3

B.S.

DCIEM Technical Report No. 77X11

HUMAN ENGINEERING ASPECTS OF A DEEP DIVE FACILITY

C. McCann

DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE
INSTITUT MILITAIRE ET CIVIL DE MEDECINE DE L'ENVIRONNEMENT

DEPARTMENT OF NATIONAL DEFENCE — CANADA

Mar[redacted]977

DCIEM Technical Report No. 77X11

HUMAN ENGINEERING ASPECTS OF A DEEP DIVE FACILITY

C. McCann

Behavourial Division
Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Downsview, Ontario M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

ABSTRACT

The Defence and Civil Institute of Environmental Medicine is designing a Deep Dive Facility which will be constructed to conduct in-house research into physiological and operational problems of deep diving. This report discusses the habitability requirements of such a facility, and considers the human engineering aspects of hyperbaric chamber design. Based on these criteria, an optimum interior layout for the chamber complex is described.

INTRODUCTION

The Defence and Civil Institute of Environmental Medicine (DCIEM) is designing and constructing a hyperbaric facility to investigate the physiological and operational problems associated with deep diving. This Deep Dive Facility (DDF) will be capable of a maximum depth of 5600 feet (2500 psi.), although it will initially be configured (in terms of gas storage, etc.) for 2500 feet maximum.

A three-compartment chamber layout was selected for the complex, consisting of two eight foot diameter cylinders connected to a central sphere, nine feet in diameter, (Fig. 1). The smaller cylinder (21' long) will be used as the main "living" chamber, having facilities for sleeping and eating. The sphere will act as a transition area between the Living Chamber and the Wet Pot (24' long) which will be used for studying actual underwater operations. Two acrylic water containment barriers attached to the floor and ceiling of the Wet Pot will permit about two-thirds of the chamber to be filled with water.

Each chamber will have a separate entrance from the outside. Entrances will be located at the extreme ends of the cylinders and at the side of the Sphere. This feature, together with the double hatch doors which separate the cylinders from the sphere, will permit the chambers to be pressurized independently and used for experiments at different depths. It will also enable extra personnel or large items of equipment to be locked into the complex during an emergency. For routine passage of material a small pass-through lock will be located in each of the Living Chamber and Wet Pot, with a larger lock opposite the entrance in the Sphere.

The chamber shells are presently being constructed by Vicker's Steel of Montreal, while the interior layout and fittings of the chambers remain the responsibility of DCIEM. The Diving Division of DCIEM requested the Behavourial Science Division to consider the habitability aspects of the chamber complex and to determine the optimum interior layout of the chambers. This report documents that work, and presents a final design.

HABITABILITY ASPECTS

General

Habitability can be generally defined as the appropriateness of the living facilities for the occupants of a certain habitat. The habitability of a diving chamber is influenced by several quantitative and qualitative factors. Among these are the relatively well-defined factors of crew size, mission duration and mission activities, and the environmental requirements of man. These considerations formed a basis for the design of the DDF. But the design was also influenced by the human requirements for privacy and for social interaction, and by the motivation, morale and experience of the crew members.

Crew Size

Maximum crew size for a habitat is a function of both mission duration and the available free volume of the habitat, as discussed by Fraser (Ref. 3). It is expected that the DDF will be used in a wide variety of configurations for many types of experimental activities, with the durations of the associated diving missions varying from one to forty days, or even more. Fraser's summary of previous confinement studies suggest that a free volume of at least 160 cu. ft. per man is required to ensure no impairment in performance for confinements of 30 days duration. Very little is known about volume requirements for missions greater than 30 days. Parker et al (Ref. 4) extrapolate known data from space missions to periods of 300 to 400 days, and conclude that 250 cu. ft. per man is an absolute minimum volume, while 250 to 400 cu. ft. would be more acceptable.

The free volume in the DDF was calculated as approximately 1450 cu. ft.* Based on the volume requirements given previously, therefore, a team of four divers could live in reasonable comfort in the DDF for dive missions extending longer than 30 days. Larger teams (6 men) could also be accommodated, but it is recommended that mission durations be reduced accordingly (2-3 weeks).

Tasks and Activities

Activities in the DDF can be separated into two main categories: personal maintenance (including day-to-day activities such as eating and sleeping) and the experimental tasks which form the actual dive protocol.

Personal maintenance activities can be broken down into the

* The calculation was based on a total volume of 1900 cu. ft. (excluding the swim area in the Wet Pot), less about one quarter of that volume for furnishings.

following categories:

a) sleeping

b) nourishment (both meals and snacks)

c) entertainment and relaxation (solitary and group)

d) personal hygiene

e) locomotion

f) housekeeping (cleaning and repair of equipment)

g) communication (both diver-to-diver and diver-to -topside)

h) medical attention

The equipment required for these activities is given in Table I, together with special design considerations that should be implemented in the layout.

It is much more difficult to predict the equipment required and the procedures that will be followed for the experimentation inside the chamber, due to the rapid development of new experimental techniques for deep dive study. As a basis for consideration of this aspect of chamber design, a survey of some of the experimental activities presently being conducted in several dive facilities was carried out. The areas of research can be broken down into three categories: experiments in diving physiology, psychological experimentation, and studies of operational equipment and procedures. The first two classes of experiments may or may not be carried out underwater, while the third usually is. A summary of some typical diving experiments is given in Table II, along with the equipment required for each one. Note that it is not necessary that all experimental equipment be kept inside the chamber for the duration of a dive. Small apparatus can be locked in (and out) through the pass-through lock as required.

Environmental Factors

The aim in shelter design should be to provide a comfortable environment, taking into consideration the activities proposed for the habitat. The environmental aspects of hyperbaric facilities include temperature, humidity, ventilation, noise control, lighting and shelter decor. A thorough discussion of the first five aspects has been presented in a previous DCIEM report (Ref. 1), and a summary of recommendations is given in Table III.

Consideration of shelter decor is an aspect of environment that has been neglected in many previous chamber designs. The use of colour provides relief from the sensory invariance common to confined quarters and may also help to alleviate some of the adverse psychological responses discussed by Fraser (Ref. 3). As well as providing sensory enrichment, colour can be used to delineate different functional areas in the habitat (e.g. sleeping areas, work areas). This is useful in habitats such as diving chambers where a single large room must accomodate several activities.

Parker et al (Ref. 4) state that light colour tints are preferred for large surfaces in confined quarters (walls and ceilings). The use of light colours would also serve to maximize the reflectance of available light inside the DDF. Saturated colours are more desirable for smaller areas, with a variety of shades being preferable.

Social Factors

The human requirements for privacy and social interaction must be considered when designing isolated habitats such as hyperbaric facilities. Celentano et al (Ref. 2) describe research which demonstrates that cramped living quarters, with little privacy, can cause fatigue and poor morale. As a result, performance is degraded.

The habitat must be designed to cater to the need of both physical and psychological privacy. Physical privacy is difficult to provide in a small habitat; however, consideration should be given to locating toilet facilities in a separate area and to shielding individual sleeping areas from the rest of the chamber (using porous curtains to permit air circulation).

Human subjects demonstrate a distinct tendency toward territorial behaviour and patterns of social withdrawl when confined (Ref. 5). These tendencies can be accommodated by providing distinct personal space for each crew member, such as a sleeping space, and by allocating individual storage for personal items.

Psychological privacy occurs when an individual is not required to co-operate or communicate actively with other crew members. Areas should be provided in the chamber for an occupant to be apart from the rest of the group if he so desires. Shelter decor can also contribute to psychological privacy by defining areas of the habitat for certain tasks.

It is necessary to balance the privacy requirements of the occupants with forms of social interaction. Provision should be made in the design of the DDF for crew members to spend some off-duty time together. This would probably involve a sharing of territory or furnishings.

Baseu, then on the proposed manning of the chamber, current and anticipated experimental tasks, personal maintenance activities, environmental factors and the other habitability considerations described previously, a recommended chamber layout was developed. A full-scale wooden mock-up of the Living Chamber and Sphere was built to aid in the design process, and to demonstrate the final configuration.

DESCRIPTION OF THE RECOMMENDED LAYOUT

General

The detailed design of the interior of the chamber complex was based on the equipment requirements established for personal maintenance and experimental activities (Table I and II). Preliminary analysis for general design purposes indicated that the major equipment required for the Living Chamber were bunks, dining table, seats, and experimental consoles.

The gener . layout of the Living Chamber was constrained by the fact that the . r. of the chamber had been fixed before any layout studies were actually conducted. The location of the viewports was also restricted to the ends of the chamber.

It was considered desirable to inc rporate several design features which were established during an earlier chamber study at DCIEM (Ref. 1). This study recommended that bunks should be stacked in tiers of two, with the upper bunk hinged along the wall, so that it could be folded down to form the back rest for a bench seat. A collapsible dining table could then be positioned in the center of the floor space between the seats, to provide a face-to-face seating arrangement for meals.

For short duration dives involving large teams of subjects, it would be possible to arrange up to four bench seats along the walls of the Living Chamber with a fold-up table in the center, or alternatively, 12 24"-wide experimental consoles on either side. This arrangement would be satisfactory for dives of less than one day's duration.

To acc mmodate a six-man* diving team, two general layouts were considered. The first was a parallel arrangement in which three sets of two tiered bunks were positioned alon the sides of the Living Chamber. Two sets of bunks occupied the entire wall along one side.

....

* Note that a four-man diving team could be accommodated by removing one tier of two bunks.

The second was a U-shaped configuration, in which two bunks were tiered across the end of the chamber (farthest from the Sphere) and the other sets were placed on either side along the walls, leaving the opposite end (adjacent to the Sphere) of the chamber free.

The second arrangement left more space for experimental consoles and provided a slightly more comfortable position for looking outside the chamber through the side viewport (a requirement for certain experiments). However, access to the cross-wise bunks was limited and the resulting dining arrangement was cramped and unsatisfactory. Also, the viewports at that end of the chamber were partially obstructed when the top cross-wise bunk was lowered. In particular, the top port, which would be used for monitoring of chamber occupants, was blocked. In view of these disadvantages, the parallel configuration was chosen as a basis for the 4-man and 6-man layout.

Because of the difficulty in specifying future experimental activity in the DDF, and considering the variety of anticipated configurations and manning, it is recommended that chamber fittings and equipment be modular. All chamber furnishings should be designed to pass-through the 30" diameter hatches, and then be attached in appropriate positions to brackets permanently mounted on the chamber walls. In this way, the layout could be changed to accommodate different requirements simply by moving the basic modules (e.g. bunks, experimental consoles, etc.). Operational requirements dictate that it should be possible to configure the Wet Pot as a dry chamber and to this end, the arrangement of mounting brackets in this chamber should be identical to that in the Living Chamber.

The proposed chamber layout based on present requirements is shown in plan view in Fig. 2. The personal maintenance and experimental activities have been split between the three chambers in the following way:

a) Living Chamber - sleeping, nourishment, entertainment and relaxation, housekeeping, medical attention and physiological and psychological experimentation.

b) Sphere - personal hygiene, locomotion (as a transfer area to the Wet Pot), housekeeping, physiological experimentation, preparation for wet dives.

c) Wet Pot - personal hygiene, operational experiments, some physiological and psychological experimentation.

Communications facilities will be required in all chambers.

Figures 3 and 4 show a complete view of the mockup of the Living Chamber, demonstrating the recommended layout. (The photographs are taken from the extreme ends of the chamber.) Figures 5 and 6 show the proposed layout of the Sphere.

A detailed description of the recommended chamber layout will now be given, indicating how it caters to the requirements of personal maintenance activities (Table I) and experimental activities (Table II).

Personal Maintenance Facilities

Sleeping

Four main bunks, arranged in two tiers, have been positioned along the sides of the Living Chamber at the opposite end to the Sphere. (Fig. 7). Each bunk is 76" long and 28" wide (bottom bunk) or 31" wide (upper bunk). Each is fitted with a 4" thick mattress covered in flameproof fabric. (These and all other cushions should be held in place with velcro strips). The arrangements of bunks along the length of the chamber allows the most efficient use of space and also permits the top bunks to be folded down to form the back-rest of a settee for face-to-face seating. To cater to this design feature, the lower bunk was positioned 17" from the floor (included the 4" mattress) and the upper bunk 27½" above the lower. With the hinge positioned on the upper bunk 1½" inboard of the chamber wall, the top bunk will fold down to form a backrest at and angle of 20° from vertical, and the resulting seat depth will be 18". The location of the bunks at one end of the chamber separates the sleeping area (a "quiet area") from the other activities which are carried out in the Living Chamber.

Six drawers have been built in under the lower bunks for daytime storage of linen, blankets and pillow, as well as some personal clothing. Two sets of adjustable shelves were located against the wall, one at the end of each tier of bunks. These provide additional storage space for personal items and are accessible from the bunks. An aisle width of 24" between the lower bunks and 27" between the upper bunks easily allows passage for one man, and also give sufficient space for men to pass back to back.

Provision has also been made in this layout to accommodate a fifth man (e.g. a medical officer, should he be required to lock in during an emergency, and then decompress with the rest of the crew). A bench seat which has been positioned adjacent to the pass-through lock along the side of the chamber (Fig. 8) could be reconfigured into a bunk by folding up a 10" flap normally hangs down in front of the bench. The resulting bunk (Fig. 9) is 76" long and 27" wide.

It is also possible to accommodate six divers (during shorter duration dives) by replacing the bench seat with two-tier bunks, of the same size and configuration as those at the end of the chamber.

Nourishment

Since all meals will be prepared outside the chamber and then locked in via the pass-through lock, it is necessary to provide only a dining area in the Living Chamber and a table for unloading and serving food. Provision has been made, therefore, for a portable dining table (24" wide and 72" long) to be set up in the aisle between the bunks. (This can be done most easily by fitting the table legs into slots in the chamber floor). With the top bunks folded down to form two bench-type seats, up to six divers can be accommodated for meals at this table (Fig. 10). When not in use, the table can be folded up and stored under one of the upper bunks.

A small table has been located under the pass-through lock for unloading food (Fig. 11).

In order to give the chamber occupants a degree of independence, and to relieve the work of the support staff, it was decided that the divers should be able to prepare snacks inside the chamber as desired. These would consist mainly of coffee, tea, hot chocolate, or soup and cookies, crackers or other dried food that can be kept without refrigeration. It is recommended that such food, cups, spoons, etc. be stored in a cabinet under the pass-through lock (Fig. 11) and that an outlet of hot water, supplied (from outside the chamber) at a fixed temperature (no greater than 170°F), also be located in the cabinet.

Entertainment and Relaxation

The strenuous nature of the experimental tasks and the length of the working day will likely encourage passive forms of recreation (e.g. reading) in the evening, rather than more active forms. Relaxation and entertainment can be carried out on an individual basis or in a group. The provision of a reading light and stereo headphones and a jack at each bunk is recommended for individual relaxation. In this way the divers can read or listen to tapes or radio at the "quiet" end of the Living Chamber. The bench seat at the opposite end of the chamber may also be used for reading and relaxing.

Group activities such as cards, cribbage or chess can be played on the dining table or at the experimental consoles, depending on the number of participants. A major group activity in many other large chambers is watching movies in the evening. The provision of a 2" viewport in the main entrance door in the Living Chamber will permit films to be projected the full length of the chamber onto a screen at the other end (a 16 mm projector equipped with a 2" lens will project a 3 foot image at this distance). Divers can view the films either lying in their own bunks or seated along the sides of the chamber receiving the audio either through headsets or on the chamber loudspeaker.

Personal Hygiene

Facilities for personal hygiene have been located in the Sphere for privacy and to keep this area of high humidity away from the main living quarters. Because of space limitations, it is recommended that a fold-up toilet unit be installed, similar in design to the Walton Products San-O-Cab. A mock-up of the latter unit was installed in the Sphere mock-up and is shown in Fig. 5 (the toilet has been folded down). The unit also has a built-in wash basin in the top. (Fig. 12). It is recommended that a stainless steel mirror for shaving be mounted above the sink.

Storage was arranged for divers' personal toilet items (toothbrush, comb, razor) as well as for dry towels. This was provided in a cabinet under the table adjacent to the pass-through lock. (Fig. 5). The table is conveniently located beside the sink, providing a place to set towels, etc. A small shelf is also shown for storage of glasses.

The shower is more easily located in the Wet Pot to facilitate drainage. If the shower head is mounted on a flexible hose, it could also be used to clean off salt from diving suits and equipment. Hooks for hanging clothing and towels as well as a shelf for soap, shampoo, etc. will be required in the shower area.

Finally, it is recommended that consideration be given to a sterilization system for all water used in the DDF. It is felt that such a system would greatly reduce infection particularly of the ear.

Locomotion

Chamber fittings should be arranged so that all areas in the complex are easily accessible. The proposed layout incorporates an aisle down the full length of the Living Chamber. The Sphere will act as a transfer area between the Living Chamber and the Wet Pot, and so its floor should be kept free of equipment. It is recommended that all floors be covered with a non-skid flooring material.

The diameter of all hatches is at least 30" which is adequate for the passage of a larger diver. Handholds should be installed over each hatch to assist passage between chambers. The hatch doors have been gimballed to facilitate door movement, reduce the area swept by the door when opened and reduce its storage space. (Fig. 13).

Housekeeping

The housekeeping aspects of chamber maintenance include the capability to clean the chamber and maintain a reasonable degree of tidiness. Hopefully, most of the major chamber maintenance will be conducted between dives, but some emergency repairs may be required during pressurized periods. On these occasions, tools and repair instructions can be locked into the chamber, and inspection or repair of equipment could be conducted on the worksurface formed by folding up backrest of the bench inside the pass-through lock. (Fig. 14).

The chamber fittings and floor should be designed to be easily cleaned with soap and water with no corners in which dirt can become trapped. Minimal cleaning materials, including a bucket, soap and clothes could be kept inside the chamber. Cleaning of the chamber between dives will be facilitated if the fittings and floor are removable.

Adequate storage has been provided in the proposed layout for bedding and some personal clothing (under the lower bunks), and for personal effects on the shelves in the Living Chamber. The cabinet under the pass-through lock in the Sphere can be used for toilet articles and towels. The Sphere will also be used as the storage area for diving equipment kept inside the chambers. Hooks should be fitted on the wall of the Sphere beside the main entrance for hanging diving suits; it is recommended that elastic cord be used to tie the suits back against the wall. Smaller equipment, tools, mitts and fins, as well as underwear should be kept under the two benches and accessed by hinged flaps in the bench top.

Finally a space should be provided in the Living Chamber for a garbage bag. In the proposed layout the bag has been positioned beside the cabinet under the pass-through lock, accessible by a hole cut in the table top. It will be essential to lock garbage and laundry out of the chamber at regular intervals.

Communication

Good audio and visual communication both between the chamber occupants themselves, and between the occupants and topside is essential for safe and effective chamber operation. An open mike and loudspeaker inside the chamber will permit the operator to monitor general chamber conversations and relay instructions to the divers. Separate communications channels (with headsets for chamber occupants) will be necessary for special activities such as experimentation. Chamber operators should have the capability to override any experimental channel or interrupt piped-in music or film soundtracks in case of an emergency.

Because the effects of helium on speech become very pronounced at depths of 2500 ft., any transmissions from the chamber to topside must be passed through a helium speech unscrambler. Helium speech also interferes with diver-to-diver communications, making it difficult and frustrating to converse at depth. It is therefore recommended that attempts be made to allow divers to communicate with each other via the helium speech unscrambler when desired. Ideally, divers would wear light-weight cordless headsets attached to a transmitter-receiver in the pocket. An interior antenna would be used to pick up diver conversations on one channel, pass the audio through the unscrambler and transmit back to the headsets.

Visual monitoring of the entire chamber complex will be provided via closed-circuit TV system of five cameras. Two cameras placed at special 2" viewports above the hatches in each end of the Living Chamber will view the full length of the chamber. Two more cameras will be similarly located in the Wet Pot. A fifth camera will be located at the top of the Sphere. A fish-eye lens is recommended for the latter camera to permit coverage of the sides of the chamber as well as the floor.

Experimental Facilities

The experimental protocols envisaged for the DDF will necessitate many different experiments being conducted during one dive, with several even running simultaneously. For example, a typical protocol might dictate that one diver and a tender conduct a test on some new breathing apparatus in the Wet Pot, while another undergoes a pulmonary function test and a fourth is tested on the force platform. Therefore, the interior layout of the chamber must allow for multiple concurrent experimental activities.

Because of the potential variety of experimental tasks and the uncertain nature of their equipment requirements, it is recommended that the Living Chamber is fitted with two individual consoles of a standard design (Fig. 15), opposite the bench. (Additional consoles could be installed, if necessary, in place of the bench.) These should be sit-stand consoles (table height of 36") with an adjustable swing-out seat. A standard console could be fitted with equipment required for a particular psychological or physiological experiment, according to the dive protocol. Sufficient penetrations must be available along this side of the chamber to accommodate the experimental requirements.

It is expected that certain psychological experiments may require the subject to view a stimulus placed outside the chamber. This type of experiment could be accommodated in the proposed layout by using the viewport opposite the shelf at the end of the bunk area in the Living Chamber. It is recommended that the viewport be placed on the horizontal centerline of the chamber to enable a subject sitting on the end of the bunk to see stimuli place outside. This seating arrangement will be satisfactory for short-duration experiments. A small table for writing has been placed under the viewport in the proposed design; it also provides a surface to lean on. A 4"-high foot space should be incorporated at the end of the bunk at the bottom.

Psychological testing of groups of divers may also be a future experimental requirement. The proposed layout could be configured to accommodate a group of up to four divers with the addition of extra consoles. If subjects are seated at the consoles facing the far end of the Living Chamber, they can view stimuli back projected on a screen hung above the aisle between the bunks. Each subject could respond via a button box placed on the console beside him.

Physiological testing requiring the use of large equipment (such as a bicycle ergometer) is more easily carried out in the Sphere. It would be helpful if such equipment were designed to fold up for storage.

Some physiological testing will be carried out in the water, as well as operational testing of equipment. The Sphere has been reserved as a preparatory area for activities in the Wet Pot. Small items of diving equipment and suits could be stored in the Sphere, and sufficient floor area is available for a diver to suit up with assistance.

The Wet Pot will require a seat for the diving tender and a table for experimental apparatus. Some equipment may be passed in through the lock as required for experiments.

Shelter Decor

The choice of colour scheme for the DDF was influenced by three specific factors. First, the fire-retardent material chosen for use on all cushions and seats in the chamber was available in only one colour (Durette "Gold"). Second, despite the seeming variety in personal colour preferences, it is generally agreed that blue is the preferred colour of the majority of the male population involved in these activities (Ref. 4). Finally, it is felt that two shades of colour should be used in the Living Chamber.

The final recommended decor is based on the use of three basic shades: cream (Munsell 5Y 9/1), blue (Munsell 7.5B) and brown (Munsell 10YR). The cream is recommended as the base colour for all three chambers (walls and ceiling) and serves to maximize the reflectance of the available light. The blue is the complementary colour of gold, whereas the brown is the same hue as that contained in the gold.

Brown, a warm colour, has been used predominantly in the personal areas at the sleeping end of the Living Chamber. In contrast, blue (a cooler colour) predominates in the working end of the chamber. It is recommended that each end of the Living Chamber be decorated in a radiating pattern with the colour graduated in four steps, starting with the saturated colours in the center (Fig. 4). It was found that this pattern makes the chamber seem visually larger. The edges of consoles, shelves and drawers through the mock-up have been trimmed with contrasting colour. The trimming will make them stand out against the lighter background, making them more visible on the closed circuit TV. The wall area to the side of each bunk has been outlined in dark brown and partially filled in with a lighter shade of brown. This provides a sense of personal space, and caters to the needs of privacy and territoriality. The floor was dark brown, broken by a strip of cream down the center.

In the Sphere, cream is the recommended base colour for the upper walls and the floor. Blue is recommended for the walls as a background colour for the chamber furnishings from a height of 40" down to the floor, as shown in Fig. 12. The use of colour for sensory stimulation is not as important in this chamber, since the diving equipment which will be stored there tends to be very bright in colour (red, yellow).

The Wet Pot should also be painted in cream (to maximize light reflectance), with a blue trim around the edges of table and seats for contrast.

CONCLUSIONS

The report has discussed the habitability aspects of diving chamber design including volume requirements, mission activities, environmental and social factors as they are applicable to the DCIEM Deep Dive Facility. These factors, together with the operational and experimental requirements, formed the basis for the proposed interior chamber layout which was described in detail. It has been recommended that all chamber furnishings be modular and designed to attach to brackets permanently mounted on the chamber walls. This will permit the DDF to cater to the wide variety of diving configurations and experimental activities anticipated during its use.

TABLE I

EQUIPMENT REQUIREMENTS FOR PERSONAL

MAINTENANCE ACTIVITIES

Activity	Equipment Required	Special Considerations
1. Sleeping	-bunk for each crew member -linen, blankets, pillows -special clothing for sleeping -storage for above -reading lights	-crew will all sleep at the same time -provide enough space to make up bunks -provide space for changing clothes -privacy considerations -noise and lighting considerations
2. Nourishment -Meals	-pass-through lock in chamber to accommodate food and utensils -dining table -storage for table -seating for all crew members at table -cleaning materials -garbage disposal	-3 meals per day -meals will be prepared outside and passed into the chamber -dining table should be easily set up -face-to-face seating desirable -table under pass-through lock to unload food
-Snacks	-table and seating (for one or more crew members) -pass-through lock to accommodate food -water or beverage heater inside chamber -food and utensil storage -garbage disposal	-snacks might not be taken together -table should be under pass-through lock -water heater must have temperature control -crew should be able to prepare some snacks inside chamber
3. Entertainment & Relaxation	-bunk/bench seat -headphones -light for reading -table	-headphone jack and light near seat
-Solitary	-books, game, writing materials	-some material may be locked in.

TABLE I (cont'd)

Activity	Equipment Required	Special Considerations
	-storage for above -pass-through lock	-privacy considerations
-Group	-seating for all or part of crew -table -headphones for films, stereo -film screen -games etc. -storage for above	-seating should be arranged so that crew can see film screen -headphone jacks should be near seats
4. Personal Hygiene		
-Waste Elimination	-fold down toilet	-privacy considerations
-Washing & Grooming	-shower -wash-basin -table for toiletries -mirror -soap -personal toiletries (razor, toothbrush, comb, etc.) -towels -storage for above -change of clothes (including storage)	-washing facilities should be separate from living area because of high humidity -fresh clothing & towels could be passed through pass-through lock
5. Locomotion	-handholds for passing through hatches -non-slip floor -steps for ingress and egress to water in wet pot	-hatch doors should be easily moved -ensure easy access to all equipment, storage
6. Housekeeping	-cleaning materials (soap, bucket, clothes etc.) -storage for above -work area for checking chamber equipment -tools	-all chamber surfaces easily cleaned -accumulated garbage and laundry will be locked out

TABLE I (cont'd)

Activity	Equipment Required	Special Considerations
	-garbage bag -pass-through lock	
7. Communication	-headsets and mikes -mike and loudspeaker -electrowriter is desirable	-helium unscrambling will be required -noise considerations -personnel should be to communicate with each other as well as with topside
8. Medical Attention	-first aid kit -materials for daily ear routine (saline, alcohol)	-equipment required for major emergencies could be locked in

TABLE II

EQUIPMENT REQUIREMENTS FOR

EXPERIMENTAL ACTIVITIES

Activity	Equipment Required	Special Considerations
1. Physiological Experiments*		
-Cardiovascular (e.g. cardiac output, blood pressure)	-electrodes attached to diver's body -pocket telemetry system	-electrodes could be attached for dive duration -telemetry system preferable for monitoring during variety of tests -antenna required
-EEG	-electrodes -telemetry system preferable	-continuous monitoring preferable
-Pulmonary Function Test	-spirometer	-used once per day -2 divers required -portable; can be stowed -could be carried out underwater
-Exercise Test	-bicycle ergometer -flowmeters -swim bar	-ergometer should be collapsible -O_2 and CO_2 analyzers are outside chamber -flowmeters should be mounted near ergometer -EEG could be measured concurrently -swim bar used under-water in conjunction with flowmeter and O_2 and CO_2 analyzers

* Many experiments require visual monitoring and/or recording.

TABLE II (cont'd)

Activity	Equipment Required	Special Considerations
-Balance & Steadiness Tests	-2 balance rails 8' long -headset for task instructions -tremor box (9" x 9" x 12") -force platform (18" x 18")	-balance rails could be split for storage -tremor test taken once per day and more often on descent -can be operated by one diver
-Heat Loss Measures	-heat flow discs -radio pill or thermometer -thermistors	-heat discs and thermistors attached to skin -radio pill used for core temperature underwater; requires antenna or readout
-Blood Bubble Dectection	-detector 3" in diameter	-strapped onto diver's chest -more often used during decompression
-Hematology	-medical bag (12" x 8" x 18") -blood containers	-equipment locked in when required
-Microbiology	-culture materials	-usually for ear and throat cultures -equipment locked in when required
-Urine Tests	-24 hour collection bottles	-locked in when required
2. Psychological Experiments**		
-Sinbad	-viewport -screen (outside chamber) -response box	-initially one diver tested at a time -seating and a small table required at viewport

** Physiological measures may be made during psychological and operational experiments.

TABLE II (cont'd)

Activity	Equipment Required	Special Considerations
-Behavioural Testing	-varies with experiment stimulus and response materials	
-Questionnaires	-table, seating	-materials could be locked in
-Pipe Puzzle	-puzzle rig (5' x 4' x 3-1/2')	-used underwater -requires wrenches
-Group Inter-Action Tests	-screen -seating -response box	-several divers tested at once -all subjects must be able to see screen
-Reaction Timer	-response box and stimulus	-one diver tested at a time
3. Operational Studies***		
-Testing Personal Dive Equipment (eg. suits)	-new gear as developed	
-Testing Breathing Apparatus		
-Test Comms Equipment	-scripts	
-Test Tools	-testing rigs	

*** All studies will require space for one or more divers to suit up.

TABLE III

SUMMARY OF RECOMMENDATIONS FOR ENVIRONMENTAL ASPECTS*

Factor	Recommendations
1. Temperature	-higher temperatures required due to increased thermal conductivity of helium -90°F at 15 atmospheres -reduce temperature variation by controlling temperature precisely
2. Humidity	-relative humidity 30%-70%
3. Ventilation	-20 ft/min. minimum -minimize air movement in bunk areas
4. Noise Control	-mufflers should be installed in the environmental control loops -use large gas inlets and outlets to reduce speed of gas and place these away from quiet areas if possible -noise levels should not exceed 65 dB at depth and 100 dB during compression
5. Lighting	-general lighting for work areas experimental areas and dining area, 30 ftC. -directional lighting required for reading at bunks -special lighting may be required for certain experimental activities

* Summarized from Ref. 1.

REFERENCES

1. BEEVIS, D. & MCCANN, C., Human factors in the design of a Deck Decompression Chamber, DCIEM Operational Report No. 74-OR-1011, February, 1974.

2. CELENTANO, J.T., AMORELLI, D. & FREEMAN, G.G., Establishing a habitability index for space stations and planetary bases, presented at AIAA and ASMA Manned Space Laboratory Conference, Los Angeles, 1963.

3. FRASER, T.M., The effects of confinement as a factor in manned space flight, NASA CR-511, Lovelace Foundation, Albuquerque, N.M., July, 1966.

4. PARKER, J.F. & EVERY, M.S., Habitability issues in long-duration undersea and space missions, Work Unit #NR-196-113, Biotechnology Inc., Falls Church, Va., July, 1972.

5. SCHOWALTER, D.J. & MALONE, T.B., The development of a luna habitability system, NASA CR-1676, Matrix Research Co., Alexandria, Va., February, 1972.

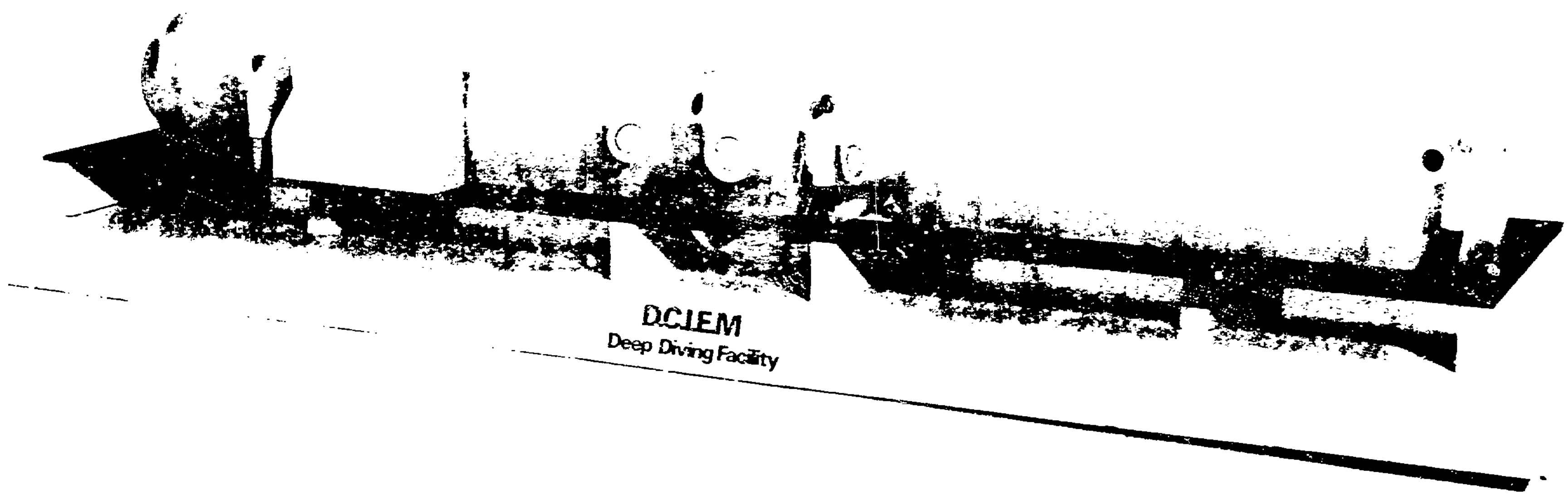

Figure 1: DDF Chamber Configuration.

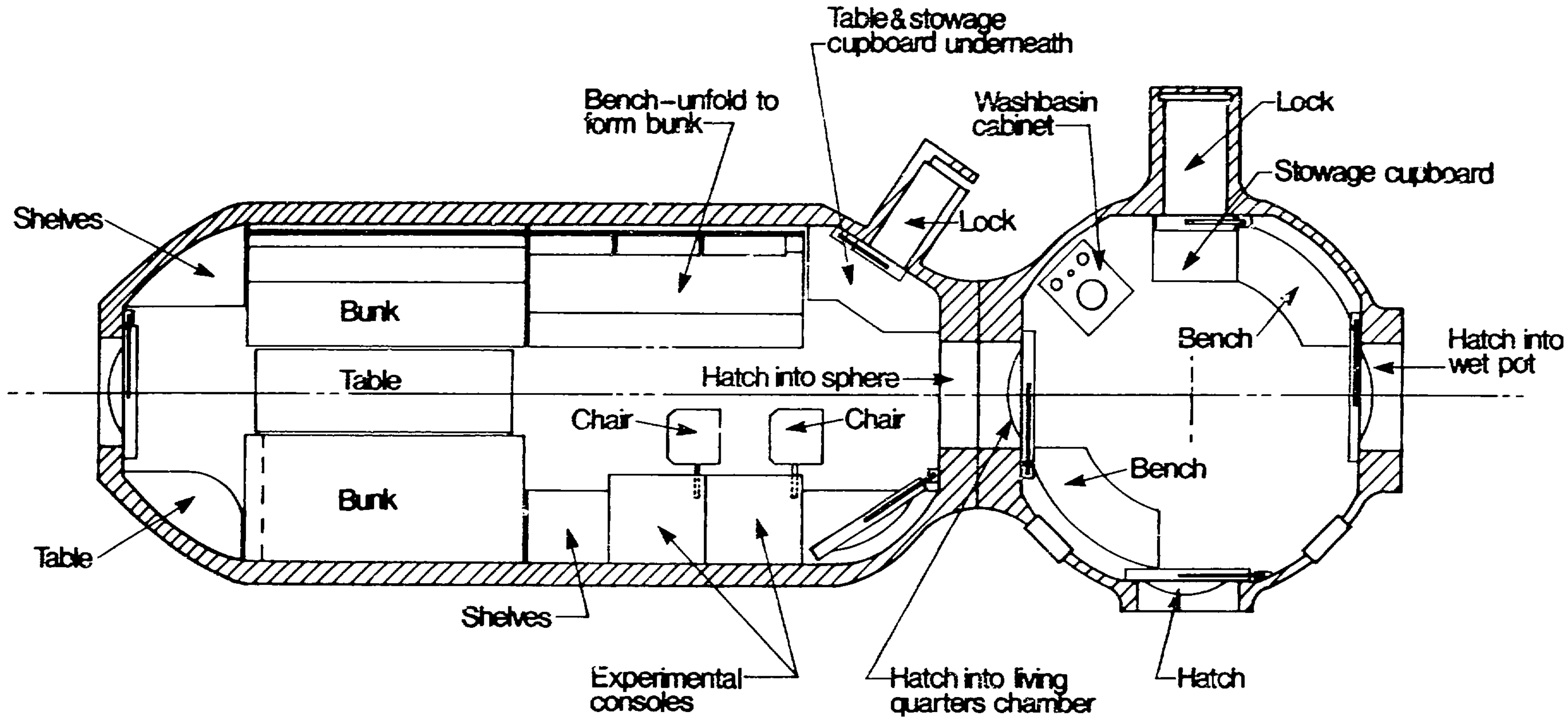

Figure 2: DDF Interior Layout (plan view).

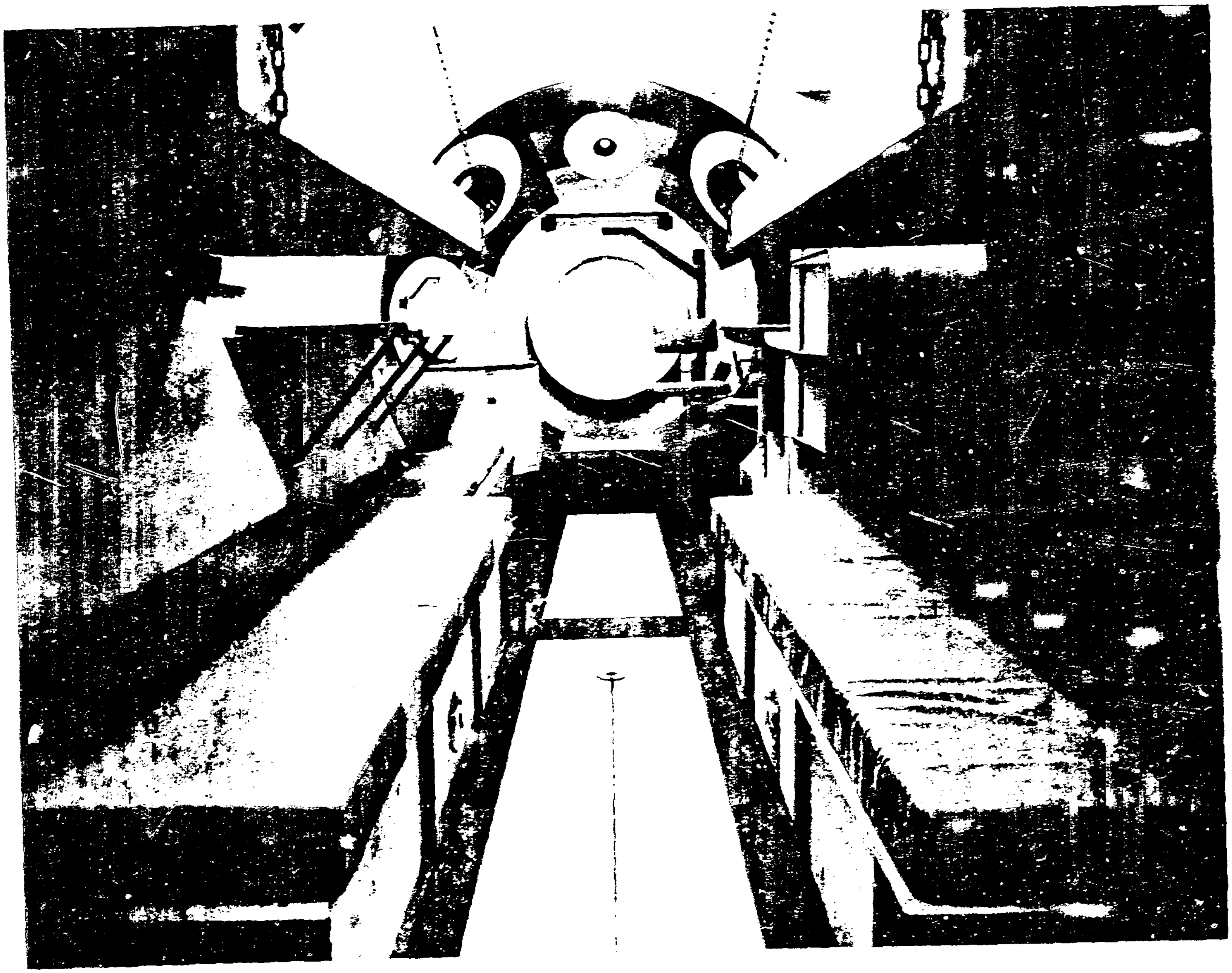

Figure 3: Living Chamber (viewed from entrance hatch).

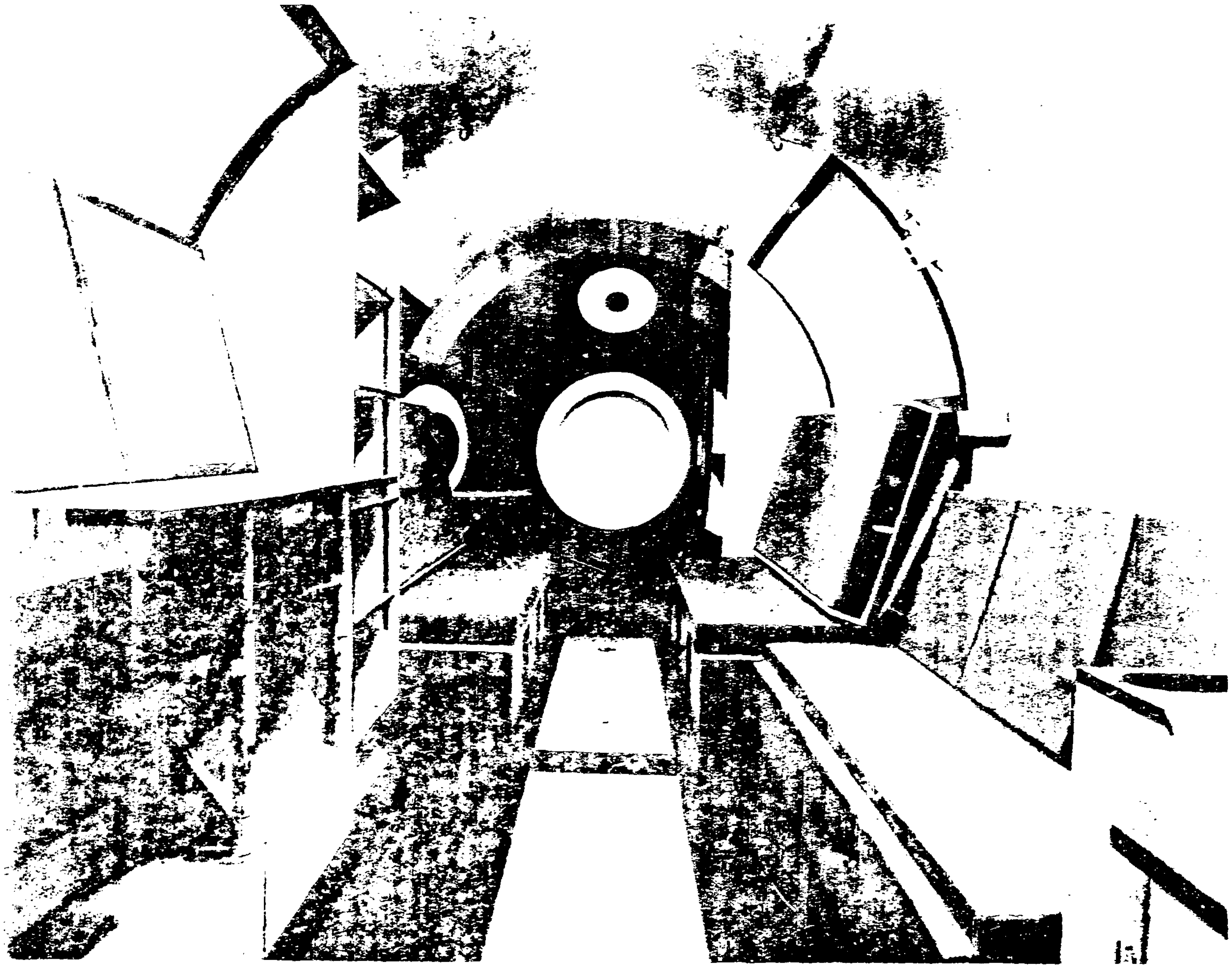

Figure 4: Living Chamber (viewed from hatch into Sphere).

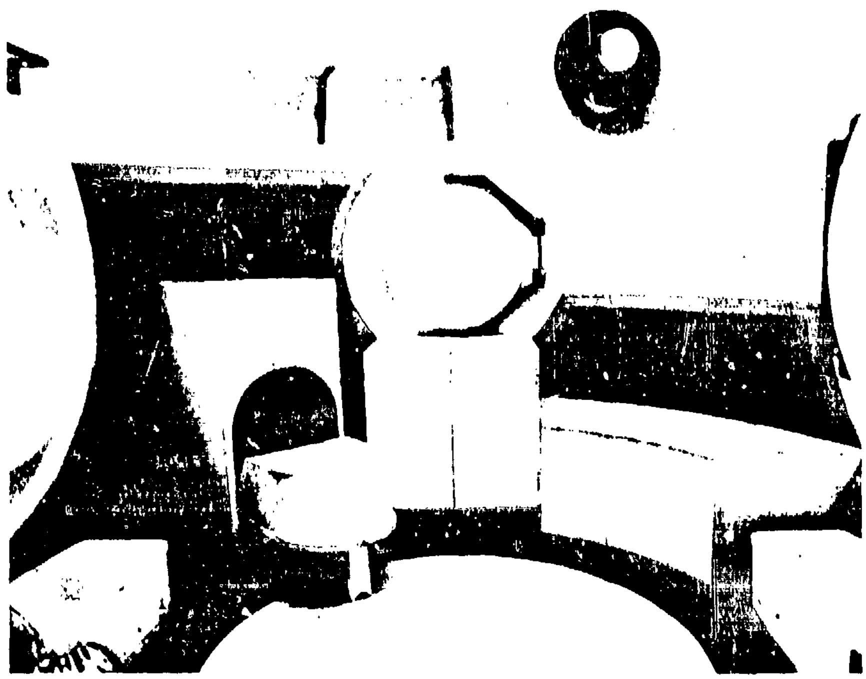

Figure 5: Sphere (viewed from entrance hatch).

Figure 6: Sphere (viewed from hatch into Wet Pot).

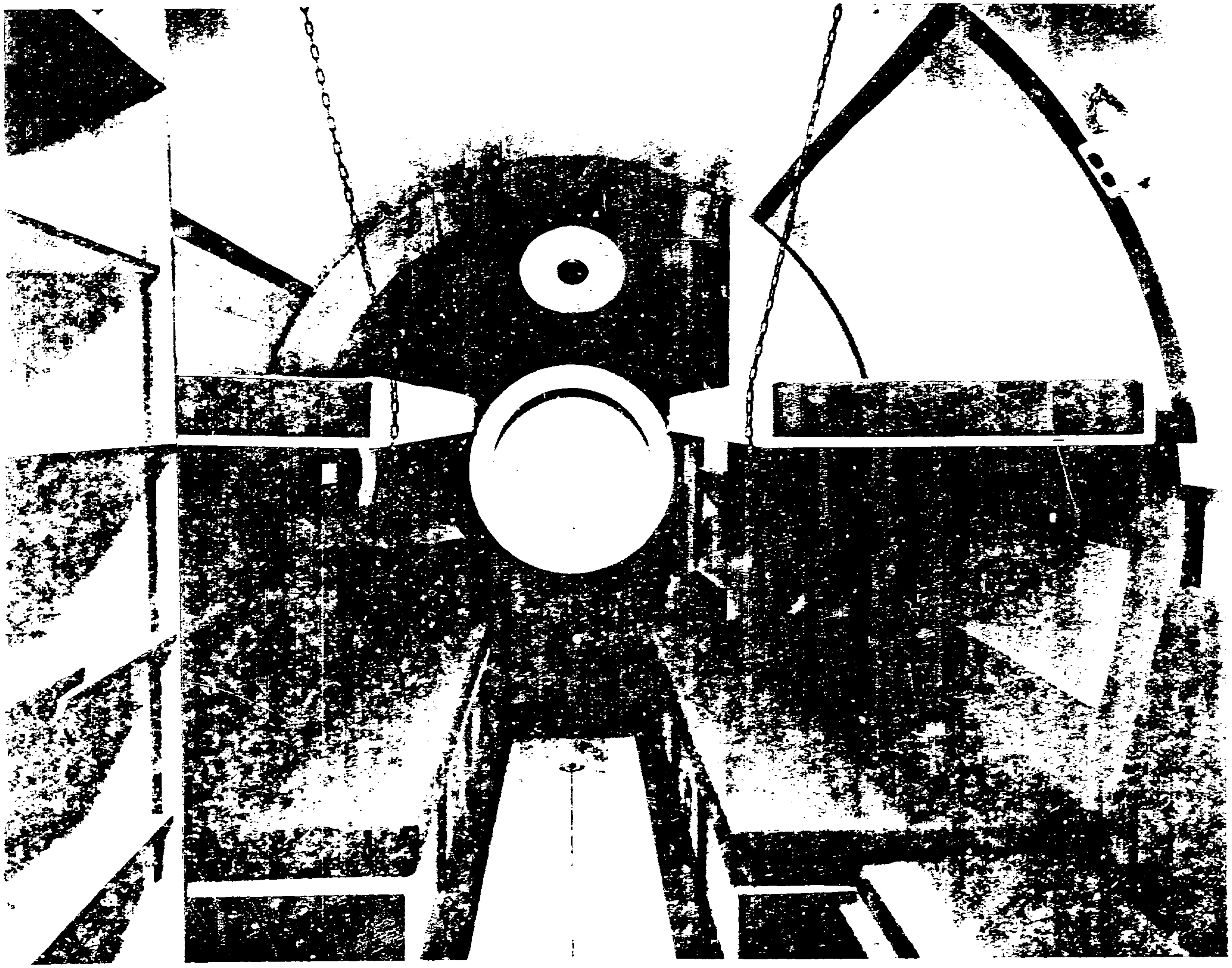

Figure 7: Living Chamber - bunk area.

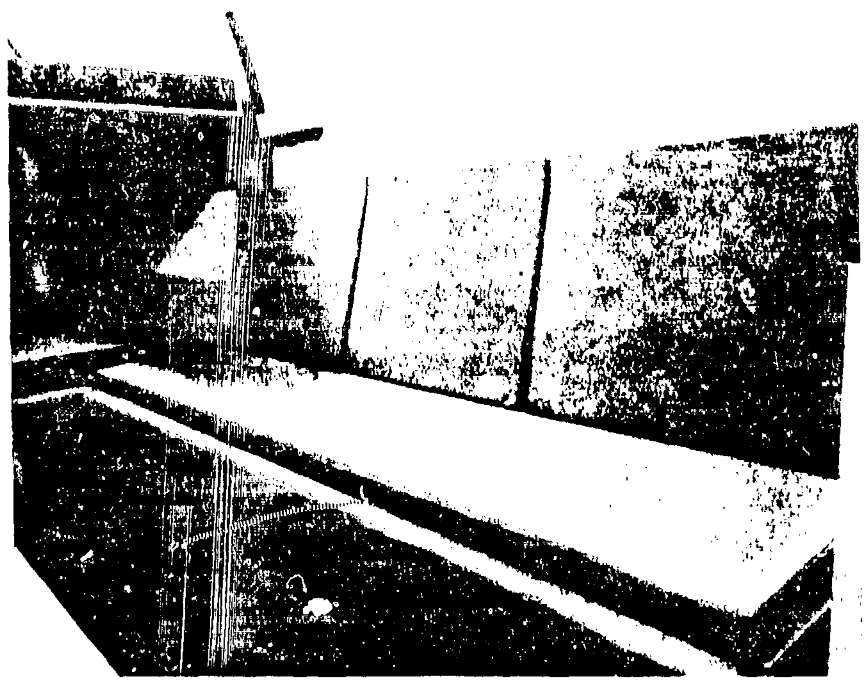

Figure 8: Living Chamber - bench seat.

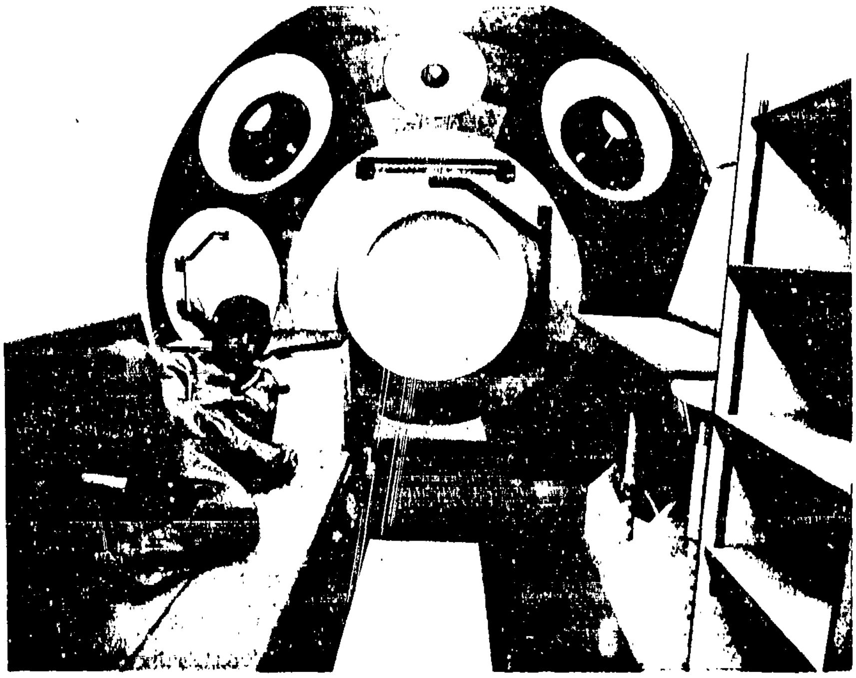

Figure 9: Living Chamber - bench seat configured as bunk.

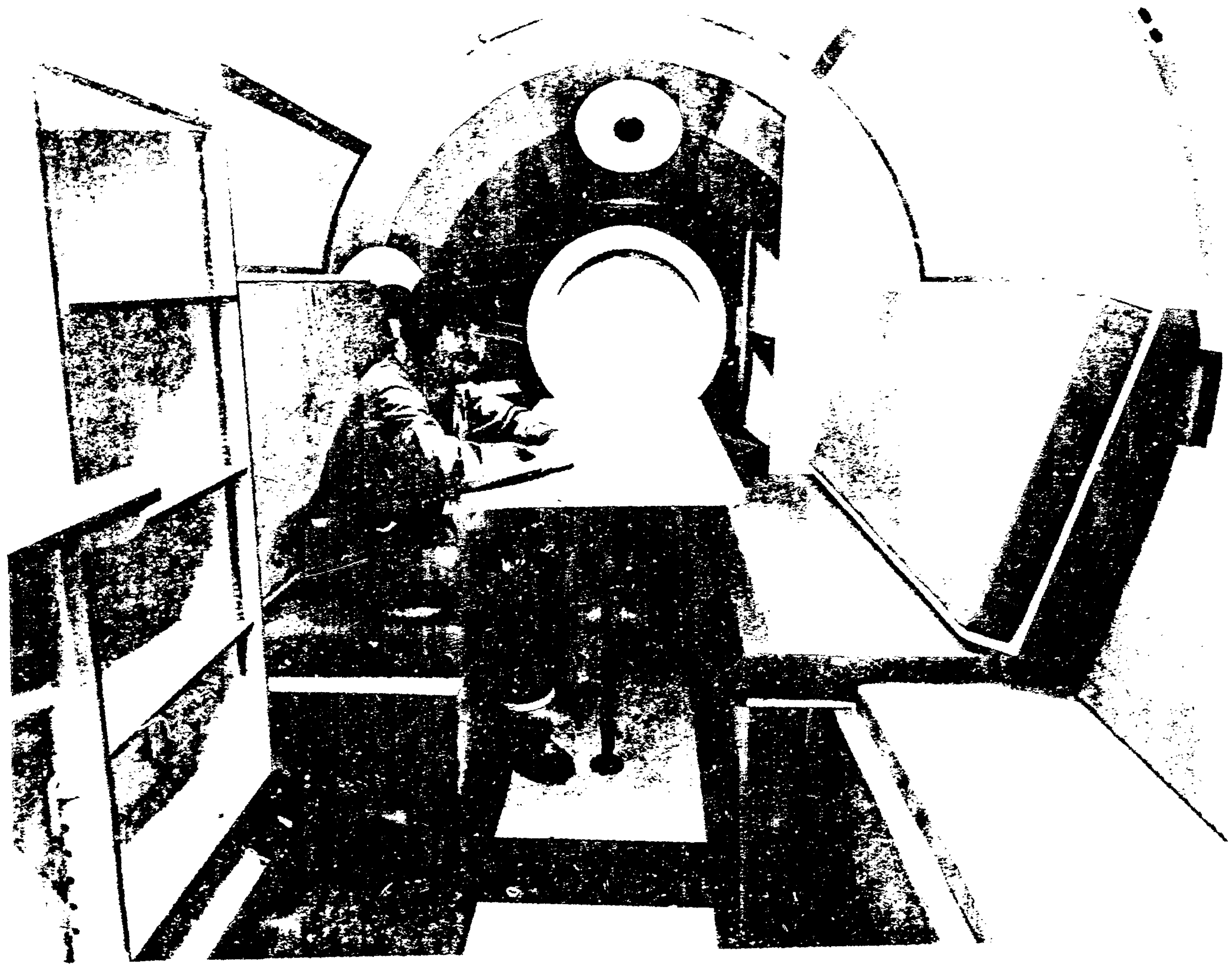

Figure 10: Living Chamber - dining area.

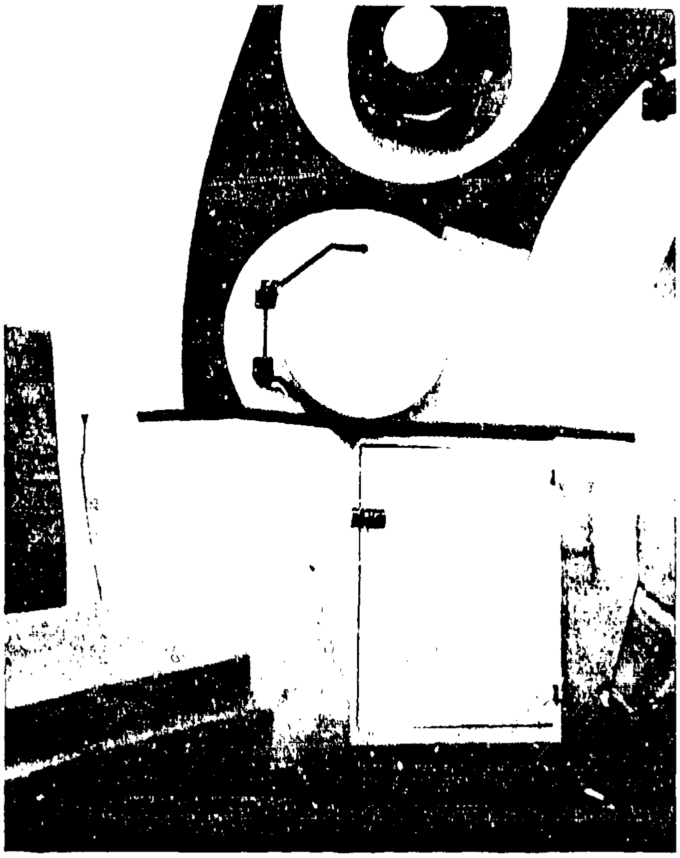

Figure 11: Living Chamber - pass-through lock, table and cabinet.

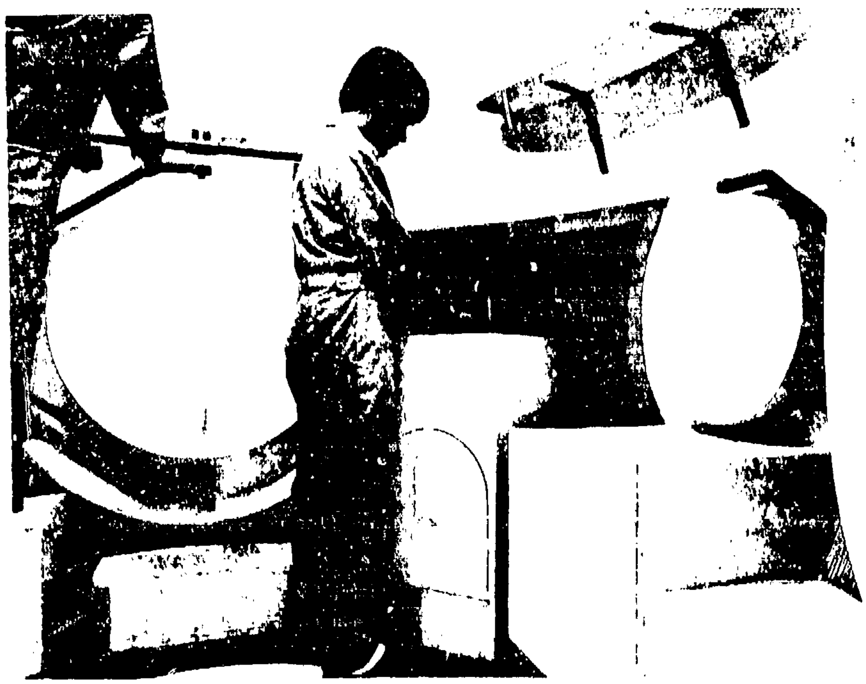

Figure 12: Sphere - toilet and washbasin unit.

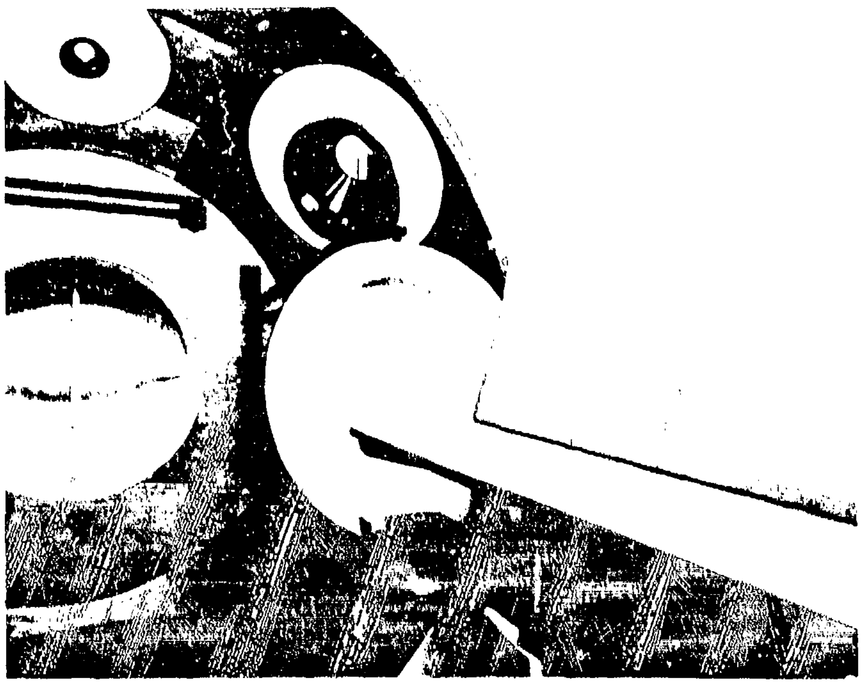

Figure 13: Living Chamber - hatch door (stored position).

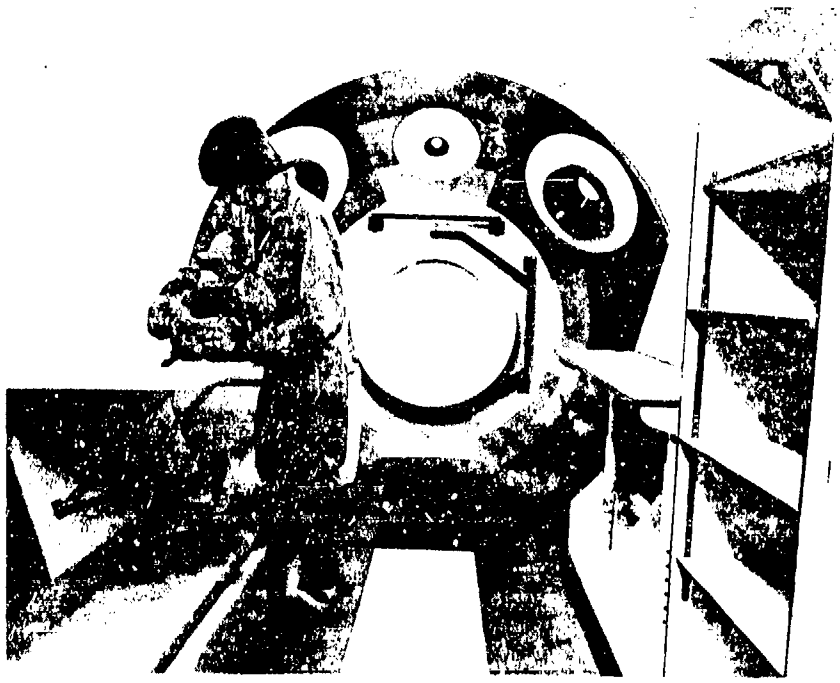

Figure 14: Living Chamber - worksurface formed by backrest of bench.

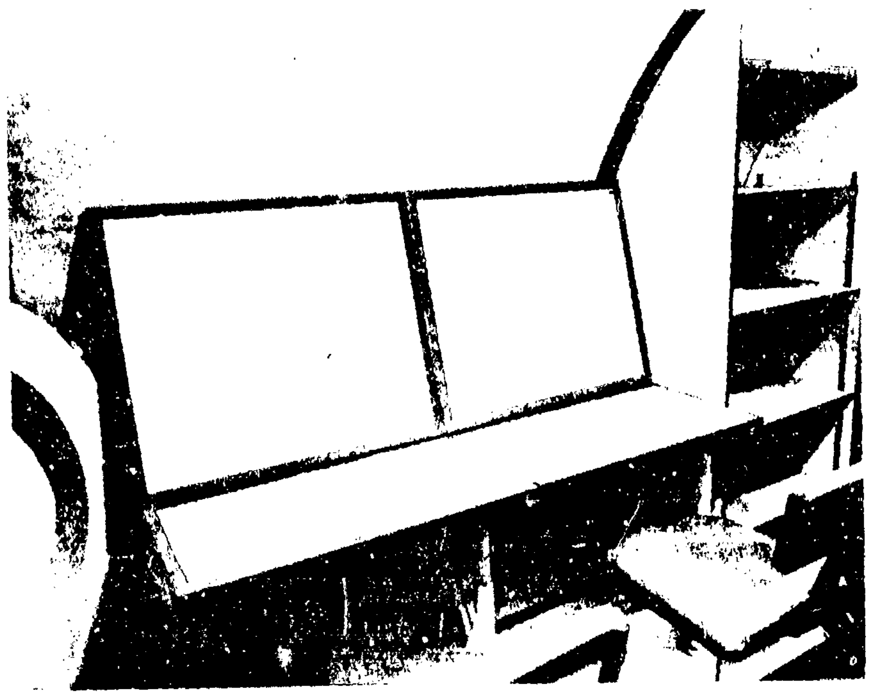

Figure 15: Living Chamber - experimental consoles.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATING ACTIVITY DCIEM	2a. DOCUMENT SECURITY CLASSIFICATION Unclassified 2b. GROUP
3. DOCUMENT TITLE HUMAN ENGINEERING ASPECTS OF A DEEP DIVE FACILITY	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical	
5. AUTHOR(S) (Last name, first name, middle initial) McCann, C.	

6. DOCUMENT DATE March, 1977	7a. TOTAL NO. OF PAGES 41	7b. NO. OF REFS 5
8a. PROJECT OR GRANT NO.	9a. ORIGINATOR'S DOCUMENT NUMBER(S) 77X11	
8b. CONTRACT NO.	9b. OTHER DOCUMENT NO.(S) (Any other numbers that may be assigned this document)	
10. DISTRIBUTION STATEMENT Unlimited		
11. SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY DCIEM	

13. ABSTRACT

The Defence and Civil Institute of Environmental Medicine is designing a Deep Dive Facility which will be constructed to conduct in-house research into physiological and operational problems of deep diving. This report discusses the habitability requirements of such a facility, and considers the human engineering aspects of hyperbaric chamber design. Based on these criteria, an optimum interior layout for the chamber complex is described.

DSIS
70-241

Unclassified

Security Classification

KEY WORDS

human factors, hyperbaric chamber, habitability, layout, design

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the organization issuing the document.

2a. DOCUMENT SECURITY CLASSIFICATION. Enter the overall security classification of the document including special warning terms whenever applicable.

2b. GROUP: Enter security reclassification group number. The three groups are defined in Appendix 'M' of the DRB Security Regulations.

3. DOCUMENT TITLE: Enter the complete document title in all capital letters. Titles in all cases should be unclassified. If a sufficiently descriptive title cannot be selected without classification, show title classification with the usual one-capital-letter abbreviation in parentheses immediately following the title.

4. DESCRIPTIVE NOTES: Enter the category of document, e.g. technical report, technical note or technical letter. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the document. Enter last name, first name, middle initial. If military, show rank. The name of the principal author is an absolute minimum requirement.

6. DOCUMENT DATE: Enter the date (month, year) of Establishment approval for publication of the document.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the document.

8a. PROJECT OR GRANT NUMBER: If appropriate, enter the applicable research and development project or grant number under which the document was written.

8b. CONTRACT NUMBER: If appropriate, enter the applicable number under which the document was written.

9a. ORIGINATOR'S DOCUMENT NUMBER(S): Enter the official document number by which the document will be identified and controlled by the originating activity. This number must be unique to this document.

9b. OTHER DOCUMENT NUMBER(S): If the document has been assigned any other document numbers (either by the originator or by the sponsor), also enter this number(s).

10. DISTRIBUTION STATEMENT: Enter any limitations on further dissemination of the document, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this document from their defence documentation center."

(2) "Announcement and dissemination of this document is not authorized without prior approval from originating activity."

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document, even though it may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (TS), (S), (C), (R), or (U).

The length of the abstract should be limited to 20 single-spaced standard typewritten lines; 7½ inches long.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a document and could be helpful in cataloging the document. Key words should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context.