PHOTOGRAPH THIS SHEET

AD-A955 053

DTIC ACCESSION NUMBER

LEVEL

INVENTORY

(1)

REPORT 863

15-GPM LIGHT DIATOMITE

WATER PURIFICATION EQUIPMENT

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS GRA&I		☐
DTIC TAB		☐
UNANNOUNCED		☒
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A-1		

DISTRIBUTION STAMP

QUALITY INSPECTED 3

UNANNOUNCED

DTIC
ELECTE
JAN 29 1986
S D
D

DATE ACCESSIONED

86 1 28 046

DATE RECEIVED IN DTIC

DATE RETURNED

REGISTERED OR CERTIFIED NO.

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDAC

DTIC FORM 70A DEC 83

DOCUMENT PROCESSING SHEET

PREVIOUS EDITION MAY BE USED UNTIL STOCK IS EXHAUSTED.

UNCLASSIFIED

~~RESTRICTED~~

PB 87071

ADF 560 177

Div III File

WAR DEPARTMENT

Report 863

15-GPM LIGHT DIATOMITE WATER PURIFICATION EQUIPMENT

12 September 1944

FOR TECHNICAL INFORMATION ONLY

Does not represent recommendations or conclusions of the Office, Chief of Engineers

Class UNCLASSIFIED

Classified

Cancelled

Date 17/2/59

By authority of Ch, Unit E

5/5/58

TECHNICAL STAFF

THE ENGINEER BOARD

Corps of Engineers, U. S. Army

Fort Belvoir, Virginia

UNCLASSIFIED

~~RESTRICTED~~

UC 21262

UNCLASSIFIED

~~RESTRICTED~~

Report 863

15-GPM LIGHT DIATOMITE WATER PURIFICATION EQUIPMENT

Project WS 443

12 September 1944

UNCLASSIFIED
Changed to ________
Classified
Cancelled ________
Date 12/2/54
By authority of Ch. [illegible] E
5/5/58

Submitted to

THE ENGINEER BOARD

Fort Belvoir, Virginia

and/or

The Chief of Engineers

U. S. Army

Washington, D. C.

FOR OFFICIAL ACTION

by

Water Supply Equipment Branch
Technical Division III
The Engineer Board
Fort Belvoir, Virginia

~~This document contains information affecting the national defense of the United States within the meaning of the Espionage Act, 50 U. S. C., 31 and 32, as amended. Its transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

~~RESTRICTED~~

UNCLASSIFIED

15-GPM LIGHT DIATOMITE WATER PURIFICATION EQUIPMENT

I. SUBJECT

1. Scope. This report covers chronologically the investigation, design, and testing of lightweight water purification equipment, leading to the development of a unit capable of producing an average of 15 gpm of potable water. The equipment described is designed to serve a dual purpose in that it can be pack-transported as well as being in the capacity range of the present standard 15-gpm portable sand filter. Components of the set are separable to permit transport as full pack loads by three pack animals or nine men.

II. AUTHORITY

2. Basic. The development of lightweight water purification equipment was initiated by a letter from the Chief of Engineers to the President, the Engineer Board, dated 23 February 1943, file No. SPESD.-671-112, subject: Development of Water Purification Equipment. The following extract gives the requirements:

> "5. It is, therefore, directed that the Engineer Board develop a water purification set which can be pack transported by man. Storage facilities for the purified water shall be furnished as a part of the set."

3. Approval of Project. Development project WS 443, "Pack Water Purification Equipment," was approved by a letter from the Chief of Engineers to the President, the Engineer Board, dated 20 September 1943, file CE SPENQ, subject: Pack Water Purification Equipment, DQP 3004.

Copies of this correspondence are included in Appendix A.

III. INVESTIGATION

A. Preliminary Phase

4. Selection of Filter Media. Since sand, the current filter medium, was too heavy for use in pack filters, lighter media were investigated. Lighter media also promised more complete removal of suspended matter than was possible with sand. Later tests indicate that all the following media completely remove cysts of *E. histolytica* when properly employed:

a. Cartridges. Brief tests of Everpure and Sparkler filters, employing replaceable cartridges of paper, asbestos, carbon, etc., indicated that excellent clarification and odor removal could be accomplished with cartridges; however, high pumping pressures were required to obtain reasonably long filter runs on all except clear waters. Once operated to completion, the cartridge could not be reclaimed. Another disadvantage of cartridges was their relatively high cost.

b. Porous Candles. Porous cylinders of clay or diatomaceous silica, similar to the Berkfield Laboratory filter, also effected excellent clarification but produced even shorter filter runs than cartridges. Unlike the cartridges, porous candles could be reused after thoroughly scraping their surfaces. Although used extensively by the Japanese, porous candles were not equal to other filter media available.

c. Paper Sheet. Sheets of paper pulp and asbestos, the type employed in Republic plate and frame filters, were similar to cartridges, effecting excellent clarification but providing relatively short filter runs. Sheets, used with a plate and frame filter, provided a large but compact filter area. Sheet filters have been used by the German Army, a number of such filters having been captured and tested.

d. Diatomaceous Silica. Diatomaceous silica (refined diatomite) was found to give higher outputs and better clarification than sand in a pilot model portable water purification unit. Unlike other filter media investigated, powdered diatomite could be added continuously to the water being filtered, maintaining the porosity of the filter cake. The initial filter cake was formed by pumping a diatomite suspension through a permeable tube. When properly used, diatomite produced considerably more clear water than any other medium investigated. Diatomite filtration has been used for approximately 20 years in the chemical industry, and is being used for water filtration by the British Army. The following tabulation in addition to other factors indicates that diatomaceous silica was the logical choice:

Bulk and Weight of Filter Media Per Square Foot of Filter Area

Type of Filter Media	Bulk (cu ft/sq ft)	Weight (lb/sq ft)
Slag	2.000	66.00
Sand	2.000	190.00
Cartridges	0.080	0.50
Porous Candles	0.045	0.80
Paper Sheet	0.035	0.25
Diatomaceous Silica	0.006	0.15

5. <u>Determination of Military Characteristics</u>. Before developing pack water purification equipment, it was necessary to consider the requirements for such equipment.

a. <u>Portability</u>. The maximum size and weight of equipment were established by the requirement of the original directive that a water purification set be developed that could "be pack transported by man". Although animals were expected to be the normal means of transportation for the larger pack equipment, dividing the set into pack loads which could be transported by men (when other means were unavailable) appeared quite logical. It was believed that a need also existed for smaller water purification equipment that could be carried by an individual, in addition to his combat equipment, for supplying water to small detachments. When development was initiated, two sizes of pack water purification equipment were considered.

(1) Filter Carried with Combat Pack. The smaller filter complete with filter media and sterilizing facilities was to weigh less than 5 pounds and produce 0.15 to 0.25 gpm.

(2) Filter Carried as Full Load. The larger filter complete with feeder and hand pump was to weigh less than 35 pounds and produce not less than 5 gpm. With hose, chlorination set, and pack, the weight of this load was not to exceed 60 pounds. Canvas tanks and supplies were to be carried in similar loads. After brief tests with hand pumps, it was apparent that a gasoline-engine-driven pump should be added to the set.

(3) Complete Unit as Single Load. All equipment and supplies necessary for a day's emergency operation were to be included with the filter in a single pack. This distribution was desirable to insure a water supply of approximately 3000 gallons when one or more of the other packs were lost. The weight of components made a complete unit possible as a man pack with the 5 gpm set and as an animal pack with the 15 gpm set.

(4) Output Required. The desired output was limited only by the weight and arrangement of equipment consistent with occasional packing by man. A minimum capacity of 300 gph was established for the larger equipment designed for Combat Engineers attached to Light Divisions.

(5) Quality of Filtrate. Complete removal of all organisms not readily destroyed by chlorination, and consistent removal of turbidity in excess of 1 ppm concentration were believed essential to the production of satisfactory water even with the normal addition of chlorine. Experiments indicated that diatomaceous silica filtration was the best method of obtaining the high outputs of the superior water required.

(6) Storage and Distribution Facilities. Filling 5-gallon metal cans directly from the filter discharge required the least manpower. A reserve supply of water could be stored in cans as easily as in a small tank; however, representatives of using organizations stated that filtered water storage tanks were desirable to increase the reserve supply.

(7) Larger Equipment. The average filter output desired with a gasoline-engine-driven pump was originally 5 gpm, or 300 gph. This capacity was expected to be adequate by using organizations; however, service testing 5-gpm equipment indicated the desirability of increasing the capacity of the pack filter to 15 gpm with an improved pump, due to an acute shortage of trained Engineer personnel for water supply work in Light Combat Battalions. The increased capacity made possible the substitution of a diatomite filter of equal capacity for the 430-pound sand filter on present portable units.

B. Development of Filters

6. Filters Carried with Combat Pack. Two experimental filters weighing less than five pounds were constructed by commercial organizations and tested. A small Japanese filter was also tested.

a. Stoneheart Model SF-1. (See Fig. 1.) Following the choice of filter media, a small gravity filter employing diatomaceous silica was designed by the Engineer Board Technical Staff and constructed by the Stoneheart Engineering Company, Newark, New Jersey. The filter was carried in a metal can, 3-inch inside diameter by 10 inches long, with screw cap and an attachment for a 1/4-inch pipe-fitting in the center of its bottom. Three feet of coated-fabric tubing connected the 10-inch carrying can to a 5-inch can containing the filter septum. The septum element was a porous tube of aluminum oxide grit with ceramic bond (Aloxite brand), approximately 1 3/4-inch outside diameter, ½-inch inside diameter, and 3.6 inches long with 0.125 square foot of filter area. Approximately six ounces of diatomaceous silica (filteraid) were provided in a fiber can. All equipment was packed inside the 10-inch can. The packed can with cloth case weighed 2.7 pounds. The filter was operated by hanging the 10-inch can on a tree limb with the filter can connected by tubing. A uniform coating of filteraid was formed on the porous element in the lower can by pouring a suspension of 1/4 ounce of filteraid in a quart of water into the top can. This operation with a diatomite filter is known as precoating. Water emerging from the filter can was caught and recirculated once. Raw water with approximately 1/4 ounce of filteraid per gallon (addition of filteraid to water being filtered is known as body feeding) was then poured into the top can and collected as filtrate from the lower can. When the flow of filtrate decreased from a continuous stream to drops, the spent cake was dislodged by reversing the direction of flow.

TABLE OF CONTENTS

Section	Title	Page
	SYLLABUS	v
I	SUBJECT	1
	1. Scope	1
II	AUTHORITY	1
	2. Basic	1
	3. Approval of Project	1
III	INVESTIGATION	1
	A. Preliminary Phase	1
	4. Selection of Filter Media	1
	5. Determination of Military Characteristics	3
	B. Development of Filters	4
	6. Filters Carried with Combat Pack	4
	7. Filters Carried as Full Load	6
	8. Service Test Models	17
	C. Selection of Pumping Equipment	20
	9. Hand Pump	20
	10. Power Pump	24
	11. Gasoline Engine	26
	D. Service Testing of 5-gpm Set	29
	12. Assembly of 5-gpm Set	29
	13. Description of Major Components (5-gpm)	29
	14. Operation of 5-gpm Set	31
	15. Packing of 5-gpm Set	32
	16. Service Tests	32
	E. Revision to Provide 15-gpm Capacity	39
	17. Revision	39

TABLE OF CONTENTS - cont.

Section		Title	Page
	F.	Recommended 15-gpm Set	40
	18.	Assembly of 15-gpm Set	40
	19.	Description of Major Components (15-gpm)	40
	20.	Operation of 15-gpm Set	48
	21.	Packing of 15-gpm Set	50
	22.	Testing of 15-gpm Set	50
IV		DISCUSSION	56
	23.	Diatomite Filtration	56
	24.	Pretreatment	57
	25.	Small Filters Carried with Combat Pack	58
	26.	Selection of Pumping Equipment	58
	27.	Design of 15-gpm Filter and Feeder	59
	28.	Future Work	60
	29.	Packing	60
	30.	Basis of Issue	60
	31.	Instructional Aids	62
V		CONCLUSIONS	62
	32.	Conclusions	62
VI		RECOMMENDATIONS	63
	33.	Recommendations	63

Appendix	Title	Page
A	AUTHORITY	65
B	SERVICE TEST REPORTS	79
C	SPECIFICATIONS AND SET LISTS, 15-GPM FILTER	129
D	TEST RESULTS DATA SHEETS	159

SYLLABUS

1. Scope. This is a report on the development of diatomite water purification equipment suitable for transportation by men and pack animals as well as by vehicles. Reasons for selecting diatomaceous silica as the filter medium are given. Brief descriptions and results of tests are given for small filters to be carried with normal combat equipment and larger filters to be carried as complete man loads, culminating in the 15-gpm set. Hand pumps, power pumps, and small gasoline engines are considered, and the results of comparative tests are presented. Reports on service tests of the 5-gpm set are reproduced in the appendices. Reasons for increasing the capacity of the set to 15-gpm are given. A description of, specifications for, and results of tests on the 15-gpm diatomite water purification set are given. Lists of equipment recommended for standardization are given in Appendix C (Water Purification Equipment, Diatomite Pack, (Man or Animal Type), 15-gpm.

2. Conclusions. As a result of tests on pack water purification equipment, it is concluded that:

a. The 15-gpm diatomite water purification set is suitable for standardization and overseas use.

b. The recommended diatomite water purification set may be conservatively rated at 15 gpm as a gasoline-engine-driven unit and 5-gpm with hand pump, emergency operation.

c. Increased capacity, over and above the original military characteristics, will satisfy requests for equipment capable of producing more water without sacrificing required portability; which requests were received from field organizations following service tests of the 5-gpm diatomite filter set.

d. The 9 pack loads of the 15-gpm diatomite water purification set may be transported either by 9 men, 3 pack animals, or a ½-ton vehicle, the heaviest pack weighing approximately 70 pounds and the set, 580 pounds.

e. The equipment will effect complete removal of cysts of *Endamoeba histolytica*, which cause amoebic dysentery, and *Cercariae of the Schistosome*, the causative agent of Schistosomiasis.

f. Operation of the 15-gpm set is simple, requiring only one man, but the technique differs sufficiently from that of sand filtration to require some provision for instruction in use of diatomite filters.

3. Recommendations. In accordance with the preceding conclusions, it is recommended that:

a. The Water Purification Equipment, Diatomite Pack (Man or Animal Type) 15-gpm, Set No. ______, (as listed in Appendix C) be standardized as class II and class IV equipment.

b. One Water Purification Equipment, Diatomite Pack (Man or Animal Type) 15-gpm, Set No. ______ be issued per 2500 troops to be supplied.

c. Training in operation of diatomite filters be established at the Engineer School; a training film on diatomite filters be produced; and trained personnel sent overseas to instruct new operators whenever possible.

This method for removing spent cake by air or water is known as backwashing.

Figs. 14 and 15, Appendix D, present results of typical tests. The filter was rated at 10 gph (0.167 gpm) on raw water with turbidity of 100 ppm. Operation of the Stoneheart SF-1 filter was satisfactory with the exception of two deficiencies. One was the requirement for something from which to suspend the filter in order to obtain maximum output. The other was the possibility of contaminating the filtered water through spillage.

b. Wallace and Tiernan Model WT-1. A second gravity filter of different construction, but similar in design, was submitted for tests by Wallace and Tiernan Company, Inc., Newark, New Jersey. The filter consisted of a canvas bucket connected by five feet of rubber tubing to a disc filter section. The filter section was a disc of Dutch-weave monel wire mesh held in place by gaskets and two dished covers with an external screw clamp. The assembly was neatly packed in a circular canvas bag. The operating method and characteristics of the WT-1 filter were similar to those of the SF-1 filter. Although both filters contained the same filter area of 0.125 square foot, the WT-1 filter produced approximately 80 percent as much filtrate as the SF-1, being rated at 8 gph (0.134 gpm) on water with turbidity of 100 ppm. Complete removal of cysts and a reduction in bacteria plate count of 80 to 95 percent were obtained with both filters. The same deficiencies of support requirements and possible contamination through spillage were present in the WT-1 filter.

c. Japanese Filter. A small Japanese filter operated with a hand pump was tested. The apparatus was captured on Guadalcanal on 6 January 1943; symbols on the nameplate translated "Medical Filter Machine". The device consisted of a wire-wound suction hose 52 inches long with a wire screen strainer, a hand-operated piston pump 7 inches long, and an attached water chamber 5½ inches long and 2 1/4-inch inside diameter, containing a porous clay tube 5½ inches long and 1½-inch outside diameter with a top outlet pipe. An 8-inch rod with foot ring was screwed into the bottom of the pump cylinder. The total weight of the equipment was approximately 4 1/4 pounds. Water was clarified by pumping through the fine pores of the clay cylinder. When filtering water having a turbidity of 200 ppm, the cleaned filter element produced one quart during the first minute, two quarts in 3 minutes and 15 seconds, and three quarts in 9 minutes and 24 seconds. After washing the filter element, one quart was obtained in 6 minutes. The element was returned to approximately its original capacity by thorough scraping and cleaning with steel wool. Filtrate turbidity was 0.1 ppm. Approximately twice the output could be obtained on water of 100-ppm turbidity. The filter was rated at 6 gph (0.10 gpm) on raw water having a turbidity of 100 ppm.

d. Work Postponed. After testing the Japanese filter, work on filters which could be carried by individuals in addition to combat equipment was postponed until development of the full load equipment was completed. Conferences with representatives of Army Ground Forces and Engineer Light Battalions indicated that the work must be concentrated solely on the development of equipment with maximum capacity consistent with man packing. Due to the pressure of work on development and procurement of 5 and 15-gpm pack sets for service tests, work on the smaller filter set has not been resumed.

7. Filters Carried as Full Load. A number of filters, weighing 15 to 30 pounds without feeders and auxiliary equipment, were tested. None of these filters was entirely satisfactory, hence it was necessary to design a filter with approximately 1.8 square feet of filter area for the 5-gpm set service tested, and later to design a 3.6-square foot filter to meet the need for higher outputs due to a shortage of operators.

a. Stoneheart No. 2. A demonstration filter was submitted by the Stoneheart Engineering Company, prior to receipt of a directive to develop pack filters. This experimental filter was operated by air pressure above the water to be filtered. Water was poured into the lower part of a chamber equipped with a hand-operated air pump. The septum element was contained in a small chamber attached by pipe fittings to the pressure chamber. Air pressure was used instead of direct pumping in order to minimize disturbance of the filter cake. The experimental filter produced moderate quantities of very clear filtrate. A suitable pack filter, employing the same method of filtration, was procured for testing. The filter element was a porous tube of bonded aluminum oxide grit, 3-inch outside diameter by 4 inches long, providing a filter area of 0.26 square foot. Weighing approximately 20 pounds, this filter produced an average output of 35 gph (0.58 gpm) of water from raw water having an average turbidity of 140 ppm; however, it was evident that a filter with sufficient output would require an excessively large air chamber owing to the necessity of recharging the chamber each time the raw water was exhausted. About 5 gallons could be filtered before recharging.

b. Stellar Jr. A laboratory demonstration filter, employing the Stellar filter element used by the British Army, was tested shortly after the Stoneheart No. 2 filter. The Stellar Jr. filter consisted of a small centrifugal pump driven by an electrical motor, and a filter with plastic shell and Stellar element. The element consisted of a continuous wire helix on a fluted brass core. Openings between adjacent wires were small enough to retain a filter cake but sufficient for passing filtrate without an appreciable friction loss; however, openings from the flutes to the inside filtrate channel were insufficient. The element was $1\frac{1}{2}$-inch outside diameter and $4\frac{1}{2}$ inches long, providing an effective filter area of approximately 0.13 square foot. Filtrate produced by the

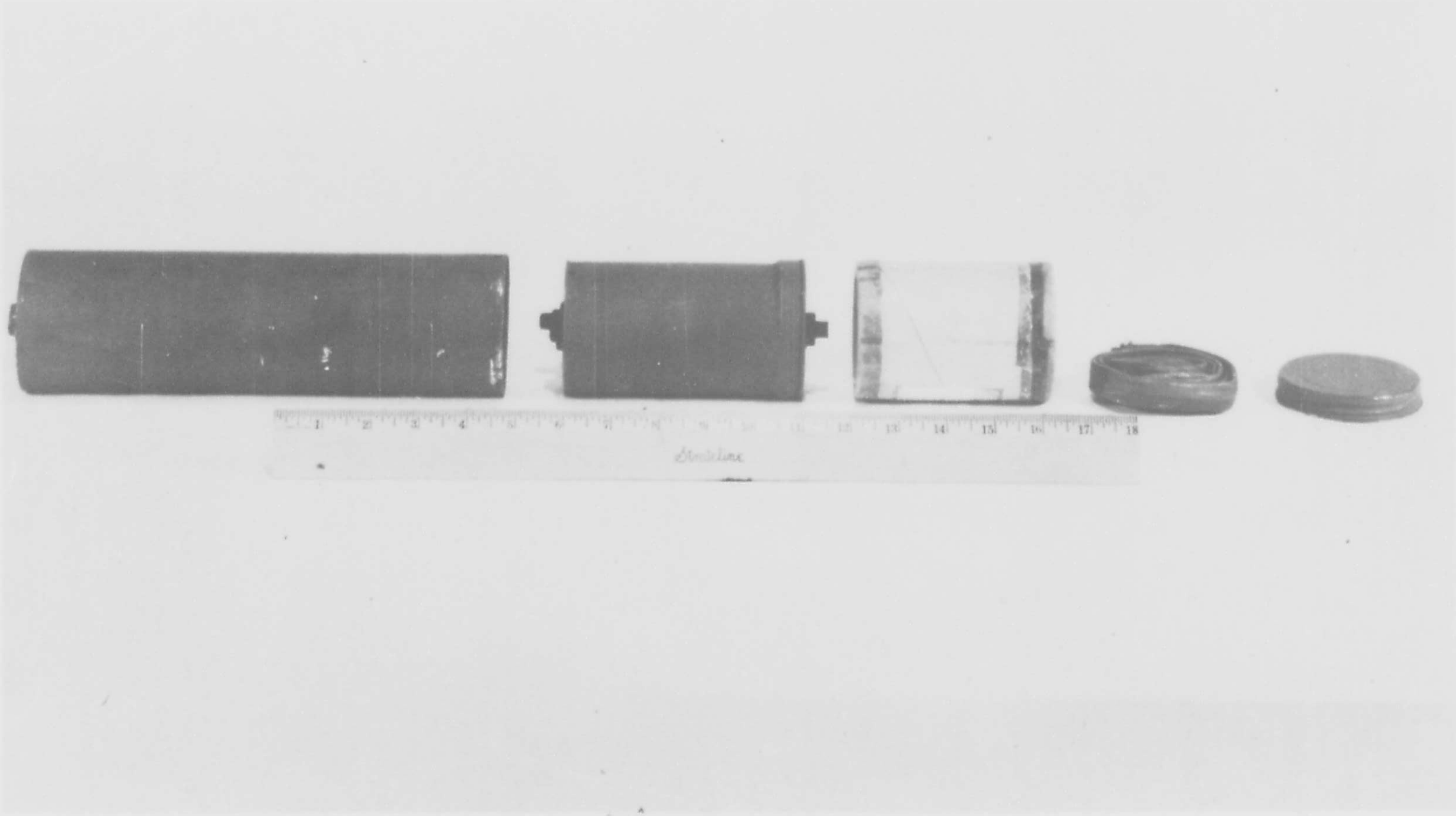


FIG. 1. GRAVITY FILTER TO BE CARRIED WITH COMBAT PACK. Stoneheart Model SF-1 Filter. Engineer Board, Fort Belvoir, Virginia.

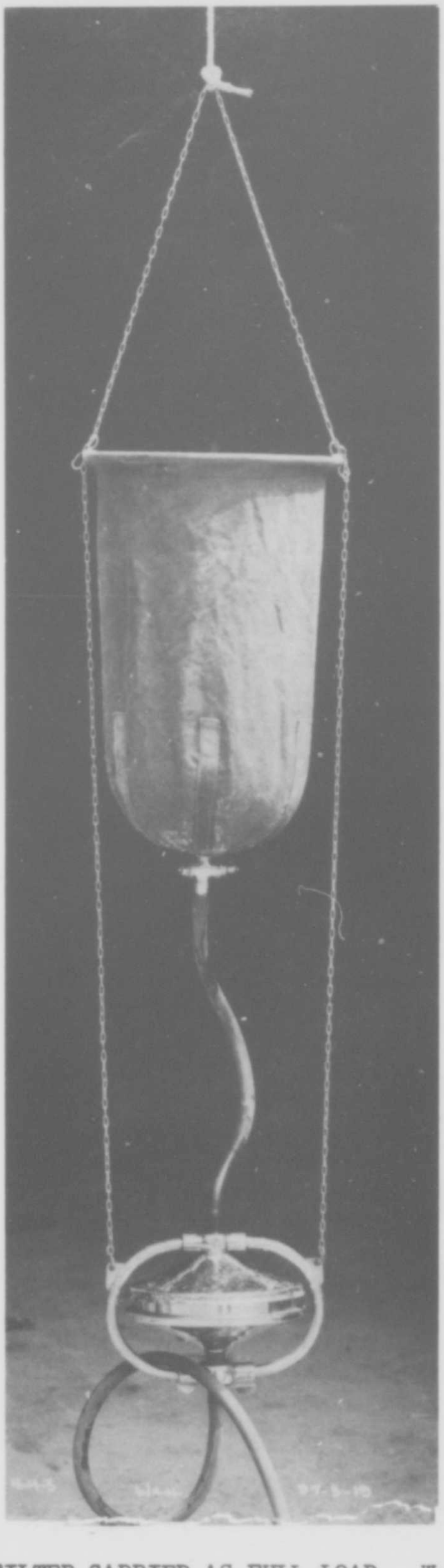


FIG. 2. GRAVITY FILTER CARRIED AS FULL LOAD. Wallace and Tiernan No. 2 Filter. Engineer Board, Fort Belvoir, Virginia.

Stellar Jr. filter was of sufficient quality to merit develop-ment of a filter with suitable capacity for pack usage; however, it was necessary to develop a suitable plastic core, instead of the brass one employed, before the weight of the Stellar element could be brought within desirable limits. Elements with plastic cores proved satisfactory.

c. Wallace and Tiernan No. 2. (See Fig. 2.) A larger gravity-head filter, similar to the WT-1 filter, was submitted for tests by Wallace and Tiernan Company, Incorporated. The filter consisted of a conical bag 18 inches long with a bottom tubing connection, two suspending chains, a 24-inch rubber tube, a flat circular filter, and a 24-inch discharge tube. The filter septum was a Dutch weave monel wire screen, corrugated with 45° angles, and supported by a circular frame 8 inches in diameter, providing a filter area of approximately 0.60 square foot. The filter assembly weighed 11.0 pounds. Packed with supplies and accessories the filter weighed 30 pounds. The filter was operated by pouring a bucket of raw water containing filteraid into the conical bag suspended from a tree. The filter produced an average output of 35 gph (0.58 gpm) when filtering raw water having an average turbidity of 150 ppm. A vertical support was required for operation, and the low head available required an excessive amount of filteraid for relatively short runs, deficiencies common to all gravity-head pack filters.

d. Hoffman No. 1. A flat screen filter with a hand pump was submitted by the U. S. Hoffman Machinery Corporation for tests. The screen of Dutch weave monel wire was stretched as a circular diaphram, 14 inches in diameter, with heavier reinforcing wire, giving a filter area of approximately 1.07 square feet. The screen was retained by two dished steel shells. A Deming Fig. 1570 No. 0 hand pump was mounted on top of the screen. The filter and pump weighed 35 pounds. The filteraid precoat was applied by pumping a suspension of diatomite from a canvas bucket. The filter produced water of satisfactory clarity (below 0.3 ppm) at lower pumping pressures, but with pressures above 10 lb/sq in., the filtrate was often turbid, being in excess of 10 ppm. The filter produced an average of 65 gph (1.1 gpm) when filtering water with an average turbidity of 170 ppm.

e. Hoffman No. 2. A second filter submitted for test by the U. S. Hoffman Machinery Corporation employed an open horizontal screen 15 inches in diameter at the bottom of a 15-inch canvas cylinder held by supporting rods and ring. The assembly weighed 13.5 pounds. This filter could be operated by suction with the hand pump or as a low head gravity filter. The filter produced an average output of 40 gph (0.66 gpm) by suction and 20 gph by gravity, when filtering water with an average turbidity of 200 ppm. Since the differential pressure across the filter cake was relatively low in either case, the output was low and the filteraid consumption high.

f. Stoneheart No. 3. A second gravity-head filter was submitted for tests by the Stoneheart Engineering Company. A 44-inch conical bag of canvas supported a cylindrical filter shell, 14 inches long and 5½-inch outside diameter, containing a porous septum tube, 14 inches long, 4 1/4-inch outside diameter, which provided a filter area of approximately 1.30 square feet. The assembled filter weighed approximately 16 pounds. It was operated by recirculating a suspension of filteraid until the effluent was clear, after which raw water, with an amount of filteraid two to three times the raw water turbidity, was poured into the bag. This filter was also tested with a "Thresher" hand pump, but the pulsating flow and the lack of baffles in the filter resulted in turbid effluents. It was later discovered that a portion of the cake was being eroded by the direct stream. With gravity-head, the Stoneheart No. 3 filter produced an average of 70 gph (1.12 gpm) when filtering raw water having an average turbidity of 120 ppm. Utilizing only a low head, its filteraid consumption was high.

g. Bowser Screen and Carbon. A complete pack water filtration unit was submitted for tests by S. F. Bowser and Company, Incorporated, of Fort Wayne, Indiana. The diatomite filter and feeders were mounted in a tubular frame. The unit weighed 50 pounds complete with back pack. A rotary hand pump with spring-loaded vanes was mounted on top of the filter. The septum element was a double wall cylinder of Dutch weave monel wire, 8 inches long, 5.75-inch outside diameter, and 5.50-inch inside diameter, giving an effective filter area of 1.96 square feet. Hypochlorite solution and diatomite slurry could be introduced through pressure pots feeding to the throat of a venturi.

When filtering clay suspensions, good clarification was obtained when the pumping pressure was below 10 lb/sq in.; but as the pressure increased a definite break in the filter cake was indicated by a sudden increase in the turbidity of the effluent which accelerated as the pressure increased. Fig. 17, Appendix D, is typical of results obtained in several tests on 100 to 200-ppm clay suspensions. An average output of 100 gph (1.67 gpm) was obtained when filtering water with an average turbidity of 150 ppm. Approximately half of this water was too turbid for use. Cysts were found to pass the filter when the break through occurred.

Porous carbon was suggested by the Technical Staff of the Engineer Board to replace screen as the filter septum. With a Carbocell 60 grade septum the Bowser filter effected excellent clarification and at a slightly higher rate throughout the run. Fig. 18, Appendix D, is typical of the results obtained. Cysts were removed completely with the carbon septum in normal operation.

Feeds of hypochlorite solution varied from 0.1 to 3.0 ppm during a run, but were generally more consistent. The amount of diatomite slurry introduced could not be predetermined or adequately controlled. Also, the capacity of the hand pump was not sufficient for the filter area provided.

h. Engineer Board Experimental Model L-2. (See Fig. 3.) None of the experimental pack filters submitted would produce the desired average output of 5 gpm. Since it was apparent that an equally light filter could be constructed that would produce over 5 gpm, a filter was designed and constructed at the Engineer Board. This filter was designed for four porous elements, each 12 inches long and 1 3/4-inch outside diameter, giving a filter area of 1.83 square feet. Actually only three of the Aloxite grade 36 elements could be obtained, and a filter with 1.37 square feet of septum was used in tests. The filter consisted of a cylindrical shell, 6 inches inside diameter and 13 inches long, with a conical bottom, three legs, and a collector head of welded sheet steel. The cylindrical elements were gasketed at each end, being held by a central pipe with cap and lock nut on its lower end. The filter weighed 17 pounds. Water entered at the conical bottom, was deflected by a baffle against the walls of the cone, flowed upward, passed through the filter cake and the porous walls of the elements into the central collector pipe through numerous holes; then it rose to the manifold in the filter head and finally to the discharge port.

The Engineer Board experimental filter produced an average output of 5 gpm when filtering water with an average turbidity of 100 ppm by using a gasoline-engine-driven Rex 3 M pump, and 3.4 gpm on 50-ppm water with a Deming Fig. 1570 No. 0 hand pump. Figs. 19, 20, and 21, Appendix D, are typical of results obtained with the power pump. Removal of cysts was complete during normal operation.

Considering that only three elements were used instead of the four specified, it was evident that a pack filter could be obtained that would weigh approximately 20 pounds and produce approximately 5 to 10 gpm. Accordingly, drawings for a similar four element filter were prepared at the completion of tests. It was believed that such a filter would be satisfactory for field service, but no adequate means for introducing the continuous feed of diatomite required to maintain cake porosity was developed at that time.

i. German Portable Haversack Filter. A pack filter captured from the German Army in North Africa was tested in comparison with the diatomite filters being considered. More complete information on the German filter is contained in Engineer Board Report 831, German Portable Haversack Filter, dated 17 June 1944. This filter was similar to commercial filter presses except that the filter media were sheets of paper pulp and asbestos fibers. Constructed compactly of light metals, the complete filter in carrying pack weighed approximately 45 pounds. The filter was operated with an integral hand pump. It effected complete removal of the cysts of E. histolytica and a high removal of bacteria. An average output of approximately 35 gph (0.58 gpm) was obtained when filtering water with an average turbidity of 100 ppm. Fig. 16, Appendix, D, reports a typical run.

j. Republic Filter. A laboratory demonstration filter was submitted for test by Republic Filters, Inc., Patterson, New Jersey. The filter medium employed in the Republic filter differed from that previously tested in that an initial precoat by asbestos fiber was formed on the septum before filteraid was applied, permitting removal of filter cake by stripping from screens. The septum in the demonstration model was a cylindrical screen of Dutch weave wire 4 inches long and 3 inches outside diameter with a glass shell to permit observation, providing an effective filter area of 0.26 square foot. The use of asbestos fiber for precoat or mixed with diatomaceous silica effected better clarification than with diatomaceous silica alone; however, the flow was somewhat reduced and definite break throughs of the cake still resulted whenever the pumping pressure was increased above 15 lb/sq in.

Asbestos fiber apparently did not improve the performance of filters sufficiently to justify its use, asbestos fiber being considerably more expensive than diatomaceous silica. Also, the Republic filter was the third successive filter equipped with conventional metal screens to fail due to break throughs at higher pumping pressures. These results were in agreement with the experience of filteraid manufacturers who believed that the septum should be rigid or stretched taut. Accordingly, the use of conventional metal screens was discouraged in preference to rigid, porous, and wire-wound elements.

k. Infilco No. 1. A pilot model 5-gpm diatomite filter was procured from Infilco, Inc., primarily to test improved Stellar elements and plastic shells for use with the pack filter. The filter was similar to the experimental filter constructed at the Engineer Board. Seven Stellar elements, each 9.5 inches long and 1.5-inch outside diameter were mounted with rubber gaskets and tie rods to a cast aluminum head, providing 1,10 square feet of actual filter area. A conical base of cast aluminum with plastic baffle nozzle and three curved legs was connected to the collector head by outside tie rods and a 6-inch outside diameter shell of seamless Lucite plastic.

When operated with larger (3/4-inch) hose, the filter produced an average output of approximately 240 gph with the Rex 3 M power pump, when filtering water with an average turbidity

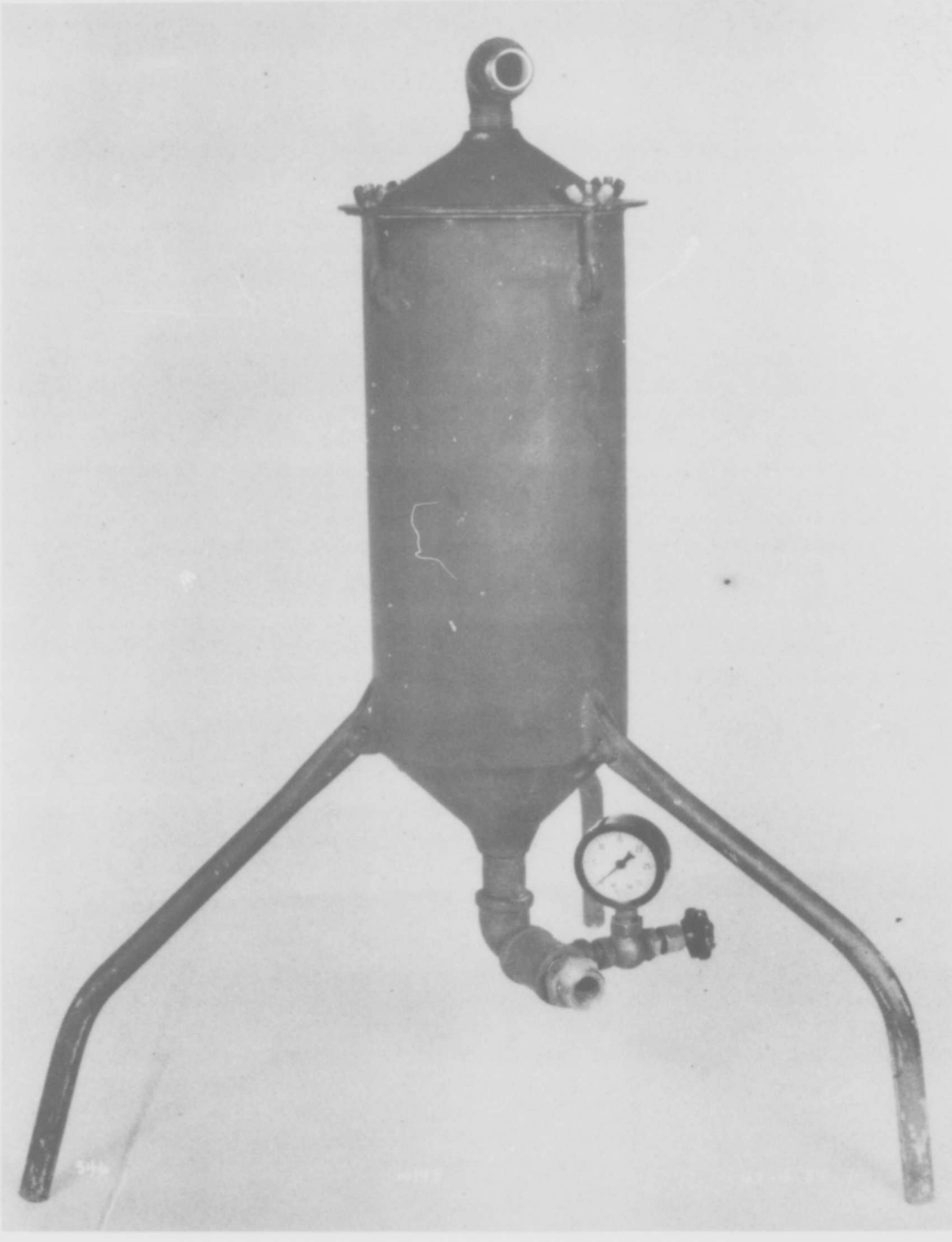


FIG. 3. ENGINEER BOARD MODEL L-2 FILTER. Experimental 5-GPM Diatomite Filter. Engineer Board, Fort Belvoir, Virginia.

of 100 ppm. Serious head losses were found in the baffle nozzle and in the elements. An impreved set of Stellar elements were tested satisfactorily, but since the output of the experimental model constructed at the Engineer Board exceeded that of the Infilco filter, it was evident that a filter with less head loss should be constructed.

1. Stoneheart No. 4. The Stoneheart Engineering Company was asked to submit drawings for a four element, 1.5-square foot filter, since this company was the only manufacturer using Aloxite porous tubes, the most desirable type at that time. The drawings were revised by the Technical Staff, and a pilot model was procured according to the revised drawings. The filter consisted of a cast aluminum collector head mounting four septum elements (Aloxite 36), each 1 3/4 inches outside diameter by 10 inches long, and a filter shell of stainless steel with a conical bottom and three curved tubular legs.

The filter produced an average output of 6.0 gpm with the Rex 3 M power pump when filtering raw water having an average turbidity of 100 ppm. When filtering coagulated and settled water, its average output was 7.0 gpm. Tests indicated that with minor improvements the filter would be satisfactory for field usage; however, a satisfactory diatomite slurry feeder had not been perfected, although several types would function.

8. Service Test Models. A letter dated 20 September 1944 from the Office, Chief of Engineers to Engineer Board, subject: Pack Water Purification Equipment, DQP - 3400, directed the procurement of 17 sets of pack equipment as developed at that time for service testing by the 71st Light Division. Since a satisfactory diatmote slurry feeder had not been perfected and a higher capacity filter would be preferable, all interested manufacturers of water purification equipment were asked to consider constructing a pilot model pack filter and slurry feeder. Faults of previous equipment and the requirements for equipment to be service tested were thoroughly discussed in a joint meeting at the Engineer Board of representatives from all interested companies. The majority submitted filters and feeders for test on or about the established deadline of 1 November 1943. Tests of the pilot models received were thoroughly reported in Engineer Board Report on Test of Pilot Model Diatomaceous Silica Pack Filters, dated 17 March 1944.

a. Bowser No. 2 (Unit A). The filter submitted for service testing by the S. F. Bowser Company was similar to the hand operated unit previously described. A filter with three cylindrical elements of porous carbon, giving a filter area of 1.57 square feet, and a closed slurry feeder were mounted in a tubular frame. The assembly weighed 22.5 pounds.

The Bowser filter (Unit A) produced an average output of 4.1 gpm when operated with its own slurry feeder in comparison with other filters on a clay suspension of 100-ppm turbidity, rating fourth in output per square foot of filter area. When operated with a common slurry feeder on Potomac river water of 37-ppm turbidity, this filter produced an average output of 4.24 gpm, again rating fourth in output. Advantages recorded for this filter were its excellent portability and the quality of its effluent. Disadvantages were its low capacity, difficulty of backwashing and precoating, lack of provision for operating with a damaged element removed, unevenness of slurry feed, septum elements too close for brush cleaning, and cake space restricted by central inlet pipe and shell.

b. Stellar No. 2 (Unit B). The filter submitted for service testing by Infilco, Inc. was similar to the smaller filter previously tested. Seven Stellar elements were mounted with a cast aluminum head, Lucite shell, and conical bottom with a plastic baffle nozzle. A closed slurry feeder with a water-motor-driven agitator and an orifice inlet of plastic and brass was provided.

During tests the slurry feeder could not be made to function due to clogging of bearings with diatomite. The Infilco filter (Unit B) produced an average output of only 4.18 gpm when operated with its own slurry feeder in comparison with other filters on a clay suspension of 100-ppm turbidity, rating last in output per square foot of filter area. When operated with a common slurry feeder on Potomac river water of 37-ppm turbidity, this filter produced an average output of 5.50 gpm, rating third in output. Advantages recorded for this filter were the quality and quantity of effluent produced. Disadvantages were its mechanically unsatisfactory slurry feeder, inadequate leg locking device, outside tie rod construction, which did not permit easy removal of the filter head, and the incomplete backwashing obtained with the Stellar elements.

c. Proportioneers (Unit C). The filter submitted by Proportioneers, Inc., Providence, Rhode Island, for service testing, was similar in construction and slurry feed design to the experimental model previously constructed at the Engineer Board and demonstrated at the meeting with manufacturers' representatives. The filter consisted of a sheet metal collector head in two sections mounting four porous elements, providing a filter area of 2.0 square feet, and a sheet metal shell with three legs. The filter weighed 22.5 pounds. The feeder was a bucket with a simple flow indicator on a rubber tube leading to the pump's suction. The slurry was stirred by hand.

In comparison with other filters on a clay suspension of 100-ppm turbidity, the Proportioneer filter, when operated with its own slurry feeder, produced an average output of 7.4 gpm, rating third in output per square foot of filter area.

When operated with a common slurry feeder on Potomac River water of 37-ppm turbidity, the filter produced an average of 6.3 gpm, rating first in output per square foot of filter area. Advantages recorded for this filter were its high output, desirable backwash and precoat features, and excellent slurry feeder. (Further testing has shown that the type of feeder employed on the Proportioneer unit will not function satisfactorily whenever the source of water is above the pump's suction.) Its disadvantages were: its three-flange, double-gasket head construction, inadequate legs, numerous tie bolts on head, and lack of air space above filter elements for cushioning a pulsating flow.

d. Titeflex (Unit D). (Fig. 4.) The filter submitted by Titeflex, Inc., Newark, New Jersey, for service testing, was similar in construction to the Stoneheart No. 4 filter, the Stoneheart Engineering Company having been absorbed by Titeflex, Inc. The filter consisted of a cast aluminum head mounting four Aloxite grade 36 porous elements, each 1 3/4-inch outside diameter by 12 inches long, providing a filter area of 1.83 square feet, and a stainless steel shell 6.75 inches inside diameter by 14 inches long with a conical bottom having a baffle and three legs. The filter weighed 22.9 pounds, the feeder 4.8 pounds. The feeder was a closed pot with a screen which retained filter-aid. The bottom of the pot was connected to the pump's discharge, and the top to the pump's suction.

In comparison with other filters on a clay suspension of 100-ppm turbidity, the Titeflex filter, when operated with its own slurry feeder, produced an average of 5.8 gpm, rating second in output per square foot of filter area. When operated with a common slurry feeder on Potomac River of 37-ppm turbidity, the filter produced an average of 5.6 gpm, rating second in output. Advantages recorded for this filter were its excellent quality and quantity of effluent, excellent backwash and precoat characteristics, provision for operating with an element removed, ruggedness, and simplicity. Its disadvantages were an unsatisfactory baffle nozzle, inadequate leg locking device, and a slurry feeder of a type not preferred. Further testing has shown the feeder employed on this unit to be preferable to the type chosen for service testing.

e. Wallace and Tiernan (Unit E). The unit submitted by Wallace and Tiernan Company, Inc., for service testing was unique in that a hand-operated diaphragm pump was mounted with the filter in a tubular frame, and a gasoline engine with speed reducer was provided with a linkage to operate the diaphragm pump. The filter was equipped with several types of elements, each set providing a septum area of approximately 1.75 square feet. Also, an air chamber and a device for air backwashing were included in the filter shell. The slurry feeder was a small diaphragm pump with a variable stroke. The filter and feeder section weighed 54.2 pounds, and the motor with reducer and linkage weighed 60.2 pounds.

In comparison with other filters on a clay suspension of 100-ppm turbidity, the Wallace and Tiernan filter, when operated with its own slurry feeder, produced an average output of 5.3 gpm, rating first in output per square foot of filter area. When operated with a common slurry feeder on Potomac River water of 37-ppm turbidity, the filter produced an average of 4.9 gpm, rating fourth in output per square foot of filter area. Advantages recorded for this filter were its easily operated hand pump, effective slurry feeder, completeness as a unit, and excellent quality of effluent. Its disadvantages were complexity, heavy weight, unsatisfactory valve arrangement, poor backwashing characteristics, and unsuitable mechanical features.

f. Design of Service Test Model. The Titeflex filter (Unit D) and the Proportioneers Feeder (Unit C) were improved for service testing with the 5 gpm set. Designs of other components for the 5 gpm set are given in the following sections.

C. Selection of Pumping Equipment

9. Hand Pump. Although the 5-gpm pack filter would normally be operated with a portable gasoline-engine-driven pump, a hand pump was also considered to be an essential component of the set for emergency operation with filter, and as a utility pump for filling containers and starting siphons. For these uses the pump should have a capacity of approximately 5 gpm and weight of less than 10 pounds. A survey of pump manufacturers data and contacts with their representatives eliminated all except five hand pumps. The pumps tested were: Deming Fig. 1570 No. 0, Deming Fig. 1570 - USCG No. 2, Blackmer Fig. 404C, Goulds Fig. 965 No. 2, and Wilcox Crittenden 18-inch Bilge.

a. Deming No. 0. The first applicable hand pump tested was Deming quadruple-acting force pump, Fig. 1570 No. 0. Constructed of brass, with a stainless steel shaft, the pump weighed 14 pounds. It was operated by pushing and pulling a side handle approximately a quarter turn. After being operated intermittently with a filter for approximately 10 hours, the pump produced the average outputs recorded in paragraph 9f below. The valves occasionally became clogged with small sticks or gravel. In considering the weight of the pump it was necessary to add the weight of a supporting base. A collapsible base constructed of bicycle tubing by Infilco, Inc., Chicago, Illinois, approached minimum weight at 7.5 pounds.

b. Deming Fig. 1570 - USCG No. 2. The Deming Fig. 1570 - USCG No. 2 pump was similar to the Fig. 1570 No. 0 model, but with a wider vane. The pump was very stiff when operated against a 20 lb/sq in. discharge pressure and required a support frame.

c. Blackmer Fig. 404C. The Blackmer Fig. 404C was a rotary pump with removable spring-loaded buckets. Being flat, the pump could be operated without additional support. Although

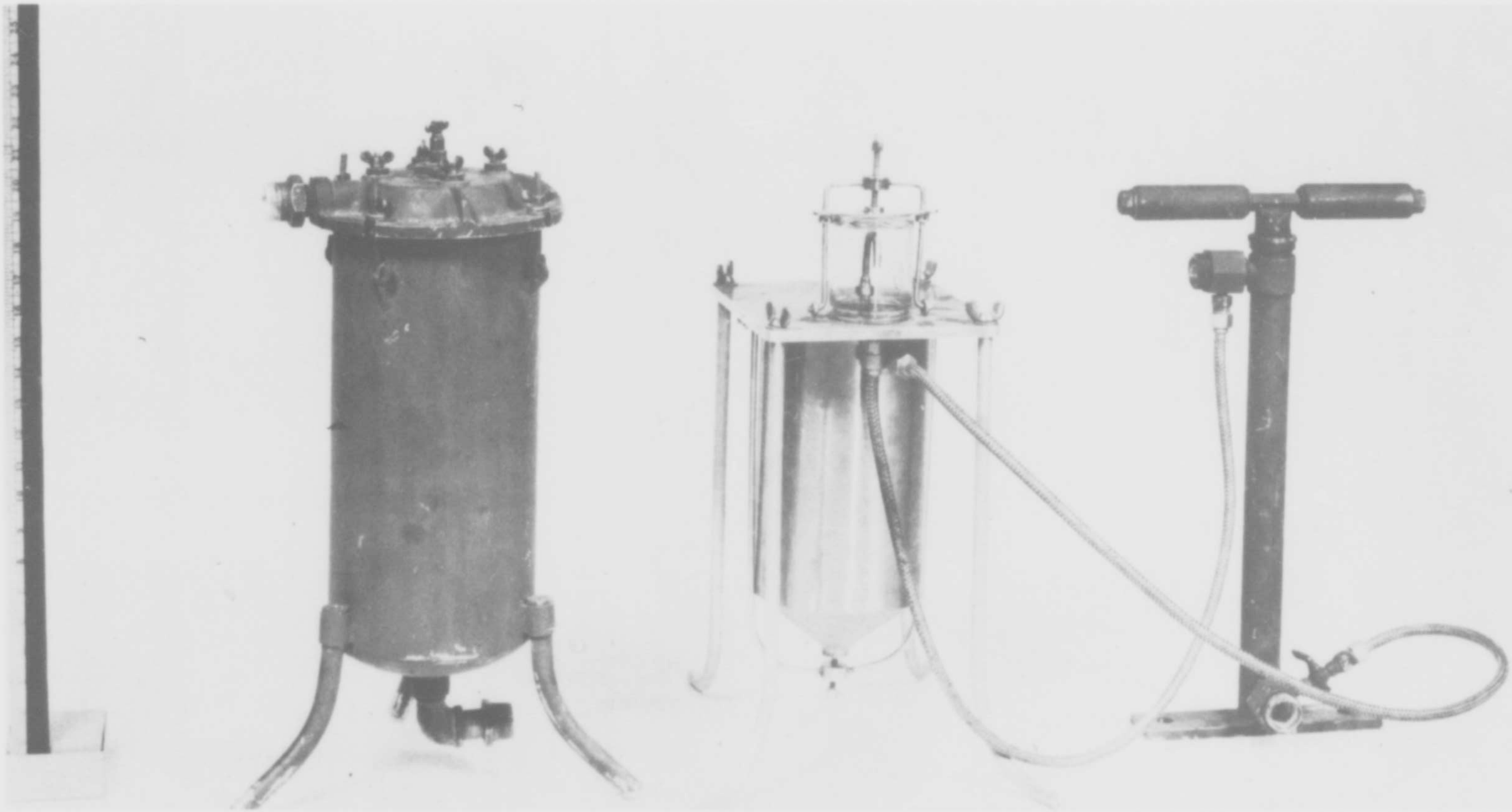


FIG. 4. FILTER AND HAND PUMP SELECTED FOR SERVICE TESTING 5-GPM SET. (Left) Titeflex Filter and Feeder. (Right) Wilcox Crittenden Bilge Pump. Engineer Board, Fort Belvoir, Virginia.

capable of being produced within the weight limit, this rotary pump was abandoned because it would not produce a discharge pressure of greater than 10 lb/sq in.

d. Goulds Fig. 965 No. 2. The Goulds Fig. 965 No. 2 pump was another oscillating pump similar to the Deming Fig. 1570 pumps, but having its valves in the oscillating wing and braided flax packing on its wing tips. The pump was also stiff to operate at higher pressures and required a supporting base. The packing was ineffective after two hours of pumping water from a flowing stream containing some grit.

e. Wilcox Crittenden 18-inch Bilge. An 18-inch bilge pump constructed by Wilcox, Crittenden and Company, Inc., Middletown, Connecticut, proved to be the most suitable type of hand pump. This double acting pump was constructed of two brass tubes with ball check valves and cup leather. Its operation was similar to that of an automotive air pump. Although an operator pumped for an hour at 25 to 50 lb/sq in. without stopping, the pump was considered to be more tiring than the oscillating type. The bilge pump was modified for emergency use with the pack filter by increasing its overall length to 24 inches and adding a double handle and foot support plate.

f. Comparison of Hand Pumps. After being operated with filters for short periods, the hand pumps were subjected to comparative tests by the same operators working in shifts. The pumps were equipped with 5-foot lengths of 3/4-inch garden hose and operated with a 4-foot suction lift and a 2-foot discharge head. The following tabulation indicates the superiority of the Wilcox Crittenden bilge pump:

Comparison of Hand Pumps

Pump	Weight of pump	5 lb/sq in.		20 lb/sq in.		
		Output (gpm)	Strokes (per min)	Output (gpm)	Strokes (per min)	Shift (min)
Deming Fig. 1570 No. 0	*14.0	3.7	54	2.0	60	7
Deming Fig. 1570 USCG	*18.0	4.6	25	1.4	38	5
Blackmer Fig. 404C	*19.5	4.0	60	0	50	5
Goulds Fig. 965 No. 2	*19.0	4.5	30	2.6	50	5
Wilcox Crittenden Bilge	5.0	5.0	32	3.4	20	5

* Note: Additional 7.5-pound base required with these pumps.

10. Power Pump. When a gasoline-engine-driven pump was considered, the pump was expected to be used for the direct filtration of raw water, making a pump with good delivery at high head essential. With the later adoption of pretreatment for most water to be filtered, another requirement was introduced, that of higher output at the low head required for filling pretreatment tanks.

a. Rotary. Several types of rotary pumps were considered. Among them were Blackmer, Viking, and Jabsco pumps. Rotary pumps were unsatisfactory due to wear and relatively low output for filling pretreatment tanks.

(1) Blackmer. A Model MDC 5, motor-driven pump, constructed by the Blackmer Pump Company, Grand Rapids, Michigan, performed satisfactorily for approximately 60 hours of normal filter operation, producing approximately 5 gpm throughout. At this time, the suction hose was allowed to fall into sandy mud without a strainer on the hose. In a few minutes the capacity of the pump was severely reduced, the casing and buckets being scored by grit. During the testing of Model MDC 5, a larger Model PA 20L was ordered. This pump would produce 20 gpm at 900 rpm, but was not recommended for operation at 3000 rpm, efficient light engine speed. The Model PA 20L pump fitted with removal liner weighed 27 pounds. The pump rotor contained bronze rectangles (known as buckets) which were thrown outward against the pump casing by centrifugal force.

(2) Viking. A Model DH - SPEC pump, constructed by the Viking Pump Company of Cedar Falls, Iowa, was tested with a Briggs and Stratton Model NP engine. Initially the pump produced an output of 50 gpm at zero lb/sq in. discharge pressure, and 14.5 gpm at 20 lb/sq in. After pumping a diatomite suspension of 1000 ppm for 163.5 hours, its capacity had dropped to 12.8 gpm at 20 lb/sq in. The Viking Pump operated by eccentric action between a sliding rotor and a removable plate.

(3) Jabsco. A Model F 1 1/4 pump constructed by the Jabsco Pump Company, Beverly Hills, California, was tested breefly. The rotor of the pump was of Neoprene with flexible vanes which folded backward at the intake and discharge ports. The pump was found to require considerable power in starting and was not recommended for operation above 1150 rpm. It weighed 16.5 pounds.

b. Screw (Moyno). The pump, whose characteristics were probably most suitable for direct filtration, was the R & M Moyno Pump constructed by Robbins & Meyers, Inc., Springfield, Ohio. The Model 1B2H Moyno Pump was considered for use with pack equipment. The manufacturer reported an output of 7.5 gpm against 60 lb/sq in. pressure and a 10-inch mercury vacuum on the suction. The pump was too long for mounting with the engine on a pack board.

The pump consisted of a single-threaded helical rotor within a stationary, double-threaded helical stator, producing a continuous flow. With the exception of lower output for filling pretreatment tanks, the characteristics of the Moyno Pump were superior to other types considered.

c. Turbine (Aurora). The Model D4 turbine pump, constructed by the Aurora Pump Company, Aurora, Illinois, possessed desirable characteristics for the dual purpose of filling pretreatment tanks and operating the filter. The pump was rated at 6.5 gpm at 60-foot total head and 1750 rpm. The turbine pump was inferior to self-priming centrifugal pumps in wear resistance and priming requirements.

d. Self-priming Centrifugal. The type of pump found to be most satisfactory for the dual purpose of filling tanks and operating the filter was a high head, self-priming centrifugal.

(1) Red Jacket. A Model MM-G pump, constructed by the Red Jacket Manufacturing Company, Davenport, Iowa, powered by Jacobsen-J100 horizontal single cylinder 2-cycle air-cooled engine was tested for use with pack equipment primarily due to the light weight of 28.1 pounds for the pump and engine assembly. The pump submitted for test by the manufacturer performed satisfactorily, duplicating manufacturer's results, but its low cut-off head of 37 feet at 3750 rpm was inadequate to meet requirements of the filter during the latter part of normal filter runs where a pressure of 40 lb/sq in. was often desirable.

(2) Carver. A Model No. 1010 self-priming centrifugal pump, constructed by the Carver Pump Company, Muscatine, Iowa, was considered. The pump was rated at approximately 17 gpm with 60-foot total dynamic head at 3000 rpm. A higher head pump is now being constructed by the manufacturer for tests.

(3) Gorman-Rupp. A Model LIIX self-priming centrifugal pump constructed by the Gorman-Rupp Company, Mansfield, Ohio, was considered for use with pack equipment. The manufacturer's pump curve showed an output of approximately 27 gpm against 60-foot total head at 3200 rpm. The pump considered was a modification of a standard "Midget" pump powered with a Lauson RSC engine.

(4) Rex 3 M. The "Rex Jr." 3 M Pump, constructed by the Chain Belt Company, Milwaukee, Wisconsin, with a net weight of 54 pounds and with a rating of 3000 gph with 15-foot total head was the most promising commercial pump for use with the pack equipment. A standard Rex 3 M pump was procured for testing. This pump was suitable for filling pretreatment tanks, but a higher head pump was

desirable for filtration. Accordingly, the company designed a self-priming centrifugal pump with a closed impeller and submitted it for testing. This pump, mounted on the extended shaft of a Lauson RSC 609 gasoline engine, produced 30 gpm against a total dynamic head of 60 feet (23.5 pounds discharge pressure) when tested with 10 feet of suction pipe, 5-foot lift, 1 1/4-inch suction and 1 1/4-inch discharge, at 3600 rpm. Under the same conditions the cut-off pressure was 48 lb/sq in. and the output at 35 lb/sq in. was 12 gpm. Rex 3 M pumps with aluminum volutes were procured for service testing with the 5 gpm set, and the special Rex pumps with closed impellers were procured for service testing with the 15 gpm set.

e. Power Pump Selected. The special Rex, self-priming, centrifugal pump with closed impeller was found to be most suitable for use with the 15 gpm diatomite water purification equipment.

11. Gasoline Engine.

a. Basis for Selection. The selection of a gasoline engine was governed primarily by the requirements of the pump chosen: weight suitable for man packing, low gasoline and oil consumption, long life under adverse conditions, and availability of spare parts.

(1) Pump Requirements. Operations of the 15-gpm filter unit with various pumps indicate that the pump delivery should be not less than 15 gpm at 34 to 35 lb/sq in. in the filter, or a water horsepower of 0.37. The engine bhp required to pump 15 gpm at 34 lb/sq in. is therefore 0.37 horsepower divided by 0.35, or 1.05 bhp, considering that the pump efficiency is approximately 35 percent under the conditions. Also, light centrifugal pumps require 3000 rpm or better for effective operation.

(2) Weights Suitable for Man Packing. Since the pump and engine set constitute the heaviest loads in the set, an engine with the minimum weight consistent with requirements must be chosen. The combined weights of pump (19 pounds), frame (9.75 pounds), packboard (4.50 pounds) is 33.25 pounds. Desirable maximum weight of a pack is 65 pounds, hence the engine should weigh only 32 pounds.

(3) Gas and Oil Consumption. Since gasoline may always be scarce, the engine should consume the minimum gasoline required to produce the desired horsepower. Also operators probably will not pay close attention to oil level; hence, an engine which does not require

frequent addition of oil would be more desirable, without considering the maintenance difficulties which parallel high oil consumption.

(4) Long Life. The engine must demonstrate its ability to perform satisfactorily for long periods under unfavorable conditions with little or no preventive maintenance. An engine with relatively low compression ratio, with a sufficient oil capacity for operation at an angle to horizontal, and with the ability to utilize Army fuels and lubricants must be obtained. A standard Corps of Engineer engine would be highly desirable to insure availability of spare parts.

(5) Availability of Spare Parts. Standardization of engines for Engineer Equipment dictated the choice of a standard engine after tests to determine the most suitable engine had been completed. The final choice is the standardized Briggs and Stratton NLP engine.

b. Engines Eliminated. A survey was made of commercial engines which most nearly approximated the requirements. The engines available are listed in Appendix D. Preliminary examination of available engines resulted in the elimination of the following:

(1) Johnson Iron Horse. The availability of this engine was doubtful, owing to full time production of outboard motors by the manufacturer. Weight for power developed was higher than other makes.

(2) Delco. The horsepower of this engine was not adequate for severe operating conditions. This engine is normally furnished only in conjunction with electric generating outfits, for which there is also a critical demand.

(3) Homelite. The horsepower of this engine was in excess of needs, resulting in excessive gasoline consumption. Information regarding weight of the engine separately was not available, as it is usually part of an electric generating plant. This introduced the same production difficulties encountered in (2) above. In addition this engine has the highest compression ratio of those considered, a feature considered undesirable for assurance of durability and long life.

c. Engines Tested. Tentative selection was therefore made of Lauson, Briggs Stratton, and Jacobsen engines, for testing.

(1) Jacobsen J100 Engines. A Jacobsen J100 Engine was procured from the Red Jacket Manufacturing Company,

Davenport, Iowa, direct coupled to a centrifugal pump. The engine was rated by the manufacturer conservatively at 0.75 hp at 1700 rpm and at 1.0 hp at 2200 rpm, the peak of the power curve. It weighs 28½ pounds in standard construction, but was lightened for test purposes so that combined weight of pump and engine was 28.1 pounds. The J100 is a two-cycle, air-cooled, single-cylinder model. The pump manufacturer adjusted the speed to 3800 rpm with 1.1 hp to meet pump requirements. Tests of the unit disclosed that excessive carbon formation in the valve ports limited operation to about 100 hours before extensive overhaul was required. Piston and rings showed severe burning, which indicated inadequate lubrication, presumably due to excessive speed beyond rated capacity. Two-cycle engines normally require non-leaded fuel and clear burning lubricants, which are not ordinarily available as regular issue. A larger engine, the Model J150, manufactured by the same company has adequate power of 1.0 hp at 1550 rpm, but like the smaller model is not designed for operation at 3000 rpm, the required pump speed.

(2) Briggs and Stratton Model NP.. One engine of this type was procured and tested. Operation was satisfactory, and tests indicate adequate operating life. However, certain modifications of the basic model were considered desirable for field use. The engine as issued weighs 39.5 pounds stripped, or approximately 41.2 pounds with accessories. Its oil capacity is one pint, requiring oil change, as recommended by the manufacturer, every 5 hours. Since field use may require operating the engine on a slope, an oil sump of at least one quart capacity is desirable to assure lubrication when part of the oil has been consumed. Weight should be reduced by substitution of light metal for cast iron where possible, shielded spark plug should be used, all accessories should be chained to prevent loss, and a crankcase float switch should be provided to protect the engine against damage when the oil level drops. These changes were discussed with the manufacturer. Weight reduction to 37.2 pounds in a Model NLP engine was accomplished, but other desired features could not be incorporated. The horsepower developed was in excess of needs, resulting in excessive gasoline consumption. Oil consumption started at approximately 1/4 pint in six hours continuous operation. Excessive carbon formation necessitated overhaul after 150 hours of operation, and oil consumption increased to 1 quart in 8 hours, showing excessive piston ring wear. The principal advantage of the Briggs and Stratton NLP engine is that the Model N engine has been standardized as Corps of Engineers Equipment. The wearing parts of the Model NLP are interchangeable with those of the Model N.

(3) Lauson Model RSC. This engine was furnished originally with all the desired special features previously listed. A similar model, of standard construction, has been in use for four years by the pump manufacturer, the Chain Belt Company, as standard for the pump selected. A number of these engines were procured and service tested with uniformly satisfactory results. One engine has been operated for approximately 500 hours on issue fuels and lubricants without major repair or overhaul, and continues to operate efficiently. The weight of the engine with all accessories is 34.5 pounds. The power is almost exactly proportioned to pump requirements, being rated by test as 1.3 hp at 3800 rpm and 1.5 hp at 3600 rpm. Operation is practically vibrationless. The Lauson engine has a considerably lower compression ratio than the Briggs or Jacobsen engines. The feature is particularly desirable, as a lower compression engine is ordinarily more durable, and capable of operation with a wider range of fuels. All Lauson RSC 609 engines tested were equipped with Stellite faced valves and valve seats for operation on 100 octane gasoline.

D. Service Testing of 5-GPM Set

12. Assembly of 5-gpm Set. Seventeen 5-gpm sets were procured for service testing. This set was divided into 6 pack loads, each mounted on a standard plywood packboard and weighing less than 65 pounds to permit man carrying. Pack No. 1 was a complete hand operated unit with a supply of filteraid sufficient for 24 hours of emergency operation. Pack No. 2 was a gasoline-engine-driven, self-priming centrifugal pump. Pack No. 3 contained a 25-pound bag of filteraid, spare filter elements, extra hose, suction strainer, spare parts, and tools. Packs No. 4, 5, and 6 each contained a 350-gallon canvas tank. The complete 5-gpm pack water purification set weighed approximately 300 pounds. An itemized list of the contents of each pack will be found in Appendix C.

13. Description of Major Components (5-gpm). The following description of the major components in the 5-gpm sets is given to assist in interpreting the results of service testing and to understand equipment later used in the 15-gpm set.

a. Filter. The 5-gpm filter consisted of a cylindrical stainless steel shell with conical bottom and a detachable cast aluminum head with filter elements attached. The shell was erected on three pivoted aluminum legs. The bottom of the shell contained a baffle plate to check direct flow. The shell was fastened to the head by four bolts with wing nuts and recessed gasket. The head was hollow and equipped with four tie rods and gasketed cups for mounting filter elements. The elements were hollow cylinders, 1 3/4 inches outside diameter and 12 inches long, giving a total area of 1.83 square feet. Three sets of interchangeable elements were provided: one of bonded aluminum oxide grit known as "Aloxite"; another of porous carbon known as "Carbocell", and another of wire wound on a fluted core known as "Stellar".

b. Feeder. The body feeder was an open aluminum can with an attached agitator and sight flow indicator. The agitator propeller was driven by a multi-vane fan actuated by the engine exhaust. The flow indicator consisted of a plastic tube clamped between two aluminum discs, with an orifice inlet near the top of the tube on one side and an outlet near the bottom of the tube on its other end. Flow was adjusted by regulating the striking point of the visible jet within the plastic tube. The orifice was connected by rubber tubes to the slurry in the aluminum can. The outlet was connected by rubber tubes to a tee fitted with tubing. One leg of the tee was connected with the suction of the pump, the other leg to the discharge through a control valve. Slurry flow in the sight chamber was adjusted by opening or closing the valve on the discharge line which increased or decreased suction through the indicator. Control by bleeding discharge into the suction line was necessary because any control valve on the suction line would be plugged with filteraid.

c. Chlorination Set. The chlorination set consisted of a color comparator, orthotolidine tablets, a one ppm chlorine test kit, two measuring cups, calcium hypochlorite can, and a measuring scoop. The chlorine comparator was a junior model Hellige Simple Tester with glasses for 0.5, 1.0, 1.5, and 2.0 ppm chlorine. Orthotolidine tablets were provided in two plastic tubes with screwed caps, each tube containing approximately 200 tablets. Instructions for making a chlorine determination were printed on the plastic tube. A less exact comparison could be made with the orthotolidine testing kit, which consisted of a plastic tube with yellow band and an inner glass tube of orthotolidine tablets. Instructions for using this kit were printed on the glass tube. The comparators and tablets were protected by a fiber case which also included a plastic stirring rod for crushing the orthotolidine tablets. A reclosable metal can similar to a half-pint paint can was provided for calcium hypochlorite. The measuring scoop was of plastic with a wire handle. The full scoop contained approximately 5.6 cc, providing enough granular calcium hypochlorite for producing a two ppm chlorine dosage. Chlorination of five-gallon cans could be accomplished by placing one scoop of hypochlorite solution in each can.

d. Hand Pump. The hand pump was a modified bilge pump of brass construction. It was equipped with double wood handles and foot support. As the pump plunger was lifted, water was sucked through a ball check valve at the base into the barrel of the pump. In the same upward stroke water was discharged from the annular space between barrel and plunger. On the downward stroke water was forced through a check valve at the lower end of the plunger then through openings in the plunger to the annular space where part of the water was discharged from the top outlet, and the other part remained in the annular space to be discharged in the next upward stroke.

e. Gasoline-Engine-Driven Pump Set. The pump set consisted of a single cylinder Lauson RSC-609 4-cycle, gasoline engine direct-connected to an open impeller, self-priming, Chain Belt centrifugal pump. The 1-inch suction hose connection was furnished with a 1/8-inch petcock. The 1-inch discharge connection was furnished with a 1-inch gate valve, a 1/8-inch valve and nipple for body feed hose, and a 1-inch male nipple. The pump delivered 15 gpm against a 30-foot discharge head with 10-foot suction lift.

f. Accessories. Thirty feet of 1-inch inside diameter wire-wound suction hose were provided in one 10-foot and four 5-foot lengths. Six standard plywood packboards, a tool roll for field repair, a float strainer, and a sanitary nozzle were also provided.

g. Filteraid. Diatomaceous silica was supplied in 15-pound multi-wall paper bags and 25-pound lined osnaburg bags. Two types of filteraid were issued: alum treated filteraids known as Dicalite 228V or 234V and Johns-Manville Sorbo-Cel, and untreated filteraid known as JM Hyflo.

h. Tanks. Four 350-gallon canvas tanks were provided. The tanks were constructed of No. 8 cotton duck, mildewproofed with cuprammonium and waterproofed with bitumen, according to the Willesden C.A.B. process. The tanks were 24 inches high and 65 inches in diameter, being similar in construction to the standard 3000-gallon tanks. The first tanks so constructed were found to leak badly at the seams. A satisfactory method for sealing the seams was devised for the remaining tanks.

14. Operation of 5-gpm Set. The 5-gpm set was connected to filter raw water directly from its source or coagulated and settled water from intermediate tanks. Direct filtration was employed on relatively clear water (less than 30-ppm turbidity), and pretreatment on more turbid water.

a. Direct Filtration. The 10-foot suction hose with attached float strainer was placed in the stream and connected to the pump. The pump discharge was connected to the bottom of the filter by a 5-foot hose. Another 5-foot hose was connected to the filter outlet for filling one of three 350-gallon tanks erected beyond the filter. The pump was primed; 1/4 pound of filteraid in ½ gallon of water was poured into the filter shell, and ½ pound of filteraid was poured into the slurry can; then the engine was started. After five gallons were discharged to waste, the filteraid was collected until the output dropped below 3 to 5 gpm. During filtration, body feed was added to raw water by adjusting the feeder valve to maintain a constant stream in the sight flow indicator. Backwashing was accomplished by interchanging suction and discharge hoses at the pump, immersing the discharge hose in the filtrate tank; thereby sucking approximately 10 gallons of filtered water through the tank in reverse. With direct filtration, chlorination was accomplished by placing a dissolved scoop of calcium hypochlorite into the filtrate tank after the bottom was covered with water.

b. Pretreatment. Operation with pretreatment was the same as for direct filtration except that a tank of coagulated and settled water was used as the source to be filtered, and calcium hypochlorite solution was added at the pretreatment tank. Alum was added by placing 1/4 pound in the pump's priming chamber. Soda ash was added by placing briquettes in the discharge stream until the observed floc was satisfactory.

15. Packing of 5-gpm Set. Packboards were found to be suitable for man carrying, but additional brackets were required to insure proper animal packing.

a. Man. Components of the 5-gpm set were divided into six loads, each carried on a standard plywood packboard for man carrying. The heaviest load was the pump and engine set, weighing 65 pounds with packboard. Tests conducted by the 126 and 271st Engineer Combat Battalions at Camp Hale, Colorado, and Camp Young, California, respectively, indicated that a man normally could carry the 65-pound load for only 5 miles over rough terrain without excessive fatigue.

b. Animals. One 5-gpm set of pack water purification equipment was sent to the Camp Hale Test Branch, Engineer Board, at Pando, Colorado, for animal packing. Good packing with ropes requires considerable experience and training; whereas packing with brackets is almost "fool proof," and is the method used for standard equipment.

16. Service Tests. In accordance with directives from the Chief of Engineers, 5-gpm sets of pack water purification equipment were sent to the following organizations for service testing:

Sets	Organization
2	126th Engineer Combat Battalion, Camp Hale, Colorado
9	271st Engineer Light Combat Battalion, Camp Roberts, California
1	Army Air Forces, 1 Troop Carrier Command, Stout Field, Indianapolis, Indiana
1	Department of Military Sanitation, Medical Field Service School, Carlisle Barracks, Pennsylvania

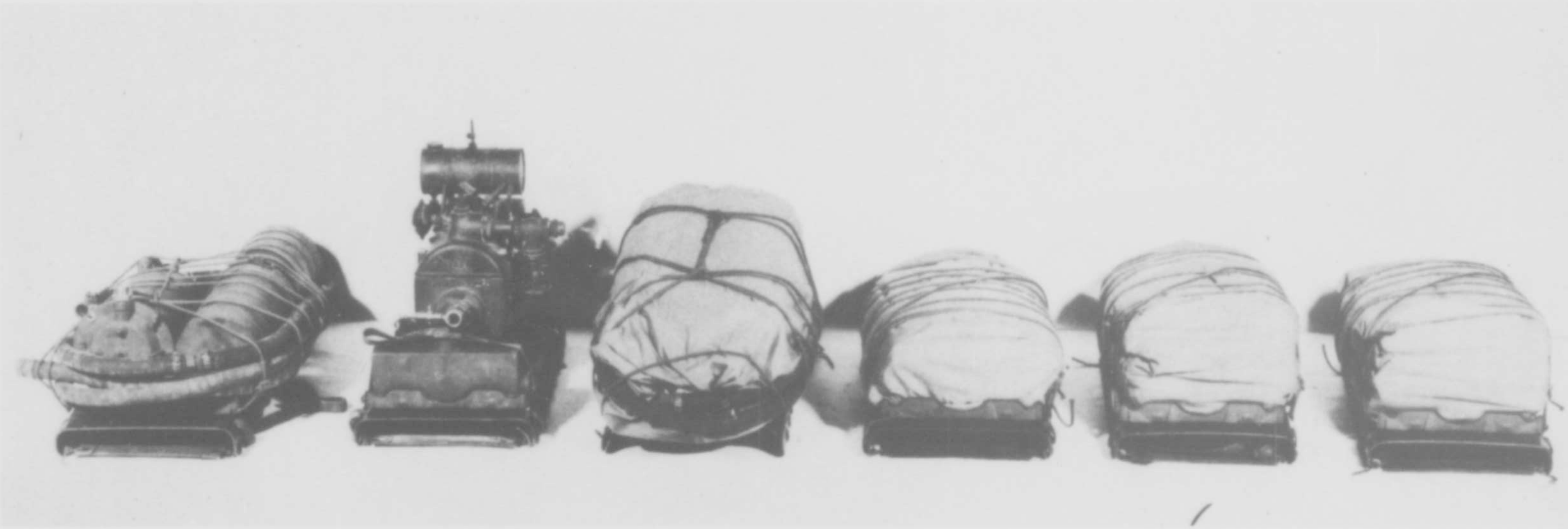


FIG. 5. 5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED). Packs for man carrying. Engineer Board, Fort Belvoir, Virginia.

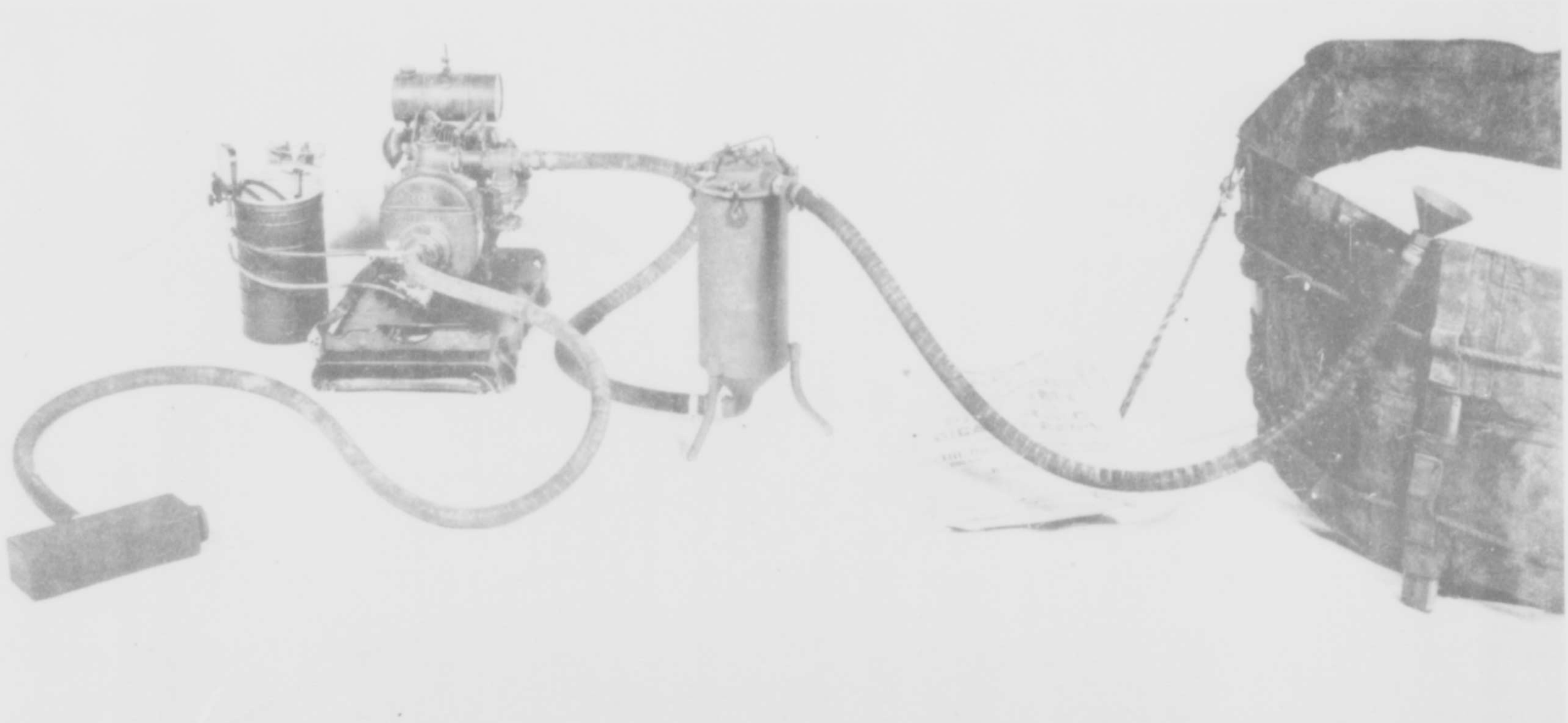


FIG. 6. 5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED). Assembly of set for power operation. Engineer Board, Fort Belvoir, Virginia.

a. Tests By 126th Engineers. Testing was begun two days after receipt of the 5-gpm sets by the 126th Engineer Combat Battalion, and was continued for ten days. In accordance with a directive the organization submitted a report to Army Ground Forces shortly after completing tests. The Camp Hale Test Branch reported unfavorable results, so a representative of the Water Supply Equipment Branch was sent to Camp Hale. The filters had been operated without precoating and with inadequate body feeding, resulting in low outputs of filtrate due to plugged elements. It was believed that this incorrect operation resulted from insufficient time for all operators to read or understand the instructions, and from a lack of illustrations in the instructions to supplement verbal descriptions. The pumping capacity was also decreased by a bushing with 3/4-inch instead of 1-inch opening at the pump's suction as specified. The equipment was reconditioned and arrangements were made for a second test.

During the second test series an average of 324 gph was obtained with the gasoline-engine-driven pump and 251 gph with the hand pump, exceeding the rated capacity of 300 and 150 gph. Tests were made at an elevation of approximately 10,000 feet, which reduced the pumping capacity to approximately 64 percent of its sea level value, and on turbid cold water at 32° F, which can be filtered twice as rapidly at 70° F. Results of the tests at Camp Hale are given in Appendix B. During tests the body feeder required frequent adjustments; otherwise the equipment performed well. A second report was submitted to Army Ground Forces recommending that one of the 10 gpm sets be supplied per Infantry Battalion, or similar organization. A copy of this report is reproduced in Appendix B.

b. Tests By 271st Engineers. Nine sets of 5-gpm pack water purification equipment were operated by the 271st Engineer Light Combat Battalion during April 1944 on maneuvers at Hunter-Liggett Reservation, California. Operated on clear mountain streams, the sets produced an average of 960 gph or 16 gpm by direct filtration. Pretreatment was not employed on the relatively clear raw water. The organization suggested the addition of a trigger-operated valve for filling cans, and favored water bags instead of metal cans, additional hose, and maintenance tools. An engine failure due to moisture in the magneto was reported. Although an output of over 15 gpm was obtained, the organization favored increasing the filter area and pump capacity due to a shortage of available operators. A copy of the questionnaire report submitted by the 271st Engineer Light Combat Battalion is included in Appendix B.

c. Tests By Army Air Forces. Army Air Forces, Headquarters, 1 Troop Carrier Command, Stout Field, Indianapolis, Indiana, reported that the 5-gpm pack water purification unit was not suitable for Air Force use in a report dated 25 April 1944, entitled:

"Equipment Testing Report." Paragraph 2 of the report's conclusions is as follows:

> "2. It is believed that this equipment may be so modified as to be vehicular borne; and that the output may be increased to reach a constant 10 to 15 gallons per minute and so make its issuance as a replacement for the present portable water purification unit feasible in Air Forces and Airborne Troops."

In considering the output per unit weight of equipment, the complete set of pack water purification equipment, weighing 300 pounds, was compared with a 40-pound pumping and filter unit producing 3 to 5 gpm. Actually the filter and hand pump of the 5-gpm set weigh 30 pounds. An average output of 15 gpm on low turbidity water was reported, but no outputs on higher turbidity water were given in the Air Corps report. A copy of this report is reproduced in Appendix B.

d. Tests By the Engineer Board. One of the 5-gpm pack water purification sets procured for service testing was operated on the Potomac River by enlisted men for approximately two weeks under the supervision of technical personnel. Tests were made to determine the rate of plugging for porous carbon elements, the outputs with direct filtration and pretreatment, the advisability of altering the body feeder, and to check operating instructions. After approximately 14 hours filtration time the Carbocell 50 grade elements were found to be slightly plugged when compared with new elements. Cleaning carbon elements would normally be accomplished by scraping with a knife, but a 1/16-inch cut was made in a lathe to insure uniformity for test purposes. The turned elements were returned to service. Performance approximated that of the clean elements. The average rates during actual filtration for the test period were 12.7 gpm with direct filtration and 11.3 gpm for pretreatment, with raw water having a turbidity of 35 to 95 ppm. The average total filtrate delivered per run was 263 gallons for direct filtration and 271 gallons for pretreatment. During approximately one-third of the tests an experimental Rex pump with closed impeller was used. The increased output obtained with this higher head pump is illustrated by data in Appendix D, Fig. 24. The output with the higher head pump was approximately 25 percent greater. Results of these tests are shown in Appendix D.

Operating instructions proved satisfactory. The open body feeder supplied with the 5-gpm set required frequent valve adjustments and would not function when the pump's suction dropped considerably as the discharge head increased, or with an elevated treatment tank. Modifying parts were assembled to convert the open feeders to a floatation type (which proved satisfactory in tests), but service tests were completed before the improvement could be effected by organizations except the Medical Field Service School.

e. Tests By Army Service Forces Department of Military Sanitation. One set of 5-gpm pack water purification equipment was tested at Carlisle Barracks, Pennsylvania, by the Department of Military Sanitation, Medical Field Service School, and the Medical Department Equipment Laboratory, primarily to determine bacterial removal efficiency. Reports, containing excellent data, from each organization are reproduced in Appendix B. Direct filtration removed 90.6 percent of initial bacteria; and pretreatment followed by filtration, 94.3 percent, based on an average of runs. It was recommended that the filter be chlorinated frequently to avoid contamination of elements. This provision was included in TB 5-295-2. Mechanical improvements recommended were also effected.

E. Revision to Provide 15-gpm Capacity

17. Revision. After service testing the 5-gpm pack water purification sets, both the 126th and 271st Engineer Combat Battalions stated that greater capacity was desirable for their use. The 126th Engineer Light Combat Battalion recommended equipment with an average capacity of 10 gpm or better in the report contained in Appendix B. Although the 271st Engineer Light Combat Battalion obtained an average of 16 gpm when operating the 5-gpm pack water purification set on relatively clear mountain streams, this organization recommended a larger filter and pump in a "Pack Water Purification Equipment Preliminary Service Test Questionnaire" transmitted by letter, dated 2 May 1944, from Headquarters 271st Light Combat Battalion, Hunter Liggett Military Reservation, APO 360, Camp Roberts, California. (See Appendix B.) During the service test a 15-gpm pack water purification set was being designed at the Engineer Board. The increased capacity was obtained by doubling the filter area, employing a higher head pump, an automatic feeder, a valve backwash, larger hose, and larger water tanks.

a. Increased Filter Area. The filter area was increased from approximately 1.8 to 3.6 square feet by using seven 2-inch outside diameter elements which provided the most economical space utilization in the filter shell. An increase of one inch in the inside diameter of the filter shell was required.

b. Higher Head Pump. The pump issued with the 5-gpm set was a self-priming centrifugal pump with open impeller, developing a maximum discharge pressure of approximately 25 lb/sq in. Previous tests have shown that an almost proportional increase in output would be obtained by increasing the pumping pressure to at least 50 lb/sq in. Several companies were asked to produce a high head centrifugal pump. The Chain Belt Company submitted a self-priming centrifugal pump with closed impeller, capable of developing a discharge pressure of 45 lb/sq in.

c. Automatic Feeder. The suction feeder tested on the 5-gpm set was unsatisfactory because it required adjustment too frequently. The feeder was redesigned for the 15-gpm set to employ a water motor for agitation, an orifice to control slurry flow, and a float valve to maintain pump suction. The feeder used on the 5-gpm set during service test was revised in order to obtain maximum utilization of the 5-gpm set; however, the modified feeder was developed too late to be of value in service tests with the exception of those conducted by the Medical Corps at Carlisle Barracks.

d. Backwashing. Backwashing the 5-gpm filter by interchanging the suction and discharge hoses at the pump required approximately two to three minutes and introduced considerable wear on hose threads. A four-way valve was added on the 15-gpm set to permit interchanging suction and discharge without disconnecting the hose. Use of the four-way valve decreased backwashing time to less than a minute.

e. Larger Hose. Reinforced suction hose with an inside diameter of approximately 1 inch was used on the 5-gpm set. Tests indicated that considerable head loss resulted from friction in this relatively small hose. A sufficient increase in capacity was obtained with 1 1/4-inch inside diameter hose to justify its increased weight, when used on the 15-gpm set.

f. 500-Gallon Tanks. The 350-gallon tanks used with the 5-gpm set were of adequate size for 5 to 10-gpm capacity, but 500-gallon tanks were desirable for the 15-gpm set in order to provide more pretreated water for an uninterrupted run and to store the increased output when necessary.

F. Recommended 15-gpm Set

18. Assembly of 15-gpm Set. The recommended 15-gpm set consists of a filter and feeder section, two gasoline-engine-driven pumps, four 500-gallon tanks, 1 1/4-inch hose, supplies for 40,000-gallon production, and accessory equipment. The set may be carried as three animal or nine man loads. Its total weight is approximately 580 pounds. The heaviest pack weighs 65 pounds when arranged for man packing. Constituents of each pack are listed in Appendix C.

19. Description of Major Components (15-gpm). A brief description of 15-gpm diatomite water purification equipment follows. Detailed descriptions are contained in Engineer Board Drawings D5104-1 through D5104-15 inclusive.

a. Filter and Body Feeder. The filter and body feeder are mounted in a tubular frame.

(1) Filter. The filter consists of a stainless steel cylindrical shell, an inlet baffle chamber with a 1-inch male pipe nipple, a cast aluminum head (supporting seven plastic-core, wire-wound filter elements, 2-inch outside

diameter by 12 inches long, suspended inside the shell) with six lug bolts and wing nuts for clamping the head to the shell on a rubber gasket. The filter head has an air-vent valve and a 1-inch female pipe connection for filtered water discharge. The filter shell is 20-gage stainless steel, welded construction, 8-inch outside diameter by 19½ inches high exclusive of the head, with two rolled rings for stiffening. The bottom nipple of the shell is furnished with a 4-way, two-directional, brass plug valve, the openings other than filter connection being furnished with 1 1/4-inch male hose adapters.

(2) Float Valve. Adjacent to the filter shell is a rectangular, aluminum float box, 4 1/4 inches square by 13 5/8 inches deep, with open reinforced top and truncated pyramidal bottom, containing a cylindrical aluminum float valve with hemispherical ends. Each end of the float is equipped with a rubber faced valve stem, to seat on a tube in the bottom of the float chamber.

(3) Weir and Slurry Can. Attached to the float chamber are a rectangular weir box and a slurry can of aluminum. The weir chamber maintains a uniform head of 2 inches of water, feeding into the slurry can through an orifice so calibrated that the net volume of the can (approximately one gallon) is replaced in thirty minutes.

(4) Accessory Pail. Attached to the bottom of the slurry can is a square aluminum pail with quick release clamps. During transportation, this pail contains spare parts, a wire chemical basket and hypochlorite, and pH test kits.

(5) Tool Box. Adjacent to the slurry can and weir box is mounted an aluminum tool box, with a snap fastened hinged cover, containing a canvas roll of hand tools.

(6) Agitator. A water motor is mounted over the slurry can (actuated by discharge flow of filtered water) for agitating the slurry by a shaft and propeller suspended in the can. The water motor discharge is furnished with a 1 1/4-inch male hose connection.

(7) Flow. In the filtering operation, raw water from the pump passes through the 4-way valve into the bottom of the filter, rises, passes through the filter cake, filter tubes and head, and on through the water motor to discharge to storage. A needle valve between the filter head and the water motor controls the feed of filtered water into the weir box, which passes a calibrated flow into the slurry can and by-passes the remainder over a weir into the float

chamber. Agitated filteraid slurry discharges into the float chamber, is drawn from the chamber through a petcock into the pump suction line, and circulates to the filter, where it deposits its filteraid on the elements.

b. Gasoline Engine and Pump.

(1) Engine. The engine furnished is a single-cylinder, 4-cycle, air-cooled, Briggs and Stratton Model NLP, developing 1.6 hp at 2800 rpm and 2.0 hp at 3600 rpm. It was adapted from the standard commercial Model NP by the substitution of aluminum castings for cast iron. The revised engine weighs 36.5 pounds. The Lauson RSC 609 engine in Fig. 7 was superseded by the Briggs and Stratton Model NLP.

(2) Pump. The pump, a Rex closed-impeller, single-stage, self-priming centrifugal, is bolted directly to the engine base, with the impeller mounted on the extended engine crankshaft. The pump has a total weight of 19 pounds. It is furnished with a 1½-inch suction and 1 1/4-inch discharge.

(3) Set. The pump and engine are mounted in a welded tubular steel frame fabricated from 20 gauge 1-inch outside diameter seamless tubing. The frame weighs 9 pounds, and is in turn covered with a waterproof fabric cover weighing approximately one pound. The entire assembly is provided with a steel clip and lashings for mounting on a standard packboard. When it is desirable to reduce its weight for man packing, the pump and engine may be removed from the frame and bolted directly to the packboard.

c. Accessories. A hand pump for emergency operation, hose, adapters, chlorination set, pH test kit, sanitary nozzle, suction strainer, and chemical basket are also included in the 15-gpm set.

(1) Hand Pump. The modified bilge pump originally developed for inclusion in the 5-gpm set has been included in the 15-gpm unit also. Description of the pump is included in the description of the 5-gpm set in paragraph 13d, above. Since the hand pump will be operated only in emergencies, owing to the failure of both gasoline-driven pumps or to the temporary unavailability of fuel, the lightest and smallest pump with adequate output was selected.

(2) Hose. The hydraulic characteristics of the 15-gpm set are best served, and with the least friction losses commensurate with light weight, by a 1 1/4-inch inside

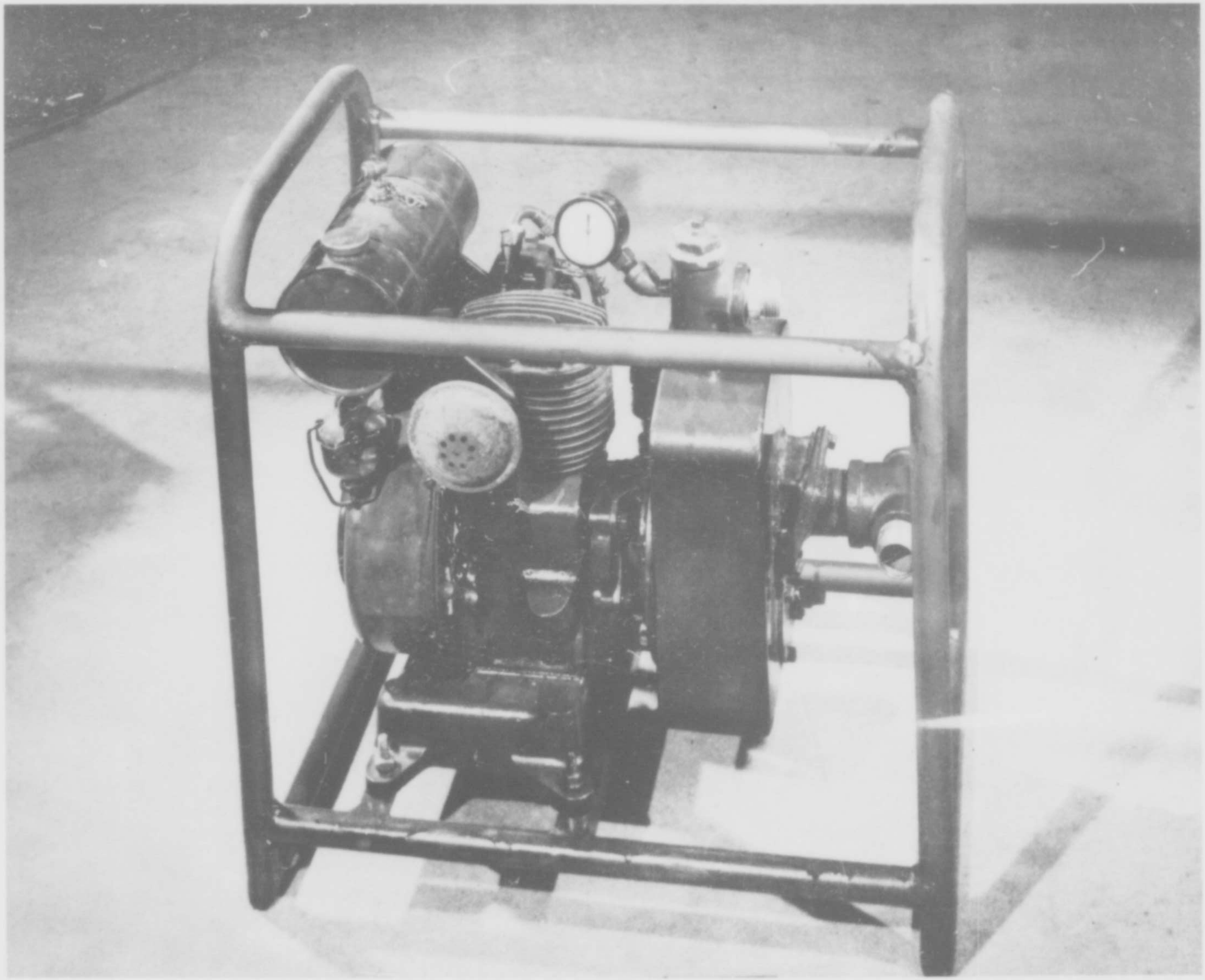


FIG. 7. PUMP AND ENGINE SET FOR 15 GPM UNIT. Lauson RSC 609 Gasoline Engine and Rex High Head Pump. Engineer Board, Fort Belvoir, Virginia.

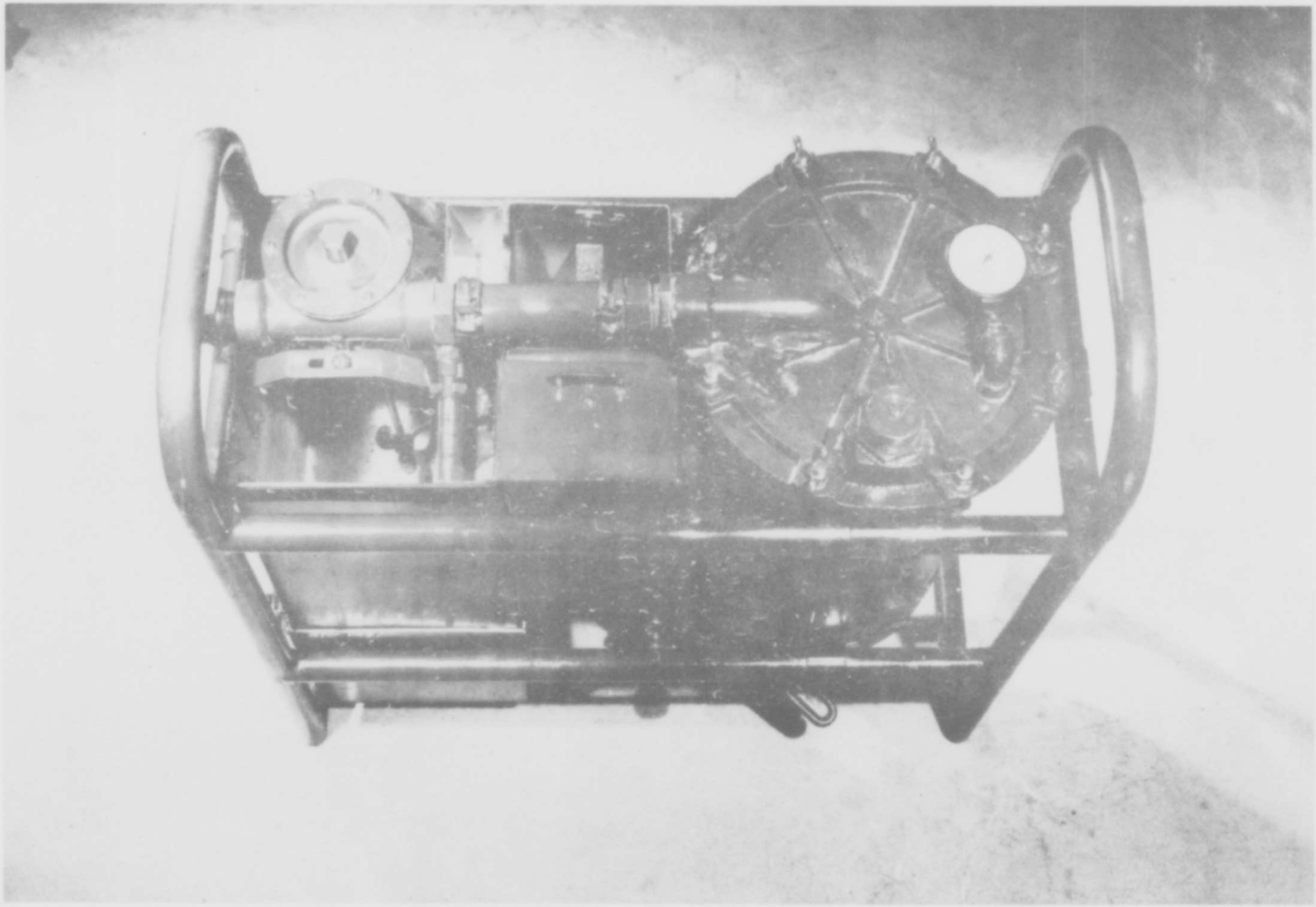


FIG. 8. TOP VIEW OF RECOMMENDED 15-GPM FILTER. 15-GPM Pilot Model Filter, Mfg. by Permutit Company. Engineer Board, Fort Belvoir, Virginia.

diameter hose. Six 10-foot lengths, male and female, and two 5-foot lengths, female and female, are provided. Since any section of the hose must serve for either suction or discharge, light weight wire-wound suction hose is supplied.

(3) Hose Adapters. All fittings on the pump and filter are provided with adapters for standard 1 1/4-inch hose fittings. Accessories include replacement adapters for standard 1½-inch hose.

(4) Chlorination Set. This set, embodying a simple Hellige comparator with a supply of orthotolidine tablets, is the same unit previously issued with the 5-gpm set in paragraph 13c, above. The plastic scoop, similar to the scoop furnished with the 5 gpm set, has been revised in shape and size to dip granular hypochlorite from the 6-ounce can. Its capacity is such that one scoop, of hypochlorite, provides a dosage of 1.8 ppm chlorine in the 500-gallon tank.

(5) pH Test Kit. This kit consists of a glass vial, containing 200 slips of nitrazine paper with a color scale and operating instructions on the glass. Dye from the paper leached with water to be tested permits a color comparison with the standard scale, thus providing sufficiently accurate pH determination for field treatment of the subject water.

(6) Sanitary Nozzle. The sanitary nozzle is an inverted funnel. It prevents direct contact of the filtered water discharge nozzle with contaminating media.

(7) Suction Strainer. The lightweight aluminum strainer, provided with 1/8-inch mesh, prevents passage of foreign matter large enough to clog or damage the pump impeller. The screen is also elevated above the solid base, to prevent sand or silt being drawn from the bottom. In treated water the strainer disperses suction to minimize the flow of settled and concentrated floc into the suction hose.

(8) Chemical Basket. This wire mesh basket, constructed of non-corrosive materials, has been found to provide the simplest practicable means of dissolving the chemicals in treatment tanks. The basket may also be fastened over the suction hose intake, and provides an emergency suction strainer in the event of loss or damage to the strainers regularly supplied.

d. Filteraid and Chemicals. Filteraid, alum, soda ash, and activated carbon are supplied in multi-wall paper bags.

The size of bags was determined by packing and consumption requirements.

(1) Diatomaceous Silica. Diatomaceous silica is furnished in 25-pound, multi-wall paper bags, with taped and sewn closures. The containers selected are light, durable, easily procured, and relatively inexpensive. Operating tests with all commercially available diatomaceous filteraids indicated that a relatively coarse grade of filteraid produced higher flow rates, while producing a filtrate of acceptable clarity. Of these materials, Celite No. 535, as manufactured by Johns-Manville, and Dicalite 4200, manufactured by the Dicalite Company, have proven most desirable, and are recommended for regular procurement. A 25-pound bag of filteraid should suffice for 20,000 gallons of filtrate.

(2) Alum. Ammonium alum is furnished in lump form, averaging 3/4 inch in diameter, packed in 10-pound multi-wall paper bags. The 10-pound bag of alum should treat 20,000 to 40,000 gallons of water.

(3) Soda Ash. Sodium carbonate is furnished in compressed briquettes, of approximately two ounces each, packed in 10-pound lots in multi-wall paper bags, of the same container size as the alum. The requirements of soda ash to raise the pH of water and assist formation of floc cannot be accurately predicted, but the 10-pound bag should treat at least 40,000 gallons.

(4) Activated Carbon. Carbon in powdered form is packed in 5-pound lots in multi-wall paper bags of the same construction and volume as the alum and soda ash bags. Five pounds of carbon should suffice for 40,000 gallons of filtrate. Since not all waters will require carbon treatment, a surplus may develop; however, waters containing a high concentration of natural or introduced contamination, including chemical warfare agents, require much higher carbon concentrations, and an adequate supply for all contingencies is assured by this allotment.

e. 500-Gallon Tanks. A revised tank of approximately 560-gallon capacity has been developed, the additional 60 gallons occupying four inches in depth, to provide for floc retention. The tank, 68 inches in diameter and 36 inches high, is constructed of water and mildew-proofed No. 8 cotton duck. Eight sectional tubular aluminum staves support the tank walls. Four guy ropes are provided for support of the tank while filling. A square cover of the same material as the tank is provided.

20. Operation of 15-gpm Set. Pretreatment of water before filtering is the normal procedure except when filtering water from a very

clear source such as a mountain stream. A 500-gallon tank is erected. While the tank is being erected, one of the pump and engine sets is connected with a 10-foot suction and discharge hose for filling this tank with raw water. Approximately 1/4 pound of lump alum held in the chemical basket is suspended from the side of the tank so that the incoming stream dissolves the alum. One scoop of calcium hypochlorite is dissolved in the measuring cup and added when the bottom of the tank is covered with water. If a heavy floc does not form when the tank is half filled, the pH is determined by nitrazine paper, and is adjusted within a range of 6.0 to 7.0 by adding soda ash or more alum. When the tank is filled, the residual chlorine concentration is determined by the comparator. If the chlorine residual is less than 1.5 ppm, another dissolved scoop of calcium hypochlorite is distributed over the top of the tank. During the filling of the first tank the second 500-gallon tank is erected. This second tank is filled immediately after the first tank.

By the time the second tank is full, water in the first tank should have settled long enough to permit filtration. If considerable floc is seen to remain in suspension, a slightly longer settling period should be allowed. Settled water may be drawn from the first tank by placing a 10-foot length of hose with a strainer on the bottom of the tank, or by connecting the hose directly to the bottom outlet and raising the flap valve. The hose from the tank is connected to the 4-way valve on the filter. The filling cap is removed on the filter head, and a funnel is installed. Two cups of filteraid mixed with sufficient water to fill the filter shell are added through the funnel. Filtered or settled water with a pinch of calcium hypochlorite powder added is used for this precoating. The filter cap is then replaced. The slurry tank is filled with similar water, containing one measuring cup of filteraid, to the level of the overflow hole into the float chamber. The air vent on the filterhead is opened. Previously, the pump was connected to the suction and discharge side of the four-way valve on the filter by two 5-foot hose lengths, female and female. When the filter is ready and the pump primed, the engine is started, and the 4-way valve is turned toward the filter shell to filtering position.

When water spurts from the air vent on the filter, the valve is closed until only bubbles pass. This adjustment permits release of entrained air without wasting water. The petcock on the water motor feed line is opened as soon as the filter starts. This flow is adjusted until water flows over the weir in a thin sheet to the float chamber. Water from the weir chamber flows in the opposite direction through a calibrated orifice to the slurry chamber, displacing an equal amount of filteraid suspension, which passes to the float chamber through an overflow hole. Approximately 10 gallons of filtered water is run to waste during the precoating period; then all filtered water is collected in a third 500-gallon storage tank or directly in containers. The filter run should be continued until the output drops below 15 or 10 gpm, depending on the supply of filteraid and water requirements.

The filter is backwashed by immersing the discharge hose in filtered water and placing the suction line in a suitable position for discharging to waste; then the lever on the 4-way valve is turned completely away from the filter. The filtered water is sucked through the filter shell, and is discharged to waste through the former suction strainer.

When the first pretreatment tank has been exhausted during filtration, the 4-way valve is turned to a neutral position, and the suction hose is placed in the second tank of pretreated water. It is preferable to use three tanks for coagulation and settling and one tank for storing filtered water. Whenever possible, containers are filled directly from the filter, thus reducing the need for pumping and storage facilities. Storing large quantities of filtered water is not advisable, since the quality of filtered water depreciates on standing, whereas the quality of pretreated water improves on standing. Water should be pretreated and allowed to stand overnight whenever possible, because such a long settling period provides a water which may be filtered at very high rates.

When water is filtered directly from its source, the suction line is immersed in raw water instead of pretreated water. The filtered water is chlorinated by adding a scoop of calcium hypochlorite solution to the bottom of the tank after it is covered with water. With an exceptionally clear water, body feed may be omitted. Direct filtration of raw water should be employed only when the source is clear and when sufficient time or equipment is not available to utilize pretreatment.

21. Packing of 15-gpm Set. Pack components are allocated to make loads of relatively uniform weight for transportation by man or mule back, as necessary. Each load is carried on a standard plywood packboard. The heaviest individual man pack is approximately 70 pounds. Three man packs are equivalent to one mule load. Man packs are numbered consecutively, the first three being combined in mule pack No. 1, etc. Components of each pack are listed in Appendix C. Additional packs may be carried for gasoline.

22. Testing of 15-gpm Set. The pump and filter were set up and operated at the ponton basin dock, using Potomac raw water. A series of tests were made, using both treated and raw waters of varying turbidities, calibrated dosages of precoat and body feed, and several commercial filteraids. In pretreatment tests, a 3000-gallon canvas tank was set up and filled with raw water. Water was treated with alum to produce a floc, and settled for periods ranging from 30 minutes to several hours. Soda ash treatment was not required, due to the alkalinity of the raw water, (pH 6.8 to 7.4). Prechlorination was employed in all instances (except where bacteria tests were made) in a concentration of 2 ppm. Activated carbon was added with the alum in approximately one half the tests. Raw water turbidities ranged from 20 to 70 ppm. Considerable algae growth was present, in addition to mild color, odor, and taste of undesirable

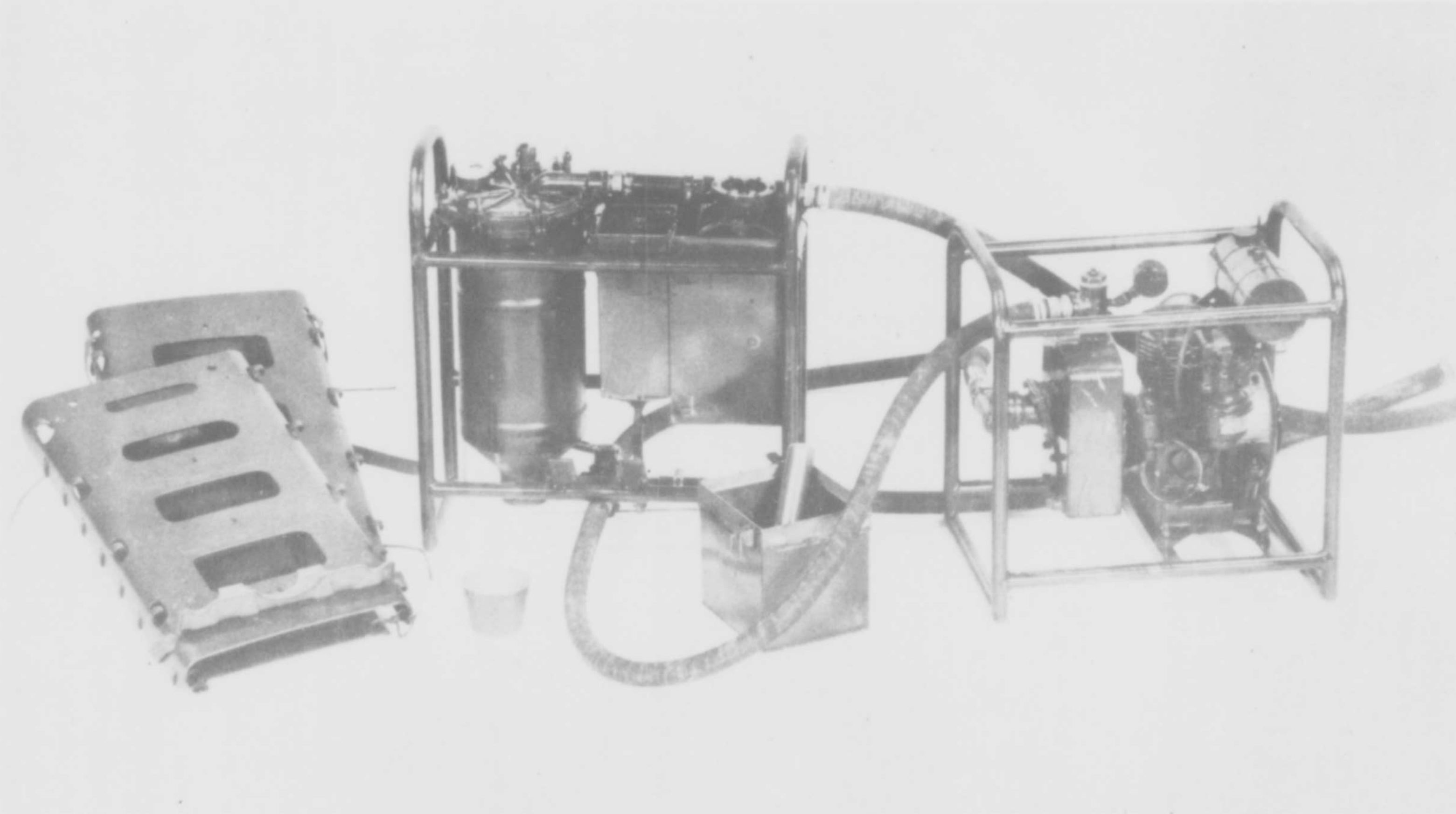


FIG. 9. 15-GPM DIATOMITE WATER PURIFICATION UNIT. Pump and Filter Connected for Operation. Engineer Board, Fort Belvoir, Virginia.

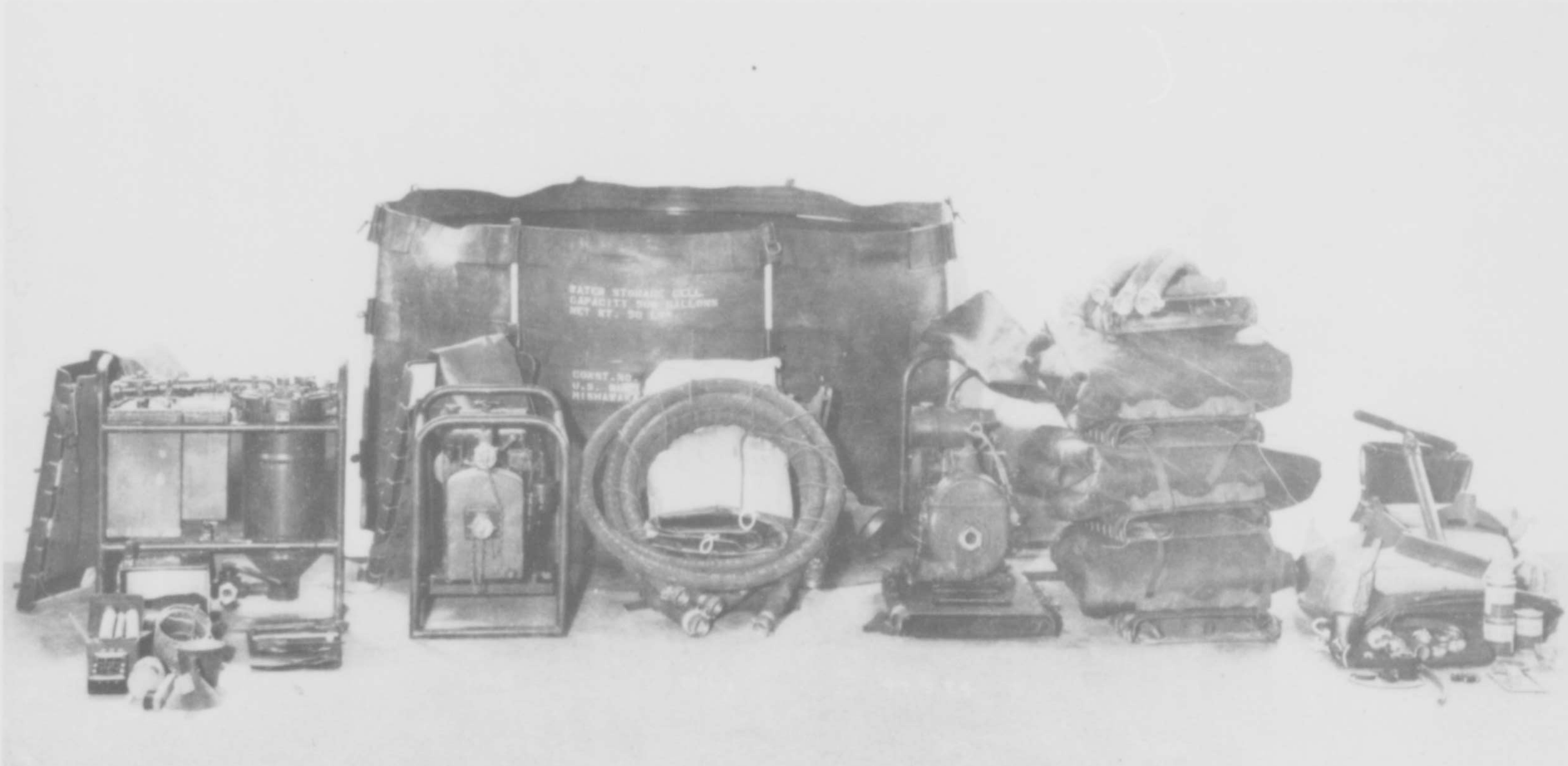


FIG. 10. 15-GPM DIATOMITE WATER PURIFICATION UNIT. Components of Standard Packs (Left to Right, Packs 1 to 9). Engineer Board, Fort Belvoir, Virginia.

character. In direct filtration, the tank was filled with raw water and filtered directly.

The suction line to the pump was submerged in the treated water, care being taken to prevent excessive disturbance of settled floc. The filter was operated with Dicalite 4200, and 228V, the latter a treated filteraid used only with raw water. Dosages for precoat and body feed were varied in increments of 1/8 pound to determine the most economical use of filteraid. Filter pressures, rates of flow, and turbidities of filtrate were taken at five minute intervals. Filter runs were continued until pressures reached at least 35 lb/sq in.; when the run was stopped, and the filter backwashed by suction, reversing the flow through the filter shell and utilizing an average of 15 gallons of filtered water. Samples of raw water, settled water (not chlorinated), and filtered water were taken in an approved manner, and tested for bacteria plate count and gas formers. Bacteria analysis was made on both pretreatment with filtration, and with direct filtration.

Summaries of representative test runs and bacteria analyses are included in Appendix D. The average filter output was 23.1 gpm. The average filteraid requirement was one pound per 1170 gallons of filtrate.

Results of tests indicated the following:

a. Satisfactory turbidities of filtrate may be obtained with either pretreatment (0.1 to 0.0 ppm) or direct filtration (0.3 to 0.1 ppm).

b. The bacteria count of raw water may be materially reduced by either method; however, pretreatment is necessary to effect complete removal of gas forming bacteria.

c. Increase in settling time up to two hours has marked affect on yields after two hours; additional settling results in only slight increases.

d. Direct filtration requires finer, and preferably treated, filteraids to produce residual turbidities equal to those produced with pretreatment and coarser filteraids. However, all turbidities were within an acceptable range for potable waters; and it does not appear necessary to stock separate types of filteraid for direct filtration.

e. The most economical dosages appear to be ½ pound of precoat and 1/4 pound of body feed per run.

IV. DISCUSSION

23. Diatomite Filtration. Water filtration with diatomaceous silica filteraids has proven superior to filtration with other media for military use. Although diatomaceous silica has been used extensively as a filteraid in chemical filtrations, its use for water filtration lacks extensive precedent in this country.

a. Diatomaceous Silica. Diatomaceous silica filteraids suitable for water filtration are produced from huge deposits (one alone containing more than one hundred million tons) of relatively pure diatomite, a sedimentary deposit of fossil shells formed by tiny marine plants called diatoms, during the Miocene period. Crude diatomite is quarried, crushed, dried, classified, flux-calcined, reclassified, and bagged as diatomaceous silica filteraid. Relatively coarse grades (particles ranging from 8 to 38 microns in diameter for Celite 535, a Johns Manville product) have proven satisfactory for filtration of pretreated water. Being principally silica, such filteraids are inert to water and water treatment chemicals.

b. Filtration Operations. Filtration with diatomite powder requires the formation of a layer of clean filteraid to protect the permeable septum, the continuous addition of rigid filteraid particles with the compressible particles of suspended material to maintain cake porosity, and the eventual removal of the filter cake when its resistance to flow becomes too great.

(1) Precoating. The protective layer of clean filteraid is established on the septum by pumping a slurry of diatomaceous silica through the permeable support. An almost uniform coating is formed over the entire septum due to the flow's being greatest through the thinnest portion of the coating, depositing more filteraid until the coating becomes uniformly thick.

(2) Body Feeding. After the protective coating or precoat is formed on the septum, filteraid must be added continuously to water being filtered in order to maintain some porosity of the filter cake. This continuous addition of filteraid is known as body feeding. Presumably, rigid particles of filteraid mix with the more or less gelatinous suspended particles, and thus prevents the formation of a continuous layer of gelatinous material, which compresses under filter pressure to become increasingly less pervious. The amount of filteraid required depends on the nature and amount of suspended material in the water being filtered. When filtering very clear water, body feed may be omitted entirely.

(3) Backwashing. When filter output becomes too low due to plugging, the filter cake may be dislodged by reversing

the direction of flow through the cake. Both air and water may be used successfully for backwashing diatomite filters, but filtered water provides the simplest method for portable equipment. With equipment now developed, backwashing is accomplished by sucking filtered water from a storage tank through the filter. Backwashing requires less than 3 percent of the filter output.

c. Advantages of Diatomite Filtration. In all respects considered, diatomite filtration is equal or superior to other methods of filtration for use in portable equipment. The principal advantages of diatomite filtration are its higher output per unit weight of equipment and supplies, superior quality of filtrate, and uniformity of output. Considering filter weight alone, a diatomite filter will weigh approximately one-tenth as much as a rapid sand filter of the same capacity. If no sand were lost, the sand filter would eventually provide a lower weight of equipment and supplies due to the continuing requirements of the diatomite filter for supplies. Diatomite filtration of pretreated water will consistently produce a filtrate of less than 0.1 ppm turbidity, complete removal of chlorine resistant organisms such as cysts of E. histolytica, and a removal of over 90 percent of all bacteria; whereas rapid sand filters cannot equal such clarification or consistency of output. Removal of cysts by diatomite filters, even with maloperation, was reported in Engineer Board Report 834, Efficiency of Standard Army Water Purification Equipment and of Diatomite Filters in Removing Cysts of Endamoeba Histolytica from Water, dated 3 July 1944.

24. Pretreatment. Aluminum sulfate and related salts, when added to water containing suitable concentrations of hydroxyl ions, form a gelatinous floc which occludes or adheres to suspended matter. The floc settles slowly to the bottom of the tank, leaving only a small portion of suspended matter. Calcium hypochlorite in solution is also added during pretreatment to destroy pathogenic organisms. When ammonium alum is used, liberated chlorine reacts with ammonia to form chloramines which are much more persistent than free chlorine. Pretreatment constitutes a necessary step in treating all except relatively clear water regardless of whether sand or diatomite filtration is employed. Direct filtration of raw water may be employed with clear water sources. Pretreatment has been adopted as the standard method of operation because higher outputs are obtained by coagulating and settling a turbid water than by filtering it directly from its sources, and because a greater removal of pathogenic organisms is obtained when pretreatment is employed. Data indicate that filtrates of pretreated water will meet present standards without chlorination, thus introducing an added safety factor. Higher outputs may be obtained by direct filtration when filtering clear water. Pretreatment requires a slightly longer period before the first filtrate is produced; however, the dependability and improved quality of filtrate obtainable with pretreatment outweigh the slightly lower

output obtained with reasonably clear water. With either pretreatment or direct filtration, diatomite filtration removes a much higher percentage of pathogenic organisms than the sand filtration now used by military forces, and will completely remove larger organisms which resist chlorination, such as cysts of Endamoeba histolytica.

25. Small Filters Carried with Combat Pack. When the development of pack water purification equipment was begun, a small filter to be carried with a man's normal combat equipment was considered, in addition to the larger equipment, which would be carried as complete man loads. Several investigators have reported that canteen sterilization with available agents cannot be relied on to produce a safe water from all sources under field conditions. Cysts of Endamoeba histolytica and other organisms may not be destroyed by the concentration of bactericidal agents in the contact time employed.* Efficient filtration will remove these organisms which are not readily destroyed by chemicals. Also filtration would be more desirable because of the improved taste and clarity of filtered water. Since easily operated filters, with adequate capacity for a squad of men, weigh less than five pounds, it is believed that such a filter which could be carried by an individual with combat equipment should be perfected and standardized for use by small detachments, such as patrols and outposts.

26. Selection of Pumping Equipment. A hand pump for emergency operation and two gasoline-engine-driven pumps for normal operation are supplied with the recommended 15-gpm unit.

a. Hand Pump. The type of hand pump for use with the 15-gpm set depends on the relative amount of hand operation required and the available operators. If hand operation will be required frequently, a heavier pump with increased leverage is justified; however, the gasoline-engine-driven pumps are so superior to hand pumps for filter operation that the hand pump will be used only when a gasoline pump cannot be operated. Also the present allotment of water supply personnel is insufficient for hand pumping. For the emergency use expected, the lightest pump consistent with the desired output should be provided. The maximum average output of one man pumping in short shifts is approximately 5 gpm over a filter cycle in which the pressure rises to 30 lb/sq in. The effort required is very fatiguing with any type of hand pump. The Wilcox Crittenden modified bilge pump was selected because of its lightness and its high output at required pressures. No other commercial hand pumps approach the effectiveness of the bilge pump, but the bilge pump is probably more fatiguing than some types. An effort is being made to develop a suitable hand pump that is easier to operate.

---

* F. J. Brady, Myrna F. Jones, and W. T. Newton, "Effect of Chlorination of Water on Viability of Cysts of Endamoeba Histolytica", War Medicine, III (April, 1943), 409-419.

b. Power Pump. Operating the filter requires a pump with good delivery against high heads, while filling the tanks requires high output at low heads. A closed impeller centrifugal pump was found to be the lightest type meeting these dual requirements. The pump was also made self-priming to minimize possibility of filter cake loss, and to decrease priming time.

c. Gasoline Engine. Tests indicated that the Lauson RSC 609 engine was more suitable for use with pack water purification equipment than the Briggs and Stratton NP or the light NLP model. The Lauson RSC 609 engine weighed approximately four pounds less than the Briggs and Stratton NLP engine with necessary modifications. The Lauson RSC 609 engine used much less oil and gasoline during service tests, and showed less evidence of wear and loss of horsepower after 500 hours than the Briggs and Stratton NP engine did after 150 hours. Also, the Lauson RSC 609 engine was designed with a quart oil capacity for operation on slopes at an angle from horizontal and a low level cut-off switch in the oil chamber, very desirable features which were not included in an experimental NLP engine but which are being considered for inclusion by the manufacturer as a result of tests. After tests to determine the most suitable engine were complete, the Briggs and Stratton N engine was standardized, making the model NLP standard also. This standardization dictated the selection of the Briggs and Stratton NLP engine for use with pack water purification equipment. The standard Briggs and Stratton model NLP engine will be suitable for use with pack water purification equipment, provided that the manufacturer includes a one-quart oil capacity and low oil cut-off switch. The Lauson RSC 609 engine should be used with the recommended 15-gpm sets procured for Air Forces use, since the RSC 609 engine is standard Air Corps equipment.

27. Design of 15-gpm Filter and Feeder. The various components of the 15-gpm pack filter and feeder were developed to provide a unit with the fewest mechanical complications, which could be produced in quantity by any qualified manufacturer. An effort was made to include no intricate, specialized, or patented devices which would limit the procurement of equipment to one firm, or which would tend to limit production capacity or delay delivery unnecessarily. The only patented device included is the Stellar filter element, which was found to have the most desirable overall characteristics for field usage; however, other elements are available.

a. Filter. The filter shell, and the relative proportions and area of the elements were developed after numerous tests. For an average yield of not less than 15 gpm continuously, the unit must produce at least 20 gpm average during each run to compensate for time expended in backwashing, recharging filter, changing oil, refueling engine, etc. Preliminary tests indicated that a flow rate of at least 6.0 gpm per square foot of filter element area would be possible; hence the filter area was established at 3.6 square feet. An average of all test runs on the completed unit indicated an average yield of 24 gpm, or 6.68 gpm per square foot of filter area. Backwashing is accomplished without difficulty or delay, the entire operation consuming one minute or less, and requiring about 10 gallons of water.

b. Feeder. The slurry feeder, consisting of an orifice box for calibrating the discharge of water, a slurry can with a water-motor-driven agitator, and a float chamber, is the result of long experimentation to determine the most satisfactory mechanical device for introducing body feed to the filter. Tabulation of the rate of diminution of filtrate flow was found to be in almost direct proportion to the diminution of rate of discharge of filteraid from a dilution type feeder. This type provided a feeder device of the greatest simplicity and dependability, and with the least complications of manufacture of any feeders studied.

28. Future Work. The development of pack water purification equipment should continue until special hand pumps have been developed and brackets for animal packing designed. Development of a special hand pump was previously discussed. The construction of brackets for animal packing must wait until four sets of pack water purification equipment arrive at Camp Hale, Colorado, for service testing, because the exact weight of equipment must be known for balancing the packs, and qualified men are available for this work only at Camp Hale. A complete set of animal pack brackets will be established for use with the pack water purification set. Whenever brackets are not available, the equipment may be carried on pack animals, if lashed in place by experienced packers.

29. Packing. The pack water purification equipment was designed primarily for animal transport, but it may be carried by men when other means of transportation are not available. The heaviest pack load for man transportation weighing approximately 70 pounds, while the carrying distance for a single man is limited to approximately 5 miles over rough terrain. By using reliefs, or the best men, much greater carrying distances are possible. For long and short man carries, the equipment is divided into nine pack loads, each carried on a standard plywood packboard. These pack loads on boards are then mounted on a pack animal with metal frames known as pack brackets. Three of the nine pack loads may be carried on each animal, making a total of three animals required for transporting pack equipment and supplies, with the exception of gasoline and oil. The nine standard packs provide supplies for approximately four days' operation (40,000 gallons) with the exception of gasoline. Five additional packboards are provided for additional supplies, gasoline, and oil.

30. Basis of Issue. The Water Purification Equipment, Diatomite, Pack, (Man or animal type), 15-gpm Set No.___ is recommended for use by Engineer Light Combat Battalions; however, use of the 15-gpm set

with or without packboards should be considered for all organizations requiring lightweight equipment; this would apply particularly to airborne organizations. The complete 600-pound pack set with additional supplies, if required, or an abbreviated set may be used.

a. Special Engineer Organizations. Since the more effective 15-gpm diatomite set with required supplies will weigh approximately one-third that of the present portable equipment, use of the 15-gpm diatomite equipment should be considered for the following organizations:

Organization	Present portable sets	Recommended 15-gpm diatomite sets
Engineer Light Combat Battalion	Pumping sets only	4
Airborne Engineer Battalion	2	2
Airborne Engineer Aviation Battalion	1	1

b. Other Engineer Organizations. With complete supplies the recommended 15-gpm diatomite set weighs approximately 700 pounds less than the Water Supply Equipment, Engineer, Set No. 1 (portable) and produces safer water; hence the 15-gpm diatomite set should be considered for use by all organizations now using portable sand filters. An alternative is the use of the 50-gpm diatomite unit.

c. Air Forces. An abbreviated 15-gpm diatomite set, consisting of a filter, one gasoline-engine-driven pump, hose, two 500-gallon tanks, spare parts, and supplies as required, should be considered for squadron use. The abbreviated set with supplies would weigh approximately 400 pounds and would produce an average of better than 10-gpm with pretreatment and 15-gpm with direct filtration, reducing operating hours required with lower capacity equipment.

d. Per Capita Allowance. In order to provide 5 gallons per man per day, the minimum desired overall allowance, at least one 15-gpm water purification unit should be provided per 2500 troops to be supplied. This allowance would provide six sets per Engineer Combat Battalion instead of the present four; an increase which should be approved by using organizations.

e. Operators Required. Two operators should be available for each 15-gpm diatomite set for single shift operation, although one man can operate a set and two sets may be operated in parallel.

31. Instructional Aids. Although the operation of diatomite filters is as simple as for sand filters, diatomite filtration does introduce new operating techniques which are not acquired by operating sand filters. A training bulletin, TB 5-295-2, has been prepared in collaboration with the Engineer School. Actually, the average man might be expected to operate diatomite filters satisfactorily after thoroughly studying this training bulletin; however, during service tests all operators had not read the printed instruction manuals, and among those who had read the printed instructions, some operators did not understand all the requirements. It is believed that a training film on the use of diatomite filters should be prepared in the near future. Also, a training program on diatomite filters should be established at the Engineer School, and trained operators should be sent overseas to assist in training personnel who will operate the equipment.

V. CONCLUSIONS

32. Conclusions. As a result of tests on pack water purification equipment, it is concluded that:

a. The 15-gpm diatomite water purification set is suitable for standardization and overseas use.

b. The recommended diatomite water purification set may be conservatively rated at 15-gpm as a gasoline-engine-driven unit and 5-gpm with hand pump, emergency operation.

c. Increased capacity, over and above the original military characteristics, will satisfy requests for equipment capable of producing more water without sacrificing required portability, which requests were received from field organizations following service tests of the 5-gpm diatomite filter set.

d. The 9 pack loads of the 15-gpm diatomite water purification set may be transported either by 9 men, 3 pack animals, or a ½-ton vehicle, the heaviest pack weighing approximately 70 pounds and the set, 580 pounds.

e. The equipment will effect complete removal of cysts of Endamoeba histolytica, which cause amoebic dysentery, and Cercariae of the Schistosome, the causative agent of Schistosomiasis.

f. Operation of the 15-gpm set is simple, requiring only one man, but the technique differs sufficiently from that of sand filtration to require some provision for instruction in use of diatomite filters.

VI. RECOMMENDATIONS

33. Recommendations. In accordance with the preceding conclusions on pack water purification equipment, it is recommended that:

a. The Water Purification Equipment, Diatomite, Pack (Man or Animal Type), 15-gpm - Set No._____ (as listed in Appendix C) be standardized as class II and class IV equipment.

b. One Water Purification Equipment, Diatomite, Pack (Man or Animal Type), 15-gpm - Set No._____ be issued per 2500 troops to be supplied.

c. Training in operation of diatomite filters be established at the Engineer School; a training film on diatomite filters be produced; and trained personnel sent overseas to instruct new operators whenever possible.

Submitted by:

M. S. Mason,
Engineer (Civil),
Water Supply Equipment Branch.

H. W. Withers,
Captain, Corps of Engineers,
Water Supply Equipment Branch.

Hayse H. Black,
Captain, Corps of Engineers,
Chief, Water Supply Equipment Branch.

Forwarded by:

Karl F. Eklund,
Lt. Col., Corps of Engineers,
Director, Technical Division III.

APPENDIX A

AUTHORITY

Item	Page
Letter from the Chief of Engineers to the President, The Engineer Board, Dated 23 February 1943, File No. SPESD.-671-112, Subject: Development of Water Purification Equipment.	67
Letter from the Engineer Board to the Chief of Engineers, Dated 27 August 1943, Subject: Pack Water Purification Equipment, with indorsements and 2 inclosures.	69
Letter from the Chief of Engineers to the President, The Engineer Board, Dated 20 September 1943, File CE SPENQ, Subject: Pack Water Purification Equipment, DQP-3004.	77

WAR DEPARTMENT
Office of the Chief of Engineers
WASHINGTON

File No. SPESD.-671-112 February 23, 1943

Subject: Development of Water Purification Equipment.

To: The President,
The Engineer Board,
Fort Belvoir, Virginia.

1. This office is in receipt of information from the General Headquarters, Southwest Pacific Area, dated November 22, 1942, indorsing a report entitled, "Report on Engineer Equipment, Organization and Training". This information was addressed to the Commanding General, Services of Supply.

2. Paragraph 1b (8), of the above mentioned report, is quoted as follows:

> "Some difficulty, has been experienced with waters with high alluvial clay content. Additional filter capacity or an additional settling tank for preliminary treatment with aluminum sulphate is necessary to treat these waters. The performance of the equipment, under normal conditions, is quite satisfactory. However, for jungle operations, there is need for portable equipment that can pack transport to supplement this equipment".

Paragraph 1f(1) of this same report is quoted as follows:

> "The present water supply equipment is not adaptable for pack transportation. It is recommended that a small pack transported water purification set be developed for issue to combat battalions".

3. The above information was brought to the attention of the Troops Division, with the suggestion that a project be initiated for the development of a purification set that is adaptable for pack transportation through dense jungles. The Troops Division concurred with the above suggestion.

4. It is believed that waters with high clay content should be taken care of by means of settling tanks rather than by increasing the filter capacity. The Troops Division concurs in this matter.

5. It is, therefore, directed that the Engineer Board develop a water purification set which can be pack transported by man.

Storage facilities for the purified water shall be furnished as a part of the set.

By order of the Chief of Engineers:

/s/ F. C. Kendall
/t/ F. C. Kendall
Major, Corps of Engineers,
Executive Officer.
Engineering and Development Branch,
Supply Division.

Yarger/apb
EXT. 76271

WAR DEPARTMENT
THE ENGINEER BOARD
Corps of Engineers, U. S. Army
FORT BELVOIR, VIRGINIA

Item 358
CETC Meeting #87

400.1

27 August 1943

Subject: Pack Water Purification Equipment

To: Chief of Engineers, U. S. Army

1. It is requested that new project WS 443 be opened for development of pack water purification equipment to consist of a filter, hand operated pump, gasoline engine driven pump, storage facilities, and accessory equipment. The equipment is to be of suitable size and weight for transportation by either man or pack animal, and constructed for efficient operation by unskilled personnel.

2. Preliminary work has been done in response to a directive from the Office, Chief of Engineers, dated 23 February 1943, outlining the need for lightweight water purification equipment.

3. Reasons for developing the pack water purification equipment may be stated as follows:

a. Present Corps of Engineers equipment for water purification is cumbersome, requires motor transport, and may not remove or destroy several of the important pathogenic organisms found in raw water.

b. The absence of motor transport for operations in jungle or mountainous terrain and the prevalence of certain important pathogenic organisms in the raw waters make development of efficient lightweight water purification equipment a fundamental and immediate necessity.

4. Inclosures "A" and "B" will furnish information pertinent to the project.

For the Board:

/s/
Peter P. Goerz,
Colonel, Corps of Engineers,
Executive Officer.

2 Incls.
Incl. 1 - "A" (in dup.)
Incl. 2 - "B" (in dup.)

CE 671.1 (27 Aug 43) SPETQ Subject: Light Weight Water Purification Unit.

1st Ind.

War Department, ASF, Office, Chief of Engineers, WASHINGTON, D. C. 24 September 1943.

To: Commanding General, Army Service Forces.

1. Reference is made to basic communication from the Engineer Board, Fort Belvoir, Virginia, to the Chief of Engineers, wherein it is requested that project WS 443 be opened for the development of pack water purification equipment.

2. Preliminary work in accordance with directive from the Office, Chief of Engineers, dated 23 February 1943, outlining the need of light weight water purification equipment has been completed, and it is therefore recommended that the above mentioned development project be approved.

3. It is also recommended that the Military Characteristics, as set forth in inclosure "A" to the basic communication, together with the following exception, informally concurred in by Headquarters, Army Ground Forces, be approved:

a. That the word "sufficient" paragraph 5, line 1, be changed to read "approximately 1,000 gallons".

4. The Military Characteristics, enumerated in inclosure "A" to basic communication, are substantially the same as those concurred in by the Army Air Forces in 1st indorsement from WD HQ AAF, AC/AS, Materiel, Maintenance and Distribution, Office of the Air Engineer, to Office, Chief of Engineers, Troops Division, Equipment Branch, dated 27 July 1943, file AFDAE-1A-3; Sup 2a (1), and by the Army Ground Forces in 3rd indorsement from Headquarters, Army Ground Forces, to the Commanding General, Army Service Forces, Attention: Development Branch, Requirements Division, dated 31 August 1943, file 67.1 (4 Aug 43) GNRQT-11/51825.

5. This development project, together with military characteristics pertaining to same, will be presented to the Corps of Engineers Technical Committee for appropriate action.

For the Chief of Engineers:

/s/
B. M. Harloe,
Col., Corps of Engineers,
Chief, Equipment Branch,
Troops Division.

2 Incls. n/c
(Dup. w/d)

Subject: Pack Water Purification Equipment.

SPRMD 671.1 (27 Aug 43) 2nd Indorsement WJN:bfl
6047

Headquarters, Army Service Forces, Washington, D. C. 30 Sept. 1943

To: Commanding General, Army Air Forces
Commanding General, Army Ground Forces IN TURN

1. Attention is invited to the preceding correspondence.

2. In view of the remarks contained in Paragraph 4, 1st Indorsement, it is contemplated approving the recommended development project.

3. Your concurrence or comments are requested relative to the proposed military characteristics.

For the Commanding General:

/s/
LEE A. DENSON, JR.,
Colonel, General Staff Corps,
Acting Director, Requirements Division.
by
F. J. DARKE, JR.,
Lt. Colonel, Signal Corps,
For
R. M. OSBORNE
Colonel, Field Artillery
Chief, Development Branch.

2 Incls. n/c

3rd Ind. AFDAE-1A-3:SUP 2a(1
WDE:rls 71741

WAR DEPARTMENT, HEADQUARTERS ARMY AIR FORCES, Washington 25, D.C.
4 Oct 1943

TO: Commanding General, Army Service Forces, Requirements Division, Pentagon Building, Washington, D. C., Attention: Colonel Lee A. Denson, Jr.

THRU: Commanding General, Army Ground Forces, Army War College, 4th and P Streets, S. W., Washington, D. C.

1. The proposed military characteristics of the Pack Water Purification Equipment are concurred in by this Headquarters. In view of the urgent requirements for this equipment, it is requested that the development be expedited and this Headquarters advised of action taken.

For the Commanding General, Army Air Forces:

/s/
T. A. LANE
Colonel, C.E.
Executive to Air Engineer
Office of Asst. Chief of Air
Staff Mat., Maint., and Dist.

2 Incls: n/c

671.1 (R) (27 Aug 43)
GNRQT-11/56464 4th Ind.

HEADQUARTERS, ARMY GROUND FORCES, Army War College, Washington, D. C.
13 Oct 1943

To: Commanding General, Army Service Forces, Washington, D. C., Attention: Development Branch, Requirements Division.

1. Proposed military characteristics outlined in Inclosure 1, as modified in Paragraph 3, 1st Indorsement, are concurred in.

2. In view of the urgent requirement for subject equipment, it is recommended that development be expedited in every practicable manner.

For the COMMANDING GENERAL:

/s/
R. J. DELACROIX
Major, A.G.D.
Asst. Ground Adj. Gen.

Subject: Pack Water Purification Equipment.

SPRMD 671.1 (27 Aug 43) 5th Indorsement WJN:bfl 6047

Headquarters, Army Service Forces, Washington, D. C. 22 Oct 1943

To: The Chief of Engineers - Troops Division, Equipment Branch.

1. The initiation of Project WS 443 for the development of pack water purification equipment is approved.

2. The military characteristics as set forth in Inclosure "A" and amended in Paragraph 3, a, 1st indorsement, are approved.

3. It is desired that this development be expedited.

For the Commanding General:

/s/
LEE A. DENSON, JR.,
Colonel, General Staff Corps,
Acting Director, Requirements Division.

by
M. M. IRVINE
Lt. Colonel, Coast Artillery
Executive, Development Branch.

INCLOSURE "A"

Project No. WS 443 Pack Water Purification Equipment

Authority for Initiation of Project

Paragraph 5 of directive dated 23 February 1943 contains authority for development work. This paragraph reads as follows:

"It is therefore directed that the Engineer Board develop a water purification set which can be pack transported by man. Storage facilities for the purified water shall be furnished as a part of the set."

Purpose of Project

It is planned to develop efficient lightweight water purification equipment capable of being transported by either man or pack animal.

Military Characteristics

The military characteristics desired in the subject equipment are as follows:

1. The complete unit may be transported by either man or pack animal, each complete pack weighing less than 60 pounds and preferably between 40 and 50 pounds.

2. All equipment, including a hand-operated pump, necessary for 24 hours of operation shall be included in a single pack, Accessory equipment, spare parts, and supplies for a 15 day operating period shall be contained in a second pack, and a gasoline engine-driven pump shall be supplied with each unit in a third pack. Other equipment, including storage and distribution facilities, shall be packed as required.

3. The unit shall be capable of producing not less than 150 gallons per hour of potable water when operated with a hand pump, and not less than 300 gallons per hour when operated with a gasoline engine-driven pump.

4. The unit shall remove 100 per cent of the cysts of Endameba histolytica, and with the addition of chlorine, shall produce a filtrate conforming to the existing requirements for a potable water.

5. Approximately 1000 gallons storage of filtered water shall be provided in tanks which may be transported in packs by man or pack animal.

INCLOSURE "B"

Project No. WS 443 Pack Water Purification Equipment

Plan for Development

14 August 1943

1. Present Status of Development

A thorough investigation of various filtering media has been completed and diatomaceous earth was found to be the most satisfactory medium for lightweight filters. Pilot models of all representative commercial filters and captured German and Japanese equipment were tested at the Engineer Board. A diatomaceous earth filter designed and constructed at the Engineer Board was found to be superior to all others considered. Completion of the pack water purification equipment now depends on the choice of a suitable hand pump, power pump, accessory equipment, and storage tanks.

2. Completion of Development

Present commercial equipment being unsatisfactory or requiring major modifications, the following work will be done by the Water Supply Equipment Branch in collaboration with selected manufacturers to complete the pack water purification equipment:

a. Hand pumps of the double-acting piston, rotary, and oscillating types will be obtained for tests at the Engineer Board to determine the most satisfactory pump.

b. Gasoline engine-driven pumps of the rotary, turbine, and self-priming centrifugal types will be procured for test at the Engineer Board to determine the most satisfactory pump.

c. Light canvas tanks (approximately 300 gallons), 5-gallon water bags, light suction hose, and accessory equipment will be procured for tests at the Engineer Board.

d. Three complete filter units will be procured from selected manufacturers for tests at the Engineer Board - two according to the manufacturers' design and one according to the Technical Staff's design - to insure any possible improvements.

e. Since the equipment is urgently needed, necessary revisions of the best equipment will be accomplished, engineering tests completed, then drawings and specifications will be prepared for immediate procurement, with recommendations for basis of issue and existing production facilities.

f. Testing of component parts and complete units will continue after procurement at the Engineer Board and by the using organizations, since some revisions may be desirable before standardization on the basis of extensive service tests.

Approved by Board 21 August 1943.

WAR DEPARTMENT
Office of the Chief of Engineers
WASHINGTON

CE SPENQ 20 September 1943

Subject: Pack Water Purification Equipment, DQP-3004.

To: President,
Engineer Board,
FORT BELVOIR, VIRGINIA.

1. Reference is made to a letter from the Engineer Board dated 27 August 1943, requesting that new project WS 443 be opened for development of pack water purification equipment consisting of a filter, hand operated pump, gasoline engine driven pump, storage facilities and accessory equipment.

2. Action has been initiated by the Chief of Engineers approving the subject project with the exception that in military characteristics number 5 as submitted by the Engineer Board the word "sufficient" has been changed to "approximately 1000 gallons". Final action approving the subject development project, has not been completed.

3. However, since an urgent requirement has developed for the equipment in question, the Army Service Forces has requested the Chief of Engineers to procure 17 of the subject water purification units for shipment directly to the 71st Light Division for test. The Chief of Engineers has informed the Army Service Forces that this equipment could be made available to the above mentioned organization for service testing in approximately six weeks.

4. It is realized that further development will possibly produce more satisfactory pumping equipment than that now being considered. However, the need of the 71st Light Division for water purification equipment of the type under development is urgent and, therefore, it is considered highly desirable that the equipment as developed at this time be furnished to that organization. In the event service tests prove the equipment satisfactory, the 71st Light Division will retain it as organic equipment.

5. Therefore, it is requested that the Engineer Board procure 17 pack water purification units as developed at this time complete with accessory equipment for service testing by the 71st Light Division. This equipment shall be shipped direct to the Headquarters 71st Light Division, Camp Carson, Colorado.

6. It is further requested that the Engineer Board establish direct contact with the above mentioned organization in setting up

the necessary details for the service testing of the equipment in question. It is also requested that the Chief of Engineers be informed as to the date procurement of this equipment will be effected.

By order of the Chief of Engineers:

/s/ JAMES H. STRATTON,
Colonel, Corps of Engineers,
Chief, Engineering Division.

APPENDIX B

SERVICE TEST REPORTS

Item	Page
Report of Test of Water Purification Unit, Pack, from Headquarters, 126th Engineer Light Combat Battalion.	81
Report of Test of Water Purification Unit, Pack, from Headquarters, 126th Engineer Combat Battalion.	88
Report of Tests: Water Purification Unit, Pack, from Headquarters, 271st Engineer Light Combat Battalion.	91
Pack Water Purification Equipment Preliminary Service Test Questionnaire from 271st Engineer Light Combat Battalion.	95
Equipment Testing Report from Army Air Forces, Headquarters, I Troop Carrier Command.	103
Report on "Pack Filter", Army Service Forces, Department of Military Sanitation, Medical Field Service School, Carlisle Barracks, Pa.	113
Letter Report, "Pack Water Filtration Equipment", from Medical Department Equipment Laboratory, Carlisle Barracks, Pa., to the Surgeon General, U. S. Army.	123

Headquarters

ARMY GROUND FORCES

Army War College

Washington, D. C.

671.1(R)(14 June 1944) GNRQT-10/83824

SUBJECT: Reports of Test of Water Purification Unit, Pack.

TO: Commanding General, Army Service Forces, Att: Research and Development Division, Room 4E-617, The Pentagon.

1. Inclosed herewith are reports of test of Water Purification Unit, Pack from the 10th Light Division and the 71st Light Division and a supplementary Report of Test of the subject equipment by the 10th Light Division.

2. It is recommended that no further consideration be given to the Water Purification Unit, Pack inasmuch as it does not satisfactorily meet all the requirements of such a unit.

3. This headquarters has been advised by the Engineer Board (Capt. H. H. Black, Chief Water Supply Equipment Branch, Engineer Board) that an improved Water Purification Unit, Pack, Model M-1 has been developed and will be available for test by the Engineer Board during the week 5 - 10 June 1944.

4. It is requested that four (4) of these Water Purification Units, Pack, Model M-1 be procured for an expedited service test. It is contemplated that two (2) of the units will be tested by the Engineer Battalion of the 10th Light Division and two (2) by some other Engineer Combat Battalion.

5. Based upon the information furnished by Capt. H. H. Black, it is recommended that upon completion of the test of Water Purification Unit, Pack, Model M-1 by the Engineer Board that this equipment be standardized subject to having incorporated in production models any essential modifications revealed as a result of the service test. The recommended basis of issue is four (4) Water Purification Units, Pack, Model M-1, per Engineer Light Combat Battalion. Further, it is recommended that the unit be

made available as a Class IV item for depot stockage for use in operations where such equipment is required.

For the COMMANDING GENERAL:

/s/ R. A. MEREDITH
Lt. Col., A. G. D.
Asst. Ground Adj. Gen.

4 Incls.
#1 - Rpt. of Test of Subj. by Hq. 126th Engr Combat Bn, 10th Inf. Div. dtd 26 Apr 44 (in trip.)
#2 - Rpt. of Test of Subj. by Hq. 271st Engr Lt Combat Bn. (in quad.)
#3 - Six (6) Photos.
#4 - Hq. 10th Inf. Div. Supplementary Rpt of Test of subj. dtd 8 May 44 to CG/AGF, Thru: CG, XVI Corps, File 414.4 GNMIG, w/2 Inds. and 1 Incl.

Subject: Reports of Test of Water Purification Unit, Pack.

SPROG (14 Jun 44) 1st Indorsement WJN:by 6047

Headquarters, Army Service Forces, Washington, D. C.

To: Chief of Engineers
Attention: Engineering and Development Division.

1. It is desired that the Chief of Engineers take the following expedited action:

a. Give no further consideration to the Water Purification Unit, Pack as indicated in Paragraph 2, basic letter.

b. Secure four (4) improved Water Purification Units, Pack, Model M-1 for expedited service test to be conducted by the organizations indicated in Paragraph 4, basic letter. In this connection, the Chief of Engineers is to advise this Headquarters when these four (4) units will be available so that shipping instructions may be obtained from Army Ground Forces.

c. Submit the item, Water Purification Unit, Pack, Model M-1 to the Corps of Engineers Technical Committee for appropriate action upon completion of service tests and tests by the Engineer Board.

For the Commanding General:

R. M. OSBORNE,
Colonel, General Staff Corps,
Director, Research and Development Division.

/s/ W. J. RENN, JR.
Lt. Colonel, AUS
Chief, General Planning Branch

4 Incls:
#1 - in dupl (trip w/d)
#2 - in trip (quad w/d)
#3 - n/c
#4 - n/c

HEADQUARTERS
10th INFANTRY DIVISION
APO #345
Camp Hale, Colorado

414.4 GNMIG

8 May 1944

Subject: Supplementary Report on Test of Water Purification Unit, Pack.

To: Commanding General,
Army Ground Forces,
Army War College,
Washington, D. C.
Thru: Commanding General, XVI Corps, Fort Riley, Kansas.

1. The attached inclosure is submitted as a supplementary report on water purification unit, pack; original report submitted by 1st Indorsement this Headquarters dated 25 April 1944, to letter Army Ground Forces file 414 (R) (31 March 1944) GNRQT-10/77431.

2. Captain H. W. Withers of the Water Supply Equipment Branch, Fort Belvoir, arrived with additional instructions regarding the use of the water purification unit, pack, after the original test was completed and the original report submitted. After a conference of the Division Engineer, Major McClarence of the Engineer Board, Pando Branch, and Captain Withers, it was mutually agreed that if these additional instructions had been received previously the findings of the tests may have been different. The tests of the purification unit sets were re-run with special reference to the following points:

a. The filter elements were precoated with the filter aid before being used.

b. The 3/4-inch reducer, originally installed in the suction side of the pump during the original test, was replaced with a 1-inch reducer as called for in the specifications of the units.

c. More detailed instructions were given the operators by Captain Withers since the original instructions received by the units were not in graphic form.

For the Commanding General:

/s/ H. F. MILLER
/t/ H. F. MILLER
Major, A. G. D.,
Asst. Adj. Gen.

Incls: 1
Report of Test of Water
Purification Unit, Pack.

HEADQUARTERS
126TH ENGINEER COMBAT BATTALION
TENTH INFANTRY DIVISION
CAMP HALE, COLORADO

6 May 1944

1. Report of test of:
Water Purification Unit, Pack, as per letter Headquarters Army Ground Forces, file 414 (R)(31 March 1944) GNRQT-10/77431.

2. Unit received 8 April 1944.

3. Test began 10 April 1944 and ran through 20 April 1944. Second test began 1 May and ran through 4 May 1944.

4. Authority for test:
Letter, Headquarters Army Ground Forces, file 414 (R) (31 March 1944) GNRQT-10/77431, Subject: Water Purification Unit, Pack.

5. Description of Unit:
(a) The unit is packed in six (6) packs for man-pack transport. Packs are mounted on a packboard of plywood material.

(b) The No. 1 pack consists of a filter, a hand pump and enough filter material for twenty-four (24) hours operation. No. 1 pack also contains three (3) lengths of hose, one (1) ten (10) foot length and two (2) five (5) foot lengths. Total weight of load: 54 lbs.

(c) The No. 2 pack consists of one (1) pump, centrifugal; gasoline engine-driven. One (1) strainer float, one (1) kit, tool; all mounted on one (1) packboard, plywood. Total weight of load: 65 lbs.

(d) The No. 3 pack consists of two (2) bags, 15 lbs filteraid or one (1) bag, 25 lbs., filteraid; four (4) elements, filter, two (2) hose, five (5) foot length, packed on one (1) packboard, plywood. Total weight of load: 47 lbs.

(e) Packs 4,5 and 6 each contain one (1) tank, 350 gallon, canvas; 10 staves, wood tank: Mounted on one packboard each. Total weight of each load is 47 lbs. Total weight of entire unit: 300 lbs.

6. Details of test:

(a) Time required to set up or dismantle the equipment is fifteen (15) minutes.

(b) Suitability for mule-pack transport: Two (2) mules can carry the unit without being overloaded. One (1) mule can carry the entire unit in case of an emergency. Packs 1, 2 and 3 complete one mule load. (see Photographs) Packs 4, 5 and 6 complete the second mule load. (see Photographs) Paragraph 5 above gives the breakdown for the packs.

(c) Suitability for man pack transport: Six (6) men can carry the unit very satisfactorily over rough terrain. It is not recommended that men carry the pack loads over five (5) miles. (For individual loads, see paragraph 5 above.)

(d) The average pumping capacity without filter was 1800 gallons per hour or 30 gallons per minute.

(e) The average pumping capacity with filter was 300 gallons per hour.

(f) The carbon filter element gave the best results.

(g) The relative differences in the filteraid were not noticeable.

(h) Pretreatment and settling of the water to be filtered took approximately one hour longer.

(i) The hand pump will produce approximately 250 gallons of filtered water in an hour in turbid water. This operation requires three (3) men working continually on five (5) minute relays.

7. Adequacy of the equipment for purposes intended:

(a) The unit will supply approximately 6000 gallons of water in 20 hours of operation during a 24 hour period. It is believed that approximately four (4) hours will be necessary for servicing the equipment.

(b) In water over 60 parts per million turbidity, the filter is not adequate without settling for at least half an hour.

(c) The one operational failure was the brass bushing which passed through the crank case wall, used as a bearing for the governor rod. The bushing was bored too large and allowed a considerable amount of oil to be forced out of the crankcase. The failure was corrected by opening the breather plug in the crankcase, which was not covered in the operation instructions.

(d) Two (2) buckets, canvas, 14 qt. should be added as part of the unit for bailing purposes.

8. Discussion:

(a) It was found that the unit fulfilled the requirements for water purification equipment to be transported by both man and pack animal in the following:

1. Weight, because it could be man or animal packed.

2. Design, because set was compact and light enough for man packing.

3. Quality, because all water filtered was exceptionally clear.

9. Recommendations:

(a) It is understood that the pack water purification set now being manufactured will produce approximately twice as much filtered water as the set tested with only a slight increase in weight. Such equipment would be preferable for mountain warfare, and it is recommended that equipment with an average capacity of 10 GPM or better be supplied.

(b) It is recommended that this organization be furnished one of the 10 GPM sets for field usage as soon as possible.

Report of test submitted by 126th Engineer Combat Battalion, Camp Hale, Colorado.

HEADQUARTERS
126TH ENGINEER COMBAT BATTALION
TENTH INFANTRY DIVISION
Camp Hale, Colorado

26 April 1944

1. Report of test of: Water Purification Unit, Pack, as per letter, Headquarters, Army Ground Forces, file #414 (R) (31 March 1944) GNRQT-10/77431

2. Unit received 8 April 1944.

3. Test began 10 April 1944 and ran through 20 April 1944.

4. Authority for test:
Letter, Headquarters Army Ground Forces, file 414 (R) (31 March 1944) GNRQT-10/77431, Subject: Water Purification Unit, Pack.

5. Description of Unit:
(a) The unit is packed in six (6) packs for man pack transportation. Packs are mounted on a packboard of plywood material.

(b) The No. 1 pack consists of a filter, a hand pump and enough filter material for 24 hours operation. No. 1 pack also contains three (3) length of hose, one 10 ft. length and two five foot length. Total weight of load: 47 lbs.

(c) The No. 2 pack consists of one (1) pump, gasoline engine-driven, one (1) strainer float, one (1) kit, tool, all mounted on one (1) packboard, plywood. Total weight of load: 65 lbs.

(d) The No. 3 pack consists of two (2) bags, 15 lbs. filteraid or one (1) bag, 25 lbs filteraid; four (4) elements, filter, two (2) hose, five foot length, packed on one (1) packboard, plywood. Total weight of load: 47 lbs.

(e) Packs, 4, 5, and 6 each contain one (1) tank, 350 gallon, canvas; 10 staves, wood, tank, mounted on one packboard. Total weight of each load is 47 lbs. Total weight of entire unit; 300 lbs.

6. Details of test:
(a) Time required to set up or dismantle the equipment is fifteen (15) minutes.

(b) Suitability for mule-pack transport; two (2) mules can carry the unit without being overloaded. One (1) mule can carry the entire unit in case of an emergency. Packs, 1, 2, and 3 complete one mule load (see photographs). Packs 4, 5, and 6 complete the second mule load (see photographs). Paragraph 5 above gives the breakdown for the packs.

(c) Suitability for man pack transport; six (6) men can carry the unit very satisfactorily over rough terrain. It is not recommended that men carry the pack loads over five (5) miles. (For individual loads, see paragraph 5 above).

(d) Average pumping capacity without filter is 360 gallons per hour or 6 gallons per minute. The average pumping capacity with filter in clear water was the same.

(e) The filter would not produce 2 gallons per minute in water with a turbidity of more than 20-30 parts per million.

(f) The carbon filter element gave the best results.

(g) The relative differences in the filteraid were not noticeable.

(h) Settling of the water to be filtered took approximately one and a half hours longer, depending on the condition of the water. No pretreatment tried because of lack of chemicals.

(i) The hand pump was not received.

7. Adequncy of the equipment for purposes intended:

(a) The unit will supply a battalion of men where water has not more than 20 parts per million turbidity.

(b) In water over 20 parts per million turbidity, the filter is not adequate without settling.

(c) The one operational failure was the brass bushing, which passed through the crank case wall, used as a bearing for the governor rod. The bushing was bored too large and allowed a considerable amount of oil to be forced out of the crankcase. The failure was corrected by making a packing gland for the bushing.

(d) No other modifications suggested.

8. Discussion:

(a) The pump unit would be satisfactory only when operating continuously under peak conditions where the water is clear enough for consumption without filtration. The filter will not supply enough water for a company in water of high turbidity, without settling and treatment.

(b) It was found that the unit fulfilled the requirements of an animal and man pack water purification unit only in the following:

1. Weight, because it could be man or animal packed.

2. Design, because all parts were light enough for man pack.

(c) It was found that the unit failed to deliver the amount of clear purified water necessary to supply a unit as small as an Infantry Battalion.

9. Recommendations:

(a) There is a very pressing need for a small unit of this type, but preliminary experiments show that this unit is too small for the amount of water needed.

(b) It is recommended that further tests be made on this or other equipment which will supply clear chlorinated water, when turbidity is above 30 parts per million, at the rate of approximately 15 gallon per minute. This is necessary because units do not have storage capacity and must be resupplied three (3) or more times in 24 hours.

(c) A light weight pump is recommended which will produce approximately 30 gallons per minute and can be detached from the power unit to make separate loads suitable for man pack transport. Also a filter unit which would be light enough to be packed by man pack transport and which would produce 10 to 15 gallons per minute.

(d) Suggested basis of issue for above unit. One (1) unit for each Infantry Battalion or similar unit of a Division.

Report of test submitted by 126th Engineer Combat Battalion, Camp Hale, Colorado.

HEADQUARTERS
271st Engineer Light Combat Battalion
Hunter Liggett Military Reservation
APO 360, Camp Roberts, California

REPORT OF TESTS: Water Purification Unit, Pack.

1. The Water Purification Unit, Pack was received less 350 gallon tanks, hand pumps, and plastic water bags.

2. The pack equipment was used to supply water for the 71st Light Division and attached troops for two phases of maneuvers and to date in base camp.

a. The time required to erect the equipment is 30 minutes and 20 minutes to dismantle and pack out on pack boards.

b. The unit is suitable in its entirety for mule transportation and can be carried on 2 mules. Special hangers are required for the pump and engine for top loading with quick release devices; as yet we have not been able to develop same. Side load boxes with hangers could be used to carry small parts that are now being mantled. When loaded on two mules the pack beard loads numbered 1, 2, and 3 load on one mule while pack board loads numbered 4, 5, and 6 go on the second mule.

c. The man pack loads all are less in weight than pack load #2 which weighs 65 pounds. Pack #3, the pack which carries the expendable filteraid decreases in weight with use of the equipment. On successive moves portions of other pack loads can be redistributed to this pack. The #2 pack at halts can be interchanged among men, thus increasing the distance the equipment can be moved without undue fatigue.

d. When pumping mountain stream clear water, the gasoline engine driven pump will produce 16 gallons per minute. Under extremely turbid water conditions caused by heavy rains, the unit could only produce 50-60 gallons of water before backwashing of the filter was necessary. The hand operated pump has not been supplied this organization for test.

e. The present equipment is slightly inadequate as it does not provide sufficient pumps to handle water from deep-cut streams to points where troops can pick it up. The number of pumps did not provide for spares in sufficient quantity when more than 3 water distributing points were set up and were widely separated by close and difficult terrain. It is thought 12 units would be sufficient if issued to the Battalion under S-4 section instead of the Lettered Companies. In this way, all types of situations in demand can be made with the least confusion in that the Battalion S-4 would control the equipment and make the adjustments.

f. The 4 cell filter does not have sufficient filtering surface for continuous high demands. Test shows need for more surface and less back washing even with clear mountain water. It is suggested that 6 cells be used instead of 4. When filteraid is added continuously the filtered matter and the filteraid form too thick a lamination with consequential discharge pressure drop over a long period until backwashing is necessary. Without the body feeder, 2000 gallons of water was filtered clear by direct application of the filteraid into the filter. During 4000 gallons of operation only two 1/4 pound additions were made for the two operations and the pressure drop did not occur until just as the 2000 gallon point was being reached. It is our opinion that by this method the larger filtered particles are not made into a mechanical mixture with the filteraid but tend to act as a primary sand filter and the filteraid the secondary or impervious layer when the filteraid is added under pre-coat conditions as recommended by the vendor of the diatomaceous silica filtering material. Tests on this premis are to be run by this organization and reported if conclusive results are obtained.

The ignition system and magneto was found to be subject to rain and humidity causing hard starting of the gasoline engine. The toggle switch is not waterproof as it now exists but can be remedied by use of a rubber covered push type switch instead. The engine governor spring arm is not fastened securely enough to prevent the loosening of the governor spring and also preventing the operator from increasing the tension and overspeeding the engine. The breaker points on the ignition system foul too easily, but can be remedied by setting a wider gap between them (.020"). The gas engine air intake is too bulky and should be replaced by one which is more compact. The grease cup lubricating the drive connection between engine and pump should be relocated as it also protrudes when the load is being lashed on a mule. Valves in engine carbonize and stick when oil level is maintained too high.

g. Essential Modifications:

(1) Increase number of filter elements per filter from 4 to 6.

(2) Increase pump capacity to 45 gallons per minute.

(3) Add illuminated comparator for night operation.

(4) Remount pump and engine assembly so engine is at top of pack board.

(5) Add combination tool for setting points and spark plug clearances.

(6) Increase quantity of hose by 20 feet.

(7) Add light weight, gasoline type, trigger operated, flexible end, can filling device with sanitary nozzle.

(8) Glass vials should be plastic.

(9) Additional spare parts consisting of gas line, spark plug cables, fly wheel puller for magneto flywheel and 2 sets of ignition points and arms, pump packing, gas line fittings.

(10) Use flare type fittings in gas lines instead of compression type now supplied.

(11) Increase strength of gas tank bracket.

/s/
O R EDDY
Major, CE
Commanding

Testing Organization **271st ENGINEER LIGHT COMBAT BATTALION** Date **1 May 1944**

PACK WATER PURIFICATION EQUIPMENT
PRELIMINARY SERVICE TEST QUESTIONNAIRE

(To be filled in by officers, noncommissioned officers, and qualified operators who participate in service tests and returned by ________ ________________ for forwarding to the Water Supply Equipment Branch, the Engineer Board, Fort Belvoir, Virginia.)

Capacity:

1. Considering the relationship of capacity and weight of equipment, under what conditions do you favor:

a. Larger equipment? Ans. - **Larger filter capacity, suggest 6 element filter, same he\[illegible\]t, increase filter body diameter.**

b. Smaller equipment? Ans. -

2. Would you favor increasing or decreasing the capacity and weight of the pack equipment, if so to what capacity and weight?

Ans. - **Increase pump output to 45 G.P.M. to accompany 1 a. above.**

3. What was the average hourly output with gasoline pump when using:

a. Coagulation and settling? Ans. - **Clear water, no test.**
b. Direct filtration of turbid water? Ans. - **480 G.P.H. by test only.**
c. Direct filtration of clear water? Ans. - **960 G.P.H.**

4. Is there a need for a small pump and filter that could be carried by an individual in addition to his combat equipment?

Ans. - **No need seen; present equipment satisfactory.**

Transportation:

5. In what percentage of the total hauling time was the equipment carried by:

a. Men? Ans. - **35%**
b. Pack Animals? Ans. - **65%**
c. Motor Vehicles? Ans. - **Not used.**

6. What was the maximum distance a man could be expected to carry the heaviest pack in a day?

Ans. - **Maximum distance 1 hrs. march with pump load. Rotation among loads allows 5 miles w/o undue fatigue.**

7. Were any of the first three packs subdivided for carrying by man; if so, how were they divided?

Ans. - **Tool kit carried in pack #3 instead of #2.**

8. Should the first pack include all equipment and supplies for a day's emergency operation in the event that other packs are lost?

Ans. - **Yes.**

9. What changes in the mounting of equipment or additional attachments would facilitate packing on animals or men?

Ans. - **Pump and Engine should be reversed on pack board so that Engine is on top side of board. Relocate Grease Cup.**

10. What additional protecting framework or covers would be desirable?

Ans. - **Guard sediment bowl. Use extra heavy pipe for grease line.**

11. Should all packs be carried on a packboard, if not, which ones?

Ans. - **Yes.**

12. Should the present distribution of 25-foot cords, quick release straps, and cargo attachments be changed, if so, how?

Ans. - **No change.**

13. Can the set of six packs be carried conveniently on a single pack animal? If not, what is distribution of load?

Ans. - **Not a single mule load, as it is too heavy and bulky for difficult terrain. Suggest packs 1, 2 & 3 for 1 mule; packs 4, 5 & 6 for 2nd mule.**

Employment:

14. How many men could be supplied by one unit when operated on:

a. 8-hour basis? Ans. - **5000 men @ 1 gal. each.**
b. 24 or 20-hour basis? Ans. - **15000 men @ 1 gal. each.**

15. During what percentage of the operating time was the equipment operated at:

a. Night? Ans. - **None, for tactical reasons.**
b. Day? Ans. - **100%.**

16. How was the water purification equipment located with respect to the consuming troops?

Ans. - **Within the perimeter defense of the unit supplied.**

17. Under what conditions was the filter operated with the hand pump?

Ans. - **Hand pump has not been received by this unit from Engineer Board.**

18. During what percentage of operating time was the source of water a:

a. Small or intermittent stream? Ans. - 60%
b. Large stream? Ans. - 40%
c. Pond or lake? Ans. - None
d. Swamp? Ans. - None

19. What were the weather conditions and their effect on equipment?

Ans. - Water from rain got into magneto, switch, and ignition cable. Switch should be rubber covered push button type. Ignition cable water-proofed and sealed at ends.

20. What percentage of the raw water was:

a. Clear? Ans. - 100% - Mountain streams
b. Turbid? Ans. - None
c. Very turbid? Ans. - None

Operation:

21. What changes in the operating procedure should be considered:

Ans. Under clear water supply conditions continuous addition of Filter-aid caused too thick a lamination of filter elements thereby reducing discharge. Without Body Feeder 2000 gal. of water was produced clear without backwashing. During 4000 gals. of operation clear water was produced with 2 1/4# additions of Filter-aid direct, omitting the body feeder all together.

22. What percentage of filtering was done with:

a. Coagulation and settling? Ans. - None
b. No pretreatment (direct)? Ans. - 100%

23. Should either coagulation and settling (pretreatment) or direct filtration be adopted as the only standard method of filtration; or should both methods be employed? What do you think of each method?

Ans. - Employ each as raw water conditions demand.

24. What containers were used for distributing water and how were they filled?

Ans. - 5 gal. water cans and covered corrugated GI cans.

25. What additional means for filling containers should be provided?

Ans. - A light weight, gasoline type, trigger-operated valve, with flexible end and sanitary nozzle.

26. How many scoops of calcium hypochlorite were required to produce a residual of 1 p.p.m. chlorine at the end of 30 minutes with:

	Granules for 350 Gallon Tanks	Solution for 5 gal. Cans
a. Raw water?	Ans. - **No test**	**No test**
b. Filtered water?	Ans. - **No test**	Ans. - **No test**

27. How long was required to set up equipment and begin filtering?

Ans. - **One half (1/2) hour elapsed time.**

28. How long was required to train an operator for normal operations?

Ans. - **Two (2) days some time of which is for supervision**

29. Were any unusual difficulties encountered during night operations?

Ans. - **Did not operate at night.**

30. How many operators were required for one unit (or set) during:

a. Day? Ans. - **3 men-minimum; 4 men maximum.**
b. Night? Ans. - **Not operated.**

31. Could the equipment be operated by an apt man after reading only the instructions?

Ans. - **Yes, if the man is mechanically inclined.**

Equipment:

A. Filter.

32. Would a filter of greater capacity and weight be desirable?

Ans. - **Yes, see Question 1 a. above.**

33. Did any of the filter elements become plugged; if so, under what conditions?

Ans. - **None have plugged as yet due to only silt in clear water and constant back washing by operators.**

34. Were any plugged filter elements cleaned, if so, by what method?

Ans. - **None.**

35. During what percentage of filtration were the following el employed and which type is preferable:

a. Ceramic (grey stone)? Ans. - 33 1/3%
b. Carbon? Ans. - 33 1/3%
c. Stellar (wire wound)? Ans. - 33 1/3% **Preferable type**

36. Were any of the filter elements broken, if so how?

Ans. - **None.**

37. Did the filter leak frequently at the head, if so why?

Ans. - **No.**

38. What changes would improve the filter?

Ans. - **See Question 1 a. above.**

39. What was the average length of a filter run before backwashing using:

a. Coagulation and settling? Ans. - **No test.**
b. Direct filtration: Ans. - **4 to 5 hrs, continuous operation.**

40. How much water was used per backwash?

Ans. - **10 gal.**

41. What were the maximum and minimum hourly outputs and what caused them?

Ans. **a. 960 gal per hr, caused by demand.**
b. 180 gal per hr, by test on muddy water.

42. How much longer did it take to produce the first filtered water when coagulation and settling was used than with direct filtration of raw water?

Ans. - **No test.**

B. Body Feeder.

43. Were any plastic chambers on the flow indicator broken, if so, how?

Ans. - **One (1) broken when mule threw the load off.**

44. Did the bearings of the air-vane agitator wear considerably?

Ans. - **No; they have been kept well oildd.**

45. Were frequent cleanings or valve adjustments required to maintain proper slurry flow?

Ans. - **Yes.**

C. Chlorination Set.

46. What parts were broken or lost?

Ans. - **Several glass vials were broken.**

47. How could the method of chlorination be made more accurate or simple?

Ans. - **Chlorination measuring cup should be graduated in 100 gal divisions.**

D. Hand Pump.

48. For what purposes was the hand pump used and how extensively?

Ans. - **Never received pumps.**

49. What parts of the pump wore rapidly?

Ans. - **Never received pumps.**

E. Hose.

50. How did the hose wear and what caused the wear?

Ans. - **No visible signs of wear.**

51. Should more hose be provided, if so, why?

Ans. - **Twenty (20) additional feet of hose should be added to set to permit operation from precarious positions in difficult terrain.**

F. Pump and Engine.

52. What stoppages of the gasoline engine or pump occurred and what caused the failures?

Ans. - **Moisture in Magneto, Switch, high tension cable and ground circuit. Magneto breaker points stuck, we dressed and reset them to .020 gap for satisfactory operation. Slush ice in pump casing caused pump to be hard to start. Valves carbon up and stick when oil level is carried at full level.**

53. What type of gasoline and oil were used?

Ans. - **Red (leaded) gasoline, S.A.E. 30 G.I. Oil.**

54. What additional spare parts or tools should be included?

Ans. - **Gasolines, Spark plug cables, hose washers, spark plub wrench, spark plug and point gauge and fly wheel puller.**

55. Should a guard frame be provided to protect the engine, considering its added weight?

Ans. - **Not favorably considered**

G. Filteraid.

56. Which type of filteraid was generally preferable?

Ans. - **Type 228 V**

57. What percentage of bags was seriously ruptured or torn, and which type was preferable:

a. Multi-wall paper? Ans, - **60% tore in field.**
c. Lined Osnaburg? Ans. - **No failures to date. Preferable type.**

58. What was the average output in gallons per pound of filteraid with:

a. 228-V? Ans, - **2500 gal.**
b. 234-V? Ans, - **2300 gal.**
c. Sorbo-Cel? Ans. - **2000 gal.**

59. Should filteraid bags be olive drab in color?

Ans. - **Yes.**

H. Canvas Tanks.

60. How many 350-gallon tanks are required per set of pack water purification equipment?

Ans. - **None on hand.**

61. What failures, such as holes, occurred in the tanks and what caused them?

Ans. - **None on hand.**

62. Did the 350-gallon tanks leak when first filled, if so, where?

Ans. - **None on hand.**

63. How often were the repair kits used?

Ans. - **None received.**

64. What was the effect of hot and cold weather and aging on the bitumen coating?

Ans. - **No tanks.**

Containers:

65. What percentage of the plastic bags developed leaks and what caused them?

Ans. - **Not received as yet.**

66. Should some type of water bag be supplied in lieu of the present 5-gallon cans for pack equipment?

Ans. - **Yes; a rubber or plastic container shaped like the present 5 gal. can. Light weight and reduced noise and ability to be collapsed would aid in mule packing.**

General:

67. What improvements in the pack water purification equipment are recommended?

Ans. - **a. Illuminated type comparator for night operation.**
b. Increase filter surface as in 1 a. above.
c. Increase hose length.
d. Spare parts listed above.

68. Would a filter unit operated only by an easily stroked hand pump be more desirable than the present gasoline engine-driven type?

Ans. - **No. Demands are too great and manpower to increase men required to operate the hand pump.**

69. What equipment should be added and why?

Ans. - **Covered in various sections throughout this report.**

Name /s/ **O. R. Eddy**
ORIN R EDDY

Rank and Organization **Major, 271st Engr L C Bn**

Assignment ______ Platoon
______ Company
Commanding Battalion

ARMY AIR FORCES
HEADQUARTERS, I TROOP CARRIER COMMAND
Stout Field, Indianapolis, Indiana

TCCMD
761.2

25 April 1944

EQUIPMENT TESTING REPORT

A. Purpose

1. To report on service tests of an experimental model pack water purification equipment unit developed under Project WS 443, by the Engineer Board, Ft. Belvoir, Virginia; to make the necessary recommendations regarding the practicability of the use of this equipment by the Army Air Forces; and to make such recommendations as may be necessary to adapt this equipment to Air Forces use.

B. Factual Data

1. See Inclosure No. 1 "Tentative Operating Instructions for Operating Model U. S. Army Pack Water Purification Equipment," Inclosures 2, 3, 4 and 5 photographs.

2. Capacity

a. The equipment, when operated with low turbidity waters, i.e., 10 to 15 ppm turbidity, will produce volumes ranging from 20 gallons per minute to 10 gallons per minute during the first hour's operation, giving an average production approximating 15 gallons per minute during the first hour. At higher turbidities, i.e., any turbidity over 100 ppm, the equipment will not successfully operate at flows above 3 gallons per minute for periods of time greater than 1/2 hour. It, therefore, becomes apparent that in the operation of this unit with any water of appreciable turbidity, pre-treatment, such as by alum and soda ash, becomes essential for the production of amounts of water commensurate with the total weight of the equipment. Whereas hand-powered units have been developed, weighing under 50 pounds, which will produce water at the rate of 3 to 5 gallons per minute, it is not felt advisable that this equipment be recommended for inclusion in the equipment of any organization smaller than that of a battalion, considering total weight; and not to any organization larger than a squadron, from a water production standpoint. It is thus apparent that on a water production: total weight relationship, this equipment is not suitable in its present state for issuance to troops. The present smaller unit of the 40 pound weight, 3 to 5 gallon per minute capacity, should be tested and developed, in order that it may be made available for squadron issue. The pack type water purification unit under consideration in this report should be further developed to such a point that its production becomes commensurate with its total weight, and it may subsequently be made available for replacement of the present W & T

800 pound portable water purification unit. The portable unit should then be developed to replace the present mobile unit.

Small water purification units of the two-quart per minute capacity, such as have been developed by the S. F. Bowser & Co. and the Wallace & Tiernan Co. should be investigated when considering the water needs of small groups, such as the squadron and the platoon, and for emergency equipment and rescue work.

In considering troop needs as they currently exist, it would appear that the present need for field water purification equipment falls into four main classes; the two to three quarts per minute requirement, the three to five gallons per minute requirement, the fifteen gallons per minute requirement, and the 75 gallons per minute requirement. In its present state, the pack water purification equipment developed under Project WS 443 does not meet the requirements of any of these classes.

b. In consideration of the Engineer Board's question regarding increasing or decreasing the capacity and weight of the pack equipment, it is not felt that this unit is suitable in its present design to be either increased or decreased insofar as weight of equipment is concerned, without altering the capacity so that it will fall into a class wherein equipment does not already exist which embodies sounder principles of design and greater adaptability to Air Forces needs.

c. (1) The average output of the gasoline pump, when employing pretreatment by coagulation and settling, using the 350 gallon storage tank for settling was, of necessity, totally dependent upon the degree to which the coagulant had settled. In a tank of such great diameter and such consequent shallowness, the time of settling becomes too prolonged for field use. Employing water which had settled for two hours, average hourly flows may be obtained of 500 gallons per hour. However, it must be noted that the remaining turbidity in water settled for two hours, is of such gelatinous character as to reduce the flow to an extent that further filtration is impracticable after one half hour. While 250 gallons may be obtained during a 1/2 hour run, this does not include time for backwashing and setting up the equipment; therefore, the actual hourly production is considerably less than 500 gallons per hour. Greater cycles may be obtained, on water which has been permitted to settle for periods of 2½ hours and upward. It is unlikely that this equipment should be considered for field use if such length of settling is necessary in order to obtain satisfactory operation. It is felt that to a great degree this fault is not the fault of the mechanical apparatus, but rather in the poorly conceived design of the storage tank, both regarding proportions and the capacity of the tank in relation to the tank weight.

(2) On the direct filtration of turbid water, the length of the operation cycle bears a direct relationship to the turbidity of the water and the particle size creating the turbidity. On waters of low turbidity high outputs may be obtained on lengthened cycles. As the turbidity increases the length of cycle and the average output drop sharply. At turbidities approaching 100 ppm, cycles in excess of 1/2 hour are impractical, due to the fact that the output has dropped to three gallons per minute or lower.

At waters with a turbidity of 10 ppm, the cycle may be extended to two hours. However, following the first hour of operation the output will have fallen below that of the first hour. Better than ten gallons per minute may be obtained throughout the first hour; however, on the second hours' operation an average of seven to eight gallons per minute may be expected. At the end of the second hour the output will have fallen to the point where backwash has become advisable. It would, therefore, become apparent that the only time at which this equipment justifies its weight will be when used on low turbidity waters. It is strongly felt, regarding the application of body feed in relation to the operational cycle, that a second factor should be introduced in addition to the water turbidity, namely the size of particle creating the turbidity. It is further felt that a need exists for a rapid method for the determination of the index of particle size and turbidity for field use. A study in this connection has been instituted and will be carried on by the joint cooperation of this Headquarters and the experimental laboratories of Purdue University.

d. Clear water may be pumped through the filter at a rate varying between 18 to 20 gallons per minute.

e. It is not believed that there exists in the Air Forces any need for a small pump and filter to be issued as individual equipment. However, a need does exist for small equipment to be carried by an individual for use by small groups.

3. Transportation

a. Insofar as the transport of this equipment may be considered for Army Air Forces use, it is felt that 99% of its use would warrant no other transportation than motorized vehicles, and in the execution of these tests at no time was this equipment transported more than ten feet by any other means.

b. The heaviest pack was assembled, and it is believed that the maximum distance which this pack should be borne by any individual should not, under the optimum of climatic conditions, exceed 1/2 mile, inasmuch as the resultant pack is offcenter to such an extent as to throw the bearer off-balance. The main objection to this pack, therefore, is not its total weight, but its unsuitability to pack adaptation.

c. For Air Forces use, it is believed that the pack system of transportation should be abandoned, and that the unit should be mounted so that all mechanical parts are inclosed on a tubular framework, the whole not to exceed 135 to 150 pounds in weight. This framework should be of such size and shape as to fit in the end of the standard 1/4 ton trailer, leaving the remainder of the trailer free for the transport of the accessory supplies and equipment. This would have the advantage that the entire equipment might be transported from the trailer by hand by two men to a water point to which the trailer might be inaccessible. Further, upon reaching a water point the equipment might readily be unloaded from the trailer and the trailer thus be made available for other use during the time of operation of the water purification unit.

4. Employment

a. The number of men which can be supplied by one unit when operated on an eight-hour basis is, of necessity, dependent upon the original turbidity of the water. It is felt that the equipment should be redesigned to such an extent that it could, with a water of any turbidity, supply potable water for a battalion, operating on an eight-to-ten-hour basis, such time of operation to include settling and intercycle setup times.

b. Due to the faulty nature of the hand-pump furnished with this equipment, the equipment was not sufficiently operated with the hand-pump to obtain any workable data. However, if the equipment is to be employed using a hand-pump, in considering the relationship between the water produced and the total weight of the equipment it is felt that superior units now exist.

5. Operation

a. It was not felt that at any time was the operation of this equipment satisfactory, and it is believed that before successful operation may be achieved, a redesigning of the equipment and a review of the principle underlying the design are absolutely essential. Therefore, comments on changes in operating procedure will not be made.

b. Regarding the employing of pre-treatment or direct filtration as the only standard method of filtration, it is felt a definite standard of turbidity should be adopted, whereby at a turbidity under this point no pre-treatment will be employed and at turbidities greater than this point standard pre-treatment will be used. It is believed that the rapid field method of determining turbidity and particle size currently being developed will give a quick, simple means for the operator in the field to determine the point at which the turbidity and particle sizes are such that pre-treatment should be employed.

c. No water distribution was employed in the testing of this equipment.

d. In consideration of the fact that this equipment is not yet capable of satisfactorily producing filtered water, it was not felt advisable to amass data on the relative chlorine demands of the raw and the filtered water which it produced.

e. It is felt that the equipment may be set up and filtration begun within 20 to 30 minutes after reaching a water point, depending upon the nature of the point.

f. It is impossible at present to determine the length of training required for an operator for this equipment, inasmuch as certain features, such as the slurry feed, now require constant attention by a trained operator, and such detailed operation is not considered advisable under field conditions.

g. With the present equipment, no less than two operators should be employed at any time, day or night.

h. It is not believed that this equipment could be operated by an apt man after reading only the instructions.

6. Equipment

a. Filter

(1) The filter furnished with the equipment is desirable insofar as capacity and weight are concerned at the flows for which it is believed that this equipment was designed.

(2) None of the filters have as yet become definitely plugged. However, there is some indication that the alumdum is becoming plugged after what would be considered an abnormally short time of operation. In the backwashing of the Stallar filter, very unsatisfactory backwash was obtained, due to the dead spaces where the plastic comes in contact with the wires.

(3) During the majority of the runs, the carbon filter was employed, due to certain apparent advantages of this unit, such as its higher degree of porosity and its greater ease and degree of cleaning by backwash.

(4) No filter elements were broken, although one Stellar element was received with a tiny dent in the wires. This naturally makes the use of this filter most undesirable.

(5) The filter leaked frequently at the head, due to the fact that the head gasket was not shellacked into the head.

(6) It became apparent shortly after commencing operations with this filter unit, that if a proper pre-coat were to be applied to the filter elements, the pre-coat slurry should as nearly as possible fill the filter unit prior to the commencement of

flow. Therefore, it is suggested that a mark be placed on the inside of the filter, to which mark the filter unit should be filled before inserting the filter elements. The amount of pre-coat slurry to be added to the unit should be equal to the volume of the unit, less the displacement of the elements. The head gasket should be cemented firmly to the head.

(7) The average length of a filter run before backwashing, using coagulation and settling, bears a direct relationship to the settling time allowed and is totally dependent upon the amount of suspended coagulant remaining in the settled water. The average length of a filter run before backwashing, using direct filtration, is directly dependent upon the initial turbidity of the water and the size of the particle causing the turbidity.

(8) Ten gallons of water were used per backwash.

(9) Hourly outputs varied between 900 gallons per hour and short runs of inconsequential production, created by high turbidities without pre-treatment.

(10) With waters of high turbidities where direct filtration is impossible for longer than five minutes, pre-treatment may be employed, thus rendering the water suitable for filtration. There is no relationship between the time required to produce the first filtered water when coagulation and settling are used and the time to produce the first water when direct filtration is used.

b. Body Feeder

(1) No plastic chambers were broken.

(2) The bearing of the air vane agitator did not show wear beyond the point of useful life.

(3) During the entire operation of this equipment, at no time other than momentarily, could it be said that the body feed operated in a satisfactory manner. In any attempt to maintain a constant differential between a take-off from the recirculation chamber of the pump and the suction from a venturi on the suction line from the pump, wherein the suction to the slurry feed is dependent upon the flow of water through the suction line, and not upon the actual suction to the pump, failure can only result, since no constant relationship exists between these two factors, and this differential may be maintained only by the constant manipulation of both the suction and the pressure line valves.

c. Chlorination Set

(1) No parts were broken or lost.

(2) The only recommendation which could be made regarding the method of chlorination might be the addition of the chlorine solution through the slurry feed.

d. Hand-pump

(1) The use of a hand-pump was exceedingly limited, due to the faulty action of the valves.

(2) The packing of the pump wore rapidly, as did the leather pump gasket, when exposed to water containing sand or grit.

(3) The maximum production of this pump was reached at three gallons per minute, operating against no head. In water containing high turbidity this production quickly fell, due to the stoppage of the valves by grit and sand, and the imbedding of sand in the leather pump gasket. It is suggested that the bearing valves be replaced by spring action valves.

(4) No provision is made for the agitation of the slurry during use of the hand-pump.

(5) The action of the hand-pump produces a flow so uneven in character that very unsatisfactory and uneven body feed is produced by a venturi in the flow line, as is recommended in the operating instructions.

e. Hose

(1) The hose showed no sign of appreciable wear.

(2) An additional ten feet of hose, broken into five foot lengths, with male and female couplings, would be advisable.

f. Pump and Engine

(1) During a portion of one day, the gasoline engine failed to work, cause undetermined.

(2) 70 octane gas and SAE 20 oil were used.

(3) Additional sockets for the socket wrench, and a pipe wrench, not smaller than 6" and not larger than 10", should be included in the tool kit. A note of interest might be found in the fact that during the first week of operation, aviation mechanics ransacked the equipment and took the only tool of value, the screwdriver. In the field, this practice of "night requisitioning" will be employed to an even greater extent than would be expected at a base in this country. Therefore, adequate storage of the equipment, and especially the tools, is necessary.

(4) A guard rail will be incorporated in the framework previously described.

g. Filter Aid

(1) Dicalite and Sorbo-Cel were furnished. Of these, Dicalite was preferable.

(2) One of the multi-papered packs was torn when received.

(3) The output in gallons per pound of filter aid is in direct relationship to the turbidity of the water and the size of the particle causing the turbidity.

(4) It would appear preferable if the filter-aid packs were olive-drab or dark brown in color.

h. Canvas Tanks

(1) No less than four 350 gallon tanks are required for the water purification set.

(2) No failures, such as holes, occurred in the tanks.

(3) The tanks leaked appreciably and all attempts to stop this leaking were to no avail.

(4) The repair kit was never received.

(5) No effect was noted on the bitumen coating, due to weathering.

i. Containers

(1) No containers were furnished.

j. General

(1) Recommendations for improvements are embodied within the above report.

(2) Considering the total weight of equipment, it is not felt that the use of a hand-pump is feasible with this equipment. However, should any hand-pump be used with this equipment, it is felt that a diaphragm pump is vastly superior to the plunger-type pump.

(3) It is felt that the present tanks are totally inadequate to meet the needs of this equipment, and should be replaced by waterproof tanks of greater capacity and proportionately lighter in weight. Such tanks can be developed without difficulty.

C. Conclusions

1. It is believed that the pack water purification equipment developed by the Engineer Board, Ft. Belvoir, Virginia,

under Project WS 443, does not meet the requirements of the Army Air Forces, nor has the equipment been developed to such a state that its issue to field troops is as yet possible or desirable.

2. It is believed that this equipment may be so modified as to be vehicular borne; and that the output may be increased to reach a constant 10 to 15 gallons per minute and so make its issuance as a replacement for the present portable water purification unit feasible in Air Forces and Airborne troops.

3. Since a need does exist in the Air Forces for water purification equipment producing 3 to 5 gallons per minute of water, and also equipment producing 2 to 3 quarts per minute of water, efforts will be continued to obtain suitable units within these outputs prior to the continuation of work on the above reported unit.

Prepared by /s/ FRANK C. HALE
/t/ FRANK C. HALE
CWO, USA

Approved by /s/ DUDLEY A. PFAFF
/t/ DUDLEY A. PFAFF
LT. COL., M.C.

ARMY SERVICE FORCES
Department of Military Sanitation
MEDICAL FIELD SERVICE SCHOOL
Carlisle Barracks, Pa.

17 July 1944

A - ABSTRACT OF REPORT

1 - Object - To determine bacterial removal efficiency of "pack filter", under development by Water Equipment Laboratory, Fort Belvoir, Virginia, and not otherwise identified.

2 - Authority - The authority for the work herein reported is Memorandum 6 May 1944, inclosure to Memorandum 9 May 1944, Office of The Surgeon General, to Director, Medical Department Equipment Laboratory, Carlisle Barracks, Pa.

3 - Results - Actual bacterial counts, and percentages of organisms remaining in treated waters, are reported. Averaging all values with the exclusion of the few which are definitely out of line, indicates that with direct filtration, 9.4% of the original bacteria remain in the filtered water. When this water has previously been coagulated and treated, 5.7% of the bacteria pass through the filtration media.

Without filter aid, the carborundum core passed a water containing 142% of the initial bacterial count, the stellar core 136% of initial count, while the carbon core passed an average of 4.5% of initial bacteria. When filter aid is used, average values with the carbon core were 5.5%; with the stellar core, 7.6%; and with the carborundum core 13.5% of bacteria pass. With the filter aids tested, by averaging all results, sorbocel passed 4.4%, dicalite 7.2% and supercel 14.4% of the initial bacterial count.

Evaluation of the efficiency of steps used in treatment shows that coagulation results in a water containing 144% of original bacterial count. This value excludes one of 1885%. Excluding two other high values, which can be attributed to a dirty receiving (coagulation) tank, coagulation results in a reduction of bacterial count to 52% of the initial count. Filtration results in a drop at the end of ten minutes to 34%, and after 20 minutes to 27%, for an average value of 31% of initial bacterial count still present. Collection of this filtered water in a storage tank resulted in a rise in bacterial count to 72% of the initial, showing again the effect of an improperly cleaned storage tank. Chlorination resulted in a reduction of the bacterial count to 1.8% of the original value after a 30 minute contact period.

The effect of chlorination was studied by doing periodic counts during the contact period. The results of chlorination after direct filtration were contrasted against those after coagulation with ammonium alum. After a ten minute period, there remained 6.2% of prechlorination bacterial count when coagulation had been practiced, against 1.6% when coagulation had not been performed. Tested with para amino dimethyl aniline, there was no free chlorine present after coagulation. Unfortunately this test was not used after direct filtration with dicalite and sorbocel (both said to contain alum). Free chlorine was present where no filter aid had been used.

The influence of a dirty core is shown in those cases where filtration resulted in an effluent containing eleven to fourteen times the original bacterial count. In

these instances, the filter had previously been used and cared for as directed in operating instructions.

With pre and post chlorination, there is no eventually superior product. The influence of dirty tanks is obvious. Chlorination in this instance is accomplished by chloramines. There is no free chlorine detectable by para amino dimethyl aniline.

Influence of treatment on bacterial flora was not completely investigated. However, it was obvious that raw waters very frequently contained spreaders of the gram positive spore forming bacillus group, while plates of the filter effluents rarely contained such spreading colonies. The bacteria which survived chlorination were found to be, almost always, spore forming gram positive rods.

4 - Conclusions -

a - The pack filter does not produce a consistently potable water from the bacteriological point of view by filtration alone. Chlorination does remove the bacteria which pass.

b - This work suggests that chlorination might be more effective if ammonium alum, which converts all chlorine to chloramine, were not used as the coagulating agent. Alternate coagulants were, however, not investigated.

c - Operating instruction should specify careful cleaning of the reservoirs, preferably with a chlorine solution, and backwashing of the filter cores at the end of a day's operation with a chlorinated water. This will avoid those instances herein reported where treated waters were many times more heavily contaminated than the initial raw water.

d - Investigative work on removal of cysts of E. histolytica are indicated, especially by the supercel filter aid.

B - DETAILED REPORT

1 - Object - The objective of this experimental work was to determine the bacterial removal efficiency of the "pack filter", under development by Water Equipment Laboratory, Fort Belvoir, Virginia, and not otherwise identified. Filtration is based on a body feed of diatomaceous earth which is retained on a filter core.

2 - Authority - The authority for the work herein reported is Memorandum 6 May 1944, inclosure to Memorandum, 9 May 1944, Office of The Surgeon General, to Director, Medical Department Equipment Laboratory, Carlisle Barracks, Pa.

3 - Method - Samples of water were collected by personnel of the Medical Department Equipment Laboratory in sterile bottles. Chlorinated waters were collected in bottles into which 1 cc. of 0.1 N sodium thiosulfate solution was placed before sterilization. Waters were plated as soon as possible after receipt, never after three hours had elapsed. They were kept in the refrigerator during waiting periods. Plating was accomplished in nutrient agar (Difco) as called for by "Standard Methods For The Examination of Water and Sewage", Eighth Edition. Counts were made after 48 hours incubation at 37.5°C., using a Quebec colony counter. Fermentation was set up in lactose broth as a check, but is not reported.

4 - Results - Results obtained are reported in Tables I, III, V, VII, and VIII. Actually 34 runs were made, and these tables compare various analogous situations. Tables II, IV, VI, VII, and IX present analyses of results in terms of the percentage of organisms which have survived various treatment procedures.

Tables II and IV present percentage reduction of bacteria by filtration alone. Without the use of the body feed of filter aid, as shown in Table II, the filter core provides little if any improvement to the water. With the carborundum filter (previously used), the effluent contains almost 1½ times the initial bacterial count. With the stellar core it contains 136% of the original count, while the carbon core passes 45% of the initial count. The improvement by carbon is not consistent, as seen in No. 15, the effluent after 20 minutes had 74% of initial count, while the ten minute effluent had only 26%. This is explained by loosening of plugged cores in the filtering material. When filter aid is used, the average of all runs (Tables II and IV) using the carbon core was 5.5% of bacteria passing, 7.6% with the stellar core, and 13.5% with the carborundum core. Contrasting the filter aids used, with sorbocel 4.4% of organisms passed, with dicalite 7.2% and with supercel 14.4%.

The influence of preliminary treatment is shown by contrasting Tables II and IV. Excluding values which are obviously out of line, these indicate that with direct filtration, 9.4% of prefiltration bacteria pass through the filtering material, while when coagulation has been previously used, only 5.7% pass.

Table V and VI present the influence of various treatment steps on the initial count. Coagulation resulted in a water containing 144% of the original count, when one value of 1885% is discarded. Eliminating the two other high values of 306% and 573%, the remaining 7 runs show a reduction to 54% of the original count. These high values must be explained on the basis of a dirty coagulation tank. Filtration resulted in a drop to 34% of the original raw water count after 10 minutes; after 20 minutes filtration it was down to 27% giving an average for the filtration step of 31% of original bacteria remaining. Impounding the filter effluent in a storage tank increases the count to 72% of the initial count, and after 30 minutes of contact with chlorine in dose sufficient to give a 10 minute residual of over 1 ppm the count drops to 1.8% of the initial value.

The effect of chlorination is presented in Table VII. In those runs where coagulation was used, there was no free chlorine detectable by para amino dimethyl aniline. In No. 8, where direct filtration was practiced with no filter aid, a deep color developed with this reagent. The test, unfortunately, was not applied to the other direct filtration runs. Sorbocel and dicalite are said to contain alum in addition to diatomaceous earth. Results presented in the table show that with preliminary coagulation with ammonium alum, after a 10 minute contact period with over 1 ppm residual chlorine, there remains 6.2% of original bacteria. Without preliminary coagulation, only 1.31% remains. There is no significant difference in the 20 and 30 minute values.

Two runs with pre and post chlorination (Table VIII and IX) gave no superior product. The influence of a dirty tank is evident. Chlorination here is accomplished by chloramines.

During the course of this work, the influence of a dirty filter core and a dirty tank became manifest by results such as in No. 17, 23, 24, and 25 (dirty cores), by No. 26, 27, 28, and 32 (dirty coagulation tanks) and No. 24 (dirty storage tank).

The influence of treatment on bacterial flora was not completely investigated. However, it was obvious that raw waters very frequently contained spreaders of the gram positive spore forming bacillus group, while plates of the filter effluents rarely contained such spreading colonies. The bacteria which survived chlorination were found to be, on direct smear and subculture, almost always spore forming gram positive rods.

5 - Conclusions -

a - The pack filter does not produce a consistently potable water from the bacteriological point of view by filtration alone. Chlorination does remove the bacteria which pass.

b - This work suggests that chlorination might be more effective if ammonium alum, which converts all chlorine to chloramine, were not used as the coagulating agent. Alternate coagulants were, however, not investigated.

c - Operating instructions should specify careful cleaning of the reservoirs, preferably with a chlorine solution, and backwashing of the filter cores at the end of a day's operation with a chlorinated water. This will avoid those instances herein reported where treated waters were many times more heavily contaminated than the initial raw water.

d - Investigative work on removal of cysts of E. histolytica are indicated, especially by the supercel filter aid.

MARCUS D. KOGEL
Lt. Colonel, Medical Corps
Director

NOTE: This work was performed by Major A. S. Benenson, M. C.

TABLE I

DIRECT FILTRATION**BACTERIAL COUNTS

Exp. No.	Core	Filter Aid	Turbidity	Raw Water Bacterial Counts: Start	End	Average	Filter Effluent Bacterial Counts: 10'	20'	30'	40'
1	Carborundum	—		3030	3000	3015	6900	3350	3700	3220
2	"	Dicalite	17	900	1700	1300	180	92	—	
3	"	"	18	4000	4200	4100	1400	640	480	
4	"	Sorbocel	10	2600	3900	3250	210	300	160	
5	"	"	18	—	3000	3000	230	120	95	
6	"	Supercel	10	2400	1600	2000	710	550	570	
7	"	"	18	3400	—	3400	320	210	310	
8	Stellar	—		2030	1570	1800	3100	1930	1420	3360
9	"	Dicalite	6	2200	3000	2600	90	80	—	
10	"	"	52	3000	2500	2750	23	81	—	
11	"	Sorbocel	23	2600	2600	2600	80	120	70	
12	"	"	15	4400	3200	3900	360	670	—	
13	"	Supercel	6	3000	2900	2950	800	820	1200	
14	"	"	52	4600	14000	9300	56	220	87	
15	Carbon	—		2700	11000	2700	700	2000	—	
16	"	—		3050	2190	2620	60			
17	"	Dicalite	24	1500	1500	1500	1760	1200	1400	400
18	"	"	27	2300	4900	3600	27	10		
19	"	Sorbocel	5	2200	--	2200	190	120	90	80
20	"	"	27	4300	3900	4100	59	11		
21	"	Supercel	27	3300	--	3300	420	560	400	
22	"	Dicalite 228V	5	3700	3800	3750	150	65	95	

TABLE II

DIRECT FILTRATION**PER CENT OF ORIGINAL BACTERIA PASSING

Exp. No.	Core	Filter Aid	Turbidity	% After Filtration 10'	20'	30'	40'	Average
1	Carborundum	--		229	111	123	107	(142)
2	"	Dicalite	17	13.8	7.1	—		10.5
3	"	"	18	33.7	15.4	11.6		20
4	"	Sorbocel	10	6.5	9.2	4.9		6.9
5	"	"	18	7.7	4.0	3.2		4.9
6	"	Supercel	10	35	27	28		30.5
7	"	"	18	9.4	6.2	9.1		8.1
8	Stellar	—		172	107	79		(136)
9	"	Dicalite	6	3.5	3.1	—		3.3
10	"	"	52	0.8	2.9	—		1.73
11	"	Sorbocel	23	3.1	4.6	2.7		3.5
12	"	"	15	9.2	17.1	—		13.2
13	"	Supercel	6	27	28	41		32
14	"	"	52	0.6	2.4	0.9		2
15	Carbon	--		26	74	—		(50)
16	"	--		79	2.3	—		(40.5)
17	"	Dicalite	24	113	80	93	26.7	(78)
18	"	"	27	0.75	0.28			0.5
19	"	Sorbocel	5	8.2	5.5	4.1		5.3
20	"	"	27	1.4	0.27			0.85
21	"	Supercel	27	12.7	17	12.1		13.2
22	"	Dicalite 22CY	5	4.0	1.7	2.5		2.7

Average (excluding circled values) - 9.4%

TABLE III

COAGULATION-FILTRATION--BACTERIAL COUNTS

Exp. No.	Core	Filter Aid	Count in Coagulation Tank Start	End	Average	Filter Effluent 10' Count	20' Count	30' Count
23	Carborundum	Dicalite	320	400	610	7200	8700	—
24	"	Sorbocel	2400	1500	1950	2200	—	—
25	"	Supercel	320	1100	710	1700	1100	—
26	Stellar	Dicalite	22600	—	22600	700	550	—
27	"	Sorbocel	12500	7100	9800	45	47	—
28	"	Supercel	950	320	635	50	70	—
29	Carbon	Dicalite	1000	1000	1000	105	130	—
30	"	Sorbocel	1600	2800	2200	1	4	—
31	"	Supercel	1100	1500	1300	33	17	—
32	"	"	20300	26100	23200	3120	3140	2940

TABLE IV

COAGULATION-FILTRATION-PER CENT OF BACTERIA PASSING FILTER

Exp. No.	Core	Filter Aid	% of Bacteria Passing Filter After: 10'	20'	30'	Average
23	Carborundum	Dicalite	1180	1425	—	(1285)
24	"	Sorbocel	113	—	—	(113)
25	"	Supercel	239	155	—	(197)
26	Stellar	Dicalite	3.1	2.4	—	2.8
27	"	Sorbocel	0.46	0.48	—	0.47
28	"	Supercel	7.9	11.2	—	9.6
29	Carbon	Dicalite	10.5	13	—	11.7
30	"	Sorbocel	0.045	0.181	—	0.113
31	"	Supercel	2.8	1.3	—	2.07
32	"	"	13	14	13	13

AVERAGE - 5.7%

Averages (circled values excluded, including Table II) - Cores - Carborundum 13.5%, Stellar 7.6, Carbon 5.5; Aids - Sorbocel 4.4%, Dicalite 7.2%, Supercel 14.4%

TABLE V

INFLUENCE ON BACTERIAL COUNT OF VARIOUS STEPS IN COAGULATION FILTRATION

Exp No.	Core	Filter Aid	Raw Water	Coagulation-Settl. Start	End	Aver.	After Filtration 10'	20'	30'	Aver.	Tank for Stor.	After 30' Chlorina.
23	carborundum	Dicalite	1200	520	700	610	7200	8700	--	7959	1460	2
24	"	Sorbocel	4500	2400	1500	1950	2200	--	--	2200	--	0
25	"	Supercel	1600	320	1100	710	1700	1100	--	1400	--	1
26	Stellar	Dicalite	1200	22600	--	22600	700	550	--	625	--	
27	"	Sorbocel	3200	12500	7100	9800	45	47	--	46	--	
28	"	Supercel	570	950	320	635	50	70	--	60	--	
29	Carbon	Dicalite	2700	1000	1000	1000	105	130	--	117	--	
30	"	Sorbocel	5900	1600	2800	2200	1	4	--	2.5	--	
31	"	Supercel	2600	1100	1500	1300	37	17	--	27	140	230
32	"	"	4050	20300	26100	23200	3120	2140	3940	3066	3600	15

TABLE VI

% OF ORIGINAL BACTERIA AFTER EACH STEP OF PURIFICATION

Exp No.	Core	Filter Aid	% after coag.	% After Filtration 10'	20'	30'	Aver.	% Storage	% After Chlorination
23	Carborundum	Dicalite	51	(600)	(725)	--	(654)	122	0.16
24	"	Sorbocel	43	46	--	--	46	--	0
25	"	Supercel	[illegible]	106	49	--	[illegible]	--	0.06
26	Stellar	Dicalite	([illegible])	58	46	--	52	--	
27	"	Sorbocel	306	1.4	1.5		1.4		
28	"	Supercel	112	8.8	12.3		10.5		
29	Carbon	Dicalite	37	3.9	4.7		4.3		
30	"	Sorbocel	37	0.077	0.068		0.042		
31	"	Supercel	42	1.4	0.6		1.0	5.2	8.5
32	"	"	[illegible]	77	78	73	76	89	0.37
Averages-excluding circled values			144	34	27		31	72	1.8

TABLE VII
EFFECT OF CHLORINATION ON BACTERIAL COUNT

Exp. No.	Previous Treatment: Core	Previous Treatment: Filter Aid	Previous Treatment: Coag.	Prech. Count	1.5' Contact Period: Count	1.5' Contact Period: % of Prech.	10' Contact Period: Count	10' Contact Period: % of Prech.	20' Contact Period: Count	20' Contact Period: % of Prech.	30' Contact Period: Count	30' Contact Period: % of Prech.
8	Stellar	None	No	4500	84	1.9	70	1.6	40	0.9	60	1.3
10	"	Dicalite	No	90	18	20	2	2.2	1	1.1	0	0
12	"	Sorbocel	No	8200			11	0.13	4	0.05	7	0.085
18	Carbon	Dicalite	No	1250			16	1.3	12	0.9	4	0.3
23	Carborundum	Dicalite	Yes	1460			25	1.7	3	0.2	2	0.14
24	"	Sorbocel	Yes	2200			20	0.9	4	0.18	0	0
25	"	Supercel	Yes	—			16	—	1	—	1	—
31	Carbon	Supercel	Yes	140			9	6.4	36	(25.7)	230	(164)
32	"	Supercel	Yes	3600			565	15.7	28	0.8	15	0.4

Averages (excluding circled values) of:	1.5' % of Prech.	10' % of Prech.	20' % of Prech.	30' % of Prech.
Direct Filtration	10.9	1.31	0.9	0.42
Coagulation		6.2	0.61	0.18

TABLE VIII
PRE AND POST CHLORINATION COUNTS

Exp. No.	Core	Filter Aid	Raw Water	Prech. & Coag. Tank Start	Prech. & Coag. Tank End	% After Filtr. 10'	% After Filtr. 20'	% After Filtr. 30'	Storage Tank	% After Post Chlor. 10'	% After Post Chlor. 20'	% After Post Chlor. 30'
33	Stellar	Supercel	2000	1810	360	—	409	303	9320	384	125	70
34	Carbon	Supercel	15000	470*	65*	173*	11*	—	66	15	16	328

TABLE IX
PRE AND POST CHLORINATION — PER CENT OF ORIGINAL CONTAMINATION

Exp. No.	Core	Filter Aid	Prech. & Coag. Tank Start	Prech. & Coag. Tank End	% After Filtration 10'	% After Filtration 20'	% After Filtration 30'	Storage Tank	% After Post Chlor. 10'	% After Post Chlor. 20'	% After Post Chlor. 30'
33	Stellar	Supercel	90	18	—	20.5	15.1	466	19.2	6.2	3.5
34	Carbon	Supercel	3.1*	0.44*	1.15*	0.07*	—	0.44	0.1	0.1	2.2

* No thiosulfate in collection bottle.

ARMY SERVICE FORCES
MEDICAL DEPARTMENT EQUIPMENT LABORATORY
CARLISLE BARRACKS, PA.

4c0.1 (WS 443) GTK/hr

IN REPLY REFER TO: T-14

20 July 1944.

SPMES 440/269
SUBJECT: Pack Water Filtration Equipment.

TO : The Surgeon General, U. S. Army, Washington 25, D. C. (Thru: The Commanding General, Carlisle Barracks, Pa.).
Attention: Director, Technical Division.

1. Authority - Letter, WD, Office of The Surgeon General, dated 9 May 1944, File SPMDH 414.4-6 (Carlisle Barracks)N.

2. Equipment - The equipment tested consisted of three (3) canvas tanks, (350 gals. capacity), which were used for storage of treated water, or as coagulation and settling basins as the need arose; a 55 g.p.m. gasoline powered pump equipped with cocks on both the volute and suction, for attachment to the feed pot and a core type filter with three types of cores and connecting hose.

The unit was supplied with soda ash briquets and ammonia alum for coagulation; three (3) types of filteraids were provided for the test to assist in filtration. HTH was provided with the equipment to be used on pre and post chlorination work.

3. Tests - The tests of the filtration unit may be divided into two parts; mechanical operation of the unit under field conditions, conducted by the Medical Department Equipment Laboratory, and the bacterial analysis of the water, conducted by the Department of Sanitation, Medical Field Service School.

The unit was first set up and tests conducted to determine the efficiency of each of the cores (carbon, stellar and carborundum) for removal of turbidity and bacteria by direct filtration without the benefit of filteraids. The test was then repeated with the use of filteraids, coagulation and settling, pre and post chlorination.

Attempts were made to obtain some results on highly turbid waters, but this was unsuccessful as no opportunities were presented to run the unit on this type of water.

4. Results of Tests -

a - From the accompanying table of results, it can be seen that the filtration unit passes approximately 10% of the bacteria, no matter which combination of cores or filteraids is used, and that these bacteria must be taken care of by chlorination. Throughout the test, it was noted that the introduction of dirty tanks or cores, definitely threw the results out of line, thereby, indicating a necessity of flushing the tanks before operation, and the cores after operation, with a chlorine wash.

b - On low, turbid waters (below 25 PPM), results were satisfactory, when direct filtration was used; on higher turbidities coagulation and settling should be used.

c - The method of feeding the filteraid from the slurry pat is necessarily variable, due to the variation of the pressure differential between the suction and volute of the pump.

d - Directions for operation of the pump are not explicit, and some difficulty was experienced in getting it to operate at first. All plugs to be removed before operation should be plainly labeled.

e - The hand pump leaves something to be desired, and improvements to ease operation, and to obtain a more even flow of water, would be desirable.

f - The filter unit operated satisfactorily, but an easier change-over from filtration to backwash would be desirable. A larger filter area would also be desirable, inasmuch as some filtration periods, particularly when coagulation was used, were short and the production of the unit was meager.

g - All tanks leaked at the seams throughout the tests. It is understood that this has been corrected by the Engineers.

5 - Conclusions - The pack filtration unit will produce between 300 and 500 gallons of potable water per hour under field conditions. The unit is easily packed and carried on the pack boards and is more easily operated by inexperienced personnel than the sand filtration unit previously used.

6 - Recommendations - It is recommended that the pack water purification unit be approved for use pursuant to the changes desired in 4c, d, e, and f above, and that consideration be given to flushing all tanks and cores with a chlorine wash.

E. D. Quinnell
Colonel, Medical Corps
Director

4 Incls.
Incl 1 - MDEL Photo #T-179 (in quad.)
Incl 2 - MDEL Photo #T-180 (in quad.)
Incl 3 - Test Questionnaire (in quad.)
Incl 4 - Report on Bacterial Analysis, Dept of Sanitation, MFSS (in quad.)

[illegible] JUL 1944

DIRECT FILTRATION
NO AID ADDED

CARBON	CARBORUNDUM	STELLAR
Flow Total - 155 gals	Flow Total - 685 gals	Flow Total - 853 gals
Flow Ave - 15.5 g.p.m.	Flow Ave - 22.8 g.p.m.	Flow Ave - 28.4 g.p.m.
Init Turb - 20 p.p.m.	Init Turb - 20 p.p.m.	Init Turb - 18 p.p.m.
Turb Red - 95%	Turb Red - 10%	Turb Red - 5%
Bact Red - 55%	Bact Red - 42%*increase	Bact Red - 36%*increase
*Increases caused by unsterile cores, bacterial building up in cores.		

DIRECT FILTRATION

CARBON SUPERCEL	CARBON SORBOCEL	CARBON DICALITE
Flow Total - 300 gals	Flow Total - 245 gals	Flow Total - 397 gals
Flow Ave - 10 g.p.m.	Flow Ave - 8.16 g.p.m.	Flow Ave - 13.2 g.p.m.
Init Turb - 27 p.p.m.	Init Turb - 5 p.p.m.	Init Turb - 6 p.p.m.
Turb Red - 100%	Turb Red - 100%	Turb Red - 100%
Bact Red - 86.8%	Bact Red - 96.03%	Bact Red - 99.5%
STELLAR SUPERCEL	STELLAR SORBOCEL	STELLAR DICALITE
Flow Total - 440 gals	Flow Total - 305 gals	Flow Total - 159 gals
Flow Ave - 14.67 g.p.m.	Flow Ave - 10.26 g.p.m.	Flow Ave - 7.95 g.p.m.
Init Turb - 6 p.p.m.	Init Turb - 23 p.p.m.	Init Turb - 6 p.p.m.
Turb Red - 100%	Turb Red - 100%	Turb Red - 100%
Bact Red - 83%	Bact Red - 91.2%	Bact Red - 97.5%
CARBORUNDUM SUPERCEL	CARBORUNDUM SORBOCEL	CARBORUNDUM DICALITE
Flow Total - 460 gals	Flow Total - 325 gals	Flow Total - 163 gals
Flow Ave - 15.3 g.p.m.	Flow Ave - 10.8 g.p.m.	Flow Ave - 8.1 g.p.m.
Init Turb - 10 p.p.m.	Init Turb - 10 p.p.m.	Init Turb - 17 p.p.m.
Turb Red - 100%	Turb Red - 100%	Turb Red - 100%
Bact Red - 80.7%	Bact Red - 94.1%	Bact Red - 84.7%

COAGULATION & SETTLING

CARBON SUPERCEL	CARBON SORBOCEL	CARBON DICALITE
Flow Total - 220 gals	Flow Total - 85 gals	Flow Total - 130 gals
Flow Ave - 11 g.p.m.	Flow Ave - 8.5 g.p.m.	Flow Ave - 6.5 g.p.m.
Init Turb - 20 p.p.m.	Init Turb - 20 p.p.m.	Init Turb - 20 p.p.m.
Turb Tank - 6 p.p.m.	Turb Tank - 4 p.p.m.	Turb Tank - 6 p.p.m.
Red by Set - 65%	Red by Set - 80%	Red by Set - 65%
Total Turb Red - 100%	Total Turb Red - 100%	Total Turb Red - 100%
Bact Red - 92.5%	Bact Red - 99.89%	Bact Red - 88.3%
STELLAR SUPERCEL	STELLAR SORBOCEL	STELLAR DICALITE
Flow Total - 245 gals	Flow Total - 160 gals	Flow Total - 180 gals
Flow Ave - 12.3 g.p.m.	Flow Ave - 8.0 g.p.m.	Flow Ave - 9.0 g.p.m.
Init Turb - 4 p.p.m.	Init Turb - 4 p.p.m.	Init Turb - 4 p.p.m.
Turb Tank - 1 p.p.m.	Turb Tank - 2 p.p.m.	Turb Tank - 1 p.p.m.
Red by Set - 75%	Red by Set - 50%	Red by Set - 75%
Total Red - 100%	Total Red - 100%	Total Red - 100%
Bact Red - 90.4%	Bact Red - 99.53%	Bact Red - 97.2%

CARBORUNDUM SUPERCEL	SORBOCEL	DICALITE
Flow Total - 200 gals	Flow Total - 190 gals	Flow Total - 150 gals
Flow Ave - 10 g.p.m.	Flow Ave - 9.5 g.p.m.	Flow Ave - 7.5 g.p.m.
Init Turb - 4 p.p.m.	Init Turb - 4 p.p.m.	Init Turb - 4 p.p.m.
Turb Tank - 1 p.p.m.	Turb Tank - 1 p.p.m.	Turb Tank - 1 p.p.m.
Red by Set - 75%	Red by Set - 75%	Red by Set - 75%
Total Red - 100%	Total Red - 100%	Total Red - 100%
Bact Red - 197%*	Bact Red - 113%*	Bact Red - 1285%*
*Tanks dirty, not cleaned - Cores not sterilized with Cl2		

POST CHLORINATION, DIRECT FILTRATION

STELLAR DICALITE DIRECT	CARBON DICALITE DIRECT
Flow Total - 110 gals	Flow Total - 335 gals
Flow Ave - 5.5 g.p.m.	Flow Ave - 11.1 g.p.m.
Init Turb - 52 p.p.m.	Init Turb - 27 p.p.m.
Turb Red - 100%	Turb Red - 100%
Init Bact - 3000	Init Bact - 1250
Bact Red Filt - 97%	Bact Red Filt - 98.7%
Bact Red Cl_2 - 3%	Bact Red Cl_2 - 1.3%
Total Bact Red - 100%	Total Bact Red - 100%
NO CARBORUNDUM TESTS RUN	

POST CHLORINATION COAGULATION

CARBON CORE SUPERCEL	CARBORUNDUM SORBOCEL
Flow Total - 215 gals	Flow Total - 190 gals
Flow Ave - 7.2 g.p.m.	Flow Ave - 9.5 g.p.m.
Init Turb - 12 p.p.m.	Init Turb - 10 p.p.m.
Turb Tank - 7 p.p.m.	Turb Tank - 4 p.p.m.
Turb Red Set - 41%	Turb Red Set - 60%
Total - 100%	Total - 100%
Bact Init - 4050	Bact Init - 4500
Bact Tank - 20,300*	Bact Tank - 2400
Bact Red Set -	Bact Red Set - 53.3%
Bact Red Filt - 25%	Bact Red Filt - 33.3%
Bact Red Cl_2 - 74.66%	Bact Red Cl_2 - 13.4%
Total - 99.66%	Total - 100%
* TANK NOT CLEANED	

PRE & POST CHLORINATION WITH COAGULATION

STELLAR SUPERCEL

Flow Total - 120 gals
Flow Ave - 6.0 g.p. m.
Init Turb - 9 p.p.m.
Tank Turb - 7 p.p.m.
Red by Set - 22%
Total Red - 100%
Init Bact - 2000
Bact Tank #1 - 1810
Red by pre Cl_1 & Set - 10%
Bact Tank #2 - 9320*
Red by Filt -
Bact Final - 70
Red by post chlorination - 86.5%
Total Red - 96.5%
* TANK NOT CLEANED

APPENDIX C

SPECIFICATIONS AND SET LISTS, 15-GPM FILTER

Item		Page
Corps of Engineers (Engineer Board) Tentative Specification EBP No. 652A, "Water Purification Unit, Pack Model, M-1", with Drawings L 5104-1 to -15 attached.		
Fig. 11.	Equipment Recommended for Standardization as Water Purification Equipment, Diatomite, Pack, (Man or Animal Type), 15-GPM Set No.___.	147
Fig. 12.	15-GPM Diatomite Water Purification Set, "Individual Man Pack Loads".	153
Fig. 13.	5-GPM Pack Water Purification Set (Service Tested), "Components of 5-GPM Water Purification Equipment Carried in Packs."	156

CORPS OF ENGINEERS
(ENGINEER BOARD)
TENTATIVE SPECIFICATION

EBP No. 652A
15 July 1944
Superseding EBP No. 652
Dated 1 June 1944

WATER PURIFICATION UNIT, PACK MODEL, M-1

A. APPLICABLE SPECIFICATIONS AND DRAWINGS.

A-1. Specifications. - The following specifications of the issue in effect on date of invitation for bids, unless otherwise indicated, form a part of this specification, except that in case of conflict, the requirements of this specification shall govern.

A-1a. Federal Specifications:

QQ-A-359 - Aluminum-Alloy (Al-3) (Aluminum Manganese); Plates and Sheets.

QQ-A-601 - Aluminum-Base-Alloys; Sand Castings.

QQ-S-763 - Steel, Corrosion-Resisting; Bars and Forgings (Except for Reforging).

QQ-S-766 - Steel, Corrosion-Resisting, Plates, Sheets, Strips, and Structural Shapes.

CCC-D-771 - Duck; Cotton, Plied-Yarns (Army, Numbered & Tent-Duck).

GGG-P-471 - Pliers and Nippers.

GGG-W-631 - Wrenches, Bolt and Nut; Adjustable, Open-End.

A-1b. U. S. Army Specifications, Nos.:

57-180 - Tubing, Round, Mechanical and Structural, Steel, Carbon and Alloy, Seamless, Welded, and Brazed.

100-17 - Mildew-Proofing of Fabrics, Threads and Cordage, Copper Processes.

A-1c. Corps of Engineers Tentative Specifications, Nos.:

T-1184 - General Specification for Finishing, Treating and Painting.

T-1483 - Maintenance Manuals and Spare Parts Catalogs for Engineer Equipment.

T-1739 - Standard Requirements for Marking Corps of Engineers Shipments.

A-2. Drawings. - The following drawings of the issue in effect on date of invitation for bids form a part of this specification:

A-2a. Corps of Engineers Drawings, Nos.:

D 5104-1 to 15 inclusive - Water Purification Unit, Pack Model, M-1.

B. TYPE.

B-1. This specification covers one type of water purification equipment unit which can be carried by man or pack animal.

C. MATERIAL AND WORKMANSHIP.

C-1. Material. - The material used in the construction of the equipment shall be as specified herein and as shown on the applicable drawings. Material not definitely specified shall be of the best quality normally used in good commercial practice for this type of work. Material shall be free from all defects and imperfections that might affect the serviceability of the finished product.

C-1a. Aluminum-Alloy Sheet. - Shall conform to Federal Specification QQ-A-359, type 1, finish II, condition A, 1/2 H or 3/4 H.

C-1b. Aluminum-Alloy Castings. - Shall conform to Federal Specification QQ-A-601, class 2.

C-1c. Steel Tubing. - Shall conform to U. S. Army Specification No. 57-180, type I, class A, as rolled condition, W.D. No. 1010 to 1035.

C-1d. Stainless Steel Rods. - Shall conform to Federal Specification QQ-S-763, class 7, type A.

C-1e. Stainless Steel Sheet. - Shall conform to Federal Specification QQ-S-766, class 1, condition a, finish 4 on one side only.

C-1f. Cotton Duck for Covers and Accessories. - Shall conform to Federal Specification CCC-D-771, type I, No. 10, which shall be mildew-proofed in accordance with U. S. Army Specification No. 100-17, type I.

C-1g. Plastic. - Shall be a material which has good dimensional stability in contact with water and one which will not darken appreciably or otherwise lose its transparency on exposure. The material shall also be resistant to the action of hypochlorite and other chemicals used in water treatment.

C-1h. Gasket Material. - Shall be made of synthetic rubber suitably compounded to withstand mild chemical solutions customarily used in water treatment.

C-2. Workmanship. - Shall be of the highest grade throughout.

D. GENERAL REQUIREMENTS.

D-1. See Section E.

E. DETAIL REQUIREMENTS.

E-1. Description. - The water purification unit covered by this specification shall consist primarily of a pressure filter, a diatomaceous silica slurry feeding apparatus, two gasoline-engine driven pumping sets, a hand pump, a chlorination set, a pH test kit, hoses, fittings and such other auxiliary equipment as listed herein or shown on the drawings.

E-2. Filter. - The filter shall be constructed as shown on the drawings. The shell shall be fabricated by welding or by spinning at the option of the contractor. The filter, assembled without the filter septums shall withstand an internal hydrostatic pressure of 75 pounds per square inch without evidence of seepage. No sealing material shall be used on the head casting.

E-2a. Pressure Gage. - The filter shall be equipped with a pressure gage as shown on the drawings. The face of the gage shall be 2 inches in diameter; the face cover shall be of transparent plastic. The gage shall be graduated from 0 to 60 psi.

E-2b. Septum Elements. - Shall be cylindrical in shape and constructed so as to be easily assembled within the filter as indicated on the drawings. Each septum element shall be not more than 12.5 inches long, not more than 2 inches outside diameter, and not less than one inch inside diameter, and each shall have a filter area of not less than 0.50 square feet and not more than 0.55 square feet. The septum shall pass clear water at 70 degrees F. at the rate of 10 gpm per square foot of surface area with a pressure differential not exceeding 0.5 inch of mercury. The filter element shall be sufficiently fine to collect and support uniformly a cake of Johns-Manville Celite No. 535 or finer filter aid when 0.1 pound per square foot is applied as a 1-1/2 percent slurry at the rate of one gpm per square foot. At this rate not more than 10 percent of filter aid shall pass the septum during this precoat operation. Inlet pressure shall be measured in the shell surrounding the elements and the outlet pressure shall be measured in the manifold chamber to which the elements are attached. The elements shall weigh not more than 1.2 pounds each. They shall be constructed of corrosion resisting materials and shall be sufficiently rigid so that pulsating flow from a reciprocating pump will not cause filter aid to pass through the septum. The elements shall withstand ordinary rough handling in position without fracture or deformation at all temperatures from minus 20 degrees F. to plus 150 degrees F. and shall withstand sudden changes of temperature within this range. Design shall be such that an equal flow of water will be obtained through each square inch of effective area during backwashing and filtration at the rate of 10 gpm per square foot of filter area. The elements shall be readily disassembled and cleaned with the hands or by use of a brush or simple tool. The contractor shall furnish to the Contracting Officer for approval a detailed description, including manufacturer's name and address, of the septum element he proposes to supply.

E-3. Slurry Feeding Apparatus. - The feeder shall be of the constant rate dilution type and constructed as shown on the drawings. With a head of two inches of water, the orifice in the head box shall pass an amount of water, in 30 minutes, equal to the usable volume of the slurry tank. The hose and fittings connecting the float chamber to the suction inlet shall have a minimum bore of 1/4 inch.

E-3a. Water Motor. - Shall be capable of maintaining suspension of 1/4 pound of filter aid in 1.7 gallons of water within the slurry tank with a flow of 10 gpm through the water motor. The water motor casing assembled with the impeller and packing gland complete shall withstand an internal pressure of 10 pounds per square inch without leakage.

E-4. Tool Box. - A tool box with hinged cover attached to the feeder tank shall be constructed as shown on the drawings.

E-5. Accessory Pail. - A pail shall be constructed and mounted on the bottom of the slurry tank as shown on the drawings. The pail shall be firmly clamped to the slurry tank.

E-6. Filter Support Frame. - The filter, slurry feeding apparatus, tool box and appurtenances shall be mounted in a steel tube frame as shown on the drawings. This frame shall be fitted with a steel clip for attachment of the frame to a packboard.

E-7. Gasoline Engine Driven Pump Sets. - Two gasoline engine driven pumping sets shall be supplied with each purification set. Each shall consist of a self-priming centrifugal pump, direct connected to a gasoline engine with a pump impeller mounted on an extended crankshaft. The pumping set shall be suitable for continuous duty under severe operating conditions and shall be capable of delivering continuously a minimum of 10 gallons per minute of water against a total dynamic head (including 5 feet of suction lift) of 88 feet; 15 gallons per minute of water against a total dynamic head (including 5 feet of suction lift) of 82 feet; and 30 gallons per minute against a total dynamic head (including 5 feet of lift) of 30 feet. The weight of the pump and engine exclusive of fittings shall not exceed 54 pounds and the overall dimensions of pump and engine shall not exceed 13-1/2 by 16-1/2 by 17-1/2 inches.

E-7a. Gasoline Engine. - Shall be a suitable, modern, 4-cycle air cooled, industrial type that is now in production and in use, and it shall develop not less than 1.2 hp at 3000 rpm. It shall be capable of operating the pump continuously at the required revolutions per minute to meet the head and capacity specified without overheating at an ambient temperature of 100° F. The fuel tank shall have a capacity of not less than 1/2 gallon and the tank shall be equipped with a lock-on filling cap. A suitable fuel filter and shut off cock shall be provided. The engine shall be equipped with radio shielding, shielded spark plugs, Stellite-faced valves and valve seats for operation on high octane gasoline, oil bath air cleaner and a carburetor that has proven satisfactory in commercial use. The engine shall be equipped with a deep base with one quart oil capacity, and this base shall be provided with a float switch which will shut off the engine as the oil level becomes too low. An oil seal shall be provided on the crankshaft and all bolts and nuts shall be wired or staked to the unit. The engine shall be equipped with a locked-on oil dip stick, and the oil breather tube shall be equipped with a readily removable plug. The engine, complete with a full reservoir of oil and a full tank of gas, shall be suitable for carrying in any position without leakage of the gas or oil and without damage to the engine. All aluminum parts shall be treated for corrosion resistance. The engine shall be provided with a rope starter, and a suitable funnel for filling the gas tank.

E-7b. Pump. - Shall be of a centrifugal self-priming type with recirculation cut-off and shall be capable of priming at all suction lifts up to and including 25 feet (corrected for sea level conditions). It shall retain sufficient water in the priming chamber in case the suction hose is vented to the atmosphere to enable the pump to reprime itself quickly as soon as the suction hose is again immersed in the water. The priming chamber shall be a part of the pump housing. The pump housing shall be provided with a suitable means of clean out and a means of drainage. The pump seal shall be of an approved type with grease being admitted between the two wearing surfaces, and it shall effectively seal the pump against both vacuum and pressure conditions. Adequate provision shall be made to insure that leakage from the pump seal cannot enter the motor bearing. All aluminum parts of the pump shall be treated for maximum resistance to corrosion, and all other metal parts shall be constructed of corrosion resistant material. The pump shall have a 1-1/2-inch threaded female suction port and a 1-1/4 inch discharge port and shall be equipped with fittings as shown on the drawings.

E-7c. Pumping Set Support Frame. - The pumping set shall be mounted in a steel tube frame as shown on the drawings. The frames shall be fitted with a steel clip for attachment of the frame to the packboard.

E-8. Hose. - Shall be smooth bore, reinforced rubber hose of 1-1/4 inch inside diameter. Six 10-foot lengths and two 5-foot lengths of hose equipped with fittings as hereinafter described shall be supplied with each set. The construction shall be as follows: (a) an inner rubber tube of 0.060-inch minimum wall thickness, (b) a layer of cotton duck, (c) a helix of 0.060-inch minimum diameter spring wire having 1/2-inch spacing and rubber filling between the coils, (d) layers of cotton duck, (e) an outer rubber cover of 0.035-inch minimum thickness. Hose ends shall be capped with the same rubber compound that is used for the tube.

E-8a. Rubber Compound. - Shall be a compound of reclaimed rubber and GRS synthetic rubber suitable for the purpose. At least 60 percent of the total rubber hydrocarbon shall be GRS synthetic rubber.

E-8b. Cotton Duck. - Shall be a 10-ounce-per-square-yard duck which shall be well, evenly, and firmly woven, as free from dirt, knots, lumps and other defects as is consistent with the best manufacturing practice. The layers shall be applied on a bias of 45°, with the edges overlapped at least 1/2 inch (not sewed), and shall be well impregnated with the rubber compound.

E-8c. Fittings. - The hoses shall be fitted with galvanized steel or brass clamps, and standard pin lug hose couplings having straight iron pipe threads. All female couplings shall be equipped with flat rubber hose washers. Fittings shall be as follows:

Six 10-foot hoses - male and female couplings.

Two 5-foot hoses - female and female couplings.

E-9. Hose Attachments. - Two suction strainers and one sanitary nozzle constructed as shown on the drawings and one gross of flat rubber hose washers shall be provided with each water purification unit.

E-10. Chlorination Set. - One chlorination set shall be furnished with each water purification unit. It shall consist of a chlorine comparator, a chlorine test case, a measuring cup, a chemical basket, a hypochlorite scoop, a funnel, and a pH test set. An accessory bag constructed of cotton duck and suitable for carrying the chlorination set shall be furnished.

E-10a. Chlorine Comparator. - Shall consist of a plastic holder or base fitted with four permanent glass color standards indicating 0.5, 1.0, 1.5, and 2.0 parts per million of residual chlorine. It shall have 3 compartments for viewing the test samples. Three suitable square or rectangular glass tubes, a plastic stirring rod 4-3/8 inches long by 1/4 inch diameter, and 2 vials of orthotolidine tablets shall be provided with the comparator.

E-10a(1). Orthotolidine Tablets. - Shall be packaged 200 to a vial. Each tablet shall contain not less than 0.6 mg. of orthotolidine dihydrochloride, and sufficient acidfying agent to adjust 10 mL of water of high alkalinity (1000 ppm as $CaCO_3$) to a pH of 3 or less. The vials shall be of transparent plastic and shall have plastic screw caps. They shall be not more than 1-1/4 inches outside diameter by 3-1/2 inches long. The following instructions shall be printed on each vial:

INSTRUCTIONS FOR USE

(1). Clean all three sample tubes and fill two tubes to the mark with water to be tested, place these tubes in the two outer compartments of the comparator.

(2). To the third tube add a few drops of the water to be tested and one orthotolidine tablet. Crush the tablet with the stirring rod, then fill the sample tube to the mark and mix thoroughly by placing clean dry portion of the hand over top of the tube and inverting a few times. Place this tube in the center compartment of the comparator. Allow five to ten minutes for maximum color to develop.

(3). Compare developed color in center tube with the glass color standards.

(4). Field water supplies should contain one part per million of residual chlorine.

E-10b. pH Test Kit. - Shall consist of one glass vial provided with suitable cover and containing 200 strips of Phenophthazine (sodium dinitrophenylazo-naphthol disulfonate) paper.

E-10b(1). Test Paper. - The paper shall be sensitive to N/10,000 acid or alkali. It shall change in color to yellow at pH 4, to mustard at pH 5, to olive at pH 6, to gray blue at pH7, to blue at pH 8, and to purple at pH 9.

E-10b(2). Container. - The container shall be a vial of clear glass measuring not more than 1-1/4 inches in diameter, not more than 3-1/2 inches in length. A color chart showing the colorimetric comparisons for pH readings of 4.0, 5.0, 5.5, 6.0, 6.5, 7.0, and 8.0 shall be provided on the inside of the vial in such position as to permit comparisons of the test sample with the color chart. Instructions for the use of the test kit shall be printed on the container and shall be substantially as follows:

(1). Fill chlorine comparator tube 1/4 full with water sample.

(2). Drop in one paper and shake until full color develops.

(3). Compare sample with color chart.

(4). To increase floc above pH 6, increase alum.

(5). To increase floc below pH 6, add soda ash (and increase alum if required).

E-10c. Chlorine Test Case. - Shall be constructed of fiberboard and shall be suitable for carrying the chlorine comparator and the pH test set.

E-10d. Measuring Cup, Hypochlorite Scoop, and Chemical Basket. - Shall be constructed as indicated on the drawings.

E-11. Accessories. - One 10-quart capacity collapsible cotton duck pail and necessary hand tools suitable for cleaning the septum elements shall be provided.

E-12. Finish and Painting. - All parts of the equipment normally painted in good commercial practice shall be finished and painted in accordance with the applicable requirements of Corps of Engineers Tentative Specification No. T-1184, type IV.

E-13. Field Erection Tools. - One set of field erection tools shall be furnished with each water purification unit. The tools shall be placed in a cotton duck tool roll, constructed suitable for packing in the tool box on the filter unit. The tools shall consist of the following:

Quantity	Unit	Item	Specification
1	ea.	Pliers, combination, slip joint.	Federal Specification GGG-P-471, type F, 6 inch.
1	ea.	Screwdriver, 4 inch, offset.	As shown on drawing No. 5104-12.
1	ea.	Wrench, 9 inch, auto.	Federal Specification GGG-W-631, type II, 9 inch.
1	ea.	Wrench, 6 inch, adjustable end.	Federal Specification GGG-W-631, type I, class A, 6 inch.
1	ea.	Wrench, socket - with detachable, sliding head tee handle. Wrench to have 1/2 inch hex socket and 3/8 inch square drive hole.	Commercial.

E-14. Covers. - The filter support frame and the pumping set support frames shall be provided with suitable covers fabricated from cotton duck.

E-15. Filter Aid Bag. - Two cotton duck bags for carrying filter aid and miscellaneous items shall be provided. Each bag shall be approximately 15 inches by 24 inches by 10 inches in size and shall be provided with a drawstring closure.

E-16. Manufacturer's Nameplates. - Filter unit and pumping sets shall have manufacturer's name and address as well as any other information usually included on this type of equipment. In lieu of the nameplate, the information may be cast integrally with, stamped upon, or otherwise permanently marked upon the item of equipment.

E-17. Spare Parts and Maintenance Tools. - A set of spare parts and maintenance tools, contained in a suitable tool box (or boxes) shall be furnished with each water purification set in accordance with lists to be furnished by the Contracting Officer.

E-18. Items to be Included with Prime Equipment. - No shipment of prime equipment shall be made unless spare parts, maintenance tools, erection tools and accessories are included with the shipment or unless written approval for shipment of the prime equipment without such items has been received from the Contracting Officer.

E-19. Maintenance Manuals and Spare Parts Catalogs. - The contractor shall furnish maintenance manuals and spare parts catalogs covering the description, adjustment, maintenance, lubrication, and spare parts lists for all equipment furnished. The cover of each manual shall state the name and model, manufacturer's name, date of approval of the manual, title of the manual and serial numbers to which the spare parts catalog applies. (The name will be as furnished by the Contracting Officer, in accordance with standard nomenclature). A preliminary dummy manuscript made up of typewritten sheets, clippings, photographs, sketches and other suitable material will be forwarded to the Contracting Officer for approval. After preliminary approval, proof sample copies, in duplicate, of the Maintenance Manual and Parts Catalog, will be forwarded with each unit, and two additional copies per unit plus manuals to the total required by the contract or invitation to bid, which will be determined by the spare parts lists for the machine, will be shipped to the Engineer Supply Officer, Columbus Quartermaster Depot, marked, "Attention: Spare Parts Branch." When specifically called for in the invitation to bid or the contract, these manuals shall conform to Corps of Engineers Tentative Specification T-1483.

F. METHODS OF INSPECTION AND TESTS.

F-1. Inspection. - Equipment furnished under this specification shall be subject to inspection, during and after the process of manufacture, by authorized Government Inspectors, who shall be afforded proper facilities for determining compliance with the specification.

F-2. Tests. - Equipment furnished under this specification shall be given such tests as may be necessary to determine compliance with the specification requirements. When tests are to be made at the site of manufacture, the contractor shall provide all necessary facilities and supplies required for the testing procedure.

G. PACKING AND MARKING FOR SHIPMENT.

G-1. Packing. - The subject commodity shall be packed for shipment in accordance with instructions issued by the Contracting Officer.

G-2. Marking. - The marking of shipping containers of the subject commodity shall conform to the requirements of Corps of Engineers Tentative Specification T-1739, except as may be modified by the Contracting Officer.

H. NOTES.

H-1. Copies of this specification and other Corps of Engineers (Engineer Board) Tentative Specifications and Corps of Engineers drawings may be obtained from the Specifications Section, The Engineer Board, Fort Belvoir, Virginia, except that requests by offices of the Corps of Engineers should be addressed to the Procurement Division, Office, Chief of Engineers. Other specifications and drawings listed herein may be obtained from the following applicable addresses.

Federal Specifications - Superintendent of Documents,
Washington, D. C.

U. S. Army and Corps of Engineers Tentative Specifications - Army Service Forces, Office of the Chief of Engineers, Washington, 25, D. C.

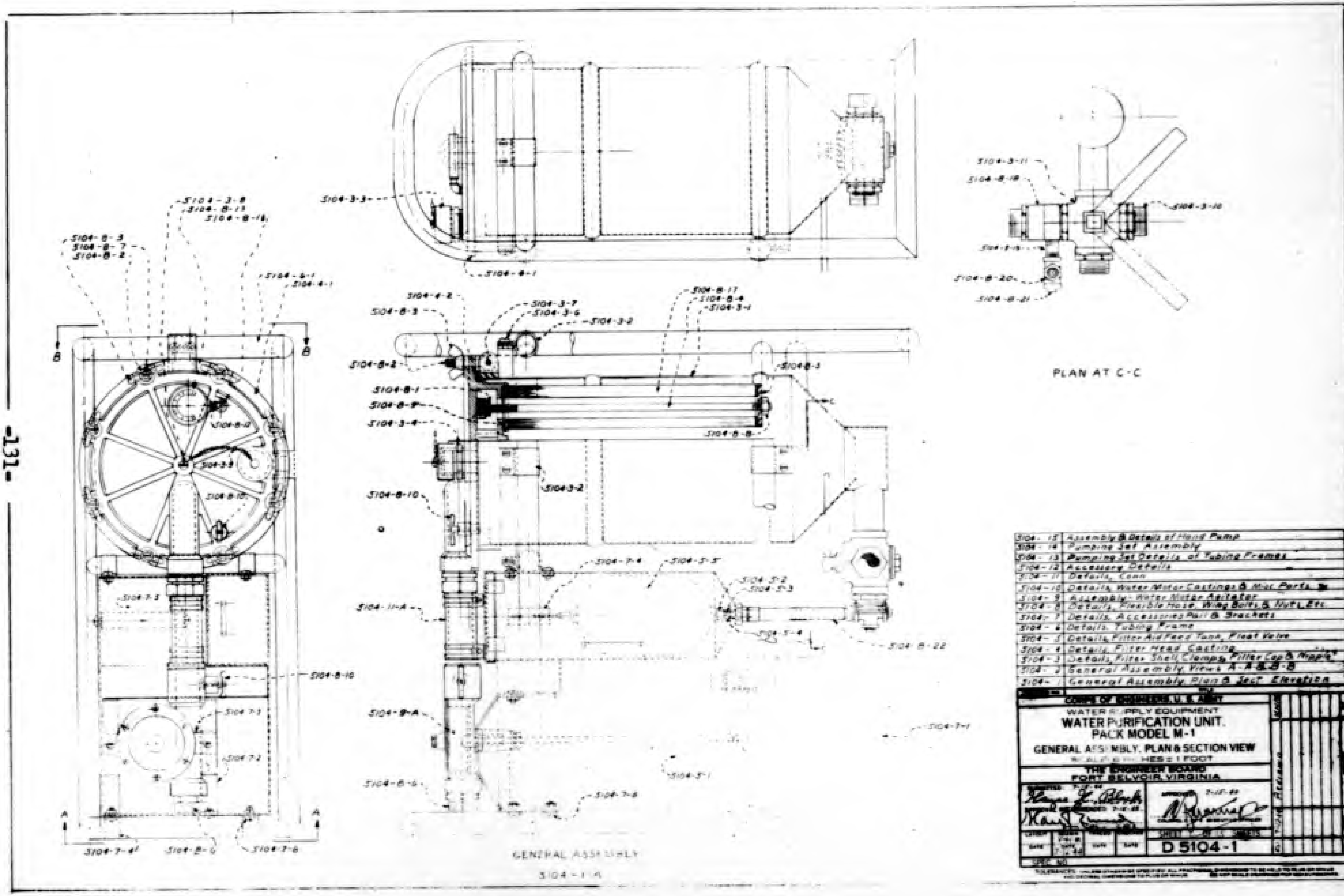
H-2. A known septum element meeting the requirements of paragraph E-2b is Stellar Element No. 52-2 as manufactured by Infilco, Inc., Chicago, Illinois. Information concerning other commercial products which meet the requirements of paragraph E-2b may be obtained from The Engineer Board, Fort Belvoir, Virginia.

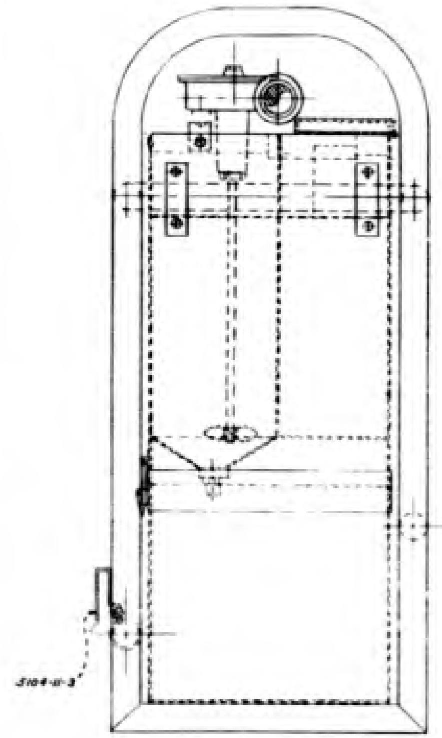
H-3. The Contracting Officer will furnish, with the invitation for bids, lists of spare parts and tools to be provided with the equipment.

H-4. Engineer Board Tentative Specifications are ad interim specifications which are intended to be converted to Corps of Engineers Tentative Specifications. They are used for the procurement of engineer equipment during development, and for the purpose of making recommendations to the Office, Chief of Engineers. They should not be accepted as indorsed by the Corps of Engineers or the Engineer Board for quantity procurement, unless accompanied by specific instructions as to their use.

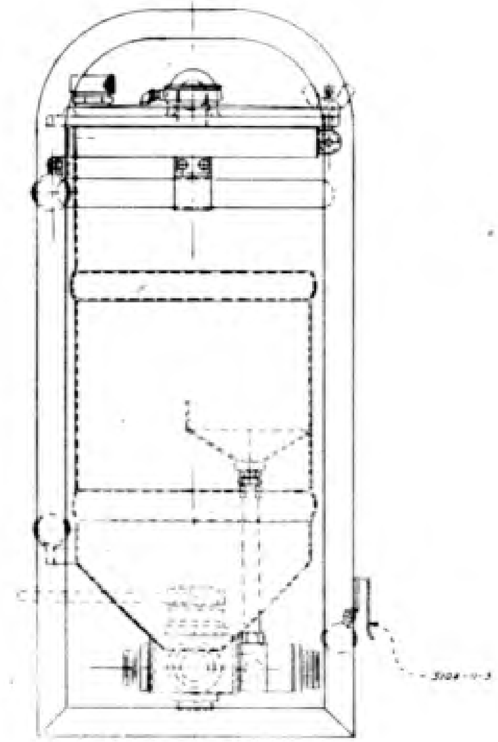
NOTICE. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

- - - - - -


PLAN AT C-C
GENERAL ASSEMBLY
5104-1-A
5104- 15 Assembly & Details of Hand Pump
5104- 14 Pumping Set Assembly
5104- 13 Pumping Set Details of Tubing Frames
5104- 12 Accessory Details
5104- 11 Details, Conn
5104- 10 Details, Water Motor Castings & Misc Parts
5104- 9 Assembly - Water Motor Agitator
5104- 8 Details, Flexible Hose, Wing Bolts & Nuts, Etc.
5104- 7 Details, Accessories Rail & Brackets
5104- 6 Details, Tubing Frame
5104- 5 Details, Filter Aid Feed Tank, Float Valve
5104- 4 Details, Filter Head Casting
5104- 3 Details, Filter Shell, Clamps, Filter Cap & Nipple
5104- 2 General Assembly Views A-A & B-B
5104- 1 General Assembly Plan & Sect. Elevation
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT.
PACK MODEL M-1
GENERAL ASSEMBLY, PLAN & SECTION VIEW
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-1

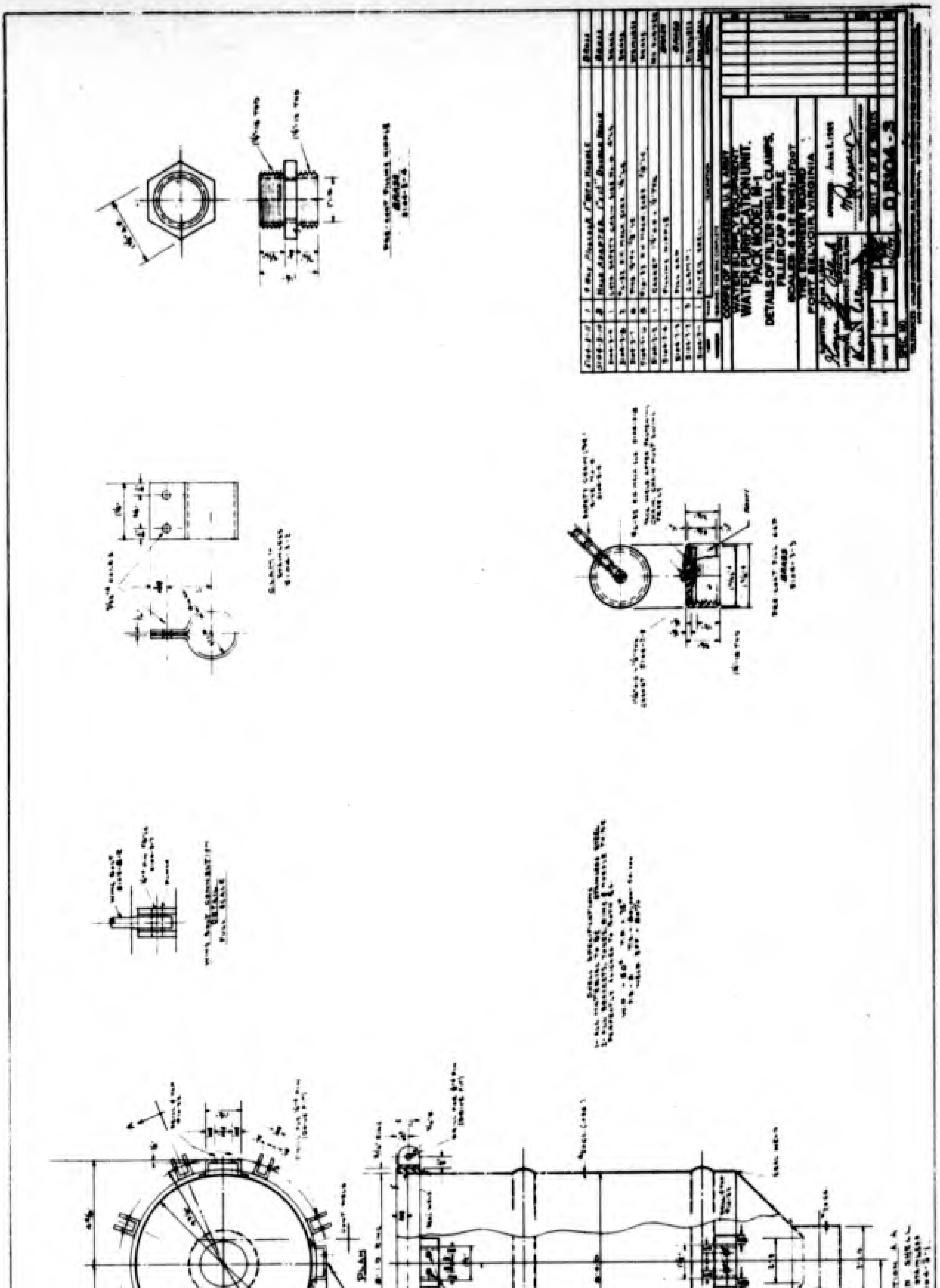


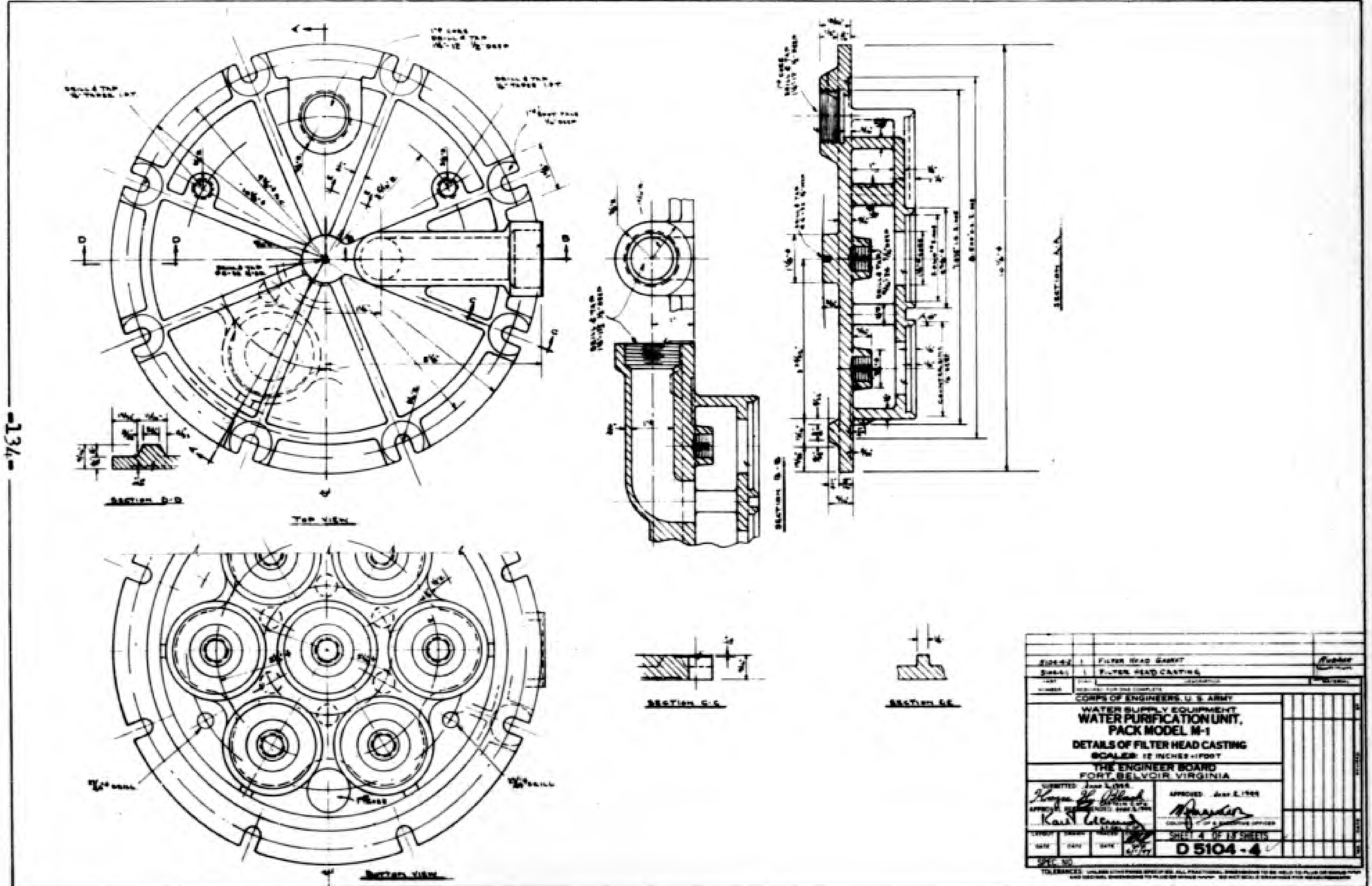
VIEW A-A

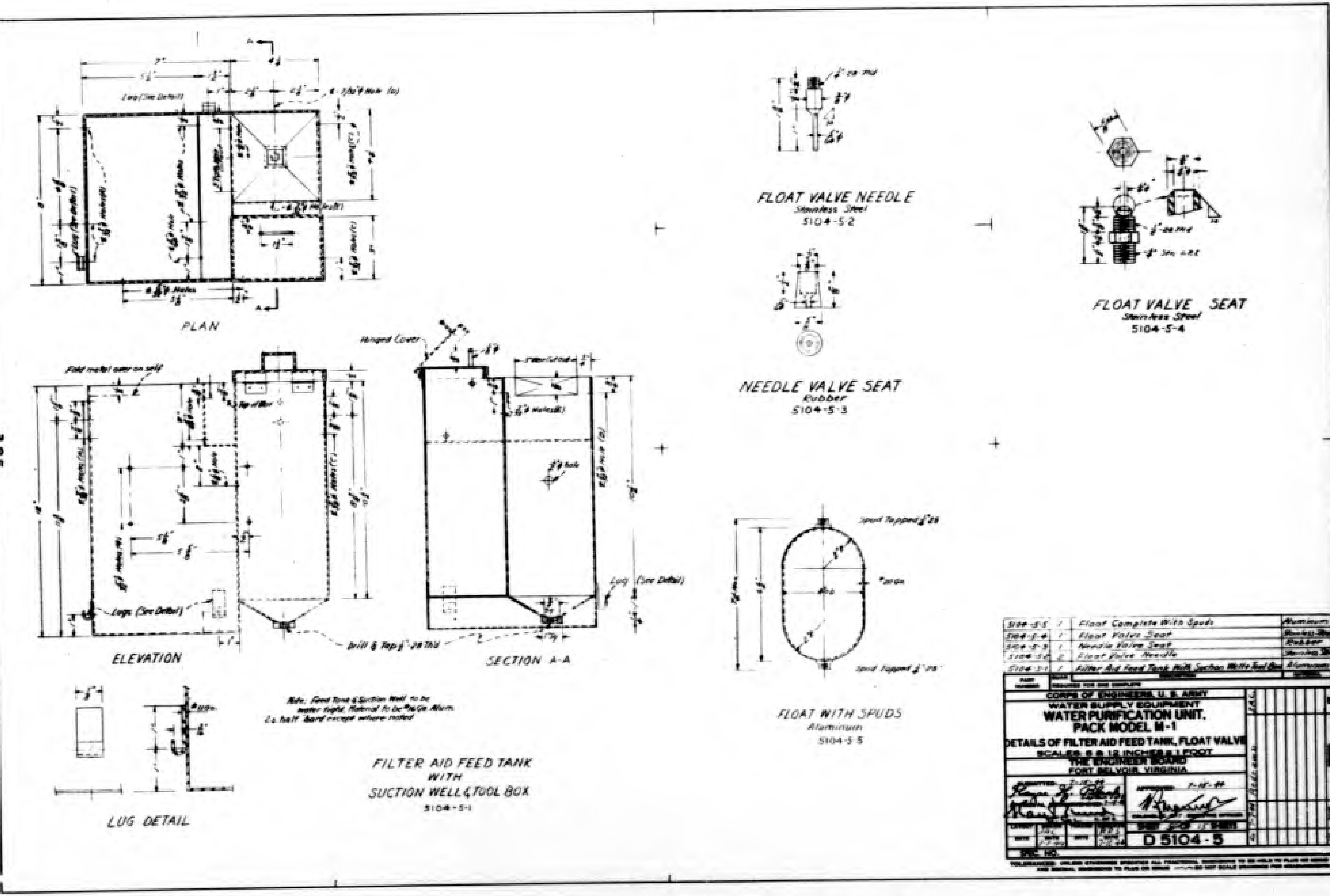


VIEW B-B

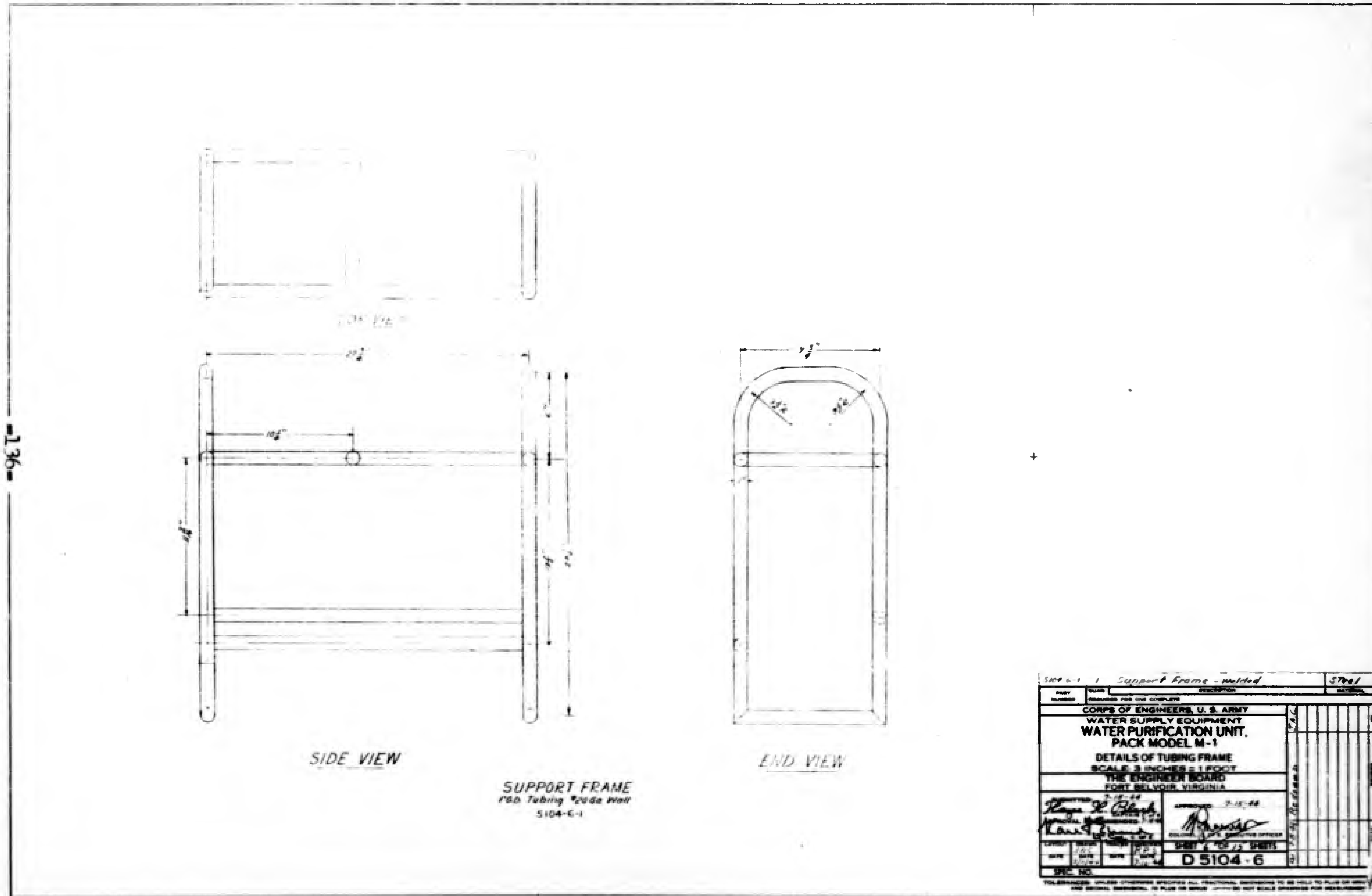
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT, PACK MODEL M-1
GENERAL ASSEMBLY VIEWS AA & BB
SCALE: 6 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-2

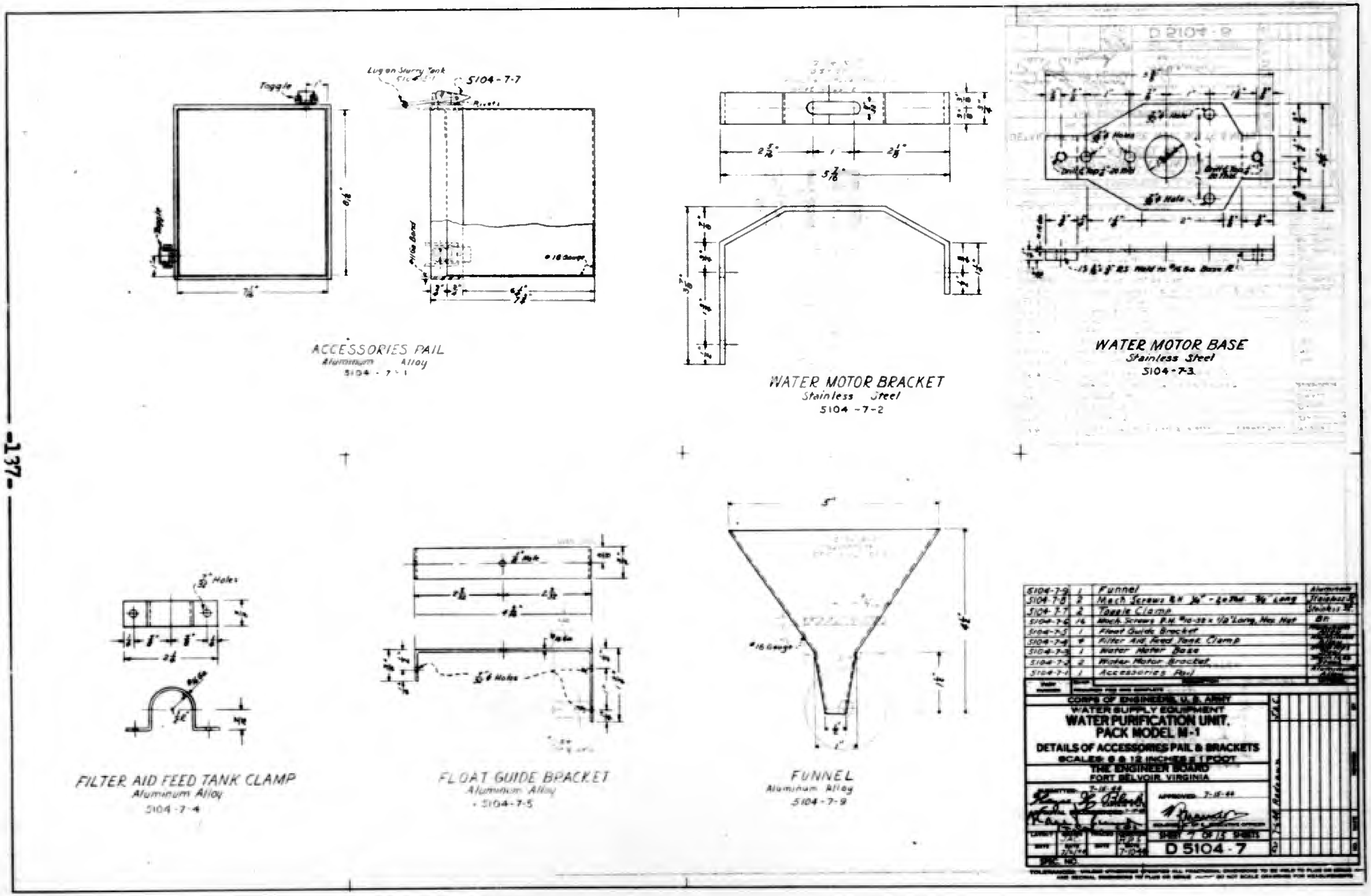


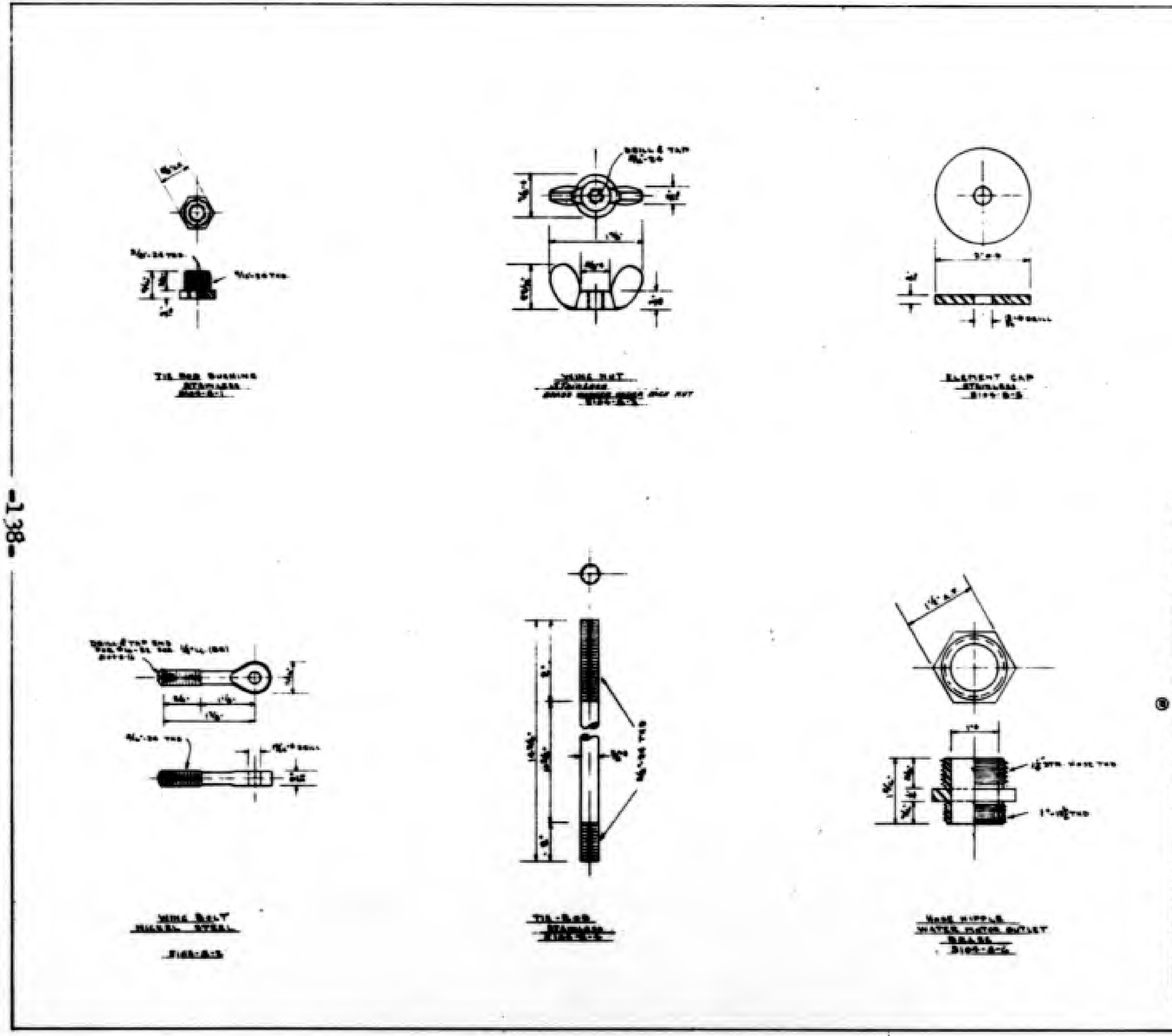

TOP VIEW
BOTTOM VIEW
SECTION D-D
SECTION B-B
SECTION A-A
SECTION C-C
SECTION E-E
FILTER HEAD GASKET
FILTER HEAD CASTING
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
DETAILS OF FILTER HEAD CASTING
SCALE: 12 INCHES=1FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
SHEET 4 OF 13 SHEETS
D 5104-4
SPEC. NO.



PLAN
ELEVATION
SECTION A-A
LUG DETAIL
Hinged Cover
Fold metal over on self
Lugs (See Detail)
Lug (See Detail)
Drill & Tap 1/8" 28 Thd
Note: Feed Tank & Suction Well to be water tight. Material to be #16 Ga. Alum. 1/2 half hard except where noted
FILTER AID FEED TANK
WITH
SUCTION WELL & TOOL BOX
5104-5-1
FLOAT VALVE NEEDLE
Stainless Steel
5104-5-2
NEEDLE VALVE SEAT
Rubber
5104-5-3
FLOAT VALVE SEAT
Stainless Steel
5104-5-4
FLOAT WITH SPUDS
Aluminum
5104-5-5
Spud Tapped 1/8" 28
5104-5-5 1 Float Complete With Spuds Aluminum
5104-5-4 1 Float Valve Seat Stainless Steel
5104-5-3 1 Needle Valve Seat Rubber
5104-5-2 1 Float Valve Needle Stainless Steel
5104-5-1 1 Filter Aid Feed Tank With Suction Well & Tool Box Aluminum
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
DETAILS OF FILTER AID FEED TANK, FLOAT VALVE
SCALES: 6 & 12 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-5


SIDE VIEW
END VIEW
SUPPORT FRAME
F&D Tubing #20 Ga Wall
5104-C-1
Support Frame - Welded
Steel
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
DETAILS OF TUBING FRAME
SCALE 3 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-6


ACCESSORIES PAIL
Aluminum Alloy
5104-7-1
Toggle
Lug on Slurry Tank
5104-7-7
Rivets
#16 Gauge
WATER MOTOR BRACKET
Stainless Steel
5104-7-2
WATER MOTOR BASE
Stainless Steel
5104-7-3
FILTER AID FEED TANK CLAMP
Aluminum Alloy
5104-7-4
FLOAT GUIDE BRACKET
Aluminum Alloy
5104-7-5
FUNNEL
Aluminum Alloy
5104-7-9
#16 Gauge
5104-7-9 1 Funnel
5104-7-8 2 Mach Screws
5104-7-7 2 Toggle Clamp
5104-7-6 16 Mach Screws
5104-7-5 1 Float Guide Bracket
5104-7-4 4 Filter Aid Feed Tank Clamp
5104-7-3 1 Water Motor Base
5104-7-2 2 Water Motor Bracket
5104-7-1 1 Accessories Pail
CORPS OF ENGINEERS, U.S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
DETAILS OF ACCESSORIES PAIL & BRACKETS
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-7



Part Number	Req.	Description	Material
5104-B-22	1	Hose ¾" with Male & Female Connections	Rubber
5104-B-21	2	Plugs ¾"	Brass
5104-B-20	1	Cross ¾"	Brass
5104-B-19	1	Nipple ¾"	Brass
5104-B-18	1	Adapter 1" with ¾" Side Outlet	Aluminum
5104-B-17	7	Filter Septum (Elements)	
[illegible]	6	[illegible]	[illegible]
[illegible]	1	Hose Nipple [illegible]	[illegible]
[illegible]	1	Gate Valve 1" [illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]
[illegible]	1	Bushing [illegible]	[illegible]
[illegible]	1	Street Ell [illegible]	[illegible]
[illegible]	2	[illegible]	[illegible]
[illegible]	14	Element Gasket [illegible]	Rubber
[illegible]	7	Hex. Nuts [illegible]	St. Steel
[illegible]	8	Flat Washers [illegible]	Brass
[illegible]	1	Hose Nipple [illegible]	[illegible]
[illegible]	7	Element Caps	St. Steel
[illegible]	7	Tie-Rods	St. Steel
[illegible]	8	Wing Nuts	St. Steel
[illegible]	8	Wing Bolts with S.S. Bush. Inserted	Ni. Stl.
[illegible]	7	Tie-Rod Bushings	St. Steel

CORPS OF ENGINEERS, U.S. ARMY

WATER SUPPLY EQUIPMENT

WATER PURIFICATION UNIT, PACK MODEL M-1

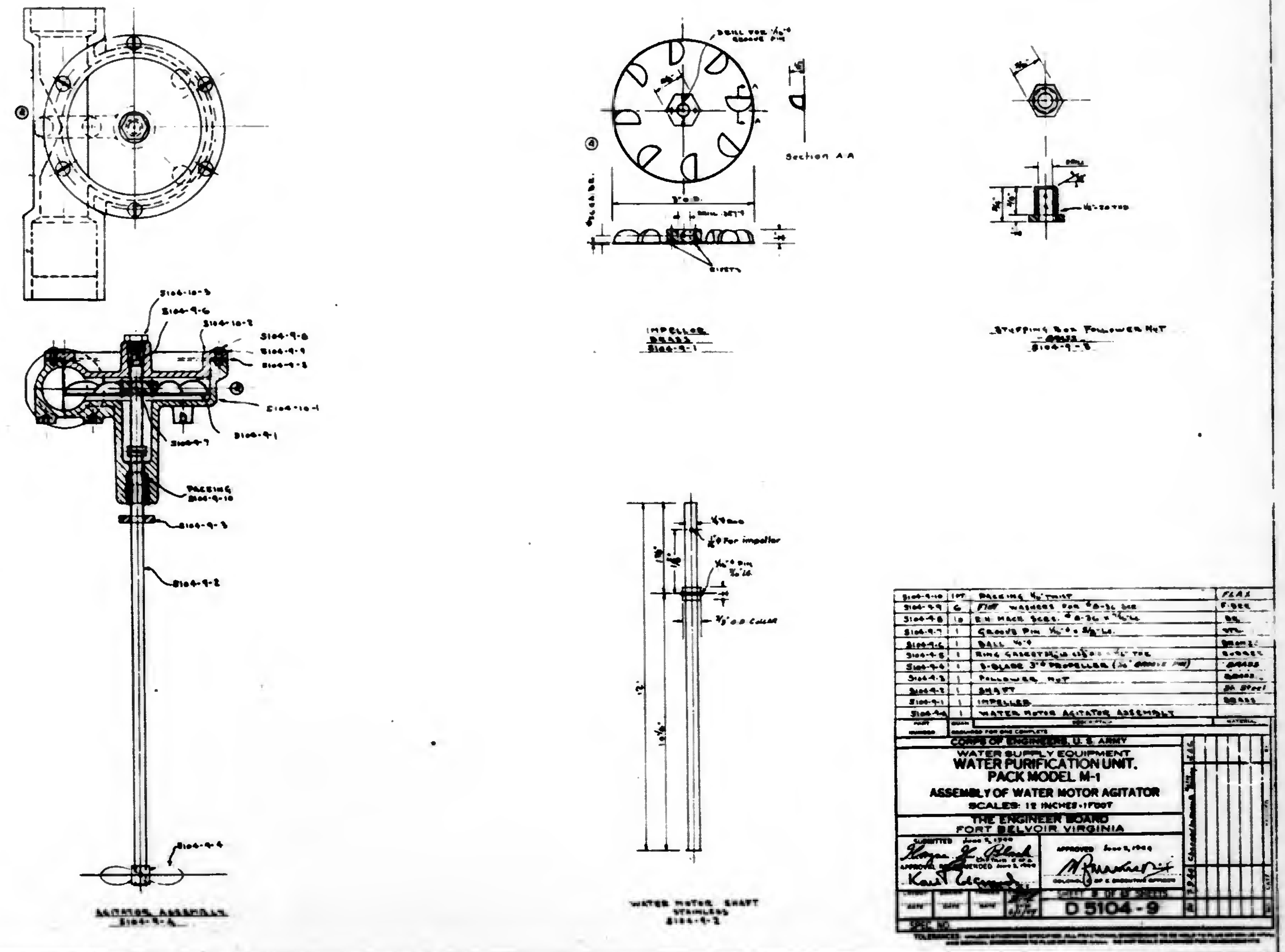
DETAILS OF FLEXIBLE HOSE, WING BOLTS & NUTS

SCALES: 12 INCHES = 1 FOOT

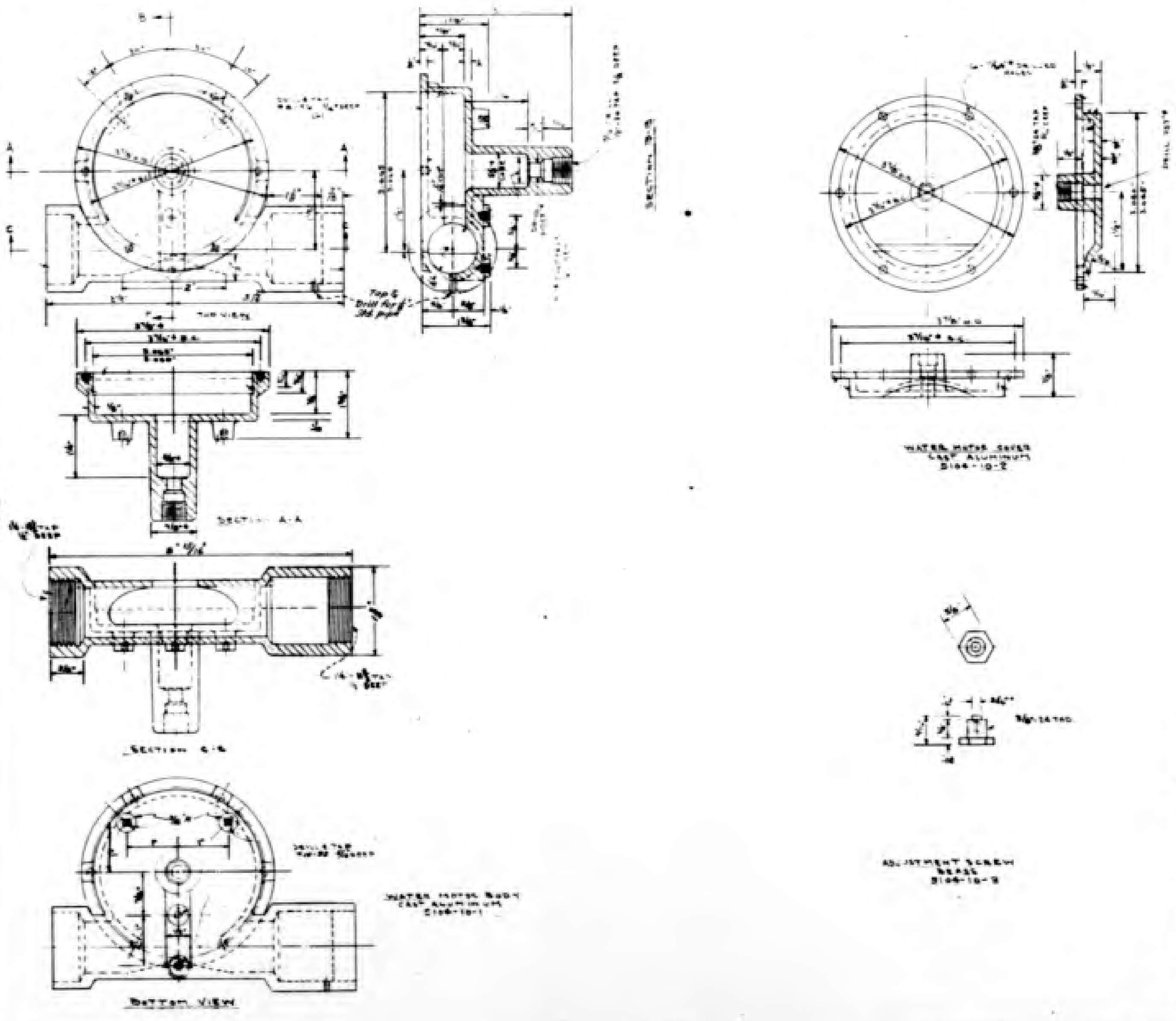
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA

SHEET 8 OF 15 SHEETS

D 5104 - 8



IMPELLER
BRASS
5104-9-1
Section A-A
STUFFING BOX FOLLOWER NUT
BRASS
5104-9-3
AGITATOR ASSEMBLY
5104-9-A
WATER MOTOR SHAFT
STAINLESS
5104-9-2
PACKING
5104-9-10
1/8" For impeller
3/8" O.D. Collar
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT.
PACK MODEL M-1
ASSEMBLY OF WATER MOTOR AGITATOR
SCALES: 12 INCHES=1FOOT
THE ENGINEER BOARD
FORT BELVOIR VIRGINIA
D 5104-9



5104-10-3	1	ADJUSTMENT SCREW	BRASS
5104-10-2	1	WATER MOTOR COVER	CAST ALUMINUM
5104-10-1	1	WATER MOTOR BODY	CAST ALUMINUM
PART NUMBER	REQUIRED FOR ONE COMPLETE	DESCRIPTION	MATERIAL

CORPS OF ENGINEERS, U. S. ARMY

WATER SUPPLY EQUIPMENT

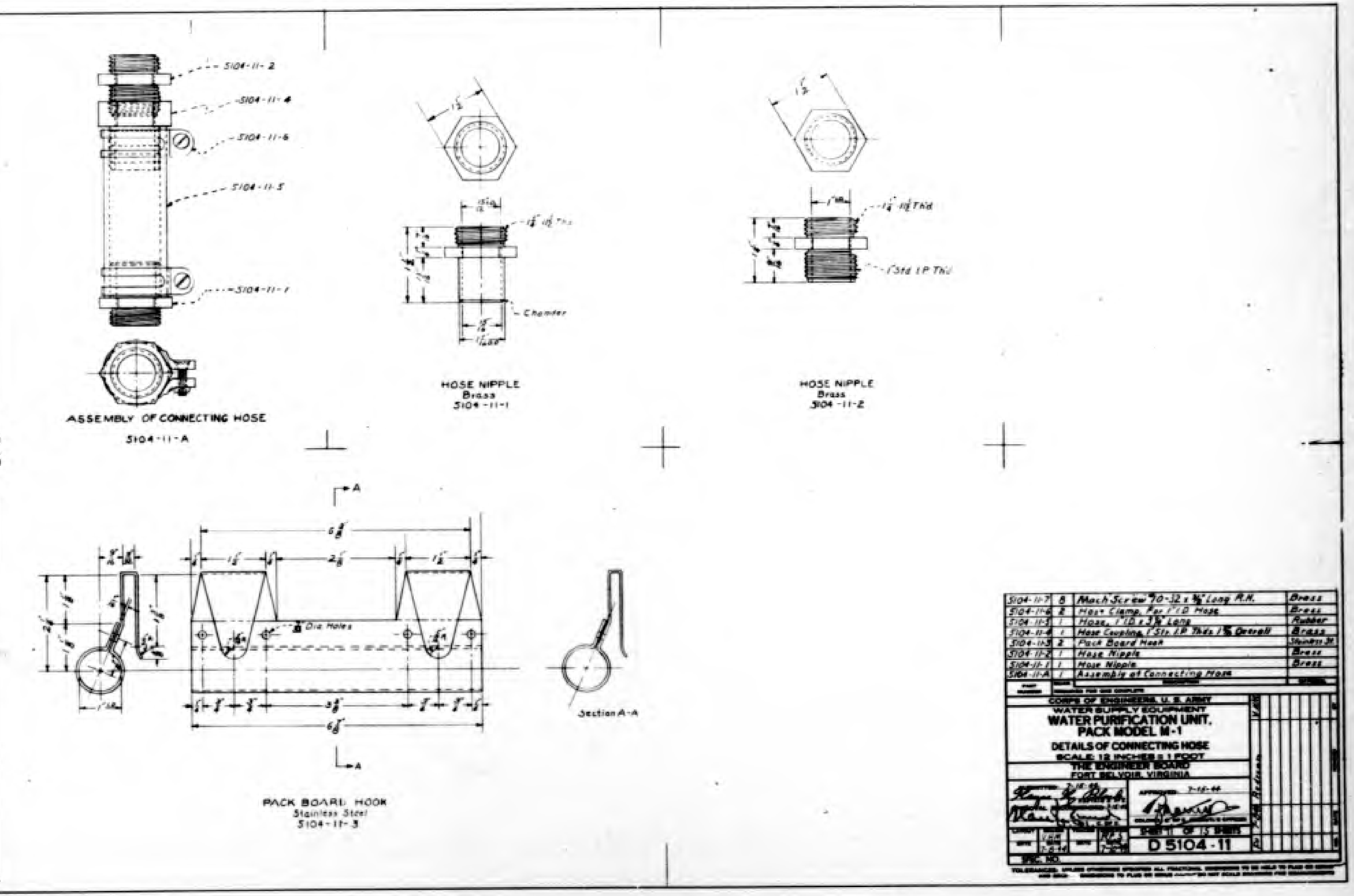
WATER PURIFICATION UNIT, PACK MODEL M-1

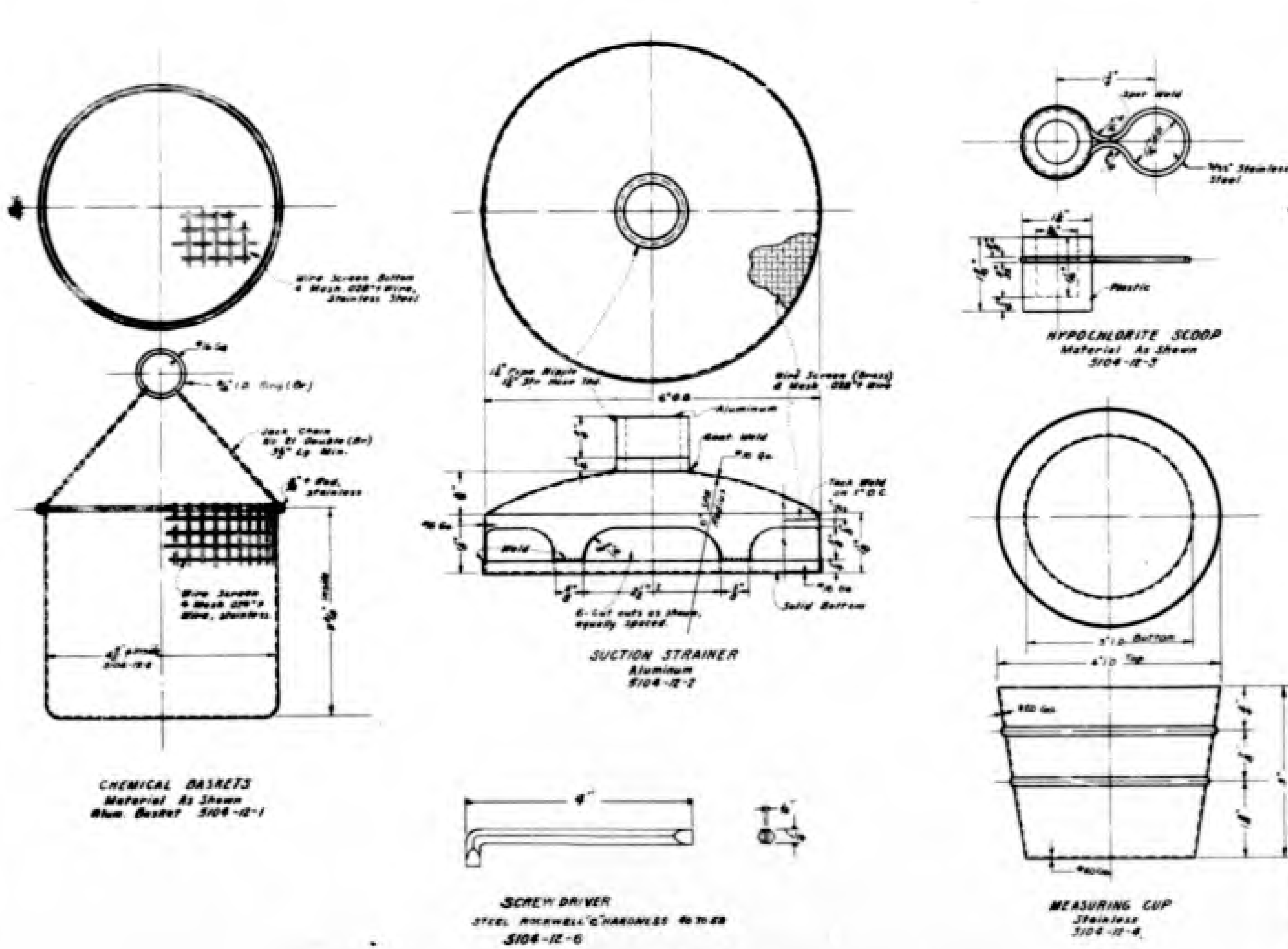
DETAILS OF WATER MOTOR CASTINGS & MISCELLANEOUS PARTS

THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA

SHEET 10 OF 10 SHEETS

D 5104-10


5104-11-2
5104-11-4
5104-11-6
5104-11-5
5104-11-1
ASSEMBLY OF CONNECTING HOSE
5104-11-A
Chamfer
HOSE NIPPLE
Brass
5104-11-1
1" Std I.P. Thd
HOSE NIPPLE
Brass
5104-11-2
Dia Holes
PACK BOARD HOOK
Stainless Steel
5104-11-3
Section A-A
5104-11-7 8 Mach Screw #10-32 x 3/8" Long R.H. Brass
5104-11-6 2 Hose Clamp, For 1" I.D. Hose Brass
5104-11-5 1 Hose, 1" I.D. x 3 1/4" Long Rubber
5104-11-4 1 Hose Coupling, 1" Std I.P. Thds 1 5/16" Overall Brass
5104-11-3 2 Pack Board Hook
5104-11-2 1 Hose Nipple Brass
5104-11-1 1 Hose Nipple Brass
5104-11-A 1 Assembly of Connecting Hose
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
DETAILS OF CONNECTING HOSE
SCALE: 12 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-11



5104-12-6	1	Screw Driver, ¼" x 4" Lg	Steel
5104-12-5	1	Sanitary Nozzle	Brass
5104-12-4	1	Measuring Cup	St. Steel
5104-12-3	1	Hypochlorite Scoop	As Shown
5104-12-2	1	Suction Strainer	Aluminum
5104-12-1	1	Alum. Basket 4⅝" I.D. x 3⅞" D.P.	As Shown

CORPS OF ENGINEERS, U.S. ARMY

WATER SUPPLY EQUIPMENT

WATER PURIFICATION UNIT, PACK MODEL M-1

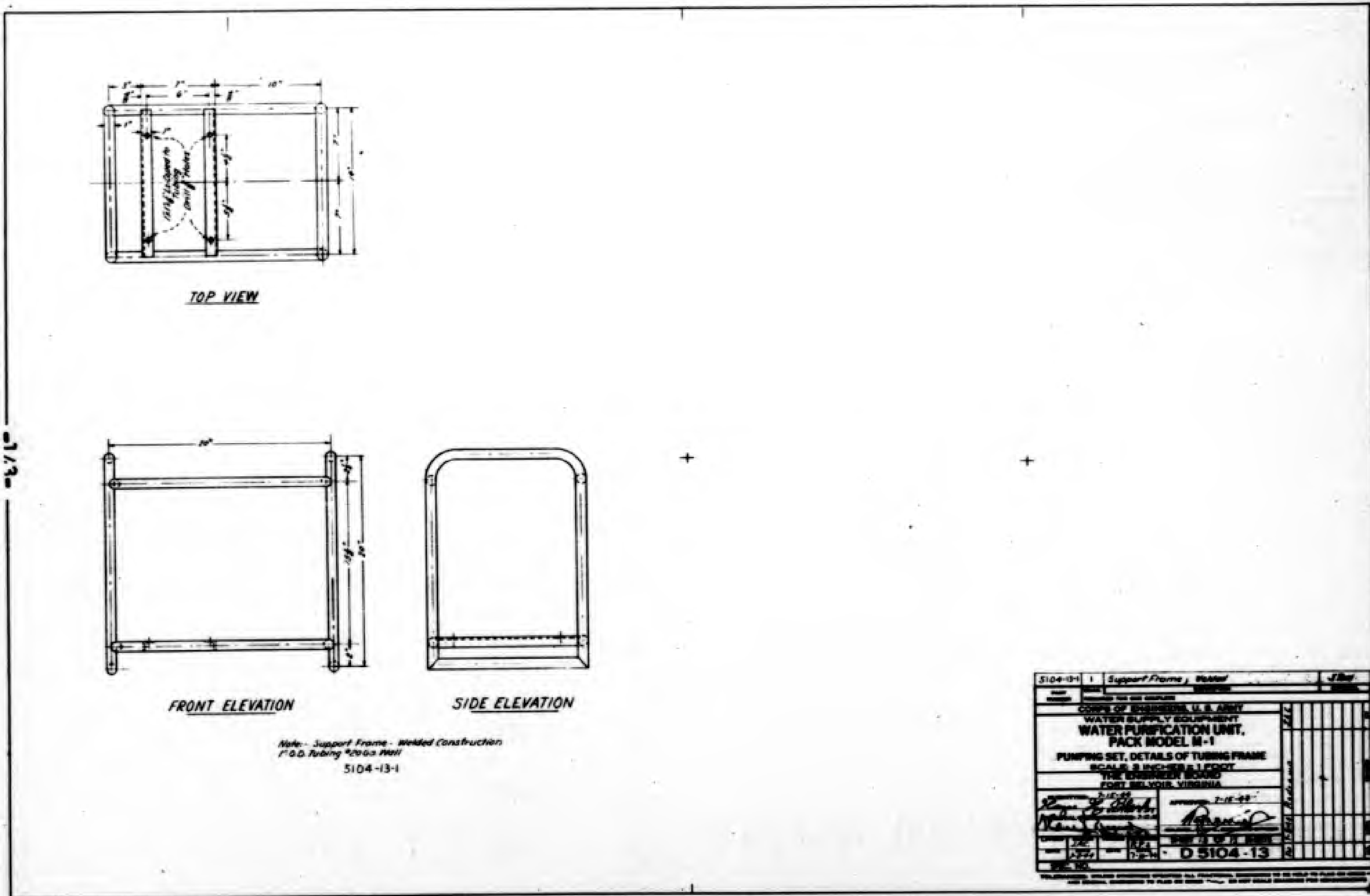
ACCESSORY DETAILS

THE ENGINEER BOARD

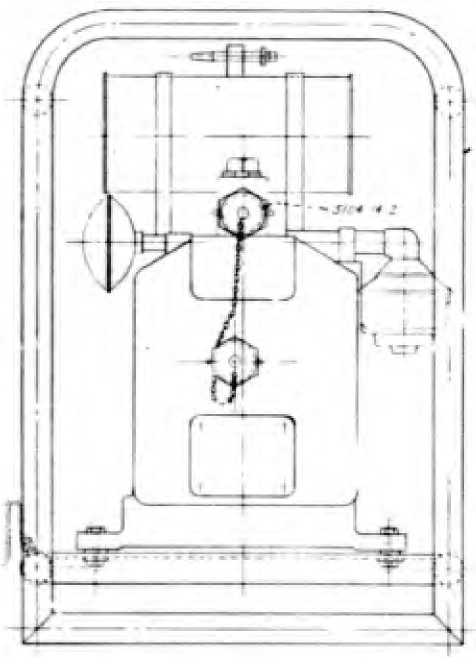
FORT BELVOIR, VIRGINIA

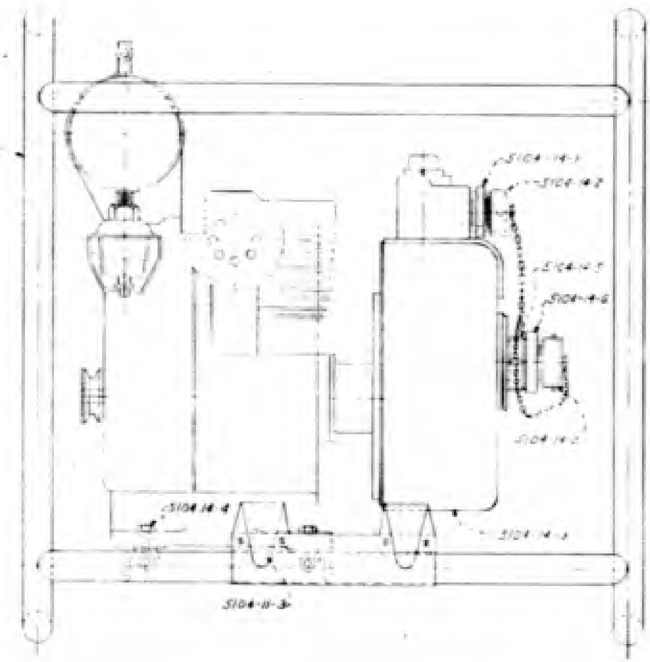
D 5104-12

SPEC. NO.



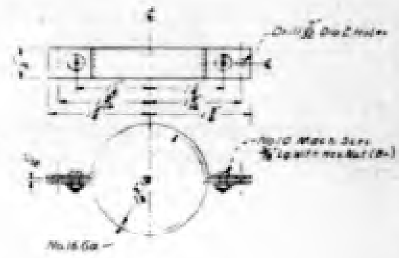
TOP VIEW
FRONT ELEVATION
SIDE ELEVATION
Note:- Support Frame - Welded Construction
1" O.D. Tubing #20 Ga. Wall
5104-13-1
5104-13-1
Support Frame, Welded
CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT,
PACK MODEL M-1
PUMPING SET, DETAILS OF TUBING FRAME
SCALE: 3 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-13





PUMPING SET ASSEMBLY

5104-14-A



CHAIN CLAMP
Brass
5104-14-5

5104-14-6	1	Adapter, 1 1/2" Male [illegible]	Brass
5104-14-5	1	Chain Clamp with Mach Scrs & Hex Nuts	Brass
5104-14-4	4	Mach Bolts [illegible] with Hex Nut & Lock Wash	[illegible]
5104-14-3	1	Pump & Motor [illegible]	
5104-14-2	2	Hose Cap, [illegible] with Chain & Gasket	Brass
5104-14-1	1	Adapter, Double Male [illegible]	Brass
5104-14-A		Pumping Set Assembly	
PART NUMBER	QUAN. REQUIRED FOR ONE COMPLETE	DESCRIPTION	MATERIAL

CORPS OF ENGINEERS, U. S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT, PACK MODEL M-1
PUMPING SET ASSEMBLY
SCALES: 6 & 12 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA

SUBMITTED: 7-15-44
APPROVED: 7-15-44

SHEET 14 OF 15 SHEETS
D 5104-14

SPEC. NO.

TOLERANCES: [illegible]

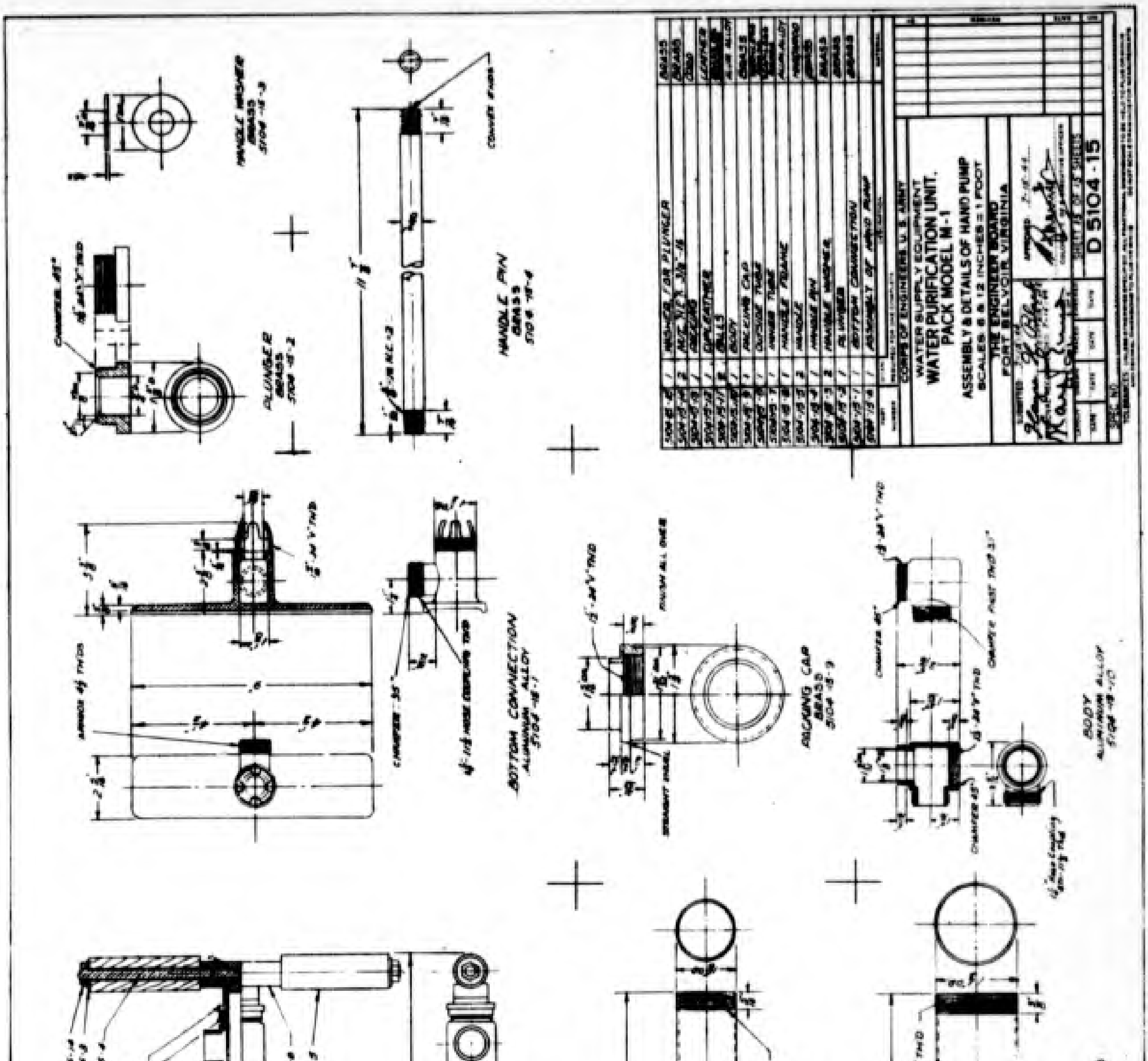

CORPS OF ENGINEERS U.S. ARMY
WATER SUPPLY EQUIPMENT
WATER PURIFICATION UNIT, PACK MODEL M-1
ASSEMBLY & DETAILS OF HAND PUMP
SCALES: 6 & 12 INCHES = 1 FOOT
THE ENGINEER BOARD
FORT BELVOIR, VIRGINIA
D 5104-15
HANDLE WASHER
PLUNGER
HANDLE PIN
BOTTOM CONNECTION
PACKING CAP
BODY
ASSEMBLY OF HAND PUMP
INSIDE TUBE
OUTSIDE TUBE
HANDLE
HANDLE FRAME

FIG. 11 cont'd.

Equipment Recommended for Standardization as:
WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______
Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF: MEASURE:	STOCK NO.	QUANTITY	REMARKS
9. Charcoal, activated, technical, 5-lb. multiwall paper bag, moisture resistant, Nuchar C-115	lb.		100	Same material as now on contract with the West Va. Pulp & Paper Co. Packaging, however, is not the same.
10. Filter Aid, diatomaceous silica, Dicalite 4200 or Johns Mansville 535, 25-lb. multiwall paper bag, moisture resistant.	lb.		1100	Dicalite 4200 is manufactured by the Dicalite Co. of Chicago New York and Los Angeles. The product known as Johns Mansville 535 is manufactured by Johns-Mansville, 22 East 40th St., New York City.
11. Funnel, aluminum, ½ pint	ea.	41-3780.200-050	1	None.
12. Manual, instructions for operating Water Purification Equipment, Diatomite, Pack (Man or Animal Type) 15 G.P.M., Tech. Bulletin No. TB	ea.		5	This manual is being prepared by the Training Branch, War Plans Division.
13. Orthotolidine Tablets, chlorine testing, 200 tablets per plastic vial, para. E-10a(1) ES-T-2110	ea.		15	None

FIG. 11

Equipment Recommended for Standardization as:

WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______

Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF MEASURE	STOCK NO.	QUANTITY	REMARKS
1. Adapter, pipe, brass, double male, 1½-inch straight, IPS to 1-inch, taper IPS	ea.		3	Not standard. Possible source of Supply, Elkhart Brass Mfg. Co.
2. Adapter, pipe, brass, double male, 1½-inch straight, IPS to 1-inch, straight IPS	ea.		1	Same as above.
3. Adapter, Pipe, Brass, 1½-inch male, taper IPS, to 1½-inch female straight IPS	ea.		1	Same as above.
4. Adapter, pipe, brass, 1¼-inch male, taper IPS, to 1½-inch female, straight IPS	ea.		1	Same as above.
5. Alum, ammonium, aluminum ammonium sulfate, technical, nut size, 10-lb. multiwall paper bag, moisture resistant.	lb.		300	Some material is now under contract with E.I. DuPont Co., Stock No. 51-2176.500-700. Packaging required, however, is not the same.
6. Attachment, packboard, plywood, cargo, Q.M.Tentative Spec. J.Q.D. No. 520	ea.		14	Can be procured from the Q.M. Corps.
7. Calcium Hypochlorite, chlorinating agent, technical, FS O-B-441, Grade AA for Water Purification Unit, 6 oz. resealing can	oz.	51-3436.600-300	720	None
8. Cap, pipe, brass with 4-inch length keeper chain No. 8 brass attached, threaded, straight IPS threads, 1¼ inch with rubber gasket.	ea.		4	Not standard - Possible source of supply is the Elkart Brass Mfg. Co.

FIG. 11 cont'd

Equipment Recommended for Standardization as:
WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______
Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF MEASURE	STOCK NO.	QUANTITY	REMARKS
14. Packboard, plywood, Q.M. Corps Tentative Spec. J.Q.D. No. 11C4	ea.		14	Can be procured from the Q.M. Corps.
15. PH Test Kit, 200 phenophthozine papers per glass vial, para. E-10b, ES-T-2110	ea.		15	None
16. Soda ash, briquettes, ES-T-1179, water purification, 10-lb. multi-wall paper bag, moisture resistant	lb.		150	Same material as shown by Stock No. 51-8140.500-500. However, packaging requirements are different.
17. Tank, Storage, Canvas, Water, 500 Gallon, ES-T-2111	ea.		4	None
18. Water Purification Unit, gasoline engine driven, pack, diatomite type, 15 G.P.M. including the following accessories, ES-T-2110			1	None
a. Hose, smooth bore, reinforced rubber, $1\frac{1}{4}$ inch inside diameter, 10 foot length, with clamps, standard pin lug, male and female, straight iron pipe threaded hose couplings, para. E-8-ES-T-2110	ea.		6	

FIG. 11 cont'd.

Equipment Recommended for Standardization as:
WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______
Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF: MEASURE	STOCK NO.	QUANTITY	REMARKS
b. Hose, smooth bore, reinforced rubber, 1¼ inch inside diameter, 5 foot lengths, with clamps, standard pin lug, female & female straight iron pipe threaded hose couplings, para. ~~E-8-~~ES-T-2110	ea.		2	
c. Strainer, suction, water, C. of E. dwg. D 5104-12	ea.		2	
d. Nozzle, water, sanitary, C. of E. dwg. D 5104-12	ea.		1	
e. Washer, hose, rubber, 1¼ inch I.D.	ea.		144	
f. Comparator, chlorine, paragraph E-10a, ES T-2	ea.		1	
g. Orthotolidine tablets, chlorine testing, 200 tablets per plastic vial, para. E-10a(1) ES-T-2110	ea.		2	
h. PH Test Kit, 200 phenopthazine papers per glass vial, para. E-10b, ES-T-2110	ea.		1	
i. Chlorine Test Case, paragraph E-10c, ES-T-2110	ea.		1	
j. Cup, measuring stainless steel, bottom I.D., 3 inch, top I.D., 4 inch by 3 inch high, para. E-10d, ES-T-2110	ea.		1	

FIG. 11 cont'd.

Equipment Recommended for Standardization as:
WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______
Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF MEASURE	STOCK NO.	QUANTITY	REMARKS
k. Scoop, hypochlorite, plastic body, stainless steel handle, para. E-10d. ES-T-2110	ea.		1	
l. Chemical basket, para. E-10d, ES-T-2110	ea.		1	
m. Bucket, Canvas, folding 10 quart, para. E-10, ES-T-2110	ea.		1	
n. Tools, hand, septum element cleaning	set		1	
o. Pliers, Combination, slip joint, FS GGG-P-471 Type F, 6-inch	pr.	41-5976.300-060	1	
p. Screwdriver, 4 inch, offset, para. E-13, ES T-2110	ea.		1	
q. Wrench, adjustable, automobile, FS GGG-W-631, Type II, 2½ inch opening x 9 inches long	ea.	41-9587.300-150	1	
r. Wrench, adjustable, crescent type, single end, FS GGG-W-631, Type I, Class B, 3/4 inch opening x 6 inches long	ea.	41-9587.500-100	1	
s. Wrench, socket, 3/8 inch square drive, 8 point opening, 1/2 in. socket	ea.		1	

FIG. 11 cont'd.

Equipment Recommended for Standardization as:
WATER PURIFICATION EQUIPMENT, DIATOMITE, PACK (MAN OR ANIMAL TYPE), 15 G.P.M. SET NO. ______
Engineer Board, Fort Belvoir, Virginia

ITEM	UNIT OF MEASURE	STOCK NO.	QUANTITY	REMARKS
t. Cover, cotton duck, filter support frame, para. E-14, ES T-2110	ea.		1	
u. Cover, cotton duck, pumping set support frame, para. E-14, ES T-2110	ea.		2	
v. Bag, cotton duck, filter aid and miscellaneous supplies, para. E-15, ES T-2110	ea.		2	
w. Pump, gasoline-engine driven, with tubular frame, para. E-7, ES T-2110	ea.		2	
x. Pump, hand, emergency para. E-11, ES T-2110	ea.		1	
y. Filter and feeder, with tubular frame, para. E-2 and 3, ES T-2110	ea.		1	

Fig. 12
15 GPM Diatomite Water Purification Set
INDIVIDUAL MAN PACK LOADS
Engineer Board, Fort Belvoir, Virginia

Load Number		Item
1	1	Filter and feeder unit, mounted in tubular steel frame
		1 Pail, accessory
		1 Bag, drawstring
		1 Basket, chemical
		2 Cups, measuring
		1 Case, chlorine test
		1 Comparator, Hellige simplex
		3 Tubes, glass, 13 mm, square
		1 Rod, plastic, stirring
		2 Vials, orthotolidine tablets, 200 each
		1 Kit, pH testing, nitrazine paper
		1 Scoop, hypochlorite
		1 Funnel, slurry
		1 Can, reclosable, hypochlorite, 6 oz.
		1 Brush, cleaning, septum
	1	Tool Roll, canvas, with tools containing:
		1 Wrench, 9 in., auto, monkey
		1 Screwdriver, 4 in., offset
		1 Socket, 1/2 in. with 3/8 in. drive
		1 Handle, socket wrench, sliding head, 3/8 in. tee
		1 Pliers, 5 in., slip joint
		1 Wrench, "Crescent", single end, 6 in. adjustable
	1	Cover, fabric
2	1	Pump and engine
	*1	Frame, tubular
	*1	Cover, fabric
3	2	10-ft. lengths of 1 1/4 in. hose, male and female connections
	2	5-ft. lengths of 1 1/4 in. hose, female and female connections
		1 Nozzle, sanitary
		1 Strainer, suction
		1 Diatomaceous Silica, 25 lb. bag
		1 Bag, carrying
4	1	Pump and engine
	*1	Frame, tubular
	*1	Cover, fabric

* May be omitted, bolting engine to packboard, when man packing for long carries.

Fig. 12 (cont.)

Load Number	Item
5, 6, 7, 8	1 Tank, 500 gallon fabric, complete with staves and cover
	1 10 ft. length of 1 1/4 in. hose, male and female connections
9	1 Bag, carrying
	1 Suction strainer
	1 Aluminum funnel, $\frac{1}{2}$ pint capacity
	1 Collapsible bucket
	5 Cans, hypochlorite
	1 Alum, ammonium, tech. nut, 10 lb. bag
	1 Soda ash, briquettes, 10 lb. bag
	1 Carbon, activated, Nuchar C-115, 5 lb. bag
	1 Pump, hand
	*1 Diatomaceous Silica, 25 lb. bag
	Spare Parts-Filter
	1 Bag, drawstring
	24 Gaskets, rubber, 1 1/4 in. hose
	2 Gaskets, rubber, element
	1 Gasket, rubber, filterhead
	1 Fitting, dural, hexagon, 1 in. taper IPS male and female thread, tapped 1/4 in. taper IPS
	12 Machine screws, RH, No. 10-32 x $\frac{1}{2}$ in. with nuts and washers
	1 Packing, water motor, graphited, 6 ft. of 1/16 in. twist
	1 Hose, connecting, rubber and fabric, 1 in. I.D., 6 in. long
	2 Clamps, hose, 1 in.
	2 Clamps, hose, 1/4 in.
	4 Clamps, hose, 1 1/4 in.
	2 Adapter, hose, 1 1/4 in. st. IPS to 1 1/4 in. taper all male
	1 Adapter, hose, 1 1/4 in. male st. IPS to 1$\frac{1}{2}$ in. male taper IPS
	1 Adapter, hose, 1 1/4 in. male st. IPS to 1 in. male taper IPS
	1 Hose, suction, rubber and fabric, 1/4 in., 1 ft. long
	1 Can, pipe joint compound

* May be omitted, bolting engine to packboard, when man packing for long carries.

Fig. 12 (cont.)

Load Number	Item
	Spare Parts-Engine and Pump
	1 Plug, spark
	1 Gasket, oil filler plug
	1 Gasket, breather body
	1 Gasket, cover plate
	1 Gasket, volute cover
	1 Gasket, inlet valve
	1 Bulb, sediment

Fig. 13.
5-gpm Pack Water Purification Set (Service Tested)
COMPONENTS OF 5-GPM WATER PURIFICATION EQUIPMENT CARRIED IN PACKS
Engineer Board, Fort Belvoir, Virginia.

No. 1 Pack

1 Filter, diatomaceous silica
1 Agitator, slurry

1 Set, body feeder
2 Cans, aluminum
1 Cover, can
1 Clamp, toggle
1 Bag, drawstring
1 Set, chlorine comparator
1 Tester, Hellige Simplex
3 Tubes, 13 mm square
1 Rod, plastic stirring
2 Tubes, 200 orthotolidine tablets
1 Kit, 1 ppm chlorine
1 Scoop, hypochlorite
2 Cups, measuring
1 Can, reclosable hypochlorite
1 Indicator, sight flow

(Spare Parts)
1 Clamp, hose
1 Nuts, cap
1 Nuts, 1/4 in.
1 Washers, 1/4 in. brass
8 Gaskets, 1 in. hose
1 Gasket, filter head
2 Gasket, element
*1 Gasket, sight chamber
1 Vent, air
1 Bushing, dielectric
1 Tubing, 2 ft. 1/4 in. rubber

(Spare Parts)
1 Fitting, 1 in. male hose
1 Coupling, 1 in. male hose
*1 Coupling, 1 in. female

1 Hose, 10 ft. suction (male and female)
1 Hose, 5 ft. pump (female and female)
1 Hose, 5 ft. filter (male and female)
1 Nozzle, sanitary
*1 Pump, hand

1 Packboard, plywood
1 Cord, 25 foot
2 Straps, quick-release
1 Attachment, cargo

* Equipment to be supplied later.

Fig. 13 (cont.)

No. 2 Pack

1 Pump, gasoline engine - driven (with fittings)
  - 1 Pump, Rex 3 M aluminum self-priming Nos. BN124,BN121
  - 1 Engine, Lauson R S C 606 A - cycle Nos. 3-34708, 3-24702

1 Kit, Tool
  - 1 Wrench, 9 in. auto monkey
  - 1 Screwdriver, 4 in. blade
  - 1 Socket, ½ in. with 3/8 in. drive
  - 1 Handle, sliding head 3/8 in. tee
  - 1 Pliers, 5 in.slip joint
  - *1 Wrench, 6 in. adjustable
    - (Present substitutes for 6 in. adjustable:)
      - 1 Wrench, end 3/8 x 7/16 in.
      - 1 Wrench, end 7/16 x 9/16 in.
      - 1 Wrench, end 19/32 x 11/16 in.
  - 1 Roll, canvas tool

1 Strainer, float

1 Packboard, plywood
  - 1 Strap, quick release
  - 1 Attachment, cargo
  - 4 Bolts, 5/16 x 1½ in. machine

* Equipment to be supplied later.

Fig. 13 (cont.)

No. 3 Pack

2 Bags, 15 lb. filteraid
or
1 Bag, 25 lb. filteraid

4 Elements, filter

1 Bag, barracks

*1 Hose, 5 ft. male and female
*1 Hose, 5 ft. female and female

1 Packboard, plywood
1 Cord, 25-foot
1 Attachment, cargo

No. 4, 5, and 6 Packs

Each
*1 Tank, 350-gallon canvas
10 Staves, wood tank

1 Packboard, plywood
1 Cord, 25-foot
1 Attachment, cargo

* Equipment to be supplied later.

APPENDIX D

TEST RESULTS DATA SHEETS

Date 4/8/43 Run No. 2 Filter No. SF-1 Pump No Gravity Aft Suction Lift 0 Ft. Element Type ~~Aloxite 36~~ 0.125 sq.ft.
Filteraid Used Sorbo-Cel Amount Precoat 0.0156 Lb. Amount Slurry Batch 0.039 Lb. Amount of Batch used 0.039 Lb.
Raw Water Source Clay in Tap Turbidity 125 ppm Temperature 48 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval Min.	Rate of Discharge GPM	Effluent Turbidity ppm	Operation	Remarks
0			Precoating	Body feed of 0.25 oz. of Sorbo-Cel per
0.5		0.10	Filtering	gallon of raw water used after first gallon.
1.5		0.05	"	
2.5	0.44	"	"	
3.5	0.40	"	"	Head on filter = 4.0 ft.
4.5		"	"	
6.5		"	"	
7.5		"	"	
8.5		"	"	
9.5		"	"	
10.5		"	"	
*	*	*	" *	* * *
14.5		"	Stopped	

Total Water Produced 2.5 Gals. Backwash Water 0 Gals Net Water Produced 2.5 Gals
Average Output (Net/Total Time) ~~11.1~~ 0.185 GPM Effectiveness of Backwash Air Blowing
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H.N. Lowe, Jr. RANK Asst. Engr.
ORGANIZATION Water Supply Equipment

FIG. 14.
STONEHEART 0.125 GPM FILTER (SF-1).
NORMAL RUN ON MODERATELY TURBID WATER.
Engineer Board, Fort Belvoir, Virginia.

Date 4/8/43 Run No. 4 Filter No. SF-1 Pump No. Gravity 4 ft. Suction Lift 0 Ft. Element Type Aloxite 36 0.125 sq.ft
Filteraid Used Sorbo-Cel Amount Precoat 0.0156 Lb. Amount Slurry Batch 0.0156 Lb. Amount of Batch used 0.0156 Lb.
Raw Water Source Clay in Tap Turbidity 125 ppm Temperature 52 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval Min.	Rate of Discharge GPM	Effluent Turbidity ppm	Operation	Remarks
0			Precoating	Body feed of 0.25 oz. of Sorbo-Cel
0.50		0.05	Filtering	per 1.25 gallons of water. One quart
1.50	[illegible]	0.05	"	filtered to waste during precoating
2.50		0.05	"	
3.75		0.05	Stopped	
				Head on filter = 4.0 ft.

Total Water Produced 1.0 Gals. Backwash Water 0 Gals Net Water Produced 1.0 Gals
Average Output (Net/Total Time) ~~16.0~~ 0.267 GPM Effectiveness of Backwash Air Blowing
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Asst. Engr
ORGANIZATION Water Supply Equipment

FIG. 15.
STONEHEART 0.125 GPM FILTER (SF-1).
SHORT RUN FOR HIGH OUTPUT RATE.
Engineer Board, Fort Belvoir, Virginia.

Date 7/6/44 Run No. 4 Filter No. - Pump No. Hand Suction Lift 3.0 Ft./Element Type Paper
Filteraid Used None Amount Precoat 0 Lb. Amount Slurry Batch 0 Lb. Amount of Batch used 0 Lb.
Raw Water Source Clay in Tap Turbidity 200 ppm Temperature 60 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0.0	1.0	0.10	Filtering	Pump operated at 80 strokes per minute.
2.0		0.05	"	
4.0		0.10	"	
6.0		0.05	"	Safety valve blew at 7.5 gallons.
7.6		0.05	"	
8.0		0.05	"	
10.0		0.10	"	
11.0		0.05	"	
15.0		0.05	"	
16.2		0.10	"	
20.0	0.75	0.05	"	
*	*	*	* *	* * *
41.3	0.10	0.05	Stop	

Total Water Produced 15 Gals. Backwash Water 0 Gals Net Water Produced 15 Gals
Average Output (Net/Total Time) 0.36 GPM Effectiveness of Backwash Pads changed
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Ass't. Engr.

ORGANIZATION Water Supply Equipment

FIG. 16.
GERMAN HAVERSACK FILTER.
OPERATION OF SHEET FILTER ON TURBID WATER.
Engineer Board, Fort Belvoir, Virginia.

Date 6/16/43 Run No. 5 Filter No. 2 MS Pump No. Hand Suction Lift 3.0 Ft. Element Type Screen
Filteraid Used Sorbo-Cel Amount Precoat 0.19 Lb. Amount Slurry Batch 0.19 Lb. Amount of Batch used 0.13 Lb.
Raw Water Source Clay in Tap Turbidity 150 ppm Temperature 70 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0				Hand pump operated at approximately
1			Precoating	60 rpm throughout Relief valve popped at
2.8	2.7		Filtering	20 lb. per sq. in.
4.7	2.7	0.2	"	
5.7	2.5		"	At 10.9 effluent was distinctly turbid.
6.6	3.0		"	indicating break in cake.
7.6	2.5		"	
8.6	2.4	1.0	"	
9.7	2.3	1.0	"	
10.9	2.1	2.0	"	
12.0	2.2	5.0	"	
*	*	*	* *	* * *
24.0	1.2	10.0	Stop	

Total Water Produced 42 Gals. Backwash Water 0 Gals Net Water Produced 42 Gals
Average Output (Net/Total Time) 1.75 GPM Effectiveness of Backwash Removed and rinsed
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. Turbidity of effluent suddenly increased at 8.6 min. and became increasingly worse, indicating break in cake.

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Ass't. Engr.

ORGANIZATION Water Supply Equipment

FIG. 17.
BOWSER FILTER 2 MS.
BREAK THROUGH WITH FLEXIBLE SCREEN SEPTUM.
Engineer Board, Fort Belvoir, Virginia.

Date 7/27/43 Run No. 1 Filter No. 5C Pump No. Hand Suction Lift 3.0 Ft. Element Type Carbocell 60
Filteraid Used Sorbo-Cel Amount Precoat 0 Lb. Amount Slurry Batch 0.16 Lb. Amount of Batch used 0.125 Lb.
Raw Water Source Clay in Tap Water Turbidity 50 ppm Temperature 65 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0			Precoating	Samples 1 to 8 showed carbon
2.25	2.2	1.5	Filtering	haze from dust formed in turning element.
4.75	2.0	1.0	"	
7.08	2.0	0.8	"	
9.75	1.9	0.8	"	
11.33	1.9	0.5	"	
13.83	2.0	0.6	"	
16.41	1.9	1.0	"	
19.00	1.9	0.7	"	
21.66	1.9	--	"	
24.23	1.9	0.2	"	
*	*	*	* * *	* *
50.52	1.6	0.1	Stop	

Total Water Produced 100 Gals. Backwash Water 0 Gals Net Water Produced 100 Gals
Average Output (Net/Total Time) 2.0 GPM Effectiveness of Backwash Scrubbing
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Ass't. Engr.

ORGANIZATION Water Supply Equipment

FIG. 18.
BOWSER FILTER 1.5 C.
IMPROVED OPERATION WITH RIGID SEPTUM.
Engineer Board, Fort Belvoir, Virginia.

Date 7/28/43 Run No. 4 Filter No. L-2 Pump No. Rex ~~C.E.~~ 3 M Suction Lift 5 Ft. Element Type Alorite 36

Filteraid Used Sorbo-Cel Amount Precoat 0.20 Lb. Amount Slurry Batch 0 Lb. Amount of Batch used 0 Lb.

Raw Water Source Potomac River Turbidity 30 ppm Temperature 68 °F

Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0	5.0	0.5	Precoating	Maximum pumping pressure was 21.0 lb.
1	5.0	0.3	Filtering	per sq. in. *with Rex 3 M pump.*
1.5	10.0	0.3	"	
2.5	5.0	0.5	"	
3.0	10.0	0.3	"	
3.5	10.0	0.2	"	
4.5	5.0	0.2	"	
5.0	10.0	0.3	"	
6.0	5.0	0.3	"	
7.0	5.0	0.3	"	
8.0	5.0	0.2	"	
*	*	*	* *	* * *
17.5	4.0	0.5	Stop	

Total Water Produced 90 Gals. Backwash Water 0 Gals Net Water Produced 90 Gals

Average Output (Net/Total Time) 5.1 GPM Effectiveness of Backwash Air blowing

Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. W. Withers RANK Capt., C. E.

ORGANIZATION Water Supply Equipment

FIG. 19.
ENGINEER BOARD 5-GPM FILTER (L-2).
OPERATION WITH PUMP INITIALLY THROTTLED.
Engineer Board, Fort Belvoir, Virginia.

Date 7/28/43 Run No. 1 Filter No. L-2 Pump No. Rex 3M Suction Lift 5.0 Ft. Element Type Aloxite 36
Filteraid Used Sorbo-Cel Amount Precoat 0.28 Lb. Amount Slurry Batch 0 Lb. Amount of Batch used 0 Lb.
Raw Water Source Potomac River Turbidity 50 ppm Temperature 70 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0.58	8.6		Precoating	No body feed used; hence runs were
1.16	8.6	1.0	Filtering	short. self-priming centrifugal pump
1.81	8.5	0.8	"	(Rex 3M) used.
2.67	6.0	0.5	"	
*	*	*	* *	* * *
6.05	2.8	0.3	Stop	
8.6	8.6	0.7	Precoating	
9.2	8.5	0.7	Filtering	
9.9	7.6	0.5	"	
10.5	8.5	0.3		
11.1	8.5	0.5		
*	*	*	* *	* * *
15.5	2.0	0.3	Stop	

Total Water Produced 65 Gals. Backwash Water 0 Gals Net Water Produced 65 Gals
Average Output (Net/Total Time) 4.2 GPM Effectiveness of Backwash Air Blowing
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Ass't. Engr.

ORGANIZATION Water Supply Equipment

FIG. 20.
ENGINEER BOARD 5-GPM FILTER (L-2).
OPERATION FOR MAXIMUM FILTERAID ECONOMY.
Engineer Board, Fort Belvoir, Virginia.

Date 7/11/43 Run No. S-1 Filter No. L-2 Pump No. DC-5 Suction Lift 5.0 Ft. Element Type Alorite 36
Filteraid Used Sorbo-Cel Amount Precoat 0.25 Lb. Amount Slurry Batch 0.40 Lb. Amount of Batch used 0.25 Lb
Raw Water Source Potomac River Turbidity 60 ppm Temperature 75 °F
Alum Applied 0 Lb. Soda Ash Applied 0 Lb. Settled 0 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
0	5.0		Precoating	Chlorine residual of 1.0 ppm was
2	5.0	0.3	Filtering	maintained consistently with rotary pumps,
5	5.0	0.2	"	Blackmer DC-5
10	5.0	0.2	"	
15	5.0	0.3	"	
20	5.0	0.3	"	
25	5.0	0.2	"	
30	5.0	0.2	"	
35	4.8	0.2	"	
40	4.8	0.2	"	
45	4.6	0.3	"	
*	*	*	* *	* * *
60	4.6	0.2	"	

Total Water Produced 280 Gals. Backwash Water 0 Gals Net Water Produced 280 Gals
Average Output (Net/Total Time) 4.66 GPM Effectiveness of Backwash Air Blowing
Coagulants Applied in the Following Manner None

Float Strainer Used? No

Remarks, Difficulties Encountered, etc. None

* River, creek, tap plus artificial turbidity

NAME H. N. Lowe, Jr. RANK Ass't. Engr.

ORGANIZATION Water Supply Equipment

FIG. 21.
ENGINEER BOARD 5-GPM FILTER (L-2).
OPERATION WITH ROTARY PUMP.
Engineer Board, Fort Belvoir, Virginia.

Date 5/3/44 Run No. 5 Filter No. Pack Pump No. Hi-Press. Suction Lift 7 Ft. Element Type Carbocell 50
Filteraid Used 4200 Amount Precoat 0.25 Lb. Amount Slurry Batch 0.25 Lb. Amount of Batch used 0.75 Lb.
Raw Water Source Potomac River Turbidity 45 ppm Temperature 62 °F
Alum Applied None Lb. Soda Ash Applied None Lb. Settled None Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
5	19.6	1.0		
10	16.8	1.0		
15	12.4	1.0		
20	12.0	1.0		
25	11.2	1.0		
30	11.8	1.0		
35	8.4	1.0		

Total Water Produced 459 Gals. Backwash Water 10 Gals Net Water Produced 449 Gals
Average Output (Net/Total Time) ~~768~~ 12.8 GPM Effectiveness of Backwash Satisfactory
Coagulants Applied in the Following Manner

Float Strainer Used? Yes

Remarks, Difficulties Encountered, etc. Duration of run limited only to maximum available pump pressure

* River, creek, tap plus artificial turbidity

NAME M. S. Mason RANK Engineer

ORGANIZATION Water Supply

FIG. 22.
5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED).
TYPICAL RUN WITH DIRECT FILTRATION.
Engineer Board, Fort Belvoir, Virginia.

Date 5/2/49 Run No. 2 Filter No. Pack Pump No. Hi-Press. Suction Lift 7 Ft. Element Type Carbocell 50
Filteraid Used 4200 Amount Precoat 0.25 Lb. Amount Slurry Batch 0.25 Lb. Amount of Batch used ~~.216~~ .169 Lb.
Raw Water Source Potomac River Turbidity 53 ppm Temperature 60 °F
Alum Applied 0.25 Lb. Soda Ash Applied None Lb. Settled 1.25 Hrs.

Time Interval (Min.)	Rate of Discharge (GPM)	Effluent Turbidity (ppm)	Operation	Remarks
5	25.2	4.0		
10	14.0	4.0		
15	12.6	4.0		
20	11.2	4.0		
25	8.4	4.0		
30	7.0	4.0		
35	8.4	4.0		

Total Water Produced 434 Gals. Backwash Water 10 Gals Net Water Produced 424 Gals
Average Output (Net/Total Time) ~~.726~~ 12.1 GPH Effectiveness of Backwash Satisfactory
Coagulants Applied in the Following Manner

Float Strainer Used? Yes.

Remarks, Difficulties Encountered, etc. Using high pressure, closed impeller, self-priming pump, which developed up to 43 psi. Very satisfactory yield results.

* River, creek, tap plus artificial turbidity

NAME M. S. Mason RANK Engineer
ORGANIZATION Water Supply

FIG. 23.
5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED).
TYPICAL RUN WITH PRETREATMENT.
Engineer Board, Fort Belvoir, Virginia.

FIG. 24.
5-GPM PACK WATFR PURIFICATION SFT (SERVICE TESTED)
SUMMARY OF RUNS WITH LOW HEAD PUMP.
Engineer Board, Fort Belvoir, Virginia.

Equipment: 5 gpm Pack Water Purification Set
Septum: Aloxite 36
Area: 1.83 Sq.ft.

Pump: Rex Aluminum 3M
Engine: Lauson R S C 609
Location: Potomac River

Precoat: 0.25 lb.

Date	Run No.	Filteraid (lb.)	Body Feed (lb.)	Body Feed Average (ppm)	Filtrate Production Total (gal.)	Filtrate Production Time (min.)	Filtrate Production Output (GPM)	Filtrate Production Rate (GPM/Sq.ft.)	Filtrate Production Economy (Gal./lb.FA)	Pretreatment Coag. (lb.)	Pretreatment Time (hr.)	Turbidity Raw (ppm)	Turbidity Set (ppm)	Turbidity Filt. (ppm)
4/25	1	545	0.25	150	200	18	11.0	6.1	400	None	—	68	—	1.0
4/25	2	545	0.25	150	200	21	9.5	5.3	400	None	—	68	—	1.0
4/25	3	545	1.00	400	300	25	12.0	6.7	240	.25	0.5	68	—	1.0
4/25	4	545	0.50	200	300	15	20.0	11.1	400	.25	2.0	68	—	0.5
4/26	1	228V	0.75	257	350	30	11.6	6.4	350	None	—	35	—	0.7
4/26	2	228V	0.37	135	330	24	13.7	7.6	528	None	—	35	—	1.0
4/26	3	228V	0.50	200	300	35	8.6	4.8	400	None	—	35	—	0.1
4/26	4	228V	0.25	200	150	30	5.0	2.8	300	None	—	35	—	0.1
4/26	5	228V	0.25	171	175	35	5.0	2.8	350	None	—	35	—	0.1

Septum: Carbocell Crade 50

Date	Run No.	Filteraid (lb.)	Body Feed (lb.)	Body Feed Average (ppm)	Filtrate Production Total (gal.)	Filtrate Production Time (min.)	Filtrate Production Output (GPM)	Filtrate Production Rate (GPM/Sq.ft.)	Filtrate Production Economy (Gal./lb.FA)	Pretreatment Coag. (lb.)	Pretreatment Time (hr.)	Turbidity Raw (ppm)	Turbidity Set (ppm)	Turbidity Filt. (ppm)
4/27	1	535	0.43	171	301	28	10.8	6.0	442	None	—	85	—	0.3
4/27	2	535	0.63	193	391	35	11.2	6.2	444	None	—	85	—	0.3
4/28	1	235	0.75	530	170	28	6.1	3.4	170	None	—	83	—	0.1
4/28	2	235	0.25	—	35	5	7.0							
4/28	3	235	1.5	1100	164	35	4.7	2.7	94	None	—	83	—	0.3
4/29	1	228V	0.25	—	61	15	4.1		—	None	—	80	—	0.2
4/29	2	4200	0.5	300	200	20	10.0	5.6	267	0.25	2.5	80	—	0.2
4/29	3	4200	0.18	180	120	10	12.0	6.7	279	.25	0.5	8-	—	1.0
4/29	4	4200	0.5	500	120	15	8.0	4.4	160	.25	0.75	80	—	1.0
5/1	1	4200	0.43	283	182	25	7.3	4.0	268	0.25	0.66	95	—	1.0
5/1	2	4200	0.5	167	358	35	10.2	5.7	477	.25	3.0	95	—	1.0
5/1	3	4200	0.56	305	220	30	7.3	4.0	272	.25	0.5	95	—	0.2
5/1	4	4200	0.5	178	336	35	9.6	5.3	448	.25	0.66	95	—	0.2
5/12	1	228V	0.25	300	100	20	5.0	2.8	200	None	—	45	—	0.2
5/12	2	228V	0.25	194	155	30	5.1	2.9	310	None	—	45	—	0.2
5/15	1	4200	0.5	666	90	10	9.0	5.0	180	None	—	50	—	0.3

FIG. 25.
5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED).
SUMMARY OF RUNS WITH HIGH HEAD PUMP.
Engineer Board, Fort Belvoir, Virginia.

Equipment: 5 gpm Pack Water Purification Set
Septum: Carbocell 50
Area: 1.83 Sq.ft.

Pump: Rex Exp. High Speed
Engine: Lauson R S C 609
Location: Potomac River

Precoat: 0.25 lb.

Date	Run No.	Filteraid (lb.)	Body Feed (lb.)	Body Feed Average (ppm)	Filtrate Production Total (gal.)	Filtrate Production Time (min.)	Filtrate Production Output (GPM)	Filtrate Production Rate (GPM/sq.ft.)	Filtrate Production Economy (Gal./lb.Fa)	Pretreatment Coag. (lb.)	Pretreatment Time (hr.)	Turbidity Raw (ppm)	Turbidity Set (ppm)	Turbidity Filt. (ppm)
5/3	5	4200	0.82	215	459	35	13.1	7.3	429	None	—	45	—	1.0
5/3	6	4200	0.75	183	493	40	12.3	6.9	493	None	—	45	—	0.1
5/5	1	545	0.80	151	637	50	12.7	7.0	607	None	—	40	—	0.5
5/5	2	545	0.25	300	100	10			200	None	—	40	—	0.1
5/5	3	545	0.5	214	280	30	9.3	5.2	373	None	—	40	—	0.2
5/2	1	4200	0.43	264	195	30	6.5	3.6	287	.25	0.63	53	—	0.2
5/2	2	4200	0.68	188	434	35	12.4	6.9	467	.25	1.25	53	—	1.0
5/2	3	4200	0.5	159	377	30	12.6	7.0	503	.25	0.5	53	—	1.0
5/3	1	4200	0.75	235	382	20	19.1	10.4	382	.25	16.5	43	—	0.0
5/3	2	228V	0.63	296	255	35	7.3	4.0	290	None	—	43	—	0.1
5/3	3	228V	0.5	210	285	30	9.5	5.3	380	None	—	43	—	1.5
5/3	4	228V	0.5	296	210	35	6.0	3.3	280	None	—	45	—	1.0

FIG. 26.
5-GPM PACK WATER PURIFICATION SET (SERVICE TESTED).
SUMMARY OF FILTER RUNS AT CAMP HALE, COLORADO.
126th Engineer Light Combat Battalion.

Run No.	Method of Operation	Raw Water Turbidity (P.P.M.)	Filter Average Output (G.P.M.)	Hourly Average Output (G.P.H.)	Filteraid Brand
1,2,3	Cleaning tubes				
4,5	Pretreatment	100	7.1	184	234-V
6	Pretreatment	150	6.5	300	Hyflo
9c & d	Pretreatment	60	4.1	246	Hyflo
7a	Direct Filtration	65	4.9	290	234-V
7b		60	5.5	330	234-V
7c & d		60	5.6	340	234-V
7 d,e,f		65-100	5.3	300	234-V
7f		65-10	6.4	383	234-V
7g		50	7.1	424	234-V
8a		35	8.4	509	234-V
8b		40-50	5.6	338	234-V
10 a & b		200-500	4.8	286	234-V
9a	Hand Pump	60-150	4.4	265	234-V
		200-500	4.8	240	234-V

FIG. 27.
15-GPM DIATOMITE WATER PURIFICATION SET.
SUMMARY OF FILTER TESTS.
Engineer Board, Fort Belvoir, Virginia.

Date	Run No.	Raw Water Temp. (°F)	Diatomaceous Silica Filter Aid Brand	Precoat (lb.)	Body Feed (lb.)	Body Feed (ppm)	Total (lb.)	Filtered Water Total (gal.)	Length of Run (min.)	Average Output (gpm)	Rate (gpm/sq.ft.)	Economy (gal./lb.FA)	Pretreatment Coag. Alum (lb.)	Settling Time (hr.)	Turbidities Raw (ppm)	Settled (ppm)	Filtered (ppm)
6/10	1	70	4200	0.36	0.36	54	0.72	835	45	19	5.3	1160	None	---	15	15	1.0
	2	70	4200	0.36	0.36	83	0.72	540	28	19	5.3	750	.28	0.5	20	15	0.1
	3	70	4200	0.36	0.13	32	0.49	510	25	20	5.6	1041	.17	1.0	20	10	0.1
	4	70	4200	0.36	0.18	43	0.54	525	25	21	5.8	972	.17	1.5	20	10	0.1
	5	70	4200	0.36	0	0	0.36	570	25	23	6.4	1583	.19	2.0	20	10	0.1
	6	67	4200	0.36	0	0	0.36	399	17	23	6.4	1108	.13	16.0	20	5	0.1
6/12	1	70	4200	0.36	0	0	0.36	585	20	29	8.1	1625	None	---	15	15	1.0
	2	70	4200	0.36	0.36	53	0.72	855	30	29	8.1	1198	.36	0.5	15	2	0.1
6/14	1	76	4200	0.5	0.5	65	1.0	960	40	24	6.7	960	.33	3.0	50	15	0.1
	2	76	4200	0.5	0.25	43	0.75	720	30	24	6.7	960	.24	3.5	50	15	0.1
6/15	1	76	4200	0.375	0.25	31	0.625	1020	45	23	6.3	1632	.265	0.5	32	13	0.1
6/16	1	78	4200	0.25	0.25	28	0.5	1100	50	22	6.1	2200	.275	0.5	28	15	0.0
	2	78	4200	0.25	0.25	82	0.5	390	15	26	7.2	780	.057	1.4	28	15	0.0
	3	80	4200	0.25	0.25	46	0.5	680	25	27	7.5	1360	.29	0.5	20	15	0.0
	4	80	4200	0.25	0.25	40	0.5	780	35	22	6.1	1560	.33	1.0	20	15	0.0
	5	80	4200	0.25	0.25	40	0.5	780	35	22	6.1	1560	.33	1.5	20	15	0.0
6/17	1	78	4200	0.5	0.0	0	0.5	600	30	20	5.6	1200	.27	0.5	15	12	0.0
	2	78	4200	0.375	0.0	0	0.375	660	30	22	6.1	1760	.30	1.0	20	10	0.0
	3	78	4200	0.5	0.25	45	0.75	690	30	23	6.4	920	.23	0.5	40	10	0.0
	4	78	4200	0.25	0.25	40	0.5	780	35	22	6.1	1560	.26	1.0	40	10	0.0
6/19	1	81	4200	0.5	0.25	58	0.75	540	20	27	7.5	720	.18	0.5	15	10	0.5
	2	81	228V	0.25	0.25	63	0.5	490	20	25	6.3	980	None	None	15	15	0.1
6/20	1	76	228V	0.25	0.25	50	0.5	630	30	21	5.8	1260	None	None	15	15	3.0
	2	76	228V	0.25	0.25	59	0.5	530	25	21	5.8	707	None	None	15	15	0.1
	3	76	228V	0.25	0.25	65	0.5	430	20	24	6.7	640	None	None	15	15	0.2

Remarks:

Raw Water - Source: Potomac River Average pH: Raw Water - 7.4 Treated Water - 6.8
Treatment (when employed) - coagulation and settling
Variation in yields of filtrate are due to variation in character of turbidity. Occasional concentrations of slimy vegetable matter caused marked reductions in volume per run, particularly Runs No. 6 on 6/10 and No. 2 on 6/16.

UNCLASSIFIED

Changed to UNCLASSIFIED

Classified

Cancelled

Date 17/2/59

By authority of Ch, [illegible] E
5/5/58

UNCLASSIFIED

FIG. 28.
COMPARISON OF GASOLINE ENGINES FOR
LIGHT WATER PURIFICATION EQUIPMENT.
Engineer Board, Fort Belvoir, Virginia.

Manufacturer	Model Number	Brake H. P.	R.P.M. at Rated H.P.	Bore	Stroke	Displacement Cu.In.	Compr. Ratio	Cycle	Weight Without Accessories	Comments
Lauson	RSC 609	1.3	2800	2"	1-7/8"	5.9	5	4	*34.5	Power equals requirement. Manufacturer incorporated special features such as larger oil capacity, aluminum castings, chained accessories, etc.
Briggs and Stratton	NLP	1.5	2600	2"	2"	6.28	5.86	4	36.25	Power in excess of needs, involving excessive gasoline consumption.
Johnson "Iron Horse"	X500	1.2	2400	2¼"	1-3/4"	6.96	4.5	4	42	Weight characteristic not as good as other makes.
Delco	4B	.9	3300 (est.)	2-1/8"	2¼"	8.0	4	4		Engine normally furnished only in connection with generator.
Jacobson	J150	1.0 1.2	1550 2100	2¼"	1-3/4"	6.93	5.5	2	38	Two cycle not desirable for operation with leaded gasoline and issue oils.
Jacobson	J100	.75 1.1	1700 3800	2"	1½"	4.71	5.5	2	28½	Same disadvantages as the J150 and H.P. too low.
Homelite		1.7	3400	2"	1½"	4.7	6	2	?	Power in excess of needs. R. P. M. and compression ratio high for assurance of longest life.

*Complete with accessories