PHOTOGRAPH THIS SHEET

AD-A953 936

DTIC ACCESSION NUMBER

LEVEL

INVENTORY

Rept # 757 BR 372

DOCUMENT IDENTIFICATION

1 July 1943

This document has been approved for public release and sale; its distribution is unlimited.

DISTRIBUTION STATEMENT

DTIC SELECTED OCT 22 1984 E

DATE ACCESSIONED

BY

DISTRIBUTION STAMP

A-1

UNANNOUNCED

DATE RETURNED

84 10 01 001

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDAC

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

UNCLASSIFIED [redacted]

AD-A953 936

WAR DEPARTMENT

Report No. 757

FIRST INTERIM REPORT

COLLAPSIBLE CONTAINERS FOR PETROLEUM PRODUCTS STORAGE

17 September 1942 to 15 June 1943

ER 372

1 July 1943

...ION ONLY

... represent recommendations or conclusions of the Office, Chief of Engineers

TRAINING PUBLICATIONS & VISUAL AIDS FILE

TRAINING PUBLICATIONS & VISUAL AIDS FILE

TECHNICAL STAFF
THE ENGINEER BOARD
Corps of Engineers, U. S. Army
Fort Belvoir, Virginia

UNCLASSIFIED

DISCLAIMER NOTICE

10 August 1943

Informal Interim Report on Collapsible Containers for Petroleum Products Storage for Period of 15 June, 1943 to 1 August, 1943.

OBJECT:

This informal report is intended to cover the period of 15 June 1943 to 1 August 1943 in the development and service testing of collapsible containers for petroleum products storage. The period prior to this time is covered by Report No. 757 prepared 1 July 1943 by the Engineer Board. A formal second interim report which will contain approximately the same information as this report is now being prepared by the Engineer Board.

The period covered by this report is considered a transition period during which responsibility for development and procurement of the subject items is being transferred from the Office, Chief of Engineers to the Office of the Quartermaster General as per A.G.O. Memorandum W850-15-43 dated April 10, 1943. The transfer is considered retroactive as of July 10, 1943.

AUTHORITY:

At a conference on 13 July, 1943 with the Director of the Technical Branch, Fuels and Lubricants Division, Office of the Quartermaster General, it was decided that the Engineer Board would continue service tests now under way and terminate them as soon as possible without effecting final results. Information not contained in this report regarding the results of the tests will be forwarded when available directly to the Office of the Quartermaster General. In addition the Office, Chief of Engineers was requested at this conference to make a study of field failures of units as reported by the Atlantic Base Section in a field report of 12 June 1943.

DISCUSSION:

a. 7-Gallon Bags -

The Tank Destroyer Board of Camp Hood, Texas in a report of June 25, 1943 concluded, on the completion of tests of a number of bags, that due to failures the bags were not suitable for use by tank destroyer units. The bags tested were an earlier type of Thiokol "N" bag which had been shown previously, through Engineer Board tests, to have definite temperature limits. The Army Ground Forces, on the basis of this report, decided to cancel further service testing of seven gallon bags at the Fort Knox, Kentucky and Fort Bragg, North Carolina Boards and concurred with the recommendations of the Tank Destroyer Board. It is pointed out however, that the bags sent to Camp Hood were of an earlier design which have since been improved.

The Army Air Forces Materiel Command, in a report of June 5, 1943 had been approved for Army Air Force use a seven gallon bag with a rated burst strength of [illegible] per sq. in., constructed of 18.4 ounce fabric, impregnated with Thiokol MF latex. The recommendation was, however, withdrawn by the Army Air Forces as a result of failures of the same

[redacted]

type of bag when tested by the Desert Test Branch of the Engineer Board in the desert at approximately 110° F. ambient temperature.

A recent informal report from the Desert Test Branch stated that initial tests on the Kimberly-Clark glue-treated paper bags housed in fabric containers had resulted in successful exposure to desert sun under temperatures of approximately 110° F. during a three day period. These bags are now scheduled for intensive hauling, handling, and moisture exposure tests at the Desert Test Branch.

The United States Rubber Co. is furnishing a number of double-walled bags for service testing at the Desert Test Branch. The inside bags are of Thiokol FA or MF latex gum construction (without fabric) housed in fabric containers. The bags appear to have possibilities but have not been service tested so far.

As a result of the above tests it appears that single walled Thiokol bags, regardless of the type of Thiokol used, will give only limited temperature service and the Engineer Board does not believe that this type of bag can be sufficiently improved to warrant further testing. No further testing of this type of bag is planned at present.

However, double walled bags of the types outlined do appear to have possibilities and tests of these types, as noted above, should be continued.

B. <u>750 Gallon and 2700 Gallon Transportable Units and 1,000 Gallon and 3,000 Gallon Stationary Units as Covered by Corps of Engineers Tentative Specification T 1678.</u>

The first interim report noted the performance of test units in this class as being satisfactory but stated that tests being conducted at the Desert Test Branch had not been completed at the time the 1st interim report had been prepared.

Tests at the Desert Test Branch have proceeded satisfactorily on a 1,000 gallon unit of late manufacture and a 750 gallon unit of the latest design. The 1,000 gallon unit has successfully held gasoline without leakage for approximately 30 days when exposed to the desert sun at temperatures varying from 100° to 130°F. The 750 gallon unit has undergone a 700 mile road test filled with water from South Bend, Indiana to the Engineer Board, and an additional 500 mile road test at the Desert Test Section and was then turned over to an armored regiment for an approximate 30 day test in actual field maneuvers. The unit has successfully withstood all these tests and has now, together with the 1,000 gallon unit, been turned over to an engineer combat battalion in the desert for further testing. These tests, together with those noted in the 1st interim report show these units to be thoroughly satisfactory for unlimited temperature service.

An Atlantic Base Section report of June 12, 1943 on the actual field experience with these units indicated that the stationary units were fairly satisfactory but that the transportable units had given a very poor service due mainly to excessive, unrepairable leakage. Upon receipt of this report all present procurement was cancelled and two similar units, one of 2,700 gallon capacity and the other of 750 gallon capacity, which had been salvaged out of a sunken ship in the same shipments as the overseas bags, were examined at the A.S.F. Depot at Richmond, Virginia. No failures were apparent on visual inspection and it was decided to test the units further at the Engineer Board. These tests are now under way. It was decided, however, that the failures in overseas units were due mainly to two faults:

(1) Improper curing
(2) Poor seam construction

A third possibility, faulty packing methods was also believed a contributing cause in failures. Improper curing and poor seam construction had been found, through service testing by the Engineer Board to be underlying causes of failure of some of the first units tested by the Engineer Board. Both of these weaknesses have since been corrected as evidenced by the recent successful service testing of units at the Desert Test Section. A method of packing has also been developed that will reduce critical packing folds to a minimum and protect these folds with reinforcing material. Relief valves have been redesigned and the size of the intake opening increased and it is now concluded that these units should give satisfactory performance under all conditions for which the units were designed.

C. 21,000 Gallon Storage Unit

This collapsible unit which is designed for insertion into earthen containers is now being service tested at the Engineer Board and has successfully passed a preliminary water storage test. It is designed for dead-end insertion into a pipe-line or for bulk filling from tank cars, trucks, etc.

D. 100,000 Gallon Storage Unit

This unit has been successfully installed in a wooden-walled container at Langley Field, Virginia and is being used for 70 octane gasoline storage without trouble. The size of this unit, however, prohibits its manufacture on a very large production scale.

E. 50,000 Gallon Underground Storage Units

Five bags, each of 9,200 gallons capacity have been inserted in a heavy lumber underground container in high ground water under 4 feet of earth cover at the Homestead, Florida Air Field and the unit is now being tested. This unit is designed as a substitute for underground steel tanks and is intended to release critical steel for other purposes. A wooden container of simplified design is now under test at the Engineer Board.

F. Proposed Engineer Board Designs.

Service tests of units believed by the Engineer Board to be more satisfactory than present units in the 750 gallon to 3,000 gallon class have not been initiated to date. The Engineer Board is procuring one 750 gallon and one 3,000 gallon unit, both of new design, for testing.

[redacted]

If service tests are satisfactory similar units should be turned over to Army Ground Force and Quartermaster Boards and Army Air Force Training units to decide which types they prefer. In the meantime, units covered by Corps of Engineers Specification T 1678 should be procured and standardization initiated.

G. Navy Department, Bureau of Aeronautics

The Bureau of Aeronautics has successfully developed a 550 gallon cell of Thiokol impregnated fabric, 3 ft. in diameter x 10 ft. long especially adapted for use in pairs to fit along each side of standard 33 ft. rearming scows. In addition a cell of similar design, 2,000 gallons in capacity, 62 inches in diamete x 12 ft. long for use with a light weight woven flotation frame as a tow unit has been developed. Neither one of these cells are contained in outside housing. Another unit for underwater storage has also been developed.

H. Army Air Forces Materiel Command, Wright Field, Dayton, Ohio

Wright Field has developed the following units:
(1) 220 gallon for Army Air Force, 2 Wheel Utility Trailer
(2) 550 gallon for 1 ton Ordnance Trailer
(3) 660 gallon for 6 x 6, 2½ ton truck

A 1,000 gallon stationary storage unit similar to the one under procurement under Corps of Engineers Tentative Specification T 1678 has also been recommended for Army Service Force procurement. Items 1, 2, and 3 above are of single bag design, without housings and service tests to date have shown them susceptable to excessiv abrasion.

I. 55 Gallon Drums

The first interim report of the Engineer Board stated that no specific [illegible] had been started on the 55 gallon drum. Since that time, a treated 55 gallon wood keg has been [illegible]. It was filled with gasoline and is being given an exposure test at the present time. Box type units made of wood are on order from [illegible] Miller Lumber Co. of Bethesda, Md. These are barrel and half-barrel sizes. The manufacturer has made numerous preliminary tests and if his [illegible] are correct it is believed that his products will have considerable [illegible] can be built in sizes from 5 gallons to 55 gallons.

J. Units Available for Further Testing

1. The following units which are either on hand or under order by the Engineer Board are available for further tests:

a. One used housing 750 gallon (original design)
b. One unused 750 gallon bag (improved design)
c. Two complete used 2,700 gallon units (original design)
d. One used complete 750 gallon unit (improved design) on test by the Desert Branch
e. One used complete 1,000 gallon unit (original design but recent manufacture) on test by the Desert Test Section
f. One unused 3,000 gallon unit of a new Engineer Board design on order

[redacted]

[redacted]

g. One unused 750 gallon unit of a new Engineer Board design on order
h. One complete unused 300 gallon unit proposed by Structiform Co. of Chicago, Illinois.
i. One used housing of Engineer Board design for a 2,000 gallon unit.

CONCLUSIONS:

A. <u>7 Gallon Bags</u>

1. Single walled bags impregnated with Thiokol regardless of the weight of duck used will have the following approximate limited service:

a. Thiokol MF latex bags - 20°F to +90°
b. Thiokol FA bags - 20°F to + 90°F
c. Thiokol N bags + 10°F to + 90°F

2. Double walled bags with outside fabric housings and inside bag liners such as the Kimberly-Clark glue treated paper bags and the U. S. Rubber Co. Thiokol gum bags appear to have unlimited temperature possibilities.

B. <u>750 Gallon to 3,000 Gallon Units (As per Corps of Engineers Tentative Specification T 1678)</u>

1. These units have been improved and weaknesses as noted in the Atlantic Base Section report of June 12, 1943 corrected and it is now believed that these units will give satisfactory, unlimited service throughout all ranges of temperature.

C. <u>Bulk Storage Units in the +10,000 Gallon Class</u>

1. Tests to date have indicated that collapsible bags can be satisfactorily inserted in all types of inclosures, specifically in open earthen inclosures and above and underground wooden storage tanks and all of these types lend themselves to T/O use, conserve shipping space, and have a high degree of mobility, and conserve critical steel.

RECOMMENDATIONS

A. It is recommended that:

1. A decision be made through Headquarters, Army Service Forces whether a limited-temperature 7 gallon bag is required for T/O use.

2. Investigation and testing of double-walled 7-gallon bags be pushed to a speedy conclusion. If tests are successful, quantities of these bags should immediately be turned over to the Quartermaster General, Army Ground Forces, and Army Air Forces units for tests of utility in specific operations.

[redacted]

[redacted]

3. Headquarters of Army Service Forces should be requested to make a definite statement on the necessity of non-steel, small capacity containers to supplement the stock of 5 gallon steel cans.

4. Immediate steps be taken to initiate standardization of the 750 gallon and 2,700 gallon transportable units and the 1,000 gallon and 3,000 gallon stationary storage units as covered by Corps of Engineers Tentative Specification T 1673.

5. Testing of proposed Engineer Board designs in the 750 gallon to 3,000 gallon class be pushed with the object of determining their utility as compared with units of similar capacities as covered by Corps of Engineers Tentative Specification T 1673.

6. Information on collapsible bags used in bulk storage units of the +10,000 gallon class be circulated to the field and needs for units of these types to conserve critical steel determined.

7. Wooden boxes in the 5 gallon to 55 gallon class as proposed by the Eisinger Miller Lumber Co. of Bethesda, Maryland be thoroughly investigated..

8. Disposition be made of the various test units noted in paragraph "J" under the heading of "Discussion" in this report.

/s/
J. H. SONNTAG,
[redacted]
Equipment Development Branch,
Engineering Division.

/s/
R. H. McPherson,
Chief, Pneumatic Equipment Section,
Bridge Branch,
Engineer Board

[redacted]

UNCLASSIFIED

[redacted]

Report No. 757

FIRST INTERIM REPORT
17 September 1942 to 15 June 1943

457 (BR 372)

Containers, Collapsible for Petroleum Products Storage

1 July 1943

Submitted to

THE ENGINEER BOARD

Fort Belvoir, Virginia

(and/or)

The Chief of Engineers

U. S. Army

Washington, D. C.

FOR OFFICIAL ACTION

By

R. H. McPherson

Chief, Pneumatic Equipment Section

Bridge Branch

[redacted]

UNCLASSIFIED

Index

[redacted]

SYLLABUS

This report covers the investigation of collapsible fuel containers for the period of 19 September 1942, to 17 June 1943. During this period collapsible containers of 500 to 3000 gallon capacities designed by the U. S. Rubber Company and the Transportation Corps were investigated and tested. As a result of this investigation specifications and drawings have been prepared covering four sizes of containers having capacities of 750, 1000, 2700, and 3000 gallons. The report recommends that these designs be considered satisfactory for present contemplated procurement. However, it is apparent that the design of these containers can be improved, and this report further recommends that the proposed designs be tested with the least possible delay. One-man containers of various designs and made from various materials have also been tested. It is concluded that this size container is a desirable unit, although it is not satisfactory at its present stage of development. It is recommended that the present test program be completed but, if the results are unsatisfactory, the project be dropped. The investigation of 55-gallon containers and 21000-gallon storage units has only recently been started. There are sufficient possibilities apparent that the development should be continued.

[redacted]

RESTRICTED

I. SCOPE OF REPORT

1. This report covers the investigation and development work on Collapsible Fuel Storage Containers from the period of 17 September 1942 to 15 June 1943. The containers investigated can be divided roughly into five main types or classifications. With the exception of the 55 gallon drum all containers are collapsible. It is possible that the 55 gallon drum may eventually be made collapsible but investigations to date indicate that a more serviceable unit will result from the rigid container. The five types are as follows:

a. 7 Gallon Bag. - To be considered as auxiliary to the 5 gallon metal Blitz can.

b. 55 Gallon Drum. - To replace the 55 gallon steel drum.

c. Stationary Bulk Storage Containers. - 500 to 3000 gallon capacities.

d. Transportable Containers. - Trucks and railroad cars.

e. Stationary Bulk Storage Containers. - 5000 to 25,000 gallon capacities.

2. Although the containers are designed primarily for the storage and transportation of gasoline, many other liquids can be safely handled in them. The cells will withstand the highly aromatic fuels produced in the Near East (up to 40% aromaticity) as well as the liquids shown in Table I, Appendix "A".

II. AUTHORITY

3. The development program is being carried out under the following directives:

a. Letter from the Office, Chief of Engineers, dated 6 October 1942, subject: "Procurement of Impregnated Fabric Fuel Cells", file 457 SPESD, to the Commanding General, A.S. F., requesting that the Chief of Engineers be designated as the agency for the development and limited procurement of collapsible fuel containers. The reasons for this request were two-fold.

(1) The Office, Chief of Engineers, was acting as the initial procurement agency for collapsible containers for Task Forces through the Transportation Corps, and

(2) The Corps of Engineers had previous experience on similar materials used in pneumatic equipment.

b. 1st Indorsement from A.S.F. to the Office, Chief of Engineers, dated 9 October 1942, file SPRMD 457.

c. Letter from the Office, Chief of Engineers, to the Engineer Board, dated 26 October 1942, subject, "Impregnated Fabric Fuel Cells," file SPESD 457.

d. Letter from the Engineer Board dated 19 November 1942, File 417 (BR 372) to the Office, Chief of Engineers, on the subject "Impregnated Fabric Cells", and 1st Indorsement thereto dated 27 November 1942.

e. Letter from the Office, Chief of Engineers, to the Engineer Board, dated 30 March 1943, subject "Cells for Storage of Petroleum Products", file SPESD.

f. Letter from the Office, Chief of Engineers to the Engineer Board, dated 24 May 1943, subject "55 Gallon Fuel Cells," File SPESD.

III. PREVIOUS INVESTIGATION

4. The investigation of Collapsible Storage Containers prior to the period covered by this report may be summarized as follows:

a. Commercial Investigation. One of the earliest conceptions of collapsible fuel containers is covered by a U. S. patent (No. 21025,90) assigned to the Glenn L. Martin Company. The development is known as the "Mareng" cell, and this name is an abbreviation of MARtin ENGineering Company. The patent primarily covers cells for use in aircraft although other uses were foreseen. One of the principal claims covered by this patent is that the inner fuel holding unit is larger than the outer supporting structure.

b. Army Air Corps. An investigation of collapsible fuel containers has been under way at Wright Field since the early part of 1941. Reports from Wright Field dated 22 and 23 January 1943 conclude that small transportable units are both practical and desirable but that the idea is not practical for very large units. (See Appendix "B" for complete report).

c. Navy Department, Bureau of Aeronautics. - A recent report dated 10 May 1943, states that transportable units up to 3000 gallon capacity are entirely satisfactory. Development of units of various sizes is continuing by the Bureau of Aeronautics.

d. Investigations Concerned Specifically With 40% Aromatic Gasoline.

(1) Other Federal Agencies. - The National Bureau of Standards and Naval Research Laboratory have studies the effect of 40% aromatic gasoline on various materials. The investigation is primarily concerned with lining material suitable for bullet proof fuel tanks in military aircraft.

(2) The Thiokol Corporation has developed the synthetic rubber known by the trade name of "Thiokol". The principal use of this synthetic is in the manufacture of equipment which handles or comes in contact with gasolines and all types of oil. Its ability to present the action of these solvents has been its outstanding characteristics. The principal disadvantages are its coldflow properties and the fact that it is thermo-plastic. Thiokol Corporation maintains a laboratory which is constantly striving to improve the product and to find new uses for it.

(3) Permanent Rigid Tanks. The Bureau of Yards & Docks of the Navy Department and the Construction Division of the Office, Chief of Engineers, have installed numerous underground storage tanks of exceedingly large capacity. Tanks built by the Bureau of Yards and Docks have been of prestressed concrete design whereas those built by the Office, Chief of Engineers, are of reinforced concrete. It has been found that these storage units can be satisfactorily coated with Thiokol Latex dipped fabric and Thiokol Type FA sheets.

(4) Semi-Permanent Tanks. The Construction Division of the Corps of Engineers has installed at Homestead Field, Florida, a 50,000 gallon bulk storage tank. This consists of five separate Thiokol coated fabric cells supported in a heavy wood structure. The cells are connected externally. The unit is designed for use underground. A unit of 100,000 gallon capacity has been installed at Langely Field, Virginia. The container is a single bag 12' x 24' x 48' supported within a rigid wood box. It is also made of Thiokol coated fabric. Neither of these units has yet been placed in operation.

IV. PRESENT INVESTIGATION

5. This investigation of collapsible fuel containers began with the initial procurement of cells for use by Task Force A. The procurement was initiated and completed without thorough testing

by any government organization.

6. The entire quantity of cells were furnished by the U. S. Rubber Company and consisted of the following quantities:

Size	Quantity
500 gallon	500 units
750 "	1000 "
1000 "	1000 "
2700 "	200 "
3000 "	200 "

7. The basic design of the 2700 gallon unit was worked out by the Transportation Corps in conjunction with engineers of the U. S. Rubber Company at Camp Claiborne, Louisiana, in October, 1942. The unit adopted was designed for rail transportation and was given a 700 mile rail test filled with varying amounts of water. The 750 gallon truck-mounted unit was patterned after the 2700 gallon unit.

8. Liaison was established with the Transportation Corps, the Quartermaster Corps, and the Ordnance Department as potential users of this type of equipment within the A.S.F. Liaison was also established with the Bureau of Aeronautics, Navy Department, the Material Command of the Army Air Forces at Wright Field, and the Office of the Air Engineer were definitely interested in the development.

9. 7 Gallon Cell. The original design of this unit was submitted by the U. S. Rubber Company, and had been inspected by the Transportation Corps. The unit was made with Thiokol Type FA as the gasoline resistant material. 250 units were ordered for shipment to Fort Bragg, North Carolina and 50 to the Engineer Board on 29 September 1942. Upon receipt of the test cells at Fort Belvoir, it was immediately found that they could not be considered as serviceable units. It was practically impossible to either fill or empty the cells, and even when filled with considerable difficulty, the pouring spout could not be made liquid-tight. These early units were made with the pouring spout as an integral part of the bag.

10. Other rubber manufacturers were requested to present their ideas on suitable bags having the spout made as an integral part of the cell. All samples submitted were found to be unsatisfactory. A discussion of the problem was held and the views of the Quartermaster Corps, the Transportation Corps and the Ordnance obtained. As a result of this discussion it was agreed that the adoption of a metallic bung or closure would be an immediate solution to the problem. Since flexible pouring spouts were already an item of issue for use with the steel can, it was agreed that the closure must be of such design as to permit the use of the flexible spout.

11. 250 new bags were procured from the U. S. Rubber Company. The closure used was similar to the metal bung used in a 55 gallon drum. It was of the screwed-in type and of such a size as to permit the use of the flexible spout. The gasoline resistant material was Thiokol Type FA.

12. 100 of this group of cells were tested at the Engineer Board. It was found that this type of closure could not be made liquid-tight unless great care was exercised in closing it with a wrench. A wrench; or tool of some kind, was also required to open it. Although the closure was unsatisfactory, the 100 bags were given a 5000 mile road test. During this test 36% of the bags failed due to improper design. These failures were in addition to the difficulty experienced with the closures. It was also determined that a bag having a higher bursting pressure was required. Laboratory tests on the material indicated that it was sufficiently resistant to the action of gasoline. All laboratory tests were conducted with 40% aromatic gasoline but road tests were conductedd with 80 octane fuel.

13. 100 cells were forwarded to the Quartermaster Board at Camp Lee, Virginia, for tests. As a result of tests by that organization it was recommended that the filler cap be improved and that the design be changed so as to permit the use of present auxiliary equipment. This applied specifically to filling with the whistling type dispensing nozzle which was in use at that time. Other changes were recommended but these had already been adopted as a result of other tests. Although more time was required to fill the bag than the metal can under blackout conditions, it was considered to be more serviceable, would permit transporting approximately 16% more gasoline on the $2\frac{1}{2}$-ton truck, and required about one seventh of the space when transported empty. (For complete report see Appendix "B").

14. No reliable figures were available on the quantity of bags which would be required if they could be proven satisfactory. However, there appeared to be a possibility of requirements for 5,000,000 bags for the [illegible] quarter of 194[illegible]. This would require approximately 6,[illegible] pounds of Thiokol FA or other synthetic rubber. Contact with WPB brought out that no such quantities were available unless Thiokol Type N could be used.

15. An additional 100 cells of an improved design and made of a Thiokol N compound were road tested. It was found that a reinforcement patch was required on the back of the container under the closure but that when this was applied failures would be under 5% in 5[illegible] miles. Container tests made at low temperatures in the Chrysler Laboratories in Detroit proved that a container made of Thiokol N could not be used at temperatures of 0° F. and below. Tests made by the Engineer Board Desert Test Branch proved that the bags would fail within a period of five hours when used at temperatures occurring in desert country. It is believed that the maximum safe temperature for Thiokol N type containers is 90° F.

16. A large number of manufacturers of rubber goods were interested in this development. In order to take full advantage of the research manpower of all these organizations without the necessity for a separate investigation of the ideas of each, an informal industry committee had been set up. A representative of WPB was also on the committee and close liaison was maintained with the Quartermaster Corps.

17. The development appeared to divide naturally into three separate problems as follows:

a. Container design.

b. Closure design.

c. Compounding and Processing.

The industry committee was therefore divided into three sub-committees to act on these separate problems.

18. As a result of the work of these committees a container which will meet the requirements and can be readily manufactured by a large number of manufacturers has been designed. An excellent closure has been developed although this is yet to be approved by the Quartermaster Corps. From the compounding standpoint, it has been determined that a container made of Thiokol N would have only a limited use. It could not be used at temperatures of 0° F. and below nor at approximately 90° F. and above. (See Appendix "B" for report by Desert Test Branch of Engineer Board). Further investigations by the Engineer Board of compounds suggested by the committee proved that Neoprene compounds were unsatisfactory.

19. It was obvious that a container having this limited use was undesirable. Contact with WPB brought out that, beginning about 15 August, additional plant capacity for the production of Thiokol FA would be in operation. It was estimated that approximately 200,000 pounds monthly could be diverted for use in these containers.

20. It was concluded that the containers would be entirely satisfactory providing Thiokol FA would stand up under desert temperature. Tests on large cells made of Thiokol FA had been satisfactory at -25° F. Additional containers were immediately ordered but these have not yet been delivered. In addition to testing these at Desert Center, some will be submitted for the approval of the A.G.F. and the Quartermaster Board. It is planned to submit containers made of Thiokol N to the A.G.F. but those furnished the Quartermaster Board will be made of Thiokol FA.

21. Various other materials have been investigated in this development. Of these, the two which appeared to warrant further consideration were Thiokol Latex and a glue-treated paper material manufactured by Kimberly-Clark Corporation. It has been informally reported that the Army Air Corps has found Thiokol Latex unsatisfactory in desert operations. Recent tests by the Desert Test Section of the Engineer Board verified this conclusion. The glue-treated paper bag must be contained within an outer canvas container. Units are on order for testing throughout all temperature ranges. One container was filled with approximately 7 gallons of gasoline and carefully weighed over a period of four weeks. At the end of that time, it had lost less than two liquid ounces.

22. One material required in the manufacture of the required glue-treated paper bag is glycerine, which is slightly critical at the present time. The Department of Agriculture has advised that about 1,000,000 pounds of glycerine would be available during the balance of this year for this equipment.

23. Possible Production of Seven Gallon Containers. As a result of investigations carried on to date it can be stated that an unlimited number of containers can be produced having a definitely limited use. These would be made of Thiokol N and would be satisfactory for use at temperatures between 0°F and 90° F. Manufacturing difficulties must be expected when Thiokol N is used. This is due to the difficulty of processing the material plus labor problems which will arise because of the extremely disagreeable odor of the material.

24. Dependent on tests now in progress, it is believed that containers having unlimited use can be manufactured at the rate of approximately 500,000 units per month by using Thiokol FA, and glue-treated paper.

25. <u>55 Gallon Drum</u>. The directive to develop a 55 gallon drum made of less critical materials than steel is the most recent directive. It is believed that this drum can be constructed of wood or plywood without an additional inner container. Preliminary models have been ordered but not yet received.

26. <u>Stationary Storage Containers</u>. Containers of 500, 1000 and 3000 gallon capacities have been tested at various places and by various organizations. A brief description follows:

a. <u>500 Gallon Container</u>. It is constructed of an inner cell of open weave fabric which is coated both inside and outside with a layer of Thiokol. The unit rests on a ground cloth of heavy cotton duck and is surrounded by a sleeve of the same material. When empty, or partially empty, it is supported by pickets placed around the supporting duck sleeve. The filler cap is held up by means of a rope tied to a supporting member which rests on two opposing pickets. Photographs are shown in Appendix B.

b. <u>1000 Gallon Container</u>. This unit is identical with the 500 gallon unit except for size. It weighs 365# and has a cubage of 23.85 cubic feet.

c. <u>3000 Gallon Container</u>. The inner cell is fabricated of the same material as the 500 and 1000 gallon sizes. The supporting sleeve is replaced with numerous interlocking plywood panels which gives a much more rigid structure. It weighs 945# and has a cubage of 61.4 cubic feet.

27. Various units have been tested at Fort Bragg, at Camp Lee by the Quartermaster Board, at Richmond, Virginia, by the Directorate of Base Services, by the Desert Test Section and Mountain Test Section of the Engineer Board, and by the Engineer Board at Fort Belvoir.

28. Since these units are similar in design it was believed that a testing program could be concentrated on the 500 gallon size. These tests indicated, in general, that such cells were satisfactory and desirable although details of design required revision. It was agreed by all concerned that the 500 gallon container was too small to be of value for practically all operations.

29. As a result of these tests it was found necessary to improve and enlarge the filler opening. This has been increased to a full six inches and has been redesigned to be leak-proof. The vent, filler cap and manhole have been combined into one unit which is the same for all of the bulk containers. Both the 1000 gallon and 3000 gallon units have three inch outlets at the bottom of the cell which permit emptying by gravity. Unless the containers can be placed on an embankment it would not be possible to fill vehicles by gravity except when the unit is full. Five gallon metal cans can be filled by gravity because of their low height. Tests by the Quartermaster Board also concluded that a more desirable method of supporting the top of the containers when only partially filled was necessary. This has also been done.

30. The 500 gallon cell has been used by the Mountain Warfare section of the Engineer Board at temperatures as low as -25° F. Cells of 500, 1000, and 3000 gallon capacities are now in use by the Desert Test Section of the Engineer Board and results to date are satisfactory.

31. Materials Required. Thiokol Type FA has been used in the construction of all cells tested. It has proved to be satisfactory in all tests to date, but those tests now being conducted near Desert Center must be completed before a maximum operating temperature can be determined. The following table gives an approximation of the amount of Thiokol FA required per container:

Size of Container	Pounds Thiokol FA
1000 gallon	105 pounds
3000 "	195 "

At present, 175,000 to 200,000 pounds per month of Thiokol FA are available for this development which includes the stationary units.

32. Present Status. Specifications and drawings are completed for both the 1000 and 3000 gallon units. However, it is not to be inferred that the designs should be considered final. Other designs are available and are believed to be superior to the present ones. Although they are believed to be satisfactory, further testing is desirable.

33. The proposed designs are similar to the 3000 gallon water tank already in use. Both these sizes are complete units in themselves and do not require any additional duck or plywood supports. For this reason they are more compact and can be installed or dismantled in less time.

34. Transportable Containers. For the transportation of gasoline by both road and rail vehicles, two collapsible containers of similar design have been developed. A unit of 750 gallon capacity can be mounted on the 2½-ton truck. The rail unit has a capacity of 2700 gallons and four of these can be set on a standard gauge flat car to give a total capacity of 10,800 gallons.

35. Rail Unit. The 2700 gallon unit was designed and tested by the Transportation Corps at Camp Claiborne, Louisiana. One of these units was given a 500 mile road test filled with water at Camp Claiborne and additional tests were made at Fort Belvoir using gasoline. The units showed no signs of failure as the result of these tests. Experienced railroad men said that the unit was handled as roughly at Fort Belvoir as it would ever be handled under normal operations. Only minor design changes have been made on the original Transportation Corps unit. These have been made mainly to reduce wear and to simplify assembly.

36. Design. The fuel containing unit consists of a cell constructed of Thiokol-coated open weave fabric with a suitable outlet and inlet. This is supported within a readily assembled plywood container of eleven sides. Plywood bulkheads at either ends of the container are held together by tie rods spaced at the intersection of the plywood panels. These rods take the stress set up by surges in starting and stopping. The pressure on the plywood panels is resisted by four steel bands which surround the units and which are tightened by turnbuckles. (This unit weighs 3126 pounds and has a cubage of 115.3 cubic feet.)

37. 2½-Ton truck Unit. The container for use on the 2½-ton truck is identical in design to the 2700 gallon unit except for being smaller in size. It weighs 1115 pounds and has a cubage of 60.5 cubic feet.

38. Tests with $2\frac{1}{2}$-Ton Truck. This unit has been tested by the Quartermaster Board, the Engineer Board and by the Desert Test Section of the Engineer Board. Some design changes were recommended by the Quartermaster Board and additional changes were made as a result of tests at Fort Belvoir. The unit was transported a distance of 5000 miles over rough roads at Fort Belvoir. The test was conducted with the cell completely filled with gasoline for about half the run and half full for the remainder of the run. No damage could be detected at the end of this test. Under desert conditions, a unit was road-tested for 500 miles by the Desert Test Section of the Engineer Board and then turned over to a gasoline dispensing company for actual use. The unit is still in operation in the California desert.

39. Proposed Designs. Although specifications and drawings have been prepared on both the 2700 and 750 gallon units described above, it is believed that these designs can be greatly improved and simplified.

40. A unit of 2000 gallon capacity has been designed and constructed for use in multiple on all types and sizes of military railroad cars. This unit will be more readily assembled and more rugged than the present 2700 gallon unit.

41. A unit of 750 gallon capacity consisting of an elliptically shaped bag and with no other supporting structure has been given a 5000 mile road test with water at Fort Belvoir. The test was made as severe as possible but only minor reinforcements were decided as being necessary as a result of this test. This unit requires approximately 20 cubic feet of shipping space and can be set up in a $2\frac{1}{2}$-ton truck in about fifteen minutes. A second unit is being made for test in the desert using gasoline.

42. 21000 Gallon Storage Containers. Three containers of 21000 gallon capacity are currently being procured. These are made of Thiokol FA coated fabric and are so designed as to require no rigid supporting structure. They are designed to rest in an earth excavation made with sloping sides. The angle of the slope will be the natural angle of repose of the soil. Some arrangement is required to support the roof of this structure such as a catenary cable supported from two poles at opposite ends of the cell.

43. The first such unit will be installed at Fort Belvoir. The other two units will be tested by the Bureau of Yards and Docks and the Army Air Corps.

V. DISCUSSION

44. General Features.

a. General Requirements. Collapsible Fuel Storage Containers are not as rugged as steel tanks erected for permanent use! This must be necessarily so because, to meet the requirements, they must be light in weight and readily and easily assembled and disassembled. Because of their extreme portability, they can be used as transportable units or for ground storage. The 750 and 2700 gallon units will serve equally well for ground storage or for transportation, the 1000 gallon unit can, in an emergency, be used to transport gasoline on a truck. Its capacity is such that it will overload the 2½-ton truck but it can be used safely on one of larger capacity. The 3000 gallon unit should not be considered as transportable. Probably the most important features of these cells is the small shipping space required and the minimum time required for placing them in operation.

b. Military Requirements. Collapsible Fuel Storage Containers should have the following military characteristics:

(1) Ability to store many types of liquids, including gasoline of 40% aromaticity without serious loss by diffusion, and without serious contamination to the stored liquid.

(2) Small cubage in knocked-down condition to conserve shipping space.

(3) Minimum time required for assembly and disassembly.

(4) Adaptability to camouflage.

(5) Light weight for ease in handling.

(6) Sufficiently rugged to withstand rough usage.

(7) Designed for emptying by gravity or pumping.

45. Advantages and Disadvantages of the Various Sizes.

a. Seven Gallon Container.

(1) Advantages. These are summarized as follows:

(a) When empty, requires about one seventh of the storage space needed for 5 gallon cans of equal capacity.

(b) Light weight. This permits hauling about 17% more gasoline on a 2½-ton truck.

(c) Will withstand rougher handling and higher pressures than the standard 5 gallon can. Bursting pressure should be 18-20 pounds per square inch.

(d) Can be suspended from many points about any vehicle.

(e) Quiet operation in handling.

(2) Disadvantages. These are summarized as follows:

(a) Longer filling time required with whistling type dispensing nozzle. This probably will not be true when using a nozzle with the automatic shut-off in the throat.

(b) Bags must be suspended while being filled.

(c) Longer time required for emptying.

(d) Approximately 25% more space required to store filled cells than is needed for 5 gallon cans.

c. 55 Gallon Drum. Since no tests have been made on units of this size nothing definite can be said. However, it is believed that a drum can be developed which will be equally as satisfactory as the 55 gallon steel drum. Its principal advantage will be that it will conserve steel.

d. Stationary Units.

(1) Advantages.

(a) Readily dispersed over storage area.

(b) Adaptable to camouflaging.

(c) Can be used in conjunction with existing pipe lines and other types of storage tanks.

(d) Portability.

(e) Can be placed underground above water table in stable soils.

(f) Readily assembled and disassembled.

(g) Small space required for transportation.

(2) Disadvantages.

(a) Not as rugged as permanent tanks.

(b) More expensive than welded or bolted steel tanks.

e. Portable Units.

(1) Advantages.

(a) Used for either ground storage or transportation.

(b) Because of ease in handling, transportation vehicles will not be tied up.

(c) Small shipping space required.

(d) Transporting in covered truck does not disclose nature of contents.

(e) Can be used with existing equipment.

(2) Disadvantages.

(a) Less rugged than permanent tanks.

(b) More expensive than welded or bolted steel tanks.

46. Requirements of the Gasoline Resistant Material.

a. Contamination. Tests conducted over a period of time by the Naval Research Laboratory and others have rather definitely determined that fuel contamination due to extracted material should not exceed 5 mgs/per 100 mls. for airplanes and 10 mgs/per 100 mls. for automotive vehicles. Tests show that the contamination approaches zero after about five days contact with the gasoline. This will generally mean that there will be no contamination of the gasoline after the bag has been used a few times. A graph showing the rate of contamination is found in appendix A.

b. Diffusion. The permissible rate of loss, or diffusion, of gasoline through the container material is an arbitrary figure. It is believed that if this diffusion did not exceed 0.15 fluid ounces per square foot per day, the material would be satisfactory. Transforming this into actual loss, it means that a bag filled to 7 gallons capacity would lose about one quart of liquid per month. This amounts to approximately 3½ per cent loss per month. However, this volume loss decreases with the larger size cells. For example, a 1000 gallon cell having the same rate of diffusion would loose about 5½ gallons per month or 1/2 per cent. The diffusion reaches a constant rate after about six days. Prior to that time, it varies somewhat. This is shown by the graph in Appendix A.

c. Pressure-Temperature Requirements. Ambient temperatures of 125° F. to 135° F. are not uncommon in the desert during the hot season. At such temperatures objects lying in the sun will have surface temperatures of 190° to 200° F. The liquid within a container such as the 7 gallon gasoline container would reach a temperature of 155° to 160° F. Because of the vaporization of the gasoline, pressures will build up at such temperatures to approximately 16 pounds per square inch. This maximum pressure is dependent on the temperature of the gasoline at the time the container is filled. Some additional allowance for stacking and rough handling must be added to this 16 pounds pressure, and it is believed that a satisfactory container must withstand a pressure of 18 - 20 pounds per square inch. For the lower limits of temperature, it is believed that all units should withstand a temperature of minus 25 to 30° F. Pressure is not important in the larger units because they are all equipped with suitable vents.

d. Other Requirements. In addition to knowing the contamination and diffusion characteristics of any particular compound, there are several other characteristics to be investigated. The cold flow property should be low and it should be resistant to the action of water. If the coating is applied to the outside as well as the inside of the container, it should have some resistance to abrasion.

VII. CONCLUSIONS

47. As a result of field and laboratory tests conducted on collapsible fuel containers by the Engineer Board and various other interested organizations, the following conclusions have been reached:

a. Collapsible containers having capacities up to 3000 gallons are practical and will fulfill the required military characteristics.

b. Collapsible containers can be designed for either ground storage or as transportable units and will not require a specially designed truck.

c. The 7-gallon bag is a desirable unit, although additional development work is required before it can be considered suitable.

d. A minimum of shipping space is required for containers of this type.

VIII. RECOMMENDATIONS

48. It is recommended that:

a. No consideration be given to collapsible fuel containers having capacities under approximately 750 gallons except a size suitable for handling by one man.

b. Collapsible fuel containers as described in paragraphs 26 b, 26 c, 36, and 37 for 1000, 3000, 2700, and 750 gallons be considered satisfactory for present contemplated procurement by the Office, Chief of Engineers.

c. Investigation of different designs as referred to in paragraphs 33, 40, and 41 be continued for the purpose of improving this equipment, and that this be concluded as promptly as practical.

d. Work be continued on a 55-gallon rigid type container to replace the present steel drum.

e. Proposed testing of the 21000-gallon unit be completed promptly at Fort Belvoir and, if satisfactory, that the unit be set up and service-tested in the California-Arizona desert area.

f. The present test program on the 7-gallon size container be pushed to a conclusion. If the results of this test program are unsatisfactory it is recommended that no further consideration be given to a container of this general design.

Submitted by:

R. M. McPherson
R. M. McPherson,
Chief, Pneumatic Equip. Section,
Bridge Branch.

Frederick J. Bogardus
Frederick J. Bogardus,
Major, Corps of Engineers,
Chief, Bridge Branch.

Forwarded:

Clayton E. Mullins
Clayton E. Mullins,
Lt. Col., Corps of Engineers,
Director, Technical Division IV.

APPENDIX A

First Interim Report

BR 372, Containers, Collapsible
for Petroleum Products Storage

APPENDIX A

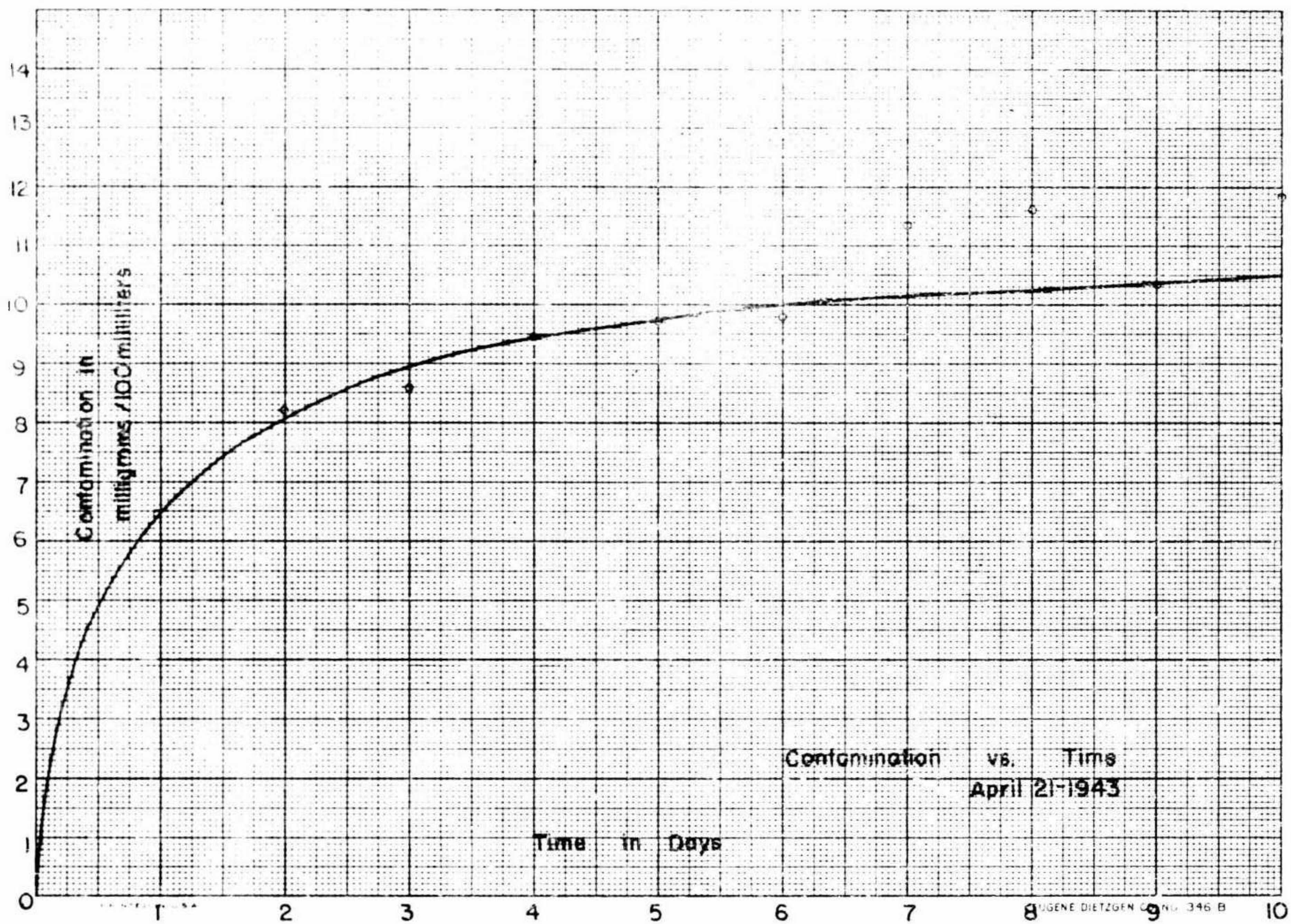
Table I

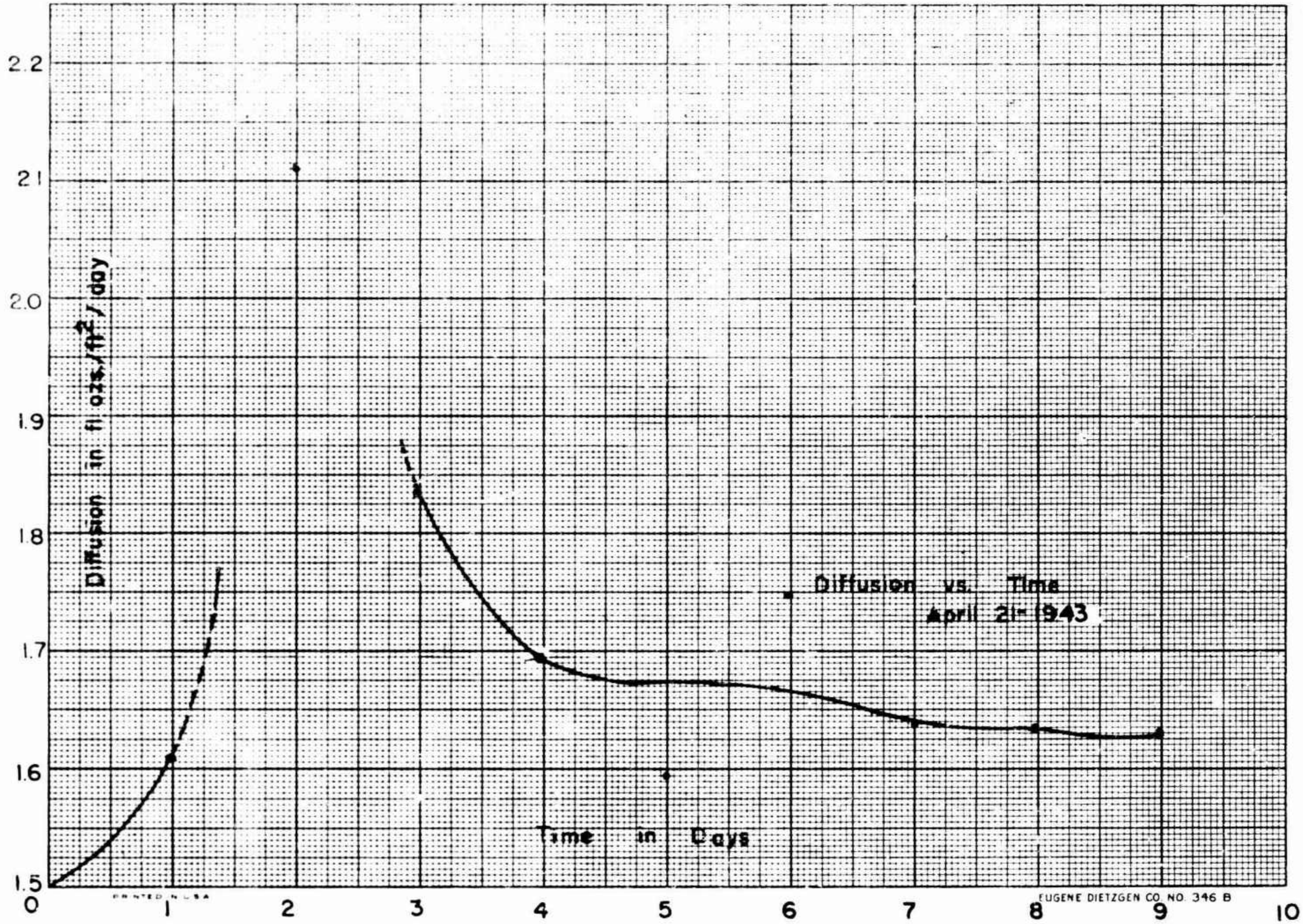
Liquids Which Can Be Transported

The liquids listed below can be safely transported in Collapsible Fuel Containers made with either Thiokol FA or Thiokol N as the liquid-containing material.

Gasoline-Straight	Corn Oil
Gasoline-Leaded	Soya Bean Oil
Gasoline-Blended	Alcohol
Gasoline-Aviation	Ethanol
Engine Oils	Acetone
Kerosene	Olive Oil*
Transil or Transformer Oil	Neats Foot Oil
Diesel Fuel	Quenching Oil
Distilled Water for Batteries	Tung Oil
Linseed Oil	Whale Oil
Cottonseed Oil	Turkey Red Oil
Lubricating Oils	Tallow Oil

*Not for human consumption.


Contamination in milligrams /100 milliliters
Contamination vs. Time
April 21-1943
Time in Days
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
EUGENE DIETZGEN CO. NO. 346 B


Diffusion vs. Time
April 21st 1943
Diffusion in fl ozs./ft² / day
Time in Days
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
0
1
2
3
4
5
6
7
8
9
10
EUGENE DIETZGEN CO. NO. 346 B

APPENDIX B

First Interim Report

BR 372, Containers, Collapsible for Petroleum Products Storage.

Appendix B contains reports from other organizations on collapsible containers for the storage and transportation of gasoline.

C
O
P
Y

ARMY AIR FORCES
MATERIEL CENTER
ENGINEERING DIVISION
MEMORANDUM REPORT ON

MRK:lmp:54-2095

Date January 22, 1943

SUBJECT: 5,000 and 10,000 Gallon Collapsible Fuel Storage Tanks.

Equipment Laboratory

Contract No.
Expenditure Order No.664-53(
Purchase Order No.

SERIAL NO. ENG-M-54-664-240-B

A. Purpose: To report on a trip to Sarasota Air Base, Sarasota, Florida, to make test installations of 5,000 gallon and 10,000 gallon collapsible fuel storage tanks.

B. Factual Data:

1. Both tanks were built over six months ago and were therefore made by the old method (i.e. cured first, then assembled from cured sheet instead of being assembled, then cured). They were, however, made of the same material of which most other tanks of this type are made; namely, a wide weave fabric impregnated with synthetic rubber. The 5,000 gallon tanks were built for underground installation, the sides of a hole in the ground supporting the tank. The 10,000 gallon tank, built primarily for above-ground installation, is a single cell unit with a collapsible plywood "structoform" type housing. (See Exhibits A, B, C - Photographs Nos. 106834, 106836, and 106837).

2. The tanks were shipped from Wright Field to Drew Field, Tampa, Florida, then re-shipped to Sarasota Air Base, Sarasota, Florida, as the latter base had no fuel storage facilities on the post, but relied upon fuel hauled via F-la refueling truck from leased commercial facilities four miles away.

3. Both tanks were set up in dispersed positions. The 10,000 gallon unit was so constructed as to make proper installation difficult if not impossible. The plywood panels were the 24 inch type designed for use with a 3,000 gallon tank. This made it necessary to use a large number of panels which brought the exterior angles of the prism very low. The panels are kept from collapsing outward by steel bands and turn buckles. It is supported against an inward collapse only by the degree to which adjacent panels are supported by each other, which in turn varies with the exterior angles of the prism. The cell itself weighed approximately 1,000 pounds. Properly supported when empty, the cell is held up by hooks joining the top edges of the cell to the top edges of the panels, with the top of the tank stretched almost flat. This throws a great load inward and downward on the panels. The structure could probably take this load

MDAC-266-WF-5-4-42-30M
Equipment Laboratory, Engineering Division
Memorandum Report No. ENG-M-54-664-240-B
January 22, 1943

a great load inward and downward on the panels. The structure could probably take this load after it was applied. However, the only practical method of setting a tank up is to have a crew of men go around the tank, reaching over the panels, pulling the cell up and hooking it panel by panel. This process will result at some point in the placing of a large load on five or six panels. This load would be great enough to pull these panels inward, collapsing the structure. On the installation at Sarasota, the cell was lifted about half way up and suspended in that position with ropes as may be seen in Exhibit D, Photograph No. 106835.

4. The 5,000 gallon tank was placed in a pit 17 feet 5 inches in diameter and 3 feet deep. The earth was of the best possible type - a firm loam with no rocks. The top of this unit was supported by four ropes crossing the tank and held by stakes driven into the ground at the edges of the pit. This installation was made easily and without incident.

C. Conclusions:

1. The wooden panels on the 10,000 gallon tank housing are too narrow to give proper rigidity and strength.

2. A simpler and more effective means of supporting the 5,000 gallon tank should be developed.

3. Tanks of these large sizes would be quite vulnerable to strafing by aircraft and would serve to concentrate an airdrome's fuel supply more than a greater number of smaller tanks.

4. Tanks of these sizes are rather unwieldy and may be transported or set up only on favorable terrain.

5. Great difficulty might be met in installing the underground tanks in rocky or soft ground or where many roots would be encountered.

D. Recommendations:

1. Pending the determination of military requirements for tanks of these sizes, it is recommended that further development be discontinued.

Concurrence:
....
....

Prepared by /s/ W. R. Knight, 2nd Lt., A.C.

Approved by /s/ G. V. Holloman, Colonel, A.C.
Chief Equipment Laboratory

Approved by F. O. Carroll, Brig.Gen., U.S.A.
Chief, Engineering Division.

Distribution:
Chief of Staff, AAF Mat.Com.
Central Files
Corps of Engineers,
(Att:Lt.J.H. Sontag)(O.C.E.)
Hdqrs.3rd Air Force(Att:Maj.G.M.Clark).

... st... tory, Engineering Division
...randum Report No. ...-210-B
... 195...

EXHIBIT A

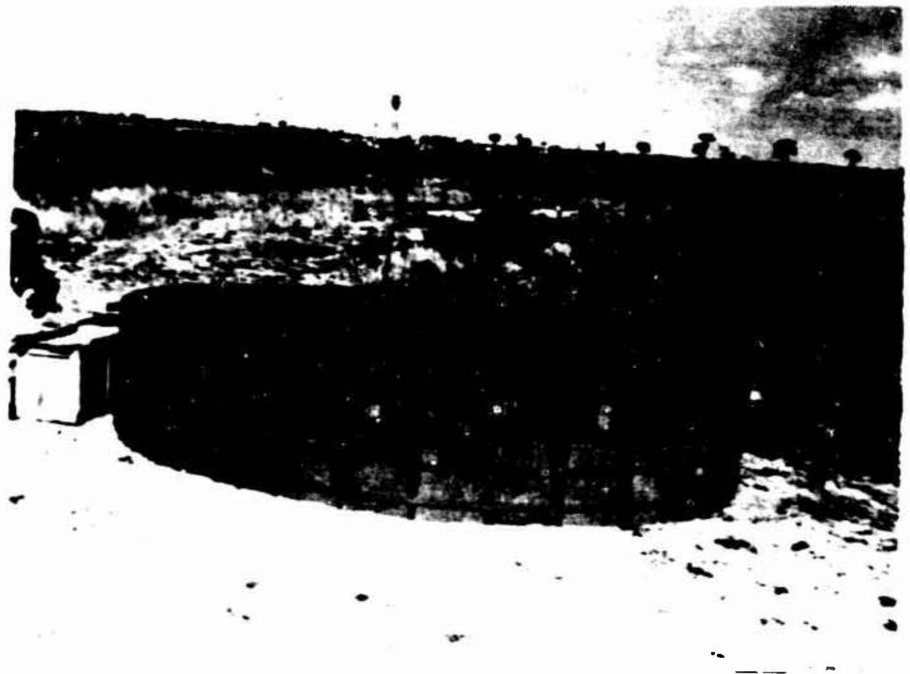
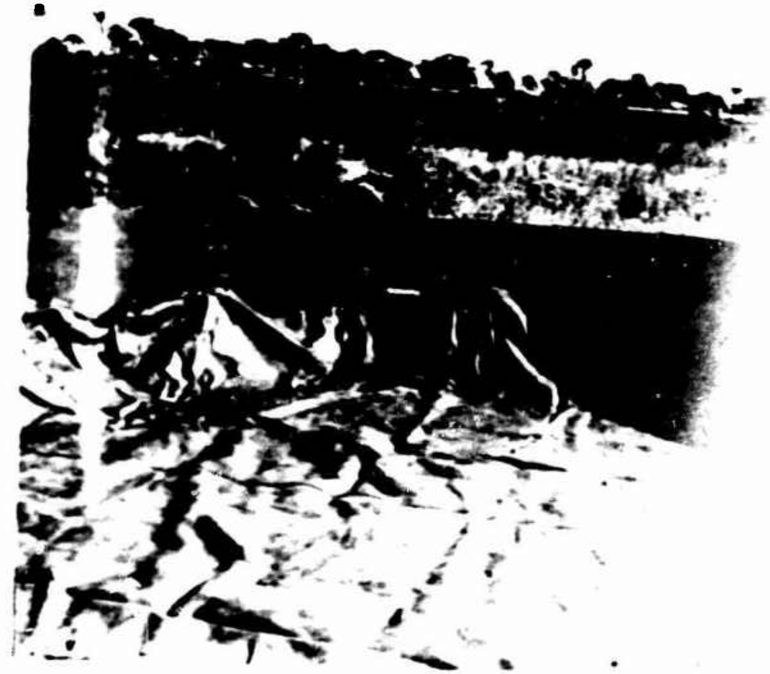


EXHIBIT B

EXHIBIT C

EXHIBIT C



C
O
P
Y

ARMY AIR FORCES
MATERIEL CENTER
ENGINEERING DIVISION
MEMORANDUM REPORT ON

WRK:lmp:54

Date January 23, 1943

SUBJECT: Collapsible Fuel Tanks, Mobile Units.

Equipment Laboratory

Contract No.
Expenditure Order No.664-530
Purchase Order No.

SERIAL No. ENG-M-54-664-240-C

A. Purpose: To report on the status of Expenditure Order No. 664-530 in regard to mobile units.

B. Factual Data:

1. After the initial development of collapsible ground fuel storage tanks, it was found feasible to develop collapsible tanks to fit in trailers and trucks to provide a simple means of transporting gasoline over short distances.

2. Three types of transportable units have been developed: a 550 gallon cell tailored to fit the standard Ordnance one ton trailer, a 220 gallon cell for the Army Air Forces two wheel utility trailer, and a 660 gallon two cell unit to fit the 2-1/2 ton 6 x 6 cargo truck. All cells were constructed of the synthetic rubber impregnated fabric previously tested and used successfully in the stationary units.

3. In designing a cell to fit the one ton trailer, it was necessary to devise a method of preventing the cell from snagging or rubbing through on any of the various bolt heads, nuts, or snipped bolts found on the inside of this trailer. The upper halves of the cell sides were tapered inward to clear the trailer side. Reinforcing patches enclosing felt buffers were placed on all parts of the lower half of the cell that would come in contact with obstructions. The cell was to be of 600 gallons capacity; however the initial cell had a capacity of 645 gallons. In order to fill properly, a cell of this type must be supported so as to retain an erect position when empty. For this support, the first cells had slots built into the sides in which 3/4" x 6" wooden uprights were inserted. The uprights were then tied loosely to the sides of the trailer. In the road test of the first cell, the surging of the liquid caused the fabric slots to be pulled away from the cell walls. With only an open vent, gasoline would leak out of the vent when the cell was on an uphill grade. The manhole door was made of Columbia Resin and contained an open vent and a 3-1/2 inch Bendix filler cap.

4. To support later cells, loop tabs were installed on two foot centers around the top corners of the cell and a rope run through them to form a ring completely around the top of the cell.

Smaller ropes were led off this ring to tie onto the overhead arches and the top horizontal member of the wooden sides. To replace the increasingly strategic Columbia Resin, manhole doors stamped of 20 gauge steel were developed. Efforts were made to get a satisfactory spring loaded vent, but it was not possible to get one that would trip consistently at the low pressure desired. A float type vent was then developed utilizing a ping pong ball that would rise to a thiokol seat when floated by gasoline. This vent, when tested, allowed vapors and air to escape without hindrance, but seated immediately when gasoline surged against it. To prevent water that accumulates on top of the manhole door from backing up into the tank, the outside of the vent takes the form of an inverted cup. To facilitate handling of fuel, a standard 2" drum fitting was added to the manhole door. The latest doors have the 3-1/2 inch Bendix filler cap replaced by a 6 inch filler of simplified design. This door is now standard on all collapsible fuel tanks, parts and doors being interchangeable. Six hundred and fifty gallons capacity exceeded the safe carrying capacity of the trailer, so the capacity was reduced to 550 gallons. A bracket of wood and steel was designed to clamp on the trailer sides and support a D-16 hand pump. This bracket is to be supplied with each cell. An A-6 pump or any pump having a suction line able to fit through the filler hole may be used with any tank having the standard manhole door.

5. Filled with water, the unit was coupled to a 1½ ton 4 x 4 tractor truck for a road test. The total weight on the two trailer wheels was 5,530 pounds, when coupled. After being towed over medium rough terrain for about 15 miles at speeds of about 20 to 35 miles per hour, the trailer showed no signs of failure or impending failure, although it was overloaded. There was no excessive abrasion or scoring of the cell apparent.

6. The initial 220 gallon cells were satisfactory after a few minor changes. A rectangular parallelopiped in shape, it fits the 2 wheel utility trailer as high as the stake sides where it is easily lashed in place. The manhole door developed for the 550 gallon cell was placed on this cell.

7. Filled with water for a road test, this unit weighed 2,330 pounds gross uncoupled; the trailer weighed 270 pounds. Coupled to a 1/4 ton 4 x 4 truck, the unit was road tested. The fuel trailer was towed for about ten miles over smooth and rough terrain at varying speeds. Some of the ground traversed was rough enough to cause both trailer wheels to leave the ground. After the run, although overloaded, the trailer showed no signs of failure or impending failure and there was no excessive abrasion of the cell apparent.

8. To avoid shipping specially built crash fire trucks to every overseas air base, a kit was made up containing all the materials necessary to convert any Quartermaster 2-½ ton 6 x 6 truck (cargo body) to a suitable crash truck. Collapsible cells are used to carry the water. The unit consists of two cells of 330 gallons capacity each, mounted fore and aft in the truck body, completely filling that space and 14" high. Two smaller cells were used in place of one large one to give a baffling effect and lessen the strains on the cell due to surging. The cells are supported in substantially the same way as the 550 gallon trailer cell. The pump, mounted in front of the truck, draws the water from a 2" bottom drain in each cell, holes for these drains being drilled through the bottom of the truck body. A special fitting has been developed for this drain incorporating a horizontal baffle plate two inches off the bottom of the cell and above the outlet to prevent vortices from forming and drawing air into the lines and pump. A standard filler door is placed in the top of each cell.

9. A two cell unit has been received from the U. S. Rubber Company, but the pump and nozzles have not arrived yet. This cell has not been tested in a truck as yet. Some difficulty may be expected from surging in the relatively flat tanks, but it is felt that it will be generally satisfactory.

10. This unit may obviously be used to carry aviation fuels. Other similar units may be built to carry a greater load by simply increasing the height of the tanks. An increase of 3½ inches would provide for a total load of about 830 gallons, which approximates the safe load of the truck.

C. Conclusions:

1. The mobile collapsible fuel tanks provide satisfactory transporting facilities for aviation gasolines and other liquids.

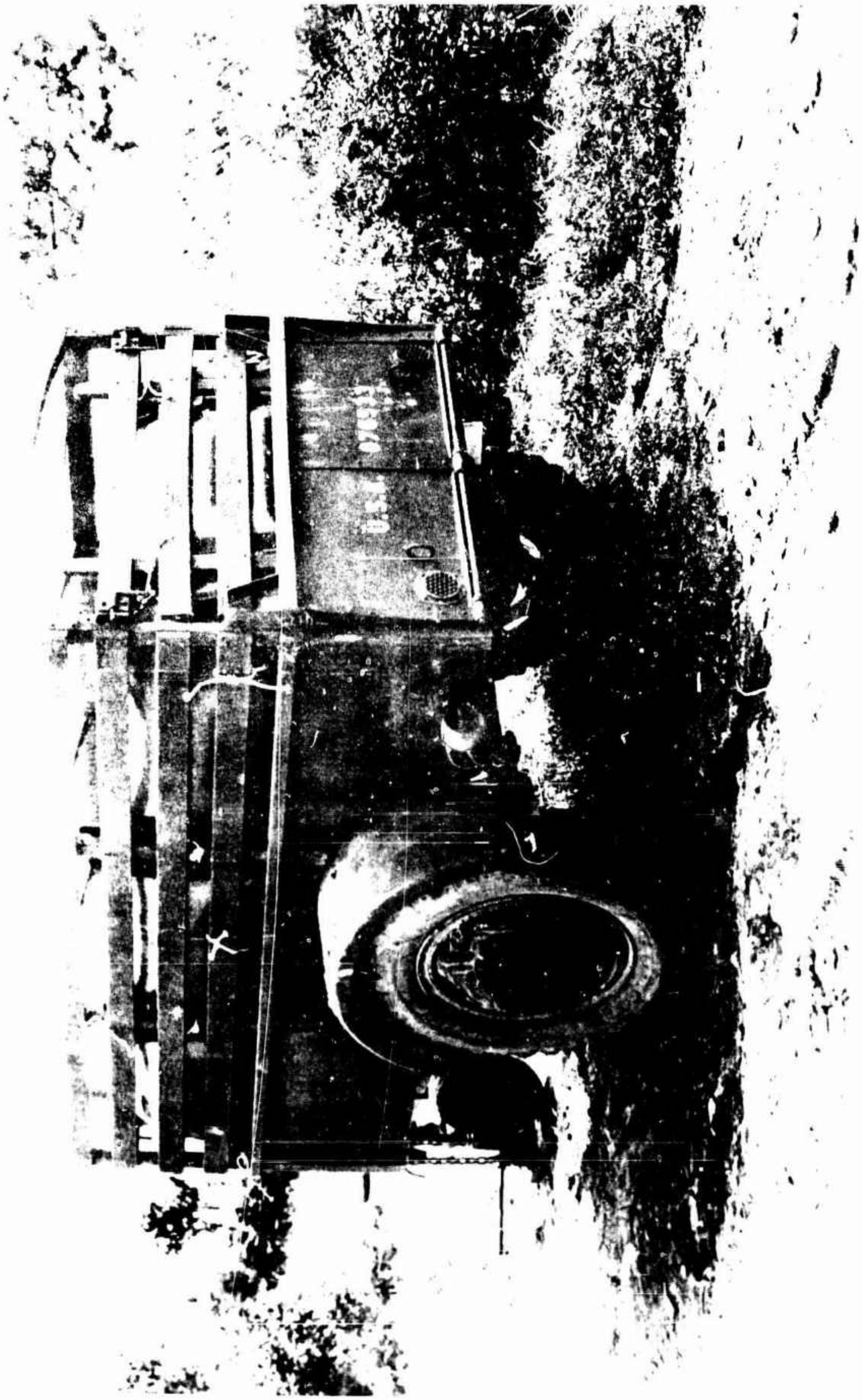
D. Recommendations:

1. That work on the development of such tanks be continued by the Equipment Laboratory of this office to improve this equipment and make it available to units in the field.

Concurrence:
....
....

Prepared by /s/
W.R.Knight, 2nd Lt.,A.C.
Approved by /s/Robert Davis,Maj.A.C.
For: G.V.Holloman,Colonel,A.C.
Chief, Equipment Laboratory
Approved by /s/ J.Minssn,Lt.Col.A.C.
For: F.O.Carroll,Brig.General,U.S.
Chief,Engineering Division.

Distribution:
Chief of Staff, AAF Mat.Com.
Central Files
Director of Military Requirements
AAF School of Applied Tactics, Orlando, Fla.
C.G., Air Forces Proving Ground Command, Eglin Field.



In Reply Refer To The Quartermaster Board
Camp Lee, Va.

February 7, 1943

QUARTERMASTER BOARD PROJECT T-98

REPORT OF TEST OF FUEL CELLS, COLLAPSIBLE

I. THE PROBLEM PRESENTED.

On December 14, 1942, The Quartermaster General, by letter, file SPQRD 400.112, directed the Quartermaster Board to conduct a test of fuel cells, collapsible, to determine the comparative utility and practicability of these cells with respect to standard equipment now in use.

II. PAPERS ACCOMPANYING.

1. Exhibit "A" - Letter, OQMG, file SPQRD 400.112, dated December 14, 1942, Subject: Fuel Cells, Collapsible - QMB T-157.

2. Exhibit "B" - Case Record of the Test (OQMG).

3. Exhibit "C" - Photographs showing the fuel cell, collapsible, stationary, 500-gallon, when set up in a wooded area and camouflaged.

4. Exhibit "D" - Photographs showing the fuel cell, collapsible, transportable, 700-gallon, mounted on 2½-ton 6 x 6 cargo truck.

5. Exhibit "E" - Photographs showing the fuel cells, collapsible, 7-gallon, piled on 2½-ton 6 x 6 cargo truck.

6. Exhibit "F" - Photographs of the fuel cell, collapsible, 7-gallon, showing deterioration of lining.

7. Exhibit "G" - Chart, showing comparison of space requirements for the fuel cell, collapsible, 7-gallon, and the can, gasoline, 5-gallon.

8. Exhibit "H" - Samples of fabric from the fuel cell, collapsible, 7-gallon.

9. Exhibit "I" - Diagram of the fuel cell, collapsible, transportable, 700-gallon, showing deficiencies in design and construction.

10. Exhibit "J" - Diagram of the closure on the fuel cell, collapsible, 7-gallon.

III. FACTS PERTAINING TO THE TEST.

1. Materials

a. The following materials were made available for test purposes by the Office of the Quartermaster General:

(1) One fuel cell, collapsible, transportable, 700-gallon, shipped to the Quartermaster Board from the Engineer Board, Fort Belvoir, Virginia.

(2) One fuel cell, collapsible, stationary, 500-gallon, shipped to the Quartermaster Board, from the Engineer Board, Fort Belvoir, Virginia.

(3) One-hundred and fifty fuel cells, collapsible, 7-gallon, shipped to the Quartermaster Board from the U. S. Rubber Company, Mishawaka, Indiana.

(4) Six nozzles, gasoline, cam-operated, shipped to the Quartermaster Board by the Motor Transport Division of the Ordnance Department.

b. The following materials used in the test were obtained locally:

(1) Twenty cans, gasoline, 5-gallon, standard issue, furnished by the 14th Provisional Truck Company, Quartermaster Replacement Training Center, Camp Lee, Virginia, were used as standards of comparison.

(2) One gasoline-driven dispenser unit, furnished by the Quartermaster Replacement Training Center Motor Pool.

(3) Two trucks, 2½-ton, 6 x 6, cargo, furnished by the 14th Provisional Truck Company, Quartermaster Replacement Training Center, Camp Lee, Virginia.

(4) Approximately 1300 gallons of gasoline, furnished by the 14th Provisional Truck Company, Quartermaster Replacement Training Center, Camp Lee, Virginia.

2. Personnel. - The test was conducted by personnel of the Quartermaster Board, assisted by 1st Lieutenant Comp of the Motor Training Division, Quartermaster Replacement Training Center, Camp Lee, Virginia.

3. <u>Information Required.</u>

a. What are the advantages and disadvantages of the fuel cell, collapsible, 700-gallon, transportable, and the fuel cell, collapsible, 500-gallon, stationary, with respect to the following:

(1) Camouflage and concealment.

(2) Transportation.

(3) Use with present auxiliary equipment.

(4) Time required for setting up and dismantling.

(5) Performance of the intake valve and outlet valve.

(6) Space required for storage when not in use.

(7) Durability.

b. What are the advantages and disadvantages of the fuel cell, collapsible, 7-gallon, with repect to the following:

(1) Transportation.

(2) Use with present equipment.

(3) Use with experimental equipment.

(4) Resistance to wear and tear.

(5) Space required for storage when not in use.

(6) Space required for storage when full.

(7) Adequacy of design.

(8) Ease of filling and emptying.

4. <u>Conduct of the Test.</u>

a. Camouflage and concealment.

(1) The fuel cell, collapsible, transportable, 700-gallon, was assembled and set on the body of a truck, 2½-ton, 6 x 6, cargo. The canopy of the truck was then replaced with the cell in place.

(2) The fuel cell, collapsible, stationary, 500-gallon, was set up and camouflaged in a wooded area.

b. Transportation.

(1) The fuel cell, collapsible, transportable, 700-gallon, was assembled and set on a truck, 2½-ton, 6 x 6, cargo. Road tests were conducted with the cell empty, half-full, and full, for approximately ten hours. 2" x 4" wooden braces were then added to the cell to prevent lateral shifting of the cell on the bed of the truck. A further road test of approximately five hours was made with the cell filled. The road tests included rapid acceleration and quick stops, travel over smooth and rough roads, and the climbing and descent of steep grades.

(2) The fuel cell, collapsible, stationary, 500-gallon, was loaded on a truck, 2½-ton, 6 x 6, cargo, and filled. The cell was then given a road test of approximately two hours similar to that given the fuel cell, collapsible, transportable, 700-gallon.

(3) Experiments were conducted to determine the best method of loading the fuel cells, collapsible, 7-gallon. A 2½-ton 6 x 6 cargo truck was then loaded with 72 of these cells filled with gasoline. The truck was then driven over rough and smooth roads for approximately two hours.

c. Utility.

(1) At various times during the progress of the test, the fuel cell, collapsible, transportable, 700-gallon, was filled by means of the regular filling station dispensing pump, the standard power-driven dispensing unit, the standard 5-gallon cans, and the fuel cells, collapsible, 7-gallon.

(2) The fuel cell, collapsible, transportable, 700-gallon, was used to dispense gas directly into the fuel tanks of twenty motor trucks of the 14th Provisional Truck Company. Observations were made to determine the saving in time gained by this method as against the present field method of dispensing using 5-gallon cans.

(3) At various times during the progress of the test, the fuel cell, collapsible, stationary, 500-gallon, was filled by gravity from the fuel cell, collapsible, transportable, 700-gallon, and from the standard 5-gallon cans and the fuel cells, collapsible, 7-gallon.

(4) The fuel cells, collapsible, 7-gallon, were filled from the following:

(a) The fuel cell, collapsible, transportable, 700-gallon, by the use of a standard dispensing hose.

(b) Drums, 55-gallon, by the use of hand-operated pumps.

(5) Fuel was dispensed from the fuel cell, collapsible, transportable, 700-gallon, by gravity, using a standard dispensing hose and whistling nozzle, the same as those with which the standard power-driven dispensing unit is equipped.

(6) Fuel was dispensed from the fuel cell, collapsible, stationary, 500-gallon, using the standard power-driven dispensing unit and a hand-operated fuel pump (for 55-gallon drums).

(7) The fuel cells, collapsible, 7-gallon, were filled from the fuel cell, collapsible, transportable, 700-gallon, by means of the standard dispensing hose, from the standard power-driven dispensing unit, and from 55-gallon drums using hand-operated pumps.

(8) A study was made of the time required for emptying the fuel cell, collapsible, 7-gallon, in daylight and under blackout conditions, as compared to the time required for emptying the can, gasoline, 5-gallon. Due to the design of the fuel cell, collapsible, 7-gallon, which precludes the proper use of the standard whistling type nozzle, no quantitative study was made of the comparative time required for filling.

d. Assembly and dismantling.

(1) A study was made of the time and effort required for setting up and dismantling the fuel cell, collapsible, transportable, 700-gallon, using a six-man crew. This operation was performed three times.

(2) A study was made of the time and effort required for setting up and dismantling the fuel cell, collapsible, stationary, 500-gallon, using a two-man crew. This operation was performed five times.

e. Inlet and outlet provisions.

(1) A study was made of the adequacy of design of the inlet and outlet provisions of the fuel cell, collapsible, transportable, 700-gallon, during the filling and dispensing operations.

(2) A study was made of the adequacy of design of the inlet of the fuel cell, collapsible, stationary, 500-gallon, during the filling and dispensing operations.

(3) A study was made of the adequacy of design of the inlet of the fuel cell, collapsible, 7-gallon, during the filling and dispensing operations.

f. Space required for storage.

(1) The space required for packing the fuel cell, collapsible, transportable, 700-gallon, and the fuel cell, collapsible, stationary, 500-gallon, was measured and recorded.

(2) The space required for storing 100 of the fuel cells, collapsible, 7-gallon, when empty and full, was measured and compared to that required for 120 of the cans, gasoline, 5-gallon.

g. Durability.

(1) Throughout the conduct of the test, examinations were constantly made for evidences of wear and deterioration in the fuel cell, collapsible, transportable, 700-gallon, and the fuel cell, collapsible, stationary, 500-gallon.

(2) Fifty of the fuel cells, collapsible, 7-gallon, filled, were loaded and thrown off a 2½-ton 6 x 6 cargo truck a total of twenty-five times. Ten of the cells were picked out at random and the operation repeated seventy-five more times. The cells were examined during the test and any cells which failed were set aside and marked for identification.

(3) Five of the fuel cells, collapsible, 7-gallon, were thrown off a truck moving at a rate of approximately 35 miles per hour. This operation was repeated until all five cells had failed.

(4) Two of the fuel cells, collapsible, 7-gallon, were dropped from a height of three, six, and nine feet, first on the side, then upright, and then on the top, one cell being dropped on earth and one on a hard surfaced road. This cycle was repeated a maximum of fifteen times from each height and cells which failed before this cycle was completed were withdrawn.

h. Adequacy of design. - The fuel cell, collapsible, transportable, 700-gallon, the fuel cell, collapsible, stationary, 500-gallon, and the fuel cells, collapsible, 7-gallon, were carefully observed throughout the test to note any points of inadequate or improper design.

IV. FINDINGS.

1. Fuel Cell, Collapsible, Transportable, 700-gallon.

a. Camouflage and concealment.

(1) The cell may be camouflaged beneath the canopy of a truck, 2½-ton, 6 x 6, cargo. (See Exhibit "D").

b. Transportation. - When making sudden stops or swerving around corners on a rough road, considerable shifting of the fuel cell occurred, particularly when it was only partially filled. This was overcome by placing the cell against the extreme front of the bed and providing 2" x 4" wooden braces to prevent lateral shifting. (See Exhibit "D").

c. Utility.

(1) No dispensing equipment was provided with the fuel cell. (See Exhibit "I").

(2) There is an estimated saving in time of 25% or more, a saving of equipment, and a saving in labor, through the use of the cell for dispensing directly into the tanks of motor vehicles in place of the present method of dispensing through 5-gallon cans.

d. Assembly and dismantling. - The time required for assembly and dismantling after two preliminary trials was as follows:

Assembly - 3 hrs. 10 min.
Dismantling - 1 hr. 6 min.
(Crew of six men used)

e. Inlet and outlet provisions.

(1) The inlet opening can be used with the can, gasoline, 5-gallon, the fuel cells, collapsible, 7-gallon, and the dispensing nozzles of the standard power-driven dispenser unit.

(2) The inlet opening measures 3" in diameter, which is too small to permit the entry of a standard discharge hose from a railway tank car or the suction hose from the standard power-driven dispenser. (See Exhibit "I").

(3) The outlet fitting was difficult to install. Standard 3" pipe fittings were supplied for attachment to the outlet, requiring the use of a 24" pipe wrench, which might not be available in the field. It was difficult to secure leakproof joints. (See Exhibit "I").

f. Space required for storage. - The unit can be packed in three boxes or crates having the following dimensions and cubic displacement:

	Length	Width	Height	Cubic Displacement
Cell proper	78 in.	34 in.	16½ in.	26.4 cu. ft.
Bulkheads	62 in.	4½ in.	59 in.	8.6 cu. ft.
Panels, tie rods, spacers, etc.	102 in.	16 in.	12 in.	11.3 cu. ft.
	Total displacement			46.3 cu. ft.

g. Durability.

(1) No observable deterioration occurred in the lining of the cell as a result of contact with gasoline during the period of the test.

(2) After being assembled and dismantled three times, the following deterioration was noted:

(a) The plywood panels showed some splintering at the edges.

(b) Three of the reinforcing patches by which the supporting studs are secured on the cell fabric were partially torn loose at the edges.

(c) Two of the stud anchor plates tore part way through the fabric of the reinforcing patch.

(d) One of the stud bosses became loose in the anchor plate.

h. Adequacy of design.

(1) See Exhibit "I" for findings in regard to mechanical design and construction of the cell.

(2) The actual capacity was found to be 700 gallons and not 750 as originally described.

(3) The vent check valve permitted excessive spilling of gasoline when the cell was used on a truck.

(4) The cell is not sectionalized as are steel tanks of approximately equal capacity, thus allowing all the gasoline to leak out through a single puncture. Motor officers have noted this as a major defect.

2. Fuel Cell, Collapsible, Stationary, 500-Gallon.

a. Camouflage and concealment properties. - (See Exhibit "C").

b. Transportation.

(1) Severe strains were created on the cell walls from the excessive surge of the contents when starting and stopping the truck.

(2) These surges could be controlled and did not appear to exceed safe limits when the suspension ropes of the cells were tied to the head end of the truck bed.

c. Utility.

(1) The unit could be filled from the can, gasoline, 5-gallon, and from the fuel cell, collapsible, 7-gallon.

(2) The standard power-driven dispensing unit was used with the cell for dispensing operations.

(3) No provision was made in the cell for supporting any sort of hand-operated pump for dispensing purposes.

(4) Experienced motor officers from the Quartermaster Replacement Training Center Motor Pool expressed the belief that a stationary storage tank of this capacity would be of no practical use under field conditions.

d. Assembly and dismantling. - The time required for setting up and dismantling using a two-man crew was as follows:

Setting up - 5.9 min.
Dismantling - 1.0 min.
(Average of five trials)

Complete operation included setting up cell and canvas housing, dismantling the cell, and moving it a few feet to a new location.

e. Inlet and outlet provisions.

(1) The inlet opening is large enough for any filling or dispensing operations which would be encountered in the field.

(2) The cover for the inlet opening fits poorly and allows the contents to seep out and dirt and water to enter.

(3) No outlet is provided to drain the contents by gravity.

f. Space required for storage. - The unit was packed in a box of the following dimensions and cubic displacement:

Length	Width	Height	Displacement
47½ in.	38½ in.	15 in.	15.9 cu. ft.

g. Durability.

(1) Several of the suspension hooks on the original set of supporting stakes bent under the weight of the cell.

(2) Several of the suspension hooks on the second set of stakes broke off due to the stress set up when driving the stakes into the ground.

(3) Two small leaks developed in the cell fabric after brief use.

(4) No deterioration was observed in the lining as a result of contact with gasoline during the period of the test.

h. Adequacy of design.

(1) The top of the cell sagged considerably even when filled to the practical limit of capacity, creating a depression in which dirt and water collected.

(2) No rope or chain was provided for suspending the access plate from the support pole. The suspension lugs on the access plate rapidly wore through a support rope supplied by the Quartermaster Board.

(3) The position of the fitting support pole interfered with easy access to the inlet opening and resulted in spilling of fuel unless considerable care was used in the filling operation.

3. Fuel Cell, Collapsible, 7-Gallon.

a. Transportation. - See Exhibit "E" for the best method of loading the cells on the bed of a 2½-ton 6 x 6 cargo truck. By using this method, no difficulty was experienced in loading the truck to weight limit of 5000 lbs. with 120 cells, fuel capacity approximately 732 gallons. Using 5-gallon cans, weight limit is reached with 125 cans, fuel capacity 625 gallons.

b. Utility.

(1) The cell must be suspended from a support when removing or replacing the cap, and when filling.

(2) The cells could be handled with much less noise than the cans, standard, 5-gallon.

(3) Following is a comparison of the time required for emptying the cell and the can, standard, 5-gallon, under daylight and blackout conditions, including the time required to open the containers, insert the flexible nozzles, empty the containers, remove the nozzles, and recap the containers:

	* 7-Gallon Cell	Standard 5-Gallon Can	Increased Time for 7-Gal. Cell	% Increase
Daylight				
Total emptying time per unit (average of 10 cycles)	1.40min.	1.03 min.		
Per 100 Gal. of fuel	23.3 min.	20.6 min.	2.7 min.	13.1
Blackout				
Total emptying time per unit	2.44min.	1.40 min.		
Per 100 Gal. of fuel	40.6min.	28.0 min.	11.4 min.	40.7

* Actually holds 6 gallons.

c. Inlet and outlet provision.

(1) See Exhibit "J" for findings on the closure of the cell. Due to the excessive binding of the keeper, it was found necessary to remove this part before the cells could be used.

(2) The position of the filler opening made it difficult to insert the pouring nozzle without loss of the contents.

(3) The whistling feature of the standard nozzle to indicate when the can is filled to capacity did not function when used with the cell due to the impossibility of seating the nozzle properly in the opening.

d. Space required for storage. - See Exhibit "G" for a comparison of the storage space required for 100 of the cells and 120 cans, standard, 5-gallon, when filled and when empty.

e. The cell weighs 5 pounds one ounce, the can, gasoline, 5-gallon, weighs 10 pounds, 12 ounces.

f. Durability.

(1) The lining of the cells chipped and flaked off after several hours of use with gasoline. This was particularly noticeable in those cells which were subjected to rough handling while filled. The flakes clogged up the strainers of the nozzles and considerable carburetor trouble was experienced with motor vehicles using gasoline from these cells, presumably due to finely divided particles which passed through the strainers. Exhibit "H" shows samples of lining cut from an unused cell, from a cell in which gasoline was stored for three weeks, and samples of the powdered lining strained from gasoline. Exhibit "F" shows photographs of deterioration of the linings.

(2) Of the 50 cells which were thrown on and off the truck twenty-five times, one developed a pin hole leak in the fabric after 16 cycles and one began to leak at the closure insert after 17 cycles. In addition, ten of the cells showed varying degrees of leakage around the closure inserts when allowed to remain piled up overnight.

(3) Of the 10 cells which were thrown on and off the truck 100 times, one developed a leak in the fabric at the 74th cycle, and three developed slight leaks around the closure insert at the 50th, 90th, and 100th cycle respectively.

(4) Of the five cells which were thrown from a moving truck, the fabric of two cells ruptured the second time they were thrown, one the third time, one the fifth, and one the seventh.

(5) Following are the results of the drop test of the fuel cell and the can, gasoline, 5-gallon, standard issue:

	*Number of Drops Before Failure			
	Earth		Hard Surfaced Road	
Distance Dropped	Can	Cell	Can	Cell
3 feet	45	45	9	45
6 feet	45	45		9
9 feet	15	18		
Total drops for each can or cell	105	108	9	54

* Note – "Failure" signifies the rupture of the cell fabric, can walls, or seams.

(6) No other observable deteriorations occurred in the external fabric or other parts of the cell as a result of handling, weathering, or contact with gasoline, with the exception of the paint on the inside surface of the closure plug which dissolved or peeled off very rapidly.

g. Adequacy of design.

(1) The practical limit of capacity is only 6 gallons and not 7 as described and labelled.

(2) The design of the cap is impracticable as it requires the use of a specially designed tool to tighten properly.

V. CONCLUSIONS.

1. Fuel Cell, Collapsible, Transportable, 700-Gallon.

a. Camouflage and concealment. - When mounted beneath the canopy on a 2½-ton 6 x 6 cargo truck, the cell is effectively concealed, and there are no outward distinguishing features to indicate the presence of a fuel tank on a truck. Therefore, the problems of camouflage or concealment are the same as those related to camouflaging an ordinary cargo truck.

b. Transportation. - The cell is not properly designed for transportation on a 2½-ton 6 x 6 cargo truck without braces or other means of preventing shifting of the cell on the bed.

c. Utility.

(1) The handling of the empty cell in moving from place to place or setting on and off the 2½-ton 6 x 6 truck does not present any serious difficulties.

(2) The use of this cell for dispensing to trucks saves time and labor over the method of dispensing through 5-gallon cans.

d. Assembly and dismantling. - The time required for setting up the cell is unnecessarily lengthened by inadequacies in design and construction.

e. Inlet and outlet provisions.

(1) The inlet opening of the cell is unsatisfactory for use with present auxiliary equipment.

(2) The outlet fittings are unsatisfactory and incomplete.

(3) The cell is not constructed properly for use with present auxiliary dispensing equipment or for dispensing by gravity.

f. Space required for storage. - The cell requires a minimum amount of storage space when not in use.

g. Durability. - The cell is of sufficiently durable construction to withstand normal use in the field with the following exceptions:

(1) The reinforcing patches for securing the stud bosses to the cell fabric be more adequately cemented.

(2) The method of securing the stud bosses to the stud anchor plates be improved.

h. Adequacy of design. - The design and construction of the cell is improper or inadequate with respect to the following details in addition to those already noted:

(1) The vent check valve allows spilling.

(2) No adequate means for the dissipation of static electricity has been provided.

(3) The workmanship in laying out holes for the suspension studs is poor.

(4) The method of tightening the suspension studs in the stud bosses is poor.

(5) Consideration should be given to the possibility of sectionalizing the cell.

2. Fuel Cell, Collapsible, Stationary, 500-gallon.

a. Camouflage and concealment. - The cell can be easily and effectively concealed or camouflaged without the use of special equipment or materials.

b. Transportation. - The cell is too unstable for safe transportation on the 2½-ton 6 x 6 cargo truck.

c. Utility.

(1) The design and construction of the cell is adequate for use with present power-driven dispensing equipment, but not for use with a standard hand-operated pump (for use with 55-gallon drums), nor for dispensing by gravity flow.

(2) The utility of a stationary cell of this capacity for field use is dubious in the opinion of motor officers.

d. Assembly and dismantling. - The time required for setting up and dismantling the cell is negligible.

e. Inlet and outlet provisions.

(1) The dimensions of the inlet opening of the cell are satisfactory.

(2) The cover for the inlet opening is inadequate and unsatisfactory.

f. Space required for storage. - The cell requires a minimum of storage space when not in use.

g. Durability. - The cell is of sufficiently durable construction for use as originally designed with the exception of the suspension hooks on the supporting stakes.

h. Adequacy of design. - The design and construction of the cell is inadequate with respect to the following details in addition to those already noted:

(1) The access plate suspension.

(2) The sagging of the top surface of the cell.

3. Fuel Cell, Collapsible, 7-Gallon.

a. Transportation. - The cells can be safely and efficiently transported on the truck, $2\frac{1}{2}$-ton, 6 x 6 cargo, up to the maximum rated load capacity. A $2\frac{1}{2}$-ton truck can carry 16% more gasoline using this cell than it can when using the 5-gallon can without exceeding weight limits.

b. Utility.

(1) The cell cannot be used properly in conjunction with present auxiliary equipment used for the can, gasoline, 5-gallon.

(2) The cell is superior to the can, gasoline, 5-gallon, with regard to quietness of operation.

(3) The amount of time required to empty the cell under blackout conditions is excessive. Redesigning the cell may cause a reduction in this time.

c. Durability.

(1) The outer fabric of the cell is sufficiently durable for use under field conditions.

(2) The cell will withstand harder use than the can, gasoline, 5-gallon.

(3) The lining of the cell is not durable when subjected to the action of motor fuel.

d. Adequacy of design. - The design and construction of the cell is improper or inadequate with respect to the following details in addition to those already noted:

(1) The closure cap.

(2) The position of the filler opening.

(3) The lack of a sufficiently rigid backing to permit proper seating of the whistling nozzle in the filler opening.

e. Space required for storage. - When empty, the cells require approximately one seventh of the space needed for 5-gallon cans of equal capacity.

VI. RECOMMENDATIONS. - It is recommended that:

1. The fuel cell, collapsible, transportable, 700-gallon, be considered practical and serviceable if redesigned in the following features:

a. Lack of transverse stability due to the high center of gravity, and the shifting on the truck bed be corrected or standard practice for bracing be formulated.

b. The size of the inlet fitting be increased to be not less than 6" in diameter.

c. The lack of a dispensing header and nozzles be corrected.

d. Standard threaded pipe fittings be used on the outlet.

e. The time required for assembly by an inexperienced crew be shortened.

f. The method or materials used in securing the suspension studs to the cell fabric be improved.

g. The improper design of the vent check valve be corrected.

h. A proper static discharge cable be provided.

i. The method of tightening the suspension studs in the stud bosses be improved.

2. The fuel cell, collapsible, stationary, 500-gallon, be considered serviceable if redesigned in the following aspects:

a. Cover of the inlet opening be redesigned for tighter closure.

b. Suspension hooks on the supporting studs be made more durable.

c. Adequate suspension be provided for the access plate.

d. Adequate suspension be provided to prevent sagging of the top surface of the cell.

3. Careful consideration be given to the field practicability and potential utility of a stationary storage tank of the capacity of the fuel cell, collapsible, stationary, 500-gallon.

4. The fuel cell, collapsible, 7-gallon, be considered serviceable and practical if redesigned in the following features:

a. Provisions made for use with present auxiliary equipment.

b. A change made in design to permit easier filling and emptying.

c. The closure be perfected.

d. A lining be evolved that will not flake or dissolve under the action of gasoline.

/s/
MAX R. WAINER,
Colonel, Q. M. Corps,
Director.

COPY

EXHIBIT "A"

WAR DEPARTMENT
OFFICE OF THE QUARTERMASTER GENERAL
WASHINGTON

In Reply Refer To SPQRD 400.112
(Cell, Fuel, Collapsible - QMB T-157). December 14, 1942.

SUBJECT: Fuel Cell, Collapsible - QMB T-157.

TO: The Quartermaster Board, Camp Lee, Virginia. Attention: Colonel Max R. Wainer.

1. The Quartermaster Board is directed to conduct tests of Fuel Cells, Collapsible, as outlined in the attached letters and memoranda:

a. Letter, Hdqrs., S.O.S., to the Q.M.G., file SPESD, dated December 2, 1942. "Proposed Tests of Impregnated Fabric Fuel Cells at Camp Lee, Virginia."

b. Memorandum "for the file" from Corps of Engineers, Civil Engineers Section, file SPESD, dated December 4, 1942, "Meeting to Determine Tests and Testing Procedure on Impregnated Fabric Cells."

c. Letter from Corps of Engineers, Technical Division, to Major E. L. Heller, O.Q.M.G., dated December 9, 1942, "Collapsible Fuel Cells."

2. The 500-gallon and 750-gallon cells were to be delivered to the Quartermaster Board by the Engineer Board, December 10, 1942, as indicated in inclosure #3. The 75-gallon bags of similar construction were to be delivered by the Engineer Board, December 14, 1942.

3. Major Heller of this office will arrive at the Quartermaster Board, Tuesday morning, December 15, 1942, to assist in setting up this test.

For the Quartermaster General:

/s/
J. L. Frink
Brigadier General, Q. M. Corps,
Assistant.

Inclosures:
#1-Ltr. SOS to QMG 12/2/42.
#2-Memo to files from Corps of Engineers 12/4/42.
#3-Ltr. Eng.Bd. to OQMG 12/9/42.

Address Reply to
Chief of Engineers WAR DEPARTMENT
U.S.Army OFFICE OF THE CHIEF OF ENGINEERS
Washington,D.C. WASHINGTON
Room 1405,Tempo G

December 2, 1942

SPESD

Subject: Proposed Tests of Impregnated Fabric Fuel Cells at Camp Lee, Virginia.

THROUGH: HEADQUARTERS, SERVICES OF SUPPLY, DEVELOPMENT BRANCH.

TO: THE QUARTERMASTER GENERAL.

1. Reference is made to a letter of October 9, 1942, Subject: Marcng Cells" from Headquarters, Services of Supply, Requirements Division and Development Branch to The Quartermaster General, charging the Corps of Engineers with the responsibility of development of impregnated fabric fuel cells.

2. Recent conferences between Quartermaster representatives and this office indicate that complete testing of fuel cells could better be accomplished by utilizing standard gasoline pumping and dispersal equipment at the Quartermaster Board at Camp Lee, Virginia. It was felt that comprehensive tests should include filling, emptying and handling of cells as would actually be done in the field.

3. Since Camp Lee is equipped to make such tests, it is requested that The Quartermaster Board at Camp Lee, Virginia, be directed to make such tests as will be outlined in joint conference by representatives of the interested Services of Supply.

4. The Office, Chief of Engineers, through the Engineer Board, is equipped to carry out the physical tests and laboratory tests on the fuel cells and will continue to carry out that portion of the tests, these also to be outlined in joint conference by representatives of the interested Services of Supply.

For The Chief of Engineers:

F. C. KENDALL,
Major, Corps of Engineers,
Executive Officer,
Engineering & Development Branch.
Supply Division.

COPY

COPY

December 4, 1942

Meeting to Determine Tests and Testing Procedure on Impregnated Fabric Cells.
Civil Engineer Section
Engineering & Development Branch,
Supply Division.

1. At a meeting of November 24, 1942, representatives of the Quartermaster Corps, Transportation Corps, Ordnance, The Engineer Board and of this Office, decided that a test program should be set up for the future testing of impregnated fabric fuel cells. The Quartermaster Corps stated that they had facilities at the Quartermaster Board, Camp Lee, Virginia, which could be utilized in making these tests. It was decided to hold a later conference at which the Quartermaster, Camp Lee, would be represented to determine tests and testing procedure.

2. This second conference was held at the Engineer Board, Fort Belvoir, Virginia, on December 1, 1942, and the following men were present:

Office, Quartermaster General, Quartermaster Board,	Lt. Colonel L. Slade
Office, Quartermaster General,	Major E. L. Heller
Office, Quartermaster General,	1st Lt. J. B. Stobaeus
Office, Quartermaster General,	C. H. Pattie
Office, Quartermaster General,	Thomas P. McNiesh
Office, Chief of Engineers,	1st Lt. J. H. Sonntag
Office, Chief of Ordnance,	1st Lt.,I. C. Tarler
The Engineer Board	R. M. MacPherson
Army Air Forces, Directorate of Base Services,	H. A. Blauvelt
U. S. Rubber Company,	P. J. Wythe
U. S. Rubber Company,	J. S. Cates

Transportation Corps had previously requested the Office of Chief of Engineers to represent that Service in the meeting.

3. It was decided to divide tests on the fabric fuel cells into two general categories:

a. Physical and Laboratory Tests.

b. Field Utility Tests.

The former tests will be carried out for the most part by the Engineer Board and the latter tests at the Quartermaster Board at Camp Lee, Virginia, which is equipped with standard Army Field gasoline handling facilities for filling and emptying units.

4. The testing program will be started immediately, and the program for the immediate future will be as follows:

a. 7-gallon bags.

(1) Quartermaster Board, Camp Lee, Virginia. - One hundred fifty (150) of the latest type bags are to be shipped immediately to Camp Lee, Virginia, directly from the U. S. Rubber Company, and the following tests made:

(a) The utility of filling the 7-gallon bags with standard 5-gallon can filling equipment will be determined.

(b) Different methods of accomplishing the filling will be tried with the purpose of determining the most practical method for filling the bags.

(c) The utility of emptying the bags will be determined by emptying the bags into storage tanks, vehicles, etc., using the flexible nozzles which are standard equipment for emptying the 5-gallon cans.

(d) The bags will be tested in cold and hot rooms under average conditions to determine if temperatures will affect the stability of the bags.

(e) Bags will be taken for short travel hauls, stacked in trucks and filled and emptied repeatedly to determine if the bags will start leaking under those conditions.

(f) The bags filled with gasoline will be dropped to determine bursting strength.

(g) Bags will be tested for resistance to abrasion.

(h) Methods of carrying bags on trucks will be determined.

(2) The Engineer Board, Fort Belvoir, Virginia. - Tests to be conducted will consist of physical tests and laboratory tests. The physical tests will be as follows:

(a) A 2½-ton truck will be loaded to 2½-tons with bags after the best method of stacking has been determined by preliminary tests. The bags will be filled with 80 octane gasoline (standard high test gasoline) which was decided to be the average gasoline to be handled.

(b) The bags will be subjected to approximately 5,000 miles road test over the Engineer Board course, which consists of good and poor roads. Travel time will consist of two 8-hour shifts per day.

(c) Truck drivers will inspect bags at the beginning of shifts by unloading and looking over the bags. One of these checks per day will be witnessed by a Government Engineer. Damaged bags will be saved and marked for record.

(d) The 5,000 miles run over this course was believed to approximate a fairly long life for the bags. If at the end of the 5,000 miles the bags begin to show evidence of failure, tests will be continued until approximately 75% of the bags fail. If, however, at the end of the 5,000 miles, the bags are still in good condition, no further tests will be made since the element required to complete tests in such a case would be out of reason.

(e) A few bags will be dropped from the truck but care equivalent to that required for handling of 5-gallon cans in the field will be taken in unloading the bags.

(f) Laboratory tests on bags will consist of the following:

(1) Bursting test (15 lbs. per sq. in. will be required as a minimum bursting strength).

(2) Diffusion.

(3) Gum absorption.

(4) Friction test.

(5) Seam pull test.

(6) Material to be saturated, both sides, with gasoline and tested for abrasion.

b. 500-Gallon Cells.

(1) Camp Lee, Virginia. - One (1) 500-gallon cell with improved access manhole will be shipped from the Engineer Board to Camp Lee, Virginia. This cell will be tested to determine utility of filling and emptying the unit with standard Army filling equipment. The cell will be filled from 7-gallon bags and 5-gallon cans and will be emptied by standard pumping operations. The unit will be given some hauling tests because it is believed that this will be attempted in the field regardless of the fact that the unit is designed for stationary storage only.

(2) The Engineer Board's physical tests on the 500-gallon cells have already been completed and no further tests are contemplated on that unit at this time.

c. <u>1000-gallon and 3000-gallon units.</u> - The 500-gallon unit is believed to be representative of the two larger sized stationary storage cells and results obtained from testing this unit are felt to be applicable to the larger units. For this reason no tests on the two larger sized units are contemplatedd at this time.

d. <u>750-gallon, 2½-ton, transportable unit.</u>

(1) Camp Lee, Virginia. - One unit is being shipped from the Engineer Board to Camp Lee for tests similar to those which will be made on the 500-gallon stationary unit. In addition, the unit will be subjected to transportation tests.

(2) <u>Engineer Board</u> - One (1) 750-gallon unit filled and partly filled with 80 octane gasoline and loaded on a 2½-ton truck will be subjected to an approximate 5,000 miles Road test over the Engineer Board course. This test is believed to represent the average physical strain to which such a unit will be subjected.

e. <u>2880 Gallon Transportation Flat Car Unit.</u> Railroad switching and hauling tests have already been completed at Camp Claiborne, Louisiana by the Transportation Corps on units filled and partly filled with water. At the request of Transportation Corps additional switching tests will be made on railroad lines inside Fort Belvoir, with the tanks filled and partly filled with 80 octane gasoline. No units will be sent to Camp Lee, Virginia, since the tests on the 750-gallon unit will indicate the utility of the 2880-gallon unit with standard filling and emptying equipment.

5. <u>General Testing Procedure.</u> - General testing is to include time studies on erection and disassembling of units and sufficient pictures to clearly show steps followed in testing, and, where possible, physical results of tests.

6. <u>Conclusions.</u> When tests are completed, recommendations based on filling and emptying operations and physical tests will be made for improving the units involved in the tests and similar units.

J. H. SONNTAG,
1st Lieut., Corps of Engineers,
Engineering & Development Branch,
Services of Supply.

CC:Lt.Col.L.Slade,Office,QMG.
CC:Major E.L.Heller,Office,QMG.
CC:R.M.MacPherson,Engineer Board
CC:P.J.Wythe,U.S.Rubber Company
CC:Major J.A.Richardson,Chief of Ordnance
CC:Captain Atkinson,Transportation Corps,Fort Meade
CC:H.A.Blauvelt, Army Air Forces, Directorate Base Service, Munitions Building, Washington, D. C.

COPY

WAR DEPARTMENT

Address Reply to Engineer Board, Fort Belvoir, Va.

THE ENGINEER BOARD
CORPS OF ENGINEERS, U.S. ARMY
FORT BELVOIR, VIRGINIA

December 9, 1942

EB 151

Memorandum to: Major Edward L. Heller
Quartermaster General
War Department
Washington, D. C.

Subject: Collapsible Fuel Cells

1. The Engineer Board is planning to forward by truck to Camp Lee on Thursday, December 10th, one 500-gallon cell and one 750-gallon cell.

2. Mr. Tuthill of the United States Rubber Company will be at Camp Lee on Friday to aid in assembling these if you so desire. He is to contact you by phone regarding this.

3. No provision was made by the manufacturer of these cells to take care of static. A static wire has been soldered to the filling cap on the 500-gallon cell, and sufficient wire will be sent with the 750-gallon cell to run through the cell from the filler cap to the outlet. This should be soldered to both filler cap and outlet pipe.

4. It is believed desirable, as a safety precaution, to run an outside static wire from filler cap to ground when pumping from these cells while resting on the ground.

5. When transporting either size of cell on a truck, it will be necessary to carry a wire from the filler cap or the outlet to the bed of the truck. A drag chain should then be attached to the truck.

6. It is requested that this information be passed on to Lt. Col. Slade of the Quartermaster Board, so that the necessary precaution will be taken to avoid an accident.

7. The inclosed Photo No. 46-1-2 is to be forwarded to Camp Lee for their information.

George W. Howard,
Major, Corps of Engineers,
Acting Director, Technical Division IV.

1 Incl.
Photo No. 46-1-2

Product Development Branch
Resources Division, Production Service
Office of the Quartermaster General

EXHIBIT "B"
CASE RECORD

1. Test of Fuel Cells, Collapsible.
(Title of Project)

2. Project Objective (including military characteristics desired):
To determine the utility and practicability of the fuel cells, collapsible, with respect to standard equipment now in use.

3. New
(New item or revised)

4.
(Date of last revision)
Items in which used:

5. Existing specification numbers:

6. Services using present item: All

7. Project initiated by: Office of The Quartermaster General.

8. Military characteristics defined by:

9. Basis for importance rating (Inventory data, pending procurement, directives specifying completion date, etc. Ref. item #15):

10. (Estimated experimental funds required) (Experimental funds used)

11. (Section responsible) (Individual)

12. Supplementary work done by:
O.Q.M.G.
Depots:
Laboratories:
Manufacturers:

13. QMB T-98
(Project Number)

14. February 7,1943.
(Date)

15.
(Importance Rating)

16.
(Date SOS Approval)

17.
(Required Completion Date)

18.
(Actual Completion Date)

19.
(Results)

Space Requirements of the Can, Gasoline, 5-Gallon,
and
the Fuel Cell, Collapsible, 7-Gallon.

	Can, Gasoline 5-Gallon	Fuel Cell, Collapsible 7-Gallon	* Percent
Number of Units	120	100	-------
Actual Capacity (Per Unit)	5 Gal.	6 Gal.	-------
Total Capacity	600 Gal.	600 Gal.	-------
Space, Empty	127.0 Cu.Ft.	17.9 Cu.Ft.	14.1%
Space, Filled	127.0 Cu.Ft.	159.4 Cu.Ft.	125.5%
Space per 100 Gallons	21.16 Cu.Ft.	26.56 Cu.Ft.	125.5%

* Percentage computed using the value for the Can, Gasoline, 5-Gallon, as 100%.

QUARTERMASTER BOARD PROJECT T-98

TEST OF FUEL CELLS, COLLAPSIBLE

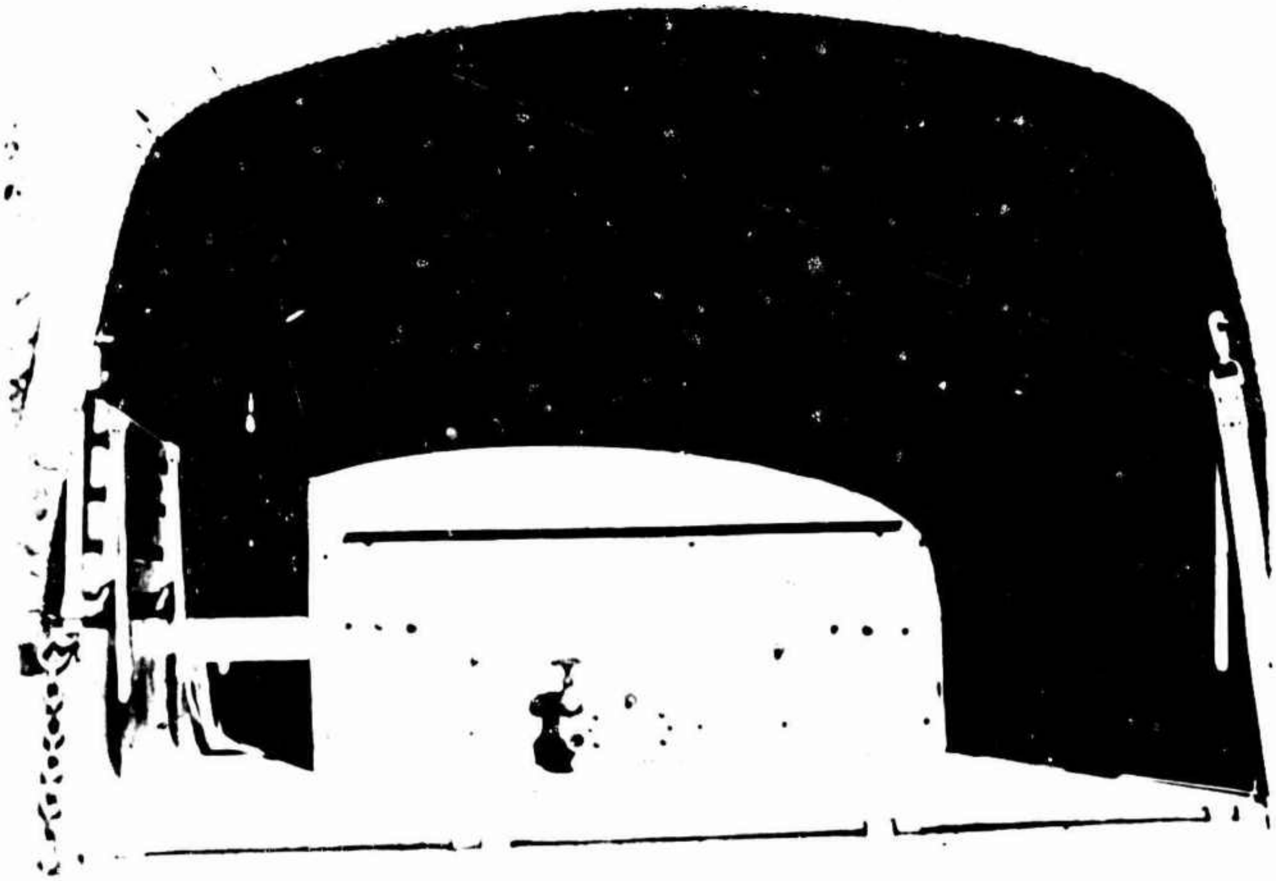
Exhibit "C"

FUEL CELL, COLLAPSIBLE, STATIONARY
[illegible]
[illegible]
[illegible]

QUARTERMASTER BOARD PROJECT T-96

TEST OF FUEL CELLS, COLLAPSIBLE

Exhibit "D"



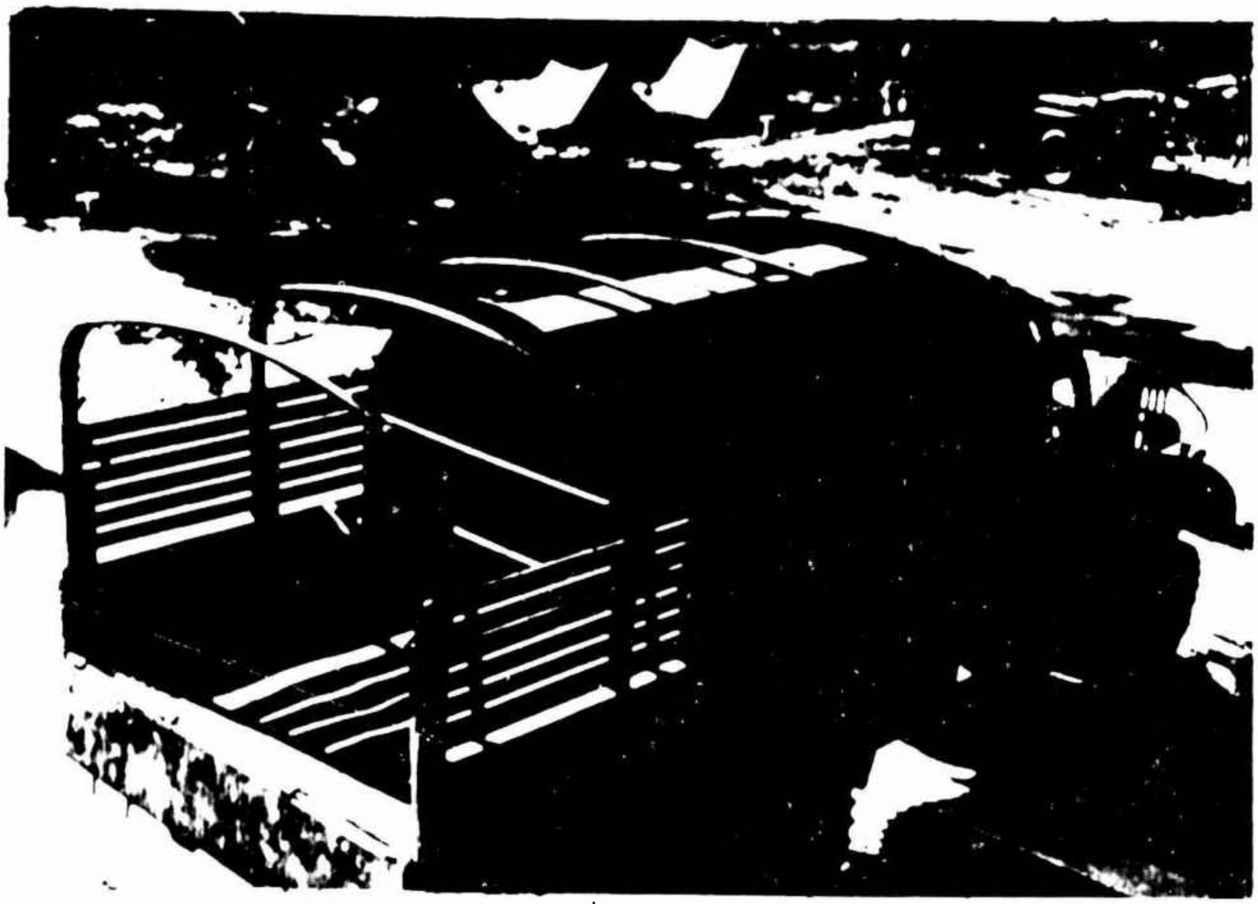
FUEL CELL, COLLAPSIBLE, TRANSPORTABLE, 700 GALLON, MOUNTED ON 2½ TON, 6X6 CARGO TRUCK WITH CANOPY IN PLACE

[illegible]: HORIZONTAL BRACES ADDED TO POSITION CELL IN CENTER OF TRUCK BED

QUARTERMASTER BOARD PROJECT T-98

TEST OF FUEL CELLS, COLLAPSIBLE

Exhibit "D"



FUEL CELL COLLAPSIBLE TRANSPORTABLE 900 GALLON MOUNTED ON 2½ TON 6x6 CARGO TRUCK WITH CANOPY REMOVED

Note: POSITION OF CELL AT EXTREME FORWARD END OF TRUCK BED TO PREVENT LONGITUDINAL ROLLING

QUARTERMASTER BOARD PROJECT T-98

TEST OF FUEL CELLS, COLLAPSIBLE

Exhibit "L"

FUEL CELLS, COLLAPSIBLE, 7 GALLON LOADED ON 2½ TON 6x6 CARGO TRUCK. BY STACKING IN THIS MANNER 100 CELLS MAY BE ACCOMMODATED IN 5 ROWS ACROSS THE BED OF THE TRUCK WITH CONSIDERABLE UNUSED SPACE AT THE END.

QUARTERMASTER BOARD PROJECT T-98

FUEL CELLS, COLLAPSIBLE, 7 GALLON

DETERIORATION OF LINING ADJACENT TO CLOSURE INSERT

ACCUMULATION FOUND AT CLOSURE CORNER OF CELL WHEN CUT OPEN

DETERIORATED LINING MATERIAL SHAKEN FROM ONE CELL. NO SOLVENTS OR MECHANICAL MEANS WERE USED IN ITS REMOVAL

Space Requirements of the Can, Gasoline, 5 Gallon,
and
the Fuel Cell, Collapsible, 7 Gallon.

	Can, Gasoline 5 Gallon	Fuel Cell, Collapsible 7 Gallon	* Percent
Number of Units	120	100	—
Actual Capacity (Per Unit)	5 Gal.	6 Gal.	—
Total Capacity	600 Gal.	600 Gal.	—
Space, Empty	127.0 Cu. Ft.	17.9 Cu. Ft.	14.1%
Space, Filled	127.0 Cu. Ft.	159.4 Cu. Ft.	125.5%
Space per 100 Gallons	21.16 Cu. Ft.	26.56 Cu. Ft.	125.5%

* Percentage computed using the value for the Can, Gasoline, 5 Gallon, as 100%.

Exhibit "H"

SHOWING FLAKING OF LINING
IN 7 GALLON CELL

CELL AFTER GASOLINE
HAD BEEN STORED IN IT

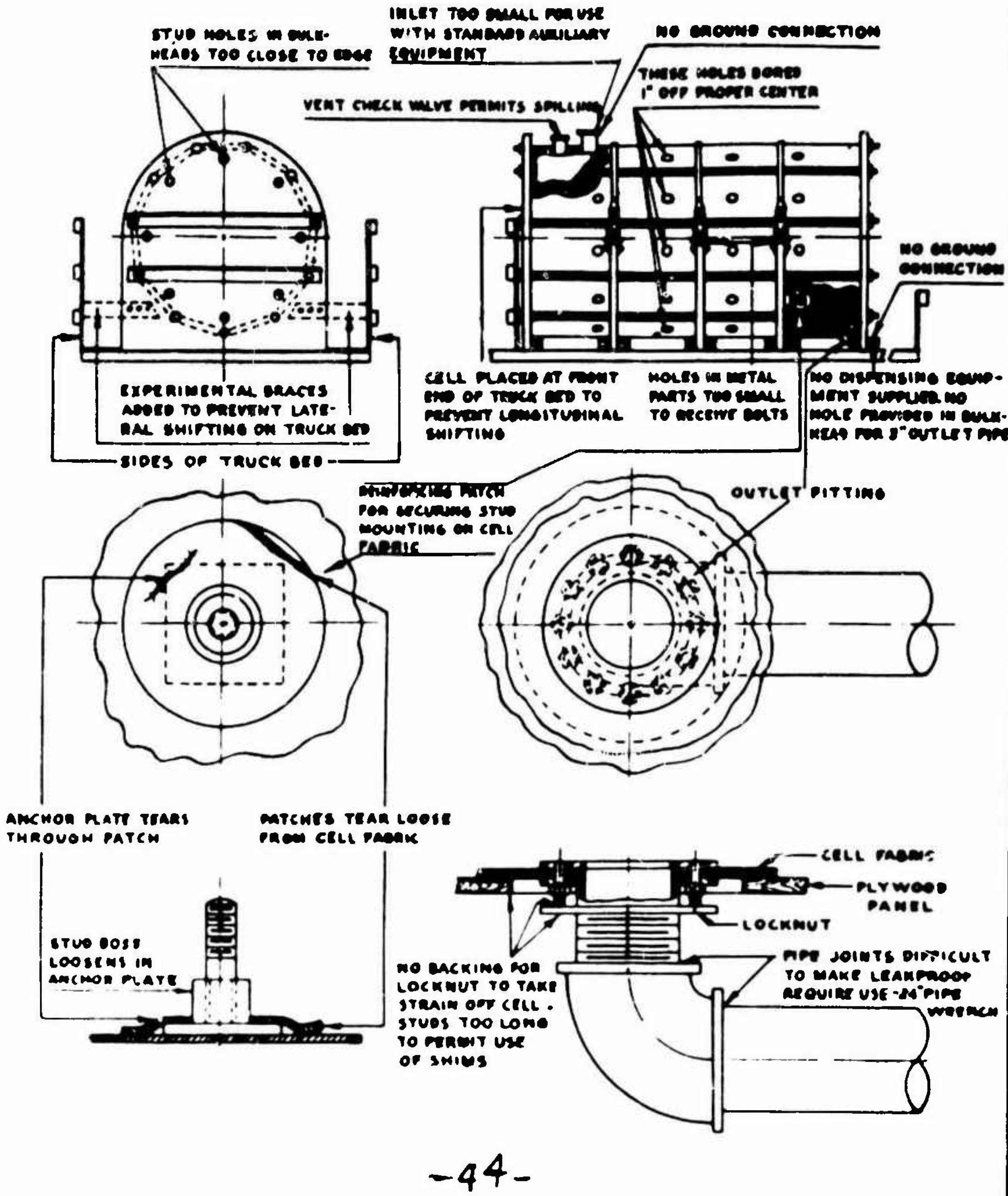
UNUSED CELL

SEDIMENT REMOVED
FROM GASOLINE

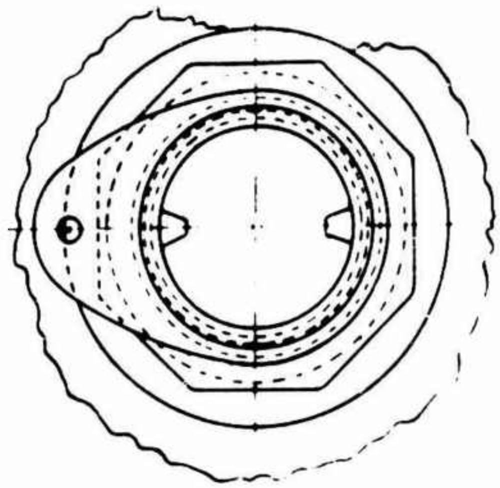
Exhibit "I"

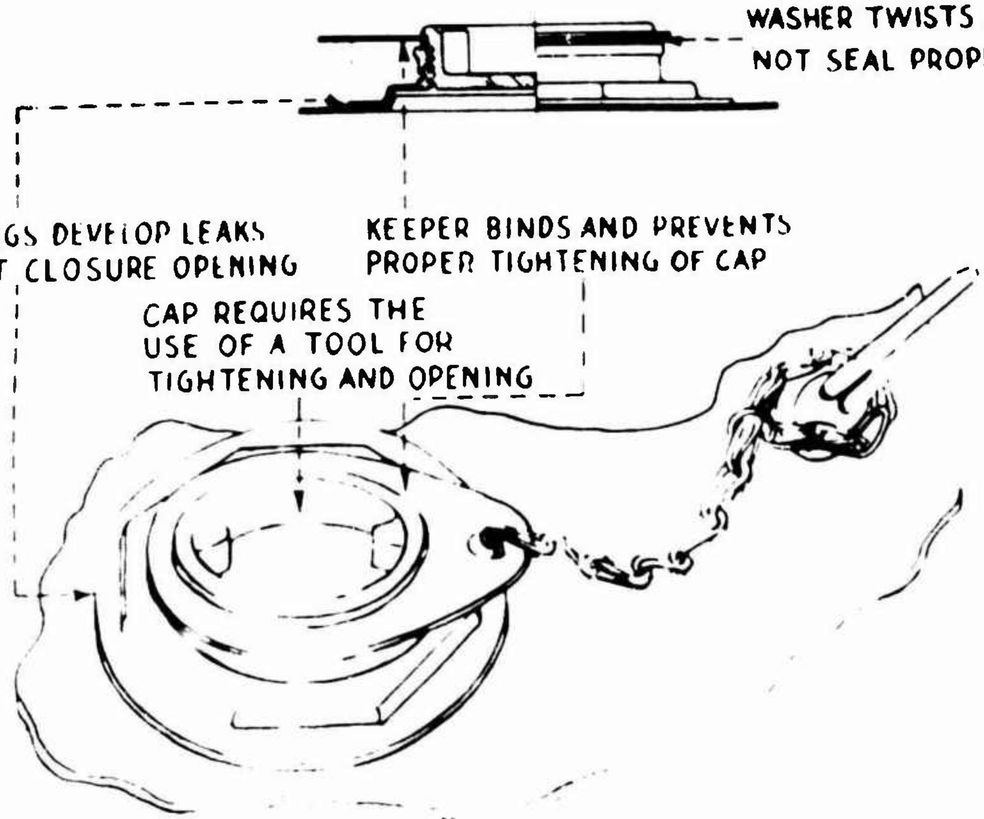
QUARTERMASTER BOARD PROJECT T-98

TEST OF FUEL CELLS, COLLAPSIBLE



TEST OF MARENG CELL, STORAGE TANK, AND EXPERIMENTAL CONTAINERS T-98





DESERT TEST BRANCH
REPORT NO. 131

Project BR 372

INFORMAL REPORT

on

750 GALLON AND 7-1/2 GALLON COLLAPSIBLE CONTAINERS FOR THE TRANSPORTATION AND STORAGE OF GASOLINE

May 20, 1943

Submitted to

The Chief

The Engineer Board, Desert Test Branch

Thermal, California

by

Mr. John E. Lewis, Jr.

Engineer

Report in ___ Pages
and ___ Appendices.

Copy ___ of ___ Copies.

THE ENGINEER BOARD
DESERT TEST BRANCH
ENGINEERING REPORT NO. 131

May 20, 1943

Title: 750 Gallon and $7\frac{1}{2}$ Gallon Collapsible Containers for the Transportation and Storage of Gasoline.

Project No. BR 372 Submitted by: John E. Lewis, Jr., Engineer.

I. SUBJECT:

A report on tests of one 750 gallon and 100 - $7\frac{1}{2}$ gallon collapsible containers for the transportation and storage of gasoline.

II. Authority:

BR 372.

III. **Factual** Data:

One 750 gallon cell and one hundred $7\frac{1}{2}$ gallon cells (30 Firestones, - 70 Goodyear) were received by the Engineer Board Desert Test Branch for test under desert conditions.

The 750 gallon cell:

The 750 gallon cell (see figure 5) was assembled on the ground by two enlisted men, 2 hours time being required **as** neither man had ever seen the cell before and no assembly prints were included with it.

Eight men then loaded the cell into the body of a $2\frac{1}{2}$ ton GMC truck. Static dissipating wires were connected to the body of the truck and to the filler cap and outlet valve assembly respectively. A length of chain was connected to the truck body and allowed to drag upon the ground. The purpose of these precautions was to form a ready and easy path of discharge to the ground for any charge of static electricity which might be generated by the friction of the truck tires or otherwise collected upon either the truck body or the gasoline cell. The cell was then filled with 750 gallons of gasoline, (motor fuel grade, approximately 70 octane rating).

No attempt was made to fasten the cell down to the truck bed nor was any blocking used to prevent the cell from skidding.

COPY

The truck was placed upon a test run. This run consisted of one mile of paved road, one mile of improved hard surfaced road, one mile of very rough hard surface road, and one mile of cross-country travel over sandy terrain. After approximately 500 miles had been traveled over this course, no damage resulted to the cell.

The 7½ gallon cell:

It was noticed that 35 of the 7½ gallon cells were manufactured by the Firestone Tire and Rubber Company and the remaining 65 were manufactured by the Goodyear Tire and Rubber Company. Thirty cells of each manufacture were filled as follows:

6 Goodyear & 6 Firestone	filled with	5	gallons	gasoline.
6 Goodyear & 6 Firestone	" "	6	"	"
6 Goodyear & 6 Firestone	" "	6½	"	"
6 Goodyear & 6 Firestone	" "	7	"	"
6 Goodyear & 6 Firestone	" "	7½	"	"

These cells were then placed in rows, flat upon the ground, exposed to the sunlight. The ambient temperature at that time was 104° F. After one hour exposure to the direct rays of the sun, enough gas had been liberated or boiled off the gasoline to cause the cells to become tightly inflated. Twenty nine of the thirty Firestone cells began leaking badly from small "pin hole" like places in the fabric, as shown in photograph No. 1. This trouble was not encountered with the Goodyear cells.

The cells continued to swell and started rupturing at the seams after about 3 hours exposure. The Goodyear cells did not leak at all until sufficient gas pressure had built up to cause failure of the seams. At the end of five hours exposure, every one of the 60 cells under test had ruptured at the seams and were rendered useless for further tests.

During the test, the temperature of the fabric of the cells were checked, using a pyrometer and thermocouple, and it was found that the temperature gradually increased from ambient (104° F) to a maximum of 173° F.

Temperatures of the gasoline within the cells was also checked repeatedly and this reached a maximum of 137° F.

No attempt was made to stack the cells in piles nor were any thrown from moving vehicles because none of the cells stood up for a long enough time to warrant these tests.

A bronze cap from one of the cells was drilled and tapped so that a pressure gauge could be attached. Six cells were tested by filling them with 7½ gallons of gasoline and screwing the cap with the pressure gauge in place. These cells were carefully observed after being placed in the sunshine and the maximum gas pressure that these cells would withstand before rupturing was found to be from 1½ to 2 pounds per square inch.

Experiments were then conducted with the cells enclosed in a bag fabricated of 16 ounce duck. This bag was tan in color and was selected because it is approximately the same color as the sand of the desert and also because this color usually remains a few degrees cooler than olive drab, because its lighter color is able to reflect heat more easily. A Goodyear cell filled with gasoline was placed within this canvas bag and exposed to the sun. A thermometer was inderted between the canvas and the wall of the cell. Temperatures were recorded and it was found that this temperature was 152° while the ambient temperature was 105°. The Goodyear cell failed at the seam when the temperature reached 144° at that point. The temperature of the gasoline was found to be 135°. This test was repeated twice more and the results were the same each time.

A water column was then constructed to determine the maximum water pressure that the cells would withstand when subjected to water pressure and exposed to the sun. This water column (see figure No. 3 inclosed herewith) was so arranged that pressures of 1, 2, 3, 4, 5, or 6 pounds could be applied to the cells under test.

Ten cells (7 Goodyear - 3 Firestone) were tested in this way and the results were that all cells would withstand 5 pounds per square inch when shaded from the rays of the sun. Four cells were tested at 6 pounds per square inch, shaded, and all four failed. The remaining 6 cells were exposed to the sun and all failed when a pressure of 5 pounds per square inch was applied.

A standard Quartermaster 5 gallon can was then prepared for test by drilling a hole through the cap and placing a pressure gauge at this point. A thermo well was inserted into the side of the can so that the temperature of the gasoline might be measured and a record of the vapor pressures kept at different temperatures. This can is pictured in figure 4. The can was then filled with 5 gallons of regular motor fuel gasoline and placed in a position where it was exposed to the rays of the sun. Observations were made for five days at 15 minute intervals of the pressure, gasoline temperature and the ambient temperature. Listed below are typical recordings obtained on one of these five days.

COPY

Time	Ambient Temp.	Temp. of Gas in Can	Pressure in lb/sq in. On Pressure Gauge
8:15 AM	80	74	0
8:30	81	82	0
8:45	83	90	.50
9:00	84	94	1.25
9:15	85	98	1.75
9:30	87	103	2.50
9:45	88	106	3.00
10:00	90	110	4.00
10:15	90	115	4.50
10:30	91	118	5.00
10:45	94	120	5.75
11:00	94	123	6.00
11:15	94	125	7.00
11:30	96	127	7.25
11:45	100	133	8.25
12:30 PM	100	134	8.50
12:45	100	134	8.50
1:00	101	134	9.00
1:15	102	134	9.00
1:30	103	138	9.75
1:45	103	138	10.00
2:00	102	138	10.00
2:15	102	138	10.00
2:30	104	138	10.00
2:45	104	138	10.00
3:00	105	138	10.00
3:15	105	136	9.75
3:30	104	136	9.74
3:45	104	134	9.25
4:00	104	132	8.50
4:15	104	132	8.50
4:30	103	131	8.40

After observing the temperatures and pressures for several days, an average of the results were plotted and a copy of this graph is included in this report as exhibit "A".

The results of this experiment show that the pressure within the can increases in direct proportion with the temperature. Reference to the "Chemical Engineer", handbook, John.H. Perry, Editor in Chief, shows that gasoline and gasoline vapors have the properties of a perfect gas, which is that the pressure varies in direct proportion to the temperature until a pressure of 50 pounds per square inch is reached or a temperature of 261 degrees Fahrenheit.

At the time these tests were conducted, 105° was the maximum ambient temperature reached and 138° was the maximum temperature reached by the gasoline in the can. In desert operations this temperature will be exceeded during the hot months. As the ambient temperature increases, the gasoline temperatures within the can will increase somewhat. Ambient temperatures of 125° to 135° are by no means uncommon in desert regions. It is, therefore, logical to expect an increase in gasoline temperature to 155° to 160°. Since the gasoline vapor pressures will increase in direct proportion to the temperature, reference to the graph will show that any container must be able to withstand a minimum of 13.2 pounds vapor pressure plus a reasonable safety factor, plus the mechanical strength necessary to withstand increased pressures caused by stacking the cells, dropping or rough handling of the cells.

IV. Discussion:

All tests of the collapsible gasoline cells were made using regular motor fuel gasoline of 70 octane rating. This gasoline was used instead of aviation gasoline because preliminary tests had shown that trouble would be experienced with these cells due to excessive vapor pressures. These high vapor pressures are encountered because of the fact that ordinary gasoline has an initial boiling point of 98° to 102°. Aviation gasoline (100 octane) is considerably more volatile than ordinary gasoline.

The 750 gallon cell, knocked down and crated for shipment, occupies 3 crates which have the following dimensions:

8.5' x 1.5' x 1' =	12.75 cu. ft.
6.5' x 3' x .6' =	11.70 cu. ft.
5.0' x 5.0' x .5' =	12.50 cu. ft.
Total	36.95 cu. ft.

To conserve shipping space, it might be possible to further reduce the cubic space needed by crating this cell more compactly. The 750 gallon metal tanks that have been received at this location have been oval in shape. The dimensions of one of these tanks are; 11.3' long x 4.2' high x 5' wide or 327.3 cubic feet. Compared to the 36.95 cubic feet occupied by the 750 gallon cell, the metal tank would require almost 7 times as much shipping space.

During the test, no trouble was experienced with the 750 gallon cell since it is equipped with a vapor escape valve. The ply-wood shell inclosing the cell protects the cell itself from the sun's rays and acts as an insulator, to some degree. This cell was road tested for about 500 miles and arrangements have been made to have it service tested by a troop unit at Desert Training Center for an additional 5000 miles. When this test is completed, a report will be submitted covering the results.

The $7\frac{1}{2}$ gallon cells were tested as thoroughly as it was possible to do so because failures were experienced very rapidly when the cells were filled with gasoline and exposed to the sunlight.

The Firestone cells are not satisfactory for the storage of gasoline because they leak badly from numerous pin holes that appear in the fabric and also because of the tendency of the bag to leak due to any abrasion or by any point where a crease is formed by folding the cell.

The Goodyear cell can be used to store gasoline if the cell is shaded from the direct rays of the sun at all times. None of the Goodyear cells tested leaked at any time except when the seams ruptured due to excessive vapor pressure. The Goodyear cells could be successfully employed to store or transport water or non volatile liquids. Their use as drinking water containers should be discouraged because of the disagreeable taste and smell imparted to the water by the thiokol used in the construction of the cells.

The pressure temperature tests were conducted with the Quartermaster 5 gallon can to determine what pressures could be expected to serve as a guide in the design of any future collapsible cells.

Inclosing the cells in canvas bags does not appear to be of much help. After a period of approximately four hours the gasoline will reach the same temperature that it would without the canvas covering.

V. Summary of Results:

The 750 gallon cell was satisfactory in the engineering tests given it. Engineering tests indicate the 750 gallon cell tested has sufficient mechanical strength and would definitely conserve shipping space.

The $7\frac{1}{2}$ gallon cells tested are not satisfactory for the storage or transportation of gasoline in desert climates. It might be used to handle water for purposes other than drinking, but is not sufficiently strong to withstand rough handling. The thiokol used in these cells gives water a bad smell and taste and water stored in them would not be very palatable for drinking.

Any container for the storage and transportation of gasoline in desert must be able to withstand vapor pressures of at least 13.2 pounds per square inch, plus a reasonable safety factor plus the necessary mechanical strength to withstand stacking, piling, and rough handling.

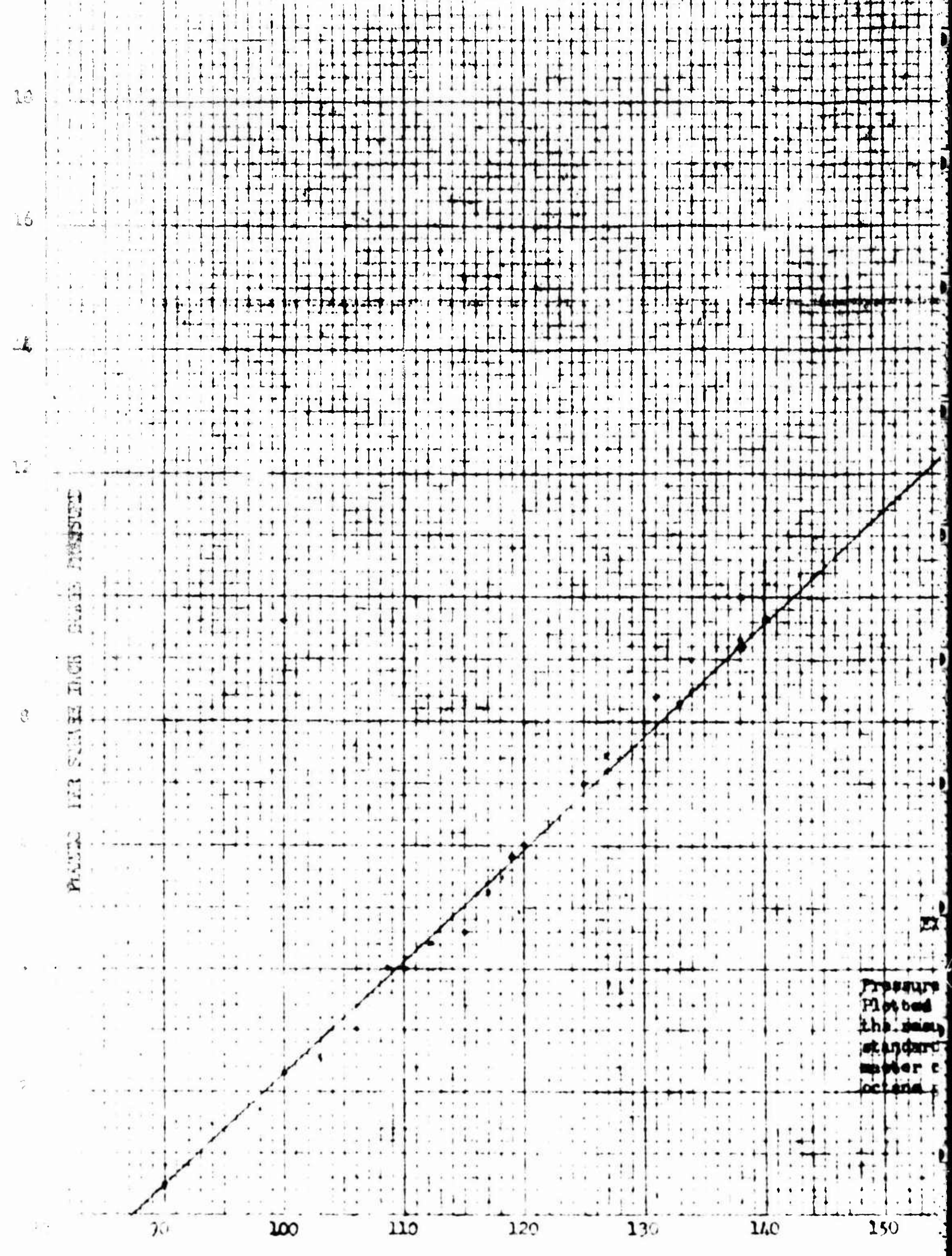
The fabric used in the Firestone cells is not satisfactory for handling gasoline.

The fabric used in the Goodyear cells is more satisfactory but it was not possible to ascertain if it would develop leaks, at the high pressures which it must withstand, because the seams failed before sufficient pressure could be applied to test the fabric.

Submitted by /s/ ______________________
John E. Lewis, Jr.
Engineer.

Approved by /s/______________________
Chief, Desert Test Branch

COPY


18
16
12
8
90
100
110
120
130
140
150
Pressure
Plotted

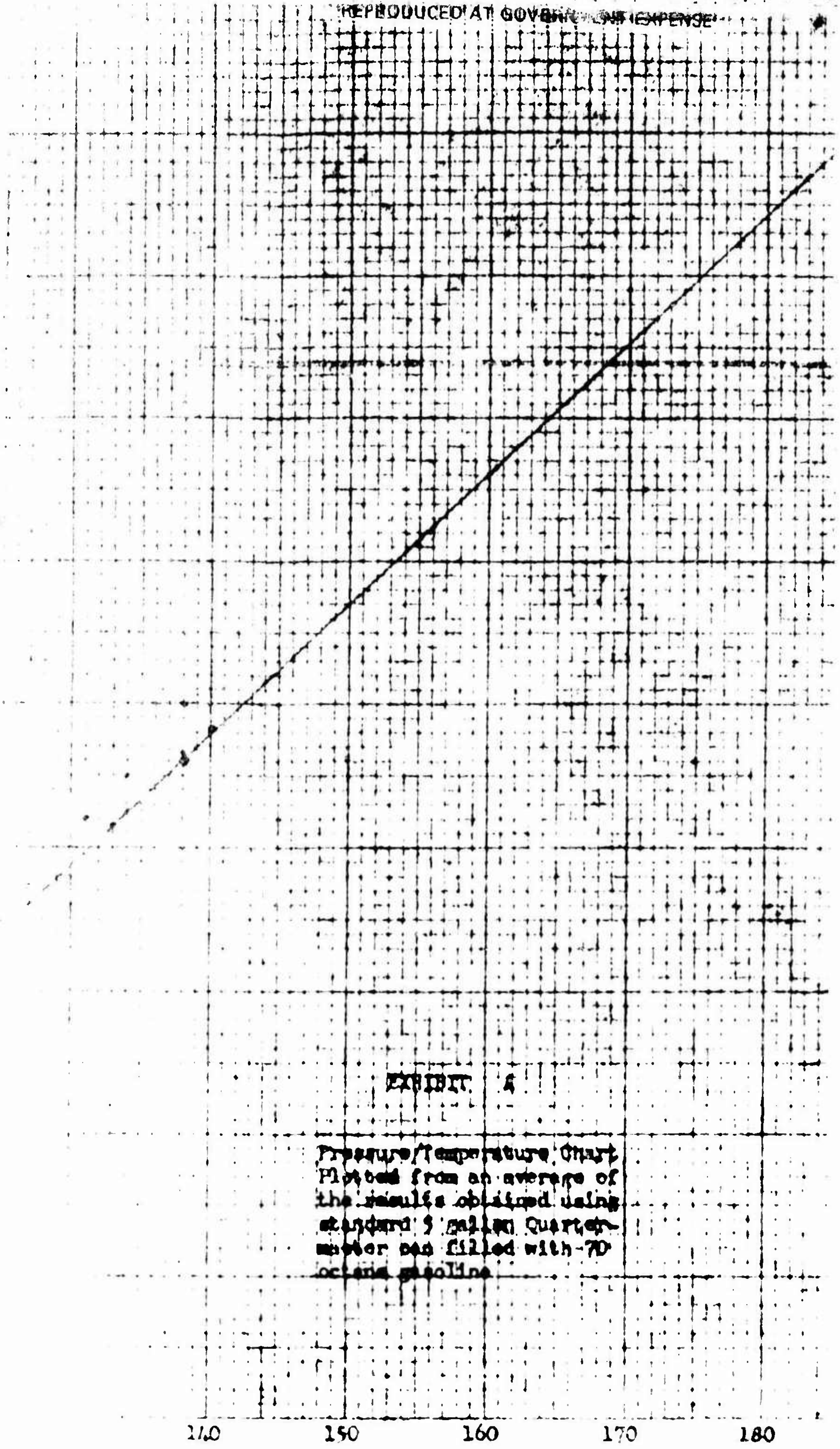


EXHIBIT 4

Pressure/Temperature Chart Plotted from an average of the results obtained using standard 5 gallon Quartermaster can filled with 70 octane gasoline

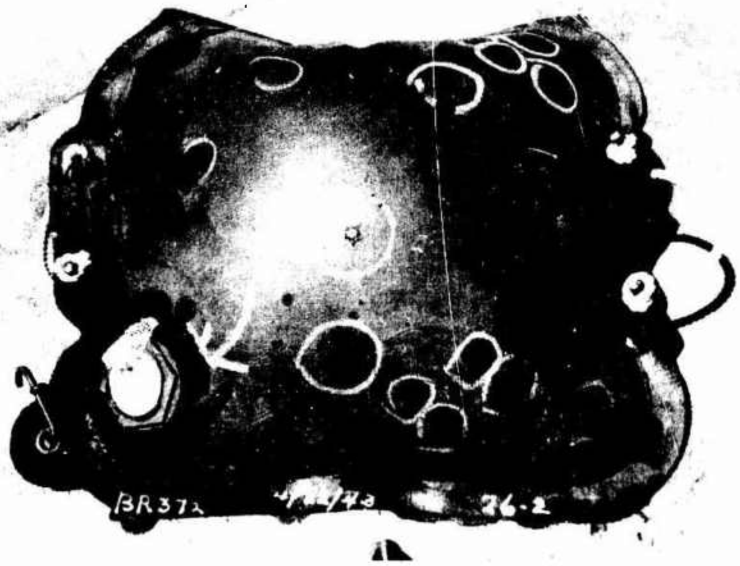


Figure No. 1. 7-1/2 Gallon Collapsible Containers for transportation and storage of gasoline. Chalk circles indicate pin hole leaks in Firestone cells.

Figure No. 2. 7-1/2 Gallon Collapsible Containers for transportation and storage of gasoline. Failure of seam of Goodyear cell caused by high gasoline vapor pressure.

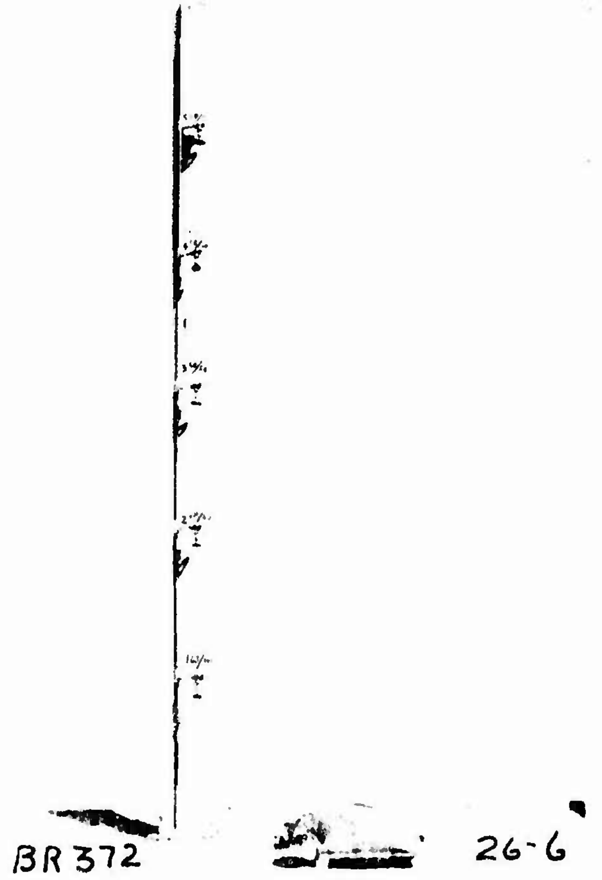


Figure No. 3. 7-1/2 Gallon Collapsible Container for transportation and storage of gasoline. Improvised water column constructed of 1/2 inch pipe. This water column was used to test collapsible cells for bursting pressures.

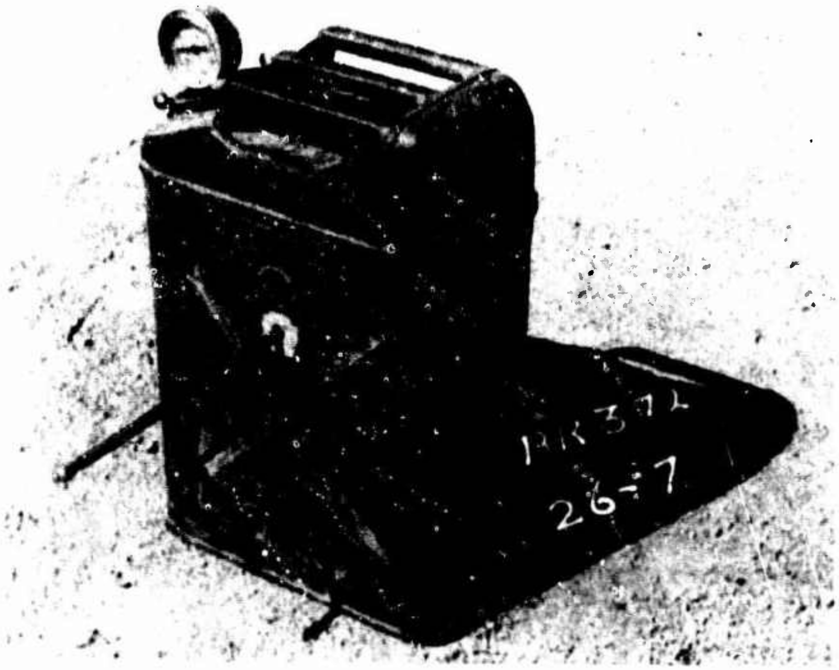


Figure No. 4. Standard QM - 5 Gallon Gasoline Can equipped with pressure gauge and thermo-well.

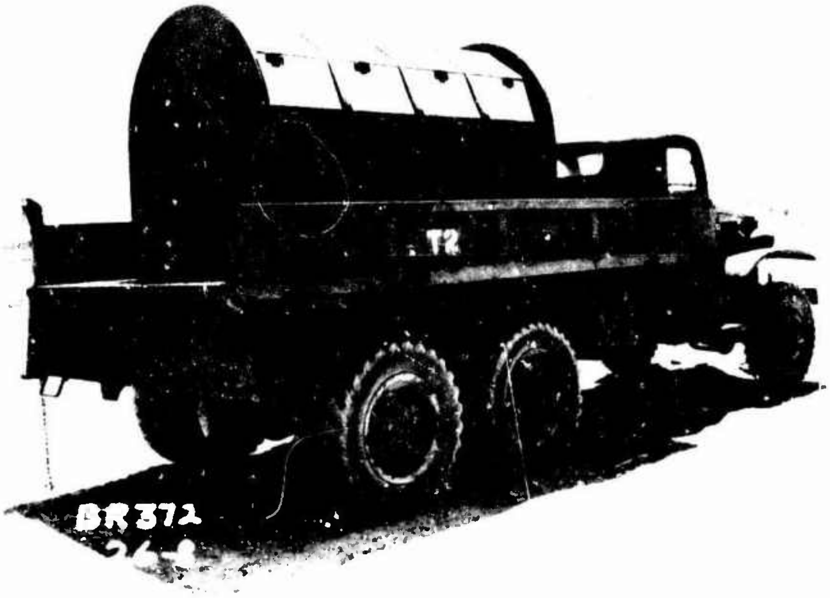


Figure No. 5. 750 Gallon Collapsible Container mounted in 2-1/2 ton, 6 x 6 truck.

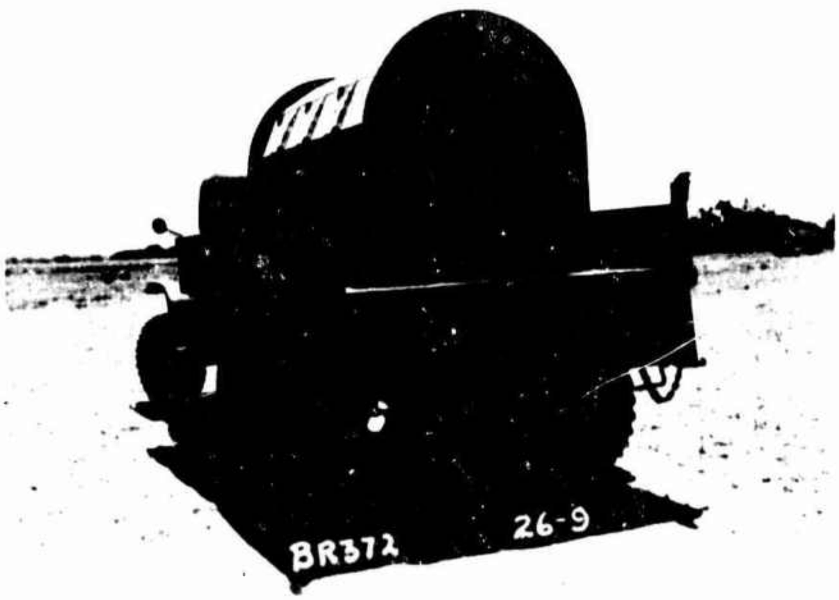


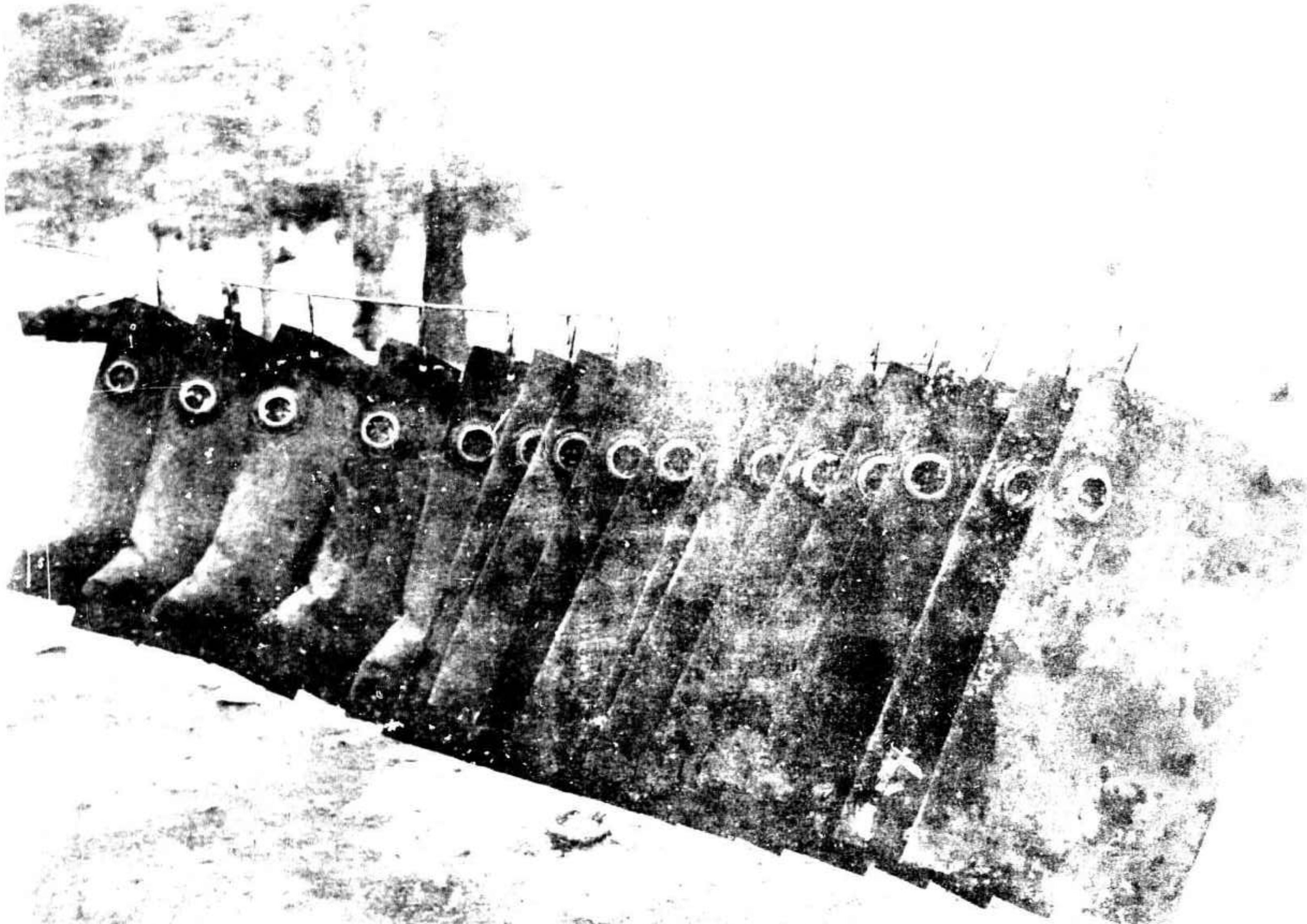
Figure No. 6. 750 Gallon Collapsible Container mounted in 2-1/2 ton, 6 x 6 truck.

APPENDIX "C"

First Interim Report

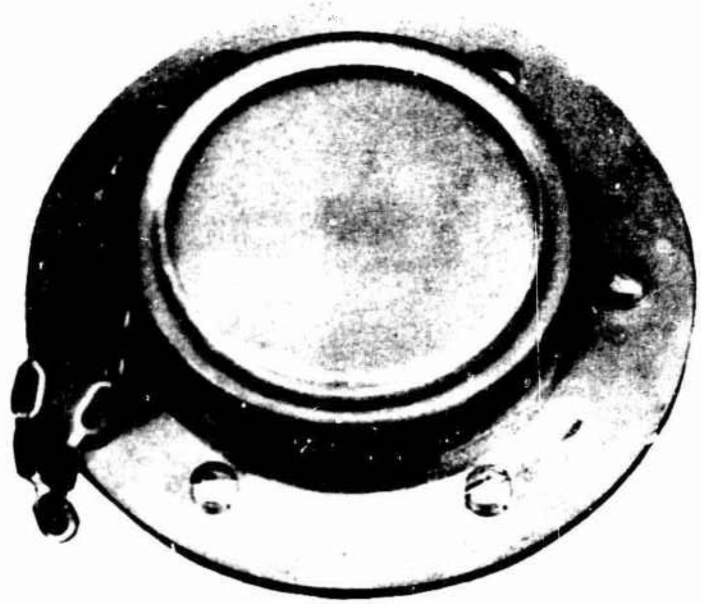
BR 372, Containers, Collapsible
for Petroleum Products Storage

Appendix "C" contains photographs and drawings of the various sizes of containers under procurement as well as various experimental types.

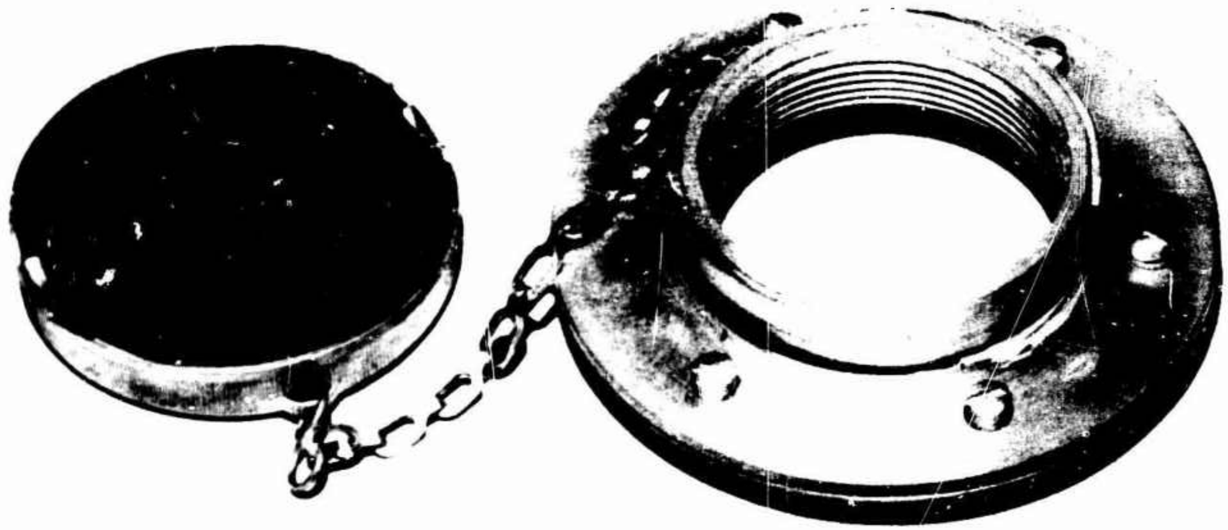


Method Of Supporting 7 Gallon Containers For Filling

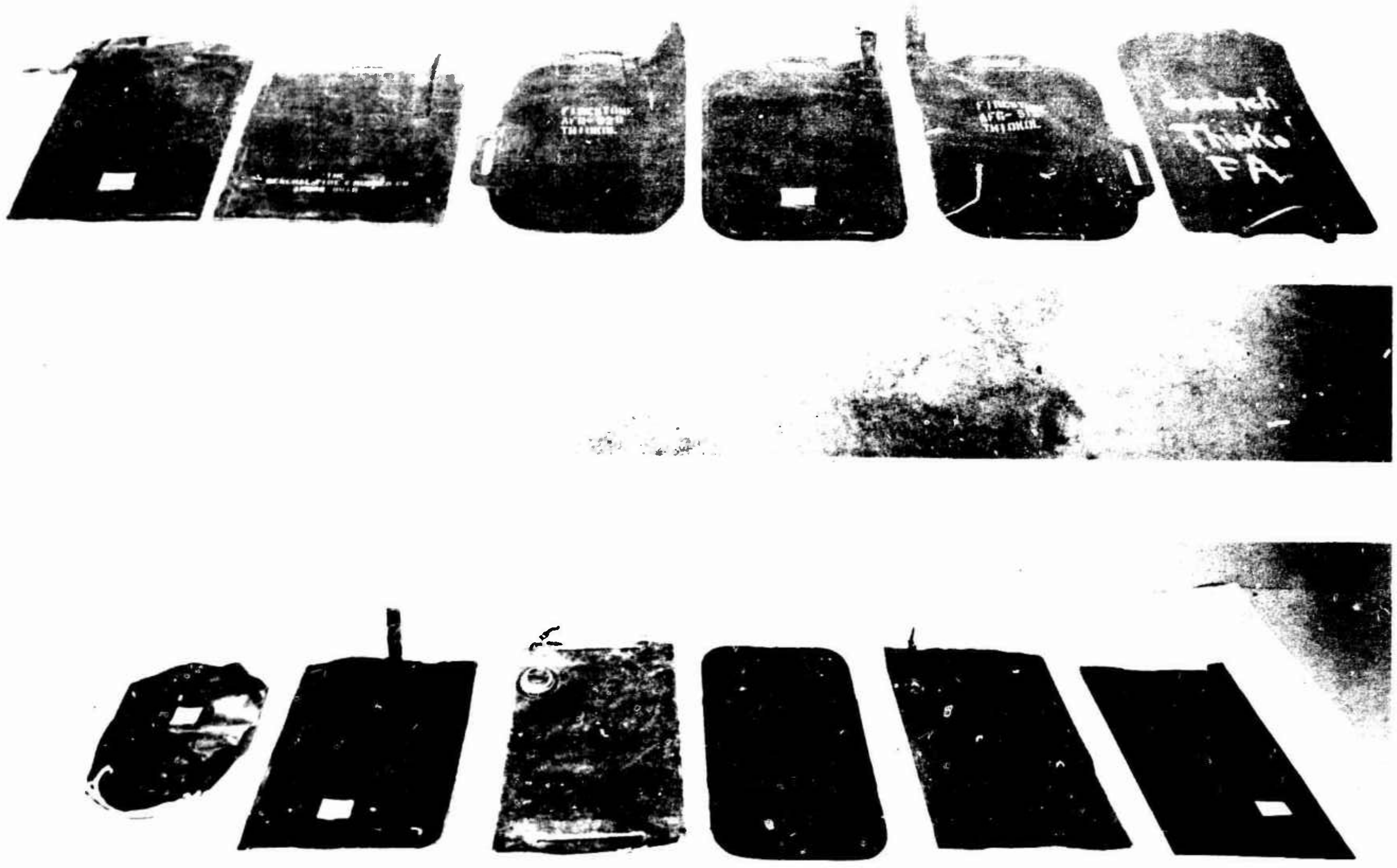
7 Gallon Cells Loaded in 2-1/2 Ton Truck



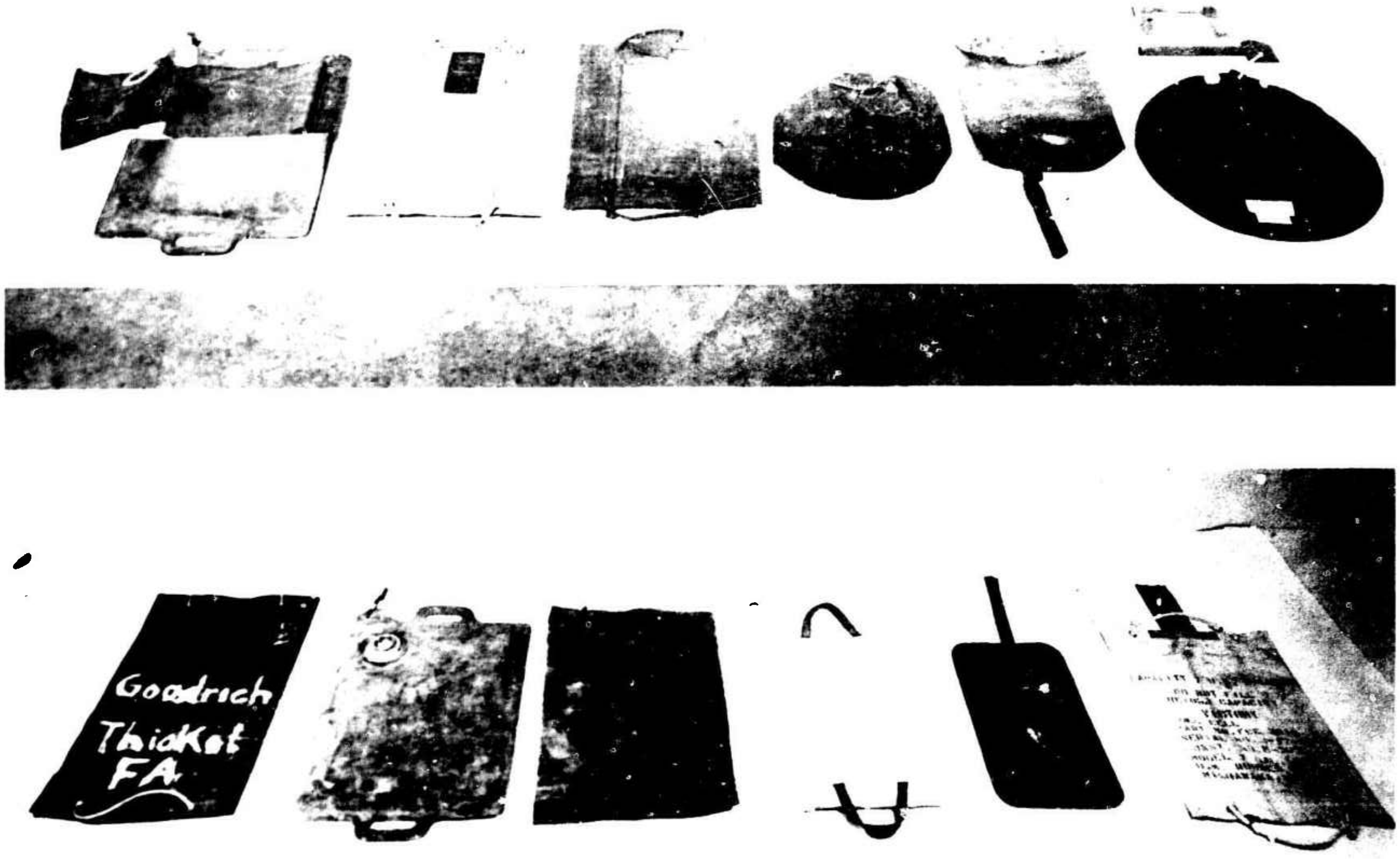
Bayonet Type Closure For 7 Gallon Cell



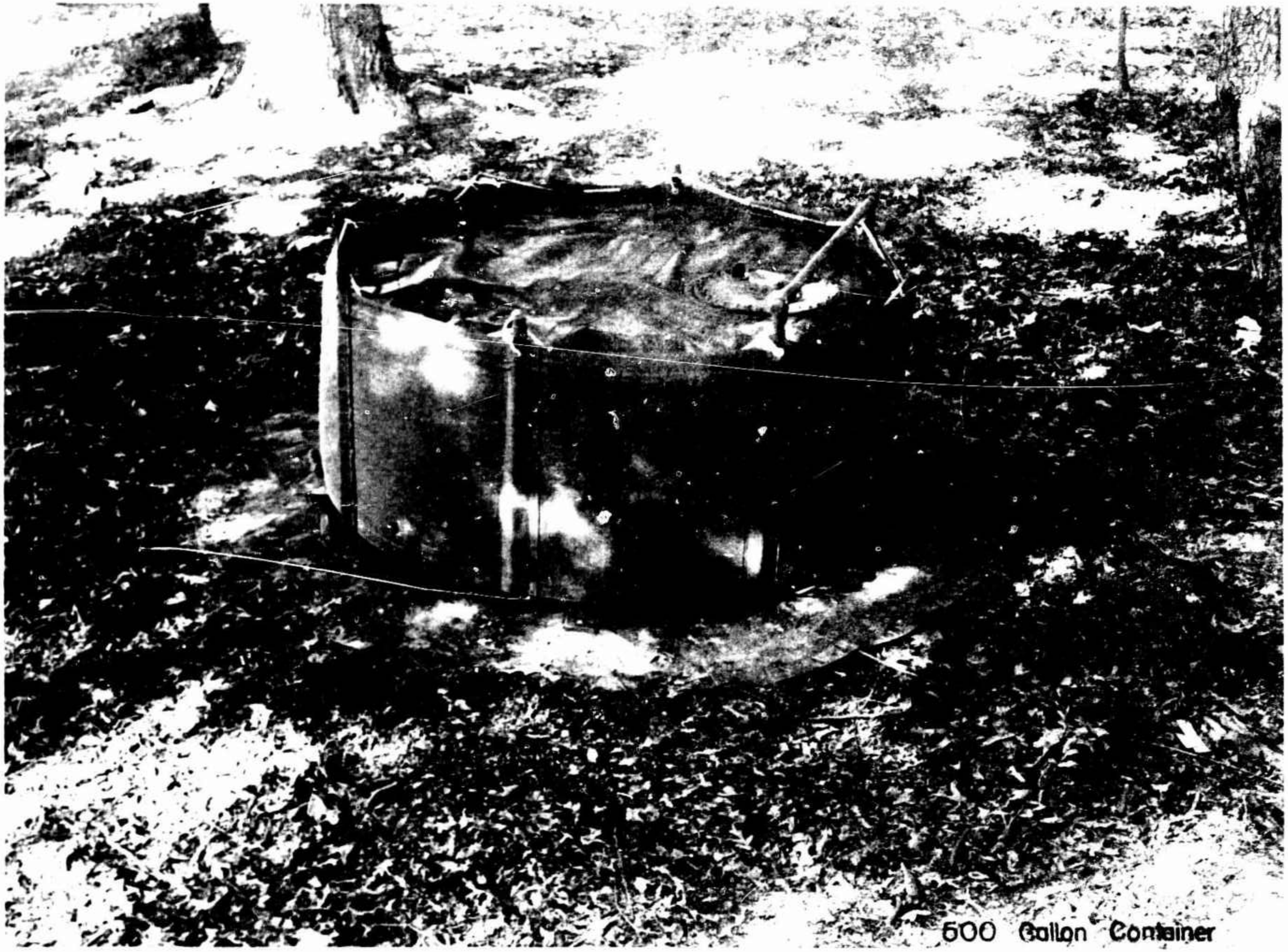
Bayonet Type Closure For 7 Gallon Cell



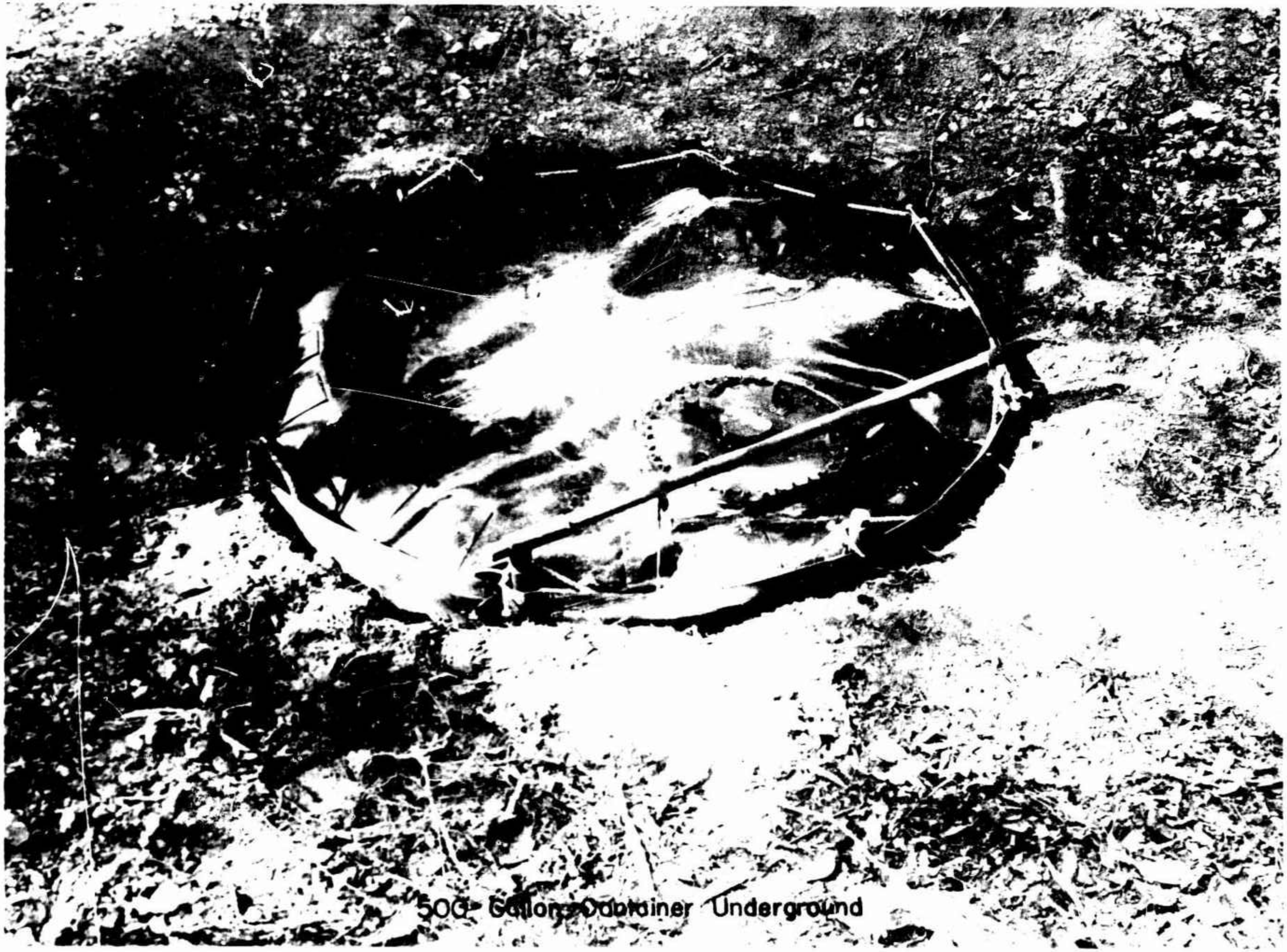
Types Of 7 Gallon Containers Investigated

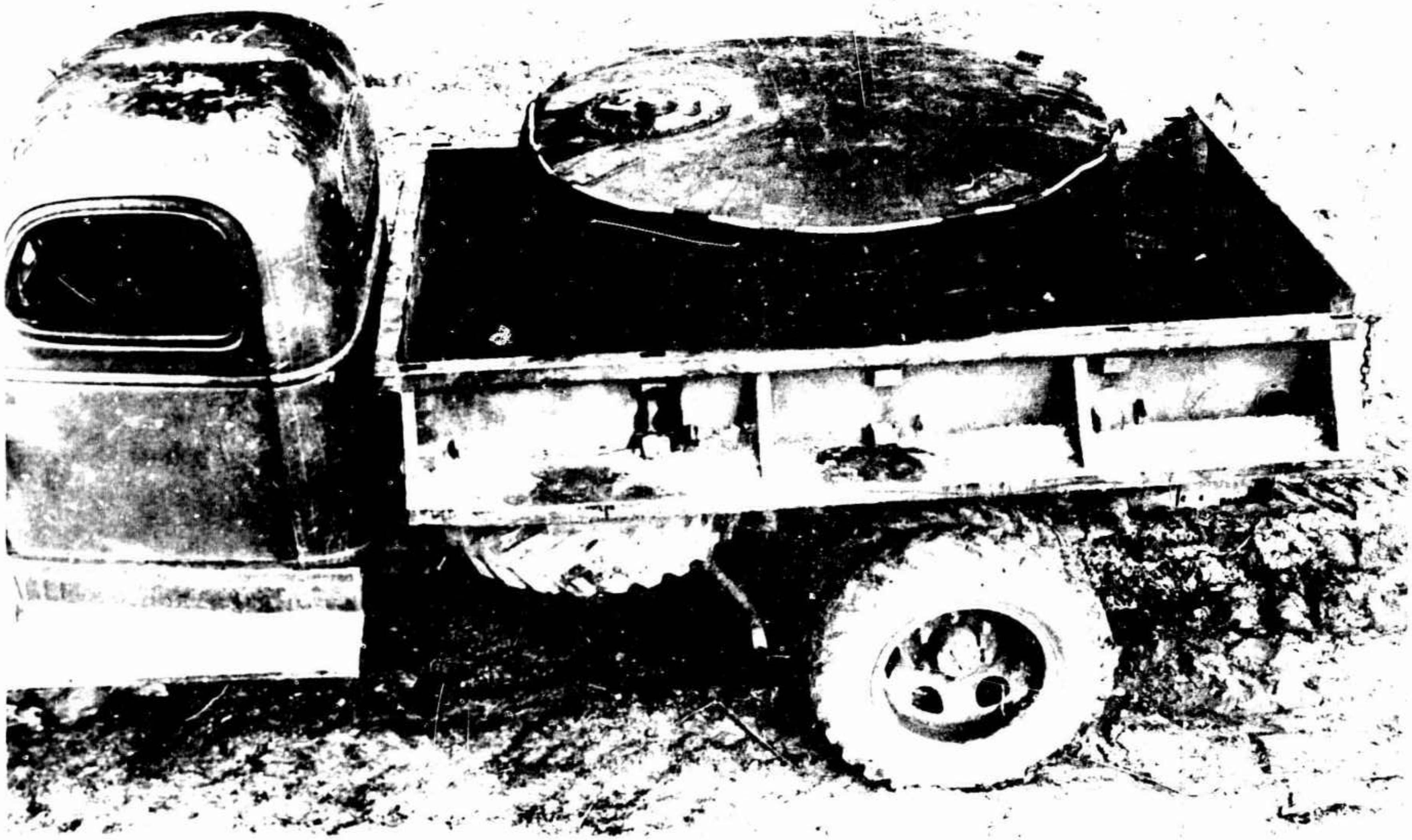


Types Of 7 Gallon Containers Investigated

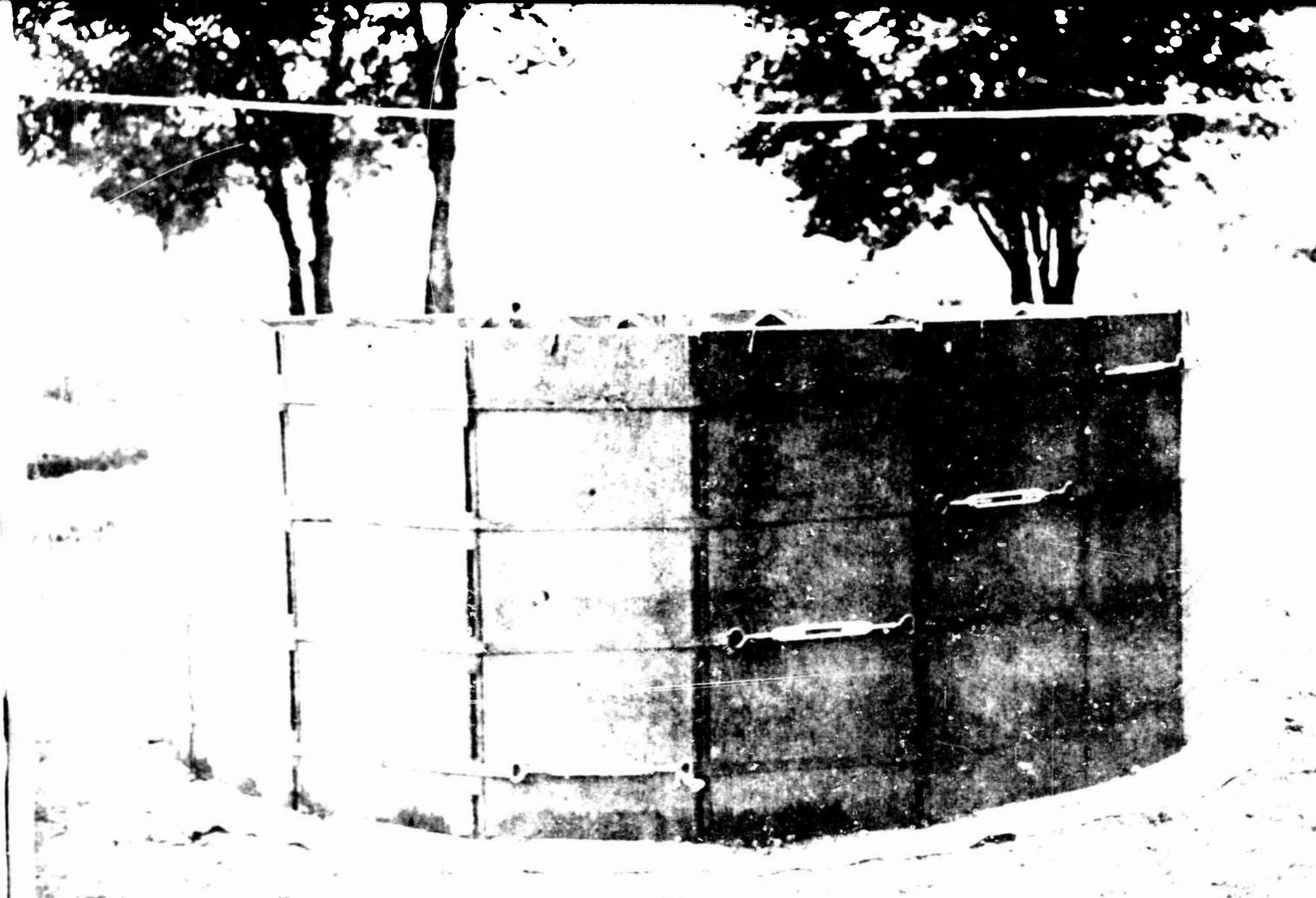


600 Gallon Container


500 Gallon Container Underground

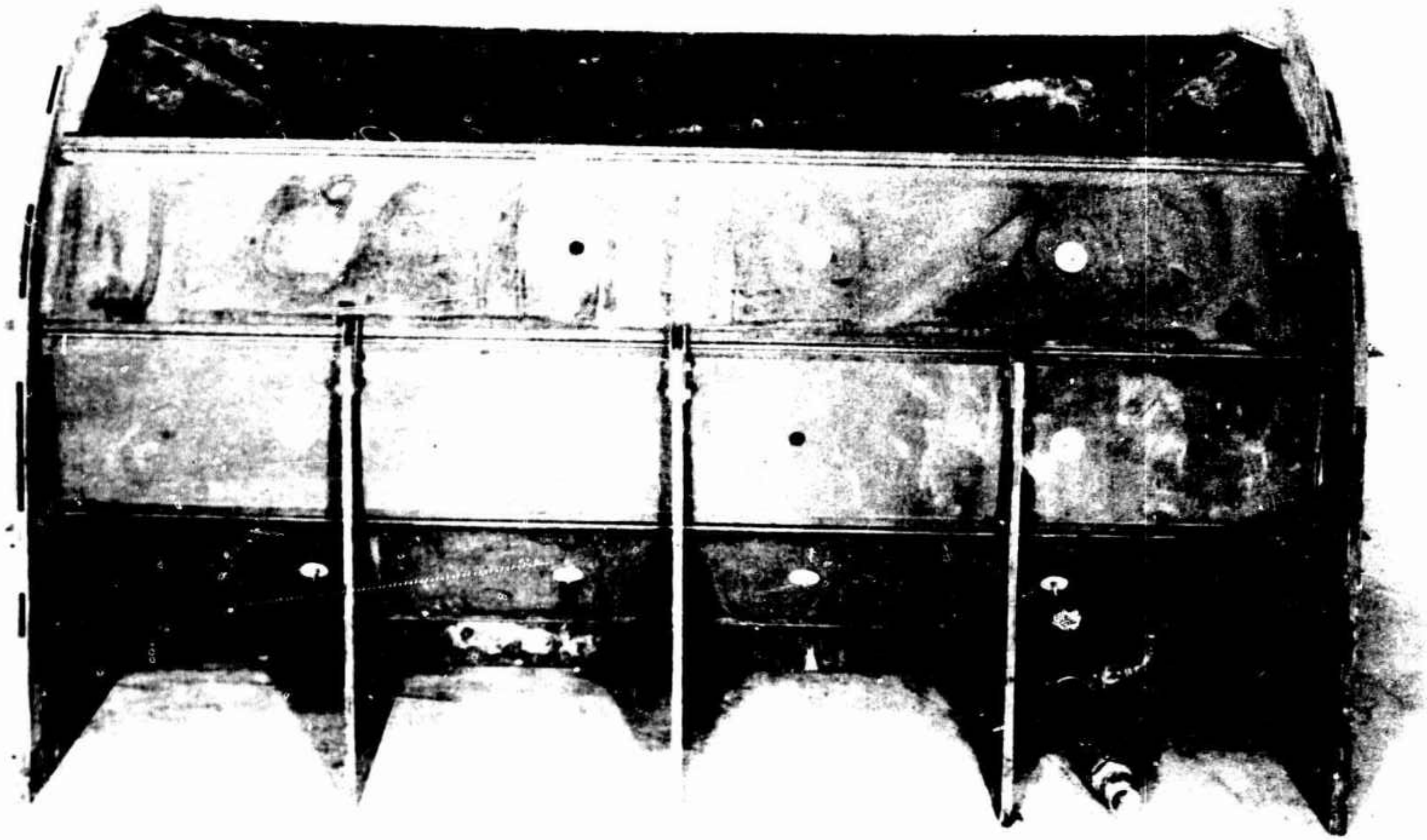


500 Gallon Container on 1-1/2 Ton Dump Truck

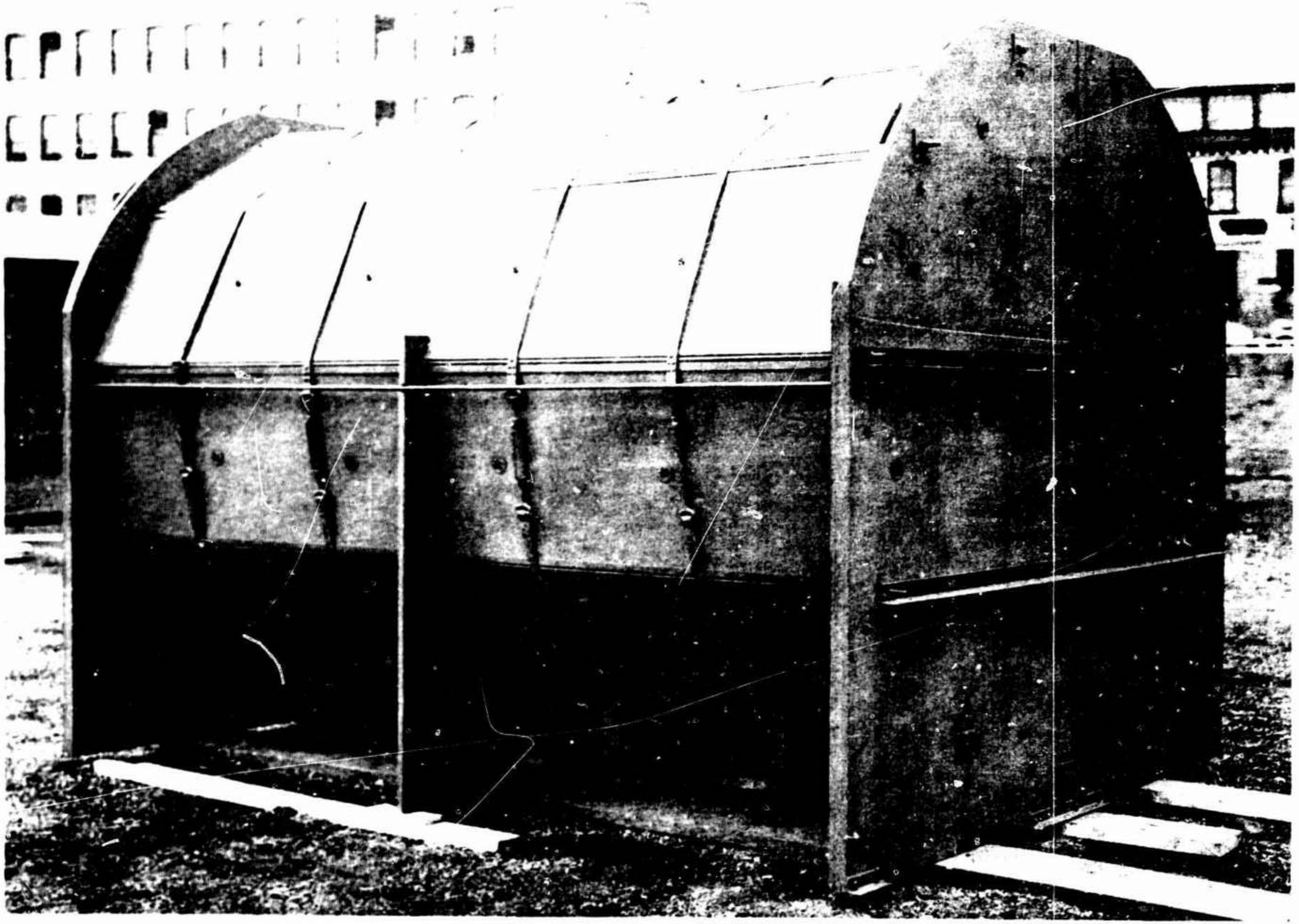


3000 Gallon Container

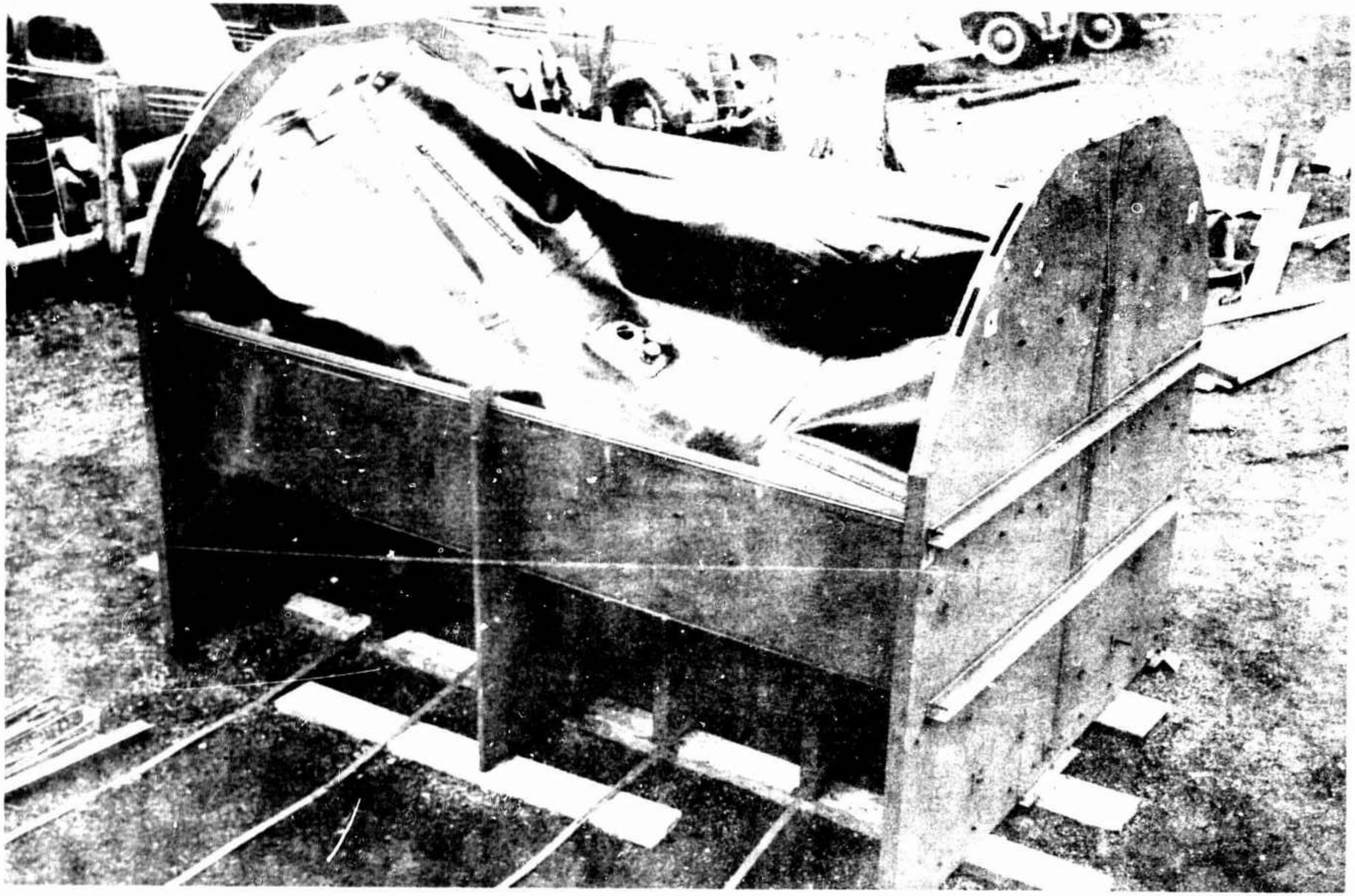
750 Gallon Container Mounted on 2-1/2 Ton Truck



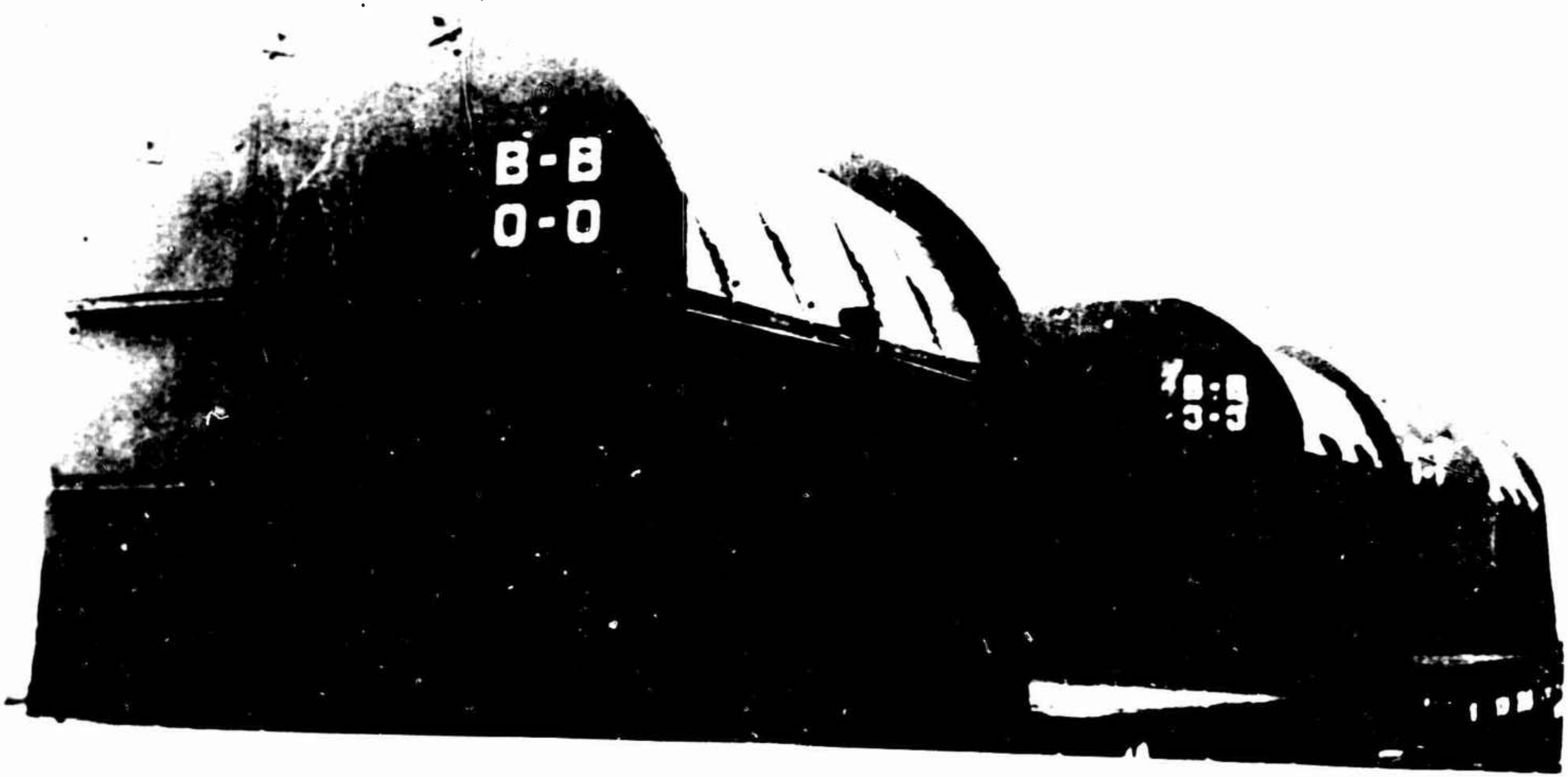
Assembly Of 750 Gallon Container



2700 Gallon Container Assembled



2700 Gallon Containter Partially Assembled



3-2700 Gallon Containers on Railroad Flat Car

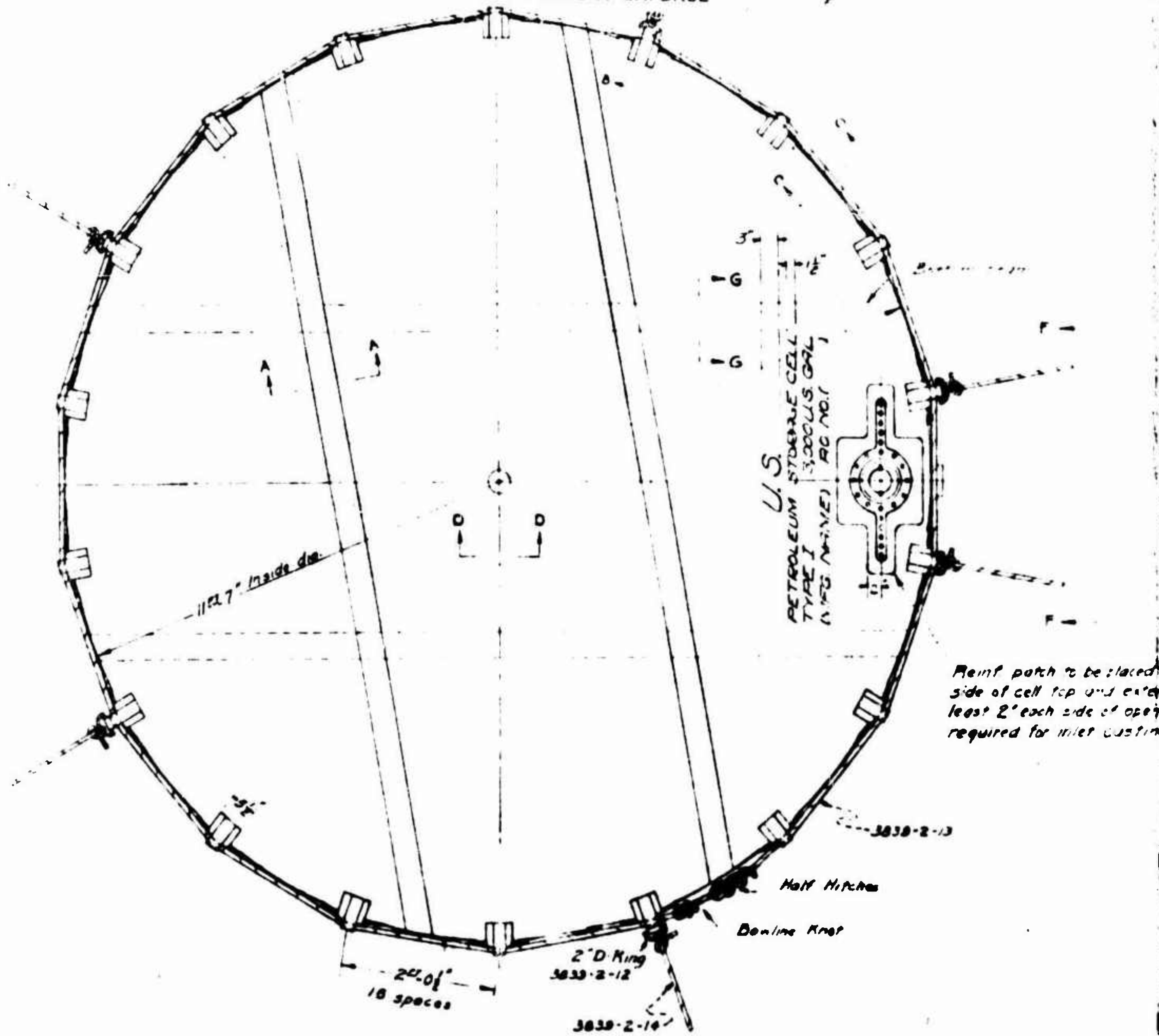
Experimental Articulator No. 1 for 750 and 2700-Gallon Containers

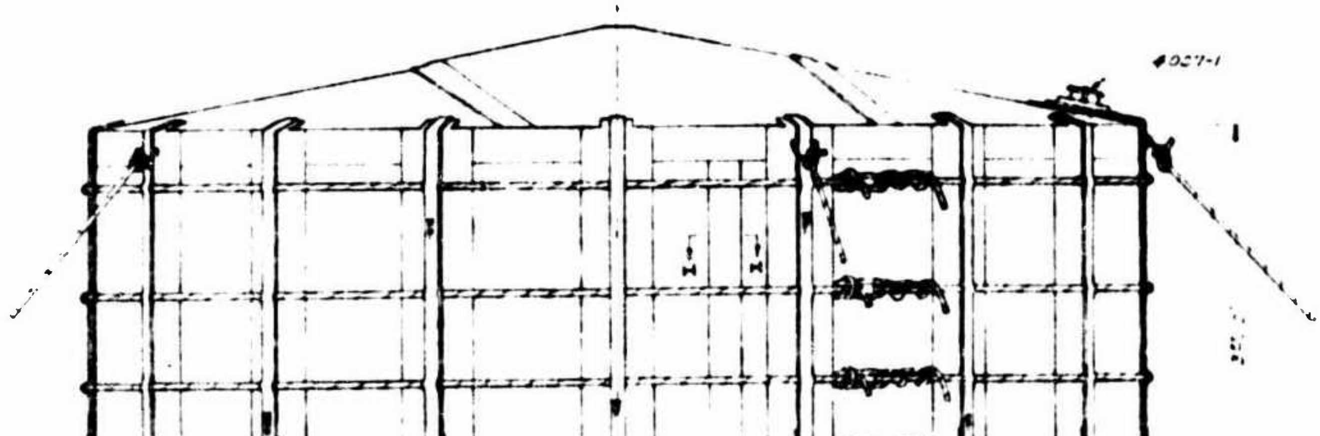
Experimental Articulator No.2 for 750 and 2700 Gallon Containers

Experimental Articulator No.3 for 750 and 2700 Gallon Containers

Embankment For 21000 Gallon Container

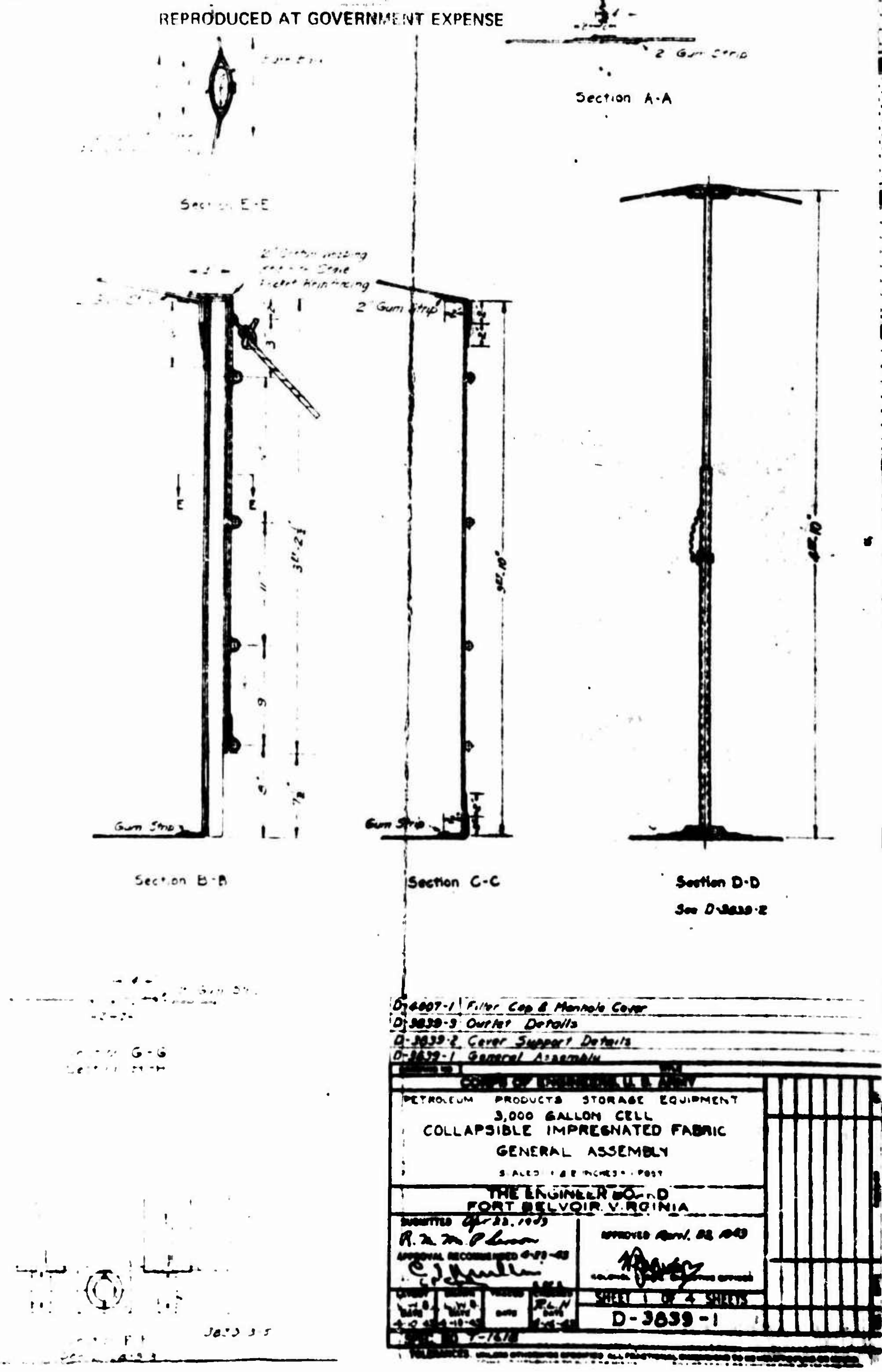
Interior of Embankment For 21000 Gallon Container Showing Outlet Trench





3839-2-7

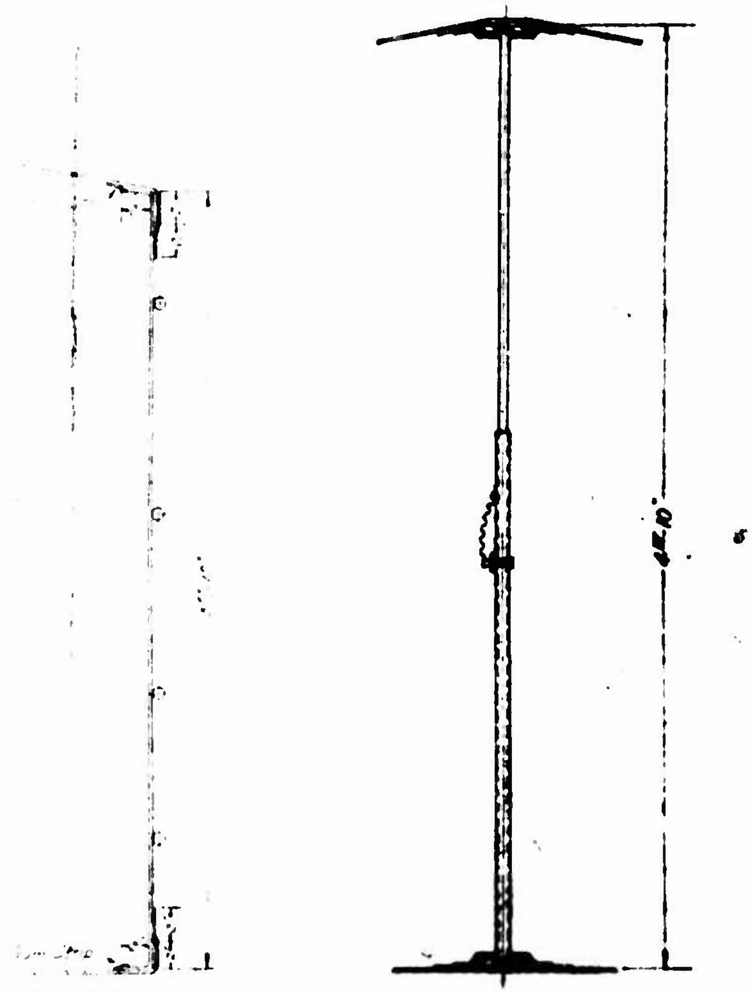
3839-3


2" Gum Strip
Section A-A
Section E-E
2" Gum Strip
Gum Strip
Section B-B
Section C-C
Section D-D
See D-3839-2
D-4807-1 Filter Cap & Manhole Cover
D-3839-3 Outlet Details
D-3839-2 Cover Support Details
D-3839-1 General Assembly
CORPS OF ENGINEERS, U. S. ARMY
PETROLEUM PRODUCTS STORAGE EQUIPMENT
3,000 GALLON CELL
COLLAPSIBLE IMPREGNATED FABRIC
GENERAL ASSEMBLY
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
APPROVED April 22, 1943
SHEET 1 OF 4 SHEETS
D-3839-1

2

2 Gum Strip

Section A-A



Section C-C

Section D-D

See D-3839-2

D-4027-1 Filler Cap & Manhole Cover
D-3839-3 Outlet Details
D-3839-2 Cover Support Details
D-3839-1 General Assembly

CORPS OF ENGINEERS, U. S. ARMY

PETROLEUM PRODUCTS STORAGE EQUIPMENT
3,000 GALLON CELL
COLLAPSIBLE IMPREGNATED FABRIC
GENERAL ASSEMBLY

THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA

SUBMITTED Apr. 23, 1943

APPROVAL RECOMMENDED 4-23-43

APPROVED April 28, 1943

COLONEL, CORPS OF ENGINEERS, PRESIDENT

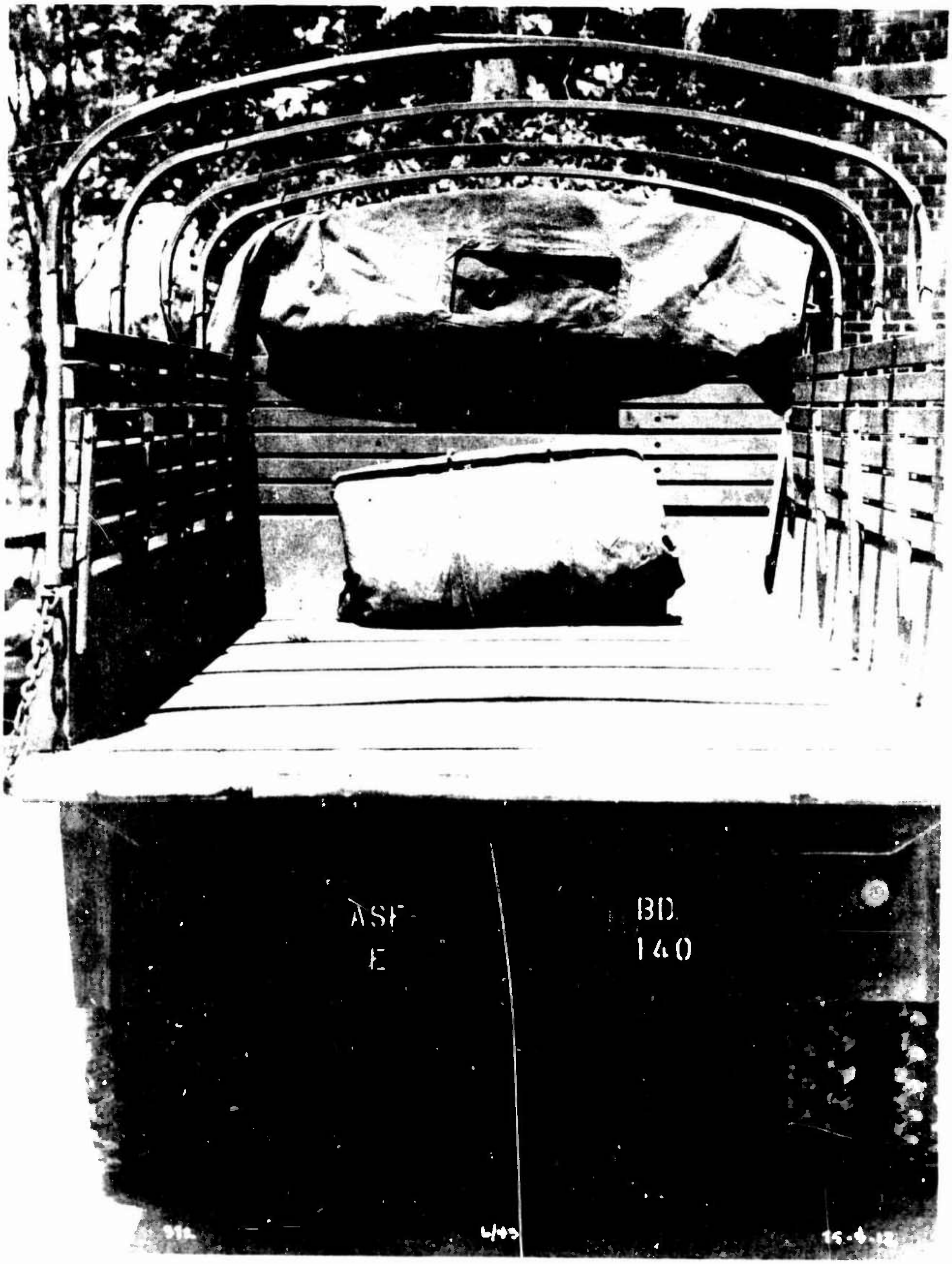
CHECKED RLH DATE 4-22-43

SHEET 1 OF 4 SHEETS

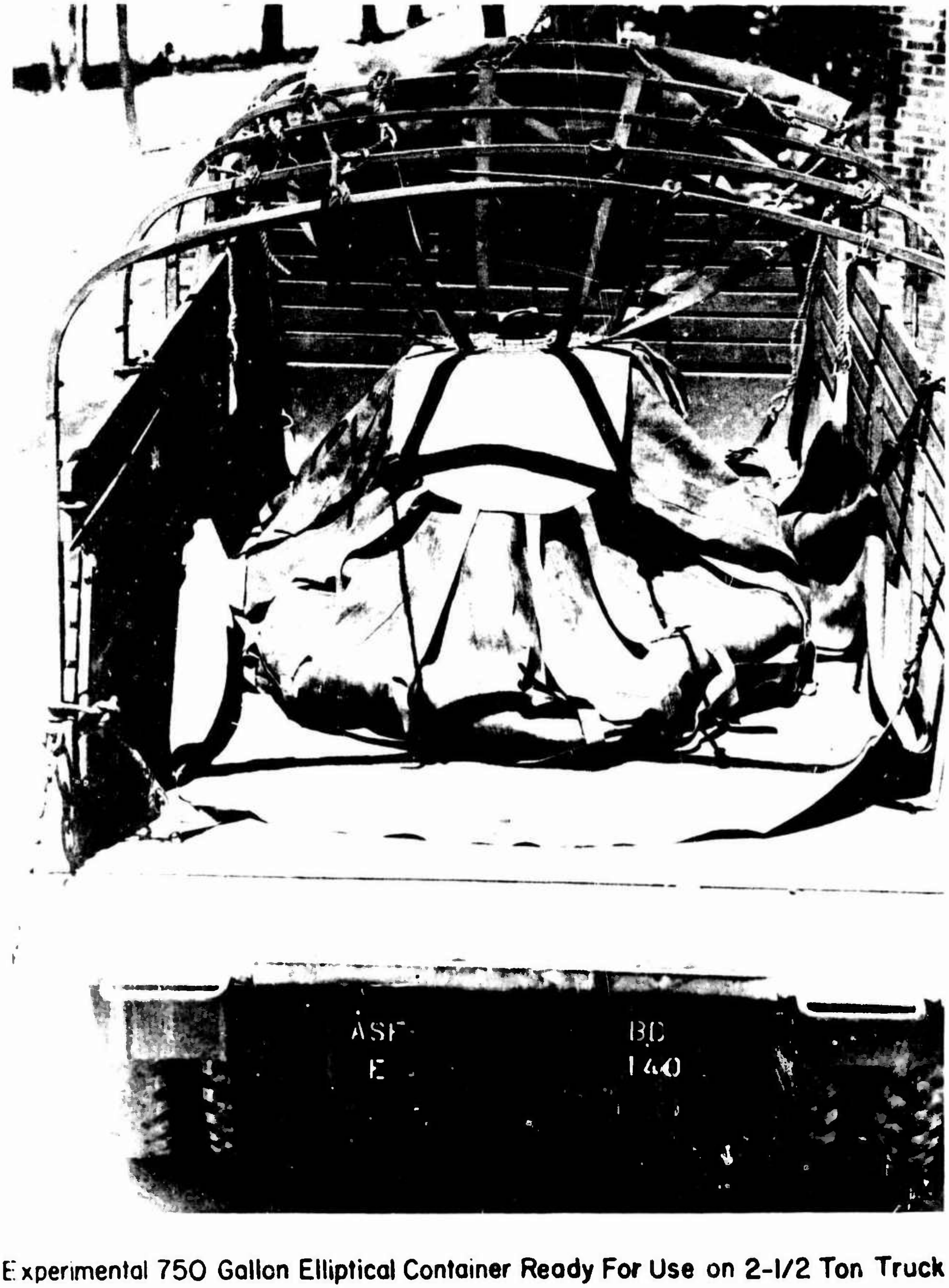
D-3839-1

SPEC NO T-1678

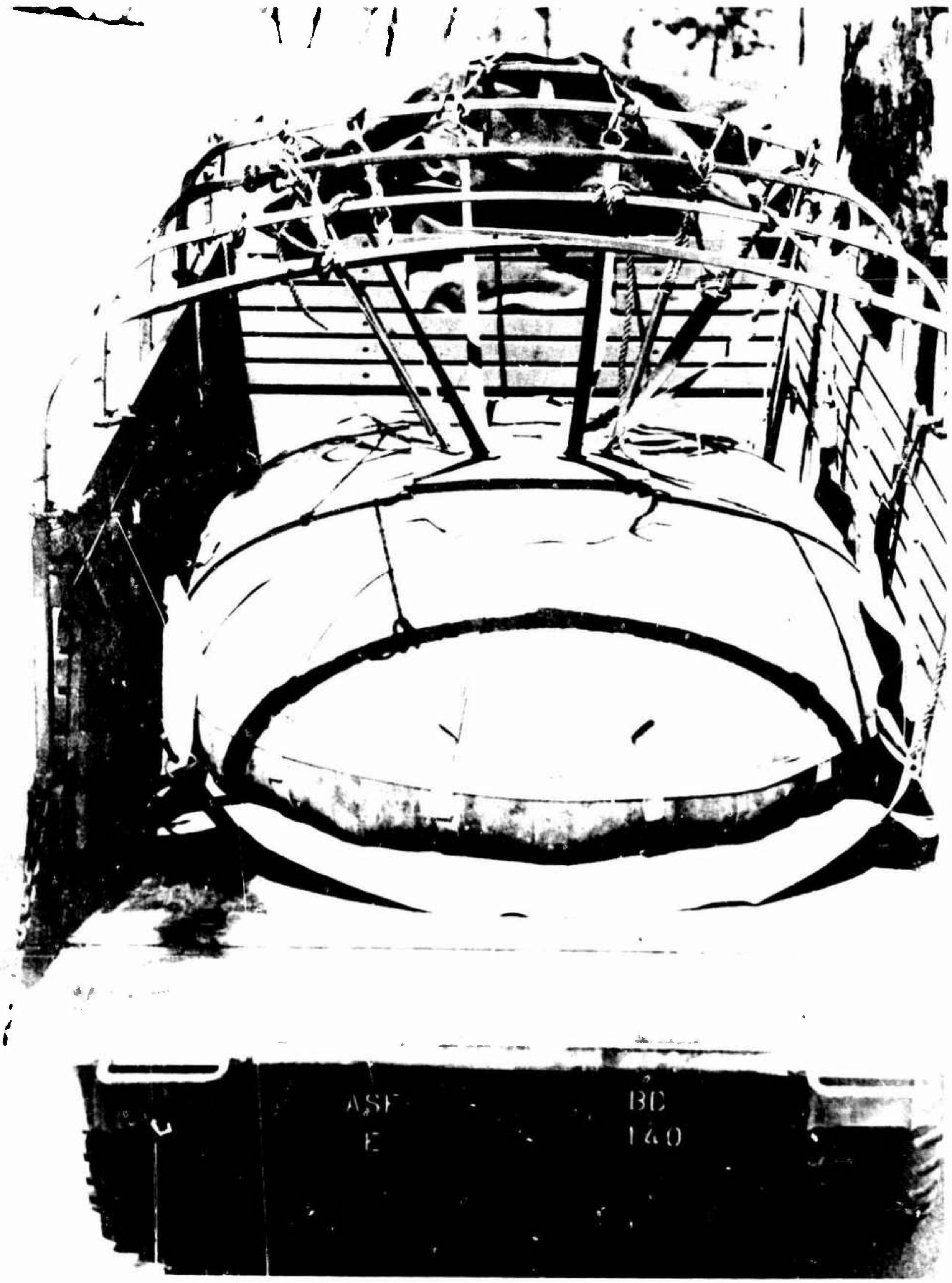
TOLERANCES: UNLESS OTHERWISE SPECIFIED ALL FRACTIONAL DIMENSIONS TO BE HELD TO [illegible]



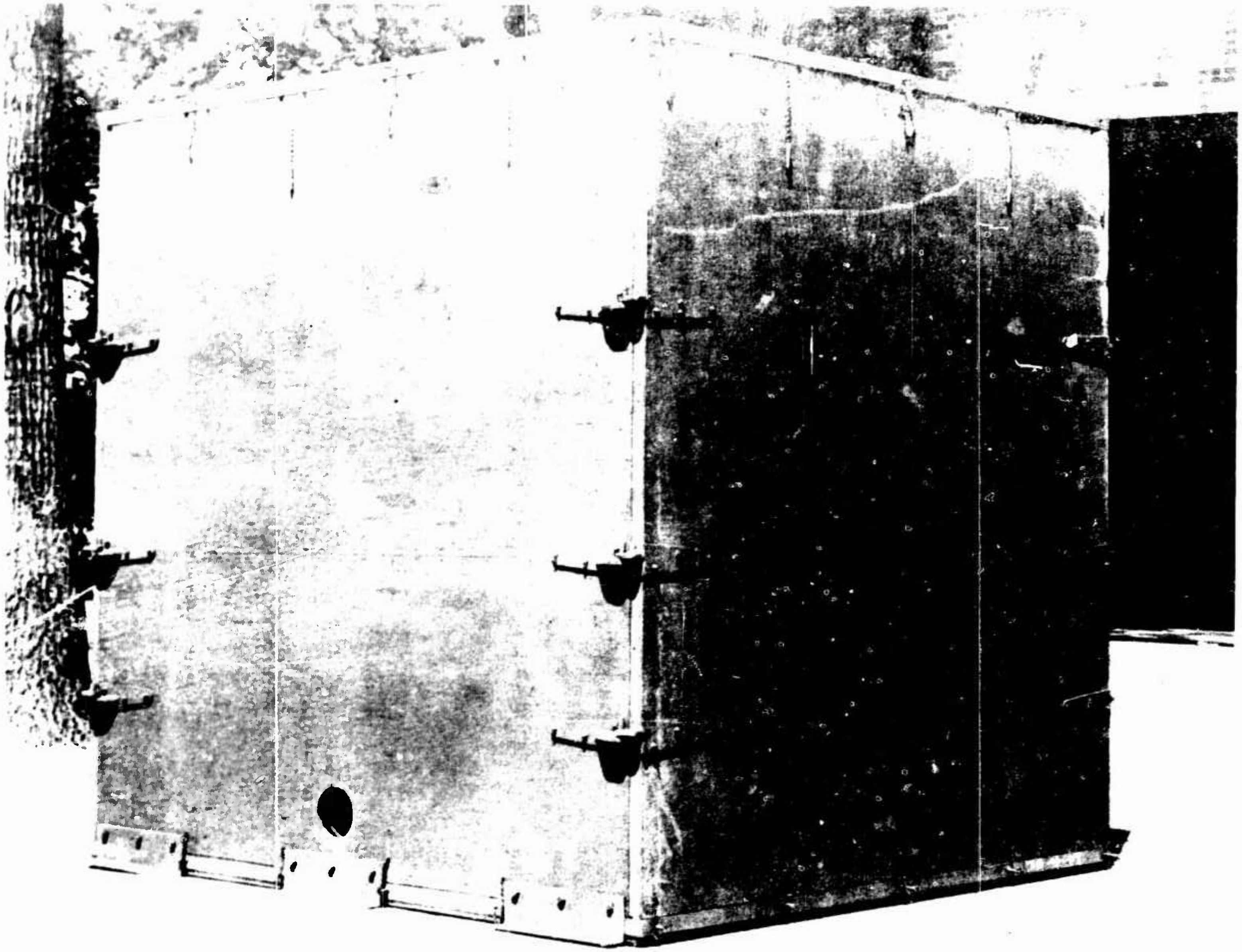
Experimental 750 Gallon Elliptical Container Rolled-Up on 2-1/2 Ton Truck



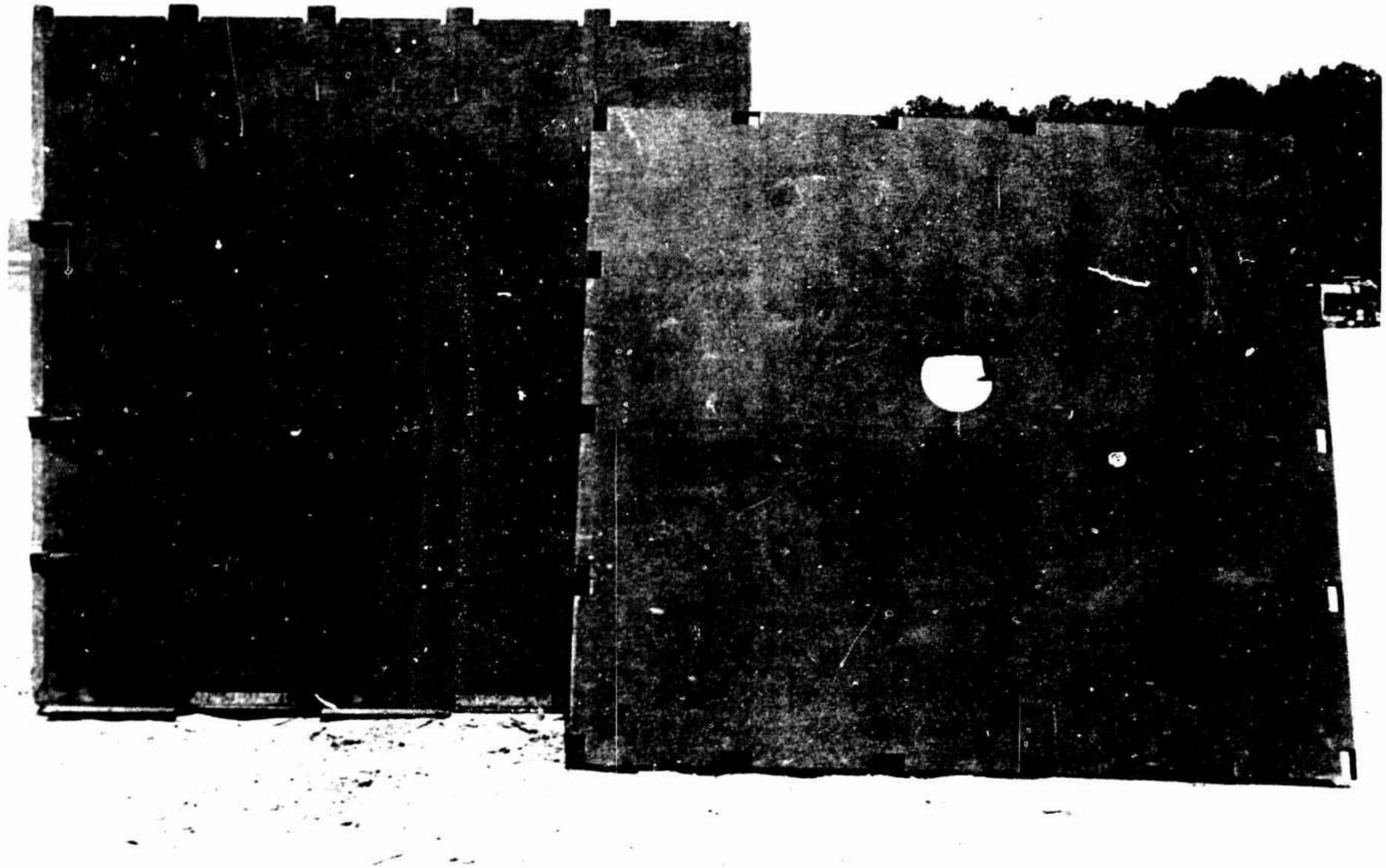
Experimental 750 Gallon Elliptical Container Ready For Use on 2-1/2 Ton Truck



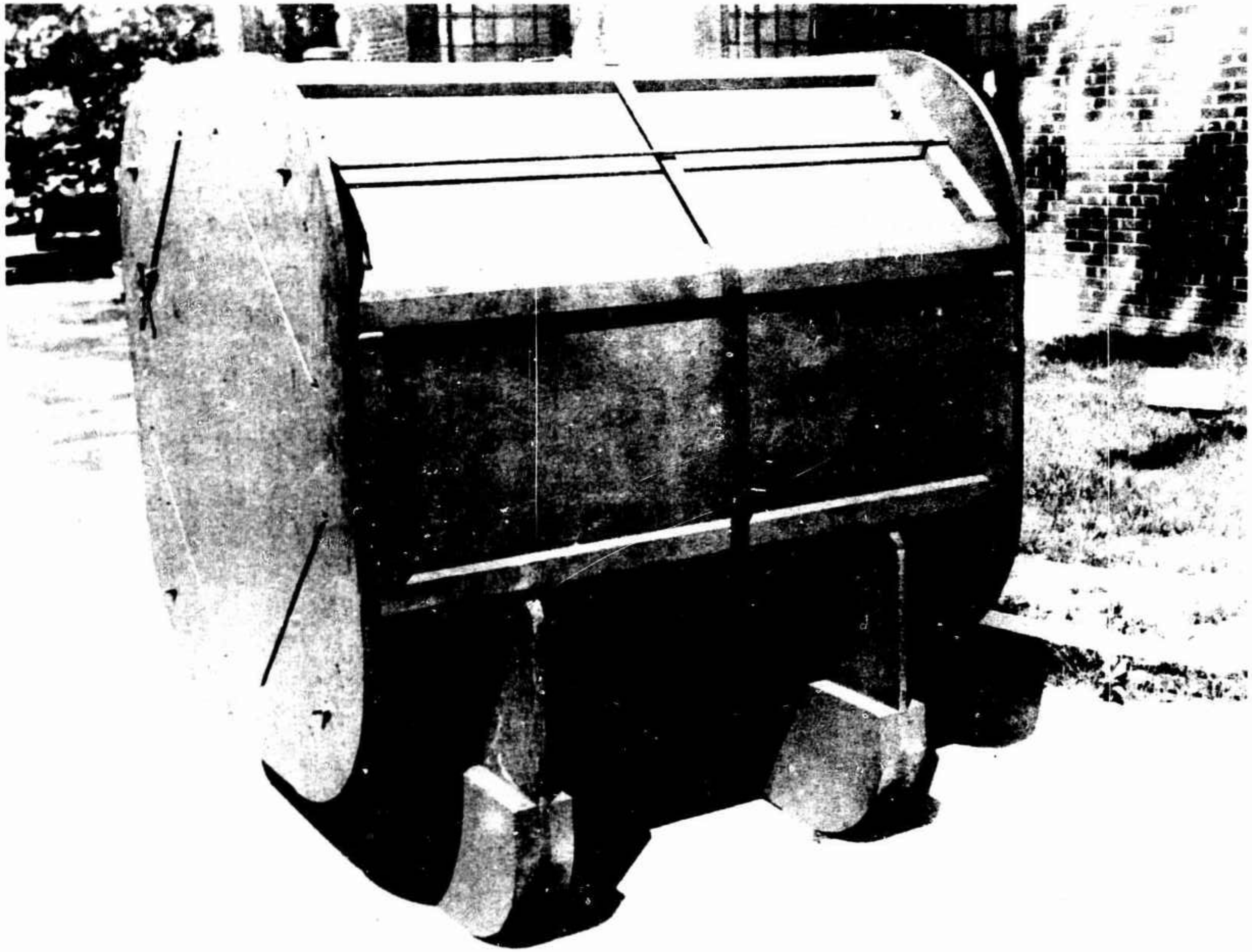
Experimental 750 Gallon Elliptical Container Filled on 2-1/2 Ton Truck



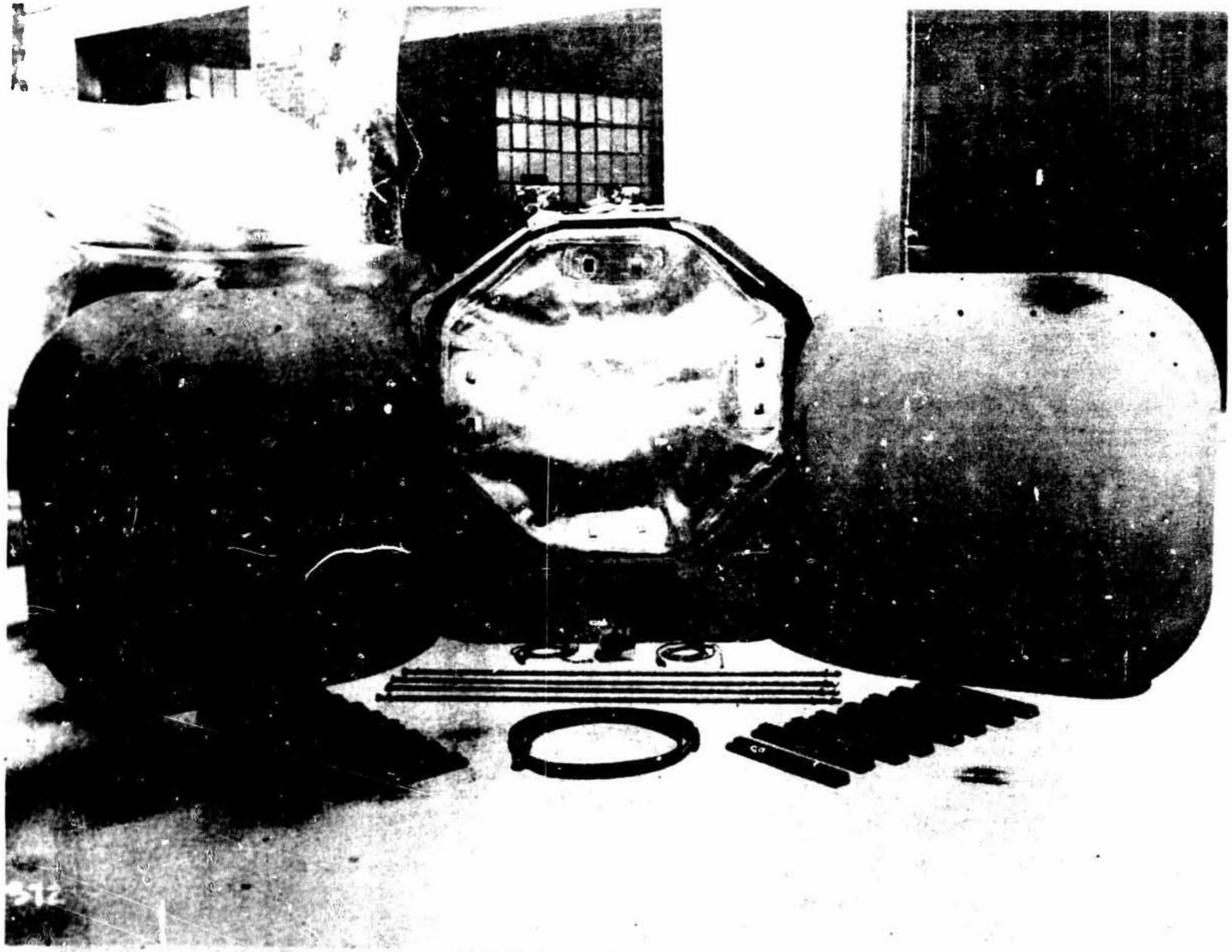
Experimental 2000 Gallon Railroad Container Assembled



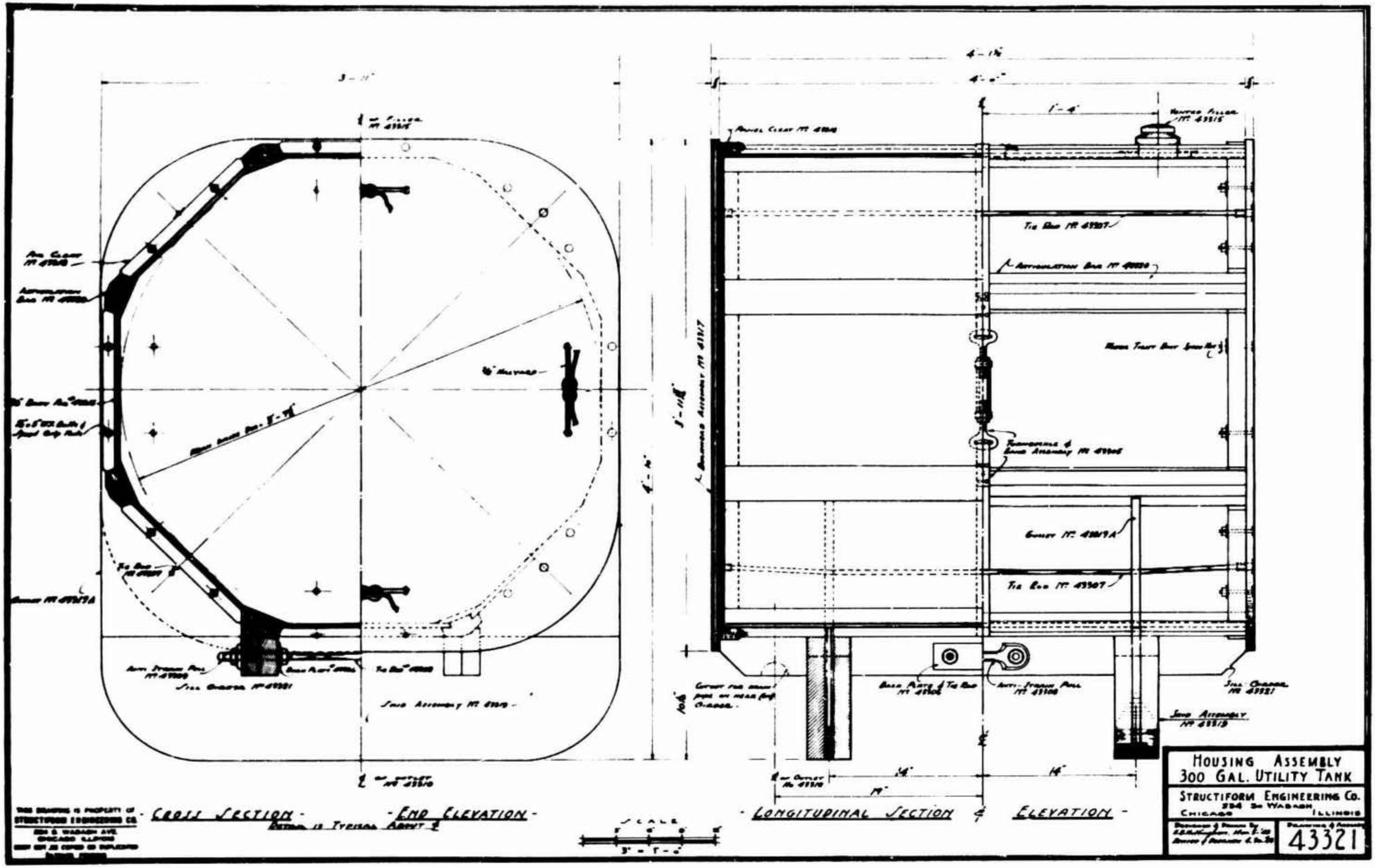
Experimental 2000 Gallon Railroad Container with Top Removed



300 Gallon Experimental Container Assembled



Construction of 300 Gallon Experimental Container



Details Of 300 Gallon Experimental Container

(UNPUBLISHED CARD)

ATI 98.462 (COPIES OBTAINABLE FROM CADO BY U.S. MILITARY ORGANIZATIONS ONLY)

U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND DEVELOPMENT LABS., FORT BELVOIR, VA. (REPORT NO. 757)

CONTAINERS, COLLAPSIBLE FOR PETROLEUM PRODUCTS STORAGE - AND APPENDIXES A - C - FIRST INTERIM REPORT - 17 SEPT 1942 TO 15 JUNE 1943

R.M. MCPHERSON 1 JULY'43 108PP PHOTOS, TABLE, GRAPHS, DRWGS

Divs 10, 14

FUELS AND LUBRICANTS(12) PETROLEUM - HANDLING AND STORAGE AND DISTRIBUTION(10) STORAGE