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Evaluation of a Soviet Low-Pressure Manned Space Flight Research and Development Facility

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EVALUATION OF A SOVIET LOW-PRESSURE MANNED SPACE FLIGHT RESEARCH AND DEVELOPMENT FACILITY

Project Officer

OSI-STIR/75-14
August 1975

CENTRAL INTELLIGENCE AGENCY
DIRECTORATE OF SCIENCE AND TECHNOLOGY
OFFICE OF SCIENTIFIC INTELLIGENCE

PREFACE

A program leading to manned lunar or certain space missions requires extensive training and testing of men and equipment under conditions simulating the expected environment. Until quite recently, evidence for the existence of such training and testing in the USSR has been lacking. This paper identifies and analyzes recent intelligence information relating to Soviet acquisition of a research and testing facility for such purposes. This report was prepared by the Office of Scientific Intelligence and coordinated within CIA. The cut-off date for information is March 1975.

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CENTRAL INTELLIGENCE AGENCY
UNITED STATES OF AMERICA

August 1975

Evaluation of a Soviet Low-Pressure Manned Space Flight Research and Development Facility

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PRÉCIS

The Soviets have awarded a major contract valued at US$35 million to the Austrian engineering and manufacturing firm, [ ] to build a research hypobaric (low-pressure) chamber facility. The chamber facility will enable the Soviets to conduct research on man in a simulated space or lunar environment, as well as to test full-pressure suits used for orbital extravehicular activity. The facility is planned to be operational by early 1977 and will enable the Soviets to conduct research on man in a low-pressure environment such as space or the lunar surface.

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PROBLEM

To describe and evaluate a Soviet manned hypobaric test facility and its use.

SUMMARY AND CONCLUSIONS

The Soviets are acquiring a research and development facility to simulate conditions found in outer space and on the lunar surface. They have contracted with an Austrian firm at a cost of US$35 million for construction of a manned hypobaric chamber, associated equipment, and a building to house the facility. The primary purpose of this facility, known as Project Katya, will be to conduct physiological testing on human subjects in a simulated space environment. Completion of the facility is scheduled for late 1976, and a test program is expected to begin early in 1977. A solar simulator and a treadmill used in combination with a block and tackle arrangement to simulate reduced gravitational force will provide the necessary means of testing a cosmonaut during both orbital and simulated lunar surface extravehicular activity (EVA).

The testing will be conducted by medical personnel and engineers. It will require at least two physicians, two physiologists, and an electronics engineer plus numerous support personnel to operate the facility. It appears that the test facility will be operated on a permanent basis and that the Soviets are anxious to have it become operational soon.

The hypobaric chamber almost certainly will be used to test space suits, investigate human physiology, and measure energy expenditures under both space and lunar conditions. The hypobaric facility is a good indicator of Soviet intentions for manned lunar missions and the Soviet contracting effort implies some urgency. Mission schedules, however, will depend as well on Soviet progress in other phases of activity, such as development of boosters and spacecraft.

DISCUSSION

INTRODUCTION

In April 1973 a [redacted] was contacted by officers of the SWEDISH FIRM [redacted] who discussed requirements for a space simulation chamber facility, known as Project Katya, to be constructed for the USSR. [redacted] specifically requested that the [redacted] build, procure, assemble, test, and deliver a complete physiological monitoring system for the chamber and provide an oxygen supply system for space suit systems in the main chamber and the observer stations in a man-lock. [redacted] was anxious for an early reply as it expected to have a firm contract from the USSR in December 1973 or January 1974 with completion of the chamber by 1976. [redacted] gave the following information to [redacted] The chamber was to be designed primarily for physiological testing; it was to be provided with a cryogenic shroud, a solar simulator, and the capability to pump down to 10^{-8} torr; it was to be used to test space suits as well as to investigate human physiology and energy expenditures under hypobaric conditions.[2]

Negotiations with [redacted] were carried on for 20 months when suddenly the Soviets awarded a contract in March 1974 to the Austrian engineering and manufacturing firm, [redacted] The chamber, fabricated by [redacted] is scheduled for completion by March 1976. The system then will be installed in a new building, probably at the Institute of Medico-Biological Problems No. 2, outside of Moscow. A test program is expected to begin early in 1977. The scheduling for delivery and installation of the chamber test facility is consistent with the hypothesis that the Soviets are anxious to move ahead with a manned lunar landing and are working toward achieving that end.[3-8]

Project Katya, a highly sophisticated chamber, will cost the USSR US$35 million, which will include the construction of the chamber, associated equipment, and a building to house the facility. This amount does not include the cost for any operating personnel or expendables required to sustain operation. The project is planned for continuous operation and will require personnel of various disciplines, such as physicians, physiologists, psychologists, physicists, electrical and mechanical engineers, and support personnel.[8]

Project Katya is of high priority and will provide the USSR with a capability for performing detailed physiological testing of human subjects, wearing full pressure suits, in the environmental conditions found on the lunar surface or in outer space. Simultaneously, in an adjacent chamber, which is connected by a man-lock, the shirt-sleeve environment of a space vehicle can be provided to permit test subjects to simulate transition to and from a spacecraft. Project Katya is not designed to test large equipment such as a capsule or orbital compartment. By comparison, the U.S. National Aeronautics and Space Administration has hypobaric chambers that are capable of testing man and machine under the extreme conditions found in space or on the lunar surface. Although Project Katya is not designed to include man/machine testing, it is believed that except for this capability the Soviets will have gained parity with similar US facilities once Project Katya becomes operational.[5-9]

THE FACILITY

The hypobaric chamber will be housed in a separate physiological research building (figure 1). The main chamber hall will have a floor area of approximately 24 x 24 meters. The remainder of the building will be divided into rooms for control, electronics, medical, and staff functions and a room to house the machinery, including cryogenic and vacuum equipment and other related equipment necessary to operate the facility. The hypobaric chamber itself is divided into three units: a horizontal chamber, a vertical chamber, and a man-lock (figure 2). The man-lock is a connecting area between the horizontal and vertical chambers which can be pressurized and unpressurized by the use of interconnecting pressure sealing doors without disturbing the artificial atmosphere of either of the chambers. The horizontal chamber will function as a crew quarters area and will contain a shower, toilet facility, and sleeping quarters. It also will contain a service lock, a TV camera to monitor the crew, and inspection windows in the walls of the chambers. The vertical chamber will contain a treadmill opposite a solar simulator which can be used for simulated lunar surface activity. A hook, located in the center top of the vertical chamber and directly above the treadmill, could be used to simulate the 1/6 force of gravity found on the lunar surface. The entire chamber will be air conditioned for environmental control. The man-lock can be used for transfer of men and equipment to and from the main chambers without disrupting the artificial environment created during prolonged testing. Additionally, the man-lock can provide the necessary means of practicing transfer to and from a spacecraft or more specifically transfer to and from the lunar surface to a lunar landing vehicle.[10]

The horizontal and vertical chambers can be used to test the extremes of protective clothing from "shirt sleeves" in a pressurized compartment to extravehicular activity (EVA) suits in a vacuum with simulated lunar-surface solar radiation.

CHAMBER EQUIPMENT

Vertical Chamber

Test equipment incorporated directly within the vertical chamber unit includes the treadmill, the solar

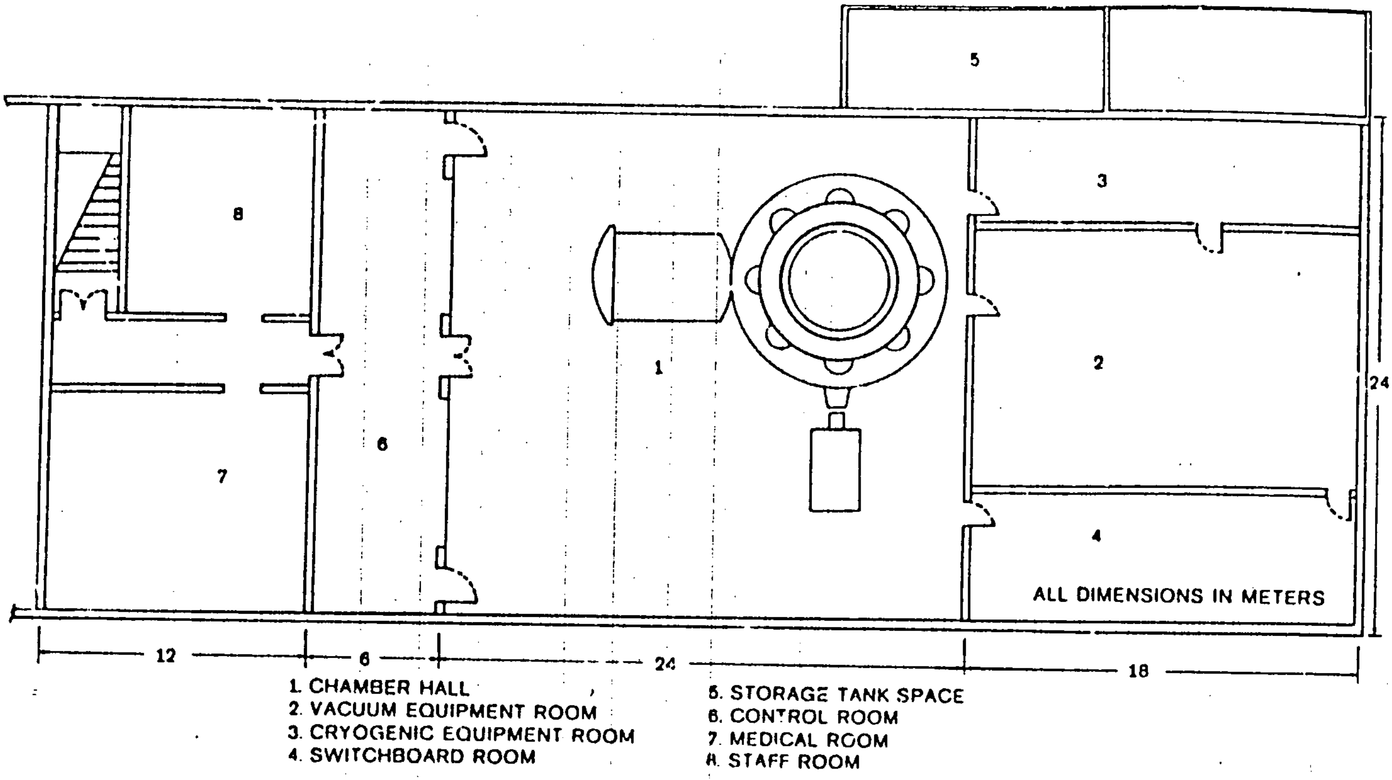


Figure 1. Basic Layout of Physiological Research Building Showing Location of Hypobaric Chamber

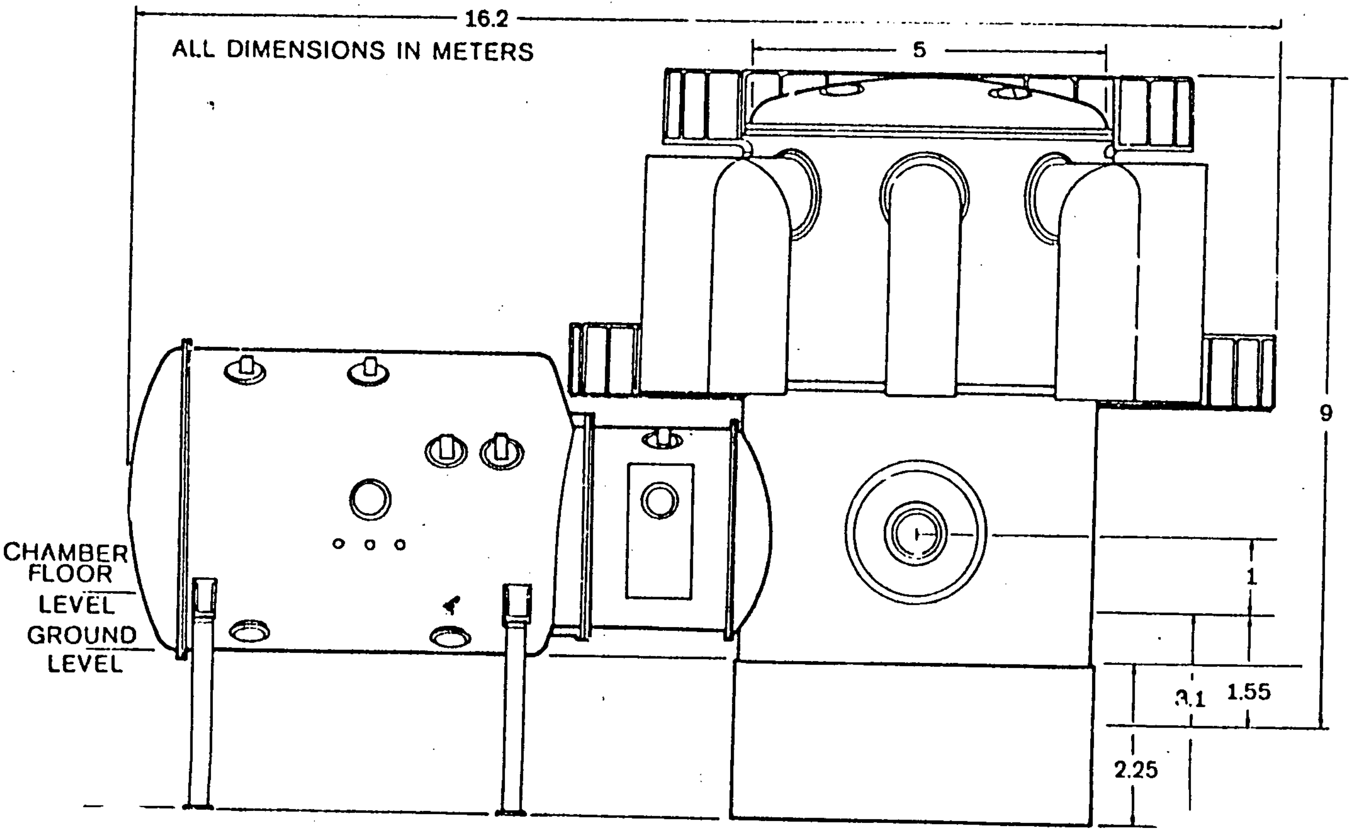


Figure 2. Schematic Drawing of Hypobaric Chamber

simulator, and a bicycle ergometer (figure 3). The treadmill is located in the floor of the vertical chamber directly in front of the solar simulator. The primary purpose of this design is to simulate a cosmonaut walking on a lunar surface while subject to the effect of solar radiation. By incorporating the hook at the top of the vertical chamber directly over the treadmill, a block and tackle type arrangement could be used to simulate the reduced gravitational effect found on the lunar surface.[4-5]

Any suit the Soviets intend to use for lunar EVA would require considerable testing utilizing the treadmill. A serious weakness in the design of Soviet space suits is that they lack the joint flexibility of US space suits. It is very difficult if not impossible for the wearer of the Soviet suit to articulate arm and leg joints, because the arms and legs of the Soviet suits resemble stove pipes and remain virtually rigid and unbending. The Soviets do not seem to have mastered the technique of combining joint flexibility with the required impermeability. The Soviets have tried in the recent past to purchase the US Apollo suit. If they are successful, they quite possibly intend ultimately to test the US space suits as well as those manufactured in the USSR in the hypobaric chamber. The treadmill would be employed for a large part of this testing.[10 11]

The treadmill would also be used for exercise by the cosmonauts during extended periods of testing. During space flight the treadmill has been effective for exercise and for promotion of proper circulation during prolonged periods of weightlessness.

A bicycle ergometer will be used for exercise and as a test unit to measure respiratory functions. It can also be used to measure the work necessary to articulate the leg and arm joints of a pressure suit and to measure the other physiological stresses involved.

The solar simulator will be controlled by an operator outside of the chamber who will have an indicator panel complete with all safety features. The solar simulation device consists of the following units and systems:

(1) radiation source with standby sources in one housing,

(2) integrator system,

(3) shutter for complete shielding of the radiation power of the solar simulator,

(4) water cooling system,

(5) suction device for the removal of harmful materials,

(6) electronic control and regulation, and

(7) electrical power supply.[5]

The radiation source has a power of 30 kilowatts. The integrator system assures uniformity of the irradiation in the test plane area. The shutter system will automatically reduce current in the radiation source within one hour of use to approximately 40 percent of the nominal value. All elements of the solar simulation system generating heat will be cooled by high- or low-pressure water recirculator systems or by cooled air. Ozone and nitric oxides along with other "harmful materials" will be removed by a suction device within double walls enclosing the whole volume of the chamber in which harmful gases are generated. The radiation intensity is to be controlled automatically by electronic devices. The desired simulated radiation intensity can be adjusted by means of a potentiometer, the probe of which is located in the test plane area. The test plane area (1 x 2 meters) is directly in front of the treadmill.[5 10–12]

To provide further simulation of the space environment, the temperature of the walls in the vertical chamber must be maintained at −170°C. This will be accomplished utilizing a closed circulating system of liquid nitrogen.[5]

Horizontal Chamber

The horizontal chamber will have a fire extinguishing system which will eject water through special jets designed to produce a fine spray, resulting in large surface area coverage capable of rapid absorption of heat released in a fire. Ventilation of the chamber will be accomplished by utilizing an air conditioning "dry cleaning" plant. The function of the dry cleaning plant is to control and maintain temperatures between 0 and 50°C ± 1.5°C and relative humidity between 10 percent and 90 percent (±5 percent). The system is planned for recirculating air only. The air will be directed into the chamber through pressure-proof connecting pipes. The communication system will include an intercom system, a black and white closed circuit TV system, and tape recorders. Data from medical experiments carried out inside the chamber will be transmitted directly from the test personnel to the outside by cable and fed directly into an online processing computer.[5]

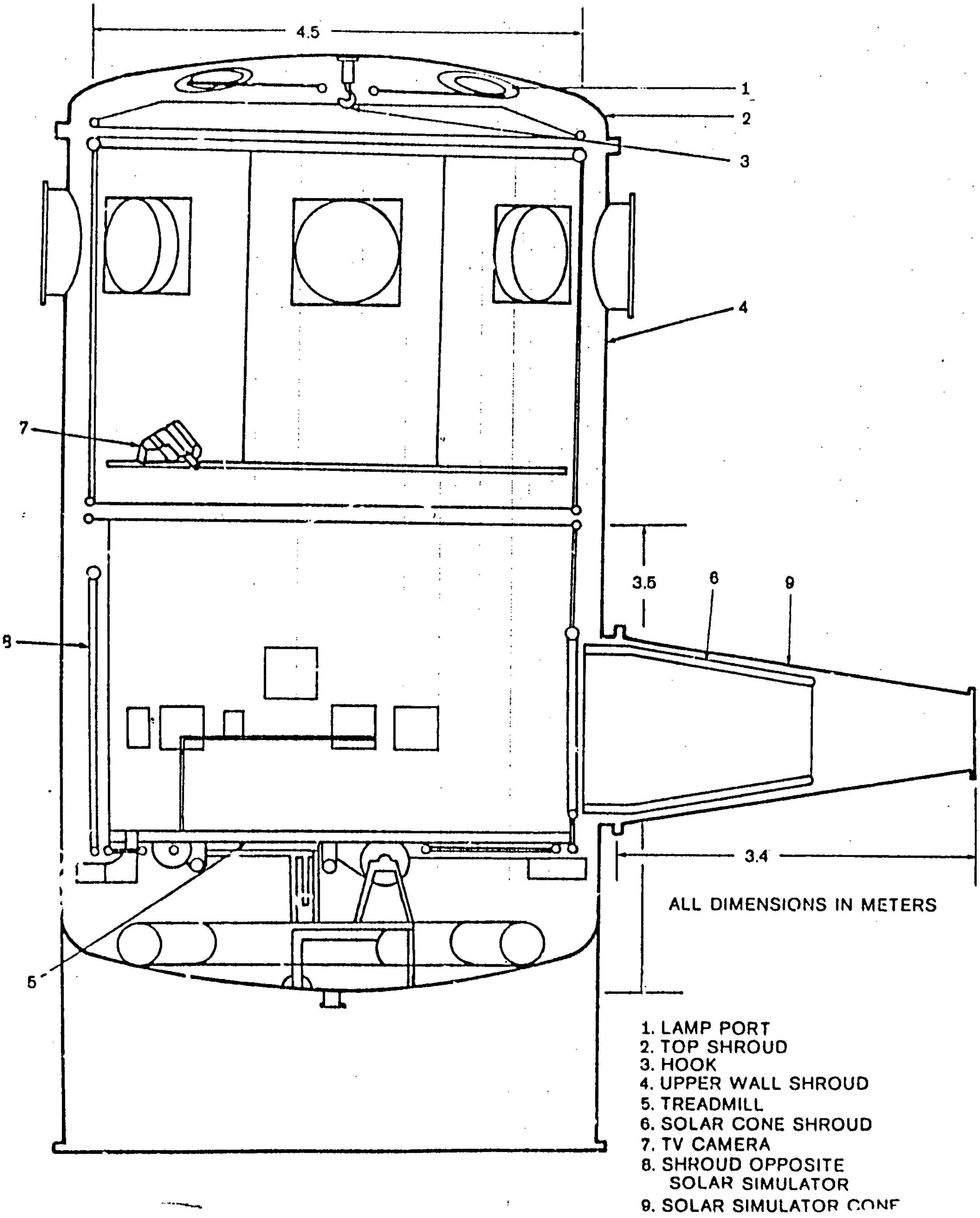


Figure 3. Cutaway Drawing of Vertical Chamber

CONTROLS AND INSTRUMENTATION

Vacuum System

The artificial atmosphere of the chamber units will be controlled by a vacuum system. It will consist of three pump stations that can be used separately or in combination. The vacuum plant is a complete entity, including measuring equipment and a special pumping stand for lift-off simulation up to approximately 12,000 meters. It will provide the capability to test operation of a space suit during simulated spacecraft pressurization failure.[5]

Oxygen System

A primary oxygen system and emergency oxygen provisions are incorporated in the hypobaric chamber design and will be capable of providing oxygen to one, two, or three persons. The instruments and controls for the oxygen supply system will be assembled in three control consoles, one each for the vertical chamber, the horizontal chamber, and the man-lock.[3] Oxygen will be provided to the test subjects inside the chamber from portable oxygen vessels contained in modules. Flexible hoses ("umbilicals") will be used to connect the test subjects to distribution panels arranged in the vertical and horizontal chambers and the man-lock.

The horizontal chamber will have three distribution panels on one side of the chamber and another set of three panels on the opposite side for alternate connection of test subjects. The man-lock will contain three distribution panels (figure 4).[13]

One oxygen supply module will be required for each test subject. Each module will contain instrumentation for pressure, temperature, flow, and humidity control. The pressure instrumentation will show the oxygen supply, emergency supply, pressure in the space suit, and the differential pressure between the suit and chamber. All of the instrumentation will be equipped with alarm systems.[13]

Simultaneous operations of three oxygen modules will be required to support three test subjects. Additionally, a fourth oxygen module will be required as a standby emergency supply source. The emergency supply system will be designed to override a malfunctioning oxygen module and will normally be controlled manually, but in some cases automatic activation of the emergency oxygen supply will be initiated by a sensing device indicating too low space suit pressure. Safety of the test subjects will be of prime importance. Every oxygen supply module will be equipped with a regulator to prevent more than 20 torr pressure above the actual chamber pressure in the space suit, an alarm system to detect leakage from the space suit, and a portable oxygen system to facilitate safe transfer of test persons to another chamber compartment.[13]

The entire oxygen system will be an open-loop system where the returned gas from the chamber is to be dumped and is not to be reused. Each test subject will be breathing 100 percent pure oxygen at all times while connected to the system. The duration of each oxygen supply module is not known, but it is assumed that each oxygen vessel could be replaced without disturbing the continuity of the system thereby maintaining 100 percent oxygen supply for an indefinite period of time.[13]

Monitoring Instruments and Controls

There will be a control room located about 50-meters cable length from the chamber. Monitoring instruments and controls will be grouped in control consoles.[13]

The doctor investigator (DI) panel, contains elaborate instrumentation to measure and monitor basic physiological parameters such as electrocardiogram, heart rate, pulse, blood pressure, oxyhemoglobin, respiratory rate and volume, partial pressure of oxygen and carbon dioxide in inhaled and exhaled air, body temperature, skin temperatures, and galvanic skin response. In addition, the doctor investigator will have numerous technical parameters displayed to monitor subjects in a space suit and will have control of the treadmill and bicycle ergometer. The doctor investigator appears to be the individual in charge of the experiments (figure 5).[11]

A doctor operator (DO) panel is similar to the DI panel but will have three TV monitors, one each for the horizontal chamber, vertical chamber, and man-lock, but will not have individual controls for the treadmill or bicycle ergometer. It will have, however, an extra stop button for the treadmill. It appears that there are positions for three medical personnel at this panel providing a complete comprehensive monitoring capability. It appears that the operator of this control panel has the capability to select a TV camera

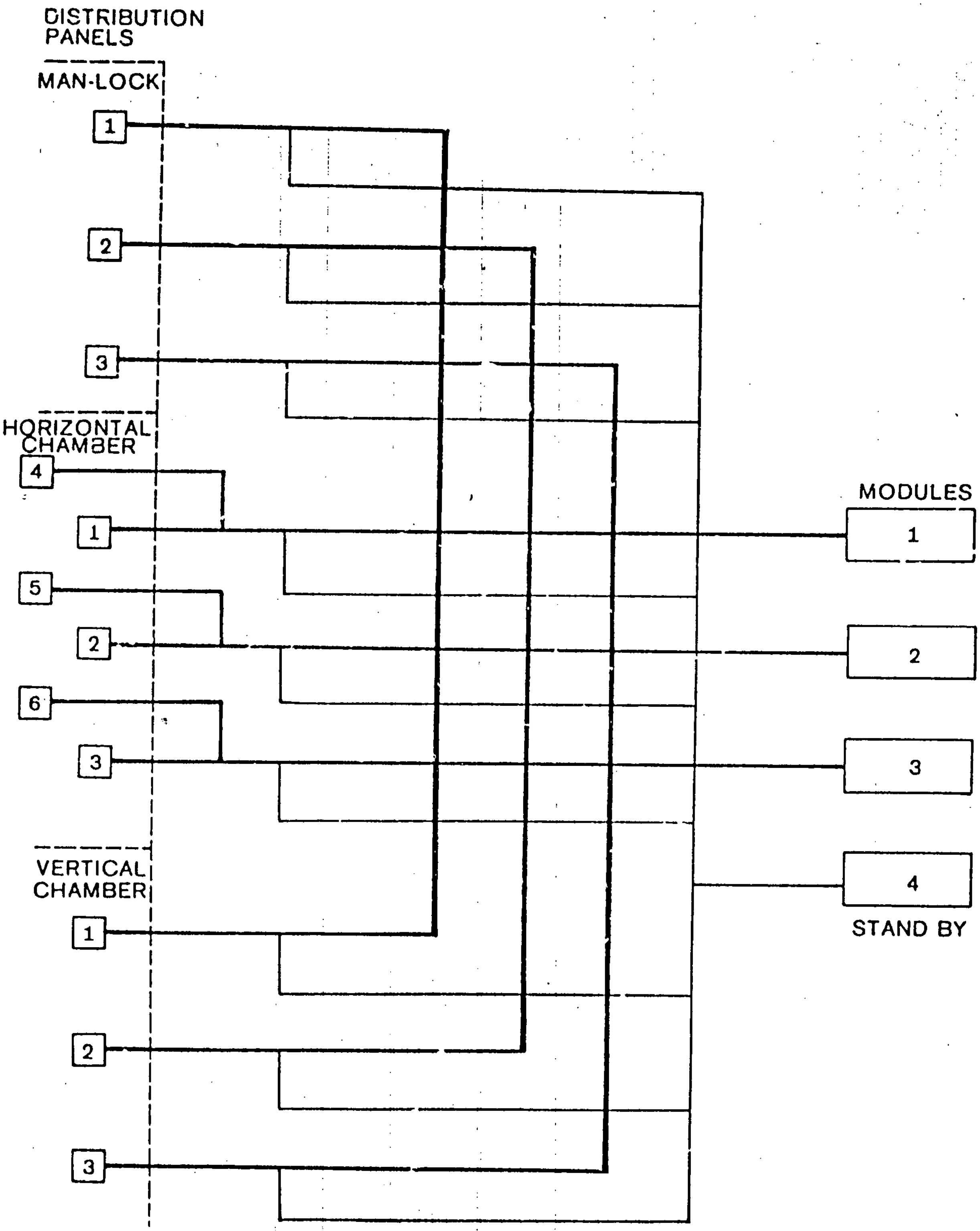
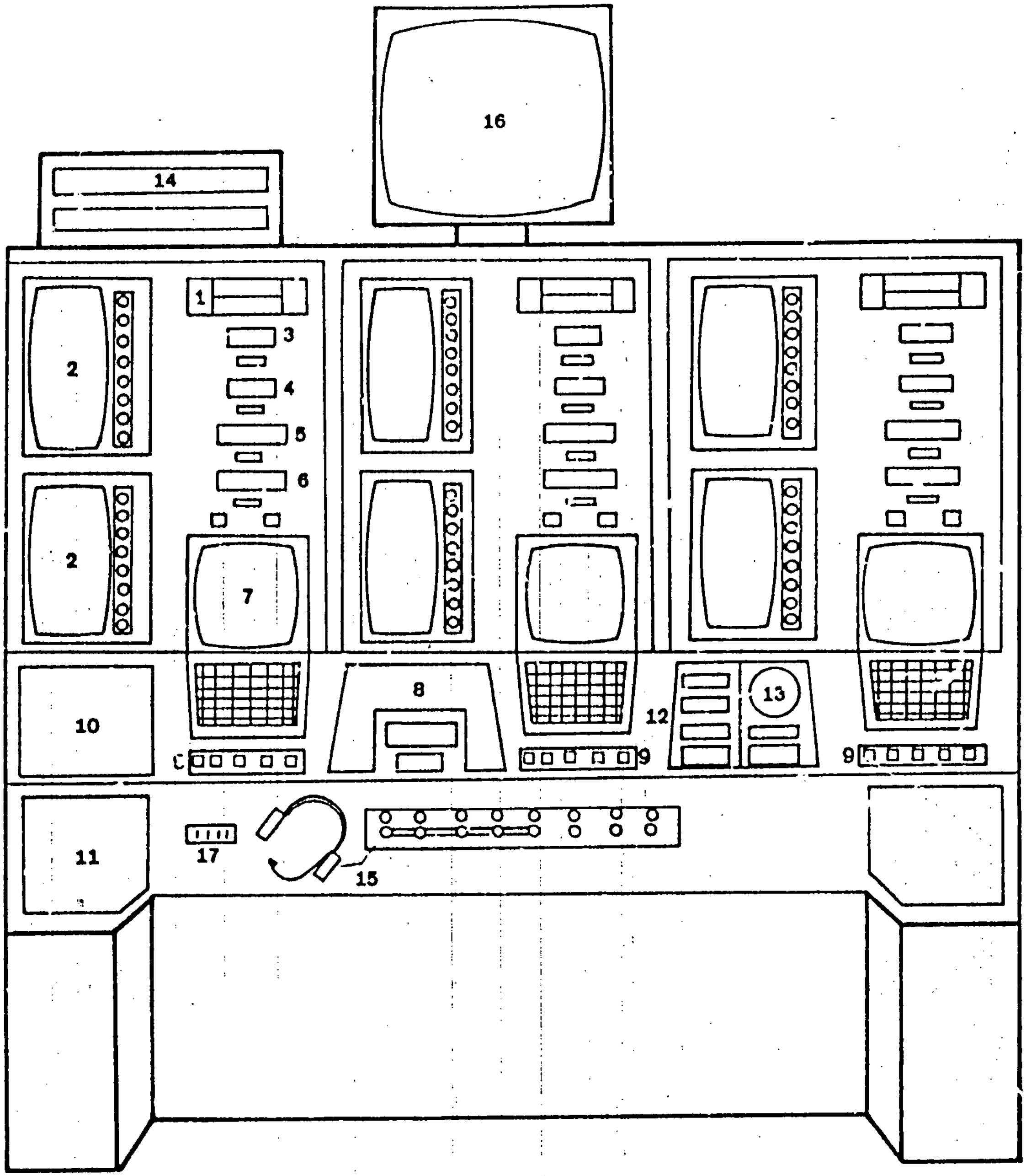


Figure 4. Oxygen System

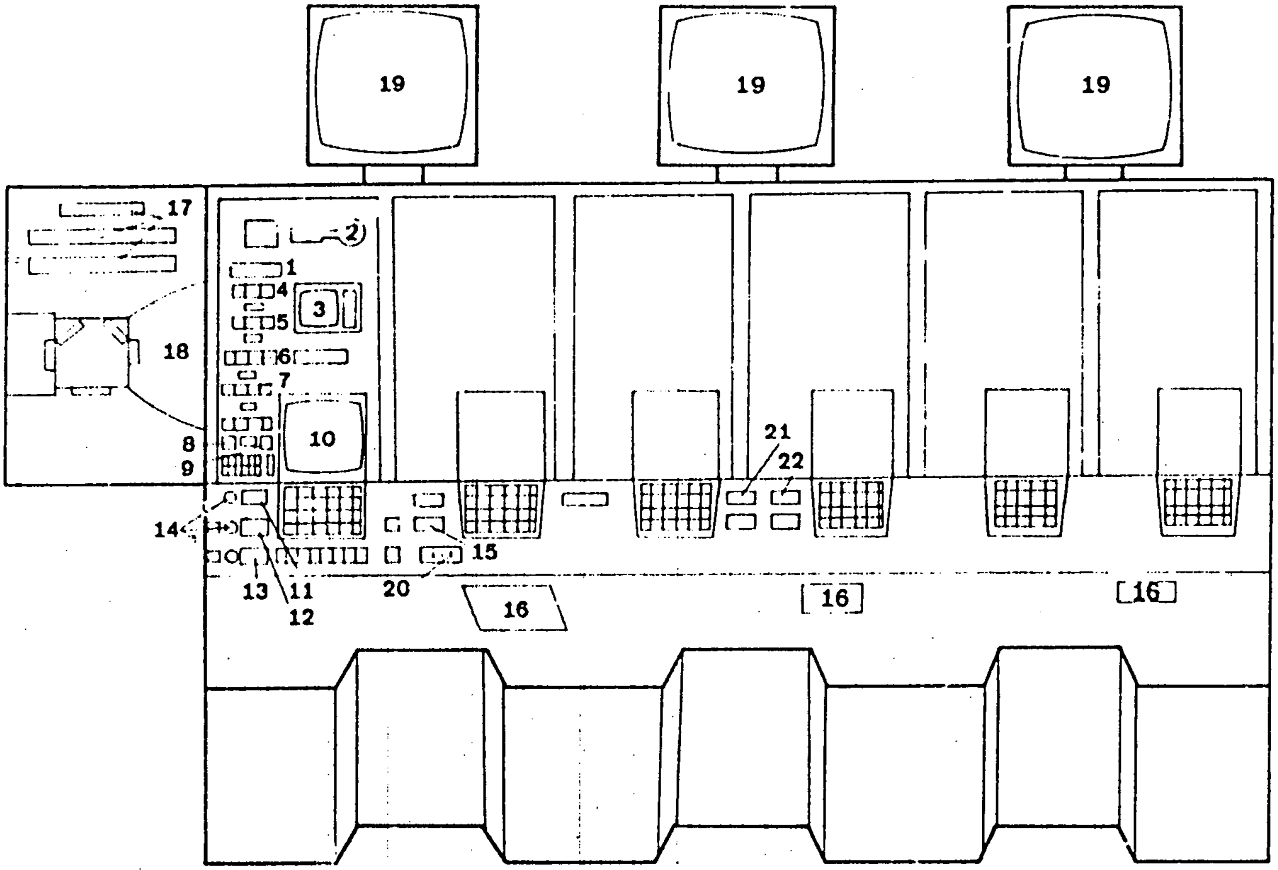


1. Indicator showing the name of test person.
2. Eight channel oscilloscope with memory and channel selector.
3. Digital display for continuous display of heart rate.
4. Digital display for continuous display of respiration frequency.
5. Digital display for continuous display of body temperature.
6. Digital display for continuous display of pressure in the space unit.
7. Oscilloscope.
8. Keyboard for supplying information into the computer
9. Pushbuttons for ordering quick-changing parameters into the computer.
10. Selector panel for input into recorders.
11. Program-selector for electrocardiogram and electroencephalogram electrodes.
12. Control panel for treadmill.
13. Control panel for bicycle ergometer.
14. Time display.
15. Communications panel.
16. TV monitor.
17. TV camera selector.

Figure 5. Doctor Investigator Panel

for any one or all of the three TV monitors (e.g., the vertical chamber could be shown on all three monitors at once) or he can select a camera to monitor the horizontal chamber, vertical chamber, and man-lock and project each one simultaneously on a separate TV monitor (figure 6).[11]

The engineer operator (EO) desk is designed for one individual who will be in charge of the entire technical work for all tests including the preparation and functioning of the hypobaric chambers and test equipment.[11] Both the DI and the DO panels contain communication systems to maintain voice contact with the test subjects and the EO desk.[11] The EO desk will be equipped with a TV surveillance system for the entire test area. Control and measuring instruments, indicators, and command devices are built into the EO desk to enable the engineer operator to receive uninterrupted data necessary for the technical control of the tests. The EO will have available digital indicators; light switch image of the actual condition of the doors in the horizontal chamber, vertical chamber, and man-lock; audio layout selection switch; TV camera; signal lamps to indicate electric power supply; signal panel for the various auxiliary systems; and a light indicator for the operating condition of all auxiliary systems.[9]



1. Indicator showing name of test person.
2. Indicator showing location of test person within chamber compartment.
3. Oscilloscope with memory showing electrocardiogram.
4. Digital display of heart rate.
5. Digital display of respiration frequency.
6. Digital display of body temperature.
7. Digital display of pressure in the space suit in torr.
8. Indicator for oxygen flow to the space suit.
9. Indicator for cooling liquid flow to the space suit.
10. Oscilloscope.
11. Horizontal chamber pressure indicator.
12. Man-lock pressure indicator.
13. Vertical chamber pressure indicator.
14. Indicators showing rate of ascent or decent of chambers.
15. Emergency stop pushbutton for treadmill.
16. Communications panel.
17. Time display.
18. Indicator showing which chamber doors are open and closed.
19. Three TV monitors, one for each chamber.
20. TV camera selector.
21. Indicator for partial pressure of oxygen in horizontal chamber.
22. Indicator for partial pressure of carbon dioxide in horizontal chamber.

Figure 6. Doctor Operator Panel

REFERENCES

The source references supporting this paper are identified in a list published separately. Copies of the list are available to authorized personnel and may be obtained from the originating office through regular channels. Requests for the list of references should include the publication number and date of this report.

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