sense to standardize your operations by using one filter type (for example, P type) that satisfies all of your requirements. This can

reduce user confusion and make purchasing and maintaining inventory simpler.

A respirator manufacturer's representative can assist you in making your selection and help you establish a timetable for changing to the new filters.

Step 2. Evaluate specific products

Purchase samples of the respirators and filters that you believe are adequate for your needs. Schedule fit testing, if required. Then evaluate the new respirators and filters in your workplace. Determine how workers react to them and how long the filters last. Identify any durability concerns. Once you've obtained this information, choose the specific respirators you want to use.

At the same time, make sure you have enough 30 CFR part 11 certified respirators and filters to last throughout your evaluation phase, then begin reducing excess inventories of those products.

Step 3. Planning and implementing the change

Implementing the change involves more than purchasing new products and controlling your inventory. You will also need to train employees, conduct fit testing where required and update your written respiratory protection program. As you take these steps, don't forget to inform management of the many changes that will be made. Cooperation among all parties is essential to ensure a smooth transition.

Begin this final stage by reviewing your 42 CFR part 84 respirator changeover schedule with your respirator manufacturer's representative. Determine needed inventory for the new products,

taking into consideration your existing inventory of 30 CFR part 11 products.

Talk with your representative about the training aids that are available. Training should describe when the new filters and respirators should and should not be used, replacement schedules for filters, and changes in maintenance and care procedures.

Fit testing may need to be scheduled and conducted when the changeover is made. If you are using a replaceable filter with an elastomeric facepiece, no additional fit testing will be necessary if the old filters are simply replaced with new 42 CFR part 84 approved filters. However, if you are changing from a disposable filtering facepiece type to another filtering facepiece type, fit testing the new respirators will be required. Even though the new respirators may look the same, there may be differences in the way they will fit.

Your written respiratory protection program will need to be modified, specifying where the 42 CFR part 84 filters are to be used. If you have respirator selection procedures defined within your operating procedures, these instructions will also need to be updated. In addition, any written procedure that lists specific respirators may need to be revised. For example, maintenance and care procedures will need to list new part numbers and reflect any changes in recommended cleaning procedures.

Ask for assistance

While the transition process is critical, it should not be trying. Respirator manufacturers and their representatives are available to assist you. Do not hesitate to contact them.

Reference

1. Personal correspondence, May 5, 1997.

1998 3M Respirator Selection Guide now available

The 3M Respirator Selection Guide helps identify properties of approximately 800 chemicals, including those that exist as particles in the air. Odor thresholds, IDLH, TLV, PEL and WEEL values and information on physical state are listed, along with chemical synonyms. Recommendations for respirator selection are included for all chemicals, including those that will be governed by 42 CFR part 84. A color-coded chart and product photographs enable easy product identification.

Customers who returned the business reply card from last year's edition of the Guide will receive a copy of the 1998 Guide.

For further information, contact your 3M sales representative or your 3M distributor.

Transition guide available for 42 CFR part 84 filters

After July 1998, paint spray, pesticide, dust/mist and dust/fume/mist filters will be no longer be readily available. Old selection criteria based on the contaminant, an exposure limit (less than 0.05 mg/m³ required a HEPA filter) and particle size will no longer apply. Instead of choosing a filter based on a worker's task, (e.g. paint spraying or welding), factors such as the presence of oil aerosol, the filter efficiency required, durability and the comfort of the respirator wearer will need to be evaluated.

This means that respirator program administrators will need to evaluate their current respirator selections and decide which of the new filters will be an acceptable replacement.

To assist you in making the transition to 42 CFR 84 filters, 3M is offering a Technical Data Bulletin that discusses selection logic for these filters and provides respirator recommendations for more than 300 chemicals that can exist as particles in the air. The bulletin also discusses respirator selection for OSHA substance specific standards.

To obtain a copy of Technical Data Bulletin #129, call your 3M sales representative. You can also leave a message for your representative by calling 1-800-896-4223.

OSHA Respiratory Protection Standard 29 CFR 1910.134 published

The Occupational Health and Safety Administration (OSHA) has published its final Respiratory Protection Standard, 29 CFR 1910.134. A copy of the standard can be found in the *Federal Register* (63:1152, 8 January 1998). Further information can also be obtained from the OSHA web site: <http://www.osha.gov/wutsnew.html>

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