

"Psychophysiological Screening for Respirator Wear"

by

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Abstract

The objective determination of worker(s) capability to wear an industrial respirator during the performance of his/her daily work tasks has provided the industrial physician with an ongoing dilemma. In this review, we provide the psychophysiological background upon which the recent American National Standards Institute promulgated many of the sub-committee recommendations of Z88.6. It is anticipated that this background will guide the industrial physician in requesting specific screening tests for workers involved in a variety of industrial tasks who are required to wear an industrial respirator.

Introduction

With the enactment of the Occupational Safety and Health Act in 1970, the need to develop measures by which individuals can be assessed for respirator wear has become an issue of medical, legal and practical importance. For example, the U.S. Nuclear Regulations Commissions Guide states:

Workers must be evaluated by competent medical personnel to ensure that they are physically and mentally able to wear respirators under simulated and actual working conditions. These evaluations should be an important part of the employee's periodic physical examinations routinely given in most industrial medical facilities. Adequate medical supervision of respirator users is indispensable in determining the extent of individual stress tolerance and in preventing potential physiological derangements (NUREG 0041. sec. 7.4., Medical limitations).

Unfortunately, simply mandating a responsibility does not provide the physician with the objective criteria for assessing a worker's ability to use a respirator. In an effort to provide some guidance, the American National Standards Institute asked a group of concerned physicians and researchers to provide a practical guideline for the "Physical Qualification for Respirator Use," euphemistically termed Z88.6. It is our intent to highlight the background used for development of the standard and to

provide specific suggestions for evaluation of emergency personnel.

Background Information

Physiological Aspects

In an initial review of the literature (Raven et al. 1979), we identified that the primary effect of all types of respirators was evidenced by discernible decrements in pulmonary function (Raven, et al., 1981a; Raven, et al. 1981b; and Raven et al. 1982). Subsequently, Myhre et al. (1979) and ourselves (Raven et al. 1977) have documented in healthy normal workers that the wearing of a self-contained breathing apparatus (SCBA) or rebreather type apparatus results in an additional work requirement because of the weight of the apparatus. This increased weight (approximately 35 lb or 16 kg) manifests itself as a 20% average increase in energy requirements for a given submaximal work load, and, consequently, results in a 20% decrease in maximal work performance (Pincus, 1978; Raven et al., 1977). The effect of the additional weight appears to override the effects of different breathing modes and the increased resistance to breathing of specific respirators. One could propose that the effects of additional weight are linear and hence, we would predict, that for each 1 lb. of apparatus weight that the increased

energy requirements or decrease in maximal work capacities will be 0.6%. However, the important concept to note is that, for any respirator that involves significant weight, a measurable increase in work load requirements will occur. Therefore, it is essential that the physician be informed of the type of respirator and the maximal level of work the job will place on the worker. For example, as a consequence of the above, workers who are required to use a SCBA or rebreather type respirator for emergency work should be evaluated using a maximal exercise stress test. If maximal work effort is limited because of cardiopulmonary disease (ischemia, arrhythmia, asthma, ventilation/perfusion and diffusion/perfusion inequality), the worker should be assigned to tasks not requiring use of the SCBA or rebreather type apparatus during heavy work.

The primary effect of all types of respirators was shown to be physiologically discernable by changes in normal pulmonary function (Raven, et al., 1981; Raven et al., 1982) and was related to the increased resistance to inspired and expired flow imposed by the respirator. The problem for the physician is discerning the degree of lung impairment that is a contraindication to respirator wear, regardless of the specific etiology of the disease, whether it be restrictive, obstructive, or

diffusion-limiting. This decision is multifactorial and is related to the normal work load usage and the duration of the work. It is unlikely that the examining physician is aware of the work load or the duration which the respirator is to be used. Therefore, it is important that the job description in terms of time and metabolic demands be provided by the company to the examining physician. This may require direct measurements of the specific work tasks, as has been done for many industries (Raven, et al., 1973) or probably could be described using the inclusive data of Passmore and Durnin (1955) on measured energy levels of specific industrial work tasks.

The nature of the pulmonary response in assuring adequate alveolar ventilation for increases in steady-state work loads is dependent upon lung and chest wall mechanics and alveolar-to-arterial gas exchange (Dempsey et al., 1980; Dempsey et al., 1977). One would presume that it would be a simple procedure to determine a clinical pulmonary function test that would be directly related to the required ventilation of a specific work task. However, the real world of industrial work tasks places a greater demand on the control systems of ventilation than a simple alteration in metabolic rate per se. For example, an assembly line worker experiences large second-by-second

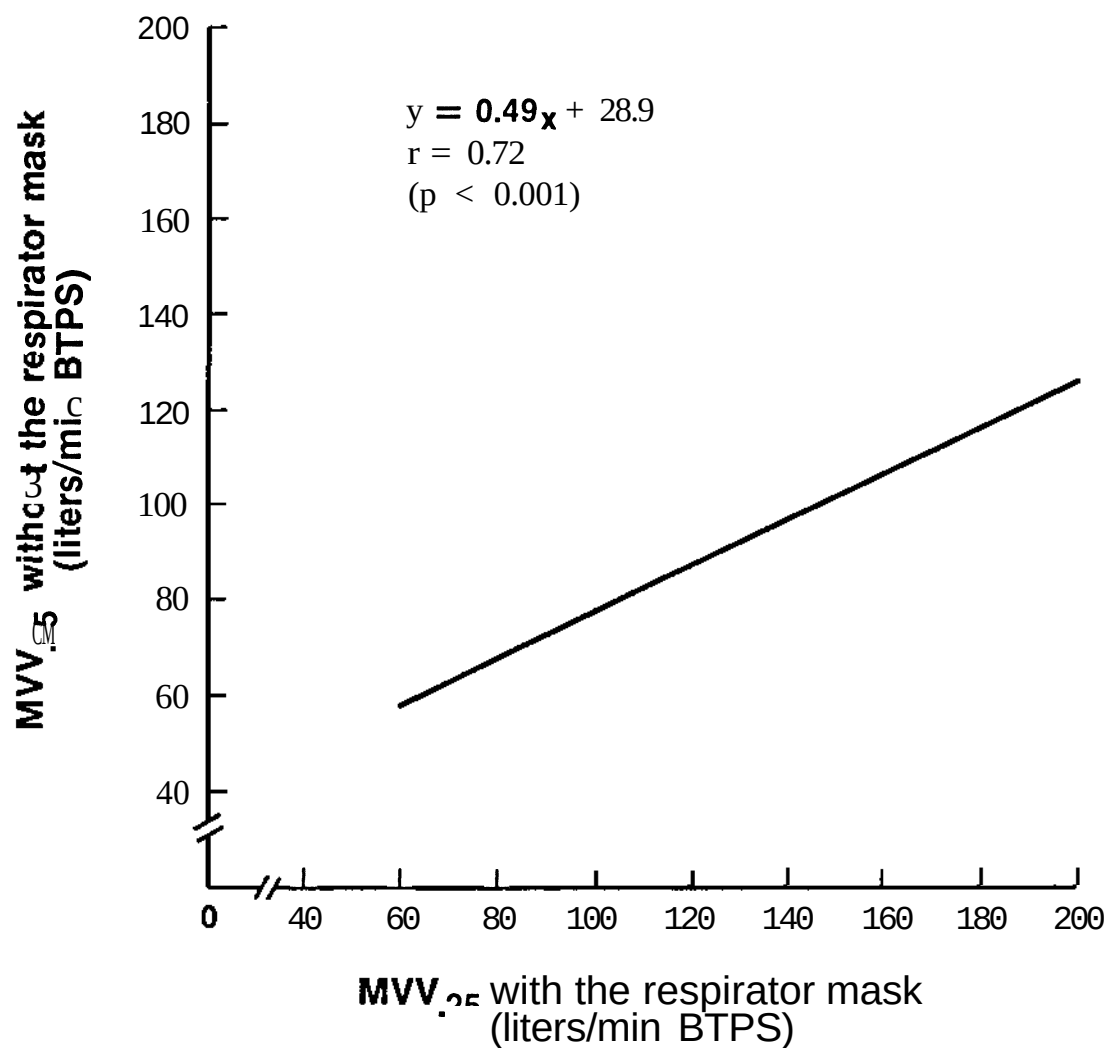
variations in tidal volume, respiratory frequency, and alveolar gases. These alterations in respiratory cycle dynamics are a result of the industrial work task requiring postural changes and static breath-hold type movements which produce intermittent acidosis and variable lung volumes, thereby altering control of efficient isocapnic hyperpnea (Passmore and Durnin, 1955; Raven et al., 1973). In addition to the complexities associated with breath by breath regulation of the alveolar-arterial oxygen gradient, the industrial worker is faced with the possibility of respiratory muscle fatigue over a period of an eight-hour shift. Also, the examining physician must be aware of the progressive increase in ventilation that occurs during prolonged steady-state work, i.e. > 40 minutes (Dempsey et al., 1977). Similarly, the physician needs to note that mature healthy diaphragm and intercostal muscles will fatigue under conditions of increased mechanical loads, abnormal respiratory times, hyperinflation, or simply a high, sustained ventilatory activity, i.e. > 50-60% of maximum voluntary ventilation (Roussos and Macklem, 1977).

Despite these complexities of respiratory control, a conservative score obtained on a standard clinical pulmonary function test is suggested as a guideline to the physician. The suggested test is the test of maximum voluntary ventilation (MVV)

over 15 seconds (MVV_{.25}). The basis for this recommendation is two-fold. First, it is a test of lung function that has been shown to be related to lung and chest wall mechanics as well as respiratory muscle fatigue (Shepard, 1967; Tenney and Reese, 1968). Secondly, it is a simple and inexpensive screening test that can be conducted in the doctor's office. Furthermore, sufficient data exists relating the MVV_{.25} score to (a) the 4 min MVV assessment of respiratory muscle fatigue (Shepard, 1967; Wiley and Lind, 1971); (b) the sustained maximal exercise ventilation (Clarke, et al. 1969; Freedman, 1970; Shepard, 1967; Tenney and Reese, 1968); and (c) the effect of respiratory resistance on the MVV_{.25} score (Clarke et al., 1969).

Freedman (1970) investigated the ability of normal subjects to sustain their MVV for 4 minutes. In 20 healthy subjects, the average 4 min MVV was 129 liters/min ranging from 108-182 liters/min. This average value represented 72% of the MVV_{.25}. In addition, they identified a maximum tolerable steady-state exercise ventilation of 102 liters/min as representing 80% of the 4 min MVV and 64% of the MVV_{.25}. Finally, they concluded that 50% of the MVV_{.25} could be sustained ad infinitum. However, these estimates do not account for the progressive increase in work ventilation that occurs during steady-state exercise (Morgan, 1983a;

Morgan, 1985b) and which may approach 30 liters/min (Dempsey et al., 1977) at high levels of work output ($> 60\% \dot{V}O_{2\max}$). Recently, Raven et al. (1981) have found that the maximum allowable inspired resistance (85 mm H₂O at 85 l/min) and expired resistance (25 mm H₂O at 85 l/min) produced a 33% average decrement in $\dot{M}\dot{V}\dot{V}_{.25}$ for a group of subjects ($N = 31$) whose average $\dot{M}\dot{V}\dot{V}_{.25} = 144.6$ liters/min (± 33.5 liters/min SD). These same resistances produced a 28% average decrement for a group of subjects ($N = 29$) whose average $\dot{M}\dot{V}\dot{V}_{.25} = 115$ liters/min (± 43.7 liters/min SD). This would suggest that the greater the lung impairment the less the reduction in $\dot{M}\dot{V}\dot{V}_{.25}$. For example, in a subgroup of subjects ($N = 11$) with clinically significant lung impairment the above inspired and expired resistances resulted in a 17% decrement from the average $\dot{M}\dot{V}\dot{V}_{.25} = 92$ liters/min (Raven et al., 1981). Obviously, not enough data points exist to provide the true description of the resistance-produced reduction in $\dot{M}\dot{V}\dot{V}_{.25}$. However, it would appear conservative to suggest that for the $\dot{M}\dot{V}\dot{V}_{.25} < 100$ liters/min but > 50 liters/min corrected to Body Temperature and Pressure Saturated (BTPS) the reduction will be 20%; between 100 and 150 liters/min BTPS the reduction will be 30% and $> 150 < 200$ liters/min BTPS the reduction will be 35% (Figure 1). It should be remembered that these reductions in



The relationship between MVV.25 measured while wearing a respirator (x ordinate) and without a respirator (y abscissa).

pulmonary performance are directly related to the inspired and expired resistance (Bentley et al., 1973) and, therefore, the smaller the resistance used in the respirator, the less the reduction. For example, many work situations require different types of respirators, these being the SCBA, the airline type, the

Table 2. Required energy cost in metabolic equivalents (METS) and required ventilation for various levels of work

<u>Job description</u>	<u>Energy cost (@ uptake)</u>	<u>Required ventilation</u>
Light work	up to 0.5 l/min or 1-2 METS*	requires 6-15 l/min
Moderate work	0.5 - 1.0 l/min or 2 - 4 METS	requires 12-25 l/min
Heavy work	1.0 - 1.5 l/min or 4 - 6 METS	requires 25-40 l/min
Very heavy work	1.5 - 2.0 l/min or 6 - 8 METS	requires 40-60 l/min
Extremely heavy work	2.0 - 3.0 l/min or 8 - 12 METS	requires 60-90 l/min
Exhaustive work	>3.0 l/min or 12 - 15 METS	requires 90-120 l/min

* 1 MET = 3.5 ml O₂/kg/min

gas mask, dust, fume and mist, chemical cartridge, and pesticide respirators. However, the general range of inspired resistances at 85 liters/min has been identified in Table 1; hence, a proportional reduction in the correction factors to be used are proposed. Ventilation increases during increasing workloads up to a maximal level which approximates 70% MVV_{.25} (Astrand and Rodahl, 1977; Bentley et al., 1973; Clarke et al., 1969; Freedman, 1970). From a resting value of approximately 6.0 liters/min (rest = 1 MET which is 1 Cal/min or 3.5 ml O₂/kg·min⁻¹), the maximal exercise ventilation increases to 100, 150, and in some extreme cases, 200 liters/min BTPS. The relationship between ventilation and energy expenditure is linear up to 70% of maximal work capacity (approximately 20-25 liters BTPS of ventilation per 1 liter of oxygen uptake). During heavy work (≥ 70% of maximum) this relationship approaches 30 to 35 liter/min BTPS per 1 liter of oxygen uptake (Astrand and Rodahl, 1977). In addition, the manual work tasks of industry have been generalized to a semi-quantitative and qualitative description, (Astrand and Rodahl, 1977; Passmore and Durnin, 1955) such that the industrial hygienist should be able to provide a summary of work tasks to the physician. An example of this classification (Astrand and Rodahl, 1977) is shown in Table 2. From this information of industrial tasks and the

relationship between $MVV_{.25}$ and work ventilation, the physician can make a judgment as to the worker's capability for wearing a respirator during work regardless of the existence of pulmonary disease. A suggested procedure is as follows:

Initially, the clinical pulmonary function evaluation including a forced respiratory volume determination for FVC, $FEV_{1.0}$ and a chest X-ray should be taken; however, as the FVC

Table 1. Inspired Resistance and Correction of $MVV_{.25}$ Score

<u>Inspired resistances</u> mm H ₂ O at 85 liters/min	<u>% Reduction of $MVV_{.25}$ score (extrapolated)</u>		
	>160 (liters/min)	<150 >100 (liters/min)	<100 >50 (liters/min)
10	4	3.5	2.4
20	8	7	4.7
30	12	10.5	7.1
40	16	14	9.4
50	20	17.5	11.8
60	24	21	14.1
70	28	24.5	16.5
80	32	28	18.8
85	35	30	20

score has little relationship to respiratory muscle fatigue, we suggest that the worker's capability to wear a respirator for a specific work task to be decided and delimited according to his individual MVV.₂₅ data and its relationship to the required work demands. It should be noted, however, that MVV.₂₅ does not delineate diffusion/perfusion problems. If a worker is suspected of having desaturation problems during work due to hypoventilation or diffusion perfusion inequalities, he should be further evaluated and placed in appropriate work tasks which require only 1 or 2 METS energy expenditure. At this time, it would appear that respirator wear has little or no effect on saturation problems, however, further investigations are needed.

The MVV.₂₅ test should be performed at a normal breathing frequency that optimizes lung metabolism, for example, 40 breaths/minute in a standing position. Tidal volumes of breathing should approximate 2/3 of the vital capacity. All volumes need to be corrected to Body Temperature and Pressure Saturated (BTPS). It is suggested that the best of three trials be used as the score, that subject motivation is monitored to ensure the highest possible motivation, and that the technician be well trained in monitoring the test.

Having obtained the maximal performance of the worker's

lung and predicting the effect of wearing the work-required respirator, the physician needs to compare this predictive/or adjusted score with the required ventilation of the worker's daily task as well as accounting for the increased ventilatory volume due to the time of carrying out the task. If the work task is only 15-30 minutes in duration, then the adjusted MVV.₂₅ score needs to be reduced to a further 30%. These recommendations are based upon the level of sustained ventilation [sustainable for 30 minutes and its relationship to MVV.₂₅ (Freedman, 1970; Tenney and Reese, 1968)], whereas if the work task is from one to eight hours, then the adjusted MVV.₂₅ score is reduced a further 50% (Figure 2). From these adjustments and by using

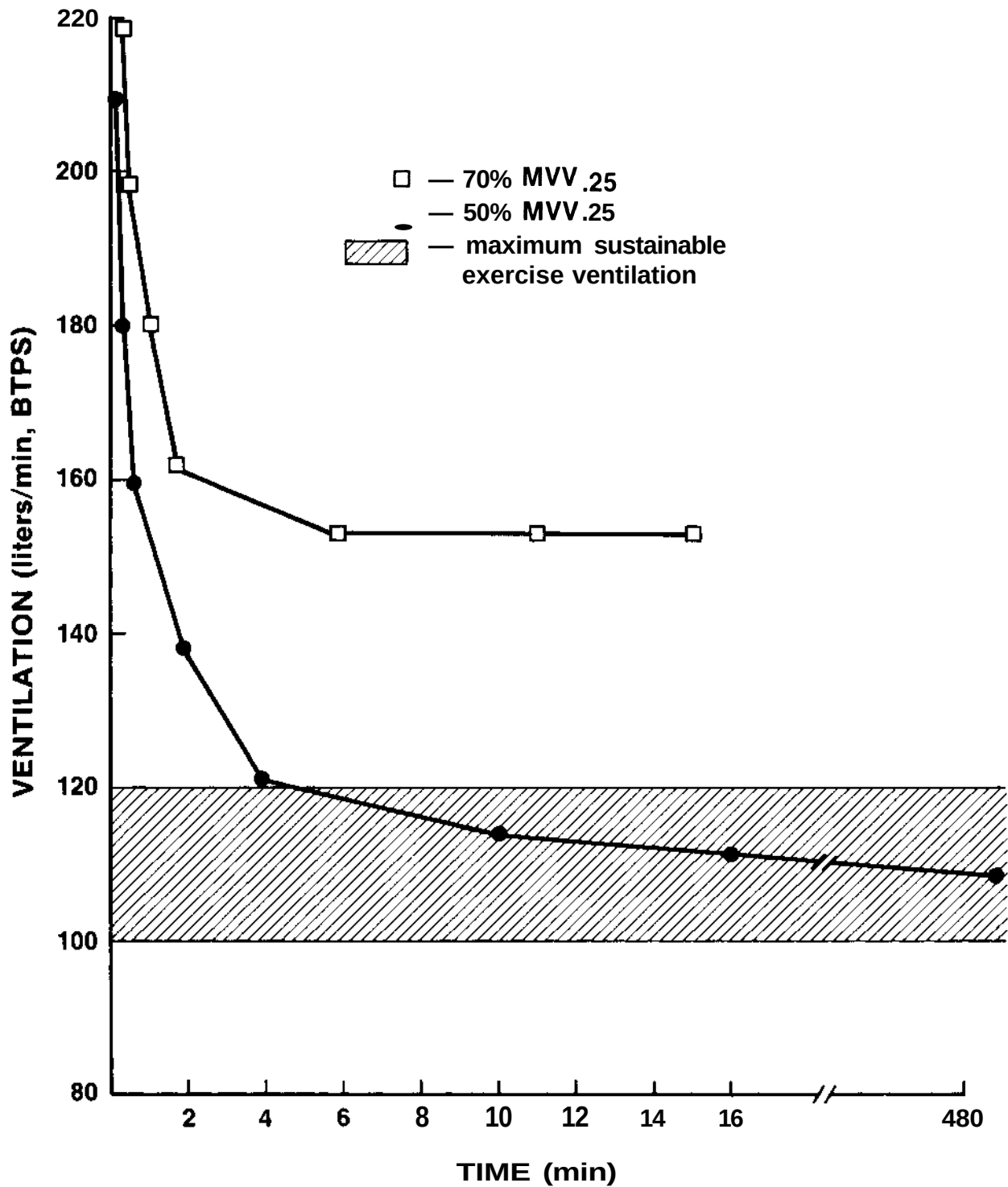
Figure 2

Table 2, the physician can now estimate whether the worker's lung function is capable of meeting the ventilatory demand of the work task.

Psychological Aspects

Discernible decrements in pulmonary function (Raven et al., 1981a; Raven et al., 1981b; and Raven et al., 1982) occur when wearing any type of respirator. Respirator wear and the consequent increase in breathing resistance is accurately detected by approximately 90% of any given sample of test subjects during both resting and exercise conditions (Morgan, 1979). Ventilatory

cues provide the basis for the perception of effort during hard, physical work; consequently, claustrophobic or high anxiety



workers who perceive that the effort is greater due to the increased resistance to breathing should not be given jobs requiring respirator wear. While approximately 90% of any given sample of test subjects are able to accurately judge the physiological cost of work (Morgan, 1973), the major problem in selecting workers for tasks in which industrial respirators must be worn is the isolation of the 10% in any given sample who experience anxiety attacks when exposed to a hostile environment and respirator wear.

Bentley et al. (1973) determined that 90% of an experimental population would experience a sensation of discomfort only if the resistance across the breathing apparatus exceeded a pressure of 17 cm H₂O. Raven et al. (1982) also found 50% of their subjects wearing a respirator mask with pressure swings greater than 24 cm H₂O were unable to complete 10 min of exercise at 80% $\dot{V}O_{2\max}$. Bentley et al. (1973) further concluded that the excessive pressure exerted during inspiration was a major factor in determining subjective tolerance.

Work by Shershow et al. (1973) indicates that the degree of psychopathology correlated inversely with CO₂ sensitivity. Subjects were administered a rebreathing test to determine CO₂-sensitivity. The Minnesota Multiphasic Personality Inventory

(MMPI) was used as a personality measure. Subjects were consistent in their own responses across several trials of CO₂ rebreathing. Shershow et al. (1973) suggested that CO₂ sensitivity is a trait and could be used to predict those who would respond to a CO₂ rebreathing test with a greater or lesser increase in ventilation volume ($\dot{V}_E$). Subjects with a $\dot{V}_E$ response less than the overall mean of 20.8 liters/min, scored significantly higher on various parameters (i.e., depression, psychopathic deviate, psychasthenia and social introversion scales) of the MMPI. The general evaluation of MMPI scores in the group of low responders to CO₂ rebreathing supports the view that respiratory response to inspired CO₂ is influenced in part by personality. A subject's ventilatory response to CO₂ appears to differ for individuals possessing different personality structures.

Individuals known to ventilate at levels in excess of the ventilatory demand of a given work load are usually classified as hyperventilators. Pincus (1978) notes that hyperventilation results from anxiety and hyperventilation in turn produces physiological changes that form the basis of subsequent fear. The abnormal breathing patterns occurring in hyperventilators may vary from mild sensations such as parathesias to full-blown anxiety attacks characterized by carpopedal spasm, tetany,

blurred vision, convulsions, tunnel vision and/or unconsciousness (Morgan, 1983b). These individuals are obviously at greater risk when placed in a stressful situation such as fighting a fire, than would other fire fighters who do not have abnormal ventilatory responses.

Rushmer et al. (1941) studied the effects of hyperventilation on the performance of aircraft pilots. Hyperventilation reduced the pilot's performance leading to potential hazards for pilot, crew and passengers. Other research has shown a deterioration in psychomotor performance with hyperventilation resulting in decreases in the partial pressure of alveolar carbon dioxide ($P_{A}CO_2$) to 20-25 mmHg, with significant deterioration occurring with a $P_{A}CO_2$ of 15 mmHg. Morgan (1983b) points out that while this research is not directly related to exercise and stress in extreme environments, it is relevant because hyperventilation is associated with significant decrements in psychomotor performance. Thus, it is necessary that individuals exposed to various extreme environments have normal ventilatory patterns.

Normal adults possess the ability to accurately detect changes in breathing under different conditions. Lum (1977) has proposed that hyperventilation (ruling out organic pathology) is essentially nothing more than a "bad breathing habit." Any

stressor (physical or emotional) can trigger the chain reaction that results in symptoms of an anxiety attack. Lum further suggests that individuals with poor "breathing habits" can be taught to breathe correctly. By diagnosing hyperventilators and teaching them to detect those symptoms, an additional portion of the 10% of the population manifesting psychological problems may learn to work while wearing a respirator.

Those symptoms which characterize the hyperventilation syndrome can be produced in certain "types" of individuals within minutes by requiring the individual to overbreathe. Overbreathing does not produce complete hyperventilatory attacks in most individuals, while some "types" of individuals are especially sensitive to the effects of overbreathing. Morgan (1983b) proposes that individuals who experience hyperventilatory attacks be identified during routine office evaluations. Those individuals who experience the hyperventilation syndrome with the resulting symptoms are considered at greater risk when performing tasks during vigorous exercise while breathing in a respirator mask. This lends further support to the recommended screening test, MVV.²⁵ It is also possible to administer standardized psychological inventories designed to measure trait anxiety. It is known, for example, that individuals who score high on trait

anxiety experience a greater stress response than do low-anxious individuals when they are challenged with a given stressor such as heat, altitude, exercise, or high CO₂ concentrations (Morgan, 1973). Thus far, research in the area of physiological and psychological responses to respirator wear have observed the level at which stress responses occur. In a recent experiment, Morgan and Raven (AIHA in press 1985) considered the predictability of determining those individuals who would experience difficulty while wearing a respirator mask during an exercise stress. Forty-five volunteer test subjects were required to exercise on a motor-driven treadmill while wearing a self-contained breathing apparatus (SCBA). Five of these subjects had elevated scores (above the group mean) on a standard measure of trait anxiety (Spielberger, 1969). It was predicted a priori that five of the subjects would experience difficulty on the treadmill task. Six of the 45 subjects experienced dizziness, claustrophobia, or anxiety attacks during heavy exercise while wearing a SCBA. The five subjects with elevated scores were among the six who actually experienced anxiety attacks. These results support Morgan's theory that certain "types" of individuals are more likely to experience anxiety attacks while wearing a SCBA and performing hard physical work than those individuals who score

within the normal range on trait anxiety. Furthermore, these individuals can be identified in advance with an acceptable degree of accuracy (83%) (Table 3). Therefore, use of a trait anxiety measure is effective where one is interested in identifying individuals who will be at risk when wearing a SCBA and performing hard, physical work in a hostile environment. These results were obtained with an objective measure of trait anxiety developed by Spielberger et al. (1969). Applications of these results should be made with the same instrument, or with a scale that is known to measure the same psychological attribute (i.e., trait anxiety). The administration and interpretation of any psychological testing should be performed by, or under the supervision of, an appropriately trained psychologist.

Summary

The physiological research reviewed in this paper demonstrates that various tests can be employed in identifying those individuals who would be compromised if required to wear a SCBA and perform heavy physical work. It has been found, for example, that the wearing of SCBA (weighing some 35 lbs) reduces maximal work effort 20%. In addition, the MVV.₂₅ assessment of lung function has been shown to provide significant information concerning the individual's lung capacity to sustain submaximal

- Lum, L.C. (1975), "Hyperventilation: the tip of the iceberg." Journal of Psychosomatic Research. 19:375-383.
- Morgan, W.P. (1983), "Psychological problems associated with the wearing of industrial respirators: A review." Am. Ind. Hyg. Assoc. J. 44:671-676.
- Morgan, W.P. (1983a), "Psychometric correlates of respiration: A review." Am. Ind. Hyg. Assoc. J. 44:677-684.
- Morgan, W.P. (1983b), "Hyperventilation syndrome: A review." Am. Ind. Hyg. Assoc. J. 44:685-689.
- Morgan, W.P. (1979), "Psychological problems associated with the wearer of industrial respirators: A review." Technical Report. Los Alamos National Laboratory.
- Morgan, W.P. (1973), "Psychological factors influencing perceived exertion." Medicine and Science in Sports. 5:97-103.
- Morgan, W.P. and P.B. Raven (submitted), "Prediction of stress for individuals wearing industrial respirators." Am. Ind. Hyg. Assoc. J.
- Myrhe, L.G., R.D. Holden, F.W. Baumgardner, and D. Tucker (1979), "Physiological limits of Firefighters." Unclassified Technical Report No. ESL-RT-79-06. Available Tyndell AFB, Florida.
- Passmore, R. and J. Durnin (1955), "Human energy expenditure." Physiol. Rev. 35:801-940.

- Pincus, J.H. (1978), "Disorders of conscious awareness: hyper-ventilation syndrome." Brit. J. of Hosp. Med. 19:312-313.
- Raven, P.B., M.O. Colwell, B.L. Drinkwater and S.M. Horvath (1973), "Indirect calorimetric estimation of specific tasks of aluminum smelter workers." J. of Occup. Med. 15:894-898.
- Raven, P.B., T.O. Davis, C.L. Shafer and A.C. Linnebur (1977), "Maximal stress test performance while wearing self-contained breathing apparatus." J. of Occup. Med. 19:802-806.
- Raven, P.B., A.T. Dodson, and T.O. David (1979), "The Physiological consequences of wearing industrial respirators: A review." Am. Ind. Hyg. Assoc. J. 40:517-534.
- Raven, P.B., R.F. Moss, K. Page, R.O. Garman, and B. Skaggs (1981a), "Clinical pulmonary function and industrial respirator wear." Am* Ind. Hyg. Assoc. J. 42:897-903.
- Raven, P.B., A.W. Jackson, K. Page, R. Moss, B. Skaggs and O. Bradley (1981b), "The physiological responses of mild pulmonary impaired subjects while using a 'demand' respirator during rest and work." Am. Ind. Hyg. Assoc. J. 42:247-257.
- Raven, P.B., O* Bradley, D. Rohm-Young, F.L. McClure, and B. Skaggs (1982), "Physiological response to 'pressure-demand' respirator wear." Am. Ind. Hyg. Assoc. J. 43:773-781.

- Roussos, C.S. and P.T. Macklem (1977), "Diaphragmatic fatigue in man." J. Appl. Physiol. Resp. Environ. and Exerc. Physiol. 43:189-197.
- Rushmer, R.F., W.M. Boothby, and H.C. Henshaw (1941), "Some effects of hyperventilation with special reference to aviation medicine." Mayo Clinic Proceedings. 16:801-808.
- Shepard, R.J. (1967), "The maximum sustained voluntary ventilation in exercise." Clin. Sci. 32:167-176.
- Shershaw, J.C., N. King and S. Robinson (1973), "Carbon dioxide sensitivity and personality." Psychosomatic Medicine. 35:155-160.
- Spielberger, C.D., R.L. Gorsuch, and R.E. Lushene (1969), The State-Trait Anxiety Inventory Manual. Palo Alto: Consulting Psychologists Press.
- Tenney, S.M. and R.E. Reese (1968), "The ability to sustain great breathing efforts." Resp. Physiol. 5:187-201.
- Wiley, R.L. and A.R. Lind (1971), "Respiratory responses to sustained static muscular contractions in humans." Clin. Sci. 40:221-234.

Table 3

Absolute Frequencies of Observed and
Predicted Respiratory Distress in
the "Demand" and "Pressure-demand"
Experiments Combined

		<u>Predicted Distress</u>			Predicted Rate
		Yes	No	Sum	
Actual	Yes	<u>5</u>	<u>1</u>	<u>6</u>	83% (5 of 6)
Distress	No	<u>1</u>	<u>38</u>	<u>39</u>	97% (38 of 39)
		6	39	45	