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DEVELOPMENT OF A QUICK CAMP SYSTEM FOR SEABEES

Richard H. Seabold

Naval Civil Engineering Laboratory
Port Hueneme, California

September 1973

Technical Report

R 796

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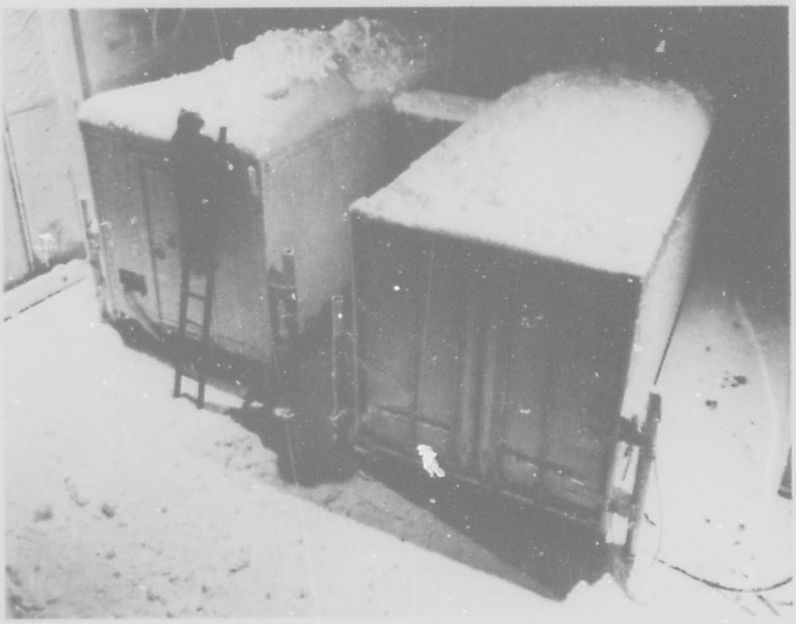
NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93043



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YF53.536.006.01.007

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ABSTRACT

Quick Camp modules are standard 8 x 8 x 20-foot shipping containers outfitted for living. They serve as habitats for Navy Seabees in the field, as temporary storage facilities when not deployed, and as cargo containers in transit. They can be transported by ships, trucks, rail cars, and aircraft, including helicopters. The facilities include berthing, messing, sanitation, administration, medical treatment, shop, laundry, recreation, and storage. The system includes structural, electrical, air treatment, and water purification and distribution subsystems.

The development objective is to use containerization and helicopters to improve operational expediency, logistical support, and pilfer resistance. User needs are to reduce set-up time to make Seabees immediately available to their primary mission, to reduce dismantling and removal time to prevent loss by friendly forces and gain by unfriendly forces, and to reduce the amount of damaged, lost, stolen, and misdirected material.

User needs and the environment were studied, a concept was formulated, and the first cycle of system analysis was performed. A contractor designed the entire system and fabricated three selected first-generation prototype modules: camp utilities, kitchen, and all purpose. To reduce the initial time and cost of development, selection of equipment items of second-order importance and preparation of final procurement drawings and specifications were deferred until the second cycle of system analysis.

Cost-effectiveness studies were performed in specific areas for making major design decisions and in general to determine the economic feasibility of the system. Structural, environmental, electrical, and operational tests were conducted and evaluated. As a result, input data for the second cycle of system analysis were generated.

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CONTENTS

FOREWORD

This technical report is organized in systems engineering format to show the chronological development of the need, definition, formulation, approach, etc. The INTRODUCTION and the sections on USER NEEDS AND THE ENVIRONMENT and COST EFFECTIVENESS show when and why the work unit was started, that a need was identified, that a problem was defined, and that the first trial solution was highly cost effective. It presents evidence to show that, in general, the benefits of Quick Camp modules can be obtained for less than the cost of strongback tents.

The remainder of this report is primarily intended for use by the technical worker who might resume the work or begin a similar task. It documents all progress and technical information, including studies, schemes, designs, tests, evaluations, and economic analyses, which show successful accomplishment of goals up to the point where the work unit was cancelled. Table 1 in the section on SYSTEM ANALYSIS provides a complete plan of development from the problem definition and concept formulation phase to the utilization phase.

Some information herein has broader application by those persons who have interest in cost effectiveness and/or in relocatable shelters. The section on COST EFFECTIVENESS (1) discusses important principles which should be used in comparing alternative relocatable shelter systems; (2) reports on studies which influenced design decisions; (3) provides time, benefits, and cost data for the Quick Camp System for use in cost-effectiveness studies; (4) outlines a procedure for comparing alternatives; and (5) demonstrates the principles and procedure by comparing Quick Camp modules with strongback tents.

INTRODUCTION

Quick Camp Mission

The Quick Camp System is to provide minimum, austere, but complete, facilities for the rapid deployment of between 13 and 104 Seabees to the same location. This location is to be considered remote or in a forward area and requires a tenure of not more than six months. These support facilities shall be deployable from an advanced base location by helicopter or truck and provide intermodal transportation capability to the advanced base site compatible with existing carrier capabilities and requirements insofar as practical. Each camp shall include completely outfitted berthing, messing, head, administrative, and minor recreation facilities. Depending on operational conditions and requirements, some camps may also include minor shops, working space, and laundry facilities.

Development Objective

The development objective is to use containerization and helicopters to improve operational expediency, logistical support, and pilfer resistance.

None of the systems used for camps in the past can perform the Quick Camp Mission. Those presently used in the field for somewhat similar missions are strongback tents and Butler buildings. Both require considerable site preparation and foundation construction, a relatively long set-up time, and are only partly relocatable as many parts are lost or damaged during dismantling and transporting. Furthermore, it is neither economically feasible nor easy to relocate a Butler building, and tents provide very low level habitability and poor durability under sustained adverse weather conditions. Both are expensive to store and to transport, have little pilfer resistance, are not containerized, and do not provide any intermodal transportation compatibility. Commercial units are not intermodally compatible, are not tailored to the military mission, and have some components of questionable durability.

History of the Work Unit

Advantages of containerization were cited by the Chief of Naval Operations[a] in 1968 when he provided policy guidelines for the development of containerization and assigned the Chief of Naval Material and the Commander, Military Sea Transport Service (later reorganized as the Military Sealift Command) primary responsibility for introducing greater usage of containerization. The need for expediently relocatable camping facilities for Seabees was recognized by the Commander, Construction Battalions, U.S. Pacific Fleet in that same year, and he suggested the use of helicopter transportation. The Naval Civil Engineering Laboratory (NCEL)[b] provided a concept for using both containerization and helicopters to satisfy the need.

In 1969 the Naval Facilities Engineering Command (NAVFAC)[c] defined the problem: need, environment, mission, and hypothetical use model. From this NCEL developed system performance requirements, partial design criteria, cost goals, tentative schemes for a modular system, and a contract schedule for system development.

There was a one-year delay in 1970: six months due to lack of contract approval, two months due to lack of personnel, and four months due to long contracting procedures.

Preliminary studies, preliminary design, and final design of the entire system and fabrication of three selected prototype modules were completed by North American Rockwell Corporation [1] under NCEL Contract N62399-71-C-0002 in 1971. Structural testing of the modules as cargo containers was performed

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[a] Chief of Naval Operations letter Op-93/dap Ser 80P93 of 14 August 1968: Policy Guidelines for the development of Containerization.

[b] NCEL Brochure: QC Modules; Quick Camps for Seabees.

[c] Commander, Naval Facilities Engineering Command letter FAC 06531/PAD/lle Ser 370 of 24 July 1969: Quick Camp Module.

by Miner Enterprises,[d] and the containers were certified by the American Bureau of Shipping [2]. Prototypes of the camp utilities, kitchen, and all purpose modules and the messing package were fabricated for testing by the Navy (Figures 1 through 3).

Tests were performed in 1972 on the kitchen module, all purpose module, and connecting passageway in the Environmental Laboratory of the Naval Missile Center. They included hot environment, cold environment, rain, and snow (Figure 4). In addition, the camp utilities, kitchen, and all purpose modules and the passageway were exercised by Seabee teams of the THIRTY-FIRST Naval Construction Regiment at Vandenberg Air Force Base (Figure 5) during a road construction project. The exercise included truck transportation, forklift handling, emplacement, leveling, complete set-up, habitability, and dismantling. The tests and the exercise were evaluated to generate data for the second cycle of system analysis. At NCEL, static and dynamic stress analyses were made of the container frames using computer codes, and a cost-effectiveness study of Quick Camp versus ABFC was made.

CONCEPT FORMULATION

User Needs and the Environment

Primary prospective users are Seabee detachments: Seabee teams; underwater construction teams; and mobile construction battalion (MCB) squads, platoons, companies, and command headquarters. Secondary prospective users are Air Force Prime Beef and Red Horse units and various Army engineering units. Also, the modules could be used for temporary housing in emergencies and for field testing facilities. Modified versions can be used by anit-submarine warfare forces as part of the CLASH exercise and the Arapaho system.

Background studies of Seabee organizations and operations, the Seabee Team Table of Allowance [3], the MCB Table of Allowance [4], and the current Advanced Base Functional Component (ABFC) [5] System were made for defining the problem and establishing requirements. Other background studies were made of the state of the art of containerization and the capabilities of both civilian and military carriers. This work included a study of some of the

Figure 1.
Commander, Naval Facilities Engineering Command (second from right) and Commanding Officer, Naval Civil Engineering Laboratory (second from left) touring the camp utilities module.

[d] Miner Enterprises, Inc. report on Project No. RD-182 of 18 March 1971.

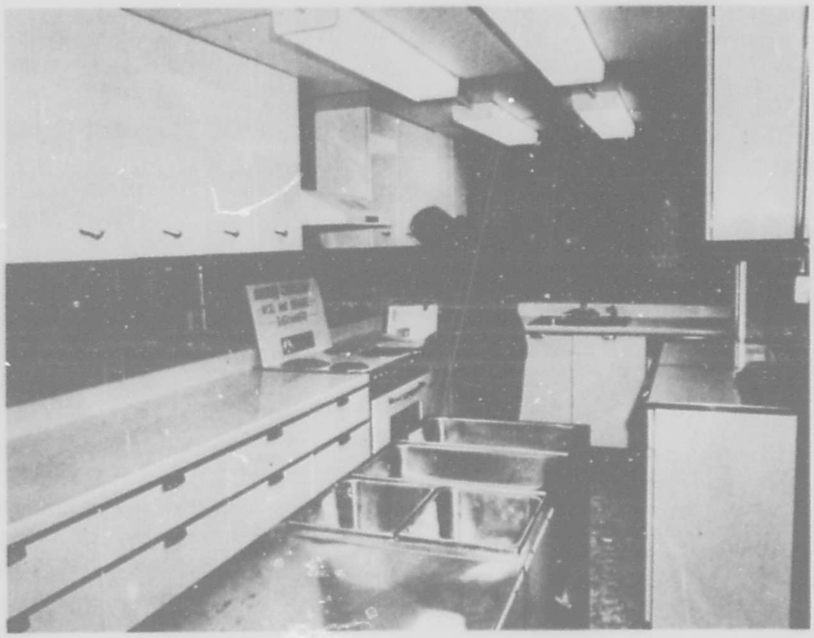


Figure 2.
Interior view of the
kitchen module.

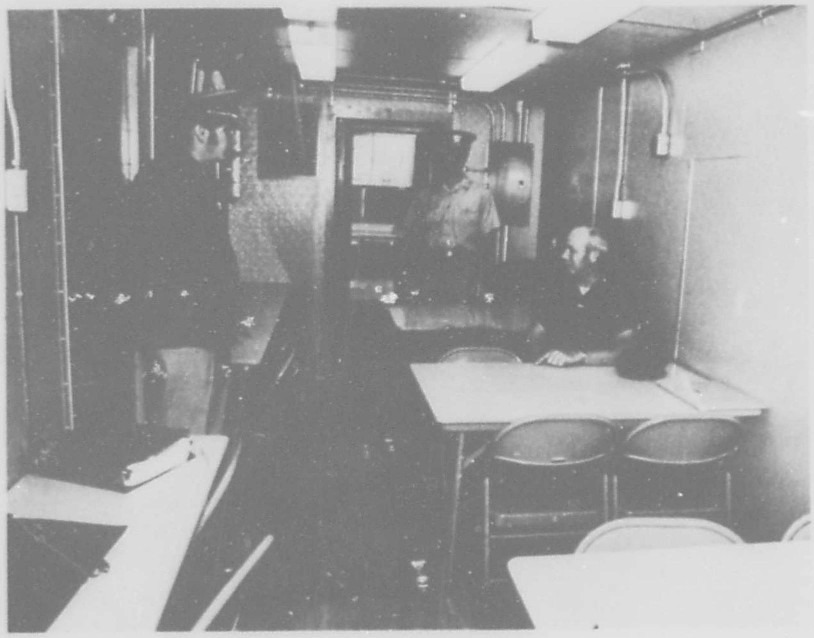


Figure 3.
Interior view of the all
purpose module with the
messing package installed.

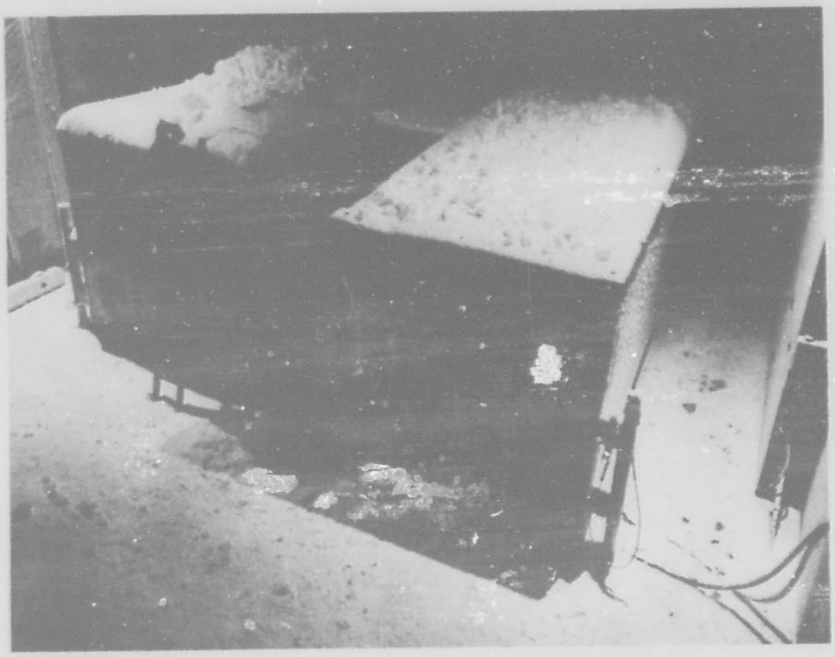


Figure 4.
All purpose module (left), flexible passageway (center), and kitchen module (right) during the snow test in the Environmental Laboratory of the Naval Missile Center.

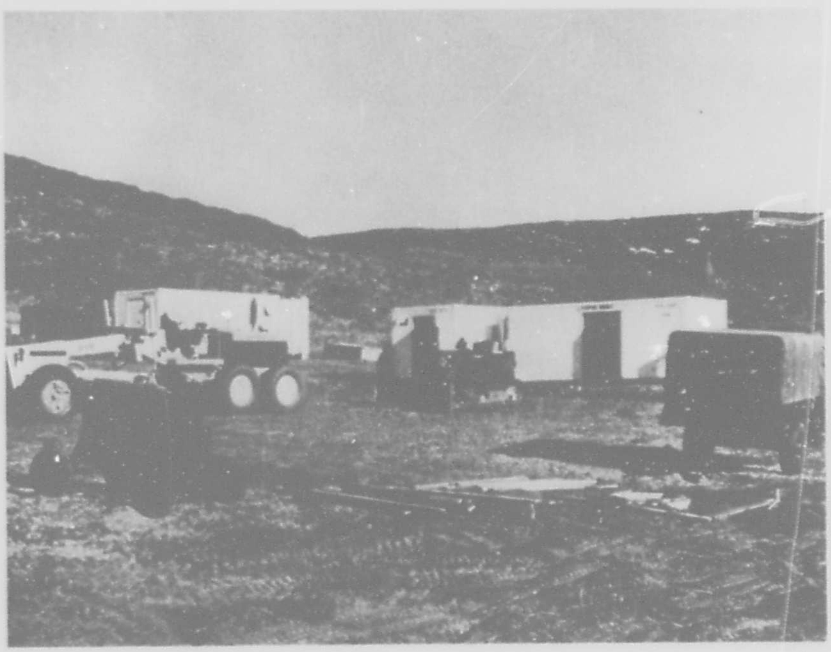


Figure 5.
Camp utilities module (left), kitchen module (center), and all purpose module (right) in use by Seebee teams during a road construction exercise at Vandenberg Air Force Base.

Air Force Bare Base [6] structures, which are relocatable and containerized, but not intermodal as specified by the International Standards Organization (ISO) [7] and American National Standards Institute (ANSI). Although many of the system analysis parameters of Bare Base are common with those of Quick Camp, figures of merit are quite different, and the Bare Base units are not economically feasible in view of the small scale and austere Quick Camp mission.

A Seabee team is a small highly mobile, air transportable construction unit which can provide disaster relief or technical assistance by constructing, supervising, or instructing. These teams, which may be tailored to fit any size task, normally consist of one civil engineer corps officer, one hospital corpsman, and eleven Seabees. A typical personnel allowance is:

1 Civil Engineer Corps Officer
3 Equipment Operators
2 Construction Mechanics
2 Builders
1 Construction Electrician
1 Steel Worker
1 Utilitiesman
1 Engineering Aid
1 Hospital Corpsman

Every Seabee in the team must be experienced at the journeyman level in at least one construction trade and have had additional practical experience in one other construction trade. Teams have been trained to concentrate on projects which provide on-the-job training or classroom instruction to a local labor force. Typical projects involve construction of roads, bridges, airstrips, earth dams, water wells, sanitation systems, and buildings. Each team carries sufficient housekeeping supplies, tool kits, and automotive and construction equipment to be self-sufficient in the field. Most of these items are listed in the Seabee Team Table of Allowance [3]. Teams have been deployed as engineers to the Army's Special Forces, as technical instructors for the Agency for International Development, and as construction advisors under various military assistance programs.

A special detachment from an MCB may be formed to meet a specific need. Usually, when a project is assigned to the battalion at a site far from the battalion's main location, a regular construction unit, platoon or company, is detached to do the job. Such special detachments are different from Seabee teams in that they are likely to be larger, less mobile, less air transportable, more specialized, less self-sufficient, singular of purpose, and to have some inexperienced personnel. They are more likely to be employed as workers and less as advisors, supervisors, and instructors.

The 23-man underwater construction teams perform construction tasks on the ocean floor. The Quick Camp System is to provide only partial facilities for these teams.

It was found that the specific operational requirements depend mainly on the work assignment at the camp, the stay time of the men, and the climate of the camp location. Flexibility in combining components to form camps of various sizes and levels of habitability is essential to meet these requirements and maintain reasonable economy.

During the evaluation of user needs and the environment, it was determined that emphasis should be placed on use by Seabee teams, small camps, short stay times, frequent relocations, and operational expediency. Furthermore, it was concluded that habitability could be improved over that of current systems with little or no increase in life-cycle cost.

The primary prospective users need:

1. To reduce set-up time to make Seabees immediately available to their primary mission.
2. To reduce dismantling and removal time to prevent loss by friendly forces and gain by unfriendly forces.
3. To reduce the amount of damaged, lost, stolen, and misdirected material.

The hypothetical use model is one deployment in each six month period with a short time between deployments for refurbishing. This is the most probable use pattern of many and was used for system analysis, including cost effectiveness studies.

System Requirements

Life. Major components shall be capable of five years of continuous service, 10 relocations, or 20 years of open storage.

Cost. The cost goal for the 5-year life cycle shall be $5,056 per man, based on production runs of 100 modules and 1971 prices. This is an average annual cost of $1,011 per man.

Efficiency. The system shall be most efficient and most economical when used by Seabee teams for short stay times (about three months) and at small camps (about 26 men).

Modular. The system shall be modular to provide flexibility in combining components to form camps of various sizes (13 to 104 men) and levels of habitability. Modules shall be standardized insofar as practical for interchange of parts.

Relocatable. Strike-down as well as set-up times shall be minimized for rapid relocation. Therefore, site selection, site preparation, foundation construction, erection, packing, dismantling, and removal times shall all be minimized. The system shall have local moving capability from one position to another at a camp site and from one site to another one nearby.

Containerized. Quick Camp modules shall be standard ISO shipping containers outfitted for living. They shall serve as habitats for Navy Seabees in the field, as temporary storage facilities when not deployed, and as cargo containers in transit. All of the applicable items in the Seabee Team Table of Allowance should be carried to the camp site in the containers insofar as possible. All furniture, equipment, tools, and supplies for a given function shall be carried in the corresponding structure insofar as practical. Built-ins shall be maximized and installed-at-the-site items minimized. Sizes, weights, centers-of-gravity, and tie-downs of packages shall be an integral part of the design of the modules which will carry them.

Intermodal. Containers shall be acceptable into international service as standardized by the recommendations of ISO and the specifications of ANSI and shall be certified by the American Bureau of Shipping. They shall be capable of being handled by helicopters, cranes, heavy duty forklifts, and straddle carriers, and they shall be transportable by ships, trucks, trains, and aircraft, including helicopters.

Independent. Camps will be dependent on periodic resupply of food and diesel fuel, and supplementary containers from other systems may be used for large volume refrigeration of food and storage of fuel when required. A camp will be dependent on resupply of water only if a water supply at the site is not available. Otherwise, camps shall be completely independent. Subsystems shall provide for electrical service, water purification and distribution service, illumination, air treatment, and sanitation.

Simple. The Quick Camp components shall be so designed that untrained personnel can install the camp facilities. However, limits on set-up and strike-down times shall be based on the use of trained personnel. Trained personnel are defined as Seabees with at least two weeks orientation in the use of the Quick Camp system; each Seabee shall have participated in at least one previous Quick Camp set-up. Components shall be easily identified, unpacked, connected, used, disconnected, and repacked as required. No special hand tools and no special mobile handling equipment (other than those items in the Table of Allowance for the appropriate Seabee unit) shall be required. Special tools and equipment are defined as items separate from the modules which are peculiar to the set-up of the modules. This requirement does not prohibit special handling devices built into the modules for handling cargo.

Habitable. Seabees will eat, sleep, work, and spend leisure time in the modules. A comfortable environment inside all modules shall be maintained by control of temperature, humidity, light, noise, and vibration; and by design of color and texture.

Design Criteria

General Discussion. In providing the Contractor with guidance, system requirements were fixed, the system cost goal was fixed, and a few of the most important or most obvious design criteria were fixed, but most of the design criteria were permitted to float. This was done to insure an economic solution of the problem, to develop realistic criteria from cost-effectiveness studies by the Contractor, and to make sure that design decisions were made by a designer and with sufficient study. This approach was also necessary to prevent bias in the Contractor's preliminary studies. Only the criteria fixed by NCEL are listed in this section; other criteria are included in a discussion of system design.

Camp Size. Camps shall be designed for 13, 26, 39, 52, 65, 78, 91, and 104 men.

Container Type. Containers shall be ISO type 1C [8].

Container Weight. Containers shall have a maximum gross weight of 16,000 pounds due to helicopter lifting capacity, gross weight rating of 25,000 pounds for the fixed wing mode, and gross weight rating of 44,800 pounds for all other modes of transportation. This permits carrying additional general dry cargo when helicopters are not used.

Sea, Rail, and Highway Transport Loads. Each module shall be designed for (1) stacking loads, (2) lifting loads, (3) floor loads, (4) front and rear panel loads, (5) side wall loads, and (6) roof loads as defined and specified in ISO Draft Recommendation 1496 [9] and ISO Draft Recommendation 1019 [10]. Furthermore, the container shall be a certified cargo container as defined in the American Bureau of Shipping Guide for the Certification of Cargo Containers [2]. The equipment in the containers shall be serviceable after application of these loads. In addition, the module shall be capable of withstanding a lateral and longitudinal concentrated load of 35,000 pounds at the top corner fittings as specified in Section 3.9.8 of Military Specification MIL-C-52661(ME) [11].

Air Transport Loads. Each module shall be designed to have sufficient structural strength to withstand without permanent deformation the static and dynamic loads and the impact shock and racking stresses encountered in normal air carrier service as specified in SAE (Society of Automotive Engineers) Aerospace Standard AS832 [12] and Military Specification MIL-A-8421C(USAF) [13]. The equipment in the containers shall be serviceable after application of these loads.

Helicopter Handling Loads. The equipment and the container shall be designed to withstand, without loss of serviceability, a free fall from rest of six inches onto a concrete surface. The container shall be designed to withstand, without loss of serviceability, a free fall from rest of 12 inches onto a concrete surface, but the equipment need not remain serviceable during and after the 12-inch drop.

Building Loads. Each module shall be designed for actual dead load; wind load of 25 pounds per square foot; snow load of 30 pounds per square foot; and deflections of L/240 for the floor, L/180 for the roof and ceiling, and L/180 for the sidewalls, where L is the clear span between supports. The design stresses of all materials shall conform to accepted engineering practice. A system of ties and earth anchors is an acceptable method of resisting wind overturning and sliding as imposed by the design loads. The structure shall be capable of transmitting the design loads to the foundation (jacking system) without causing an unsafe deformation or abnormal internal moment of the structure or its structural parts.

Dissimilar Metals. Contact between dissimilar metals shall be avoided insofar as possible. Where the use of dissimilar metals is necessary, galvanic and electrolytic action between dissimilar metals, as defined in Military Standard MIL-STD-889 [14], shall be prevented by the application of zinc chromate primer conforming to Military Specification MIL-P-8585A [15] to each of the metal surfaces and by insulation of one surface from the other surface by application of an elastomer gasket, electrical tape, or other effective means, preventing any direct contact. Asphaltic-type compounds shall not be used.

Weather Resistance. Exterior coverings shall be of moisture and weather resistive materials attached with corrosion-resistant fasteners to resist wind and rain. Metal coverings shall be of corrosion-resistant materials. Each module shall be capable of passing Test No. 9 as specified in Section 5.10 of Draft ISO Recommendation 1496 [9].

Condensation Resistance. An appropriate means of preventing water vapor condensation within the panels shall be provided. Insulation shall not be hygroscopic.

Fire Resistance. Interior surfaces shall be faced with materials whose flame-spread classification shall not exceed Class C as defined in Section 6.2114 of NFPA (National Fire Protection Association) Code 101-1967 [16].

Vermin Resistance. Exterior surfaces shall be effectively sealed so as to prevent the entrance of rodents. All materials, including cores, shall be vermin resistant.

Health and Safety. Each module shall be designed with respect to electrical, plumbing, heating, health, and safety features in accordance with ANSI Standard A119.1 [17] and the National Electrical Code [18].

Electrical Service. Electrical service for each module shall be 120/208 VAC, 3-phase, 4-wire. Service entry shall be made weathertight and vermin proof. Service entry shall be accessible when module doors are fully open. An electrical disconnect and distribution panel shall be connected to the service entry through conduit. Internal branch wiring shall also be enclosed in either rigid or flexible metallic conduit. No less than four duplex receptacles shall be provided for 120 VAC, 1-phase service within the module and one weathertight receptacle for 120 VAC, 1-phase service outside. An external 208 VAC, 3-phase, 4-wire weathertight service shall be provided for a plug-in air conditioner. Provision shall be made for an accessible connection to an externally driven ground rod. The generators used must be approved by Project Manager, Mobile Electrical Power (PM-MEP).

Air Treatment. The Quick Camp System shall provide a comfortable operating environment within the modules when exposed to a low temperature of minus 10°F and a high temperature of 95°F at 80 percent relative humidity and a high temperature of 125°F at negligible humidity. The modules shall also remain functional in a storage mode at temperatures from minus 65°F to plus 160°F. The over-all coefficient of heat transfer of each module shall not exceed 0.25 Btu/hr/ft^2/$^{\circ}$F. Cold air shall not discharge directly on personnel. The temperature of the air at floor level and at head level shall not differ from each other by more than 10°F. Vents shall be provided in each module for pressure equalization and natural ventilation. Vents and fans shall be designed according to the following minimum requirements:

Camp Function	Air Flow (cfm)
All purpose	200
Administrative/medical	250
Berthing	250
Kitchen	600
Head	300
Shop	200
Camp utilities	400

Illumination. Sufficient electrical lighting shall be installed in each module to provide a minimum of 70 foot-candles of light at a distance of 32 inches above the floor throughout the module. Lighting circuits shall include normal circuit breakers and switches. Lighting shall be fluorescent type with RFI shielding. Emergency lighting for each module shall be provided by battery-powered lamps which shall be energized automatically in the event of power failure. These emergency lights shall be demountable for use as hand-carried lanterns.

Sanitation. Head facilities shall be provided for personal cleanliness. The kitchen shall have smooth working surfaces and a steam table that can be removed and disassembled for cleaning. A means shall be provided for heating dishwater to at least 160°F.

Potable Water. A water purification system conforming to public health service requirements shall be included in the camp utilities module. The system shall be capable of supplying each man with 25 gallons of water per day.

Entrances for Utilities. Entrances for utilities shall be provided as required by the equipment in the modules during the camp mode. Entries shall be made weathertight and vermin proof and shall be accessible when module doors are fully open.

Doors. Each module shall have at least one personnel door. The berthing module shall be provided with a secondary exit for combat emergency. All exterior doors shall have locks and all other exterior apertures shall have protective coverings that can be secured from inside.

Fire Extinguisher. Each module shall have a 20-pound wall-mounted chemical fire extinguisher.

Human Engineering. Human engineering design criteria as given in Military Standard MIL-STD-1472 [19] shall be applied as appropriate.

Maintenance. Maintenance shall consist of not more than painting, cleaning, and decontaminating. If exterior surfaces are to be painted, the cost of labor and materials for painting at two-year intervals shall be considered in the operating cost. The roof surface shall be designed in such a way that water will drain off when the surface is flushed with water. The water shall not drain in front of doorways. Exterior surfaces shall be smooth and contain a minimum of folds and cracks for ease in decontamination of nuclear sources and biological and chemical agents.

Repair. Wall and roof panels shall have high puncture resistance, and ease in repairing punctures shall be a major consideration in selecting materials for the panels. A repair kit shall be provided with each module for repairing minor damage at the camp site.

Site. The site will be free of trees, but small tree stumps will be permitted. The ground will have a bearing capacity of at least 3,000 psf and a slope of not more than 10 percent. If the natural site does not meet these requirements, site preparation will be required.

Supports. All Quick Camp modules shall contain supports and a leveling system with hand operated jacks and visual level indicators for accommodating a site with a 10 percent slope. Also, the system shall be capable of lifting the module off level ground with three feet of clearance underneath. The foot pads of the supports shall be designed for a soil bearing capacity of 3,000 psf. The level indicators shall be recess mounted and provided with a protective cover plate.

Set-Up Time. When the natural site meets the site criteria, set-up time shall not exceed one hour plus one-half hour per module when trained Seabees do the work.

Strike-Down Time. Strike-down time shall not exceed two hours plus one-half hour per module when trained Seabees do the work.

SYSTEM ANALYSIS

Approach

Quick Camp System development is primarily a systems engineering problem as it involves unique uses of a relatively new item, the intermodal shipping container, but no new technology in materials or methods. The challenge is in weighing the merits of a large number of alternatives to arrive at a practical, simple, and cost-effective solution.

The solution has been approached from the low performance and low cost direction. Thus, as modifications to improve performance are suggested, corresponding increases in cost can be estimated and only justified changes authorized.

It was recognized in the beginning that two or three cycles of system analysis would be required before an operational system could be developed. The first cycle was used to confirm requirements and first-order criteria, to determine the economic feasibility, and to obtain an over-all design of the entire system. Three selected prototype modules were fabricated merely as samples of the design and as subjects for tests to determine the second-order criteria. The selection of equipment items of second-order importance and the preparation of final procurement drawings and specifications were deferred until the second cycle. This was done to minimize the investment in things that surely would be modified.

The amount of work necessitated contracting for design and fabrication, but the problem was small enough in scope for one contractor to do all of the first cycle design work. Delegating as much decision making as possible to the contractor made it possible to create a balanced composition. It also simplified coordination.

Procedure

A cycle of system analysis usually consists of design, fabrication, test, and evaluation. The results of the evaluation are used as input for design in the next cycle.

Two cycles were planned for the development of the Quick Camp System in the following steps.

1. First Cycle:
   a. Design the entire system.
   b. Fabricate three selected prototype modules representative of the system.
   c. Test the prototypes.
   d. Evaluate the entire system based on the testing of the selected prototypes.
2. Second Cycle:
   a. Modify the design of the entire system.
   b. Fabricate prototype components for a complete 26-man camp (entire system).
   c. Exercise the prototype facility using 26 Seabees with helicopter support.
   d. Evaluate the entire system based on the results of the exercise.

The status of system development as of 30 June 1972 is outlined in Table 1.

SYSTEM DESIGN

Preliminary Studies

System design and the fabrication of three selected prototype modules was done by North American Rockwell (NAR) Corporation under NCEL Contract N62399-71-C-0002. The work was accomplished and reported by NAR in four phases: (1) preliminary studies [20, 21], (2) preliminary design [22 25], (3) final design [26-29], and (4) fabrication of selected modules and packages [30, 31].

Table 1. Status of Quick Camp System Development as of 30 June 1972

Phase of Development	Status	Needs	Plans	Possible Future Work
Problem definition and concept formulation	Completed: mission statement, needs research, environment research, and system requirements. In progress: design criteria about 80% complete.	Design criteria for second-order equipment and human factors.	Complete design criteria by evaluating criticism by 31st NCR, NELC, L51, L62, L85, and NAVFAC; and by evaluating the tests performed on three selected prototype modules. Increase the system requirements to include operating in temperatures down to minus 30°F.	Increase scope of system to include complete facilities for underwater construction teams. Increase system requirements to include large volume refrigeration of food and storage of fuel.
Preliminary studies	Completed: scheme for grouping functions, scheme for grouping modules, selection of structural materials, selection of nonexpandable and complexed modules, and revision of criteria for economic feasibility.	None	None	None anticipated.
Preliminary design	Completed: plant layout for each module, layout for each subsystem, selection of first-order equipment, and design calculations.	None	None	Preliminary design of unique underwater construction team facilities, such as a diving equipment module. Selection of containers for refrigeration of food and storage of fuel.

continued

Table 1. Continued

Phase of Development	Status	Needs	Plans	Possible Future Work
Final design	Completed: developmental drawings, developmental specifications, and cost estimates. In progress: stress analysis about 75% complete.	Stress analysis for dynamic loading conditions. Stress analysis for three-point support condition.	Analyze the structural design using finite element theory and computer codes and compare the results with measurements from tests.	Final design of unique underwater construction team facilities. Integrate reefer and fuel containers into the system.
Fabrication of selected prototype components	Completed: camp utilities module, kitchen module, all purpose module, messing package, and flexible passageway.	None	None	None anticipated.
Test and evaluation of selected prototype components	Completed: structural, environmental, electrical, and operational tests and evaluations. In progress: rail impact and drop tests in the planning stage about 10% complete.	Confirmation of the design for dynamic loads during the rail transport and helicopter handling modes.	Conduct and evaluate rail impact test. Conduct and evaluate flat and rotational drop tests. Compare stresses measured during the tests with those obtained in the stress analysis.	Conduct and evaluate additional over-the-road tests.
Design modification	In progress: design modifications and changes to developmental drawings about 40% complete.	Correct system deficiencies. Complete system design. Refine system design.	Redesign deficient details. Select equipment to replace unsatisfactory first-order equipment. Select second-order equipment. Up-date developmental drawings. Up-date developmental specifications. Up-date cost estimates.	Conduct another cycle of system analysis if required as a result of exercise and evaluation of the prototype system.

continued

Table 1. Continued

Phase of Development	Status	Needs	Plans	Possible Future Work
Fabrication of a complete prototype facility	None	Prototypes of all components for exercising as a complete system.	Procurement of all components needed for a 26-man facility.	Procurement of unique underwater construction team modules. Procurement of reefer and fuel modules.
Test and evaluation of the entire system	None	Confirmation of trouble-free operation and practical use of all components.	Field exercise in a cold climate using two Seabee teams with helicopter support. Human factors evaluation of the entire system.	Field exercise in a hot climate using two Seabee teams with helicopter support. Field exercise using one underwater construction team. Long-term exercise including reefer and fuel modules.
Utilization	Completed: 10-min film with color and sound, 15-min Vu-graph presentation, and 20-min slide presentation. In progress: operation manual about 30% complete.	Final documentation.	Complete operation manual. Prepare procurement drawings and specifications. Compile maintenance manuals.	Provide consulting service during first production run. Observe first deployment.

The preliminary studies concerned:

1. Schemes for grouping camp functions into modules.
2. Schemes for grouping modules into camp layouts.
3. Cost effectiveness of alternate panel materials and construction techniques.
4. Cost effectiveness of using expandable shelters.
5. Feasibility of the economic goals.

The objectives were:

1. To insure that the Contractor and the Government proceeded toward the same development goals.
2. To insure that the development goals were well defined and feasible.
3. To insure that certain design decisions would be justified with adequate study.
4. To establish a general system plan prior to detailed design.

Two rough schemes were provided by NCEL, one using expandable shelters and one using nonexpandables. These tentative schemes were samples to set the level of camp completeness and to provide a basis for comparing alternatives. The Contractor considered a large number of alternate schemes and then developed the two by NCEL and four of his own for complete evaluation. Of the six evaluated, three involved expandable modules, two involved complexed modules, and one involved neither expandable nor complexed modules. NAR [21] refers to these as three schemes in expandable and nonexpandable form.

The Contractor ranked one of the NCEL schemes first and one of his own schemes second, but the difference was considered within the precision of the data. The Laboratory's evaluation of NAR's work resulted in the authorization of either, or a combination of both schemes because certain merits of the second-best scheme could be incorporated into the best scheme without compromise. Thus, the selected scheme is a hybrid of the best merits of the two. This scheme, consisting of seven modules and four special packages, is shown for various camp sizes in Table 2. The total number of modules is the number of containers required. Special packages are assemblies of furniture and equipment carried in the containers and installed at the camp site.

Table 2. Number of Modules and Packages Required for a Normal Quick Camp Facility

Modules and Packages	Number of Modules and Packages Required for—							
	13 men	26 men	39 men	52 men	65 men	78 men	91 men	104 men
Modules								
All Purpose	2	2	3	3	4	5	5	6
Work Shop	1	2	3	3	4	4	5	5
Administrative/Medical	1	2	3	3	4	5	5	6
Kitchen	1	1	2	2	2	3	3	3
Berthing	2	4	6	8	10	12	14	16
Sanitation	1	1	2	2	2	3	3	3
Camp Utilities	1	1	2	2	2	3	3	3
Total	9	13	21	23	28	35	38	42
Packages								
Messing	1	1	2	2	3	3	4	4
Laundry	1	1	1	1	1	1	2	2
Recreation	1	1	1	1	1	1	2	2
Team	1	2	3	4	5	6	7	8
Total	4	5	7	8	10	11	15	16

Modules are for all purpose, work shop, office and medical treatment, kitchen, berthing, head, and camp utilities. The all purpose module can be used for laundry, messing, or recreation by installing the appropriate special package, or for storage and general dry cargo. The work shop module can be packed with three different assemblies of equipment and supplies for use by construction electricians and utilitiesmen, builders and steel workers, or construction mechanics and equipment operators. The administrative/medical module provides an office and a medical treatment station for use by an engineer, engineering aid, and hospital corpsman. The kitchen module and all purpose module can be connected by a flexible passageway to form a complete messing facility. The sanitation module contains chemical toilets, showers, and lavatories. Six berths are provided in each berthing module, and two berths are provided in each administrative/medical module. The camp utilities module carries most of the components of the electrical and water subsystems.

Almost all items of furniture and equipment are either built-in or selected from the Seabee Team Table of Allowance (TOA) [3]. The general scheme for shipping these items in the modules is shown in Table 3. Each module carries its own legs and foot pads. One set of leveling jacks is included in each Team Package. The specific packaging plan and center-of-gravity study were not done in the first cycle of system analysis. They were planned for the second cycle.

Table 3. General Packing List

Module Type	Included Items	TOA Designation
All purpose	general dry cargo	none
	recreation package	none
	laundry package	none
	soil test kit	0963
Work shop	electrician's equipment and supplies	0950
	utilitiesman's equipment and supplies	0954
	builder's equipment and supplies	0951
	steel worker's equipment and supplies	0955
	mechanic's equipment and supplies	0952
	miscellaneous tools	0956
	consumable hardware	0957
Administrative/medical	surveyor's equipment and supplies	0953
	administrative equipment and supplies	0958
	medical and dental equipment	0959
	communications equipment	0960
	photographic equipment and supplies	0961
	barber equipment	0962
	reference and training material	0972
Kitchen	flexible passageway	none
	messing package	none
	camp components (applicable items)	0968
Berthing	team package	none
	clothing	0964
	infantry equipment	0965
	provisions	0966
Sanitation	camp components (applicable items)	0968
Camp utilities	electrical generators	none
	miscellaneous spare parts	none
	camp components (applicable items)	0968

Figures 6 through 13 show recommended camp layouts for 13, 26, 39, 52, 65, 78, 91, and 104 men, respectively. Major considerations in arriving at these layouts were (1) noise from camp utilities modules, (2) sewage from sanitation modules, (3) length of electrical cable and water pipe, (4) number of traffic crossings over cable and pipe, and (5) separation of living and working areas. Twenty-foot vehicle traffic lanes are between each column of containers and 10-foot pedestrian lanes between each row. More compact and more disperse plans are possible.

The recommended layouts should be suitable for most missions and climates. However, exceptions occur in the cases of 26-man, 65-man, 91-man, and 104-man camps where (1) the layouts do not provide for water service to every administrative/medical module and (2) the layouts provide for marginal or insufficient electrical power for high electrical heating loads in cold weather. Recommended alternate layouts for use in cold weather or when water service to all administrative/medical modules is required are shown in Figures 14 through 17 for 26-man, 65-man, 91-man, and 104-man camps, respectively. Each of the alternate layouts contains one camp utilities module in addition to those listed in Table 2.

Expandable shelters make longer clear spans possible and also make it possible to reduce the amount of transported volume. However, they also tend to create:

1. Longer set-up and strike-down times.
2. Less durability.
3. Little, or no, volume available for built-ins.
4. Higher cost.
5. Operational problems in cold environments.
6. Requirements for more maintenance.
7. Requirements for more training of personnel.
8. Difficulty in accommodating to unimproved sites.

The transported volume needed for built-ins and TOA items was nearly as large as the volume needed for habitation. Therefore, alternate schemes using expandable modules allowed little, or no, reduction of the number of lifts. Reduction of lifts varied from none for 13-man camps to about 12 per camp installation for 104-man camps. Savings in transportation costs were more than offset by penalties in other costs.

If expandable modules were used for Quick Camps, the cost of the system would far exceed the cost goal. The high cost of expanded volume is due to the materials, detailing, fabrication techniques, and cost of labor required to obtain the expandable feature. The cost-effective nonexpandable was found to be made of FRP (fiber glass reinforced plastic) on plywood panels enclosed in a steel frame; the cost-effective expandable shelter was found to be made of aluminum skin and paper honeycomb core panels enclosed in an aluminum frame. The nonexpandable container can be obtained from commercial sources for about \$2,000 and modified with insulation, plumbing, and wiring for about \$4,000, which is a total of \$6,000. Thus, three nonexpandables would cost about \$18,000. On the other hand, a three-to-one expandable with insulation, plumbing, and wiring costs about \$40,000 and involves higher maintenance cost. In conclusion, since expandables are more than twice the cost of nonexpandables, a strong need for longer clear spans must exist to justify using expandables. For the Quick Camp mission, longer spans are desirable, but a strong need does not exist.

If a system were to be developed for camps larger than 104 men, functions and modules should be grouped differently to achieve greatest efficiency at larger camps by reducing duplication of elements at large camps and allowing more over equipage at small ones. In that case, expandable modules are more likely to be cost competitive.

As a result of the preliminary studies, the following changes were made to the Quick Camp System design requirements:

1. The list of system components and the general packing list were revised as recommended by the Contractor. Tables 2 and 3 contain the revision.

2. The grouping of shop functions was changed from three unique modules with custom packaging to a combination of work shop modules, all purpose modules, and palletized cargo.

3. The requirement for removable side panels or side doors for access to special packages in the all purpose module was deleted. The large cargo doors at the end were found satisfactory.

4. A requirement was established for side-by-side connection of the kitchen module with the all purpose module by approval of the contractor's scheme to complex the kitchen and all

purpose modules instead of expanding of the kitchen to form a complete messing facility.

5. The use of four individual showers instead of a gang shower and the use of chemical toilets instead of flush water closets and a trough-type urinal were adopted as recommended by the contractor.

6. An exception was made to allow forklift tineway spacing of 62.25 inches out-to-out, which is the SAE requirement and conflicts with the ISO requirement.

7. An exception was made to allow the use of wall heating units, since the use of baseboard units was not feasible.

8. During the course of the work, the numbers of modules in the hypothetical camps for computing cost goals were increased due to findings that additional administrative/medical modules were needed in the larger camps for berthing purposes, an additional kitchen module was needed in the larger camps because of space limitations, and a work shop module and an additional all purpose module were needed in the smallest camp to transport applicable equipment. The revised requirements, called normal facility, are given in Table 2.

9. The ground bearing capacity for use in sizing foot pads was increased from 2,000 psf to 3,000 psf, which permitted a relatively large reduction in foot pad size and weight compared to a very small compromise in site selection or site preparation.

10. Inflation of six percent per year was applied to the cost goals.

11. Exceptions were made to the SAE requirements by omitting the flat bottom plate and the lower rail slots, because the roller system they were intended to be used with is not in common use.

Preliminary Design

Preliminary design consisted mainly of selecting a container for the basic structure, selecting materials for insulation and interior finish, plant layout for each type of module, layout for each subsystem, and selection of components for the subsystems. Some furniture and equipment were selected also.

A commercially available 8 x 8 x 20-foot, ISO type 1C, dry cargo container was selected for the basic structure. The roof, side walls, and front wall are single panels of 3/4-inch Douglas Fir plywood with a 0.03-inch layer of 24 ounce woven roving/polyester bonded to each side. Total thickness is 0.80 inch. Rear panels are double steel cargo doors (Figures 18 and 19), which act as shear panels when closed. The wooden floor is supported on steel cross beams which frame into steel side rails (girders) which, in turn, transmit the load to the lower corner castings. Floor planks are laminated oak 1-1/8 inches deep and 12 inches wide. Cross beams have "Z" shapes, are 3/16 inch thick, have 4-inch web depth and flanges 1-3/4 inches wide, and are typically spaced 13 inches on center. Side rails have complex box shapes (special to the purpose of handling by straddle carrier) 0.188 inch thick and about 4 inches wide and 5-1/2 inches deep.

An inch of rigid insulation and an interior panel of 1/4-inch plywood were added to the ceiling and walls, including the cargo doors. An aluminum face sheet was bonded to the plywood, embossed, and coated with baked enamel to obtain an aesthetic and easily maintained inside finish. Undercoating of the container provided additional floor insulation.

A number of floor plans for each type of module were developed and studied, from three alternatives for the work shop module to eight for the sanitation module. Selection was made by a committee of four persons, three of NAR and one of NCEL, who represented various technical specialties. The selected plans are shown in Figures 20 through 26.

Each module has (1) an intake vent and filter at one end and an exhaust vent and fan at the other end, (2) a port which can be closed with a plywood panel or opened for mounting an air conditioner, (3) one or two personnel doors, and (4) an entry for utilities. The one exception is the camp utilities module which has a water distribution panel, an electrical distribution panel, and a cable entry instead of the typical entry for utilities. Parts and details are the same, or very similar, among modules to keep the number of parts and details to a minimum, but the positions of the openings are different to avoid interference with other things in the floor plans. All modules have the double cargo doors of the original container except for the administrative/medical module and sanitation module where the doors are replaced with a wall panel like the one at the other end of the container. The cargo doors in the kitchen module were retained for easy access for maintenance of plumbing and for additional ventilation in hot weather if an air conditioner is not available (Figures 27 and 28).

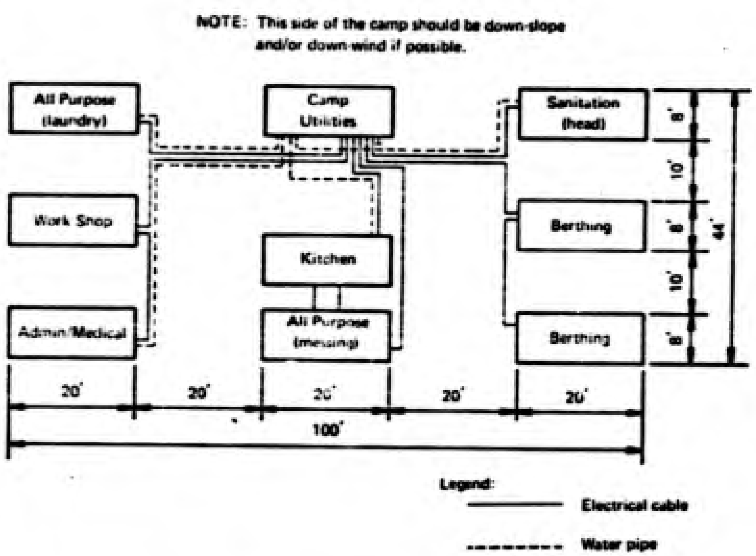


Figure 6. Recommended layout for a 13-man camp.

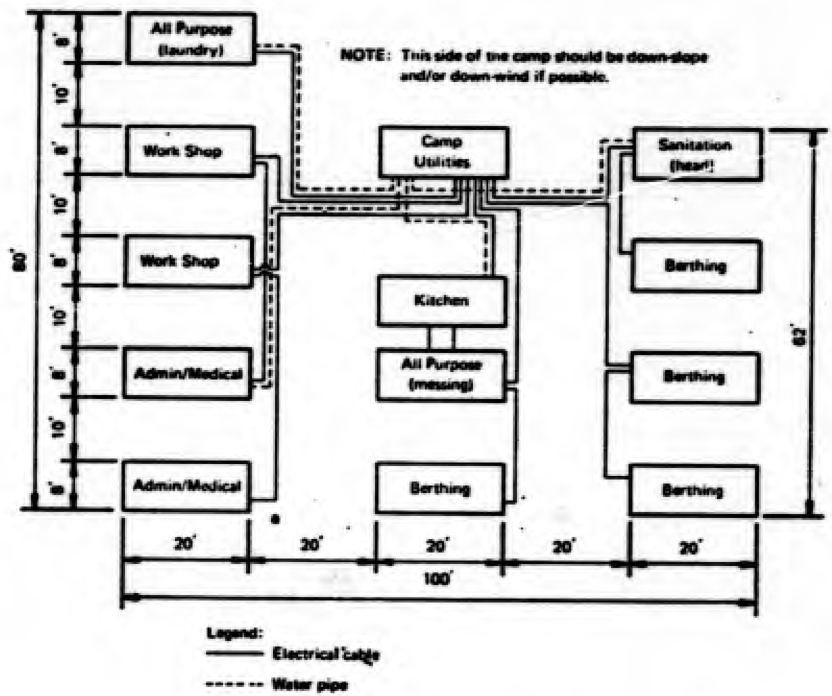


Figure 7. Recommended layout for a 26-man camp.

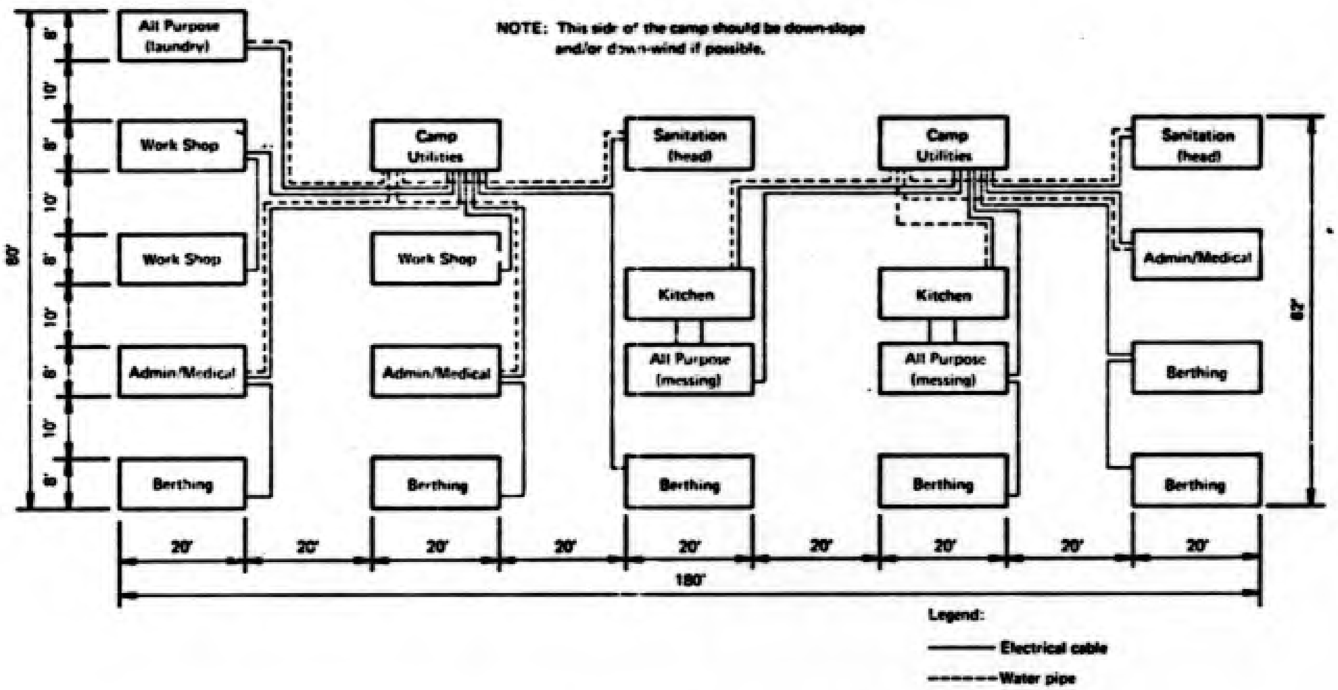


Figure 8. Recommended layout for a 39-man camp.

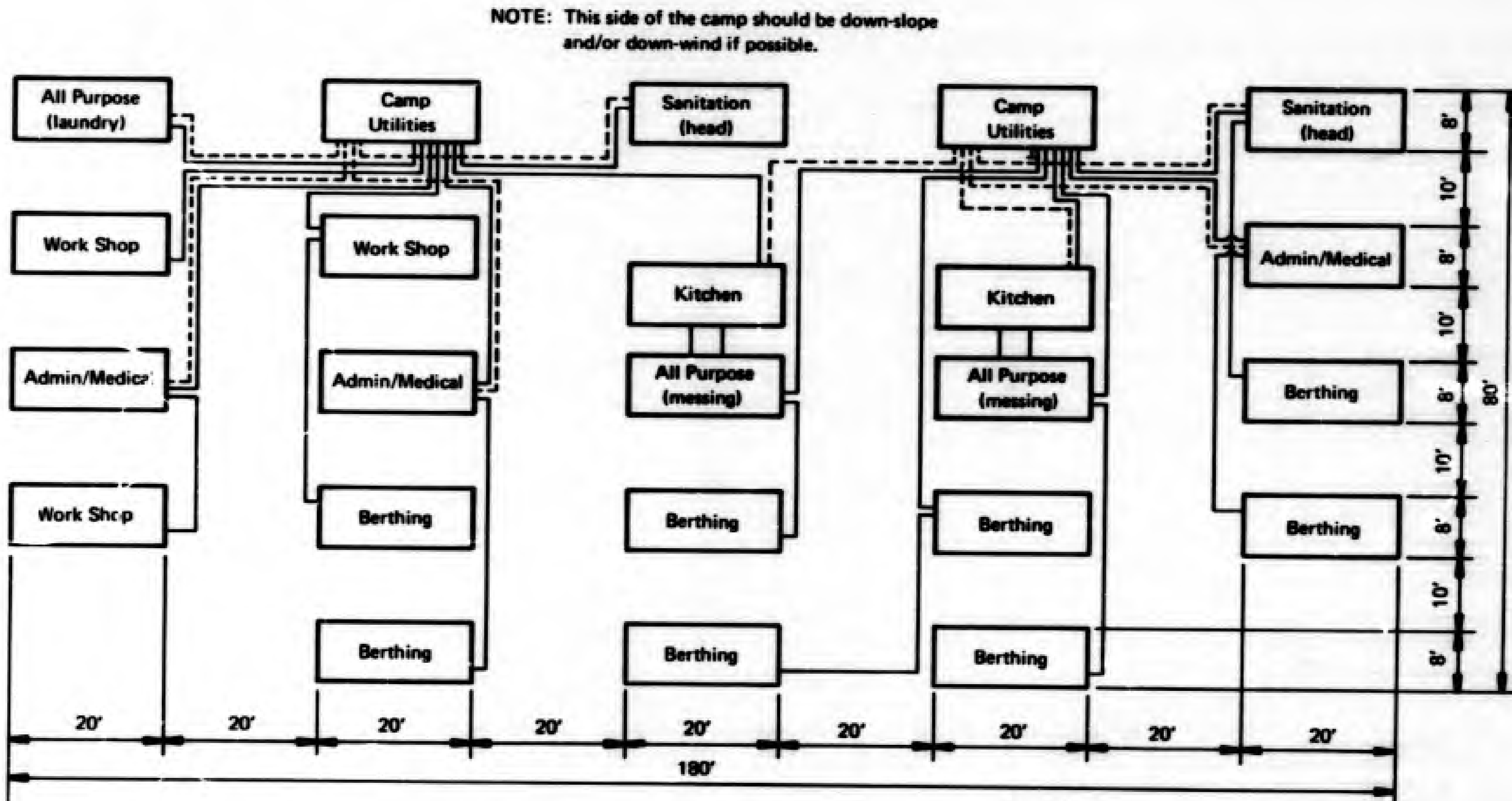


Figure 9. Recommended ıayout for a 52-man camp.

NOTE: This side of the camp should be down-slope and/or down-wind if possible.

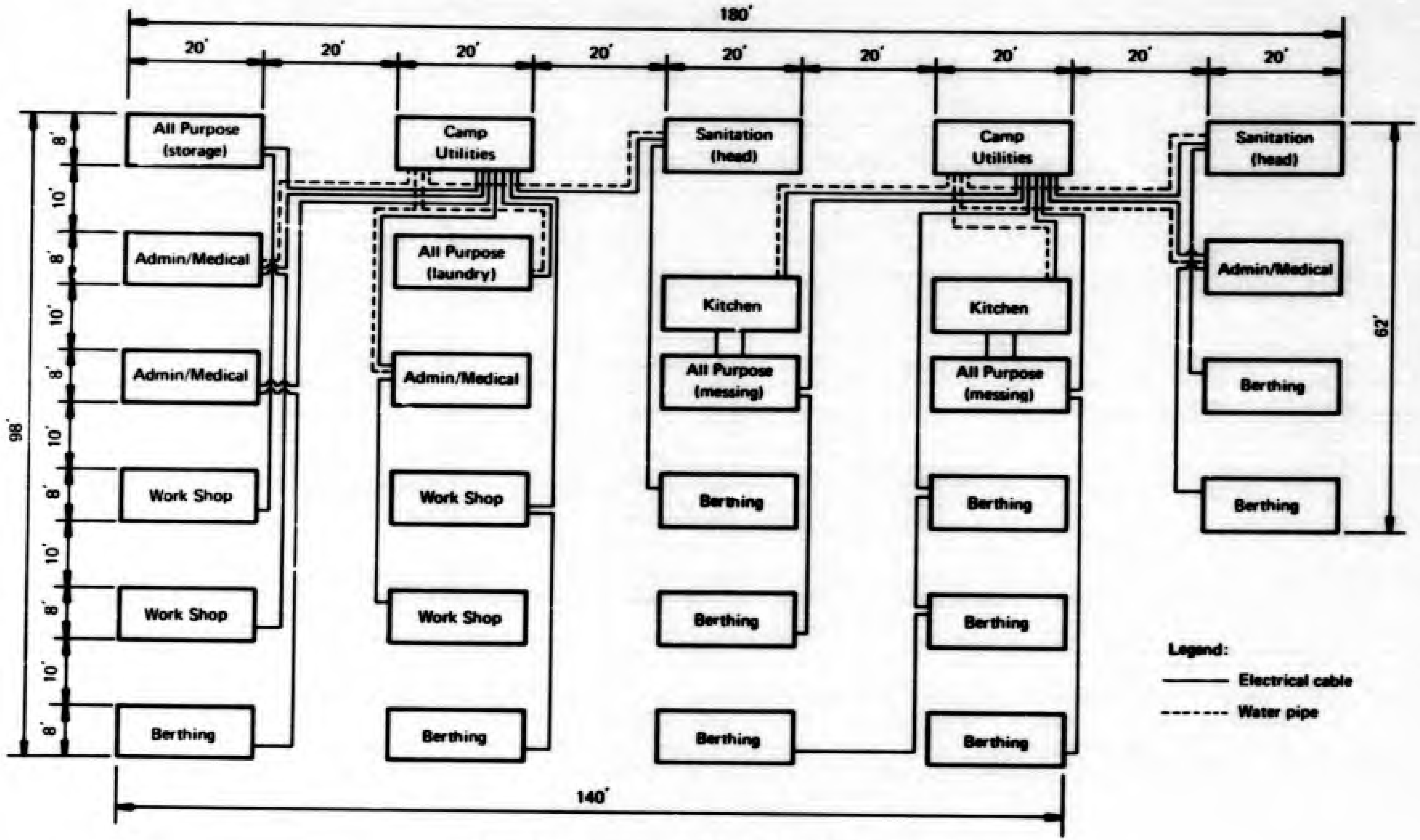


Figure 10. Recommended layout for a 65-man camp.

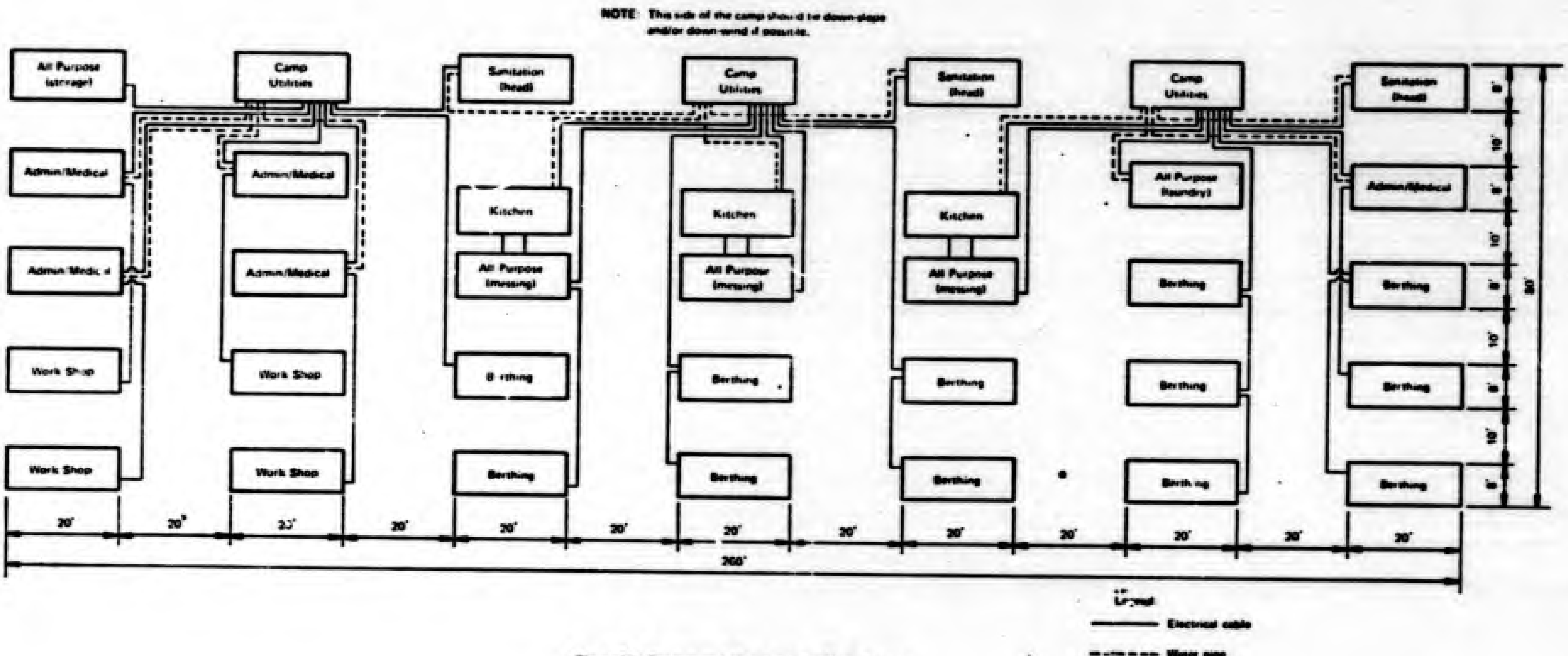


Figure 11. Recommended layout for a 78-man camp.

NOTE: This side of the camp should be down-slope and/or down-wind if possible.

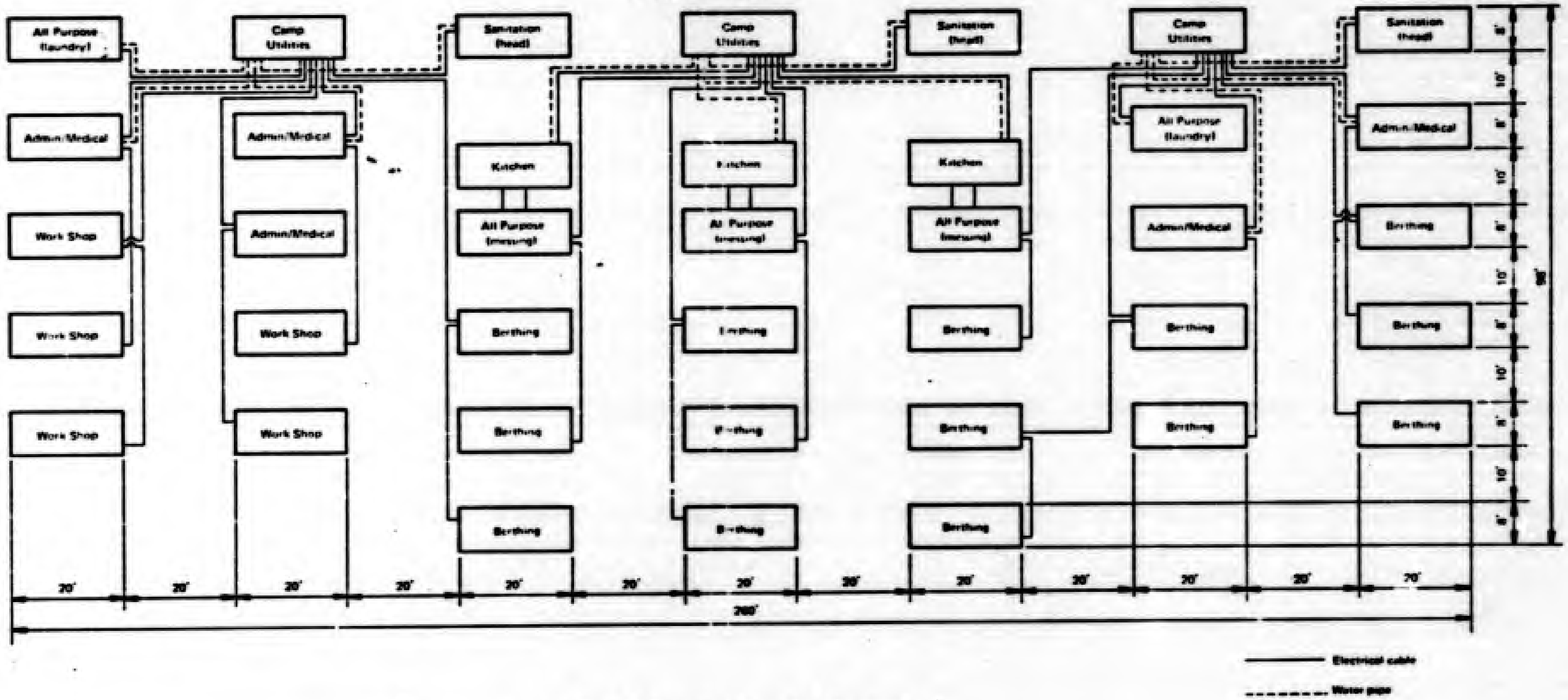


Figure 12. Recommended layout for a 91-man camp.

NOTE: The side of the camp should be down-slope and/or down-wind if possible.

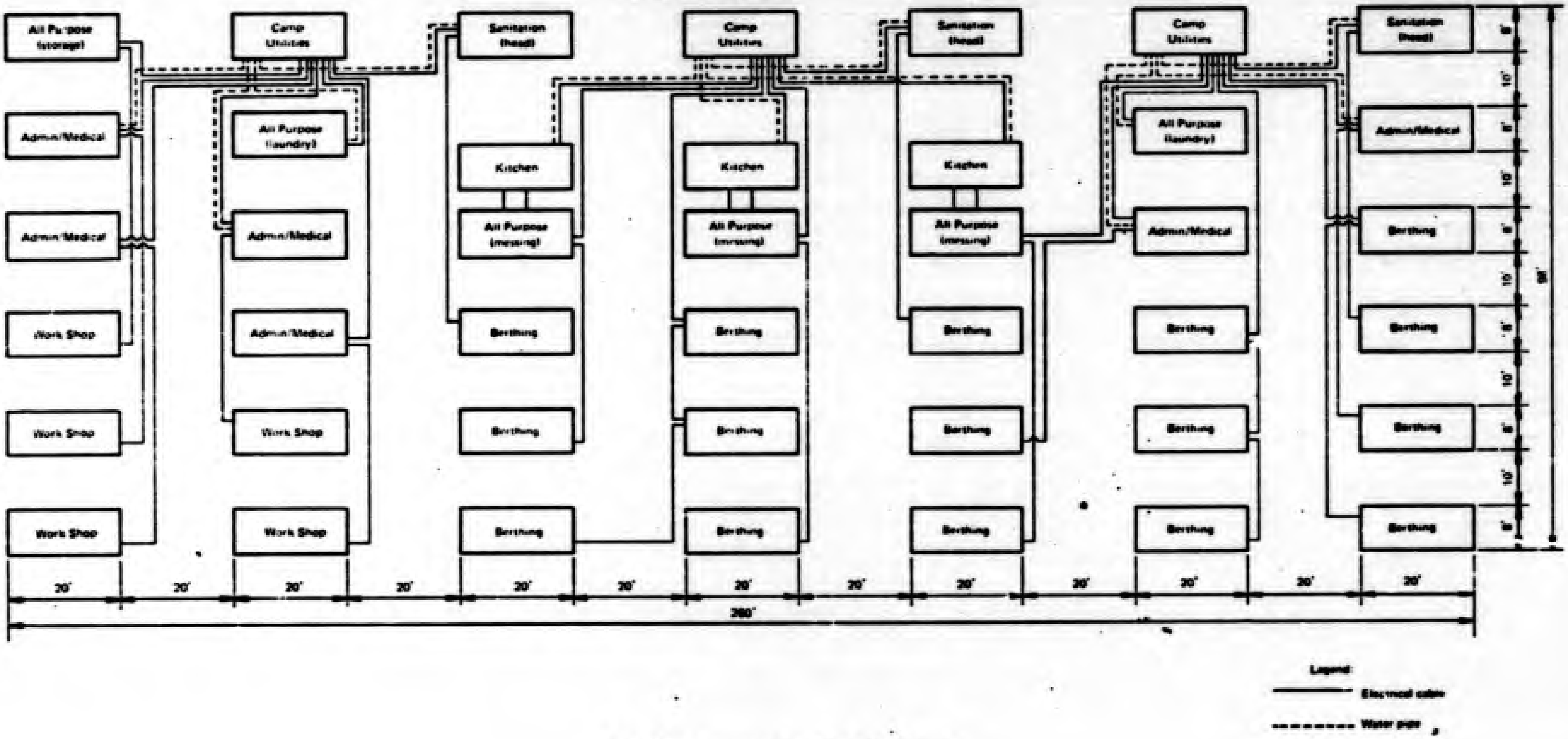


Figure 13. Recommended layout for a 104-man camp.

NOTE This side of the camp should be down slope and/or down wind if possible.

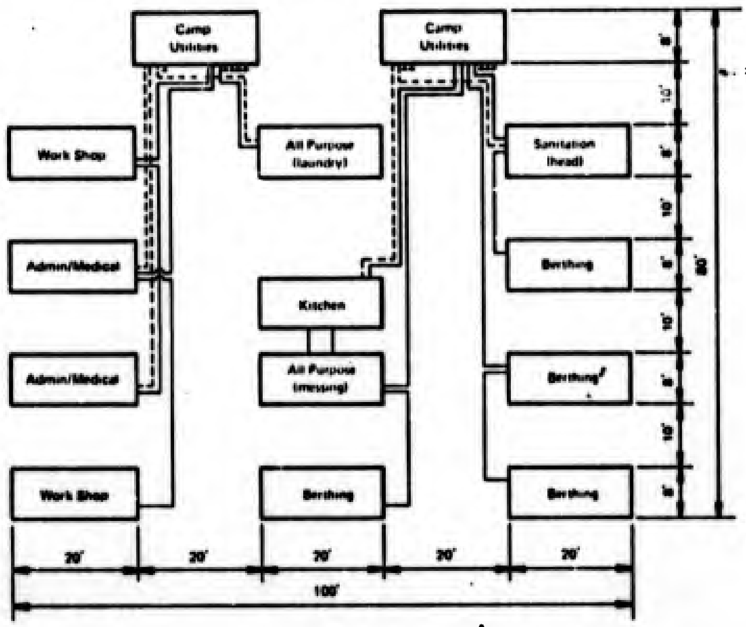
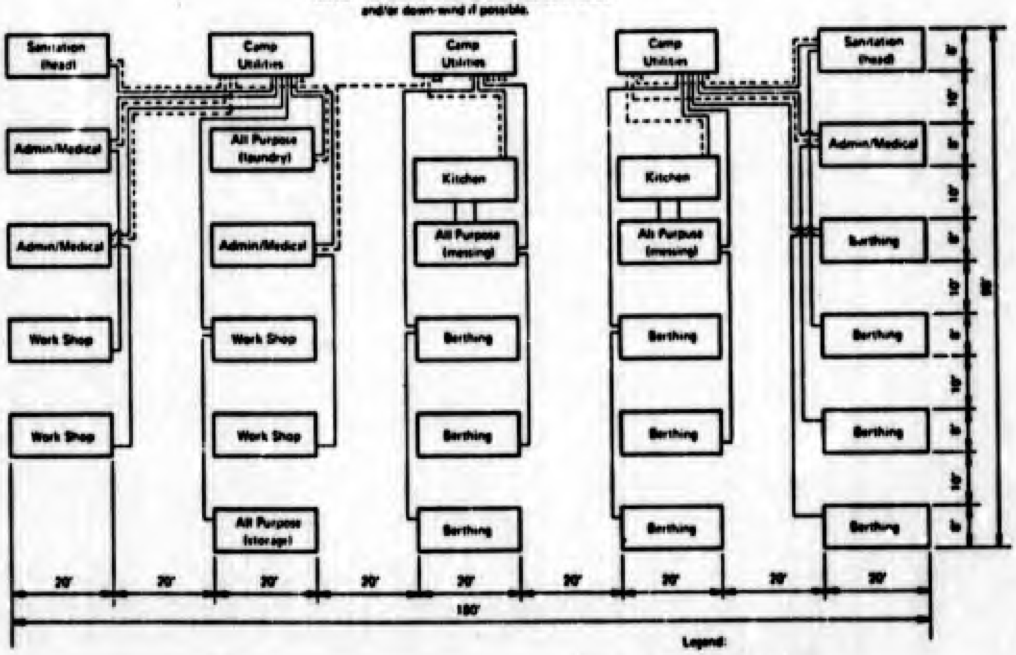


Figure 14. Recommended alternate layout for a 26-man camp for use in cold weather or when water service to all administrative/medical modules is required.

Legend:
Electrical cable
Water pipe

NOTE: This side of the camp should be down-slope and/or down-wind if possible.



Legend:
Electrical cable
Water pipe

Figure 15. Recommended alternate layout for a 65-man camp for use in cold weather or when water service to all administrative/medical modules is required.

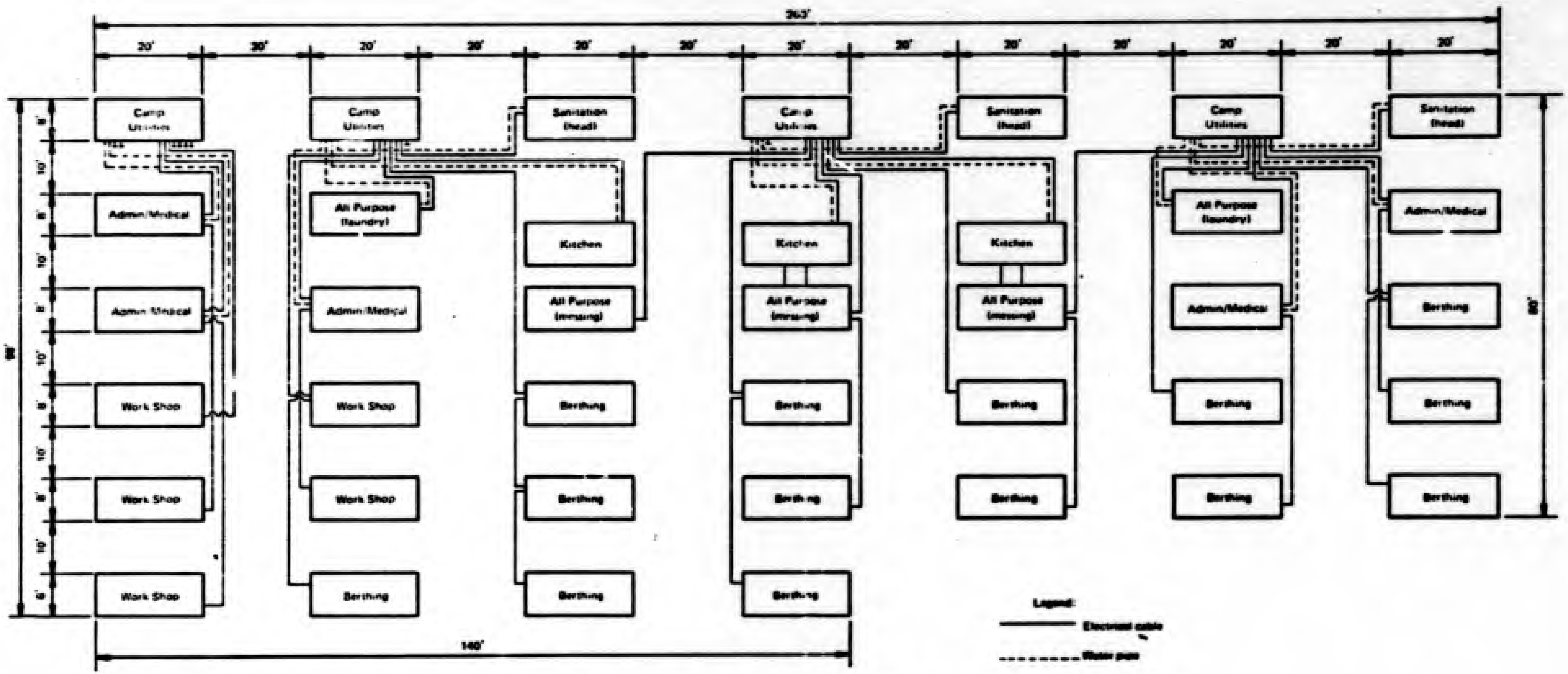


Figure 16. Recommended alternate layout for a 91-man camp for use in cold weather or when water service to all administrative/medical modules is required.

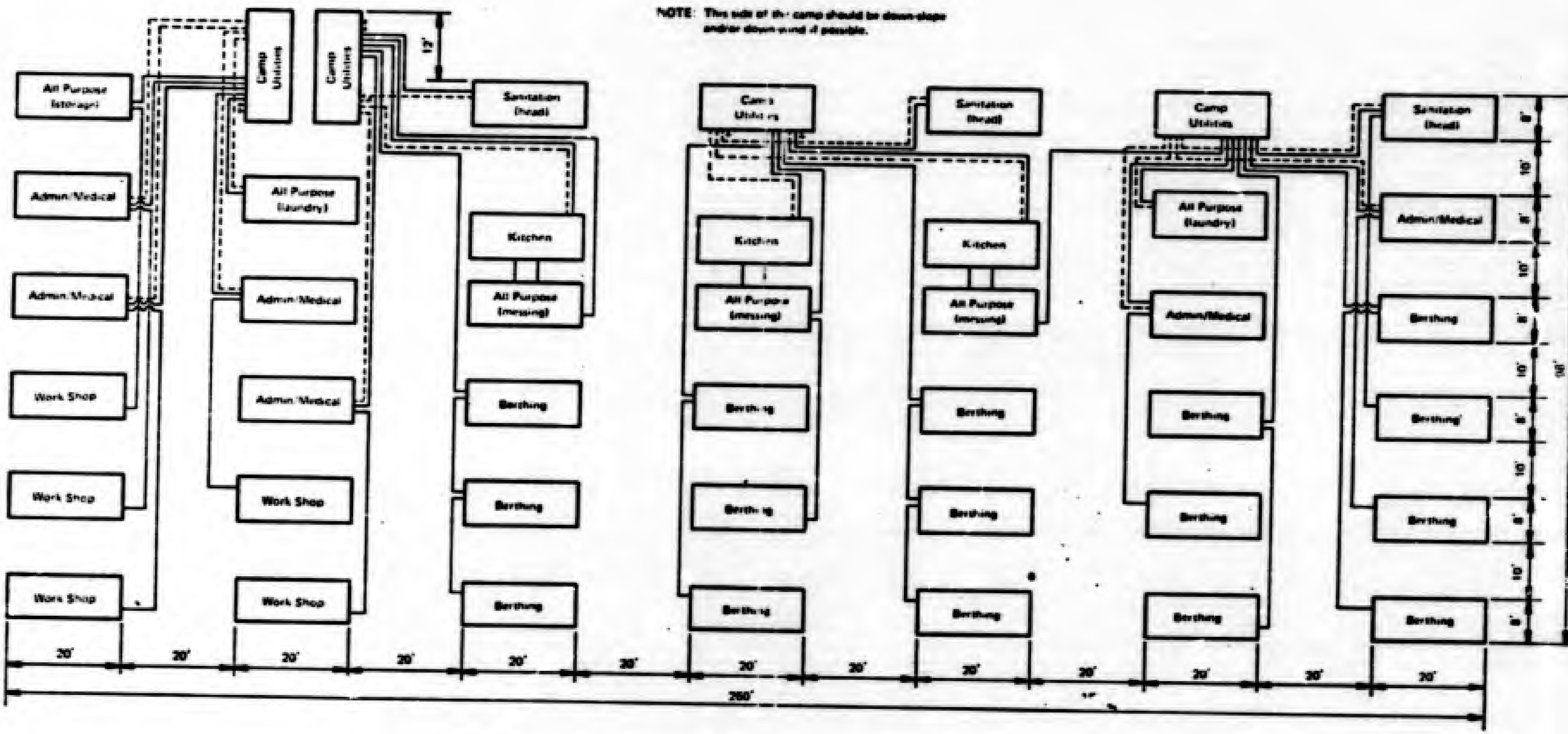


Figure 17. Recommended alternate layout for a 104-man camp for use in cold weather or when water service to all administrative/medical modules is required.

Legend:
——— Electrical cable
- - - - - - Water pipe

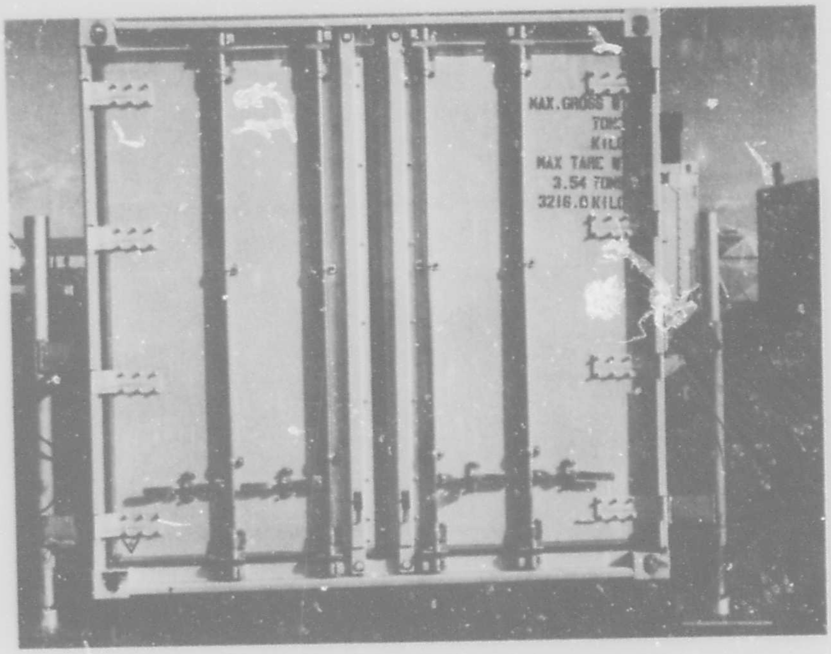


Figure 18.
Exterior view of all purpose module showing cargo doors and module supports.

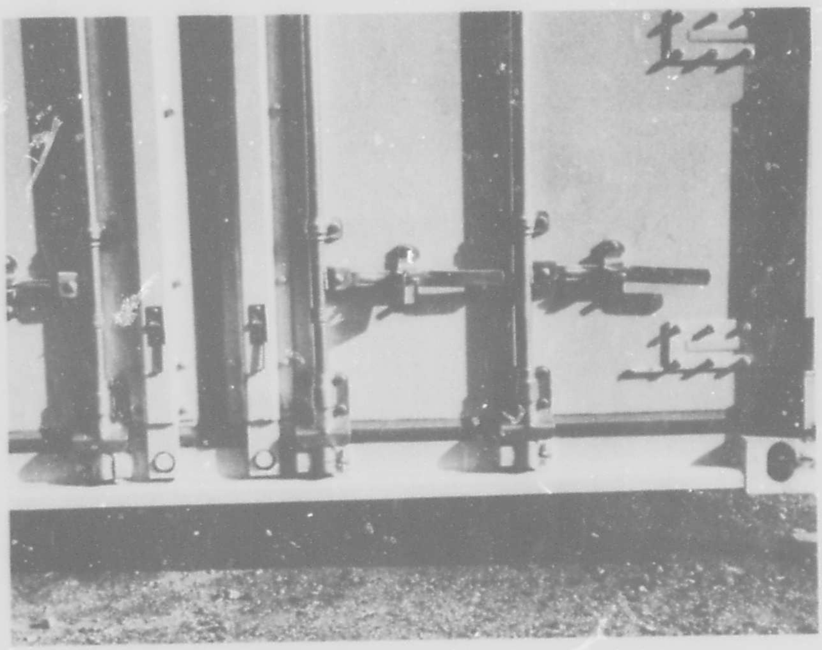


Figure 19.
Cargo door dog, handle, and padlock.

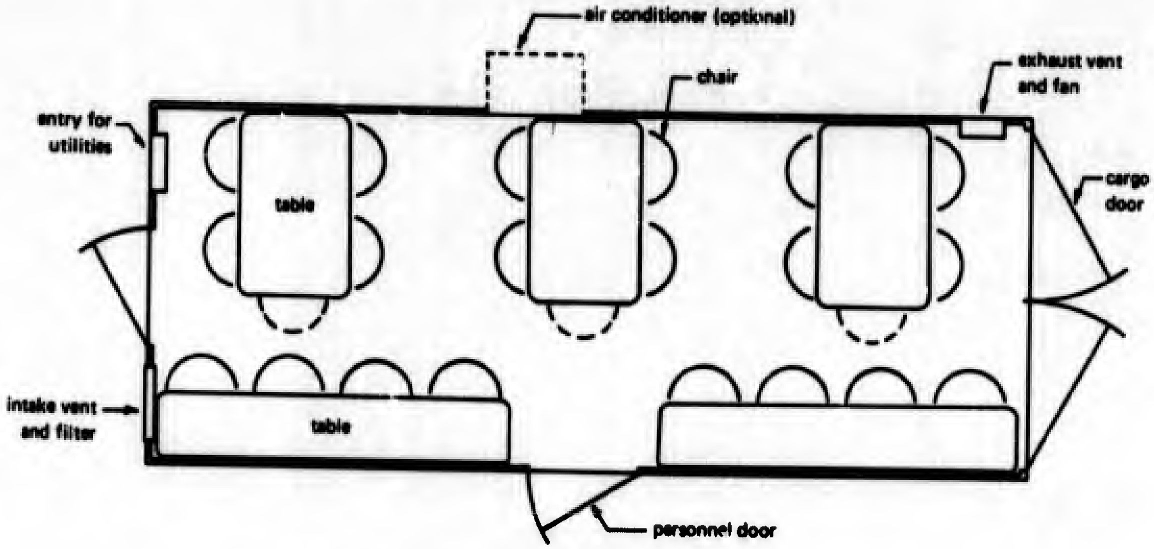


Figure 20. Floor plan of all purpose module with messing package installed.

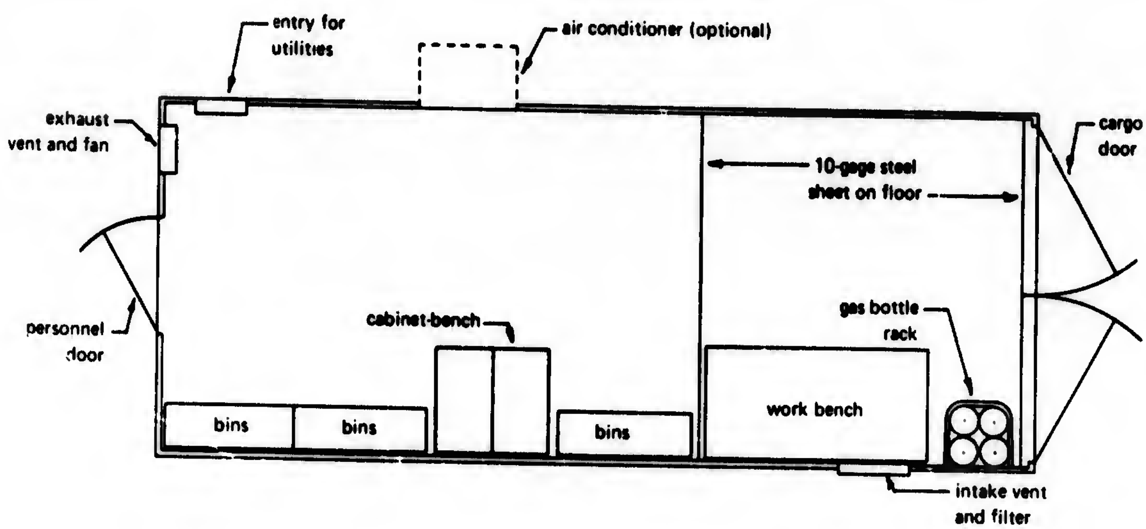


Figure 21. Floor plan of work shop module.

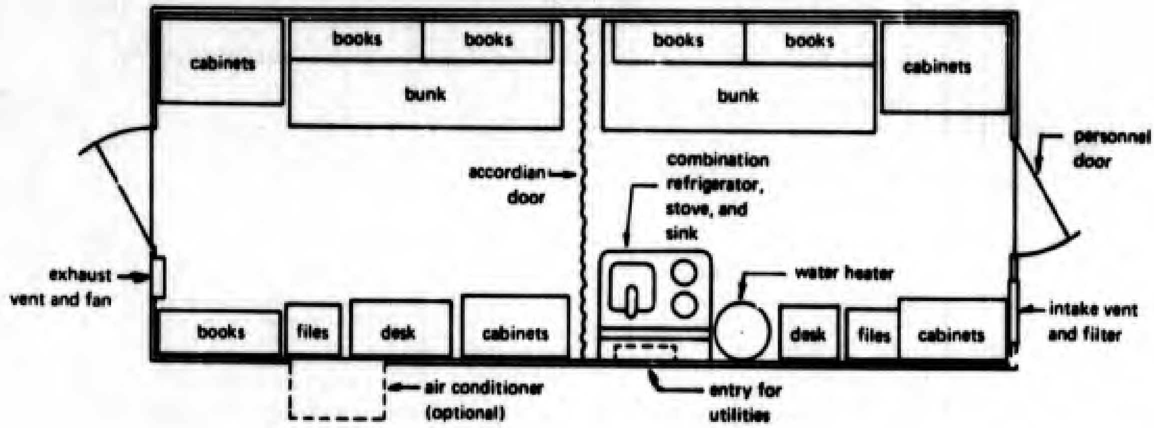


Figure 22. Floor plan of administrative/medical module.

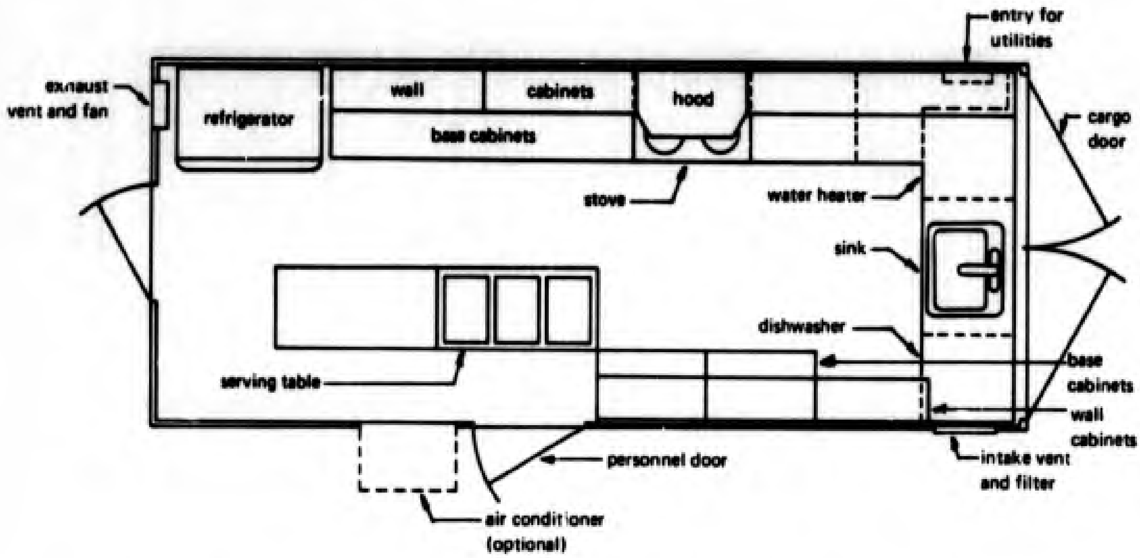


Figure 23. Floor plan of kitchen module with the serving table positioned for serving a meal.

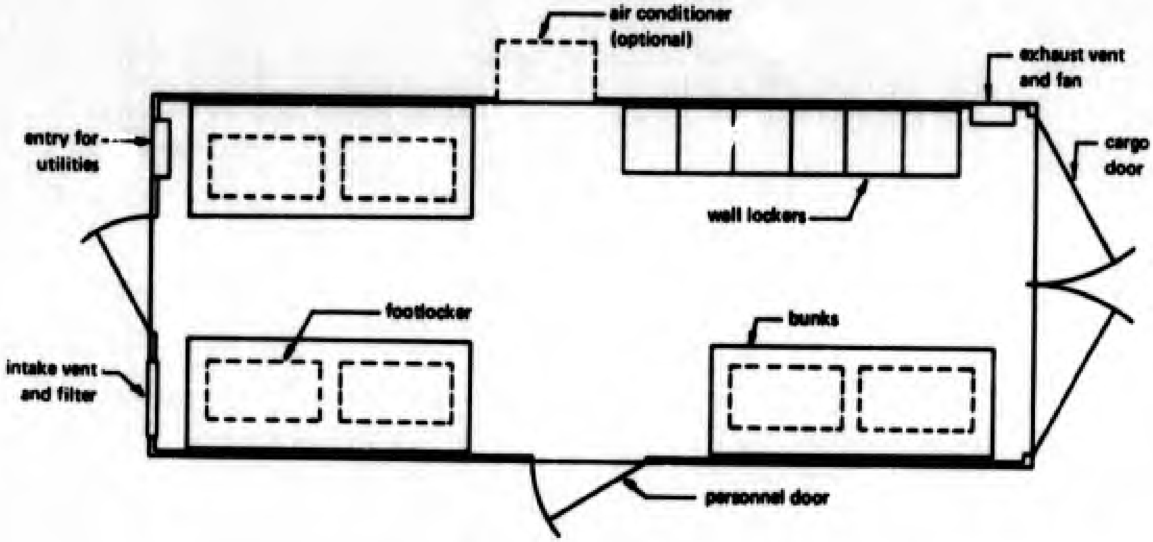


Figure 24. Floor plan of berthing module.

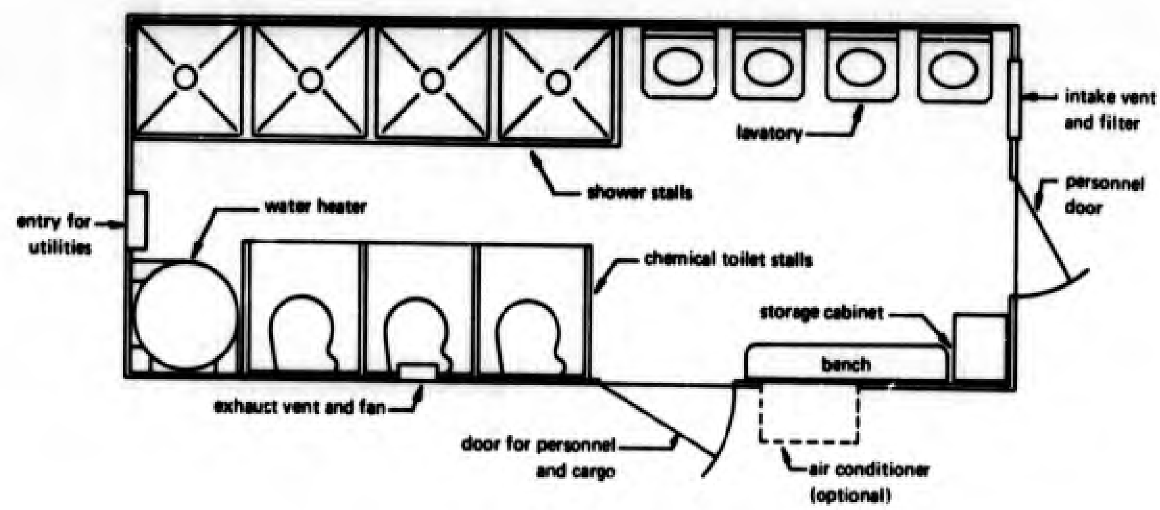


Figure 25. Floor plan of sanitation module.

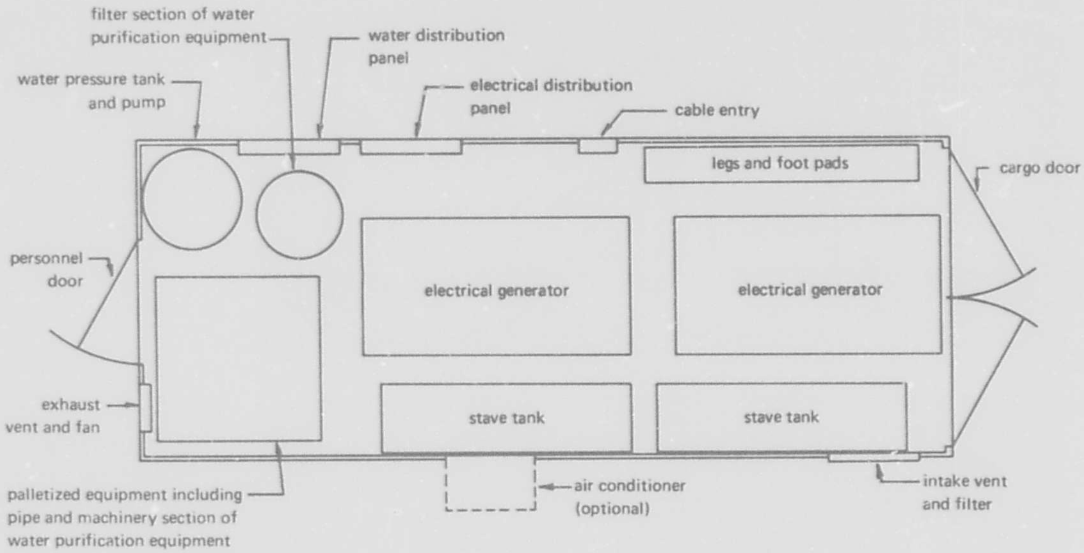


Figure 26. Floor plan of camp utilities module with equipment packed for shipment.

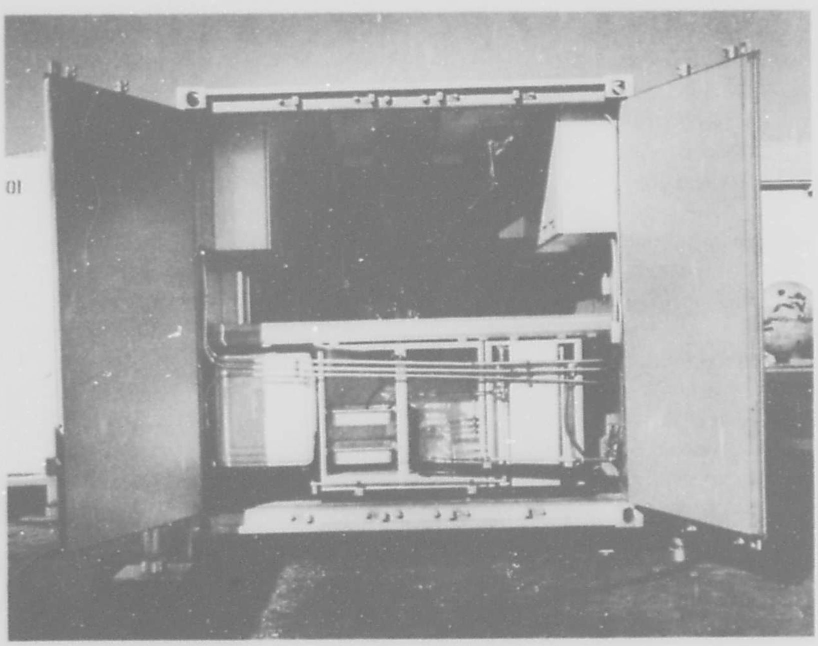


Figure 27.
Interior view of kitchen module from outside with cargo doors open showing ease of plumbing maintenance.

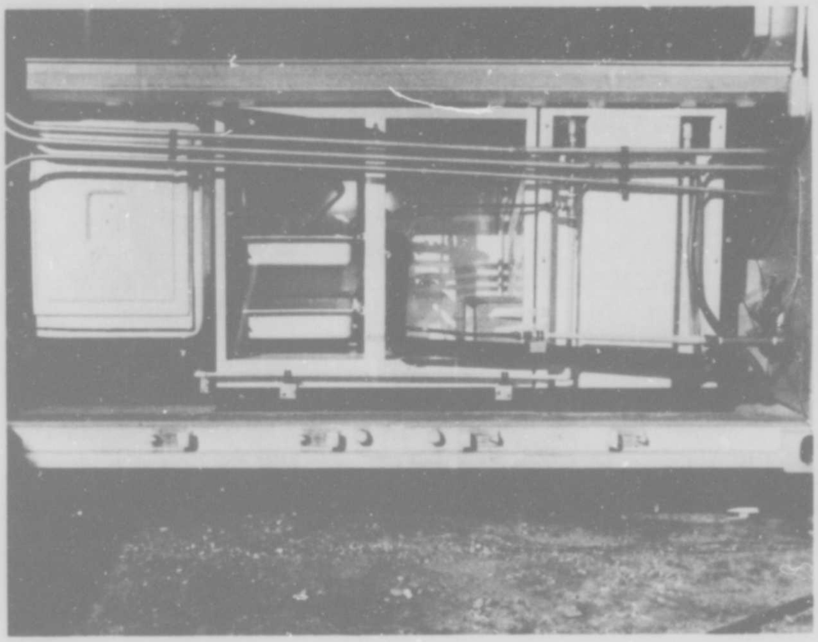


Figure 28.
Detail view of kitchen plumbing showing dishwasher (left), sink (center), and water-heater (right) with the cargo doors open.

The floor plan of the all purpose module (Figure 20) shows the messing package installed. The package contains five tables and 26 chairs. Table space was sacrificed to allow two personnel doors and adequate aisle space for emergency egress. The module will accommodate 20 men in comfort, 23 men with rather tight aisle space, and a maximum of 26 men with some hardship. Crowded conditions when 26 men are present can be relieved by the cooks eating in the kitchen (23 men in one module and three in the other), by eating in shifts, or by using an additional all purpose module. Any number of all purpose modules can be connected together by flexible passageways.

When the laundry package is installed, only about half of the floor space is needed for the laundry function; the other half is available for storage or general working space.

The floor plan of the work shop module (Figure 21) shows a gas bottle rack, work benches, cabinets, and bins. Ten-gage steel sheet is used to protect the floor at one end where welding can be done indoors.

The floor plan of the administrative/medical module (Figure 22) shows an accordian door which can separate the office from the medical treatment station. The office has a desk, a filing cabinet, wall cabinets, book shelves, and a bunk. The medical treatment station has a desk, a filing cabinet, wall cabinets, book shelves, a bunk, a water heater, and a combination refrigerator, stove, and sink. With the accordian door open, the module can be used as one large administrative office. This module also can be used as camp headquarters, providing a living and working apartment for the camp commander and his clerk. In addition, administrative/medical modules and a camp utilities module can be used at very small camps to provide office, berthing, and food preparation facilities without a need for the other types of modules.

The kitchen module (Figure 23) has a combination refrigerator-freezer, base cabinets, wall cabinets, stove with oven and hood, water heater, sink, dishwasher, and serving table. The serving table has an electrical heating element and is on casters. It can be stored against the wall when food preparation is in progress and then moved to the position shown in the figure for serving meals. The wooden floor of this module is covered with tile.

The berthing module (Figure 24) has bunks, footlockers, and wall lockers for six men. The bunks fold against the wall when not in use and the footlockers provide seating accommodations.

The sanitation module (Figure 25) contains lavatories, shower stalls, chemical toilets, a water heater, a bench, and a storage cabinet. The wooden floor of this module is covered with tile. This module also has a large side door for both personnel and cargo.

The floor plan of the camp utilities module (Figure 26) shows the positions of major power and water equipment when packed for shipment. The water pressure tank and pump are permanently fixed in the position shown; the water purification equipment, stave tanks, and electrical generators are portable. The stave tanks are used outside the module, and the electrical generators may be used either inside or outside. The cable entry shown in the figure is used when the generators are located outside. This flexibility of operational mode makes it possible to operate generators remote from the layouts shown in Figures 6 through 17. Rails for mounting the generators can be seen in Figure 29.

The water subsystem contains the 25-gpm water purification unit (Federal Stock No. 4610-132-5442) and 3,000-gallon fabric stave tanks (Federal Stock No. 5430-355-4486) listed in the TOA. These units have been proven trouble free, and one purification unit has ample capacity for the largest camp (104 men). Portability allows flexibility of use at camp sites, and outdoor use results in additional habitable space in camp utilities modules.

Nonpotable water is moved by a portable pump from a raw water source through a hose to one of the stave tanks for settling and storage. During intermittent operation of the water purification equipment, a pump in the machinery section forces water from the nonpotable water tank through the filter section to the other tank for storage in potable form. Immersion heaters are used in both tanks in cold weather to prevent freezing. Next, the potable water passes from the storage tank through the pressure tank and pump (Figure 26) to the water distribution panel in the side of the module. Water distribution can be one way in warm climates or recirculating in cold climates to prevent freezing. Each camp utilities module can service four user modules. Quick disconnect couplings for distribution pipelines, return pipelines, and pipes to storage tanks can be seen in the right half of Figure 30. The larger couplings and valves in the top row are for the distribution pipelines.

Water service is provided to laundries in all purpose modules, medical treatment stations in administrative/medical modules, kitchen modules, and sanitation modules. Each user module has two flexible plastic pipes 60 feet long, one distribution line and one return line, which can be connected to any pair of couplings on any camp utilities (service) module. Therefore, user modules must be within 60 feet of a service module to receive water service. This limitation is satisfied in all of the recommended layouts (Figures 6 through 13) and alternate layouts (Figures 14 through 17).

Figure 29.
Interior view of camp utilities module with the generators and stave tanks removed showing the intake vent and filter on the wall in the left foreground and the mounting rails for the generators on the floor.

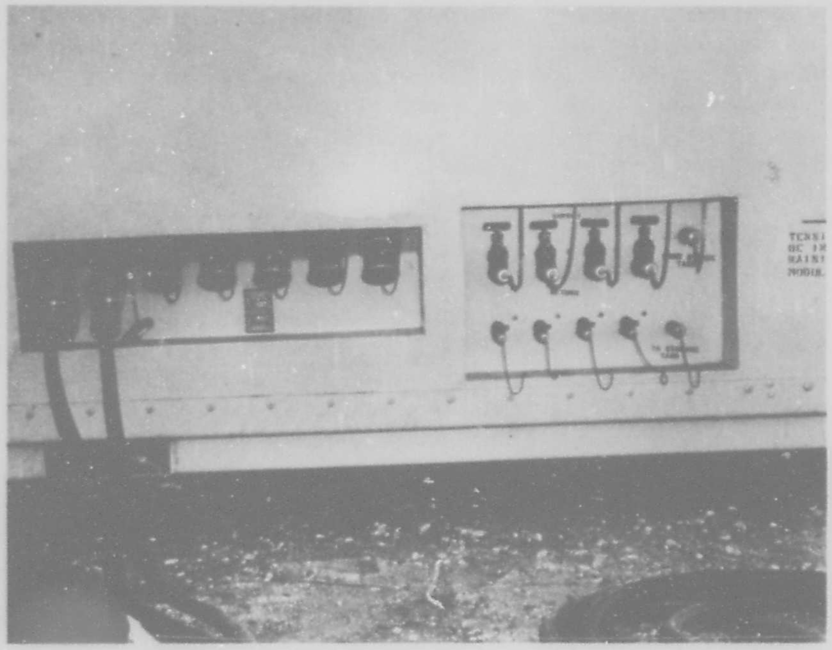


Figure 30.
Exterior detail view of camp utilities module showing electrical service connectors (left) and water service couplings (right).

In the layouts for 26, 65, 91, and 104 men (Figures 6, 10, 12, and 13), not all of the administrative/medical modules receive water service, because only four users can be served by a service module. Under ordinary circumstances, this is satisfactory, because the medical treatment stations in some modules would be active for office and berthing space only, not as sick bays. If water service to all administrative/medical modules is required, the alternate layouts (Figures 14 through 17) should be used.

Each camp utilities module is outfitted to carry a pair of diesel-engine-driven electrical generator sets of either 30 kw (Federal Stock No. 6115-880-1945) or 60 kw (Federal Stock No. 6115-880-1946) capacity with paralleling capability. Therefore, each camp utilities module will have a maximum power output of 60 kw or 120 kw, depending on the generators selected. The electrical distribution panel (Figure 26) has eight 60-ampere load centers. One of these is internally wired for service to the camp utilities module itself; the other seven are wired to cable connectors on the outside of the module (left half of Figure 30) for service to user modules.

Electrical service is provided to all modules. Anticipated power and current requirements for each type of module are listed in Table 4. The table contains values for use with heating, with air conditioning, and with no heating or air conditioning.

Each module, except the camp utilities module, has a 60-ampere cable 60 feet long, which can be connected to any of the seven connectors on any camp utilities module. User modules can be connected in series with other user modules up to the 60-ampere limit on load centers, except for the kitchen which should not be connected in series because of its high current requirement. Therefore, each module must be positioned within 60 feet of another module and each kitchen within 60 feet of a camp utilities module to receive electrical service. All recommended layouts and alternate layouts (Figures 6 through 17) satisfy the limits imposed by cable length, and also those imposed by maximum load center current for the worst case (with heating).

The number of camp utilities modules needed at a given camp might be governed by the number of generators or the number of water distribution lines required; and the total load (power requirement) will govern the number and size of generators. Meeting the 60-ampere current limit is merely a matter of distributing the load properly among load centers. Table 5 is a list of the number and size of generators recommended for normal Quick Camp facilities in mild, hot, and cold climates for various camp sizes.

The following sample calculations demonstrate how the number of camp utilities modules and the number and size of generators were determined for the normal 39-man camp in a cold climate with

Table 4. Anticipated Power and Current Requirements for Modules

Module Type	Power and Current Requirements					
	With Heating		With Air Conditioning		With No Heating or Air Conditioning	
	Power (kw)	Current (amp)	Power (kw)	Current (amp)	Power (kw)	Current (amp)
All purpose (laundry)	17	47	15	40	11	31
All purpose (other uses)	11	30	9	24	5	14
Work shop	9	25	7	18	3	8
Administrative/medical	12	33	10	27	6	17
Kitchen	22	60	20	56	16	46
Berthing	7	20	5	14	2	4
Sanitation	13	37	11	31	8	21
Camp utilities	8	24	6	17	2	7

Table 5. Number and Size of Generators Required for Normal Quick Camp Facilities in Mild, Hot, and Cold Climates

Camp Size (number of men present)	Number and Size of Generators		
	Mild Climate (without heating or air conditioning)	Hot Climate (with air conditioning)	Cold Climate (with heating)
13	2 at 30 kw	2 at 60 kw	2 at 60 kw
26	2 at 60 kw	2 at 60 kw	4 at 60 kw[a]
39	4 at 30 kw	4 at 60 kw	4 at 60 kw
52	4 at 30 kw	4 at 60 kw	4 at 60 kw
65	4 at 60 kw	4 at 60 kw	6 at 60 kw[a]
78	6 at 30 kw	6 at 60 kw	6 at 60 kw
91	6 at 60 kw	6 at 60 kw	8 at 60 kw[a]
104	6 at 60 kw	6 at 60 kw	8 at 60 kw[a]

[a] Alternate layout used.

heating, assuming that water service is required to all administrative/medical modules. This procedure applies to any size, mission, and climate:

1. Determine the number of water user modules (see Table 2).

All purpose (laundry)	1
Administrative/medical	3
Kitchen	2
Sanitation	2
Total	8

2. Compute the number of service modules (C) required to supply water.[e]

$$C = \frac{\text{8 user modules}}{\text{4 user modules per service module}} = \text{2 service modules}$$

3. Calculate the number of generators (G) that can be carried in the service modules. Since two generators can be carried in each service module,

$$G = 2C = 2(2) = 4 \text{ generators}$$

4. Determine the total electrical load (K) (see Tables 2 and 4).

All purpose (laundry)	1 at 17 kw	= 17 kw
All purpose (other uses)	2 at 11 kw	= 22 kw
Work shop	3 at 9 kw	= 27 kw
Administrative/medical	3 at 12 kw	= 36 kw
Kitchen	2 at 22 kw	= 44 kw
Berthing	6 at 7 kw	= 42 kw
Sanitation	2 at 13 kw	= 26 kw
Camp utilities	2 at 8 kw	= 16 kw
Totals	21 modules	230 kw

5. Compute the average load (K_a) on the generators to determine whether water or electrical requirements govern.

$$K_a = \frac{K}{G} = \frac{230}{4} = 57.5 \text{ kw} < 60 \text{ kw}$$

Water requirements govern.

6. If the water requirements govern, the number of service modules is satisfactory; select the generator size. If the electrical requirements govern, use 60 kw generators and compute the number of generators and service modules required.

$$\text{Use 4 at 60 kw} = 240 \text{ kw} > 230 \text{ kw}$$

7. Check the layout (see Figure 8) to make sure that water and cable lines do not exceed 60 feet and that water lines and kitchen electrical lines are not in series with those of other units.

8. Compare load center current demands (see Table 4) with the 60-ampere limit. Total values for each load center are given in the following table.

Service Module Location	Load Center[a]							
	1[b]	2	3	4	5	6	7	8
	Current Demand (amp)							
Left	24 — 24	47 — 47	25 25 50	33 20 53	25 — 25	33 20 53	20 — 20	37 — 37
Right	24 — 24	60 — 60	30 — 30	60 — 60	30 20 50	20 20 40	33 — 33	37 — 37
All values are equal to or less than 60 amp; OK.								

[a] Load centers are numbered from left to right as they appear on the layout.
[b] Load Center 1 is wired directly to the camp utilities module itself.

9. Compare the total load with the maximum power output (K_m) of each service module (see Table 4). Since 60-kw generators were chosen,

$$K_m = 60\,G = 60(2) = 120 \text{ kw}$$

Values of total load are given in the following table.

[e] See List of Symbols after References.

User Module Type	Power Demand	
	For Service Module at the Left	For Service Module at the Right
All purpose (laundry) All purpose (other uses) Work shop Administrative/medical Kitchen Berthing Sanitation Camp utilities	1 at 17 kw = 17 kw 0 at 11 kw = 0 3 at 9 kw = 27 kw 2 at 12 kw = 24 kw 0 at 22 kw = 0 3 at 7 kw = 21 kw 1 at 13 kw = 13 kw 1 at 8 kw = 8 kw	0 at 17 kw = 0 2 at 11 kw = 22 kw 0 at 9 kw = 0 1 at 12 kw = 12 kw 2 at 22 kw = 44 kw 3 at 7 kw = 21 kw 1 at 13 kw = 13 kw 1 at 8 kw = 8 kw
Totals	11 modules 110 kw	10 modules 120 kw
Both totals are equal to or less than 120 kw; OK.		

Final Design

Detail and assembly drawings, specification control drawings, a structural verification analysis, detailed cost estimates, and a draft operation manual were products of the final design phase of the contract.

The detail and assembly drawings [30] were completed during the final design phase, revised during the fabrication phase, and then resubmitted. NAR drawing numbers and short titles are:

Drawing Number	Short Title
FD-FF-001	Quick Camp System Components (cover sheet)
-002	Module Structure
-003	Kitchen Module
-004	All Purpose Module
-005	Camp Utilities Module
-006	Latrine/Shower Module (sanitation module)
-007	Administrative/Medical Module
-008	Berthing Module
-009	Shop Module
-010	Utility Assembly (entry for utilities)
-011	Frame Assembly–Air Filter
-012	Recreation Package
-013	Laundry Package
-014	Module Supports (legs and foot pads)
-015	Support Package (pallets for legs and foot pads)
-016	Jack Package (pallets for leveling jacks)
-017	Walkway Assembly (flexible passageway)
-018	Team Package

The specification control drawings [29] also were completed during the final design phase, revised during the fabrication phase, and then resubmitted. NAR drawing numbers and titles are:

Drawing Number	Title
ME62399-001	Light Fixture
-002	Support Jack
-004	Ventilation Fan
-005	Bunk Mattress
-006	Vertical Locker
-007	Footlocker
-008	Stove Vent Hood
-009	Refrigerator/Freezer
-010	Dishwasher

-011	Electric Cook Stove
-012	Hot Serving Table
-013	Serving Table
-014	Kitchen Sink
-015	Base Cabinet
-016	Base Cabinet
-017	Base Cabinet
-018	Wall Cabinet
-019	Wall Cabinet
-020	Sink Cabinet
-021	Water Heater
-022	File Cabinet
-023	Wall Desk
-024	Storage Locker
-025	Storage Cabinet
-026	Storage Shelf
-027	Bookshelf
-028	Sink/Stove/Refrigerator Unit
-029	Bunk
-030	Lavatory
-031	Commode
-032	Stall Shower
-034	Shelf Mirror
-035	Water Heater
-036	Work Bench
-037	Storage Bin
-038	Storage Cabinet
-039	Water Pressure Tank
-041	Clothes Dryer
-042	Clothes Washer
-043	Chair
-044	Table
-045	Room Heater
-046	Water Heater
-047	Table
-048	ISO Shipping Container
-049	Door Bolting System
-050	Door Bolting System

In addition to the structural verification analysis performed by the Contractor [26], NCEL performed static and dynamic analyses of the container. Loading conditions of special interest are the 12-inch drop onto concrete and support on three legs with maximum static load. An NCEL technical note on the structural analyses has been prepared [32].

Detailed cost estimates [28] are discussed in another section of this report on the subject of cost effectiveness.

Reference [27] is an interim operation manual for use during test and evaluation.

Details designed during the final design phase include:

guys and earth anchors
supports and support pallets
level indicators
forklift tineways
flexible passageway
personnel doors and door frames
ventilators and ventilator port frames
entries for utilities
ports for air conditioners
insulation and interior finish
electrical wiring
plumbing
fire extinguisher brackets
lighting and emergency lighting
floor coverings
cargo tie-down rings
equipment and furniture tie-downs
messing package
laundry package
recreation package
team package

Four aluminum supports are provided for each module. They are secured on a special pallet in the module during transit and bolted to the corner posts of the container after arrival at the camp site. A single support can be carried and bolted into place by one man. Four large lugs with hexheads are inserted through holes in the support brackets and screwed into threaded holes in the corner post. A support (Figure 31) consists of a leg and a foot pad. The leg is a tube within a tube. The length can be adjusted simply by sliding one tube over the other and inserting a pin through one set of holes, spaced one inch on center, which can be seen in the figure. The pin is permanently tethered to the support to prevent loss. The foot pad is attached to the leg with a bushing which can swivel 13 degrees in any direction. With this swivel and the 3-foot vertical travel in the legs, the support can meet the 10-degree-slope criterion under the most adverse conditions: diagonally from corner to opposite corner. The figure also shows one of the portable jacks which can be used to adjust the leg length. Four jacks are mounted on a special pallet and packed in each team package during transit. A guy wire permanently tethered to the support also can be seen in the figure wrapped around the tube, not rigged.

The forklift tineways, flexible passageway, and personnel doors can be seen in Figure 32, and the tineways can be seen in use in Figure 33. The passageway can connect the all purpose module to the kitchen module either side-to-side or end-to-side. Figure 34 shows the telescoping rods used to bridge between modules and support the floor, roof, and fabric cover of the passageway. Precise positioning of

Figure 31. Exterior detail view of module showing support attached and jack in place.

containers is not required because the passageway can be adjusted to any length between three feet and five feet and the door openings can be misaligned several inches both laterally and vertically. The fabric passes under the floor as well as over the roof, is closed by a zipper to form a closed cylinder, and then snapped to the container at each end (Figure 35).

An intake vent and filter can be seen in Figure 29, and an exhaust vent and fan can be seen in Figure 36.

The entry for utilities of the kitchen module is shown in Figure 37. In the left compartment from top to bottom are the water return coupling, water distribution coupling, and drain plug. In the right compartment from top to bottom are the stud and nut for connecting a ground wire, electrical service connector with cable connected, and a pair of convenience outlets. One of the level indicators can be seen a short distance to the left of the entry for utilities. Other modules, which can be connected electrically in series, have two electrical service connectors as can be seen in Figure 33. These connectors are different to prevent incorrect set-up.

The 60-foot, 60-ampere cables used between modules are all the same. One connector is male within a female cap and the other female within a female cap; therefore, the cable can be oriented only one direction for set-up. Connectors on the modules are male within a male and female within a male; therefore, a user only can be connected to a source. It is impossible to connect a user to a user, a source to a source, or to form a loop containing a service module. Thus, it is impossible to set-up the electrical service cables wrong, without modifying the cables or modules. Two 100-foot spare cables are to be carried in each camp utilities module to substitute for damaged cables and to make exceptions to the 60-foot spacing limit where necessary. Cables used between generators and distribution panels are different; they are 200 amperes, are larger in diameter, and are hard wired to the generators by stud-and-nut type terminals.

The over-all coefficient of heat transfer for the modules is about 0.1 Btu/hr/ft^2/^{o}F, which is well within the maximum limit of 0.25 Btu/hr/ft^2/^{o}F specified in the design criteria. Heat transfer calculations are summarized as follows:

General Equation for Coefficient of Heat Transfer (U)

$$\frac{1}{U} = \frac{1}{h_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots + \frac{x_n}{k_n} + \frac{1}{h_o} \qquad (1)$$

U = coefficient of heat transfer (Btu/hr/ft^2/^{o}F)

h_i = convective heat transfer of inner air film (Btu/hr/ft^2/^{o}F)

x = thickness of material (ft)

k = thermal conductivity of material (Btu/hr/ft/^{o}F)

n = number of materials in the cross section

h_o = convective heat transfer of outer air film (Btu/hr/ft^2/^{o}F)

Conductivity of Materials (k)

Wood . . . . 0.07 Btu/hr/ft/^{o}F
Polyurethane Foam . . . . 0.02 Btu/hr/ft/^{o}F
Fiber Glass Reinforced Plastic . . . . . . 2.35 Btu/hr/ft/^{o}F

Convective Heat Transfer to Air (h)

Inner Surface (66^{o}F) . . . . 0.40 Btu/hr/ft^2/^{o}F
Outer Surface (0^{o}F) . . . . 0.44 Btu/hr/ft^2/^{o}F

Section Through Roof, Side Walls, and Front Wall

Warm Air Film . . . . 66^{o}F
Paint . . . . neglected
Aluminum Sheet . . . . neglected

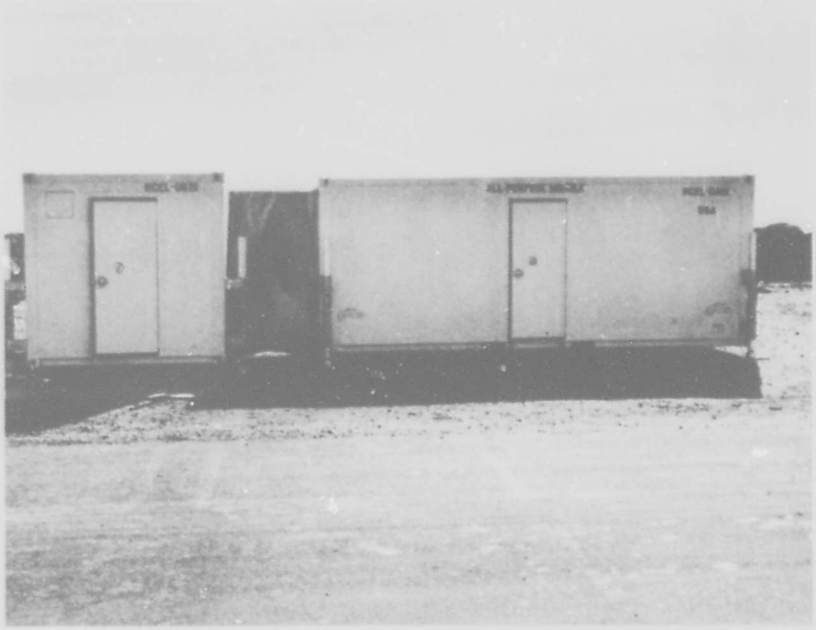


Figure 32.
Flexible passageway between kitchen module (left) and all purpose module (right).

Figure 33.
Forklift loading the all purpose module onto a flatbed semi-trailer.

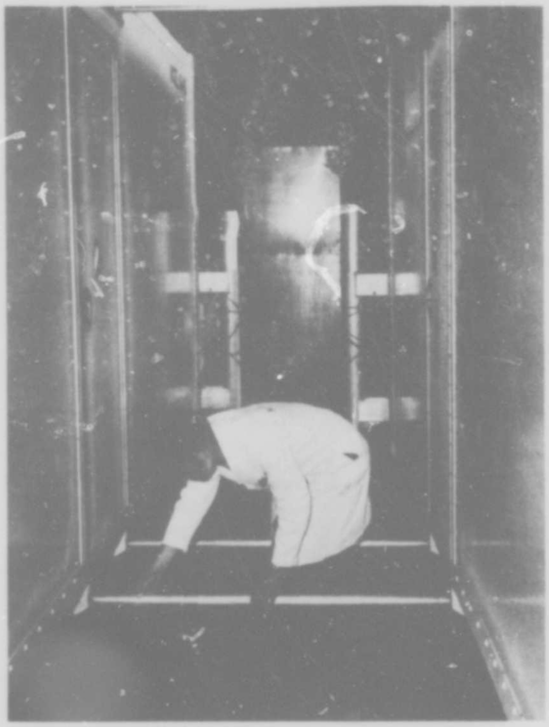


Figure 34. Telescoping supports for the flexible passageway.

Figure 35. Exterior detail view of flexible passageway showing snaps.

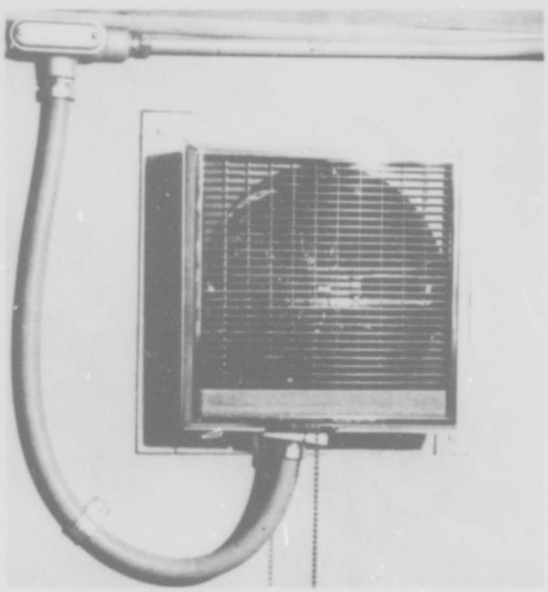


Figure 36. Interior detail view showing exhaust fan.

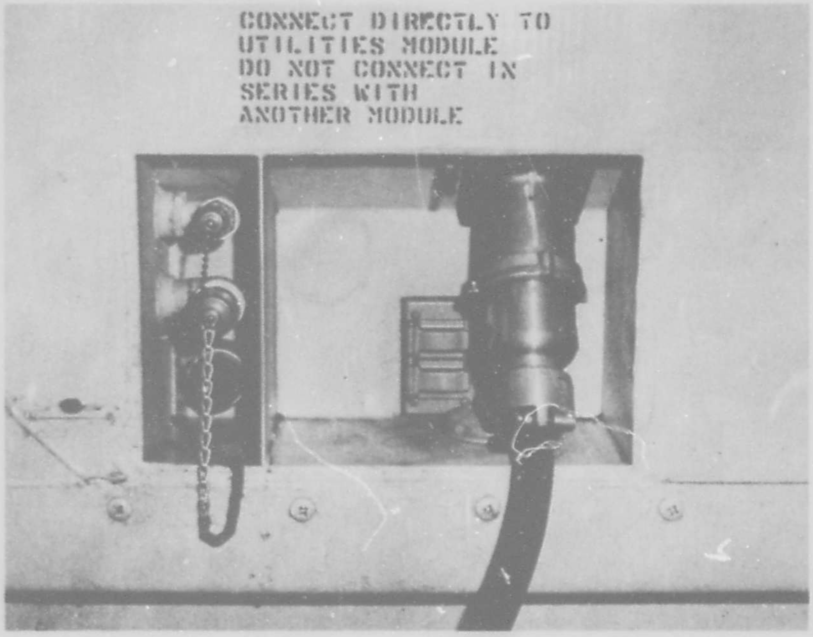


Figure 37.
Exterior detail view of kitchen module utility assembly showing water distribution, return, and drain connectors on the left and convenience outlets, grounding connector, and electrical service line on the right.

Plywood	1/4 in.
Polyurethane Foam	1 in.
Fiber Glass Reinforced Plastic	1/32 in.
Plywood	3/4 in.
Fiber Glass Reinforced Plastic	1/32 in.
Paint	neglected
Cold Air Film	$0^{\circ}F$

Section Through Rear Wall

Warm Air Film	$66^{\circ}F$
Paint	neglected
Aluminum Sheet	neglected
Plywood	1/4 in.
Polyurethane Foam	1 in.
Steel Door	neglected
Cold Air Film	$0^{\circ}F$

Section Through Floor Between Floor Beams

Warm Air Film	$66^{\circ}F$
Wooden Floor	1-1/8 in.
Undercoating	1 in.
Cold Air Film	$0^{\circ}F$

Section Through Floor at Points of Contact With Floor Beams

Warm Air Film	$66^{\circ}F$
Wooden Floor	1-1/8 in.
Steel Beam	neglected
Cold Air Film	$0^{\circ}F$

Thickness of Equivalent Roof, Side Wall, and Front Wall Section (x)

Wood . . . . x_1 = 1/4 + 3/4 = 1 in. = 1/12 ft
Polyurethane Foam . . . . . x_2 = 1 in. = 1/12 ft
Fiber Glass Reinforced Plastic . . x_3 = 1/32 + 1/32 = 1/16 in. = 1/192 ft

Thickness of Equivalent Rear Wall Section (x)

Wood . . . . x_1 = 1/4 in. = 1/48 ft
Polyurethane Foam . . . . . x_2 = 1 in. = 1/12 ft

Thickness of Equivalent Floor Section Between Floor Beams (x)

Wood . . . . x_1 = 1-1/8 in. = 9/96 ft
Polyurethane Foam . . . . . x_2 = 1 in. = 1/12 ft

Thickness of Equivalent Floor Section at Points of Contact With Floor Beams (x)

Wood . . . . x_1 = 1-1/8 in. = 9/96 ft

Coefficient of Heat Transfer for Roof, Side Walls, and Front End Wall

$$\frac{1}{U} = \frac{1}{0.40} + \frac{1}{12(0.07)} + \frac{1}{12(0.02)} + \frac{1}{192(2.35)} + \frac{1}{0.44} = 10.2$$

$$U = \frac{1}{10.2} = 0.098 \text{ Btu/hr/ft}^2/^{\circ}\text{F}$$

Coefficient of Heat Transfer for Rear Wall

$$\frac{1}{U} = \frac{1}{0.40} + \frac{1}{48(0.07)} + \frac{1}{12(0.02)} + \frac{1}{0.44} = 9.3$$

$$U = \frac{1}{9.3} = 0.11 \text{ Btu/hr/ft}^2/^{\circ}\text{F}$$

Coefficient of Heat Transfer for Floor Between Floor Beams

$$\frac{1}{U} = \frac{1}{0.40} + \frac{9}{96(0.07)} + \frac{1}{12(0.02)} + \frac{1}{0.44} = 10.3$$

$$U = \frac{1}{10.3} = 0.097 \text{ Btu/hr/ft}^2/^{\circ}\text{F}$$

Coefficient of Heat Transfer for Floor at Points of Contact With Floor Beams

$$\frac{1}{U} = \frac{1}{0.40} + \frac{9}{96(0.07)} + \frac{1}{0.44} = 6.1$$

$$U = \frac{1}{6.1} = 0.16 \text{ Btu/hr/ft}^2/^{\circ}\text{F}$$

The poorest feature in the design with respect to heat transfer is the direct contact between the wooden floor and the steel cross beams. The over-all coefficient of heat transfer for the floor of the module is between 0.16 and 0.097 Btu/hr/ft^2/$^{\circ}$F as determined by the calculations summarized above.

Modules have few openings, and all closures have seals. Therefore, heat loss through cracks is nil.

Tie-down rings are provided on the floors of all modules. Some rings are positioned to accommodate the special pallets for supports, others for special packages, and others for standard 4 x 4-foot cargo pallets.

During the preliminary and final design phases, the following changes were made to the Quick Camp System design requirements:

1. Exceptions were made to the requirement that all exterior apertures have protective coverings that can be secured from inside.
2. The requirement for protective cover plates over level indicators was deleted.
3. An exception was made by placing the electrical outlets for air conditioners on the inside instead of the outside of the modules.
4. An exception was made by allowing a dry heat serving table instead of a steam table.

Fabrication of Selected Prototype Components

One each of the camp utilities module, kitchen module, all purpose module, flexible passageway, and messing package were fabricated by North American Rockwell Corporation at the Tulsa Division plant. The box to house the recreation package was fabricated also. The basic structures are off-the-shelf containers purchased by the Contractor from the Container Division of Hussmann Refrigeration, Inc.

The main objective of the contracted work was to obtain a design of the entire system. Selected components were fabricated merely as samples of the design and as subjects for tests to determine the second-order criteria.

The Contractor was not required to perform any tests. Since preliminary studies and preliminary design were included in the contract, there was no way of knowing at the onset which tests would apply.

COST EFFECTIVENESS

Purpose and Scope of Studies

Cost effectiveness studies were performed in specific areas for making major design decisions and in general to determine the economic feasibility of the system.

This section on cost effectiveness (1) discusses important principles which should be used in comparing alternatives; (2) reports on studies which influenced design decisions; (3) provides time, benefits, and cost data for the Quick Camp System for use in cost-effectiveness studies; (4) outlines a procedure for comparing alternative relocatable shelter systems; and (5) demonstrates the principles and procedure by comparing Quick Camp modules with ABFC tents.

Principles

Dimensions. Cost-effectiveness studies are three-dimensional problems, and the three dimensions are of equal importance in selecting an alternative. The dimensions are time, benefit, and cost; and furthermore, there are usually a large number of variables in all three directions. Rules of logic and the use of mathematics are essential to solve such problems, because the mind is not able to consider a large number of variables in three dimensions without omissions and bias. Experience has shown that when people try to think through the problem without using proper procedures and record keeping, they tend to omit or deemphasize the time dimension. Even after all benefits and costs have been adjusted properly for the effects of time, the best trained minds tend to emphasize cost over benefits and, thus, distort the two-dimensional array of values. On the other hand, one should not develop a false sense of security in using numbers. The quality of the solution is no better than the judgment used to select and quantify the input.

Boundary Conditions. Valid comparisons of competing systems may be made only when all comparisons are based on a common planning horizon and all systems are within the minimum performance limitation and the maximum cost limitation. These three references provide boundary conditions for the three dimensions. The planning horizon is the reference most often forgotten or misused, as is its dimension, time. Also, the minimum performance (minimum benefit) limitation is often more difficult to establish than the maximum cost limitation.

Units. It is advantageous to convert all values of time, benefit, and cost from their various units into equivalent U.S. dollars at present worth to reduce the danger of adding "apples and oranges." In doing so, inflation, discounting, and replacement should be accounted for, since dollars last year, dollars this year, and dollars next year are not of the same value. Another method is to nondimensionalize everything.

Figures of Merit. Figures of merit are usually dimensionless numbers used to weigh the relative importance of variables. They may be used as additional coefficients in the equations of detailed studies, as simple priorities in decision making in simple studies, or they may be used in both forms in complex problems. Another alternative is to apply the figures of merit to the conversion factors, if all values are being converted into equivalent values with common units, such as U.S. dollars at present worth. The assignment of figures of merit is very important in making sure that the study is relevant to one's own mission rather than someone else's. The lesson to be learned here is that adapting someone else's solution to one's own needs should be done only with great care. Although the problems might seem similar on the surface, with similar variables, the appropriate emphasis (figures of merit) might be very different.

Consider volume, weight, durability, and set-up *time*, which are variables likely to be important to all relocatable shelters. In the case of certain Air Force shelters, the priorities appear to be (1) weight, (2) volume, (3) set-up time, and (4) durability; whereas, in the case of Quick Camp shelters, the priorities are (1) set-up time, (2) durability, (3) volume, and (4) weight. The fact that these priorities are different does not mean that one is correct and the other is wrong. If the missions, operational model, specific operational requirements, and the purse are different, there is no reason why the priorities should be the same and, thus, no reason why the engineering design should be the same. The point to be made here is that there is room for various makes and models. Before a system designed to one set of requirements is used to satisfy different requirements, it is necessary to determine whether or not sufficient similarity of requirements exists.

Influence on Design Decisions

A number of studies of limited scope have been completed. One of these was an unpublished simple two-dimensional study of volume versus cost between nonexpandable and three-to-one expandable shelters, done at ATCO Industries Ltd. Research and Development Center. Results were discussed at the Lightweight Shelter Seminar, University of Cincinnati Design Research Collaborative, 15-18 June 1971. It was found that a three-fold increase in volume by the hinged panel method of expansion is accompanied by a five-fold increase in price. Therefore, volume provided by expandable shelters is more expensive than an equal volume provided by nonexpandable shelters by a ratio of five to three. Since the price of expanded volume is high, one must have a good reason to justify the use of expandable shelters. Nonexpandable volume is less expensive mainly because less expensive materials can be used, less detailing is required, fewer tolerances are critical, less quality control is needed in production, and less expensive labor, tools, and procedures are needed in production.

A two-dimensional study of two-to-one expansion of shelters by the telescoping method was done by North American Rockwell Corporation as part of the Quick Camp contract. Results were published in Reference 21. The study included three separate schemes for grouping camping functions into modules and modules into camps of various sizes using nonexpandable modules and three schemes using expandable modules, six schemes in all. It included structural, electrical, and mechanical subsystems; a complete range of benefits classified as personnel convenience, operational efficiency, and operational reliability; and detailed cost estimates for maintenance as well as purchase. This work was updated and summarized in References 1 and 31. It was found that a two-fold increase in volume is accompanied by a slightly greater than two-fold increase in cost, and the small disadvantage of expandable shelters is due mainly to higher maintenance cost. The larger factors which led to the selection of a nonexpandable scheme were in the areas of reliability and durability. Additional expense would be necessary to advance the state of the art of lightweight expandable shelters in order to satisfy all of the Quick Camp requirements. Particular problems encountered in the past are delamination of panels, poor impact and puncture resistance, water damage to core materials, poor air tightness related to tolerances and seals for large hinged panels, and lack of simple methods of field repair.

In an unpublished study, North American Rockwell compared the cost of Quick Camp modules with TACOSS (Tactical Container Shelter System) units. TACOSS is a relocatable, containerized, and intermodally transportable shelter system for Seabees designed by NAR. It consists of a combination of expandable and nonexpandable units with aluminum skin, paper core panels. Comparisons were based on a common planning horizon and the Quick Camp use model; life cycle costs included transportation, maintenance, purchase, and replacement; and separate comparisons were made for various sizes of camps (13 to 104 men) and numbers of relocations (0 to 10). It was concluded that the system using expandable shelters would cost between three and eleven times as much as the nonexpandable system depending on usage (number of men present, number of relocations required, etc.). This study was incomplete in that benefits were not quantified to determine whether or not the higher costs of the expandable system are justified by more benefits; however, the large difference in costs suggests that TACOSS units should not be used to perform the Quick Camp mission.

The TACOSS mission includes support of Seabees for camp sizes from 13 men to a very large unspecified maximum. It appears that the practical maximum would be a Naval Mobile Construction Battalion (between 500 and 750 men). Quick Camp modules cannot compete at 500-man and 750-man camps because of awkwardness of operation due to a large number of small components and over-duplication of elements.

If a nonexpandable shelter is to be used and intermodally carried, one should use a shipping container as a shelter and not a shelter as a shipping container. The distinction exists because the transportation and handling loads govern in virtually every case, not the building type loads. Also, by converting an off-the-shelf container, additional cost savings can be realized due to high volume production of the basic structure.

The Army Mobility Equipment Research and Development Center (MERDC) [33, 34] has been studying both performance and cost of standard cargo containers for several years. Conclusions were based on statistical data on damage during 10,000 container movements [33]. "Of the several container types, FRP/plywood panel containers clearly had a lower damage rate—roughly 60% of the other types.... Life cycle cost analysis shows that FRP/plywood containers are the preferred type.... The total annual costs for containers of FRP/plywood, aluminum, and steel types are found to be, respectively: $286, $345, and $524...."

As part of the Quick Camp contract, NAR performed a cost-effectiveness study of container materials and detailing techniques, which was greatly influenced by knowledge of the MERDC work. NAR studied five-year costs, consisting of purchase, maintenance, and repair, of FRP/plywood, aluminum skin/stringer, steel skin/stringer, FRP/foam, fiber glass honeycomb, aluminum honeycomb, aluminum paper honeycomb, and aluminum foam sandwich, and found FRP/plywood to be best.

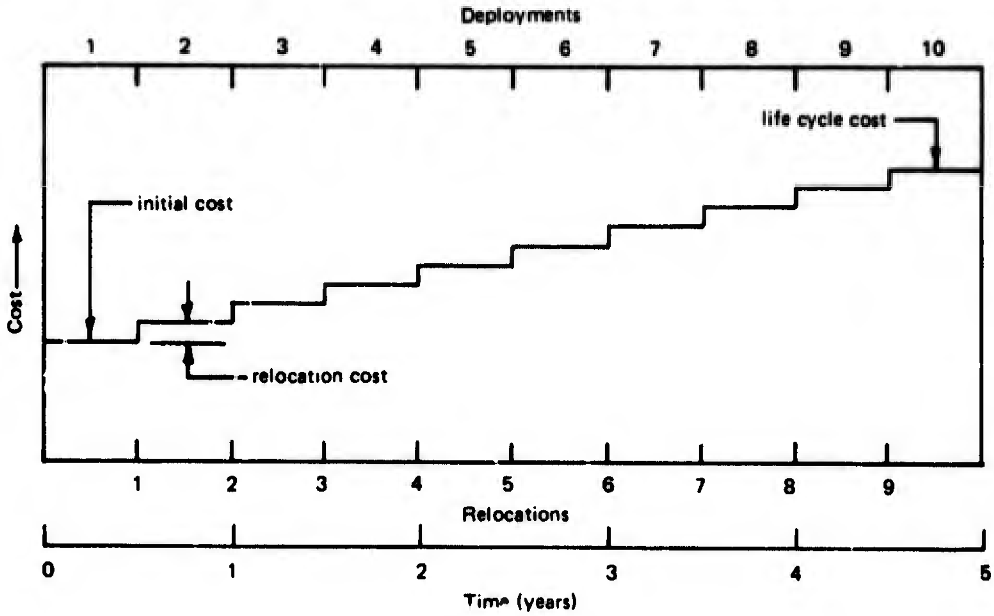
MERDC found that FRP/plywood containers perform best, and NAR found that they cost least. Therefore, it is difficult to justify using anything else, as long as expandability is not a requirement.

System Life

Major components were designed to be capable of five years of continuous service, 10 relocations, or 20 years of open storage.

The hypothetical use model used in cost-effectiveness studies is one deployment in each six-month period with a short time between deployments for refurbishing. It is the most probable use pattern of many.

A life cycle of five years was used, assuming the service life governs. Thus, the life cycle consists of 10 deployments of six months each, and the life cycle cost is the sum of one initial cost and nine periodic relocation costs as shown in the following diagram.



The life cycle model, diagrammed above, does not include 10% of the relocating capacity and all of the long term storage capacity of the system.

System Benefits

List of Specific Benefits. System benefits include:

- short set-up time
- short strike-down time
- short relocation time
- pilfer resistance
- little or no site preparation required
- little or no foundation construction required
- little or no storage facilities required
- multiplicity of function
- intermodal transportability
- helicopter transportability
- local moving capability
- ease of handling
- ease of administering
- ease of repair
- ease of cleaning
- ease of decontamination
- high degree of self containment
- high degree of independence of operation
- high degree of standardization
- high degree of interchangability of parts
- high degree of compatibility of components
- high efficiency in utilization of space (compactness)
- high weather resistance
- high durability
- high level of habitability
- few instructions required

- few tools and equipment required
- relatively long life cycle (infrequent replacement)
- relatively light weight
- flexibility of camp size
- flexibility of mission

Mobility. The most important benefits relate to mobility. They are apparent in the following statements, which are in chronological order over the deployment cycle:

1. Equipment, furniture, and supplies are prepacked and stored in the modules, ready for deployment at short notice.

2. Modules can be carried by commercial and military ships, trains, trucks, and planes and reach final destination by helicopter.

3. Structures are emplaced, not constructed or erected, and foundation construction is not required.

4. An entire camp can be emplaced and the utilities connected in one hour plus one-half hour per module, 5-1/2 hours for a normal 13-man camp and 22 hours for a normal 104-man camp.

5. Repair kits are provided to make rapid repairs to containers, if damaged in transit.

6. Structures can be moved for short distances by helicopter, crane, heavy duty forklift, and straddle carrier, and at some sites can be dragged over the ground without harm.

7. Both commercial and military trucks have been developed that can retrieve a module without the use of handling equipment.

8. An entire camp can be disconnected, packed, and lifted away in two hours plus one-half hour per module, 6-1/2 hours for a normal 13-man camp and 23 hours for a normal 104-man camp.

9. Most maintenance can be done at a central facility between deployments.

10. Modules are replenished and then either stored or redeployed.

Local Moving Capability. Local moving capability of Quick Camp modules is almost completely unique. It is easy to reposition modules at a camp site or to move the entire camp to a more favorable site a short distance away. On one occasion at NCEL, a forklift moved a module about three feet without disconnecting the utilities and with men working in the module. The work was not even interrupted. On another occasion, a module was repositioned during the tour of an important visitor. The module was taken to the visitor instead of having the visitor walk to the module; it was done just to shorten the tour. These events demonstrated a very high degree of local moving capability.

Pilfer Resistance. The second most important benefits relate to transportation and logistics, of which pilfer resistance is the dominant benefit. Data compiled by the Military Traffic Management & Terminal Service (MTMTS)[f] shows tremendous savings by pilfer resistance in the containerization of military cargos. This data alone justifies the use of a containerized system.

Multiplicity of Function. Quick Camp modules serve as habitats for Seabees in the field, as temporary storage facilities when not deployed, and as cargo containers in transit. Because of this multiplicity of function, much of the investment in the system will be returned in savings in storage and transportation. Benefits realized at the camp site are only part of the total benefit of the system.

Impact of Change on Seabee Operations. For some missions where buildings or tents are now used, a change to the use of Quick Camp modules would result in the following operational gains:

1. More camp sites will become accessible; helicopters carrying modules can provide rapid transportation into and out of many areas inaccessible by all other modes, and the modules can accommodate to unimproved sites.

2. Site preparation will be eliminated almost entirely as the modules accommodate brush, soft ground, and a 10% slope.

3. Foundation construction will be eliminated as the modules have foot pads, adjustable supports, jacks, and level indicators.

4. Erection will be eliminated entirely as modules are emplaced instead of erected.

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[f] Paper: "Military Interface With Commercial Shipping," by CAPT Jack Bishoff, SC, USN, Deputy Commander, Western Region Military Traffic Management & Terminal Service, presented at The Fourth International Shipping & Containerization Exposition & Congress, Oakland, CA, 13-15 September 1971.

5. Set-up time will be reduced from days or weeks to hours.

6. Level of habitability will be raised, increasing the productivity of personnel; negative effects of small volume will be far less than positive effects obtained by control of temperature, humidity, lighting, noise, vibration, color, and texture.

7. Ease of field maintenance will be improved through easily cleaned smooth surfaces, repair kits, and spare parts.

8. Local moving capability will become available for rapid relocation as the military tactical situation changes.

9. More relocations, more frequent relocations, and shorter stay times will be possible during the life cycles of the structures.

10. The amount of damaged, lost, stolen, and misdirected material will be reduced; monetary loss will be reduced from about 18% to about 2% of the value of the cargo every time carried.

11. Cost of transportation will be reduced and ease of transportation improved as the system provides its own shipping container.

12. The cost of storage between deployments will be reduced and the need for closed storage almost completely eliminated.

13. Response time to contingencies will be reduced as the modules can be refurbished, prepacked, replenished with consumables, and then kept ready for immediate response.

14. Compatibility with MTMTS container operations will be gained; all equipment procured to handle Army MILVANs will be able to handle Quick Camp modules.

Values of Benefits. Values of benefits were the least precise values in the studies and, thus, governed the precision of values of cost effectiveness. When the Quick Camp System was compared with other systems, nondimensional figures of merit and absolute values of benefit were not used. Dollar values of the difference between benefits of alternatives (relative values) were used, and figures of merit were implied in the estimates of dollar values. For example, the differential benefit in pilfer and damage resistance of System A relative to System B for any number of relocations can be expressed as:

$$\Delta_p = (L_B P_B - L_A P_A)(1 + N_r) \qquad (2)$$

where Δ_p = differential benefit in pilfer and damage resistance for System A relative to System B ($)

L_B = loss rate of System B (ratio)

P_B = purchase cost of System B ($)

L_A = loss rate of System A (ratio)

P_A = purchase cost of System A ($)

N_r = number of relocations

System Costs

All cost data are based on a production run of 100 units and 1971 prices. The price of a single unit would be about 30% more. Prices include containers, insulation, interior finish, doors, wiring, plumbing, and all items covered by specification control drawings. They do not include the electrical generators, water purification equipment, stave tanks, and other items listed in the TOA.

Prices of system components are listed in Table 6. Complete itemized cost estimates are in Reference 1. Purchase costs, maintenance costs, and life cycle costs of normal Quick Camp facilities are listed for various camp sizes in Table 7. Normal facilities consist of the modules and packages listed in Table 2. The life cycle cost is the sum of the purchase cost and the maintenance cost for five years, and the maintenance cost includes repair and replacement of parts as well as cleaning, painting, service, and lubrication.

The cost goal for design was $3,371 per man for the purchase cost and $337 per man per year for maintenance. Therefore, the total maintenance cost goal for five years was $1,685 per man, and the total life cycle cost goal was $5,056 per man. This would result in an average annual cost of $1,011 per man per year for the over-all system.

The cost goal was achieved for every camp size, except the smallest size, as shown by the average annual costs and ratios of cost and cost goal listed in Table 8.

Cost in dollars per square foot or dollars per cubic foot were not used in the cost-effectiveness study because those units imply that area or volume are the only merits of the systems. If they are used with benefits data, all volume or area benefits will be counted twice, and probably every figure of merit will be multiplied by a wrong number. This is probably the most common error in comparing alternative shelter systems.

Table 6. Prices of Quick Camp Components

Component	Price ($K)
Modules	
All purpose	6.4
Work shop	6.8
Administrative/medical	8.1
Kitchen	10.3
Berthing	6.9
Sanitation	9.6
Camp utilities	8.2
Special packages	
Messing	0.6
Laundry	0.8
Recreation	0.2
Team	0.2

Table 7. Costs of Normal Quick Camp Facilities

Camp Size (men)	Purchase Cost		Maintenance Cost		Life Cycle Cost	
	$K	$K/man	$K/year	$K for 5 years	$K	$K/man
13	71.5	5.5	1.7	8.6	80.1	6.2
26	100.6	3.9	2.3	11.6	112.2	4.3
39	164.7	4.2	3.9	19.4	184.1	4.7
52	178.8	3.4	4.2	20.9	199.7	3.8
65	214.9	3.3	4.9	24.6	239.5	3.7
78	271.6	3.5	6.3	31.6	303.2	3.9
91	294.1	3.2	6.8	34.0	328.1	3.6
104	322.7	3.1	8.6	43.0	365.7	3.5

Table 8. Average Annual Cost of the Quick Camp System

Camp Size (men)	Average Annual Cost ($/man)	Ratio of Cost and Cost Goal
13	1,233	1.22
26	863	0.85
39	944	0.93
52	768	0.76
65	737	0.73
78	778	0.77
91	721	0.71
104	703	0.70

Procedure for Comparing Alternative Systems

The following general procedure is recommended for evaluating cost effectiveness of relocatable shelters:

1. Determine the minimum performance limitations.
2. Evaluate the performance of each system and reject those with performance below the limits.
3. Determine the maximum cost limitation.
4. Determine the common planning horizon.
5. List the costs of the systems.
6. Adjust all costs for the planning horizon.
7. Convert all cost values into U.S. dollars at present worth.
8. Determine the total cost for each system and reject those with cost above the limit.
9. List the benefits of the systems.
10. Quantify the benefits of each system.
11. Apply figures of merit to conversion factors and convert all benefit values into U.S. dollars at present worth.
12. Determine the total benefit for each system.
13. Arrange the systems in ascending order of cost.
14. Use the standard elimination procedure of differential benefit versus differential cost to choose the cost-effective system.

The advantages of the recommended procedure are (1) elimination of unsatisfactory systems as soon as possible to reduce the number of computations, (2) adjustment of all benefits and costs for the effects of time to reduce the problem to two dimensions, and (3) application of figures of merit to conversion factors to provide a short cut, justified by the low precision of benefits input data.

The elimination procedure, listed as step 14 in the general procedure, is based on the concepts of differential benefit (Δ benefit) and differential cost (Δ cost).

A benefit/cost ratio has meaning, is useful, but has very little significance in choosing an alternative. If it is greater than unity, the single alternative is better than doing nothing; if it is less than unity, the single alternative is worse than doing nothing. The numerical value of the ratio has no other meaning and cannot be used in comparing one alternative with another, nor can it be used to rank a group of alternatives.

A Δ benefit/Δ cost ratio has greater significance. For a comparison of one alternative with one other alternative, it not only indicates which is better, it also indicates generally how much better. It can be used indirectly to rank a group of alternatives by an elimination procedure. This procedure can be demonstrated by use of the hypothetical data in the following sample decision table for five systems designated A through E.

Parameter	System				
	A	B	C	D	E
Benefit	3	4	1	7	8
Cost	1	1	2	3	7
Benefit/Cost	3.0	4.0	0.5	2.3	1.1
Δ Benefit	3	1	-3	3	1
Δ Cost	1	0	1	2	4
Δ Benefit/Δ Cost	3.0	∞	-3.0	1.5	0.25
Better?	Yes	Yes	No	Yes	No

The units of benefits and costs shown in the table are not relevant to the decision and, thus, are not designated. The systems are arranged in ascending order of cost merely to make all Δ cost values zero or positive and thus eliminate the necessity of a lengthy discussion of sign convention. A system is preferred over another system when the Δ benefit/Δ cost ratio is greater than one.

First, assume that nothing is done; both benefit and cost are zero. Second, compare A with nothing to see if A is better. The benefit/cost ratio of A is greater than unity, so A is better and should be used instead of nothing. The Δ benefit/Δ cost ratio is not needed to make the decision, but is shown in the table to confirm it.

Third, now that doing nothing has been eliminated, compare B to A to see if it is better. Since the benefit/cost ratio of B is greater than one, it is better than nothing and should be considered. The Δ benefit/Δ cost ratio is infinity; therefore, B is better than A, and A is eliminated. It is infinitely better because additional benefits are gained at no additional cost.

Fourth, compare C to B. The benefit/cost ratio of C is less than one, so C is worse than doing nothing and, thus, worse than B; therefore, B is better. The Δ benefit/Δ cost ratio is not needed to make the decision, but is shown to confirm it.

Fifth, compare D to B, since B is the best system considered so far. The Δ benefit/Δ cost ratio is greater than one, so D is better than B.

Finally, compare E to D. The Δ benefit/Δ cost ratio is less than one; therefore, E is not as good as D, and D is chosen as the best of the five systems. It should be noted that the benefit/cost ratio of D is not the largest or the smallest of the group. The fact that it is greater than one indicates that System D is better than nothing, but has nothing to do with choosing D as the best.

Equation 2 was used to show how Δ benefit in pilfer and damage resistance (Δ_p) can be quantified. That same equation can be used to show how cost effectiveness can be determined.

Suppose that System A is containerized with a loss rate of 2% per time carried, System B is breakbulk with a loss rate of 18% per time carried, and the planning horizon includes nine relocations. Under those conditions, Equation 2 reduces to

$$\begin{aligned} \Delta_p &= (0.18P_B - 0.02P_A)(1 + 9) \\ &= 1.8P_B - 0.2P_A \end{aligned} \tag{3}$$

where Δ_p = Δ benefit in pilfer and damage resistance for System A relative to System B ($)

P_A = purchase (replacement) cost of System A ($)

P_B = purchase (replacement) cost of System B

If replacement costs are the only costs involved, the Δ cost (Δ_C) is

$$\Delta_C = P_A - P_B \tag{4}$$

Next, suppose that System A costs $2,000 and System B costs $1,000. If pilfer and damage resistance is the only benefit involved,

$$\Delta \text{ benefit} = \Delta_p = \$1{,}400$$

$$\Delta \text{ cost} = \Delta_C = \$1{,}000$$

$$\text{cost effectiveness} = \Delta_p/\Delta_C = 1.4$$

This shows that the containerized system should be used instead of the breakbulk system, because the containerized system is cost effective. By changing from the breakbulk system to the containerized system, an increase in initial cost of $1,000 would result in a saving in pilferage and damage of $1,400

Breakeven analysis can be performed by setting cost effectiveness equal to one and solving for the premium that can be paid and still breakeven (have systems of equal merit). Thus,

$$\frac{\Delta_p}{\Delta_C} = 1 \quad \text{(to breakeven)} \tag{5}$$

Substituting Equations 3 and 4 into Equation 5, and solving for the cost of the containerized system (P_A) in terms of the cost of the breakbulk system (P_B),

$$P_A = 2.33P_B$$

Thus, for the supposed conditions, one can afford to pay 133% more for the containerized system and still breakeven.

Quick Camp Modules Versus ABFC Tents

Background. The Civil Engineering Support Office (CESO), Naval Construction Battalion Center, Port Hueneme[g] compared the benefits and costs of a large number of relocatable shelters, including ABFC

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[g] Naval Construction Battalion Center, Port Hueneme. Unpublished Draft Report: "Building Evaluation System of Advanced Base Functional Components," by William Hoey. Port Hueneme, CA.

buildings (Butler buildings), ABFC tents, TACOSS units, and Quick Camp modules. It was necessary to establish very low performance limits and very high cost limits, because of the broad scope of the study, which included shelters with rather diverse characteristics. The problem was reduced to two dimensions and the performance limits removed by using quantified differential benefits to penalize the costs of the lower performing systems. This method reduced the problem to the time and cost dimensions only. Also because of the broad scope, it was difficult to select a common operational use model. The model selected is a 10-year planning horizon, five deployments of one year each, and one year of storage between deployments. This model was necessary to include the less mobile systems, but penalizes the more mobile systems, such as Quick Camp and TACOSS. CESO is studying the possibility of computer coding of general equations which will permit rapid reevaluation for any planning horizon and combination of deployments and storage periods. The weakest link is poor precision in quantification of benefits, due to a lack of a human factors data base, as is the case with the studies by NCEL, NAR, and NAVFAC.[b]

One of CESO's conclusions is of particular interest; Butler buildings are not truly relocatable, because the cost of relocation, including refurbishing, is greater than the cost of initial purchase and installation.

NCEL did not compare Quick Camp with TACOSS, because of the large difference in price and in scope of mission. Since comparisons should be made to study the economic feasibility of these systems, Quick Camp modules should be compared with strongback tents and TACOSS units with relocatable buildings.

Objective of the Study. This cost-effectiveness study of Quick Camp (QC) modules versus ABFC tents was made (1) to determine the feasibility of the QC cost goal and (2) to demonstrate the procedure, discussed in the previous section, for comparing relocatable shelter systems.

Performance and Performance Limits (Steps 1 and 2). Tent camps for 25, 50, and 100 men are listed in the ABFC catalog [5] and for 13 men in the team TOA [3]. They cannot perform the QC mission; they are neither containerized nor intermodally transportable. They do not come close to satisfying the system requirements or design criteria; therefore, a valid comparison of QC modules versus ABFC tents for the QC mission cannot be made. The Quick Camp modules are the only alternative.

There are other missions, however, where modules could replace tents. It is for these missions that a valid comparison can be made. Therefore, the question was: should ABFC tents be replaced by QC modules where either system can be used?

Because of the ABFC tent performance limits, only camps for 13, 25, 50, and 100 men are considered. In applying QC data, the 104-man camp is used for 100 men, the 52-man camp for 50 men, the 26-man camp for 25 men, the 13-man camp for 13 men, and the intermediate sized camps are ignored. This results in slightly overequipped camps and lack of recognition of flexibility, thus a small penalty to the QC system. In applying tent data, the Seabee team camp component assembly is used for 13 men in lieu of ABFC tents. This causes anomalies, because the benefits of the two tenting systems are not the same, resulting in favor for tents at 13-man camps.

Maximum Cost Limit (Step 3). The maximum cost limit was arbitrarily set at an average annual cost of $2,000 per man per year.

Planning Horizon (Step 4). The five-year life cycle of modules was used as the common planning horizon. The operational use models, including nine relocations in the five years, of the two systems are almost identical. The only way the tents are different is in the fact that about 25% of the camp is replaced after each deployment instead of all at once at the end of a life cycle. Since replacement occurs on a continuing basis, any length of time, more than two years, can be used as the life cycle. Five years was chosen to correspond with the life cycle of the modules, thus simplifying the problem.

Costs (Step 5). System costs of QC modules and ABFC tents are listed in Table 9. Values are given for purchase cost, replacement and maintenance cost, set-up cost, cost of initial installation, cost of relocation, life cycle cost, and average annual cost.

The 1969 prices of ABFC tents for 25, 50, and 100 men [5] and 1970 price of a tent camp for 13 men [3] were inflated at 6% per year to a 1971 price

[b] Naval Facilities Engineering Command. "An Economic Analysis of Relocatable Structures." Washington, D. C., March 1971.

base, which is the base for QC prices. These prices are listed as purchase cost in the table. Values are higher for modules for every camp size.

Replacement and maintenance costs for ABFC tents were computed for each relocation, assuming that the portion of the camp which is not reuseable is 25%. Replacement and maintenance costs for QC modules were computed for each relocation as half the annual cost (Table 7), since the use model calls for two relocations per year. The values in Table 9 show that replacement and maintenance costs are higher for tents for every camp size.

Set-up costs are estimated on the basis of labor cost alone, assuming that labor is worth about $15.00 per man-hour. The time required to set-up a tent camp is estimated as two hours plus one and one-half hours per tent with everyone at the camp employed. Since a 25-man camp has nine tents, the total time required is 15.5 hours, the number of man-hours is 388, and the cost is $5,810. Quick Camps are set-up with everyone at the camp employed. The time required is one hour plus one-half hour per module. Since a camp for 25 men has 13 modules, the total time required is 7.5 hours, the number of man-hours is 188, and the cost is $2,810. Values in the table show that set-up costs are higher for tents for every camp size.

The cost of initial installation of camps is defined as the sum of the purchase cost and the set-up cost. Values are given in the table; they are higher for modules for every camp size.

The cost of relocation of camps is defined as the sum of the replacement and maintenance cost and the set-up cost. Strike-down and removal were not included, resulting in slight favor to tents. Values in the table show that it costs more to relocate tents for every camp size.

The life cycle cost is defined as the sum of the costs of initial installation and nine relocations. Values in the table show that life cycle costs are higher for tents for every camp size, except the smallest size. Life cycle costs for QC modules in Table 9 are greater than those in Table 7, because they include the cost of labor for set-up.

Adjustment of Costs for the Planning Horizon (Step 6). Adjustment of costs for the planning horizon is not necessary, since the life cycle of the modules, life cycle of the tents, and planning horizon are all the same, five years.

Conversion of Cost Values to Present Worth (Step 7). Discounting to adjust costs for the effects of time was not done. Adjustments over the relatively short planning horizon would be small compared to the inaccuracy in quantifying benefits; therefore, additional accuracy in cost data was unnecessary.

Total System Costs Versus Maximum Cost Limit (Step 8). Average annual costs for modules and tents are given in Table 9. The highest cost of $1,800 per man per year is for ABFC tents for a 25-man camp. This is within the maximum cost limit of $2,000 per man per year. The lowest cost of $900 per man per year is for the Seabee team camp component assembly, which is the most austere system. The over-all system costs are about $1,300 per man per year for Quick Camp modules and about $1,700 per man per year for ABFC tents, assuming that nine relocations take place. Thus, the benefits of the Quick Camp System can be obtained for less than the cost of tents.

Differential Cost. Differential cost (Δ cost) was computed for use in Step 14. It was defined as the cost of modules minus the cost of tents, and only positive values were used. Since only two alternatives were being considered, this effectively arranged the systems in ascending order of cost and simplified the sign convention. Values of Δ cost are listed in Table 10 for various camp sizes and numbers of relocations to show the influence of relocation capacity on Δ cost. The blank field in the table indicates where QC modules are cost effective with zero or any positive differential benefits, since they cost less there. Four or more relocations of a 25-man camp, five or more of a 50-man camp, or six or more of a 100-man camp will give modules a cost advantage. Thus, for all camp sizes, except the smallest size, only a part of the relocation capacity of QC modules is needed to gain a cost advantage.

Benefits (Step 9). System benefits were grouped into four categories for quantification. Greater detail was unnecessary in view of the precision of estimated input data. The categories were:

1. Transportation and Storage.
2. Reduction of Set-Up Time.
3. Pilfer and Damage Resistance.
4. Habitability.

Table 9. System Costs of QC Modules and ABFC Tents

System	Camp Size			
	13 men	25 men	50 men	100 men
	Purchase Cost ($K)			
QC Modules	72	101	179	323
ABFC Tents	13	52	65	84
	Replacement and Maintenance Cost ($K)			
QC Modules	0.9	1.2	2.1	4.3
ABFC Tents	3.2	13.0	16.2	21.0
	Set-Up Cost ($K)			
QC Modules	1.07	2.81	9.38	33.0
ABFC Tents	1.85	5.81	20.6	54.8
	Cost of Initial Installation ($K)			
QC Modules	73	104	188	356
ABFC Tents	15	58	86	139
	Cost of Relocation ($K)			
QC Modules	2.0	4.0	11.5	37.3
ABFC Tents	5.0	18.8	36.8	75.8
	Life Cycle Cost ($K)			
QC Modules	91	140	292	692
ABFC Tents	60	227	417	821
	Average Annual Cost ($K/man/year)			
QC Modules	1.4	1.1	1.2	1.4
ABFC Tents	0.9	1.8	1.7	1.6

Table 10. Δ Cost of QC Modules Versus ABFC Tents

Number of Relocations	Δ Cost ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	58	46	102	217
1	55	31	77	178
2	52	16	51	140
3	49	2	26	102
4	46	–	1	63
5	43	–	–	24
6	40	–	–	–
7	37	–	–	–
8	34	–	–	–
9	31	–	–	–

Differential Benefits (Steps 10 and 11). Only about 70% of the investment in the Quick Camp System will be returned by the system in its function as a habitat at the camp site. The other 30% will be returned by the system in its functions as a shipping container in transit and storage facility when not deployed. Thus, benefits in the amount of 30% of the purchase cost of the system are realized in ease of storage, cost savings in storage, ease of transportation, cost savings in transportation, ease of handling, and multiplicity of function. The ABFC tents return no appreciable benefits in these areas. In fact, they incur a rather large liability in the area of cost of storage. The penalty (negative benefit) for storage of the ABFC tents, with associated equipment and supplies, is roughly estimated as $300 per shelter, uniformly distributed over the planning horizon. Thus, the general equation for differential benefits in transportation and storage is:

$$\Delta_{TS} = 0.30\,P_{qc} - \left(-300\,N_t\,\frac{N_r}{9}\right)$$

which can be simplified to:

$$\Delta_{TS} = 0.30\,P_{qc} + 33.3\,N_t\,N_r \qquad (6)$$

where Δ_{TS} = Δ benefit in transportation and storage ($)

P_{qc} = purchase cost of QC modules ($)

N_t = number of shelters at tent camps

N_r = number of relocations

The number of shelters at tent camps is (1) four for 13 men, (2) nine for 25 men, (3) 17 for 50 men, and (4) 23 for 100 men.

Savings in set-up time are available to the primary mission at the camp site and, thus, can be counted as benefits. As stated before, set-up time for modules is one hour plus one-half hour per module and for tents estimated as two hours plus one and one-half hours per shelter, with everyone at the camp employed. Assuming that time made available to the primary mission is worth $15.00 per man-hour, the general equation for Δ benefit in reduction of set-up time is:

$$\Delta_T = 15.00\,N_m\,[(2 + 1.5\,N_t) - (1 + 0.5\,N_{qcm})]\,(1 + N_r)$$

which can be simplified to:

$$\Delta_T = 15\,N_m(1 + 1.5\,N_t - 0.5\,N_{qcm})(1 + N_r) \qquad (7)$$

where Δ_T = Δ benefit in reduction of set-up time ($)

N_m = number of men present

N_t = number of shelters at tent camps

N_{qcm} = number of Quick Camp modules

N_r = number of relocations

The QC modules are completely containerized with a loss rate of about 2% of the value of the cargo every time carried. The ABFC tents are transported breakbulk with a loss rate of about 18% of the value of the cargo every time carried. Therefore, the general equation for Δ benefit in pilfer and damage resistance is:

$$\Delta_P = (0.18 P_t - 0.02 P_{qc})(1 + N_r) \quad (8)$$

where Δ_P = Δ benefit in pilfer and damage resistance ($)

P_t = purchase (replacement) cost of tents ($)

P_{qc} = purchase (replacement) cost of modules ($)

N_r = number of relocations

All habitability benefits are grouped to simplify this study. These benefits are difficult to quantify with any realistic accuracy, but they certainly are realized by increased productivity of individuals. It is roughly estimated that differential benefits in habitability are at least $200 per man for each six month period of camp usage; therefore, the general equations for Δ benefit in habitability is:

$$\Delta_H = 200 N_m (1 + N_r) \quad (9)$$

where Δ_H = Δ benefit in habitability ($)

N_m = number of men present

N_r = number of relocations

Discounting to adjust benefits for the effects of time was not done. Adjustments over the relatively short planning horizon would be small compared to the inaccuracy in quantifying benefits.

Values of Δ benefit for various camp sizes and numbers of relocations are listed in Tables 11 through 14 for transportation and storage, reduction of set-up time, pilfer and damage resistance, and habitability, respectively. Equations 6 through 9 were used to calculate the data. The data show that each of the four categories of benefits makes a significant contribution to the total differential benefit. In fact, each one has a point in the spectrum of camp sizes and numbers of relocations where its value is greater than the other three. For instance, at camps relocated one, two, or three times, transportation and storage makes the largest contribution; at 50-man and 100-man camps relocated four or more times, reduction of set-up time makes the largest contribution; at 25-man camps relocated four or more times, pilfer and damage resistance makes the largest contribution; and at 13-man camps relocated eight or nine imes, habitability makes the largest contribution.

Total Differential Benefit (Step 12). The Δ benefit of the QC system with respect to the ABFC Tent system was computed as:

$$\Delta \text{ Benefit} = \Delta_{TS} + \Delta_T + \Delta_P + \Delta_H \quad (10)$$

Values are listed in Table 15 for various camp sizes and numbers of relocations.

Cost Effectiveness of Modules Versus Tents (Steps 13 and 14). The systems were effectively arranged in ascending order of cost when Δ cost was defined as cost of modules minus cost of tents and Δ benefit defined as benefit of modules minus benefit of tents.

The final step was to compute the Δ benefit/Δ cost ratio to determine which system is cost effective. Values of Δ benefit (Table 15) were divided by values of Δ cost (Table 10) to obtain values of Δ benefit/Δ cost, which are listed in Table 16 for various camp sizes and numbers of relocations. Modules are better where values are greater than one; tents are better where values are less than one. Theoretically, modules and tents are equally good where values are equal to one, but in practical application, the decision should be made in favor of the current system, since the proposed system should have an advantage to merit the cost of making a change.

Table 11. Δ Benefits in Transportation and Storage

Number of Relocations	Δ Benefit, Δ_{TS} ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	21.6	30.3	53.7	96.9
1	21.7	30.6	54.3	97.7
2	21.9	30.9	54.8	98.4
3	22.0	31.2	55.4	99.2
4	22.1	31.5	56.0	100.0
5	22.3	31.8	56.5	100.7
6	22.4	32.1	57.1	101.5
7	22.5	32.4	57.7	102.3
8	22.7	32.7	58.2	103.0
9	22.8	33.0	58.8	103.8

Table 12. Δ Benefits in Reduction of Set-Up Time

Number of Relocations	Δ Benefit, Δ_T ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	0.5	3.0	11.2	21.8
1	1.0	6.0	22.5	43.5
2	1.5	9.0	33.8	65.2
3	2.0	12.0	45.0	87.0
4	2.4	15.0	56.2	108.8
5	2.9	18.0	67.5	130.5
6	3.4	21.0	78.8	152.2
7	3.9	24.0	90.0	174.0
8	4.4	27.0	101.2	195.8
9	4.9	30.0	112.5	217.5

Table 13. Δ Benefits in Pilfer and Damage Resistance

Number of Relocations	Δ Benefit, Δ_P ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	0.9	7.3	8.1	8.7
1	1.8	14.7	16.2	17.3
2	2.7	22.0	24.4	26.0
3	3.6	29.4	32.5	34.6
4	4.5	36.7	40.6	43.3
5	5.4	44.0	48.7	52.0
6	6.3	51.4	56.8	60.6
7	7.2	58.7	65.0	69.3
8	8.1	66.1	73.1	77.9
9	9.0	73.4	81.2	86.6

Table 14. Δ Benefits in Habitability

Number of Relocations	Δ Benefit, Δ_H ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	2.6	5.0	10.0	20.0
1	5.2	10.0	20.0	40.0
2	7.8	15.0	30.0	60.0
3	10.4	20.0	40.0	80.0
4	13.0	25.0	50.0	100.0
5	15.6	30.0	60.0	120.0
6	18.2	35.0	70.0	140.0
7	20.8	40.0	80.0	160.0
8	23.4	45.0	90.0	180.0
9	26.0	50.0	100.0	200.0

Table 15. Δ Benefit of QC Modules Versus ABFC Tents

Number of Relocations	Δ Benefit ($K) for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	26	46	83	147
1	30	61	113	198
2	34	77	143	250
3	38	93	173	301
4	42	108	203	352
5	46	124	233	403
6	50	140	263	454
7	54	155	293	506
8	59	171	322	557
9	63	186	352	608

Table 16. Cost Effectiveness of QC Modules Versus ABFC Tents

Number of Relocations	Δ Benefit/Δ Cost for—			
	13-Man Camp	25-Man Camp	50-Man Camp	100-Man Camp
0	0.45	1.0	0.81	0.68
1	0.54	2.0	1.5	1.1
2	0.65	4.8	2.8	1.8
3	0.78	46	6.6	3.0
4	0.91	∞	200	5.6
5	1.1	∞	∞	17
6	1.2	∞	∞	∞
7	1.5	∞	∞	∞
8	1.7	∞	∞	∞
9	2.0	∞	∞	∞

The data show that tents are cost effective for all camp sizes where no relocations occur; however, in practical application neither modules nor tents would be used there. The ABFC buildings probably would be used at camps with five-year stay times and no relocations. Tents are cost effective for 13-man camps relocated four or less times; modules are cost effective for all the other cases covered in the table. In 15 of the 40 cases in the table, where the ratio is infinity, a change from the use of tents to the use of modules would result in both increased benefits and reduced costs.

Breakeven Analysis. Breakeven analysis was done for camps relocated nine times to determine how much the cost of the Quick Camp System can be increased during subsequent cycles of system analysis and still breakeven. Therefore, the question was: how much can be afforded for the purchase of QC modules and still be cost effective with respect to tents?

Breakeven analysis was performed by setting cost effectiveness equal to one and solving for the premium that can be paid and still breakeven. The general equation is:

$$\frac{\Delta \text{ Benefit}}{\Delta \text{ Cost}} = 1 \tag{11}$$

Equations 6 through 10 were used to find Δ Benefit as a function of P_{qc} (purchase cost of QC modules), and the following equation was used to find Δ Cost, also as a function of P_{qc}.

$$\Delta \text{ Cost} = C_{qc} - C_t \tag{12}$$

where C_{qc} = life cycle cost of QC modules ($)

C_t = life cycle cost of ABFC tents ($)

Life cycle cost of QC modules can be expressed as:

$$C_{qc} = P_{qc} + C_1 + 9C_2 \tag{13}$$

where P_{qc} = breakeven purchase cost of QC modules ($)

C_1 = set-up cost of QC modules ($)

C_2 = cost of relocation for QC modules ($)

The procedure is best shown by the following example. For the 25-man camp,

N_m = 25—number of men present

N_r = 9—number of relocations

N_t = 9—number of shelters at tent camp (from Reference 5)

N_{qcm} = 13—number of modules at Quick Camp (from Table 2)

P_t = $52,000—purchase cost of tents (from Table 9)

C_t = $227,000—life cycle cost of tents (from Table 9)

C_1 = $2,810—set-up cost of modules (from Table 9)

C_2 = $4,000—cost of relocation for QC modules (from Table 9)

From solving Equations 6 through 10,

Δ_{TS} = $0.30\,P_{qc}$ + $2,697

Δ benefit in transportation and storage

Δ_T = $30,000

Δ benefit in reduction of set-up time

Δ_P = $93,600 - $0.2\,P_{qc}$

Δ benefit in pilfer and damage resistance

Δ_H = $50,000

Δ benefit in habitability

Δ Benefit = $0.1\,P_{qc}$ + $176,297

Δ benefit of the systems

From solving Equations 13 and 12, respectively,

C_{qc} = P_{qc} + $38,810

life cycle cost of modules

Δ Cost = P_{qc} - $188,190

Δ cost of the systems

Finally, from solving Equation 11,

P_{qc} = $405,000

breakeven purchase cost of modules

Thus, the premium that can be paid is:

$$\left(\frac{P_{qc} - P_t}{P_t}\right) 100 = 678\%$$

This procedure was repeated for the other camp sizes, and the results are listed in Table 17. The data show that modules can cost several times as much as tents and still breakeven.

The amount by which the cost of QC modules can be increased during subsequent cycles of system analysis and still breakeven is given in Table 18. These data show that the purchase price could escalate about 50% and still breakeven with the tents in the Seabee team camp component assembly, and about 250% and still breakeven with the tents in the ABFC catalog.

Conclusions. The following conclusions were made:

1. ABFC tents should be replaced by QC modules for missions where modules can be used.
2. The Quick Camp cost goal is feasible.
3. Some cost escalation can occur during further development of Quick Camp modules and still have the modules remain competitive with tents.

Limitations. Unknown bias favoring the Quick Camp System exists due to the author's special interest in this system. Known bias exists due to simplification of the study, mostly concerning:

1. Selection of minimum performance limitation.
2. Selection of maximum cost limitation.

Table 17. Results of Breakeven Analysis

Camp Size (men)	Purchase Cost of Tents, P_t ($K)	Breakeven Purchase Cost of Modules, P_{qc} ($K)	Breakeven Premium for Modules (%)
13	13	107	723
25	52	405	678
50	65	710	993
100	84	1140	1260

Table 18. Allowable Increase in Purchase Cost of Modules During Subsequent Cycles of System Analysis

Camp Size (men)	Purchase Cost of Modules, P_{qc} ($K)	Breakeven Purchase Cost of Modules, P_{qc} ($K)	Allowable Increase to Breakeven (%)
13	72	107	49
25	101	405	301
50	179	710	297
100	323	1140	253

3. Estimating replacement rate of tents to obtain a common planning horizon.

4. Estimating conversion factors to convert benefits from hours or man-hours to dollars.

5. Selection of camp sizes for study.

6. Selection of benefits for quantification.

7. Estimating figures of merit for benefits.

8. Selection of sources for cost information.

9. Omission of discounting.

All known bias was slanted against the choice of Quick Camp modules in order to offset the unknown bias and the cost of changing systems. This provides a safety factor against needless change.

Individual judgment was used to convert subjective thinking into numerical, objective data. Then mathematics and logical systems engineering decision processes were applied. This was done to weigh the merits of a large number of variables at one time and to prevent error in logic. This was not done to claim high precision, which is not present. Finally, the decision making must be tempered with individual judgment.

TESTS

Structural Tests

Tests were conducted to confirm conformance to the load criteria for sea, rail, and highway transportation. The containers were fabricated by the Container Division of Hussmann Refrigeration, Inc., were tested by Miner Enterprises, Inc.,[i] and were certified by the American Bureau of Shipping (ABS) [2].

The two containers used in the tests were from the same lot as those used for the basic structure of the prototype Quick Camp modules. All tests were conducted in accordance with ABS and Australian requirements with additional forces required by the ISO [9] and the U.S. Army [11].

[i]Miner Enterprises, Inc. report on Project No. RD-182 of 18 March 1971.

The tests were conducted in the following order:

Test	Specification Authority
1. Dimensional Check Before Testing	ABS
2. Stacking	ABS/ISO
3. Lifting From the Top	ABS/ISO
4. Lifting From the Bottom	ABS/ISO
5. Concentrated Floor Strength	ABS/ISO
6. Roof Strength	ABS/ISO
7. Restraint	ABS/ISO
8. Connected Lift From the Top	Army
9. Racking	ABS/Army
10. Side Wall Strength	ABS/ISO
11. Front End Wall Strength	ABS/ISO
12. Rear End Wall Strength	ABS/ISO
13. Weathertightness	ABS/ISO
14. Roof Tightness	Australian
15. Dimensional Check After Testing	ABS

The connected lift and racking tests were specified by the Army for MILVANs, which are used as twin twenties. Twin twenties are 8 x 8 x 20-foot containers which can be connected end-to-end for handling as 8 x 8 x 40-foot containers. One of the test specimens underwent the connected lift test and dimensional checks only; the other one underwent all tests.

The prototype modules were not subjected to these tests after penetrations were made in the panels for personnel doors, intake vents, exhaust vents, entries for utilities, and openings for air conditioners. No modifications were made to steel elements, except for the addition of forklift tineways and the drilling and threading of holes in the corner posts for attaching module supports.

Environmental Tests

Objective and Scope. Tests were performed on prototypes of the kitchen module, all purpose module, and connecting passageway in the Environmental Laboratory of the Naval Missile Center to confirm conformance to weather resistance, condensation resistance, air treatment, illumination, door, and some human engineering design criteria. Electrical power was supplied to the modules by the diesel-engine-driven generators of the Quick Camp System, but the generators were operated outside the test chamber (Figure 38). The water purification and distribution subsystem was not tested. Four tests were conducted in different environments: cold environment test, snow test, hot environment test, and rain test.

Measurements. Two humidity and 15 temperature measurements were recorded continuously during all tests. One humidity measurement was taken at the point where air entered the test chamber (outside the modules) and the other on the kitchen counter near the refrigerator (inside the kitchen module). One temperature measurement was taken at the point where air entered the test chamber (outside the modules), another near the top of the left-rear support of the all purpose module (outside the module), and another near the top of the right-front support of the kitchen module. The other 12 temperature measurements were taken inside the modules. Inside each module, there were three thermocouples located one foot from the ceiling and three one foot from the floor along the centerline of the module. Of each group of three, one was located one foot from the front wall, another at the center of the container, and another near the rear. The thermocouples near the rear were positioned one foot from the wall in the all purpose module and one foot from the sink in the kitchen module.

General Procedure. The modules were elevated on their supports with a one-foot clear distance between the bottom of the container and the floor of the chamber (Figure 39). Air was circulated over, under, and around the modules during the tests. Inside surfaces of modules were checked periodically for condensation during all of the tests. During the rain test, a strong draft in the chamber imparted a horizontal component to the rain, which can be seen in the Quick Camp movie [35].

Cold Environment Test Procedure. During the cold environment test:

1. Modules were placed in the test chamber, all equipment turned off, and all doors opened.

2. Temperature in the chamber was lowered to minus $10^{\circ}F$ and modules cold soaked about 18 hours.

3. Doors of modules were closed and all equipment, except air conditioners, turned on.

4. Equipment was inspected for cold starting and materials checked for low temperature characteristics.

5. Equipment, except heaters, were turned off and modules evacuated of personnel.

6. Temperatures were monitored to check heater capacity and temperature distribution with no air circulation other than that provided by fans in heaters.

7. For the kitchen module only, after reaching the comfort zone, heaters were turned off and moved down to baseboard height and doors opened.

8. For the kitchen module only, after reaching an inside temperature of minus $10^{\circ}F$, Steps 3 through 6 were repeated to study the influence of height of the heat source.

9. After reaching the comfort zone, doors of both modules to the flexible passageway were opened and modules evacuated of personnel.

10. Temperatures were monitored to check heater capacity and temperature distribution with the passageway in use.

11. All doors were closed.

12. After reaching the comfort zone, all equipment was turned off and modules evacuated of personnel.

13. Temperatures were monitored to determine rate of heat loss, and the test was completed when the temperature reached $32^{\circ}F$ inside the modules.

Snow Test Procedure. During the snow test:

1. All equipment in the modules was turned off and cargo doors opened.

2. Temperature in the chamber was lowered to minus $30^{\circ}F$, about 18 inches of snow was created in the chamber, and modules were cold soaked in the snow about 19 hours.

3. Doors of modules were closed and all equipment, except air conditioners, turned on.

4. Equipment was inspected for cold starting and materials checked for low temperature characteristics.

5. Equipment, except heaters, was turned off and modules evacuated of personnel.

6. Temperatures were monitored to check heater capacity and temperature distribution with no air circulation other than that provided by fans in heaters.

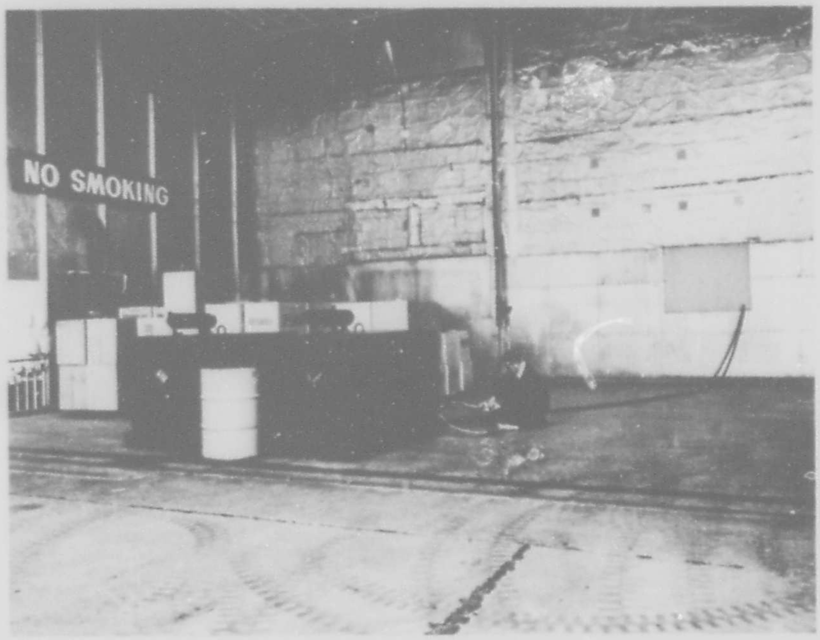

Figure 38.
Diesel-engine-driven generators supplying power outside the test chamber during environmental tests.

Figure 39.
Measuring clear height between module and chamber floor prior to environmental tests.

7. Live load of two working men was applied to the roofs for about 10 minutes each to create the loading conditions of live load plus dead load plus snow load.

8. For the all purpose module only, an electric fan was placed in a corner, directed straight upward, and turned on, and the module was evacuated of personnel.

9. For the all purpose module only, temperatures were monitored to check temperature distribution with forced air circulation in addition to that provided by fans in heaters.

10. Heater thermostats were checked at various settings.

11. Temperature in the chamber was raised to 76°F to melt the snow rapidly.

12. Modules were checked periodically for leaks as the snow on the roofs melted over a total period of more than two days, and then the test was completed.

Hot Environment Test Procedure. During the hot environment test:

1. All equipment in the modules was turned off and cargo doors opened.

2. Air conditioners were installed; all equipment was checked for proper operation and then turned off, except for luminaires which remained on.

3. Temperature and humidity in the chamber were set at 95°F and 80%.

4. Doors of modules were closed, air conditioners set on "Air In" and "Full Cool," and modules manned with one person in each module.

5. Temperatures were monitored to check cooling capacity and temperature distribution, and air conditioners were observed for cycling to obtain proper temperature control.

6. After reaching the comfort zone, doors of both modules to the flexible passageway were opened.

7. Temperatures were monitored to check cooling capacity and temperature distribution with the passageway in use.

8. All doors were closed.

9. For the kitchen module only, the stove (all burners), oven, broiler, and hood fan were turned on full and the module manned with two persons.

10. Temperatures were monitored and interior materials inspected for the effects of maximum possible heat load.

11. Stove, oven, broiler, and hood fan were turned off.

12. For the all purpose module only, the air conditioner was set on "Air Out" and temperature monitored to check the "Air Out" setting.

13. For the all purpose module only, the end personnel door was opened and closed every 30 seconds for 15 minutes to simulate men entering at mealtime, and temperatures were monitored.

14. For the all purpose module only, the end personnel door was opened for five minutes, and temperatures were monitored.

15. All power to both modules was turned off, temperatures monitored to determine rate of heat gain, and the test was completed when the temperature reached 95°F inside the modules.

Rain Test Procedure. During the rain test:

1. Temperature in the chamber was set at 70°F.

2. Air conditioners were removed and port covers installed.

3. Doors and ports were closed, and the modules were manned with two persons in the all purpose module and three persons in the kitchen module.

4. Rain was applied at a rate of four inches per hour for about 30 minutes, and leaks were traced and recorded.

5. Air vents were opened and exhaust fans started.

6. Rain was applied at a rate of two inches per hour for about 30 minutes, and leaks were traced and recorded.

7. Doors of both modules to the passageway were opened.

8. Rain was applied at a rate of two inches per hour for about 30 minutes with the passageway in use, leaks were traced and recorded, and then the test was completed.

Heaters. Wall heaters had plenty of heating capacity, and their fans were pleasantly quiet; however, they did not create satisfactory temperature distribution because discharge from the fans was horizontal and could not be directed otherwise. After cold soaking at minus 30°F for about 19 hours, the average temperature was brought up from a cold start to the comfort zone in about two hours, but at that time, the extremes were 128°F one foot from the ceiling and 22°F one foot from the floor, a difference of 106°F. This difference would be less with personnel in the modules, would be less without cold soaking, was only 10°F with the heaters lowered to baseboard level, and was zero (73°F one foot from the ceiling and floor) with additional air circulation by another fan. Thermostats functioned properly.

Cargo Doors. Cargo doors operated freely at all temperatures and did not leak during either the rain or the snow test.

Personnel Doors. Personnel doors were too tight under ideal conditions and would not close after cold soaking for 18 hours at minus 10°F. The doors were closed only after the seals were heated. The end personnel door of the kitchen leaked during the rain test, but at the point where wires to the thermocouples displaced the door seals.

Luminaires. Only two of the fluorescent tubes lighted at minus 10°F, two tubes were inoperative before the test started, and the other eight tubes lighted after the temperature inside the modules was increased.

Exhaust Vent and Fan. The pull chain for operating the exhaust vent and fan of the kitchen broke; otherwise, the exhaust vents and fans functioned properly throughout the tests, and the vents did not leak during either the rain or the snow tests.

Intake Vent. The intake vent of the all purpose module leaked badly during the rain and the snow tests. The one in the kitchen had leaked during a rain storm before the tests were started and had been sealed prior to testing.

Entry for Utilities. The entry for utilities of the all purpose module leaked badly during the rain test, but did not appear to leak during the snow test. The entry for utilities of the kitchen module did not leak at all. The water couplings were not tested. The electrical connectors functioned properly.

Kitchen Equipment. The refrigerator, stove, and the cabinet doors functioned properly. The dishwasher was not checked.

Floor Tile. Kitchen floor tile became brittle at minus 10°F, buckled near the baseboards, and lost adhesion with the wooden floor when wet. One square of tile broke (Figure 40).

Material Properties. During the cold environment test and the snow test, no brittle behavior was noticed with regard to any materials, except the kitchen floor tile. The electrical cable fittings, light switches, and circuit breakers functioned properly, and the plastic covers on the luminaires were flexible. During the maximum heat load part of the hot environment test, the aluminum panel on the wall back of the stove buckled, and the paint would rub off the panel in the sink area. About 50% of the metal finishing strips, used to cover seams between interior panels, came loose sometime during the four tests.

Condensation. No condensation problems were noticed.

Floors. Floors were cold to the touch all the time during the cold environment and the snow tests. The wooden floor of the all purpose module was permanently stained by the water that leaked in during the rain and the snow tests.

Passageway. Use of the passageway did not degrade the inside environment during the hot environment test; it lowered the temperature in the kitchen by about 10°F and did not change the temperature in the all purpose module during the cold environment test. The passageway leaked badly during the rain test.

Roof. The roof was watertight during both the rain and the snow tests.

Air Conditioners. Air conditioners and their thermostats functioned properly in the "Air In," "Air Out," and "Air Off" modes (intake, exhaust, and recirculation of air modes). Air conditioners had sufficient cooling capacity, except for the one in the kitchen during the maximum heat load part of the hot environment test.

Insulation. Insulation was excellent and door seals were tight. When the heaters were turned off, it took more than two hours for the inside temperature to drop from 73°F to 32°F with an outside temperature of minus 30°F. This was better than expected.

Electrical Tests

Electrical testing consisted mainly of inspection, and of observation of practical use during the environmental and operational tests, to confirm conformance with electrical service and safety design criteria. Evaluation was primarily a critique of specifications, drawings, and subsystem design, not an evaluation of performance during tests.[j]

Inspection revealed several discrepancies between the prototypes and the drawings with regard to number of circuit breakers in user modules and their wiring arrangement in user module distribution panels. Some of this wiring was not in accordance with the applicable electrical code.

The eight main circuit breakers in the distribution panel of the camp utilities module are not coordinated with the main circuit breakers in the modules. On one occasion, this caused the circuit breaker in the service module to open instead of the one in the user module near the fault.

The heating elements of the wall heaters were wired to one circuit breaker; whereas, the fans were wired to a different circuit breaker, and the handles of the circuit breakers were not connected. Thus, if one turns off the circuit breaker to the fans, the fans will stop, and one is wrongly led to believe that the entire unit is deenergized. This constitutes an electrical shock hazard.

Generators, cables, switches, and other electrical equipment were trouble free.

A computer simulation of power system short circuits showed no problems with the current interrupting capacities of installed circuit breakers. In the simulation, various camp layouts were used, and only a 0.5 kw maximum difference in generator loading resulted.

Operational Tests

Objective and Scope. All prototype components were exercised by Seabee teams of the THIRTY-FIRST Naval Construction Regiment at Vandenberg Air Force Base (Figure 5) during a road construction project. The exercise included truck transportation, forklift handling, emplacement, leveling, complete set-up, habitability, and dismantling (strike-down).

Observations. Technical observers from NCEL and the Naval Electronics Laboratory Center (NELC) visited the exercise on the first and last day to observe, photograph, and time operations. The commander of the regiment visited on another day. Both verbal and written[k] comments were received from the Seabees after the exercise.

Site Conditions. The site was sandy and had a slope of about 7%. On the day of arrival, the sand was wet and partly covered with short grass. Only tracked and four-wheel-drive vehicles could negotiate the site; therefore, the forklift was towed by a bulldozer, as can be seen in Figure 41. The mud ruts in the figure show the severe conditions under which the test was conducted. The all purpose module was connected end-to-side with the kitchen module, with the long axis of the all purpose module directed down the slope (Figure 5) to test leveling capability. On the day of departure, the sand was dry and nearly devoid of grass.

Set-Up and Strike-Down Times. The estimated set-up time was 2.5 hours with 13 men working (32.5 man-hours). The actual time was 3.0 hours with only seven men working (21.0 man-hours). Thus, it took only two-thirds the anticipated effort, under hardship site conditions and with only two of the men having any prior experience with the modules.

The estimated strike-down time was 3.5 hours with 13 men working (45.5 man-hours). The actual time was about two hours with about 10 men working (approximately 20 man-hours). Thus, it took less than half the anticipated effort for strike-down.

At the same camp, men erected two strongback tents for sleeping quarters. The estimated time was four hours with 13 men working (52 man-hours). The actual time was seven hours with about 10 men working (70 man-hours), more than estimated. Strike-down was not timed. It was very rapid, but only the fabric was saved. The wood and nails were discarded.

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[j] Naval Civil Engineering Laboratory. Mechanical and Electrical Engineering Department. "Evaluation of Electrical Power System for Quick Camp Modular Forward Area Camp," by K. W. Lucci. Port Hueneme, CA, May 1972.

[k] Commander, THIRTY-FIRST Naval Construction Regiment letter R20:aw 1580 Ser 545 of 17 March 1972. Evaluation of the Quick Camp Modules.

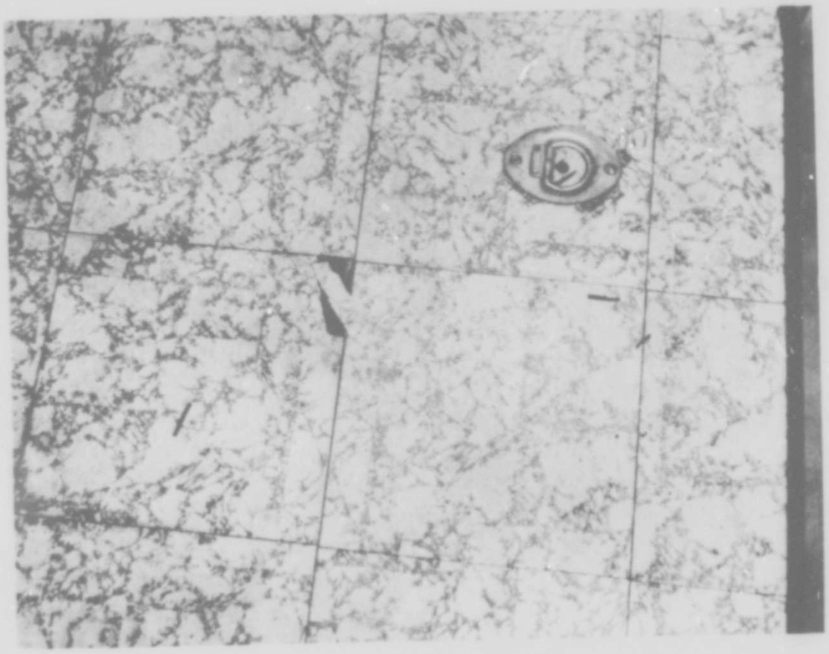

Figure 40.
Broken floor tile in the kitchen during the cold environmental tests.

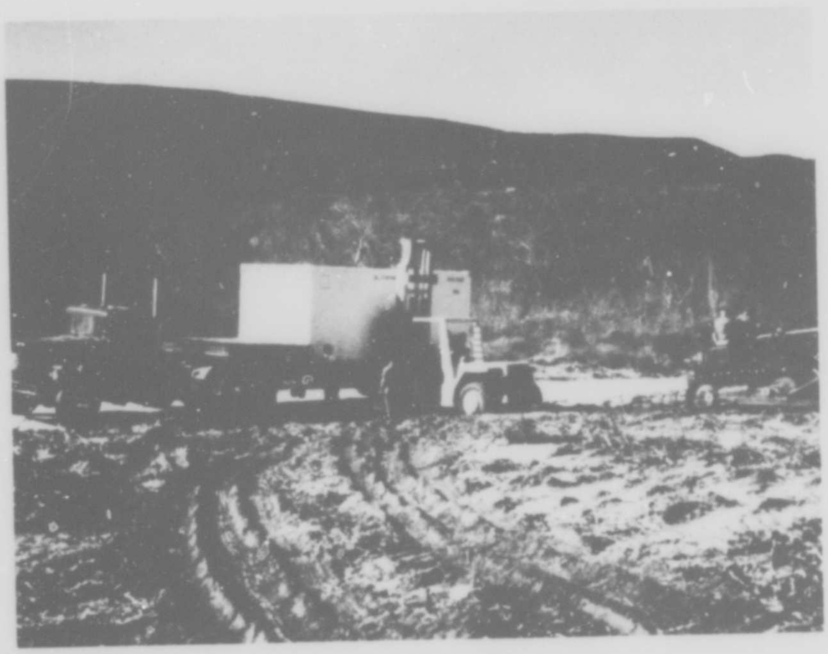

Figure 41.
Forklift handling a Quick Camp module during field tests by Seabees at Vandenberg Air Force Base.

Habitability. The Seabees preferred Quick Camp modules over strongback tents, despite their smaller size, due to greater habitability. Specifically, the modules provided better noise and weather insulation, better heating, better furnishings, and better light. Several team members had strong feelings about the lack of windows. It was felt that windows are needed in the dining, recreation, and berthing spaces where men would spend long periods of idle time.

Doors. The tolerance between personnel doors and doorjambs was too small, outside door handles of personnel doors were difficult to operate, and the finishing materials on panels applied to the inside of the cargo doors became loose at a few places.

Jacks. The manual method of jacking the modules was unsatisfactory. The jacks had insufficient capacity, simultaneous jacking was required, jacks did not have safety brakes, and the jacks loaded the footpads eccentrically, causing the moving parts of the supports to bind.

Supports. The supports were trouble free when lifting equipment (front end loader or forklift) were used to level the modules. However, supports were unsatisfactory when jacks were used. Footpads provided adequate bearing surface.

Entry for Utilities. The drain plug in the left compartment of the entry for utilities (Figure 37) was recessed too far for easy access.

Hot Water Heater. The heating element in the kitchen hot water heater shorted, causing a gasket to fail and, in turn, flooding in the kitchen module. This was the incident when the circuit breaker in the camp utilities module actuated instead of the one in the kitchen.

Electrical Subsystem. The electrical subsystem was trouble free, except for the lack of timing between the user module and service module circuit breakers.

Water Purification and Distribution Subsystem. Hoses and connectors were not included with the 3,000-gallon stave tanks; therefore, the tanks were not used. There was no bypass for the kitchen hot water heater; therefore, it was necessary to secure the water supply to the kitchen while the water heater was being repaired.

Lighting. Lumination was good and equipment trouble free. Rechargers for emergency lanterns were noisy.

Kitchen Equipment. The refrigerator, stove, and hood all had marginal or insufficient capacity. On the other hand, there was more cabinet space than needed.

Ventilation. Vents and fans had ample capacity.

EVALUATION

Bonuses

The cost goal of the Quick Camp System is feasible. In addition, Quick Camp modules are highly cost effective with respect to ABFC tents. The cost can be allowed to escalate a considerable amount to improve performance and still remain cost effective with respect to the tents. Average annual costs for various camp sizes (Table 9) show equal cost per man at the smallest and largest camps and minimum cost per man at 26-man camps, which is considered to be ideal.

A favorable relationship between volume needed to transport cargo and volume needed for habitation resulted in modules of suitable size and weight for helicopter transportability and resulted in cargo densities light enough to allow use of less expensive, heavier, and more durable materials than those in other relocatable and containerized systems.

Set-up and strike-down times achieved are far better than those believed possible at the onset, and set-up times are much better than for strongback tests. Set-up and strike-down times in the system requirements can be achieved with only half the manning level of the camp and with little, or no, orientation for personnel.

Local moving capability achieved far exceeds that anticipated, due to complete elimination of site preparation, foundation construction, and floor construction, and also due to ease of handling by ordinary construction equipment, such as a front end loader.

Set-up and operation of the system are simpler than anticipated. A two-week orientation period for Seabees is not required. How to determine the number and size of generators and how to distribute the electrical load are the only instructions required.

The container used as the basic structure is mass produced, inexpensive, and very durable. Cargo doors are trouble free in both hot and cold environments. During the operational tests, modules were dragged over the ground by a bulldozer without harm [34]. With an inch of polyurethane insulation added, a heat transfer coefficient of about 0.1 Btu/hr/ft^2/^{o}F was achieved, much better than the specified 0.25 Btu/hr/ft^2/^{o}F. Although operation at minus 10^{o}F was the original objective, tests showed that the system can be operated successfully at minus 30^{o}F.

Lighting level and distribution are exceptionally good.

Deficiencies

There are other areas where performance fell short of expectations and improvements are likely to be costly. The worst deficiencies concern leveling jacks, weathertightness, temperature distribution, personnel doors, and kitchen equipment. None of these involve the basic scheme or the basic structure. The necessary improvements can be made with present technology, but require time for redesign, and they will cause increases in the prices of system components.

Specific deficiencies are covered in this report in the section on tests, and proposed improvements are covered in the following section on recommended modifications.

RECOMMENDED MODIFICATIONS

First-Order Modifications

First-order modifications are either necessary for safety, necessary for trouble-free operation, or very inexpensive; therefore, they should be given the highest priority. The following first-order modifications are recommended:

1. Redesign guys and anchors. Change the points of attachment of guys from the supports to the upper corner castings of the containers, select or design earth anchors better than the screw type now used, and add both power and manual drivers if driven type anchors are chosen.

2. Redesign supports to permit loading on flatbed trucks without handling equipment and to eliminate unsafe conditions when jacking modules. Increase the horizontal clear distance between footpads so a flatbed can be backed under or driven out from under the elevated modules. Redesign bracket flanges to improve accessibility to stud heads for turning by a wrench. Select jacks better than the bumper jacks now used, and design attachment points for the jacks if necessary.

3. Redesign personnel doors and doorjambs to achieve trouble-free operation. Add door holds at 90 and 180 degrees. Change door seals to obtain a looser fit so that doors will open and close easily, sacrificing some seal tightness if necessary. Change locks and latches using a more reliable product, and change door handles to larger ones with more leverage.

4. Redesign the flexible passageway to improve weathertightness and ease of set-up. Add a roof panel under the fabric, add a gasket between the fabric and the snaps, and replace the metal zipper by a lacing or a large nonmetallic zipper.

5. Add valves to the plumbing in the kitchen to isolate the water heater, dishwasher, and faucets.

6. Revise details to improve weathertightness. Change details of the intake ventilator port and the utility assembly to prevent leaking.

7. Reselect kitchen equipment and redesign built-ins. Change the stove to an industrial type with grill and two large burners, and change the ventless hood to a hood vented to the outside. Change the refrigerator-freezer to a large refrigerator and add a cabinet type freezer.

8. Redesign circuit breaker wiring diagrams to remove electrical shock hazard. Draw a detailed wiring diagram for the circuit breaker box in each module. Design the wiring arrangement in such a way that a single switch will deenergize both the heating element and the fan in the heaters.

9. Change the heating equipment to improve temperature distribution either by selecting a different heater with louvers to direct the air flow or by adding a fan. Another alternative would be to redesign the ventilation system to achieve better air circulation.

10. Replace the cable entry ports of the camp utilities module with cable connectors.

11. Add an exhaust port to the camp utilities module for use when generators are operated inside.

Second-Order Modifications

Second-order modifications would improve habitability or ease of operation and are of moderate cost; therefore, they should be included if time and funds are available. The following second-order modifications are recommended:

1. Design windows and screens and select an air conditioner to improve habitability. Specify a 2-ton air conditioner as optional equipment, redesign the cover for the air conditioner port, and design a frame for around the port. Design optional window and screen panels for the air conditioner port to provide the option of using the port (1) with the cover panel, (2) with an air conditioner, (3) with a window, or (4) with a screen. Design a screen panel for use inside the cargo doors of the kitchen, all purpose, and berthing modules.

2. Delete the serving table. Select a smaller serving table and mount it on the floor along the wall of the kitchen under the heater and beside the storage space for chairs.

3. Delete the floor covering in the kitchen and sanitation modules. Select a continuous wall-to-wall floor covering of water resistant fiber.

4. Provide positive catches or locks on drawers and cabinet doors in the kitchen to prevent opening during shipment of modules.

5. Provide a splash guard at least 10 inches high behind the sink.

6. Change cargo tie-down plans for modules, if necessary, to position module supports near a personnel door during shipment for easy access upon arrival at destination.

7. Add night lights to the berthing module and the administrative/medical module.

8. Select interior paint colors for all surfaces, including electrical conduit.

9. Add a light switch to the kitchen module in order to provide a switch at both entrances.

10. Delete the paralleling switch from the camp utilities module.

11. Design for the coordination of the eight main distribution circuit breakers of the camp utilities module with the modular mains.

12. Improve tineway design.

13. Improve center-of-gravity of the camp utilities module.

14. Provide more space in the kitchen for storing trash.

15. Code the tie-down anchors and straps for rapid packing.

16. Specify screws instead of nails at certain places for attaching finishing materials to the inside panels of the cargo doors.

17. Provide a counter surface near the stove which will resist hot items.

18. Design a waste water subsystem in the kitchen, all purpose, and administrative/medical modules.

19. Select better locking pins for the module supports.

Third-Order Modifications

Third-order modifications require further study because of either questionable merit or high price; therefore, they should be given lowest priority. The following studies are recommended for possible third-order modifications:

1. Stainless steel or wooden cabinets for the kitchen.
2. Screen doors for personnel doors.
3. Panic bar type door handles for the inside of personnel doors.
4. Rheostats for lighting equipment in the all purpose, berthing, and administrative/medical modules.
5. Grounding by a conductor in the electrical distribution cable.
6. Cover plates for leveling bubbles.
7. Step pockets for climbing to the roofs.
8. Vestibule for the kitchen and all purpose modules.
9. Relocation of the circuit breaker box in the kitchen module to a higher position.

A study was made of the feasibility of using Romex cable for internal branch wiring instead of ordinary wire and conduit. It had been suggested that Romex is better because it is less expensive. Local 1972 prices were used in the study.

The number of circuits protected by the conduit varies between one and five. Romex cables would be used for each circuit. Therefore, at any given location, one to five Romex cable lines would be required to replace a single conduit with wires.

Cost data shown below is for a specific case in the kitchen module on the wall over the counter where the conduit contains three circuits, believed to be a typical case.

Conduit and Wire

7—#10 wires at $33.60/1,000 ft	$0.235/ft
3/4-inch E.M.T. (tube) at $10.51/100 ft . .	$0.105/ft
Total	$0.340/ft

Romex Cable

2—#10 wires and ground is $116.55/1,000 ft	
3 cables (circuits) at $0.11655/ft	$0.350/ft

Thus, the conduit and wire is less expensive for three or more parallel circuits, and the total costs, relative to the entire system, are virtually the same.

Use of conduit provides better protection, requires fewer clips for attachment, makes the lines more compact, looks better, and can be painted easily. In congested areas, such as in the kitchen near the circuit breaker box, the use of Romex cable would virtually cover the wall with wires. Therefore, for human factors reasons, Romex cable is not recommended as a third-order modification.

Revision of Drawings and Specifications

Table 1 shows the status of Quick Camp System development as of 30 June 1972 when the sponsor, Naval Facilities Engineering Command, decided to abandon Quick Camp development, because of a lack of a requirement for such a system.[1] The first cycle of system analysis was completed, except for rail transportation impact tests and flat and rotational drop tests to confirm conformance to the dynamic load design criteria. The second cycle, necessary to correct system deficiencies, complete system design, and refine system design, was not started. Important design tasks intended for the second cycle included:

1. Recreation package.
2. Team package.
3. Selection and mounting of second-order equipment.
4. Human factors evaluation and resulting design changes.
5. Packaging design for items in Table 3.
6. Center-of-gravity study and cargo tie-down plan.

Thus, the system reached the maturing development stage, but was not completed.

It was stated[1] that "if future requirements develop, the information gained in the original Quick Camp prototypes is sufficient for the rapid preparation of a procurement specification." However, the Quick Camp Drawings and specifications were revised to incorporate most of the recommended first-order and second-order modifications. This was done to make use of all information which was available on 30 June 1972. Thus, drawings and specifications of the procurement of Quick Camp modules at that stage of development are available at the Naval Civil Engineering Laboratory.

[1] Naval Facilities Engineering Command, Memorandum 062/ASP:jd of 30 June 1972: Quick Camp.

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LTJG James P. Bremkamp, USNR, Officer-in-Charge, Seabee Team Training, THIRTY-FIRST Naval Construction Regiment, provided background information on Seabee teams during the concept formulation stage, provided consulting service during the preliminary studies, and proposed and executed the field test using Seabees. He assumed this work and responsibility in addition to his regularly assigned duties; and in doing so, he provided a valuable link between research, training, and operations.

Seabees of the THIRTY-FIRST Naval Construction Regiment not only performed the field test, they also acted in the Quick Camp movie [35].

Dr. Lyle E. Hufford, engineering psychologist, of the Naval Electronics Laboratory Center assisted with observation and evaluation of human factors of all the tests.

Mr. Kenneth Tinklepaugh, task engineer, of the Naval Missile Center provided the necessary coordination for successful conduct of the environmental tests. Special effort was applied in making a large quantity of snow.

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LIST OF SYMBOLS

C	Number of service modules
C_1	Set-up cost of Quick Camp modules ($)
C_2	Cost of relocation for Quick Camp modules ($)
C_{qc}	Life cycle cost of Quick Camp modules ($)
C_t	Life cycle cost of ABFC tents ($)
G	Number of generators
h	Convective heat transfer (Btu/hr/ft^2/^{o}F)
h_i	Convective heat transfer in inner air film (Btu/hr/ft^2/^{o}F)
h_o	Convective heat transfer of outer air film (Btu/hr/ft^2/^{o}F)
K	Electrical load (kw)
K_a	Average electrical load (kw)
k	Thermal conductivity of material (Btu/hr/ft/^{o}F)
L_A	Loss rate of System A (ratio)
L_B	Loss rate of System B (ratio)
N_m	Number of men present
N_{qcm}	Number of Quick Camp modules
N_r	Number of relocations
N_t	Number of shelters at tent camps
n	Number of materials in the cross section
P_A	Purchase cost of System A ($)
P_B	Purchase cost of System B ($)
P_{qc}	Purchase cost of Quick Camp modules ($)
P_t	Purchase cost of tents ($)
U	Coefficient of heat transfer (Btu/hr/ft^2/^{o}F)
x	Thickness of material (ft)
Δ	Differential
Δ_C	Differential cost ($)
Δ_H	Differential benefit in habitability ($)
Δ_P	Differential benefit in pilfer and damage resistance ($)
Δ_r	Differential benefit in pilfer and damage resistance for System A relative to System B ($)
Δ_T	Differential benefit in reduction of set-up time ($)
Δ_{TS}	Differential benefit in transportation and storage ($)