

University of Montana

ScholarWorks at University of Montana

Graduate Student Theses, Dissertations, &
Professional Papers

Graduate School

1991

The effects of breathing resistance on pulmonary function and work capacity

Zachary Mead
The University of Montana

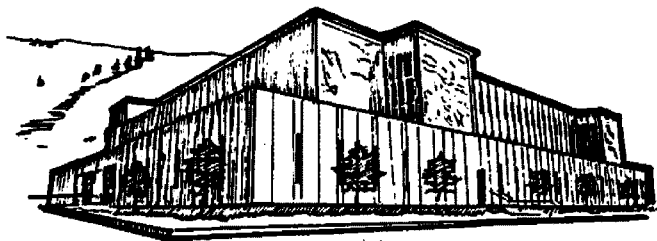
Follow this and additional works at: <https://scholarworks.umt.edu/etd>

Let us know how access to this document benefits you.

Recommended Citation

Mead, Zachary, "The effects of breathing resistance on pulmonary function and work capacity" (1991).
Graduate Student Theses, Dissertations, & Professional Papers. 7215.
<https://scholarworks.umt.edu/etd/7215>

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.



Maureen and Mike
MANSFIELD LIBRARY

Copying allowed as provided under provisions
of the Fair Use Section of the U.S.
COPYRIGHT LAW, 1976.

Any copying for commercial purposes
or financial gain may be undertaken only
with the author's written consent.

University of
Montana

THE EFFECTS OF BREATHING RESISTANCE ON PULMONARY
FUNCTION AND WORK CAPACITY

by

Zachary Mead

B.S. California State University, Bakersfield, 1987

Presented in partial fulfillment of the
requirements for the degree of
Master of Science

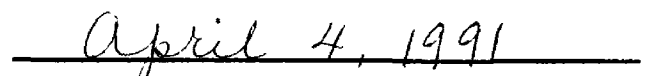
University of Montana

1991

Approved by:


Chairman, Board of Examiners


Dean, Graduate School


Date

UMI Number: EP38016

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



UMI EP38016

Published by ProQuest LLC (2013). Copyright in the Dissertation held by the Author.

Microform Edition © ProQuest LLC.

All rights reserved. This work is protected against unauthorized copying under Title 17, United States Code



ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

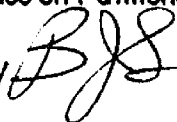
ABSTRACT

Mead, Zachary P., M.S. March 1991

Exercise Physiology

The Effects of Breathing Resistance on Pulmonary Function and Work Capacity (47pp.)

Director: Dr. Brian J. Sharkey



The purpose of this study was to examine the relationship of several pulmonary function variables and the ventilatory threshold (VT) to work performance ($\dot{V}O_2$ max and submax) while wearing an air purifying respirator. It was anticipated that one of the pulmonary function variables might be identified as a possible screening test to identify workers capable of doing strenuous work (1.5 Liters O_2 /minute) while wearing an air purifying respirator.

Fifteen male subjects underwent pulmonary function testing, force vital capacity (FVC), forced expiratory volume in one second (FEV_{1.0}), Forced expiratory flow 25-75 (FEF₂₅₋₇₅), and the maximal voluntary ventilation in 15 seconds (MVV₁₅) both with and without the respirator mask. Subjects also performed two maximal treadmill tests at a walking speed of 4 mph with grade increases of 2.5% every 1 to 2 minutes. One treadmill test was performed with an air purifying respirator mask and one was performed without the mask.

The results of this study show that working with an air purifying respirator device significantly ($p < 0.05$) reduces ventilation, $\dot{V}O_2$ max, MVV₁₅ and the ventilatory threshold (VT), as compared to the no respirator condition. When the pulmonary function values were correlated ($r = 0.36$) with work performance ($\dot{V}O_2$ max) the MVV₁₅ pulmonary function test emerged as a possible test. The MVV₁₅ is also a negative correlate ($r = -0.44$) of the ventilation requirement to perform submaximal work (22-25 ml O_2 /kg/min). The results of this study show that the MVV₁₅ in combination with other variables such as fitness ($\dot{V}O_2$ max) and the ventilatory threshold (VT) could become a screening test for workers that may be assigned to strenuous work tasks which require them to wear air purifying respirator devices.

ACKNOWLEDGMENTS

I would like to thank Dr. Brian Sharkey for involving me with this project and other endeavors related to the U. S. Forest Service. The rest of the members of my thesis committee also deserve thanks for the suggestions they made regarding this manuscript.

A big thanks goes to the young men that served as subjects in this study. The testing was sometimes less than pleasant yet the subjects always seemed interested and were always willing to give their all.

I would especially like to thank my dear friend Greg Farnum for all the help with the data collection and the recruitment of subjects. A very big thanks goes to my best friend Zoe Alderfer. She provided me with endless support and the required amount of prodding to get me through this project.

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGMENTS	iii
LIST OF TABLES	vi
LIST OF FIGURES	vii
<u>CHAPTER</u>	<u>PAGE</u>
I. INTRODUCTION	1
Significance of Problem	2
Delimitations	3
Limitations	3
Hypotheses	4
Definitions	5
II. LITERATURE REVIEW	6
III. METHODOLOGY	12
Phase One	12
Phase Two	13
Phase Three	15
IV. RESULTS AND DISCUSSION	16
Results	16
Discussion	26
V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	34
Summary	34
Conclusions	36
Recommendations	38
REFERENCES	39

<u>APPENDIX</u>	<u>PAGE</u>
A. MEDICAL HISTORY QUESTIONNAIRE	43
B. INFORMED CONSENT	46

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
1	Descriptive Characteristics of the Subjects	18
2	Group Means for Several Pulmonary Function Tests	19
3	Mask/No Mask Differences For the Pulmonary Function Variables	20
4	Significant Differences Among Selected Variables	21
5	Correlations Among Selected Variables	22
6	Dyspnea Scale (RPE Scale)	23

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
1	Subject Performing a Pulmonary Function Test	24
2	Subject Undergoing a Treadmill Work Test	25

CHAPTER I

INTRODUCTION

Many occupational settings expose workers to harmful atmospheres. Respiratory protective devices of many types are used to shield the worker. These respiratory protective devices fall within three categories: 1. air purifying devices; 2. supplied-air respirators; and 3. self contained breathing apparatus (SCBA). This paper will deal with the air purifying devices and the physiological variables that are influenced by their use.

In the last ten years, much research has dealt with the physiological consequences of respirator wear. It has been demonstrated that metabolic demand is increased while wearing a respirator (Raven et al. 1979; Thompson & Sharkey, 1966). This becomes particularly important when workers are doing strenuous physical exertion like fighting forest fires. As a result, the fitness and pulmonary function of the workers that must wear respirators has become a concern. Workers with reduced pulmonary function or low maximal oxygen uptake ($\dot{V}O_2$ max) values may have problems with the increased inspiratory and expiratory resistance placed on breathing, and the increase in metabolic demand needed to overcome this resistance during prolonged submaximal work.

This study attempted to provide information about the relationships of several physiological variables as they pertain to respirator wear. Raven et al. (1979) has shown that the MVV_{15} (see definitions) pulmonary function

test predicts a persons ability to perform work while wearing a pressure demand respirator. This study measured the MVV_{15} as well as other pulmonary function tests and the maximum oxygen uptake. The results of these tests were correlated with work performance during the work trials on the treadmill. Work performance in this case was oxygen consumption submaximally as well as maximally. Tests were conducted both with and without a respirator mask. The ventilatory threshold is also a variable that was looked at in relation to pulmonary function.

The purpose of this study was to examine the relationship of pulmonary function values and the ventilatory threshold to work performance while wearing an air purifying respirator, and identify one or several of these pulmonary function variables which might be used as a screening test to identify workers capable of working while wearing a respirator. This study also explored some of the changes in pulmonary function, ventilation, and VO_2 that can occur while wearing an air purifying respirator

SIGNIFICANCE OF PROBLEM

This study attempted to compare several pulmonary function values (MVV_{15} , FEV1.0, FVC, and FEF₂₅₋₇₅) with a persons ability to work while wearing a respirator mask (see definitions). Work was defined as the VO_2 max both with and without the respirator mask. By correlating the pulmonary function values with work performance and ventilatory threshold, a pulmonary function test was identified that could be used to predict a persons ability to work while wearing a respirator.

The information obtained in this study adds to the body of knowledge already available on this subject. More importantly the results may help develop tests to screen workers who must wear the air purifying respirators during prolonged submaximal work.

DELIMITATIONS

The delimitations of this study include the following:

1. The sample population was limited to 15 males, between the ages of 19 and 33 years of age.
2. There was no minimum fitness level required (VO_2 max value).
3. Each subject was involved in three phases of the study.
 - a. Pulmonary function testing.
 - b. Each subject performed two maximal exercise trials walking on a motorized treadmill. One test was performed with the respirator mask and one test without the respirator mask.
4. All subjects were required to wear the U.S. Forest Service clothing and pack during both exercise tests.

LIMITATIONS

1. It was not possible to completely regulate the health habits, outside activities, sleep, and dietary habits prior to the testing of the subjects.
2. It was not possible to control the level of motivation among the subjects.
3. It was not possible to control or compensate for an increase in efficiency during exercise due to a learning component or familiarity with the task

taking place.

HYPOTHESES

The following hypotheses were tested at the $p \leq 0.05$ level.

1. The MVV_{15} with the respirator will be a significant predictor of work performance based on the VO_2 max.
2. The MVV_{15} with the respirator will be a significant correlate of ventilation at a submaximal level.

DEFINITIONS

FVC- (Forced Vital Capacity) The volume of air that can be forcefully expelled from the lungs after a maximal inspiration.

FEV1.0- (Forced Expiratory Volume 1.0) The amount of air that can be forced from the lungs in one second after a maximal inspiration. It is the first second of the FVC and is often expressed as a percentage of the FVC.

FEF25-75- (Forced Expiratory Flow 25-75) Refers to the flow rate (liters per second) of air during the middle 50% of the forced vital capacity.

MVV15- (Maximal Voluntary Ventilation 15) The maximal volume that can be moved into and out of the lungs in 15 seconds. Usually measured as the amount expired per a given time. This study refers to MVV_w and $MVV_{w/o}$ to designate MVV's performed with or without a respirator.

V_E - (Ventilation) The amount of air that is being moved into or out of the lungs per minute. Usually measured during expiration.

$\dot{V}O_{2\max}$ - (Maximum Oxygen Consumption) This is the greatest amount of oxygen that can be taken in, transported and utilized by the tissues in one minute, This is a very good indicator of aerobic fitness.

VT- (Ventilatory Threshold) This occurs when the ventilation increases disproportionately with the increase in oxygen consumption. This usually corresponds to what is termed the anaerobic threshold.

CHAPTER II

REVIEW OF LITERATURE

This section reviews pertinent research that has been done to establish some of the physiological variables that are altered while wearing a respirator.

Resistance:

Two studies have shown that an increase in inspiratory resistance from respirator wear causes a decrease in ventilation and an increase in inspiratory time during submaximal exercise (Wilson et al. 1989; Babb et al, 1989).

According to Raven in his review (1979), the increased inspiratory time as a result of increased resistance is compensated for in the human ventilation system. The body is able to compensate by decreasing expiratory time in order to keep the breathing frequency constant and the metabolic cost of ventilating relatively unchanged. An increase in expiratory resistance has also been shown to decrease ventilation and to decrease tidal volume (Louhevarra, 1984). A study by Tabakin et al. (1960), showed that an increase in expiratory resistance (51mm H₂O at 0.7 liters per second) caused the ventilation rate, oxygen consumption, and carbon dioxide production to decrease abruptly. However, the oxygen consumption and carbon dioxide production values adjusted to reference values after several minutes. The ventilation values stayed below those measured when no resistance was present.

The studies most pertinent to this project are ones that combine both inspiratory and expiratory resistances. Louhevaara (1984) has shown that air purifying respirators have inspiratory resistances ranging from 31-52mmH₂O at a flow rate of 1.4 liters/second. The expiratory resistance reported is slightly less with amounts ranging from 20-31mmH₂O at a flow rate of 1.4 liters/second.

Cerretelli et al. (1969) and Gee et al. (1968) demonstrated that ventilation was consistently decreased during submaximal exercise with increased inspiratory and expiratory resistance. During near maximal exercise, ventilation was decreased 30 to 50% in comparison to the values measured without the added resistance. Gee and associates (1968) suggested that an increase in resistance during the expiratory phase of breathing tends to have a greater negative effect than does resistance during the inspiratory phase of breathing.

Dead Space:

Increased dead space is another condition caused by respirator wear. The air purifying designs show increased dead spaces ranging from 195 to 500ml depending on the brand and whether the mask is a full-face or half-face design (Louhevaara, 1984). A study by Harber et al. (1982) showed the increase in dead space from an air purifying mask increased tidal volume thereby increasing ventilation. Increased dead space also tended to decrease the inspiratory time. The Harber study involved subjects pedaling a bicycle ergometer at a submaximal workload determined by each subject. The submaximal values were used to show that lower work levels could elicit physiological alterations while wearing an air purifying

device.

In his review, Luohavaara (1984) cites several studies where the ventilation rate increased almost linearly as the size of the external dead space increased. This ventilation increase was shown repeatedly to come from increased tidal volume.

Individual variations between subjects regarding their responses to the various external dead space sizes may stem from their individual sensitivity to carbon dioxide, since the increases in ventilation result from the hypercapnoeic drive.

Increased Weight:

Another consideration of respirator wear is the increased metabolic demand that results from carrying the device. In his review, Louhevaara (1984) summarizes some of the effects caused by the extra weight of a SCBA device. The weight has been shown to increase ventilation, oxygen consumption and heart rate at submaximal exercise workloads. During heavy exercise, the relationship between workload and the aforementioned variables is not linear. The extra weight from wearing a respirator can cause a significant decrease in maximal physical work capacity. In addition to the increased respiratory resistance, it is another factor contributing to the decrease in performance (Raven et al., 1977).

Decreased Work Performance:

In his review, Raven (1979) discusses several studies that demonstrate the increased resistance to breathing resulting from respirator wear significantly affects worktime at both maximal and submaximal levels. In a

study by Van Huss et al. (1967) thirteen highly trained distance runners were required to run a timed half mile on a track while wearing several air purifying devices. The respirators significantly increased running times as compared to the control times. Van Huss also required these runners to do a run to exhaustion on a level treadmill at ten miles per hour. Times to exhaustion were reduced when compared to control conditions.

Craig et al. (1970) required subjects to exercise with an air purifying respirator mask while the filter cartridges were detached. They found that with the mask alone, work time was decreased. He also showed that wearing an air purifying device with the filters attached, reduced work time approximately 21 to 27%. In a recent investigation, Wilson et al. (1989) showed that pressure demand respirators decrease submaximal work (at 70% of $VO_2\text{max}$) from an average 69.1 to 55.6 minutes (19.5%) due to the increased work of breathing.

In a study by Martin and associates (1979), subjects performed bouts of submaximal exercise. As the core temperature of the subjects rose as a response to the work, the ventilation increased as well. This occurred during steady state work. The frequency of breathing and tidal volume profiles changed during the work. Tidal volume became lower and the frequency of breathing became accelerated. With workers in a situation where respirators are required, the submaximal ventilation would increase as the core temperature increased. The ventilation would then be higher in order for the worker to accomplish the same amount of work. If the ventilation was held constant, the rate of work would be decreased. Work performance would continue to decline so the ventilation volume could remain unchanged as the core temperature increased. In wildland fire situations, workers

could be exposed to an additional radiant heat load which would further raise the core temperature. The addition of the radiant heat load could compound the increase ventilation phenomena. When combined with the increase in body temperature as a result of the muscular work, this could lead to a dramatic decrease in work performance.

Employee Selection:

As a result of the increased physiological demand that is imposed by respirator wear, two authors have discussed possible certification measures for potential respirator wear (Kraut, 1988; Hodous, 1986). Although both articles are vague in regard to specific measures, it is apparent that there is a concern with the amount of work the individual is able to do (Intensity and Duration), and the pulmonary function of the individual.

Studies by Raven et al. (1981; 1989) have attempted to identify a simple pulmonary function test that could predict a workers ability to wear a respirator. Utilizing multiple regression techniques, Raven et al. (1981; 1989) have found the MVV_{15} to be the pulmonary function test of choice. The MVV_{15} measured while wearing a respirator correlates significantly with a persons' maximal work capability while wearing a respirator.

Raven has shown that the MVV_{15} can be decreased 7 to 33% while wearing a respirator. This is important since Freedman (1970) showed that 64% of the MVV_{15} was a maximal tolerable ventilation value for short term work. Freedman concluded that 50% of the MVV_{15} could be maintained during prolonged work shifts.

Raven et al. (1988) explains that a ventilatory drift (creep) or increased ventilation can occur during work under steady state conditions. A ventilation increase of up to 30 liters/minute can occur with this creep. This becomes important for the worker when wearing a respirator. For example, a worker that is wearing a respirator may have their MVV_{15} reduced anywhere from 7 to 33%. When this decline in capacity is combined with the ventilatory drift, this could raise ventilation above the 50% value that could be maintained during prolonged work. This is where the level of work becomes important. According to Astrand & Rodahl (1986), a workrate of 1.5 to 2.0 liters of oxygen per minute requires a ventilation of 40 to 60 liters/minute. A worker's capacity or reserve level may not be high enough to allow him to work at this level. The respirator could become a substantial hinderance for a worker trying to sustain a reasonable work rate, or for a worker in a life threatening situation.

Dypsnea:

Raven (1982) has suggested a method to determine whether a respirator should be contraindicated. The dyspnea index (V_E/MVV_{15}) which is calculated by dividing the ventilation required to do the work by the individuals MVV_{15} with a respirator. If the value is greater than 70% (50% for prolonged work) the respirator should not worn by that individual. This scale is based on the premise that the workload may be too great for the respiratory system to maintain the required ventilation. This could provide a way to screen workers for strenous work based on reduced pulmonary function values caused by the resistance of the breathing device.

CHAPTER III

METHODOLOGY

Subjects:

This study utilized 15 volunteer male subjects between the ages of 19 and 33 years of age (Table 1). Subjects were not required to meet a minimum fitness requirement (VO_2 max). The participants in this study were all required to sign an informed consent, and a medical history questionnaire form before any testing was done (Appendix A, B) All testing was done in the Human Performance Laboratory on the University of Montana Campus. The testing was done in three phases as follows.

Phase One: Pulmonary Function Tests

The first phase of testing was a battery of pulmonary function tests using a Vitalograph portable spirometer. This machine was calibrated before use each day's use with a syringe of known volume (3 liters). The FVC, FEV_{1.0}, and the FEF₂₅₋₇₅ measures were determined for each subject using this machine. Each subject performed the tests with a nose clip. The procedures for proper technique when giving pulmonary function tests can be found in a booklet titled Clinical Spirometry, which was published by the Warren Collins Corporation (Collins, 1961). The MVV was determined using a Tissot 600 liter spirometer. The MVV test consisted of four trials on each subject. The first two trials were performed using a mouthpiece attached to a Rudolph valve ($\text{MVV}_{w/o}$). Subjects wore a nose clip during this test. The

second set of trials was completed with the subjects wearing the respirator (MVV_w). The collection hose was attached to the outlet valve on the respirator with a hose clamp. All the values were converted from atmospheric temperature pressure saturated (ATPS) to body temperature pressure saturated (BTPS) conditions.

During the MVV_w , the subjects were instructed to apply pressure to the respirator with the hands to insure a good seal during the test. Timing during this testing was done with a hand held stopwatch. Subjects were given instructions before performing the MVV trials and were encouraged during the actual testing.

The MVV measures used in this study were obtained ad lib. The subject used the breathing rate and depth that he felt would elicit the greatest values. Other studies have used a breathing rate of 40 breaths per minute during an MVV trial (Shephard, 1982). The reasoning for this method is an attempt to standardize the MVV test. The MVV or maximal voluntary ventilation is not really a maximal voluntary effort if the subject is limited to a rate other than the one he chooses. Shephard (1982) has shown that MVV_{40} values underestimate the true value. Calculations for respirator wear based on the MVV_{40} , will require a correction factor since this method will disqualify otherwise capable workers. This issue of MVV test procedure needs clarification if the MVV is to be used for worker certification.

Phase Two: Maximal Graded Exercise Test: No Respirator

The second phase of testing required each subject to perform a graded maximal treadmill test. The test protocol involved the subjects walking at

4 miles per hour on a Quinton motorized treadmill, with constant grade increases of 2.5% every 1 to 2 minutes based on each subject's level of fitness. This determination was arbitrary since the graded exercise test was to last ideally between 9 and 15 minutes. The subjects with lower fitness levels would not have the capacity to increase grade each minute and still have the test last the minimum amount of time. For this reason, the subjects with elevated heart rates and respiratory quotient values at an early stage were given a grade increase every 2 minutes. Each subject wore pants and a shirt made from a fire retardant material (Nomex). A U.S. Forest Service pack (24 pounds) was also worn by the subjects.

Expired gases were collected using a metabolic measurement cart (Beckman) which was calibrated with known gas concentrations before each test. Data obtained from this device included $\dot{V}O_2$ ml/kg/min, $\dot{V}O_2$ liters, and VE. Heart rates during the tests were monitored using a telemetry device (CIC Heartwatch). Subjects were asked every 2nd minute for their degree of breathlessness or dyspnea (1 to 10 scale with 1 meaning no breathlessness at all, to 10 very breathless). The dyspnea scale used in this study was based on a perceived exertion scale developed by Borg and a co-worker (1974). The use of this scale for perceiving the degree of breathlessness that a subject was experiencing during exercise was proposed by Bakers and Tenney (1970). During the maximal tests, subjects were given verbal encouragement. They were also instructed that they could quit at any time if the need arose. The subjects seemed to be highly motivated and they all pushed themselves to their limit with little hesitation.

Phase Three: Maximal Graded Exercise Test While Wearing a Respirator

Phase three of the testing was done much like phase two, except the subjects performed the work on the treadmill while wearing a respirator mask. The masks used during this study were of the air purifying type. The specific model was the COMFO II, which is manufactured by the Mine Safety Appliances Company. The respirator was a half-faced rubber device which straps over the head with a multiple strap yoke. The mask had a lower set of straps that went around the back of the neck to insure a good seal at the chin.

This respirator met the NIOSH (National Institute for Occupational Safety and Health) and MSHA (Mine Safety and Health Administration) specifications. During this study, the masks were equipped with two filter cartridges of the GMC-H type. These are high efficiency particulate filters (HEPA) that are approved for respiratory protection against organic vapors, chlorine, hydrogen chloride, sulfur dioxide, chlorine dioxide, dust, fumes, mists, asbestos containing dusts and mists and radionuclides. Cannisters were changed after every four tests to insure the minimum amount of inspiratory resistance possible with this system.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

Descriptive statistics were determined for all data. Paired T-tests were used to establish the significance of differences between the no respirator vs. respirator variables. Pulmonary function values were correlated with work performance using the Pearson Product Moment Correlation. All data was analyzed using an Apple Macintosh Computer, using Statview 512K for the Macintosh.

Descriptive characteristics of the 15 subjects are listed in Table 1. The mean VO_2 max without the respirator mask was 48.5 ml/kg/min. The group had an above average level of aerobic fitness based on the VO_2 max. The U.S. Forest Service requires a minimum VO_2 value of 45 ml/kg/min for wildland firefighters. Most of the subjects met this requirement. Table 2. lists some of the pulmonary function variables tested in this study and the mean scores for the fifteen participants. These tests were performed without a respirator.

Table 3. deals with respirator/no respirator differences for several of the variables obtained during pulmonary function and exercise testing. The MVV was reduced significantly with the respirator. A mean reduction of 23.8% occurred with a respirator of medium resistance. The VO_2 max was also reduced 6% while wearing the respirator.

Table 4 lists the level of significance between pairs of variables which

were affected by the increase in resistance brought about by the respirator. The MVV, VO_2 max, Max Ventilation and the ventilatory threshold all show significant differences ($p \leq 0.05$) when compared in paired-t tests.

Table 5 lists the correlations between the MVV's, and different levels of work and the ventilatory threshold (VT). The correlations are shown with their t values and the levels of significance. There were no significant correlations ($p \leq 0.05$) between the MVV values and the work performed.

The dyspnea values for the submaximal and maximal work levels were significantly different when the respirator/no respirator tests were compared. Submaximal tests elicited dyspnea means of 1.27 for no respirator work and 2.07 for the respirator work ($t = 2.567$, $p = 0.022$). The dyspnea values for the maximal work trials (VO_2 max) were 8.06 without the respirator and 9.33 with the respirator ($t = 2.738$, $p = 0.016$). The dyspnea scale of breathlessness can be found in table 6.

Table 1

DESCRIPTIVE CHARACTERISTICS OF THE 15 SUBJECTS

Variable	Mean \pm SD
AGE (yr)	26.13 \pm 3.75
HEIGHT (cm)	177.76 \pm 5.35
WEIGHT (kg)	82.56 \pm 14.423
FITNESS (VO_2)	48.52 \pm 7.71

Table 2

GROUP MEANS FOR SEVERAL PULMONARY FUNCTION TESTS

<u>Variable</u>	<u>Mean Volumes (L) \pm Sd</u>
FVC	5.78 \pm .52
FEV 1.0	4.39 \pm .68
FEV 1.0/FVC	75.6% \pm 8.25

Table 3

RESPIRATOR/NO RESPIRATOR DIFFERENCES FOR SEVERAL PULMONARY
FUNCTION VARIABLES (Group means for 15 subjects)

VOLUMES(L.)			
<u>VARIABLE</u>	<u>RESPIRATOR</u>	<u>NO RESPIRATOR</u>	<u>%CHANGE</u>
MVV ₁₅	143.49	189.86	(-23.8)
VO ₂ max	45.6	48.52	(-6.01)
MAX VE	111.42	128.98	(-13.61)
VT	75.93	81.13	(-6.40)

Table 4

SIGNIFICANT DIFFERENCES AMONG SELECTED VARIABLES
(Paired t-test values)

<u>VARIABLE</u>	<u>DF</u>	<u>PAIRED-T</u>	<u>PROBABILITY</u>
$MVV_w - MVV_{w/o}$	14	-7.1	.0001
$VO_2 \max_w - VO_2 \max_{w/o}$	14	-3.784	.002
$VT_w - VT_{w/o}$	14	-2.599	.021
$MAX VE_w - MAX VE_{w/o}$	14	-5.151	.0001

Note: The variables in the table are subscripted with W and W/O to designate measures with a respirator and without a respirator respectively.

Table 5

CORRELATIONS AMONG SELECTED VARIABLES

<u>VARIABLES</u>	<u>r</u>	<u>t</u>	<u>SIGNIFICANCE</u>
MVV _w - VO ₂ max _{w/o}	0.313	1.188	0.20
MVV _{w/o} - VO ₂ max _{w/o}	0.361	1.395	0.20
MVV _w - 22-25 ml O ₂ /min	-0.386	1.508	0.20
MVV _{w/o} - 22-25 ml O ₂ /min	-0.447	1.801	0.10
MVV _w - VT _w	0.303	1.150	0.20
MVV _{w/o} - VT _w	0.371	1.440	0.20

Table 6

DYSPNEA SCALE (Perceived Exertion Scale)

0	NOTHING AT ALL
1	VERY WEAK
2	WEAK
3	MODERATE
4	SOMEWHAT STRONG
5	STRONG
6	
7	VERY STRONG
8	
9	VERY, VERY STRONG
10	MAXIMAL

NOTE: The following scale was used to assess the workers degree of breathlessness during work both with and without the air purifying respirator mask. The 0, was considered not breathless at all and the 10 was maximum breathlessness.

(Borg & Noble, 1974)



Figure 1 Subject performing a pulmonary function test.



Figure 2 Subject performs a work trial on the treadmill. The exhale valve is attached to the metabolic measurement cart. The subject in this photograph is not wearing the Forest Service backpack. Clothing is the Nomex fire resistant wear worn by the wildland firefighter.

DISCUSSION

This study investigated some of the effects or changes caused when a subject wears an air purifying mask of medium resistance.

RESPIRATOR VS NO RESPIRATOR

The results in Table 4 show the significant differences between certain variables that were affected by the use of the respirator mask. The VO_2 max was reduced by 2.9 ml O_2 /kg/min or 6%. This reduction in VO_2 max, may suggest that agencies, such as the U.S. Forest Service need to re-examine their minimum fitness requirements if respirators are to be worn during strenuous work. There seems to be no relationship between the level of fitness and the reduction in VO_2 during work as a result of wearing the respirator device.

The maximal ventilation was reduced by the respirator, although it was not affected as much as the MVV. This was probably due to the fact that the air volumes flowing through the mask during the maximum minute ventilation were less than during the MVV tests.

MAXIMAL VOLUNTARY VENTILATION (MVV)

The results show that the mean reduction in MVV_w trials vs. $MVV_{w/o}$ trials was 23.8%. The maximum ventilation values show a mean reduction of 13.6% in respirator - no respirator comparisons. The results obtained in this study were similar to those reported by Raven and co-workers (1981). The subjects with higher $MVV_{w/o}$, showed the greater reduction in MVV_w . This is due to the greater resistance at higher flow rates, thereby lowering

the mask trials. The subjects with lower MVV values were affected much less when wearing the respirator.

The $MVV_{w/o}$ was correlated with the VO_2 max. ($r = 0.361$, $p = 0.20$) While not a significant correlation, it was the highest relationship of a pulmonary function value correlated with maximal work performance (VO_2 max). The MVV_w was correlated to the VO_2 max with the respirator ($r = 0.313$, $p = 0.20$). A similar study, (Wilson & Raven, 1989) reported correlations of 0.31-0.36 when the MVV with and without a respirator was correlated with the VO_2 max. Although the correlations were low in their study, they were statistically significant due to the larger number of subjects ($n = 38$). In this study, the MVV_w was not significantly correlated with the VO_2 max; however, it was the best indicator of maximal work performance (VO_2 max). With more subjects, the correlation would be more likely to show significance. Since the MVV is not a significant predictor of work performance at the ($p \leq 0.05$) level of significance, the first hypothesis must be rejected.

The correlation ($r = -0.447$ $p = 0.10$) between the MVV_w and the submaximal ventilation at the 22-25 ml O_2 /kg/min workload was negative. The correlation shows that with higher MVV tests, the ventilation requirement for steady state work is lower for that level of work. The subjects with the high MVV's in this study are generally the ones with the better aerobic fitness. This could suggest that the improvement in efficiency comes from the training effect which would lead to a reduced metabolic acidosis at a submaximal level. The decreased metabolic

acidosis during levels of submaximal work as a result of training would lead to a lessened drive by the system to increase the ventilation (deVries, 1980). This would allow the worker to have a lower ventilation for a given submaximal $\dot{V}O_2$.

The second hypothesis, stated that the MVV_w pulmonary function test would be a significant correlate of submaximal ventilation. The $MVV_{w/o}$ was the best pulmonary function correlate to the submaximal ventilatory requirement, but neither it nor the MVV_w was significant. The second hypothesis must be rejected since the level of significance did not reach the $p \leq 0.05$ level. The correlation was significant at the $p = 0.10$ level and with more subjects in the study, the $p = 0.05$ level might have been reached. The mean ventilation at the 22-25 ml O_2 /kg/min workload for the subjects in this sample was 47.66 liters which fits the category of very heavy work according to Astrand & Rodahl(1989).

The MVV pulmonary function test has an important application to the screening of potential respirator wearers. The MVV is a test that provides a direct indication of the respiratory muscles' ability to convert chemical energy into ventilatory work. It has been shown that endurance training, which leads to higher $\dot{V}O_2$ max values, can augment the MVV values by 14%. Training leads to a level where the subject can maintain 96% of the MVV for fifteen minutes of heavy exercise. The gains in the MVV can be attributed to respiratory muscles that don't fatigue as rapidly due to the training effect (Shephard, 1982).

The ventilatory threshold data (VT) obtained from this study was

determined by plotting oxygen uptake against ventilation (Astrand & Rodahl, 1986). The threshold values were compared for both respirator and no respirator trials. The difference was not significant ($t = 0.942$, $p = 0.36$) in this group of subjects. When MVV's were correlated with the ventilatory threshold while wearing the respirator, correlations were high but not significant (Table 5).

In this study the Ventilatory Threshold is as important as the VO_2 max values. Workers will rarely be asked to perform work at their VO_2 max, and if they were it could not be maintained for a very long period of time. Forest Service firefighters work at a submaximal level for prolonged periods (over 8 hours). The $MVV_{w/o}$ could be an indicator of the workers ability for prolonged work since the higher the MVV, the higher the ventilatory threshold. In addition, the greater difference between the ventilatory threshold and the ventilation required to achieve the 22-25 ml O_2 /kg/min work level, the longer the worker could maintain the submaximal work.

ORDER OF TESTING

During this study testing was done in a pre-determined order. The work trials were not done in random order to compensate for the learning component from one trial to the next. Since the order effect was not controlled, it could be hypothesized that the second trial would have been more familiar and thus easier, possibly minimizing the effects of the respirator. In this study, the VO_2 max was reduced by 6.01% during the

respirator trial. With controls for order effects the respirator may have reduced the $\dot{V}O_2$ max to lower levels in relation to the no respirator trials. The testing started with the no mask work trial and was followed by the trial with the respirator. This was due to the nature of the testing.

The $\dot{V}O_2$ max test on a treadmill is not a pleasant test. It is one that many subjects will perform once if given the option. By using a respirator during the first work trial, many subjects may not have wanted to come back for another trial. The increased discomfort caused by the respirator during work was a concern of the subjects. By doing the no respirator trial first, the subjects were able to experience a max test without the added discomfort of the respirator.

OVERHEATING/DYSPNEA

After the respirator trial, subjects complained consistently about the feeling of overheating and the difficulty of getting the large air volumes required to do the work. The subjects comments' regarding the overheating sensation could suggest that the increased dead space of the device causes the subject to re-breathe an amount of already warmed gas. Another factor that may have a great deal to do with the heat stress caused by the respirator is that it is manufactured from a rubber material that covers approximately half the face. (See Picture, Figure 2) This blocks a large amount of exposed skin that is normally available for the evaporative cooling of sweat.

The increased inspiratory and expiratory resistances placed on the subject during the respirator trials lead to higher dyspnea values during the

later stages in the testing as compared to similar workloads during the no respirator trials. The dyspnea values (Table 6) during this study were determined using a perceived exertion scale. The subjects identified their level of breathlessness on a scale from one to ten. The lower numbers indicated that the work did not make the subject feel breathless, and the higher numbers signified that the work required a level of ventilation that was very difficult to achieve.

The results of this study indicate that at the submaximal workload (22-25 ml O₂/kg/min), the mean dyspnea values with the respirator were 2.07 as compared to a mean value without the respirator of 1.27 (t = 2.567, p = .022) These values are not that different at the lower workload, although they are significantly different (p ≤ 0.05). Despite the significance levels between the dyspnea values, it could be suggested that accomplishing submaximal work with the addition of the respirator mask does not add a great deal to worker discomfort. At the higher workload (VO₂ max), the dyspnea values were 9.33 with the respirator and 8.06 without the respirator (t = 2.738, p = .016). Although these values do not seem markedly different, the comments regarding the increased difficulty of breathing during the mask trials indicated a noticeable difference.

EMPLOYEE SELECTION?

The MVV values with a respirator showed a mean reduction of 46.3 liters. The mean MVV values while wearing a respirator for the group sampled was 143.49 liters. Work done by the wildland fire fighter can be classified on the basis of oxygen requirement. The prolonged work of a Forest Service

firefighter requires an oxygen consumption of 22-25 ml/kg/min (Jukkula, & Sharkey, 1988). To achieve a $\dot{V}O_2$ of this value, a ventilation of 47-50 liters is required. Astrand & Rodahl (1986) classify this as very heavy work.

Researchers have said that a ventilation of 50% of the MVV can be maintained for extended periods (Freedman, 1970). The mean value of this group was 143.49 liters. Half of this value is 71.7 liters. The work requirement of 47-50 liters would not tax this group as a whole, but several individuals would be borderline. And while the mean values show a sustainable ventilation capacity, the ventilatory drift could compromise the workers over a long period of time (Raven et al., 1988).

Subject #10 in this study showed an $MVV_{w/o}$ of 136.17. That value was reduced 57.47 liters to 78.7 while wearing the respirator. Fifty percent (.50) of the MVV_w yields a value of 39.35 liters. This subject would have difficulty doing the work at the level required while wearing the respiratory protective device. With the addition of a heat load, the ventilation requirement could be increased, thereby increasing the ventilatory requirements of the work (Martin et al. 1979).

The subjects in this study had a range of fitness values from 32 - 57 ml O_2 /kg/min ($\dot{V}O_2$ max). The subjects with $\dot{V}O_2$ max values at or above the 45 ml O_2 /kg/min level are capable of performing the submaximal work (22 -25 ml O_2 /kg/min). The subjects with low $\dot{V}O_2$ scores had a ventilation that was below the ventilation requirements of the work. This could suggest that the minimum fitness value of 45 ml O_2 /kg/min is an adequate level of

aerobic capability to insure the success of a male worker who must use a respirator.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

Fifteen male subjects between the ages of 19 and 35 underwent a battery of pulmonary function tests and two graded exercise tests to maximum ($\dot{V}O_2$ max). The maximum voluntary ventilation was determined using a 600 liter spirometer. MVV values were obtained both with and without the respirator mask. Treadmill tests were given at a speed of 4 miles per hour, with grade increases of 2.5% every minute or every second minute for the less fit subjects. One test was performed without an air purifying respirator and one test was performed with a respirator. Gas collection was done with a Beckman metabolic measurement cart. Values obtained were $\dot{V}O_2$ and ventilatory data.

The primary purpose of this study was to determine the effects of air-purifying respirators on work performance and pulmonary function. The results show that MVV, $\dot{V}O_2$ max, the ventilatory threshold (VT) and the minute ventilation were all significantly reduced during work trials with the respirator as compared to trials without the respirator.

In addition, the MVV with the respirator was correlated ($r = 0.313$, $p = 0.20$) with the $\dot{V}O_2$ max. It was hypothesized in this study that the MVV_w would be a significant predictor of performance based on the $\dot{V}O_2$ max. This hypothesis was rejected ($p > 0.05$). The submaximal ventilation at a $\dot{V}O_2$ of

22-25 ml O₂/kg/min. was correlated ($r = -0.447$ $p = 0.10$) with the MVV with the respirator. The second hypothesis of this study stated that the MVV_w would be a significant correlate of ventilation at a submaximal level. This hypothesis was rejected since it didn't reach the $p = 0.05$ level of significance. This correlation demonstrates that as the MVV is higher, the ventilatory requirement for submaximal work seems to be lower.

The subjects of this study responded to a scale of perceived dyspnea during the treadmill work. The results show that the subjects felt a significantly greater level of breathlessness during the point where VO₂ max occurred during the work trial with the respirator as compared to the no respirator trial. The dyspnea values for respirator/no respirator trials were 8.06 and 9.33 respectively ($t = 2.738$, $p = 0.016$) (See Table 6 for dyspnea scale). At the submaximal work level, (22-25 ml O₂/kg/min) the dyspnea values for respirator/no respirator bouts were significantly different. The mean values were 1.27 for the no respirator trial and 2.07 for the trial with the respirator ($t = 2.567$, $p = 0.022$). Although the dyspnea values are significantly different at the submaximal workload, the addition of the respirator at this level of work does not add too much to the discomfort of the worker.

CONCLUSION

The air purifying respirators used in this study made dramatic changes to several physiological variables during work. The respirator increased the level of breathlessness (dyspnea) that the subjects experienced both at maximal and submaximal levels. Further, the MVV pulmonary function test was reduced approximately 24% when the respirator was added.

The VO_2 max was reduced 6% when comparing work with the respirator to work without the respirator. These findings seem to suggest that the fitness level of the worker is paramount if the tasks that must be accomplished require an air-purifying respirator. The greater the fitness level of the subject, the greater the ventilatory reserve will be over and above the level of the work. It is important that industrial hygienists or trained medical personnel know the characteristics of the work that is to be performed and its metabolic cost when screening potential workers for respirator wear. It is also essential that the fitness levels (VO_2 max) of the potential workers are determined before they are assigned to specific duties that require the use of a respirator.

The MVV without the respirator was correlated to the ventilation at a submaximal worklevel. The results show that the larger the MVV the subject has, the lower the ventilation required to perform the submaximal work.

This study also determined that the MVV is the best predictor of work performance based on the VO_2 max, and could be used as a possible screening method for respirator wear. This is due in part to the fact that the MVV test gives an indication of the conditioning of a subjects' respiratory

muscles. The values of an MVV pulmonary function test are augmented with endurance conditioning. By improving the level of condition, through a training program, the worker has conditioned the respiratory muscles which insure a good MVV test (Shephard, 1982). Asthmatics may have decreased MVV's despite their level of fitness. This would be due to the restrictive nature of the disease (bronchoconstriction).

The MVV test could be used as follows: The subject performs an MVV while wearing a respirator. This value is then halved since studies have shown that fifty percent (.50) of the MVV can be maintained for prolonged periods (8 hours) (Freedman, 1970). The individual or agency doing the screening must then look at the level of the work based on its ventilatory requirement. The ventilatory requirement is then compared to the workers' adjusted MVV value and a determination is made. The person or agency doing the screening must know the physical requirements of the work and the extraneous variables which may affect the worker. These can include high temperature, humidity and altitude. Based on the MVV test, the workers' VO_2 max and the demand of the work, an intelligent decision could be formulated regarding the workers suitability for respirator wear.

RECOMMENDATIONS

1. Based on a drop in VO_2 max from no respirator to respirator conditions, and the expected drop in work performance, there may be a need to raise minimum fitness requirements if respirators are to be worn for arduous work.
2. Additional data is needed on female subjects since the average female has lower pulmonary function, MVV and VO_2 max scores.
3. The subjects in this study may have been too fit to show dramatic results in the respirator/no respirator comparisons. Future studies should include subjects with a wider range of fitness values.
4. There is a need to compare an MVV done with a breathing frequency of 40 breaths per minute with the maximal voluntary ventilation, based on the rate and depth chosen by the subject. The reduction to the MVV and the MVV at a frequency of 40 breaths per minute as a result of respirator wear could be compared. A study of this type would demonstrate if there should be a specific set of standards adopted for MVV methodology.

REFERENCES

- Astrand, P. O., & Rodahl, K. (1986). Textbook of Work Physiology, (3rd ed.). New York: McGraw Hill.
- Babb, T., Turner, N., Saupe, K., & Pawelczyk, J. (1989). Physical performance during combinations of hypercapnic, resistive, and hot air breathing. American Industrial Hygiene Association Journal, 50, (2), 105-111.
- Bakers, J. H., & Tenney, S. M. (1970). The perception of some sensations associated with breathing. Respiratory Physiology, 10, 85-92.
- Borg, G. A. V., & Noble, B. J. (1974). Perceived exertion. Exercise and Sport Science Reviews, 2, 131-154.
- Craig, F., Blevins, W., & Cummings, E. (1970). Exhausting work limited by external resistance and inhalation of CO₂. Journal of Applied Physiology, 29, 847-861.
- Cerretelli, P., Sikand, R., & Farhi, L. (1969). Effects of increased airway resistance on pulmonary ventilation and gas exchange during exercise. Journal of Applied Physiology, 27, 597-600.
- Clinical Spirometry (1961). Boston, Massachusetts: Warren E. Collins Inc.
- Demedts, M., & Anthonisen, R. (1973). Effects of increased external airway resistance during steady state exercise. Journal of Applied Physiology, 35, 361-366.
- deVries, H. A., (1980). Physiology of Exercise for Physical Educators and Athletics. (3rd ed.). Iowa: Wm. C. Brown Company Publishers.
- Freedman, S., (1970). Sustained maximal voluntary ventilation. Respiration Physiology, 8, 230-244.

- Gee, J. , Vassallo, B. , & Gregg, J. (1968). Effects of external airway obstruction on work capacity and pulmonary gas exchange. American Review of Respiratory Disorders, 98, 10003-1012.
- Harber, P. , Tamimie, R. , Bhattacharya, A. , & Barber, M. (1982). Physiological effects of respirator dead space and resistance loading. Journal of Occupational Medicine, 24, (9), 681-689.
- Hodous, T. (1986). Screening prospective workers for the ability to use respirators. Journal of Occupational Medicine, 28, (10), 1074-1080.
- Jones, N. , Levine, G. , Robertson, D. , & Epstein, S. (1971). The effect of added dead space on the pulmonary response to exercise. Respiration, 28, 389-398.
- Jukkula, H. , & Sharkey, B. , (1988). An improved wild land firefighting hand tool. U. S. Forest Service Project Report.
- Kraut, A. (1988). Industrial Respirators: Certifying the workers. American Family Physician, 37, (1), 117-126.
- Louhevaara, V. (1984). Physiological effects associated with the use of respiratory protective devices: A review. Scandinavian Journal of Work and Environmental Health, 10, (5), 275-281.
- Martin, J. , Morgan, E. , Zwillich, C. , & Weil, J. (1979). Influence of exercise hyperthermia on exercise breathing pattern. Journal of Applied Physiology, 47, 1039-1042.
- Raven, P. , Davis, T. , Shafer, C. , & Linnebur, A. (1977). Maximal stress test performance while wearing a self contained breathing apparatus. Journal of Occupational Medicine, 19, 802-806.
- Raven, P. , Dodson, A. , & Davis, T. (1979). The physiological consequences of wearing industrial respirators: A Review. American Industrial Hygiene Association Journal, 40, 517-534

- Raven, P. , Bradley, O. , Young, D. , McClure, F. , & Skaggs, B. (1982). Physiological responses to "pressure demand" respirator wear. American Industrial Hygiene Association Journal, 43, 773-781.
- Raven, P. , Moss, R. , Page, K. , Garmon, R. , & Skaggs, B. (1989). Clinical pulmonary function and industrial respirator wear. American Industrial Hygiene Association Journal, 42, 897-903.
- Shepard, R. J. (1982). Physiology and Biochemistry of Exercise, New York: Preager Publishers.
- Thompson, S. , & Sharkey, B., (1966). Physiological cost and air flow resistance of respiratory protective devices. Ergonomics, 9, 495-499.
- Tabakin, B. , & Hanson, J. (1960). Response to ventilatory obstruction during steady state exercise. Journal of Applied Physiology, 15, 579-582.
- VanHuss, W. , Hartman, F. , Craig, F. , & Steinhaus, A. (1967). Respiratory burden of the field protective mask under exercise load. (Abstract) Fed. Pros. 26, 721.
- Wilson, J. , Raven, P. , Zinkgraf, S. , & Morgan, W. (1989). Alterations in physiological and perceptual variables during exhaustive endurance work while wearing a pressure demand respirator. American Industrial Hygiene Association Journal, 50, 139-136.
- Wilson, J. , & Raven, P. , (1989). Clinical pulmonary function tests as predictors of work performance during respirator wear. American Industrial Hygiene Association Journal, 50, 51-57.
- Wilson, J. , Raven, P. , & Morgan, W. (1989). Effects of pressure demand respirator wear on physiological and perceptual variables during progressive exercise to maximal levels. American Industrial Hygiene Association Journal, 50, 85-94.

APPENDIX A
MEDICAL HISTORY QUESTIONNAIRE

MEDICAL HISTORY QUESTIONNAIRE

Name: _____ AGE: _____
 Date : _____

List the date of your last:

Physical Exam: _____

EKG: _____

1. Have you been told by a doctor that you have or have had any of the following (please check each response) :

- | <u>Yes</u> | <u>No</u> | |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | Rheumatic Fever |
| <input type="checkbox"/> | <input type="checkbox"/> | An enlarged heart |
| <input type="checkbox"/> | <input type="checkbox"/> | Epilepsy |
| <input type="checkbox"/> | <input type="checkbox"/> | Heart or vascular disease |
| <input type="checkbox"/> | <input type="checkbox"/> | Metabolic disorders |
| <input type="checkbox"/> | <input type="checkbox"/> | Heart Murmurs |
| <input type="checkbox"/> | <input type="checkbox"/> | Lung or Pulmonary disorders |
| <input type="checkbox"/> | <input type="checkbox"/> | Thrombophlebitis (Blood Clots) |
| <input type="checkbox"/> | <input type="checkbox"/> | High blood pressure |
| <input type="checkbox"/> | <input type="checkbox"/> | Abnormal EKG pattern |
| <input type="checkbox"/> | <input type="checkbox"/> | Diabetes |
| <input type="checkbox"/> | <input type="checkbox"/> | Stroke |
| <input type="checkbox"/> | <input type="checkbox"/> | Allergies/ Asthma |
| <input type="checkbox"/> | <input type="checkbox"/> | Abnormally high blood lipids (Cholesterol/triglyceride levels) |

2. Please list any drugs, medication or dietary supplements PRESCRIBED by a physician that you are currently taking:

3. Have you ever had to wear an industrial respirator in a work situation.

Yes () No () If yes, for how long: _____

What work were you involved in: _____

What type of respirator were you wearing:

Pressure Demand

Air Purifying

SCUBA

4. Do you smoke now? Yes () No ()

a. If yes, how many cigarettes do you smoke per day? _____

b. If no, Have you ever smoked? Yes () No ()

1. How long ago did you quit? _____

5. Are you currently under a great deal of stress either at work, school, or personally? Yes () No ()

6. Do you actively relieve stress through exercise, meditation or other methods? Yes () No ()

7. Are you currently on a regular exercise program? Yes () No ()

Type of exercise you are involved in: _____

Frequency per week: _____

Duration each day: _____

The answers to this questionnaire are true and complete and to the best of my knowledge I am in good health.

Signed: _____ Date: _____

APPENDIX B
HUMAN INFORMED CONSENT

HUMAN INFORMED CONSENT: AIR PURIFYING RESPIRATOR STUDY

You will be involved with three phases of testing. One phase will consist pulmonary function testing. The next two phases will consist of treadmill exercise to a maximal level.

First Phase: This phase of the study will involve some basic pulmonary function measures. You will perform several pulmonary function tests both with and without an air-purifying respirator mask.

Second Phase: The exercise will be a graded exercise test to your maximum capacity for exercise. This test will begin at a level you can easily accomplish and will advance in stages. We may stop the test at any time due to signs of fatigue or you may stop when you wish because of personal feelings of fatigue or discomfort.

There exists the possibility of certain changes occurring during the test. They include abnormal blood pressure, fainting, disorder of heart beat, and in rare instances, heart attack or death. Every effort will be made to minimize these through the preliminary examination and by observations during testing.

Third Phase: This will involve a second maximal exercise test done while walking on a treadmill with increasing grades. During the performance of this test, the work will be done with an air purifying respirator mask. This will increase the resistance to breathing and possibly make you feel fatigued at an earlier point during the exercise. You may stop the test at any time during this trial due to personal feelings of fatigue or discomfort.

The results obtained from this study will help agencies and safety organizations in the future, screen prospective workers for their ability to wear a respirator. If this goal is not met, the information obtained will still contribute to the knowledge base regarding respirators and workers.

If you have any questions about the procedures used in the exercise tests or anything else regarding this study and the information obtained during it, please feel free to ask.

In the event that you are physically injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University or any of its employees you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M. C. A. , Title 2, Chapter 9. In the event of a claim for such physical injury, further information may be obtained from University Legal Counsel.

Your permission to participate in this three-phase study is voluntary. You are free to deny your consent if you so desire.

I have read this form and I understand the testing procedures that I will perform. I consent to participate in this test.

Date: _____ Signature: _____

Witness: _____