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ARMSTRONG LABORATORY

METABOLIC MONITORING OF HYPOBARIC SUBJECTS

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The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The Office of Public Affairs has reviewed this paper, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This paper has been reviewed and is approved for publication.

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13. ABSTRACT (Maximum 200 words)

The objective of Task Order No. 0013, amendment to USAF Contract No. F33615-89-C-0603, was to quantify the metabolic activity of subjects during isometric and isotonic exercise to develop procedures for individualized exercise performance during simulated high altitude exposures. To satisfy the stated objective, KRUG Life Sciences performed the following tasks: 1) designed and instrumented a stack-weight machine suitable for isometric or isotonic exercise performed with the arm or legs; 2) provided and operated an advanced metabolic measurement system capable of breath-by-breath analysis of low-level oxygen consumption data; 3) provided for administration of criterion tests for maximal oxygen consumption (VO_2 max) and maximal voluntary contraction; 4) developed procedures for equating and individualizing the isometric and isotonic work by means of oxygen consumption (% of VO_2 max); and 5) provided procedures for training subjects on the individual exercise programs.

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Oxygen consumption; Oxygen uptake; Isotonic; Isometric

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METABOLIC MONITORING OF HYPOBARIC SUBJECTS

INTRODUCTION TO THE TASK ORDER

Introduction

In a 1987 joint research proposal the United States Air Force School of Aerospace Medicine (USAFSAM, now Armstrong Laboratory) and the National Aeronautics and Space Administration (NASA) detailed a study to compare the effects of isometric (static) and isotonic (dynamic) exercise on incidence of altitude decompression sickness (DCS) (1). The study called for subjects to be exposed to simulated high altitude while resting, performing isometric exercise with the arms or legs, or performing isotonic exercise with the arms or legs. To determine which exercise type would have a more significant impact on DCS occurrence and bubble formation, the prescribed isometric and isotonic exercises, performed on a stack-weight machine, must elicit equivalent metabolic responses within each subject. The criterion for equating the types of work was established as a percentage of each individual's maximal oxygen consuming ability (% Vo_2 max).

In March, 1990, the Crew Technology Division of Armstrong Laboratory initiated Task Order No. 0013, amendment to Contract No. F33615-89-C-0603, requiring KRUG Life Sciences to support efforts to quantify the metabolic activity of hypobaric subjects. This report provides details of the materials, methods, and results accomplished in accordance with the Task Order.

Task Order Objective

The specific objective of Task Order No. 0013 was to quantify the metabolic activity of subjects during isometric and isotonic exercise to develop individualized procedures for exercise performance during simulated high altitude exposures.

Task Order Description of Work

The Description of Work required that the contractor perform the following tasks:

(1) Operate an advanced metabolic monitoring system.
(2) Design and instrument a stack-weight machine suitable for isometric or isotonic exercise performed with arms or legs.
(3) Conduct ground-level, criterion tests for aerobic capacity and strength measures.
(4) Develop details of the exercise protocol to include equating and individualizing isometric arm and leg, and isotonic arm and leg, work.
(5) Train subjects (at ground level) on the exercise protocols.

MATERIALS

Isometric/Isotonic Weight Machine

Figure 1 shows the stack-weight machine used to perform isotonic and isometric work, with either the arms or legs, during ground-level exercise pretests and high altitude exposures. The machine was built by Challenger Gym Products of San Antonio, and modified by KRUG Life Sciences and AL/DOM.

All exercises are performed while seated on the machine. The isotonic arm exercise consists of raising and lowering the weight stack by pulling on a center bar, connected by cable to the weight stack. For the isotonic leg exercise the center bar is lowered to ankle height perpendicular to the floor, and the exercise is performed by extension of the knees. A universal shear beam load cell (rated capacity 227 kg (500 lb)) is connected to the center bar. Force in millivolts (4 mV = 2.2 kg (1 lb)) is displayed on a digital pressure/tension indicator throughout the full range of motion. An analog signal can be linked to several peripheral devices, i.e.,strip-chart recorder or computerized data acquisition system.

Converting the machine for isometric exercise is a 2-step procedure which takes approximately 10 min. For isometric exercise, the cable is disconnected from the weight stack and reattached to an immovable plate at the top of the machine (Figure 1 configuration). A "stopper" slides and locks into place eliminating movement in the cable. For upper body isometrics, the subject pulls on the load-cell-connected center bar; and for lower body isometrics, the subject pushes against the center bar at ankle height. The isometric exercises are performed at approximately 120° of the 180° isotonic range of motion.

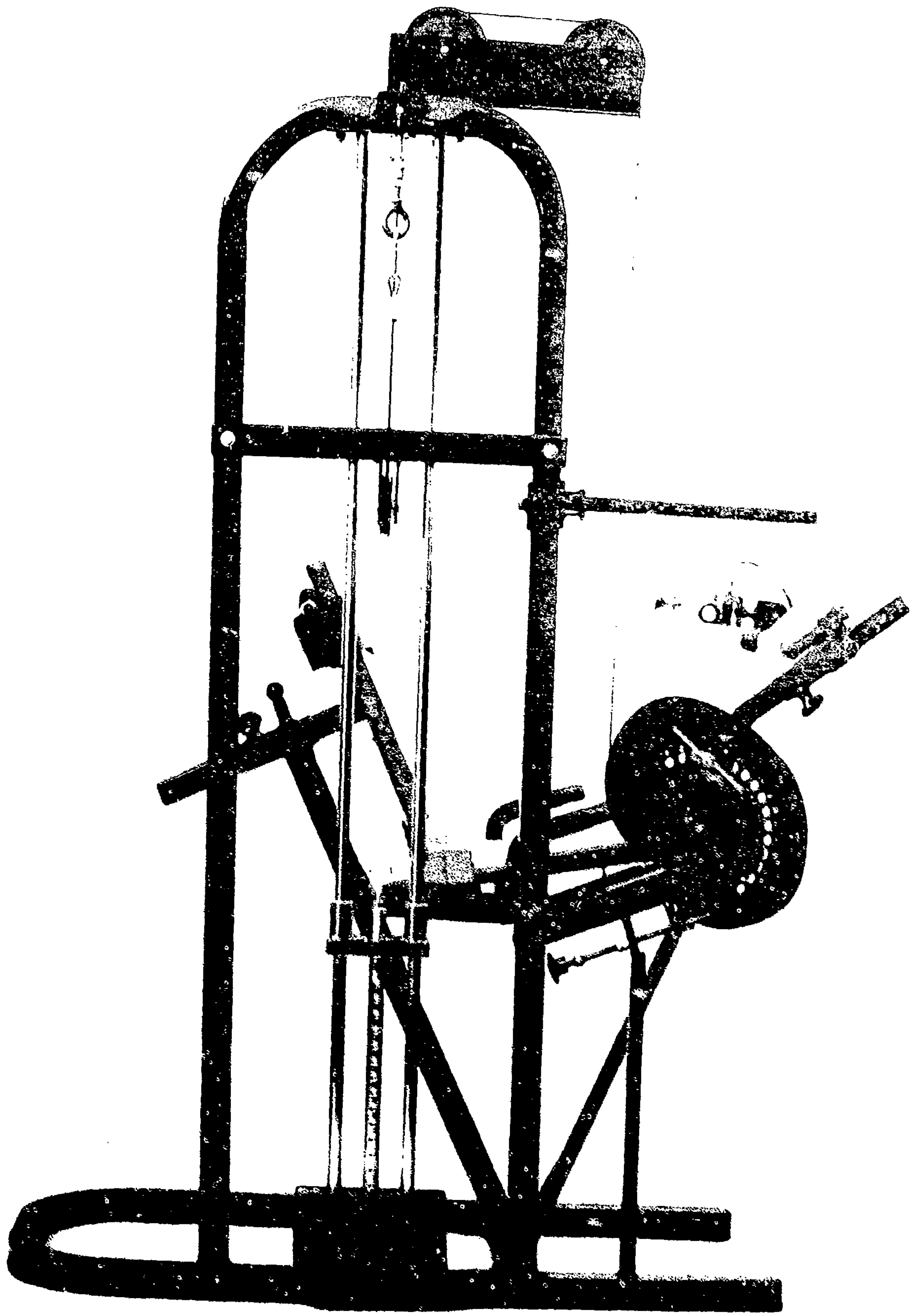

Figure 1. Isometric/Isotonic stack-weight machine.

The stack-weight machine adjusts to accommodate individual variances in buttocks-to-knee length, arm length, and sitting height. The seat back slides forward or backward to provide a comfortable buttocks-to-knee length. The center bar is moved closer or further from the subject by adjusting the cam setting, and higher or lower by adjusting the center bar height. Chest and hip straps are provided to stabilize the subject during criterion tests for maximal isometric strength.

Metabolic Measurement System

a. SensorMedics 2900z overview

As stated in the description of work, KRUG Life Sciences was required to operate an advanced metabolic measurement system. Since no such system existed within AL/CFT, the SensorMedics 2900z advanced metabolic measurement cart (MMC) was purchased. The MMC provides a computerized measuring system for automated analysis of gas exchange and respiratory parameters during steady state and graded exercise testing. The system was equipped with appropriate hardware/software for breath-by-breath interval analysis of low-level oxygen consumption data obtained during the isometric and isotonic exercises. Standard computer for the MMC is the IBM PS/2$_{TM}$, Model 50, with 30 Mbytes hard disk drive and 12 in. color monitor with video graphics array (VGA). The system also includes portable transducer housing, indirect calorimetry software, dynamic mixing chamber, automatic calibration, and Perma-Pure drying system. A complete list of all accompanying parts and accessories is provided in Appendix A.

1. Basic components of the system

The instruments for determination of metabolic variables by the MMC include a mass flow anemometer for gas volume measurement, infrared (IR) carbon dioxide (CO_2) analyzer, and zirconium oxide (ZrO_2) electrochemical oxygen analyzer (2). The mass flow anemometer measures mass, not volumetric, rate of flow over a range of 1.5-750 liters/min. The anemometer operates on the principle of thermal conductivity and consists fundamentally of a pair of heated wire filaments across which expired air flows. The amount of current required to maintain a constant resistance ratio between the heated wires is inversely proportional to the mass of the gas molecules. The anemometer operates in such a way to enable the MMC to distinguish between the end of one breath and the beginning of another.

The carbon dioxide analyzer is based on a nondispersive IR concept. The rate at which carbon dioxide absorbs characteristic wavelengths of light is a function of gas concentration. The analyzer operates from a beam of IR light being passed from the source through a filter and into a sample cell. Measurement occurs when the output signal containing zero gas in the sample cell is compared to the output signal of the gas being analyzed.

The oxygen analyzer is a 2-chamber cell separated by an ion-conducting, solid electrolyte with porous electrodes on each side. The device functions as an oxygen analyzer when the cell is superheated, enabling the solid electrolyte to conduct oxygen ions. As the ions pass over the porous electrodes, the electromotive force between the 2 electrodes is measured. The output signal is interpreted in a logarithmic formula that reflects the ratio of the partial pressure of oxygen at each electrode.

Figure 2. MMC in use with treadmill (mixing chamber mode).

2. Mixing chamber and breath-by-breath modes

Figure 2 shows the MMC, in mixing chamber mode, in use during a criterion test for maximal oxygen consumption. When operating in the standard mixing chamber mode, expired air passes from the flowmeter to a 7-liter mixing chamber where it is sampled through 1 of 3 sample ports, which are minute-ventilation dependent. As workload increases, a sample port located further back in the mixing chamber will be used. Adjusting the sample port based on minute-ventilation ensures the appropriate chamber size, better mixing of gases, improved response time, and less influence from tidal volume changes. The mixing chamber mode provides data in 20-s intervals.

Figure 3 shows the MMC, in breath-by-breath mode, in use during an isometric test administration. The tubing used for the breath-by-breath sample line, and used at all internal sample ports, is a semipermeable membrane that allows water vapor in the sample line to equilibrate to ambient water vapor without any loss of O_2 or CO_2. The breath-by-breath mode provides ventilation and gas exchange data on a per breath basis during exercise.

Figure 3. MMC in use with stack-weight machine (breath-by-breath mode).

b. Instructional manuals

The manuals described in the following sections can be obtained from Sensor Medics, or are located in this report as Appendix B.

1. Operator's training course manual

The Operator's Training Course Manual describes in detail the 4-day MMC operator's training course offered by SensorMedics. The objective of the course, as described in the manual, is to provide the customer with a basic working knowledge of the SensorMedics Metabolic Measurement Cart. The manual includes an overview of the course, system description, maintenance information, test and calibration details, sample labs, and relevant references.

2. 2900z operator's manual

The 2900z Operator's Manual provides step-by-step instruction on use of the MMC with software version IMS-OD. The manual includes information on component location, applications, shipping and installing, loading software, calibrating and testing, editing, generating reports, formatting screen displays and peripheral devices, and managing data files. The operator's manual is easy to use and understand and, for generic testing, is quite complete.

3. Abbreviated operating instructions

Much of the MMC software has been formatted/customized for more specific application in the isometric/isotonic protocol and criterion tests. Therefore, KRUG Life Sciences has summarized operating instructions for use of the MMC purchased by KRUG Life Sciences in March of 1990. Included are sections on using the large "H"-size cylinder gas tanks, formatting analog devices for force measurement and heart rate, digital and graphic real-time screen displays, final report formats, creating ASCII files, and maintenance. The Abbreviated Operating Instructions are included in this report as Appendix B.

METHODS

Exercise Test Procedures

All participants in the isometric/isotonic protocol were required to take part in preliminary exercise sessions. The ground-level exercise tests and training were necessary to develop the individualized programs for exercise performance during exposures to simulated high altitude.

To minimize day-to-day variation in the data, subjects were asked to abstain from food, caffeine, and tobacco products within 2 h of an experimental session. Twenty-four hours before each session, the subjects avoided exercise, medications (including aspirin), and alcohol. All isometric and isotonic exercise sessions were performed at about the same time of day with at least 24 h between sessions.

a. Criterion test administration

Maximal oxygen consuming ability (Vo_2 max) and maximal strength were obtained for all subjects. In session I, Vo_2 max was determined by means of a graded exercise test known as the Bruce treadmill protocol (3). The Vo_2 max provided a description of the subject's cardiovascular fitness and served as a criterion reference to describe the subject's workload during isometric and isotonic exercise (e.g., 22% of Vo_2 max). The subjects were also tested for lean body mass by means of 3-site skinfold testing, according to procedures described by Pollack et al. (4).

During session II, maximal voluntary contraction for arms and legs (MVC) was measured as the maximal isometric force, in kg that a subject could sustain for 3-4 s. Three consecutive tests for each MVC were conducted, with 5-min rest between tests. The MVC provided a description of the subject's muscular strength and served as a criterion reference to describe the subject's work intensity during isometric and isotonic exercise (e.g.. 17% of MVC).

b. Isometric/Isotonic exercise test administration

The isometric and isotonic test administrations were initiated every 20 min during sessions II-V. Each exercise test administration lasted 4 min with a brief rest from 2:00 - 2:12 min. A single cycle of isometric work consisted of a 4-s contraction followed by a 1-s rest. During an isotonic cycle, the subjects flexed and extended at a rate of 1 cycle each 3 s. The same repetition rates were used for all subjects; however, work intensity (force in kg) was adjusted to cause an increase or decrease in the workload (oxygen consumption). Repetition rates were monitored by a light flashing on during the contraction phase and off during relaxation. During all ground-level test administrations, metabolic data and force were collected on the MMC 4-min before, 4-min during, and 4-min immediately after exercise.

During session II, the subjects completed 4 isometric arm exercise profiles at forces equal to 20, 25, 30, and 35% MVC. The subjects pulled against the center bar until a preassigned number appeared on the digital meter, and sustained the contraction until the light went off. In most cases, the 35% profile was subjectively assessed as too difficult to complete 12 consecutive times as required by the isometric/isotonic altitude protocol. However, the subjects performed the 25-30% MVC tests comfortably. Subjects rested 1 hr before repeating the same procedures using 4 isometric leg exercise profiles (20, 25, 30, and 35% leg MVC).

During session III, the subjects performed 5 isotonic arm profiles at levels of 12-20% MVC, created by the amount of weight on the weight stack. The first profile is usually performed at 12% MVC. For each subsequent test, the weight on the stack is increased or decreased to elicit a metabolic response that is within 5% of a targeted isometric workload determined in session II. Subjects rested 1 hr before repeating the same procedures using 5 isotonic leg profiles (0, 5, 10, 15, and 20 lb ankle weights).

c. Subject training

The data were then examined, the highest isometric arm work that could be comfortably repeated was selected and, for each of the other 3 exercise types, work intensities were selected to elicit comparable Vo_2. During session IV, the subjects completed up to 5 consecutive isometric arm profiles at the selected force in order to assess the repeatability of the data. During the isometric training, verbal and visual feedback was provided to any subject who overshot the target number at the beginning of a contraction, took too long to achieve the target number, or released the center bar too early. After a 1-hr rest, subjects completed up to 5 consecutive isometric leg profiles.

During session V, the subjects completed up to 5 consecutive isotonic arm profiles with the predetermined amount of weight on the weight stack. During the isotonic training, verbal feedback was provided to subjects who did not fully extend during the relaxation phase of each 3-s cycle. After a 1-hr rest, subjects completed up to 5 consecutive isotonic leg profiles.

REPRESENTATIVE RESULTS

In the following section, data obtained from 4 subjects are presented as representative of procedures used during upper body exercise pretests for the isometric/isotonic study. With relative regard to muscular strength (MVC) and cardiovascular fitness [Vo_2 max ($ml/kg \cdot min^{-1}$)], the subjects are representative of the following 4 "fitness" groups:

Subject A	Low MVC	Low Vo_2
Subject B	Low MVC	High Vo_2
Subject C	High MVC	High Vo_2
Subject D	High MVC	Low Vo_2

Description of the Subjects

Descriptive statistics for the subjects are presented in Table 1.

TABLE 1. DESCRIPTIVE STATISTICS FOR THE SUBJECTS (N=4)

Variable		Subject No. A	B	C	D
Height	(cm)	158.8	168.3	178.0	173.0
Weight	(kg)	68.6	81.0	83.0	87.0
Body Fat	(%)	19.8	15.0	19.3	18.0
MVC	(kg)	119.3	114.4	161.4	190.3
Vo_2 max	(1/min)	2.40	4.43	3.90	3.79
Vo_2 max	($ml/kg \cdot min^{-1}$)	34.79	54.69	46.94	43.51

Results of the Isometric/Isotonic Tests

Data from Subject A's arm tests during sessions II through V are represented in Figures 4-8. It should be noted that during Subject A's session II and III metabolic data were collected for only a 2-min post-exercise period, rather than the 4-min period used for all other tests. Therefore, for Figures 4-6, 0-240 s represent rest, 241-480 s represent isometric or isotonic arm work, and 481-600 s represent recovery.

Figures 4 and 5 show Subject A's results from session II (isometric) and session III (isotonic) arm tests performed at various levels of MVC, respectively. The figures suggest that, for this subject, Vo_2 data may be nearly equivalent for the 30% isometric profile and the 18% isotonic profile. This relationship is better illustrated in Figure 6. The 18% isotonic profile elicited a 10-min average Vo_2 that was within 1% of average Vo_2 for the selected isometric profile. The higher % MVC used in isometric work was an expected result of the study.

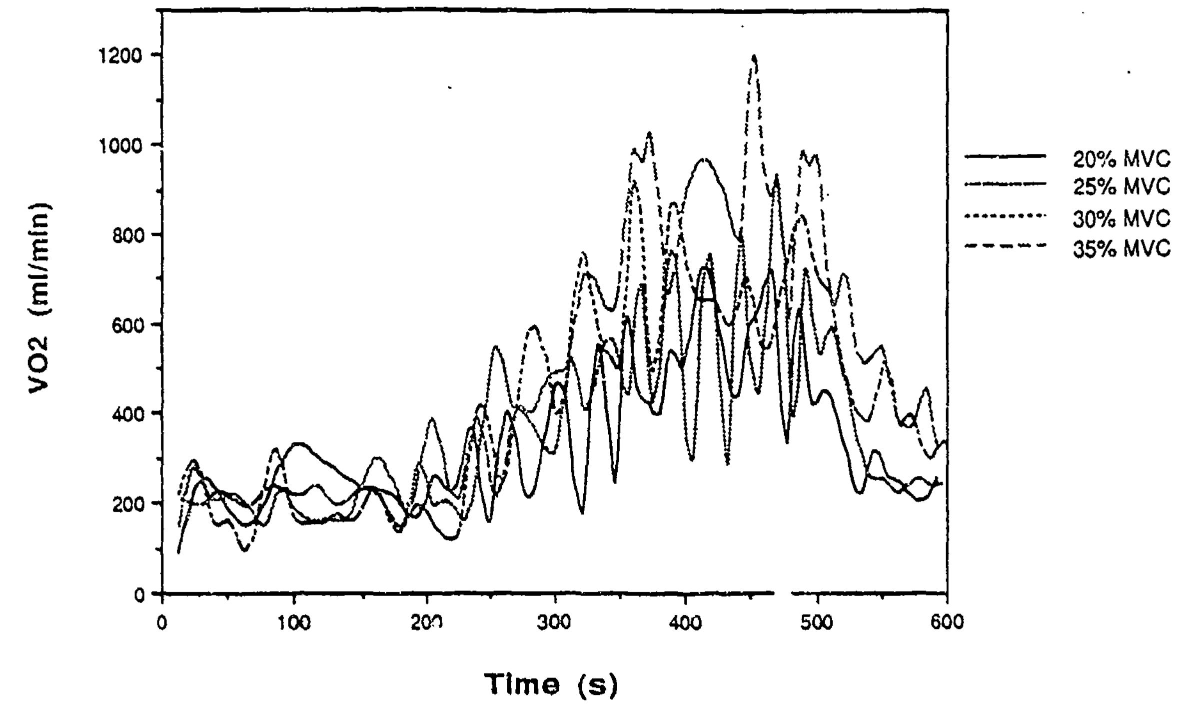

Figure 4. Results of Subject A's isometric arm tests performed at 20, 25, 30, and 35% MVC.

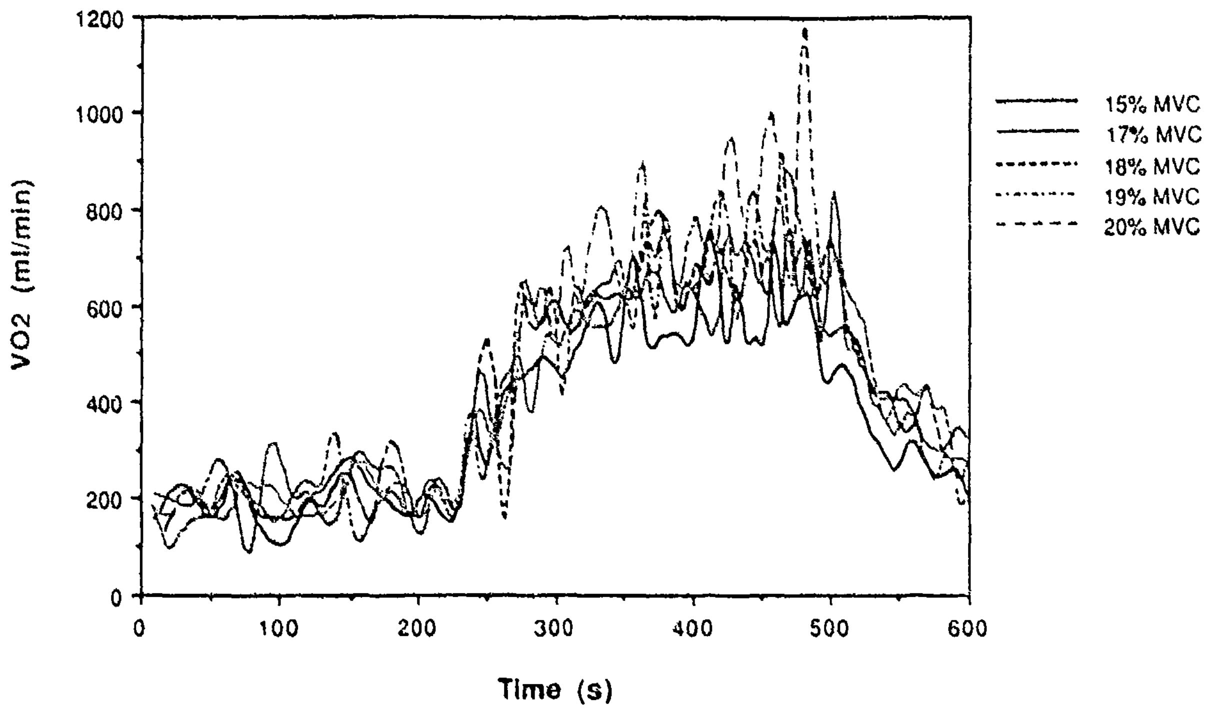

Figure 5. Results of Subject A's isotonic arm tests performed at various percentages of MVC.

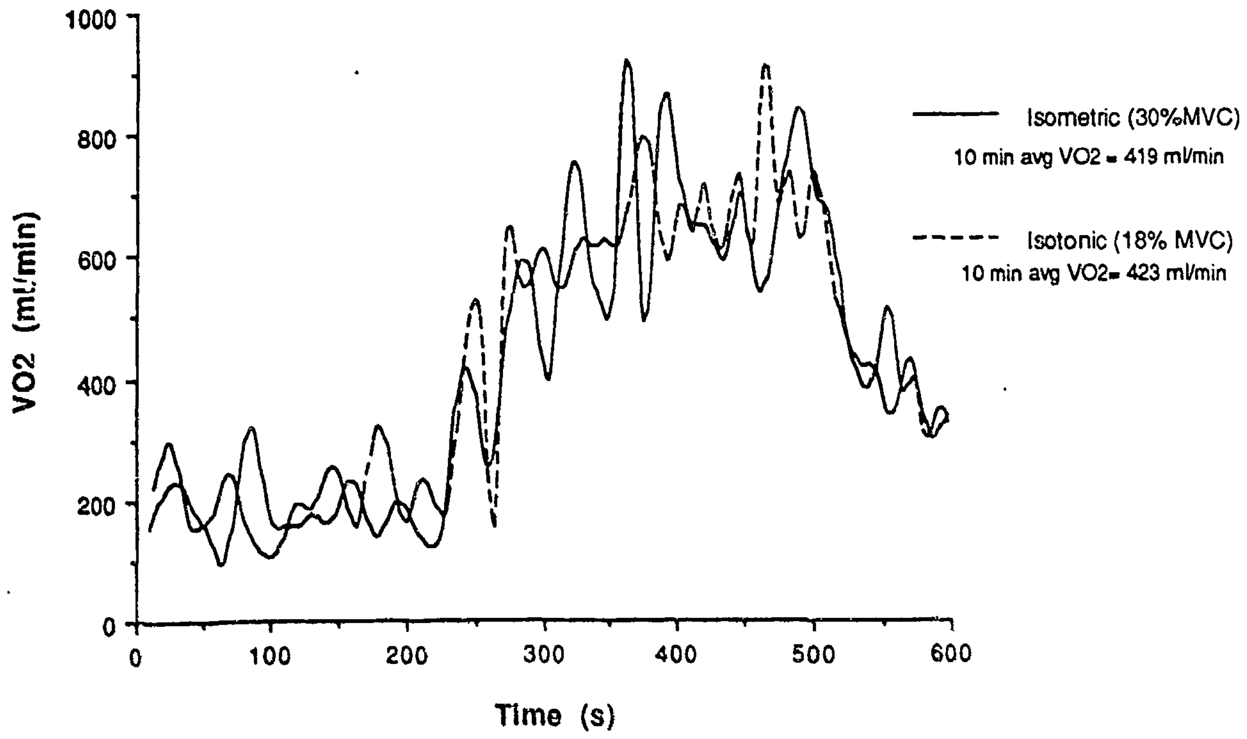

Figure 6. A comparison of isometric and isotonic workloads for Subject A.

Figures 7 and 8 describe Subject A's results from session IV and V training for repeatability of isometric and isotonic armwork, respectively. The figures, and accompanying values for 12-min average Vo_2 suggest that little cumulative effect occurred during consecutive efforts initiated each 20 min.

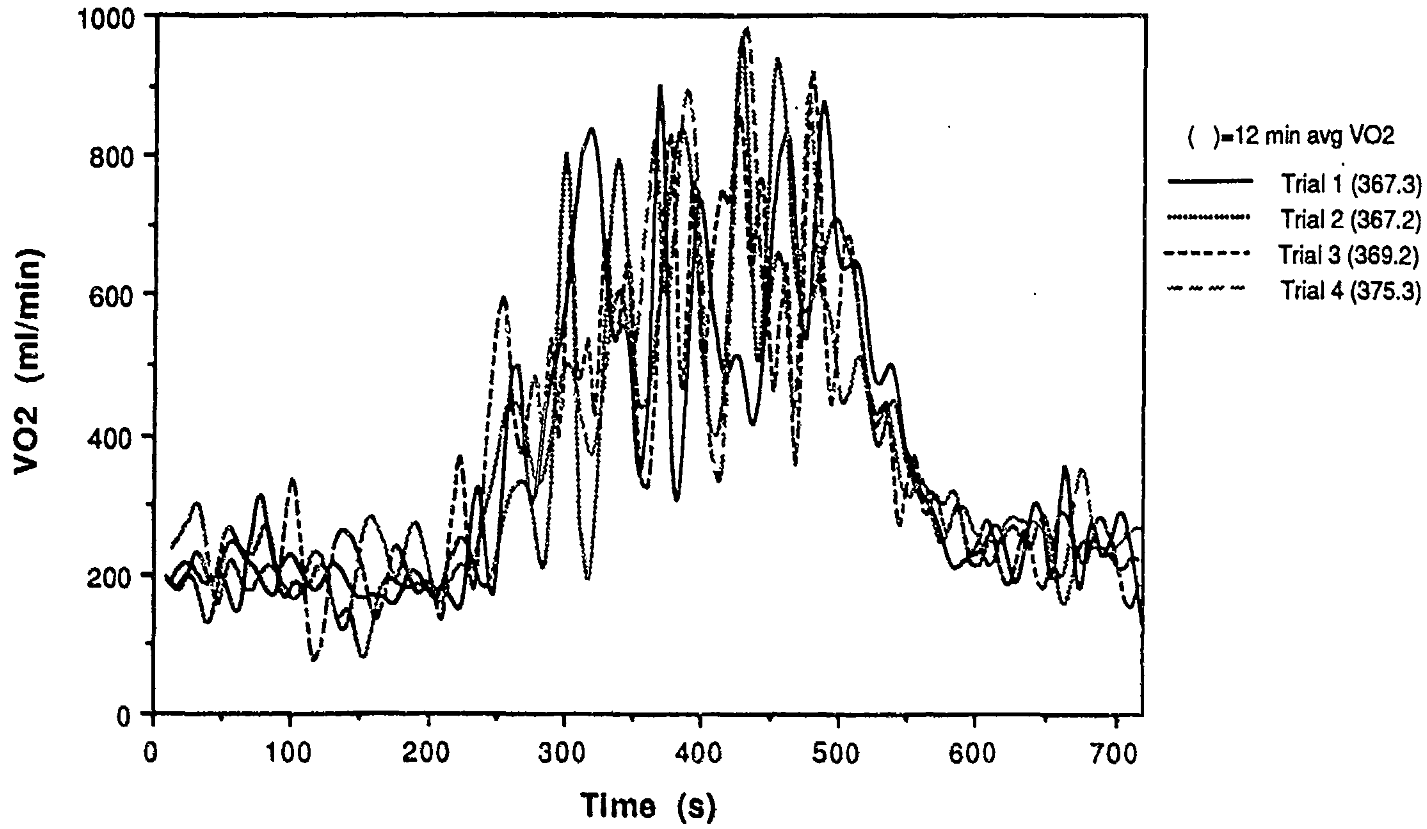

Figure 7. Consecutive isometric tests performed at a selected percentage of MVC.

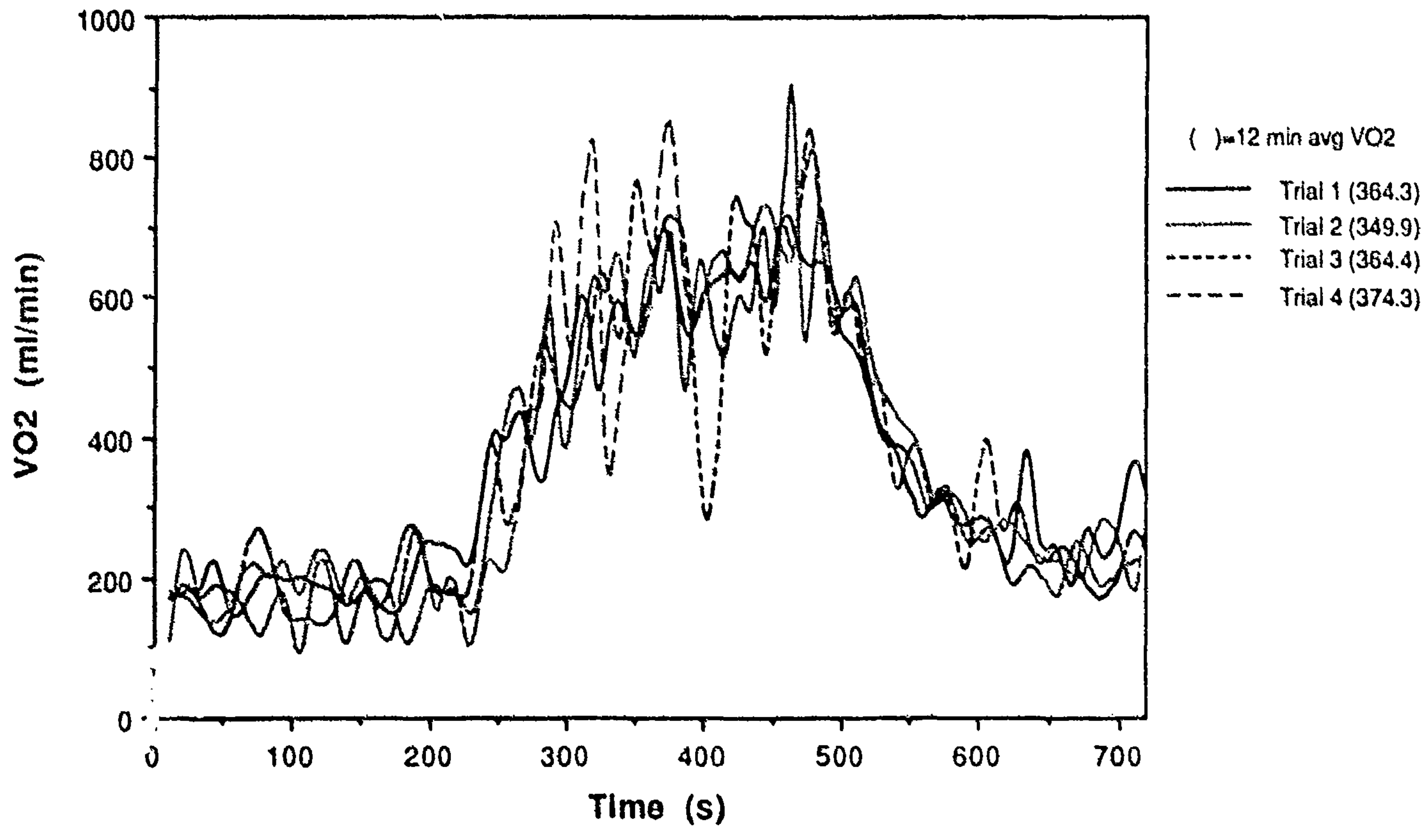

Figure 8. Consecutive isotonic tests performed at a selected percentage of MVC.

Using data from Figures 7 and 8, Subject A's average performance during the individualized isometric and isotonic exercise programs are presented in Table 2. Data for Subjects B, C, and D, having undergone the same procedures, are also included in numeric form in Table 2.

TABLE 2. AVERAGE Vo_2(ml/min) FOR EACH 4-MIN PERIOD OF THE ISOMETRIC AND ISOTONIC EXERCISE PROGRAMS OF SUBJECTS A-D

	Isometric/Isotonic A		Isometric/Isotonic B		Isometric/Isotonic C		Isometric/Isotonic D	
4-min rest	204	185	239	221	254	241	325	301
4-min work	577	575	598	608	506	565	720	717
4-min recovery	337	333	373	337	363	324	461	426
12-min average	370	363	403	389	374	377	502	481

SUMMARY

The objective of Task Order No. 0013, amendment to USAF Contract No. F33615-89-C-0603, was to quantify the metabolic activity of subjects during isometric and isotonic exercise in order to develop procedures for individualized exercise performance during simulated high altitude exposures. To satisfy the stated objective, KRUG Life Sciences performed the following tasks: (1) designed and instrumented a stack-weight machine suitable for isometric or isotonic exercise performed with the arm or legs; (2) provided and operated an advanced metabolic measurement system capable of breath-by-breath analysis of low-level oxygen consumption data; (3) provided for administration of criterion tests for maximal oxygen consumption (Vo_2 max) and maximal voluntary contraction; (4) developed procedures for equating and individualizing the isometric and isotonic work by means of oxygen consumption (% of Vo_2 max); and (5) provided procedures for training subjects on the individual exercise programs. Results obtained from metabolic data and force measurement demonstrate that techniques described in this document provide a valid means of quantifying the metabolic activity of hypobaric subjects of varying fitness levels.

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APPENDIX A
LIST OF PARTS AND ACCESSORIES

Printer

1. Fujitsu DX2300 S/N 033481
2. Printer cable
3. Printer stand
4. Printer basket
5. Printer table w/instructions

Computer

1. IBM PS/2 Model 50Z SN 23-7266164 w/instructions
2. Monitor S/N 72-0819407
3. Keyboard S/N 4032724

Software

1. Software Kit for PS/2 (set of 3 disks)
   a. DOS Startup/Operating Disk
   b. IBM PS/2 Reference Disk
   c. PS/2 Reference Utility Disk Rev #03
2. Software Kit 2900 (set of 10 disks)
   a. 2900 MD Software Rev #OD, Disks 1-7
   b. Pulmonary File Maintenance Rev #09
   c. Norm Set Data Files Disk Rev #01
   d. IMS-0104-DF 2900 File Fix

Software Manuals

1. IBM PS/2 Model 50 Quick Reference
2. IBM User's Guide

Accessories

1. Two-way rebreathing valve assembly
2. Mouthpieces
3. Nose clips
4. Regulators
5. Syringe assembly S/N 3032
6. Gas tanks

Other

1. SensorMedics Accessories and Supplies Catalog
2. Operator's Training Course Manual
3. 2900z Operator's Manual
4. KRUG Life Sciences' Abbreviated Operating Instructions

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APPENDIX B

SensorMedics 2900z
Metabolic Measurement System

ABBREVIATED OPERATING INSTRUCTIONS

February 1991

KRUG Life Sciences

San Antonio, Texas

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PART I. GAS TANKS

Purpose: to describe the use of large "H"-size cylinders in MMC calibration and testing, as a substitute for the smaller cylinders that accompany the MMC.

FOLLOW ALL RULES FOR SAFE USE OF THE TANKS AND REGULATORS!

Preparation:

1. Disconnect Span 1 and Span 2 lines from the back of MMC.
2. Ensure that cylinder valves are in "off" position (clockwise-right).
3. Ensure that the two-stage regulator is in "closed" position by turning the adjusting screw counterclockwise-left to loosen.

Gas on:

1. Check gas line connection at regulator (slight L turn).
2. Turn cylinder valve slightly to L (check 8000 psi).
3. Open regulator by turning adjusting screw slowly to R to register 8-11 psi.
4. Test pressure by gently tapping on the end of the gas line (listen for hissing sound).
5. Attach gas lines to appropriate ports on the MMC back panel (snap the "O" ring locking system into place to ensure seal).

Gas off:

1. Turn cylinder valves R to close off gas flow.
2. Disconnect Span 1 and Span 2 tank lines from back panel of MMC 2900.
3. Turn connector (where gas line meets regulator) L to loosen seal between the gas line and regulator.
4. Ensure that the two-stage regulator is in "closed" position by turning the adjusting screw L to loosen.
5. Bleed the pressure out through the disconnected line and view the regulator gauge drop to 0.

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PART II. PERIPHERAL DEVICES

I. To format external device for online data collection:

1. Attach the external device to one of the input channels on the MMC back panel, Ch. 8-11, (i.e., heart rate to channel 8, force to channel 9).
2. Set external device to produce a mid-range voltage.
3. Starting at main menu, select "Utilities". (F7)
4. Select "Analog and Digital Control". (F1)
5. Select "Program Analog Input ". (F5)
   Select the channel engaged on the back panel and enter.
   Select the number of the corresponding formatted parameter and enter.
   Re-read the incoming voltage. (F9)
   Menu-driven screen directions appear for operator.
   Indicate the units that correspond to the mid-range voltage currently displayed.
   Insert a value for the maximum unit reading expected from the external device.
6. Return to previous menu. (F10)
7. Visually check the channel and parameter name to verify their listing.
8. Scan the formatted channel. (F2)
   Increase or decrease the voltage output from the external device.
   The units should reflect the voltage change made at the site of the external device.

II. To manually input data from peripheral devices while conducting a test:

1. Select (F4)
2. i.e., HR = heart rate
   SaO_2 = arterial oxygen saturation
   WorkWatts = workload
   TMil = speed of treadmill
   Elevation = grade of treadmill
   Stages = stages during the test
   Rpe = rating of perceived exertion
   Blood Pressure = systolic and diastolic
   Event = incidents during the test
3. Select (F5)
4. Pause to pause data collection
   Resume to continue after pausing
   Output
   End to stop collecting data

III. To manually input "stage" during tests:

1. Initialize test.
2. Press "B" to begin.
3. To indicate the stage of the test:

Step 1: Select Stages (F4)
Step 2: Select Baseline
Warm up
Exercise or
Recovery

PART III. A. SCREEN DISPLAYS

I. To format test screen displays:

1. Starting at main menu, select "Utilities". (F7)
2. Select "Test Displays". (F4)
3. Toggle test mode for Exercise Test. (F1)
4. Press Enter to toggle between B x B interval data or mixing chamber mode.

a. Graphic Display Menus:

To select variables for graphs that will appear on CRT during a test.

There are 3 test menus each having graph O and graph 1 (total 6 graphs).

See Part III. B., this document, for numeric codes for each metabolic variable

See Part III. C. and D., this document, for graphs displayed during aerobic capacity and isometric/isotonic tests, respectively.

In test mode, graphs are displayed by typing F1, followed by menu number (1-3).

b. Digital Display Menus:

To select variables for digital display on CRT during a test.

There are 3 test menus each having 6 variables (total 18 variables).

See Part III. B., this document, for numeric codes for each metabolic variable.

See Part III. C. and D., this document, for digital displays used during aerobic capacity and isometric/isotonic tests, respectively.

Select variables by highlighting, then typing the code number.

In test mode, menus are displayed by typing F1, followed by menu number (1-3).

II. To format displays for printing **during** test:

See Part III. B., this document, for numeric codes for each metabolic variable to be printed.

See Part III. C. and D., this document, for variables printed during tests for aerobic capacity and isometric/isotonic exercise, respectively.

PART III. B. SYSTEM 2900 REAL TIME DISPLAY
CRT/Printer Variable List

1. TIME
2. % EO2
3. % ECO2
4. % IO2
5. % ICO2
6. % EQCO2
7. %ETCO2
8. VE (STPD)
9. VE (BTPS)
10. RR
11. HR
12. HR - %PRED
13. TV
14. VO2
15. VCO2
16. VEO2
17. VECO2
18. R
19. VO2/KG
20. METS
21. KCAL/DAY
22. STAGE
23. WRK-WATTS
24. WORK-KPM
25. SPEED-MPH
26. SPEED-KPH
27. GRADE
28. SBP
29. DBP
30. PaO2
31. SaO2
32. pH
33. PaCO2
34. RPE
35. PEAK PR
36. TRUE O2
37. O2 PULSE
38. A-aDO2
39. % ETO2
40. VD/VT
41. PETCO2
42. PEQCO2
43. Q
44. SVOL
45. DP
46. DI
47. VE-PAT TX
48. NPR
49. PEAK FLOW
50. EVENT
51. LACTATE
52. KCAL/MIN
53. TcO2
54. MEFR
55. PULSE PR
56. VELOCITY
57. Vpump
58. MET-WATTS
59. PACE
60. REE/BSA
61. REE/KG
62. CI
63. ST LEVEL
64. ST SLOPE
65. Q-T TIME
66. BE
67. HCO3
68. PAO2
69. PvO2
70. VE (ATPS)
71. SvO2
72. VA
73. Q DIRECT
74. CaO2
75. CvO2
76. VA/Q
77. Qs/Qt
78. CcO2
79. BBTIME
80. ECTPIC CT
81. ET
82. IT
83. FORCE lbs
84. HR-ART
85.
86.
87.
88. ST INTEG
89. PETO2
90 %MAX VO2P
91.
92.
93.
94.
95.
96.
97.
98.
99.
100.

PART III. C.
SELECTED TEST DISPLAY VARIABLES (GRAPHIC, DIGITAL, AND PRINTER) FOR AEROBIC CAPACITY TESTS

Graphic Section:

	MENU 1		MENU 2		MENU 3	
	Graph 0	Graph 1	Graph 0	Graph 1	Graph 0	Graph 1
Y-Label	9 VE (BTPS)	19 VO2/kg	14 VO2	15 VCO2	15 VCO2	18 Force
Y-Min	0	0	0	0	40	0
Y-Max	160	60	5000	5000	200	2
X-Label	14 VO2	1 Time	1 Time	1 Time	14 VO2	1 Time
X-Min	0	0	0	0	0	0
X-Max	5000	20	20	20	20	20

Digital Section:

Time	MENU 1	MENU 2	MENU 3
Unit 1	9 VE (BTPS)	9 VE (BTPS)	9 VE (BTPS)
Unit 2	14 VO2	14 VO2	14 VO2
Unit 3	15 VCO2	15 VCO2	15 VCO2
Unit 4	18 R	18 R	18 R
Unit 5	19 VO2/kg	90 %MaxVO2	19 VO2/kg
Unit 6	16 VEO2	11 HR	11 HR
Unit 7	17 VECO2	20 METS	23 Force

Printer Section:

TIME	MENU 1	MENU 2	MENU 3
Unit 1	9 VE (BTPS)	9 VE (BTPS)	9 VE (BTPS)
Unit 2	14 VO2	14 VO2	14 VO2
Unit 3	15 VCO2	15 VCO2	15 VCO2
Unit 4	18 R	18 R	18 R
Unit 5	19 VO2/kg	19 VO2/kg	11 HR
Unit 6	11 HR	11 HR	16 VEO2
Unit 7	20 METS	90 % Max VO2	17 VECO2

PART III. D.
SELECTED TEST DISPLAY VARIABLES (GRAPHIC, DIGITAL, AND PRINTER) FOR ISOMETRIC/ISOTONIC TESTS

	MENU 1	MENU 2		MENU 3		
	Graph 0	Graph 1	Graph 0	Graph 1	Graph 0	Graph 1
Y-Label	9 VE(BTPS)	19 VO2/kg	14 VO2	15 VCO2	15 VCO2	23 Force
Y-Min	0	0	0	0	0	0
Y-Max	60	25	2000	2000	2000	100
X-Label	14 VO2	1 Time	1 Time	1 Time	14 VO2	1 Time
X-Min	0	0	0	0	0	0
X-Max	2000	12	12	12	2000	12

Digital Section

TIME	MENU 1	MENU 2	MENU 3
Unit 1	9 VE (BTPS)	9 VE (BTPS)	9 VE (BTPS)
Unit 2	14 VO2	14 VO2	14 VO2
Unit 3	15 VCO2	15 VCO2	15 VCO2
Unit 4	18 R	18 R	18 R
Unit 5	19 VO2/kg	19 VO2/kg	19 VO2/kg
Unit 6	16 VEO2	11 HR	11 HR
Unit 7	17 VECO2	20 METS	23 Force

Printer Section

TIME	MENU 1	MENU 2	MENU 3
Unit 1	9 VE (BTPS)	9 VE (BTPS)	9 VE(BTPS)
Unit 2	14 VO2	14 VO2	14 VO2
Unit 3	15 VCO2	15 VCO2	15 VCO2
Unit 4	18 R	18 R	18 R
Unit 5	19 VO2/kg	19 VO2/kg	19 VO2/kg
Unit 6	23 Force	11 HR	16 VEO2
Unit 7	20 METS	23 Force	17 VECO2

PART IV. A. FINAL REPORTS

1. Starting at main menu, select Utilities (F7)

2. Select Final Reports (F6)

3. Select Heading (F1)

   -Type no more than 4 lines total

4. Select Text Reports (F2)

   -Select desired profile (9 to choose from)

   Use "Steady State Real Time Profile" (F6) for isometric/isotonic study.

   Use "Incremental Real Time Profile" (F5) for treadmill testing.

   -If not using one of the two aforementioned profiles then you may wish to select desired variables from variable list in section IV. B., this document.

5. Select Graphic Reports (F4)

   -Select your desired profile (9 profiles to choose from).

   -Four graphs (plots A-D) will be available for each profile.

6. Select y-axis (F1) and x-axis (F4) variables

   -See final reports variable list to match variables with a coded number.

7. Select scale values (range) for y (F2, F3) and x (F5, F6).

8. The final reports (text reports and graphic reports) used in the isometric/isotonic study are described in Section IV. C., this document.

PART IV. B. SYSTEM 2900 FINAL REPORTS PRINTER VARIABLE LIST

1.	HEART RATE B/MIN	2.	MIN VENTILATION L/MIN (BTPS)
3.	O2-PULSE ML/BEAT	4.	OXYGEN UPTAKE L/MIN (STPD)
5.	VO2/KG ML/KG/MIN	6.	CO2 PRODUCTION L/MIN
7.	TRUE O2	8.	TIDAL VOLUME L (BTPS)
9.	RESPIRATORY RATE	10.	RESPIRATORY QUOTIENT (R)
11.	BLOOD PRESSURE SBP-DBP	12.	DYSPNEA INDEX
13.	DOUBLE PRODUCT	14.	VD/VT
15.	VENTILATORY EQUIVALENT (O2)	16.	VENTILATORY EQUIVALENT (CO2)
17.	SATURATION %	18.	pH
19.	PaCO2	20.	PaO2
21.	A-a GRADIENT	22.	WORK WATTS
23.	WORK KPM	24.	TIME MIN
25.	VEO2 - VECO2	26.	METS
27.	SPEED MPH	28.	% GRADE
29.	FEO2 %	30.	FECO2
31.	FETCO2 %	32.	PETCO2 mmHg
33.	MIN VENTILATION L/MIN (STPD)	34.	VE-PAT TMP
35.	SPEED KPH	36.	CARDIAC OUTPUT (Q)
37.	STROKE VOLUME ML	38.	PEQCO2 mmHg
39.	FEQCO2 %	40.	PEAK FLOW LPM
41.	KCAL/DAY	42.	NON PROTEIN R
43.	URINARY NITROGEN G/DAY	44.	FIO2 %
45.	FICO2 %	46.	PEAK PRESSURE mmHg
47.	KCAL/MIN	48.	Vpump
49.	MET-WATTS	50.	PvO2
51.	MIN VENTILATION L/MIN (ATPS)	52.	EXPIRATORY TIME
53.	TcO2	54.	MEFR
55.	PULSE PR	56.	VELOCITY
57.	PACE	58.	REE/BSA
59.	REE/KG	60.	CARDIAC INDEX
61.	ST LEVEL	62.	ST SLOPE
63.	Q-T TIME	64.	BE
65.	HCO3	66.	PAO2
67.	SvO2	68.	VA
69.	Q DIRECT	70.	VA/Q
71.	Qs/Qt	72.	LACTATE
73.	FETO2	74.	BXBTIME
75.		76.	FORCE (lbs)
77.		78.	
79.		80.	
81.	ST INTEGRAL	82.	ECTOPIC COUNT
83.	PETO2 mmHg	84	%PRED MAX VO2

99. REMOVE FORMATTING

PART IV. C.
SELECTED FINAL REPORT VARIABLES (TEXT AND GRAPHIC) FOR THE ISOMETRIC/ISOTONIC STUDY

To initiate this procedure, select Utilities (F7 function key). Next, select Final Reports. Then select Text Reports or Graphic Reports to view metabolic variables. The lists below contain selected variables used in the "Isometric/Isotonic" Exercise Study:

<u>Text Reports (F2)</u>: (9 profiles total)

(F5) Incremental Real Time Profile: (print positions 79)

Testing Purpose: Treadmill VO2 max

Variables Selected:

Time	METS	
Speed	VCO2	
Grade	R	
HR		VEO2
VE BTPS		VECO2
VO2		%Max VO2P
VO2/Kg		

(F6) Steady State Real Time Profile: (print positions 79)

Testing Purpose: Iso/Iso Correlation

Variables Selected:

Time	VO2/Kg	
Work		METS
VE BTPS		R
RR		VEO2
TV		VECO2
VO2		

<u>Graphic Reports (F4)</u>: (9 profiles total)

(F6) Isometric/Isotonic Profile:

Plot A:
- X axis Oxygen Uptake l/min (STPD)
  - range Min. 0
  - Max. 2
- Y axis Minute Ventilation l/min (BTPS)
  - range Min. 0
  - Max. 60

Plot B:
- X axis Time (minutes)
  - range Min. 0
  - Max. 12
- Y axis VO2/kg ml/kg/min
  - range Min. 0
  - Max. 20

Plot C:
- X axis Oxygen Uptake l/min (STPD)
  - range Min. 0
  - Max. 2
- Y axis CO2 Production l/min
  - range Min. 0
  - Max. 2

B. 9

Plot D:
- X axis Time (minutes)
  - range Min. 0
  - Max. 12
- Y axis Oxygen Uptake l/min (STPD)
  - range Min. 0
  - Max. 2

(F7) Muscle Contraction Correlation Profile:

Plot A: X axis Oxygen Uptake l/min (STPD)
range Min. 0
Max. 2
Y axis Work (watts)
range Min. 0
Max. 100

Plot B: X axis Time (minutes)
range Min. 0
Max. 12
Y axis Work (watts)
range Min. 0
Max. 100

Plot C: X axis Time (minutes)
range Min. 0
Max. 12
Y axis Minute Ventilation l/min (BTPS)
range Min. 0
Max. 60

Plot D: X axis Time (minutes)
range Min. 0
Max. 12
Y axis VO2/kg ml/kg/min
range Min. 0
Max. 20

(F8) Maximal Oxygen Uptake Profile:

Plot A: X axis Oxygen Uptake l/min (STPD)
range Min. 0
Max. 6
Y axis Minute Ventilation l/min (BTPS)
range Min. 0
Max. 160

Plot B: X axis Oxygen Uptake l/min (STPD)
range Min. 0
Max. 6
Y axis Heart Rate (bpm)
range Min. 45
Max. 220

Plot C: X axis Oxygen Uptake l/min (STPD)
range Min. 0
Max. 6
Y axis Carbon Dioxide Production l/min
range Min. 0
Max. 6

Plot D: X axis Time (minutes)
range Min. 0
Max. 15
Y axis Oxygen Uptake l/min (STPD)

(F9) VO2 Correlation Profile:

Plot A: X axis Time (minutes)
range Min. 0

Max. 15
Y axis VO2/kg ml/kg/min
range Min. 0
Max. 65

Plot B: X axis Time (minutes)
range Min. 0
Max. 15
Y axis Minute Ventilation l/min (BTPS)
range Min. 0
Max. 160

Plot C: X axis Time (minutes)
range Min. 0
Max. 15
Y axis Heart Rate (bpm)
range Min. 45
Max. 220

Plot D: X axis Time (minutes)
range Min. 0
Max. 15
Y axis Carbon Dioxide Production l/min
range Min. 0
Max. 6

PART V. ASCII FILES

Purpose: to describe procedures for converting the MMC data to ASCII format (.txt).

<u>I. To select the file:</u>

1. Select "Reports". (F4)
2. Select the file that will be converted to an ASCII file by selecting:
   - -report on last patient tested (Fl) ,then skip to Step 6 or
   - -search/retrieve data (F2), and continue to Step 3.
3. If known, enter the MMC ID or filename.
4. If unknown, then press Return key to view first page of file listings and use cursor to locate desired file.
5. Mark the entry of the selected file by pressing Insert key.
6. Press the Escape key to retrieve the data.

<u>II. To create the text report:</u>

1. Select Text Reports. (F1)
   - -toggle the path to "file" (press 1 to toggle)
2. Select desired report format profile in the Text Reports.
   - -"Filename?" will appear on the screen
   - -type in the desired filename for the ASCII file being created
   - -press Enter Key
3. Exit to DOS (series of F10 keys).
4. In DOS, the ASCII file will appear under filename assigned, followed by TXT.

PART VI. MAINTENANCE

I. Disinfection Schedule

Daily: 1. Rubber mouthpiece
2. Breathing valve
3. Leaflets

- Required maintenance through disassembling and rinsing with soap and warm water, then cold soaked in Cidex for at least 10 minutes for germicidal effect and 10 hours for complete sterilization.

Weekly: 1. Breathing Hose
2. Water Trap (sputum collector)
3. Flow Meter Clean- performed in system calibration mode

- These items are not a source of cross-contamination ; therefore, recommended cleaning is with a cold soak (soap and water), rinse and aerate.

II. Replace Schedule for Expendables

Every 4-6 months: 1. Perma-Pure breath-by-breath sample line
2. Leaflets for 2700 breathing valve

Every 6-8 months: 1. Printer color ribbon cartridge

III. Gas Tanks

Refill when the regulator pressure falls below 500 psi.

IV. Dessicant Chamber

Refill Sodasorb when the color of the crystals changes from white to purple/pink.

V. Environmental Recommendations

Operating:	1. Temperature Range	14c to 30c
	2. Humidity (relative)	20% to 90%
	3. Warm Up Time	30 minutes
Storage:	1. Temperature Range	-20c to 50c
	2. Humidity (relative)	20% to 90%