DOT/FAA/AM-89-5

Office of Aviation Medicine
Washington, D.C. 20591

"OPERATION WORKLOAD" A STUDY OF PASSENGER ENERGY EXPENDITURE DURING AN EMERGENCY EVACUATION

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March 1989

Final Report

U.S. Department of Transportation

Federal Aviation Administration

Technical Report Documentation Page

1. Report No.
DOT/FAA/AM/89/

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

"OPERATION WORKLOAD" - A STUDY OF PASSENGER ENERGY EXPENDITURE DURING AN EMERGENCY EVACUATION

5. Report Date

6. Performing Organization Code

8. Performing Organization Report No.

7. Author(s)

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10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

Office of Aviation Medicine
Federal Aviation Administration
800 Independence Avenue, S.W.
Washington, D.C. 20591

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

Research leading to preparation of this report was performed under tasks AM-B-87-PRS-81.D and AM-B-88-PRS-81.D

16. Abstract

In an earlier study at the Civil Aeromedical Institute, workloads were determined for passengers during an emergency evacuation. The evacuation tests were conducted in an orderly manner and were suggested as representative of a moderate workload. The current study is a continuation and amplification of that study and utilizes similar techniques for determining workload. In this study, passengers were required to avoid the aircraft aisles and to traverse over seat backs to the exit in order to simulate a maximum effort which might be anticipated in an emergency. Thus, maximum workload could be estimated more realistically. This information is necessary to formulate qualification requirements for passenger protective breathing equipment. Recommended values proposed in the first study should be modified. Original recommendations are listed below and are crossed out when change is indicated, then followed by the recommended new value.

1) A 20-min work profile consisting of:
   15-min at 0.7 W/Kg body weight; 2 min at 1.2 W/Kg body weight;
   1 min at ~~1.5~~ (2.0) W/Kg body weight; 2 min at 1.2 W/Kg body weight.
2) The volume of the smoke hood - type PPBE should exceed the volume that encloses the head and neck by 3.0 Liters.
3) The device should provide 3.0 L/min oxygen for 20 minutes.
4) The device should probably be capable of absorbing ~~45~~ (30) L of CO_2.

The subject population should include one or two individuals who meet or exceed the weight of the 95th percentile male.

17. Key Words

Passenger Protective Breathing Equipment, Emergency Evacuation, Smoke/Fume Environment

18. Distribution Statement

Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report): Unclassified

20. Security Classif. (of this page): Unclassified

21. No. of Pages: 36

22. Price

ABSTRACT

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ACKNOWLEDGMENT

This study is one of two concerned with ways in which workload might be assessed for Passenger Protective Breathing Equipment. These two workload studies formed a portion of four aviation-related projects devised and organized under the auspices of Linacre College, Oxford University. Financial support for all these events came from worldwide donations and grants made by many organizations and individuals.

Volunteers to take part in the workload tests were recruited through local radio phone-in programs and facilities provided by the personnel departments of Land Rover Limited and the local authority offices at Solihul. These tests were conducted at Birmingham Airport which furnished the aircraft, power supplies, security services, fire tender and an ambulance. The Airport Fire Service undertook on-site preparations and provided staff in support of the test program.

Drs. J.A.S. Ross and S.J. Watt, carrying out the other workload study undertaken under the auspices of Linacre College, conducted the medical screening process and monitoring of participants. First Aid support on site was drawn from the St. John's Ambulance Brigade. Pretest calibration of specific participants and the required physiological parameter measurements were carried out by the Department of Physical Education, Birmingham University.

The Air Accident Investigation Branch of the Department of Transport and the Civil Aviation Authority furnished comment and recommendations during the development of the test protocol; the latter extended their insurance coverage to include the tests. British Airways provided the Cabin Attendants who served to conduct the emergency evacuations for the four trials in this study. British Airways also fitted the escape slide, and set up the seats to the proper tension in the rear cabin of the Trident Aircraft.

Three members of the team established by Linacre College, Mr. J. McNab, Mr. M. Ellery, and Mr. J. Boath of the Offshore Fire Training Center at Montrose, took part in the event fulfilling the roles of "Controller," "Safety Officer," and "External Marshall." A further member, Mr. D.D. Dempster handled public relations matters. Mrs. H. Brunton and Mr. P. Reynolds, seconded by the C.S.V. Newcastle, handled the Mercia Radio phone-in programs and the organization of volunteers. Mrs. E.A. Higgins, with help from Mrs. J. Boath, assisted Dr. Higgins to prepare participants for the heart rate monitoring during the tests and the coding of records.

Following the data collection phase, Mrs. P. Lyne and Mr. J.T. Saldivar, Jr., were responsible for much of the data reduction and analysis.

The authors wish to express their sincere thanks to the Principal and Fellows of Linacre College for their agreement and support for these tests. In turn, gratitude is expressed to Mr. R. Taylor, M.B.E., Managing Director, Birmingham International Airport and Mr. B. Wood, his Assistant Director - Operations; all those who so generously denoted funds in support of the program, and to more than 400 people who gave their time and efforts in many ways to help to identify means by which passenger safety in aviation can be improved.

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INTRODUCTION

In an earlier study at the Civil Aeromedical Institute in Oklahoma City (1), workloads were determined by correlation with heart rate for passengers during an emergency evacuation. The evacuation tests were conducted in an orderly manner and were suggested as representative of a moderate workload. Values for a maximum effort were not measured, only estimated. The current study is a continuation and amplification of that study and utilizes similar techniques for determining workload. In this study passengers were required to avoid the aircraft aisles and to traverse over seat backs to the exit to simulate a maximum effort which might be anticipated in an emergency. Thus, maximum workload could be estimated more realistically. This information is necessary to formulate qualification requirements for passenger protective breathing equipment.

METHODS

Calibration tests were conducted on 56 volunteer subjects at the University of Birmingham Department of Physical Education using a Monarch bicycle ergometer and an Oxycon respiratory gas analyzer. After a preselection physical examination, subjects were tested while exercising on the ergometer beginning at 30 watts, with the workload increased by 20 W every 2 min until either the 150-W workload was complete or heart rate (HR) exceeded 80 percent of the individual's predicted maximum HR (calculated as 220 minus age[2]).

Subjects were fitted with adhesive chest electrodes for HR measurement during the exercise test. Prior to each test, subjects were fitted with a noseclip to assure that all air exchange was via the mouth. Expired air was measured for volume, O_2 and CO_2 content, as well as respiratory rate. This computer-assisted system reported on-line data for each 30-s period of the test. Parameters reported were:

i) time in 0.5 min intervals:
ii) VE (expiratory volume), BTPS, in liters/min to nearest 0.1 liter;
iii) respiratory frequency, in breaths/min to nearest whole number;
iv) VT (tidal volume), BTPS, to nearest hundreth of a liter;
v) percent of O_2 in the expired air to nearest tenth of a percent;
vi) percent of CO_2 in the expired air to nearest tenth of a percent;
vii) $\dot{V}O_2$, STPD (volume of O_2 used), in liters/min to nearest hundredth;

viii) $\dot{V}O_2$/Kg, STPD to nearest tenth in mL/Kg;

ix) $\dot{V}CO_2$, STPD (volume of CO_2 expired) in liters/min to nearest hundredth;

x) $\dot{V}CO_2$/Kg, STPD, to nearest tenth in mL/Kg; xi) RQ (respiratory quotient), a ratio of CO_2 produced to O_2 consumed, to nearest hundredth; and,

xii) heart rate in beats/min in whole numbers.

In analyzing these data, the values for the low 30-W exercise level were not used. The 30-W 2-min period was considered a warm-up period for stabilization of the subject. In most instances, data collected during the last 30-s period of each 2-min workload segment were used for the statistical treatment. If data for the final 30-s period for any one workload segment appeared to be out-of-line with other data, primarily due to rounding-off error with low respiratory rates, then data for the entire last minute were used as more representative. The full-minute values were retained only if they yielded a higher correlation coefficient for the line-of-best-fit than did the final 30-s data.

Subsequently, four evacuation trials were conducted from a Trident III aircraft, with 40 subjects seated to the rear of the rear compartment.

Of the 56 participants who were calibrated, 48 were monitored for HR, in groups of twelve during the four evacuation trials. For each evacuation trial, 28 non-instrumented subjects were included to fill the 40-passenger total. For each test, three of the 12 subjects who were monitored for heart rate were also measured for oxygen consumption via an "Oxylog" analyzer system by Dr. Ross and Dr. Watt for inclusion in separate studies (3,4).

Figure 1 shows a typical seating arrangement for the rear cabin of the Trident III aircraft during the evacuation trials. Rows 8 through 16 were left vacant, with seated subjects starting in row 17. Those subjects who were not monitored are indicated with the letter "F" (fillers); those monitored for both heart rate and the Oxylog are indicated with the letter "B"; those monitored for heart rate only are indicated with the letter "H."

Heart rate monitoring was accomplished by use of portable Marquette, Series 8500, Holter HR recorders. The first 12 calibrated subjects who reported for the evacuation tests were instrumented. Heart rate electrode skin sites were cleaned with alcohol and mild abrasion; NaCl-pumice type electrode paste was applied to the skin sites, then disposable AG/AgCl electrodes were applied. Two Electrocardiogram (EKG) electrode placements, CM-5 and a modified V-1, were monitored. The CM-5 (5) is manubrium to the 5th intercostal space, anterior axillary line. The electrode sites for the modified V-1 are below left clavicle, just lateral to the

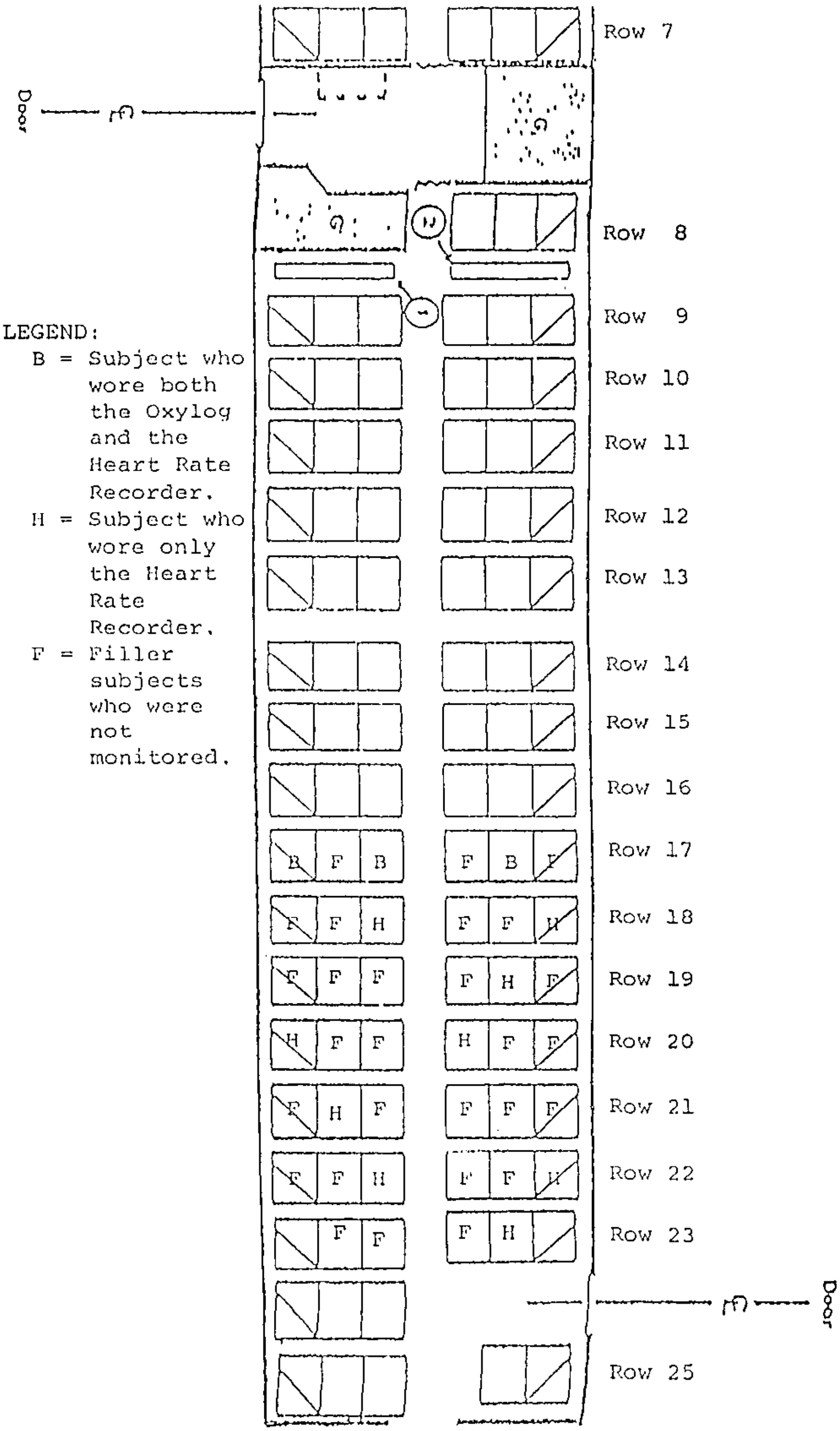

Figure 1
Typical Seating Arrangement for the Rear Cabin of the Trident III Used During the Four Trials

mid-clavicular line to V-1. V-1 is below the left clavicle, just lateral to the mid-clavicular line to the 4th intercostal space, right sternal edge.

At the conclusion of the evacuation tests, the Holter monitor tapes were returned to the CAMI laboratory where the tapes were played on a Marquette Series 8000 T Playback Analysis System and HR values were determined for the evacuation test period.

RESULTS

Of the 48 subjects monitored for HR during the evacuation trials (12 per trial), usable data were obtained for 45 subjects. Of the three subjects for whom data were not used, two appeared to have experienced a disconnect from the recorder between the time of the hookup and evacuation trial and no data were on the tape. For the other subject, data were obtained, but were totally inconsistent with the calibration data (high HR's were recorded during calibration, very low HR's were recorded during evacuation trial). The reason for this inconsistency is not readily apparent. The subjects not included are nos. 1-12, 3-04, and 3-08.

Tables I through VII present the determinations made from the workload calibration tests for the 45 subjects for whom valid data were obtained during the evacuation trials. Table VIII contains the heart rates recorded during the evacuation trials in 0.5-min increments from the time the emergency was declared with the order to evacuate. Because all participants evacuated the craft in less than 1 minute, the heart rate assessment was made only for 2 minutes. Table IX lists the workloads calculated from heart rate based on the calibration data. The data in Tables X and XI present oxygen consumption and oxygen consumption per Kg, and expired carbon dioxide and carbon dioxide per Kg values calculated for the evacuation trials workload data using the relationships determined in the calibration tests. The blanks in Tables VIII through XI during the final 30-s period are not due to lost data, but are due to the HR upon which they are based being below calibration values. Because all subjects were evacuated and away from the aircraft in the first minute, and because none registered a peak heart rate during either 30-s segment of the second minute, the first minute of data will be used to represent the maximum workload experienced during these evacuation tests.

In Table XII data are presented from the first minute of the evacuation trials. When all subjects are considered, the mean workload per kg body weight is 2.029 watts per kilogram

DISCUSSION

To better determine any differences between categories of test subjects, data were divided by the four test trials for all subjects in the group, by those wearing the Oxylog equipment and those without the Oxylogs. Because data appear to be different for the fourth trial, and the subjects from the first three trials appeared similar, the subjects from these first three trials were grouped as being representative of one population. Group IV appeared to be a very intense group determined to "be the best group, with the most rapid evacuation time." Tables XIII through XV list the mean, standard error and sample sizes for each subject population and the P values for statistical differences between these groups for age, and weight (Table XIII), for the first-minute evacuation test heart rate (Table XIV), and for the first-minute workload, and workload per unit weight (Table XV). Table XVI lists the oxygen consumption (mL/min) and oxygen consumption per kg body weight based on the calibration regression equations for workloads at 0.7 W/Kg (low work-load), 1.2 W/Kg (intermediate workload), and workload of the first minute of the evacuation test (high workload). Table XVII lists the carbon dioxide production (mL/min) and carbon dioxide production per kg body weight based on the calibration regression equations for workloads at 0.7 W/Kg (low workload), 1.2 W/Kg (intermediate workload) and workload of the first minute of the evacuation test (high workload). Table XVIII gives the oxygen consumption (in liters) and the carbon dioxide production (in liters) based on the proposed 20-min workload profile. Table XIX gives the means, standard errors, and sample size for the various populations of subjects, as well as the tests for significant differences between these groups for the values listed in Table XVIII.

For seven of 19 comparisons, the statistical difference when comparing group IV to the other three groups proved to be significant (Tables XIII, XIV, XV, and XIX). Their total evacuation time was much faster than those of the other three groups (33 s compared to 46 s, 41 s, and 43 s, respectively). Their exertion was probably higher, and thus workload, CO_2 production, and O_2 consumption were greater. In 10 of 19 comparisons, those wearing oxylogs showed statistically significant difference when compared to those who were not wearing oxylogs. One possible explanation for this difference is found in Table XIII. The subjects wearing oxylogs were significantly lighter in weight than those without oxylogs (a mean of 66.5 kg vs. 79.2 kg). It is also possible that those wearing oxylogs proved different from the other subjects because they were placed on the front row of those evacuating the aircraft and had to make the effort required to fold down eight rows of seats on their way to the exit. None of the other subjects wearing heart rate recorders had to accomplish this task.

Data from eight of the twelve subjects wearing the Oxylogs in this study, have been reported by Drs. John Ross and Stephen Watt (3). Their report also includes data from several subjects not covered in this report.

For those eight subjects which the two reports have in common, we were able to make the following determinations: During the brief (14 to 24 s) periods of the subjects' evacuation, they report an average O_2 uptake of about 39.6% (range = 23.7 to 53.5%) of the predicted average O_2 utilization based on heart rate. This, in itself, is not surprising for several reasons. First, during a brief rapid increase in work, the O_2 utilization is partially accounted for by utilization of stored O_2 and not just the O_2 uptake. Another possible explanation for the differences is that the higher heart rate could be psychogenically induced and not due solely to physical exertion, which would result in a higher predicted workload than is actually the case.

Then, by extending the time for both sets of data to 2 min, their reported total O_2 uptake rose to 59.8% (range = 46.5 to 75.2%) of the predicted O_2 utilization. This probably indicates that the O_2 uptake still does not equal the O_2 used within that time frame. There is also the fact that, with an abrupt increase in workload, it is not unusual to see an initial drop in O_2 uptake. This is not indicative of a decrease in workload, nor in O_2 utilization. This decrease is temporary. As evidence, a table of data (Table XX) taken from the calibration tests at the University of Birmingham has been included. This table presents the change in O_2 uptake from the final 30 s of a 2-min workload segment to the first 30 s of the next higher workload. Frequently there is a decrease, even though these are for changes of only 20 watts. This is also supported in Åstrand's Textbook of Work Physiology (6), where it states: "The kinetics of the increase in oxygen uptake during the first minutes of an exercise, which lead to a steady state situation, have a time constant of about 30 s, or about 20 s when a given moderate exercise is preceded by a warming-up period." Thus, one must be cautious in interpreting a drop in O_2 uptake as indicating a decline in workload, or a lessening of O_2 utilization, especially when it occurs during the first 30 s after an abrupt increase in activity level.

A direct measurement of O_2 uptake, assuming reliable equipment and techniques, should provide a better estimate of O_2 requirements for a specific test condition than an indirect method such as the one used for this study. If, however, it is intended to include the brief maximum exertion as a part of a longer-term profile, then there is justification to utilize an indirect measurement, especially when employing a large subject population. For a brief isolated exertion, O_2 uptake would better reflect total O_2 requirements. For a more complex workload profile with a longer time frame, in which O_2 debt could be repaid, then O_2 utilization would be needed to reflect the total O_2 requirements imposed by that brief maximum exertion.

By employing the regression equations developed for the calibration workload tests, values can be determined for each test subject for predicted O_2 consumption and CO_2 production at the low workload of 0.7 W/Kg, for the intermediate workload of 1.2 W/Kg, and for each individual`s estimated 1-min workload during the evacuation trial (Tables XVI and XVII). These values can then be used to determine O_2 flow requirements and CO_2 absorption requirements for a 20-min work profile of 15 min at 0.7 W/Kg, 4 min at 1.2 W/Kg, and 1 min at a maximum workload. Of course, other scenarios can be described and other determinations made for varying times at each of the three workload levels. Results for all 45 subjects are given in Table XVIII.

If it is assumed that the total group is representative of a desired population (see Table II for description of subject population), then by applying the mean values for overall O_2 consumption and CO_2 production the requirements for the 20-min work profile described above for a 95th percentile male (100.1 Kg) would be 28.38 L of O_2 consumed and 23.36 L of CO_2 produced for the 20-min period.

In this study there were four subjects who exceeded 100 Kg in weight (No. 2-11 [106 Kg], No. 3-07 [103 Kg], No. 4-10 [103 Kg], and No. 4-11 [102 Kg]). In considering the data from these four, the 20-min profile for exercise would yield O_2 requirements of 28.43, 28.87, 28.82, and 29.41 L respectively. The average of the four is 28.88 L of O_2 required (compared to the 28.38 L predicted for the 95th percentile male). The one subject in the prior study (1) representative of the 95th percentile male had an O_2 requirement of 29.0 L. The mean CO_2 production for these four subjects in the current study was 24.63 L (with 23.36 L predicted for 95th percentile male). The prior study reported 24.7 L. These values are very comparable.

In the original study, allowances were made for the possibility of greater CO_2 production. However, the data of this study indicate that significantly higher production will not occur. The highest calculated value was for subject 4-11 and was 26.11 L. Thirty L of CO_2 absorption capacity should be adequate. Carbon dioxide absorption can be described in terms of the total amount required for the 20-min period, but for required O_2 supply, peak flow requirements must be considered. Although only two subjects exceeded 3.0 L/min O_2 consumption during peak workload (Subjects 3-01 and 4-10, Table XVI), the device should probably be capable of providing that 3.0 L at any time during its functional life.

Table VII indicates that although eight individuals exceeded a maximum tidal volume of 3.0 L, the greatest value was only 3.15 L. Therefore, the earlier estimate of 3.0 L for the volume that the hood-type PPBE should exceed the enclosed head and neck for devices with a breathable air supply is supported by these data, particularly when those devices have an inboard flow of 3L O_2 per minute. However, these values are for subjects with normal inspired CO_2 levels. If the CO_2 levels are increased for significant periods of time, this maximum tidal volume could be higher.

CONCLUSIONS

Under the conditions of this study, and with the techniques used for determining O_2 consumption and CO_2 production, certain recommendations might be made concerning the respiratory requirements for passenger protective breathing devices. In considering the recommended values proposed in the earlier study (1), some modifications should be made. Original recommendations will be crossed out when a change is indicated, then this will be followed by the new value based on data from this study:

1) A 20-min work profile consisting of:
   15 min at 0.7 W/Kg body weight
   2 min at 1.2 W/Kg body weight
   1 min at ~~1.5~~ 2.0 W/Kg body weight
   2 min at 1.2 W/Kg body weight.

2) The volume of a hood-type PPBE should exceed the volume that encloses the head and neck by 3.0 Liters.

3) For a breathable-air type, the device should provide 3.0 L/min oxygen for 20 minutes.

4) The device should probably be capable of absorbing ~~45~~ 30 L of carbon dioxide.

The subject population studied should include one or two individuals who meet or exceed the weight of the 95th percentile male.

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TABLE I
Calibration Data: Workload vs Heart Rate

Workload =	50W	70W	90W	110W	130W	150W
Subject Number	Heart Rate (BPM)					
1-01	76	90	100	108	120	132
1-02	116	116	122	130	142	-
1-03	94	104	116	128	144	-
1-04*	104	114	126	142	156	-
1-05*	102	108	118	130	140	-
1-06	76	82	92	92	100	110
1-07	108	122	144	-	-	-
1-08*	96	102	114	126	146	154
1-09	78	84	88	100	104	110
1-10	100	108	120	130	138	148
1-11	90	98	108	114	122	132
2-01*	110	120	138	-	-	-
2-02*	110	114	126	144	152	162
2-03	90	98	108	116	132	140
2-04	110	118	128	138	152	-
2-05	112	112	126	136	-	-
2-06	86	90	102	112	128	142
2-07*	118	127	134	148	-	-
2-08	88	94	106	110	116	124
2-09	102	116	126	142	160	-
2-10	86	94	100	110	124	134
2-11	90	96	104	118	134	146
2-12	84	92	102	112	124	132
3-01*	72	78	86	90	98	102
3-02*	94	96	114	122	140	154
3-03	98	106	112	118	129	136
3-05	110	124	138	152	-	-
3-06	82	86	96	104	114	124
3-07	98	104	116	124	134	146
3-09	98	104	116	124	144	-
3-10*	102	112	120	130	144	158
3-11	92	100	112	118	132	144
3-12	102	110	114	126	134	144
4-01	112	120	124	136	158	-
4-02	100	104	116	126	138	148
4-03	106	118	124	134	150	164
4-04	100	112	116	130	138	146
4-05*	96	102	118	128	144	160
4-06	86	94	96	112	124	140
4-07*	92	108	116	116	128	124
4-08*	98	112	128	138	-	-
4-09	92	102	114	128	144	-
4-10	115	112	118	120	130	140
4-11	112	118	122	130	144	-
4-12	92	102	108	120	124	130

*Subjects also monitored with the Oxylog.

TABLE II
Subject Population Data

Subject Number	Age (Yrs)	Weight (Kgs)	Height (Cm)
1-01	39	66	179
1-02	41	86	178
1-03	37	63	168
1-04*	27	71	175
1-05*	22	70	175
1-06	26	79	178
1-07	33	65	178
1-08*	22	73	182
1-09	32	93	190
1-10	35	86	186
1-11	32	71	163
2-01*	38	70	166
2-02*	20	58	171
2-03	32	80	181
2-04	27	75	180
2-05	40	70	168
2-06	26	72	168
2-07*	35	73	175
2-08	29	71	173
2-09	20	66	185
2-10	35	81	183
2-11	32	106	177
2-12	24	89	180
3-01*	38	67	177
3-02*	24	68	177
3-03	29	73	180
3-05	33	56	167
3-06	34	76	181
3-07	38	103	171
3-09	31	86	171
3-10*	18	56	168
3-11	23	71	179
3-12	23	85	180
4-01	23	81	176
4-02	32	94	172
4-03	20	69	174
4-04	26	72	170
4-05*	20	62	165
4-06	33	86	182
4-07*	24	64	183
4-08*	29	66	174
4-09	29	66	173
4-10	27	103	192
4-11	42	102	171
4-12	21	70	175

*Subjects also monitored with the Oxylog.

TABLE III
Calibration Data: Oxygen Consumption (mL/min, STPD)

Workload = Subject Number	50W	70W	90W	110W	130W	150W
1-01	740	1000	1330	1580	1670	1890
1-02	890	940	1190	1640	1730	-
1-03	690	900	1160	1350	1670	-
1-04*	800	1040	1180	1380	1690	-
1-05*	890	1070	1440	1650	1750	-
1-06	1240	1340	1470	1780	1880	2340
1-07	870	990	1290	-	-	-
1-08*	700	1230	1370	1670	1930	2060
1-09	1050	1230	1470	1600	1600	1970
1-10	960	1120	1390	1460	1700	1980
1-11	1050	1120	1360	1690	1780	1990
2-01*	830	1110	1230	-	-	-
2-02*	740	1130	1230	1520	1750	2060
2-03	930	1060	1440	1440	1850	1880
2-04	890	1180	1300	1510	1600	-
2-05	830	1120	1280	1380	-	-
2-06	1030	1080	1360	1390	1590	2030
2-07*	1120	1170	1350	1530	-	-
2-08	730	1130	1190	1370	1520	1820
2-09	790	890	1120	1340	1530	-
2-10	910	1100	1330	1450	1740	1970
2-11	1030	1200	1420	1560	1980	2040
2-12	930	1450	1390	1680	1880	2310
3-01*	1080	1130	1320	1600	1810	2120
3-02*	1040	1130	1270	1640	1600	2070
3-03	1030	1250	1250	1450	1860	2000
3-05	890	970	1300	1460	-	-
3-06	790	950	1160	1310	1610	1870
3-07	1000	1230	1400	1740	1940	2220
3-09	1090	1220	1310	1450	1710	-
3-10*	860	990	1130	1530	1510	2050
3-11	1130	1200	1390	1400	1600	2040
3-12	1140	1170	1260	1740	1870	2000
4-01	1140	1270	1390	1680	2320	-
4-02	1010	1260	1350	1770	1790	2120
4-03	985	1090	1500	1560	1920	2060
4-04	1000	1160	1500	1560	1920	2060
4-05*	930	880	1310	1420	1600	2220
4-06	790	1220	1070	1490	1640	1900
4-07*	890	1140	1420	1530	1600	1830
4-08*	740	1100	1350	1940	-	-
4-09	880	870	1280	1340	1770	-
4-10	950	1080	1350	1940	2080	2240
4-11	1150	1340	1460	1710	1850	-
4-12	860	1110	1300	1280	1770	1730

*Subjects also monitored with the Oxylog.

TABLE IV
Calibration Data: Oxygen Consumption (mL/min, STPD) per Kg Body Weight

Workload = Subject Number	50W	70W	90W	110W	130W	150W
1-01	11.2	15.2	20.2	23.9	25.4	28.7
1-02	10.3	11.0	13.8	19.0	20.1	-
1-03	10.9	14.3	18.4	21.5	26.4	-
1-04*	11.3	14.6	16.7	19.5	23.8	-
1-05*	12.7	15.3	20.5	23.6	25.0	-
1-06	15.7	16.9	18.7	22.6	23.8	29.6
1-07	13.4	15.3	19.8	-	-	-
1-08*	9.6	16.9	18.8	22.9	26.5	28.3
1-09	11.3	13.3	15.8	17.2	17.2	21.2
1-10	11.2	13.0	16.2	17.0	19.8	23.0
1-11	14.8	15.8	19.2	23.8	25.1	28.0
2-01*	11.9	15.8	17.5	-	-	-
2-02*	12.8	19.5	21.1	26.2	30.1	35.6
2-03	11.6	13.2	18.0	18.0	23.1	23.6
2-04	11.9	15.8	17.3	20.1	21.3	-
2-05	11.9	16.0	18.2	19.6	-	-
2-06	14.3	15.0	18.9	19.3	22.1	28.2
2-07*	15.3	16.0	18.4	21.0	-	-
2-08	10.3	15.9	16.8	19.3	21.4	25.6
2-09	11.9	13.5	16.9	20.3	23.2	-
2-10	9.9	12.0	14.4	15.7	18.9	21.4
2-11	9.7	11.3	13.4	14.7	18.7	19.3
2-12	10.5	16.3	15.6	18.9	21.1	25.9
3-01*	16.1	16.8	19.7	23.9	27.0	31.7
3-02*	15.3	16.5	18.7	24.0	23.5	30.4
3-03	14.1	17.1	17.1	19.8	25.4	27.4
3-05	15.8	17.4	23.3	26.0	-	-
3-06	10.3	12.5	15.3	17.2	21.1	24.5
3-07	9.7	12.0	13.6	16.9	18.8	21.5
3-09	12.7	14.1	15.2	16.8	19.8	-
3-10*	15.4	17.7	20.2	27.3	27.0	36.6
3-11	16.0	16.9	19.5	19.7	22.5	28.8
3-12	13.4	13.7	14.9	20.4	22.0	23.5
4-01	14.1	15.7	17.2	20.7	28.6	-
4-02	10.8	13.4	14.4	18.8	19.1	22.6
4-03	14.2	15.8	21.7	21.0	25.8	29.5
4-04	13.9	16.2	20.8	21.6	26.7	28.6
4-05*	15.0	14.2	21.1	22.8	25.9	32.6
4-06	9.2	14.2	12.5	17.4	19.0	22.1
4-07*	14.0	17.9	22.2	23.9	25.0	28.6
4-08*	11.2	16.7	20.4	29.4	-	-
4-09	13.3	13.1	19.3	20.2	26.8	-
4-10	9.2	10.5	13.1	18.9	20.2	21.8
4-11	11.3	13.2	14.3	16.8	18.1	-
4-12	12.3	15.8	18.6	18.3	25.2	24.8

*Subjects also monitored with the Oxylog.

TABLE V
Calibration Data: Expired Carbon Dioxide (mL/min, STPD)

Workload = Subject Number	50W	70W	90W	110W	130W	150W
1-01	560	750	1050	1320	1440	1670
1-02	830	720	1010	1440	1640	-
1-03	560	690	1040	1200	1570	-
1-04*	650	860	1120	1370	1720	-
1-05*	720	920	1380	1690	1900	-
1-06	860	980	1120	1360	1520	1830
1-07	780	970	1370	-	-	-
1-08*	580	960	1190	1460	1850	2100
1-09	770	980	1230	1290	1370	1670
1-10	690	870	1130	1260	1510	1830
1-11	800	890	1160	1520	1570	1840
2-01*	660	990	1190	-	-	-
2-02*	580	900	1150	1510	1820	2120
2-03	770	940	1290	1350	1750	1840
2-04	830	1030	1190	1420	1560	-
2-05	720	940	1240	1200	-	-
2-06	730	850	1050	1200	1440	1850
2-07*	760	900	1100	1200	-	-
2-08	660	1070	1160	1390	1660	1890
2-09	680	780	950	1220	1520	-
2-10	820	990	1240	1340	1720	2070
2-11	840	1030	1250	1440	1940	2180
2-12	710	1140	1180	1440	1650	2110
3-01*	730	850	970	1200	1450	1740
3-02*	830	950	1220	1530	1650	2070
3-03	830	1110	1130	1400	1790	2020
3-05	730	910	1250	1490	-	-
3-06	710	740	890	1100	1410	1590
3-07	780	1060	1230	1590	1870	2090
3-09	970	1110	1340	1500	1830	-
3-10*	710	820	1080	1490	1600	2100
3-11	820	910	1140	1200	1420	1820
3-12	960	890	1070	1410	1700	1780
4-01	880	1100	1220	1560	1910	-
4-02	780	1050	1160	1620	1770	2210
4-03	830	880	1390	1340	1660	1990
4-04	750	970	1280	1360	1680	1920
4-05*	890	690	1080	1260	1600	2060
4-06	710	1030	910	1380	1620	2000
4-07*	710	900	1350	1440	1630	1800
4-08*	570	740	1040	1530	-	-
4-09	700	740	1170	1190	1700	-
4-10	890	800	870	1440	1680	1900
4-11	1000	1100	1290	1570	1820	-
4-12	700	950	1070	1170	1580	1660

*Subjects also monitored with the Oxylog.

TABLE VI
Calibration Data: Expired Carbon Dioxide (mL/min, STPD) per Kg Body Weight

Workload = Subject Number	50W	70W	90W	110W	130W	150W
1-01	8.5	11.4	15.9	20.0	21.8	25.3
1-02	9.7	8.4	11.7	16.7	19.1	-
1-03	8.9	11.0	16.5	19.0	24.9	-
1-04*	9.2	12.1	15.8	19.3	24.2	-
1-05*	10.3	13.1	19.7	24.1	27.1	-
1-06	10.9	12.4	14.2	17.2	19.2	23.2
1-07	12.0	14.9	21.1	-	-	-
1-08*	7.9	13.2	16.3	20.0	25.3	28.8
1-09	8.3	10.5	13.2	13.9	14.7	18.0
1-10	8.0	10.1	13.1	14.7	17.6	21.3
1-11	11.3	12.5	16.3	21.4	22.1	25.9
2-01*	9.4	14.1	17.0	-	-	-
2-02*	10.0	15.5	19.8	26.0	31.4	36.6
2-03	9.6	11.8	16.1	16.9	21.9	23.0
2-04	11.1	13.7	15.9	18.9	20.8	-
2-05	10.3	13.4	17.7	17.1	-	-
2-06	10.1	11.8	14.6	16.7	20.0	25.7
2-07*	10.4	12.3	15.1	16.4	-	-
2-08	9.3	15.1	16.3	19.6	23.4	26.6
2-09	10.3	11.8	14.4	18.5	23.0	-
2-10	10.1	12.2	15.3	16.5	21.3	25.6
2-11	7.9	9.7	11.8	13.6	18.3	20.6
2-12	8.0	12.8	13.3	16.2	18.5	23.7
3-01*	10.9	12.7	14.5	17.9	21.6	26.0
3-02*	12.2	14.0	17.9	22.5	24.3	30.4
3-03	11.4	15.2	15.5	19.2	24.5	27.7
3-05	13.0	16.3	22.3	26.6	-	-
3-06	9.3	9.7	11.7	14.5	18.6	20.9
3-07	7.6	10.3	11.9	15.4	18.2	20.3
3-09	11.3	12.9	15.6	17.4	21.3	-
3-10*	12.7	14.6	19.3	26.6	28.6	37.5
3-11	11.5	12.8	16.1	16.9	20.0	25.6
3-12	11.3	10.5	12.6	16.6	20.0	20.9
4-01	10.9	13.6	15.1	19.3	23.6	-
4-02	8.3	11.2	12.3	17.2	18.8	23.5
4-03	12.0	12.8	20.1	19.4	24.1	28.8
4-04	10.4	13.5	17.8	18.9	23.3	26.7
4-05*	14.4	11.1	17.4	20.3	25.8	33.2
4-06	8.3	12.0	10.6	16.0	18.3	23.3
4-07*	11.1	14.1	21.1	22.5	25.5	28.1
4-08*	8.6	11.2	15.8	23.2	-	-
4-09	10.6	11.2	17.7	18.0	25.8	-
4-10	8.6	7.8	8.4	14.0	16.3	18.4
4-11	9.7	10.7	12.5	15.2	17.7	-
4-12	10.0	13.6	15.3	16.7	22.6	23.7

*Subjects also monitored with the Oxylog.

TABLE VII
Maximum Minute Volumes and Tidal Volumes Measured During Workload Calibration Tests

Subject Number	Maximum Minute Volume (Liters/min)	Maximum Tidal Volume (Liters)
1-01	44.3	2.63
1-02	41.9	2.41
1-03	40.4	2.02
1-04*	44.2	2.10
1-05*	57.7	2.06
1-06	40.9	2.16
1-07	44.0	3.14
1-08*	50.1	1.73
1-09	45.8	3.04
1-10	43.2	2.16
1-11	50.9	1.83
2-01*	35.1	1.86
2-02*	58.2	1.75
2-03	51.5	2.22
2-04	50.4	1.80
2-05	47.7	3.15
2-06	43.5	2.15
2-07*	36.0	1.56
2-08	59.1	3.12
2-09	47.7	2.51
2-10	54.8	2.61
2-11	59.1	3.12
2-12	53.9	2.45
3-01*	45.3	1.97
3-02*	57.4	2.10
3-03	55.6	2.57
3-05	40.5	2.03
3-06	38.0	2.86
3-07	54.3	2.69
3-09	46.5	1.94
3-10*	55.9	1.46
3-11	48.3	1.58
3-12	44.2	2.71
4-01	44.8	2.24
4-02	58.3	3.07
4-03	53.8	2.00
4-04	47.5	2.18
4-05*	53.3	1.84
4-06	55.2	3.10
4-07*	51.4	1.79
4-08*	32.0	3.01
4-09	45.6	2.29
4-10	48.1	2.88
4-11	47.6	1.96
4-12	45.3	2.16

*Subjects also monitored with the Oxylog.