NRL Report 6656

Studies of the Naval Facilities Engineering Command Protective Shelter

II. Summer Trials

Prepared Cooperatively by

Naval Research Laboratory
Naval Facilities Engineering Command
Naval Medical Research Institute
Army Medical Research and Nutrition Laboratory

March 29, 1968

NAVAL RESEARCH LABORATORY
Washington, D.C.

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Previous Report in This Series

"I Winter Trials," E.A. Ramskill, *et al*, NRL Report 5882, Dec 1962

CONTENTS

Abstract ii
Problem Status ii
Authorization ii
Preface iii

CHAPTER 1 - INTRODUCTION 1

CHAPTER 2 - CONSTRUCTION AND SUPPLIES 3
Howard E. Hassler and J.T. White, LTJG, CEC, USNR

CHAPTER 3 - ENVIRONMENTAL MONITORING 21
H.F. Bogardus and E.A. Ramskill

CHAPTER 4 - SELECTION OF SUBJECTS 41
J.E. Rasmussen, CAPT, MSC, USN

CHAPTER 5 - ORGANIZATION AND MANAGEMENT 45
J.T. White, LTJG, CEC, USN and
J.E. Rasmussen, CAPT, MSC, USN

CHAPTER 6 - NUTRITION STUDIES 59
Robert Van Reen,
Nicholas Raica, Jr., and
Richard A. Nelson

CHAPTER 7 - PHYSIOLOGICAL STUDIES 71
D. Minard, CAPT, MC, USN and
A.R. Dasler, LT, MSC, USN

CHAPTER 8 - PSYCHOLOGICAL STUDIES 95
J.E. Rasmussen, CAPT, MSC, USN,
C.M. Wagner, CDR, MSC, USN, and
C.A. Morris

CHAPTER 9 - MEDICAL ASPECTS 123
D. Minard, CAPT, MC, USN

CHAPTER 10 - BACTERIOLOGICAL STUDIES 131
John A. Davies, LCDR, MSC, USN

CHAPTER 11 - SUMMARY AND CONCLUSION 134

CHAPTER 12 - RECOMMENDATIONS 141
ACKNOWLEDGMENTS 143

APPENDIX A - Shelter Schedules: Initial Organization Phase 145

APPENDIX B - Test Scales for Psychological Studies in NAVFACENGCOM Protective Shelter 149

APPENDIX C - Results of Statistical Treatment of Data Obtained from Likert-Type Scales of Subjective Discomfort 161

APPENDIX D - Comparative Results from the Winter and Summer Trials of the Navy Experimental Underground Shelter, Bethesda, Maryland 169

APPENDIX E - Glossary 171

ABSTRACT

A 2-week summer trial was conducted at Bethesda, Maryland, during August 1962, in a protective shelter (blast, radioactive fallout, and biological and chemical warfare) designed by the Bureau of Yards and Docks, now Naval Facilities Engineering Command. Navy volunteers served as the shelter subjects. Two naval officers served as shelter commander and medical officer. Since the primary purpose of this trial was to study the engineering features of the shelter, it was considered desirable to conduct the trial with a carefully selected, reasonably homogeneous group of shelterees. Therefore, the shelterees, selected from a group of volunteers, were screened both medically and psychologically.

The shelter equipment performed satisfactorily, and the trial was conducted successfully. The ration, basically survival ration crackers and soup, provided approximately 1860 calories per day. Weight loss and exercise tolerance studies indicated that this ration was marginal, but adequate. Water was unlimited for drinking purposes but, except for brushing teeth and decontamination showers, prohibited for personal hygiene. The average total water consumption was 3.3 quarts/man/day during the first week and 2.8 quarts/man/day during the second week for a total of 1025 gallons. The average daily inlet effective temperature was 74°F during the first week and 67°F during the second week. The average daily shelter effective temperature was 85°F during the first week and 80°F during the second week. It is highly improbable that the men could have survived a second week of 85°F average effective temperature. Hot bunking (50 bunks for 100 men) proved to be acceptable. Psychological studies indicated that lack of water for washing, temperature and humidity, food, crowding, and dirt consistently produced the most discomfort.

PROBLEM STATUS

This is the final report on this problem. Unless otherwise notified, this problem will be considered closed 30 days after the issuance of this report.

AUTHORIZATION

NRL Problem C08-35
BUDOCKS Project Y-E011-05-331

Manuscript submitted October 4, 1967.

PREFACE

In 1961 the Bureau of Yards and Docks, now the Naval Facilities Engineering Command (NAVFACENGCOM), constructed an experimental shelter on the grounds of the National Naval Medical Center, Bethesda, Maryland. The shelter, which provides blast protection and protection against chemical and biological warfare agents, was designed to accommodate 100 men. Three trials were run to determine the engineering adequacy of the shelter under both winter and summer conditions. A 48-hour trial using 100 volunteers from naval stations in the Washington area was conducted starting January 31, 1962. A 2-week winter trial was conducted starting February 17, 1962 and ending March 3, 1962. A 2-week summer trial was conducted starting August 1, 1962 and ending August 15, 1962. The report of the winter trials was published in 1962 (NRL Report 5882).

Unfortunately, several of the authors were not able to complete their chapters for the report of the summer trial immediately. It is believed that the publishing delay has not detracted from the value of the information in this summer report.

Where applicable, the authors are shown with their current titles. Where authors have moved to other commands or other places of business, their current affiliation is shown in parenthesis.

STUDIES OF THE NAVAL FACILITIES ENGINEERING COMMAND PROTECTIVE SHELTER

II. SUMMER TRIALS

CHAPTER 1

INTRODUCTION

In accordance with Navy Regulations, the Naval Facilities Engineering Command (NAVFACENGCOM) has responsibility for the design and construction of shelters for the Naval shore establishment. To meet its responsibility NAVFAC designed an experimental, 100-man protective shelter and contracted for its construction at the National Naval Medical Center (NATNAVMEDCEN), Bethesda, Md. Construction of the shelter was completed in January 1962.

During the design phase of the experimental shelter, NAVFAC requested NRL to determine the engineering adequacy of the shelter in a series of trials using Navy volunteers (1,2). This request was accepted by NRL (3,4). NAVFAC agreed to arrange for adequate medical assistance with the Bureau of Medicine and Surgery (BUMED) (1). Such assistance was arranged and furnished by the Naval Medical Research Institute (NAVMEDRSCHINSTITUTE) (5,6).

Although the primary objective of the trials was to determine the adequacy of the engineering aspects of the shelter, it became evident very early that several other aspects would necessarily be encountered. Among these may be mentioned the medical, physiological, psychological, nutritional, management, and shelter-organization aspects. It was decided that these additional aspects would be studied to the greatest extent possible with available manpower and funds but not to the extent of interfering with the primary purpose.

During the planning phase of the trials, maximum advantage was taken of the experiences gained in previous shelter trials. Notable among these were the trials conducted by the Naval Radiological Defense Laboratory (NRDL) in 1959 and 1960 at Camp Parks, California (7,8). Also, the trials conducted by the American Institute of Research (AIR) from March to June 1960 were of great value (9).

Two winter trials were conducted during the period of January 31 – March 3, 1962. The results of the winter trials are described in Ref. 10. On the basis of the winter trials, some minor additions were made to the physical plant, viz., the installation of shelves along both sides of the shelter in the bunk area and the painting of stripes on the shelter floor indicating passageways. These additions are more fully described in Chapter 2.

A 2-week summer trial was conducted in August 1962. The results of the summer trial are described in the subsequent chapters of this report.

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CHAPTER 2

CONSTRUCTION AND SUPPLIES

Howard E. Hassler and J.T. White
Naval Facilities Engineering Command

INTRODUCTION

The basic design criteria for this specific experimental shelter called for 75 psi overpressure blast protection, a radiation-protection factor of 5000, and virtually absolute filtration of biological and chemical agents and fallout particles. As part of the biological, chemical, and fallout requirements, it was necessary to provide facilities for decontaminating entering personnel. As a basis for design, a stay time of 2 weeks was established. In addition, the habitability level to be provided during this period was such that personnel would be physically able to fight and/or begin the tasks of recovery upon emergence.

CONSTRUCTION DETAILS

Structure

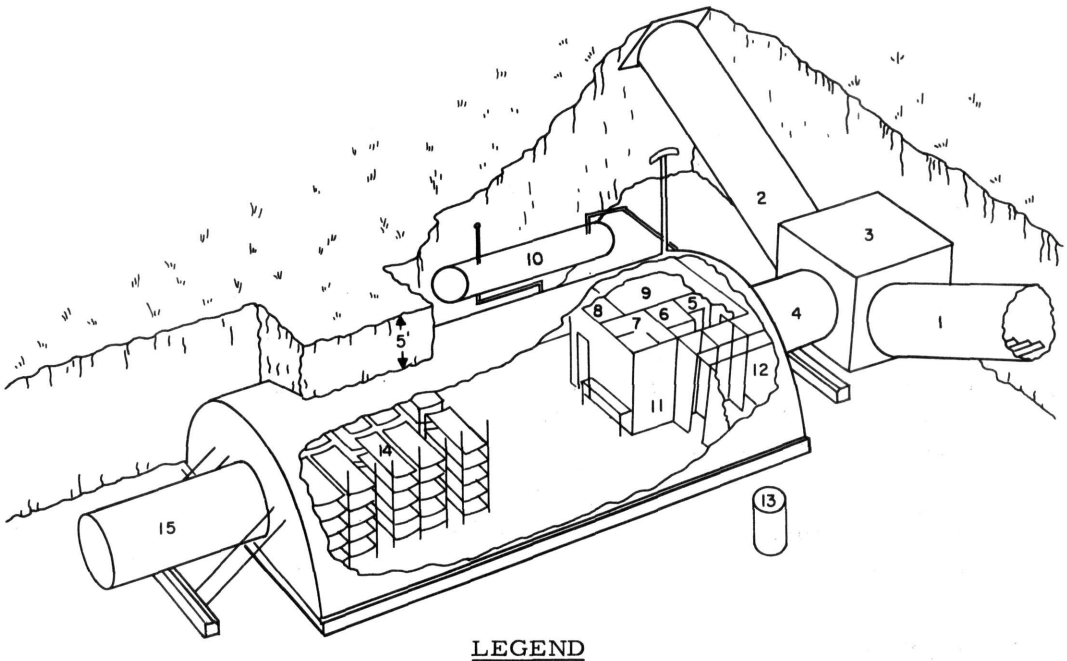
The basic shelter is a buried corrugated-steel-arch structure, 25 ft by 48 ft, similar to the Navy's standard ammunition magazine.

The outer covering of the shelter arch is 10-gauge galvanized corrugated steel, while the end walls and the circular culvert sections used as passageways are 8-gauge galvanized corrugated steel. The end walls of this structure are braced by a horizontal "I" beam connected to a concrete deadman buried outside the structure. All exterior steel surfaces are coated with an asphaltic coating which serves as a moisture seal.

Within the shelter itself, there are 6-in.-12.5-lb-curved "I" beams spaced every 4 ft throughout the length of the shelter. These semicircular reinforcing ribs increase the blast resistance of this type of structure. Buried structures of a similar type and configuration to that used here have been previously tested under atomic blast loadings at Operation Plumbbob (1) and were found able to withstand peak overpressures in the 75 psi range. The layout of components is shown in Fig. 1. The vertical loading is transmitted to a 12-in.-wide-by-15-in.-high reinforced concrete footing which is continuous around the periphery of the shelter. The floor is a concrete slab placed on 4 in. of gravel and is separated from the foundation footing by a 1/2-in. premolded expansion joint.

Entrance (Fig. 2)

As indicated by item 1 of Fig. 1, entrance to the shelter is provided by a 7-ft-diameter culvert section with wooden steps 3 ft wide for quick access. Item 2, Fig. 1, is an identical culvert section directly opposite the entrance section. This section has been provided to keep reflected blast waves from building up in the reinforced concrete room housing the motor generator and to provide additional ventilation for the motor generator. To make it easier to remove or bring in large equipment, steps have been omitted from item 2.



LEGEND

1. Entrance
2. Potential entrance section
3. Motor-generator room
4. Entry passage - blast door between 3 and 4 not shown
5. Waiting room
6. Undressing room for decontamination teams
7. Shower room
8. Drying room
9. Filter room
10. 4000-gallon water tank
11. Deepsink occupies this space
12. Chemical toilets (six units)
13. Dry well
14. Bunk area (capacity 50)
15. Emergency exit

Fig. 1 - Perspective cutaway drawing of shelter showing arrangement of bunk area and separate rooms

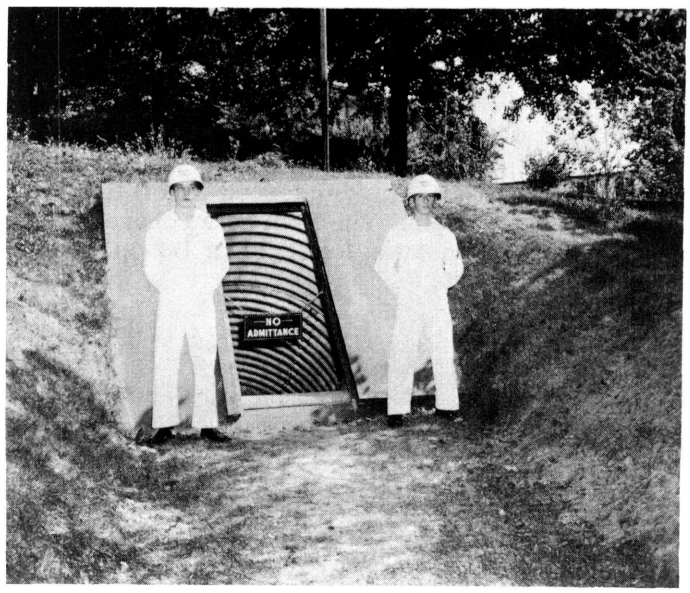


Fig. 2 - Entrance to the shelter

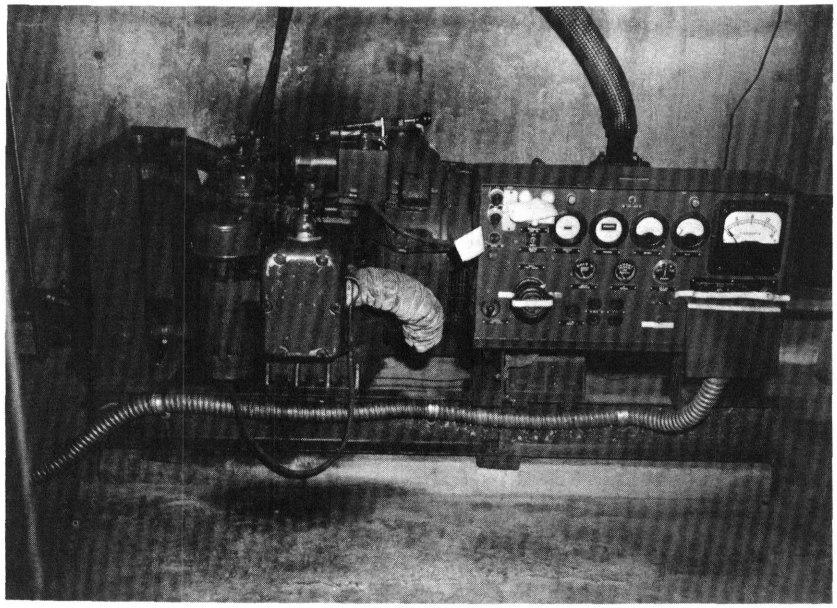


Fig. 3 - 10-kw diesel generator

Motor-Generator Room (Fig. 3)

Item 3 of Fig. 1 is a reinforced concrete room, 9 ft square and 8 ft high, inside dimensions, which contains a 10-kw diesel generator. The roof and walls are 12 in. thick and designed to withstand a blast pressure of 75 psi.

Blast Door (Fig. 4)

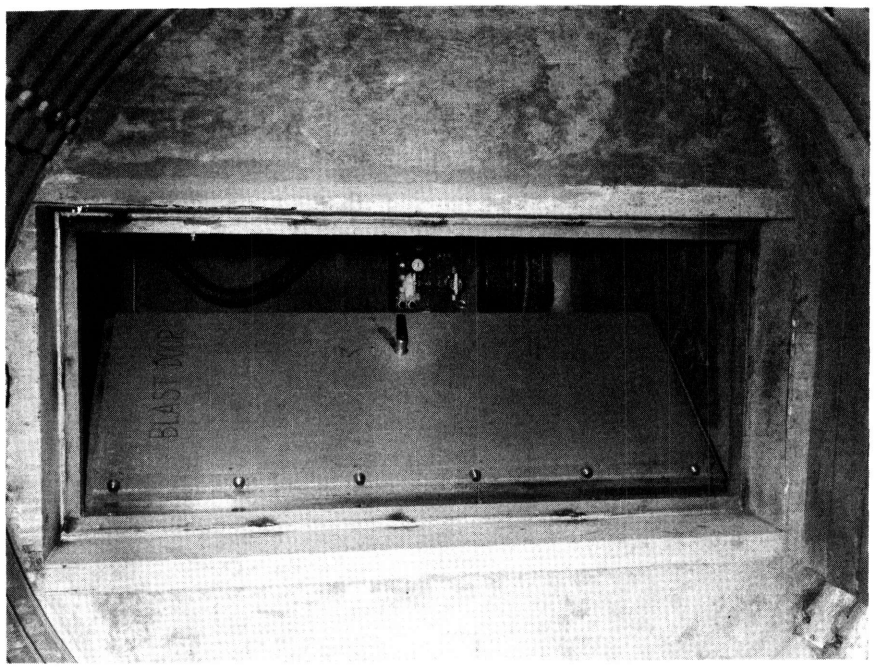
A 32-in.-by-73-in. bank-vault-type door which is designed to withstand overpressures up to 100 psi, provides the entrance to the shelter proper with blast protection.

The blast door is located in the generator room at the entrance to the passageway (item 4 of Fig. 1) which leads to the main shelter structure. The connecting passageway to the main structure is a 7-ft-diameter steel culvert section approximately 9 ft long.

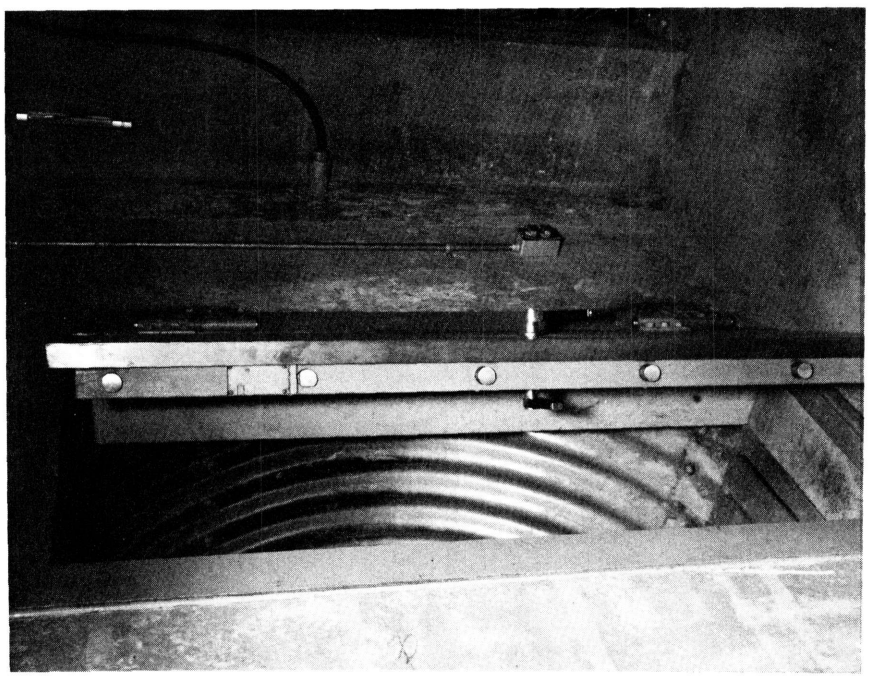
Decontamination Area and Ventilation System (Figs. 5 and 6)

Entrance to the living portion of the shelter is through the personnel decontamination area, items 5, 6, 7, and 8 of Fig. 1. Also in this 12-ft-by-14-ft area is located the filter room (item 9 of Fig. 1). The filter room contains the Army's standard M9A1 Gas-Particulate Filter Unit. This unit affords biological, chemical, and fallout protection by means of particulate filters and trays of activated charcoal.

Air is drawn from the outside through an intake pipe and the filter unit by a blower having a rated capacity of 600 cfm. The air is conveyed through a duct along the longitudinal center line of the shelter to three diffuser outlets located near the ceiling over the bunking area. The air then circulates back toward the forward part or entrance end of the shelter where it escapes through small openings in the doors of the drying and dressing room, shower room, and undressing room into the waiting room. From there it is vented through a pipe to the outside by a 300-cfm exhaust blower. By this method,



(b) Blast door as seen from the entrance passage



(a) View of the blast door from inside the motor-generator room

Fig. 4 - Blast door

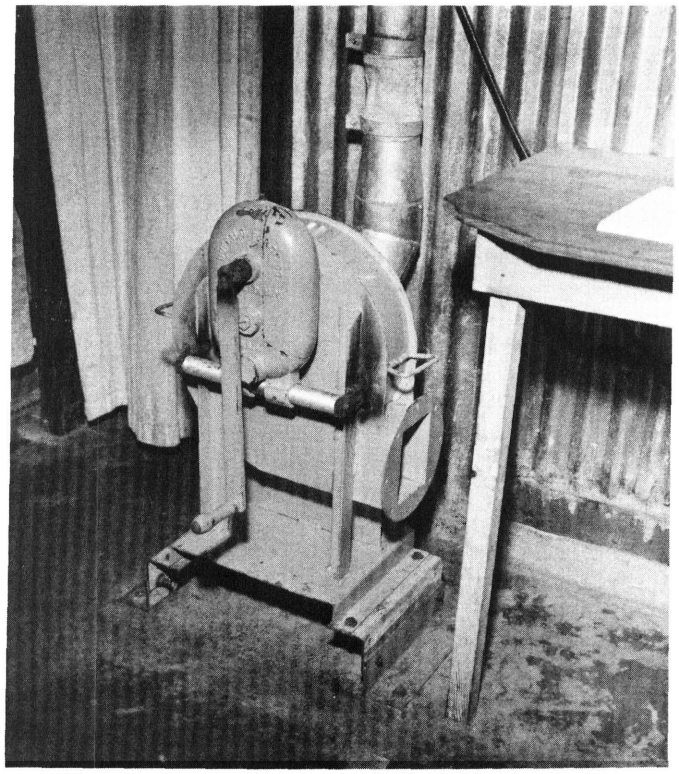


Fig. 5 - Hand-operated blower

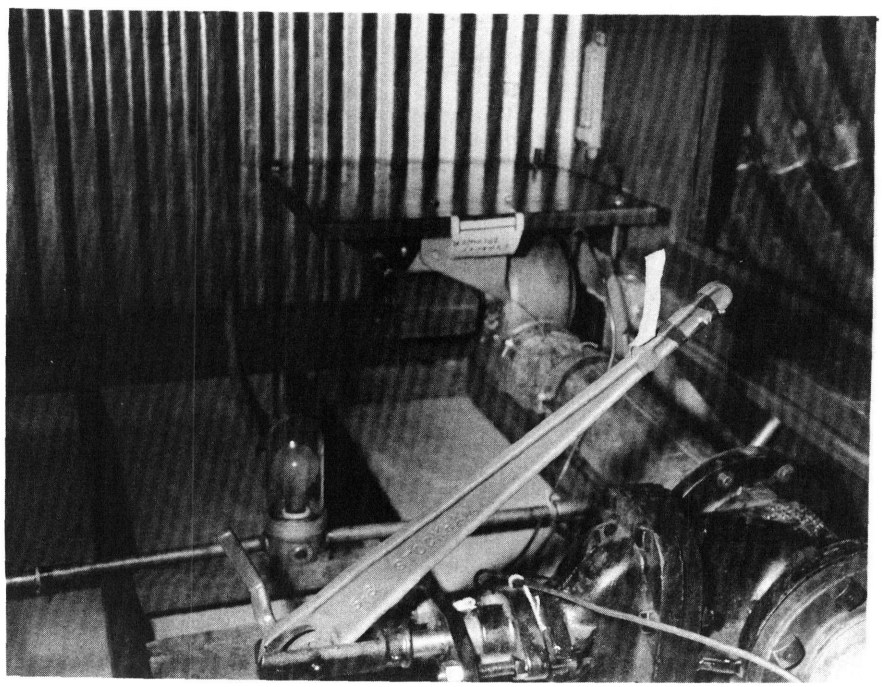


Fig. 6 - Blast valve and exhaust blower

the clean atmosphere in the shelter is maintained at a higher pressure than the atmosphere on the outside, which helps prevent contaminated particles outside the structure from gaining entrance through small openings.

The intake and exhaust ducts have manually operated, quick-closing gate valves located inside the shelter. These valves are designed to withstand 75 psi and must be closed during the blast phase to prevent blast pressures from entering the main shelter.

An emergency manually operated blower having a capability of providing 200 cfm of fresh air is located near the entrance end of the main shelter living area. The air intake for the blower is connected to the regular air-intake duct so that this air may be filtered before entering the main part of the shelter. However, by use of a by-pass valve, air may be brought in directly from the outside.

Water System (Figs. 7 and 8)

Water for drinking and decontamination purposes is supplied from a 4000-gallon steel storage tank buried outside the shelter (item 10, Fig. 1). The tank can be filled from the local water-supply system by means of a valve located within the shelter. The tank can also be filled directly by outside means through a fill pipe which can be reached at the surface over the tank. The air vent for the tank is located within the shelter thereby eliminating the necessity of providing a blast closure valve at the surface. Two water outlets are located within the shelter in the area indicated by item 11, Fig. 1.

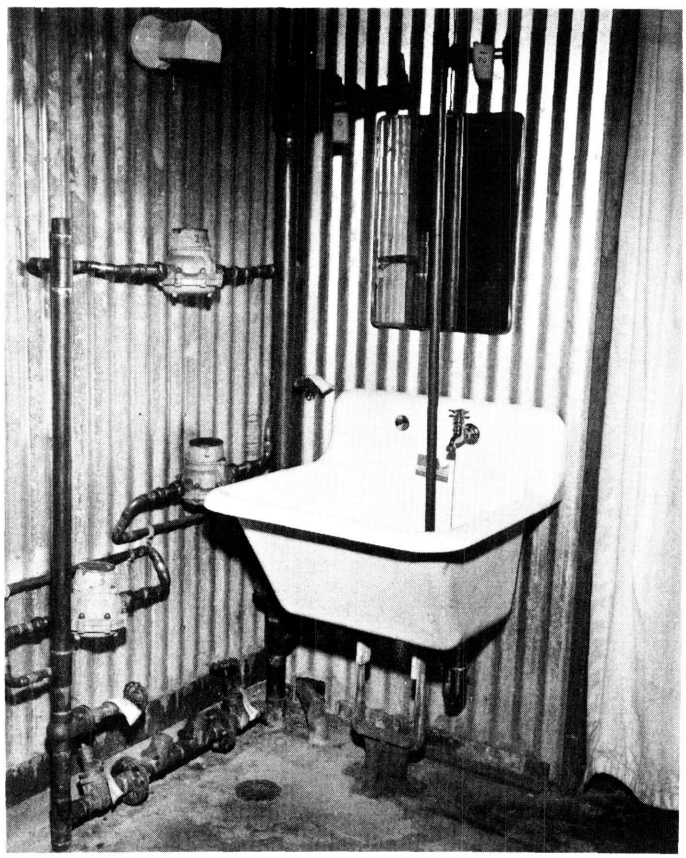


Fig. 7 - Deep sink

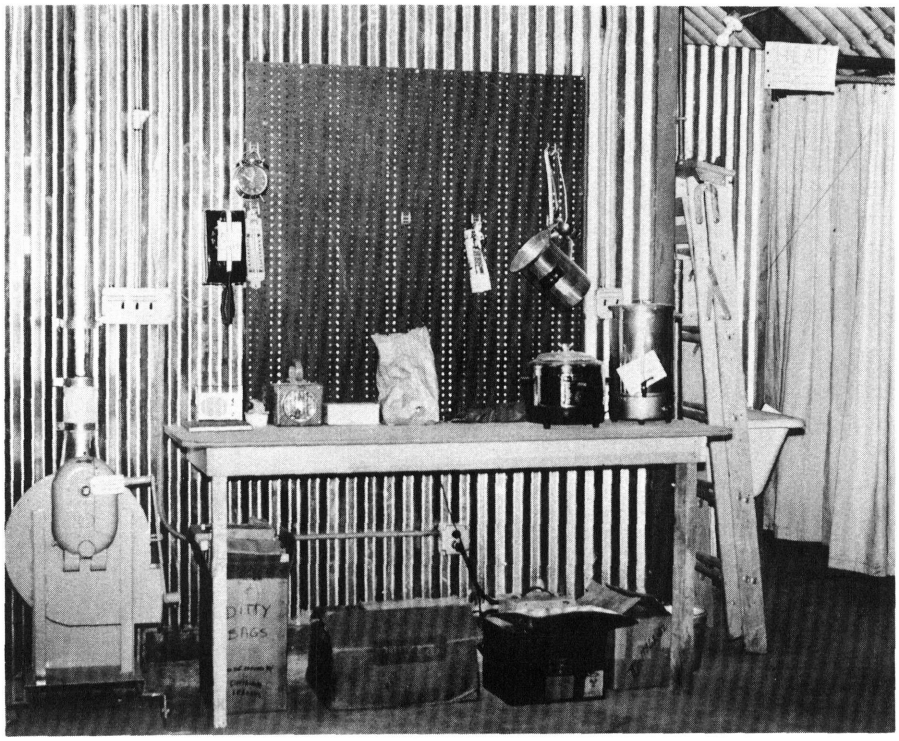


Fig. 8 - Forward area of shelter showing manual blower, cooking area, and head

Sanitary System (Fig. 9)

Toilet facilities consist of six chemical units located in the area designated by item 12 in Fig. 1. These units have an individual storage capacity of 9 gals, which by opening a gate valve may be drained into a 6-ft-diameter and 7-ft-deep dry well, located outside the shelter (item 13, Fig. 1). The units are partitioned with cement, asbestos board, and canvas curtains. Each time the unit is to be used a small quantity of a special chemical is added. The purpose of this chemical is to suppress odors and gases and to aid in the decomposition of matter, thereby, facilitating passage of the sewage through the piping system to the dry well.

Bunk Layout (Fig. 10)

The bunks are arranged in two longitudinal rows, five deep and five tiers high item 14, Figure 1), thus requiring an alternate sleeping schedule, commonly known as "hot-bunking." The bunks are made of No. 10 duck canvas supported between two 1-in.-diameter standard galvanized-iron pipes. The pipes are supported at both ends on steel plates 4 in. wide and 1/4 in. thick, which are, in turn, bolted to vertical pipe stanchions of standard 2-in.-diameter galvanized-iron pipe. The 1-in. pipes are capped at each end to prevent them from slipping off their supports. The bunks are 78 in. long by 27-1/2 in. wide and are spaced vertically 20 in. on center. The lower bunk is approximately 12 in. from the floor. Transverse aisleways, 2 ft wide, are provided between every other set of tiers. The bunks and frames may be easily disassembled if the area is to be used for other purposes. In the event a blast should occur with the bunks in the assembled position, a slip connection has been provided between the top of the bunk stanchions and the shelter overhead. This slip connection allows the arch to deflect under loading without transmitting large forces to the bunk stanchions.

Fig. 9 - Chemical toilet

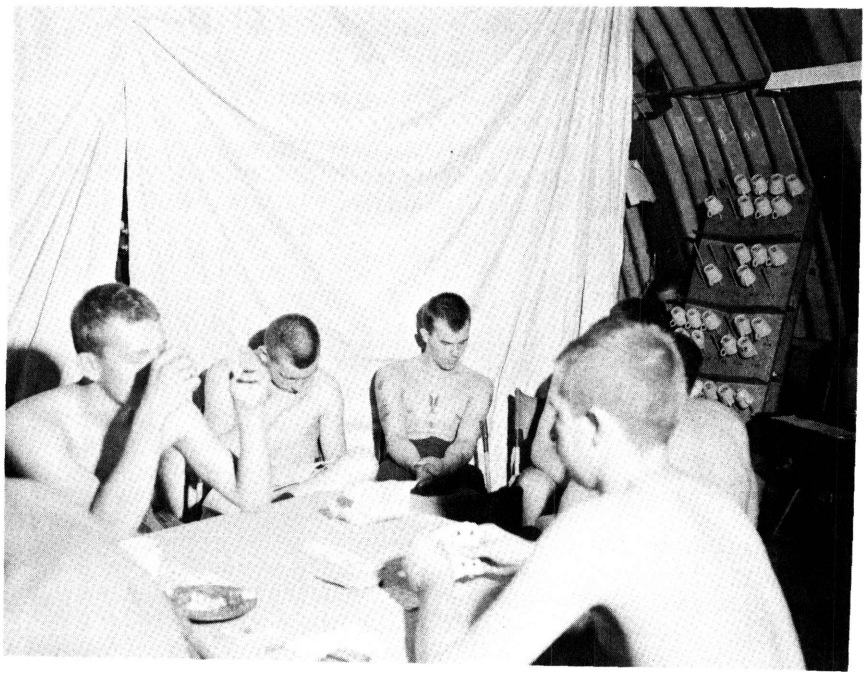


Fig. 10 - Canvas hung in front of bunk area to reduce light intensity

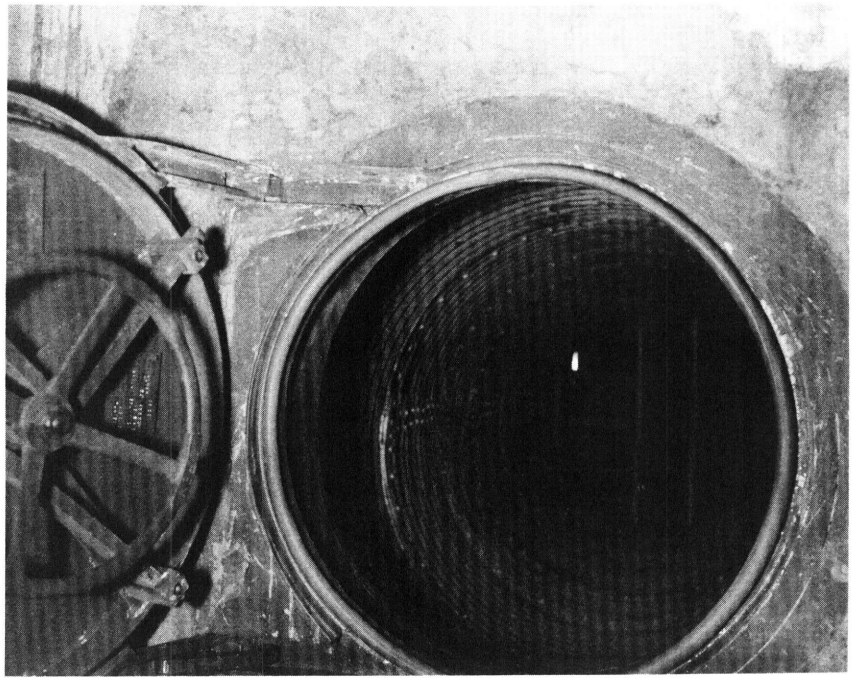


Fig. 11 - View of emergency escape tunnel, looking toward the shelter. The escape hatch can be seen to the right.

Lighting and Power

The shelter living area is lighted by twelve 40-w fluorescent units. Eight of these units are located in the forward area and provide approximately 25 ft-c at the working surface. This intensity is comparable to that usually provided for reading areas in private residences. There are no lights in the bunk area itself but two lights along either side of the bunks provide approximately 5 ft-c of light to the bunking area. This intensity is comparable to that provided in the foyer of a motion-picture house. The toilet area, decontamination areas, and passageways have incandescent fixtures for illumination. Circuit breakers for the shelter are located in the filter room, item 9 of Fig. 1. Electrical outlets are provided in the forward area for cooking appliances.

Power is supplied either by the normal city distribution system or from the emergency 10-kw diesel generator by means of suitable switchgear. The generator has a 275-gal-capacity steel fuel tank buried above it outside the concrete generator room. This capacity will provide fuel for approximately 14 days of continuous usage. The exhaust fumes from the generator engine are vented to the outside through a 2-1/2-in. steel pipe. Fresh air for combustion and cooling is provided through the entrance tunnels. To keep the generator from overheating, the outside doors to the culvert entranceways must be kept open.

Communications

In this design a capped opening leading to the surface has been provided for radio antennas. However, for test purposes a telephone has been substituted for radio communications.

Emergency Exit (Fig. 11)

The rear of the shelter is connected by a 42-in.-diameter steel culvert section to an existing underground passageway which joins buildings of the National Naval Medical

Center. This emergency exit, item 15 on Fig. 1, is approximately 12 ft long. A standard 24-in.-diameter submarine hatch is used to prevent blast pressures from entering the shelter. Ordinarily, a shelter emergency exit would lead directly to the ground surface.

EQUIPMENT AND SUPPLIES (Fig. 12)

The following is a list of the equipment and supplies used during the Summer Habitability Studies and the recommended list of equipment and supplies for standard shelters:

ITEM	USED IN TESTS	RECOMMENDED FOR 100-MAN SHELTERS
Furniture		
6-ft wooden benches	10	10
Folding camp chairs (canvas with tubular steel frame)	48	48
Folding card tables	6	6
8-ft built-in food-preparation table	1	1

Fig. 12 - Personal equipment: amobelts, canteens with holders, and ditty bags

ITEM	USED IN TESTS	RECOMMENDED FOR 100-MAN SHELTERS
Food Preparation and Serving		
5-qt deep frier	1	1
2-1/2-gal coffee urns	2	2
1-gal measure (stainless steel)	1	1
Mixing spoons (stainless steel)	2	2
6-oz ladle (stainless steel)	1	1
Tablespoons (stainless steel)	4	2
Plastic cups with handles	105	105
55-peg drainboards for cups	2	2
Paper bowls	1500	1500
Plastic knives	3000	3000
Plastic spoons	5000	5000
Masonite pegboard for wall storage of cooking utensils (4 ft by 4 ft)	1	1
Cleaning and Sanitation		
Mops	2	1
Push brooms	2	1
Toilet scrub brush	1	1
Sponges	4	4
Dustpan (steel)	1	1
10-qt buckets (plastic)	2	1
10-qt bucket (galvanized steel)	1	1
Ash trays	25	25
12-cu-ft plastic trash bags	60	60
Packages of paper towels	35	35
Paper-towel dispenser	1	1
Rolls of toilet paper	12	20
Wet packet napkins	5600	5600
Tubes of tooth paste	6	10
Boxes of facial tissue	60	60
Air sickness bags	0	100
Cans of foot powder	25	36
Terry-cloth bath towels	58	30
Gallons of antiseptic	1	0
Pairs of rubber gloves	2	2
Gallons of chemical for toilets	12	12
Active Ingredients		
Phosphoric acid 15.95%		
Nonylphenoxypolyethoxy ethanol-iodine complex 12.60%		
Polyethoxypolypropoxypolyethoxy ethanol-iodine complex 4.85% (providing 1.75% available iodine)	12	12
Inert ingredients 66.60%		
100.00%		
Bars of soap	12	12

ITEM	USED IN TESTS	RECOMMENDED FOR 100-MAN SHELTERS
Protective Equipment		
Individual permeable protective suits	10	30
Gloves	0	30
M9A1 field protective masks	10	30
Sets of underwear & socks	0	30
Pairs of boots	2	30
Dosimeters	0	12
0-50 Roentgen Radiac Meter	0	1
0-500 Roentgen Radiac Meter	0	1
0-500 Milliroentgen Radiac Meter	1	0
Chemical-warfare-agent Detector	0	1
Tools and Miscellaneous		
Plumber's plunger	1	1
Plumber's snake	0	1
Screwdrivers	2	2
Pair of pliers	1	1
Wrench (adjustable)	1	1
Generator tool kit	0	1
Roll of electrical tape	1	1
Battle lanterns (w/replacement bulbs and batteries)	3	4
CO_2 fire extinguishers	2	2
6-ft stepladder	1	1
Wall mirror	1	1
Clock	1	1
Can openers (large industrial type)	2	2
Can openers (3 roll type - 3 punch type)	6	6
4 ft-by-4 ft blackboard	1	1
Erasers (blackboard)	2	1
Box of chalk	1	1
Crow bar	0	1
Shovel	0	1
Sledge hammer	0	1
Walkie-talkie	0	1
AM battery-radio receiver with replacement batteries	0	1
Electric-powered hand megaphone	0	1
60-w public-address system with six speakers	1	0
Feet of small line	200	200
Ditty bags	110	110
Memorandum books for use as diaries	110	110
Religious services kit	1	1
Large log books	2	2
Small log books	4	4
Fluorescent light tubes	6	6
Light starters	6	6
Quarts of lubricating oil (diesel generator)	2	(one complete oil change)

ITEM	USED IN TESTS	RECOMMENDED FOR 100-MAN SHELTERS
Tools and Miscellaneous (cont'd)		
Electric razor	1	1
Safety razor kit w/blades	1	1
Water meters	3	0
Electric power meters	3	0
Canvas (painter's drop cloths)	6	2
Blankets	6	50-100
Extra bunk canvases	0	6
Cots	3	0
Chlorine-water tester with stock of chlorine pills	0	1

Note: Cigarettes and matches were not stocked during any of the trials. The participants brought their own, which were issued from a pool, as requested. Food, medical supplies, and instruments used in the environmental studies are listed in their appropriate sections.

PLANS FOR THE SUMMER TRIAL

All of the recommendations specified in the Winter Report (2) were accomplished prior to the start of the 2-week summer trial. These recommendations included: (a) the repairing and testing of the diesel generator, (b) the cutting of a 6-in.-square opening in the head partition allowing odors from the head to escape directly to the exhaust area, (c) the repairing of the manual blower, which involved strengthening the supporting frame of the blower as well as reattaching the handle, (d) the moving of the telephone from its position above the manual blower to a new location in the administrative area, (e) the tightening of loose regulating vanes on the filter-unit blower, (f) the painting of stripes indicating passageways on the shelter floor, (g) the installation of a 60-w public-address system with six speakers, (h) the installation of shelves along both sides of the shelter in the bunk area to define natural aisles in those areas, (i) the replacing of the existing 600-cfm blower with a 1200-cfm unit to insure the trial running the full 2 weeks. Based on winter trial data, preliminary calculations indicated that the existing 600-cfm blower would be inadequate during the hot weather conditions expected for this trial. In addition to increasing the ventilation rate to 1200 cfm, 6 tons of air conditioning was installed outside the shelter for use if needed.

TWO-WEEK SUMMER TRIAL

Entry

One-hundred men entered the shelter on August 1 for a 2-week trial.

Blast Door

Although the blast door was not tested structurally during these trials, several observations were made regarding its operation. It was noted, for instance, that in this humid atmosphere the appearance of rust along the edges of the door and along the door jamb caused the door to bind and made opening difficult.

Decontamination Area

The decontamination area as such was not tested. However, one observation regarding its usage during the trials is worth mentioning. On the seventh day it was necessary to remove one of the shelter occupants for medical reasons. Because of lack of clearance in the present configuration it was impossible to pass a stretcher through the decontamination area doorways.

Ventilation System

The modified ventilation system performed satisfactorily from the mechanical standpoint (see also Chapter 3 "Environmental Monitoring"). No experiments as such were run with the manual blower during the summer trial. However, for a 1-hr period on day 3 when the diesel generator was out of operation, this unit was used to supply the shelter ventilation requirements. As in the winter trial the men each took turns operating the manual blower for a period of 1 min each.

Water System

The water tank was flushed and filled 3 days prior to the trial. Water samples were taken and tested for chlorine and bacteria daily throughout the trial. No harmful bacteria were detected, although the chlorine content had essentially disappeared before the end of the trial. A total of 1025 gal of water was used for all purposes. Approximately 860 gal went for internal consumption, the remainder was used for the taking of 58 showers, washing teeth, charging heads, and disinfecting the cooks' hands prior to their handling of food. The amount of water used for decontamination showering was unrepresentative, however, as only 2.9 qt per man per shower was used.

Sanitation

During this trial as in the winter trial, only three of the six chemical units were used. This amount was sufficient to adequately handle the conditions experienced during this trial. An estimated 270 gal of sewage was generated during this period. Twelve gal of chemical were used during the test, which provided sufficient odor control.

Bunk Layout

Although several bunk pipes were slightly bent at the termination of these trials, nonetheless, they were all in a usable condition. None of the canvas bunks were torn nor did any of the seams show signs of coming apart.

Lighting and Power

The lighting proved to be adequate for the shelter activities without interfering with the sleep of the men in the bunk area. Power was supplied to the shelter by the 10-kw diesel generator throughout the period of the trial except during the first hour immediately following entry and for 1 hr during a breakdown on day 3. This latter interruption was corrected when the shelter engineers noted that the stoppage was caused by a fuel filter cartridge which had worked loose and allowed air to enter the fuel feed system. Upon retightening this cartridge and fitting and repriming the system, the generator started and ran well for the duration of the trial. Average power required from the generator was about 5 kw. Temperatures in the diesel-generator room varied between

ambient and 119°F with the average running 100-110°F. The water temperature of the generator, however, ran consistently at 170°F. A total of 275 gal of fuel was consumed over 334 hrs of operation for an average consumption of 0.82 gal/hr.

Communications

Communications as such were not tested during these studies. The new location of the telephone in the administrative area made use of the telephone a less obvious distraction to the volunteers than during the first two trials, when the telephone was located in the main activity area.

Trash

An estimated 210 cu ft of trash were generated during this trial. Trash was taken out to the motor-generator room twice a day by the engineering team. Outside support personnel then removed it to prevent its accumulation from creating a fire hazard in the generator room.

Emergency Exit

The emergency-exit space was used during all the trials for storage of some of the supplies, thus freeing a greater proportion of the shelter floor area for general use.

Equipment and Supplies

Wooden benches and folding camp chairs with back rests were provided in sufficient quantities so that all 100 men had a place to sit. Folding card tables were provided for recreational use and also for the preparation of meals. The permanent food-preparation table is built-in to the shower-room partition at the entrance end of the shelter living space. Three folding chairs were damaged beyond use during the summer trial.

The food-preparation and serving equipment included a 5-qt deep frier for heating soup and two 2-1/2-gal coffee urns for providing hot water for coffee and tea. A plastic cup was provided for each man which could be hung on a pegboard to drain after usage rather than using water for washing the cups. The spoons provided were used to measure out the food issued at the meals.

Cleaning and sanitation equipment included: wet packet napkins, four of which were issued to each man daily for washing face and hands; an antiseptic in solution, used by the cooks for cleaning their hands prior to handling the food; soap and bath towels, used by the engineering teams when they showered in the decontamination process; other items used in the normal housekeeping functions.

The protective equipment provided was the minimum required to simulate outside monitoring tasks for trial purposes. In stocking for an actual emergency, sufficient protective clothing would have to be stocked so that immediate reuse of the clothing would not be required.

Tools and miscellaneous equipment included a plumber's plunger, which was needed because the chemical commodes had only a 2-in.-diameter drain in the bottom. Can openers included both hand type for use on soup cans and the large table-mounted industrial type for use on the deep-lipped biscuit cans. Ditty bags were used for the storage of individual personal items. Log books were used for the shelter and division records.

CONCLUSIONS

Entrance

Results from the personnel loading tests, which were run before the winter trial, indicate that 100 healthy males can enter this shelter, when lighted, in approximately 2 min from a queued position just outside the outer shelter door. This entrance time indicates that the entrance design is adequate for expedient entry of this type population under the above conditions.

Motor Generator Room

This room is sufficiently large to handle the diesel generator without restricting entrance of people into the shelter. Air-circulation patterns around the generator were adequate to permit continuous generator operation even during the hot weather experienced during the summer trial.

Blast Door

A definite requirement for periodic maintenance to ensure proper operation of this item was indicated by these trials.

Decontamination Area

The summer trial indicated realignment of the decontamination-facility doors is necessary to permit ingress and egress of personnel on stretchers.

Ventilation System

From the results of the winter and summer trials a positive venting of the head directly to the exhaust was found to facilitate odor removal (see also Chapter 3 "Environmental Monitoring").

Water System

The water capacity provided for this shelter was more than adequate to meet trial conditions. However, the specific mission of any given shelter, especially as it pertained to decontamination operations, would have to be specified before a total design water capacity could be determined.

Sanitary System

Results indicate that the three chemicals units used adequately met the needs experienced during these trials.

Bunk Layout

The bunk-layout system was adequate. The provision of only 50 bunks introduced no insurmountable problems, although it necessitated "hot-bunking."

Lighting and Power

The light level throughout the shelter was more than adequate and yet it did not interfere significantly with the sleep of the participants. The size of the generator unit was more than adequate to meet the power demands of the shelter during these trials.

Communications

Handling communications by telephone was satisfactory for the artificial conditions imposed during these trials.

Equipment and Supplies

The equipment and supplies provided generally met the requirements of the summer and winter trials. From a purely survival standpoint some of these items could be reduced in quantity or eliminated. However, in an actual situation some items, primarily protective and communication equipment, should be increased.

RECOMMENDATIONS

Entrance

Although it was shown that 100 men could enter this shelter in approximately 2 min under ideal conditions, it is recommended that additional studies be conducted on this and other entrance designs while using a more representative population. Where women and children would be users of this type shelter, it is recommended that a hand rail be installed along one side of the entrance stairs.

Blast Door

It is recommended that (a) blast doors be studied to determine allowable edge tolerances, (b) the blast door should be periodically checked by maintenance crews to ensure proper operation, (c) some means for locking or bolting this door be provided from the inside, and (d) consideration be given to welding a large bracket or grip to the surface of this door so that it may be opened more easily.

Decontamination Area

It is recommended that the decontamination area be redesigned so as to permit the passage of a stretcher through it.

Ventilation System

It is recommended that the head be positively vented to prevent odors from circulating into the shelter living area.

Water System

It is recommended that a sight glass, or other means of checking the amount of water in the tank, be installed in lieu of the special test water meters.

Bunk Layout

It is recommended that additional studies be conducted on other bunk configurations and materials. Also, a study evaluating the feasibility of providing bunks for 1/3 of the shelter population is recommended.

Lighting and Power

It is felt that the lighting level provided was adequate for command posts and, therefore, could be reduced in those shelters anticipated as personnel shelters alone. It is recommended that the circuit breakers be accessible from the main shelter living area. It is also recommended that the smallest generator possible to do the job should be utilized because of the heat generating problem.

Equipment and Supplies

A recommended equipment and supplies list is incorporated in the original listing beginning on page 12. This list is directly applicable only to situations closely approximating the conditions of this test.

REFERENCES

1. Albright, G.H., et al., "Evaluation of Buried Corrugated-Steel-Arch Structures and Associated Components," Project 3.3, Operation Plumbbob, WT-1422, U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif., Feb. 28, 1961

2. Ramskill, E.A., et al., "Studies of the Bureau of Yards and Docks Protective Shelter, I. Winter Trials," NRL Report 5882, Dec. 31, 1962.

CHAPTER 3

ENVIRONMENTAL MONITORING

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INTRODUCTION

During both the winter and summer trials in the NAVFAC protective shelter, the atmosphere within the shelter was monitored. The temperatures, relative humidity, ventilation rates, and the concentration of carbon dioxide, carbon monoxide, oxygen, and aerosol were followed and are discussed in the subsections which follow. In addition, this section has been expanded to included water consumption, quantity of electricity used, sound level, and photographic coverage.

TEMPERATURE AND VENTILATION

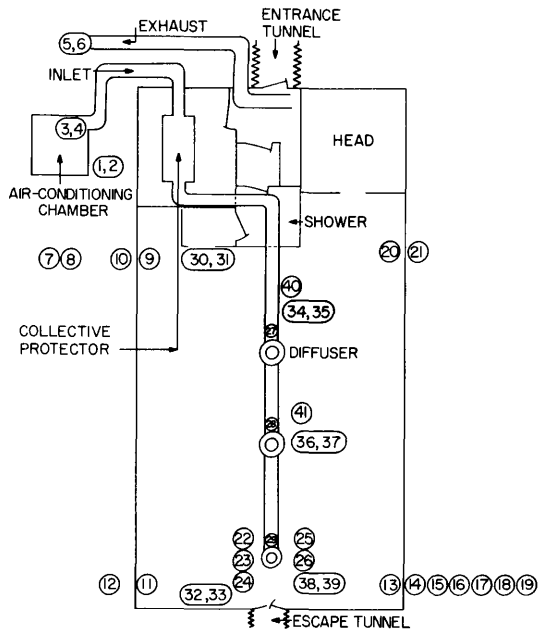
The location, type, and frequency of reading of the temperature-measuring instruments used in the summer trial are shown in Fig. 13. The data are shown in Figs. 14-16 and in Tables 1-5. The term "effective temperature" (ET), used extensively throughout this report, is based upon physiological response. It may be defined as any combination of temperature and humidity which produces the same physiological response as 100% relative humidity at that temperature. Figure 17 shows the relationship between dry-bulb temperature and relative humidity for a series of effective temperatures.

The ventilation rates over the 2-week period are shown in curve A of Fig. 14. The general activity level, i.e., when men were in bunks and when meals were prepared and served, is shown in curve B.

The dry-bulb temperatures at the inlet to the shelter (topside), at the first diffuser, and in the fore part of the shelter are shown by curves C, D, and E, respectively, of Fig. 14, and the averages are shown in Tables 1-3. The ventilating blower for this trial was a 1200-cfm vaneaxial fan from a standard army 1200-cfm collective protector.

During the winter trials a 600-cfm collective protector unit was used to ventilate the shelter. Calculations based on the winter trials indicated that the 1200-cfm unit and air conditioning might be necessary during the summer trial. Since space was not available in the shelter for a complete 1200-cfm collective protector, only the blower was installed for this trial. Essentially all of the heat generated by the motor was added to the supply air. During the period when the shelter was being ventilated at 300 cfm, the peak dry-bulb temperature at the first diffuser exceeded 100°F. Even at the higher ventilation rates the temperature at the first diffuser substantially exceeded the temperature at the inlet (curve D, Fig. 14, and Tables 1 and 2). During the winter trial this situation was desirable; however, it was obviously not desirable during the summer trial.

During the winter trials, when the inlet temperatures were low, the temperature in the rear of the shelter was 5 to 6 degrees lower than the fore part of the shelter. During the summer trial, the temperature in the rear of the shelter was a maximum of 2 degrees lower than in the fore part of the shelter (Table 3). Diurnal temperature variations in the shelter were almost nonexistent (curve E, Fig. 14). The exhaust temperatures taken



Number	Location	Measured Temperature of	Type	Read by	Frequency of Reading
1,2	Inlet to air-conditioning chamber	Inlet air, wet and dry bulb	Battery-powered psychrometer	Monitoring team	Hourly
3,4	Exhaust from air-conditioning chamber	Cooled air, wet and dry bulb	Battery-powered psychrometer	Monitoring team	Hourly
5,6	Exhaust from shelter	Exhaust air from shelter, wet and dry bulb	Battery-powered psychrometer	Monitoring team	Hourly
7	In the ground, three ft from the shelter, level with the deck	Soil	Thermistor probe	Scientist-in-charge	Daily
8	In the ground, ten ft above No. 7	Soil	Thermistor probe	Scientist-in-charge	Daily
9	Bulkhead, 6 in. from deck	Bulkhead	Thermocouple	Engineering team	Hourly
10	Soil, 15.3 cm from No. 9	Soil	Thermocouple	Engineering team	Hourly
11	Bulkhead, 6 in. from deck	Bulkhead	Thermocouple	Engineering team	Hourly
12	Soil, 15.3 cm from No. 11	Soil	Thermocouple	Engineering team	Hourly
13	Bulkhead, 6 in. from deck	Bulkhead	Thermocouple	Recorder	Every 15 min.
14	Soil, 15.3 cm from No. 13	Soil	Thermocouple	Recorder	Every 15 min.
15	Soil, 30.3 cm from No. 13	Soil	Thermocouple	Recorder	Every 15 min.
16	Soil, 45.3 cm from No. 13	Soil	Thermocouple	Recorder	Every 15 min.
17	Soil, 60.3 cm from No. 13	Soil	Thermocouple	Recorder	Every 15 min.
18	Soil, 75.3 cm from No. 13	Soil	Thermocouple	Recorder	Every 15 min.
19	Soil, 90.3 cm from No. 13	Bulkhead	Thermocouple	Recorder	Every 15 min.
20	Bulkhead, 6 in. from deck	Bulkhead	Thermocouple	Engineering team	Hourly
21	Soil, 15.3 cm from No. 20	Soil	Thermocouple	Engineering team	Hourly
22	Deck	Deck	Thermocouple	Engineering team	Hourly
23	33 cm below No. 22	Soil	Thermocouple	Engineering team	Hourly
24	48 cm below No. 22	Soil	Thermocouple	Engineering team	Hourly
25	Overhead	Inside surface	Thermocouple	Engineering team	Hourly
26	15 cm above No. 25	Soil	Thermocouple	Engineering team	Hourly
27	Inlet air, prior to first diffuser	Inlet air, dry bulb	Thermocouple	Engineering team	Hourly
28	Inlet air, prior to second diffuser	Inlet air, dry bulb	Thermocouple	Engineering team	Hourly
29	Inlet air, prior to third diffuser	Inlet air, dry bulb	Thermocouple	Engineering team	Hourly
30,31	Three ft from deck	Air in fore area of shelter (wet and dry bulb)	Battery-powered psychrometer	Engineering team	Hourly
32,33	Three ft from deck	Air in aft area of shelter (wet and dry bulb)	Battery-powered psychrometer	Engineering team	Hourly
34,35	Three ft from deck	Air in fore area of shelter (wet and dry bulb)	Battery-powered psychrometer	Medical team	Every half-hour
36,37	Three ft from deck	Air in midbunk area of shelter (wet and dry bulb)	Battery-powered psychrometer	Medical team	Every half-hour
38,39	Three ft from deck	Air in aft area of shelter (wet and dry bulb)	Battery-powered psychrometer	Medical team	Every half-hour
40	Seven ft from deck	Air	Globe Thermometer	Engineering team and Medical team	Every half-hour
41	Seven ft from deck	Air	Globe Thermometer	Engineering team and Medical team	Every half-hour

Fig. 13 - Location of temperature-measuring instruments

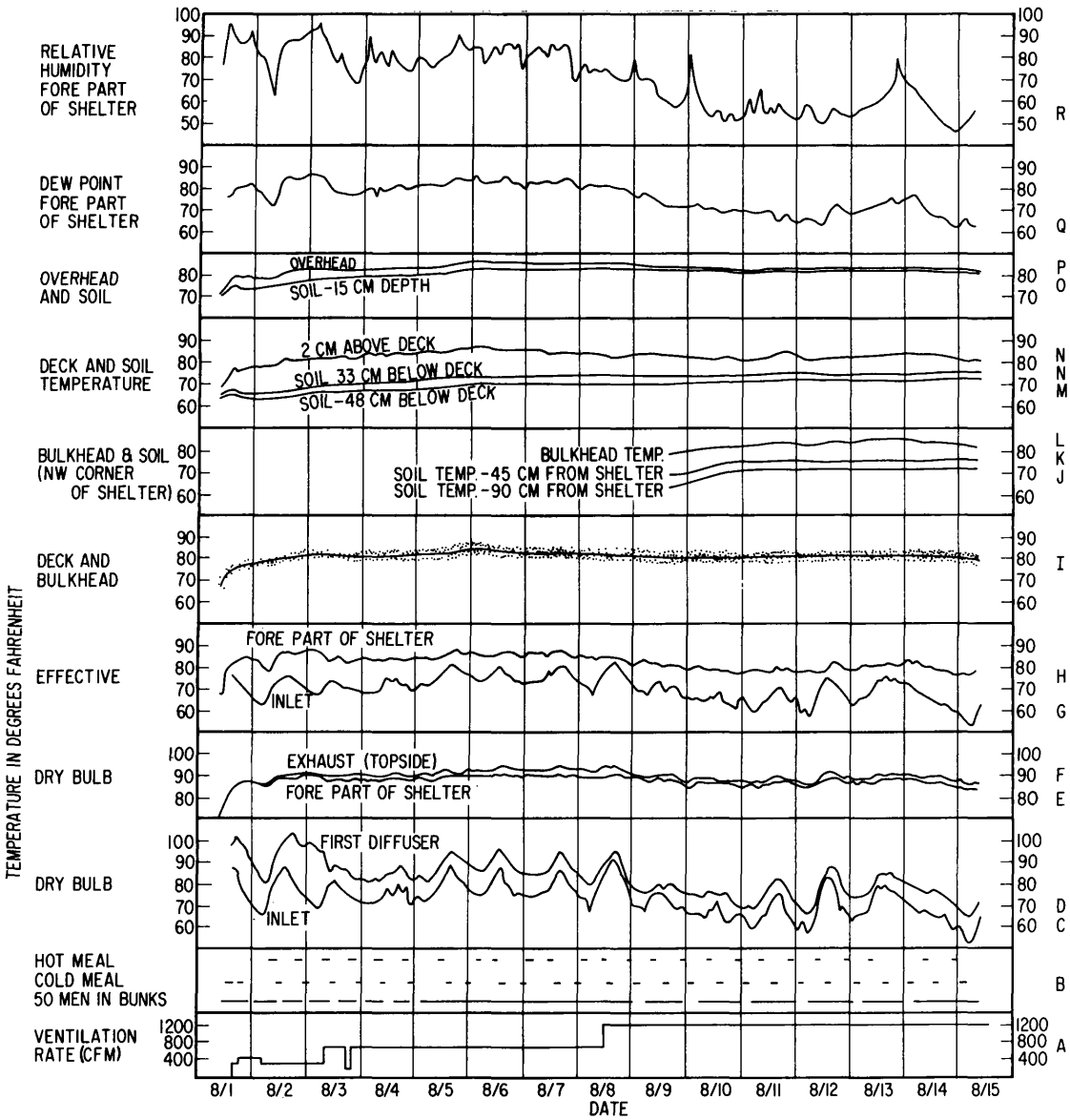


Fig. 14 - Temperature and relative humidity

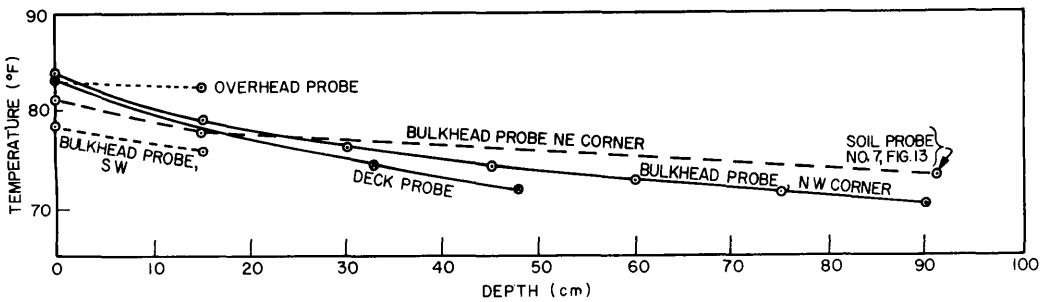


Fig. 15 - Average probe temperatures for Aug. 13, 1962

topside were generally a few degrees higher than the corresponding temperatures in the fore part of the shelter (curves E and F, Fig. 14). The major portion of the experimental equipment was located in the collective protector room. Some of the heat generated by this equipment was carried out by the exhaust air and, thus, did not serve to increase the heat load on the shelterees.

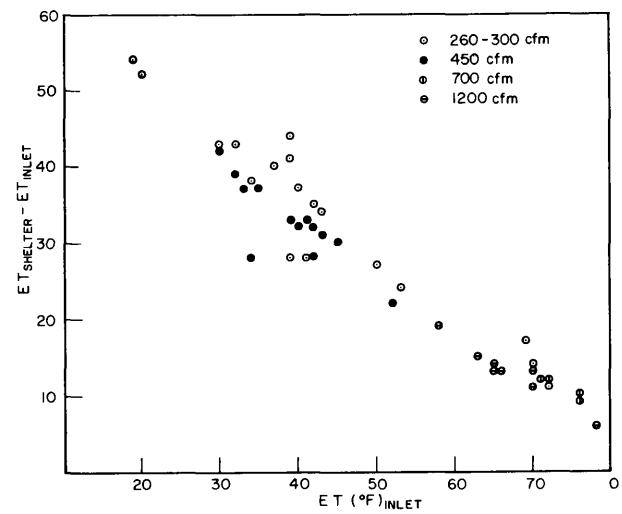


Fig. 16 - Effective-temperature differential as a function of the inlet effective temperature

Table 1
Average Temperatures for the Summer Trial

Day	Time Period*	Ventilation Rate (cfm)	DB			ET		
			Inlet	Diffuser†	Shelter	Inlet	Diffuser†	Shelter
1	1600-2400	300	80	97	86	72	78	83
2		300	77	93	87	70	79	84
3	0100-0800	300	74	96	90	69	81	86
	0900-2400	700	76	86	88	71	76	83
4		700	75	84	88	72	76	84
5		700	79	89	89	76	80	85
6		700	79	90	90	76	81	86
7		700	79	88	90	76	80	86
8	0100-1200	700	75	84	89	72	77	84
	1300-2400	1200	84	90	91	78	80	84
9		1200	73	79	88	70	77	81
10		1200	67	75	87	65	70	79
11		1200	69	76	87	65	70	78
12		1200	71	78	88	66	71	79
13		1200	74	81	88	70	74	81
14	0100-0600	1200	73	80	89	70	75	83
	0700-2400	1200	66	76	87	63	70	78
15	0000-1000	1200	59	68	85	57	64	76

*Unless otherwise specified, the time period is 24 hours.
†Readings taken at the first diffuser. Differences at diffusers 2 and 3 were negligible.

Table 2
Average Temperatures

Ventilation Rate (cfm)	DB			ET		
	Inlet	Diffuser	Shelter	Inlet	Diffuser	Shelter
300	77	95	88	70	79	84
700	77	87	89	74	78	85
1200	71	78	88	67	72	80

Table 3
Average Dry-Bulb Temperatures

Day	Time Period*	Ventilation Rate (cfm)	Fore	Mid	Aft
1	1600-2400	300	86	-	86
2		300	87	-	86
3	0100-0800	300	90	-	90
	0900-2400	700	88	-	87
4		700	88	-	88
5		700	89	-	89
6		700	90	90	90
7		700	90	90	90
8	0100-1200	700	89	90	89
	1300-2400	1200	91	92	91
9		1200	88	88	87
10		1200	87	86	86
11		1200	87	87	86
12		1200	88	87	87
13		1200	88	88	87
14	0100-0600	1200	87	88	88
	0700-2400	1200	87	85	86
15	0000-1000	1200	85	83	83

*Unless otherwise indicated, the time period is twenty-four hours.

Table 4
Comparison of Average Dry-Bulb and Average Globe Temperatures

Day	Time Period*	Ventilation Rate (cfm)	Fore		Midbunk	
			DB	Globe	DB	Globe
1	1600-2400	300	86	86	-	-
2		300	87	87	-	-
3	0100-0800	300	90	89	-	-
	0900-2400	700	88	88	-	-
4		700	88	88	-	-
5		700	89	89	-	-
6		700	90	90	90	91
7		700	90	91	90	91
8	0100-1200	700	89	90	90	90
	1300-2400	1200	91	91	92	92
9		1200	88	88	88	89
10		1200	87	87	86	87
11		1200	87	88	87	88
12		1200	88	88	87	89
13		1200	88	89	88	89
14	0100-0600	1200	89	89	88	89
	0700-2400	1200	87	88	85	88
15	0000-1000	1200	85	86	83	85

*Unless otherwise specified, the time period is 24 hours.

Table 5
Average Effective Temperatures

Day	Time Period*	Ventilation Rate (cfm)	Fore	Midbunk	Aft
1	1600-2400	300	83	-	83
2		300	84	-	81
3	0100-0800	300	87	-	85
	0900-2400	700	83	-	81
4		700	84	-	82
5		700	85	-	84
6		700	86	85	84
7		700	86	85	85
8	0100-1200	700	84	85	83
	1300-2400	1200	84	83	84
9		1200	81	80	80
10		1200	79	78	78
11		1200	78	78	77
12		1200	79	79	78
13		1200	81	80	79
14	0100-0600	1200	82	81	81
	0700-2400	1200	78	77	77
15	0000-1000	1200	76	74	74

*Unless otherwise specified, the time period is 24 hours.

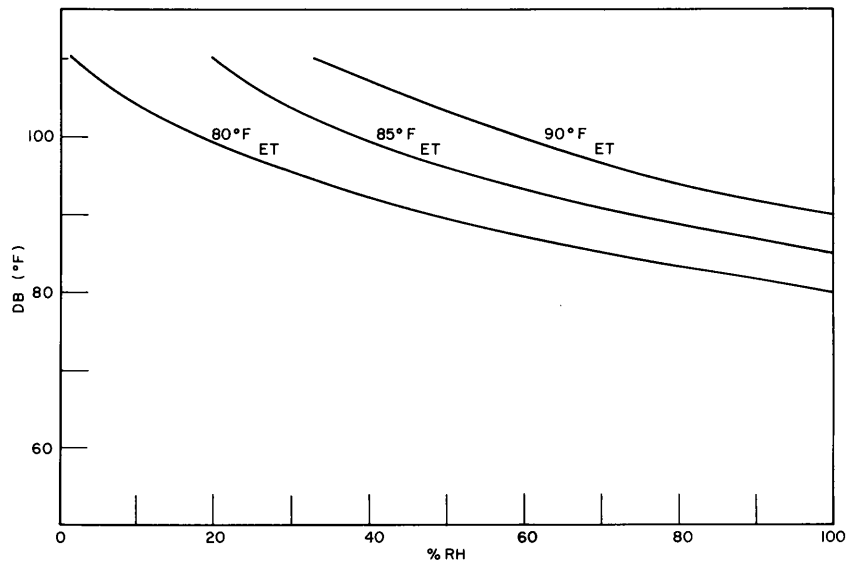


Fig. 17 - Effective temperature nomograph from "Physiology of Heat Regulation" by Newberg

The average globe (to integrate radiant heat) and dry-bulb temperatures are shown in Table 4. Until the air-conditioning units were activated, the globe and dry-bulb temperatures were essentially the same.

The effective temperatures are shown in curves G and H of Fig. 14 and in Tables 1, 2, and 5. As with the dry-bulb temperatures, diurnal variations within the shelter were very small. The most significant point is that the average effective temperature never exceeded 86°F for a 24-hour period; during the first week when medical problems were at their peak, the overall average was 85.

The deck and bulkhead temperatures increased rapidly during the first 2 days of the trial and then leveled off in the range of 75-85°F. The lower temperatures occurred on or near the deck. During the first week the dew point in the shelter was high (curve Q, Fig. 14), and the deck and bulkheads were damp from condensation. However, this dampness was not a serious problem. The condensate did not collect and drop down upon the shelterees; neither did water run down the bulkheads. During the second week the dew point was relatively low and the shelter became quite dry, although some condensation still occurred on the bulkheads close to the deck.

Representative soil-temperature data are shown on curves J through P of Fig. 14 and in Fig. 15. During the last 4-1/2 days of the trial the average soil-temperature gradient for the overhead probe was 0.01°C/cm and 0.12(+ 0.07 - 0.03)°C/cm for the deck and bulkhead probes.

Figure 16 shows the effective-temperature differential between the shelter and the inlet air as a function of the effective temperature of the inlet air for the various ventilation rates. This relationship is plotted as [ET_{inlet} vs ($ET_{shelter}$ - ET_{inlet})] and includes the data from both the winter and the summer trials. The heat generated in a shelter of this type must be dissipated either into the surrounding soil or into the exhaust air. As long as both the soil and the air are cool enough to serve as adequate heat sinks, changes in ventilation rate will serve to shift the heat dissipation from one heat sink to the other. As the temperatures of these natural heat sinks approach the survival level, it becomes increasingly difficult, and ultimately impossible, to remove the heat generated within the shelter by these means. When this point is reached, the only answer is air conditioning.

HEAT BALANCE

The heat input to the shelter is composed of heat produced by the 100 men and heat produced by the electrical equipment in the shelter. The heat is dissipated from the shelter via the ventilating air and the surrounding soil. The heat produced by the men was calculated from the CO_2 data, and the heat produced by the electrical equipment was calculated from watt-hour-meter data. The quantity of heat carried out by the ventilating air was calculated from temperature, humidity, and ventilation-rate data. The average quantity of heat generated during the winter and summer trials is shown in Table 6. During the summer trial a larger ventilating blower and more experimental equipment were used. These items increased the heat output 34 Kcal/min.

Table 6
Average Heat Generated

Type of Heat Generated	Kcal/min	
	Winter	Summer
Electrical		
Normal	37	53
Experimental	22	40
Physiological	142	142
Total	201	235

The quantity of heat carried out of the shelter by the ventilating air is composed of three parts: (a) the quantity of heat absorbed in heating water vapor in the inlet air to the exhaust temperature, (b) the quantity of heat absorbed in heating the ventilating air from the inlet to the exhaust temperature, and (c) the quantity of heat absorbed by the water which was evaporated in the shelter. The data are shown in Fig. 18. During the second week of the trial the temperature and humidity of the inlet air were low (curves C and E, Fig. 18), and the ventilation rate was high. The net result was an increase in the quantity of heat carried out by the ventilating air and a decrease in the quantity dissipated into the soil. For limited periods of time (see curves K and L, Fig. 18) heat was desorbed from the soil and carried out by the ventilating air. This was most evident on August 15, when the air-conditioning equipment was in operation. The data are summarized in Tables 7 and 8.

AIR CONDITIONING

In preparing for the summer trial, it was agreed that steps should be taken to keep the effective temperature in the shelter from going above 85°F. A survey of summer conditions in the Washington area showed that the effective temperature of the atmosphere might go above 85°F. Extensive calculations were made in an effort to predict the effective temperature in the shelter during the summer trial. These calculations took into account past weather conditions, the caloric output and sweat rate of sedentary men, the heat dissipated through the walls from the winter trial, and various ventilation rates. To guarantee a full 2-week trial during the worst Washington weather and not exceed an effective temperature of 85°F in the shelter, it was obvious that standby air conditioning would be required. The calculations indicated that the air-conditioning unit should be designed for maximum moisture removal, but a unit of this type was not immediately available. To provide the standby air conditioning, 8-cu ft chamber was built topside. Six 1-ton home air conditioners were installed so that the ventilating air for the shelter could be cooled as it was drawn through the chamber. The summer of 1962 was the coolest Washington summer in nearly 40 years. During the 2-week trial

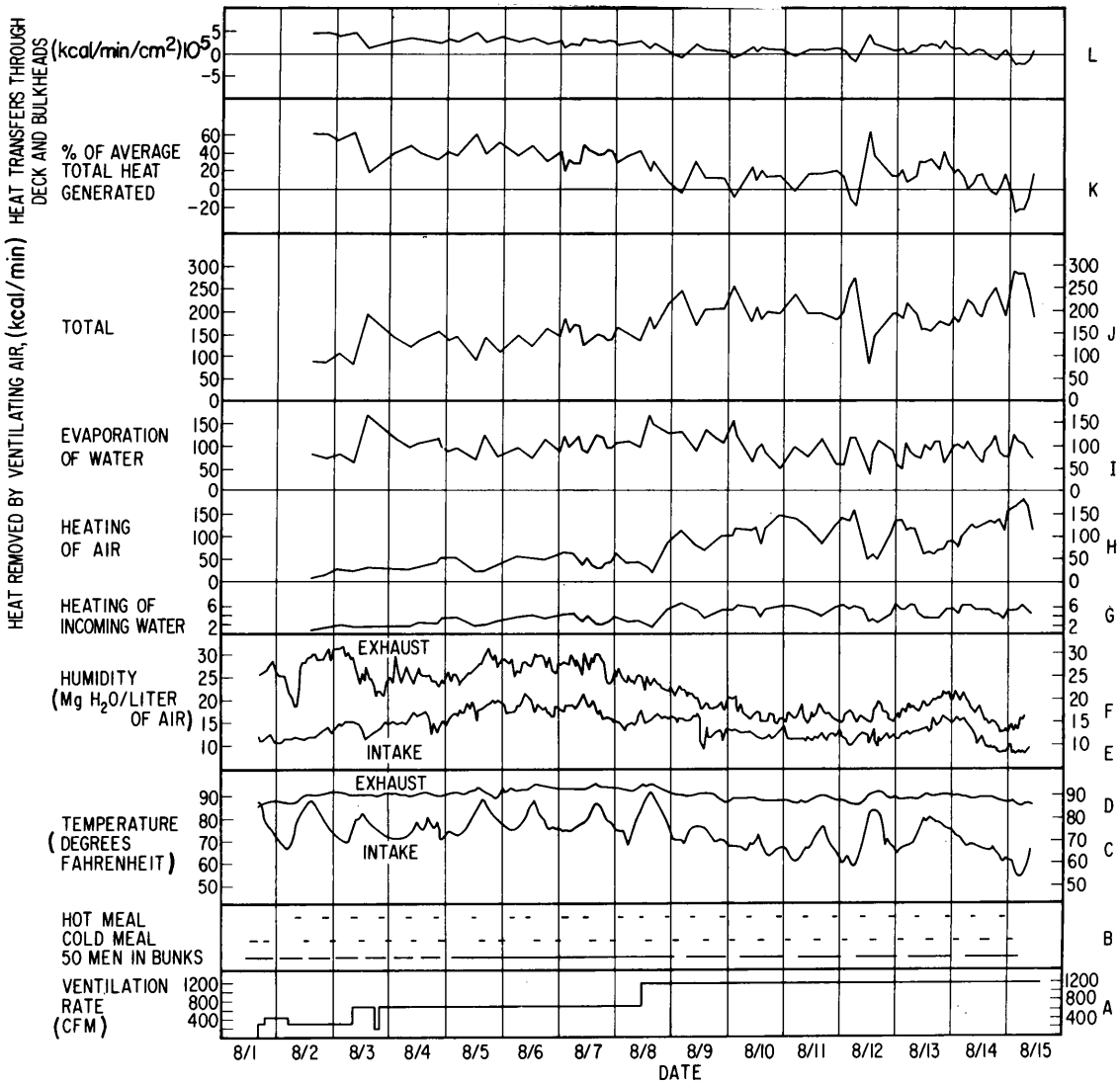


Fig. 18 - Heat balance

Table 7
Average Heat Carried Out by Ventilating Air During Summer Trial

Ventilation Rate (cfm)	Kcal/min			
	Heat Air	Evaporate Water	Heat Water	Total
300	14	76	1	91
700	39	102	2	143
1200	102	93	5	200

Table 8
Average Heat Dissipation

Ventilation Rate (cfm)	Kcal/min		
	Air	Walls	Total
Winter			
260	79	122	201
450	127	74	201
Summer			
300	91	144	235
700	143	92	235
1200	200	35	235

the average effective temperature of the inlet air to the shelter did not exceed 78°F, and the average of the 2 weeks was 70°F. Nevertheless, to evaluate the installation the air conditioners were used during the last 29 hours of the trial. The units were turned on one at a time beginning at 6:00 a.m. on August 14. The data are shown in Fig. 19 and Table 9. The most obvious conclusion is that this was a very inefficient air-conditioning assembly.

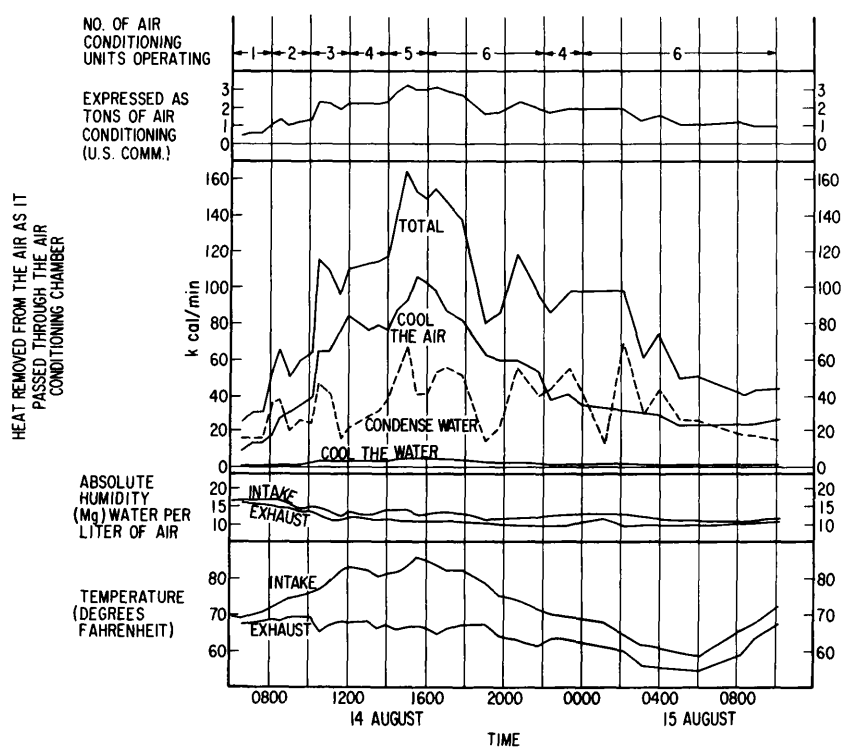


Fig. 19 - Air-conditioning chamber

Table 9
Air-Conditioning Chamber Summary

No. of Units	Temperature (°F)		Absolute Humidity (mg H_2O/liter)		Cooling (Tons of Air Conditioning)
	Inlet	Outlet	Inlet	Outlet	
1	70	68	16.6	15.5	0.7
2	74	69	15.4	14.0	1.2
3	80	67	13.4	11.8	2.1
4	81	67	12.9	11.6	2.2
5	84	66	13.2	10.7	3.0
6	83	66	13.1	10.4	2.9
6	68	62	11.5	9.7	1.7
6	68	63	10.8	9.9	1.0

CARBON DIOXIDE

During the summer trial, as in the winter trial, the CO_2 concentration was monitored with Drager CO_2-detector tubes and with a Beckman Model LB-1 infrared CO_2 analyzer. The data shown in Fig. 20 and Table 10 are essentially the same as comparable data obtained during the winter trials. During the buttoned-up period, which lasted 4 hr and 40 min, the CO_2 level reached a peak of 3.2 vol-%. The data agree very well with the expected levels for men essentially at rest. If the number of occupants and the volume of a shelter, or the ventilation rate when the shelter is being ventilated, are known, the CO_2 level can be calculated as accurately as it can be measured with any simple, inexpensive instrument suitable for consideration as standard shelter equipment. For this calculation it may be assumed that each occupant produces 0.6 cu ft of CO_2 per hr.

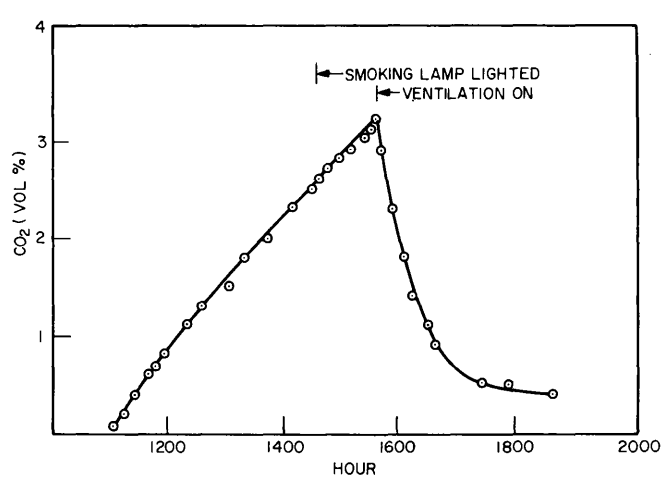


Fig. 20 - Carbon dioxide concentration on Aug. 1, 1962

Table 10
Average Carbon Dioxide Concentration

Ventilation Rate (cfm)	CO_2 (volume-%)
300	0.44
700	0.21
1200	0.13

CARBON MONOXIDE

Two instruments were used for the measurement of carbon monoxide concentrations, the Bacharach detector tube and a Mine Safety Appliances Company infrared analyzer. The data are shown in Fig. 21 and Table 11. The data are very similar to the CO data from the winter trial. During the period between entry and the time the smoking lamp was lighted, carbon monoxide was desorbed from the blood of the smokers and was exhaled into the shelter atmosphere. Composite data from the winter and summer trials showing the quantity of CO exhaled per man per hour during the no-smoking period are shown in Table 12. After smoking began the CO level increased rapidly until the ventilation was turned on. The average cigarette produces 48 cc (STP) of carbon monoxide. From this average volume it was calculated that 130 cigarettes were smoked during the buttoned-up period at the beginning of the summer trial, or about 2 cigarettes per smoker.

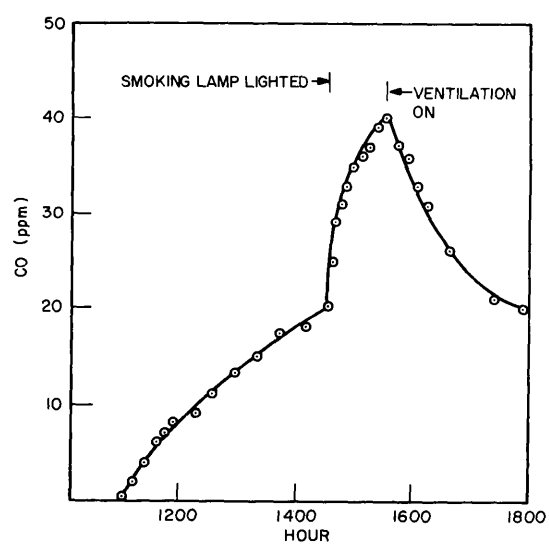


Fig. 21 - Carbon monoxide concentration on Aug. 1, 1962

Table 11
Carbon Monoxide Concentration

Ventilation Rate (cfm)	CO (ppm)
300	10-20
700	5-15
1200	5-10

Table 12
Exhalation of Carbon Monoxide During No-Smoking Period
(cc(STP)/man/hour)

Hour After Entry	2-day Winter Trial	2-week Winter Trial	2-week Summer Trial
1st	19	18	23
2nd	11	12	14
3rd	8	9	14
4th	-	-	9

The maximum acceptable concentration of carbon monoxide is 100 ppm for a 40-hour week. On nuclear submarines the maximum acceptable concentration is 25 ppm. During the periods when the ventilation was off the carbon monoxide did not go above 42 ppm and remained below 25 ppm at other times. Thus, even with unlimited smoking carbon monoxide was not considered a problem. Nevertheless, under actual conditions smoking should not be permitted until the ventilation blower has been started. Under such conditions it is not likely that the carbon monoxide concentration would ever exceed 20 ppm.

The Bacharach tubes were used principally by the shelter engineering team to sample the outside air and the air in the motor-generator room. For this purpose 1/4-inch-O.D. copper tubing was run through the shelter wall to the outside and to the motor-generator room. Thus, the team could determine the CO concentration in these spaces without leaving the protected area of the shelter. In an actual situation, this procedure is considered to be of utmost importance. If there is or has been a fire of any nature topside, it will not be safe to ventilate the shelter until the air outside is proven free of carbon monoxide. Likewise, if the exhaust system of the motor generator is not tight, carbon monoxide may be released into the motor-generator room. The space should be proved free of carbon monoxide before the engineering team exits to check the motor generator. In making this determination, allowance must be made for the air space within the sampling tube.

OXYGEN

The oxygen concentration in the shelter was monitored with a Pauling Oxygen Meter; this meter uses the paramagnetic property of oxygen to measure concentration. During the buttoned-up period the oxygen concentration decreased to about 17 percent. After the ventilation blower was started, the oxygen concentration increased rapidly and remained above 20 percent during the remainder of the trial. In a nonventilated shelter the increase in carbon dioxide may be expected to produce more serious physiological results than will the corresponding decrease in oxygen. Hence, it is considered that the oxygen-concentration measurement is not critical, provided the carbon dioxide content of the shelter is known and that it is possible to ventilate the shelter before the CO_2 level exceeds 4 percent.

ELECTRICITY

Kilowatt-hour meters were installed to monitor the electrical power consumption. During the 2-week trial 142 kw-hr were used for food preparation, 471 kw-hr for lights, and 624 kw-hr for ventilation. This power was supplied by a 10-kw diesel-powered generator. The lights and ventilating system used 3.4 kw during normal operation. The power requirements for starting would be slightly higher. The total power requirements for the two coffee urns and the soup kettle was 4.1 kw. However, the electrical outlets

for the food preparation appliances were equipped with 15-amp circuit-breakers. Therefore, the food preparation was so scheduled that only one of the appliances would be on high-heat at any one time. As a result the peak-power requirement for the shelter was approximately 4.9 kw.

AEROSOL CONCENTRATION

The concentration of dust and smoke in the shelter atmosphere was monitored continuously with a Sinclair-Phoenix light-scattering dust and smoke photometer. In addition, samples were collected on tared filter papers and weighed to determine the average mass concentration of aerosol in micrograms per liter over a specified period.

The light-scattering meter was calibrated to read 100 percent when subjected to a 0.3-micron-diameter dioctylphthalate (DOP) aerosol having a mass concentration of 80 micrograms per liter. Aerosol data during the first 4 hours of trial, as determined by the light-scattering meter, are shown in Fig. 22. During the period before smoking began, a relatively small quantity of dust was in the atmosphere. After smoking was permitted, the aerosol concentration increased very rapidly. After the ventilation was started the concentration decreased rapidly and finally began to fluctuate as a function of degree of activity, ventilation rate, and the number of men smoking.

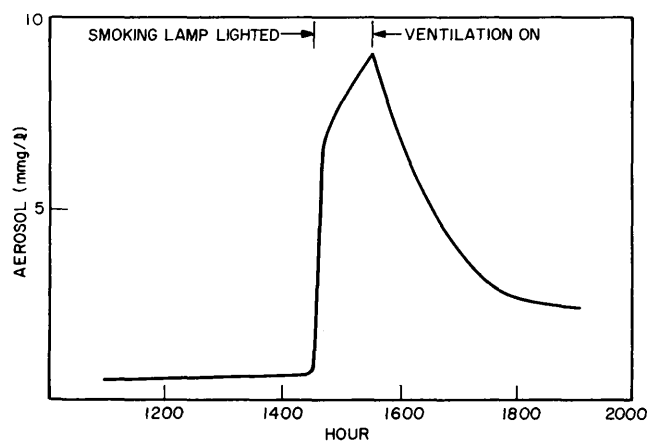


Fig. 22 - Concentration of aerosols on Aug. 1, 1962

The average aerosol-mass-concentration data from both the winter and summer trials are shown in Table 13 and Fig. 23. By comparison, the average mass concentration on board a nuclear submarine is about 0.2 micrograms per liter. While the very high aerosol concentrations encountered in these shelter trials were acceptable for this select group, such high concentrations would be objectionable, and perhaps dangerous, for older persons, young children, and persons suffering from severe respiratory diseases.

SOUND LEVEL

The sound-level readings are shown in Table 14. The ventilation blower was the principal source of noise. This noise was rather high-pitched and made normal conversation difficult. In order for the shelter commander and others in authority to make

Table 13
Concentration of Aerosols During
Summer and Winter Trials

Ventilation Rate (cfm)	Aerosol Concentration (mmg/l)	
	50% in Bunks	All Up
260	1.6	3.6
300	1.3	2.8
450	1.1	2.6
700	1.0	-
1200	0.7	1.4

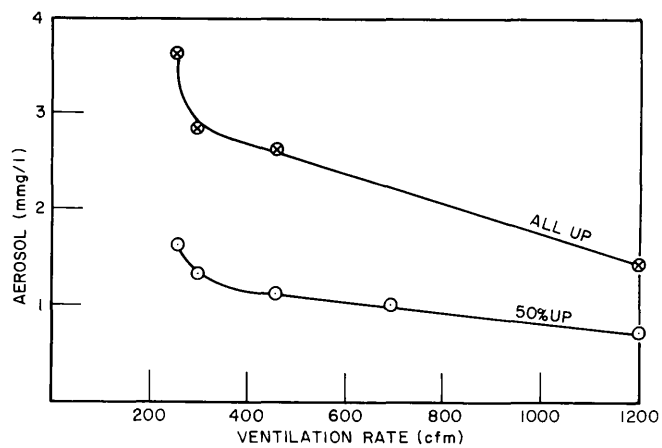


Fig. 23 - Average aerosol mass concentration

Table 14
Sound Level

Activity Level	Sound Level (db)	
	Average	Spread
Ventilation off:		
Prior to entry	48	(one reading)
Everyone up	66	(one reading)
Ventilation on:		
50% up	74	65-82
Everyone up	78	71-85

themselves heard and understood by the entire group it was necessary to install a loudspeaker system. A 60-watt system was used and six speakers were arranged in the shelter; thus, everyone could hear, and at the same time no single speaker was turned up so high that those sitting close to it were made uncomfortable by the loudness of the speaker.

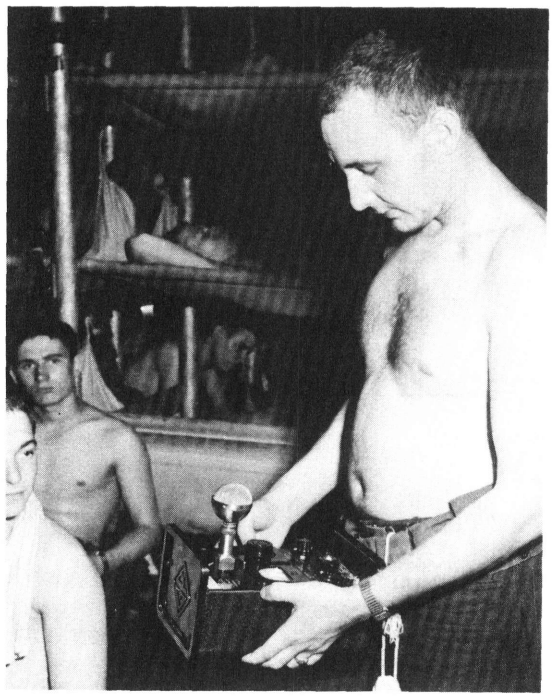


Fig. 24 - Reading the sound level in the shelter

Noise from the ventilation blower would be reduced if the blower were placed upstream of the particulate and gas filters. However, the collective-protector space would be contaminated and would have to be outside of the living space.

WATER CONSUMPTION

The data for water consumption as calculated from water-meter readings are shown in Table 15 and Fig. 25. The slightly lower water consumption shown in Chapter 7 are calculated from a log showing the number of times each man filled his canteen plus the quantity he consumed with soup. The differences between these figures is far less significant than the difference between the water consumption actually found in this trial and the one quart per man per day figure which is frequently described as being adequate.

Table 15
Water Consumption*

Season	Water Consumption (quarts/man/day)		Average Effective Temperature (°F)
	Drinking and with soup	All other	
Winter	1.5	0.3	73
Summer			
1st week	2.9	0.4	85
2nd week	2.4	0.4	80

*Calculated from water-meter readings.

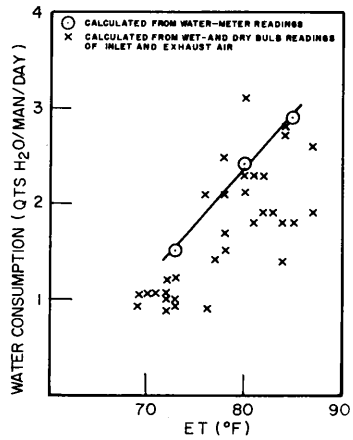


Fig. 25 - Water consumption as a function of effective temperature: summer and winter trials

PHOTOGRAPHY

A 16-mm Auricon Super 1200 camera with a 5.7-mm focal-length lens was mounted above the decontamination tunnel and focused on the area between the bunks and the food-preparation bench. Tri-X film was used so that pictures could be obtained with available light. The camera was operated at 24 frames per second. The camera was remotely controlled from the administration area, and it was possible to obtain good candid shots of shelter life. In addition a rated photographer was equipped with (a) a 16-mm 100-ft magazine-loaded camera equipped with a 13-mm lens, (b) a 4 × 5 speed graphic for black and white stills, and (c) an Eastman Kodak fixed-focus camera with flash attachment for color transparencies.

SUMMARY

The shelter exhaust system was too small to handle the required 1200-cfm ventilation air during the summer trial. Therefore, the shelter blast door remained open, and the shelter was not pressurized. For NBC warfare protection a minimum of 0.3 inch of water positive pressure within the shelter is recommended.

The temperature and ventilation data show clearly that for prolonged occupancy in many areas of the country, ventilation with ambient outside air will not be sufficient to maintain a habitable atmosphere within a shelter of this type. If the average effective temperature remains above 85°F for very long, serious medical problems will be encountered, particularly if the shelter is occupied by people of all ages and all physical conditions. After emergence from the shelter, the medical officer stated that he did not believe the men could have survived a second week of the 85°F average effective temperature existing during the first week.

The vaneaxial fan, used to provide ventilating air for the shelter, added heat to the shelter. During the winter this was desirable but during the summer it was definitely not desirable. It is recommended that the blower system be so designed that the heat from the fan may be used to help heat the shelter or may be exhausted without adding heat to the living space.

A ventilation rate of 2.7 cfm per man (see Winter Report) was found to be sufficient to maintain a habitable atmosphere with respect to oxygen, carbon dioxide, and carbon monoxide even when unlimited smoking was permitted. Nevertheless, it was recommended that smoking be limited to an area where the smoke will be carried out without contaminating the entire living space. For an unventilated shelter smoking should not

be permitted. Under these conditions where ventilation will be available within a few hours CO_2 and O_2 monitoring is not considered necessary. The CO_2 concentration can be calculated readily by assuming a CO_2 production rate of 0.6 cubic feet per man per hour. As long as the CO_2 concentration remains below 4 percent, the oxygen level can be assumed to be adequate. If the shelter cannot be ventilated by the time the CO_2 concentration reaches 4 percent, CO_2 removal and oxygen replenishment will become necessary. Under those conditions a match may be used to monitor the oxygen level; as long as the match will burn the O_2 level will be sufficient. It will be helpful to have available CO_2 detector tubes covering the range of 1 to 5 percent.

The peak electrical power requirement for the shelter was approximately 4.9 kw. A total of 1237 kw-hr were used during the 2-week period. This total did not include the power required to operate the air conditioning used during the last 29 hours of the trial.

The aerosol concentration, while high, was acceptable for this select group of shelterees. It might not be acceptable for a nonselect group. Much of the aerosol in the air resulted from unlimited smoking.

The sound level was very high, reaching 85 db at times. For people under stress this is a dangerously high level. The ventilation blower was the principal source of noise. It is recommended that this source of noise be insulated from the living space.

The water-consumption figures indicate that for hot-weather occupancy, a minimum of 2 and preferably 3 quarts of water per man per day should be stocked for drinking (or ingestion with food). A minimum of 1 pint per man per day should, if possible, be stocked for hygienic purposes. If the shelter is to serve as an active control center, men may be required to don protective clothing and leave the shelter for brief periods while the area outside is still contaminated. Water will have to be stocked to enable these men to take an adequate decontamination shower. A minimum of 4 gal per man per shower is recommended for this purpose. Since the men will not get an adequate decontamination shower from cold water, a temperature of 100-105°F is recommended. Therefore, a means of heating the shower water to this temperature should be provided.

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CHAPTER 4

SELECTION OF SUBJECTS

J.E. Rasmussen
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INTRODUCTION

The selection of subjects for the summer trial duplicated the procedures previously used and was carried out with three broad criteria in mind. First, every effort was made to insure that each subject participating in the study actually would complete the test. Secondly, inasmuch as certain psychological studies were conducted as an integral part of the engineering habitability experiment, it was considered necessary that the men serving as subjects present no evidence of medical defect or disease. Third, to reduce management problems to a minimum, relatively stringent psychiatric standards were established. Because of the anticipated heat stress, much more stringent selection standards were established for the summer trial than for the winter test.

After obtaining appropriate Bureau and Command clearances, volunteers were requested from among recruits graduating at the Naval Training Center, Great Lakes, Illinois. Approximately half of the recruits solicited actually volunteered for the study. The training center personnel officer arbitrarily selected a pool of 150 men for physical and psychiatric examinations. It should be noted that this group of 150 men was a definitely biased sample of the recruit population. As a result of certain administrative restrictions imposed upon the selection of subjects for the trial, all of the volunteers were selected from men scheduled for general sea duty rather than attendance at service school. The precise influence of this sampling artifact was not explored. However, it is reasonable to assume that, for the most part, the better educated, more intelligent, and culturally privileged recruits were excluded from the sample of men available for selection.

The actual examination procedure was supervised by two Medical Department officers from the Naval Medical Research Institute.* Just prior to examination, the pool of 150 volunteers was briefed in detail as to the purpose of the study and the general nature of the conditions under which they would live. An effort was made during the indoctrination lecture to point out clearly the negative aspects of the study as a means of crystallizing weak or nonspecific motivation. Great emphasis was placed on the fact that no assurance whatsoever could be given as to the duration of the test, and the volunteers were urged to drop out unless they were willing to enter into the trial without knowledge as to the time they would be confined. In addition, the subjects were offered no incentive or reward for participating in the study. Some indication was given regarding the fact that heat stress might be encountered. Approximately one-third of the initial recruits devolunteered following the indoctrination lecture. This decrease in recruits necessitated obtaining another sample of 100 recruits to provide enough men for the selection procedure.

PSYCHIATRIC ASSESSMENT

The neuropsychiatric assessment was conducted at the Recruit Evaluation Unit of the Administrative Command Medical Department. In addition to the psychologists from

*Captain D. Minard, MC, USN and Captain J.E. Rasmussen, MSC, USN.

NMRI, the entire staff of the NP Unit, three psychiatrists, and two clinical psychologists participated in the actual examination procedures. Records providing a complete documentation of any contact a recruit may have had with the psychiatric unit were reviewed, along with a current Company Commander's report on the candidate's performance in training immediately prior to the examination.

Each man was interviewed for approximately 30 minutes. The psychologist or psychiatrist conducting the interview had the above material before he saw each of the subjects. Inasmuch as the recruits had completed approximately 7 weeks of training time, a considerable amount of information was available on their adjustment to service. In addition, the information on preservice adjustment, routinely obtained on all recruits, also was available to the examiner. It was possible, therefore, to conduct a relatively intense evaluation during the somewhat limited time available.

Each examiner was requested to use the interview technique with which he felt most comfortable. The factors receiving particular attention during the psychiatric assessment are listed below. Items were included in this list because of their demonstrated effectiveness in selecting personnel for the winter trials.

Ego Strength and Adequacy of Defense Mechanisms

The emphasis in this area was directed toward detection of possible incipient psychosis and evaluating the adequacy of defense mechanisms to prevent personality disintegration under stress. Providing the defense mechanisms were considered effective, no specific effort was made to rule out neurotic symptomatology. Even minimal evidence of defect in this assessment factor was considered justification for an unequivocal disqualification.

Psychosexual Conflict

A volunteer possessing any evidence of disturbance in the psychosexual area, either overt or latent, was clearly disqualified.

Stability of Interpersonal Relationships

Individuals presenting a history of schizoid adjustment or discomfort in close interpersonal relationships were disqualified. Particular emphasis was placed on the stability and duration of interpersonal relationships rather than the number of relationships per se.

Attitude Toward Authority

Men presenting a history of parental conflict and/or conflict with teachers or authority figures of the naval service were disqualified.

Antisocial and Acting-Out Behavior

Heavy emphasis was placed on the elimination of any volunteers who exhibited a propensity for acting-out or antisocial behavior in the nature of fighting, conflict with police, hot-rodding, excessive drinking, etc.

Motivation and Attitude

Effort was made to assess maturity indirectly by a qualitative evaluation of motivation and the degree to which the individual realistically perceived the situation for which he volunteered.

Family Status

All men were questioned as to possible family problems, such as a wife with a complicated pregnancy, financial problems, or parents with serious medical or economic difficulties. Evidence of any such difficulty was considered adequate justification for disqualification.

GENERAL MEDICAL ASSESSMENT

Subsequent to his acceptance by the psychiatric evaluation unit, each volunteer was examined by medical and dental officers at the Naval Training Center. The subjects' health records were reviewed by the NMRI Medical Officer supervising the examinations to evaluate the significance of any illnesses which may have occurred during recruit training. The following laboratory tests completed the examination procedure: blood studies, including hemacrit, white-cell count, and differential; urinalysis, including routine tests for pH, specific gravity, albumin, sugar, and microscopic examination of the sediment; finally, chest x ray on 70-mm film by photofluoroscopy.

RESULTS OF ASSESSMENT PROCEDURES

Slightly over 50 percent of the men undergoing neuropsychiatric and physical examinations were disqualified. The overwhelming majority of the disqualifications were for psychiatric reasons. An additional ten recruits were examined and placed in the standby pool so that provision could be made for replacing any subject who might have to be dropped from the study after graduation from recruit training and before beginning the shelter test in Bethesda.

As might be expected, the rejection rate on the basis of clinical and laboratory examinations was low in view of the fact that these men had undergone identical examinations a few months previously in qualifying for recruit training. Several men were disqualified on the basis of skin conditions or a history of extreme sensitivity to heat.

The subjects were examined daily following their arrival in Washington and just before their entry to the shelter in Bethesda. While these examinations were conducted primarily to establish baselines for the physiological studies carried out in the shelter, an opportunity also was provided to detect early signs of illness.

The mean age of the 91 recruits serving as subjects in the summer trial was 19.2 years with a standard deviation of 1.5 years. A number of Negroes were included in the group, but no racial breakdown was obtained. All religious faiths also were represented, but no tabulation was made of religion.

The selection procedure used in the summer trials was considered quite satisfactory. While the rejection rate for the volunteer population was quite high, the staff participating in both studies generally were of the opinion that the quality of subjects was higher in the summer than in the winter trial.

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CHAPTER 5

ORGANIZATION AND MANAGEMENT

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INTRODUCTION

The organization and management of this trial was patterned very closely after that used during the 2-week winter trial. The theoretical and pragmatic considerations which led to the development of the specific organization and management procedures used in this study are set forth in considerable detail in the report of the winter trial (1). However, several of these considerations are sufficiently basic to the present study as to merit repetition.

Inasmuch as the present investigation was undertaken to study the prototype shelter in terms of engineering habitability, no attempt was made to study behavioral problems which would require systematic manipulation of management and scheduling variables. To accomplish the research goals and at the same time keep management problems at a minimum, it was not considered feasible to attempt an exact simulation of fallout shelter conditions. As before, three major artifacts were introduced into this study which make it inappropriate to generalize conclusions related to problems of management or schedule effectiveness to specific civilian or military civil defense situations. In this connection the subjects in this trial were carefully selected and did not constitute a true random sample of the American population, either military or civilian. Secondly, there was daily telephone communication from the monitoring center in connection with administrative problems related to the collection of medical research data. Thirdly, the shelter-management schedules were constructed so as to facilitate the collection of medical research data. This requirement introduced a significant amount of activity which would not be found under actual fallout shelter conditions.

In spite of the biases built into the management aspects of the trials to enhance the engineering studies, other factors were introduced to add realism and stress to the shelter experience. As in the winter trial, the subjects were given no advanced information as to the length of the trial beyond the fact that they would not be in the Washington area in excess of 30 days. The manner in which the subjects computed the duration of their confinement will be described subsequently. A further note of realism was added in that no incentive or reward of any type was offered as an inducement for the subjects either to volunteer or to actually complete the trials.

While the specific shelter schedules and management procedures used in this trial were a direct outgrowth of the 2-week winter trial, they are basically patterned on procedures developed in the American Institute for Research studies (2) and those conducted by the Naval Radiological Defense Laboratory (3).

GENERAL MANAGEMENT CONSIDERATIONS

Leadership Approach

The shelter program was structured around a combination of authoritarian and democratic leadership techniques. It was planned that a direct authoritarian leadership approach would be used on all matters pertaining to health and safety; however, it was intended that problems arising outside of this category be solved by the subjects themselves through democratic processes, with the leader executing group decisions. The organization of the subjects and the command hierarchy was structured in such a way as to encourage positive decisions, as well as the resolution of conflict pertaining to everyday routine, at a level in the hierarchy below that of the shelter commander. Whenever possible, it was desired to remove the shelter commander from direct involvement in settling routine disciplinary infractions or interpersonal conflicts.

It would appear that a combination of factors led to a lack of spontaneity on the part of the participants as far as their making suggestions which would lead to any significant change in routine over that which was originally set up and scheduled. In actuality, the leadership approach during the summer trial tended to be somewhat more authoritarian than originally intended. The subjects recently had completed recruit training where they were subjected to a tight disciplinary control and appeared to expect such control. Further, the pretest program was structured in such a way that the subjects were required to closely observe a number of rules and regulations. With this background the initial organization and routine phases of the schedule, on the surface, apparently were perceived as hard to change in an advantageous way because of the requirements for collection of research data.

On the basis of recommendations derived from the winter trial, a Navy chief petty officer and a first class petty officer were assigned as section leaders. Both of these men had training in the disaster recovery field and the chief petty officer was an experienced instructor. The section leaders were quite successful in carrying out their assigned roles.

The division leaders who were responsible to the section leaders were selected by vote of the men in each of their divisions. Although they had been elected as temporary division leaders, subject to change later, they all proved to be capable in the execution of their responsibilities, and substitutions were not necessary.

It was planned that division leaders would meet regularly with their section leaders, preferably on a daily basis. This plan was for the purpose of maintaining a leadership responsive to the feelings of the participants as well as one which could effectively administer a large group under adverse conditions. These meetings were effective in establishing formal daily contact between all the leaders. However, they became less necessary after establishment of the routine and thus were scheduled on "as required" basis during the second week.

As during the winter trial, complaints and suggestions were encouraged but were to be routed through the chain of command.

Discipline

As before, a conscious effort was made to maintain discipline and social conformity through group pressure. Figure 26 through 28 show the vehicles which were used for instituting group pressure: the "Eightball Club" and the "Kangaroo Court." Individuals guilty of minor infractions of shelter regulations were awarded a large "eightball" emblem which they were required to wear

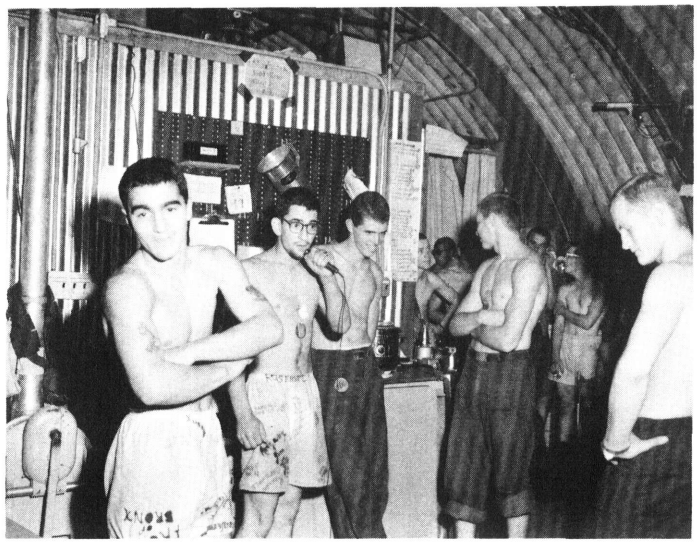


Fig. 26 - Kangaroo court

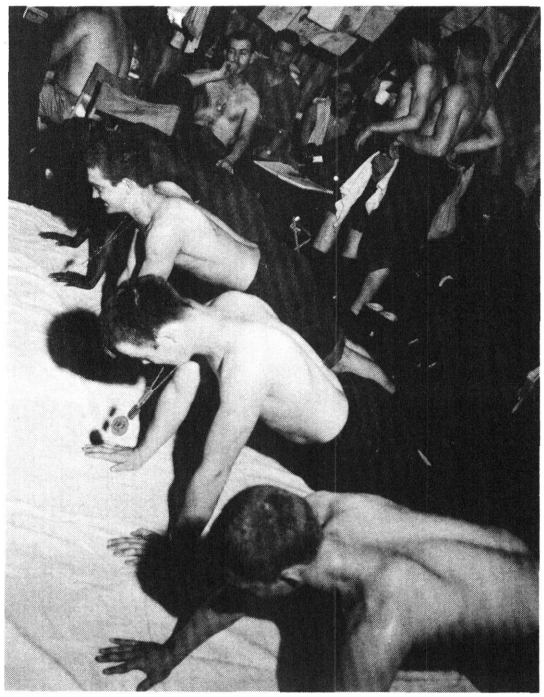


Fig. 27 - Members of "Eightball Club" doing pushups

around their neck until the daily meeting of the Eightball Club. At that time the individual was able to relinquish his "eightball" emblem by doing a prescribed number of pushups in front of the assembled shelter population. Men receiving three or more "eightballs" also appeared before a mock court where additional punishments were decreed, such as acting out ridiculous pantomine sketches. Although provision was made for more serious offenses to be handled directly by the shelter commander through a variety of punishments ranging from special clean-up details to expulsion from the shelter, actually only one offense occurred which might even be considered to border on the category of serious. This offense was a fist fight which broke out on the tenth day of the test and was quickly terminated. The test was far along towards completion at the time of the fist

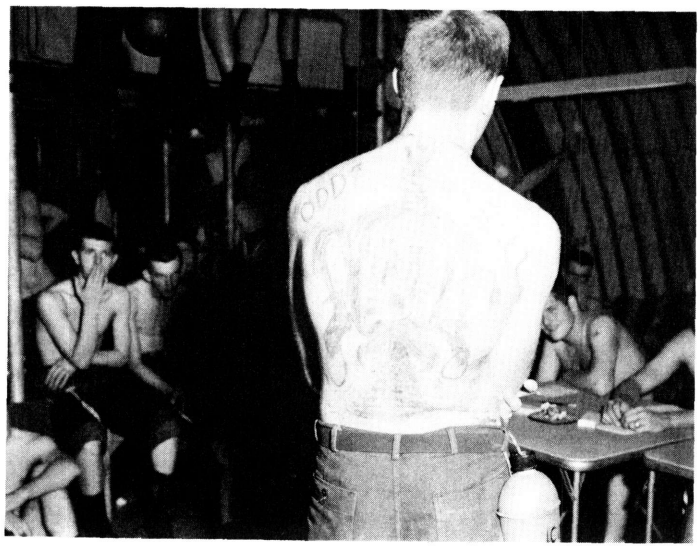


Fig. 28 - "Kangaroo Court" discipline

fight so that group cohesiveness and desire to complete the trial had grown very strong. As a result, the shelter commander's promise of expulsion upon a recurrence proved to be an effective corrective measure.

Morale

Morale was considered satisfactory throughout the period of this trial. However, some fluctuations were apparent. It was noticeable that spirits lagged during the latter part of the first week when the heat and humidity conditions were oppressive. In fact, a general lethargy settled on the population at that time, and there was a prevailing attitude on the part of most occupants that it was too hot for activity of any sort, including reading or even talking to one's neighbor.

The men entered the shelter without knowing the duration of their stay. The duration was determined by the engineering monitoring team measuring a radioactive source in the generator room once a day (Figs. 29-30). Every day these men would place their radiac instrument on a predetermined spot. The source was then placed at a greater and greater distance from this spot each day so as to simulate the natural decay of an actual fallout field.

Several of the first week's readings were inconsistent, however. This inconsistency meant that it was not until the eighth day that a prediction of stay time could be made with any degree of assurance. The preliminary readings seemed to indicate an 8-to-11-day stay time. Needless to say, when later readings indicated a 14-day trial, spirits sagged. In fact, some individuals had become so firmly convinced that the trial would last only 10 days that they would not believe the later readings which consistently indicated a 14-day stay time.

However, morale was also helped on day 8 when the ventilation rate was increased and at the same time, the outside temperatures dropped making the temperature and humidity conditions inside the shelter much more comfortable.

Group entertainment which was conducted on days 8, 10, and 13 also had an uplifting effect on morale as it served to break the monotony of the routine schedule (Figs. 31 and 32). This entertainment included such things as individual and group singing, pantomine skits, telling of jokes, a limbo contest, and twist dancing (Fig. 33).

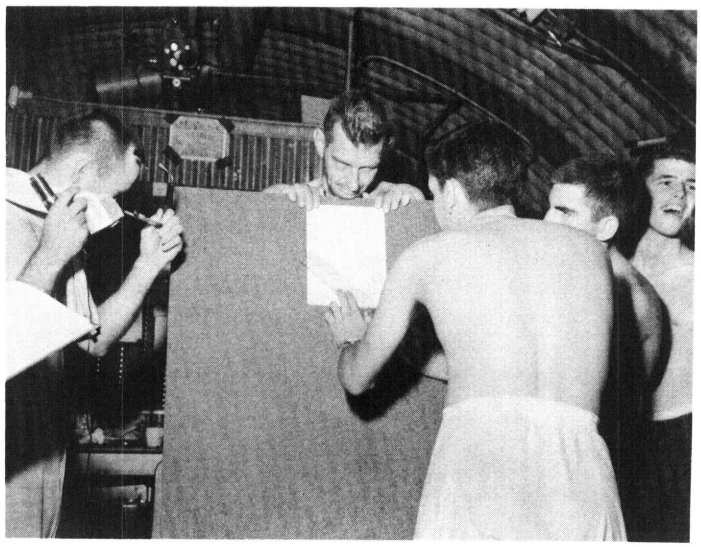


Fig. 29 - Drawing up radioactivity decay chart to determine when it will be safe to leave the shelter

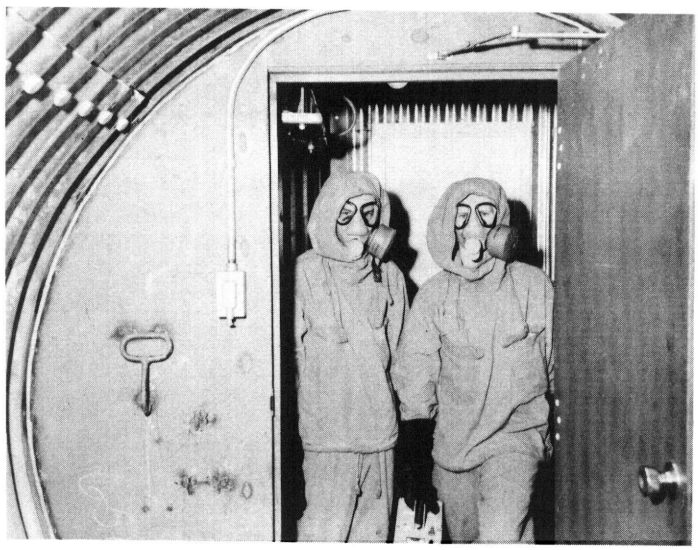


Fig. 30 - Men in protective clothing and masks going out to determine the radioactivity level topside

Fig. 31 - Different forms of shelter recreation

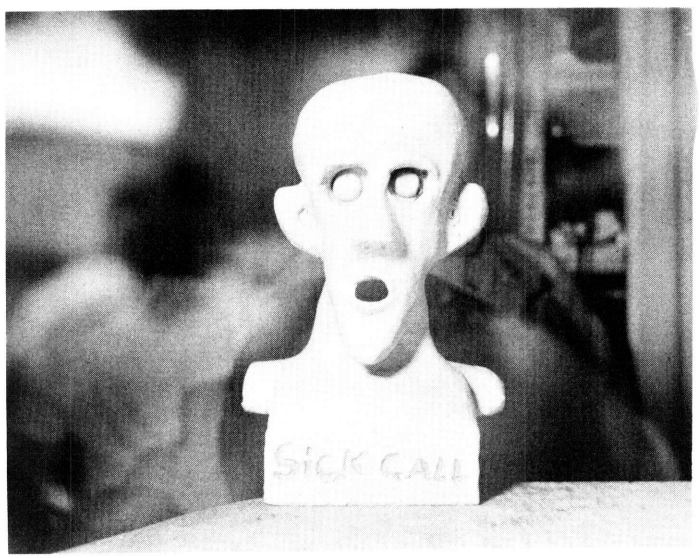
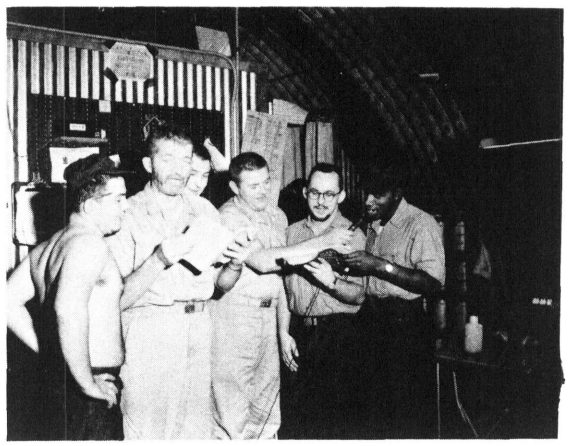
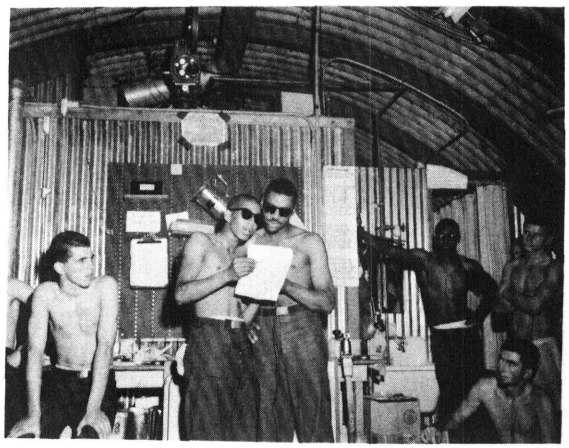


Fig. 32 - Clay model presented to Captain Minard by a shelteree





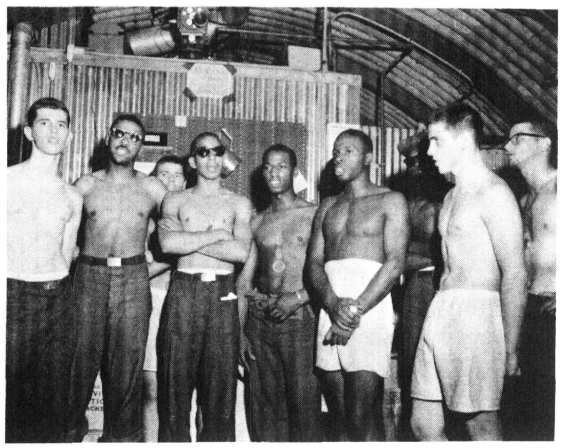


Fig. 33 - Group entertainment

Other Management Aspects

In this trial, as in the winter trial, no set system of job rotation was established. It was felt that allowing participants to select their own section and division largely eliminated the need for variation in shelter duties. This assumption proved correct.

Although it was originally planned to try several methods of rotating individual bunk assignments during this trial, this plan was not carried out as it interfered unduly with other testing aspects. An official vote taken on day 12 showed only 2 favoring changing bunk assignments and 88 against, of the 90 men voting. A man's bunk, it turns out, was really about the only space within the shelter which an individual could call his "own" and this ownership was only for a limited period of time. That this personalized space was jealously guarded was evident when analyzing the source of verbalized complaints, e.g., bumping against the occupied bunk and throwing paper and trash into the bunk. In most cases these could be traced back to a violation of the bunk or this personalized space.

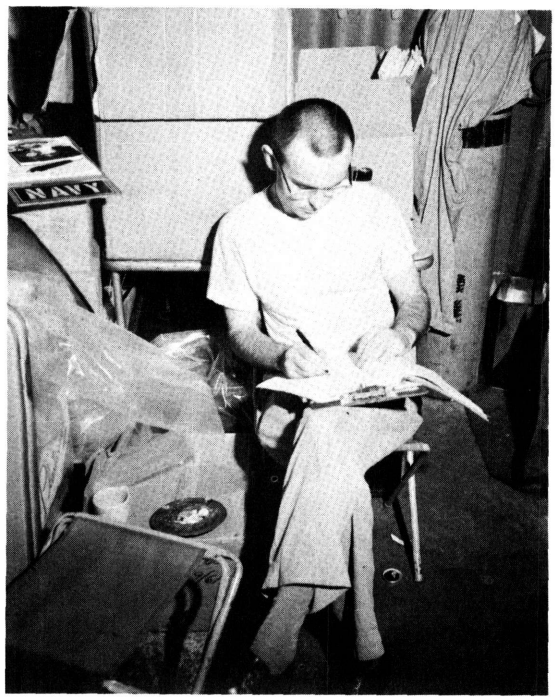


Fig. 34 - Shelter commander preparing daily report

The same records were kept during this trial as during the winter trial, which were: (a) official shelter activity log, (b) division logs recording activities and expenditure of supplies, (c) shelter commander log recording significant problems and incidents, (d) appropriate medical and engineering data records, and (e) personal diaries.

No simultated Civil Defense radio message was used in this trial. As recommended after the winter trial, the telephone was moved into the administration area, affording a greater degree of privacy (Fig. 34). The amount of telephone traffic was reduced in the summer trial by scheduling only one call per day, with the provision that additional calls could be made on an emergency basis. Thus, only a few additional calls were warranted and made.

Greater reliance was placed on the shelter inhabitants during this trial to meet emergencies in the daily routine. Therefore, when the generator stopped, due to an air leak in the fuel-feed system, it was repaired by a shelter engineering team within 1 hour. No assistance was received from the "outside" supporting staff. It is to be noted that the defect was minor and involved no replacement of parts. The trial was in jeopardy due to a mechanical failure on only this occasion.

Discussion and Conclusions

Management problems as such were few and minor as intended. As a result of the winter trial, several recommendations were made to correct management problems which occurred during the earlier trial. One of these recommendations involved the installation of shelves along either side of the shelter in the bunk area in order to eliminate congestion due to the lack of naturally occurring aisleways. The results of this trial indicate this suggestion was good, since it effectively eliminated the problem of congestion in these areas and provided much needed table area for eating and other purposes. The suggestion for painted aisleways also contributed toward a more efficient use of this space.

The problem experienced in the winter trial regarding difficulty of the men hearing announcements was corrected by the use of a 60-watt public-address system which had eight speakers located throughout the shelter.

Due to the many unrealistic conditions imposed during these trials, e.g. the use of a carefully screened volunteer, young, healthy, all-male military population, and the fact that one could not simulate actual blast and fallout conditions, means that it is considered inappropriate to generalize conclusions related to problems of management effectiveness to the general Civil Defense situation.

With the above qualification it would appear that:

(1) An authoritarian approach to management, with some channels for democratic changes in those areas not associated with health and safety, has given satisfactory results with this type of population.

(2) Although the procedures used in relation to discipline produced the results desired here, it is not recommended as a model to be emulated by management during actual attack situations.

(3) Although morale was good throughout all trials, many realistic elements were lacking which would tend to be upsetting. These elements could lead to serious management problems, including panic, hysteria, and other severe psychological reactions, which might be expected under actual attack conditions.

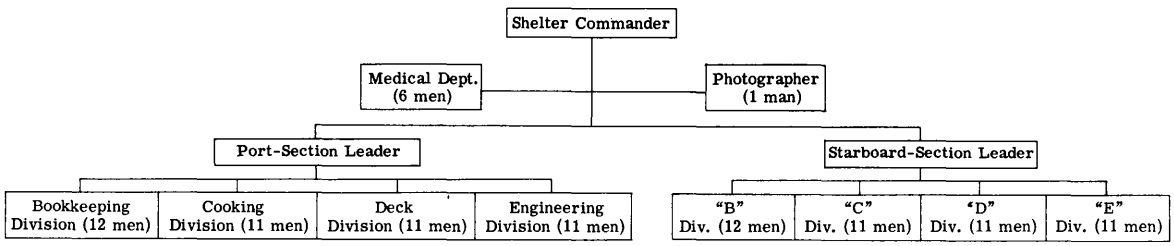
(4) The addition of shelves at a very small cost served to effectively eliminate a strong and persisting complaint, arising from the winter trial, on movement along the bunk area.

(5) The PA System was effective in overcoming high-background-ventilating noise and producing effective communication with the group.

ORGANIZATION

Section and Divisions

The organization planned for this trial was the same as that used during the 2-week winter trial; that is, 90 of the occupants were divided into two sections, "port" and "starboard," with 45 men in each section. Each section was further subdivided into 4 divisions of 11 or 12 men each with certain responsibilities or jobs to perform. The remaining ten men made up the Administration Division. The organization in a line diagram form is presented below:



The specific responsibilities for each division were as follows:

Bookkeeping Division – It was the responsibility of the "B" Division to maintain continuous official records and water-monitor watches, to keep a running log of shelter activities, and to insure receipt and storage of appropriate division reports.

Cooking Division – It was the responsibility of the "C" Division to keep records on food inventory and meals served, to prepare and serve all meals, and to clean up the food preparation area at the termination of each meal. In addition, it established a "recreation-and-supply" watch, whose duty it was to see that individuals sign for and were responsible for the return of recreation gear and other items checked out of the stock area.

Deck Division – The "D" Division was responsible for moving bunks into the ready-to-use or stowed positions when required and conducting a thorough shelter sweep down twice a day, as illustrated in Fig. 35.

Engineering Division – It was the responsibility of the "E" Division to operate and maintain the shelter equipment, primarily the diesel generator and ventilating equipment, to service the heads and estimate the amount of sewage being generated, to service and monitor shelter instruments, and once a day to monitor a radioactive source placed in the generator room by the NNMC Staff to simulate the decay of an actual fallout field.

Each division elected one man to represent the division on a recreation committee whose job was to initiate and plan recreation activities with the supplies available. This reinstallation of a recreation committee helped fill the void noted during the winter trial. They were in the forefront of suggesting and planning the group entertainment and game competition.

The recreation equipment supplied for 2-week summer trial was the same as in the winter trial, with the addition of 50 one-pound blocks of modeling clay and six books obtained from the Public Library on riddles, puzzles, and games. On day 12 and day 13 a competition was staged between divisions and sections in each of the stocked recreational events. This competition generated considerable interest among the participants and the other spectators.

The shelter commander, medical staff, photographer, and section leaders were grouped for identification purposes into a fifth division, the "A" or Administrative Division. These ten men also were split into groups of five so that half of the Administration Division was on duty while each section was sleeping.

After the initial breakdown of men into sections and divisions, there apparently was little desire by this group to exchange jobs outside their own divisions. Only 3 out of 90 men voted on day 12 that they would have liked to have exchanged divisions in order to do a different job during this trial. This satisfaction may have been partly due to the fact that the men were assigned to the division of their choice to begin with and the security associated with knowing a specific job well.

Shelter Instructions

Instructions regarding the operation of equipment and a general outline of division responsibilities were printed on sheets and stocked in the shelter. Such instructions are considered to constitute an integral part of shelter equipment. The instructions actually used during these trials were not too detailed, thus, requiring some briefing of occupants by administrative personnel. For emergency situations, however, instructions would be required to be in such detail so that occupants could operate the shelter and its equipment properly without depending on knowledgeable personnel being able to reach the shelter in time.

(a) Field day

(b) Accumulated trash

Fig. 35 - A thorough shelter sweep down

Discussion and Conclusions

The organization used here was undoubtedly only one of many variations which could have produced the desired results. This organization was effective, but since no manipulation was carried out, no conclusions can be reached regarding the relative effectiveness of other possible schemes.

However, the slight change made between the 2-day winter and 2-week winter trials making the organization somewhat simpler appears to have improved the management of the test.

SCHEDULE

Schedules Used

An attempt was made during this trial to evaluate several different shelter schedules. On the basis of recommendations evolved from the winter trial, several schedules were outlined in which the bunk time was increased with a resulting decrease in the activity level. The schedules tested during the summer are contained in Appendix A. The "8-4-8-4" schedule used the first 4 days was the same as that used in the winter trial and provided a base line for comparison with that trial. This schedule was followed by 4 days on the "8-8-4-4" schedule and 7 days on the "9-9-6" schedule.

The designation "8-4-8-4" indicates that 50 men occupy the bunks for 8 hours, all 100 men are up for the 4-hour "common" period, and the other 50 men are in the bunks for the next 8 hours. This phase is again followed by the 4-hour "common" period, with all 100 men up, which completes a 24-hour cycle.

The "8-8-4-4" schedule called for one section of 50 men to be in the bunks for 8 hours, followed by 8 hours in the bunks for the other 50 men. This phase was followed by the first 50 men returning to the bunks for 4 hours, after which the second 50 men occupied the bunks for the last 4 hours. The "8-8-4-4" schedule provides the lowest activity level with 50 men in the bunks at all times. The "9-9-6" schedule provided for 50 men to be in the bunks for 9 hours, followed by another 9-hour bunk period for the other 50 men, with all 100 men "up" for the remaining 6-hour "common" period. Tests were administered periodically throughout the trial to evaluate these schedules. The findings are reported in the chapter on psychological response. However, a vote taken on day 12 showed no votes favoring the 8-4-8-4 schedule, 54 votes favoring the 8-8-4-4 schedule, and 36 votes favoring the 9-9-6 schedule. Although it was originally planned to use the most favored schedule on days 13 through 15, it was decided by the administration that although the 8-8-4-4 was most favored, the 9-9-6 was most advantageous for the carrying out of the various tests associated with the trial.

It is interesting to note that many entries in the men's diaries indicated they believed it to be cooler during the 8-8-4-4 schedule than during the previous 8-4-8-4 schedule. However, temperature data indicates the hottest periods were reached during the 8-8-4-4 schedules. Apparently the men "felt" cooler during this period due to the decreased activity level.

Special Activities

Based on the experience gained from the winter trial, religious services were conducted on the Sundays during the summer trial (Fig. 36). To this end, 25 Army-Navy Religious Field Manuals were stocked in the shelter along with 25 rosaries and several Bibles. This material was considered sufficient to conduct Protestant, Jewish, and Catholic services, such as might be held aboard small ships where a Chaplain was not available.

Other special activities mentioned in the preceding sections included lectures on atomic, biological, and chemical warfare, "Amateur Hour" entertainment, competition in the stocked recreational games, and the mock courts.

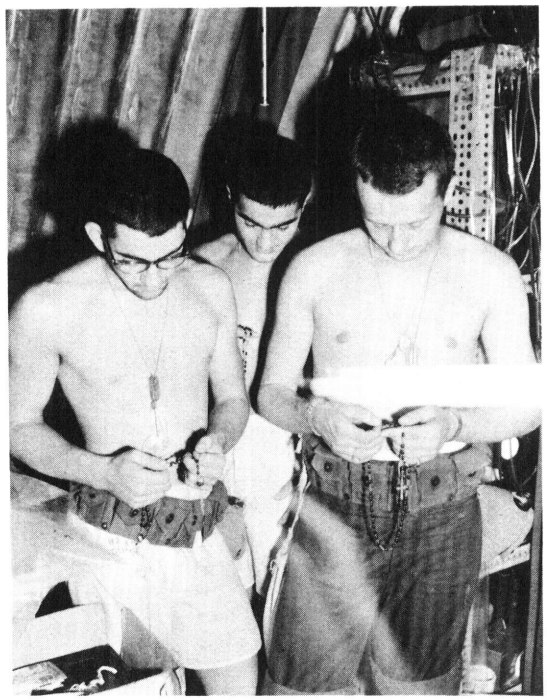


Fig. 36 - Religious service

Discussion and Conclusions

The "hot bunking" schemes set forth under all three schedules again during this trial, as during the winter trial, had little apparent effect on the ability of individuals to sleep while the lights were on and noise levels were high. This population, however, was similar to that in the winter trial in that the men were young, healthy males who were accustomed to sleeping in open barracks which could be a conditioner for sleeping under these conditions.

In an actual attack a great amount of the "common" time would not be taken up with special tests as was the case in these trials. Under those conditions a greater proportion of this time would be devoted to survival instructions for which there would be a great need. In addition there would be a more varied population in regard to age and background which should provide an additional impetus to any entertainment program.

Specific conclusions on the schedules themselves are contained in the chapter on psychological response.

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2. "Psychological and Social Adjustment in a Simulated Shelter," American Institute for Research, Pittsburgh, Pa., Nov. 1960

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CHAPTER 6

NUTRITION STUDIES

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INTRODUCTION

The nutritional and biochemical data used to evaluate the adequacy of a survival cracker during a 2-week winter-shelter habitability trial with young naval recruits have been reported elsewhere (1,2). The rational involved in the selection of the cereal-grain cracker for the major source of nutrition has been described and need not be repeated here since the same principles are applicable (1). In planning the summer habitability trial it was decided that it would be desirable to use the same dietary conditions as in the winter trial so that the prime variables would be the environmental conditions relating to temperature and humidity. Furthermore, it was considered expedient to repeat the complete nutritional evaluation of the ration in view of the entirely different environmental conditions anticipated during the summer. In the winter trial the ration appeared to fulfill the requirements for which it was designed, and although the diet contained relatively low levels of riboflavin, niacin, and pyridoxine, no overt signs of nutritional deficiency other than weight losses were encountered. It was concluded that the austere type of ration used could be employed with safety in a 2-week shelter trial under the conditions specified. The present study was conducted to determine whether the same ration would be adequate under the more stressful conditions expected during the summer period.

ENVIRONMENTAL CONDITIONS

The overall size and facilities of the shelter have been reported in Chapter 2. The temperatures and humidities encountered during the trial from Aug. 1 through Aug. 15, 1962 are an important part of the study, whereas during the winter trial they did not present a stressful situation. Effective temperatures up to 78°F usually represent the maximum level of environment heat at which comfort can be maintained. Effective temperatures as high as 88°F were encountered during the first week of the trial resulting in much physical discomfort and heat rash. The second week of the trial was considerably more comfortable although still above the normal comfort zone. In view of the different environmental conditions, the data for food intake, acceptability of the crackers, etc., have been broken down into the two weekly periods.

THE SUBJECTS

One-hundred Navy personnel participated in the test. Ninety-two recruits who had just completed their basic training were the subjects of the dietary, biochemical, and water balance studies. The remaining eight men were members of the staff who participated in all phases of shelter life but who were not included in the nutritional studies reported here. All participants were volunteers, and each recruit underwent rigid

physical and psychiatric tests to insure as much as possible that each subject would actually complete the tests (see Chapter 4). The mean age of the recruits was 19.2 ± 1.5 years.

THE RATION

The ration shown in Table 16 was utilized during the summer trial. Two meals were provided each man in a 24-hour period with a cold meal contributing approximately 898 Kcal and a hot meal providing 963 Kcal, making a total value of 1861 Kcal per day. It should be noted that during the winter trial, a reduced ration was issued during the first 8 days and the complete ration as shown in Table 16 during the last 6 days of the trial. The ingredients in the commercial Survival Ration Crackers* were described in the report of the winter trial (1), which should be referred to for detailed information concerning their composition and mineral, vitamin, and amino acid contents. As in the winter trial, a variety of jams, including cherry, strawberry, current, and grape, were used. Different soups were also served including chicken rice, tomato, vegetable beef, and beef noodle. Figure 37 shows the various activities and duties that were typical during chow time. The caloric values of the jams and soups are somewhat different; therefore, the mean values were used to determine the mean caloric values given in Table 16.

Table 16
Protective Shelter Ration

Food	Cold Meal (g)	Hot Meal (g)
Crackers	172	172
Jam	20	-
Soup, Condensed	-	90
Peanut Butter	-	16
Sugar	13	6
Pream	8	4
Approximate Kilocalories	898	963

During the entire period of the summer trial, 344 g of crackers were issued each day, providing about 1510 Kcal or 81% of the total calories of the ration. It is quite obvious that the major portion of the ration was provided in the form of the survival cracker; thus, to a large degree the nutritional adequacy of the ration is related to the adequacy of the crackers.

Since high rates of perspiration were anticipated during the summer trial, it was decided to supplement the salt found in the ration. Accordingly, 2.0 g of supplementary salt was given with each meal for the first week and then 0.66 g per meal for the remaining period. The only exception was a group of twelve water-balance subjects who were not given supplementary salt after the sixth day. None of the biochemical test subjects were in this latter group. As in the winter trial, the crackers provided approximately 3.4 g of salt per day in addition to the supplement.

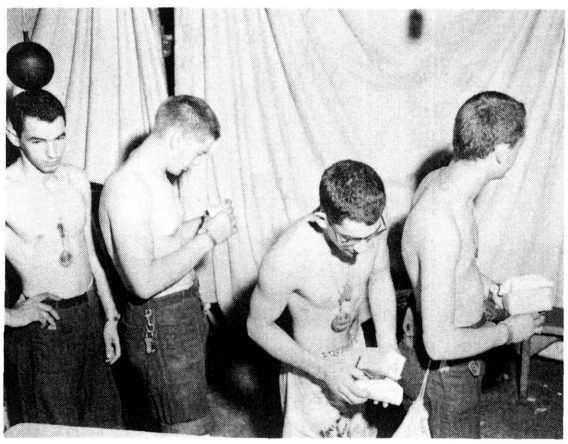
ACCEPTABILITY OF THE CRACKERS

Crackers were issued to each man with each meal. Any crackers remaining from a meal were turned in before a new issue was made. The rejects were either counted or

*Prepared by the National Biscuit Co.

(a) Preparation of hot soup

(b) Ration being weighed



(c) Chow line

(d) Food being served

(e) Water line-note coffee pot used as water heater

Fig. 37 - Food preparation and serving in the shelter

weighed, and this quantity subtracted from that issued to estimate the quantity of crackers consumed. Data concerning the acceptability of the crackers are divided, in Table 17, into two periods, the hot and humid first week and the less oppressive second week. It was observed that the acceptability of the crackers was higher during the second week of the trial for both the starboard and port divisions. The overall acceptability of the crackers was 88% of that issued. It is interesting that the overall acceptability of the crackers during the winter trial was 96% of that issued. The lowered acceptability during the summer appears to be due to the less comfortable conditions in regard to temperature, humidity, and the other unpleasant environmental features of the trial. The decreased acceptability of the crackers was also noted from the fact that in the winter trial 44 of the 96 subjects did not return any crackers during the 2-week period, whereas in the summer only 20 men of 92 men consumed all crackers issued to them.

Table 17
Acceptability of the Crackers

Division	Days	Crackers Issued Per Man Per Day (g)	Crackers Consumed Per Man Per Day (g)	Acceptability (%)
Starboard	1-7	344	282	82
	8-14	344	297	86
Port	1-7	344	306	89
	8-14	344	323	94
Both	1-14	344	302	88

CALORIC INTAKE

Data concerning the actual caloric intake during the summer trial are presented in Table 18. Again the data have been divided into two periods. The caloric value of the foods consumed during the first week of the trial was less in both the starboard and port sections than during the second, the more comfortable week. The mean caloric value of the foods consumed by 91 recruits was 1641 Kcal during the first week and 1712 Kcal during the second week. It was observed that the starboard section consumed less food than the port section; there is no obvious explanation for this.

Table 18
Mean Daily Caloric Issue and Intake Per Man

Division	Daily Issue and Intake (Kcal)			
	Days 1-7		Days 8-14	
	Issue	Intake	Issue	Intake
Starboard	1856	1583	1867	1647
Port	1869	1700	1870	1779
Both	1862	1641	1868	1712

WEIGHT RESPONSES

The weight changes during the summer protective shelter trial are recorded in Fig. 41. A mean weight loss of 5.0 lb per man was recorded during the 2 weeks. It is interesting that the pattern of weight loss was somewhat different from the winter test, where the loss was precipitous during the first week. The weight losses during the

summer were fairly steady and may be a reflection of the uniform level of calories provided during the entire trial. The loss of weight continued for 24 hours after the subjects emerged from the shelter in spite of a return to an unrestricted diet; then weight gains were observed. The failure to re-establish the preshelter weights within 9 days of leaving the shelter suggests that the weight losses during the trial were not due to a water deficit but rather were due to a catabolic breakdown of tissues.

WATER BALANCE

The mean fluid intake and urinary output of 24 men designated as "water-balance" subjects, measured over the 2-week period, were 2209 ml and 697 ml respectively. The water consumed in the foods was estimated as about 170 ml per day, approximately 100 ml from the crackers and 70 ml from the soup. The water contributed to the body by oxidation of the foods was estimated from the total protein, fat, and carbohydrate of the ration. The loss of body weight during the trial was assumed to be loss of body mass and the oxidation of this estimated to yield 149 ml of water per day. The loss of water via evaporation was estimated in a number of subjects from weight losses over a 2-hour period using a scale accurate to ±10 g. The subjects were instructed not to eat, drink, void urine, or defecate between weighings.

A fairly good water balance was estimated from the data obtained (see Chapter 7) thus suggesting that the weight losses were due to body tissue losses rather than dehydration.

BIOCHEMICAL STUDIES TO EVALUATE NUTRITIONAL STATUS

The procedures used to evaluate the nutritional status of the recruits before and after shelter habitation were essentially the same as for the winter trial, and reference should be made to the report of that study for the details of methodology (1,2). The procedures were mainly those established by the Interdepartmental Committee on Nutrition for National Defense (ICNND) as published in their Manual for Nutrition Surveys (3).

Two days before entering the shelter, blood and urine samples were obtained from 26 of the recruits. Six-hour-fasting urine samples and 24-hour urine samples were obtained as well as venous blood samples using vacuum tubes. All analytical work on the blood and urine was completed at the Army Medical Research and Nutrition Laboratory, Fitzsimons General Hospital, Denver, Colorado. A similar procedure was followed to obtain blood and urine samples at the termination of the shelter trial using the same subjects.

The various foods used in the winter trial were assayed for vitamin B_1, vitamin B_2, niacin, and vitamin B_6, and the estimated intakes have been reported (1,2). The same foods were used in the summer trial; therefore, repeat assays were not made. The approximate vitamin intakes along with the ICNND's acceptable intakes in parentheses follow: vitamin B_1, 2.14 mg/day (0.3 to 0.5 mg/1000 Kcal); vitamin B_2, 0.23 mg/day (1.2 to 1.5 mg/day); niacin, 5.6 mg/day (10 to 15 mg/day); vitamin B_6, 0.15 mg/day (no guideline available).

BLOOD STUDIES

Vitamin A and Carotene

The mean plasma vitamin A levels at the start and at the end of the shelter study are shown in Table 19. There was a slight, but insignificant, decrease in the mean vitamin A level during the course of the experiment as had been observed during the winter trial. Plasma carotene levels, presented in Table 19, showed a 23% decrease in the 2-week period. The drop in carotene concentration was not as marked as during the winter study when the starting carotene level was lower (91.2 mmg/100 ml). All of the subjects had acceptable or high levels of vitamin A and carotene both at the start and end of the summer trial; thus, no nutritional problem was associated with these factors (Tables 20 and 21).

Table 19
Selected Vitamins in Plasma at Beginning and End of Two-Week Trial

Vitamin	Concentration (mmg/100 ml)	
	Beginning	End
A	51.7 ± 2.2	46.9 ± 2.1
Carotene	131.4 ± 10.4	100.7 ± 5.8
C	570 ± 70	360 ± 40

Table 20
Plasma Vitamin A Distribution in Subjects at Beginning and End of Two-Week Trial

Rating	Plasma Vitamin A Distribution (mmg/100 ml)	Number of Subjects	
		Beginning	End
Deficient	< 10	0	0
Low	10 - 19	0	0
Acceptable	20 - 50	14	17
High	> 50	11	9

Table 21
Plasma Carotene Distribution in Subjects at Beginning and End of Two-Week Trial

Rating	Plasma Carotene Distribution (mmg/100 ml)	Number of Subjects	
		Beginning	End
Deficient	< 20	0	0
Low	20 - 39	0	0
Acceptable	40 - 100	9	13
High	> 100	16	13

Vitamin C

The mean plasma vitamin C level was 0.57 mg/100 ml at the start of the study which is a relatively high level (Table 19). Nevertheless, four of the test subjects had levels of ascorbic acid in the range of 0.10 to 0.19 which is considered to be low (Table 22). The mean vitamin C level dropped to 0.36 mg/100 ml by the end of the shelter study with six of the subjects falling into the low or deficient ranges. Because of the short duration of the investigation, no overt signs of scurvy were expected; indeed, none were seen in a complete oral examination conducted immediately after emerging from the shelter. There was, however, an increase in the periodontal index of 22 of the subjects which is discussed elsewhere (4).

Table 22
Plasma Vitamin C Distribution in Subjects at Beginning and End of Two-Week Trial

Rating	Plasma Vitamin C Distribution (mmg/100 ml)	Number of Subjects	
		Beginning	End
Deficient	< 100	0	1
Low	100 - 199	4	5
Acceptable	200 - 400	7	13
High	> 400	15	7

Hemoglobin and Hematocrit

The mean values for hemoglobin, hematocrit, and mean corpuscular hemoglobin are presented in Table 23. There was a slight increase in hemoglobin and hematocrit levels during the trial, but the change was small. This result is quite different from the winter test, where both these factors rose, suggesting some dehydration. The results are surprising since more water loss might have been expected during the hot weather and particularly in view of the excessive temperatures encountered.

Table 23
Hemoglobin, Hematocrit, and Mean Corpuscular Hemoglobin (MCHB)

Measured Blood Fraction	Average Values	
	Beginning	End
Hemoglobin (g/100 ml)	14.9 ± 0.1	15.5 ± 0.2
Hematocrit (percent)	45.5 ± 0.6	46.3 ± 1.7
MCHB (percent)	32.8 ± 0.3	32.3 ± 0.3

Erythrocyte Transketolase

A discussion of the use of the erythrocyte transketolase activity as a measure of thiamine nutrition was presented in the previous report (1,2). In brief, the stimulation of activity with added thiamine pyrophosphate (TPP) is taken as a measure of thiamine, status; i.e., a low stimulation indicates adequate functional thiamine,

whereas a high stimulation suggests an inadequate level of dietary thiamine. In the present study thiamine nutrition appeared to be adequate in all subjects since the transketolase system was not stimulated by added TPP (Table 24). This thiamine adequacy was expected since the survival crackers are supplemented with thiamine to provide approximately 1.0 mg thiamine/2000 Kcal. The results also correspond closely with the findings of the winter trial, where the erythrocyte transketolase activity was not stimulated by TPP.

Table 24
Increase in Erythrocyte Transketolase Activity
With the Addition of TPP

Rating	Increase (%)	Number of Subjects	
		Beginning	End
Deficient	> 20	0	0
Low	16 - 20	0	0
Acceptable	10 - 15	0	0
High	< 10	26	26
Average Increase for 26 subjects (%)			
Beginning 1.9			
End 1.6			

Plasma Proteins

Determinations were made of total plasma proteins as well as the two major fractions, albumin and globulin. The data in Table 25 indicate that during the 2-week shelter habitation there was a slight increase in total protein levels which was due to increases in both of the fractions and, thus, only changed the albumin/globulin ratio slightly. During the winter trial there was an unexplained decrease in the globulin level resulting in a high A/G ratio. This decrease in the globulin level may have been due to the lower caloric value of the foods offered during the first week of the study.

Table 25
Plasma Proteins

Measured Blood Fraction	Average Values	
	Beginning	End
Total Protein (g/100 ml)	7.82 ± 0.07	8.27 ± 0.08
Albumin (g/100 ml)	4.50 ± 0.08	4.88 ± 0.06
Globulin (g/100 ml)	3.32 ± 0.09	3.39 ± 0.09
Albumin/Globulin	1.40	1.48

Red Blood Cell Riboflavin

The level of riboflavin in the erythrocyte has been used as a measure of nutritional status in regard to this vitamin. The values for RBC riboflavin during the summer trial, shown in Table 26, indicate a slight rise in vitamin-B_2 concentration after 2 weeks. It

is quite interesting that there was an increase in RBC riboflavin during the winter trial also; in fact, the increase was of a greater magnitude than in the present case. The cause of the increases is not clear. It will be seen in Table 27 that the excretion of riboflavin decreased markedly during the test period although not to a deficient level (Table 28). It may be possible that the RBC tend to conserve riboflavin when the dietary source is deficient. Also, some of the change may be related to the slight hemo concentration observed, in both the summer and winter trials.

Table 26
Red Blood Cell* Riboflavin

Rating	Red Blood Cell Riboflavin (mmg/100 ml)	Number of Subjects	
		Beginning	End
Deficient	< 10	0	0
Low	10.0 - 14.9	13	9
Acceptable	15.0 - 19.9	12	13
High	⩾ 20.0	0	3
Vitamin B_2 Average for 25 Subjects (mmg/100 ml RBC)			
Beginning	14.5 ± 0.4		
End	15.6 ± 0.6		

*Erythrocyte

Table 27
Selected Vitamins in Urine from Subjects at Beginning and End of the Two-Week Trial

Vitamin	Vitamins Excreted in 6 Hours (mmg)		Vitamins Excreted in 24 Hours (mmg)	
	Beginning	End	Beginning	End
B_2	301 ± 39	213 ± 14	1769 ± 153	690 ± 50
N'-Methyl Nicotinamide	2180 ± 170	2200 ± 260	6210 ± 410	9350 ± 760
Niacin	170 ± 10	210 ± 20	700 ± 60	770 ± 60
B_1	55.6 ± 6.0	86.2 ± 10.2	261.0 ± 27.0	323.0 ± 30.0
B_6	37.2 ± 3.6	11.5 ± 0.8	103.0 ± 6.0	56.0 ± 4.0

Table 28
Distribution of Vitamin B_2 in Six-Hour Urine Samples From Subjects at Beginning and End of Two-Week Trial

Rating	Weight (mmg)	Number of Subjects	
		Beginning	End
Deficient	< 10	0	0
Low	10 - 29	0	0
Acceptable	30 - 100	1	0
High	> 100	25	24

EXCRETION STUDIES

Riboflavin

High levels of riboflavin were excreted by all subjects except one before entering the shelter, with an average of 301 mmg vitamin B_2 excreted/man during a 6-hour fasting period (Table 27). The level of excretion dropped to 213 mmg vitamin B_2/6 hours, but this level is still considered to be a high rate of excretion (Table 28). The findings are very similar to those of the winter trial and confirm the suggestion made previously that for the 2-week period on the survival ration, riboflavin nutrition is not severely influenced.

N'-Methylnicotinamide (N'-MN) and Niacin

The excretion of N'-MN has been taken as a reflection of niacin nutrition in numerous investigations since it usually is excreted in quantities about tenfold that of niacin itself. The data in Tables 27 and 29 indicate that there was no problem in regard to niacin during the shelter habitation. The levels of N'-MN excreted before entering the shelter was 2.18 mg per 6 hours and on emerging was 2.20 mg per 6 hours. The excretion of niacin was also similar in the preshelter and postshelter tests, amounting to a little less than 1/10 of the N'-MN levels.

Table 29
Distribution of N -Methylnicotinamide in Six-Hour Urine Samples From Subjects at Beginning and End of Two-Week Trial

Rating	Weight (mmg)	Number of Subjects	
		Beginning	End
Deficient	< 200	0	0
Low	200 - 599	0	0
Acceptable	600 - 1600	3	10
High	> 1600	23	14

Table 30
Distribution of Vitamin B_1 in Six-Hour Urine Samples From Subjects at Beginning and End of Two-Week Trial

Rating	Weight (mmg)	Number of Subjects	
		Beginning	End
Deficient	< 10	0	1
Low	10 - 24	1	1
Acceptable	25 - 50	13	5
High	> 750	12	17

Thiamine

In addition to evaluating vitamin-B_1 nutrition by means of RBC transketolase activity, the excretion of thiamine was studied as well (Table 27). The mean 6-hour-fasting level of thiamine excretion fell in the high zone, according to the ICNND standards for both the preshelter and postshelter examinations (Table 30). At the start one subject excreted a

low level of thiamine, and at the termination of the study two subjects were low or deficient. In the winter trial, three subjects fell in the deficient range at the end of the shelter stay in spite of the fact that the crackers were supplemented with 1.0 mg of the thiamine per 2000 Kcal. During the current study, the one man who excreted what is considered a deficient level of thiamine also had a low food intake and demonstrated levels of excretion less than the means for niacin, vitamin B_2, and N'-MN.

Vitamin B_6

Total vitamin B_6 in the urine was estimated by the microbiological method using the yeast, saccharomyces carlsbergensis, as the test organism. This method detects total vitamin-B_6 activity including pyridoxine, pyridoxamine, and pyridoxal. The data from the summer trial in regard to pyridoxine excretion are presented in Tables 27 and 31 where it can be seen that the subjects were excreting considerable quantities of the vitamin previous to shelter entry. On emerging the pyridoxine excretion diminished to about 1/3 of the pretest levels; however, the mean excretion value was still adequate according to the criterion that 7.5 mmg vitamin B_6/6 hours indicates adequate pyriodoxine nutrition. One subject fell into the low zone, but a check of his blood levels of other nutrients and his excretion of other vitamins indicated no other abnormalities. This very striking decrease in urinary vitamin B_6 is quite interesting in view of the results of the winter trial which showed the same situation only to a more severe extent; that is, all of the subjects ended with low excretion values after 2 weeks. In the winter the starting level of vitamin B_6 was only about 60% of the summer level, which may account for the excretion rates dropping to the low level.

Table 31
Distribution of Vitamin B_6 in Six-Hour Urine Samples From Subjects at Beginning and End of Two-Week Trial

Rating	Weight (mmg)	Number of Subjects	
		Beginning	End
Low	<7.5	0	1
Acceptable	>7.5	26	23

GENERAL CONSIDERATIONS

In the report of the winter shelter habitability trial (1,2) it was indicated that the Food and Nutrition Board of the National Research Council, National Academy of Sciences was considering recommendations of minimal allowances of food and water for fallout shelter survival. Some of the rationale behind the recommendations were also discussed and will not be repeated here. The Navy's winter shelter habitability trial provided experimental confirmation of the adequacy of the austere, cereal-based ration for the survival of a group of healthy and well-adjusted young men for a 2-week period. The results of the summer trial reported here substantiate the earlier findings in regard to the austere ration. These findings are not to suggest that the ration is adequate in all respects for all groups of individuals or for a longer period of time. During the summer trial an average weight loss of 5.0 lb was observed, some decreases in either blood levels or excretion of vitamins were found, and some minor alterations in periodontal conditions were observed in the course of dental examinations which have been reported elsewhere (4). In spite of these changes the men appeared in excellent physical condition on emerging from the shelter, and their performance of physical fitness tests were not statistically different from pretest values.

The water intake during the summer trial averaged 2.2 liters/man/day. On one day during the first week the mean daily water intake reached as high as 2.9 liters/man; however, as the effective temperature dropped, the water consumption was somewhat reduced. For the entire study the range of individual water intakes was from 0.85 to 4.7 liters/man/day. The suggested recommendation of the Food and Nutrition Board NRC (1,2) of 1.9 liters/person/day appears reasonable since this is an overall figure without reference to age or sex. The question of the proper water allowance will still require some discussion, however, since 1.9 liters a day may be too liberal for areas having a mild climate and too little for an area having very hot, humid conditions. In the present trial it is estimated that there would have been a water deficit of 5.2 liters if water had been restricted to 1.9 liters/day.

The acceptance of the ration was good with 88% of the issued crackers consumed. It is of considerable interest that while food was one of the two prime sources of both acute discomfort and general discomfort in the winter trial, it dropped to a much lower source of discomfort during the summer trial. Lack of water for washing, dirt, temperature, and humidity ranked much higher as sources of acute discomfort than the food. One is tempted to conjecture that in an actual survival situation food would no longer pose a major source of discomfort.

CONCLUSIONS

The biochemical results of the summer habitability study confirm the findings of the winter trial. It is concluded that the austere type of ration used in the studies can be employed with safety during a 2-week shelter life under the conditions encountered. It should be emphasized again, however, that in this study the subjects were young, healthy, well-adjusted young men, and the results can only be interpreted in terms of such a group.

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CHAPTER 7

PHYSIOLOGICAL STUDIES

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PRELIMINARY CONSIDERATIONS

Factors in shelter living which may lead to excessive strain on physiological mechanisms of homeostasis can be related to physical and chemical stresses in the environment, on the one hand, and to the capacity of the individual to adapt to these stresses, on the other. In the past 2 decades man's ability to adapt to extreme changes in ambient temperature, pressure, and gaseous composition of the atmosphere has been intensively studied in healthy young men. In general, these studies have been concerned with acute rather than prolonged exposures and have dealt with single rather than multiple factors in the environment. Extrapolation from such data to prolonged exposure to multiple stresses is thus impossible. Moreover, little is known of age, sex, physical fitness, and disease as factors limiting man's tolerance to environmental stresses.

The aims of these shelter habitability trials and the rationale for selecting young, healthy Navy recruit graduates have been outlined earlier. It is worth repeating, however, that the group thus selected represented a relatively homogeneous segment of the population with less spread in physiological tolerance to stress than would be found in a group selected at random either within the Navy or from the population at large. Once having established conditions of habitability required for the group selected, one can then proceed to determine the extent to which numerous human and engineering factors may demand modifications in shelter design and/or approaches to shelter habitability.

PHYSIOLOGICAL MEASUREMENTS

Because thermal factors were regarded as potential stressors of primary importance in a shelter environment, particularly during the summer trial, physiological measurements were selected which would detect strain on thermoregulatory mechanisms (Fig. 38). Indices of heat strain included rising body temperature, elevated pulse rate, and increased sweat production with its resulting drain on body reserves of water and salt. Twenty-four-hour urine specimens were to provide important information on renal excretion of water and electrolytes and their balance in the body economy. Qualitative analysis of the same specimens for glucose, protein, and ketone bodies, together with microscopic examination of urinary sediment for blood cells and other abnormal particles, served as a screening procedure to detect metabolic disorders or disease processes. Quantitative analysis of some of these specimens for 17-hydroxycorticosteroids (17-OHCS) was introduced in the summer trial. Activation of the adrenal cortex by a neurohumoral mechanism involving the hypothalamus and anterior pituitary gland is a nearly universal response to a wide variety of stresses. 17-OHCS has been shown experimentally and clinically to enhance resistance of the organism to stress.

Finally, exercise tolerance is a useful index of physical fitness. Ability to perform brief but exhausting work can be measured by a modification of the Harvard step test (1,2). Deterioration in physical fitness during the shelter trials would indicate failure to some degree in the adaptation to stress.

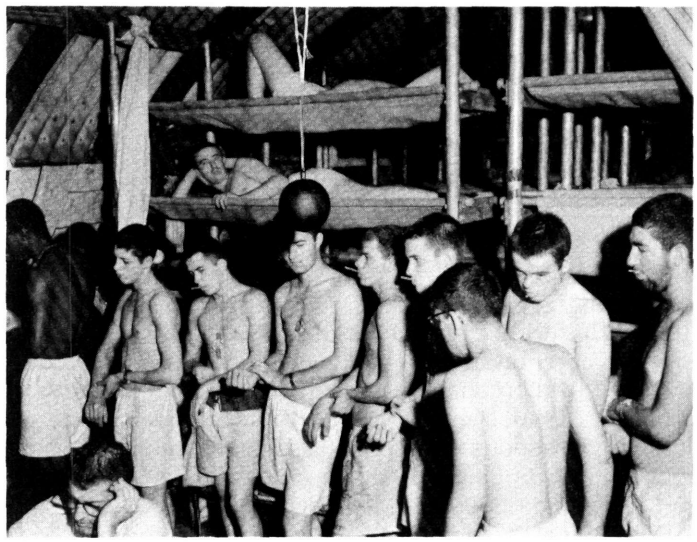

Fig. 38 - Daily physiological measurements

PROCEDURE

Body weight, pulse rate, and oral temperature, together with intake of food and water, were the only physiological measurements made during the 2-day trial.

In the 2-week winter trial body weight, pulse rate, and oral temperature were measured daily in all 96 test subjects, beginning 4 days before entry and ending 2 days after leaving the shelter. These measurements were taken again on the ninth day after the subjects had left the shelter. During the pretrial period these measurements were made approximately 2 hours after reveille and 1 hour after breakfast. During and after the 2-week trial the three measurements were made within 1 hour after reveille, after the subjects had voided urine but before they had ingested food or water.

In the 2-week summer trial body weight, pulse rate, and oral temperature were measured daily in all 92 subjects beginning 5 days before entry, each day of the trial, daily for the first 2 days after leaving the shelter, and lastly, on the seventh and eighth day after shelter exit. All measurements were made within 1 hour after reveille, after the subjects had voided but before they had ingested food or water.

Body weight was measured in pounds on a high-quality bathroom-type scale graduated in 1/2-lb divisions. The scale gave reproducible readings with an accuracy of ±1/4 lb. In the winter trial the subjects were dressed in dungaree uniform, including regulation shoes. Accessory gear, such as the ditty bag, cap, and jacket, was not weighed. In the summer trial the subjects were weighed wearing shorts and socks only.

Oral temperature was measured by a standard clinical thermometer retained in the mouth at least 5 minutes. Men of each division were given thermometers after voiding but prior to weighing. The subjects were cautioned not to drink water before measurement was taken and not to talk or breathe through the mouth.

Pulse rate was measured for 1 minute while the oral temperature was being taken. All subjects had been instructed in the technique for palpation of the radial pulse. The observer instructed the men of each division when to start and when to stop counting.

Fig. 39 - Filling canteen with water

Upon completion of the count and while the subject was standing on the scale, one recorder removed and read the oral thermometer. The other recorder took the weight reading and then asked the man to report his pulse rate. All three measurements were then entered on the data sheet.

Water intake and food intake were the other measurements recorded daily on all test subjects during the 14-day trials. Methods for estimating food consumption are described in Chapter 6. Water intake was recorded by a water monitor on a tally sheet. This record showed the number of cups of water and/or coffee drawn by the subject for each 24-hour period, beginning at 1100. Each cup, when filled to within 3/8 in. of the brim, contained 170 ml. The 6-ounce daily ration of soup contributed an additional 160 ml of water to the daily fluid intake. In the summer trial each man was issued a canteen, a canteen cover, and cartridge belt. The measured mean volume of the canteens was 935 ml. Thus, the number of canteens of water and number of cups of water and/or coffee issued to each man ad libitum were recorded by the monitor (Fig. 39).

Urinary output was measured in 24 men designated as "water-balance" subjects. For the winter trial these subjects had been selected from volunteers for this assignment on Feb. 13. After entering the shelter, the 24 water-balance subjects were equally divided between the two sections. A preliminary 24-hour collection for control studies had been obtained beginning at 2300 on Feb. 14. Aliquots of the initial 6-hour sample and of the entire 24-hour specimens were acidified with meta-phosphoric acid and chilled on ice in preparation for air shipment to the Army Medical Research and Nutrition Laboratory (AMRNL). After entering the shelter, the 12 water-balance subjects in each section were instructed to void and discard the urine immediately before starting their initial 8-hour sleep period. Routine collection of the total urine output for each 24-hour period thus began at 1400 on Feb. 17 and continued daily to Feb. 28 for the night section (scheduled to sleep from 1400-2200) and at 0200 on Feb. 18 and continued daily to Mar. 1 for the day section (scheduled to sleep from 0200-1000). Specimens designated for air shipment to AMRNL were obtained during a collection period beginning

at 1400 on Feb. 28 for the night section and at 0200 on Mar. 1 for the day section. These specimens were handled in the same manner as the control specimens collected on Feb. 14.

Similar procedures were followed in the summer trial, except that a preliminary pre-entry 24-hour urine specimen was obtained from 0600 July 31 to 0600 Aug. 1. After entering the shelter water-balance subjects of the night section began collecting their initial shelter sample at 2200 on Aug. 1. This 16-hour collection ended at 1400 on Aug. 2 when the first routine sleep period for the night section began. The day section started its initial 24-hour collection at 0200 on Aug. 2 at the commencement of their first routinely scheduled period for sleep (0200-1000). The 24-hour specimen designated for air shipment was collected between Aug. 13-14. The day section collected a final 24-hour specimen in the shelter ending at 0600 on Aug. 15, and the night section collected a final 16-hour specimen ending at the same time. Because bunking schedules were changed, the day section collected a 29-hour specimen from 0200 on Aug. 4 to 0700 on Aug. 5. The 24-hour collection period then remained at 0700-0700 for 2 days and then from 0600-0600 for the remainder of the trial for this section. The night section was on a 1400-1400 schedule throughout except for the final specimen from 1400 on Aug. 14 to 0600 on Aug. 15. Collection of the first 24-hour specimen after the trial for all water-balance subjects actually began at 0600 on Aug. 15 within the shelter and ended at 0600 on Aug. 16 at the Naval Station barracks. The final urine specimen was collected from 0600 on Aug. 16 to 0600 on Aug. 17.

Urine-analysis specimens were collected in wide-mouth 1-gal plastic bottles clearly labeled with name and shelter number of the subject. Separate racks for 12 bottles were provided for each section. For routine analysis the specimens were preserved with crystals of thymol. Because the specimens for vitamin assay at AMRNL were acidified with meta-phosphoric acid containing sodium phosphate, it was not possible to use these specimens for routine analysis of sodium and pH.

Routine analysis included the following determinations: 24-hour urine volume, specific gravity, pH, albumin, glucose, ketone bodies (acetone), and microscopic examination of the sediment. Special analyses of the daily specimens included quantitative measurement of sodium and potassium concentration by flame photometry and measurement of chloride concentration using an automatic titrator.

During the summer the above analyses were performed, and in addition daily urinary total 17-OHCS determinations were made on 54 percent of the water-balance group. The method employed in the 17-OHCS determinations is a Naval Medical Research Institute modification (3) of the technique described by Porter and Silber (4). These urine-steroid analyses were performed on specimens from the water-balance subjects distributed in the following manner: day section-two subjects from the Bookkeeping, three from the Cooking, two from the Deck, and one from the Engineering Divisions and night section-two from the Cooking, one from the Deck, and two from the Engineering Divisions.

Evaporative water loss was measured as weight loss in subjects clothed only in shorts, the period being carefully timed for 2 hours. A precision balance was used which was accurate to ±10 g. The subjects were instructed not to eat, drink, void urine, or defecate between weighings. The change in weight thus represents insensible water loss through the skin and respiratory tract, plus sweat loss either by evaporation or by dripping off the body. It is assumed that evaporative water loss during sleep is one-half the hourly rate of that during the waking state.

Comparative water balance between winter and summer was obtained following the method described by Houssay, et al. (5). For this analysis it is assumed that 75 percent of the weight loss was anhydrous fat and 25 percent lean tissue containing 25 percent protein and 70 percent water. Factors of minor consequence, such as the difference between the weight of oxygen consumed and CO_2 produced, were not taken into consideration.

In the winter test respiratory quotient and resting metabolic rate were measured in eight subjects by collecting a 5- or 10-minute sample of expired air in a Douglas bag. Each subject was fasting and recumbent, having been wakened after spending 6 to 7 hours sleeping in his bunk. A sample of the gas was transferred to a tonometer. The total volume was measured by a dry-gas meter. The concentration of O_2 and CO_2 in the samples was analyzed by the Haldane method. For estimating metabolic rate gas volumes were corrected to conditions of standard temperature and pressure. Measurements of metabolic rate were not performed in the summer trial.

Physical fitness was measured in the 24 water-balance subjects using a modification of the Harvard step test (1,2). In this test the man steps onto a bench 20 in. high and back to the deck at a rate of 30 times per minute for 3 minutes or until exhausted. Post-exercise pulse rates are recorded for the periods from 1 to 1.5, 2 to 2.5, 3 to 3.5, and 4 to 4.5 minutes after exercise. The sum of the pulse counts is an index of fitness for hard work. High counts indicate poor fitness. A correction is necessary if the period of stepping is less than 3 minutes. A formula is available for deriving the correction factor (1,2). Instructions and commands for timing the exercise were recorded on magnetic tape. Each test of physical fitness was conducted by play-back of the same tape record. Two practice sessions were given to all subjects on the fourth and third days before entering the shelter. Control scores were then obtained on the second and first days before entry by successive tests on six groups of four subjects each. The same routine was followed in conducting the tests at 1 hour, 24 hours, 48 hours (winter and summer), and at 9 days (winter) after the subjects had left the shelter.

RESULTS

Two-Day Winter Trial

Results of physiological studies conducted in the 2-day shelter trial are summarized in Table 32. Because nearly 10 hours elapsed after entry before the routine schedule was started, it was not possible to collect two complete sets of data on both sections. Hence, Table 32 includes body-weight, temperature, and pulse-rate data for the port section only. Caloric intake as well as water intake is given for both sections on each of the 2 days. The composition and caloric content of the diet were identical with that described for the last 6 days of the 2-week winter trial (Chapter 6). With the exception of the lower food acceptance, data in the 2-day trial show essential agreement with those obtained in the 2-week winter trial.

Two-Week Trials

The results of measurements involving all 96 subjects in the winter and 92 subjects in the summer are presented in Tables 33-40 and Figs. 40-46.

Table 33 illustrates the comparative age, weight, and height of water-balance subjects prior to preparations for shelter entry. These subjects were selected at random and represent 25 percent of the total group of subjects in each respective trial.

Body Weight – It is improbable ($p < 0.05$) that the successive decrements of body weight observed during the first 8 days of the winter trial occurred by chance alone (Fig. 40, Table 35). When decrements are considered for 48-hour intervals, the findings become highly significant ($p \ll 0.01$). On the other hand, the increase in body weight on the ninth day is not statistically significant. It is interesting to note that the decline continued for 24 hours after the subjects left the shelter, despite their return to a completely unrestricted diet, both at the noon meal shortly after shelter exit as well as a large meal the same evening. Less than 50 percent of the total weight loss was recovered

Table 32
Physiological Measurements in Subjects of the 2-Day Winter Shelter Trial, Jan. 30 - Feb. 1, 1962

Test Group	Measurement	Day 1		Day 2	
		Mean	S.D.*	Mean	S.D.
Port Section Only (47 men)	Body Weight (lb)	162.8	20.3	161.4	20.3
	Pulse Rate (beats/min)	80.8	4.8	89.2	13.6
	Oral Temp (°F)	96.8	1.0	97.1	1.0
Both Sections (92 men)	Caloric Intake	1412	327	1347	476
	Acceptance of Calories Offered (percent)	75	-	72	-
	Water Intake (ml)	1559	564	1009	461

*Standard deviation.

Table 33
Comparative Age, Weight, and Height of Water-Balance Subjects

Trial	Age (yr)		Weight (lb)		Height (in.)	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.
Winter	19.0	1.6	153.7	27.2	68.1	2.3
Summer	19.2	1.5	157.1	18.7	69.3	2.4

*Standard deviation.

Table 34
Comparative Physiological Observations in Winter and Summer Trials of the Navy Protective Shelter, NNMC, Bethesda, Md., 1962

Daily Mean Value	Seasonal Changes	
	Winter (Feb. 17 - Mar. 3)	Summer (Aug. 1 - Aug. 15)
Caloric Intake Offered (cal)	1645	1865
Caloric Intake Consumed (%)	96	89
Water Intake (ml)	1313	2272
Urine Output (ml)	790	697
Input:Output Ratio	1.66	3.30
Sodium (meq)	87	121
Potassium (meq)	44	33
Chloride (meq)	77	95
Evaporative Loss (g)	1200	1911
Pulse Rate (per min)	82.1	79.3
Oral Temperature (°F)	96.9	97.9
Physical Fitness (Y score)		
Pretest	246	239
Post-test (no significant difference)	244	229
Total Weight Loss for 2 Weeks (lb)	5.4	4.8

Table 35
Physiological Measurements in 96 Subjects Before, During and After the 2-Week Winter Shelter Trial, Feb. 13 - Mar. 5, 1962

Measurement	Pretest (4-day mean)		Day 1		Day 7		Day 14		Recovery (48 hr after exit)	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Body Weight (lb)	160.1	18.4	159.6	18.9	155.3	17.7	154.2	17.3	154.2	17.5
Oral Temp (°F)	98.3	0.7	97.3	1.2	97.1	1.2	96.8	1.0	97.7	1.3
Pulse Rate (beats/min)	80.2	10.0	80.4	14.8	85.9	8.8	81.6	7.7	82.7	8.4
Water Intake (ml)	-	-	1106	437	1537	513	1480	636	-	-

*Standard deviation.

Table 36
Physiological Measurements in 92 Subjects Before, During, and After the 2-Week Summer Shelter Trial, July 27 - Aug. 17, 1962

Measurement	Pretest (6-day mean)		Day 1		Day 7		Day 14		Recovery (48 hr exit)	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Body Weight (lb)	152.0	17.2	151.8	17.3	149.0	16.6	147.0	16.0	147.2	16.3
Oral Temp. (°F)	97.4	0.6	98.7	0.6	98.2	0.5	97.1	0.7	97.4	0.7
Pulse Rate (beats/min)	74.6	9.0	81.4	10.1	79.3	8.9	77.0	8.7	76.9	8.5
Water Intake (ml)	-	-	2415	720	2511	767	1706	815		

*Standard deviation.

Table 37
Comparative Water Balance in Twenty-four Subjects of the Shelter Habitability Study, NNMC, Bethesda, Md.

Water-Balance Factors	Winter Gains (ml) (Feb. 17 - Mar. 3)	Summer Gains (ml) (Aug. 1 - Aug. 15)
Mean Daily Water Intake*	1263	2209
Water Content of Food*	170	170
Oxidative Water, Food*	235	235
Oxidative Water, Tissue†	157	149
Tissue Water‡	33	32
Total Gain	1858	2795
	Winter Losses (ml)	Summer Losses (ml)
Mean Daily Urine Volume*	790	697
Evaporative Water, Waking*	960	1433
Evaporative Water, Sleeping	240	478
Fecal Water	100	100
Total Losses	2090	2708
Gains/Losses (percent)	89	103

*By direct measurement or from known composition and quantity of food.
†Winter - 142 g fat and 12 g protein; summer - 135 g fat and 11 g protein.
‡Winter - 47 g lean tissue; summer - 45 g lean tissue.

Note: Mean daily weight loss of 189 g/day in winter and 180 g/day in summer.

Table 38
Respiratory Quotient and Resting Metabolic Rate in Eight Subjects During 2-Week Shelter Trial, Feb. 17 - Mar. 3, 1962

Measurement	Mean	Standard Deviation
Respiratory Quotient	0.86	0.07
Metabolic Rate (kcal/hour)	66.2	10.9

Table 39
Physical Fitness in 24 Subjects Measured by a Modified Harvard Step Test Feb. 15 - Mar. 5, 1962

Measurement	Before Entry				After Exit					
	Feb. 15		Feb. 16		Mar. 3		Mar. 4		Mar. 5	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Resting Pulse	71.8	9.4	77.6	10.7	82.2	7.4	73.4	9.3	78.6	7.6
Pulse 1 Min Postexercise	130.1	12.1	135.9	13.1	137.9	14.2	131.0	11.2	141.6	13.9
Cumulative Pulse Count	235.3	16.3	245.7	22.0	244.4	23.5	239.1	23.8	248.5	24.3
Duration of Stepping (min)	2.91	0.20	2.94	0.17	2.91	0.25	2.85	0.40	2.95	0.14

*Standard deviation.

Table 40
Physical Fitness in 24 Subjects Measured by a Modified Harvard Step Test, July 30 - Aug. 17, 1962, NNMC, Bethesda, Maryland

Measurement	Pretrial				Post-trial					
	July 30		July 31		Aug. 15		Aug. 16		Aug. 17	
	Mean	S.D.*	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Resting Pulse	73.4	9.3	74.9	7.1	75.8	7.2	73.6	9.1	74.4	9.6
Pulse 1 Min Postexercise	133.5	12.7	135.0	11.0	131.1	11.2	132.9	12.7	126.6	12.8
Cumulative Pulse Count	232.9	18.3	239.1	16.9	229.2	21.4	228.7	21.6	225.5	20.5
Duration of Stepping (min)	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00	3.00	0.00

*Standard deviation.

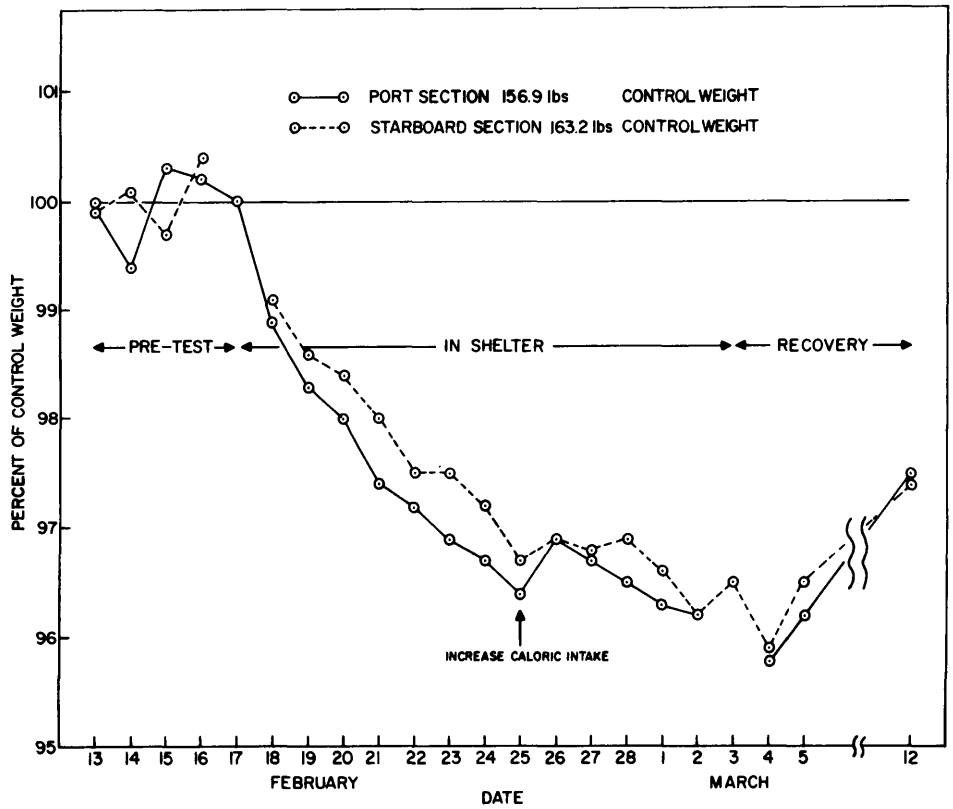

Fig. 40 - Weight change in 96 subjects before, during, and after 2-week shelter test, Bethesda, Md., Feb. 13 - Mar. 12, 1962

by 9-days post-test. These findings suggest that weight loss was chiefly from catabolic breakdown of tissue and that dehydration was not a significant factor.

Body-weight changes during the summer trial, Fig. 41 and Table 36, need little additional comment other than that the maintained higher caloric intake in the summer trial contributed to the lower rate of weight loss. Endocrine responses in the summer test may have led to water and salt retention during the first 4 to 5 days. These responses will be described below. Reasons for the differences in caloric intake in the two tests were discussed in the previous chapter (Nutritional Studies).

Oral Temperature – Mean values for oral temperature are shown in Tables 34-36 and Fig. 42. In the winter trial, a significant decline occurs in this measurement between Feb. 23 and 24. This decline coincides with the increased ventilation rate on Feb. 24, which resulted in an abrupt lowering in ambient temperature. Correlation coefficients for daily mean values for oral temperature vs daily mean effective temperature* (ET) were not significant in the winter ($r = 0.2329$) but were significant in the summer ($r = 0.9523$).

Water Intake – Mean daily water intake for all subjects is shown in Figs. 42 and 43. Statistically the difference between water intake on days 1 and 7 of the winter trial is highly significant ($p << 0.01$) (Table 35). Corresponding data for the summer trial is

*Effective Temperature in this situation is calculated by the wet-bulb-globe-temperature (WBGT) Index formula of 0.7 wet bulb + 0.3 dry bulb. Daily mean ET is obtained as the mean of twelve readings recorded every 2 hours in the forward portion of the shelter near the medical area on the starboard side.

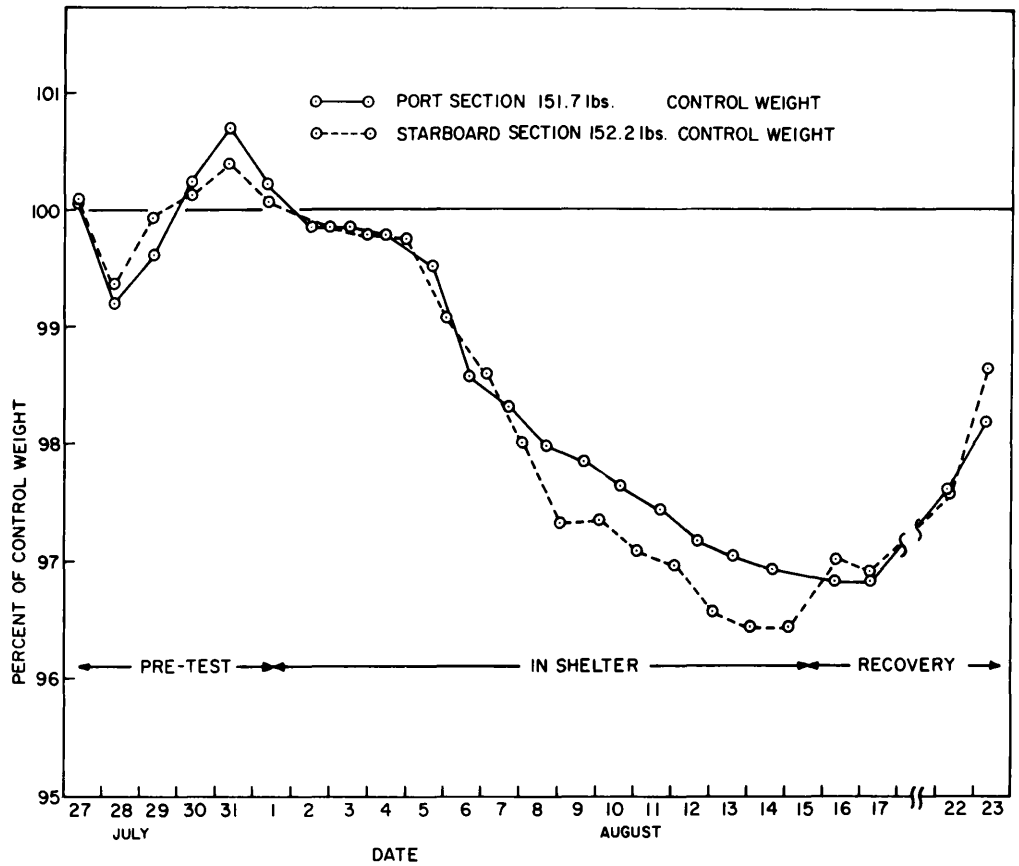

Fig. 41 - Weight change in 92 subjects before, during, and after 2-week shelter test, Bethesda, Md., July 27 - Aug. 23, 1962

shown in Table 36. During the summer trial mean daily water intake exceeds that observed in the winter trial by approximately 1 liter (Fig. 42 and Table 36). The correlation coefficient for mean daily water intake for all subjects vs mean daily ET during the summer trial is r = 0.9121 (Fig. 44). A higher value is obtained between water intake and wet-bulb temperature (r = 0.9389), whereas the correlation coefficient between water intake and dry-bulb temperature is lower (r = 0.5420). Figure 47 is a graph of air temperature, black globe temperature, and wet-bulb temperature measured every 2 hours in the forward area of the shelter near the medical station.

Urinary Excretion – Results from the 24 water-balance subjects appear in Table 34 and Fig. 45. Figure 45 includes data for the 24- and 48-hour recovery specimens during the winter trial and pretrial and posttrial data during the summer trial. Daily water intake and weight loss in the water-balance subjects did not differ significantly from the values shown for the entire group in Tables 34-36.

Features of principal interest in Fig. 45 are in initial rise in water intake and a fall in urinary volume, coupled with a rise in urinary specific gravity and a fall in urinary excretion of sodium and chloride. This disparity between volume of water intake and urinary output is an index of extrarenal water loss through sweating. The striking difference between daily water intake and urinary output in the summer, when sweating was profuse, compared with the winter, when sweating was moderate, bears this out. That the increase in intake did not exceed the requirement for sweating is evident from the

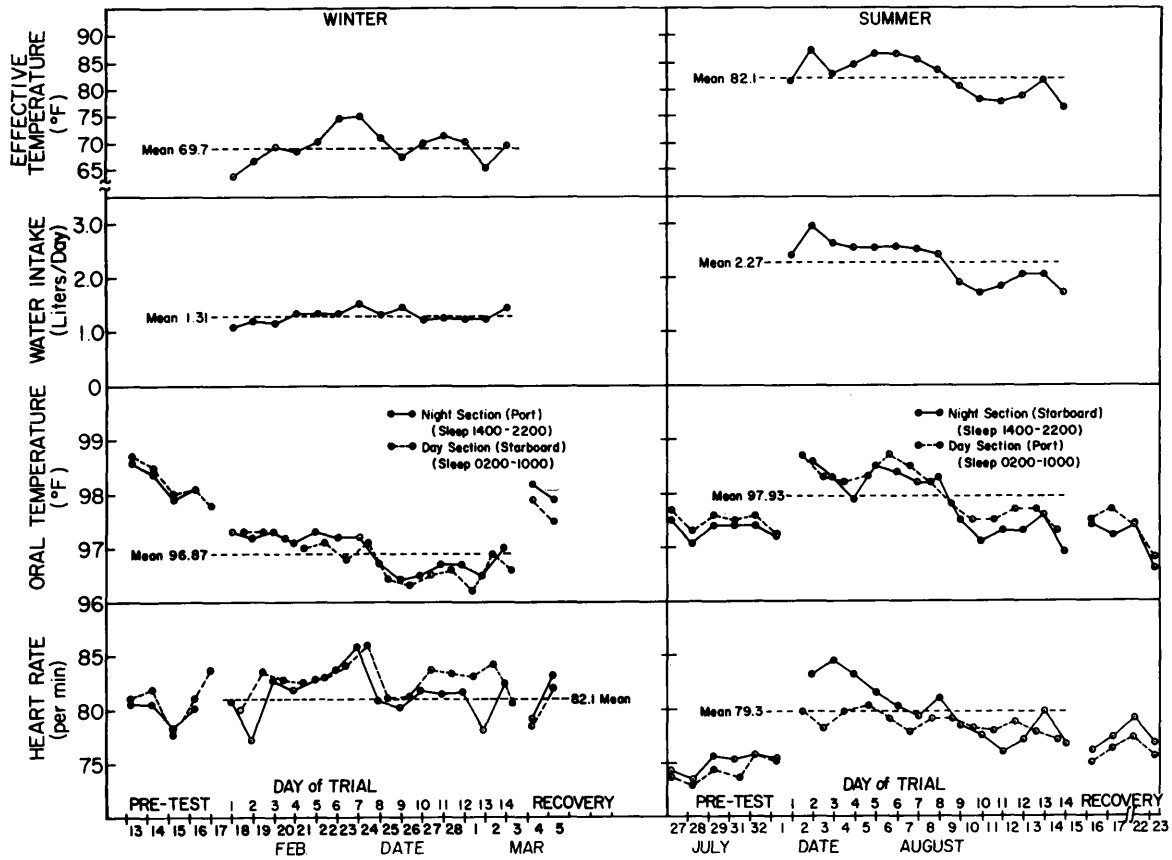

Fig. 42 - Physiological factors related to environmental temperature, shelter habitability trials, Bethesda, Md., winter - Feb. 17 to Mar. 3, summer - Aug. 1 to Aug. 14, 1962

fact that the urinary output was no greater in the summer but, in fact, less than in the winter.

During the winter trial about 50 percent of the increase in urinary output of sodium and chloride after the eighth day can be accounted for by the increased salt intake which was contributed by the increased cracker ration in the diet. Although salt deficiency in the summer trial had been anticipated as a potential problem, our results suggest but do not prove that the supplement in the summer trial was not needed to prevent serious salt depletion, some of the additional salt being excreted in the urine. The abrupt drop in sodium on day 8 of the summer trial corresponds in time with the reduction in intake of salt by all subjects with 12 of the water-balance subjects starting a regime with no salt supplement (Fig. 45).

During the periods when demands were made on body salt lost in sweating, the Na/K ratios were low and rose as these demands subsided. Both urinary volume and electrolyte excretion increased strikingly during the 48-hour recovery period, the subjects having returned to a diet unrestricted in salt. The statement above, however, that the salt supplement is probably not needed to prevent serious salt depletion still holds.

Urinary potassium was relatively constant after adaptation to the diet, and potassium appears to be independent of the sodium and chloride excretion rates observed. As was expected, chloride output closely paralleled sodium output. Changes in the sodium: potassium ratio observed in the summer trial are explained, in part, by considering adrenal activity through urinary levels of 17-OHCS.

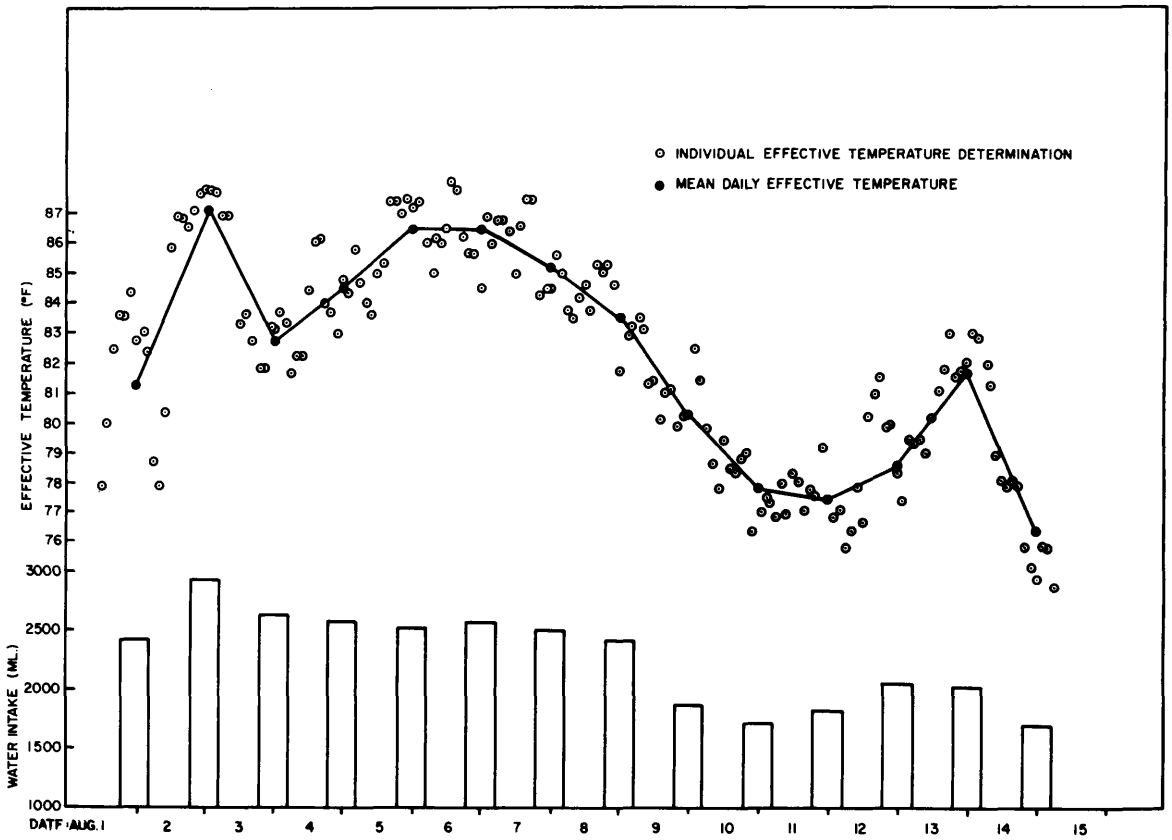

Fig. 43 - Mean daily water intake for 92 subjects and effective temperatures within shelter during 2-week summer shelter habitability test, NNMC, Bethesda, Md., Aug. 1 - Aug. 15, 1962

From Fig. 46 it is apparent that the urinary 17-OHCS levels increased on day 1 of confinement, fell during the 2-week period, and returned toward the control level after shelter exit. A low correlation coefficient between 17-OHCS excretion and urinary volume ($r = 0.1073$), under the conditions of this study, implies that these functions are independent. Also, correlations between 17-OHCS vs effective temperature ($r = 0.0231$), Na/K vs effective temperature ($r = 0.00004$), and Na/K vs urinary volume ($r = 0.3590$) are low and probably not significant. On the other hand, the correlation between urinary volume and effective temperature ($r = 0.6245$) and between 17-OHCS and Na/K ($r \cong -0.8104$) appear significant.

Evaporative Water Loss – During the winter trial evaporative water loss was determined from 55 weight-loss measurements in 24 water-balance subjects. These measurements were conducted over a 2-hour period on 4 separate days. Mean water loss by evaporation was estimated to be 1 g/min, or 60/hr (mean 1.02 g/min, S.D. 0.58 g), during waking activity, a value which is double the figure which is generally accepted for insensible weight loss in the waking adult male at complete rest (30 g/hr)(6). Evaporative weight loss observed in the winter trial is consistent with the comfortable thermal conditions and low level of activity during this trial.

Similar measurements were made at various times during 13 days in the summer trial. The mean evaporative weight loss in the summer trial, based on 303 measurements, was 1.5 g/min or 89.5 g/hr (Mean 1.49 g/min, S.D. 0.72 g).

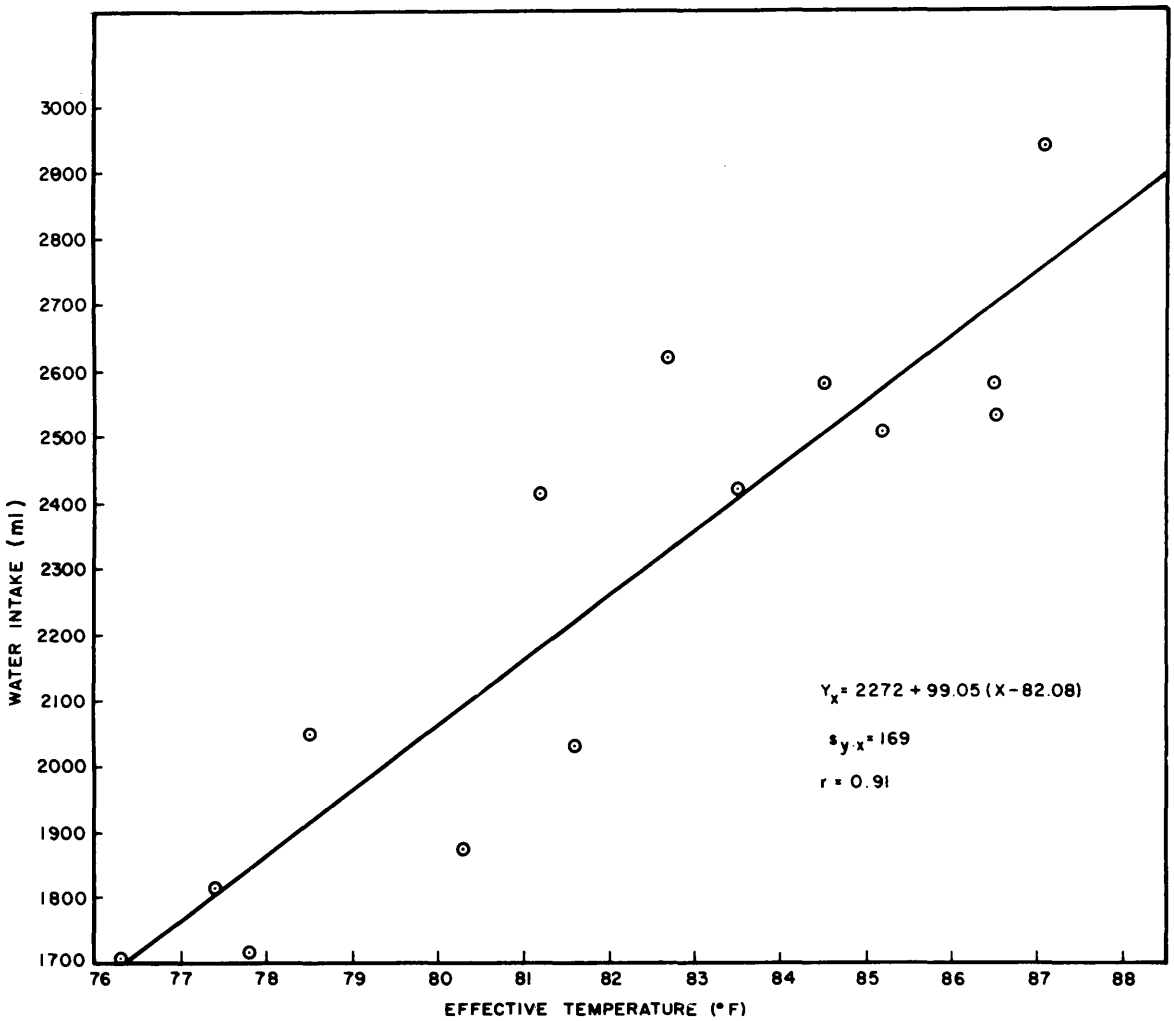

Fig. 44 - Mean daily water intake for 92 subjects vs mean daily effective temperature in 2-week summer shelter test, NNMC, Bethesda, Md., Aug. 1 - Aug. 15, 1962

Water Balance – Table 37 lists factors of gain and loss to the water economy of the body for 24 hours, based on mean daily values obtained in each shelter trial. It is noted that factors of greatest weight on each side of the balance sheet are those which can be measured directly. Gains from breakdown of body tissue are based on an observed weight loss of 189 g/day during the winter trial and a mean weight loss of 180 g/day during the summer trial. The percentage relationships between anhydrous fat, lean tissue, protein, and water from lean tissue loss have been expressed previously ("Physiological Measurements").

Considering the limitations of the methods used, the balance between gains and losses is satisfactory.

Respiratory Quotient and Metabolic Rate – These data appear in Table 38. Although the metabolic rate is consistent with that expected of subjects of average age 19 yr and weight 154 lb, the respiratory quotient showed greater variation than expected in consideration of the uniform diet. No metabolic rates or respiratory quotients were determined during the summer trial.

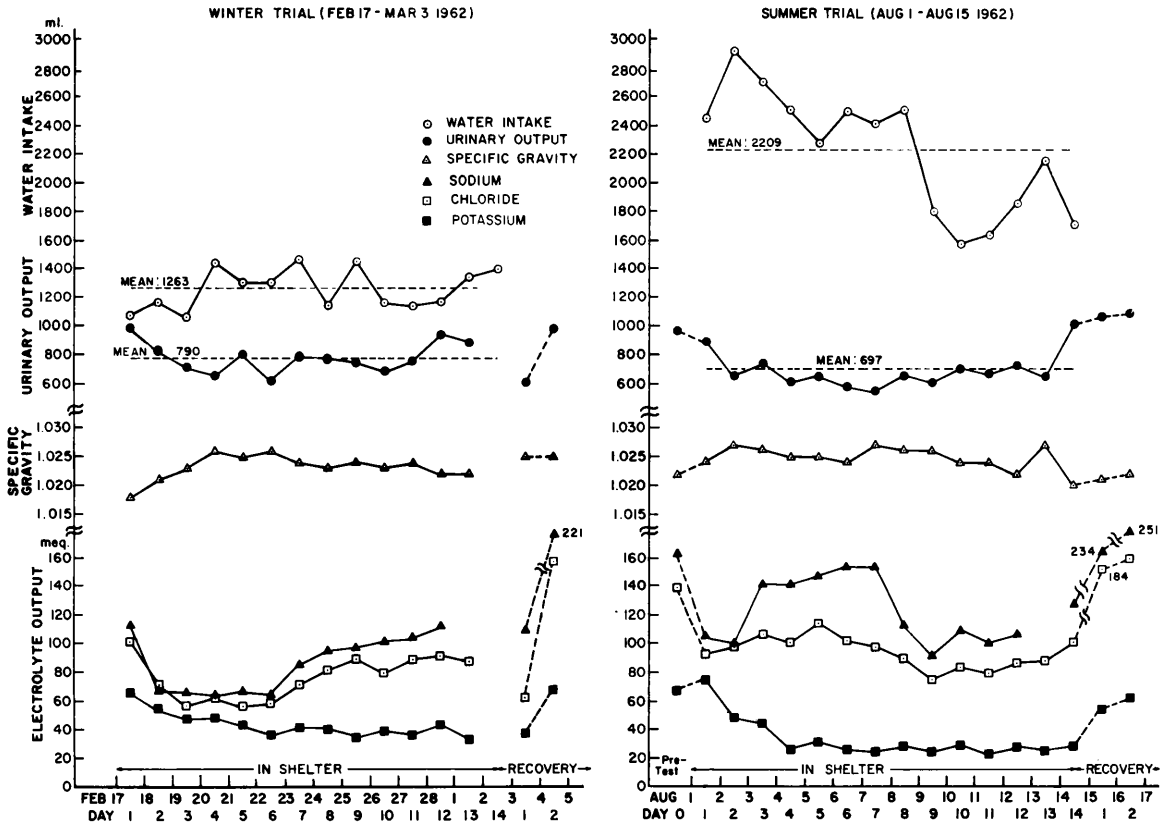

Fig. 45 - Water intake and urinary output (per 24 hr) of water and electrolytes in 24 subjects of the shelter habitability study, NNMC, Bethesda, Md.

Physical Fitness - Tables 39 and 40 are summaries of measurements on physical fitness using the AMRNL modification of the Harvard step test for the 24 water-balance subjects (for age, weight, and height see Table 33). During the winter physical-fitness scores obtained on Feb. 15 and 16, prior to entering the shelter, do not differ significantly from those obtained immediately after the subjects left the shelter on Mar. 3. It is interesting to note, however, that the 1-minute postexercise pulse rate recorded on Feb. 15 is significantly lower ($p < 0.01$) than on Mar. 5. The basis for the lower rate on Feb. 15 as compared with the rate on Mar. 3 and Mar. 5 is not apparent. Observers state that motivation seemed appreciably higher after the shelter confinements than 2 days later. On the other hand, motivation is a factor more likely reflected in the duration of stepping rather than in the pulse rate. It is interesting to note that statistically no significant differences are evident in the summer trial.

DISCUSSION

Physiological tests in these two trials were designed primarily to measure strain on thermoregulatory mechanisms, including water and electrolyte balance, resulting from stresses imposed on shelterees by the thermal environment. It was expected, however, that significant effects of heat on these physiological measurements would not be encountered in the winter trial. Rather, data from the winter trial were considered as being useful mainly in providing baselines for measurements to be obtained in the summer trials during which heat stress was expected to be a severe, and possibly limiting, factor in shelter habitability. Analyses of the results of the winter trial, however, indicate that

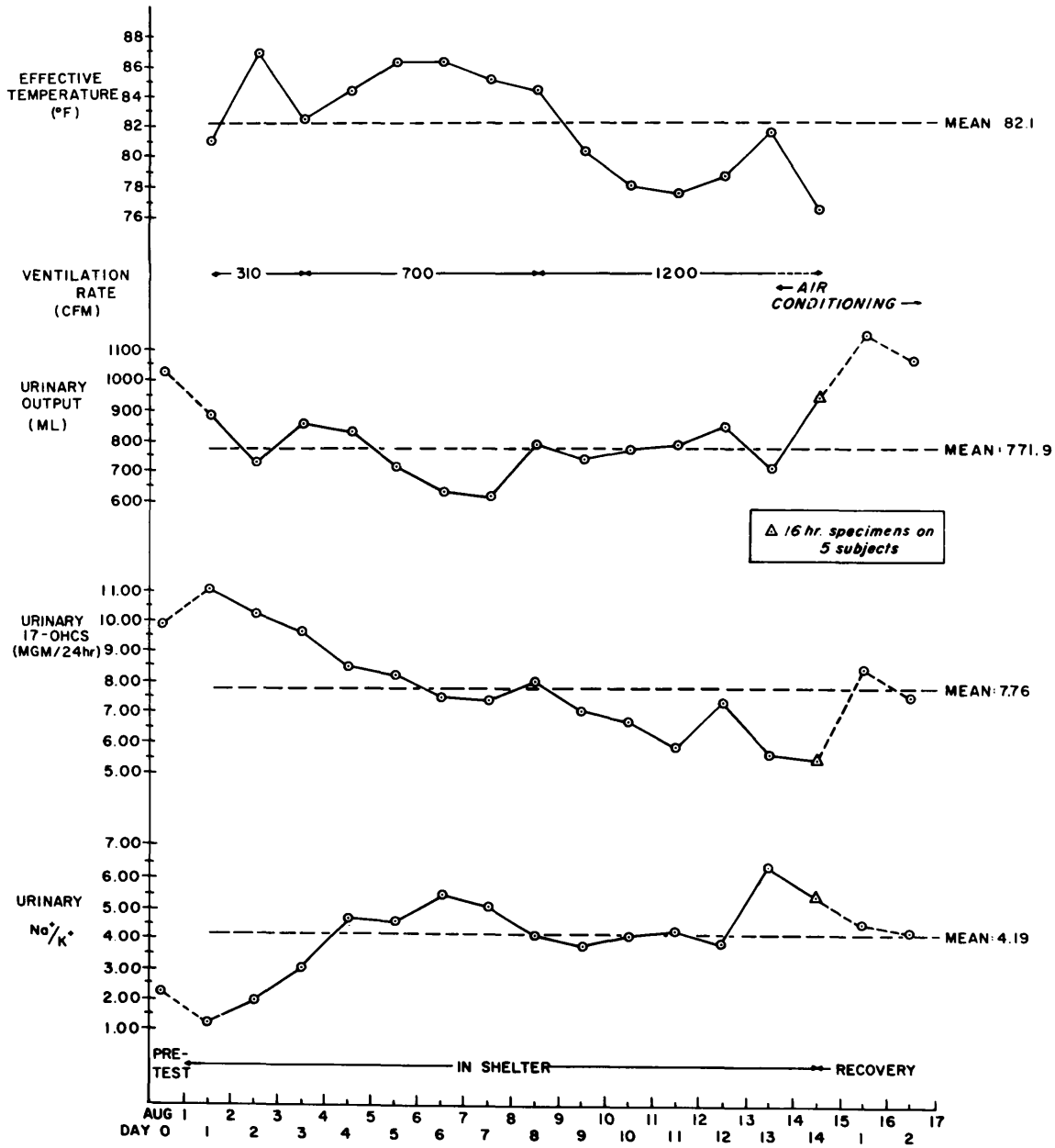

Fig. 46 - Mean daily urinary output, 17-hydroxycorticosteroid, and sodium-potassium ratio in 13 subjects and effective temperatures within shelter during 2-week summer shelter habitability study, NNMC, Bethesda, Md., Aug. 1 - Aug. 15, 1962

increases in heart rate, oral temperature, water intake, and urinary specific gravity with decreases in urinary output of water and electrolytes, while of minor degree, did occur as the ambient temperature rose during the first week, reaching a maximum effective temperature of 78°F. These levels of environmental heat up to 78°F ET are within the so-called "comfort zone" of the ET scale and are easily tolerable indefinitely. Subjectively, feelings of chilliness during the 2-day winter trial and during the first 2 or 3 days of the 2-week winter trial proved to be a greater source of discomfort than heat.

In contrast to the comfortable thermal environment which prevailed throughout most of the winter trial, environmental heat was a stress factor of major importance

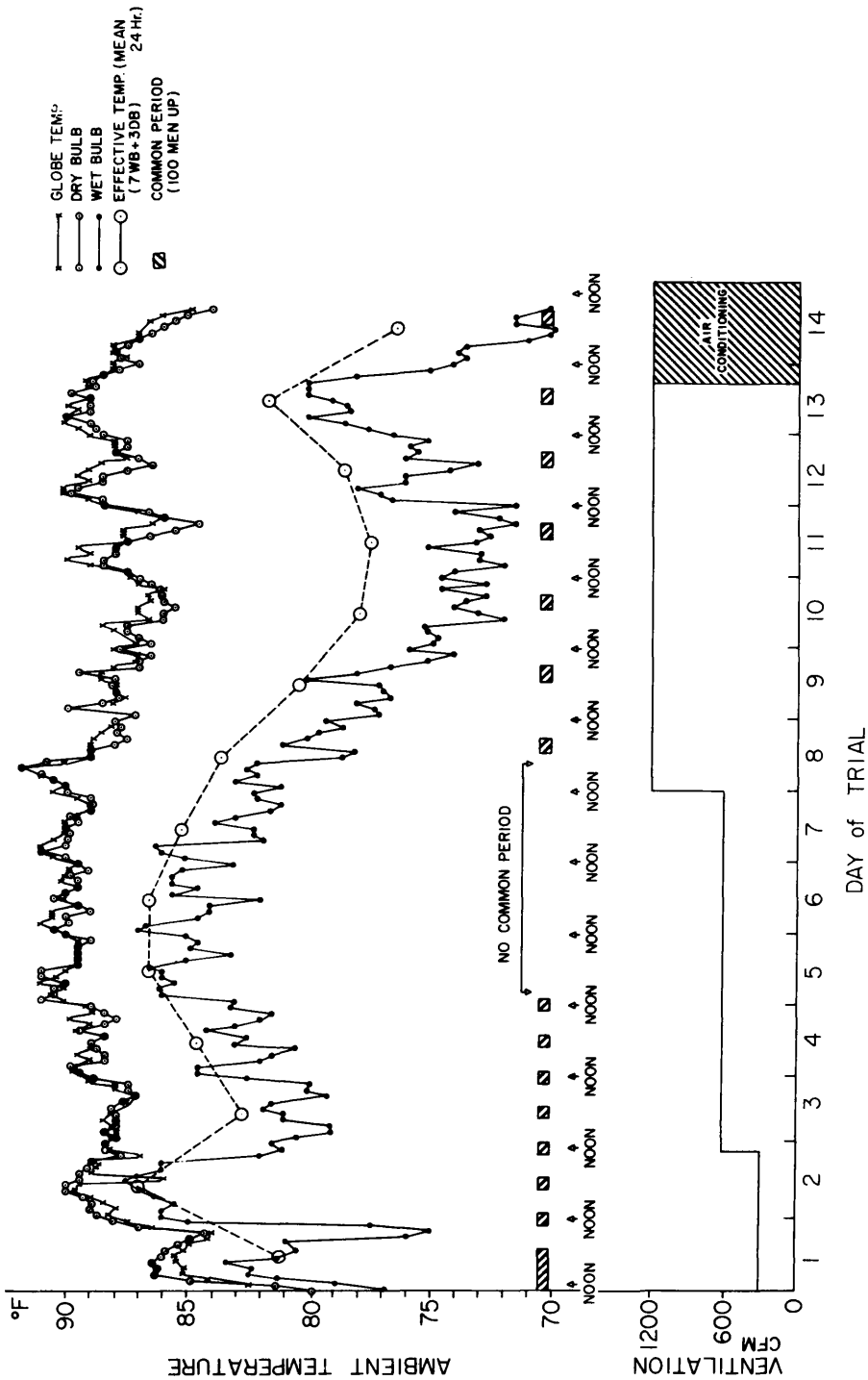

Fig. 47 - Temperature, activity schedule, and ventilation rate in summer shelter habitability trial, NNMC, Bethesda, Md., Aug. 1 - Aug. 14, 1962

during the summer trial. The mean daily ET for the 2-week period measured in the forward medical area was 82°F. During the first 7 days, indeed, the mean ET was 85°F with peaks up to 89°F (Figs. 43 and 47). Significant correlations between ET and water intake, sweat rate (as indicated by extrarenal water loss), heart rate, and body temperature were observed.

Direct measurement of sweat evaporation indicated the true nature of the problem. Although nearly every subject during the first week displayed a skin which was constantly beaded or running with sweat, the rate of sweat evaporation was relatively low, being only 50 percent greater than during the winter trial. Thus, the major environmental factor contributing to the discomfort was the high ambient water-vapor pressure which prevented efficient evaporation. The high water-vapor pressure also manifested itself by condensation of moisture on the bulkheads and deck of the shelter, the temperatures of which were below the dew point of the atmosphere. The continuous presence of residual sweat on the skin led to a high incidence of heat rash (34 percent). New cases of heat rash continued to appear, and treatment was relatively ineffective until the mean daily ET dropped below 82°F on day 8, thus largely confirming earlier studies conducted at the Naval Medical Research Institute in which 82°F ET at high humidity was found to be the threshold for occurrence of heat rash (7).

In normal environments (air temperature 68°F and 50 percent relative humidity) the lightly clothed subject at rest dissipates approximately 75 percent of his metabolic heat production by radiation to cooler surfaces and by convective loss to cooler air, the remaining 25 percent being lost by insensible evaporation of moisture from the skin and respiratory tract (6). The latter amounts to 30 g/hr in the individual of average size with normal resting metabolism. As environmental temperatures rise, progressively less heat is lost by radiation and convection, body heat balance being maintained, first, by an increase in blood flow to the skin thus increasing the temperature gradient between the body surface and the environment (vasomotor regulation) and, second, by evaporation of increasing quantities of moisture secreted on the skin as sweat (evaporative regulation).

One would therefore predict that evaporative sweat rate, and water intake as well, would increase as a function of ambient temperature (7) and would be independent of ambient water-vapor pressure up to the point that the skin became completely wetted. Under conditions which limit evaporation, the skin does become completely wetted, sweat is not completely evaporated, heat is stored in the body, resulting in a rise in core temperature, and heat balance can be re-established only by further elevation of skin temperature.

In the summer trial air temperature was only moderately elevated and varied within a relatively narrow range of 88°F to 90°F during the first week, with occasional peaks as high as 92°F. The major environmental factor contributing to heat stress, as stated above, was the high water-vapor pressure which reflected itself in the wet-bulb temperatures (Fig. 47) which, in contrast to the relatively stable dry-bulb temperature, ranged upward to peaks of 86 to 88°F WB during the period of maximum stress, dropping to levels as low as 70°F during the second week. Peaks in the wet-bulb temperature tended to occur when both sections were up, as a result of increased metabolic heat production of the occupants, the added heat of metabolism being dissipated into the ambient atmosphere largely as insensible heat (water vapor).

Of the estimated 2000 kcal produced per day per man, measurements of evaporative weight loss while waking and estimates of evaporative loss while asleep (Table 37) suggest that as a mean for the 2-week trial slightly more than 50 percent of the total calories produced were dissipated by evaporation and the remainder through radiation and convection. The losses of water were not constant, however, as indicated by the difference between mean daily water intake and mean urinary output (Fig. 45). Because urinary

output was relatively constant, as were water gains from other sources, extrarenal water loss, which is largely represented by insensible evaporation and sweating, is thus closely correlated with water intake which in turn shows a high correlation with both ET and wet-bulb temperature. Since dry-bulb temperature during the trial was fairly constant, these relationships suggest that water intake and, therefore sweating, varied with ambient water-vapor pressure. The implication of the relative constancy of ambient air temperature is that heat loss by radiation and convection varied relatively little during the entire 2 weeks; thus, the conclusion one reaches is that the heat loss per gram of sweat produced varied inversely with the ambient water-vapor pressure.

To analyze specific data in support of this view, one can compare extrarenal water loss on day 3 and day 12 and from this comparison derive the factor of efficiency for heat loss by sweating. The mean air temperature on both days was close to 88°F. Therefore, as a first approximation, heat loss by radiation and convection on each of these days would be equal. The humidity, on the other hand, was higher on day 3 than on day 12, resulting in a mean daily ET of 83°F on day 3 compared with 79°F ET on day 12. From data of Gagge, et al. (6), heat loss by radiation and convection at an ambient temperature of 88°F is estimated to be 1100 kcal/day for a man of average surface area (1.8 m^2). If one assumes that the average shelter subject produced 2000 kcal/day, the heat remaining which must be dissipated by evaporation to maintain heat balance is therefore 900 kcal. By reference to Figs. 43 and 45 and Table 37 one can estimate 24-hour sweat loss as the total water gains for each day minus urinary and fecal losses. This loss closely approximates 2500 g for day 3 and 1600 g for day 12. The calories lost per gram of sweat can then be estimated as follows:

$$\text{day 3} \qquad \frac{900}{2500} = 0.36 \text{ kcal/g}$$

$$\text{day 12} \qquad \frac{900}{1600} = 0.56 \text{ kcal/g}$$

The latent heat of evaporation of water at 33°C is 0.58 kcal/g. Therefore, the factor of efficiency for evaporation is 62 percent on day 3 and 98 percent on day 12.

Another interpretation of the observed data might be that the metabolic rate was higher on day 3, requiring a greater amount of sweat to be evaporated than on day 12. Observations both from within the shelter and by television monitor indicate, on the contrary, that spontaneous activity seemed suppressed during the first week when heat stress was higher. One can assume, therefore, that, if anything, metabolic rate was less on day 3 than on day 12. Another interpretation of the observed data might be that radiative losses were not the same but less on day 3 than one day 12. Again, observations do not support this interpretation. On day 3 black-globe temperature readings taken at a height of 6-1/2 ft from the deck were, on the average, about 1/4 degree below air temperature on day 3 and about 1/2 degree above air temperature on day 12. The reason for this difference seems clear. While temperatures of the wall up to a height of 7 ft and the temperatures of the deck remained below air temperature throughout the trial, the temperatures of the wall and deck gradually rose, the temperature differences between wall and air becoming less with time. Thus, on August 5 the deck temperature in the medical area was 79.5°F and on August 11 it was 82.5°F. The explanation for the fact that the globe temperature exceeded air temperature in the latter part of the trial, even though deck and wall temperatures remained below air temperature, is explained on the basis that an important factor contributing to the mean radiant temperature of the environment was the skin surfaces of the occupants which were warmer than air temperature. With the data in hand it is not possible to estimate the extent to which transfer of heat by radiation from the skin of an occupant to cool walls and the deck was blocked by the presence of warm bodies of the other occupants. It is certain, however, that radiant heat loss was not less on day 3 than on day 12 but instead was greater

because of the lower mean radiant temperature early in the test. Any correction for differences in heat loss by radiation on day 3 and day 12 would thus lead to a lowering of the factor for evaporative efficiency on day 3.

The air supply, on the other hand, was twice as great on day 12 as on day 3. Although the mean dry-bulb temperature was essentially the same, the increased volume of air would in effect double the directional component of air velocity and thus increase convective heat loss. The extent to which this increased air supply might explain the difference in total sweat loss needs to be examined.

The cross-sectional area of the shelter is estimated to be 200 ft^2. The directional component of air velocity at 600 cfm would thus be 3 fpm, and at 1200 cfm the directional component of velocity would be 6 fpm. Although actual measurements of air flow were not made, it appears likely that any differences in heat loss resulting from this difference in directional flow would be small compared with nondirectional air movement caused by natural convection at the skin surfaces of the subjects and that resulting from the convection currents created by differences in wall and air temperatures in the shelter.

Under ideal conditions in the laboratory with wall and air temperatures equal, nondirectional air movement leading to heat loss by natural convection is not less than 25 fpm. It can be assumed that in the shelter nondirectional air movement was at least 50 fpm, even at the lowest air supply. Therefore, doubling the air supply from 600 to 1200 cfm would not double the effective air movement but in effect would add 3 fpm to the directional component. The overall air movement, both directional and nondirectional, would thus increase only from 50 fpm to 53 fpm.

Applying a recently proposed expression for convective exchange (8), one can estimate heat loss by convection for a 95°F skin temperature as follows:

$$C = 0.27\ V^{0.6}\ (Ta = 95),$$

where C = heat loss by convection (kcal/hr)

V = air velocity in fpm

Ta = air temperature in °F.

If, as assumed, air velocity was 50 fpm on day 3 and 53 fpm on day 12, heat loss by convection is found to be 20 kcal/hr on day 3 and 21 kcal/hr on day 12. This difference of 10 percent cannot explain the 35 percent greater sweat production on day 3. Moreover, because of the lower effective temperatures, skin temperature on day 12 was probably closer to 93°F than to 95°F. Heat loss by convection on day 12, based on the lower skin temperature, would be 15 kcal/hr instead of 21 kcal/hr.

As indicated earlier, it had been predicted that water requirement would vary with dry-bulb temperature (7). In the summer trial, on the contrary, sweating as indicated by water-balance studies showed a poor correlation with dry-bulb temperature but a high correlation with effective temperature (0.7 WB + 0.3 DB) or with wet-bulb temperature alone. In view of the foregoing discussion, it is evident that this relationship cannot be explained on the basis of differences in metabolism or differences in rates of heat loss by radiation and convection. Therefore, the initial assumption appears to be valid, namely that in the summer trial heat loss per gram of sweat produced varied inversely with the ambient water-vapor pressure. At the low ambient water-vapor pressure represented by day 12, the heat loss per gram of sweat approximates the theoretical value of 0.58 kcal/g. At the moderately elevated water-vapor pressure represented by day 3, the estimated heat loss per gram is only 60 percent of this value. At the higher water-vapor pressures observed in the summer trial it would be even less. This change in efficiency can be explained if all the sweat formed is not evaporated on the skin but

drips off or is wiped off. Low efficiency of evaporation might also occur if evaporation takes place from clothing surfaces not in immediate contact with the skin. Whatever the explanation, it is evident that water allowance based on coefficients of heat loss which are now generally accepted by physiologists will underestimate water needs if conditions prevail such as those which existed in the summer trial.

In the shelter-occupancy tests conducted at Camp Parks (9), average daily water intake during the trial in December 1959 was 1860 cc, and the average daily urinary output was 1100. During the period from December 3 to December 17, the ET ranged from a minimum of 62°F to a maximum of 74°F with daily means ranging from 68°F to 70°F ET. This mean ET is comparable to conditions in the winter trial reported here. In the 5-day summer-occupancy trial at Camp Parks (July 25-29, 1960)(10) the average daily water intake was 2500 cc with a urinary output of 700 cc. Our mean values for the 2-week summer trial are closely comparable. In the Camp Parks trial, on the other hand, the maximum ET was 81°F. In the summer trial reported here the mean ET for the 2 weeks was 82°F with occasional readings during the first week as high as 89°F ET.

Therefore, the observations made here relating water intake and sweating to high ambient vapor pressure cannot be compared with the Camp Parks trial in which humidity was considerably lower. In three 1-week trials and one 2-week trial reported by the American Institute of Research (AIR)(11) groups of 30 subjects of both sexes and varying in age were exposed to "hot" conditions (up to ET of 85°F) during one of the 1-week trials and during the first week of the 2-week trial. The periods of maximum heat stress were relatively brief and the wet-bulb temperature did not exceed 79°F. Hence, the water-vapor pressure was considerably lower than during the first week of the summer trial reported here in which the wet bulb exceeded 80°F during essentially the entire period, with peaks to 88°F. Although water balance was not measured in their subjects, the AIR investigators report that during periods of heat stress up to 85°F ET, profuse perspiration was evident with behavioral responses characterized by reduced activity, removal of shirts and undershirts, and verbal complaints. In pilot studies of short duration with ET up to 86°F, subjects also reported headache and nausea, and there was elevation of body temperature.

In the first week of the 2-week AIR trial there was some indication that tolerance to heat improved with time, but the evidence for this tolerance was regarded as unreliable. Also, the heat seemed to be better tolerated in the group undergoing the test in June than in a similar group tested in the heat earlier in the year, suggesting that acclimatization already acquired may have been a factor. The group in June, however, had good leadership whereas the other group did not. Of 21 comfort factors graded subjectively, heat and humidity ranked first in the two AIR tests in which shelter temperatures were elevated. The authors support the recommendations by OCDM and by Yaglou (12) that ET in shelters should not exceed 85°F.

In the summer trial reported here, there was no indication that tolerance to heat improved with time. Physiological responses, including heart rate, oral temperature, and sweating, were proportional to the degree of heat stress not only early in the trial but also during the terminal buildup of heat during days 11, 12, and 13 (see Fig. 42). Moreover, the cases of heat exhaustion reported in the chapter on the medical aspects occurred during the middle period as heat approached the second maximum, rather than during the initial peak of heat stress (day 2).

Although acclimatization to heat can be acquired as effectively under hot, humid conditions as in dry heat, it had been generally agreed that a subject does not acquire heat tolerance through heat exposure alone but only if he also performs work (13,14). Recently Fox and his collaborators (15) have demonstrated that controlled hyperthemia in resting subjects to levels of oral temperature of 99.14°F (37.3°C) or higher for periods varying from 1/2 to 2 hours a day for 12 days results in acclimatizing responses as indicated by a significant increase in sweat rate. There is, however, little indication of

improved cardiocirculatory efficiency. Tolerance to the elevated temperature did not improve but instead deteriorated during the period of treatment.

Mean oral temperatures in the summer trials did not exceed 99°F (37.2°C), although these temperatures were taken on arising and doubtless increased during activity. In view of the lack of exercise, however, and the relatively small elevation of internal temperature in our subjects, it is reasonable to assume that significant levels of heat acclimatization were not acquired. This assumption might explain earlier observations by others (16) in which subjects who worked several hours each day appeared to tolerate continuous exposure to heat at levels of 85°F ET for 30 days with less difficulty than subjects in the summer trial reported here.

Work at levels of sufficient intensity and for sufficient duration to improve heat tolerance is probably not a feasible procedure in 100-man shelters under summer conditions, because the increased metabolic heat output would substantially increase the environmental heat load, thus offsetting what advantage might derive from improved physiological tolerance to heat.

Although tolerance to heat did not appear to improve with time, physiological responses of an adaptive character were, nevertheless, evident in the urinary output of 17-hydroxycorticoids and in the urinary Na^+/K^+ ratio (Fig. 46). The decline in urinary 17-OHCS with time after entering suggests that the increase between pretest and day 1 represented an adrenal cortical activation in response to stress. That the stress agent was not heat seems apparent from the lack of association between urinary 17-OHCS and mean daily ET. Instead, stress caused by anxiety may have been an important factor, which diminished with time as the subjects became accustomed to the new environment. The close inverse relationship between urinary 17-OHCS and urinary Na^+/K^+ suggests that blood levels of adrenal corticoids act to increase sodium reabsorption from the renal tubules in exchange for potassium.

SUMMARY AND CONCLUSIONS

1. Indices of physiological strain under heat stress in these shelter studies included oral temperature and pulse rate on arising, sweat rate, and the intake and excretion of water and electrolytes.

2. In the winter trial small, but statistically significant, differences were observed between water intake, pulse rate, and oral temperature in the 96 test subjects during the period of maximum temperature on day 7 (78°F ET) as compared with cooler periods before or after day 7. Mean daily water intake in the winter trial was 1313 ml and total water gains, including that in food and tissues, was 1858 ml. Mean daily urine volume in the winter trial was 790 ml, and total daily losses of water were estimated to be 2090 ml.

3. No significant changes were observed before and immediately after the winter trial in test scores of 24 subjects performing a Harvard step test for physical fitness. This result was also true of the summer trial.

4. In the 2-week summer trial all indices of heat strain were significantly higher than in the 2-week winter trial.

5. From August 1-14, 1962 the mean daily ET based on readings taken every 2 hours in the forward medical area of the shelter was 82°F. The mean daily ET for the first week was 85°F.

6. The following measures showed the following coefficients of correlation with mean daily ET: water intake, r = 0.9121; heart rate, r = 0.7757; oral temperature, r = 0.9345.

7. Water intake showed a higher correlation with wet-bulb temperature than with ET (water intake vs wet-bulb temperature, r = 0.9389).

8. Mean daily water intake for 92 subjects in the summer trial was 2272 ml with estimated total water gains of 2795 ml. Mean daily urinary volume was 697 ml in 24 subjects with total water losses estimated to be 2708 ml.

9. Mean daily sweat loss in the summer trial was estimated to be 1900 g compared with 1200 g in the winter.

10. The high correlation between water intake and ET (or wet-bulb temperature) was an unexpected finding because it had been predicted that water intake (and sweat rate) would vary with dry-bulb temperature.

11. The high correlation between water intake and wet-bulb temperature (r = 0.9389) and the low correlation with dry-bulb temperature (r = 0.5420) indicates that in this trial efficiency of evaporative cooling of the body varied inversely with ambient water-vapor pressure.

12. By way of example, mean daily dry-bulb temperature on day 3 (high humidity) and day 12 (low humidity) were essentially the same (88°F), but because of the difference in humidity the ET was 83°F ET on day 3 and 79°F ET on day 12. Sweat loss was estimated to be 2500 g on day 3 and 1600 g on day 12.

13. If one assumes heat loss by radiation and convection to be the same on both days as indicated by nearly equal dry-bulb temperatures, then the heat loss per gram of sweat was 0.36 kcal on day 3 and 0.56 kcal on day 12. This difference in efficiency of evaporative cooling is real and not a result of differences in metabolic rate, wall temperature, or air movement on the 2 days.

14. It thus appears that water intake under shelter conditions observed in these trials cannot be predicted from air temperature alone. Wet-bulb temperature is a better index of water requirements than dry-bulb temperature.

15. There was no evidence that the subjects in these trials became adapted to heat. In fact, there were indications that heat tolerance was lower at the midpoint in the trial than at the beginning.

16. Our results do not provide evidence that healthy, but physically inactive, young men can tolerate heat stress at levels of 85°F ET for 2 weeks because exposure to heat stress at this level lasted only 1 week. Medical problems resulting from heat rash and heat exhaustion reached a peak at the end of the first week and subsided during the second week as ambient water-vapor pressure declined.

17. In the summer trial urinary excretion of 17-OHCS exhibited an initial elevation followed by a gradual decline, suggesting a response to stress followed by adaptation. The sodium-potassium ratio was inversely related to the urinary 17-OHCS. That heat stress was not the principal factor in adrenocortical activation was evident from the lack of correlation between output of urinary corticosteroids and the mean daily ET.

18. Supplementary salt was given to all except selected test subjects throughout the summer trial. The selected subjects received no supplementary salt from day 8 onward. Although no signs of salt deficiency were evident at any time, it cannot be concluded that

supplementary salt is unnecessary, because all subjects received supplementary salt during the period of maximum heat stress (days 1-7).

19. It is concluded that the physiological stresses of shelter living can be tolerated for 2 weeks by healthy young men under winter conditions (max. ET = 78°F) and under summer conditions (mean ET = 82°F) with diet, water, and salt intake as provided in these trials.

20. Although laboratory experiments reported by others indicate that acclimatized men can tolerate exposure to heat levels of 85°F ET for 2 weeks or more, the recommended allowance of heat levels up to 85°F ET for 2 weeks of habitation in shelters should not be accepted without further trials using groups of unacclimatized as well as acclimatized subjects.

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CHAPTER 8

PSYCHOLOGICAL STUDIES

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INTRODUCTION

The psychological studies reported here constitute an extension of the research effort carried out in connection with the winter trials. Thus, the present studies were planned to assist in evaluating the engineering habitability of a specific prototype shelter rather than dealing with broad issues of emotional and behavioral response to shelter living. Emphasis was placed primarily on identifying and measuring subjective sources of discomfort of importance in evaluating human tolerance to the NAVFAC shelter under conditions of high heat and humidity encountered in the summer trial. Data also were collected on the more generalized psychological or emotional response of subjects in this particular shelter trial. As radical changes in environmental factors also will be accompanied by significant shifts in subjective discomfort, one section of the present report is concerned with relating the psychological results obtained in the summer and winter trials.

The procedures used in this study were substantially the same as those previously employed; however, two of the objectives included in the winter study were omitted from the summer trial. In the winter trial it had been considered necessary to establish that subjects were sufficiently in agreement in their evaluation of discomfort sources that some generalization of results across individuals could be made. Analysis of the winter trial data indicated that this objective was met. Inasmuch as the same measuring instruments were used in the summer trial and the subjects were drawn from the same general population as those in the winter trial, the objective was not repeated in the present study.

A second objective omitted in the summer trial involved determination of the relationship between relative subjective importance of discomfort factors as anticipated prior to shelter entry and as experienced after several days of shelter occupancy. Analysis of the winter data indicated that subjects were strikingly accurate in predicting the rank order of discomfort actually experienced during the shelter trial. Again, because the subjects for both trials were drawn from the same population pool, it was considered unnecessary to include this objective in the present study.

OBJECTIVES OF PRESENT STUDY

The objectives of the summer study were as follows:

1. To determine the relative importance of various sources of psychological discomfort, in terms of both "acuteness" and "generality" of discomfort. "Acuteness" refers to discomfort approaching the limits of individual tolerance, regardless of the frequency with which experienced during the test period. "Generality" refers to discomfort which is present and noticeable over prolonged periods of time but does not necessarily approach limits of human tolerance.

2. To determine the relationship between relative subjective importance of discomfort factors as experienced during the earlier and later phases of shelter occupancy.

3. To determine the significance of the interaction* between and among discomfort factors and other variables which appear of major importance in protective shelter habitability.

4. To provide, through diaries and debriefing, (a) information of a more qualitative or comprehensive nature about the discomfort sources found to be most important to the subjects and (b) Information on emotional or psychological factors, not assessed by discomfort scales, which could be significant in shelter habitability.

5. To determine differences in psychological response to discomfort factors between the summer and winter trials, in terms of:

(a) Changes between trials in response to individual discomfort factors in terms of discomfort acuteness and generality during earlier and later phases of shelter occupancy. For example, on day 12 of the winter study "crowding" as a discomfort factor received a mean acuteness rating of 2.95; therefore, the question is considered: "Did discomfort attributable to crowding remain at this level during the summer trial, or did it significantly increase or decrease?"

(b) Changes between within-trial relationships among discomfort factors, acuteness and generality of discomfort, and earlier and later phases of a given shelter trial. An example of the type of question which might be asked under this objective would be: "In the winter study, lack of water for washing produced significantly more acuteness of discomfort on day 12 than on day 2; therefore, does this same kind of relationship appear to hold in the summer trial?"

(c) Interactions between and among discomfort factors and other variables over the two seasons.

METHOD

Data for the present study were collected through the use of a discomfort rating scale, debriefing interviews, and personal diaries. The rating scale, which contains Likert-type items, was designed to assess 13 specific psychological discomfort factors. Ratings are obtained on each factor both for "acuteness" and for "generality" of discomfort. The scale permits a rank ordering of the discomfort factors in terms of their relative importance and a statistical evaluation of the significance of difference between the ranks. Development of the scale is described in Appendix B.

PROCEDURE

The discomfort scale was administered on day 2 and day 12 of the shelter trial, which permitted assessment of psychological discomfort at two different intervals during the trial as well as providing information on shifts over time in response to the discomfort indices. Within a given administration of the scale, a counter-balanced presentation of the acuteness and generality sections was used to offset possible biases from order in presentation. Thus, at each administration half of the subjects received the acuteness section followed by the generality section, and the remaining subjects received the sections in the reverse order.

* An explanation of interaction and examples of its meaning are given in Chapter 8, page 93, of the report on the winter trial.

Fig. 48 - Men assembled after coming out of shelter and just prior to debriefing interviews

The debriefing interviews were conducted immediately after the subjects left the shelter. The men were interviewed for a period of 1 hour in groups containing from four to seven men by psychiatrists and psychologists from the Naval Hospital, Bethesda, and NMRI.

RESULTS

As in the winter trial, data obtained from the 2-week summer trial made it possible to accomplish all of the objectives set forth above.

Figure 49,* derived from Table C2 (see Appendix C), presents a list of the 13 discomfort factors used in the Likert-type scale, along with their summary values obtained by combining the measures of acuteness and generality obtained on the second and twelfth days of the trial. As will be noted, the five leading sources of discomfort in the summer trial were lack of water for washing, temperature and humidity, food, crowding, and dirt. This is, of course, a summary finding, and the rank order among these five factors did differ between the two administrations of the scale as well as between the acuteness and generality sections of the scale. However, apart from such shifts in rank order, these same five factors led the list, irrespective of scale sections and time of scale administration. Thus, it may be concluded with reasonable confidence that these five factors were those among the 13 measures which consistently produced the most discomfort during the summer trial.

With regard to clustering† of factors, Fig. 49 indicates that lack of water for washing, temperature and humidity, food, and crowding did not cluster. That is, from the statistical

*In all figures representing data from the summer shelter trial, it will be noted that the abscissa is scaled in terms of both "true mean score" and "mean divided by two." This dual scaling arose from the analysis of summer trial data by a computer program which differed in some respects from the program used for winter-trial-data analysis. "True mean score" refers to summer trial means as printed out by the computer, which does not allow comparison with winter trial means.

†An explanation of the significance of clustering is given in Chapter 8, page 85, of the report on the winter trial.

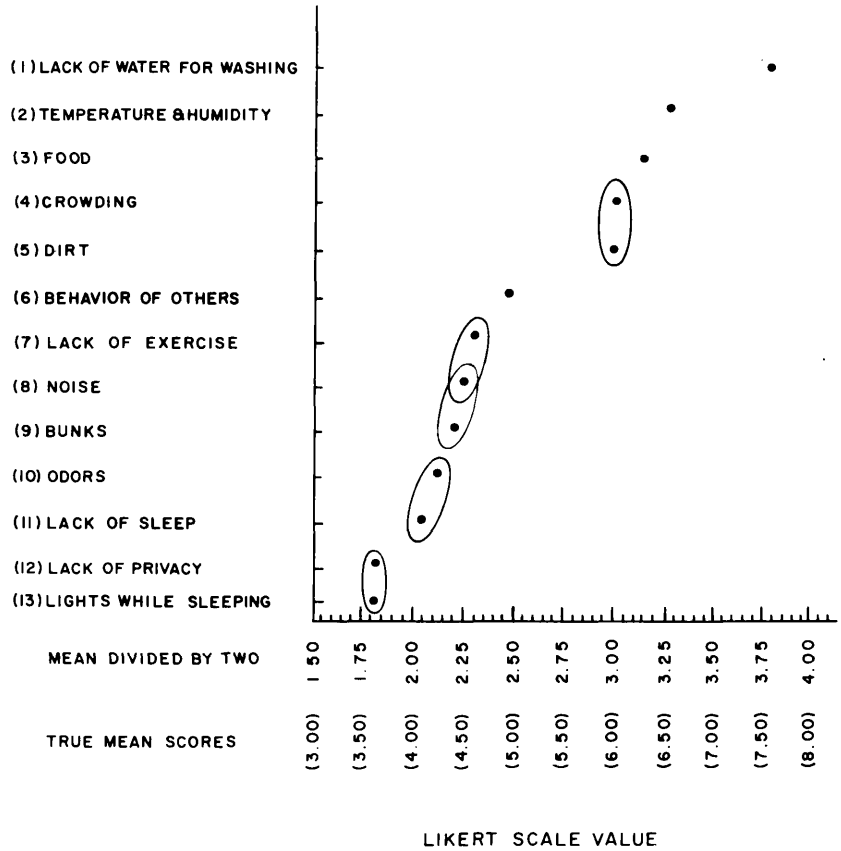


Fig. 49 - Mean scores of discomfort factors based on acuteness and generality with measures from day 2 and day 12 combined, summer trial

standpoint, these four factors differed significantly from one another, in the order indicated, as concerns overall discomfort produced. Crowding and dirt did cluster and so did not show other-than-chance differences from each other as sources of discomfort, but both produced significantly more discomfort than behavior of others. Interpreting the clustering of the remaining factors in this same manner, it is evident that significant differences existed between behavior of others and lack of exercise, between bunks and odors, and between lack of sleep and lack of privacy, as discomfort sources. The remaining differences sufficed for a rank ordering of factors but cannot be considered to represent genuine or nonchance differences in discomfort produced.

RESULTS APPLIED TO SPECIFIC TEST OBJECTIVES

The Relative Importance of Various Sources of Psychological Discomfort in Terms of Both "Acuteness" and "Generality" of Discomfort

The reasons for the acuteness-generality distinction are discussed in the winter trial report and will not be detailed here. Basically, however, it is possible that a given discomfort factor may occupy highly similar hierarchical ranks in the acuteness and generality dimensions and at the same time differ significantly in terms of measurable

magnitude of discomfort. This condition did actually exist in the summer trial data, as indicated in Table C1.

Figures 50 and 51, derived respectively from Tables C3 and C4, show the specific locations of these differences on day 2 and day 12 of the summer shelter trial. Wherever these significant differences existed, acuteness of discomfort exceeded generality. On day 2 lack of water for washing, crowding, lack of exercise, behavior of others, lack of sleep, and odors were rated as providing significantly more acute than general discomfort. By day 12, this difference had become insignificant for all of the above six factors except behavior of others. On the other hand, dirt, temperature and humidity, lack of privacy, and lights while sleeping, in addition to behavior of others, were the discomfort factors rated significantly higher on the acuteness than on the generality scale on day 12. The fact that evidence of such differences was adduced lends further weight to the notion that the acuteness-generality distinction is meaningful in evaluating fallout shelter discomfort.

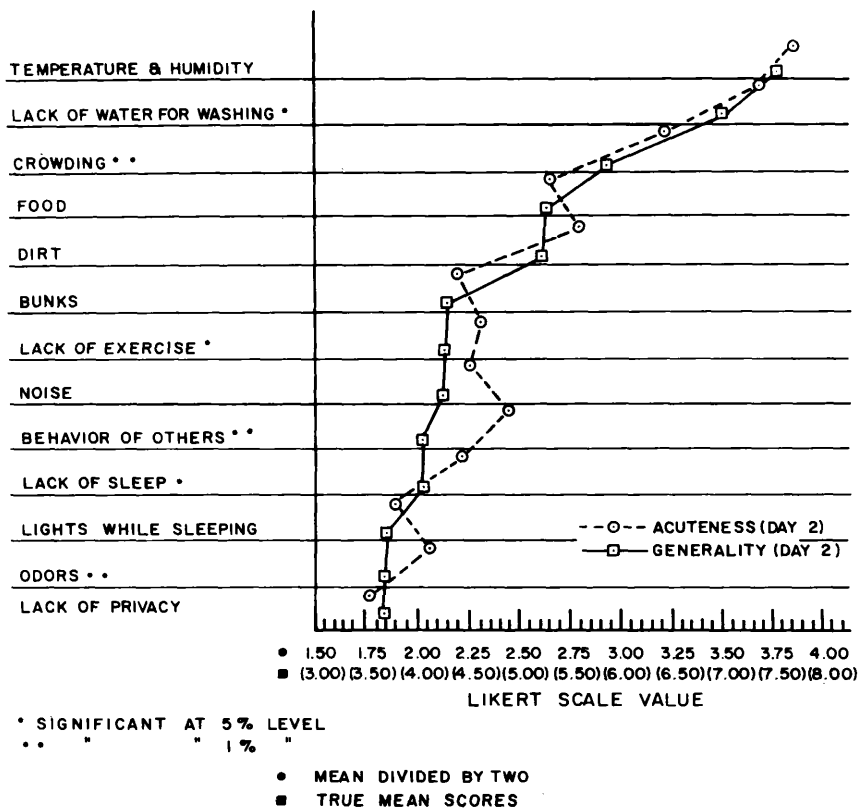


Fig. 50 - Differences between acuteness and generality of discomfort on day 2, summer trial

The Relative Subjective Importance of Discomfort Factors as Experienced During the Earlier and Later Phases of Shelter Occupancy

During the course of shelter occupancy, the discomfort attributable to the several factors measured could have remained constant, could have increased or decreased uniformly for all factors, or could have increased for some and decreased for others.

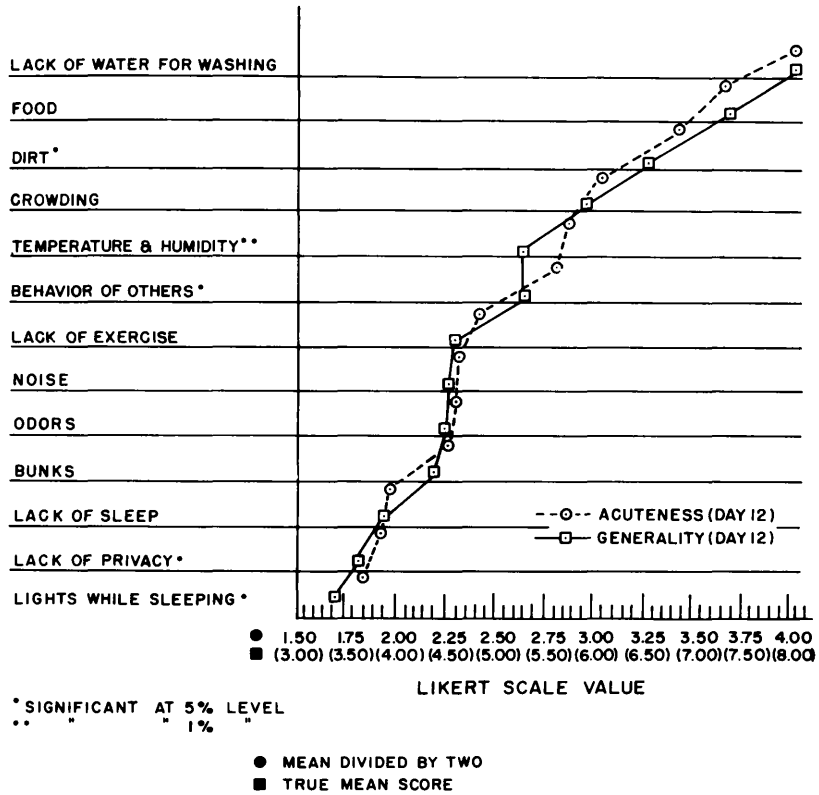


Fig. 51 - Differences between acuteness and generality of discomfort on day 12, summer trial

The third of these possibilities occurred in the summer trial. Table C1 indicates that no significant, uniform changes occurred over time in all discomfort factor means, although there were changes in several factors. The specific locations and nature of these differences, both on the acuteness and on the generality dimensions, are represented in Figs. 52 and 53, derived from Tables C5 and C6. It is apparent that the most extensive change is in discomfort attributed to temperature and humidity. On both the acuteness and the generality scales, this factor dropped virtually a full discomfort scale point between day 2 and day 12. This drop was sufficient to reduce temperature and humidity from first to fifth rank in terms of discomfort, both on the acuteness and on the generality scales. There were two environmental changes which may account for this shift in psychological response. First, there was a marked decrease in the temperature outside the shelter toward the end of the first week. Secondly, the air flow in the shelter was increased from 300 cfm on day 2 to 1200 cfm on day 12. If this inferred causal relationship is real, it can offer reassurance that the paper-and pencil measures used in this study have some validity for the tapping of psychological responses to environmental sources of discomfort.

No factors other than temperature and humidity showed significant decreases on both the acuteness and generality scales over time. However, crowding and lack of sleep were characterized by decreases on the acuteness scale alone. This decrease on the acuteness scale suggests that "peaks" of discomfort attributable to these sources declined with time as adaptation to shelter living occurred but that the general level of associated discomfort did not.

No factor showed an increase on either the acuteness or the generality scale alone, but significant increases were shown on both scales by five factors: lack of water for

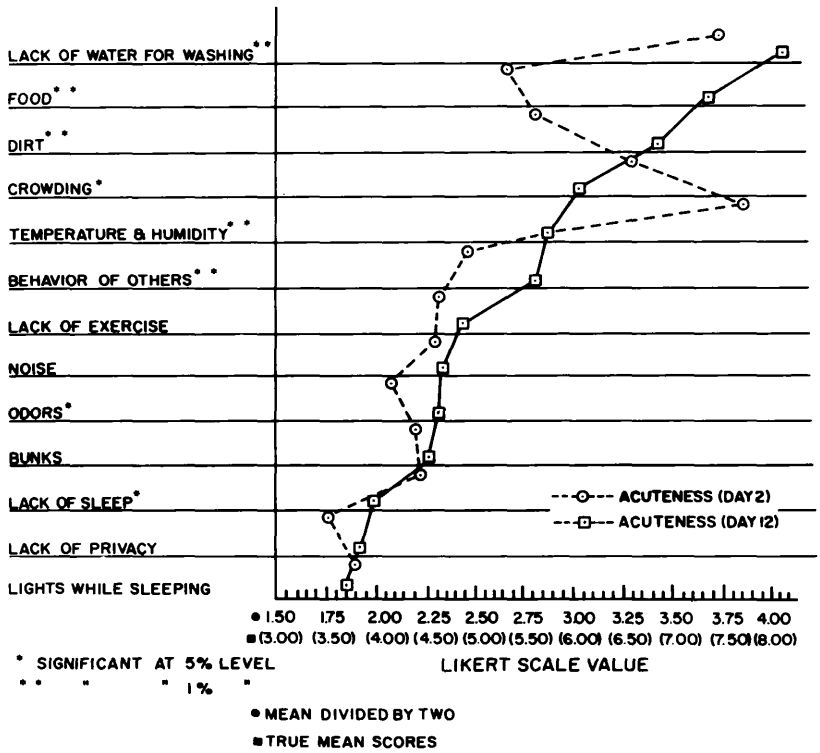


Fig. 52 - Differences in acuteness of discomfort between day 2 and day 12, summer trial

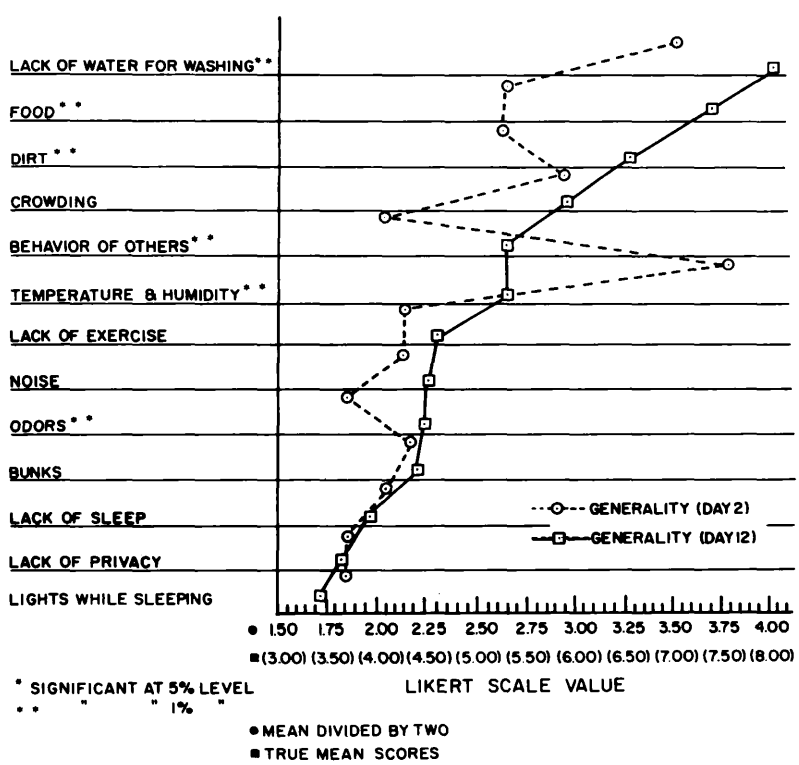


Fig. 53 - Differences in generality of discomfort between day 2 and day 12, summer trial

washing, food, dirt, behavior of others, and odors. Because of the importance of other people and of food in everyday living, the increases in discomfort attributed to these factors are not surprising. However, it is interesting that lack of water for washing, dirt, and odors also showed significant increases. While these factors appear logically related to one another, they would seem also related to temperature and humidity, a factor which showed a significant decrease in discomfort over time. It appears that the marked increase in air flow and decrease in external temperature occurring between day 2 and day 12 did not suffice to offset increased discomfort attributable to lack of water for washing, dirt, and odors.

In any application of the above findings, it should be remembered that they are based on measurement at only two points in the time continuum. Therefore, they do not necessarily represent the minimum and maximum discomfort experienced during the period of shelter occupancy. If, in the future, studies are designed in which subjective discomfort is a prime object of research, discomfort should be measured at least three times, if not more often, in order to determine more precisely shifts in discomfort during prolonged shelter occupancy.

The Significance of Interation Between and Among Discomfort Factors and Other Variables Which Appear of Major Importance in Protective Shelter Habitability

As was noted in the report of the winter study, the individual consideration of discomfort factors, acuteness-generality, and time is justified for purposes of discussion, but such a separation does not fully represent reality. That is, in shelter occupancy by a number of individuals, there are interactions between and among subjects, discomfort factors, and the acuteness-generality of discomfort which may shift over time. Therefore, the influence such combinations of the major variables exert upon the measurement of discomfort also must be considered.

Table C1, in which all possible interaction effects and their respective levels of significance are presented, yields the following interpretations. When combinations of two variables are considered, it is evident that uniformity or agreement among shelterees in their responses to discomfort depended upon (a) the time at which discomfort was measured, (b) the particular discomfort factor tapped, and (c) whether discomfort was measured on the acuteness or on the generality dimension. Similarly, the magnitude of discomfort attributed to a given source depended upon (a) the time at which discomfort was measured, (b) the subjects responding, and (c) whether the discomfort was rated in the acuteness or generality dimension. The only instance of nonsignificance among the two-way interactions indicated that the differences between responses to the acuteness and generality scales were uniform over time, i.e., independent of the time at which the scale was administered.

All of the interactions among three variables were significant. Thus, the extent to which subjects changed their responses over time depended upon the particular discomfort factor being tapped, as well as whether the acuteness or the generality dimension of discomfort was considered. Similarly, the degree to which discomfort attributable to the several factors varied over time and among subjects depended upon whether one viewed the measurement of discomfort on the acuteness scale or on the generality scale.

In summary, it is evident that the relationships among values of any of the four major variables in the present study have limited generalization over the other variables. This limitation indicates that the problem of measuring response to discomfort in fallout shelters is extremely complex. Thus, in discussing subjective discomfort, one must necessarily be quite specific and avoid attempts to generalize without consideration of all relevant variables involved.

Differences in Psychological Responses to Discomfort Factors Between the Summer and Winter Trials

Before proceeding with the discussion of differences in response to discomfort factors between the summer and winter trials, it is noted that it would be inappropriate to combine data from the two seasonal trials. As shown in Table C7, significant differences in discomfort attributable to seasonal effects were obtained. Significant interations between seasons and discomfort factors and among seasons, time of scale administration, and discomfort factors were also obtained. Therefore, combination of data from the two seasonal trials would be quite artificial and misleading, even for purposes of discussion. Further, it would be inappropriate to consider seasonal differences in terms of within trial summary values of each discomfort factor. As was previously noted, such summary values take into account neither differences between acuteness and generality of discomfort nor discomfort changes over time. While use of such values for separate discussion of each seasonal trial is considered to be appropriate, their use for intertrial comparisons departs too far from the actual data to be meaningful.

Differences Between Winter and Summer Trials in Response to Individual Discomfort Factors in Terms of Discomfort Acuteness and Generality During Earlier and Later Phases of Shelter Occupancy

As indicated in Fig. 54, based on Table C8, acuteness of discomfort on day 2 of the summer trial exceeded that on day 2 of the winter trial for eight of the 13 discomfort factors tapped. Moreover, in four of these eight factors, the differences were significant. Lack of water for washing, bunks, temperature and humidity, and odors all were rated

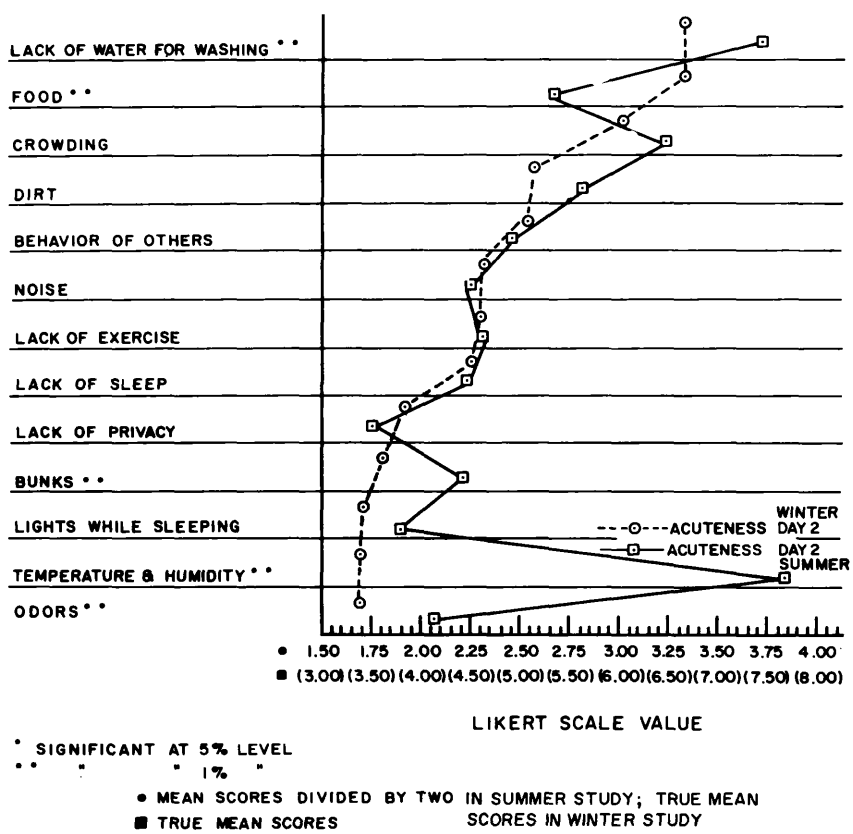


Fig. 54 - Differences in acuteness of discomfort between day 2, winter trial, and day 2, summer trial

as producing significantly more acuteness of discomfort on day 2 of the summer trial than on day 2 of the winter trial. These differences are not surprising if one assumes that, initially at least, discomfort attributable to lack of water for washing, odors, and bunks bears some degree of logical relationship to temperature and humidity. If such an assumption is valid, the extreme of acute discomfort attributed to temperature and humidity could be causally related to and enhanced by the other three significant differences.

Figure 54 also shows that five factors were rated as producing less discomfort acuteness on day 2 of the summer trial than on day 2 of the winter trial. Of these five differences, only discomfort attributable to food was significant. At first this difference appears unusual because the winter trial and summer trial diets were identical. Thus, the decreased discomfort acuteness attributable to food in the summer trial cannot be explained by increased palatability of food. However, it should be noted that the Likert-type scales used to measure discomfort are not ratio scales with a fixed and known zero point but are interval scales with an unknown, perhaps floating, zero point. Because the interval scale is thus not anchored at a fixed known zero point, the range of subjective responsiveness measured by it can shift. In essence, the numerical values of the discomfort factors actually must be considered relative rather than absolute. A shift in zero points appears to have occurred between the winter and summer trials. Thus, the discomfort acuteness mean values on day 2 of the winter trial range from 1.69 to 3.35, while on day 2 of the summer trial, this range was from 1.76 to 3.84. With this kind of shift occurring, a discomfort factor which in fact produced highly similar amounts of subjective discomfort during the winter and summer trials could well receive a lower numerical rating in the summer trial. This shift in ranking is particularly true if it held a rank near the upper end of the scale and if other factors which had held lower ranks during the winter study assumed greater importance in terms of subjective discomfort during the summer study. Thus, the decreased discomfort acuteness attributable to food between trials on day 2 could have reflected an unavoidable artifact stemming from the nature of the scales used. For the present it seems more appropriate to rest upon this kind of explanation than to seek a more esoteric psychological explanation.

As indicated in Fig. 55, which presents data from Table C9, differences in terms of generality of discomfort followed a pattern highly similar to that for acuteness of discomfort. Generality of discomfort on day 2 of the summer trial exceeded that on day 2 of the winter trial for seven of the 13 discomfort factors tapped. In five of these seven factors, the differences were significant, i.e., lack of water for washing, dirt, bunks, odors, and temperature and humidity. Except for dirt, these factors are the same as these showing significant increases in discomfort acuteness. Six of the 13 discomfort factors tapped showed decreases between trials on day 2; however, the only significant decrease was that associated with food. Overall, these significant differences in discomfort generality appear amenable to the same explanation as were offered for the differences in discomfort acuteness.

Differences between trials in terms of acuteness and generality of discomfort on day 12 were similar in many respects to those described above for day 2. As indicated in Fig. 56 and Table C10, increases in discomfort acuteness between trials on day 12 were observed for nine of the 13 factors. However, these increases were significant in only four factors: lack of water for washing, temperature and humidity, odors, and bunks. These were the same four factors showing significant increases in discomfort acuteness between trials on day 2. It seems particularly noteworthy that temperature and humidity showed such an increase. That is, it will be recalled that in the summer trial, temperature and humidity showed a marked decrease in discomfort acuteness between day 2 and day 12. Yet, even with this decrease, discomfort acuteness attributable to temperature and humidity on day 12 of the summer trial significantly exceeded that on day 12 of the winter trial. This pattern of differences highlights the discomfort produced by temperature and humidity in summer fallout shelter living.

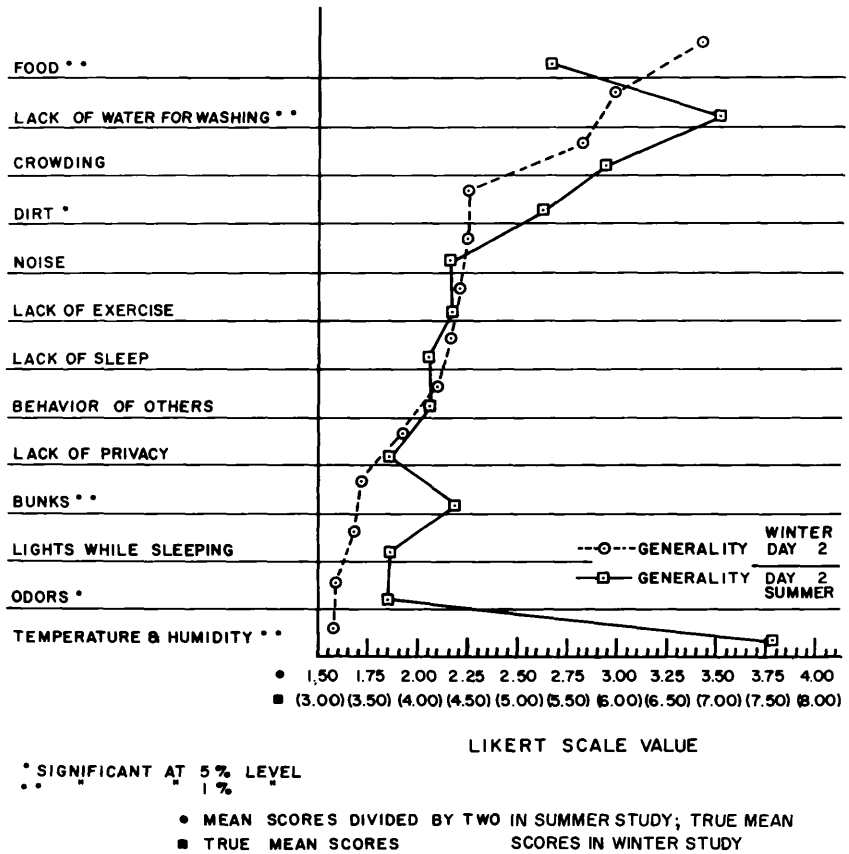


Fig. 55 - Differences in generality of discomfort between day 2, winter trial, and day 2, summer trial

In Fig. 56 it also will be observed that four factors showed decreases between trials in terms of discomfort acuteness on day 12. However, none of these decreases were significant. It is of particular interest that, contrary to the difference observed on day 2, food did not show a significant decrease in discomfort acuteness between day 12 of the winter trial and day 12 of the summer trial. To the contrary, it showed a noticeable although statistically nonsignificant increase. Thus, although food was rated as producing relatively less acute discomfort early in the summer trial, it became increasingly important so as to ultimately receive a rating equivalent to that received on day 12 of the winter study. This "catching up" seems most plausibly interpreted in terms of the scaling artifact discussed earlier. That is, by day 12 of the summer study, temperature and humidity had dropped from its top-ranking position on the second day to a position more nearly like the one it occupied on day 12 of the winter study. This drop in the discomfort acuteness of temperature and humidity removed a restraint, so to speak, on the scale rating of the discomfort acuteness of food. Thus, similar diets were rated as producing the same degree of discomfort acuteness on day 12 of the summer study as on day 12 of the winter study.

Comparisons of the discomfort generality on day 12 of the two seasonal trials followed much the same pattern as described above. As Fig. 57 and Table C11 show, ten factors were rated as producing greater generality of discomfort on day 12 of the summer study than on day 12 of the winter study, but only lack of water for washing, bunks, odors, and temperature and humidity showed significant increases. It will be observed that these are the same four factors that showed significant increases on the discomfort

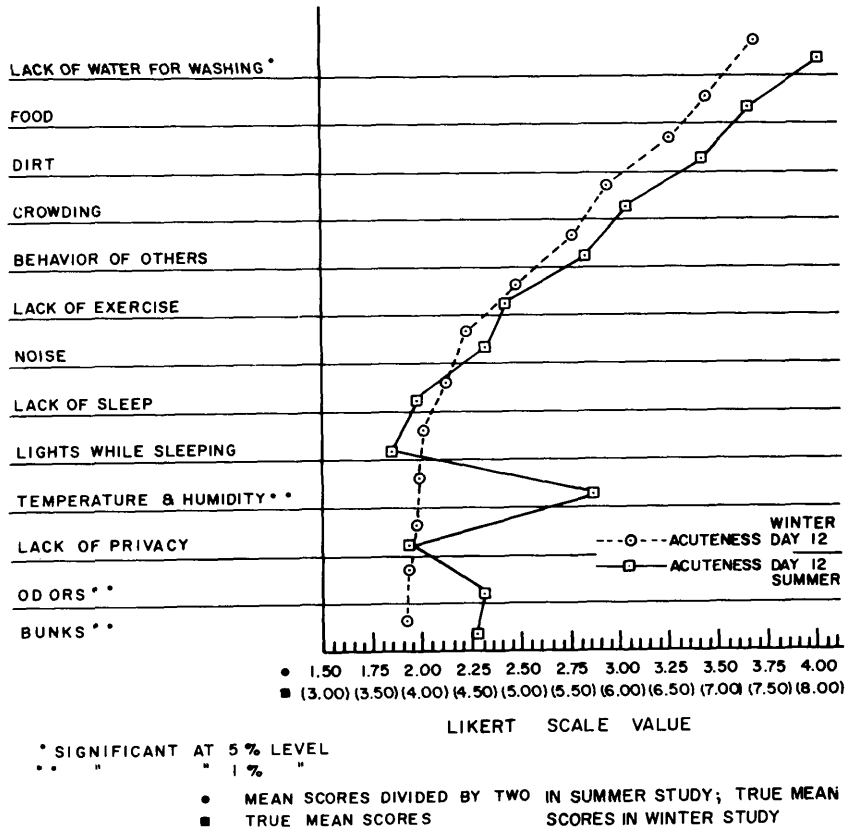


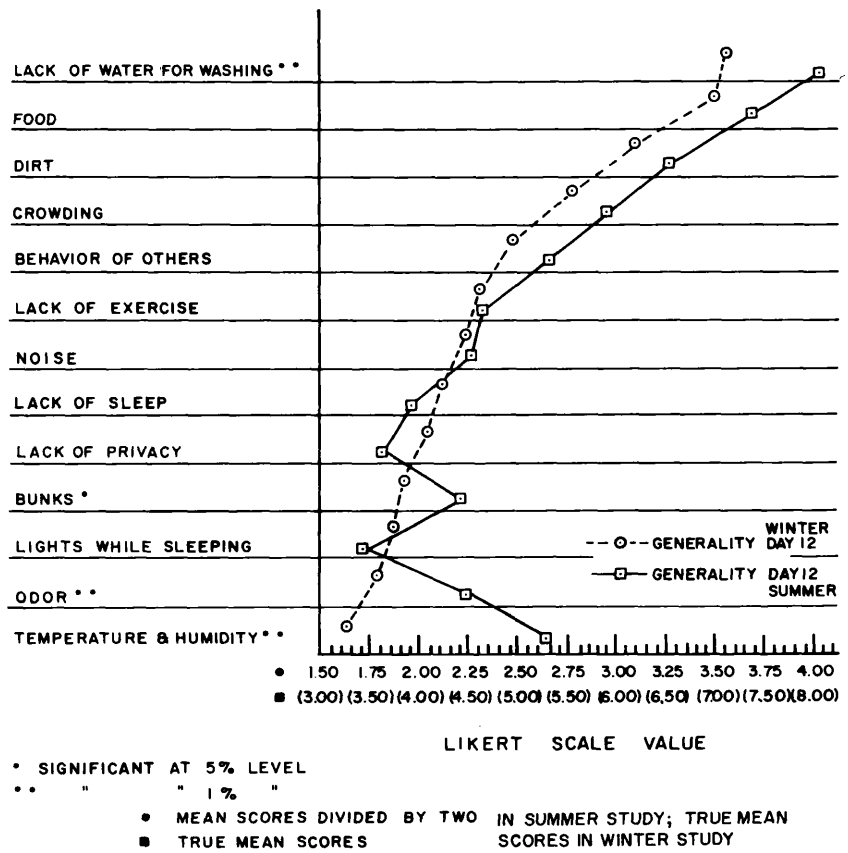
Fig. 56 - Differences in acuteness of discomfort between day 12, winter trial, and day 12, summer trial

acuteness dimension. Three factors were rated as producing less discomfort generality on day 12 of the summer study than on day 12 of the winter study, but these differences are not sufficiently large as to be statistically significant.

Differences Between Winter and Summer Trials in Terms of Within-Trial Relationships Between Discomfort Acuteness and Discomfort Generality and Between Earlier and Later Phases of Shelter Occupancy for Individual Discomfort Factors

The kinds of differences to be discussed in this section anticipate, in a sense, the subsequent discussion of interaction effects. That is, these differences illustrate a few within-trial relationships which generalize across both trials and a larger number of relationships which are unique to either the winter trial or the summer trial. One could speculate at length on the reasons for these between-trial similarities and differences, but the data available do not suffice to either support or negate such speculations. Therefore, the purposes of the present discussion are to point out relationships which generalize across trials where they exist and to highlight the need for caution in generalization where such relationships do not exist.

As indicated in Fig. 58, and Table C12, all significant differences between acuteness and generality of discomfort on day 2 of both trials were based on acuteness exceeding generality. Lack of water for washing and behavior of others were the only two factors in which acuteness significantly exceeded generality of discomfort on day 2 of both trials.



* SIGNIFICANT AT 5% LEVEL
** " " 1% "
• MEAN SCORES DIVIDED BY TWO IN SUMMER STUDY; TRUE MEAN SCORES IN WINTER STUDY
■ TRUE MEAN SCORES

Fig. 57 - Differences in generality of discomfort between day 12, winter trial, and day 12, summer trial

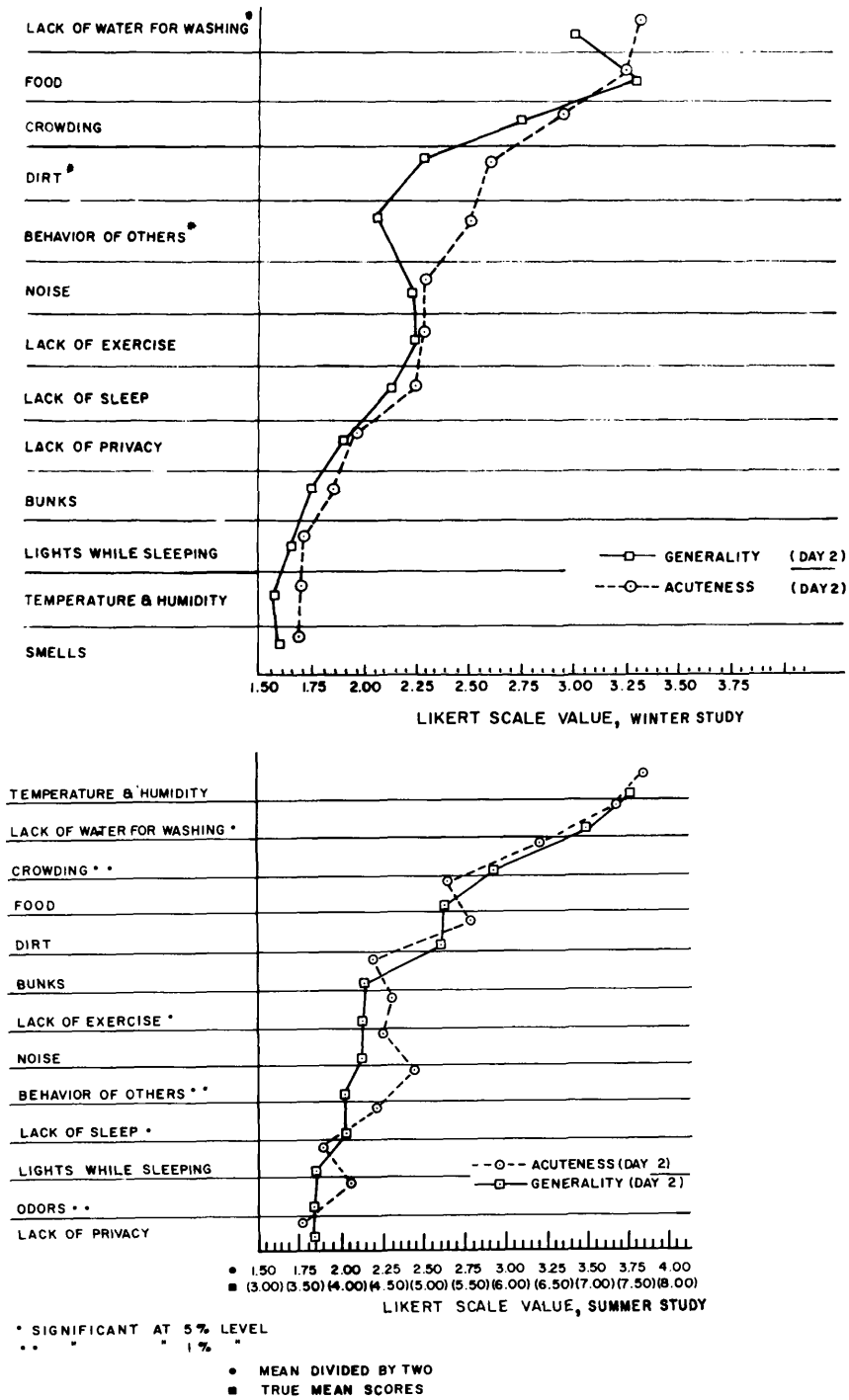


Fig. 58 - Differences between acuteness and generality of discomfort on day 2, winter trial, and on day 2, summer trial

All remaining significant differences on the second day are unique to one seasonal trial. In the winter trial discomfort acuteness exceeded generality for dirt on day 2; in the summer trial crowding, lack of exercise, lack of sleep, and odors all showed significant excesses of acuteness over generality.

Figure 59 and Table C13 reveal that all significant differences between acuteness and generality also were based on a greater acuteness of discomfort on day 12 of both trials. This result parallels the related finding on day 2. Further, acuteness significantly exceeded generality of discomfort for temperature and humidity and for behavior of others on day 12 of both trials. All other significant differences on day 12 were unique to the summer trial and included greater acuteness of discomfort for dirt, lack of privacy, and lights while sleeping.

Comparisons between seasonal trials in terms of changes in acuteness and generality between day 2 and day 12 disclose both across-trial generalizations and findings unique to one trial. Figure 60 and Table C14 indicate discomfort acuteness to be greater on day 12 than on day 2 for lack of water for washing and dirt in both trials. All other significant changes in acuteness between day 2 and day 12 were unique to the summer trial. These changes included significant increases in acuteness attributable to food, behavior of others, and odors. Significant decreases in acuteness are found for crowding, temperature and humidity, and lack of sleep.

Figure 61, based in Table C15, illustrates between-trial comparisons of changes in discomfort generality from the second to the twelfth day. In both trials generality of discomfort attributable to lack of water for washing, dirt, and behavior of others increased significantly between day 2 and day 12; all other significant changes in discomfort generality again were unique to the summer study. These changes included significant increases in discomfort generality for food and odors and a significant decrease for temperature and humidity. In terms of across-trial and across-scale generalizations, for both trials lack of water for washing and dirt showed significant increases in acuteness as well as generality between day 2 and day 12.

The occurrence of so across-season generalizations and a larger number of effects unique to a single seasonal trial is not unreasonable. With the major variation in seasonal conditions between trials, in combination with the potential for significance of interaction effects of the fourth order of complexity, it is gratifying that even a few across-season generalizations were evident. In terms of practical problems of shelter habitability, those across-season generalizations which did occur may be viewed with some confidence. Where, in contrast, effects unique to a single season were evident, the research results could serve as inputs to decisions concerning desirable degrees of flexibility in shelter design, stocking, and management.

Differences Between the Winter and Summer Trials in Terms of Interactions Between and Among Discomfort Factors and Other Variables

Many specific instances of interaction effects have been mentioned in the preceding discussion of differences between seasons in subjective responses to discomfort factors. At this point, these specific instances may be subsumed under a number of broader statements, based on data summarized in Table C7. For purposes of present discussion, only those combinations of variables which include both seasons and discomfort factors are relevant.

The two-way interaction of discomfort factors with seasons was significant, as might be expected. This significance means that, in general, the magnitude of discomfort attributed to a given discomfort factor depends upon whether subjective response was

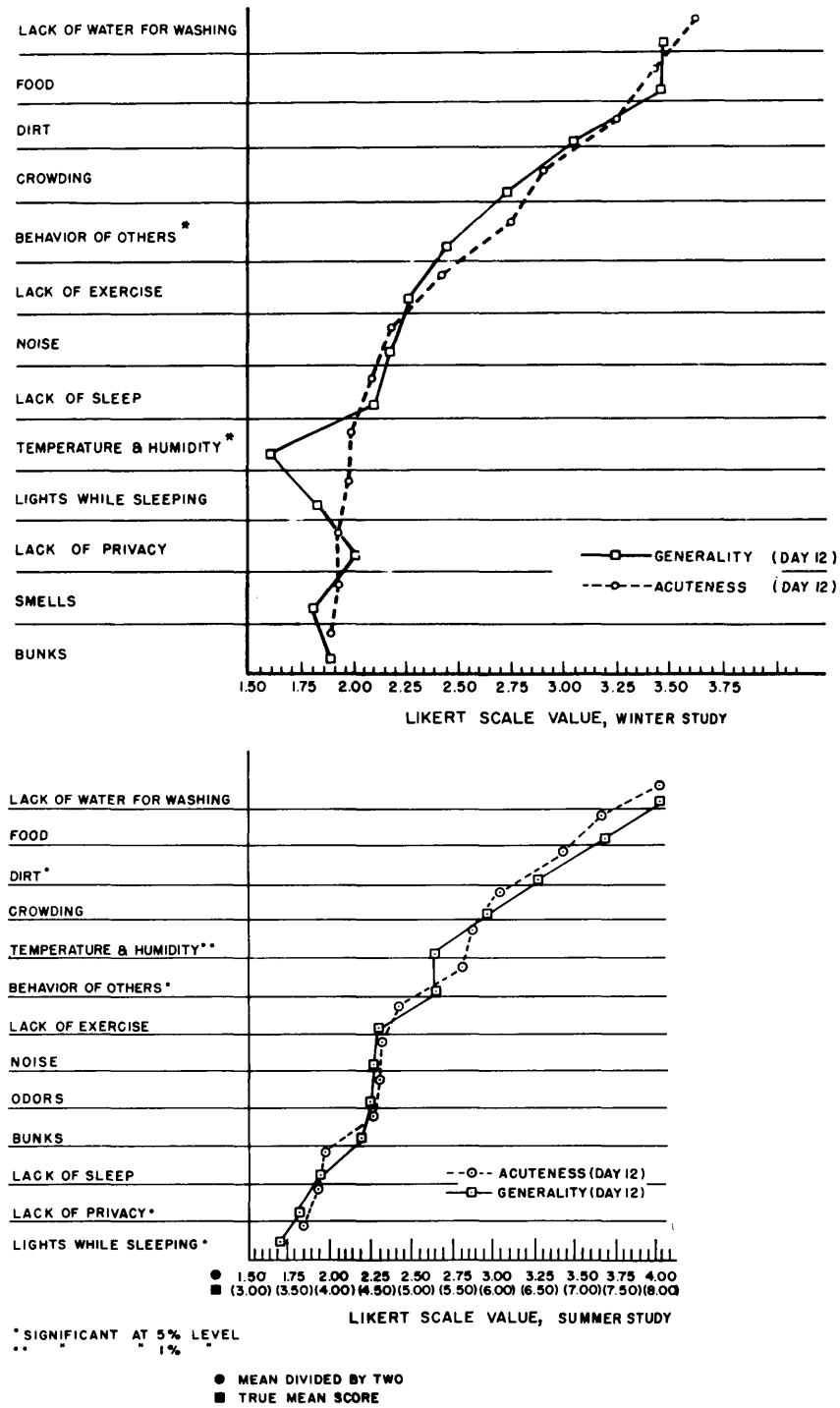
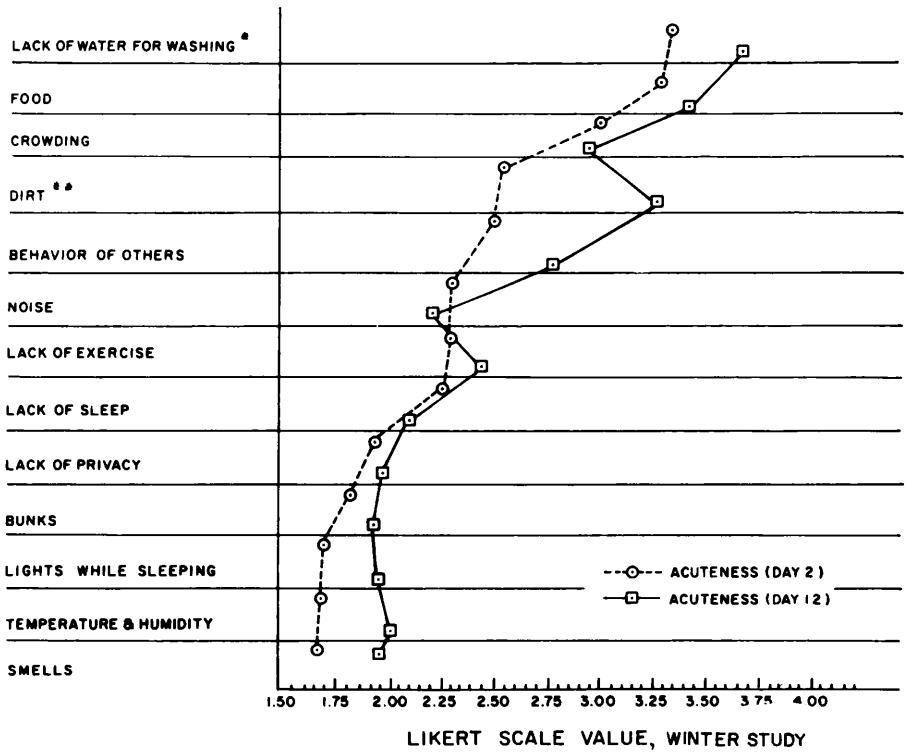


Fig. 59 - Differences between acuteness and generality of discomfort on day 12, winter trial, and on day 12, summer trial



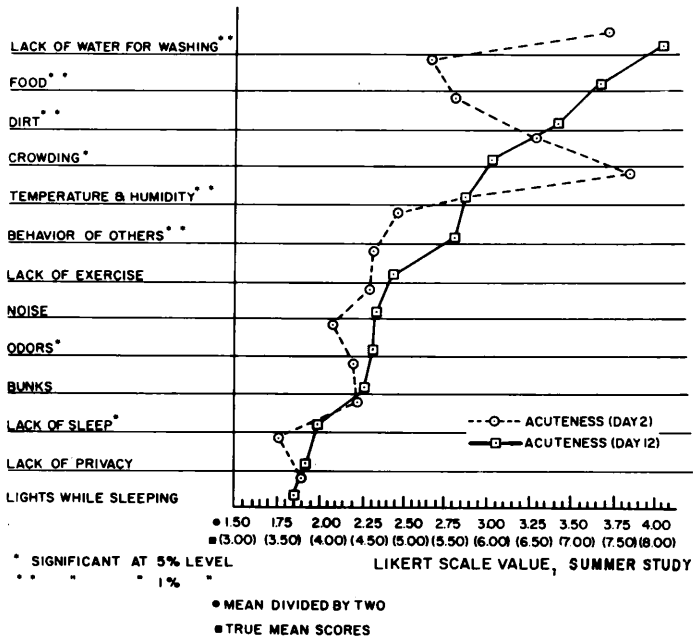


Fig. 60 - Differences in acuteness of discomfort between day 2 and day 12 of winter trial and of summer trial

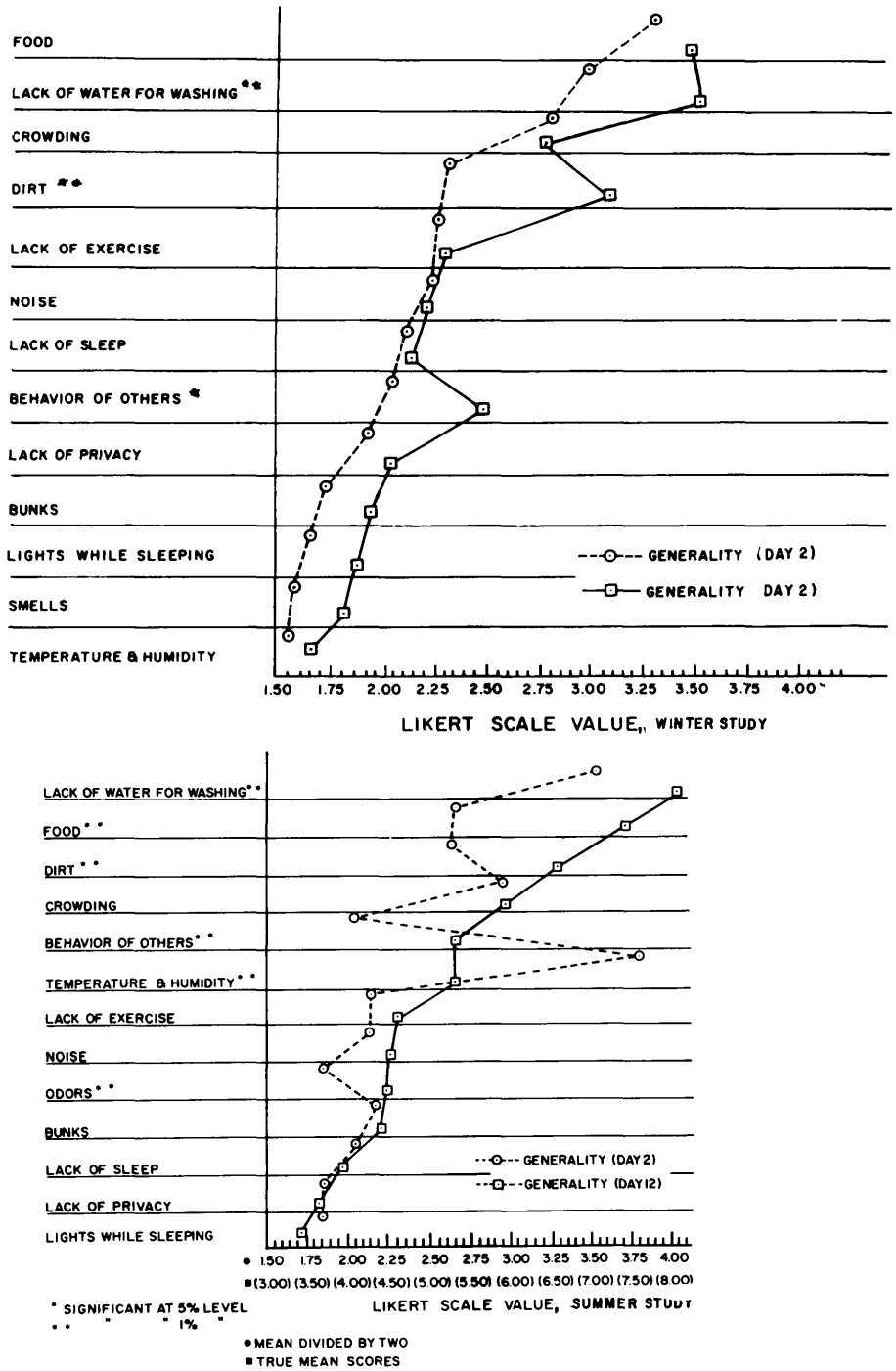


Fig. 61 - Differences in generality of discomfort between day 2 and day 12 of winter trial and of summer trial

measured in the winter trial or in the summer trial. It is emphasized that this generalization is applicable to the 13 discomfort factors as a group and does not contradict the findings presented earlier that certain specific factors showed across-trial similarities in attributed discomfort.

Examination of the three-way interactions reveals that seasons, time of administration, and discomfort factors significantly interacted. That is, shifts in response to discomfort factors between the two administrations, within a given seasonal trial, depends upon which seasonal trial is considered. On the other hand, seasons, discomfort factors, and acuteness-generality did not significantly interact. Thus, differences between discomfort acuteness and discomfort generality attributed to a given factor do not depend upon which seasonal trial is considered. This statement focuses upon differences between acuteness and generality of discomfort for a given factor and not upon differences between factors in terms of overall discomfort. The statement is therefore not inconsistent with the earlier interpretation of the significant interaction between seasons and discomfort factors.

Finally, the interaction involving all four of the major variables was not significant and may be interpreted to mean that although shifts in response to discomfort factors between the two administrations within a given trial do depend upon which trial is considered, this kind of dependence relationship does not differ between the acuteness and generality dimensions of discomfort.

The above findings reaffirm the need for specifity in discussing subjective discomfort in fallout shelter living, as well as the need to avoid attempts at generalization unless all major relevant variables have been considered.

Debriefing Interviews

The interviews were semistructured in nature, and each interviewer was expected to cover specific material during the hour spent with a given group. No requirement was imposed as to interview technique or the order in which the information was obtained. Written reports were prepared immediately after each interview.

Cooperation during the interviews was excellent and, in general, the subjects were quite responsive and eager to discuss their shelter experience. While several of the interviewers felt that the subjects would have been more expressive of their feelings in an individual interview, this problem was not considered of sufficient magnitude to invalidate or distort the interview findings.

The material presented below has been summarized from the individual reports. The first five discomfort factors reflect qualitative consideration related to the leading sources of discomfort as ranked on the Likert scale.

Lack of Water for Washing – Lack of water for washing was a particularly significant and emotionally charged source of discomfort during the summer trial for several reasons beyond simple disruption of established personal cleanliness habit patterns. First, the subjects reported a feeling of general "stickiness" from excessive perspiration which was made even more acutely unpleasant by the tendency for particles of dirt to cling to the skin. The wash and dry pads were considered unsatisfactory by the majority of the men inasmuch as they tended to increase the feeling of stickiness or greasiness on the skin. It should be noted, however, that approximately five out of the 100 men felt that the wash and dry pads were satisfactory. Whereas body odor occasioned by lack of bathing was not considered a major problem during the winter trial, the summer trial subjects complained that both their own and the body odor of others at times was almost overpowering.

This problem was intensified by the fact that the same clothing was worn for 2 weeks. A large number of men attributed the development of heat rash to their inability to bathe. Finally, a surprising number of subjects saw the extreme discomfort arising from lack of personal cleanliness as a major contributing factor in their generalized irritability. This was especially true during the early phase of the trial when the heat and humidity were at an extreme.

Temperature and Humidity – The vast majority of subjects freely verbalized a belief that they could not have completed the trial if the heat and humidity experienced during the first week had continued. The psychological response to this source of discomfort was described as being cumulative over time, with a progressively increasing listlessness, irritability, and sleep disturbance.

The constant perspiration, which never evaporated, was described as a demoralizing aspect of the heat and humidity. Conscious efforts were made to avoid any unnecessary physical activity under the extreme heat conditions. A number of men expressed concern as to how the shelter would have been managed with women and children present in view of the minimum clothing worn when the temperature was high. Little, if any, concern was experienced with heat and humidity after the rather drastic change in weather conditions toward the end of the first week.

Food – Complaints about food were frequent but not as pronounced or emotionally charged as those about the heat or lack of water for washing. The primary objections to the food centered on the crackers. While they were considered satisfactory for the first couple of days, the crackers became progressively less appetizing with the passing of time. They were described as lacking in taste, being too dry, and becoming monotonous. Several men claimed to have thrown their crackers away on occasion. The soup was considered to be the high point of the day and was well received. Several men disliked the peanut butter because it was too dry and difficult to spread on the crackers. The water supply was criticized as having the taste of the rubber hose through which it was funneled. Repeated suggestions were made that tea or other beverages should be provided in addition to coffee. Generally speaking, except for the soup and topping for the crackers, the food did not provide a source of emotional or psychological gratification. It should be noted that the chewing gum, which was passed out towards the middle of the trial, was responded to as a major morale factor.

With the intense discomfort occasioned by lack of water for washing, temperature, humidity, and crowding during the summer trial, the complaints and comments about food did not assume anywhere near the magnitude found during the winter trial. However, the attitudes and opinions expressed about food were strikingly similar in content to those expressed during the winter trial. It is interesting to note that the hot soup was considered one of the most positive morale factors even during the period of intense heat and humidity.

Crowding – Crowding apparently was less of a problem in the summer trial than during the winter test but did assume significant proportions when all subjects were up at the same time. As before, the most acute difficulty in this connection was created by individuals moving about in the shelter. Such movement was accompanied by an unavoidable bumping and jostling of others. The same deterioration of social amenities noted in the winter trial was reported by subjects during the present test. With the passing of time, there was progressively less apologizing for bumping others. As before, this decrease in common courtesy became a significant source of irritability among the subjects. The subjects quite specifically and consciously related the anger and irritability to the problem of crowding, and a conscious awareness of a need for self control was verbalized by almost all of the men. As during the previous trials, surprisingly little need for privacy was expressed by the subjects. It is entirely possible, however, that the lack of desire for privacy among this subject population may be attributable to their having completed

recruit training just prior to the trial. The second bunking schedule, which involved half of the men remaining in bed all of the time, was repeatedly mentioned as a positive factor in reducing crowding.

Dirt – There were no complaints of dust in the shelter during the summer trial. The primary concern with dirt already has been mentioned. With the lack of water for washing and the constant perspiration, the skin was literally covered with small particles of dirt. The psychological response to this was well summarized by the following quotation: "There was dirt all over; it just rolled off our bodies. We never could get free of the dirt." The bunks were a source of particular irritation as they remained wet from perspiration and also tended to hold particles of dirt. This situation became a matter of concern to the subjects when they got into a bunk which had just been vacated by another man. Only minimal concern was expressed by the subjects about dirt not related to personal cleanliness. However, the tendency to discard papers, cigarette packages, etc., at random about the shelter was a source of particular irritation to one of the older administrative staff members with long naval service.

Behavior of Others – As in the previous trial, the primary problem with regard to interpersonal behavior pertained to the problem of bumping into others while moving about in the shelter. Beyond this, few examples were elicited of behavior which was considered unacceptable. In every situation such behavior involved lack of consideration for the rights of others or a failure to really accept one's own responsibility for participating in the shelter routine.

No incidents of overt aggression were reported. Moreover, except for the clear and rather pronounced racial hostility expressed by one small group of subjects, there was no evidence of the cliques and intragroup frictions reported during the winter trials.

Leadership – The subjects were remarkably consistent in their complimentary evaluation of the shelter leadership. Without exception, the leaders were seen as positive, well-organized individuals, very efficient in carrying out their assigned duties, and at the same time providing considerable understanding and emotional support for the subjects. The overwhelming consensus of the men was to the effect that the leadership approach used during the summer study could not have been improved. There were some comments, however, which indicated a need for stricter supervision, particularly with regard to use of recreational material. Where such expressions of individual need were encountered, other members of the group immediately volunteered a belief that more rigid structuring in the leadership situation would have produced a marked deterioration in morale.

Outstanding Individual Participants: Were there certain people in the shelter who made your stay easier? – Response on this item fall into two rather specific categories. The leaders, particularly the medical officers, were singled out as being of primary importance in making the shelter stay tolerable. Secondly, the entertainers were repeatedly mentioned as making a significant contribution to the group.

Morale: Could group cooperation and morale have been higher? If so, how could they have been raised? – On the whole, morale was considered quite satisfactory throughout the trial. This generalization does not mean that morale was uniformly high at all times. For example, the early period of the trial with the high heat, humidity, bumping, perspiration, and dirt led to what was generally acknowledged as rather low morale. On the basis of the interview material, there is no reason to believe that this low morale was a reflection of defective shelter organization or management. Rather, the low morale at this period is interpreted as being the normal response of a healthy group of men who are living under adverse environmental conditions. Morale increased with the lifting of the heat stress. Some dip in morale was reported by a substantial number of individuals to have occurred the day before the trial was ended because of

unfound rumors regarding the time of termination. There is no evidence that the problem assumed any significant magnitude. The distribution of chewing gum on Sunday was pointed out as a significant morale booster. Among suggestions for improving morale were better food, more games, a radio, and control of heat and humidity.

Anticipation of Shelter Experience: How did shelter life differ from what you expected it to be? – There was no unanimity of response on this item. Some men had anticipated the shelter would be larger and others expected it would be smaller. The noise was a greater problem than expected for many. On the whole, the shelter was more elaborate and better equipped than the subjects had anticipated. It would appear from the interview material that the indoctrination lecture at the time the men volunteered to serve as subjects led to the expectation that the shelter experience would be more stressful than it subsequently was found to be.

Tolerance for Shelter Living: How would you feel about spending a month in this shelter? – Individual responses ranged from those of men who believed they would be absolutely incapable of surviving over a month in the shelter to subjects who stated they could remain indefinitely. Except for a very small minority, it was quite universally felt that it would not be possible to withstand any prolonged period of confinement under the conditions of high heat and humidity. Many individuals were quite uncertain as to what their response to the shelter would be in case of an actual nuclear attack. It was made quite clear that they believed it was not possible to generalize from a simulated to a genuine situation with regard to tolerance for shelter living.

What do you remember as your most unpleasant shelter experience? – The heat and humidity during the first few days of the trial was the most immediate and overwhelming response to this question. The generalized physical discomfort throughout the trial ran a close second in terms of unpleasantness. The head odors, food, and dirt all received a substantial number of votes as the most unpleasant aspect of the shelter living. At the same time, it was apparent that there was no single incident which stood out uniquely as constituting an unusually unpleasant experience.

What do you remember as your most pleasant shelter experience? – Again, no single incident or experience was agreed on as constituting the most pleasant aspect of the shelter trial. The variety shows were most frequently mentioned as being the most enjoyable experience of the trial. The public handling of discipline problems or through the "eightball club" ceremonies also was considered to be a high part of the day. A substantial number of individuals considered the hot meal to be the most pleasant aspect of the shelter living.

Aside from making the shelter bigger, what changes in it would make things easier or more pleasant for the shelterees? – A flood of responses was made to this inquiry. The suggestions ranked from the totally impractical and ridiculous, through general griping, to some excellent and constructive criticism. A number of subjects were of the opinion that the shelter space could be better used in storage of equipment and supplies. For example, the ceiling area was considered to be poorly used, and it was suggested that shelves be constructed, particularly above the shower and head areas. It was suggested that detachable trash containers be attached to the sides of the shelter as a means of cutting down on discarded litter. In a like vein, it was suggested that hooks be supplied at the end of the bunks so that an individual could remove his shoes and keep them in his immediate bunking area. Another suggestion which merits serious consideration is that of painting the interior of the shelter in a bright color as a means of making the shelter more aesthetically pleasing and acceptable. A lack of adequate storage for recreational gear was repeatedly mentioned as being a problem in need of correction. In this connection it was considered that the primary reason for loss of cards, etc., in the recreation material was lack of adequate storage. A reduction in the noise level was recommended. The only comment about discomfort from smoking came out when a recommendation was

made that the amount of smoking be correlated with the change in rate of air flow in the shelter. A number of subjects recommended removing three of the heads and using this space for storage. Among the more impractical suggestions were the installation of dehumidifiers, movie projectors, and air conditioning in the shelter.

What suggestions could you give to future shelterees which would make their stay easier and more pleasant? – The information volunteered on this question was more valuable in terms of insight into the psychological mechanisms of shelter living than in providing information which might be used for indoctrination purposes.

Considerable emphasis was placed on informing shelterees that the first few days of their confinement would be most difficult. It would appear that the subjects in this trial actually felt more anxiety and stress during the early part of the test than they were willing to admit in a group interview situation. On the whole, there was far less concern with providing information on techniques which assist in passing time, dissipating anxiety, etc., than was found during the winter trial debriefing. The only comments seriously offered in response to this item were concerned with maintenance to group morale and interpersonal effectiveness. Thus, there were repeated comments concerning the importance of individual self control and common courtesy under conditions of crowding.

Was there any evidence of concentration difficulty or any other impairment of psychological functioning? – The most commonly reported phenomenon was an impairment of concentration during the period of high temperature and humidity. Several men reported that upon leaving the shelter they felt slowed down and tired and were conscious of a certain degree of physical awkwardness or uncoordination. No direct evidence of perceptual distortion was obtained; however, a few men reported difficulty in judging distances immediately after leaving the shelter. Several men reported that the shelter appeared to grow larger with the passing of time.

If you could have had additional recreational items in the shelter, what would they be? – No really meaningful suggestions were obtained in response to this question. There was a rather pronounced division of opinion as to the adequacy of the reading material. A fairly substantial segment of the men complained that the reading material was not sufficiently intellectually stimulating. On the other hand, an equally large group was of the opinion that more superficial material, such as found in True Magazine, should be added to the reading supply. The nature of the comments were such that it became quite clear that any supply of reading material would have been subject to criticism. A number of men suggested that games such as Monopoly be introduced. However, these suggestions were immediately countered with comments as to the excessive space such games would require.

Generalized Emotional Response to Shelter Experience

In addition to obtaining qualitative information on the psychological discomfort factors, the interviews were designed to provide mechanisms for releasing tension and detecting any evidence of emotional disturbance which might be present among the subjects as a result of their experience. The examiners were uniformly of the opinion that none of the subjects showed any residual emotional disturbance; however, it also was quite obvious that the experience had been extremely stressful.

Two men were removed from the shelter for psychological reasons. The first, a 38-year-old staff member, was removed on the second day of the trial. This man was one of three individuals participating in the test who was not screened. The nature of this individual's duties was such that he had relatively frequent contact with support staff outside the shelter. On several occasions the second day he made verbal request to leave the shelter and sent out four written notes requesting that he be removed.

The individual in question was sent out of the shelter at approximately 1630 and interviewed for approximately 2 hours. At first, he completely denied any desire to leave the shelter and rationalized his behavior as normal "bitching" which he considered to be entirely consistent with the situation. There was an absolute denial of personal problems in any sphere or any time, past or present. Coupled with this almost pathological denial of difficulty as a strongly and freely verbalized rationalization was the complaint that his professional capabilities were not being used in the shelter. Although there was no evidence of gross emotional disturbance, the manner in which he requested release from the shelter, coupled with his almost pathological denial of difficulty, was considered indicative of sufficient disturbance to preclude his further participation in the trial. While it was considered inadvisable to probe deeply into the underlying causes of this man's behavioral response, there were indications of claustrophobia, as well as strong suggestions that unconscious psychosexual conflicts had been activated by the enforced contact of the men in the shelter. Arrangements were made to replace this man with another staff member in such a way as to avoid any "loss of face" for his having failed to complete the shelter trial.

The second man, a recruit subject, was removed from the shelter on the seventh day of the trial. This man experienced a dramatic loss of consciousness while being examined by the medical officer. The detailed description on this incident is contained in the chapter on medical aspects of the trial. In spite of the acute and seemingly serious nature of the subject's symptoms, he showed an equally dramatic recovery on his way to the admission room at the Naval Hospital. A diagnostic interview disclosed this man to be a passive dependent individual who found the shelter trial to be quite stressful. After careful medical and psychological evaluation, it was concluded that this man experienced an acute episode of hyperventilation, and his symptoms were of a hysterical origin. Repeated examination showed no sequela, either physical or psychological, although it was considered highly desirable to minimize the incident so as to prevent development of secondary gain. Accordingly, he was assigned to duty in an NMRI laboratory with the shelter support staff and performed in a highly satisfactory manner throughout the remainder of the trial.

At least five other subjects were identified as demonstrating clear-cut evidence of mild to moderate emotional disturbance. Primarily, this distrubance took the form of depression and pronounced withdrawal from the remainder of the group. In one case the emotional stress was reflected in repeated physical complaints which resulted in the subject being medically evaluated for possible appendicitis. All of these individuals were handled quite effectively by the medical officer and showed no signs of impairment by the last day of the trial.

There was no evidence of behavioral contagion or specific patterning of those overt symptoms which were observed within the shelter. Moreover, because of the group interview technique used at debriefing, it was not possible to obtain information on the more subtle emotional fluctuations in individual emotional response. No evidence of psychosexual conflict was detected during the summer trial, except possibly in the case of the one individual described above.

The response of the subjects to the acute medical emergencies during the early part of the trial is of considerable interest. At the time these incidents occurred, the shelter commander and medical officer were unable to detect any apparent response, either positive or negative, on the part of the other men. This lack of response was contrary to expectation in view of the rather dramatic nature of the incidents. Accordingly, this matter was specifically probed during the debriefing interviews. Only minimal evidence of anxiety or concern over personal health and well-being was elicited from the subjects. To a man, they reported an almost childlike confidence in the medical officer and apparently were successful in denying the possibility of illness through a belief that

they were perfectly safe as long as Dr. Minard was in the shelter. The presence of a warm and accepting physician, who was an excellent father figure, and a lack of knowledge as to medical difficulties which could occur under heat stress would appear to have provided a major source of emotional support and security.

One incident occurred during the summer trial which very clearly illustrates the significance of unconscious behavior on the part of leaders in the shelter situation. Several of the debriefing groups reported a drop in morale on the last day of the trial which was related to the fact that one of the Chief Petty Officers had shaved for the first time since entering the shelter. The Petty Officer made no comment as to why he chose to shave on this particular occasion. However, the behavior was interpreted by the men as indicating the trial would terminate in the immediate future, and an active rumor was circulated to this effect. When there was no confirmation of the rumor, the morale of the subjects dipped. However, in debriefing the Petty Officer himself, it became apparent that he was totally unaware of his behavior in shaving being related in any way to the dip in morale.

Daily Diaries

Each man was encouraged to keep a daily diary, although there was no requirement that this be done. It was anticipated that the diaries might be of some value in minimizing the retrospective falsification of events which is brought about by their being described at the debriefing interview rather than at the time of occurrence. Moreover, it was felt that the diary entries might elicit attitudes and information not obtained in the regular debriefing session.

Thirty-eight of the 91 subjects made no entries whatsoever in their diary. Thirty-six men made minimal comments, and 15 individuals made serious attempts at recording their experience. A summary of the information from the diaries is presented below. The vast majority of the comments are similar to those obtained in the debriefing interviews. However, it is considered desirable to present data from both sources, inasmuch as the duplication actually constitutes increased support for the validity and accuracy of the psychological data.

Temperature and humidity appeared to be the most annoying factor of all. Subjects reported at the beginning of the experiment that during the interval when air was not being circulated from outside the temperature and humidity progressively increased until the blower was started. They reported that the air became so thin that they had difficulty in lighting their cigarettes. Once the cigarettes were lighted the smoke became quite annoying until the blower dissipated it. They expressed relief from these three factors once the blowers were started. There were increased complaints as time progressed to the effect that the shelter became hotter and hotter and that the walls and deck became wet and slippery. The shelter subjects expressed the feeling that when half were in their bunks and half were up temperature and humidity was less than it was when all were up. It was reported that the front of the room was warmer than the rear area near the bunks and that the ceiling was warmer than the area near the deck.

The crowded condition of the shelter was reported to be most acute at meal time and at the common period when all of the shelterees were up. Contact with each other and the failing of shelterees to show courtesy to each other when they bumped into another was a common complaint. Many of the shelterees expressed the opinion that if a neat storage area for games, reading material, etc., was devised crowding in the shelter would be decreased.

Perspiring was a very common complaint, particularly when the power failed and the shelterees had to operate the blower manually. Many expressed the opinion that those

working the blower produced body heat which appreciably increased the shelter temperature. Those manning the blower expressed a feeling of weakness after this exercise.

The factor of dirty skin was strongly disliked. One man reported that in trying to wipe off the dirt and perspiration dirt would just roll into balls and cling to the skin. Immediately upon completing this cleaning process, his skin would again be covered with perspiration.

As the air blower output was increased the heat and humidity discomfort was reportedly decreased.

From the beginning of the experiment to the end, the subjects expressed a hope that the others would be able to control their tempers so that friction would be avoided in the group. When a man lost sleep or felt the beginning of a common cold, he expressed an increased sensitivity to the decreased expressions of courtesy or animosity displayed by others. One man expressed a concern for not being able to control his feelings of anger. Another expressed the opinion that some of the shelterees must actually enjoy being dirty.

Those who complained of the food complained that there wasn't enough of it. They generally disliked the "crackers" either alone or with the soup. This dislike for the crackers appeared to be acquired during the course of the trial as they were well accepted at the beginning of the shelter experience. One shelteree stated that he would not eat the crackers as a method for expressing his resentment to the shelter experience. Another reported a deep dislike for the crackers which coincided with the onset of a common cold, but upon recovery the subject found the crackers to be more acceptable. Loss of appetite was related in most instances to a desire to avoid eating the crackers. All of the subjects generally liked the soup or "hot meal" and the topping for the crackers. The water was disliked by many because of its taste. Some preferred coffee to water. Several complained of nausea related to taking salt tablets.

Many of the men keeping diaries showed a mild preoccupation with watching their weight. Only one or two, however, expressed any strong concern over losing weight.

Thoughts about the outside world usually served as a means of temporarily escaping the shelter environment. Individual fantasy activity and group discussion centered on aspects of home, friends, family, experiences, hopes, and plans. Another common theme related to the outside world was evaluation of their experience as it might relate to utility for civilian use.

Heat rash was a common experience, apparently of short duration. It reportedly was very uncomfortable, especially with the attendant aggravation due to perspiring.

Insomnia was reported to be related to lights, heat, noise, and not being sufficiently tired (lack of exercise) to sleep. The shelterees all adjusted to changes in sleeping schedules, although they produced periodic discomfort.

Boredom resulted when one could not find enough to occupy his time, and some men expressed a regret that their preferences in reading material were not accommodated. This complaint was the exception rather than the rule as subjects considered the selection of reading material and games very good.

Some subjects complained that "time dragged" because they couldn't find enough to occupy themselves. On such occasions they generally became preoccupied with the inadequacies of the shelter. Most of the men, however, proved to be quite resourceful in expending their time through activities, such as learning new games, painting pictures, and taking time to reappraise their relationships back home.

Odors from one's person, from his fellow shelterees, and from the heads were a source of discomfort. There was no agreement as to which was generally considered the worst. Each individual reacted differently where odors were concerned.

A number of individuals raised a question as to the possible relationship between dirt in the shelter and the coughing which many experienced. Further, dirt was particularly annoying because it easily became mixed with the perspiration on their bodies.

Discarding books and other objects about the shelter without regard for the comfort of others was noted as a source of irritation. Those commenting on this problem attributed the difficulty to an attitude of noncooperation by those who were at fault.

A few isolated subjects complained that they "couldn't think straight" because of the increasing monotony of the environment or because of the noise and confusion. This complaint was elaborated to the effect that their physical surroundings, haphazard structuring of use of their time, and the continuous lighting of the shelter confused them in their attempts to associate relative time intervals. Confusion about a reference for time also grew out of the changes of bunking schedules.

Most reported that they were able to sleep quite comfortably and were very glad to get into their bunks, even if they used the time to stretch out for writing and reading. But a few occasionally complained that to them the bunks were uncomfortable. Generally, one's bunk was considered private domain when one occupied it, and most of the other men would respect this privacy. Two men complained that they were very irritated when another would put his belongings, in one case, and his feet, in another instance, on the complainant's bunk.

SUMMARY AND CONCLUSIONS

The present research effort is an extension of the psychological discomfort studies made during the winter trial. As before, the work is oriented toward evaluating the engineering habitability of a specific prototype shelter rather than investigating the broader emotional problems of response to shelter living. Emphasis was placed primarily on measuring and evaluating the same sources of psychological discomfort identified during the winter trial. Secondarily, a limited amount of data was collected on the more generalized emotional response of the subjects to this particular shelter trial. In addition to presenting results from the summer trial, a comparison is made of these results with those obtained during the winter trial.

Two changes in procedure were made during the summer trial. First, it was considered unnecessary to establish the adequacy of the measuring instrument as this was accomplished during the first trial, and the subjects were drawn from the same basic population. No attempt was made to determine the relationship between relative subjective importance of discomfort factors as anticipated prior to entry and as experienced after several days of shelter occupancy. The winter subjects were surprisingly accurate in predicting the rank order of discomfort as actually experienced; therefore, little was to be gained by repeating the procedure. Quantitative measures of psychological discomfort were obtained from a Likert-type scale developed for the winter trial, and qualitative information was obtained from debriefing interviews and an analysis of the subject's daily diary entries.

All the objectives of the trial were accomplished, and it is possible to reach a number of broad conclusions regarding the relative importance of a number of sources of psychological discomfort during this test. Likewise, several gross cross-trial conclusions are reached. The five leading sources of discomfort during the summer trial were lack of water for washing, temperature and humidity, food, crowding, and dirt.

There were some shifts in the specific order of these factors depending upon the phase of the trial during which they were measured, as well as in terms of acuteness and generality of discomfort; however, at no time did any of these factors fall below fifth place. The temperature and humidity factor was one of the least important factors during the winter trial. With this factor assuming second place during the summer, the discomfort from the behavior of others dropped to sixth place. Food, lack of water for washing, crowding, and dirt were primary sources of discomfort regardless of the season under consideration.

The discomfort arising from the lack of water for washing was intense. The stickiness, body odor, and dirty clothes resulting from a lack of water were considered a source of emotional irritability during the early stages of the summer trial. The wash and dry pads were considered unsatisfactory for maintaining personal cleanliness. The vast majority of subjects felt they would have been unable to complete the trial if the temperature and humidity had remained at the level of the first few days after entry. In addition to listlessness, irritability, and sleep disturbance, the constant perspiration became increasingly demoralizing. The complaints about food were less emotionally laden during this trial than during the winter trial, primarily because of the overwhelming response to the heat and humidity. However, the nature and content of the complaints were quite similar. Further, it is interesting to note the marked shift on the Likert rating scale after the heat stress diminished; at that time, food occupied essentially the same position as it had during the winter trial. As before, crowding was a problem primarily when all of the subjects were up at the same time. There was evidence in this trial that discomfort due to crowding could be reduced through use of a bunking schedule where only half of the subjects were up at any given time. With addition of the shelves along the shelter walls, there was less complaint about difficulty in moving about the shelter than was found during the winter trial. Dirt was a significant problem as particles clung to the skin during the period of intense perspiration. In this sense complaints about dirt seemed to carry a possibly more acutely irritating quality then during the winter.

The distinctions between acuteness and generality of individual discomfort factors observed during the previous trial not only were found here, but they were more pronounced. As before, there were significant shifts in the acuteness-generality rating during the course of trial. From an analysis of these shifts, it is possible to obtain an insight as to the relative significance of the various discomfort factors as a potential source of acute psychological disruption at various chronological periods in the shelter occupancy.

One of the most striking aspects of the statistical analysis carried out on the data from the two trials is the complex interaction of the many variables which are significant in determining psychological discomfort during shelter living. Essentially, this means that discomfort must be discussed in context with, or qualified by, a number of key variables, such as time in shelter and season. Generalizations beyond those made in this summary section would not be appropriate without consideration of all relevant variables involved. This does not mean that psychological discomfort in shelter living cannot be measured and evaluated. Rather, the results of this study add further reinforcement to the long established, but frequently neglected, axiom that one must be quite specific when discussing human behavior under conditions of stress.

CHAPTER 9

MEDICAL ASPECTS

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PRELIMINARY PLANS

The medical staff in the winter trial consisted of a medical officer and two hospitalmen as assistants. In anticipation of a greater incidence of medical disorders in the summer trial, an additional hospitalman was added to the medical staff. In both 2-week trials one shelter subject from each section was assigned to the medical staff. A medical kit was provided containing an assortment of symptomatic remedies and antibiotics. Surgical supplies consisted of sterile packs of instruments and dressings for performing minor surgical operations and also a resuscitator. A dental kit was available for emergency care of acute dental problems. Definitive treatment of major medical or surgical problems would not be attempted. Such cases would be transferred to the Naval Hospital.

Fig. 62 - Medical staff of the shelter

Sick call for each section was held immediately after the quiet period. Interviews by the medical officer with each subject followed the morning measurement of body weight, pulse rate, and temperature. Lectures on hygiene and sanitation were given to the group as a whole, in addition to special instructions to the food handlers.

TWO-DAY WINTER TRIAL

A total of 26 patients was seen at sick call during the 46 hours of the trial. Fifteen of these complained of headache, the majority of which appeared to be caused by the accumulation of CO_2 and tobacco smoke during the initial 3 hours with no ventilation.

Seven patients presented symptoms of mild upper respiratory infection (URI) without fever. Treatment both of headache and URI was symptomatic only. The remaining four cases consisted of one with laceration of the finger incurred while opening a cracker tin, two cases complaining of sleeplessness, and one case complaining of sinus pain. The only complaints unearthed by medical interview were chilliness while sleeping and lack of enthusiasm for the ration. During the 2-day trial there were not enough blankets to provide two per bunk, as planned.

TWO-WEEK TRIALS

Table 41 lists the total attendance at sick call and the number of new cases in each diagnostic category. Figure 63 compares the incidence rate of all disorders and Fig. 64 the incidence rate of febrile and nonfebrile upper respiratory infection. Also included in the summer graph (Fig. 64) is the number of cases with signs and symptoms of bronchitis. There were two dental cases in the winter, both requiring temporary fillings. Emergency dental treatment in the summer trial was limited to one case of pericoronitis (impacted wisdom tooth with infection) successfully treated with parenteral penicillim.

Table 41
Comparative Medical Observations in Winter (Feb. 17 - Mar. 3) and Summer (Aug. 1 - Aug. 15) Trials of the Navy Protective Shelter, NNMC, Bethesda, Md., 1962

Medical Observation	No. of Cases, Winter Trial	No. of Cases, Summer Trial
Total Attendance at Sick Call	167	656
Total New Cases	75	224
Case Rate by Category		
URI (afebrile)	32	68
URI (febrile)	16	4
URI with Bronchitis	-	12
Headache	13	21
Gastritis	2	14
Heat Exhaustion (mild)	-	4
Heat Edema	-	3
Diarrhea	1	-
Diarrhea (mild)	-	11
Insomnia	4	1
Emotional Disorder	1	4
Conjunctivitis	1	14
Otitis Externa	-	2
Skin		
Heat Rash	-	34
Other	3	23
Dental	2	1
Miscellaneous	-	8

Winter Trial

During the 2 weeks in the shelter, 59 of the shelter inhabitants were seen one or more times at sick call (Table 41). On the average, each of these 59 subjects attended sick call at least once on 2.8 different days during the trial.

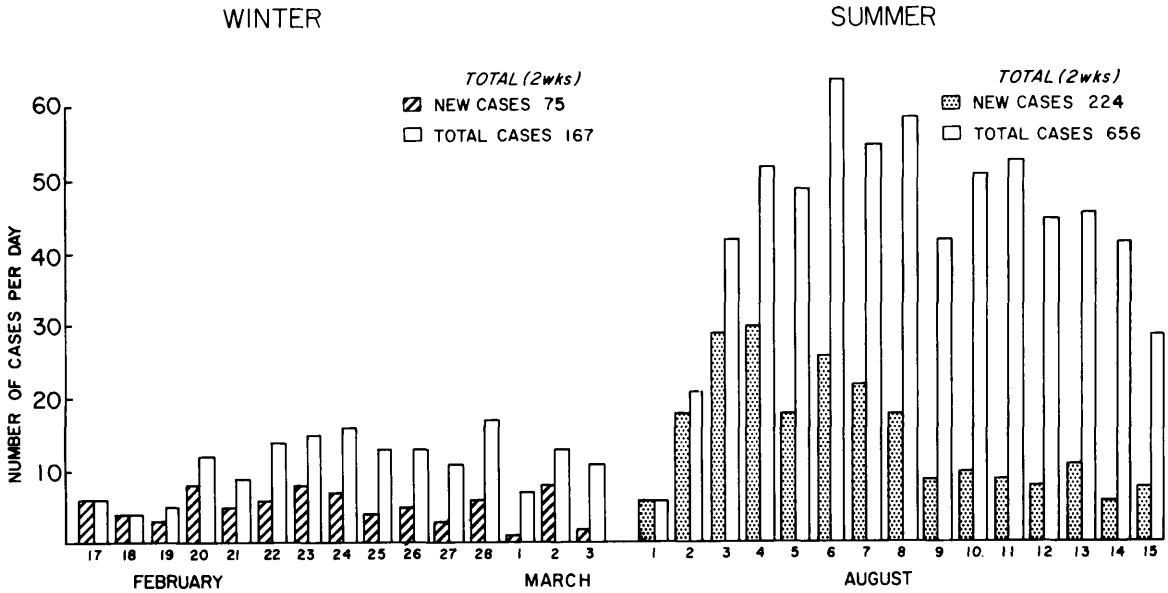

Fig. 63 - Daily incidence and prevalence of illness in 100 subjects during the winter (Feb. 17 - Mar. 3, 1962) and summer (Aug. 1 - Aug. 15, 1962) shelter habitability trials, NNMC, Bethesda, Md.

Forty-nine of the total of 77 new cases complained of upper-respiratory symptoms, chiefly those of the common cold. Fifteen, however, presented a picture of moderate to severe tonsillitis or pharyngitis, with patchy areas of exudate and ulceration in the more severe cases, fever up to 104°F, local lymphadenopathy, pain on swallowing, mild headache, and malaise. Throat cultures were negative for pathogenic bacteria, leading to the conclusion that a virus was the probable causative agent. This conclusion was supported by the finding that oral tetracycline and/or intramuscular penicillin used in the early cases before reports of throat cultures were available were ineffective, and this form of treatment was abandoned in treating the later cases. Routine treatment thus became dependent only upon administration of APC's, throat lozenges, saline gargles, forced fluids, and bed rest. The duration of the illness varied from 2 days in mild cases to 5 days in the more severe ones. Recovery was invariably complete and uneventful.

Whether a common agent caused this illness is uncertain. The daily incidence pattern of febrile URI (Fig. 63) suggests this possibility. It is postulated that in the initial outbreak, which occurred between Feb. 18 and 25, were cases who entered the shelter in the incubation period and the later outbreak, beginning on Feb. 27, involved secondary cases from contacts made within the shelter itself. The source of infection may have been the man described in the section on selection who was sent to the dispensary on Feb. 15 with pharyngitis and fever.

Dermatological problems were rare, despite lack of facilities for personal hygiene. One case of dyshidrosis occurred, which appeared functional in origin, being precipitated by a heated argument the patient had with a member of the division of which the patient was leader. One case of fungus infection of the skin of the trunk and one case of folliculitis of the scalp were the only other skin diseases encountered.

Summer Trial

Significant differences between the winter and summer are observed both in total attendance at sick call as well as in the incidence rate of illnesses in the various categories (Table 41 and Figs. 63 and 64).

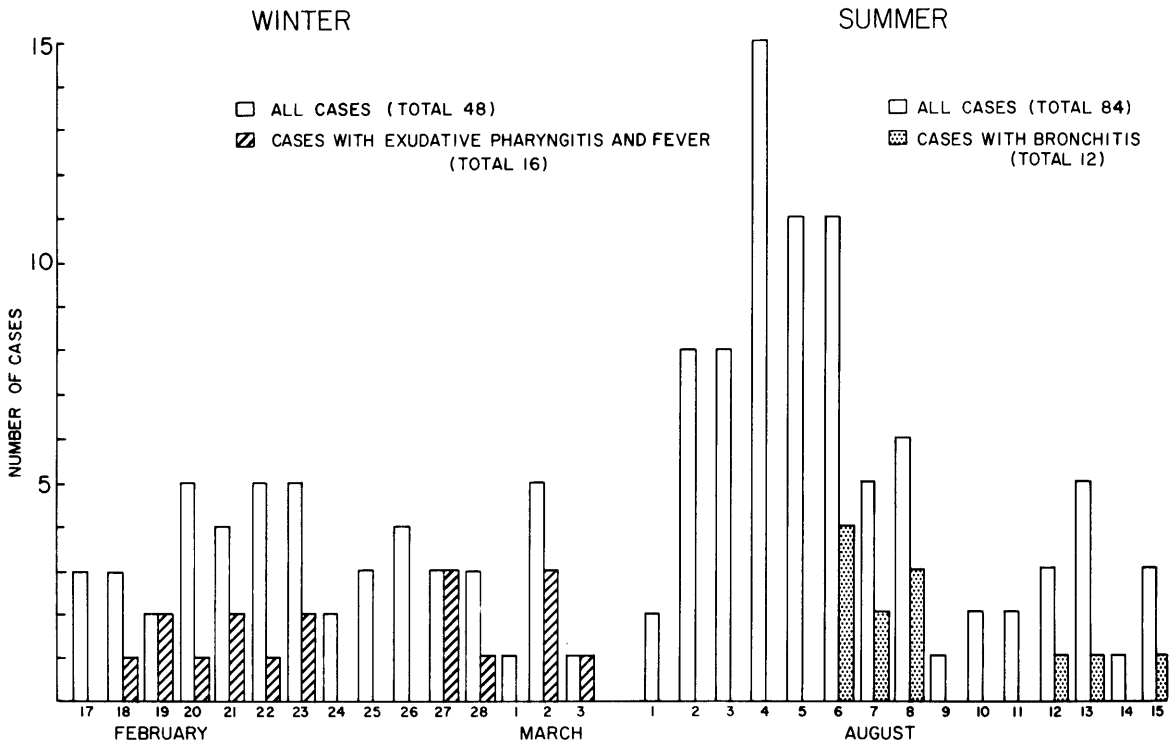

Fig. 64 - Daily incidence of upper respiratory infections in 100 subjects during winter (Feb. 17 - Mar. 3, 1962) and summer (Aug. 1 - Aug. 15, 1962) habitability trials, NNMC, Bethesda, Md.

In the summer trial 83 of the 92 shelter subjects were seen at least once at sick call. Each of these was seen on the average of 7.9 times during the 2-week period. The incidence rate of afebrile URI was twice as great as in the winter trial, but the incidence of URI associated with fever was less. No cases of exudative pharyngitis, described as typical of the febrile disorders in the winter trial, were seen in the summer trial. On the other hand, 12 cases of URI developed signs and symptoms of acute bronchitis, characterized by nonproductive cough and extensive coarse inspiratory and expiratory rales and ronchi, frequently wheezingor sonorous in character, over one or both lung fields. Recovery was slow in the shelter, but all cases cleared rapidly within 48 hours after emerging. Chest x rays of those with residual signs on auscultation at the end of the shelter trial were negative when examined within 24 hours after leaving. The majority of cases of URI in the summer trial were typified by mild to moderate redness and edema of the pharynx and tonsilla region, nasal congestion and serious discharge, and injection of the conjunctival vessels. Complaints of cough, sore throat, and headache were commonly associated with these findings.

Heat rash was a major problem in the summer trial. Figure 66 shows the daily incidence of new cases in relation to the mean daily effective temperature. No new cases occurred when the ET dropped below 80° F. Most cases were relatively mild, but a small number were severe enough to be partially incapacitating. Attempts to provide a cooler environment by changing bunk location to one near an inlet terminal and in one case placing the bunk in the escape tunnel were only partially successful. It was not until ambient temperature was reduced by the combined effect of increased ventilation rate and lowered weather temperatures that the cases improved. In almost every case punctate pustules developed in the affected area but remained discrete in most cases. Absence of facilities for skin hygiene probably contributed to the secondary infection of the primary lesions.

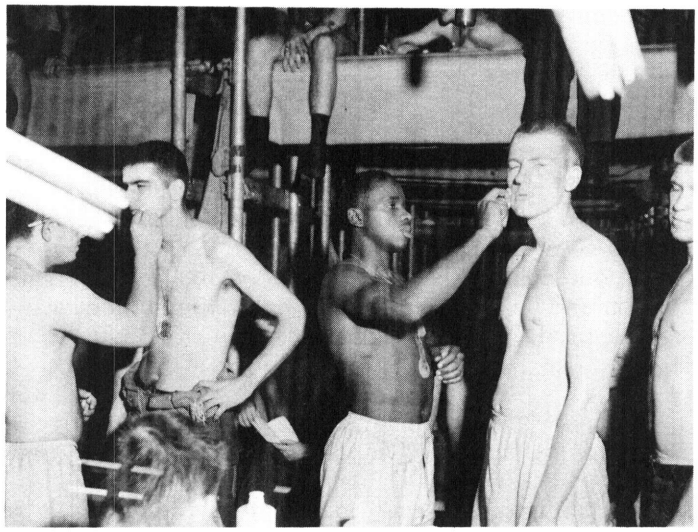

Fig. 65 - Men being treated for heat rash

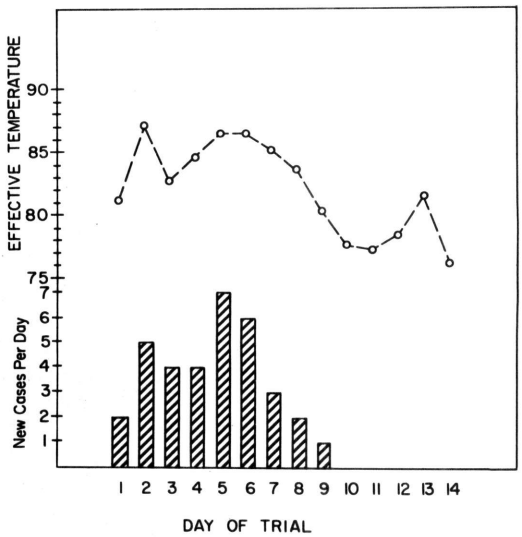

Fig. 66 - Mean daily effective temperature and incidence of heat rash, summer shelter habitability trial, Aug. 1 - Aug. 15, 1962, NNMC, Bethesda, Md.

The category of skin disorders listed in Table 41 as "other" includes primarily skin diseases which existed prior to entering the shelter, chiefly acne vulgaris and epidermophytosis. One case of taenia versicolor was seen. Both acne and the fungus infections were effectively controlled by treatment and foot hygiene. Periodic examinations revealed no extension of these eruptions, and in many cases the disorders had improved during the shelter stay.

Conjunctivitis, otitis externa, and heat edema were three other conditions not encountered in the winter trial which were probably related to the high temperature and humidity. The probable cause in most cases of conjunctivitis was the dripping of sweat from the forehead into the eyes. Heat edema was limited to the feet and ankles, usually being a pitting edema but in one case associated with redness and tenderness. All cases cleared as shelter temperature subsided.

The higher incidence of gastritis in the summer was probably related to the intake of salt tablets with inadequate consumption of liquid. When the subjects were instructed to take the tablets immediately before meals with ample water, gastric complaints largely disappeared.

The other category which relates to heat stress in the summer trial is that of heat exhaustion. These cases occurred toward the end of the first week and were characterized by weakness, vertigo, loss of appetite, and mild abdominal distress in some cases. The Fantus test indicated no deficiency in salt in the urine. Physical findings were essentially negative, except in one case with pain and tenderness in the right lower quadrant both on external palpation and by rectal examination. This subject was evacuated and examined at the Naval Hospital. Acute appendicitis was ruled out, and the subject was returned to the shelter.

Another of the four cases, although showing no positive findings on initial examination, developed a hyperventilation syndrome with periodic breathing and marked orthostatic hypotension. While being transferred from an upper to a lower bunk, his blood pressure fell to 80/0 in the upright position. He was immediately placed in the recumbant position, at which time it was noted that he was completely apneic and unconscious. Resuscitation was given by mouth-to-mouth artificial respiration followed shortly by oxygen administration using intermittent positive pressure with a resuscitator. He was evacuated to the Naval Hospital where he recovered completely within 15 minutes. This subject was not returned to the shelter and was the only subject in either of the two tests who did not remain for the entire 2-week period.

Diarrheal diseases in both trials did not present a problem. A common complaint during the first week was the infrequency of bowel movements. Many subjects did not have a bowel movement for several days. In most cases normal patterns were restored about midway through the trial. In some cases two or three bowel movements a day were noted after the first week, leading to a complaint of "diarrhea" (see Table 41). However, these were not generally associated with cramps or tenesmus, and the stool itself was not watery in character. These frequent bowel movements probably represent physiological responses to the condensed ration and low activity levels.

Emotional disorders of a clinical nature were uncommon. In the winter trial one man exhibited evidence of an emotional disturbance characterized by anxiety, depression, and withdrawal. Librium(R), 10 mg/day, was administered for 4 days. Improvement was gradual but complete. At the end of the 2-week trial he appeared well-adjusted and happy, entering into group activities with enthusiasm. Of four cases complaining of insomnia, in only one did there appear to be an underlying anxiety reaction as a basis for his difficulty. Treatment consisted of mild sedation and reassurance.

In the summer trial four cases were treated for mild emotional disorders. Three of these also exhibited symptoms of heat exhaustion. It was not possible to dissociate underlying emotional imbalance from the physiological strains imposed by the relatively high levels of heat stress as factors contributing to the picture of heat exhaustion. These cases of emotional disorder were treated either with Librium(R) or Meprobamate, together with reassurance. There is reason to believe that the initiating factor in the case displaying the hyperventilation syndrome was a failure to adapt to prolonged heat exposure which in turn led to an anxiety reaction characterized by hyperventilation.

The medical interview was time-consuming and of questionable value, except in revealing the onset of acute diseases at an early stage of development. During the interview, however, the subject was encouraged to air any complaint, medical or otherwise, and this procedure may have alleviated emotional tensions to some extent.

DISCUSSION

Crowding coupled with high environmental temperatures in the summer trial are the two factors which contributed most to the medical problems encountered in these trials. Lack of facilities for personal hygiene is a secondary factor leading to secondary infection in cases of heat rash.

Close contact between shelter inhabitants was unavoidable even while sleeping, despite the regulation head-to-foot orientation. Fortunately, the organisms which cause the more severe upper respiratory infections were either not highly contagious or were spreading through a population which was already largely immune. In any event, the attack rate was low, being appreciably less than for the milder forms of afebrile URI. In the summer trial the higher incidence of URI might indicate either (a) lack of specific immunity, (b) greater viability and virulence of the agent, or (c) lowered resistance resulting from heat strain on the subjects. It is not possible to determine which of these factors or combination of factors is responsible. That spread of the organism is direct, and not through contamination of the environment, is suggested by the fact that dust content of the air was visibly much less in the summer than in the winter because of the dampness of the deck and other surfaces. Nevertheless, the incidence rate of respiratory diseases was appreciably higher in the summer trial.

It is not pleasant to contemplate the conditions that would prevail in a shelter if the agent of a highly contagious disease were introduced into a susceptible shelter population by an immune carrier or by an infected case who was in the incubation period of the disease at time of entry. No doubt the problem of communicable diseases was minimized in this trial because these men had lived in fairly close contact with each other for several months of recruit training immediately before the trial began and had thus acquired immunity from agents which by then were more or less uniformly distributed through the group. The bacteriological studies reported here indicate the ease with which the spread of throat organisms can occur under conditions of close contact.

In a report published after his death, Yaglou (1) proposed that 85°F ET was the maximum level of heat stress which could be tolerated by the general population under shelter conditions for 2 weeks. This proposal assumed that ill or debilitated persons would be cared for in special shelters. Our results support this view. During the first week, although the average daily effective temperature was 85°F, temperatures often exceeded 85°F for periods of hours or even a day or more at a time. During this first week the incidence rate of disorders resulting from heat was appreciable. Moreover, there was general deterioration in appetite and in the ability of subjects to obtain restful sleep. It is our opinion that incidence of disorders related to heat and cumulative fatigue would have become unacceptably high if the conditions existing during the first week had prevailed throughout the 2-week period. There were no clear indications that the subjects became acclimatized. The question which can be answered only by laboratory investigation is whether heat stress imposed by a uniform level of heat and humidity is comparable in its physiological effects to cycling conditions of environmental heat which result in the same mean level. It seems quite possible that peaks of heat stress, resulting from diurnal changes in weather conditions outside or with patterns of activity of a shelter population may impose more strain than under laboratory conditions in which engineering controls maintain a steady level of heat and humidity.

CONCLUSIONS

Crowding, high temperature, and lack of facilities for personal hygiene are major factors contributing to the medical disorders encountered in these two trials. In the summer trial environmental heat caused a high incidence of heat rash as well as a small number of other heat illnesses. One case of heat exhaustion was evacuated on day 7 of the summer trial.

The total incidence of clinical disorders was 3 times higher in the summer trial than in the winter trial. To what extent the greater environmental stress may have been a contributing factor is uncertain.

Pathogenic bacteria were not a significant factor in the etiology of illness in these trials, but the rapid spread of respiratory diseases of virus origin indicates that the control of diseases transmitted by direct contact and by droplets is a major unsolved problem in shelter habitability.

REFERENCE

1. Yaglou, C.P., "Limits for Cold, Heat, and Humidity in Underground Shelters," Arch. Environ. Health 2:110-115 (1961)

CHAPTER 10

BACTERIOLOGICAL STUDIES

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PRELIMINARY CONSIDERATIONS

Bacteriological studies are an important aspect of a comprehensive shelter study. Such studies serve as a backup for the medical and physiological studies and as a means of estimating the extent to which pathogens may be transmitted throughout a shelter population. In addition the Bacteriology Division assumed the responsibility of ascertaining that the water remained safe for drinking purposes throughout the trial.

PROCEDURES

The materials and methods used for the winter trial (1) were again used in the summer trial, together with a blood-sampling procedure. In the report of the winter trials it was noted that there was a need for virological or serological backup for the bacteriological studies. In the event of an outbreak of either an upper respiratory or enteric nature, which could not be accounted for bacteriologically, identification of the etiological agent would be of greatest importance. Therefore, blood for sera was drawn on all subjects in the bacteriological surveillance group. The sera was frozen and stored in the deep-freeze pending possible use. The schedule of sampling of the shelter subjects for bacteriological and serological studies is shown in Table 42. Air and water samples were taken daily throughout the trial.

Table 42
Schedule of Sampling for Bacteriological and Serological Studies

Day of Trial	Date	Blood Sample	Throat and Rectal Swabs
Entry - 2	7/30/62	port and stbd.	port and stbd.
Entry + 1	8/2/62	-	port
Entry + 3	8/4/62	-	stbd.
Entry + 5	8/6/62	-	port
Entry + 7	8/8/62	-	stbd.
Entry + 9	8/10/62	-	port
Entry + 11	8/12/62	-	stbd.
Entry + 13	8/14/62	-	port and stbd.
Exit	8/15/62	port and stbd.	-

RESULTS

Neither shigella nor salmonella were found in any of the rectal cultures. The enteropathogenic coliform recovered from the rectal cultures are shown in Table 43. Only one of the isolations was made prior to entry into the shelter, the rest being found during the confinement period. After careful examination of the sleeping and eating assignments, and taking into consideration the diversity of strains found, the possibility of this number of recoveries being due to spread among the shelterees during confinement is considered remote. The difference between these numbers and those found in the winter trial can probably be considered a population variation only.

Table 43
Enteropathogenic Coliform Recovered from Rectal Cultures

Strain	No. of Isolations	No. of Shelter Subjects Represented
0126:B16	11	6
0127:B8	6	5
0128:B12	7	6
0124:B17	3	3
0125:B15	3	3
055:B5	1	1
026:B6	1	1

Throat Cultures

The predominating organisms found from the throat cultures were, in descending order of predominance, nonhemolytic streptococcus, staphlococcus, neisseria, and diphtheroids.

Beta hemolytic streptococcus had been isolated in the winter trial but was not found in the summer trial. All of the organisms isolated in the summer trial can be considered normal throat flora.

Blood Samples

It was decided that the four cases of URI (febrile) and the eleven cases of mild diarrhea did not justify analysis of the blood sera that had been collected and frozen. Nothing further was done with the blood samples.

Air Samples

No unusual organisms were isolated from the air samples (Table 44). Although day to day fluctuations occurred, the air contaminants remained essentially unchanged throughout the trial. The number of organisms recovered from the air samples was extremely low. It is believed that this low recovery of organisms was due to the high humidity within the shelter, the small amount of dust suspended in the air, and the low level of activity of the shelter subjects.

Table 44
Air Samples (AGI) - Summer Shelter Trial

Date	Time Taken	Time Received at Laboratory	Sweepdown Prior-Time	Number of Men		Total Bacterial Count (organisms/ml)	Predominating Organism
				In Bed	Up		
8-2-62	0937-0952	1400	No	50	50	62	Staphylococcus
8-3-62	0915-0930	1100	No	50	50	73,800	Staphylococcus
8-4-62	0945-1000	1100	No	50	50	38	Streptococcus
8-5-62	0858-0907	1030	No	50	50	16	-
8-6-62	0840-0855	1100	No	50	50	12	B. Subtilus
8-7-62	0848-0902	1100	No	50	50	66	B. Subtilus
8-8-62	0923-0937	1100	No	49	50	109	Staphylococcus
8-9-62	0853-0908	1030	No	49	50	54	B. Subtilus
8-10-62	0830-0845	1030	0530	49	50	46	B. Subtilus
8-11-62	0830-0845	0930	No	50	49	31	B. Subtilus
8-12-62	0830-0845	0930	No	49	50	49	B. Subtilus
8-13-62	0830-0845	1045	No	49	50	32	Staphylococcus
8-14-62	0830-0845	0930	No	49	50	21	-
8-15-62	0830-0852	0930	0530	49	50	27	Staphylococcus

Water Samples

The water was treated by a one-shot chlorination technique 3 days prior to the beginning of the trial. Although the residual chlorine fell to below 0.1 ppm during the trial (Table 45) and the total number of organisms in the water increased substantially, the water remained safe for drinking.

Comparative results from the winter and summer trials are given in Appendix D.

Table 45
Water Samples - Summer Shelter Trial

Date	Time Taken	Time Received at Laboratory	5-Tube Lactose Broth Test-Pos/		Total Bacterial Count (organism/ml)	Predominating Organism	Chlorine Residual (ppm)
			24 hr	48 hr			
7-30-62	-	-	0/5	0/5	-	-	0.2
8-2-62	1000	1400	0/5	0/5	17	Staphylococcus	<0.1
8-3-62	0940	1100	0/5	0/5	10	Staphylococcus	<0.1
8-4-62	1000	1100	0/5	0/5	1	Staphylococcus	<0.1
8-5-62	0915	1030	0/5	0/5	4	N.G.	<0.1
8-6-62	0900	1100	0/5	0/5	20	G. pos rods	<0.1
8-7-62	0915	1100	0/5	0/5	Contaminated	G. pos rods	<0.1
8-8-62	0940	1100	0/5	0/5	31	Staphylococcus	<0.1
8-9-62	0915	1030	0/5	0/5	47	Staphylococcus	<0.1
8-10-62	0835	1030	0/5	0/5	22	N.G.	<0.1
8-11-62	0835	0930	0/5	0/5	65	B. subtilus	<0.1
8-12-62	0835	0930	0/5	0/5	84	G.N.R.	<0.1
8-13-62	0840	1045	0/5	0/5	108	G.N.R.	<0.1
8-14-62	0835	1030	0/5	0/5	800	N.G.	<0.1
8-15-62	0855	0930	0/5	0/5	112	Staphylococcus	<0.1

REFERENCE

1. Ramskill, E.A., et al., "Studies of the Bureau of Yards and Docks Protective Shelter, I. Winter Trials," NRL Report 5882, Dec 31, 1962

CHAPTER 11

SUMMARY AND CONCLUSIONS

PRELIMINARY REMARKS

This chapter contains a brief summary of the results obtained in the summer trial of the NAVFAC protective shelter. Only those items considered most significant are included here; the reader is referred to the appropriate chapters for detailed information.

SUMMARY

A 2-week summer trial was conducted in August 1962 in a protective shelter designed by BUDOCKS (now NAVFAC) and constructed on the grounds of the National Naval Medical Center, Bethesda, Md. The shelter was designed to provide overall blast protection of at least 75 psi overpressure, a radiation-protection factor of 5000, and complete NBC warfare protection. The shelter is a re-enforced Quonset hut, 25 ft wide, 48 ft long, and 12 ft high along the center line. Electric power is supplied by a 10-kw diesel generator. Ventilating air is supplied by an army-gas-particulate filter unit. The shelter design called for a 600-cfm unit. On the basis of the winter trials, it was decided that a 1200-cfm unit would be required for the summer trials. Because the space available for the gas-particulate filter unit was insufficient for the complete 1200-cfm unit, only the blower was used during the summer trials. In addition to the increased ventilation capacity (six 1-ton window units) of standby air conditioning were installed in a specially designed chamber outside of the shelter. Water for the shelter is supplied from a 4000-gal steel storage tank buried outside the shelter. Toilet facilities consist of six chemical units which are connected to a dry well. The bunks are canvas supported between 1-in.-diameter standard pipes. Fifty bunks are provided for 100 men. An emergency tunnel connects the rear of the shelter to an underground passageway joining buildings of the National Naval Medical Center.

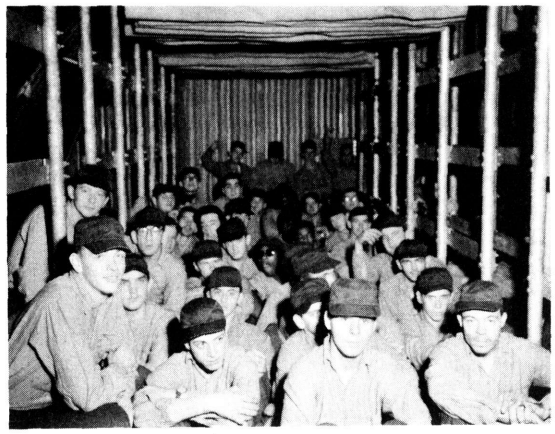
The subjects for the summer trial were 100 carefully screened Navy volunteers. Two naval officers served as shelter commander and medical officer. A chief petty officer and a first class petty officer served as section leaders.

The ventilation rates and average effective temperatures are shown in Table 46.

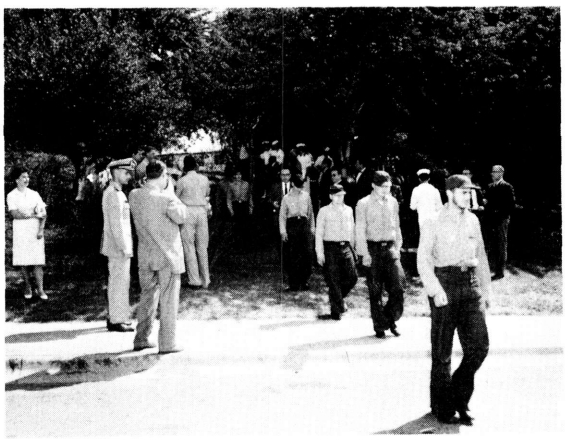
Table 46
Ventilation Rates and Effective Temperatures

Days	Ventilation Rate (cfm)	Effective Temperatures (°F)		
		Inlet	Diffuser	Shelter
1-2	300	70	79	84
3-7	700	74	78	85
8-14	1200	67	72	80

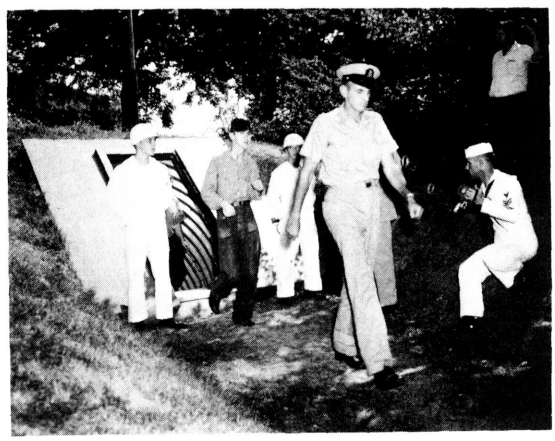
(a) Final field day in shelter



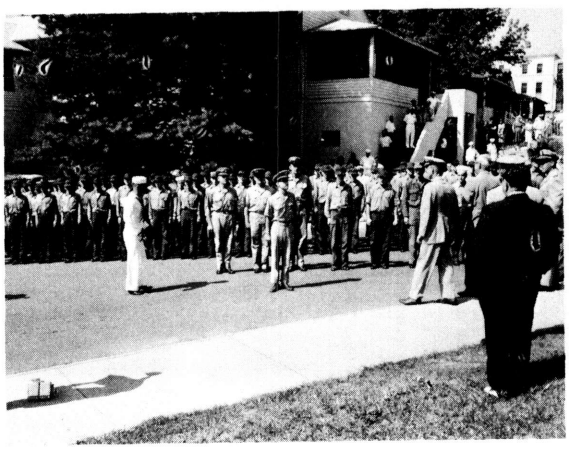
(b) Final assembly in shelter



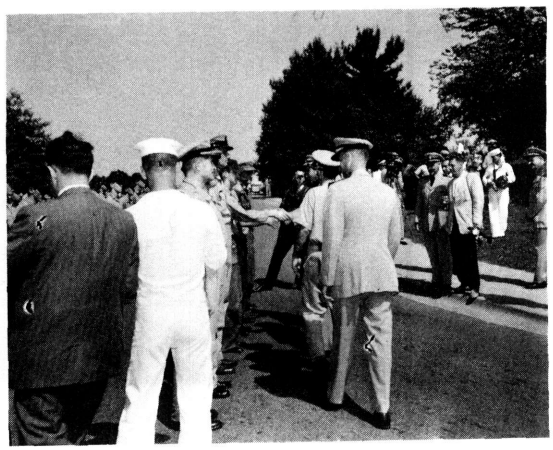
(c) Sunlight again



(d) Sunlight again



(e) Congratulations



(f) Congratulations

Fig. 67 - Summer shelter trial coming to an end

The temperature difference between the inlet and the diffuser was due to heat from the vane axial blower. A careful study of the data in Chapter 3 indicates that the decrease in the effective temperature in the shelter living space was due largely to the decrease in inlet temperature, and little, if any, was due to the increased flow rate.

There was no evidence in these trials that the subjects became adapted to heat. In fact there were indications that heat tolerance decreased during the first week of the trial, i.e., during the period when the average ET was 85°F.

A ventilation rate of 2.7 cfm per man was found to be sufficient to maintain a habitable atmosphere with respect to O_2, CO_2, CO, and aerosols, even with unlimited smoking. Unless the shelter is to remain unventilated for long periods of time, O_2-generating and CO_2-removal systems are not necessary. The CO_2 concentration can be calculated by assuming a CO_2 production rate of 0.6 cu ft/hr/occupant. As long as the CO_2 concentration remains below 4%, the oxygen level can be assumed to be adequate, and the CO_2 will not cause anything more serious than a headache, unless there are some shelterees suffering from respiratory diseases or heart weakness.

A total of 1237 kw-hr of electrical power were used during the 2 weeks with a peak load of approximately 4.9 kw.

The aerosol concentration, while very high, was acceptable for this select group of shelterees.

The sound level was very high, reaching 85 db at times. The major source of noise was the ventilation blower.

The water-consumption figures indicate that for hot weather occupancy a minimum of 2 and preferably 3 qt H_2O/man/day should be stocked for ingestion. In addition, a minimum of a pint of water per man per day should be stocked for hygenic purposes. If it is a command shelter, then sufficient water must be stocked to allow for decontamination showers (see Summary of Chapter 3).

With the exception of the commanding officer, the medical officer, and certain staff members, the shelterees were recruits recently graduated from the Naval Training Center, Great Lakes, Illinois. Because of the anticipated heat stress during the summer trial, very stringent physiological and psychological standards were set for the shelterees. The mean age of the recruits selected was 19.2 years.

The organization and management were designed to be authoritarian with respect to all matters pertaining to health and safety and democratic for problems arising outside this category. The shelterees were divided into two sections and each section was subdivided into four divisions, each division having certain tasks to perform. This arrangement maintained a management hierarchy and provided for the orderly accomplishment of housekeeping and other necessary tasks.

Hot bunking was acceptable to this group. Nevertheless, during the first week, the rough canvas appeared to aggravate the heat rash, and many of the bunks never had a chance to dry out.

Two meals were served during each 24-hour period. A cold meal consisting of survival ration crackers, jam, and coffee with sugar and cream and a hot meal consisting of survival ration crackers, soup, peanut butter, and coffee with sugar and cream. The survival ration crackers accounted for 81% of the total calories of the ration. The overall acceptability of the crackers issued was 88% during the summer trial compared with 98% during the winter trial. Biochemical studies showed that this austere ration can be employed with safety during a 2-week shelter life under the conditions encountered.

For the summer trials physiological measurements were selected which would detect strain on thermoregulatory mechanisms. These measurements included body temperature, pulse rate, sweat production, exercise tolerance, and the intake and excretion of water and electrolytes. During the summer the correlation coefficient between the effective temperature in the shelter and body temperature was $r = 0.9523$.

The mean daily water intake ranged from 1600 to 3000 ml. The data show clearly that water intake under the shelter conditions observed in these trials cannot be predicted from air temperature alone. The correlation coefficient between water intake and dry-bulb temperature was only 0.5420 while the coefficient between water intake and wet-bulb temperature was 0.9389. This relationship is not surprising because, as the air temperature approaches skin temperature, evaporative cooling becomes more and more important as the heat-regulating mechanism for the body.

Exercise tolerance, as determined by the Harvard Step Test, did not decrease during the 2-week trial. A post-trial study of the data shows clearly that the physiological and psychological low point of the trial was the end of the first week, i.e., end of 85°F average ET, and that the lower average ET during the second week gave the men an opportunity to recuperate.

Psychological studies showed that lack of water for washing, temperature and humidity, food, crowding, and dirt consistently produced the most discomfort during the summer trial. Lack of water for washing was a particularily significant and emotionally charged source of discomfort. The subjects reported a feeling of general "stickiness" from excessive perspiration aggravated by the tendency of particles of dirt to stick to the skin. The wash-and-dry pads tended to increase the feeling of stickiness. The vast majority of subjects freely verbalized that they could not have completed the trial if the heat and humidity experienced during the first week had continued. During the first week the men's bodies were constantly wet from perspiration.

The crackers became progressively less appetizing with the passage of time. The soup was considered to be the high point of the day.

Crowding assumed significant proportions when all the subjects were up at the same time. Movement about the shelter was accompanied by an unavoidable bumping and jostling of others.

Two men were removed from the shelter for psychological reasons. One, a 38-year old staff member who had not been screened prior to the trial, was removed on the second day. In a debriefing following his removal from the shelter the subject exhibited indications of claustrophobia as well as strong suggestions that unconscious psychosexual conflicts had been activated by the enforced contact with the men in the shelter. The second man, a recruit subject, was removed on the seventh day following loss of consciousness while being examined by the medical officer. After careful medical and psychological evaluation, it was concluded that this man experienced an acute episode of hyperventilation, and his symptoms were of hysterical origin. The subject's recovery was rapid, and he was assigned duties outside of the shelter. At least five other subjects exhibited mild to moderate emotional disturbance, but all cases were handled effectively by the medical officer, and all successfully completed the trial. In debriefing, it became apparent that the subjects had an almost childlike confidence in the medical officer and believed that they were safe as long as Dr. Minard was present.

In the summer trial, 83 shelter subjects were seen at least once on sick call, the average being 7.9 times during the 2-week period. Heat rash was the major problem. Most cases were relatively mild, but a small number were severe enough to be partially incapacitating. The incidence rate of afebrile URI was twice as great as in the winter trial although the incidence of URI with fever was lower than in winter. One case of heat

prostration occurred (see above). During the first week (average ET 85°F) the incidence rate of disorders resulting from heat was very high, and it is the opinion of the authors that it would have been necessary to terminate the trial if the 85°F average ET had continued into the second week.

Bacteriological studies were conducted as a means of estimating the extent to which pathogens may be transmitted throughout a shelter population. Neither shigella nor salmonella were found in any of the rectal cultures. Although a number of entero pathogenic coliform was recovered from rectal cultures, the data do not indicate that the coliform were spread among the shelterees during the confinement.

The organisms isolated from throat cultures taken during the summer trial can all be considered normal throat flora.

The number of viable organisms recovered from the air samples was extremely low.

The water treated by a one-shot chlorination technique 3 days prior to the trial remained safe for drinking even though the total number of organisms in the water increased substantially.

CONCLUSIONS

With the exception noted under recommendations, this particular shelter as designed by BUDOCKS and as modified for the summer trials is adequate from an engineering standpoint. One-hundred healthy men, accustomed to an authoritarian regime, having confidence in their leaders, successfully survived under the austere conditions imposed by this shelter trial. With the possible exception of that period of time when the average ET was 85°F the men were physically combat ready. The men survived 1 week of 85°F average ET, but it is highly improbable that they could have survived a second week of the same conditions. The diet, consisting largely of survival rations crackers, was unpopular, but it supplied the necessary elements for survival as evidenced by the fact that weight losses were moderate, and the men were in good physical condition at the end of the trial. With the exception of the heat rash existing during the first week when the average ET was 85°F the physiological problems were not severe. With the exception of two men who had to be removed from the shelter the psychological problems were not severe.

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CHAPTER 12

RECOMMENDATIONS

The recommendations contained here are for changes in or additions to the shelter as it was installed at the Naval Medical Center. This "shelter" is a "command type" for occupancy by up to 100 healthy males. For a survival shelter the decontamination tunnel could be deleted and the water supply reduced to 1200 gallons.

NUTRITION

It is recommended that a survival ration cracker be stocked but not as the main source of food. Equal emphasis should be given to a broad spectrum of dehydrated foods. Emphasis must be given to food-storage containers which will withstand long term storage, can be opened without special tools, and, once opened, will not present a trash-storage problem.

MEDICAL

It is recommended that a shelter medical kit be devised. The kit, including detailed instructions, should enable the shelter commander to treat not only common bruises, colds, nausea, etc., but also the effects of chemical warfare agents.

RECREATION

It is recommended that a wide assortment of paperback books and games be stocked.

ORGANIZATION AND MANAGEMENT

It is recommended that detailed instructions on the organization and management of a shelter be drawn up and made a part of a shelter kit using the information contained in this report and in the report of the winter trials.

EQUIPMENT AND SUPPLIES

The recommended list of equipment and supplies is shown in Chapter 2.

CONSTRUCTION

It is recommended that:

1. All essential equipment and supplies be moved into the shelter and either attached to the skin of the shelter or supported by the concrete slab which forms the deck (this slab is free to move in relation to the skin). For example: (a) Water tanks could be designed to fit in the overhead. These tanks could be hung from the skin or

supported by the bunk framework. (b) The fuel supply for the diesel generator should be on the same platform as the diesel. If a suitable noise-absorption system can be designed, the diesel could be moved inside of the shelter. The exhaust air from the shelter would be sufficient to provide combustion and cooling air for the diesel. By installing an auxiliary radiator, the heat generated by the diesel could be used to heat the shelter in winter.

2. The blast door be redesigned to provide a door which will not be jammed by blast, corrosion, or minor errors in installation.

3. The decontamination area be redesigned to (a) permit passage of a stretcher without loss of pressure in the shelter living space, (b) provide adequate air sweep through the decontamination area, and (c) provide for the proper disposal of contaminated clothing.

4. The ventilation system be redesigned to (a) use a collective protector which has good blast resistance, such as the NRL filter units, (b) protect the living space from blower noise, (c) provide protection against radioactive material on the particulate filter, (d) provide for the positive ventilation of the head to prevent odors from circulating into the living space (a design which placed the head, the decontamination tunnel, and the equipment room in a straight line along one side of the shelter would serve this recommendation and recommendations 1(b), 3(a), and 3(b)), (e) provide for a minimum of 0.3 inch of H_2O positive pressure in the living space, and (f) reduce the collective protector capacity to 300 cfm.

5. Other bunk configurations and materials be evaluated and the feasability of providing bunks for only 1/3 of the shelter subjects be studied.

6. Circuit breakers be accessible from the main living space.

7. Adequate storage space for supplies be provided.

8. A simple light barrier be installed between the bunk space and the more brightly lighted space.

9. A suitable trash-disposal system be designed. The trash which accumulates in a shelter presents not only a problem of sheer volume, but it is a fire hazard and may be a health hazard.

10. The water storage tank be reduced to 1500 gallons (1200 gallons for personal use and 300 gallons for decontamination)

11. A water heating system be installed to provide 105°F water for decontamination showers.

12. An air-conditioning recirculation system of sufficient capacity be installed to prevent the average daily effective temperature of the air in the living space from rising above 80°F. For a large part of the year for a large part of this country, survival would be impossible without such an air-conditioning system.

ACKNOWLEDGMENTS

The success of a task of the magnitude of the shelter trials described here depends upon the combined efforts of many persons. While it is not possible to recognize everyone associated with the trials, the authors particularly commend the following persons whose assistance contributed significantly to the success of the trials:

1. From the Naval Medical Research Institute:

   Dr. W.W. Haythorn
   Lewis Copman, LCDR, MC, USN
   R.L. O'Brien, HMC, USN
   C.R. Lindberg, HMC, USN
   R.J. Lachappelle, HM2, USN
   R.C. Hanson, HM2, USN

2. From the American Institute for Research:

   Dr. James W. Altman

3. From the Potomac Electric Power Co.:

   Mr. Goldsborough

4. From the Naval Facilities Engineering Command:

   Edward M. Saunders, CAPT, CEC, USN

5. From the Naval Research Laboratory:

   Jack L. Bitner
   William H. Echols
   Robert C. Clark
   Wendell L. Anderson
   Vernon P. Robey
   Thomas J. Robinson
   Garland Delauder
   George F. King
   Edward O. Merryman
   Edward R. Follin
   Richard L. Orndorff
   John C. Ballard

6. From the Naval Hospital, Bethesda, Md.:

   Staff of the Neuropsychiatric Service who cooperated in debriefing and examination procedures

7. From the Naval Medical School, Bethesda, Md.:

   Staff of the Television Division under William B. Pitzer, CDR, MSC, USN (Deceased)

8. From RAND Corporation:

   Dr. Anders Sweetland

9. From Army Medical Research and Nutrition Laboratory

   C. Frank Consolazio

10. From among the shelterees

    P.H. Goselin, S.A. USN (Shelter Photographer)

APPENDIX A

Shelter Schedules
Initial Organization Phase

1100	Enter shelter - close doors and valves
1105	SC identifies self - instruction for blast preparation
1110	"Blast" - lights go out - appoint recorder and call for volunteers to start generator - instruct on organization
1130	Lights go on - instructions on setting bunks down - 50 men into bunks
1150	Divide the "up" men into divisions
1200	Activate heads and water watch
1210	Divisions elect leaders
1220	Log in men, pass out diaries, ditty bags and canteens
1300	Pass out division instructions - send divisions to selected areas - SC go over instructions with divisions
1330	Cooking division begins preparation of the cold meal
1415	Cold meal
1500	Clean-up and stb'd section gets out of bunks - port section into bunks
1530	Organization into divisions
1550	Divisions elect leaders
1600	Log in men - pass out diaries, etc.
1645	Pass out division instructions
1700	SC go over instructions with each division
1730	Cooking division prepares cold meal
1815	Cold meal
1900	Clean up
1930	More comprehensive briefing on program, etc. - questions and answers
2100	Pick up normal schedule

8-4-8-4 Schedule

0000	
0100	
0130	Clean shelter - set up bunks
0200	Port section into bunks
0300	
0400	
0500	
0600	
0700	
0800	
0900	Hot meal for stb'd section - daily report - prepare cold meal
1000	Port section out of bunks - bunks secured - medical check
1100	Port section eats cold meal
1200	
1300	Sick call
1400	Set up bunks - stb'd section in bunks
1500	
1600	
1700	
1800	
1900	
2000	
2100	Hot meal for port section
2200	Stb'd section out of bunks - secure bunks - medical check
2300	Stb'd section eats cold meal
2400	

8-8-4-4 Schedule

0000	
0100	Sick call (stb'd section)
0200	
0300	Stb'd section "C" division prepare hot meal
0330	Stb'd section into bunks
0400	Port section eat hot meal
0500	
0600	Sick call (port section)
0700	Port section into bunks for sleeping - quiet hour
0800	
0900	Daily report
1000	
1100	
1200	Stb'd section "C" division prepare hot meal
1300	Stb'd section eat hot meal
1400	Sick call (stb'd section) - stb'd section "C" division prepare cold meal
1500	Port section out of bunks - medical check - cold meal - stb'd section into bunks for sleeping
1600	Quiet hour
1700	
1800	Sick call (port section)
1900	
2000	
2100	
2200	
2300	Port section prepare cold meal
2400	Stb'd section out of bunks - medical check - cold meal - port section into bunks

9-9-6 Schedule

0000	
0030	Port section eat hot meal
0100	Stb'd section out of bunks for medical tests (port section put up bunks - prepare cold meal)
0200	Stb'd section eat cold meal
0230	Clean up
0300	Sick call (both sections)
0400	
0500	
0600	Port section in bunks for sleeping - stb'd section put bunks down - quiet hour
0700	
0800	
0900	Daily report
1000	Stb'd section prepare hot meal
1100	Stb'd section eat hot meal
1200	
1300	Sick call (stb'd section)
1400	Stb'd section prepare cold meal
1500	Port section out of bunks for medical tests - Stb'd section in bunks for sleeping
1600	Port section eat cold meal - quiet hour
1700	
1800	Sick call (port section)
1900	
2000	
2100	
2200	
2300	
2330	Port section prepare hot meal

APPENDIX B

Test Scales for Psychological Studies in NAVFACENGCOM Protective Shelter

INTRODUCTION

Likert-type scale composed of multiple-choice items was employed to tab responses to discomfort factors. This scale was based on 13 of the 21 factors utilized in the ranking scale. The use of a smaller number of factors was based on the desirability both of limiting the period of scale administration to approximately one hour, and of reducing data-processing requirements. The 13 factors selected were those which had been found by Altman, et al. (1960) to be ranked highest, and/or which appeared likely to be most salient under the conditions of the present study. A copy of the scale is contained later in this appendix.

The scale was constructed by developing, for each discomfort factor four multiple-choice items, two items pertaining to acuteness of discomfort and two items relating to generality of discomfort. Acuteness items and generality items were presented, with appropriate instructions, in separate sections of the scale, and the order of items was random within a section. The entire scale was presented at each administration. The Likert-type scale, like the ranking scale, was pretested during the two-day trial, for purpose of determining its operational validity and clarity of instructions. A Spearman rho between rankings based on acuteness and ratings based on generality was equal to 0.94, which was significant beyond the 0.001 level. As before, this correlation coefficient indicated a high degree of agreement, but there was sufficient variability unaccounted for to justify retention of separate acuteness and generality ratings. Since it was considered possible that differences between the ranking scale and the Likert-type scale, in item form and instructions, would tap responses to discomfort factors in different ways, it was considered desirable to measure the relationship between the two types of scales. A Spearman rho was therefore calculated between acuteness on the two types of scales and between generality on the two types of scales. The rho based on acuteness was equal to 0.90, and the rho based on generality equalled 0.95, both significant beyond the 0.01 level. The magnitude of these correlation coefficients allowed the conclusion that the two types of scales were tapping responsiveness to discomfort factors in similar ways, and that meaningful comparisons could be made between sets of data obtained from the two types of scales.

Likert-Type Scale, Administration #1

NAME: _____ AGE: _____ HIGHEST SCHOOL

SERVICE NUMBER: _____ GRADE COMPLETED _____

SHELTER NUMBER: _____

As you have found out by this time, life in a fallout shelter isn't exactly like life at home. Almost everybody finds at least some things about shelter living to be uncomfortable. However, the things that bother one man might not really be important to others. In order to learn more about living in shelters, the Navy must find out the things that bother people. In the next few minutes, you are going to be asked to answer some questions about things which bother you. Remember in answering all of these questions, we are concerned only about the things that bother you; do not worry about whether you answer the questions in the same way as your buddies.

The next few pages contain a number of different statements about things which may bother you in shelter living. In each question a statement will be made at the beginning of a sentence, and after this will be five endings for the sentence. You are to make a check mark alongside the sentence ending which best describes how the thing bothers you.

Past studies in fallout shelters have shown that there are two ways in which people are made uncomfortable by shelter living. First, some things about the shelter may be uncomfortable almost all of the time; however, you could probably stand to live with them for a long time. On the other hand, there are certain factors in shelter living which don't make you uncomfortable very often; but, at the same time they are things you find very hard to take at those times they do occur. Because we know that things can be uncomfortable and bother people in these two different ways, the statements in this questionnaire are divided into two sections. In one section, the statements have to do with how often things bother you even though they may not make you too uncomfortable at any one time. In the other section, the questions deal with how much these things make you uncomfortable at any one time, even though they may not bother you too frequently. Please be sure that you understand the difference between the way you are to answer the statements in the two sections before you start working on the questionnaire.

If you are certain you understand what you are expected to do, turn to the next page and follow the instructions.

This section has to do with how much things bother you at any one time, even though they may not bother you too often. You tell us how much they bother you by making a check mark alongside the sentence ending that best describes how much you are bothered.

If none of the sentence endings describes exactly how much you are bothered, check the ending that comes nearest. Be sure to answer all of the things.

1. Compared to other things that disturb me in the shelter the problem of dirt is

   a. ( ) almost the toughest to take
   b. ( ) worse than many others
   c. ( ) about average
   d. ( ) better than many others
   e. ( ) almost the easiest to take

2. Compared to other problems in the shelter, lack of privacy upsets me

   a. ( ) nearly the least of all
   b. ( ) less than many others
   c. ( ) about average
   d. ( ) more than many others
   e. ( ) nearly the worst of all

3. Lack of sleep in the shelter causes me

   a. ( ) no discomfort
   b. ( ) not much discomfort
   c. ( ) medium discomfort
   d. ( ) quite a bit of discomfort
   e. ( ) extreme discomfort

4. Compared to other problems in the shelter, noise upsets me

   a. ( ) nearly the worst of all
   b. ( ) more than many others
   c. ( ) about average
   d. ( ) less than many others
   e. ( ) nearly the least of all

5. Lack of water for washing in the shelter disturbs me

   a. ( ) not at all
   b. ( ) fairly little
   c. ( ) about medium
   d. ( ) quite a bit
   e. ( ) very badly

6. Lack of privacy in the shelter causes me

   a. ( ) extreme discomfort
   b. ( ) quite a bit of discomfort
   c. ( ) medium discomfort
   d. ( ) not much discomfort
   e. ( ) no discomfort

7. Compared to other problems in the shelter, lack of exercise upsets me

   a. ( ) nearly the least of all
   b. ( ) less than many others
   c. ( ) about average
   d. ( ) more than many others
   e. ( ) nearly the worst of all

8. The behavior of other people in the shelter disturbs me

   a. ( ) very badly
   b. ( ) quite a bit
   c. ( ) about medium
   d. ( ) fairly little
   e. ( ) not at all

9. Compared to other things that disturb me in the shelter, the problem of crowding is

   a. ( ) almost the easiest to take
   b. ( ) better than many others
   c. ( ) about average
   d. ( ) worse than many others
   e. ( ) almost the toughest to take

10. The chow in the shelter causes me

   a. ( ) no discomfort
   b. ( ) not much discomfort
   c. ( ) medium discomfort
   d. ( ) quite a bit of discomfort
   e. ( ) extreme discomfort

11. Compared to other problems in the shelter, lack of sleep upsets me

   a. ( ) nearly the worst of all
   b. ( ) more than many others
   c. ( ) about average
   d. ( ) less than many others
   e. ( ) nearly the least of all

12. The temperature and humidity in the shelter disturb me

   a. ( ) very badly
   b. ( ) quite a bit
   c. ( ) about medium
   d. ( ) fairly little
   e. ( ) not at all

13. Compared to other things that disturb me in the shelter, the problem of lack of water for washing is

   a. ( ) almost the toughest to take
   b. ( ) worse than many others
   c. ( ) about average
   d. ( ) better than many others
   e. ( ) almost the easiest to take

14. Dirt in the shelter disturbs me

a. ( ) not at all
b. ( ) fairly little
c. ( ) about medium
d. ( ) quite a bit
e. ( ) very badly

15. Compared to other problems in the shelter, temperature and humidity upset me

a. ( ) nearly the worst of all
b. ( ) more than many others
c. ( ) about average
d. ( ) less than many others
e. ( ) nearly the least of all

16. Compared to other things that disturb me in the shelter, the problem of food is

a. ( ) almost the easiest to take
b. ( ) better than many others
c. ( ) about average
d. ( ) worse than many others
e. ( ) almost the toughest to take

17. Smells in the shelter cause me

a. ( ) no discomfort
b. ( ) not much discomfort
c. ( ) medium discomfort
d. ( ) quite a bit of discomfort
e. ( ) extreme discomfort

18. Compared to other things that disturb me in the shelter, the problem of lights while sleeping is

a. ( ) almost the easiest to take
b. ( ) better than many others
c. ( ) about average
d. ( ) worse than many others
e. ( ) almost the toughest to take

19. Compared to other problems in the shelter, the bunks upset me

a. ( ) nearly the worst of all
b. ( ) more than many others
c. ( ) about average
d. ( ) less than many others
e. ( ) nearly the least of all

20. Noise in the shelter causes me

a. ( ) extreme discomfort
b. ( ) quite a bit of discomfort
c. ( ) medium discomfort
d. ( ) not much discomfort
e. ( ) no discomfort

21. Lack of exercise in the shelter disturbs me

a. ( ) not at all
b. ( ) fairly little
c. ( ) about medium
d. ( ) quite a bit
e. ( ) very badly

22. Compared to other problems in the shelter, the behavior of others upsets me

a. ( ) nearly the least of all
b. ( ) less than many others
c. ( ) about average
d. ( ) more than many others
e. ( ) nearly the worst of all

23. The bunks in the shelter cause me

a. ( ) no discomfort
b. ( ) not much discomfort
c. ( ) medium discomfort
d. ( ) quite a bit of discomfort
e. ( ) extreme discomfort

24. Crowding in the shelter disturbs me

a. ( ) very badly
b. ( ) quite a bit
c. ( ) about medium
d. ( ) fairly little
e. ( ) not at all

25. Lights while sleeping in the shelter cause me

a. ( ) extreme discomfort
b. ( ) quite a bit of discomfort
c. ( ) medium discomfort
d. ( ) not much discomfort
e. ( ) no discomfort

26. Compared to other things that disturb me in the shelter, the problem of smells is

a. ( ) almost the toughest to take
b. ( ) worse than many others
c. ( ) about average
d. ( ) better than many others
e. ( ) almost the easiest to take

DO NOT GO ON TO THE NEXT SECTION UNTIL YOU HAVE FINISHED THIS ONE. ONCE YOU HAVE GONE ON TO THE NEXT SECTION DO NOT TURN BACK TO THIS ONE.

This section has to do with how often things bother you, even though they may not bother you too much at any one time. You tell us how often they bother you by making a check mark alongside the sentence ending that best describes how often you are bothered.

If none of the sentence endings describes exactly how often you are bothered, check the ending that comes nearest. Be sure to answer all the things.

27. Compared to other things that make me uncomfortable, dirt in the shelter bothers me

    a. ( ) much more often
    b. ( ) somewhat more often
    c. ( ) just about as often
    d. ( ) somewhat less often
    e. ( ) much less often

28. Compared to other things that make me uncomfortable, lack of privacy in the shelter bothers me

    a. ( ) much less frequently
    b. ( ) somewhat less frequently
    c. ( ) just about as frequently
    d. ( ) somewhat more frequently
    e. ( ) much more frequently

29. Lack of sleep in the shelter bothers me

    a. ( ) almost none of the time
    b. ( ) little of the time
    c. ( ) about half of the time
    d. ( ) much of the time
    e. ( ) almost all of the time

30. Compared to other things that make me uncomfortable, noise in the shelter bothers me

    a. ( ) much more frequently
    b. ( ) somewhat more frequently
    c. ( ) just about as frequently
    d. ( ) somewhat less frequently
    e. ( ) much less frequently

31. Lack of water for washing in the shelter bothers me

    a. ( ) less than 1/4 of the time
    b. ( ) about 1/4 of the time
    c. ( ) about 1/2 of the time
    d. ( ) about 3/4 of the time
    e. ( ) more than 3/4 of the time

32. Lack of privacy in the shelter bothers me

    a. ( ) almost all of the time
    b. ( ) much of the time
    c. ( ) about half of the time
    d. ( ) little of the time
    e. ( ) almost none of the time

33. Compared with other things that make me uncomfortable, lack of exercise in the shelter bothers me

a. ( ) much less frequently
b. ( ) somewhat less frequently
c. ( ) just about as frequently
d. ( ) somewhat more frequently
e. ( ) much more frequently

34. The behavior of other people in the shelter bothers me

a. ( ) more than 3/4 of the time
b. ( ) about 3/4 of the time
c. ( ) about 1/2 of the time
d. ( ) about 1/4 of the time
e. ( ) less than 1/4 of the time

35. Compared to other things that make me uncomfortable, crowding in the shelter bothers me

a. ( ) much less often
b. ( ) somewhat less often
c. ( ) just about as often
d. ( ) somewhat more often
e. ( ) much more often

36. The chow in the shelter bothers me

a. ( ) almost none of the time
b. ( ) little of the time
c. ( ) about half of the time
d. ( ) much of the time
e. ( ) almost all of the time

37. Compared to other things that make me uncomfortable, lack of sleep in the shelter bothers me

a. ( ) much more frequently
b. ( ) somewhat more frequently
c. ( ) just about as frequently
d. ( ) somewhat less frequently
e. ( ) much less frequently

38. The temperature and humidity in the shelter bother me

a. ( ) more than 3/4 of the time
b. ( ) about 3/4 of the time
c. ( ) about 1/2 of the time
d. ( ) about 1/4 of the time
e. ( ) less than 1/4 of the time

39. Compared to other things that make me uncomfortable, lack of water for washing in the shelter bothers me

a. ( ) much more often
b. ( ) somewhat more often

c. ( ) just about as often
d. ( ) somewhat less often
e. ( ) much less often

40. Dirt in the shelter bothers me

a. ( ) less than 1/4 of the time
b. ( ) about 1/4 of the time
c. ( ) about 1/2 of the time
d. ( ) about 3/4 of the time
e. ( ) more than 3/4 of the time

41. Compared to other things that make me uncomfortable, temperature and humidity in the shelter bother me

a. ( ) much more frequently
b. ( ) somewhat more frequently
c. ( ) just about as frequently
d. ( ) somewhat less frequently
e. ( ) much less frequently

42. Compared to other things that make me uncomfortable, food in the shelter bothers me

a. ( ) much less often
b. ( ) somewhat less often
c. ( ) just about as often
d. ( ) somewhat more often
e. ( ) much more often

43. Smells in the shelter bother me

a. ( ) almost none of the time
b. ( ) little of the time
c. ( ) about half of the time
d. ( ) much of the time
e. ( ) almost all of the time

44. Compared to other things that make me uncomfortable, lights while sleeping in the shelter bother me

a. ( ) much less often
b. ( ) somewhat less often
c. ( ) just about as often
d. ( ) somewhat more often
e. ( ) much more often

45. Compared to other things that make me uncomfortable, the bunks in the shelter bother me

a. ( ) much more frequently
b. ( ) somewhat more frequently
c. ( ) just about as frequently
d. ( ) somewhat less frequently
e. ( ) much less frequently

46. Noise in the shelter bothers me

a. ( ) almost all of the time
b. ( ) much of the time
c. ( ) about half of the time
d. ( ) little of the time
e. ( ) almost none of the time

47. Lack of exercise in the shelter bothers me

a. ( ) less than 1/4 of the time
b. ( ) about 1/4 of the time
c. ( ) about 1/2 of the time
d. ( ) about 3/4 of the time
e. ( ) more than 3/4 of the time

48. Compared to other things that make me uncomfortable, the behavior of others in the shelter bothers me

a. ( ) much less frequently
b. ( ) somewhat less frequently
c. ( ) just about as frequently
d. ( ) somewhat more frequently
e. ( ) much more frequently

49. The bunks in the shelter bother me

a. ( ) almost none of the time
b. ( ) little of the time
c. ( ) about half of the time
d. ( ) much of the time
e. ( ) almost all of the time

50. Crowding in the shelter bothers me

a. ( ) more than 3/4 of the time
b. ( ) about 3/4 of the time
c. ( ) about 1/2 of the time
d. ( ) about 1/4 of the time
e. ( ) less than 1/4 of the time

51. Lights while sleeping in the shelter bother me

a. ( ) almost all of the time
b. ( ) much of the time
c. ( ) about half of the time
d. ( ) little of the time
e. ( ) almost none of the time

52. Compared to other things that make me uncomfortable, smells in the shelter bother me

a. ( ) much more often
b. ( ) somewhat more often
c. ( ) just about as often
d. ( ) somewhat less often
e. ( ) much less often

Likert-Type Scale, Administration #2

NAME: _____ AGE: _____ HIGHEST SCHOOL

SERVICE NUMBER: _____ GRADE COMPLETED: _____

SHELTER NUMBER: _____

Not too long after the test started, you were given a questionnaire to learn what things about shelter living made you feel uncomfortable. From other tests which have been made in fallout shelters, we know that the things which both people at first sometimes are not the same as the things which bother them after they have been in the shelter longer. Thus, today we would like you to go through the same questionnaire that you took before and answer them according to how you feel after being here for a longer period of time. Because things which made you uncomfortable early in the study might not be important to you now; or, other things now seem to bother you more, do not try to remember how you answered the first questionnaire. At this time, we are interested in learning only how you feel about these things now. The instructions for answering the questionnaire, which are the same as before, are given below.

The next few pages contain a number of different statements about things which may bother you in shelter living. In each question a statement will be made at the beginning of a sentence, and after this will be five endings for the sentence. You are to make a check mark alongside the sentence ending which best describes how the thing bothers you.

Past studies in fallout shelters have shown that there are two ways in which people are made uncomfortable by shelter living. First, some things about the shelter may be uncomfortable almost all of the time; however, you could probably stand to live with them for a long time. On the other hand, there are certain factors in shelter living which do not make you uncomfortable very often; but, at the same time, they are things you find very hard to take at those times when they do occur. Because we know that things can be uncomfortable and bother people in these two different ways, the statements in this questionnaire are divided into two sections. In one section, the statements have to do with how often things bother you even though they may not make you too uncomfortable at any one time. In the other section, the questions deal with how much these things make you uncomfortable at any one time even though they may not bother you too frequently. Please be sure that you understand the difference between the way you are to answer the statements in the two sections before you start working on the questionnaire.

If you are certain you understand what you are expected to do, turn to the next page and follow the instructions.

NOTE: The questions appearing in this questionnaire are the same as those in the first questionnaire in all details.

Debriefing Outline

1. In what particular ways did the following things bother you, and how could things be improved so they would bother you least?

   a. Lack of water for washing
   b. Chow
   c. Crowding
   d. Dirt
   e. Behavior of others

2. Compared to the way things looked before you went into the shelter, do you notice any differences in the sizes or distances of things now? If so, what?

3. What were some of the problems you think could have been avoided or better handled by more effective leadership? How?

4. Were there certain people in the shelter who made your stay easier? Who and why?

5. Could group cooperation and morale have been higher? If so, how could they have been raised?

6. How did shelter life differ from what you expected it would be?

7. How would you feel about spending a month in this shelter?

8. What do you remember as your most unpleasant shelter experience?

9. What do you remember as your most pleasant shelter experience?

10. Aside from making the shelter bigger, what changes in it would make things easier or pleasanter for the shelterees?

11. What suggestions could you give to future shelterees that would make their shelter stay easier or more pleasant?

12. Do you have any other comments which you think might be helpful to us in our future studies, or anything else you would like to get off your chest?

APPENDIX C

Results of Statistical Treatment of Data Obtained From Likert-Type Scales of Subjective Discomfort

Table C1
Sources of Variance of Discomfort Factor Scores Obtained From the Likert-Type Scale, Summer Trial

Source	Significance
Times (T)	N.S.*
Subjects (S)	$p < 0.001$
Discomfort Factors (DF)	$p < 0.001$
Scale Sections (AG)	$p < 0.001$
T × S	$p < 0.001$
T × DF	$p < 0.001$
T × AG	N.S.*
S × DF	$p < 0.001$
S × AG	$p < 0.001$
DF × AG	$p < 0.01$
T × S × DF	$p < 0.001$
T × S × AG	$p < 0.001$
T × DF × AG	$p < 0.01$
S × DF × AG	$p < 0.001$

*Not significant

Table C2
Differences Between Ranked Means of Discomfort Factors Based on Acuteness and Generality With Measures From Day 2 and Day 12 Combined, Summer Trial

Discomfort Factors	Means	Difference Between Means
Lack of Water for Washing	3.81	
		0.53*
Temperature and Humidity	3.28	
		0.13*
Food	3.15	
		0.12*
Crowding	3.03	
		0.01
Dirt	3.02	
		0.53*
Behavior of Others	2.49	
		0.19*
Lack of Exercise	2.30	
		0.05
Noise	2.25	
		0.04
Bunks	2.21	
		0.09*
Odors	2.12	
		0.07
Lack of Sleep	2.05	
		0.21*
Lack of Privacy	1.84	
		0.01
Lights while Sleeping	1.83	

*$p < 0.05$

Table C3
Differences Between Means of Acuteness and Generality of Discomfort Based on Likert-Type Scale Data for Day 2, Summer Trial

Discomfort Factor	Mean Acuteness	Mean Generality	Difference Between Means
Temperature and Humidity	3.84	3.78	0.06
Lack of Water for Washing	3.71	3.51	0.20*
Crowding	3.24	2.93	0.31†
Food	2.65	2.64	0.01
Dirt	2.81	2.62	0.19
Bunks	2.21	2.17	0.04
Lack of Exercise	2.31	2.15	0.16*
Noise	2.26	2.14	0.12
Behavior of Others	2.45	2.05	0.40†
Lack of Sleep	2.23	2.05	0.18*
Lights while Sleeping	1.90	1.86	0.04
Odors	2.07	1.85	0.22†
Lack of Privacy	1.76	1.85	0.09

*$p < 0.05$
†$p < 0.01$

Table C4
Differences Between Means of Acuteness and Generality of Discomfort Based on Likert-Type Scale Data for Day 12, Summer Trial

Discomfort Factor	Mean Acuteness	Mean Generality	Difference Between Means
Lack of Water for Washing	4.02	4.02	0.00
Food	3.65	3.67	0.02
Dirt	3.41	3.26	0.15*
Crowding	3.03	2.94	0.09
Temperature and Humidity	2.87	2.64	0.23†
Behavior of Others	2.81	2.64	0.17*
Lack of Exercise	2.42	2.31	0.11
Noise	2.32	2.26	0.06
Odors	2.31	2.25	0.06
Bunks	2.27	2.20	0.07
Lack of Sleep	1.98	1.95	0.03
Lack of Privacy	1.93	1.82	0.11*
Lights while Sleeping	1.85	1.72	0.13*

*$p < 0.05$
†$p < 0.01$

Table C5
Differences Between Means of Acuteness of Discomfort on Day 2 and Day 12 as Derived from Likert-Type Scale Data, Summer Trial

Discomfort Factor	Acuteness Mean Day 2	Acuteness Mean Day 12	Difference Between Means
Lack of Water for Washing	3.71	4.02	0.31†
Food	2.65	3.65	1.00†
Dirt	2.81	3.41	0.60†
Crowding	3.24	3.03	0.21*
Temperature and Humidity	3.84	2.87	0.97†
Behavior of Others	2.45	2.81	0.36†
Lack of Exercise	2.31	2.42	0.11
Noise	2.26	2.32	0.06
Odors	2.07	2.31	0.24*
Bunks	2.21	2.27	0.06
Lack of Sleep	2.23	1.98	0.25*
Lack of Privacy	1.76	1.93	0.17
Lights while Sleeping	1.90	1.85	0.05

*$p < 0.05$
†$p < 0.01$

Table C6
Differences Between Means of Generality of Discomfort on Day 2, Winter Trial, and Day 2, Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Generality Mean Day 2	Generality Mean Day 12	Difference Between Means
Lack of Water for Washing	3.51	4.02	0.51*
Food	2.64	3.67	1.03*
Dirt	2.62	3.26	0.64*
Crowding	2.93	2.94	0.01
Behavior of Others	2.04	2.64	0.60*
Temperature and Humidity	3.78	2.64	1.14*
Lack of Exercise	2.15	2.31	0.16
Noise	2.14	2.26	0.12
Odors	1.85	2.25	0.40*
Bunks	2.17	2.20	0.03
Lack of Sleep	2.05	1.95	0.10
Lack of Privacy	1.85	1.82	0.03
Lights while Sleeping	1.86	1.72	0.14

*$p < 0.01$

Table C7
Sources of Variance of Discomfort Factors
Obtained from the Likert-Type Scale
Summer and Winter Trials Combined

Source	Significance
Seasons (S)	$p < 0.001$
Time (T)	N.S.*
Discomfort Factors (DF)	$p < 0.01$
Scale Sections (AG)	$p < 0.05$
S × T	N.S.*
S × DF	$p < 0.001$
S × AG	N.S.*
T × DF	N.S.*
T × AG	N.S.*
DF × AG	$p < 0.001$
S × T × DF	$p < 0.001$
S × T × AG	N.S.*
S × DF × AG	N.S.*
T × DF × AG	$p < 0.05$
S × T × DF × AG	N.S.*

*Not significant

Table C8
Differences Between Means of Acuteness of Discomfort
on Day 2, Winter Trial, and Day 2, Summer Trial, as
Derived from Likert-Type Scale Data

Discomfort Factor	Acuteness Mean Day 2, Winter	Acuteness Mean Day 2, Summer	Difference Between Means
Lack of Water for Washing	3.35	3.71	0.36*
Food	3.30	2.65	0.65*
Crowding	3.02	3.24	0.22
Dirt	2.58	2.81	0.23
Behavior of Others	2.52	2.45	0.07
Noise	2.32	2.26	0.06
Lack of Exercise	2.31	2.31	0.00
Lack of Sleep	2.26	2.23	0.03
Lack of Privacy	1.94	1.76	0.18
Bunks	1.84	2.21	0.37*
Lights while Sleeping	1.71	1.90	0.19
Temperature and Humidity	1.70	3.84	2.14*
Odors	1.69	2.07	0.38*

*$p < 0.01$

Table C9
Differences Between Means of Generality of Discomfort on Day 2, Winter Trial, and Day 2, Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Generality Mean Day 2, Winter	Generality Mean Day 2, Summer	Difference Between Means
Food	3.32	2.64	0.68†
Lack of Water for Washing	2.98	3.51	0.53†
Crowding	2.80	2.93	0.13
Dirt	2.28	2.62	0.34*
Noise	2.23	2.14	0.09
Lack of Exercise	2.24	2.15	0.09
Lack of Sleep	2.13	2.05	0.08
Behavior of Others	2.07	2.05	0.02
Lack of Privacy	1.91	1.84	0.07
Bunks	1.74	2.17	0.43†
Lights while Sleeping	1.66	1.86	0.20
Odors	1.58	1.85	0.27*
Temperature and Humidity	1.57	3.78	2.21†

*$p < 0.05$
†$p < 0.01$

Table C10
Differences Between Means of Acuteness of Discomfort on Day 12, Winter Trial, and Day 12, Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Acuteness Mean Day 12, Winter	Acuteness Mean Day 12, Summer	Difference Between Means
Lack of Water for Washing	3.69	4.02	0.33*
Food	3.44	3.65	0.21
Dirt	3.28	3.41	0.13
Crowding	2.95	3.03	0.08
Behavior of Others	2.78	2.81	0.03
Lack of Exercise	2.45	2.42	0.03
Noise	2.22	2.32	0.10
Lack of Sleep	2.12	1.98	0.14
Lights while Sleeping	1.99	1.85	0.14
Temperature and Humidity	2.01	2.87	0.86†
Lack of Privacy	1.96	1.93	0.03
Odors	1.95	2.31	0.36†
Bunks	1.93	2.27	0.34†

*$p < 0.05$
†$p < 0.01$

Table C11
Differences Between Means of Generality of Discomfort on Day 12, Winter Trial, and Day 12, Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Generality Mean Day 12, Winter	Generality Mean Day 12, Summer	Difference Between Means
Lack of Water for Washing	3.53	4.02	0.49†
Food	3.47	3.67	0.20
Dirt	3.09	3.26	0.17
Crowding	2.77	2.94	0.17
Behavior of others	2.48	2.64	0.16
Lack of Exercise	2.29	2.31	0.02
Noise	2.21	2.26	0.05
Lack of Sleep	2.14	1.95	0.19
Lack of Privacy	2.03	1.82	0.21
Bunks	1.92	2.20	0.28*
Lights while Sleeping	1.86	1.72	0.14
Odors	1.82	2.25	0.43†
Temperature and Humidity	1.66	2.64	0.98†

*$p < 0.05$
†$p < 0.01$

Table C12
Differences Between Means of Acuteness and Generality of Discomfort Based on Likert-Type Scale Data for Day 2, Winter Trial, and Day 2, Summer Trial

Discomfort Factor	Acuteness Mean minus Generality Mean Day 2, Winter	Acuteness Mean minus Generality Mean Day 2, Summer
Temperature and Humidity	0.13	0.06
Lack of Water for Washing	0.37*	0.20*
Crowding	0.22	0.31†
Food	-0.02	0.01
Dirt	0.30*	0.19
Bunks	0.10	0.04
Lack of Exercise	0.07	0.16*
Noise	0.09	0.12
Behavior of Others	0.45*	0.40†
Lack of Sleep	0.13	0.18*
Lights while Sleeping	0.05	0.04
Odors	0.11	0.22†
Lack of Privacy	0.03	-0.09

*$p < 0.05$
†$p < 0.01$

Table C13
Differences Between Means of Acuteness and Generality of Discomfort Based on Likert-Type Scale Data for Day 12, Winter Trial, and Day 12, Summer Trial

Discomfort Factor	Acuteness Mean minus Generality Mean Day 12, Winter	Acuteness Mean minus Generality Mean Day 12, Summer
Lack of Water for Washing	0.16	0.00
Food	-0.03	-0.02
Dirt	0.19	0.15*
Crowding	0.18	0.09
Temperature and Humidity	0.35†	0.23†
Behavior of Others	0.30*	0.17*
Lack of Exercise	0.16	0.11
Noise	0.01	0.06
Odors	0.13	0.06
Bunks	0.01	0.07
Lack of Sleep	0.02	0.03
Lack of Privacy	-0.07	0.11*
Lights while Sleeping	0.14	0.13*

*$p < 0.05$
†$p < 0.01$

Table C14
Differences Between Means of Acuteness of Discomfort on Day 2 and Day 12, Winter Trial and Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Day 12 Acuteness Mean minus Day 2 Acuteness Mean, Winter Trial	Day 12 Acuteness Mean minus Day 2 Acuteness Mean, Summer Trial
Lack of Water for Washing	0.34*	0.31†
Food	0.14	1.00
Dirt	0.70†	0.60†
Crowding	-0.07	-0.21*
Temperature and Humidity	0.31	-0.97†
Behavior of Others	0.26	0.36†
Lack of Exercise	0.14	0.11
Noise	-0.10	0.06
Odors	0.26	0.24*
Bunks	0.09	0.06
Lack of Sleep	-0.14	-0.25*
Lack of Privacy	0.02	0.17
Lights while Sleeping	0.28	-0.05

*$p < 0.05$
†$p < 0.01$

Table C15
Differences Between Means of Generality of Discomfort on Day 2 and Day 12, Winter Trial and Summer Trial, as Derived from Likert-Type Scale Data

Discomfort Factor	Day 12 Generality Mean minus Day 2 Generality Mean, Winter Trial	Day 12 Generality Mean minus Day 2 Generality Mean, Summer Trial
Lack of Water for Washing	0.55†	0.51†
Food	0.15	1.03†
Dirt	0.81†	0.64†
Crowding	-0.03	0.01
Behavior of Others	0.41*	0.60†
Temperature and Humidity	0.09	-1.14†
Lack of Exercise	0.05	0.16
Noise	-0.02	0.12
Odors	0.24	0.40†
Bunks	0.18	0.03
Lack of Sleep	0.01	-0.10
Lack of Privacy	0.12	-0.03
Lights while Sleeping	0.20	-0.14

* $p < 0.05$
† $p < 0.01$

APPENDIX D

Comparative Results from the Winter and Summer Trials of the Navy Experimental Underground Shelter, Bethesda, Maryland

TRIAL DATA

Water

Water samples were taken daily from a tap within the shelter and tested bacteriologically according to standard methods for the examination of water and sewage.

	5-tube lactose broth test
Winter test -	Negative throughout trial
Summer test -	Negative throughout trial

The water was determined to be safe for human consumption throughout both trials.

Air

Air samples were taken daily throughout both trials by drawing air through an All Glass Impinger (AGI) containing 40 ml Brain Heart Infusion broth (Difco), for 15 min at approximately the same time of day. The predominating organism and approximate numbers of organisms in the samples were determined.

	Predominating organisms
Winter trial -	Staphylococcus, B. subtilis
Summer trial -	B. subtilis, Staphylococcus

The number of organisms recovered from the air was significatly less in the summer trial as compared to the winter trial. The numbers varied throughout both trials, but the counts indicated a normal range of organisms in the air throughout both trials.

Throat Cultures

No significant difference was noted between the winter and summer trials in studying the throat flora for predominating organisms. The predominating organisms found from the throat culturings were, in descending order of predominance:

1. Nonhemolytic Streptococcus
2. Staphylococcus
3. Neisseria
4. Diphtheroids
5. Beta-hemolytic Streptococcus. (Not found in the summer trial.)

All of the above can be considered normal flora with the possible exception of Beta-hemolytic Streptococcus. Inasmuch as the Beta-hemolytic Streptococcus seen in these trials was not accompanied by clinical symptoms and the organism was not recovered twice in succession from any subject, in these instances this organism can only be considered transient and not pathogenic.

Rectal cultures

No significant difference was noted between the winter and summer trials in studying the intestinal flora for enteric pathogens.

		Pre-entry	During confinement
Winter test	- Shigella	none found	none found
	Salmonella	none found	none found
Summer test	- Shigella	none found	none found
	Salmonella	none found	none found

A greater number, as well as a greater variety of strains of Enteropathogenic E. coli was recovered from the subjects of the summer trial as compared with those of the winter trial, but this can only be considered a population variation inasmuch as there was no indication of spread during confinement.

CONCLUSIONS

1. Enteric pathogens would seem to be no problem in these trials. The dietary regime would most certainly preclude the spread of enteric disease even if present in some of the subjects, unless a full-blown outbreak should occur shortly after entry. In this case the proximity brought about by the limited space might be contributory to spread.

2. In both the winter and summer trials the throat flora was essentially normal nonpathogens throughout. There was noted in both trials a tendency toward a common throat flora among the subjects as the studies progressed. These data would indicate the possibility of spread if an upper-respiratory infection should get started during the period of confinement.

3. No major significant difference was noted between the winter and summer trials from the standpoint of the bacteriological studies accomplished.

APPENDIX E

Glossary

afebrile – without fever

AMRNL – Army Medical Research and Nutrition Laboratory

anterior cervical lymphadenopathy – inflammation of the lymph glands in the front part of the neck

artifact – an artificial factor; a situation which probably will not exist under normal conditions

catabolic – that aspect of metabolism which pertains to the breakdown of body tissue

coryza – nasal catarrh, a cold in the head

dyshidrosis – a disorder of the sweat glands

enteric – pertaining to the intestines

erythrocyte – a red blood corpuscle

exogenous – developed or originating outside of the body

febrile – with fever

Ghon complex – a calcified area generally representing a healed tuberculin lesion

glycosuria – the presence of an abnormal amount of glucose in the urine

hematocrit – a centrifuge for separating the corpuscles from whole blood

hematuria – the discharge of blood in the urine

hemostasis – the controlling of bleeding

homeostasis – a tendency to uniformity for stability in the normal body status of the organism.

ICNND – Interdepartmental Committee on Nutrition for National Defense

insensible weight loss – weight loss which occurs without active sweating

Kendall coefficient of concordance (W) – a measure of the relation among several rankings of n objects or individuals

ketosis – a condition marked by the buildup of ketones in the body

Likert-type scale – a scale composed of multiple-choice items. Ordinarily the range of responses corresponds to five points on a continuum of evaluation ranging from one extreme through a neutral point to the opposite extreme

lymphadenopathy – disease of the lymph glands

NP assessment – neuropsychiatric assessment

pyridoxal – the 4-aldehyde of pyridoxine

pyridoxamine – the amine derivative of pyridoxine

pyridoxine – Vitamin B_6

reality-testing – the ability to perceive objective reality; to form meaningful judgments and to make appropriate responses

riboflavin – Vitamin B_2

S.D. – Standard deviation

Spearman rho – a coefficient of correlation based on a technique used with data which is in terms of rank order rather than in terms of actual measurement

Student's t – a number used to determine the significance of differences between samples which are too small in size to justify the use of standard deviations

thiamine – Vitamin B_1

tonometer – an apparatus used to collect gas and to keep it at atmospheric pressure

transketolase – one of the enzymes in the conversion of ribose-5-phosphate to glucose-6-phosphate

URI – upper respiratory infection

Security Classification

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY *(Corporate author)*
Naval Research Laboratory
Washington, D.C., 20390

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
STUDIES OF THE NAVAL FACILITIES ENGINEERING COMMAND PROTECTIVE SHELTER. II. SUMMER TRIALS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
This is a final report on this problem.

5. AUTHOR(S) *(First name, middle initial, last name)*
H.F. Bogardus, et al.

6. REPORT DATE
March 29, 1968

7a. TOTAL NO. OF PAGES
177

7b. NO. OF REFS
37

8a. CONTRACT OR GRANT NO.
NRL Problem C08-36

b. PROJECT NO.
BUDOCKS Project Y-E011-05-331

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
NRL Report 6656

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Department of the Navy (Naval Facilities Engineering Command) Washington, D.C., 20360

13. ABSTRACT

A 2-week summer trial was conducted at Bethesda, Maryland, during August 1962, in a protective shelter (blast, radioactive fallout, and biological and chemical warfare) designed by the Bureau of Yards and Docks, now Naval Facilities Engineering Command. Navy volunteers served as the shelter subjects. Two naval officers served as shelter commander and medical officer. Since the primary purpose of this trial was to study the engineering features of the shelter, it was considered desirable to conduct the trial with a carefully selected, reasonably homogeneous group of shelterees. Therefore, the shelterees, selected from a group of volunteers, were screened both medically and psychologically.

The shelter equipment performed satisfactorily, and the trial was conducted successfully. The ration, basically survival ration crackers and soup, provided approximately 1860 calories per day. Weight loss and exercise tolerance studies indicated that this ration was marginal, but adequate. Water was unlimited for drinking purposes but, except for brushing teeth and decontamination showers, prohibited for personal hygiene. The average total water consumption was 3.3 quarts/man/day during the first week and 2.8 quarts/man/day during the second week for a total of 1025 gallons. The average daily inlet effective temperature was 74°F during the first

(Abstract continues)

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Fallout shelter						
Personnel protection						
NBC warfare shelter						
Survival rations						
Heat tolerance						
Psychological screening						

Abstract continued
week and 67°F during the second week. The average daily shelter effective temperature was 85°F during the first week and 80°F during the second week. It is highly improbable that the men could have survived a second week of 85°F average effective temperature. Hot bunking (50 bunks for 100 men) proved to be acceptable. Psychological studies indicated that lack of water for washing, temperature and humidity, food, crowding, and dirt consistently produced the most discomfort.