SCREENING PROSPECTIVE WORKERS

FOR THE ABILITY TO USE RESPIRATORS

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ABSTRACT

A physician should make the determination of the ability to use respirators, taking into account the employee's health, the respirator, and the work conditions. A medical history and at least a limited physical examination are recommended. While a chest x-ray and/or spirometry may be medically indicated in some fitness determinations, they should not be routinely done. The fit-testing exercise should be expanded to serve as an important aspect of the overall determination of ability to use respirators. The recommended periodicity of fitness exams varies, but could be as infrequent as every 5 years. Examining physicians should realize that usually the main stress of heavy exercise with a respirator is on the cardiovascular system, and that heavy (e.g., self-contained, atmosphere supplying) respirators can substantially increase this stress. Accordingly, exercise stress tests, with electrocardiographic monitoring, should be considered in these circumstances when cardiovascular risk factors are present.

Based on limited evidence, it seems that subjects with a modest degree of lung disease can satisfactorily tolerate the pulmonary stresses imposed by respirator use. Although conflicting data exist, it appears that the positive pressure feature, found in some respirators, does not unduly stress the cardiopulmonary system.

The above points and other suggested physician guidelines will be discussed in the presentation. Available literature will be noted which should help physicians screen workers for the ability to use respirators.

I. INTRODUCTION

Several million U.S. workers are currently using respirators, that is, personal protective masks, in the workplace, and increased reliance on their use is being considered by the Department of Labor[1]. Present Federal Regulations require a physician to determine an individual's fitness to wear a respirator[2]. However, many physicians are relatively unfamiliar with the effects of respirator wear, and there is little data on the effects of respirator wear among workers who have some physiologic impairment. The purpose of this report is to concisely review the effects of respirator wear, and to provide referenced reasonable guidelines for determining fitness to wear respirators.

The viewpoints expressed in this report are those of the author, based on a review of the literature, research experience, discussion with various professionals, and review of public comments to OSHA regarding respirators[3]. The recommendations are meant to serve only as guidelines which should be modified as needed to fit an individual situation. Two recent publications are noted which also provide useful information on this topic[4,5].

This report generally does not address aspects of the protection provided by a respirator. It thus examines what a respirator does <u>to</u> a wearer, and not what it does <u>for</u> a wearer. Obviously, respirator selection, appropriate fit-testing, etc., which would also involve individual worker evaluation, are critical elements in any effective respirator program.

II. MEDICAL EFFECTS OF RESPIRATOR WEAR

Table 1 summarizes the major medical effects of respirator wear. Some amplification is given below, but interested readers are referred to recent reviews for more detailed analysis of the data[6,7]. Table 2 presents a brief classification of respirator types.

Pulmonary: In general the added inspiratory and expiratory resistances and dead space of most respirators cause an increased tidal volume, and decreased respiratory rate and ventilation (including a small decrease in alveolar ventilation). These respirator effects have usually been small both in healthy individuals and among individuals with impaired lung function[8-12]. This generalization is applicable to most respirators meeting Federal Regulations where resistances (particularly expiratory resistance) are low[13-15]. While most studies report minimal physiological effects during submaximal exercise, the resistances commonly lead to reduced endurance and maximal exercise performance[16-20]. The dead space of a respirator (reflecting the amount of expired air that must be rebreathed before fresh air is obtained) tends to cause increased ventilation. At least one study has shown substantially increased ventilation with a full face respirator, a type which can have a large effective dead space[21]. However, the net effect of a respirator's added resistances and dead space is usually a small decrease in ventilation[9-10,17-19,22].

The potential for adverse affects, particularly decreased cardiac output, from the positive pressure feature of some respirators has been reported[23]. However, several recent studies suggest that this is not a practical concern, at least in healthy individuals[24-26].

Theoretically, the increased fluctuations in thoracic pressure, while breathing with a respirator, might constitute an increased risk for subjects predisposed to spontaneous pneumothorax. Little data is available in this area. While using a negative pressure respirator with relatively high resistance during very heavy exercise, the usual maximal peak negative oral pressure during inhalation is about 15-17 cm H_2O[24]. Similarly, the usual maximal peak positive oral pressure during exhalation is about 15-17 cm H_2O, which might occur with a respirator in positive pressure mode, again during very heavy exercise[24]. By comparison maximal positive pressures, such as those during a vigorous cough can generate 200 cm H_2O pressure[27]. The normal maximal negative pleural pressure at full inspiration is -40 cm H_2O[28], and normal subjects can generate -80 to -160 cm H_2O negative pressure[27]. Thus while vigorous exercise with a respirator does alter pleural pressures, the risk of barotrauma would seem to be substantially less than that of the cough maneuver.

In some asthmatics an attack may be exacerbated or induced by a variety of factors including exercise, cold air, and stress, all of which may be associated with respirator wear. While most well-controlled asthmatics should not have problems with respirators, a physician's judgement and a field trial may be needed in selected cases.

Cardiac: The added work of breathing from respirators is small, and in several studies could not be detected[8-9]. A typical respirator might double the work of breathing from 3% to 6% of the oxygen consumption, but this is probably not of clinical significance[8]. In concordance with this view is the finding of several studies that heart rate does not change with respirator wear at the same workloads[9,25,29-31].

In contrast, the added cardiac stress due to the weight of a heavy respirator may be considerable. Self-contained breathing apparatus (SCBA), particularly those using compressed air cylinders, may weigh up to 35 pounds. Heavier respirators have been shown to reduce maximum external workloads by 20% and similarly increase heart rate at a given submaximal workload[17]. In addition it should be appreciated that many SCBA uses (e.g., firefighting and hazardous waste work) also necessitate 10-25 pounds of protective clothing to be worn.

Raven et al[10,29] found small ($\leq$ 10 mm Hg systolic; 0-2 mm Hg diastolic) but significantly higher systolic and/or diastolic blood pressures during exercise with a respirator, whereas Arborelius et al[25] did not find significant differences with respirator wear during exercise.

Temperature: The main concern here is with the closed circuit self-contained breathing apparatus which produces oxygen via an exothermic chemical reaction. Inspired air with these respirators may reach 120^{o}F (49^{o}C), thus depriving the wearer of a minor cooling mechanism, and causing discomfort. Obviously this can be more of a problem with heavy exercise and

when ambient conditions and/or protective clothing further reduce the body's ability to lose heat. Since heart rate increases with increasing temperature, this also represents an additional cardiac stress.

Closed-circuit breathing units of any type have the potential for heat stress since warm expired gases (after CO_2 removal with or without O_2 addition) are rebreathed. Respirators with large dead space also have this potential problem, again because of partial rebreathing of warmed expired air[21].

Diminished Senses: These effects in general are self-explanatory (See Table 1). Besides the potential for reduced productivity, these effects may result in reduced industrial safety. These factors may also contribute to a general feeling of stress[32].

Psychological: This important topic is discussed in recent reviews by Morgan[32-33]. There is little doubt that virtually everyone suffers some discomfort when wearing a respirator. The large variability and the subjective nature of the psycho-physiological aspects of respirator wear, however, make studies and individual recommendations difficult. Fit testing obviously serves an important additional function in providing a trial to determine if the wearer can psychologically tolerate the respirator. General experience indicates that the great majority of workers can tolerate respirators, and that experience aids in this tolerance[33]. However, some individuals are likely to remain psychologically unfit for respirator wear.

Local Irritation: Allergic skin reactions may rarely occur from respirator wear, and skin occlusion may exacerbate pre-existing conditions such as pseudofolliculitis barbae. Facial discomfort from the pressure of the mask may occur when the fit is unsatisfactory.

Other: A few specific respirator-workplace-wearer situations are noted.

1. Perforated tympanic membrane. While inhalation of toxic materials through a perforated tympanic membrane (ear drum) is possible, scientific evidence indicates the airflow would be minimal and rarely if ever of clinical importance[34-35]. In highly toxic or unknown atmospheres, use of positive pressure respirators should insure adequate protection[34].

2. Contact lens. Contact lens are generally not recommended for use with respirators, presumedly for several possible reasons:

a. Corneal irritation or abrasion might occur with the exposure. This would of course be primarily a problem with 1/4 and 1/2 face masks and especially with particulate exposures. However, exposure could occur with full face respirators due to leaks or if the respirator were inadvisedly removed for any reason. While corneal irritation or abrasion might also occur without the contact lens, their presense as a foreign body is known to substantially increase this risk.

b. Loss or misplacement of a lens during respirator wear might prompt the wearer to remove the respirator, thereby exposing himself to the hazard as well as the potential problems noted in (a).

c. The contact airflow of some respirators, such as PAPR's or continuous flow airline respirators, might irritate a contact lens wearer.

Summary: Heavy respirators add a substantial additional stress to the wearer at all exercise levels. Most studies also show that maximal exercise performance is reduced by respirator wear, even without any added weight factor. However, most studies of lighweight respirators involving submaximal exercise levels report relatively minor cardiopulmonary effects, compared to the stress of mild to moderate exercise alone. This appears to be true for people with impaired lung function as well, although the data is preliminary. The other effects of respirator wear may be important for individual persons and specific work conditions.

III. FITNESS GUIDELINES AND COMMENTS

A. General Recommendations:

1. A physician should make the determination of fitness to wear a respirator, taking into account the employee's health, the respirator, and the work conditions.

2. A medical history and at least a limited exam are recommended.

3. While a chest x-ray and/or spirometry may be medically indicated in some fitness determinations, they should not be routinely done.

4. The recommended periodicity of fitness exams varies according to several factors, but could be as infrequent as every 5 years.

5. The fit-testing exercise should be expanded to serve as an important aspect of the overall determination of the ability to use respirators.

6. Examining physicians should realize that usually the main stress of heavy exercise with a respirator is on the cardiovascular system, and that heavy (e.g., self-contained, atmosphere supplying) respirators can substantially increase this stress. Accordingly, exercise stress tests, with electrocardiographic monitoring, should be considered in these respirator uses when cardiovascular risk

factors are present, or when extremely stressful conditions are expected.

7. An important concept is that "general work limitations and restrictions identified for other work activities also shall apply for respirator use"[36].

8. Because of the variability in types of respirators, work conditions, and employees' health status, many companies may wish to designate categories of fitness to wear respirators, thereby excluding some workers from strenuous respirator work situations.

B. Comments on General Recommendations by Number

1. Physician Determination - This satisfies present OSHA regulations, and leaves the final decision in the hands of the person who should be best qualified to evaluate the multiple clinical and other variables. Much of the clinical and other data could be gathered by other personnel, however. It should be emphasized that the clinical exam alone is only one part of the fitness determination, and that collaboration with foremen, industrial hygienists, and others may often be needed to better assess the respirator and work condition factors.

2. History and Physical Exam - The medical history and physical examination should emphasize the evaluation of the cardiopulmonary system and elicit any history of respirator use. The history is perhaps the most important tool in all medical diagnosis; it should detect most problems that might require further evaluation. The physical examination should confirm the clinical impression based on the history, and also detect important medical conditions (such as hypertension) that may be essentially asymptomatic.

3. Chest X-ray and Spirometry - It is realized that in most cases, the hazardous situations requiring respirator wear will also mandate periodic chest x-ray and/or spirometry for exposed employees. Obviously when such information is available, it should be used in the determination of fitness to wear respirators.

Routine chest x-rays and spirometry are not recommended because it is felt that, in most cases with a negative clinical exam (history and physical), they are unlikely to influence the respirator fitness determination, and because an x-ray is a source of radiation exposure to the employee. Chest x-rays in general do not accurately reflect a person's cardiopulmonary physiological status, and limited studies suggest that mild to moderate impairment detected by spirometry should not preclude most respirator wear. It is therefore recommended that these tests be done when clinically indicated.

4. Frequency of Fitness Testing - The frequency of fitness determinations should obviously follow federal or other regulations. The guidelines for most respirator-work conditions are shown in Table 3, and are similar to those recommended by ANSI[4], which recommend annual determinations after age 45. The more frequent exams with advancing age relate to the increased prevalence of most diseases in older people. More frequent exams are recommended for strenuous SCBA work because less significant abnormalities (perhaps occurring at an earlier age) might preclude such respirator wear. These guidelines, like the others in this report, should be adjusted as clinically indicated. It is important to realize that a system must be included to evaluate intercurrent illness or symptoms, just as would be needed in any medical surveillance program.

5. Fit-testing Expansion - In addition to its other, obvious purposes, fit testing should be expanded to serve as a test of an employee's response to respirator wear. This is perhaps the best way at present to detect extreme anxiety or claustrophobic reactions. For this purpose, the respirator should be worn for at least 30 continuous minutes. During at least part of this time, he should engage in some exercise which approximates the actual working situation.

This recommendation is not new. In fact, present regulations state that an employee should be provided an opportunity to wear the

respirator "in normal air for a long familiarity period ..."[37]. The point to be made here is that this trial period should also be used to evaluate the ability and tolerance of the employee to respirator wear[5]. This trial period need not be associated with respirator fit testing, and in any case should not compromise the effectiveness of the vital fit testing procedure.

6. Exercise Stress Test - As noted earlier, some respirators may weigh up to 35 pounds, and may increase workloads by 20%. While this added stress could be compensated for by a lower activity level[38], this may not always be possible. Physicians should also be aware of other added stresses, such as heavy protective clothing and intense ambient heat, which would increase the employee's cardiac demand. As an extreme example, firefighters who use SCBA inside burning buildings may work at maximal exercise levels under life-threatening conditions.In such cases it would seem prudent to rule out occult cardiac disease which might manifest itself only under heavy stress.

In such cases, some authors have either recommended stress testing[39], or at least its consideration in the fitness determination[4]. Kilbom[39] has recommended stress testing for firefighters using SCBA at five-year intervals below age 40, and at two-year intervals from ages 40-50. He further suggested that firemen over age 50 not be allowed to wear SCBA.

Exercise stress testing has not been recommended for medical screening for coronary artery disease in the general population[40,41]. It has an estimated sensativity and specificity of 78 and 69 percent, respectively, when disease is defined by coronary angiography[40,42]. In a recent, six-year prospective study it had a (positive) predictive value of a coronary event of 27 percent when the prevalence of disease was 3 1/2 percent[43,44].

While stress testing thus has limited effectiveness in medical screening, it would also serve to detect those individuals who may not be able to complete the heavy exercise required in some jobs. It would seem reasonable, therefore, to recommend at least an initial exercise test for those individuals whose respirator job will entail near maximal exercise stress.

Those SCBA activities with mild to moderate overall stress levels would in most cases not require stress tests.

7. General work limitations - In many cases, if an employee is able to safely do his job without a respirator, he will also be able to safely do it while wearing a respirator.

8. Restricted respirator use - One could have several categories of permissible respirator wear depending on the various circumstances. Tables 4 and 5, however, illustrate one scheme. This would lead to three overall categories: full respirator use, no respirator

use, and limited use (excluding heavy -SCBA- respirators and strenuous work). As the astericks indicate, these are intended only as guidelines and could be substantially modified by practical experience, further research, and individual circumstances.

Note that, in Table 4, points 4 through 7 would prohibit most work even without a respirator, and contact lens wear would prohibit work in dusty areas. (Note that regular lens can be adapted for use inside most full face respirators.) This again points out the importance of general work limitations noted in part 7.

As discussed earlier, it seems unlikely that respirator wear would play any significant role in causing a pneumothorax. However, theoretically it could play some role, and it seems that without good evidence to the contrary, the prudent decision would be to prohibit respirator wear in these rare cases.

Table 5 again itemizes what could be considered general work restrictions. Moderate lung disease is used as defined by the Intermountain Thoracic Society[45], which would mean a forced expiratory volume in one second divided by the forced vital capacity (FEV_1/FVC) percent of 45 to 60%, or a FVC of 51 to 65 percent of predicted. Similar arbitrary limits could be set for age and moderate hypertension. It would seem more reasonable, however, to

combine several risk factors into an overall estimate of fitness to wear respirators under certain conditions. Here the judgment and clinical experience of the physician are needed. Even many impaired subjects will be able to safely work while wearing respirators if they can control their own work pace, and are allowed adequate rest breaks.

C. Summary

Individual judgement is needed in each case in determining fitness to wear respirators. While many of the preceeding guidelines are arbitrary and/or based on limited evidence, they should provide a useful starting point in a respirator fitness screening program. Further research is obviously needed to validate these recommendations and others currently in use. Of particular interest would be laboratory studies involving physiologically impaired individuals, and studies in the field under actual day-to-day work conditions.

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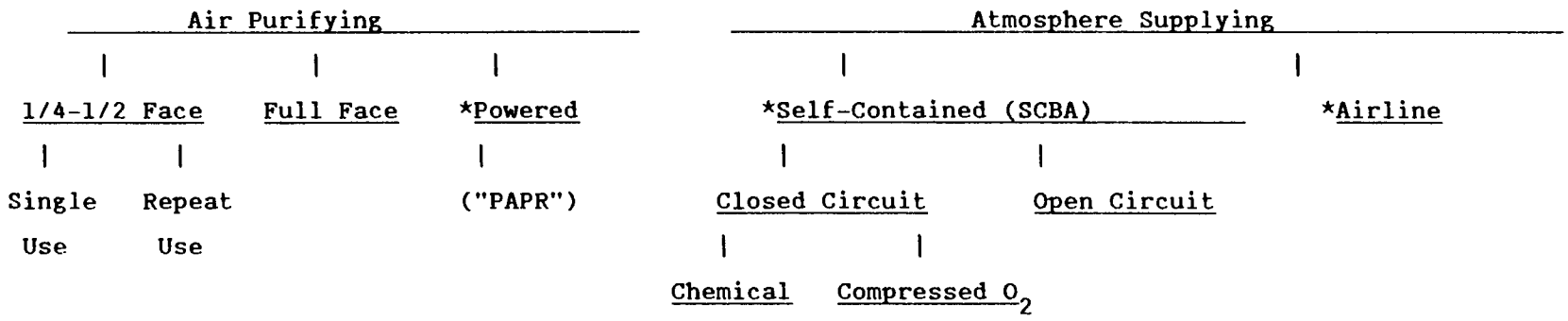
TABLE 1

MAJOR MEDICAL EFFECTS OF RESPIRATOR WEAR

Function/System Affected	Mechanism	Effects	Other Considerations
Pulmonary	↑ resistance ↑ dead space	↑ work of breathing ↓ ventilation ↓ maximal work	fatigue, discomfort ↑ risk of pneumothorax ?
Cardiac	↑ work of breathing respirator weight	↑ cardiac work ↓ maximal external work	
Temperature	↑ temp of inspired air partial recirc. of warm expired air ↓ temperature of inspired air	↑ body temperature and discomfort cooling effect	↑ temperature → ↑ heart rate
Diminished Senses	partial mask obstruction of visual fields covering of mouth covering of ears; respirator noises	reduced visual fields decreased voice clarity and loudness decreased hearing	
Psychological	enclosures of face/head other effects	claustrophobia loss of "habits" (chewing, spitting, blowing nose, scratching, etc.) ↑ generalized stress	in susceptible subjects
Local Irritation	mask face pressure allergic occlusion of skin	discomfort discomfort, rash folliculitis	 in susceptible subjects in susceptible subjects

TABLE 2

BRIEF CLASSIFICATION OF RESPIRATORS



*May have positive pressure

TABLE 3

FREQUENCY OF FITNESS DETERMINATIONS*

	Employee Age (Years)		
	< 35	35 - 45	> 45
Most Respirator-Work Conditions	Every 5 yrs	Every 2 yrs	1-2 Years
Strenuous Work Conditions with SCBA**	Every 3 yrs	Every 2 yrs	Annually

*Interim testing would be needed if changes in health status occur.

** SCBA = Self-contained Breathing Apparatus

TABLE 4

MEDICAL CONTRAINDICATIONS TO RESPIRATOR WEAR
(Not including inadequare protection aspects)

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*1. History of spontaneous pneumothorax

*2. Claustrophobia/anxiety reaction

*3. Contact lens wear

*4. Severe pulmonary disease

*5. Angina pectoris, significant arrhythmias, recent myocardial infarction

*6. Symptomatic or uncontrolled hypertension

7. Other general work restrictions

*Not well studied or proven

TABLE 5

MEDICAL FINDINGS RESTRICTING RESPIRATOR WEAR
(e.g., no SCBA, no strenuous work)

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*1. Moderate pulmonary disease

*2. Age limit

*3. Moderate hypertension

*4. History of myocardial infarction

*Not well studied or proven