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MSA

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July 21, 1994

Ms. Diane Manning
NIOSH Docket Office
Robert A. Taft Laboratories
Mail Stop C34
4676 Columbia Parkway
Cincinnati, OH 45226

Dear Ms. Manning:

Enclosed is Mine Safety Appliances Company's comments to the NIOSH docket on 42CFR84. If you have any questions, please do not hesitate to contact me.

Sincerely,

Wayde B. Miller, Jr.
Vice President and Director
Product Planning and Engineering

Enclosure

JUL 22 1994

MSA Company's Comments to the National Institute of Occupational Safety and Health's Notice of Proposed Rulemaking on Respiratory Protective Devices -- 42 CFR Part 84

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MSA Company's Comments to the
National Institute of Occupational Safety and Health's
Notice of Proposed Rulemaking on
Respiratory Protective Devices -- 42 CFR Part 84

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Summary and Overview

The Mine Safety Appliances Company (MSA) supports the effort by the National Institute of Occupational Safety and Health (NIOSH) to upgrade the 60-year old certification requirements for respiratory protective devices. MSA also supports the modular approach that NIOSH is taking to more quickly promulgate this rule. However, the NIOSH proposed 42 CFR Part 84 rule has some very serious deficiencies and oversights that we believe can adversely affect worker safety and this deeply concerns MSA. We believe that these concerns must be addressed prior to a final rule being adopted. We believe that NIOSH can better meet their stated goals for 42 CFR Part 84 and improve safety for all workers with certain modifications to the proposed rule. MSA has recommended certain specific alterations to the proposed rule that will make the standard more effective and make its requirements more realistic and reproducible in the laboratory and the workplace. Specifically, MSA makes the following 22 recommendations:

- Regarding Particulate Filter Testing:
  1. MSA recommends that the "solid only" particulate filter certification class be eliminated and that only one certification class be established. That particulate filter certification class should be "liquid and solid".
  2. MSA recommends that the particulate filter penetration test be continued until filter penetration has stabilized and no longer shows increasing penetration performance (i.e., degrading filter performance).
  3. MSA recommends that the test protocol not be strictly written around cold-nebulized DOP in order that thermally generated DOP test equipment might also be used. This improves reproducibility among various labs and reduces capital expenditure burdens on manufacturers. NIOSH acceptance of recommendation #2 (continuing the test until performance levels off) obviously mitigates the disparity often seen in using cold or hot DOP, provides very reproducible results between the two generation methods, and allows manufacturers greater flexibility with existing equipment.
  4. MSA recommends that NIOSH provide greater specificity regarding the exact chemical composition of DOP used as the challenge test aerosol for liquid and solid certifications (e.g., provide a GCMS "fingerprint" of acceptable DOP composition).
  5. MSA recommends that §84.184 be renamed "Particulate filter penetration characteristics test".
  6. MSA recommends that the rule specify the following preconditioning requirements: a method to ensure uniform conditioning of all filter elements tested; that the gas tight container be no more than three times the volume of the products stored; that the test products be placed within the container immediately after conditioning; and that products remain within the container for no more than 24 hours before being tested.

7. MSA recommends that NIOSH include an allowable airflow tolerance of ±2% for resistance testing.

8. MSA recommends that NIOSH change the resistance requirements to 35 mm H_2O max. inhalation resistance and to 25 mm H_2O max. exhalation resistance.

9. MSA recommends that a scanning mobility particle sizer (SMPS), or equivalent, be used to determine particle size distribution.

- Regarding Powered Air-Purifying Respirators (PAPRs):

10. MSA recommends that NIOSH add a separate module for powered air-purifying respirators (PAPRs) rather than include the incomplete requirements proposed in 42 CFR 84; that new tests for PAPRs not be included in the first module; and that the PAPR module be given high priority and inserted into the NIOSH plan at the earliest possible point.

- Regarding Creation of a User's Notice

11. MSA recommends that NIOSH make as a part of the 42 CFR Part 84 rule, a comprehensive section that will enable clear understanding and cross-referencing of existing particulate respirators approved under 30 CFR Part 11 to the new classes of respirators approved under 42 CFR Part 84. This document must address which (of the hundreds of airborne workplace hazards) will be classified in a way that "solid only" particulate respirators can be used and which will be classified such that "solid and liquid" particulate respirators can be used.

12. MSA recommends that this document be a part of the 42 CFR Part 84 rule and not simply a "user's notice" from NIOSH that may lack interagency corroboration from OSHA, EPA and DOE, as well as the support of the respirator and industrial hygiene community.

- Regarding Grandfathering Provisions:

13. MSA recommends that NIOSH accept applications to 42 CFR 84 immediately upon its publication as final and continue to accept new applications to 30 CFR 11 for six months after the publication of 42 CFR 84 as final.

14. MSA recommends that manufacturers be permitted to sell and ship products certified to the 30 CFR 11 criteria as NIOSH-certified respirators for four years after the date of publication of the final rule.

15. MSA recommends that NIOSH limit the application of the grandfathering sales restrictions to respirators under the manufacturers control and state that those respirators already in the distribution channel are not affected.

16. MSA recommends that where changes to filter media or filter specifications would affect filter performance, submittals for extensions of existing product approvals be accepted for two years after the rule becomes final.

17. MSA recommends that where a manufacturer makes non-substantial changes to respirators that do not affect filter performance, extensions be granted for existing product approvals for four years after the rule becomes final.

18. MSA recommends that NIOSH confirm that products approved under 30 CFR 11 criteria do not lose their certified status after the sales deadline passes.

- Regarding Filter Efficiency and Classification:

19. MSA recommends that proposed Types A, B and C be reclassified as Class 3, 2 and 1, respectively; or,

20. MSA recommends that if the proposed 6 classes of particulate filters are adopted in 42 CFR Part 84 that they be differentiated as Types A, B and C for "liquid and solid" certifications and as Types D, E and F for "solid only" certifications (in decreasing efficiency rating order).

- Regarding Filter Penetration Test Statistics:

21. MSA recommends that the K factor be changed to 1.778.

- Regarding Health Care Workers and the Control of TB Transmission

22. MSA recommends that NIOSH maintain their earlier recommendation (and OSHA's current enforcement policy) that health care workers wear only high efficiency particulate filter respirators when caring for patients with confirmed or suspected tuberculosis. The lack of scientific evidence regarding the safe exposure level at which transmission will not occur; the size, size distribution and number of particles containing viable TB that are generated by patients; and the lack of a quantitative method for determining the concentration of TB droplet nuclei in the workplace would dictate that the prudent approach be to maintain the HEPA respirator recommendation, not compromise it.

MSA looks forward to working with NIOSH to complete this rulemaking and offers its technical resources and expertise to help advance this and subsequent modules.

Introduction

MSA supports the efforts of the National Institute of Occupational Safety and Health (NIOSH) to publish a proposed update to the 60-year old respirator certification testing requirements found in 30 CFR Part 11. However, we believe that 42 CFR Part 84 is being rushed to meet a pressing health care need for inexpensive, lower-efficiency respirators (without any scientific basis for allowing use of these lower efficiency respirators against TB) and will not likely result in the significant improvements in worker protection or respirator designs we had all hoped for.

MSA was founded 80 years ago by two Bureau of Mines engineers with one overriding vision as their guide, "that men and women everywhere may work in safety." Today, with over 4,000 employees worldwide and operations in 22 countries, MSA is proud to say that we are the world's largest company solely dedicated to producing a complete range of safety equipment and systems for protecting people's health and the environment. Much has changed over the past 80 years, but one fact has never changed -- MSA's commitment and dedication to be the leading innovator and provider of quality products and services that protect people's health, safety and the environment. And it is in that spirit that we write you in responding to NIOSH's request for public comment to the proposed 42 CFR Part 84 rule. MSA believes the NIOSH proposed 42 CFR Part 84 rule has some very serious deficiencies and oversights that can adversely affect worker safety and this deeply concerns us. We believe that these concerns must be addressed prior to a final rule being adopted.

MSA is one of the oldest, largest and most respected names in the U.S. respirator manufacturing business. Our product lines bridge more types and classes of NIOSH-certified respirators than any other U.S. respirator manufacturer. Additionally, Mine Safety Appliances Company was rated by the Frost & Sullivan/Market Intelligence Research Corp. in 1993 as the clear market leader in reusable half mask and full face respirators manufactured and sold in the United States. MSA was one of the founders of the Industrial Safety Equipment Association (ISEA) in 1933 and has held the position of Chairman or President of the ISEA 14 times over its 61-year history. At MSA, we believe we know respirators and the user-community that depends on NIOSH-approved respirators for protection against airborne hazards. And it is from that knowledge base that we express our concern to you that the proposed rule will not significantly improve worker safety or the types of respirators being manufactured today. And it is our sincere hope that NIOSH will listen carefully to the stakeholders of this process -- stakeholders like MSA and the end-user -- and incorporate changes to the proposed 42 CFR Part 84 rule that will significantly improve the level of protection provided to wearers of respirators.

MSA Recognizes that Respirators are a Critical Asset in Protecting Workers

Respiratory protective devices are an invaluable component of any workplace health and safety program. MSA recognizes the established hierarchy of controls where an employer looks first to engineering controls to eliminate or mitigate occupational hazards. In certain situations, however, workplace conditions dictate that engineering controls are not feasible and an alternative means of providing protection must be utilized. This is especially true at many nuclear, chemical, construction, petrochemical, agriculture, mining and maritime workplaces.

Where engineering controls would fail to provide adequate protection or are not otherwise feasible, respirators and other personal protective equipment are recognized as an effective means of protecting employees against the dangers of the workplace. In other instances, equipment failure or routine maintenance operations may necessitate the use of respirators.

The degree of protection that a particular respirator provides is dependent upon a number of factors, one of which is filter performance. Because we recognize the value of well-engineered performance in respirators, MSA considers this rulemaking to be of critical importance to the industry and to the end user. MSA shares NIOSH's goal of protecting workers from respirable hazards in the workplace and see this module on filter performance as the first step towards bringing the agency's certification criteria up to date with modern science and technology.

What NIOSH Said It Wanted... and What MSA Wants Too

In the Federal Register, NIOSH said it expected at least four benefits to come from implementation of the proposed rule:

> *1). "Produce significant improvements in the level of protection provided to wearers of respirators."*
>
> *2). "Enable users to easily discern the level of protection that can be expected when using a respirator."*
>
> *3). "Enable classification of filters on their ability to inhibit the penetration of particulates of the most penetrating size."*
>
> *4). "Address an important public health need regarding the control of TB transmission... with six classes of respirators expected to be markedly less expensive than respirators with HEPA filters."*

MSA supports those very worthy goals. Our concern, however, is that, as written, 42CFR84 will likely only provide cheaper respirators to the health-care industry for protection against TB, it will permit usage of these respirators without a clear scientific basis for their use against TB, and it will not significantly improve the levels of respiratory protection for the millions of industrial workers depending on respirators.

MSA Supports the Modular Approach to Rulemaking

"inch by inch, it's a cinch!"

MSA supports NIOSH's decision to use a modular approach in this rulemaking. The lack of success that NIOSH had with earlier attempts to update the existing requirements in 30 CFR 11 demonstrates that an incremental approach to the rulemaking might be a more feasible alternative. The agency chose to accomplish this by releasing its proposed respiratory certification criteria in a series of steps or "modules," rather than as one overwhelming new regulation.

While in the past the agency attempted to release overly burdensome new regulatory schemes as entire packages that turned out to be confusing and excessive, this new format should permit NIOSH to release focused and concise portions of the rule that ultimately will be incorporated into an overall respirator certification scheme. Each module would be more easily understood and addressed by the regulated public, and the entire rulemaking process should speed up as a result.

Two key elements to a successful modular development program are the sequence and timing of module release. Air-purifying respirators are the most widely used class of respirator. Updating the filter performance requirements within the first module will have the largest potential health contribution and MSA agrees it should receive priority. Furthermore, MSA agrees with the overall sequence proposed for issuance of the 42 CFR 84 modules and strongly recommends the addition of separate modules for powered air-purifying respirators (PAPRs) and air-purifying/supplied-air combination respirators. Additionally, because of the interrelation of assigned protection factors (APFs), the need for well defined PAPR system test requirements, and combination gas/vapor/particulate cartridges, the PAPR module and the gas vapor module should be scheduled for release simultaneous to, or immediately after, that on APFs.

The timing for release of the remaining modules should be maintained as proposed to ensure that revision of the entire rule is complete. MSA suggests that no greater than a five-year overall schedule be added as a requirement for completion of all of the proposed modules.

In addition to sequence and timing, MSA is concerned about certain ambiguities inherent in 42 CFR 84 as proposed. These areas of concern include the extent to which the different modules interrelate, any overlap among the different modules and their requirements, and the increased costs of research and development associated with this overlap. These costs may include research and development to meet the certification criteria of the first module as well as retooling and recertification to comply with the requirements of future modules. The implications of various grandfathering provisions for each module figure into these concerns, as do the potential costs of retooling existing manufacturing processes. MSA welcomes open communication with NIOSH scientists in the development of future modules. Development of test requirements and laboratory time are significant and costly, for both NIOSH and MSA. A close functional working relationship between MSA and NIOSH will help reduce costs to the market that often result from unrealistic performance requirements and will help expedite the placement of advanced products on the market through focused research and product development.

Regarding the "User's Notice"

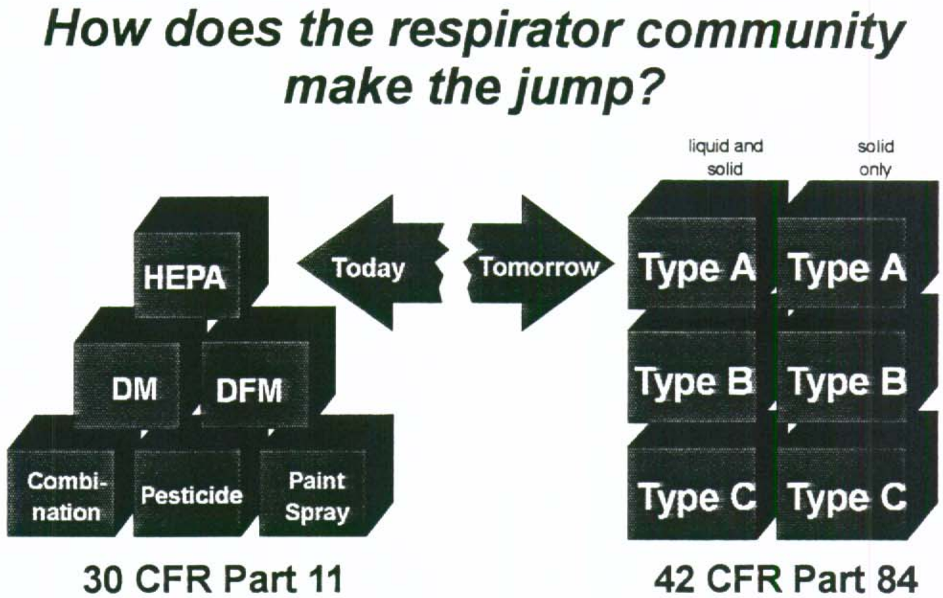
Comprehensive Cross-Reference and Interagency Coordination Need Priority Attention

As the proposed respiratory certification criteria contained in 42 CFR 84 move toward promulgation as a final rule, it is crucial that NIOSH reassert its interagency leadership role. Both the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) have delayed publication of their respective standards on respiratory protection until after release of the NIOSH certification rule.

Now that the first of the proposed NIOSH modules is publicly available, however, OSHA and MSHA have indicated that they soon will advance their respective respiratory protection rules. Respirator certification by NIOSH ties directly to the respiratory protection requirements of OSHA and MSHA as well as those of certain other agencies such as the Environmental Protection Agency and the Nuclear Regulatory Commission and to industry respiratory protection programs.

It is especially important for NIOSH to link the new performance standards to faceseal leakage requirements and assigned protection factors. APFs traditionally have been the responsibility of OSHA; under the revised standard, however, NIOSH will take the lead in setting APFs. We believe NIOSH is the appropriate agency to evaluate overall respirator performance under workplace conditions, and to determine APFs for the different respirator classes with input from respirator users and manufacturers.

Although the schedule included in the preamble to the proposed rule indicates that APFs are to be included in a future module, the agency needs to provide some indication of what uses or applications are appropriate for the various new classes of respirators. The practical applicability of respirators produced under the new standard must be understandable to end users and manufacturers for product mix and planning purposes. For example, NIOSH must address how user's make the jump from today's product matrix under 30 CFR Part 11 to tomorrow's matrix under 42 CFR Part 84:



NIOSH has indicated in the preamble to 42 CFR 84 that it will be issuing a Respirator User's Notice simultaneous with publication of the final rule. This notice must provide users with enough information for them to determine which respirators are appropriate for particular hazardous exposures. It will be used to cross-reference the new classes of respirators under 42 CFR 84 with particular workplace hazards against which the respirators are intended to protect workers (e.g. nuisance dusts, paints, pesticides, and substance-specific standards). It is our understanding that this document would provide guidance to both manufacturers and end users until the module on APFs is released. However, one significant area of concern is the lack of discussion regarding who and how the hundreds of hazardous aerosols found in the U.S. workplace will be classified as either a "solid only" aerosol or a "liquid and solid" aerosol.

MSA strongly supports creation of whatever document will enable a clear understanding to respirator manufacturers and end users and recommends that NIOSH develop this comprehensive Respirator User's Notice in conjunction with OSHA, MSHA, EPA, end users and manufacturers. Interagency coordination, led by NIOSH, is essential to creating a cross-reference tool that will provide guidance to manufacturers to help direct their research and development efforts and will be readable and understandable to the end user. All of this must be accomplished in a manner that enables users to easily discern the level of protection that can be expected when using any of the six classes of respirators that are proposed.

Empowering Industry Can Expand Resources Available to NIOSH

The current NIOSH respirator certification program is composed of five primary elements:

- certifying respirators;
- assuring quality in the manufacturing process;
- investigating field complaints;
- providing technical assistance to the respirator community; and
- developing respirator standards.

In combination, these elements are extremely resource-intensive, affecting directly the overall respirator certification process. Delays in processing certifications, outdated regulations and limited product auditing are common results of the increasing demands placed on the certification program.

In the face of increasing demands on internal resources and shrinking federal budgets, NIOSH must find more efficient ways to conduct its certification program. MSA understands that a vision has been developed for the agency that would broaden the influence of the certification program without requiring significant additional resources. MSA supports NIOSH's vision, which is based on integrating four philosophies: continuous improvement, industry empowerment, matrix management, and goal champions.

In particular, MSA strongly supports the concept of industry empowerment, which could greatly expand the resources and expertise within NIOSH by creating partnerships with the private sector. Empowering industry would broaden significantly the base of resources available to NIOSH and simultaneously free federal funds to be applied directly to other projects designed to improve workplace health and safety.

MSA encourages NIOSH to establish processes that will permit the creation of cooperative partnerships between the government and private sector companies, such as MSA. Areas that could be explored include the use of consensus standards as encouraged by OMB Circular A-119 ("Federal Participation in the Development and Use of Voluntary Standards"), the establishment of a standard peer review process that would allow use of scientific studies conducted outside of NIOSH, use of qualified laboratories to perform standardized performance tests, and use of certified ISO 9000 quality auditors to conduct manufacturing audits. Three of MSA's Safety Products Division plants in America and two of our European factories have already gained certification for ISO-9002. And our Instrument Division is now certified to ISO-9001.

Regarding Health Care Workers and the Control of TB Transmission

The current outbreak of TB among health care workers and the disparity in recommendations for proper TB respiratory protection between CDC and OSHA has clearly been a strong impetus for NIOSH to move module 1 of 42 CFR Part 84 out the door. By anyone's account, 42 CFR Part 84 is on the fast track and not without merit. As stated earlier, MSA supports the modular approach to rulemaking and NIOSH's initiative in moving this first module along. However, we are very concerned that compromises in worker safety are being made in order to assure the health care industry that inexpensive respirators are available to solve their current TB outbreak concern.

We recognize that one of NIOSH's stated goals for 42 CFR Part 84 was to "address an important public health need regarding the control of TB transmission... with six classes of respirators expected to be markedly less expensive than respirators with HEPA filters." However, we suggest that this should not be a driver for promulgating 42 CFR Part 84. And we're not sure there is sufficient scientific fact that supports anything to the contrary.

The Centers for Disease Control stated in their October 13, 1993 "Draft Guidelines for Preventing the Transmission of Tuberculosis in Health Care Facilities" that:

> "...neither the smallest infectious dose nor the highest level of exposure at which TB transmission will not occur have been conclusively defined."

CDC went on to say:

> "... the size, size distribution, and number of particles containing viable TB that are generated by patients has not been studied."

At the NIOSH public meeting held in Washington D.C. on June 24th, Ms. Jacalyn L. Bryan representing the Association for Professionals in Infection Control and Epidemiology, Inc., stated that "this (42 CFR Part 84) proposal essentially eliminates the earlier impractical NIOSH recommendation to use powered air purifying respirators and allows options other than the current OSHA-mandated HEPA (respirators). In essence, it is a step forward in developing a more scientific approach to the prevention of occupational exposure to TB."

If there is no established safe exposure limit to TB and if there is no quantitative method for determining the concentration of TB in the air, how can NIOSH or CDC let the need for inexpensive respirators for health care facilities be a driver of this new regulation? Furthermore, how does the health care industry, that supports the proposal for six new classes of respirators that are markedly less expensive than HEPA masks, say they support it based on "scientific evidence?" There appears to be a paucity of data that supports moving away from higher levels of protection to lower levels of protection.

MSA recommends that NIOSH endorse OSHA's mandated HEPA filter respirator enforcement policy for control of TB transmission. We believe it is the only prudent, safe, "scientific", recommendation that one could make with the data available today.

Specific Issues Regarding 42 CFR 84 as Proposed

Regarding Particulate Filter Testing Requirements

First, we believe two classes provides a confusing "tiered" system for certified masks...
NIOSH is saying that particulate filters will be classified according to their demonstrated efficiency ratings against discriminating challenge aerosols. Under the proposed rule, there will be three efficiency ratings:

Type A = 99.97% efficient (HEPA)
Type B = 99% efficient
Type C = 95% efficient

Furthermore, NIOSH proposes two certification classes of each of these types -- one class is for "solid only" particulates (like dusts) and the other is "liquid and solid" (like dusts and mists). We believe this establishes a tiered system of "better/best" protection, relying heavily on the user-community to identify the potential hazard as a "solid only" or a "liquid and solid" hazardous atmosphere. Six new respirator groups will emerge:

NIOSH Classes and Resulting 6 Groups		*BEST* "Liquid and Solid" Certification	*BETTER* "Solid Only" Certification
Type A	99.97% efficient	1	4
Type B	99% efficient	2	5
Type C	95% efficient	3	6

Two things are almost certain; first, Type A, B and C filters for "solid only" particulates won't look like the same efficiency-rated filters in the "liquid and solid" classification and the "solid only" certified filters and respirators will likely be a lot less expensive. We believe this parity in efficiency, yet disparity in price will encourage (and perhaps ensure) respirator misuse and misapplication in dust and mist environments. Secondly, and very much related to the first issue, users will not understand and correctly characterize the hazardous environment they are working in and will likely choose the inexpensive (i.e., wrong) respirator for the hazardous environment. This fact was most clearly communicated by Mr. Bruce Mahan of the International Chemical Workers Training Center of Cincinnati, Ohio at the Public Meeting on June 23rd in Washington, D.C. When NIOSH's Dr. Don Campbell asked Mr. Mahan if he could "characterize the ability of typical respirator users to characterize the size of the aerosol that they're concerned with," Mr. Mahan responded by saying that "the typical respirator user doesn't know what the word "aerosol" means, let alone characterize anything as a result." Clearly, requiring the unsophisticated user to characterize his hazardous environment is both unrealistic and not in the best interest of protecting workers who potentially don't even know the meaning of the word "aerosol."

It would seem that NIOSH's stated goals of 42CFR84 providing *"significant improvements in the level of protection to wearers"* and *"enabling users to easily discern the level of protection that can be expected when using a respirator"* would be better satisfied by not having this tiered system of respiratory protection, but by requiring that for any of the proposed filter efficiencies, the filter would have to meet the "liquid and solid" requirements. In doing so, the safety professional and the worker would both know, for example, that the 99.97% efficient particulate respirator they're using is providing respiratory protection to the highest level the government requires.

When NIOSH first published 42CFR84 for public comment in 1987, that's exactly what they required -- that all filters would be tested against liquid and solid challenge aerosols and that the filter efficiency rating would be based on how well it did against both challenges. MSA believes that this 1987 NIOSH position is still the best from a worker protection point of view.

We understand that NIOSH was convinced to change this position based on a limited study conducted by Erik Balieu of 3M Europe and the Dansk Toksikologi Center of Denmark in 1986 for the 3M Company. In the study, it was concluded that based on the working population of Danish workers in various Danish industries that the "solid exposure index was 75.6%" and thus "the number of liquid aerosols in the working environment is actually much smaller than the number of solid aerosols." While we know of no similar U.S. study that has been conducted to characterize U.S. occupational aerosol exposures, we would caution NIOSH that the Danish study is based on 1984 Danish manufacturing industries that are not representative of today's U.S. industries and that the study of a small European country's working population represents only a small fraction of the more than 56 million U.S. workers involved in general industry today. Additionally, this study is not available to the public from the Dansk Toksikologi Center and their response to inquiries has stated that "the report is not a published report and is the property of the 3M Company" (copy of this fax response included for the public record).

MSA recommends that the prudent approach for NIOSH to take that would significantly improve the level of protection to wearers and enable users to easily discern the level of protection that can be expected when using a respirator would be the elimination of the tiered, two class system and the adoption of a single certification class -- that class being liquid and solid certifications. To adopt the two class system based on a study that has not been peer reviewed and was conducted for a disposable respirator manufacturer in a small European country seems questionable when compared to the importance of worker safety.

Secondly, a test is proposed that can overstate a filter's efficiency and a users confidence...
NIOSH scientists have recommended a very specific, and in many respects, a much improved test procedure for respirator filter penetration testing. However, the new procedure is significantly deficient, from a worker protection point of view. Under the proposed rule, a "liquid and solid" respirator filter is tested against a challenge aerosol and depending on the efficiency of the filter in trapping the aerosol, the respirator filter is classified as either a Type A, B or C filter (99.97%, 99% or 95% efficient, respectively). Since workers could potentially be exposed to thousands of aerosols, NIOSH has indicated that their intent is to test with the most penetrating challenge aerosol known to them. In fact, their Federal Register stated goal is that 42CFR84 will "enable

classification of filters on their ability to inhibit penetration of particulates of the most penetrating size."

The new NIOSH-proposed test procedure will call for a polydispersed and neutralized, cold-nebulized DOP challenge aerosol instead of a monodispersed, thermally generated (sometimes called "hot") DOP aerosol. Additionally, the proposed rule requires that exposure to the challenge aerosol will continue only until 100 or 200 mg of DOP has contacted the filter element (if it is a filter used in a pair configuration, the limit is 100 mg., if it is a filtering facepiece disposable-type respirator, the limit is 200 mg.) NIOSH scientists have stated that either aerosol generation method produces an acceptable particle size distribution and that in their testing, either aerosol generation method gives the same filter penetration test result. NIOSH is quick to add that their comparative testing has been limited principally to mechanical HEPA filter media, not all classes of filter efficiency and not the very large class of filters known as electrostatics.

We believe that it is this thinking that is deficient and where potential compromises in worker safety begin because filter efficiencies can be easily overstated if a lesser penetrating test method is used and if the penetration test is stopped at an arbitrary point such as the 200 mg. loading limit and well before filter penetration has stabilized and leveled off.

The problem is that the testing stops before percent penetration has leveled off...

As an alternative to mechanical filter media (on which NIOSH has done much testing), there is the other broad class of filter media known as "electrostatic" or "electret" media. Electrostatic filters are widely used in respirators because their electric field enhances filtration efficiency and, unlike mechanical filters, can utilize a small filter area without causing unwanted increases in air flow resistance (which can make breathing more difficult). It is a well known fact, however, that exposure (i.e., use) of electrostatic filters to challenge aerosols produces a cascade of effects that begins with a reduction in both the electric fiber charge and filter efficiency, and ends with a potential reduction in respiratory protection. And while some will have you believe that this is a problem isolated only to DOP exposure, it is not. In a July, 1986 Journal of the ISRP article, Dr. Ernie Moyers and other NIOSH scientists wrote:

> *"NIOSH is concerned that certain respirator particulate filters degrade under typical use and storage conditions... Furthermore, NIOSH studies have shown significant degradation of electrostatic filter media in coke oven (Smith, 1979) and pesticide environments (Kennedy, 1983).*

In a seminar given by Dr. Moyers at this year's 1994 AIHCE, he wrote in his handouts:

> *"Electrostatic media have good initial filter efficiencies, but the filter degrades with increased particulate loading. This loading causes a masking or loss of electrostatic charge (filter degradation) resulting in reduced filter efficiency and increased worker exposure. This is possible since there are no end-of-service-life indicators for such respirators. Note that the longer the wearer continues to use this respirator under these conditions the higher the exposure level."*

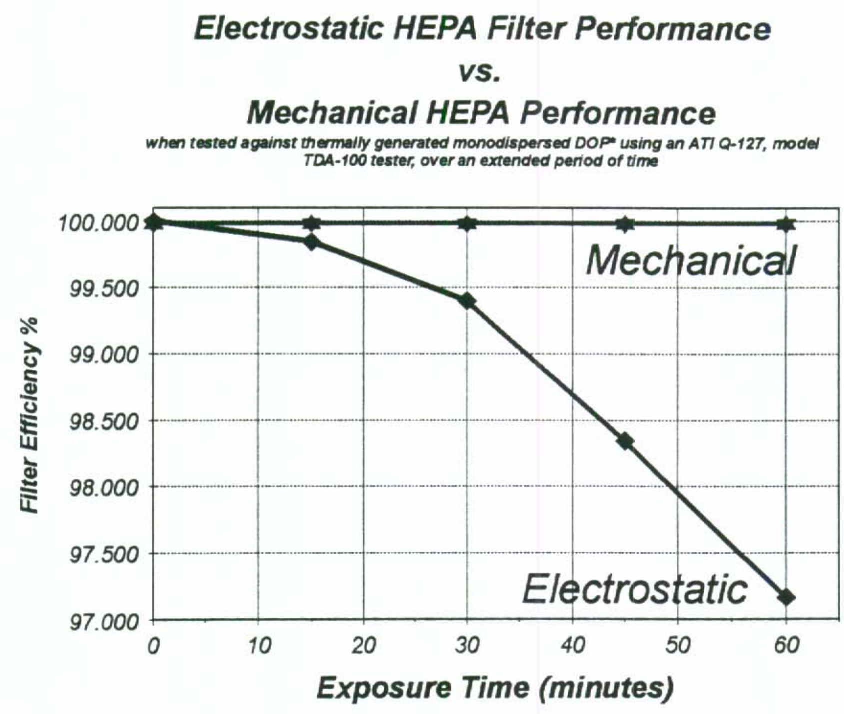
Additionally, independent studies have shown (see Blackford, et al., attached for the public record) that commonplace industrial aerosols such as silkstone coal dust, foundry fettling fume, foundry burning fume, carbon brick dust, lead smelting fume, lead battery dust and ammonium chloride all cause reduction in electrostatic filter efficiency performance. The point is, this isn't just an argument over DOP. This is an argument over a certification test that is intended to use the most penetrating particle size to ensure worker safety. Lastly, in OSHA's Compliance Officer Instruction Guide, CPL 2-2.54, Chapter 2, Paragraph K, it states:

"Only "mechanical type" high efficiency particulate air filters... are acceptable for protection against any particulate exposure because efficiency of these filters does not change with dust loading and ambient conditions."

To the unsophisticated user not steeped in respirator-ese, it might seem as though everyone **except** the user-community is aware of the degrading performance of electrostatic filters. And that should be a real concern, because the user certainly doesn't know that filter efficiency is degrading with use.

NIOSH must address these concerns prior to 42CFR84 being published as a final rule, because if they don't, the certification and testing procedures they've specified will continue to permit filters with known efficiency-degrading performance characteristics to enter the workplace.

Mechanical filter media, which NIOSH has based much of its test protocol on, does not show the same characteristic loss of performance with exposure to the most penetrating challenge aerosol, as indicated in the graph on the right.



It is important to note that in roundrobin testing conducted by respirator manufacturers, the electrostatic filter media was continuing to lose its filtration ability with exposure to the aerosol when the arbitrary NIOSH test limit of 100 mg. loading was reached. It is disturbing in that following the proposed 42CFR84 requirement, the testing was stopped prior to the maximum percent penetration being reached. And yet these same general characteristics of "reduced filter performance with exposure" were shown in the Blackford study using not DOP, but common industrial aerosols such as foundry dusts and lead fumes.

And what's truly unacceptable is that the user, who is depending on the electrostatic filter for respiratory protection, has (as NIOSH has stated) no "indicator" that the electrostatic filter is losing its efficiency -- there is no "breakthrough" or "warning properties" that the user can detect, taste or smell; only his uncontrollable, unwitting, unwanted exposure to the hazard. This issue is not just a "hot DOP vs. cold DOP" argument, this is a worker safety issue that must be addressed by NIOSH prior to 42CFR84 being published as a final rule.

While it is true that mechanical filter media penetration is unaffected by the amount of aerosol loading, clearly the electrostatic media performance is breaking down over a short period of time. Wouldn't it make more sense not to arbitrarily limit the aerosol loading, but rather to continue the test until filter performance levels off? Wouldn't this be a better indicator of the minimum level of protection a worker can expect from a NIOSH-certified respirator?

It does make more sense and, in fact, is exactly what NIOSH had recommended in their 1987-released 42CFR84 proposal. Their reasons for revising the test since then are unknown although some have speculated that NIOSH set a cutoff point based on their testing of mechanical filter media (which doesn't degrade with exposure) and their feeling that the time required to conduct the tests would be unreasonably long. This simply isn't true. While the test time for electrostatic filters would necessarily increase, limited testing has shown that the increase in test time would not be unreasonably long. The benefit in product performance and worker protection would surely offset the slight increase in certification test time at Morgantown.

What Should be Done?

Since NIOSH truly wants to:

- "Produce significant improvements in the level of protection provided to wearer's of respirators."

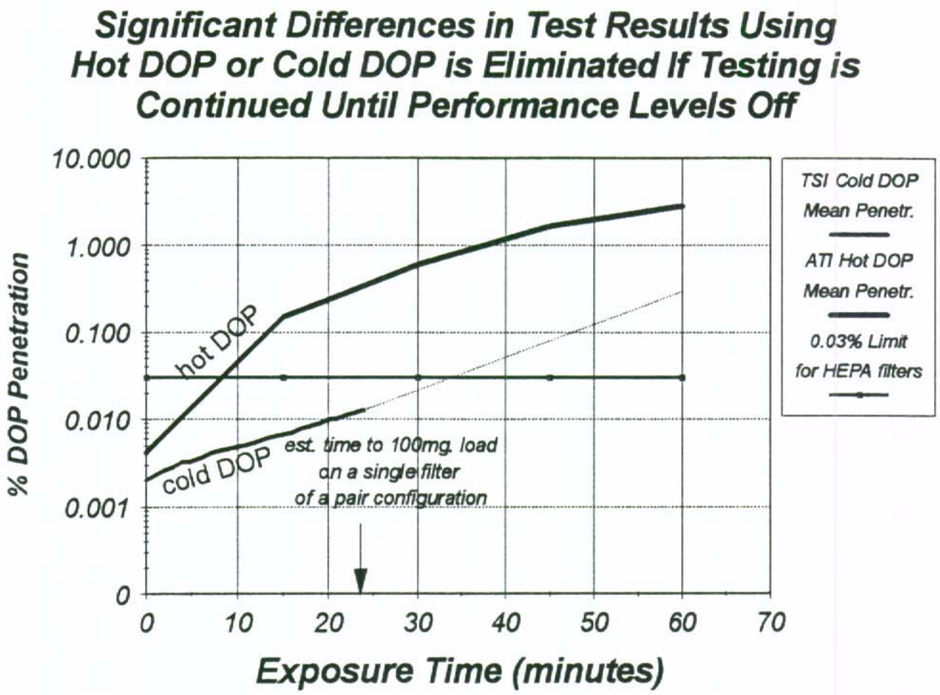
- "Enable users to easily discern the level of protection that can be expected when using a respirator."

- "Enable classification of filters on their ability to inhibit the penetration of particulates of the most penetrating size."

Then it should require:

- That just as they originally intended back in 1987, only one filter certification class be established -- "liquid and solid" aerosols to minimize the opportunity for misuse and misapplication of certified filters and respirators.

- That the filter penetration test not be arbitrarily stopped at a particular loading limit, but that testing continue until penetration and efficiency ratings have stabilized, thus enabling users to easily discern the level of protection expected when using a respirator -- another key goal of 42CFR84! Again, this is simply restating what NIOSH originally called for in the 1987-released proposal, that the test continue until filter penetration levels off and stabilizes. This has the added benefit of eliminating controversy surrounding the issue of thermally generated DOP or cold nebulized DOP test results. This is because if the test is continued to the point where penetration stabilizes, either aerosol generation method provides the same percent penetration value. This performance is indicated in the graph that follows.



42CFR84 could be much improved and more along the lines of what health and safety professionals have been asking NIOSH to promulgate for over a decade, if these "changes" (which were actually a part of the originally proposed 42CFR84 in 1987) were incorporated.

Other Issues And Recommendations Regarding Filter Testing:

ISSUE: While dioctyl phthalate (DOP) is specified as the appropriate challenge aerosol for "liquid and solid" certifications, specificity regarding exact chemical composition of the DOP is lacking and a specific method of aerosol generation is not identified. There is simply too much that is not known about this test protocol and those factors that influence test outcomes such as the purity of DOP, preconditioning and challenge aerosol concentration to promulgate this into a final rule, as written.

RECOMMENDATION: MSA recommends that NIOSH provide greater specificity regarding the exact chemical composition of DOP used as the challenge test aerosol and that NIOSH provide more detail regarding the aerosol generation methodology in the 42 CFR Part 84 test description.

MSA welcomes the opportunity to work with NIOSH scientists in further developing a filter penetration test that both improves the proposed regulation and satisfies NIOSH's stated intent to significantly improve the protection provided to wearers of respirators and enable the classification of filters based on their ability to inhibit the penetration of particulates of the most penetrating size.

RATIONALE: NIOSH has previously stated that their testing has shown no difference in test results (and subsequent filter efficiency ratings) if filters are tested against today's benchmark, thermally generated DOP, or the intended tester, a cold nebulized DOP generator. For mechanical filter media, this is accurate and has been confirmed by industry testing. However, for electrostatic filter media, limited testing has shown considerable disparity in test results and the resulting filter efficiency classifications for particulate filter elements. This disparity appears to be dependent upon the method of aerosol generation, i.e. "hot" or "cold". Recently, NIOSH has reported that the disparity in test results has more to do with the purity of DOP than with the method of aerosol generation.

Based on the limited comparative testing which NIOSH has conducted (mechanical filters only), the disparity in test results seen in the respirator manufacturers round robin test program and the importance of successfully launching this first module, MSA strongly urges NIOSH to reevaluate the proposed test protocol and test equipment, and to take a leadership role in developing a filter penetration test that is consistent, repeatable and ultimately improves worker safety for the next generation of NIOSH-certified respirators -- whether testing on a hot DOP machine or a cold DOP machine. In conducting further work with manufacturers such as MSA, NIOSH will reduce the potential for disputes between NIOSH and the many respirator manufacturers, users and researchers within the industrial hygiene community.

ISSUE: Section 84.184 currently is titled *"Particulate instantaneous penetration filter test."*

RECOMMENDATION: MSA recommends that §84.184 be renamed *"Particulate filter penetration characteristics test."*

RATIONALE: The test as specified in the proposed rule would measure filter penetration in discrete increments over a period of time and would not provide a continuous measurement as implied by the existing title. Therefore, it is not accurately termed a measure of "instantaneous" penetration. This is a function of the sensitivity of the measuring instrumentation and the frequency with which it can take measurements of filter penetration. Additionally, the recommended title more accurately represents the objective of the test.

ISSUE: The humidity preconditioning requirements of §84.184(c) state that "filters shall be sealed in a gas tight container." However, §84.184(c) does not provide:

1). detail regarding uniform preconditioning;
2). the size of the container;
3). the "allowable time after conditioning" at which filter media must be placed within the container; nor
4). the allowable time for the filter to remain within the container until tested.

RECOMMENDATION: 1) NIOSH should specify a circulation air chamber and a means of filter separation of filtering elements to provide uniform conditioning. 2) The rule should specify a maximum size for the gas-tight container. MSA recommends that the volume of the container be no more than three times the volume of the products stored. 3) The rule should specify the allowable time after conditioning within which the filter media must be placed in the container. MSA recommends that the rule require that filters be sealed in the gas-tight container immediately after pre-conditioning. 4) The rule should specify an allowable time for the filter to remain within the container until tested. MSA recommends that testing be conducted within 24 hours after the filters are sealed in the container.

RATIONALE: These recommended test parameters would help ensure uniformity in testing among different laboratories and other test facilities. This, in turn, will help NIOSH reduce disparities in test results between the agency and others within the respiratory protection community that conduct these tests. By not specifying these parameters, disputes in penetration test results could occur depending on their interpretation. For example, if conditioned filters were placed in a very large gas tight container (perhaps a freezer sized bin) drying could occur which might influence the penetration test results.

ISSUE: The proposed rule requires an airflow of 85 lpm for resistance testing as specified in section 84.183 (a) but does not include an allowable airflow tolerance.

RECOMMENDATION: MSA recommends that NIOSH include in section 84.183 (a) an allowable airflow tolerance of ±2% for resistance testing.

RATIONALE: Specifying an allowable airflow tolerance of ±2% would help ensure uniformity in testing among different laboratories and other test facilities. This, in turn, will help NIOSH reduce disparities in test results between the agency and others within the industrial hygiene community that conduct these tests.

ISSUE: Section 84.183 states that the resistance of a complete respirator mounted on a fixture must be tested at a continuous airflow rate of 85 liters per minute. The initial inhalation resistance of the respirator must not exceed 30 mm H_2O and its initial exhalation resistance must not exceed 20 mm H_2O.

RECOMMENDATION: Although proposed resistance requirements in 42 CFR 84 are the same as those in 30 CFR 11, the filter efficiency requirements are much more stringent. It is generally accepted that all filter media (particularly mechanical filters) have two competing characteristics: resistance and efficiency. Given the restrictions on filter size and surface area inherent in current facepiece designs, MSA recommends that NIOSH change the resistance requirements in the proposed rule to 35 mm inhalation resistance and 25 mm exhalation resistance.

RATIONALE: When filter efficiency goes up, the resistance of the filter will rise as well. The limits for certain chemical cartridge combinations under 30 CFR 11 already allow substantially higher inhalation resistance levels. The suggested changes will grant manufacturers more latitude in respirator design. Higher resistance requirements also make it more feasible for manufacturers to develop respiratory protection equipment without exhalation valves for the medical markets.

Leaving the resistance requirements as proposed might require manufacturers to pleat particulate filters (even Type B and Type C filters) to increase the surface area enough that it lowers a filter's resistance to a level below the requirement.

ISSUE: Section 84.184(h) specifies that a differential mobility particle sizer (DMPS) be used to determine particle size distribution.

RECOMMENDATION: MSA recommends that a scanning mobility particle sizer (SMPS) or equivalent be specified.

RATIONALE: The DMPS is obsolete and no longer available, and has been effectively replaced by the SMPS.

Regarding Powered Air Purifying Respirators (PAPRs)

ISSUE: The proposed rule inappropriately includes systems tests for PAPRs within the first module, section 84.185.

RECOMMENDATION: MSA recommends that NIOSH add a separate module for PAPRs that will focus specifically on these devices and contain requirements and tests that will adequately assess their performance. Furthermore, MSA recommends that the PAPR module be given a high priority and inserted in the NIOSH plan at an early stage.

MSA recommends that NIOSH not include any new tests for PAPRs within the first module of the proposed rule.

RATIONALE: Simply applying filter penetration tests for PAPRs within the first module neglects the unique aspects of PAPRs. This is evidenced by the fact that NIOSH is proposing systems tests different than that already in 30 CFR 11. Until all performance requirements of PAPRs are adequately addressed, the existing tests as codified in 30 CFR Part 11 should remain in effect.

For most types of PAPRs, the airflow, filter efficiency, and respirator inlet covering or facepiece "fit" all interact strongly, and it is not possible to specify or determine any one of these parameters without some knowledge of the other two. The combination of these factors leads to the overall assigned protection factor, the key parameter for the wearer. MSA recognizes that the discussion of APFs will be covered in the second module of 42 CFR 84. For PAPRs, however, it is not possible to address fully the filter efficiency questions in the first module without also specifying airflow and duration tests, for example. NIOSH has recognized this principle by including new tests in §84.145, and by adding PAPR-related amendments to several of the test criteria. Unfortunately, the tests proposed in 42 CFR 84 are not consistent with themselves or with modern powered air designs.

MSA strongly recommends that PAPRs be covered under a separate module. (There is precedent in doing this with the European standards.) All of the following points also help lead to this conclusion.

The battery life of each PAPR submittal should be specified by the manufacturer.
Manufacturers are unable to meet the needs of the various users of PAPRs because of the arbitrary requirement that battery life must be a minimum of 4 hours. Paragraphs 84.185 (a) and (b) state that airflow must be maintained "for a period of at least 4 hours unless otherwise

specified." Clarification that the manufacturer can specify service lives *lower* than 4 hours, when "otherwise specified" is required. An example where this need is required is in the health care industry--the very industry which is driving this legislation. Workers are currently required to wear bulky, heavy battery packs in order to obtain the higher level of protection provided by positive pressure PAPRs. The minimum 4-hour time requirement originates from the heavy industrial coke battery requirements. Numerous workers in other industries would happily make use of PAPRs to better protect themselves if they were not forced to wear the heavy batteries associated with current devices. If the regulations allowed manufacturers to make lighter units (i.e., with shorter service times), the health of the American worker would be better protected. The proposed regulations are unclear on this matter, and should be revised to clearly allow service times under 4 hours.

Likewise, the ***filter life requirements of paragraph 84.184 (g) are too restrictive***. Why require a worker to carry a filter that will last for days, when all they want is a filter that will last for an hour or two? This too is burdening the workers on assumptions based on heavy industrial exposures. Many respiratory applications today, including Tuberculosis, do not require long duration filters. Categories of service lives for particulate filters should be developed, so that employers could select the style that best fits their need. It may not be necessary for every filter to be able to handle a high degree of loading.

In paragraphs 84.184 (g) (1) and (2), a definition of the term "filter unit" is needed. Does a filter unit mean that all of the filters on a PAPR are proportionately tested against 2,000 mg? (eg., 2-filter PAPRs would be tested at 1,000 mg each). Does this challenge concentration offer any real benefit to the user? The test would take about 10 to 20 hours to complete. We would recommend that manufacturers be given other service life options to allow development of alternate smaller filters for PAPRs.

The $\pm$ 50 mg allowance on the total loading of 2000 mg test in paragraphs 84.184 (g) (1) and (2) is beyond the capability of the Model 8110 tester. This requirement amounts to $\pm$ 2.5% when the accuracy of flow measurement alone is $\pm$ 2.0%. When this $\pm$2.5% is added to the actual variation in flow and mass concentration of the aerosol, all of which directly impact total mass challenge, it is obvious that $\pm$ 50 mg is not within the capability of the equipment. Without real-time indication of the cumulative challenge, it is not possible to know when to stop the test.

The above point furthers the suggestion that the test should not be arbitrarily stopped at any particular mass loading, because individuals performing the test cannot know that a particular minimum has been achieved. Therefore, the test should be run until the maximum penetration is achieved, due to equipment/technology limitations.

Paragraph 84.184 (f) discusses "(PAPRs) with loose-fitting facepieces." It is important that this term be used correctly. The ANSI Z88.2 1992 terminology should be used to differentiate the difference between hoods, helmets, and loose-fitting facepieces. While all may be tested similarly, they should be identified separately to avoid confusion, especially when mentioned in future modules.

Paragraph 84.184 (f) does not adequately address the potential deficiencies associated with loose-fitting PAPR designs. Depending on environmental factors impacting some designs of this style of PAPR, the protection and pressure inside the facepiece can be affected. For example, it is possible to degrade the protection afforded by some designs of these PAPRs by introducing an air draft across the sealing area. Controlled tests of these types of factors are needed in the NIOSH regulations. Since these types of PAPRs have unique sealing surfaces which impact their effectiveness based on factors not addressed in the regulations, we would recommend that they not be included in this module, but be addressed in a separate module where these environmental factors could be more fully considered.

Paragraphs 84.185 (a) and (b) require PAPRs to have minimum flow rates depending on design style. This is design restrictive. Breath-responsive PAPRs that give very little flow when the user requires only a little flow, and very high flow when needed to maintain positive pressure are feasible with existing technology. MSA recently introduced this type of product in Europe at last year's A+A safety show and exhibition in Germany. The proposed 42 CFR Part 84 requirements would not allow approval of such devices because a continuous flow is required. The goal of a PAPR should be to maintain positive pressure, not constant air flow. Constant flow PAPRs consume more battery power (requiring more weight on the user), and use up the filters faster because of the constant flow of contaminants through them (also requiring either bigger filters or more frequent changes of the filters). The test should be changed to reflect positive pressure, not constant air flow.

If 84.185 (a) and (b) are allowed to remain with minimum flow rates, new higher flow rate classifications should be made that would allow NIOSH to establish different classes of PAPRs. There is data (R.A. da Roza, C.A. Cadena-Fix, and J.E. Kramer Powered-Air Purifying Respirator Study, ISRP, Summer 1990) which clearly demonstrates that 4 CFM will not maintain a positive pressure in the facepiece of a tight-fitting PAPR. (This Lawrence Livermore National Laboratory study shows that tight-fitting PAPRs do not go negative at flow rates of 6 CFM, but do go negative at 4 CFM.) This regulation should address the very real differences in protection afforded by higher flow rate PAPRs, so that when the Assigned Protection Factor (APF) module is discussed, there will be tests that allow superior designs to gain higher APFs.

We need clarification that the measurement of the PAPR flow rate (required in paragraph 84.185 (a) and (b) is done on the head form, not at the outlet of the blower or breathing tube, as is currently done at NIOSH. PAPRs are inherently back-pressure sensitive, and therefore the design of the facepiece or other Respiratory Inlet Covering impacts severely on the final flow to the user. The health and safety of the American worker is impacted by not having higher flow rate classifications, combined with proper measurement of these flows.

The TSI 8110 tester, which is, in essence, required for testing of PAPR filters, has a maximum flow rate of less than that which is required for the PAPR test (i.e., less than 115 lpm--it is only 110 lpm). Therefore, it ***would not work with single filter PAPRs.*** (There is a potential to split the flow in half, but the impact of this is not researched yet.)

The TSI 8122, which will have higher flow rates, is not completely developed yet. It is unfair to write a specification for testing based on a product that has not even been tested fully. The 8122 won't be available until at least September 1994--and will cost at least $86,000.

The loading test requires that either a salt or a salt and DOP test be performed on the PAPR. The salt loading test takes about 10 to 20 hours to perform, plus the actual flow test which requires another 4 hours.

Limited PAPR efficiency ratings are design restrictive to PAPRs. Paragraph 84.170 includes only two classes--A & B--rather than the three allowed for negative pressure respirators. This is overly restrictive on PAPRs, and does not consider that currently many manufacturers are promoting interchangeability of their PAPR filters with their negative pressure respirators. All three classes should be available for approval.

Paragraph 84.185 (c) says that PAPRs "shall be provided with an acceptable mechanism and appropriate instructions whereby the user can routinely and simply determine that the minimum airflow is maintained." This is very unclear. "Routinely" needs to be better defined. Does this mean that a flow check device independent of the PAPR can be used? We would presume so, but would request that NIOSH not require that *every* PAPR be required to have one. This is an undue burden on employers, who often will buy hundreds of PAPRs at a time, but will already have the flow check meters. Likewise, on any given job site, users can share the flow check. It makes more sense to require manufacturers to have a means of measuring air flow rate, but not require the manufacturer to have a flow check device in every PAPR shipped.

If Paragraph 84.185 (c) intends to have a built-in airflow measuring device, NIOSH should recognize that this will have a significant impact on the cost associated with a PAPR. Additionally, there should be more stringent requirements for the accuracy of such devices, as this could vary significantly, and impact on the cost of the indicator, and the security of protection provided the worker.

Paragraph 84.170 (d) filter efficiencies should be related to the expected APFs of respirators so that the two modules will dovetail. If this is not addressed in this module, a confusing combination of filter efficiency and faceseal leakage will result, that will leave users unable to easily determine which respirator/filter combination to use for their varying exposures.

Paragraph 84.182 (c) is design restrictive for manufacturers of PAPRs that use particulate-only filters. A PAPR may not be able to flow as high once an organic vapor cartridge is installed instead of a particulate filter, and therefore may fail when tested, even though it would have passed with a particulate filter. Likewise, it is possible that the converse could be true.

Regarding Grandfathering Provisions:

ISSUE: All applications submitted to NIOSH after 42 CFR 84 becomes effective will be required to meet the filter penetration criteria of the new rule. The rule will take effect 30 days after publication as final in the *Federal Register*. During this 30-day period, NIOSH will continue to accept submittals that purport to meet the requirements of 30 CFR 11.

RECOMMENDATION: MSA recommends that NIOSH accept applications to 42 CFR 84 immediately upon its publication as final and continue to accept new applications to 30 CFR 11 for six months after the publication of 42 CFR 84 as final.

RATIONALE: MSA recommends that 30 CFR 11 applications be accepted for six months from the date of publication of 42 CFR 84 as final so that valuable research and development efforts and dollars that are currently being invested in improved 30 CFR 11 designs are not wasted.

ISSUE: Two years after publication of the final rule, manufacturers may no longer sell or distribute respirators certified to the 30 CFR 11 criteria as NIOSH-certified respirators.

RECOMMENDATION: MSA proposes that manufacturers be permitted to sell and ship products that are approved under 30 CFR 11 as NIOSH-certified respirators for four years after the date of publication of the final rule.

RATIONALE: This four-year period was chosen for several reasons. First, the experience of manufacturers in Europe indicates that three-plus years are required to develop respirators that meet the updated criteria. Second, NIOSH proposed a five year transition period in the 1987 version of 42 CFR 84 and has given no reason for the change. Third, NIOSH has limited resources with which to approve respirators within the time frame it has proposed. Fourth, the experience of the Bureau of Mines as it transferred certification authority to NIOSH and MSHA demonstrated the need for a sufficient time in which to make such a transition. Fifth, the lack of available filter media in all filter categories will slow manufacturers' efforts to develop respirators meeting the new 42 CFR 84 criteria.

ISSUE: Two years after publication of the final rule, manufacturers may no longer sell or distribute respirators certified to the 30 CFR 11 criteria as NIOSH-certified respirators.

RECOMMENDATION: MSA recommends that NIOSH limit application of the grandfathering period to respirators that remain under the manufacturer's control.

RATIONALE: Manufacturers have limited control over respirators once they have entered the distribution channels.

ISSUE: NIOSH will continue to process previously-submitted applications for approval under 30 CFR 11 criteria for six months after publication of the final rule. The proposed rule does not address extensions of existing product approvals involving changes in filter media or filter specifications affecting filter performance.

RECOMMENDATION: MSA recommends that in situations where a manufacturer wants to make changes in filter media or filter specifications affecting filter performance, MSA recommends that submittals for extensions of existing product approvals be accepted for two years after publication of the final rule.

RATIONALE: The proposed rule needs to account for changes made to respirators previously certified under 30 CFR 11 that require the manufacturer to obtain an extension of approval. Some of these changes affect filter performance and others will not. A manufacturer that changes the vendor or supplier of its filter media, for instance, would need to obtain an extension of approval under the existing system of 30 CFR 11. It is essential that the proposed rule account for changes affecting filter performance that would not normally need to proceed through the entire certification process. A two year period would provide an adequate amount of time for manufacturers to make these types of changes before shifting over to the new criteria of 42 CFR 84.

ISSUE: NIOSH will process previously-submitted applications for approval under 30 CFR 11 criteria for six months after publication of the final rule. The proposed rule does not address extensions of existing product approvals involving non-substantial changes to respirators that do not affect filter performance.

RECOMMENDATION: MSA recommends that in situations where a manufacturer wants to make a non-substantial change to respirator that do not affect filter performance, MSA proposes that extensions to existing product approvals be accepted for four years after publication of the final rule.

RATIONALE: As stated previously, the proposed rule needs to account for changes made to respirators previously certified under 30 CFR 11 that require the manufacturer to obtain an extension of approval. Some of these changes affect filter performance and others will not. Some examples of non-substantial changes that would not affect the filter's performance and that would need an extension of approval under the existing system of 30 CFR 11 include: changing the face mask color; changing the exhalation valve material; changing the headband supplier; or adding a qualification for formaldehyde to an acid gas/mist/dust cartridge.

It is essential that the proposed rule account for non-substantial changes that do not affect filter performance that would not normally need to proceed through the entire certification process. A four year period would provide an adequate amount of time for manufacturers to make these types of changes before shifting over to the new criteria of 42 CFR 84.

ISSUE: The proposed rule does not address clearly whether distributors or users who receive respirators certified under 30 CFR 11 prior to the sales deadline will be able to continue to sell or use these products as NIOSH-certified after the deadline passes.

RECOMMENDATION: MSA recommends that NIOSH confirm that products approved under 30 CFR 11 criteria do not lose their certified status after the sales deadline for manufacturers passes.

RATIONALE: MSA is concerned that, once the deadline passes, distributors and users, operating under the assumption that these products are no longer NIOSH-certified, will start returning previously-approved respirators to the manufacturer. Not only would this needlessly confuse the end users who the proposed rule is intended to protect, but it also would create a costly logistical nightmare for manufacturers and distributors.

Distributors and users should be allowed to continue selling and using 30 CFR 11 NIOSH-certified respirators after the deadline passes. Products that have been certified by NIOSH should retain their certified status.

Regarding Filter Efficiency and Classification

ISSUE: That filter efficiencies are classified as Type A, B and C depending on the percent penetration exhibited during the particulate filter penetration test, independent of whether the filter is certified as a "solid only" filter or a "liquid and solid" filter.

RECOMMENDATION: That filters be reclassified as Class 3, 2 and 1, respectively, in decreasing order of efficiency with some letter designation to solid (S) or liquid and solid (LS); or that filters liquid and solid certified filters be classified as Type A, B and C and solid only filters be classified as Type D, E and F (in decreasing efficiency order).

RATIONALE: To provide greater differentiation to the user-community and will hopefully make it easier for them to select the appropriate filter for the application.

Regarding Test Statistics:

ISSUE: NIOSH has proposed a K factor of 2.22, which represents a 95% confidence level that 95% of the filters produced will meet or exceed specifications. We believe this K factor is unreasonably high.

RECOMMENDATION: MSA recommends that NIOSH use a K factor of 1.778, which is equivalent to what would have been used for 30 samples in the 1987 proposal and represents a 95% confidence level that 90% of filters meet or exceed the requirements.

RATIONALE: MSA has determined that the proposed K factor of 2.22 was derived from one-sided tolerance limits for normal distributions. With a sample size of 30 filters, this represents a 95% confidence level that 95% of filters produced meet or exceed specifications. In the 1987 proposal, NIOSH proposed a K factor of 6.158 with a sample size of three filters. This represented a 95% confidence level that 90% of filters would meet or exceed specifications. The equivalent K factor extrapolated to maintain the confidence levels proposed in 1987 and made applicable to a sample size of 30 filters, would be 1.778. MSA believes that increasing the confidence level to 95% is burdensome and may increase the costs of particulate filters.

Conclusion

MSA supports NIOSH's proposal to upgrade its certification requirements for particulate filter respirators. MSA also supports the modular approach that NIOSH is taking with this rulemaking as a novel and effective method of modernizing a complex and important worker safety standard.

MSA urges NIOSH to work with OSHA, MSHA, EPA, other agencies, end users and manufacturers to develop a document that will explain to users the proper applications for the various new respirator categories. This will make for a smooth transition to the new 42 CFR 84 requirements and will avoid some of the confusion inherent in the process of creating a new standard. Efforts at international harmonization will make acceptance and understanding of the agency's new rule easier in the global safety product market.

MSA has suggested some specific areas that we believe could be improved, including: external cooperation, grandfathering provisions, testing parameters, filter efficiency, and test statistics. MSA also recommends that a separate module be scheduled for powered air-purifying respirators and all PAPR requirements be deleted from the proposed rule.

42CFR84 is on the fast track and not without some merit; however, changes must be made. Influencing these corrections to the proposed rule needs to be the focus of attention for everyone who is dedicated to improving worker safety.

42 CFR Part 84 could be much improved and more along the lines of what health and safety professionals have been asking NIOSH to promulgate for over a decade, if the MSA recommended "changes" (many of which were actually a part of the originally proposed 42 CFR Part 84 in 1987) were incorporated.

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TELEFAX - INFO PAGE

FROM:

DTC / NAME	Lisbeth Valentin Hansen
Date	15. juli 1994

TO:

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Company	MSA
Attention	Paula L. Reed

MESSAGE:

Total no. of pages incl. this info page: 1

Dear Mrs. Reed,

Thank you for your call today.

The report mentioned is not published as it is the property of the company 3M.

I have passed on your request to 3M Denmark where Erik Balieu will handle it.

Best regards,

Lisbeth Valentin Hansen

ALTERATION IN THE PERFORMANCE OF ELECTROSTATIC FILTERS CAUSED BY EXPOSURE TO AEROSOLS.

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ABSTRACT

Electrostatic filters are widely used in respirators because their electric field enhances filtration efficiency without causing any increase in airflow resistance; but exposure to aerosols reduces their performance. Results are given of the loss of filtration efficiency caused by the exposure of a variety of electrostatic filter materials to aerosols of various types. Industrial fumes vary considerably in the extent to which they cause deterioration in performance. The general characteristics of the degradation process are outlined, and a simple semi-empirical theory is developed to enable the degrading ability of aerosols for materials to be quantified and correlated with their physical characteristics.

INTRODUCTION

Electrically charged filter materials are widely used in respirators giving personal protection against respirable dust; and much has been written on the behaviour of electrically charged filter fibres and aerosol particles during filtration (see for example Davies, 1; Pich 2, 3). Electric forces augment the filtration efficiency without causing any increase in airflow resistance; and so an electrically charged filter has a fundamentally better quality than a filter that is similar in structure but uncharged.

Some of the materials used in respirators rely so heavily on their electric charge that, if the effect of that charge is lost, their filtration efficiency is reduced to a low level (Brown and Wake, 4). The charge on electrostatic filters can be reduced or rendered less effective by storage in adverse environmental conditions, by exposure to ionising radiation, or by exposure to aerosols. The last of these is by far the most important, because this process is inevitable if the filters are to be used at all; and it is important that this effect should be understood and quantified, so that the protection offered by a respirator after a reasonable degree of aerosol loading can be predicted, and its acceptability assessed.

Provision for measuring the aerosol penetration through filters after loading with coal dust exists in the British Standard Test for filtering facepieces (5); and some measurements of the degradation of filters after exposure to coke oven atmospheres have been published (Smith et al, 6), but quantitative data on this effect are few. This paper describes part of a continuing programme of work aimed at quantifying and understanding the process of degradation of electrostatic filter materials by both industrial aerosols and aerosols generated in the laboratory.

TYPES OF ELECTROSTATIC MATERIAL USED IN THE EXPERIMENTS

Four different types of electrostatic material were used in the investigations:-

Resin-wool material

This material has existed for several decades. It contains highly charged resin particles, attached to wool fibres with a charge of the opposite sign. The fibres are usually about 17μm in diameter, and can carry the highest surface charge density observed by the authors, though not in the most efficient configuration. The material is described in detail by Feltham (7).

Electret material

This material is now in widespread use, and has been described by van Turnhout et al (8). The fibres, which are comparable in size with wool fibres, are produced by shredding a sheet of polymer that has been charged by an electric corona, and they retain a high electric charge.

Electrostatically spun material

The two materials described above are produced in the form of fleeces or felts by carding

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the fibres. Electrically charged material can be made from fibres that are too fine to be carded, but which are extruded by electric fields, and made into fibrous material by air-laying. The fibres are typically about 4μm in diameter, and they carry charges of both signs, but at a lower level than the materials of carded fibres. Such material should be regarded as partly electrostatic and partly mechanical. Two types of material, which are chemically different and produced by different processes, are used in the tests. They are a polycarbonate material produced from a solution (Schmidt, 9) and a polypropylene material produced from a melt (Trouilhet, 10).

EXPERIMENTAL PROCEDURE

The filters were exposed to aerosols in batches of 36, using the apparatus shown in Figure 1. Dust laden air was drawn through the box at a rate such that each filter received air at a face velocity of 0.04 ms^{-1}. Equal distribution of flow was ensured by backing all of the test filters with identical high resistance filters, and the flow was controlled with a simple electronic feed-back device.

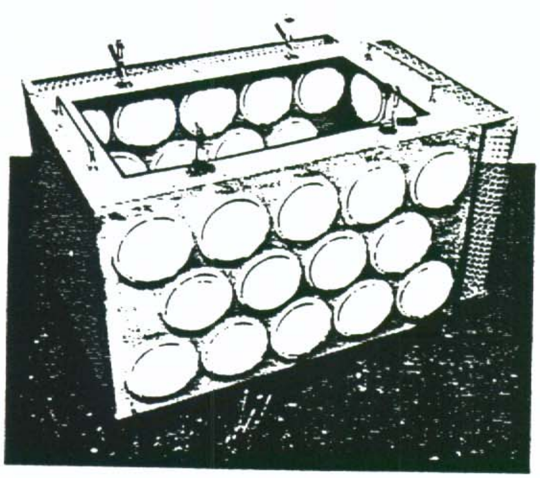

Fig.1 - Apparatus used for exposure of filters to industrial aerosols

Batches of filters were exposed, on site, to the following aerosols: aerosols produced at a foundry by the removal of superfluous material from steel castings using an abrasive wheel (fettling), or an oxygen-acetylene torch or electric arc (burning); refractory brick dust with a high carbon content; lead-containing aerosol produced by condensation at a lead smelter, and by dispersion, cold, at a lead battery assembly plant. In addition filters were exposed to coal dust in our own dust tunnel (Blackford and Heighington, 12) and to ammonium chloride aerosol produced by sublimation and condensation.

From time to time during the exposure the filters were removed, to be dried and weighed, and to have their pressure drop and BS 4400 standard sodium chloride aerosol (13) penetration measured, at a face velocity of 0.04 ms^{-1}.

SPECIMEN RESULTS

Many measurements have been made, and it is not possible to present all of the results here. However, a number of results can be usefully shown in detail, to illustrate the general trends observed. Figure 2 shows the penetration of the standard aerosol through electret filters as a function of the mass per unit area of deposited aerosols of various types, and it gives a general illustration of the difference in the extent to which equal masses of various aerosols cause reduction in filter performance.

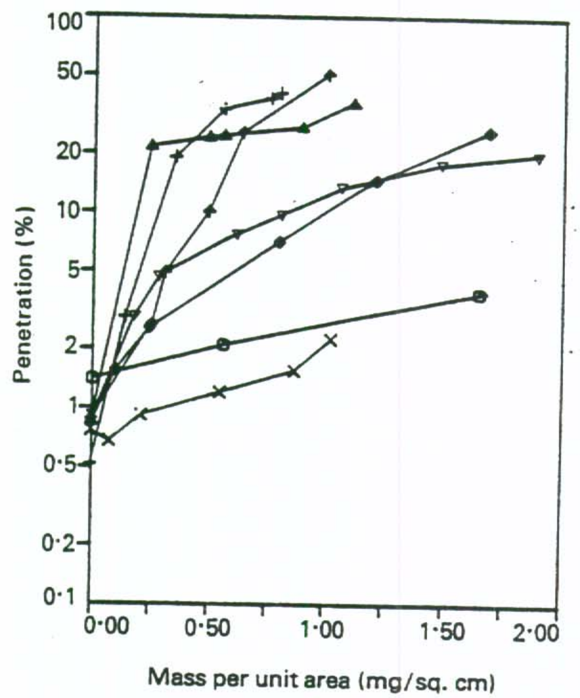

Fig.2 - Standard aerosol penetration through electret filters loaded with various aerosols

⊡ - Silkstone coal dust
△ - Foundry fettling fume
+ - Foundry burning fume
× - Carbon brick dust
◇ - Lead smelting fume
▲ - Lead battery dust
▽ - Ammonium chloride

The results for electret material are shown, because its mechanical stability and very low moisture regain enable repeatable measurements to be obtained. Other materials show similar trends, but experimental scatter is greater. All the aerosols listed in Figure 2 cause a practically monotonic increase of penetration with load, and there is no evidence that electret material clogs significantly in the form used, and under the conditions of these tests. Several filters were tested in each environment, but the figure shows only the filter that is closest to the average in its behaviour. The units on the x axis at Figure 2 are such that at this filtration velocity of 0.04 ms^{-1}, 1 mg cm^{-2} of aerosol would be deposited in 7 hours if the ambient aerosol concentrations were 10 mg m^{-3}; or, in general terms, a concentration of K mg m^{-3} and an exposure time of t hours would result in a deposition of $Kt/70$ mg cm^{-2} of aerosol.

Figure 3 shows, for a larger number of electret filters, the effect of the two types of foundry aerosols. Figure 4 shows the fine polycarbonate material after exposure to the different lead-containing fumes. The fundamental difference apparent here is that this fine-fibred material clogs.

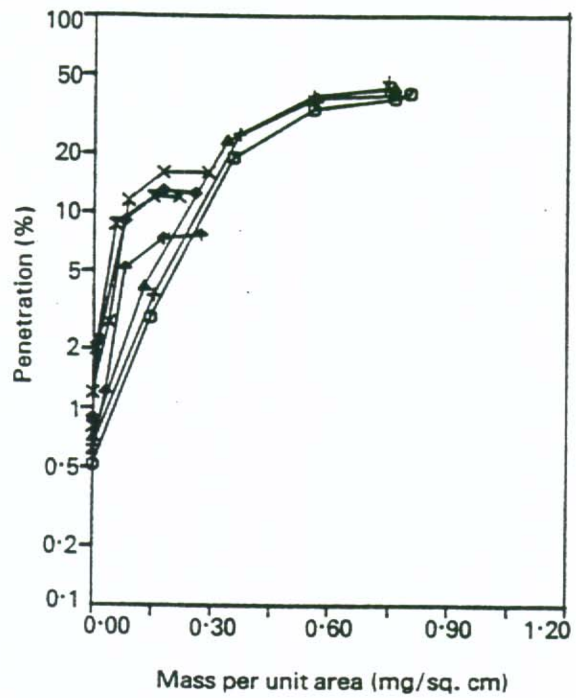

Fig.3 - Standard aerosol penetration through electret filters loaded with foundry aerosols
□△+- Burning fume
×◇♦×- Fettling fume

In Figures 2 to 4, the penetration is shown on a logarithmic scale, for convenience's sake. Moreover, the figures are computer graph plots, with successive data points joined by straight lines. This method of connecting points serves, principally, to illustrate which points correspond to readings made on the same filter. The graphs do not give reliable estimates of intermediate penetration values, but, in general, the characteristics obtained from the data do not require this, and the data points are not sufficiently precise to make the exercise of developing a better interpolation program worthwhile.

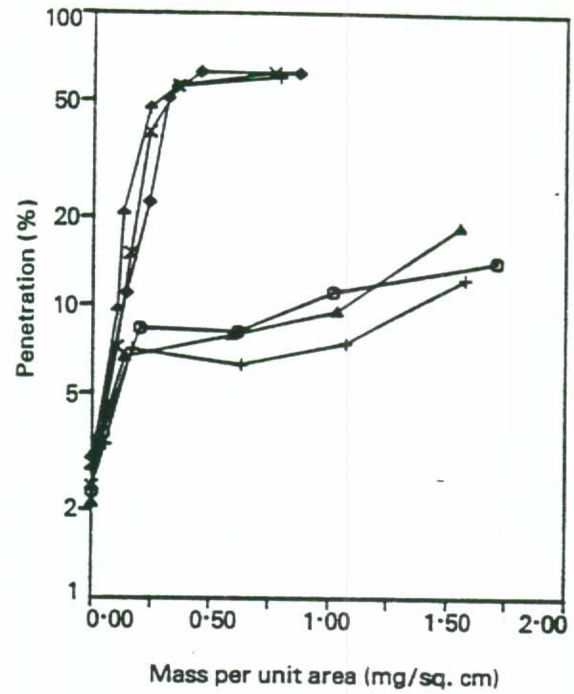

Fig.4 - Standard aerosol penetration through polycarbonate filters loaded with lead aerosols
□△+- Lead smelting fume
×◇♦- Lead battery dust

SEMI-EMPIRICAL THEORY OF FILTER DEGRADATION

The results shown so far illustrate that the process of degradation of electrostatic filters by aerosols is very complicated, and that the development of a quantitative theory to explain all that is observed will prove difficult. Deposition of aerosol within a filter is not uniform; the initial layers will be more heavily loaded. Their loss of filtration efficiency will cause a greater penetration of aerosol to the underlying layers, which will result in loss of efficiency here; and so the aerosol deposition profile will creep through the filter. A complete analysis will probably result in partial differential equations in a large number of interrelated variables.

It is important, though, even at this stage in the work, to obtain some link between theory and practice; and this is possible if attention is directed towards the early stages of each test, when the filters have light aerosol loads. Under such conditions it should be possible to develop a linear theory. Moreover, it frequently happens that a simple relationship holds well outside the range of parameters for which it can be rigorously justified. Let us start with the expression for the penetration, P, of an aerosol of identical particles through a filter (1).

$$P = \exp(-\alpha d) \qquad (1)$$

The parameter, α, can be called the layer efficiency, and it is a measure of the filter material quality. Although it will depend on the nature of the aerosol, the filtration velocity, and the packing fraction of the filter, it will not depend on the filter thickness, d, and has, therefore, a useful degree of generality. In practice, most aerosols consist of particles with a range of different penetrations, but equation 1 holds reasonably well if an average value is used for α, provided that the size distribution of the aerosol is not too wide. In practice it is usually possible to increase α by compressing the filter; but the penalty paid for this is an increase in pressure drop.

Equation 1 does not attempt to relate what is observed to fundamental aerosol properties, but it does enable the observed behaviour of an aerosol to be expressed by means of a single simple parameter. In the working that follows, a similar parameter, describing the effect of aerosol loading on filter performance, will be sought; and the theory will be developed for the general case in which the test aerosol is different from the loading aerosol.

Equation 1 can describe the penetration of a test aerosol through an unloaded filter, with an appropriate choice of α, α_T say. It can also describe the penetration of the loading aerosol, with its particular layer efficiency, α_L say; and it is straightforward to show that the mass of aerosol deposited, per unit volume of filter, $\mu(x)$, is given by

$$\mu_L\ (x) = \mu_o \exp\ (-\alpha_L x) \qquad (2)$$

μ_o is a constant, the meaning of which will become clear below. x is the coordinate in the direction of aerosol flow, and, within the filter, 0<x<d. We now make the assumption that the layer efficiency for the test aerosol is reduced by an increment that is proportional to μ.

$$\alpha\ (\mu_L) = \alpha_T - B_{TL}\ \mu_L \qquad (3)$$

β_{TL} is a constant of proportionality, which is a measure of the effectiveness of the loading aerosol in reducing the layer efficiency for the test aerosol. This assumption of a linear relationship can be justified, in the low loading limit, for any of the existing theories of particle capture by electric forces (3, 4, 14). Moreover, it has the appeal of being the simplest assumption possible; but the best justification of linear theory will be the quality of agreement between prediction and observation. Equations 2 and 3 can be incorporated into the differential equation for test aerosol concentration, C, in a lightly loaded filter under test.

$$\frac{dC_T}{dx} = [-\ \alpha_T + \beta_{TL}\ \mu_o \exp\ (-\ \alpha_L x)]\ C_T \qquad (4)$$

The solution of equation 4 is

$$\ln\left|\frac{C_T\ (x = d)}{C_T\ (x = o)}\right| = -\ \alpha_T d + \frac{\beta_{TL}\ \mu_o}{\alpha_L}\ [1-\exp\ (-\alpha_L d)] \qquad (5)$$

The mass of loading aerosol deposited, per unit area of the face of the entire filter, M, is

$$M_L = \int_o^d \mu_L(x)\ d = \frac{\mu_o}{\alpha_L}\ [1 - \exp(-\alpha_L d)] \qquad (6)$$

Combining equations 5 and 6, using the fact that the left hand side of equation 5 is, by definition, the logarithm of the penetration of test aerosol through a loaded filter, and the fact that the first term on the right hand side is the logarithm of the penetration of test aerosol through an unloaded filter, P_o, the result follows that

$$\ln\left|\frac{P_T}{P_o}\right| = \beta_{TL}\ M_L \qquad (7)$$

Equation 7 is precisely the sort of relationship that we require. β_{TL} is a parameter giving a simple quantitative estimate of the effectiveness of the loading aerosol in reducing the electrostatic filtration efficiency of the filter. β_{TL} does not depend on filter thickness, nor does it depend, explicitly, on α_L. All of the other unknowns in equation 7 can be easily measured.

This simple result means that scaled graphs can be used to obtain β_{TL}, which is simply the gradient of the logarithm of the penetration quotient as a function of loading, measured at the origin; though it must be reiterated that the simplicity of the prediction is the result of the simple assumptions made in deriving it.

ANALYSIS OF RESULTS

The validity of the approximations made in the preceding section will be revealed by the quality of fit of the experimental results to the corresponding predictions. The best illustration of this is given by the results obtained with electret filters subjected to foundry burning fume. These filters are chosen as before, because experimental scatter is small, and because both single and double thicknesses of material were used. Straightforward results for penetration against load are shown in Figure 5, where the graphs appear to differ considerably. In Figure 6, the logarithm of the penetration quotient is plotted, as in equation 7. Complete agreement with equation 7 would result in all of the graphs lying on the same straight line close to the origin. It is clear that the behaviour is roughly as the equation predicts; and the spread in the results may be due to slight compression of the thicker filters.

It is not possible to show all of the relevant graphs in this paper, but in most cases, a quality approaching that of Figure 6 is achieved. In certain cases anomalous results have been

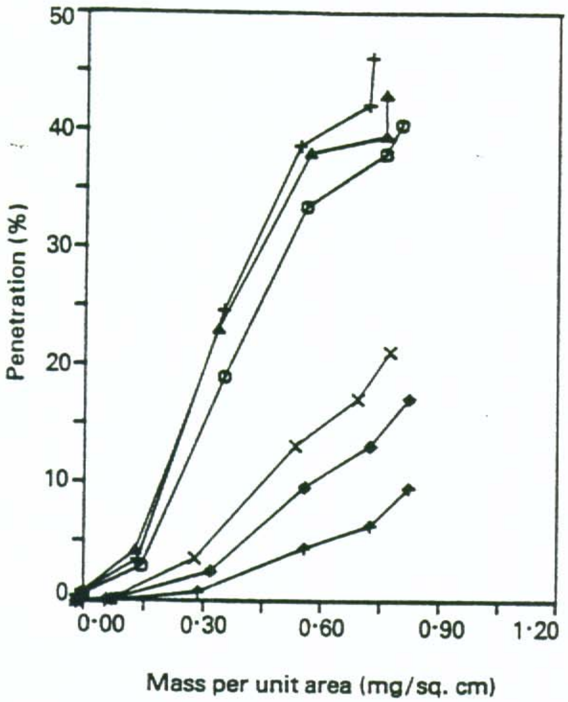

Fig.5 - Standard aerosol penetration through burning - fume laden electret filters

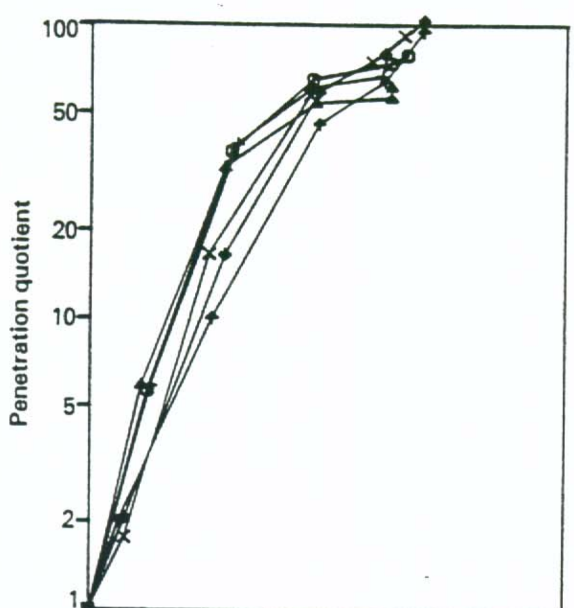

Fig.6 - Log (quotient) plot of standard aerosol penetration : same data as figure 5

rejected, because it is always possible that, when left in industrial conditions without supervision, a filter may be damaged or contaminated by the normal activities of industry carried out in a careless fashion.

The results are summarised in Table 1. Some data, particularly those on resin wool filters, and on filters with a hygroscopic scrim, were not analysed directly. Instead, penetrations were referred to exposure time, amd the weights obtained with other filters under the same conditions were used as presumed weight increases. Results to which this applies are bracketed. The tabulated values of β_{TL} are averages taken from a log (quotient)/linear plot of the experimental results for each batch of similar filters exposed to the same aerosol. Where the spread of individual results is very high, limits are quoted.

TABLE 1

Low Load Degradation Parameter, β_{TL} (m^2 g^{-1}), for Various Filter Materials and Aerosols

FILTER MATERIAL

AEROSOL	Electret	Resin Wool	Poly-carbonate	Fine Poly-propylene
Silkstone Coal Dust	0.08	0.06	0.007-0.05	0.03-0.21
Carbon Brick Dust	0.11	(0.55)	C.16	-
Lead Smelting Fume	0.55	(0.79)	0.81	(3.00)
Lead Battery Dust	0.63	(0.92)	1.05	0.70
Foundry Burning Fume	1.31	(1.43)	1.02	-
Foundry Fettling Fume	3.41	(2.05)	1.57	(0.43)
Ammonium Chloride	0.96	-	0.75	0.42

The most striking feature of those results is the large range in values of β_{TL}. For instance, it varies by a factor of almost fifty for electret filters. It is also clear that, if the aerosols are ranked according to the amount of degradation that they cause, then with the exception of the ammonium chloride aerosol, they are in the same order for electret and resin wool filters, and in a basically similar order for the other filters. However, just as a complete study of a new filter requires both layer efficiency and pressure drop, a full analysis of a loaded filter needs both β_{TL} and the rate of increase of pressure drop.

CLOGGING AND PRESSURE DROP INCREASE

Clogging of the filters by an aerosol may well increase their filtration efficiency and, therefore, reduce the effect of charge loss. This would tend to reduce the value of β_{TL} measured, and might cause the anomalies in Table 1. This advantageous effect is associated with the drawback of increased airflow resistance, and a simple linear treatment of this effect will be worthwhile. Such an exercise follows exactly the same lines as that for the penetration, except that equation 1 is replaced by

$$\Delta p_o = \varepsilon d \qquad (8)$$

where ε describes the resistance of an incremental layer of filter material. α_L appears in exactly the same way as before, and it is assumed that ε increases linearly with aerosol load in the following way

$$\varepsilon\ (\mu_L) = \varepsilon_o + \alpha_L\ \Delta\ p_o \mu_L \qquad (9)$$

The plus sign expresses the expectation that pressure drop will increase with aerosol loading and Δp_o in equation 9 is simply a scaling factor to ensure that the constant of proportionality, γ_L, has the same dimensions as β_{TL}. The result of the analysis is

$$\frac{\Delta p\ (\text{loaded}) - \Delta p_o}{\Delta p_o} = \gamma_L\ M_L \qquad (10)$$

TABLE 2

Pressure drop increase parameter, γ_L (m^2 g^{-1}), for various filter materials and aerosols

AEROSOL	FILTER MATERIAL Electret	Resin Wool	Poly-carbonate	Fine Poly-propylene
Silkstone Coal Dust	0.00	0.00	0.27	0.08
Carbon Brick Dust	0.00	(-0.03)	0.00	-
Lead Smelting Fume	0.01	(0.02)	0.12	(0.00)
Lead Battery Dust	0.00	(-0.02)	0.02	0.24
Foundry Burning Fume	-0.02	(-0.03)	(0.06)	-
Foundry Fettling Fume	-0.04	(-0.11)	0.07	(0.52)
Ammonium Chloride	0.00	-	0.04	0.05

The parameter, γ_L, can be extracted from the pressure drop data, though these results show more scatter than those of the penetration.

The results are shown in Table 2, where it can be seen that the anomalous results are associated with rapidly clogging filters. As expected, the coarse filter materials hardly clog at all; in fact, in many cases the pressure drop actually falls. This reduction in pressure drop is due to alterations in structure caused by both aerosol loading and manipulation of the material during removal from and replacement on the test apparatus. Different batches of polycarbonate and of fine polypropylene filters were used in the tests on coal dust and lead battery dust, and this may account for the greater clogging of polycarbonate by coal dust and polypropylene by lead battery dust.

AEROSOL CHARACTERISTICS

The basic similarity of the value of β_{TL} for the same aerosol acting on different materials suggests that the properties of the aerosol are critical in this process. Fundamental aerosol characteristics likely to affect the rate of degradation are size distribution, charge distribution, and chemical nature.

The aerosol size distributions for the carbon brick dust and the two types of foundry dust were measured with an aerodynamic particle sizer; but it was not possible to carry out such measurements on the lead-containing aerosols, and so in these cases, and in the tests using coal dust, Coulter analysis of the dust deposited on the filters was carried out. The ammonium chloride aerosol was examined with an Electrical Mobility Analyser. The results are shown in Table 3. Some information on the chemical nature of the aerosols was obtained by analysis of the X-rays emitted by particles captured on membrane filters subjected to electron bombardment from a scanning electron microscope. This technique, applied to our apparatus, enables elements with an atomic number greater than 10 to be identified, but it gives no accurate information on the relative abundances of the elements, nor on their state of chemical combination. The elements observed by this technique, or otherwise known to be present, are listed in Table 3.

DISCUSSION

A number of measurements have been carried out on the loss of performance of electrically charged filter materials after exposure to aerosols. It has been shown that the effect of the aerosols, in the low exposure limit, can, to an approximation, be described by a simple linear theory, expressing the effect of the aerosol on the filter material in terms of a single parameter, β. This parameter is about as fundamental a property as the single fibre efficiency, in that it can be considered constant throughout a filter of homogeneous structure, but that it will vary with filter packing fraction and filtration velocity.

TABLE 3

Aerosol Size Distribution and Chemical Composition

Aerosol	Number Average Dia. (µm)	Mass Average Dia. (µm)	Size Analysis Method	Chemical Composition
Silkstone Coal Dust	5.7	10.7	Coulter	Carbon and Incombustible matter
Carbon Brick Dust	0.7	5.3	APS	Carbon and Kaolin
Lead Smelting Fume	3.6	16.0	Coulter	Compounds of Pb,Sn,Ca,Si
Lead Battery Dust	3.9	9.6	Coulter	Compounds of Pb,Si,Ca,Fe
Foundry Burning Fume	1.3	4.7	APS	Compounds of Fe,Na,Al,Si, S,Cl,K,Ca,Ti, Cr,Mn
Foundry Fettling Fume	0.9	5.3	APS	Compounds of Fe,Na,Al,Si, S,Cl,K,Ca,Ti, Cr,Mn
Ammonium Chloride	0.05	0.32	Mobility Analyser	NH_4Cl

N.B. The average sizes are means in the case of Coulter Counter and Mobility Analyser results, and Medians in the case of APS results.

β appears to be more sensitive to aerosol type than to filter type, though there may simply be less variation amongst the materials used than amongst the aerosols encountered.

A Spearman rank correlation test (Freund,15) carried out on the order of β_{TL} for electret and resin wool materials and the average size for the industrial aerosols gives a correlation coefficient of -0.43 for the mass average and -0.37 for the number average. Perfect correlation would give a value of -1, and no correlation would give zero. The values above probably underestimate the importance of size, because two different methods of size analysis have been used; and it is clear that a correlation exists. It is also clear that this parameter alone is not sufficient to explain what is observed. The data on chemical nature of the aerosols are too few for any conclusions to be drawn; and the effect of the electric charge on the aerosol is a subject for future study.

Finally, a word of warning must be added about the direct use of β_{TL} as an estimate of filter quality. The parameter is as good in this respect as single fibre efficiency or layer efficiency. That is to say it gives some information, but not complete information. The value may be altered simply by making a material more tightly packed, but the penalty paid will be an increase in the parameter γ_L; just as layer efficiency may be improved by compression, but only at the expense of a higher pressure drop.

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