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Army Land Warfare Lab ltr dtd 24 Sep 1973

TECHNICAL REPORT NO. 73-07

PORTABLE BATTALION TACTICAL OPERATIONS CENTER (BTOC)

Testbed Design, Fabrication, and Design Engineer Test

TASK 04-M-70

FINAL REPORT

By

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U. S. ARMY LAND WARFARE LABORATORY

Aberdeen Proving Ground, Maryland 21005

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ABSTRACT

This report describes a portable modular enclosure which was devised for use as a battalion tactical operations center (BTOC). In a rapidly changing situation, a single module would function as the portable BTOC. In a more stable situation a grouping of four BTOC modules could be used to form a more permanent battalion headquarters. The single BTOC module is approximately 14 feet long by 7 feet wide by 7 feet high. It weighs approximately 4,000 pounds. Testbed BTOC modules were fabricated by the US Army Land Warfare Laboratory (LWL), and were tested by LWL and by the US Army Test and Evaluation Command (TECOM). The test results indicate that the testbed modules are capable, when appropriately sandbagged, of withstanding direct hits by rocket and mortar fire. They are easily transportable by CH-47 helicopters and by 2 1/2-ton trucks, and are considered to be of practical configuration for use as the battalion's TOC enclosure.

FOREWORD

Toward the end of the Vietnam conflict the US Army, Vietnam (USARV) requested that LWL develop a portable modular enclosure which would be suitable for use as a tactical operations center in a rapidly changing situation, which could be sandbagged sufficiently to withstand enemy mortar and rocket fire, and which could be used in a group of approximately 4 modules to form the battalion's larger command post facility (the BTOC).

In essence, the need was for a portable and bunkerable house from which the battalion commander can safely direct and control his combat operation. The first order of business was to try and get answers to some architect-oriented questions; i.e. how big, what shape, how much interior furnishings, and how transportable do most field commanders believe the BTOC should be. Answers to those questions were as varied as the experiences and personal differences of the field commanders who were questioned. A small segment of the potential users expressed a preference to operate from their "hip pocket". On the other extreme, a small minority felt that the battalion TOC should be no less than a completely secure fortress.

The Army supply system does not include a TOC unit of equipment. The current situation, therefore, requires that each field commander build and/or improvise his own command post facilities. Manpower and resources for building the TOC are almost always scarce. Generally speaking, no two TOC facilities are the same, principally because the field commanders seldom fall heir to the same field resources, and seldom encounter the same field conditions of enemy resistance and operational circumstances. Within this widely divergent frame of reference, a set of Design Characteristics had to be "hammered out". The objective was to develop a set of Design Characteristics which would satisfy the requirements and expectations of the greatest majority of potential troop users.

A considerable effort was made to get opinions of potential troop users. Informal comments were received from several field commanders and ex-commanders at Fort Bragg and Fort Benning. Additionally, questionnaire-type responses of opinion were obtained by direct field contact with several troop units in Vietnam. Such questionnaire responses were received from the following units in Vietnam during the March-July 1971 time frame:

CDR, 1st Bn. 61st Inf. (M)
CDR, HHC, 1st Bde, 5th Inf. Div. (M)
CDR, HHC, 3rd Bn, 1st Inf.
CDR, HHC, 1st Bn, 20th Inf.
CDR, HHB, 1st Bn, 14th Artillery
CDR, HHB, 23rd Inf. Div. Artillery
CDR, 1st Bn, 6th Inf.
CDR, 1st Bn, 52nd Inf.
CDR, HHC 101st ABN (AMBL)
CDR, HHB, 24th Corps Artillery
CDR, 4th Bn, 503rd Inf.
CDR, HHC, 1st Bn, 11th Inf.
Chief, Test Eval. Div., ACTIV

By properly weighing and assessing all the comments and troop user's opinions, a characteristic description of a universally adaptable TOC enclosure (the field commander's operations house) was made. It is believed that a TOC module which incorporates most of these characteristics will be acceptable to most field commanders - whether they be infantry, artillery, airborne, or whatever; though for some of them it will be a matter of accepting the "least undesirable" trade-off against the time and resources required to build their own command post facility.

By the time that the portable BTOC module concept was being engineer-design tested at Aberdeen Proving Ground, the US involvement in Vietnam was being closed out. Detail design and fabrication of prototype BTOC modules were, therefore, postponed indefinitely. This report, which documents the portable BTOC concept development, will be of value to the Army when and if it is determined that the Army's field commanders do need a portable TOC which can provide command protection from mortar and rocket fire.

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INTRODUCTION

When faced with the battlefield threat of mortar and rocket fire, the Army combat troops need a portable modular enclosure for use as the housing of a bunkered battalion tactical operations center (BTOC). It is necessary that the portable module be designed with a structural configuration which, when appropriately sandbagged, can provide protection against point detonating mortar and rocket fire. The single module would serve as the portable BTOC in a rapidly changing situation. In a more stable situation, a group of four (4) modules would be used to form the battalion headquarters facility.

The purpose of this program was to develop the concept of a portable BTOC modular structure which could be sandbagged for protection against mortar and rocket fire, and which could be further refined into a TOC enclosure suitable for most of the Army's TOC structure requirements. The basic consideration throughout the development was structural adequacy to withstand the weight of the sandbags and the forces resulting from direct hits by rocket and mortar firings. (It should be noted that commercially available office trailers could be procured for use as portable BTOC structures; but they cannot withstand the sandbag loading and rocket blasts.)

LWL conducted a study to establish appropriate characteristics for a BTOC which would satisfy the requirements of most field commanders, conducted preliminary design of a BTOC module which incorporates those characteristics and fabricated and tested two testbed modules. Though the Design Characteristics which evolved were formulated by LWL, they are based heavily upon the opinions and comments of potential user troops at Fort Bragg, Fort Benning, and in Vietnam.

The testbed modules were tested for LWL by the Material Test Directorate, USATECOM. A detailed formal report of the test, including structural endurance tests and transportability tests, is presented in Appendix A (USATECOM Report No. APG-MT-3881, "Engineer Design Test of Portable Battalion Tactical Operations Center").

The overall plan of this report is to begin by stating the Design Characteristics which were developed for the BTOC, and then to follow with a discussion of the testbed module design, fabrication, and test.

SECTION NO. 1

DESIGN CHARACTERISTICS FOR A PORTABLE BATTALION TACTICAL OPERATIONS CENTER (BTOC)

1. OPERATIONAL CHARACTERISTICS:

a. The using unit will receive the portable BTOC in fully assembled mode, less the battalion TO&E equipment such as radios, telephones, antennas, power units and lighting sets. The using unit will at battalion level, install the battalion's TO&E equipment.

b. The BTOC module will be transported by 2 1/2-ton or CH-47 helicopter, and will be emplaced by troop labor.

c. The using unit will either sandbag the module or emplace it with the aid of a bulldozer.

d. After the structure is emplaced, 5 to 7 personnel will operate inside using mapboards, telephones, and the numerous radios to control the battalion's assets.

e. The single BTOC module will function as the portable BTOC in a rapidly changing situation. In more stable situations, a grouping of approximately four BTOC modules will be used to provide the battalion headquarters.

f. Each BTOC module will have the capability of functioning alone or being connected (mechanical linking system not required) to any number of other modules to form larger command posts.

g. The BTOC module structure will be capable of supporting enough sandbags to provide protection without damage from small arms fire and from 82mm mortar round fire (direct hits). The sandbagged structure will provide protection with only minor damage from a point detonating 122mm rocket (direct hit).

h. The BTOC module will require no maintenance other than organizational level maintenance. No special training will be required for assembly, disassembly, and safe operation in accordance with AR 602-1, dated 4 March 1968 and AR 385-16, dated 11 February 1967. Introduction of the item into the Army inventory system would require no additional personnel spaces in TO&E of using units.

2. PHYSICAL CHARACTERISTICS:

a. Weight of the BTOC module, excluding all ancillary and battalion TO&E equipment, will not exceed 4,000 pounds. The operational BTOC, including all ancillary equipment will not weigh more than 8,000 pounds.

b. Each module will be capable of transport by a CH-47 helicopter and by a 2 1/2-ton M36 truck in an erected and fully equipped (less antennas) mode.

c. Maximum outside dimensions will be limited to what can be safely carried by a 2 1/2-ton M36 cargo truck without restriction (for oversize load clearances) on any highway. Maximum height will be 96 inches, maximum width will be 87 inches, and maximum length will be 18 feet.

d. The inside of the BTOC module will be large enough to accommodate five people for normal operations. The inside height will be not less than 78 inches, and the inside width not less than 80 inches.

e. The BTOC module will be furnished with hinged tables and shelves, chairs, and map boards. Provision will be made for tie-down of all interior furnishings in preparation for transport of the BTOC in the fully equipped mode, including all battalion TO&E equipment.

f. After the BTOC module has been equipped with the battalion TO&E equipment (radios, antennas, communications equipment, etc.), and after the completely equipped BTOC module has been transported to and set in place, it must be capable of conversion to or from an operational mode with common hand tools by two to four personnel within one hour excluding sandbagging or covering with loose fill material. The principal deployment operations will be to install and hook-up to antennas, remove all transport tie-downs, and put the powerplant (TO&E) and utilities into service.

g. Provisions will be made for installation of the following TO&E equipment (actual installation of equipment to be made by the user units):

(1) Light Set, Portable, FSN 6230-299-7077, and power cables to operate unit radios from a remote source.

(2) Four (4) automatic tuning vehicular type antennas and one remote RC-292 antenna (radio antenna mounts will be provided).

(3) TO&E radios (brackets capable of mounting the radios and secure voice equipment without modification of radios or standard mounts will be provided).

h. The BTOC module will be designed for climatic categories 1 and 2 in accordance with AR 70-38.

i. The BTOC module will be provided with adequate ventilation for personnel and radios. As a minimum, air vents with simple sliding doors will be provided in the walls near the ceiling.

j. The BTOC module will be equipped with a door or doors with the following capabilities:

(1) Removable

(2) Will not interfere with interior operations and will not be blocked if sandbagged entrance way collapses.

(3) Can be opened from inside or outside in such manner that a person on the inside can always get out.

k. The BTOC module will be equipped with weatherproof access holes for electrical power cables, telephone connections, and antenna cables.

l. The BTOC module floor will be flat and of sufficient strength to carry 4,000-pound load inside.

m. Outside of the BTOC module will be painted non-reflective O.D. color.

SECTION NO. II

PRELIMINARY DESIGN CHARACTERISTICS

1. GENERAL CONFIGURATION:

There was considerable diversity of opinion as to whether the BTOC should be a conventionally shaped structure comparable to an oversized CONEX container, or a round cornered structure optimized for lightweight and economy of construction. Because of the significant diversity of preferences between the two shapes, it was necessary to properly consider the trade-offs involved before establishing detail design of the BTOC. Two testbed BTOC modules were, therefore, designed and fabricated. One was a rectangular shape as shown in Figure 1A. The other was a round cornered shape as shown in Figure 1B. A more thorough description of the two testbeds will be given in subsequent paragraphs of Section No. II, herein.

2. MATERIALS AND CONSTRUCTION TECHNIQUES:

Several different structural techniques, materials, and combinations of materials were explored. None were found to be superior to a brand of deeply corrugated aluminum structural plate which is normally used for culvert materials in highway construction. The material is commercially available in 57 1/2-inch wide corrugated sheets with 2 1/2-inch deep by 9-inch pitch corrugations. The physical properties and description of the deeply corrugated aluminum structural plate material are given in Figure No. 2. When used as the basic materials for a "skin-type" structure, i.e. as shown in Figure No. 1, the deeply corrugated aluminum structural plate is especially attractive from the viewpoint of blast loading capability, strength to weight structural properties, material cost, and manufacturing economy. For this BTOC application in which blast loading capability is of special concern, the deeply corrugated aluminum structural plate appears outstanding in the following respects:

a. Skin-Type Structure: Conventional construction requires the use of roof beams and side-wall columns in addition to roof and side-wall sheathing, and requires that the beam and column structure be designed to carry the total applied static and dynamic loading. In contrast, the unique properties of the deeply corrugated aluminum structural plate make it possible to build a skin-type structure (the BTOC module shown in Figures 1 through 11) which does not need roof beams and side-wall columns. The roof and side-wall sheathing serve also as roof and sidewall structure.

b. Structure Composed of Relatively Wide Beams: The deeply corrugated aluminum sheets perform under load as a relatively wide beam. From "Formulas for Stress and Strain" by R. J. Roark, Mr. Roark states that relatively wide beams are more rigid than conventional beams, and that the stiffening effect factor can be accounted for by using, in the formulas for deflection and curvature, "$E/(1-V^2)$" instead of "E" (the quantity "E" is modulus of elasticity, and "V" is Poissons' Ratio). Because of this increase in actual strength over theoretical strength - due to the wide beam factor - the deeply corrugated aluminum skin structure is capable of higher unit loading than conventional design would indicate.

c. Structure Composed of Flexible Thin Plates Undergoing Large Deflection: The deeply corrugated aluminum sheets perform under static and dynamic load as a flexible thin plate undergoing large deflection. In "Formulas for Stress and Strain" by R. J. Roark, Mr. Roark shows that when the deflection in a thin plate becomes larger than about 1/2 the plate thickness, the resulting direct stress enables the plate to carry part of the load as a diaphragm in direct tension, provided the tension is balanced by radial tension at the edges and the edges are held. Consequently, such a thin plate undergoing large deflection is stiffer than indicated by ordinary theory, and stresses for a given load are less than the ordinary theory indicates.

d. Structure Subjected to High Strain Rate: When subjected to the blast loading of mortar and rocket fire, the deeply corrugated aluminum sheet structure is subjected to high strain rate loading on the localized area directly opposite the exploding round. The high peak loading is of an unusually short duration - a few milliseconds. This short time duration results in an effective unit loading on the structure which is significantly lower than the actual peak load, generally by a factor of 2 or more (i.e. the peak load is 2 or more times the effective load). Experimental investigators have shown that both yield and ultimate strengths of materials under dynamic loading increase with increasing strain rates; i.e., the structure can carry higher loading and higher stresses without failure under dynamic loading (high peak loads of short duration) than under comparable static loading. The increase in strength is proportional to the increase in strain rate.

e. The Structure Allows Localized Deformation of the Corrugations: When subjected to mortar and rocket blasts, the beam like corrugations tend to flatten out (deflect) at the area opposite the exploding round. This results in a situation in which a small localized area of the corrugated sheet is deflected toward a flat-plate diaphragm configuration, the diaphragm stresses being balanced by the surrounding non-deflected areas. Concurrently, the blast loading is carried proportionately by the following:

(1) The strain action of the corrugations' flattening out process.

(2) The flat plate diaphragm action.

(3) The bending stress/strain action due to the conventional bending moment.

(4) The cumulative effect of the high strain rate factor serves to double or perhaps triple the actual capacity of each of the actions (1), (2), (3) above.

3. DETAILED DESIGN CRITERIA:

There was no specific dynamic design criteria available for use in detail designing a sandbagged structure comparable to the BTOC module. In addition to the variables discussed in paragraph 2 above, a detailed analysis would be subject to yet other uncontrollable variables associated with the characteristics of the earth-fill material in the sandbags. These variable characteristics affect the degree to which the blast forces are attenuated between the exploding munition and the corrugated aluminum structure.

For purposes of structurally designing the testbed module (structural analysis), several preliminary design assumptions were made, and the uniquely special properties of the corrugated material (as described in paragraph 2 above) were taken into account. This is in effect an empirical approach tempered with some fairly reliable design assumptions and intuition. Proven empirical design criteria could be developed via an extensive test program, but such extensiveness was beyond the scope of this program. The objective, rather, was to build a structure which could be shown to withstand the mortar and rocket firing effects, relegating refinements of design criteria to future developments and production engineering.

SECTION NO. III

TESTBED DESIGN AND FABRICATION

1. EXTERIOR DESIGN:

The overall size of the testbed BTOC module is limited to what can be safely carried by a 2 1/2-ton cargo truck, M36. The inside body dimensions for the M36 truck are 88 inches in width by 211 inches in length. The maximum overall dimensions of the BTOC module were, therefore, set at 86 inches wide by 14 feet long. The maximum weight of the module was set at 4,000 lbs., not including ancillary equipment such as radios, mounts, antennae, and power units. A door is required in each end. The door in one end is equipped with an upper hatch-type panel which opens inward to provide assurance against blocked doorways. Antenna mounts are installed on each corner at the roof line. Tie-downs and lifting points are provided for transport as a helicopter sling load or as a cargo load on a 2 1/2-ton truck.

2. INTERIOR DESIGN:

The inside dimensions of the BTOC module are approximately 80 inches wide by 13 feet-6 inches long. The interior is equipped with hinged tables, shelves, and map boards. The shelves and tables are suitable for mounting radios and all other TOE communications equipment. Provisions are made for use of the Light Set, Portable, FSN 6230-299-7077.

or other suitable portable lighting/power units which may be available. A ventilating fan is installed at each end of the module. Air vents with simple sliding doors are provided in the end walls near the ceiling. Waterproof access holes are provided in each end wall near the ceiling for electrical power and antenna cables.

3. FABRICATION:

Two BTOC testbed units, a rectangular module and a round cornered module, were built. It was reasoned that the round cornered module would be the most desirable as concerns structural adequacy and strength to weight characteristics, and that the rectangular module would be the most desirable as concerns transportability and interior space utilization. By this line of reasoning, it would be necessary to subject only the rectangular module to the mortar and rocket firing tests, and only the round cornered module to transportability and functional tests.

The round cornered BTOC testbed module was equipped with six each 24-inch by 42-inch hinged tables, four each 18-inch by 42-inch hinged shelves which are convertible to four each 42-inch by 48-inch map boards, and two each 42-inch by 48-inch map boards. This interior arrangement is shown in Figure No. 3. Additionally, six each field chairs were provided, one at each table. The following items of dummy communications equipment were installed, as shown in Figure No. 3:

a. 5 each VRC-46 radios
b. 2 each VRC-47 radios
c. 1 each GRC-106 radio
d. 1 each GRR-5 radio
e. 1 each VRC-24 radio
f. 2 each KY-8 Krypto units
g. 1 each SB-22 switchboard
h. 2 each power supply PP-1104 C/G converters (installed on the floor)
i. 4 each detachable antenna bases were mounted on the BTOC testbed module, as shown in Figure No. 4.

SECTION NO. IV

ENGINEERING DESIGN TEST

1. OBJECTIVES:

a. Structural Endurance: The first and foremost objective was to determine if the testbed BTOC modules, when bunkered with sandbags, can withstand direct hits by Chinese 82mm mortar, US 81mm mortar, and Soviet 122mm rocket rounds.

b. Transportability: The second objective was to determine if the BTOC modules can be transported by CH-47 helicopters and by 2 1/2-ton trucks.

c. Functionability: The third objective was to determine if the testbed BTOC modules provide an interior arrangement which is practical and suitable for use as a battalion tactical operations center module.

2. TEST PROCEDURES:

a. Structural Endurance and Transportability Tests: The structural endurance and transportability tests were conducted by USATECOM, and reported in USATECOM Report No. APG-MT-3881 dated June 1971, "Engineer Design Test of Portable Battalion Tactical Operations Center". The TECOM report is included herein, Appendix A, as a supporting element to this LWL report.

The rectangular-shaped BTOC module, shown as Module 1 in Figures 1-1 through 1-22 of Appendix A, was subjected to mortar and rocket firing tests. The module was covered with sandbags to a depth of two feet for the mortar round tests and five feet for the simulated rocket firing test. The test arrangements are shown in Figures 12 and 14, herein. A complete description of these tests and test procedures is given in Appendix A.

The round cornered BTOC module, shown in Figures 5 through 11 herein, was subjected to transportability tests. It was transported by the CH-47 helicopter and by the 2 1/2-ton trucks (the M35 and M36). A complete description of these tests is given in Appendix A.

b. Functionability Tests: The functionability tests were conducted by LWL personnel. This test consisted of an exercise in which realistic TOC operations were simulated, using the round cornered BTOC module, Figure No. 3, as the TOC housing. Use of the hinged tables, shelves, and map boards were evaluated. Adequacy of the interior working space and compatibility with the TOE communications equipment were also evaluated. Figures No. 5, 6, and 7 show a simulated operational capability while the BTOC module is being transported by 2 1/2-ton truck.

3. SUMMARY OF TEST RESULTS:

a. Transportability Tests: Figures 5 through 7 illustrate transportability by 2 1/2-ton truck. Complete details of the truck-transport tests are given in Appendix A. Results of the tests state that the BTOC module was loaded and transported without difficulty. There is an excess in truck bed length of approximately 3 feet when the BTOC is loaded on the 2 1/2-ton M36A2 truck, though this does not present any problem. The BTOC extends to the end of the tailgate when loaded on the M35A2 truck. No weight rests on the tailgate, however, so this does not present any problem.

Figures 8 through 11 illustrate the helicopter transportability tests. Complete details of the tests are given in the Test Report, Appendix A. The Test Report concludes that the BTOC module can be transported by air and land with relative ease.

b. Functionability Tests: The functionability tests results indicated that the space arrangement of the round cornered BTOC module, Figure No. 3, provides a practical and suitable working situation for the TOC application. Six LWL military personnel conducted the simulated TOC operation. Generally speaking, the interior arrangement was considered adequate, though the following problem areas were indicated:

(1) The aisle between tables is too narrow for personnel passage when two people are working back to back at opposite tables. The depth of the tables can be decreased to provide adequate aisle space.

(2) The evaluators recommended that the map boards be eliminated and that the troop users be required to provide their own map boards.

c. Structural Endurance Tests: The structural endurance tests and test results are described in Appendix A. Results of these tests support the conclusion that the BTOC is structurally adequate for use as a bunkered BTOC module. Figure 12 shows an 81mm mortar round positioned for static detonation over the BTOC module, and Figure 13 shows the cratering effect resulting therefrom. The 81mm mortar did not damage the structure. Figures 14 and 15 show a 122mm rocket round positioned for static detonation. This round, containing approximately 14.5 pounds of explosive, was separated from the BTOC structure by a five (5) foot thickness of sandbags. Figures 16 and 17 show the cratering effect.

After completion of all the firing tests, as more fully described in Appendix A, the only significant damage incurred by the BTOC module was a sway in the roof as shown in Figure No. 18; the roof sheet incurred a permanent deflection of approximately 4 1/2 inches at mid-section.

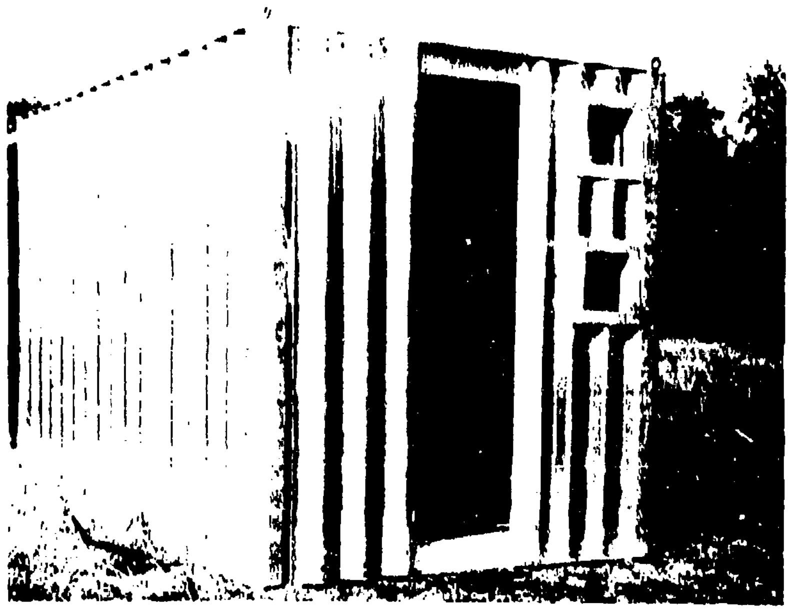
CONCLUSIONS

a. The consensus expressed by potential troop users indicates that a portable BTOC designed generally in accordance with the Design Characteristics set forth in Section No. I, herein, would meet the expectations of most Army field commanders.

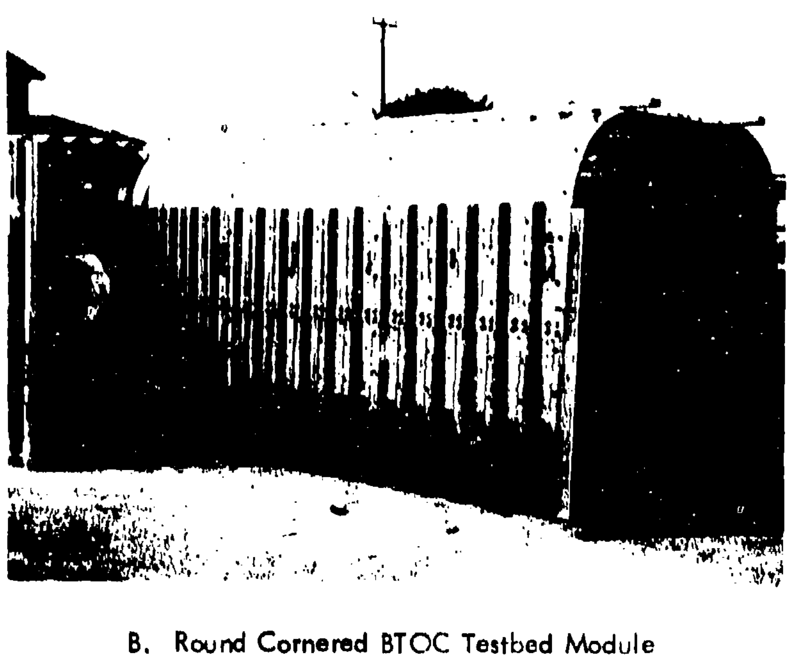
b. Either of the two testbed modules, when detail designed from testbed to prototype items, will meet the Design Characteristics stated in Section No. I of this report.

c. The round-cornered BTOC module is superior to the rectangular-shaped BTOC module in all significant aspects.

d. Prototypes of the round-cornered BTOC module concept should be designed, fabricated, and user tested when and if it is determined that further development is warranted.



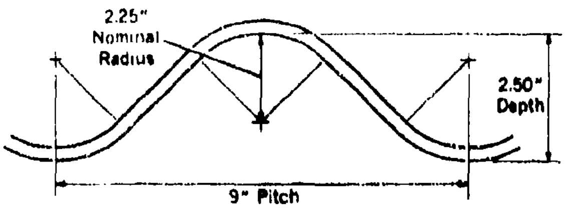
A. Rectangular-Shaped BTOC Testbed Module



B. Round Cornered BTOC Testbed Module

FIGURE NO. 1

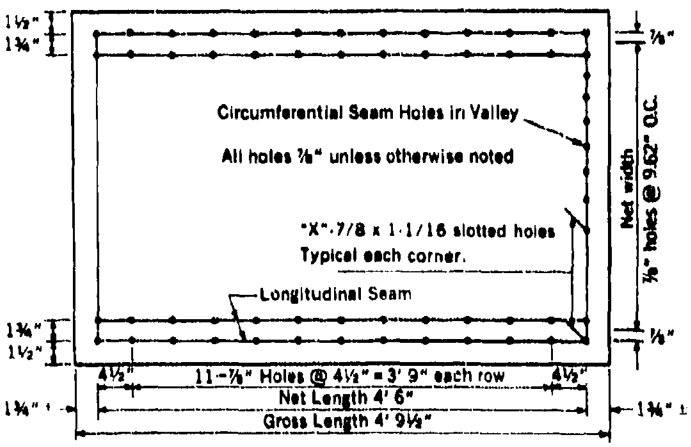
PHYSICAL PROPERTIES OF CORRUGATION



Thickness Inches	Moment of Inertia in.⁴/in.	Section Modulus in.³/in.	Radius of Gyration in./in.	Area of Section in.²/in.
.090	.082	.066	.883	.105
.100	.091	.073	.883	.117
.125	.114	.091	.883	.146
.150	.136	.109	.883	.175
.175	.159	.127	.883	.204
.200	.182	.145	.883	.234
.225	.205	.164	.883	.263
.250	.227	.182	.883	.292

NOTE: This data subject to manufacturing tolerances. Data computed per inch of horizontal projection.

STANDARD PLATE SIZES



UNCURVED PLATE DETAIL

Net Width		Gross Width	X
N*	Inches	Inches	
8	76.96	81.71	4
9	86.58	91.33	4
10	96.20	100.95	4
11	105.82	110.57	5
12	115.44	120.19	5
13	125.06	129.81	5
14	134.68	139.43	5

*N=9.62"

PLATE WEIGHTS (POUNDS)

Thickness Inches / Width	.090	.100	.125	.150	.175	.200	.225	.250
8 N	47.3	52.6	65.8	78.9	92.1	105.2	118.4	131.5
9 N	52.9	58.8	73.5	88.2	102.9	117.6	132.3	147.0
10 N	58.5	65.0	81.3	97.5	113.8	130.0	146.3	162.5
11 N	64.1	71.2	89.0	106.8	124 6	142.4	160.2	178.0
12 N	69.7	77.4	96.8	116.1	135.5	154.8	174.2	193.5
13 N	75.2	83.6	104.5	125.4	146.3	167.2	188.1	209.0
14 N	80.8	89.8	112.3	134.7	157.2	179.6	202.1	224.5

Notes (1) Weights are based on nominal thicknesses only.
(2) Bolt holes have not been deducted

FIGURE NO. 2: Table of Physical Properties of Deeply Corrugated Aluminum Structural Plate Material.

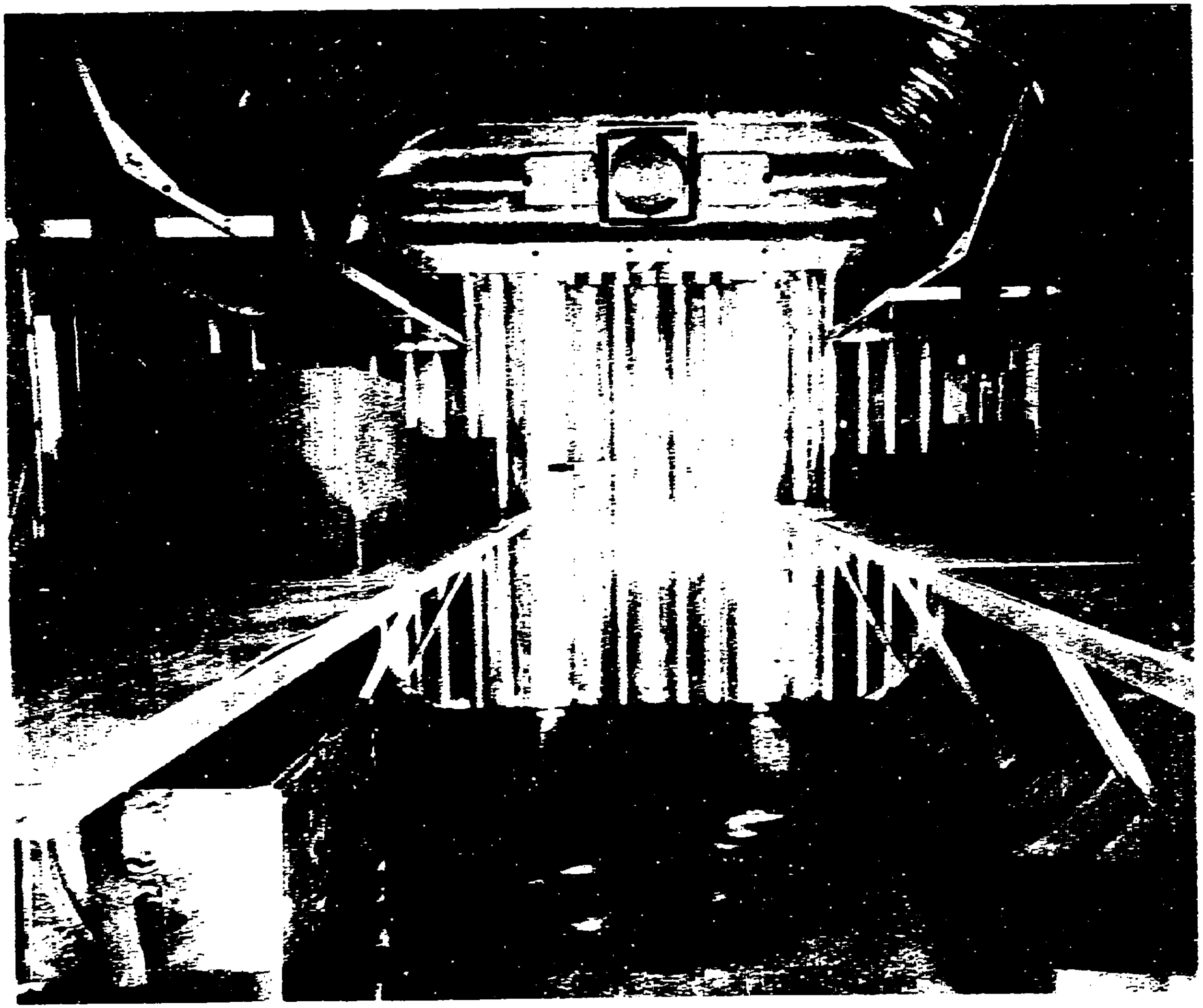


FIGURE NO. 3: Interior View of the Testbed Battalion Tactical Operations Center Module (BTOC)

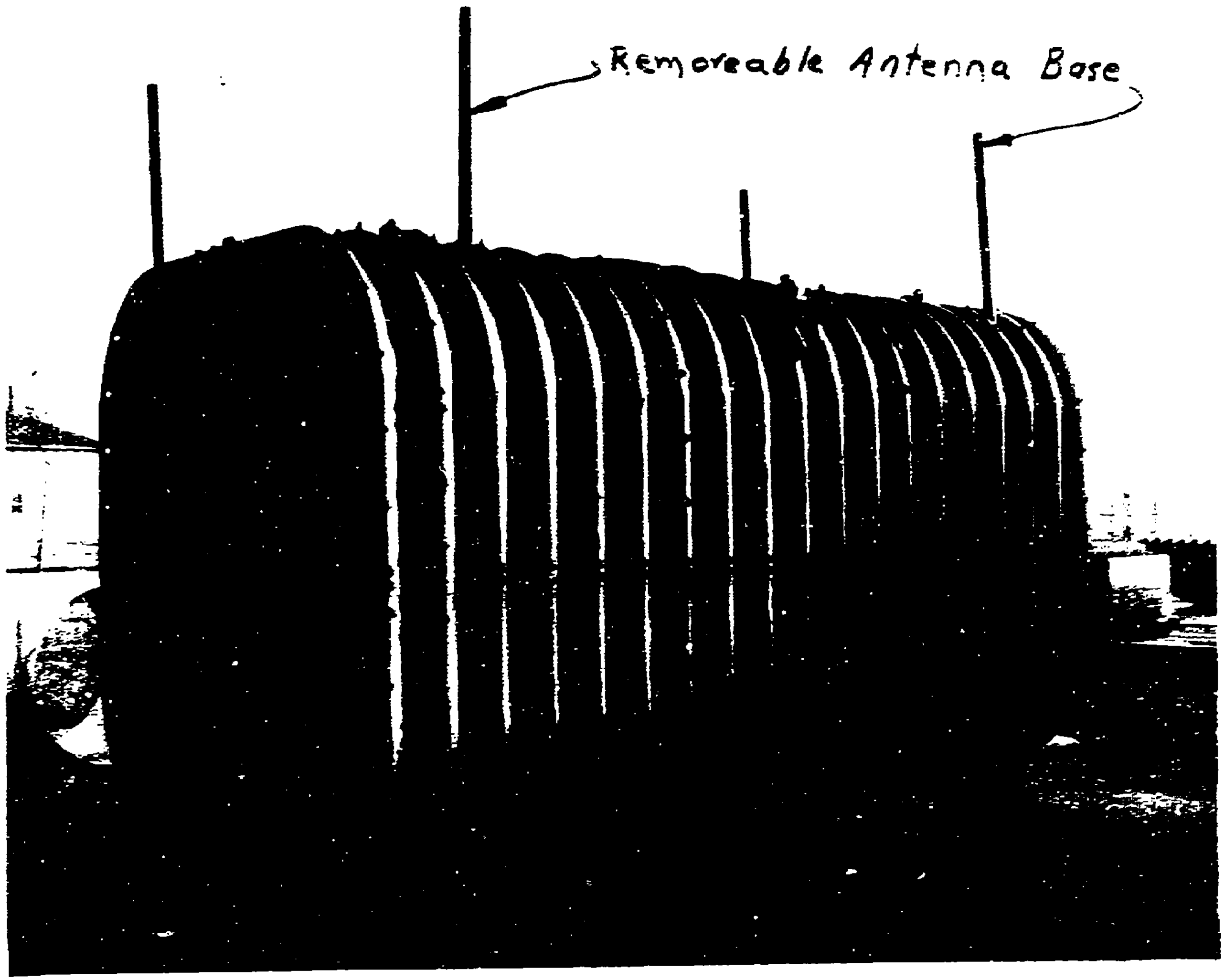


FIGURE NO. 4: BTOC, Showing Antenna Bases Which are Removeable Prior to Transport

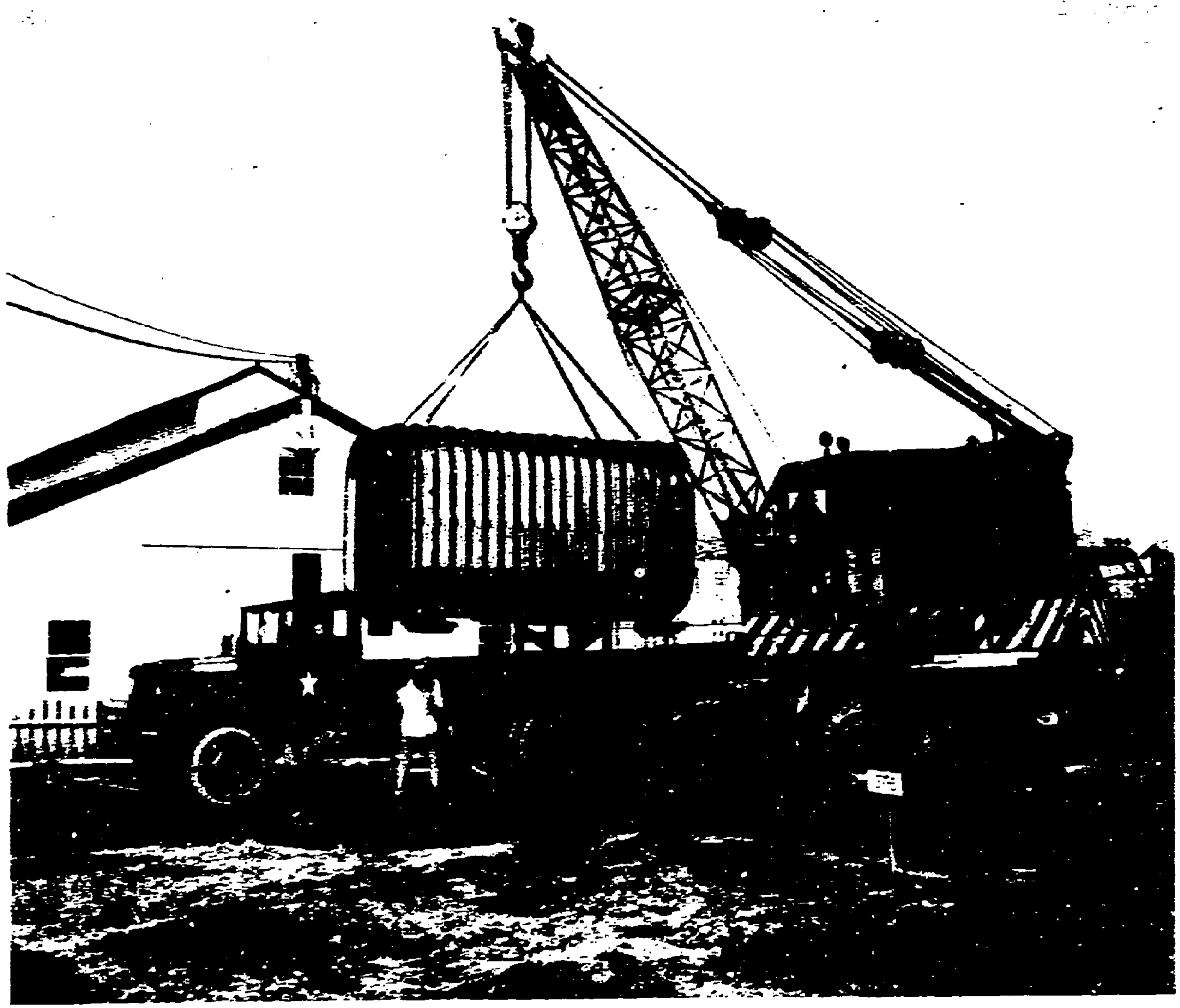


FIGURE NO. 5: The BTOC Being Loaded onto a 2 1/2-Ton M36A2 Tactical Truck

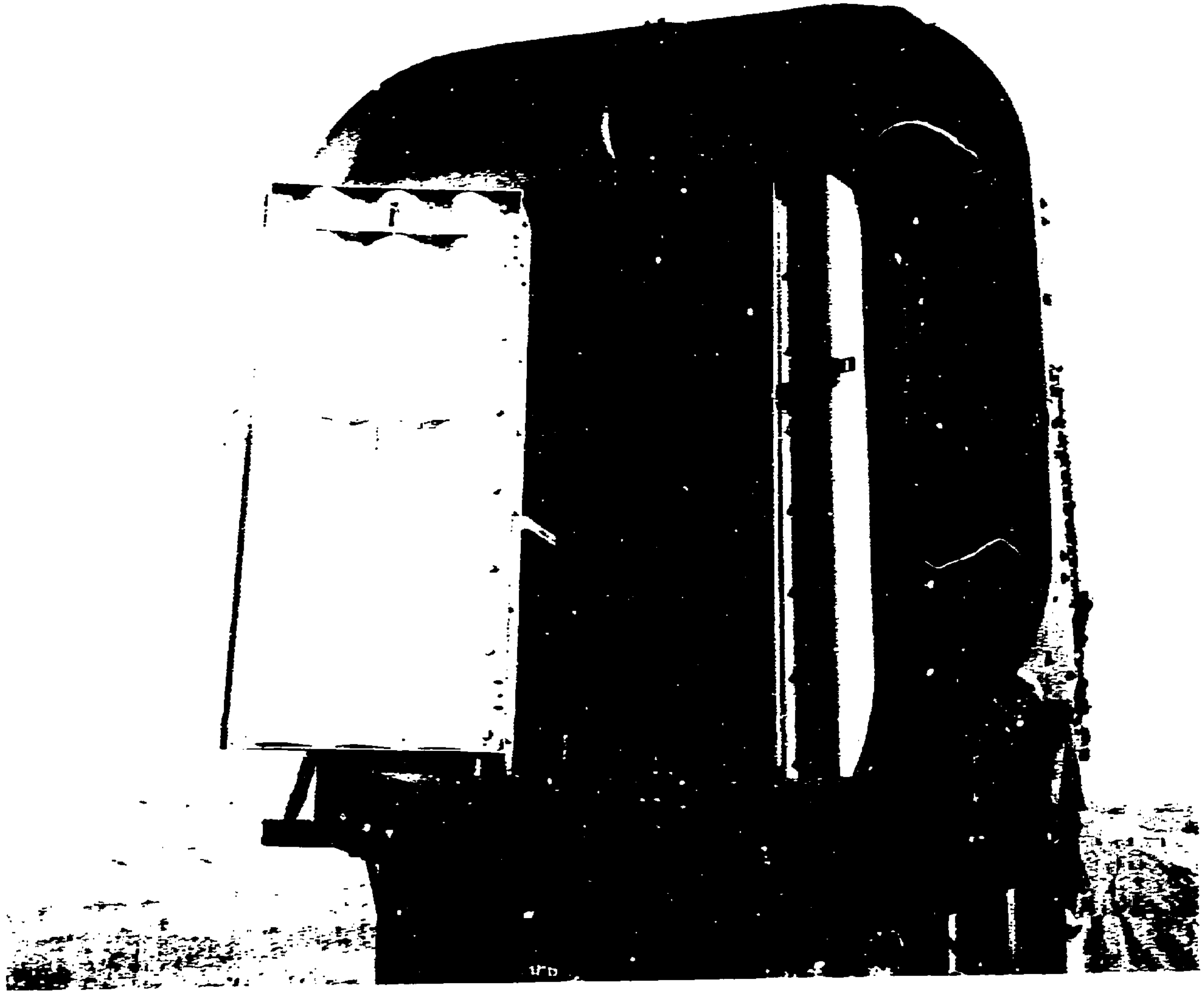


FIGURE NO. 6: The BTOC Being Transported by the 2 1/2-Ton M35A2 Tactical Truck

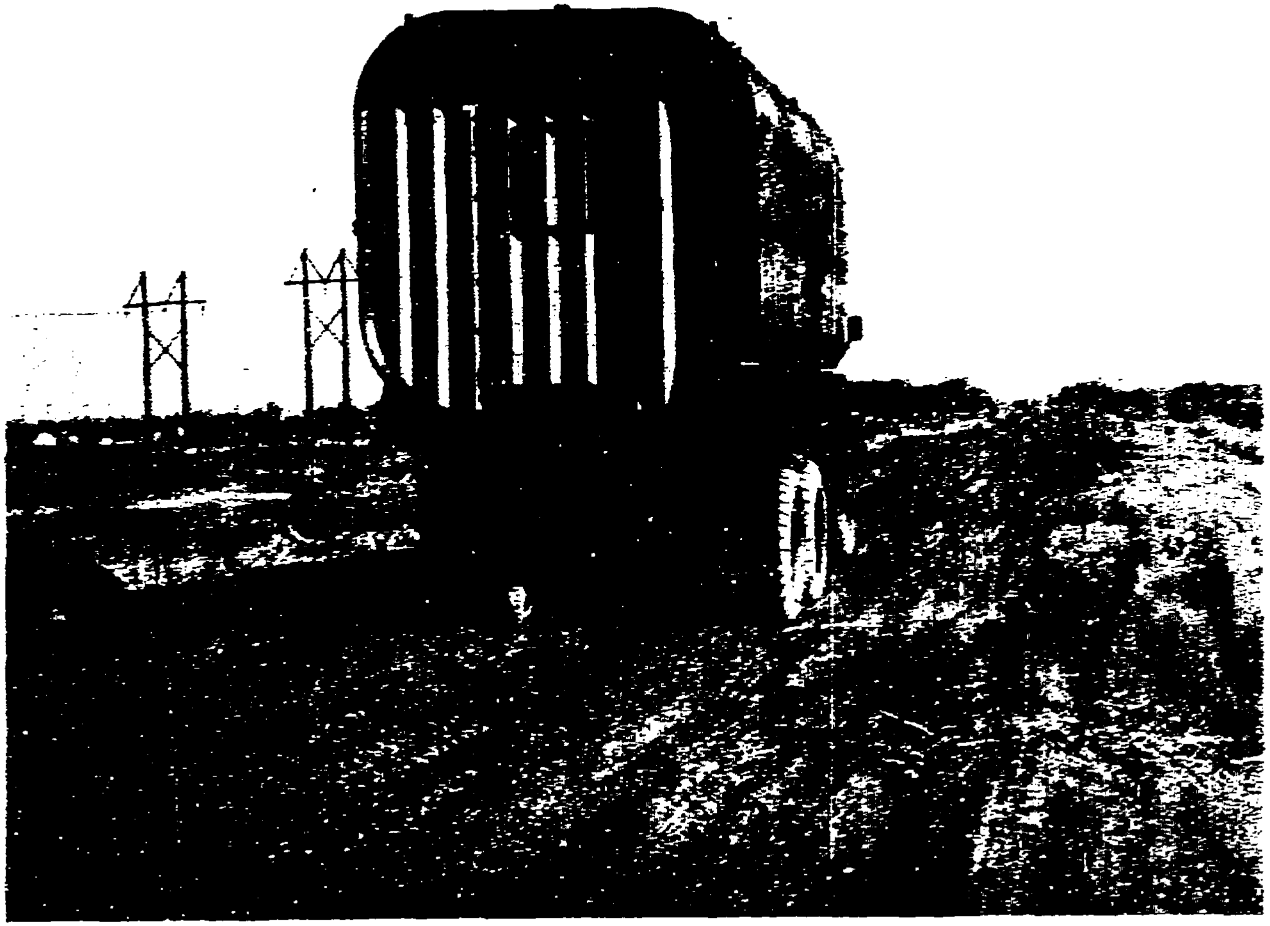


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FIGURE NO. 9: The BTOC Module Being Lifted Off by CH-47 Helicopter

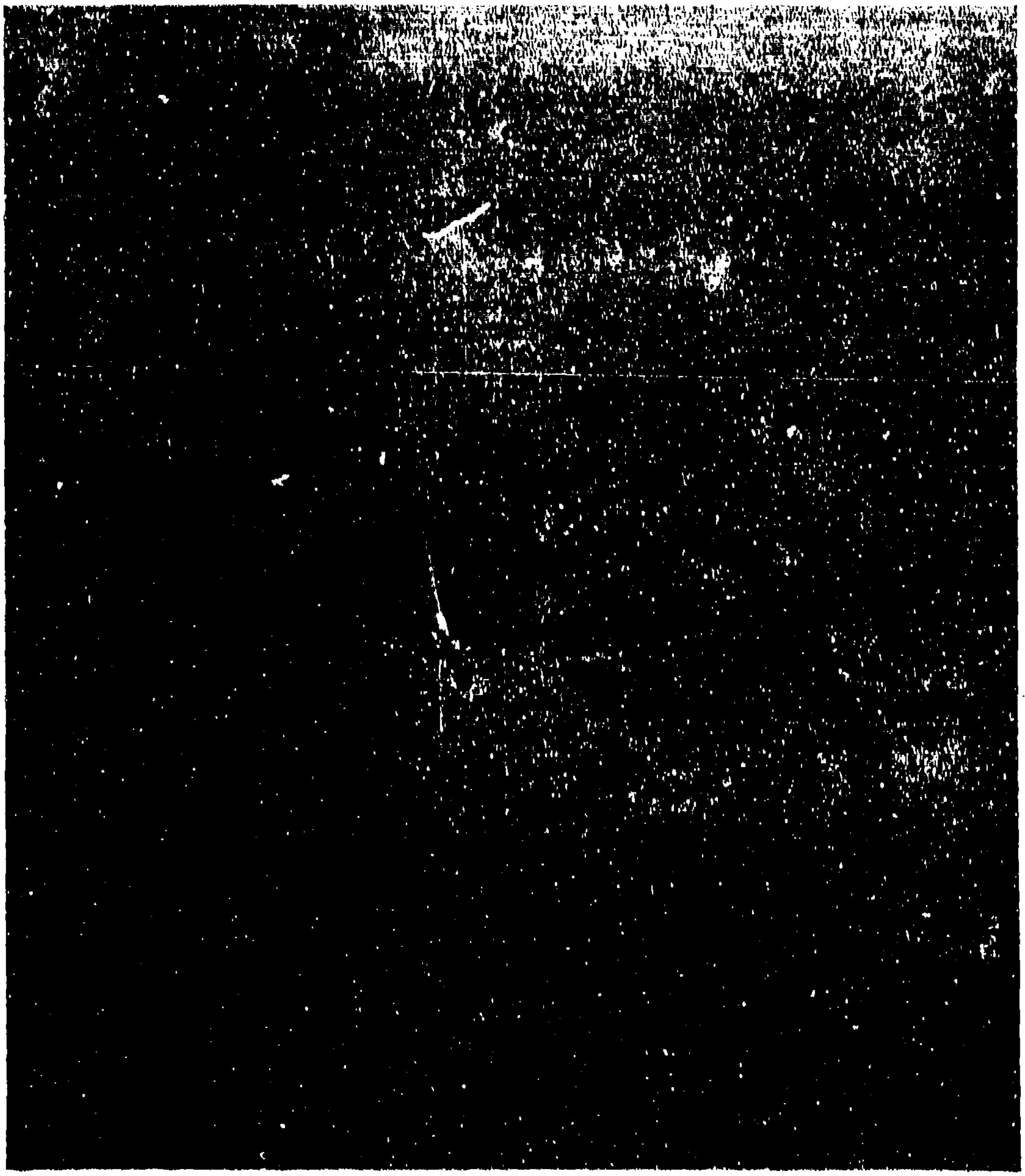

FIGURE NO. 10: The BTOC Module Being Transported by CH-47 Helicopter

FIGURE NO. 11: The BTOC Module Being Delivered by CH-47 Helicopter

FIGURE NO. 12: An 81mm Mortar Round Positioned for Static Detonation Over the BTOC Module, Over 24" Thickness of Sandbags.

FIGURE NO 13: Cratering Effect Caused by the 81mm Mortar Round

FIGURE NO. 14: Simulated Rocket Round Containing 14.5 Pounds of Explosive, Positioned for Static Detonation Over a 5-Foot Thick Sandbag Cover.

FIGURE NO. 15: Simulated Rocket Round Containing 14.5 Pounds of Explosive, Positioned for Static Detonation Over a 5-Foot Thick Sandbag Cover.

FIGURE NO. 16: The Cratering Effect Caused by the Simulated Rocket Round

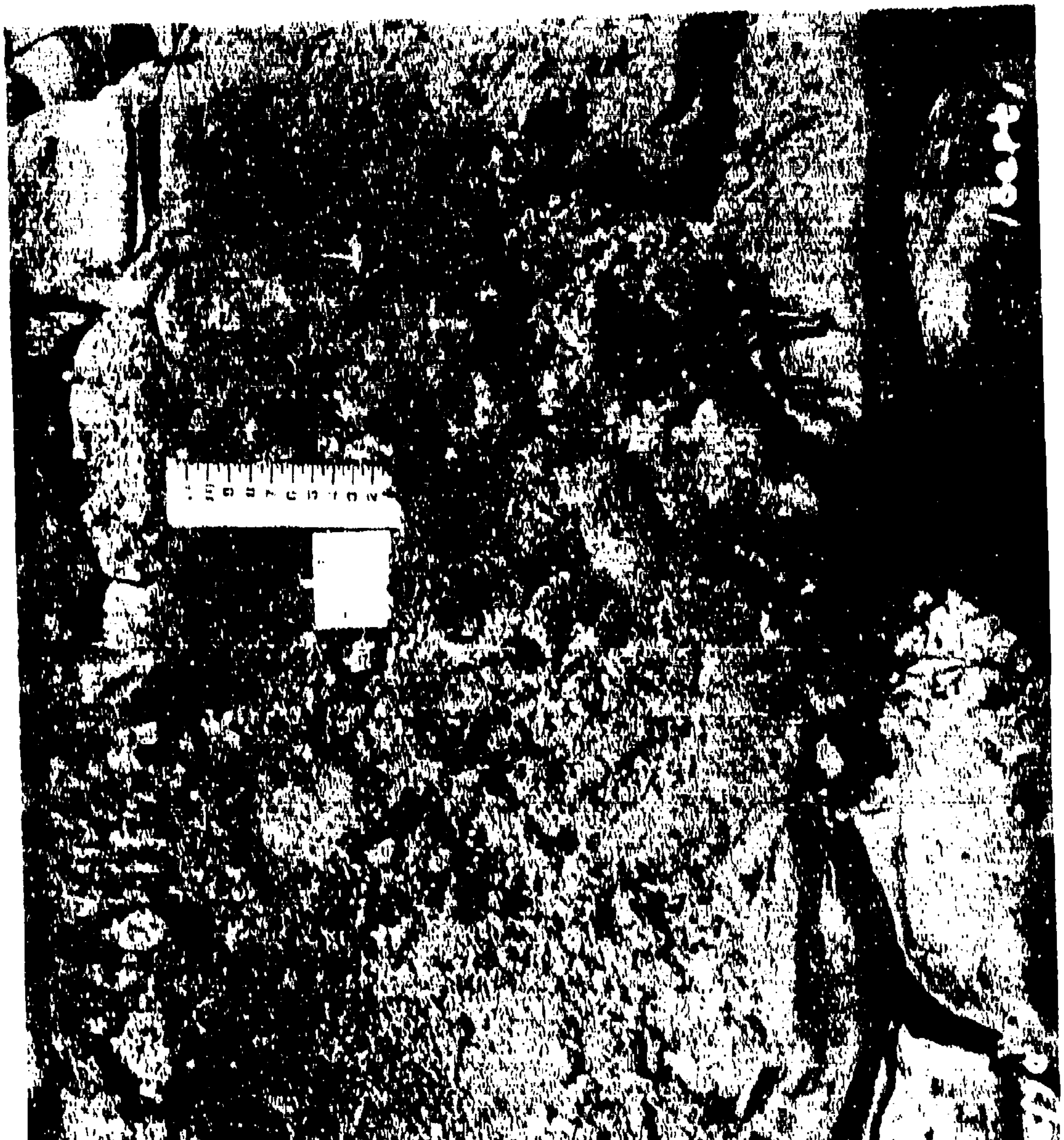

FIGURE NO. 17: The Cratering Effect Caused by the Simulated Rocket Round

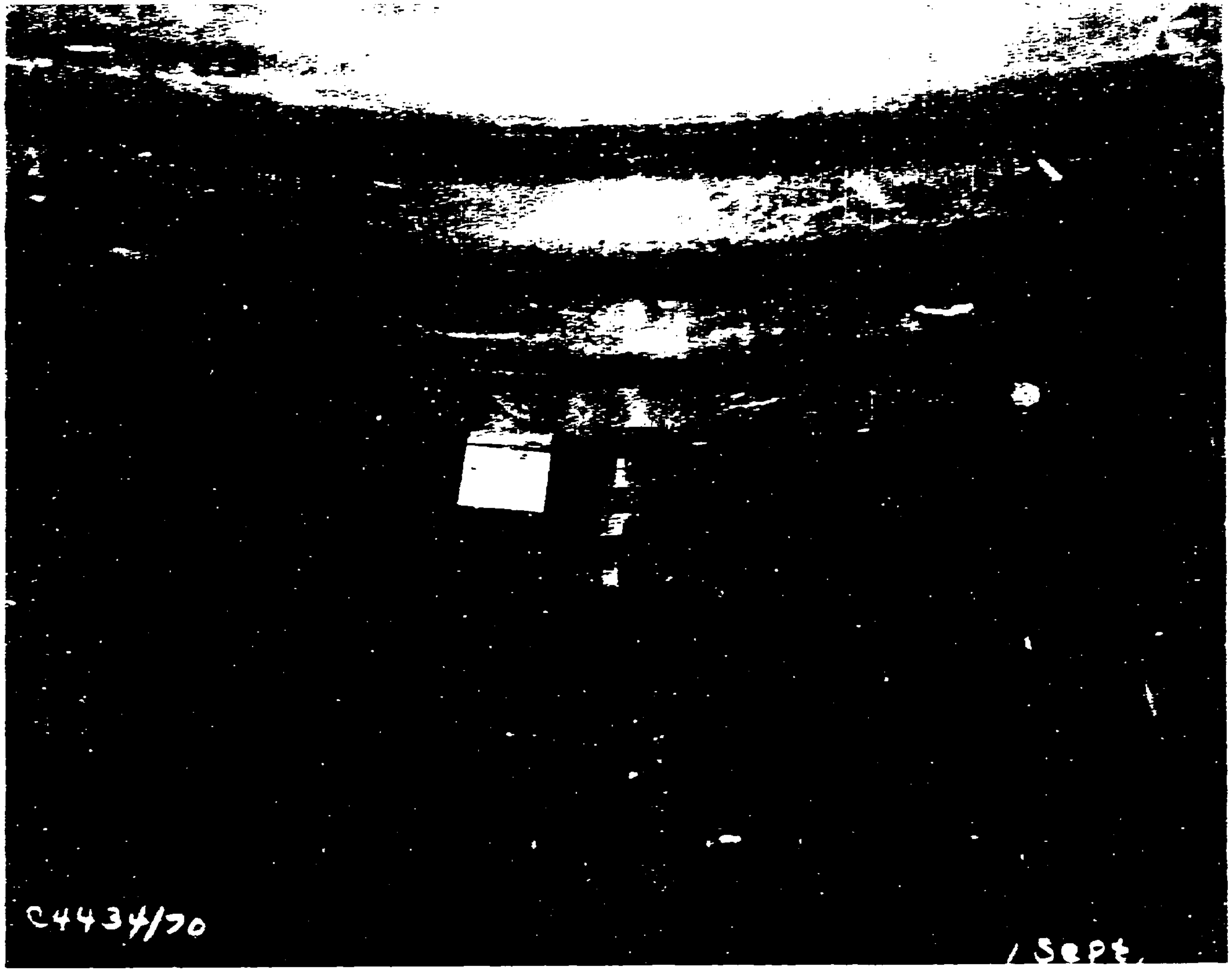

FIGURE NO. 18: Interior of the Rectangular-Shaped BTOC Testbed Module Shown After Completion of all Firing Tests. Note the Minor Sway in the Roof Sheet, a Permanent Deflection of Approx. 4 1/2-in, at Mid-Section.

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UNCLASSIFIED
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DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY (Corporate author)
US Army Land Warfare Laboratory
Aberdeen Proving Ground, Md. 21005

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
Portable Battalion Tactical Operations Center (BTOC); Testbed Design, Fabrication, and Design Engineer Test - Final Report

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)
Joseph T. Gurganious

6. REPORT DATE
February 1973

7a. TOTAL NO. OF PAGES
27

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.

b. PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
Technical Report No. 73-07

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
Each transmittal of this document outside the Department of Defense must have prior approval of the U. S. Army Land Warfare Laboratory.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT
The Portable BTOC is a portable modular enclosure suitable for use as the TOC in a rapidly changing situation, though a grouping of 4 modules would be used to form the battalion's larger command post facility. Testbed modules were fabricated and tested. The test results indicate that the BTOC module, when detail designed and prototyped, will be suitable for tactical use as a Portable BTOC; and that the modules will be capable of being sufficiently bunkered with sandbags to withstand direct hits by mortar and rocket fire.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT

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APPENDIX A

AD

RDT&E PROJECT NO. OR FSN NOT AVAILABLE
USATECOM PROJECT NO. 7-ES-975-TOC-001
REPORT NO. APG-MT-3881
USALWL PROJECT NO. 04-M-70
USACDC AC NO. NOT AVAILABLE

ENGINEER DESIGN TEST OF PORTABLE BATTALION TACTICAL OPERATIONS CENTER (U)

FINAL REPORT

BY

LARRY W. OVERBAY

JUNE 1971

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(U) TABLE OF CONTENTS

SECTION 1. SUMMARY

SECTION 2. DETAILS OF TEST

SECTION 3. APPENDICES

[redacted] ABSTRACT (U)

An engineer design test of the Portable Battalion Tactical Operations Center was conducted at Aberdeen Proving Ground from 31 July 1970 to 26 May 1971. Testing consisted of a structural endurance test, a helicopter-transportability test, and a truck-transportability test. Slight damage occurred to the center during the structural endurance test, but it was easily transported by the CH-47 helicopter and by 2-1/2 ton trucks. It was concluded that the center (module I) can safely withstand the detonations of the Vietcong 82-mm and Soviet 122-mm rounds when it is sufficiently bunkered with sandbags; the center (module II) can be transported by air and land with relative ease.

(U) FOREWORD

The Land Warfare Laboratory was responsible for planning the test and conducting the two transportability subtests. The Materiel Testing Directorate was responsible for conducting the structural endurance test and preparing the test report.

ABERDEEN PROVING GROUND
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USATECOM PROJECT NO. 7-ES-975-TOC-001

FINAL REPORT ON ENGINEER DESIGN TEST OF
PORTABLE BATTALION TACTICAL
OPERATIONS CENTER (U)

31 JULY 1970 TO 26 MAY 1971

SECTION 1. SUMMARY (U)

1.1 (U) BACKGROUND

Air-mobile combat troops do not have a suitable shelter for use as a bunkered tactical operations center (a communication base from which the battalion commander can direct the combat activity of his troops). Such a command-module structure must be transportable by CH-47 helicopter and by 2-1/2 ton truck and must withstand a direct hit by the VC 82-mm mortar round and the Soviet 122-mm rocket when sufficiently bunkered with sandbags. In order to meet these requirements, the USALWL has developed the portable BTOC for use in air-mobile operations, fire posts, and remote outposts.

1.2 (U) DESCRIPTION OF MATERIEL

Two BTOC test modules were tested. Test module I (Figure I-1), tested for structural endurance, is rectangular in shape and is approximately 8 feet high, 8 feet wide, and 16 feet long. Test module I consists of a skeleton structure made from extruded aluminum shapes (zee-, angle-, and tee-members) covered with 0.15-inch (thick) corrugated aluminum structural plate with 2-1/2 by 9-inch corrugations. The module weighs approximately 3200 pounds.

Test module II (Figure I-23), tested for ease of transportability by air and land, is rectangular in shape with rounded flexible corners and is approximately 8 feet high, 8 feet wide, and 20 feet long. Except for the door frames, the module is made entirely from 0.15-inch (thick) corrugated aluminum structural plate with 2-1/2 by 9-inch corrugations. The module weighs approximately 1800 pounds.

The BTOC is designed so that two or more modular units can be connected to form a larger command post. The single modular unit can function as the BTOC in a rapidly-changing situation, but in some areas the battalion fire-base command posts become semipermanent positions and are occupied for 60 days or longer. These positions will require expanded facilities such as a lights-and-power system, map boards, ventilating fans, hinged tables, hinged shelves, and other desired items. Future tests of BTOC's will include these expanded facilities.

1.3 (U) TEST OBJECTIVES

a. To determine if the BTOC can withstand a direct hit from the VC 82-mm mortar round and from the Soviet 122-mm rocket when sufficiently bunkered with sandbags.

b. To determine if the BTOC can be transported by CH-47 helicopters and by 2-1/2 ton trucks.

1.4 (U) SCOPE

Two BTOC modules were used for testing. The BTOC module I (Figure I-1) was used for the structural endurance test and BTOC module II (Figure I-23) was used for the truck- and helicopter-transportability tests. The USALWL representative conducted and recorded the data for the transportability tests and the MTD conducted the structural endurance test under USALWL directives.

1.5 SUMMARY OF RESULTS (U)

[redacted] The BTOC (module I) safely withstood the detonations of the VC 82-mm mortar round (as simulated by an M43A1 81-mm round) and the Soviet 122-mm rocket with slight damage (para 2.1.3).

(U) The BTOC (module II) had some tendency to twist, but was air-transported with relative ease by the CH-47 helicopter.

(U) The BTOC (module II) was transported on the M36A2 and M35A2 2-1/2 ton trucks with no major problems.

1.6 CONCLUSIONS (U)

(U) It is concluded that:

a. [redacted] The BTOC (module I) can safely withstand the detonations of the VC 82-mm and the Soviet 122-mm rounds when sufficiently bunkered with sandbags (ref para 2.1.4).

b. (U) The BTOC (module II) can be transported by air and land with relative ease (ref para 2.2.4 and 2.2.5).

1.7 (U) RECOMMENDATIONS

None.

SECTION 2. DETAILS OF TEST (U)

2.1 STRUCTURAL ENDURANCE TEST (U)

2.1.1 (U) Objective

The objective was to determine if the BTOC structure, when protected by approximately 2 feet of sandbags, will withstand a direct hit by the VC 82-mm mortar round (as simulated by the M43A1 81-mm round) and, when protected by approximately 5 feet of sandbags, will withstand a direct hit by the Soviet 122-mm rocket.

2.1.2 (U) Method

The BTOC module I (Figure I-1) was used for this test. Sandbags filled with dirt were used to bunker the BTOC to an over-all depth of at least 2 feet for detonations of the 82-mm rounds. Five feet of sandbags were used for detonations of the 122-mm round.

The fuze and tail assembly were removed from the mortar rounds and the rocket motor and fuze were removed from the 122-mm round. Composition C-4 explosive was packed in the nose of the rounds and an M6 electric blasting cap was used to statically initiate the rounds.

2.1.3 Results (U)

(U) The BTOC sustained one broken weld and deflection of the roof (5-1/4 inches of cumulative deflection from nine firings). No fragments penetrated the BTOC.

(U) The results are presented in Table 2.1-I.

Table 2.1-I [redacted] Summary of Structural Endurance Test Firings (U)

Rd No.	Date Fired	Type Rd[a]	Sandbag Moisture	Approximate Thickness of Sandbags, feet	Coded Position and Orientation of Round[b]	Approximate Crater Depth, inches	Damage to Sandbags[c]	Damage to BTOC Module I	Ref Figure No.
1	20 Aug 70	82-mm	Dry	3	A	7	30	None.	I-6, I-7, I-8
2	20 Aug 70	82-mm	Dry	2	A	6	20	None.	I-9, I-10
3	20 Aug 70	82-mm	Dry	2	B	6	10	None.	I-11, I-12, I-13
4	25 Aug 70	82-mm	Damp	2	C	24	25	1/4-inch deflection where round detonated; weld pulled loose.	I-14, I-15, I-16
5	25 Aug 70	82-mm	Damp	2	A	14	20	1/4-inch additional deflection from roof to floor.	I-17
6	1 Sep 70	122-mm	Dry	5	F	30	140	3-3/4 inch additional deflection from roof to floor.	I-18, I-19, I-20, I-21, I-22
7	11 Feb 71	82-mm	Frozen[d]	2	D	4	7	No additional damage.	-
8	11 Feb 71	81-mm	Frozen[d]	2	E	4	12	No additional damage.	-
9	3 Mar 71	81-mm	Wet	2	G	12	17	1-inch additional deflection.	-

See footnotes on following page.

Table 2.1-I (Cont'd)

[a]The M43A1 81-mm mortar round with 1.2 pounds of explosive was used to simulate the VC 82-mm round. The 81-mm round was the M362, with 2.2 pounds of explosive. The 122-mm round was a Soviet 122-mm rocket with 14.5 pounds of explosive.

[b]The key for each position and orientation is as follows:

A = Round located on top of BTOC along the longitudinal centerline, approximately halfway between the lateral centerline and the front end, with the round oriented at 65° to horizontal, nose down, and parallel to the longitudinal centerline.

B = Round located on the front edge of the top of the BTOC at the longitudinal centerline (above the point where the roof line meets the sidewall lines); the round was oriented at 65° to the horizontal, perpendicular to the corrugations, nose down, and nose toward the front edge of the bunker.

C = Round located on the lateral centerline of the BTOC at the top of the left sidewall; the round was oriented 65° to the horizontal and parallel to the corrugations with the nose down and pointing toward the left sidewall of the bunker.

D = Round located on top of the BTOC approximately 42 inches from the front edge of the top and approximately 36 inches from the right sidewall; the round was oriented 60° to the horizontal and perpendicular to the corrugations with the nose down and pointing toward the back edge of bunker.

E = Same as D except that the round was approximately 58 inches from the right sidewall.

F = Same as A except the round was 22° to the horizontal.

G = Round located 18 inches from the rear edge of the top and on the longitudinal centerline; the round was oriented 65° to the horizontal and perpendicular to the corrugations with nose down and pointing toward the rear edge of the BTOC.

[c]Represents the approximate number of sandbags either badly torn or thrown off the bunker by blast.
[d]The BTOC was exposed to a cold climate for approximately one week. The bags were frozen solid.

2.1.4 (U) Analysis

The US M43A1 81-mm round with 1.2 pounds of explosive was used to simulate the VC 82-mm round, which has 0.98 pound of explosive. Since the BTOC withstood the US round with 0.22 pound more explosive, it was assumed that the BTOC could withstand the VC round.

2.2 (U) HELICOPTER TRANSPORTABILITY TEST

2.2.1 Objective

The objective was to determine if the BTOC (module II) is transportable by the CH-47 helicopter.

2.2.2 Method

A standard aviation lifting sling was connected to the four I-bolts located on top of the BTOC (Figure I-23). A swivel was placed between the lifting hook of the helicopter and the sling. The BTOC was transported for approximately 25 miles at speeds up to 60 knots.

2.2.3 Results

The BTOC had some tendency to twist, but it was transported with relative ease by the CH-47 helicopter.

2.2.4 Analysis

The BTOC (module II) was suitable for air transport and can be moved with relative ease providing lifting equipment is available.

2.3 (U) TRUCK TRANSPORTABILITY TEST

2.3.1 Objective

The objective was to determine if the BTOC (module II) is transportable by the M35A2 and M36A2 2-1/2 ton trucks.

2.3.2 Method

The BTOC (module II) was lifted, using a 20-ton 1020A truck with a 30-foot boom, and was loaded into the M35A2 and, later, into the M36A2 trucks (Figure I-28). A standard sling used for tiedown of cargo in aircraft was used for lifting the BTOC; this was also used for securing the module to the bed of the truck (Figure I-30).

The BTOC was transported on the M35A2 for the following distances: 4 miles on level cross-country roads, 5 miles on hilly cross-country roads, and 46 miles on paved roads. The BTOC was transported on paved roads at speeds up to 50 mph. On the M36A2 truck, the BTOC was transported 4 miles on level cross-country roads and 32 miles on paved roads; the speeds on paved roads were up to 45 mph.

2.3.3 Results

The BTOC was loaded and transported without difficulty.

There is an excess in length of approximately 3 feet of truck bed when the BTOC is loaded on the M36A2 2-1/2 ton truck. The BTOC extends to the end of the tailgate when loaded on the M35A2 truck; however, no weight rests on the tailgate.

2.3.4 Analysis

The BTOC (module II) can be moved with relative ease providing lift equipment is available.

SECTION 3. APPENDICES (U)

APPENDIX I - PHOTOGRAPHS (U)

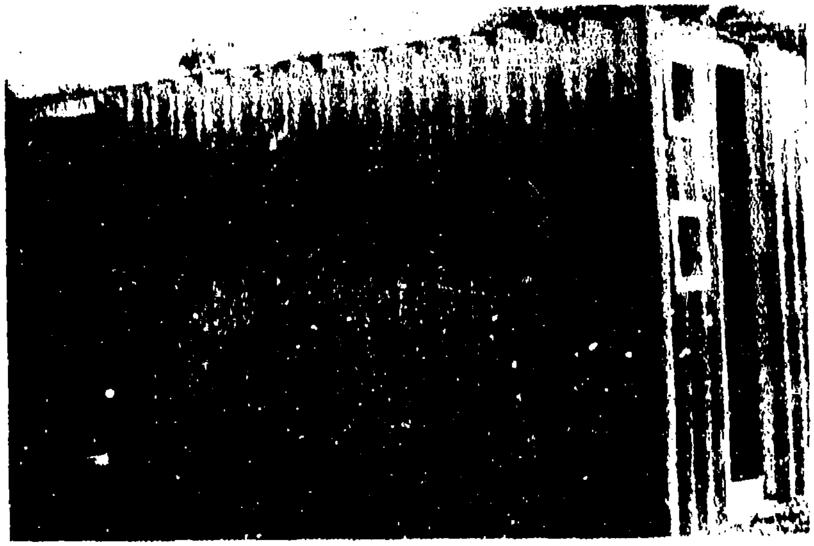

Figure I-1 (U): The BTOC Module I (U).

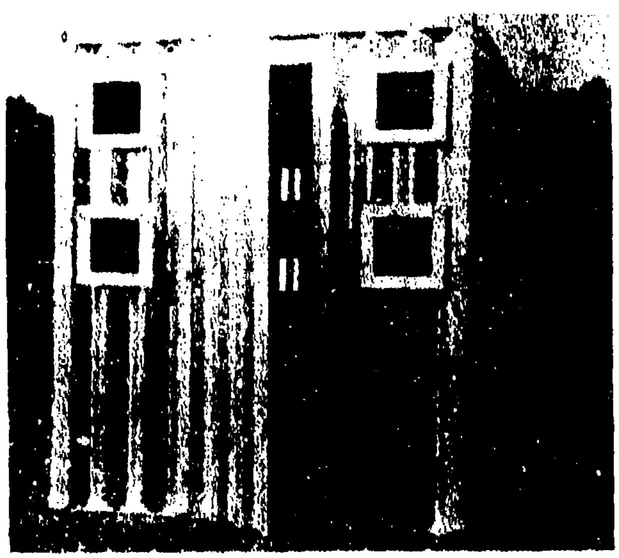

Figure I-2 (U): Front View of the BTOC Module I (U).

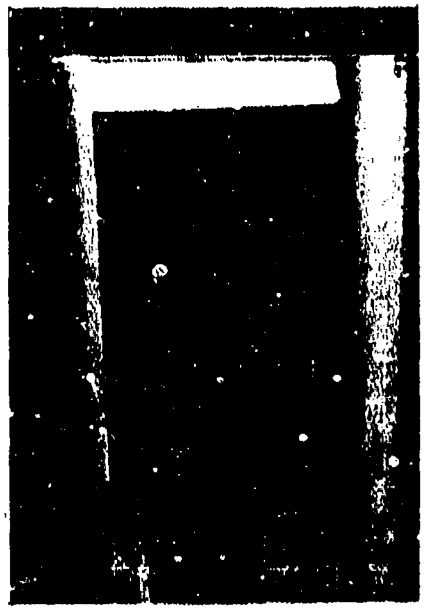

Figure I-3 (U): Rear of BTOC Module I; Note Eyebolts on Top Used for Lifting BTOC (U).

Figure I-4 (U): The BTOC Being Constructed (U).

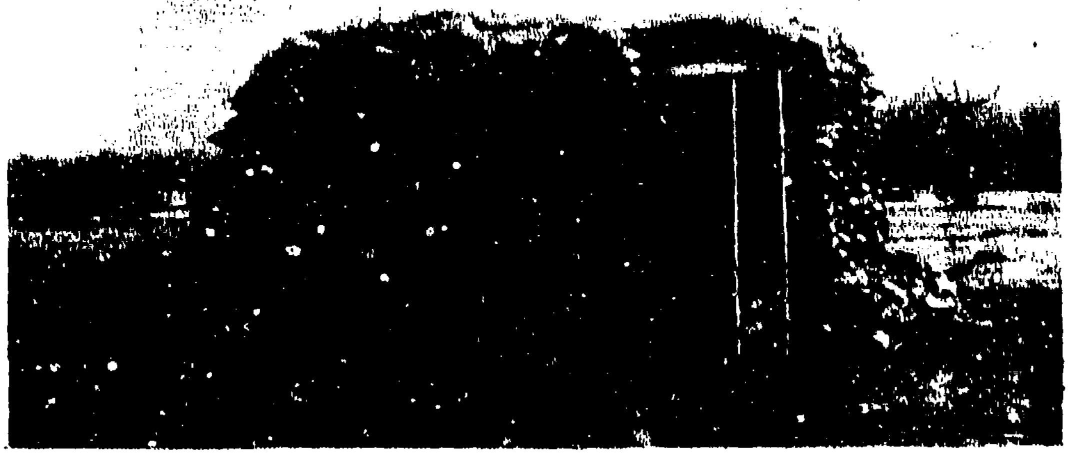

Figure I-5 (U): The BTOC Setup for Test Purposes (U).

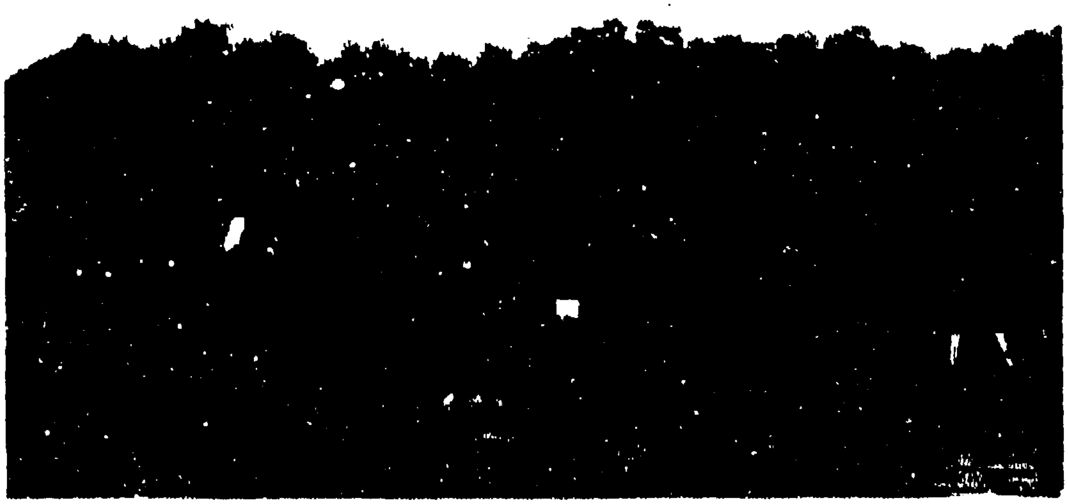

Figure I-6 (U): The BTOC Covered with at Least 2 Feet of Sandbags (U).

Figure I-7 (U): Setup for Round 1 with 3 Feet of Sandbags Below Round (U).

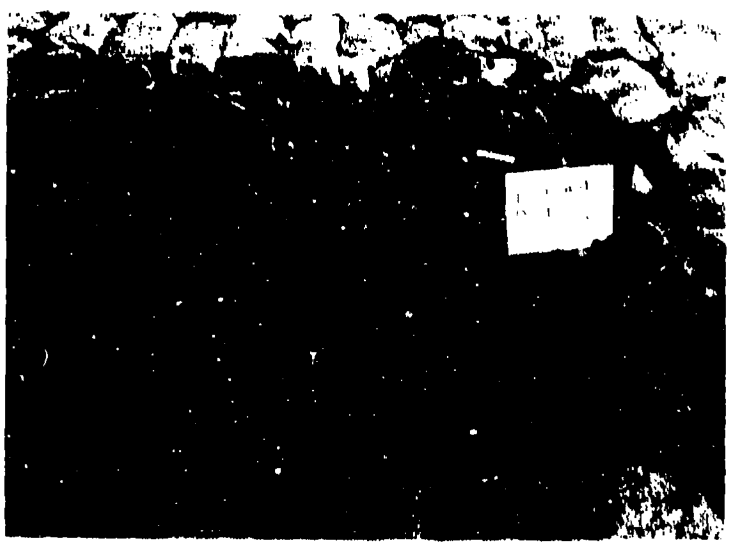

Figure I-8 (U): Damage from Round 1 (U).

Figure I-9 (U): Setup for Round 2 with 2 Feet of Sandbags (U).

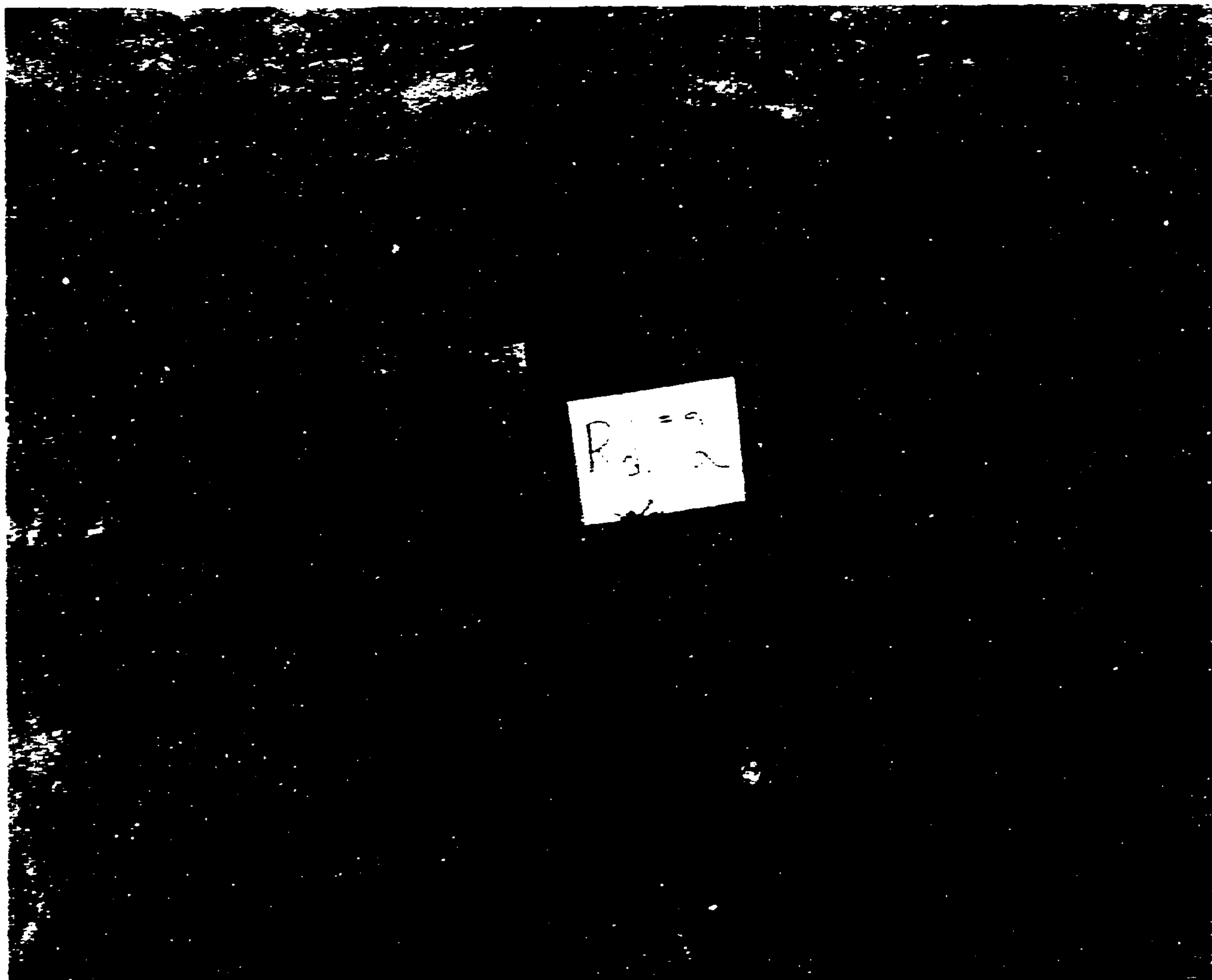

Figure I-10 (U): Damage from Round 2 (U).

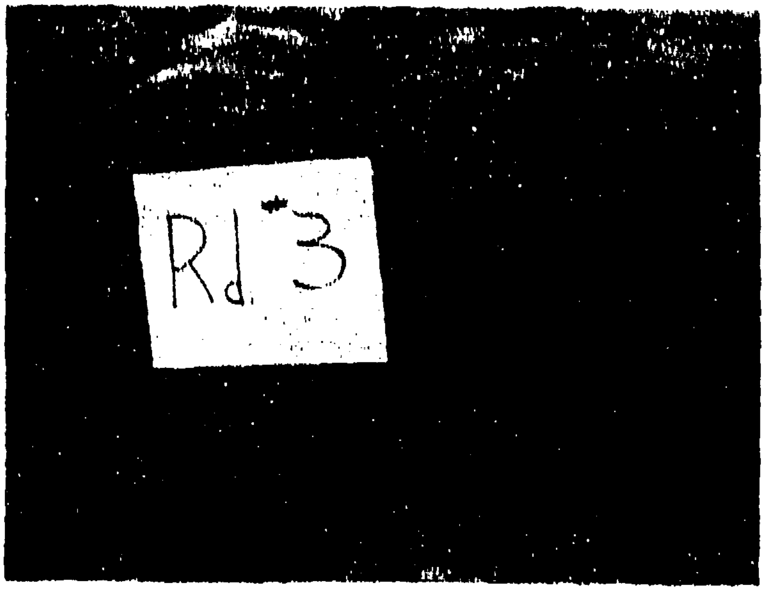

Figure I-11 (U): Setup for Round 3 (U).

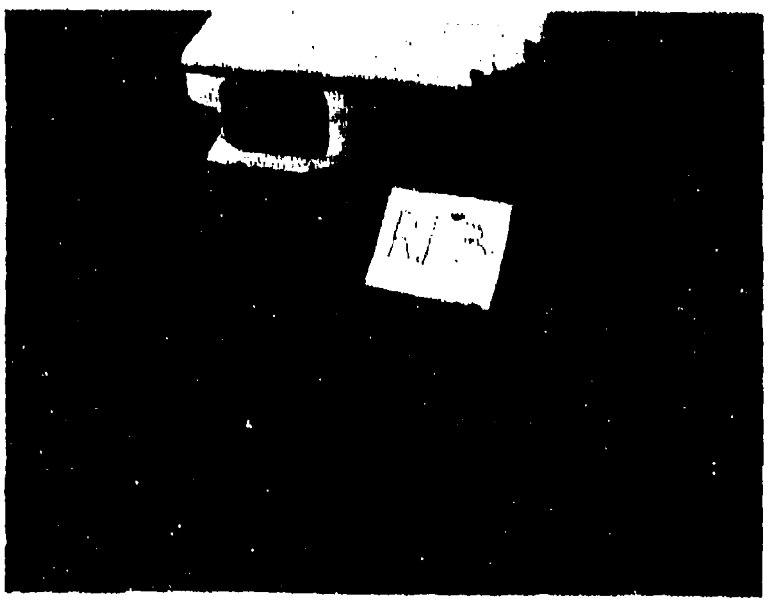

Figure I-12 (U): Damage from Round 3, First View (U).

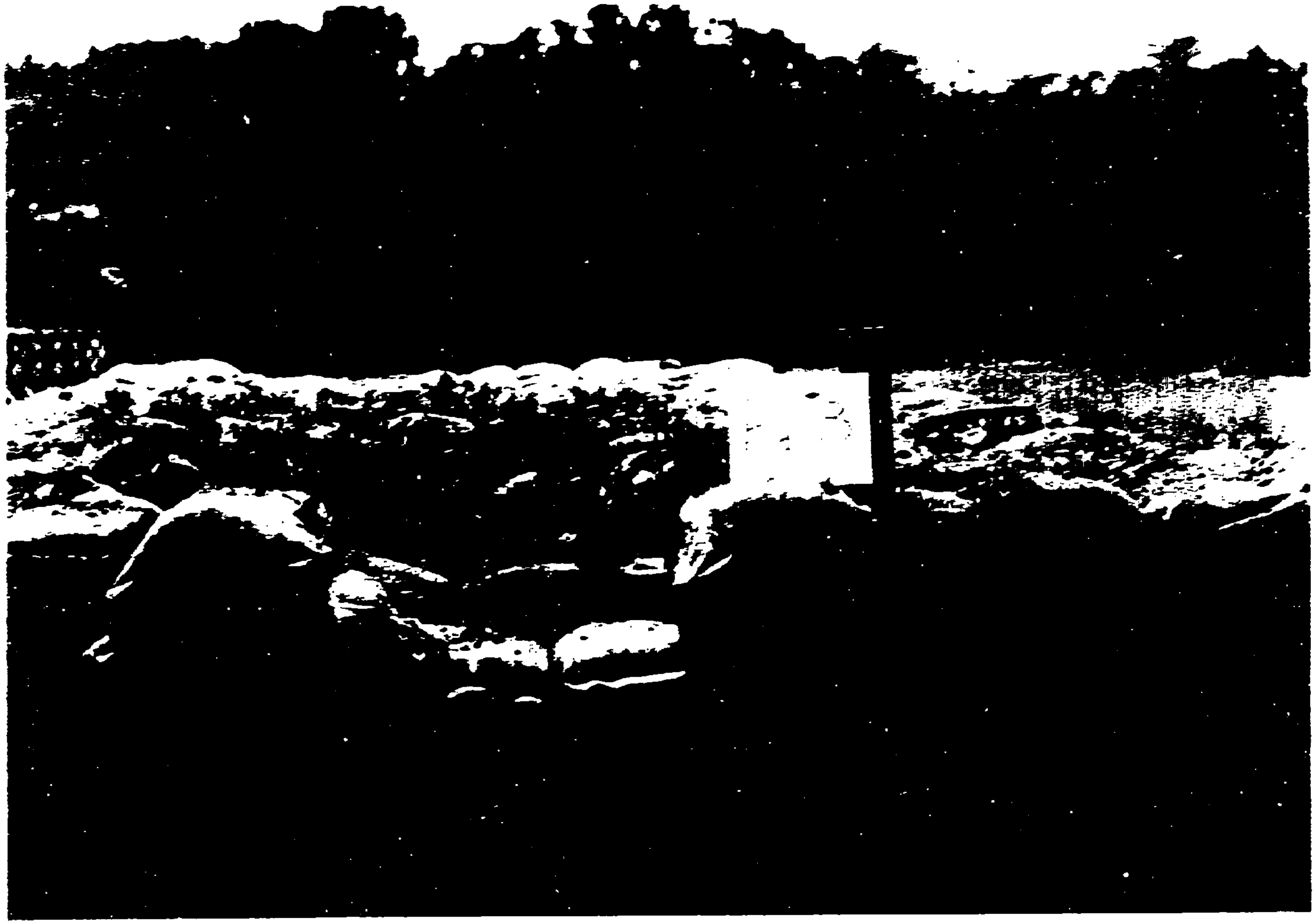

Figure I-13 (U): Damage from Round 3, Second View (U).

Figure I-14 (U): Setup for Round 4 (U).

Figure I-15 (U): Damage from Round 4; Top of Module (Arrow) Is Exposed by Blast (U).

Figure I-16 (U): Damage to Module from Round 4; Note Broken Weld (U).

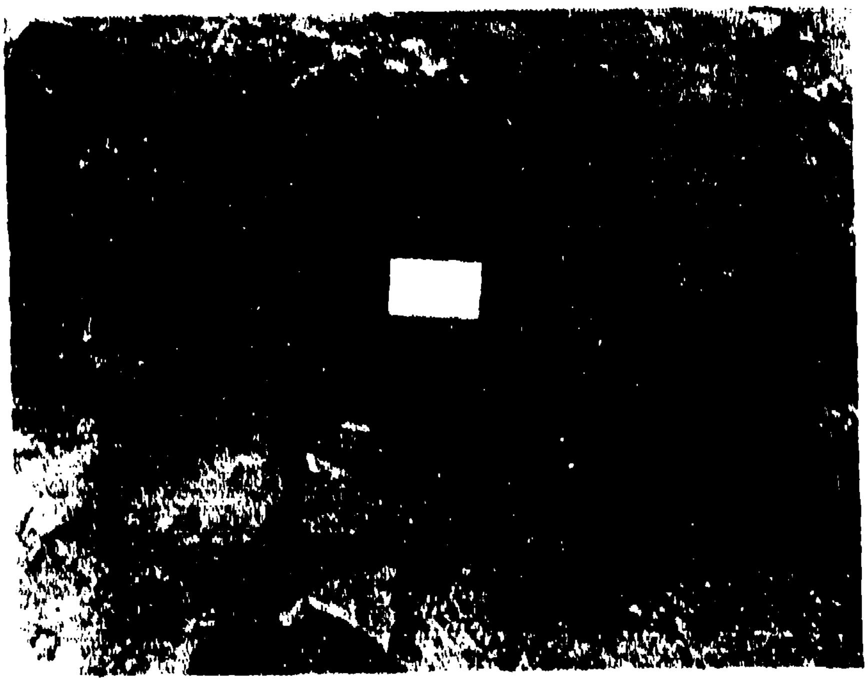

Figure I-17 (U): Damage from Round 5 (U).

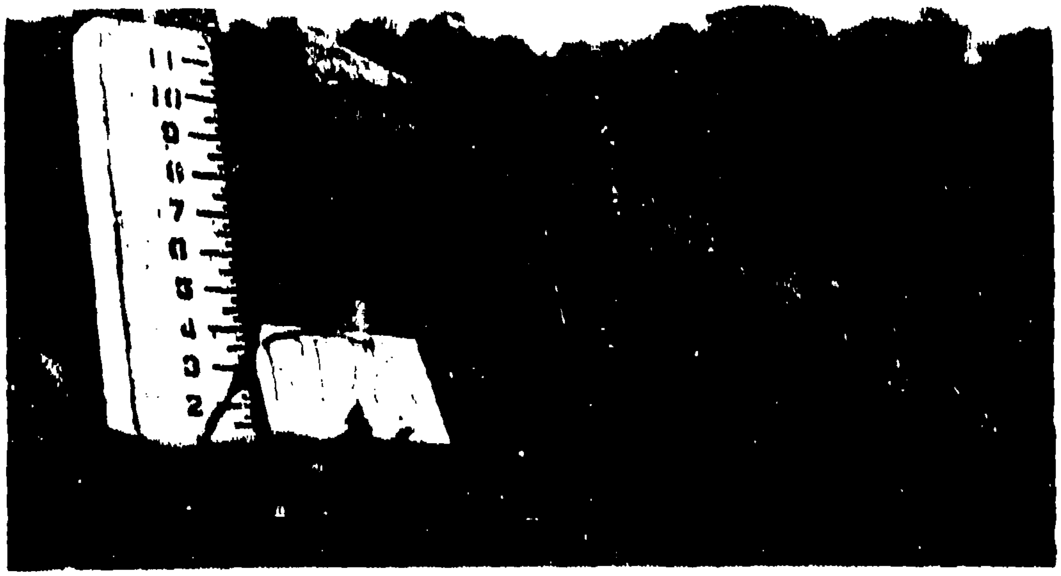

Figure I-18 (U): Setup for Round 6 (U).

Figure I-19 (U): Five Feet of Sandbags between Round and Module for Round 6 (U).

Figure I-20 [redacted] Damage to BTOC from Round 6 (U).

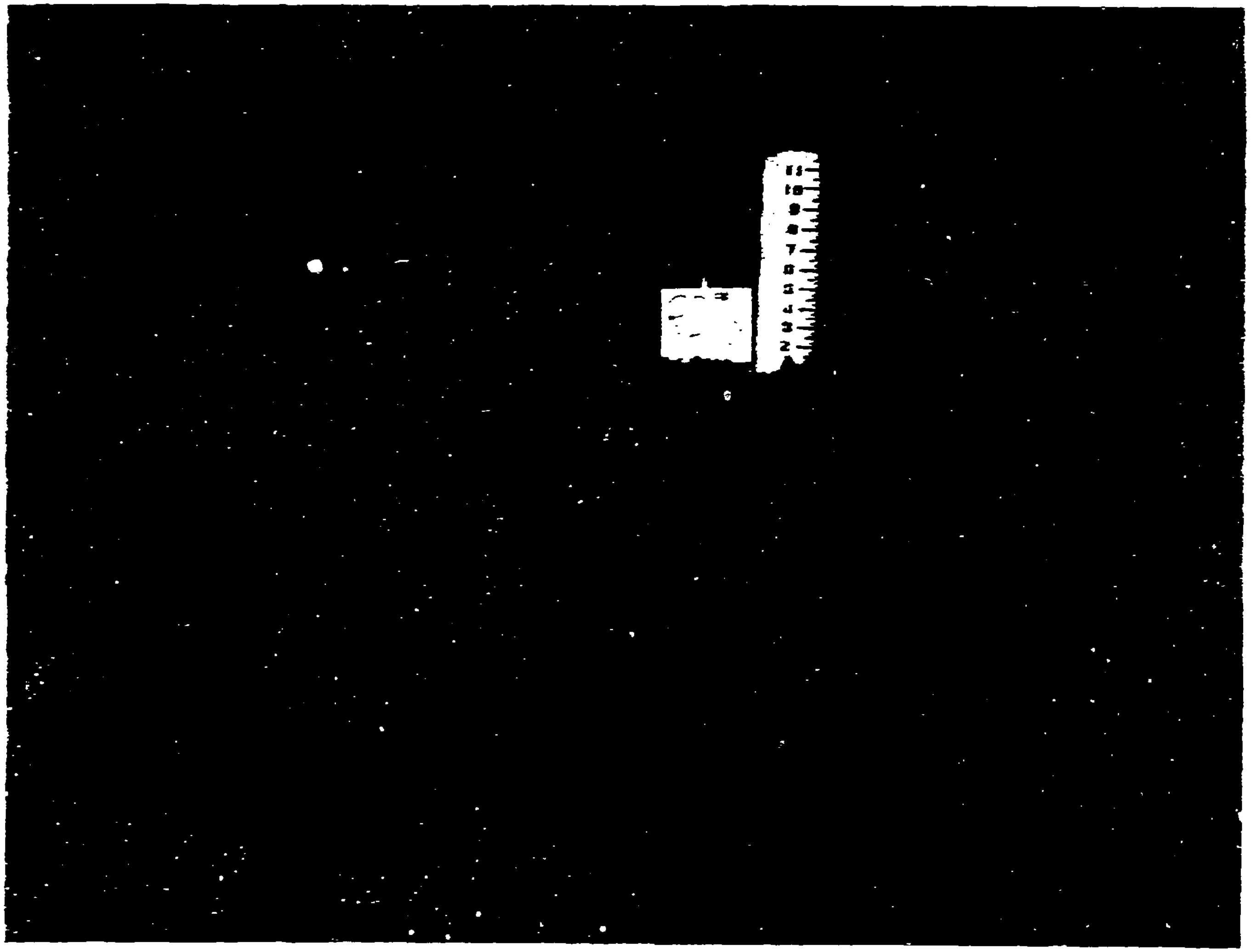

Figure I-21 [redacted]: Damage from Round 6 (U).

Figure I-22 [redacted]: Damage to Module from Round 6; Note the Sway in Roof Line (U).

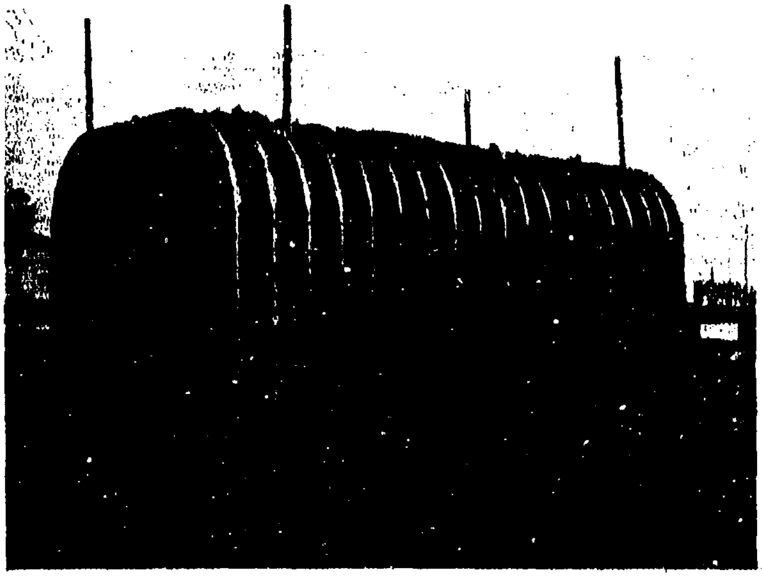

Figure I-23 (U): The BTOC Module II (U).

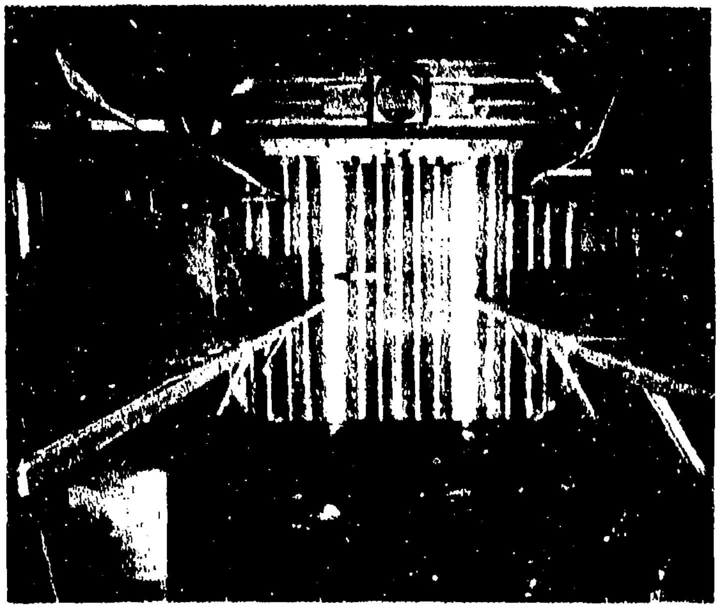

Figure I-24 (U): Inside of the BTOC Module II (U).

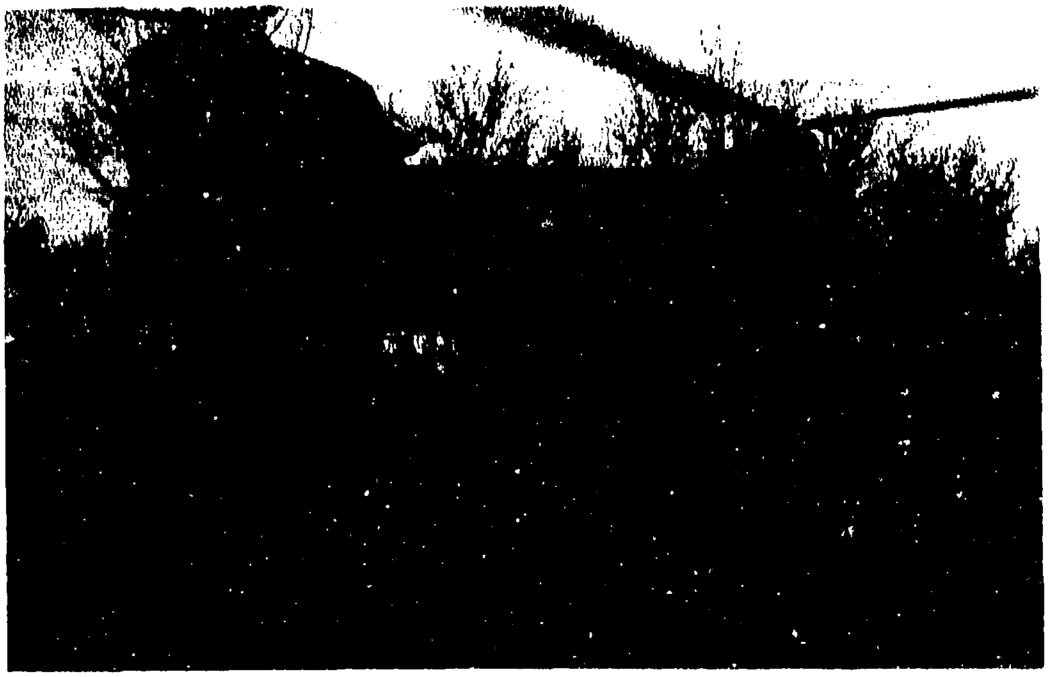

Figure I-25 (U): The BTOC Being Connected to a CH-47 Helicopter (U).

Figure I-26 (U): The BTOC Being Transported by CH-47 (U).

Figure I-27 (U): The BTOC Being Lowered to the Ground after Transported by Air (U).

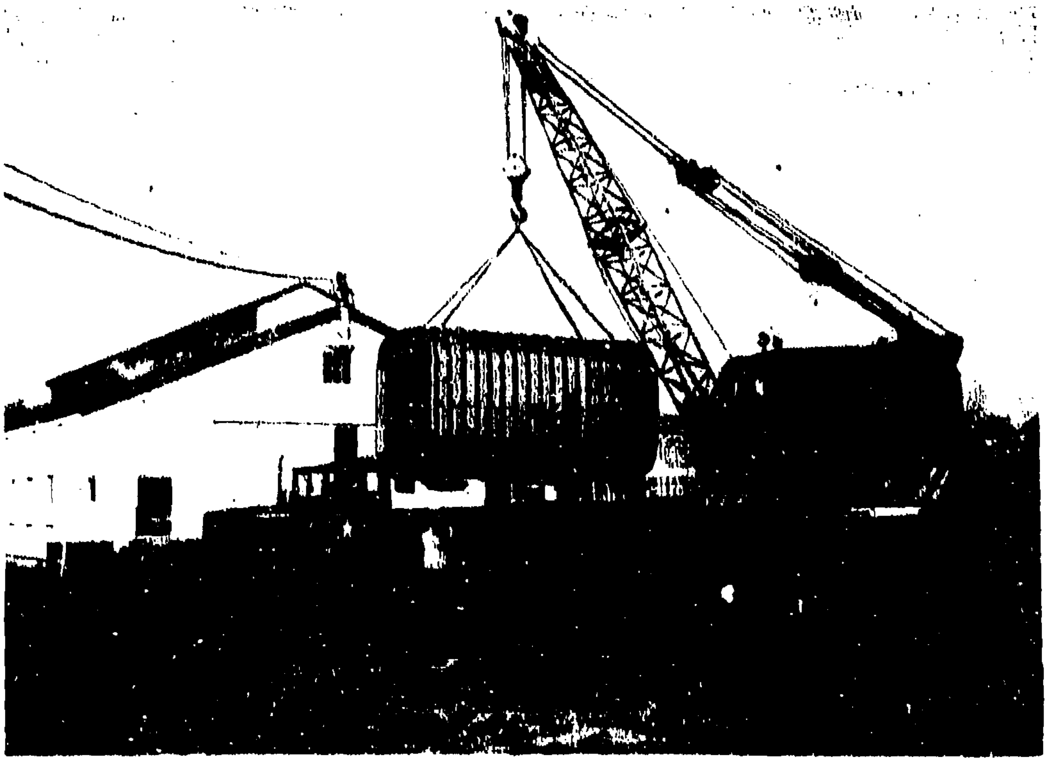

Figure I-28 (U): The BTOC Being Loaded on the M36A2 2-1/2 Ton Truck (U).

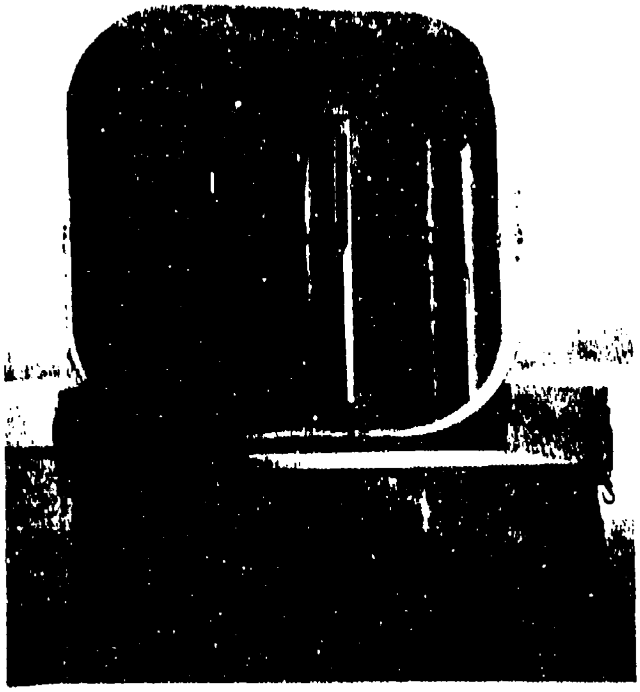

Figure I-29 (U): The BTOC Loaded on the M36A2 (U).

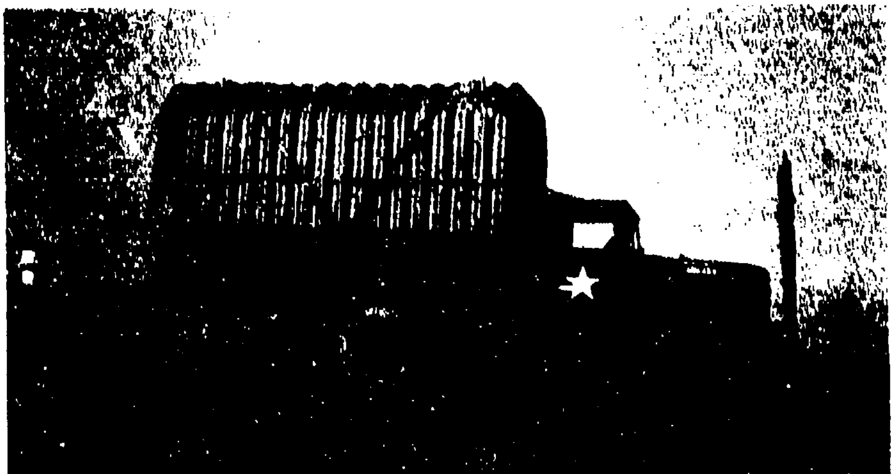

Figure I-30 (U): The BTOC Loaded on the M35A2 2-1/2 Ton Truck (U).

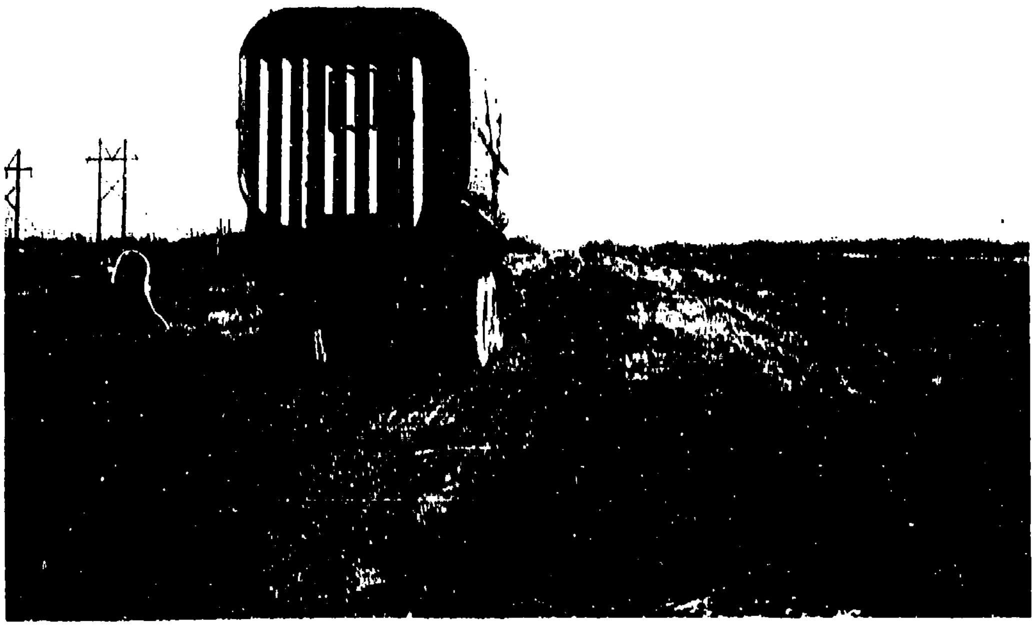

Figure I-31 (U): The BTOC Being Transported on Cross-Country Roads (U).

Figure I-32 (U): The BTOC Being Transported on Hilly Cross-Country Roads (U).

APPENDIX II - (U) REFERENCES

1. Test Directive, USATECOM, AMSTE-GE, Portable Battalion Tactical Operations Center, 28 May 1970.

2. Letter, USATECOM, AMSTE-GE, Amendment to USATECOM Project No. 7-ES-975-TOC-001, 25 September 1970.

3. Letter, US Army Aberdeen R&D Center, AMXRD-BVL, Enhancement in Blast Pressure Due to Motion of Charge, 20 August 1971.

4. Overbay, L., Engineer Design Test of Sandbag Bunker Kit. Aberdeen Proving Ground. Firing Record No. B-15731, 14 April 1970.

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APPENDIX III - (U) ABBREVIATIONS

BTOC	=	battalion tactical operations center
MTD	=	Material Testing Directorate
USALWL	=	US Army Land Warfare Laboratory
VC	=	Vietcong

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DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY (Corporate author)
Material Testing Directorate
Aberdeen Proving Ground, Maryland 21005

2a. REPORT SECURITY CLASSIFICATION

2b. GROUP
[redacted]

3. REPORT TITLE
ENGINEER DESIGN TEST OF PORTABLE BATTALION TACTICAL OPERATIONS CENTER (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
(U) Final Report 31 July 1970 to 28 May 1971

5. AUTHOR(S) (First name, middle initial, last name)
(U) Larry W. Overbay

6. REPORT DATE
(U) June 1971

7a. TOTAL NO. OF PAGES
(U) 36

7b. NO. OF REFS
4

8a. CONTRACT OR GRANT NO.
(U) Not applicable

b. PROJECT NO.
(U) USATECOM Project No. 7-ES-975-TOC-001

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
(U) APG-MT-3881

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT
(U) Distribution limited to U. S. Government Agencies only; Test and Evaluation; June 1971. Other requests for this document must be referred to Commanding Officer, US Army Land Warfare Laboratory, ATTN: CRDLWL-8C.

11. SUPPLEMENTARY NOTES
(U) None

12. SPONSORING MILITARY ACTIVITY
(U) USALWL

13. ABSTRACT

[redacted] An engineer design test of the Portable Battalion Tactical Operations Center was conducted at Aberdeen Proving Ground from 31 July 1970 to 28 May 1971. Testing consisted of a structural endurance test, a helicopter-transportability test, and a truck-transportability test. Slight damage occurred to the center during the structural endurance test, but it was easily transported by the CH-47 helicopter and by 2-1/2 ton trucks. It was concluded that the center (module I) can safely withstand the detonations of the Vietcong 82-mm and Soviet 122-mm rounds when it is sufficiently bunkered with sandbags; the center (module II) can be transported by air and land with relative ease.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Portable battalion tactical operations center						
Operations center, battalion, portable						
Helicopter transport of operations center						
Truck transport of operations center						
Tactical operations center						
Soviet 122-mm rocket						
Vietcong 82-mm round						
Sandbag						
Air-mobile operations						
Fire posts						
Remote outposts						