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FLEXIBLE HOLDING TANK FOR PLEASURECRAFT SANITARY SYSTEMS

ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

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FLEXIBLE HOLDING TANK FOR PLEASURECRAFT SANITARY SYSTEM

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EPA Review Notice

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ABSTRACT

The purpose of this effort was to develop a flexible holding tank to collect waste products in small pleasurecraft. Its use is primarily proposed as a convenient means for modifying existing craft so as to comply with proposed standards for the discharge of sewage from vessels.

A survey delineated numerous locations where a flexible tank could be located in the various craft under consideration and a corrugated design was conceived which will conform to most of these.

The placement of the flexible tank in several locations was successfully demonstrated using a boat mock-up. Performance tests, also conducted, showed that the tank could be used both as a simple holding tank or as a reservoir in a recirculating sanitary system.

Potential construction materials were tested by immersion in a variety of solutions with which a container might come into contact. The list included fuel and lubricating type hydrocarbons and aqueous solutions of several sanitary-system cleaners and treatment chemicals. Nylon fabric coated with NBR, Neoprene or polyurethane proved to be satisfactory for the application.

Rocking tests proved that wear is not a serious factor as regards the application of a flexible holding tank on small pleasurecraft.

Installation of the flexible holding tank is relatively simple. An overall installation cost was not projected, however, because the cost of the container itself will vary considerably with the number produced and an economic study was not undertaken as a part of this effort.

This report was submitted in fulfillment of Contract #14-12-506 under the sponsorship of the Federal Water Quality Administration.

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SECTION I

CONCLUSIONS AND RECOMMENDATIONS

It has been shown that a flexible container made of elastomer-coated nylon fabric provides an acceptable and versatile holding tank for upgrading a sanitary system on small pleasurecraft. It is particularly suited to craft in the 22 to 28 ft length classification where open space is not generally available for the installation of a rigid tank.

An accordion tank design with a 14 in. x 24 in. cross section can be installed in a majority of the hidden spaces found on small pleasurecraft. It can be folded and inserted through a relatively small access opening and used as a simple holding tank or as a reservoir in a recirculating sanitary system. Clean out is readily accomplished with a diaphragm type sludge pump which would be located at dock side servicing stations.

Used as a simple holding tank, a 20 gal. unit will provide approximately 40 flushes and thereby be suitable for a party of four for a weekend or two-day cruise. The same size tank used as a reservoir in a recirculating system will provide about 140 flushes.

Prototype flexible holding tanks should be fabricated and installed on a variety of craft where their operation can be monitored and their practical usefulness demonstrated to the general public and potential manufacturers.

SECTION II

INTRODUCTION

Until recently, the type and operation of pleasurecraft sanitary systems have not been seriously regulated. Consequently the vast majority now in operation discharge waste products directly into the surrounding water. This is generating a sizable pollution problem in many of our lakes and harbors - especially around marinas where boats are generally concentrated. The Department of the Interior, working with industry and Coast Guard figures, have estimated that there now exist a total of 8,000,000 recreational watercraft in the United States (1967) and that over 1.3 million are equipped with toilet facilities, most of which contribute to this problem.

Several methods are available for handling sanitary waste on small pleasurecraft other than dumping it over the side. The most direct involves collecting it in a holding tank for later transfer into a shore facility. Manufacturers who supply integrated toilet and holding tank units to the house trailer and aircraft industries are now offering them for use on boats. Macerator/chlorinators are available which incompletely treat the sewage before it is discharged into the sea. One manufacturer offers a unit in which the sewage can be incinerated. For large boats involving a sizeable crew, complete treatment systems should be considered and used.

Two service organizations exist whose interests include sanitary systems on small boats. One of these, the Yacht Safety Bureau, Inc., is sponsored by a marine manufacturing association and several insurance companies. It is set up to test and certify products for the boating industry. This organization is mainly interested in the safety aspects of a product to the user, however, and does not specifically concern itself with the resulting problem of pollution. The second organization, the National Sanitation Foundation, on the other hand is actively concerned with pollution and has undertaken to formulate specifications for watercraft sewage disposal systems with this basic viewpoint in mind.

The main impetus to adopting improved means for handling sewage on boats is the adoption of appropriate codes by state and federal legislative bodies. Unfortunately (at least for the present) the laws are quite inconsistent, one from the other, but a preference does seem to be developing for the holding tank technique for controlling the pollution problem. Officials favor tamper-proof permanent hook-ups that lend themselves to pumping out at dock side only. Both the City of Chicago and the State of New York now require the use of holding tanks of this type. Federal standards will not specify any type of equipment but will merely set effluent requirements.

SECTION III

OBJECTIVES

It was our objective under the subject contract to demonstrate the capabilities of a flexible holding tank for upgrading the sanitary systems of existing pleasurecraft to the point where they conform to new antipollution codes. These codes require that sewage generated on a boat be collected and stored for later delivery to a shore treatment facility. A flexible (collapsible) tank lends itself to being installed in hidden and out-of-the-way spaces on existing boats with a minimum amount of structural dislocation.

To demonstrate that a flexible container would adequately serve as described, a program involving three phases was undertaken:

Phase I - An Application Analysis

Phase II - A Design and Fabrication Effort, and

Phase III - A Testing Program

SECTION IV

APPLICATION ANALYSIS

The application analysis was directed at answering the following questions:

1. What are the merits of the various means for controlling the pollution problem caused by small pleasurecraft?

2. How should a holding tank be integrated into a pleasurecraft sanitary system?

3. Does a flexible holding tank offer unique possibilities for upgrading an existing pleasurecraft sanitary system?

4. What is the optimum size (and shape) for a flexible holding tank to be used on small pleasurecraft?

Information of a general interest concerning the above was obtained from the following sources:

1. State and federal laws.

2. Manufacturer's literature.

3. Specifications promulgated by the Yacht Safety Bureau and National Sanitation Foundation.

4. Interviews.

5. Field trips.

Regulations vary widely from state to state on the subject of controlling the discharge of waste from watercraft. Some states still have no regulations. A majority of the states that have regulations express a preference for a holding tank, but many also permit the use of a macerator/chlorinator.

Toilets on existing pleasurecraft are generally designed to discharge sanitary waste products directly into the surrounding water. Hand pumps are used on cheaper models and electric pumps on the more elaborate but the effect on pollution is the same. The practice is particularly objectionable in harbors and marinas where the relatively high concentration of boats in a limited space results in a serious pollution problem.

The macerator/chlorinator is a type of holding tank wherein sanitary wastes are broken up and treated with chlorine for a short interval prior to dumping overboard. When operated properly these are effective for killing bacteria, and several states have approved their use on pleasurecraft. Many health officials are reluctant, however, to approve a device which is so completely subject to operator control and which does not, in any event, prevent solid nutrients from being discharged into the water.

Toilets designed to incinerate waste are not popular for small pleasurecraft because of the reluctance of owners to carry, let alone, burn, highly inflammable products on their boats. Self-contained treatment plants are generally too bulky to install on small boats.

Owners confronted with laws that require holding tanks have generally followed two courses of action. Some have installed rigid tanks and integrated them into their existing sanitary system. Others have replaced their toilets with small self-contained units in which toilet and tank are integrated into one compact assembly of the type that was developed for the aircraft and house trailer industries.

Holding tanks can be used strictly as a collection basin or as a reservoir in a recirculating system. Advocates of the former stress the value of a clean water flush while advocates of the latter point to the greater number of flushes that are possible. In the recirculating set up, the reservoir is initially half-filled with water. To this is added a highly perfumed chemical which acts to break down solids. The water is used over and over again for flushing until the added waste products fill the tank.

Flexible containers have not been offered to the trade for use as holding tanks. To determine if this is a feasible proposition and if it would offer any unique advantages over the rigid tank installation, a survey was conducted to ascertain the space available for holding tanks on existing pleasurecraft ranging in length from 20 to 50 feet. This information was obtained by studying plans in books and magazines, and viewing boats in a variety of locations. Facilities visited included:

1. New York Boat Show, New York, N. Y.
2. Yacht Haven Showroom, Stamford, Conn.
3. Doan Harbor Marina, Stamford, Conn.
4. Norwalk Cove Marina, East Norwalk, Conn.
5. Hammel's Marine Center, Freeport, L. I., N. Y.

6. Viking Boat Co., New Gretna, N. J.

7. Barnagat Marine Mart, Barnagat, N. J.

8. Sanborn's Marina, Waretown, N. J.

9. Chicago Municipal Dock, Chicago, Ill.

Where possible, photographs were taken of areas on the many boats viewed which would accommodate a holding tank. Also, physical measurements were made and sketches were produced for later analysis and review.

Four basic classes of boats were investigated. The most prominent was the powered yacht, usually with inboard engine, or lately with inboard-outdrive power. All are over the 20 foot length classification and are generally equipped with some type of toilet. Outboard powered runabouts, event those over 20 feet in length, were not included in the survey because they normally have no toilet facility.

The second class comprised the auxiliary powered sailboats. These vary in length from slightly under 20 feet to over 50 feet for the more elaborate models. The smallest models generally do not have toilets.

Sailboats without power range from below 12 feet to above 50 feet, again the smaller models do not have toilets.

The final classification considered was the houseboat. The popularity of this craft has developed only in recent years. Prior to 1965 there were probably less than 3,000 boats of this type in actual use. In that year, however, 1,250 additional units were built. This was increased to 3,000 in 1968 and several builders planned to double their output in '69 and '70. Houseboats are planned for complete liveability and practically all are provided with galleys as well as toilets.

Flexible tanks appear to best meet the requirements of boats between 22 and 28 feet. Above 28 feet, space is occasionally available for installing a rigid tank and above 35 feet this is almost always true. Below the 22 foot length classification, boats are rarely equipped with or need toilets.

Ideally, space for a holding tank is an area or cubby hole which the owner does not consider he needs for another purpose. Except on the larger boats, therefore, it generally consists of hidden space under decking and/or behind bulkheads. We found it to comprise a variety of configurations and quite often to be limited in size. To apply a rigid tank in these situations would require that it be custom built for each application. To install it would require the removal of at least one complete wall of the selected confined cavity.

Normally a flexible tank would be oversize of the anticipated installa-

tion space. This type of tank could be folded to insert through a relatively small access opening and would expand, when used, to the maximum confines of the space in which it is located. One design should serve a variety of space configuration needs as should become amply clear in the remainder of this report.

SECTION V

DESIGN ANALYSIS

Criteria for the design of a prototype holding tank are summarized below:

1. Moderately low first cost
2. Simple to operate
3. Negligible maintenance
4. Tamperproof
5. Compatible with dockside pump out and storage facilities
6. Odor free
7. Light weight and easily handled and installed
8. Applicable to large numbers of watercraft
9. Resistant to salt water and other corrosion and fatigue effects.

To meet these criteria the entire system is involved and is so discussed below:

Sizing Considerations

A holding tank should be as large as possible to reduce the inconvenience and expense of purging it and, of course, must be large enough to satisfy the owner's needs. On the other hand, space is likely to be a limiting factor and the effect of a relatively large tank on boat trim must be taken into account. These are matters for the boat owner to consider when he plans his installation.

For our purpose it was assumed that the owner will want a holding tank that tends to match his particular boat design. One that is planned to accommodate four people for a week-end cruise, therefore, should have a holding tank suitable for eight man-days use. Based on advertizers literature (and later verified by our own tests), sanitary waste (including flushing water) accumulates at a rate of approximately 2-1/2 gallons per day per individual. Applied to several arbitrary boat classifications, this works out as follows:

Boat Length Class	Occupancy	Suggested Waste Tank Capacity[a] (gal)	No. of Flushes Provided
22 - 28	2 to 4	10 - 20	20 - 40
28 - 35	4 to 6	20 - 35	40 - 70
35 - 50	6 to 8 +	35 - 50 +	70 - 100 +

[a]Suitable as simple holding tank for two-day cruise

Since the flexible tank will show up to greatest advantage in a small boat with limited space, it follows that a 20 gallon size is probably optimum for this particular product. Unrestricted, it should be large enough for most boats in the 22 to 28 foot classification and for many in the 28 to 35 foot group. Actually, however, the number of flushes provided may be limited by the space selected for its installation. If space is excessively limiting, a recirculating system which will facilitate 3-1/2 times as many flushes might have to be considered. This type of hook-up could, in fact, make the 20 gallon tank suitable for even the largest size pleasurecraft.

A flexible tank larger than 20 gallons would require such elaborate supporting means that its advantage over a rigid tank would be negligible.

Based on the survey conducted under Phase I of this program, it was noted that the space which is available for the installation of a holding tank is generally rectangular, both in plan view and in elevation when viewed along the length of the boat. The shape coincident with the boat's cross-section, however, is usually similar to one of the several shown in Fig. 1. It became gradually apparent that an accordion-pleated tank would conform to all of these configurations (see lightface lines in Fig. 1) and furthermore that a 14 x 24 in. cross section was the proper size for most applications. Such a tank is shown schematically in Fig. 2.

From a fabrication point of view, it was agreed to provide ten 60° V-shaped pleats to form the accordion. Normally this tank will hold 18 gallons of fluid but will collapse to fit a much more restrictive space and can actually expand to 21 in. to provide a capacity of nearly 25 gallons.

To facilitate hooking the tank into the sanitary system, two access ports are required. These were placed side by side along the shortest edge of one of the flat end surfaces of the tank. Each comprises a flanged hollow rubber sleeve which is integrally cured into the tank and into which fittings can be inserted and clamped. The tank inlet

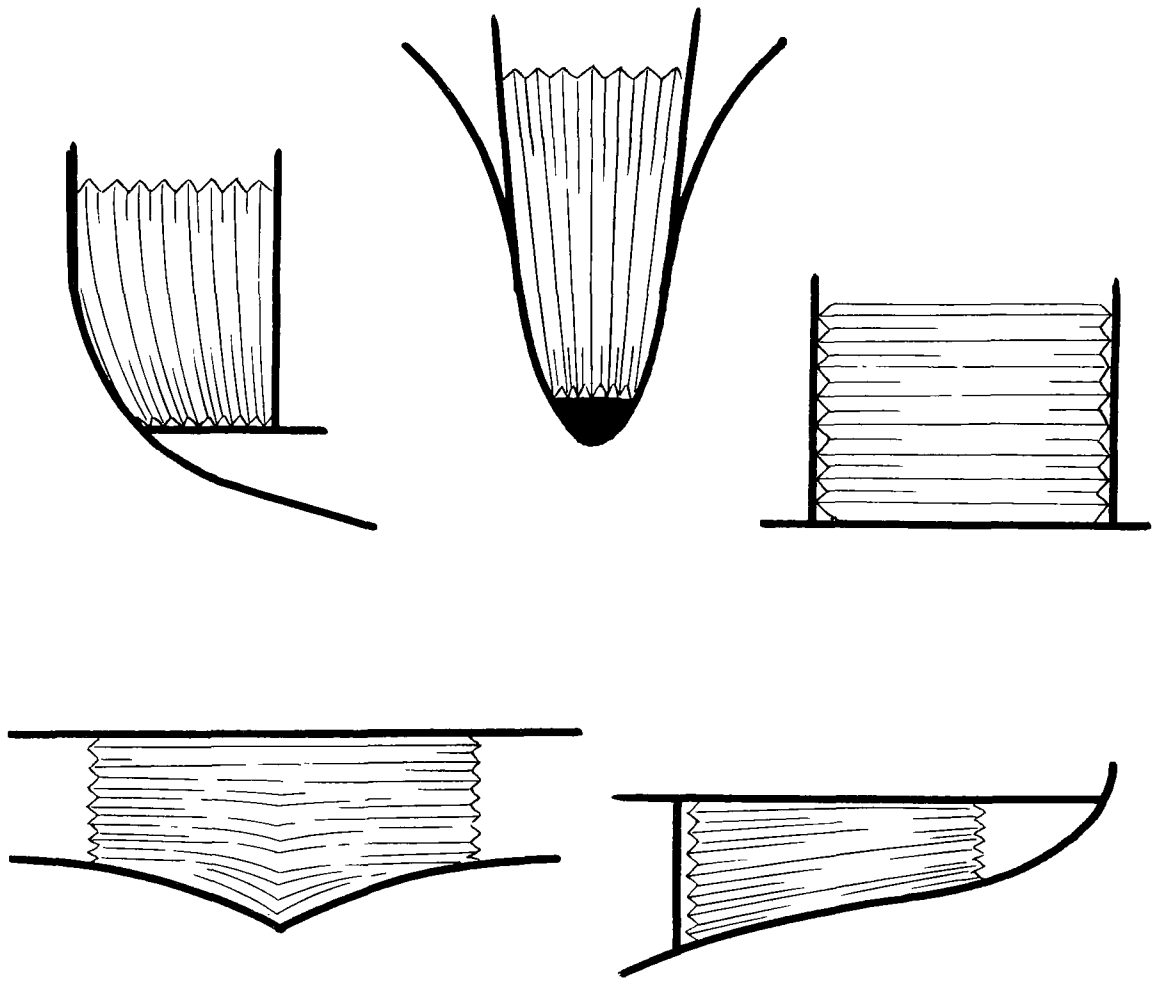


Figure 1. Typical Space Configurations and Accordion Design Holding Tank

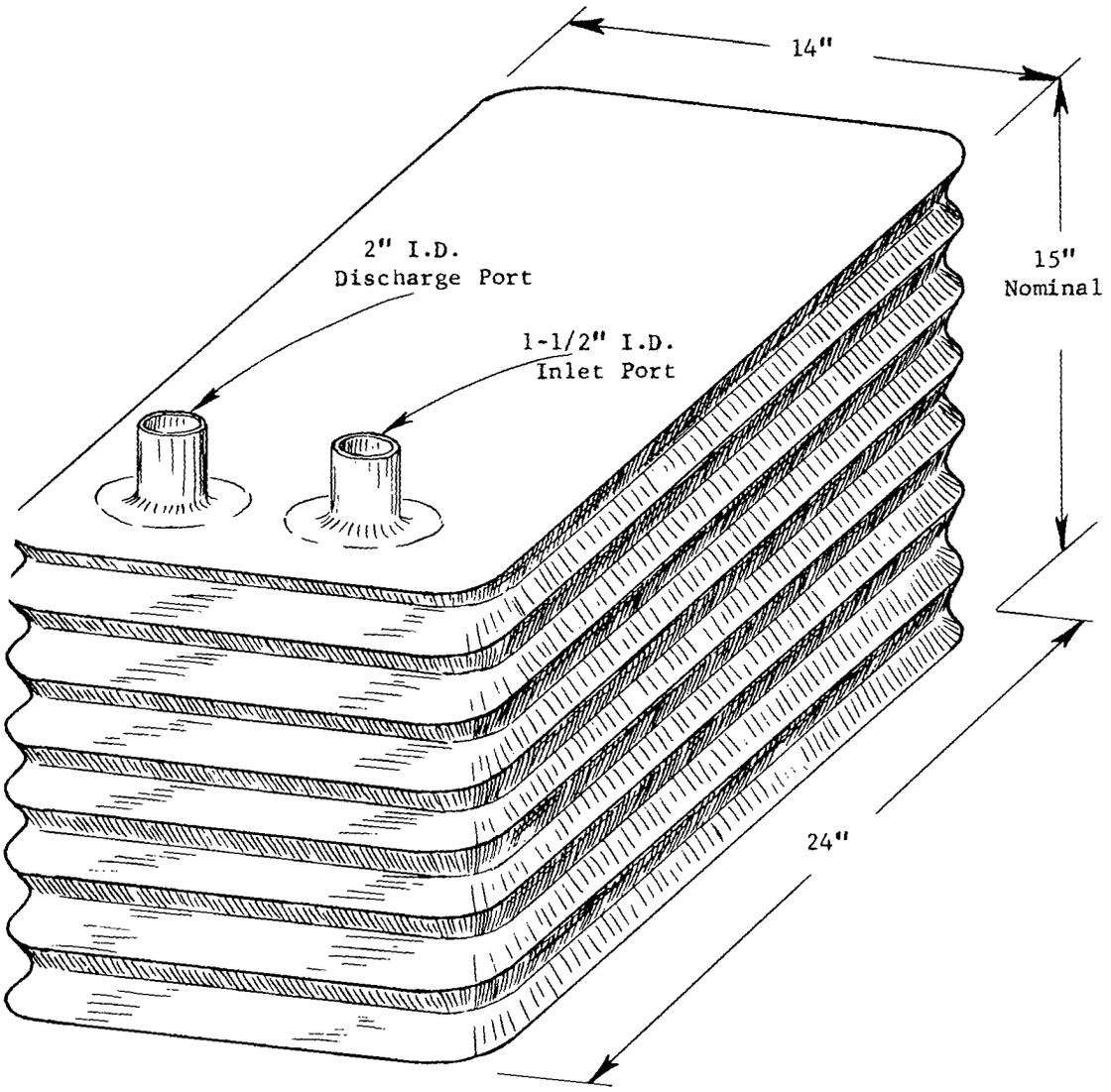


Figure 2. Accordion Design Flexible Holding Tank Configuration

port I.D. is 1-1/2 in. to match the usual toilet discharge line. The exit port is made with a 2 in. I.D. to permit insertion of the special fitting and dip pipe assembly. The vent opening is located and cut after the orientation of the installed tank is established.

Construction Materials

To achieve real flexibility combined with ruggedness and reasonable weight required that the tank be made of an elastomer-coated fabric. The specific construction selected, based on considerable experience in the manufacture of flexible tanks, is as follows:

Elastomer type: nitrile rubber, Uniroyal Compound No. 3010

Fabric reinforcement: Fiberthin nylon, 2 oz/sq yd

Wall construction: 0.042 in. total thickness, 30 oz/sq yd total weight

Elements of tank wall:

(a) single-ply impregnated fabric, 0.012 in. thick, 7 oz/sq yd, Uniroyal Style No. 5200 (rubber and fabric as described above)

(b) nonreinforced rubber liner, 0.030 in. thick, Compound No. 3010 as above.

The prototype tank made for the test program was assembled by a hand layup technique which is familiar to fabricators throughout the industry. Sheeting was cut to size, taped and pan cured into the finished item. The corrugations were formed from a series of frames taped to one another at their inner and outer edges. Tooling and more modern production techniques would be required for the fabrication of a commercial product. Tests described later in this report have shown that both the nitrile rubber used to impregnate the reinforcing fabric and the nonreinforced tank liner could be replaced by either Neoprene or a polyurethane rubber at the manufacturer's discretion.

Systems Layout

The majority of small pleasurecraft sanitary facilities are comprised simply of a water closet (toilet) and a dual action pump connected directly into the surrounding water. This hookup is shown in Fig. 3.

The system can be altered to include a holding tank as shown in Fig. 4, or can be converted into a recirculating system, wherein the tank becomes a reservoir as shown in Fig. 5.

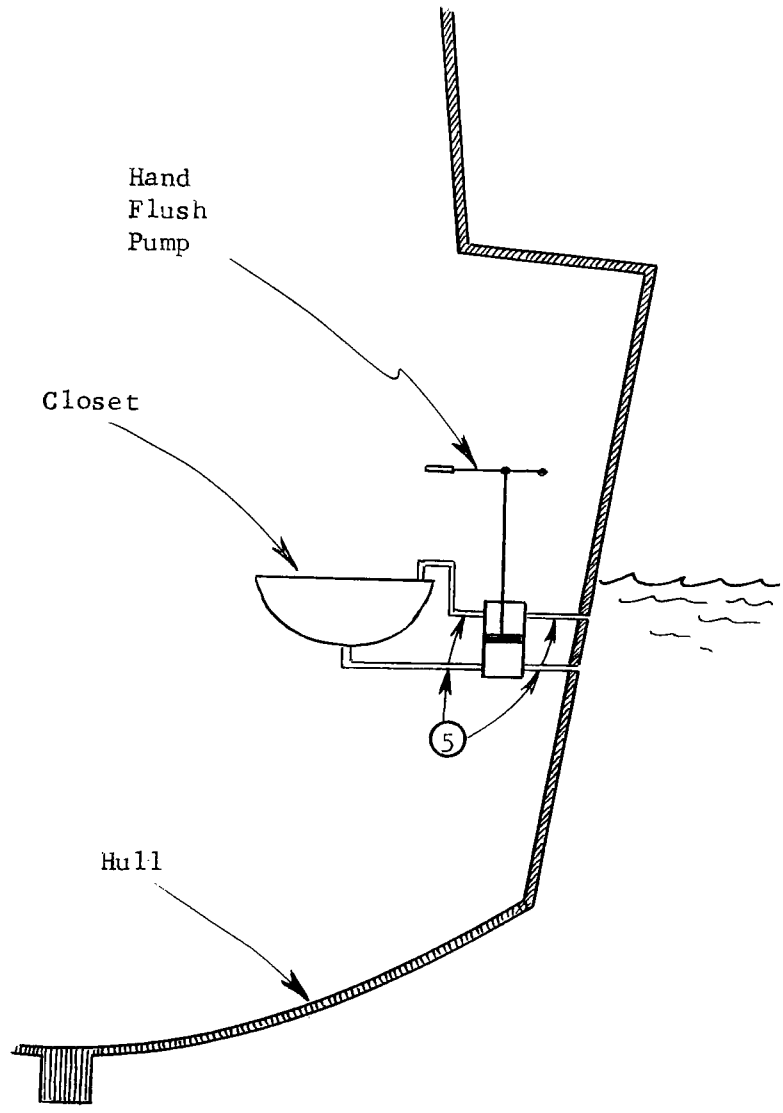


Figure 3. Typical Pleasurecraft Sanitary Hook-Up

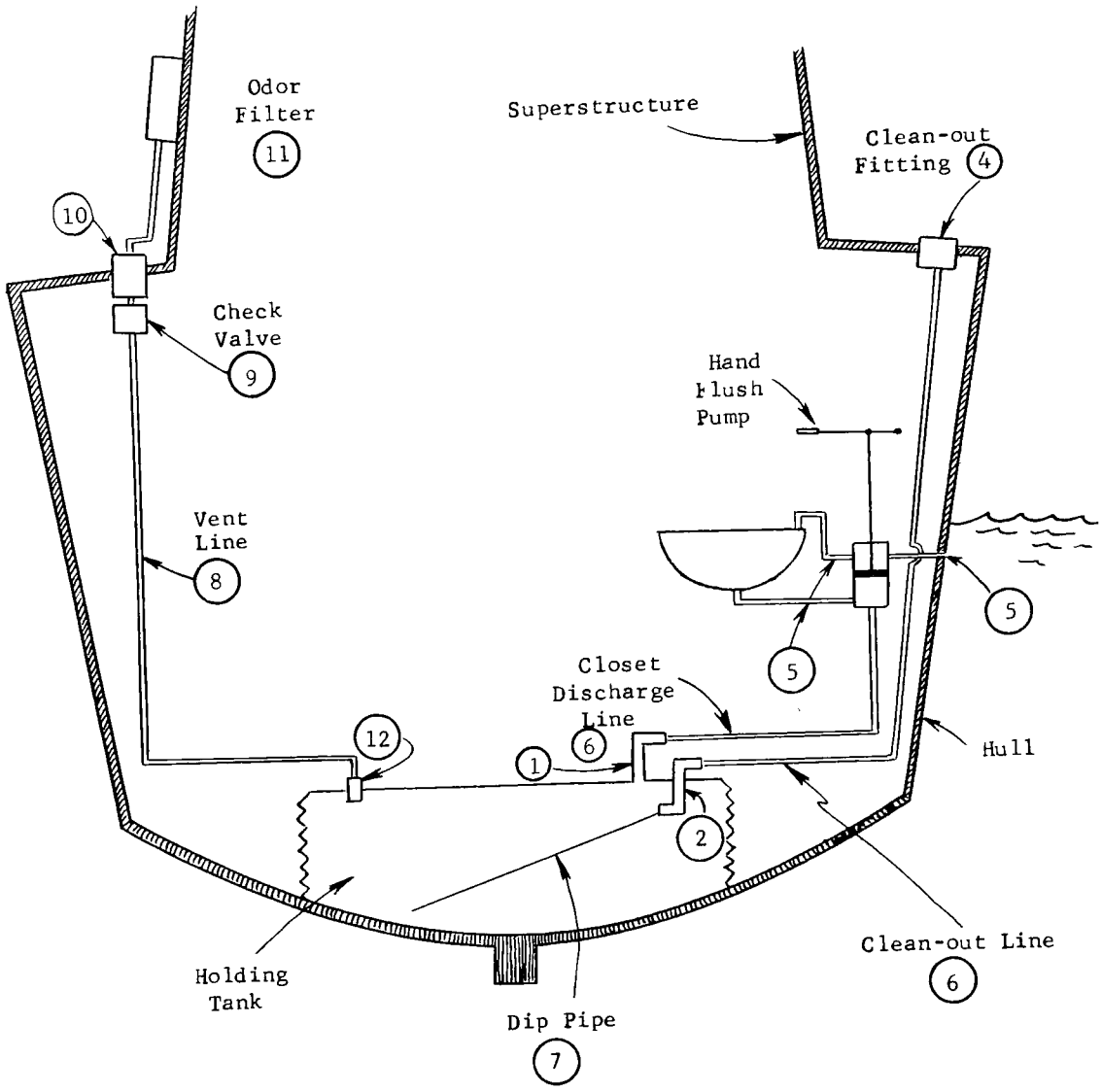


Figure 4. Sanitary System with Holding Tank

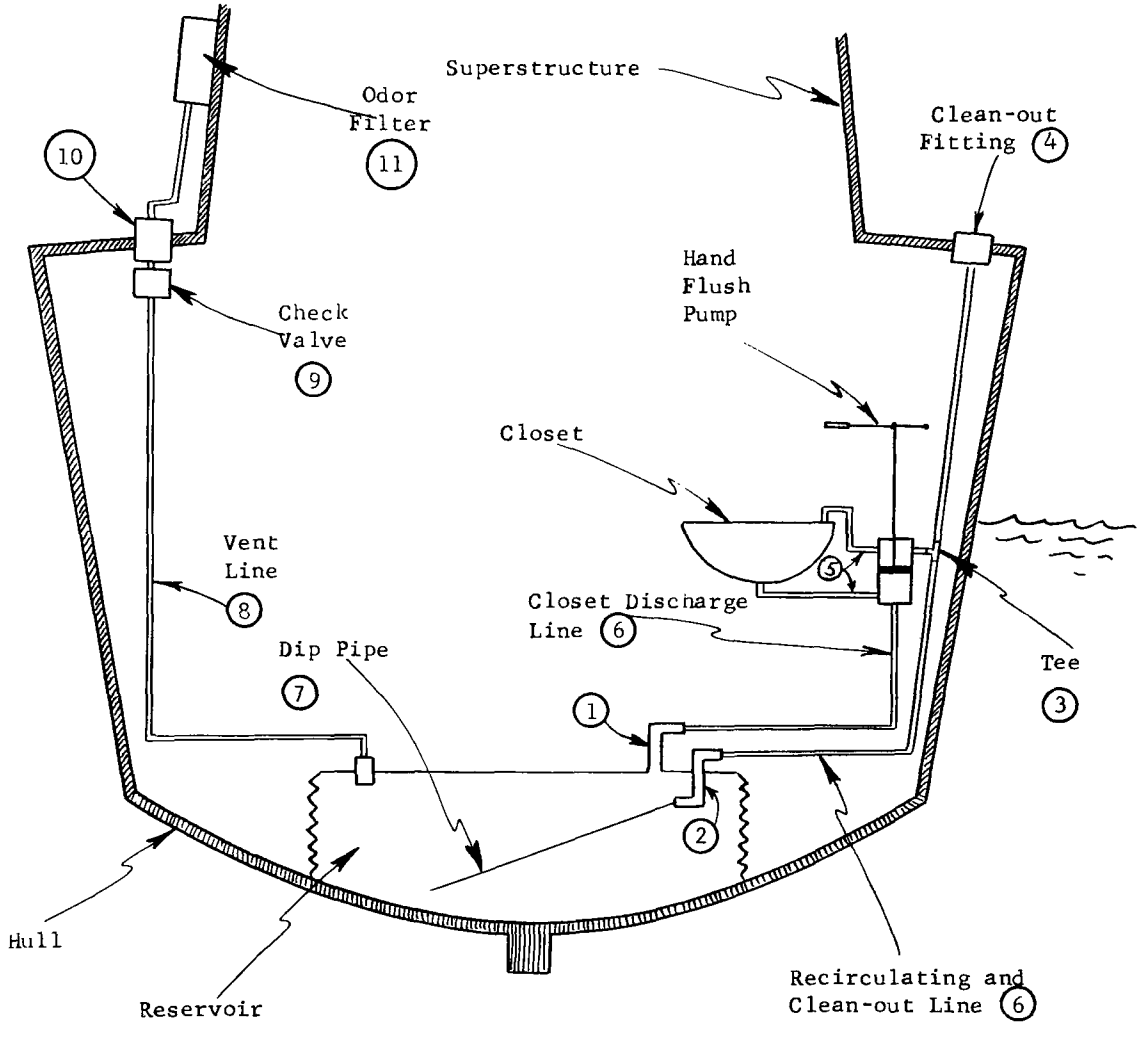


Figure 5. Recirculating Type Sanitary System

For the holding tank hookup, the pump discharge line is connected into the holding tank filling port. A cleanout line is attached to the exit port and terminates at a cleanout fitting. The vent line is attached to the top surface of the tank and terminates in a housing which can be filled with activated carbon to trap odors that emanate from the tank. It is generally convenient to handle the carbon in a small cloth bag and simply insert it unopened into the vent filter housing.

The hookup is similar for the recirculating system, except that the water supply line is cross-connected into the tank cleanout line. A sealed closure on the cleanout fitting makes it possible to circulate the fluid from the tank through the closet with the closet pump. To put into operation, the tank must be filled with water to roughly half its designed capacity. This water is treated with a chemical designed to break down the solids and control the odor problem. When operated, the tank fills at a much slower rate than it does when used as a simple holding tank hookup because additional flushing water is not being added to the system on each use.

A dip pipe installed in the bag prevents the latter from sealing off the discharge port prematurely during the purging or cleanout operation.

Regulating ordinances are not in general concerned with waste from galleys, and basically, the galley on a small runabout is not an important contributor to the pollution problem. Cooking is discouraged by the fact that water needed to pursue this activity has to be carried aboard the craft. Also, garbage from a picnic-style meal is usually easily bagged and carried off the boat. If the owner desires, however, a galley sink suitably equipped with a masticator, positive discharge, and check valve can be connected into a holding tank in common with a toilet.

Transfer Line Details

The major elements of the fluid transfer lines as shown in Figures 4 and 5 are numbered ① through ⑦ respectively. Elements of the tank vent line are numbered ⑧ through ⑫. While a choice of materials does exist here, a convenient combination which was used for our own testing program is summarized below:

① 1-1/2 in. insert type PVC elbow

② pair of 1-1/2 in. insert type PVC elbows modified as shown in Fig. 6

③ 1-1/2 in. insert type PVC tee

④ 1-1/2 in. pump out bulkhead fitting (modified fuel bulkhead fitting as shown in Fig. 7)

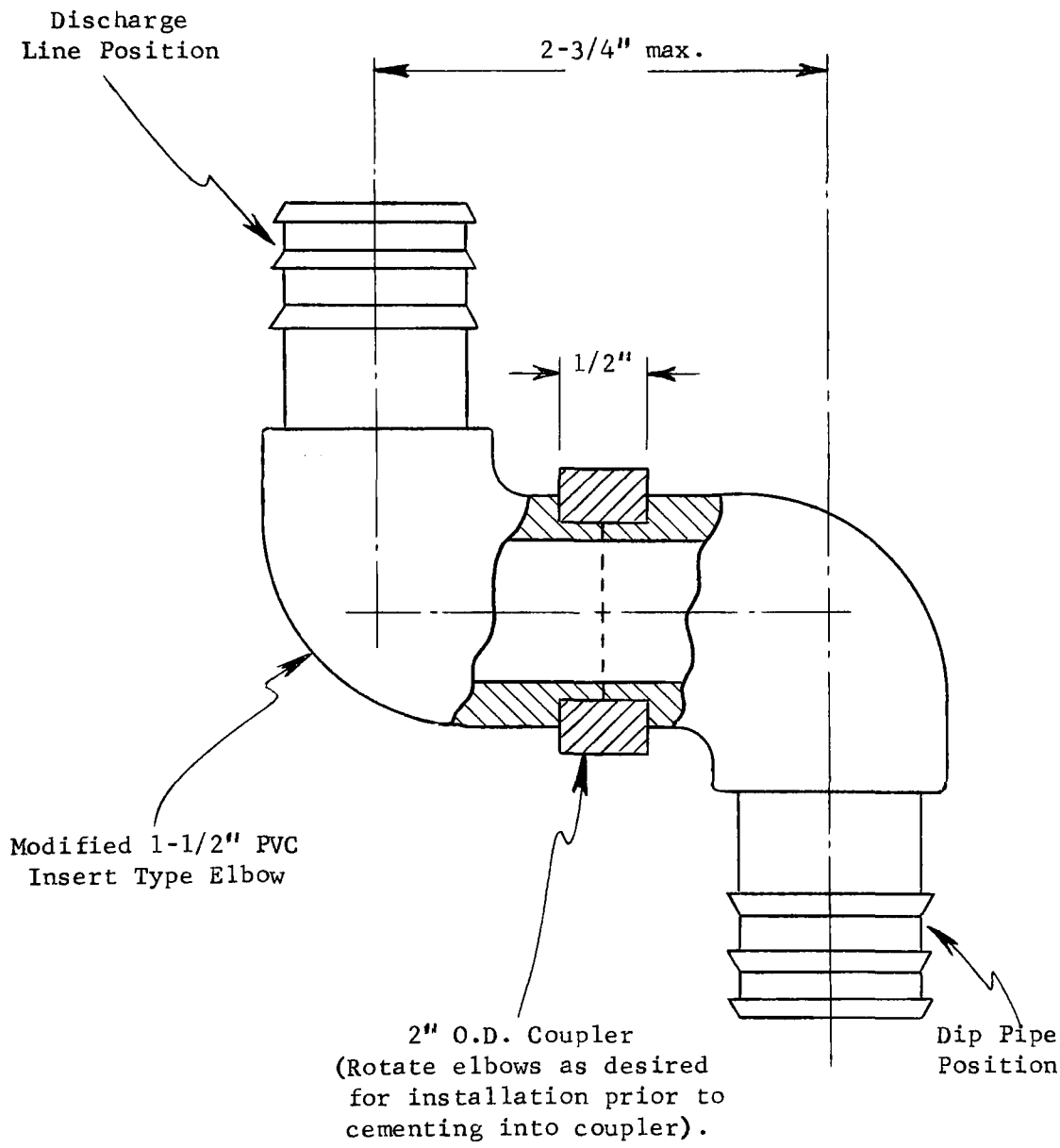


Figure 6. Tank Discharge Port Fitting

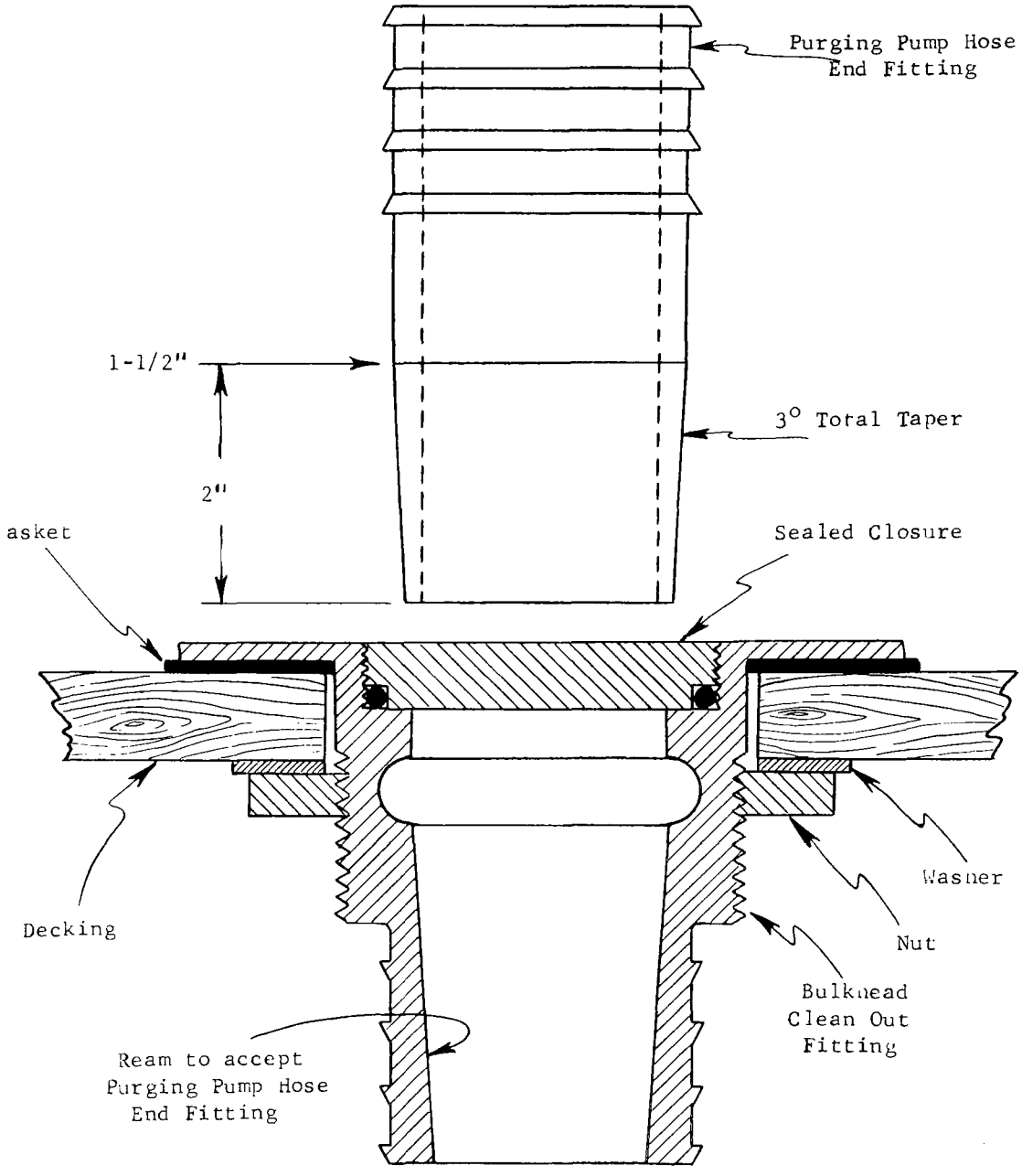


Figure 7. Bulkhead Clean Out Fitting and Purging Pump Hose End Fitting

⑤ existing lines as recommended by closet supplier

⑥ 1-1/2 in. flexible reinforced vinyl hose

⑦ 15 in. length - 1-1/2 in. flexible reinforced vinyl hose perforated with 3 dozen 3/16 in. x 3/4 in. slotted openings distributed evenly throughout its wall

⑧ 5/16 in. Tygon tubing

⑨ 1/4 in. Imperial brass ball check valve with spring removed

⑩ 3/8 in. bulkhead fitting shown in Fig. 8

⑪ Perforated charcoal container (filter housing) shown in Fig. 8

⑫ Penetration fitting shown in Fig. 9

The vent is necessary to release gas formed by the decomposition of sewage in the holding tank, since the pump-out fitting and toilet flushing pump prevent its escape via the larger lines. To be effective, the vent penetration fitting should be located at the highest point in the bag. It is designed to fasten into a bulkhead or decking so as not to sag, clog, or become submerged in the fluids in the tank and thus become inoperative. This is shown by Fig. 9.

The check valve in the vent line is required to insure complete discharge of the fluids from the tank during the clean-out operation. The discharge pump is designed to expel air and develop a suction sufficient to remove the sewage, and an open vent line could cause this operation to malfunction. Removal of the spring in the ball check is necessary to prevent any inadvertent build-up of pressure from occurring in the holding tank.

Any supplier of flexible holding tanks must arrange to make the required fittings available to the user - probably in the form of a kit. Most can be obtained from either an industrial or commercial supply house, but it might be difficult for the average boat owner to locate all of them. Also a few must be modified for this particular application.

The modified bulkhead fitting shown in Fig. 7 is equivalent to the fitting being used by boat owners on Lake Michigan. All municipal pump-out stations are equipped with a hose end-piece designed to match this fitting for executing the pump-out operation.

Flexible reinforced vinyl hose and associated PVC fittings are available from any plumbing supplier. Holes can readily be cut into a short

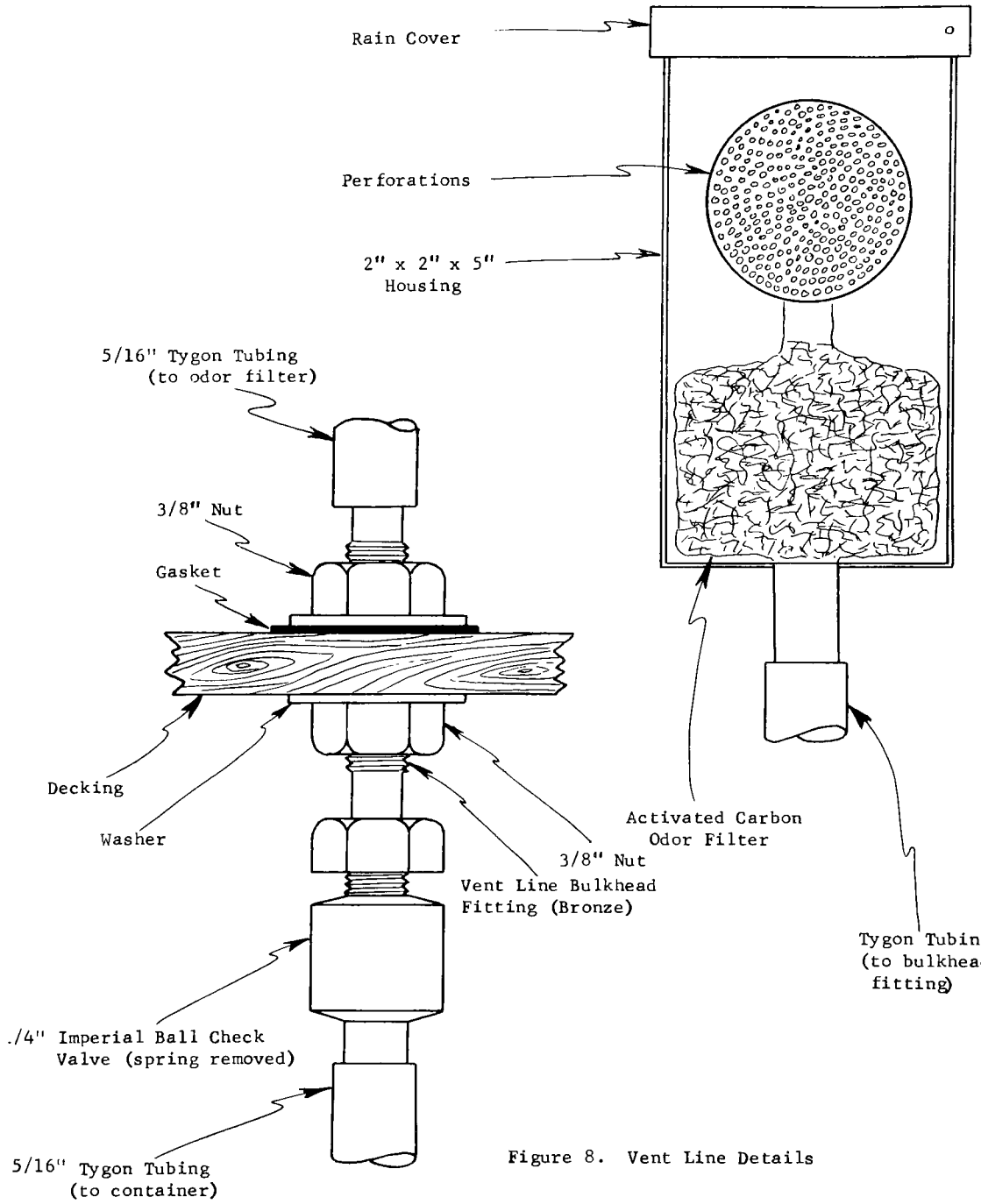


Figure 8. Vent Line Details

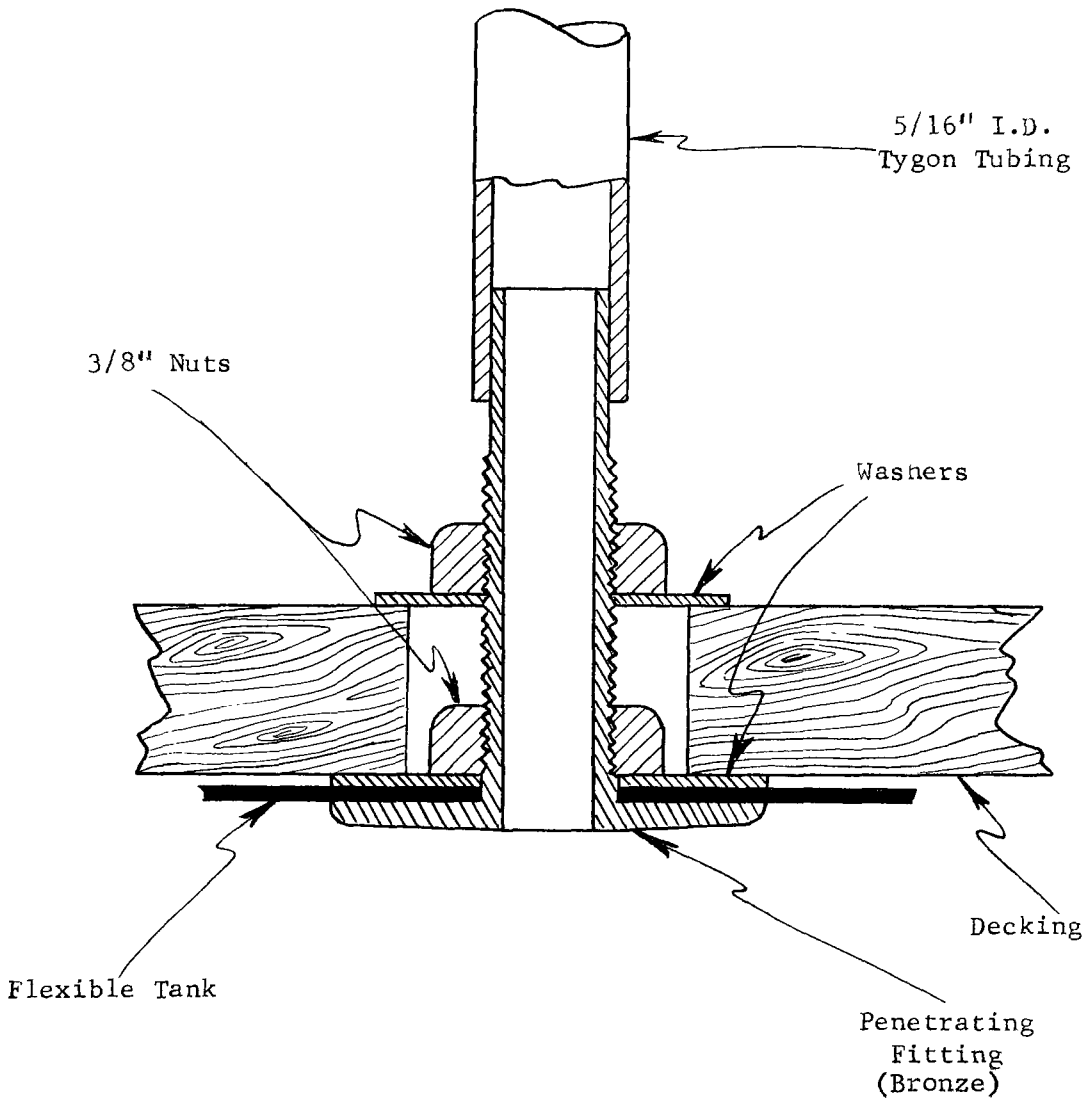


Figure 9. Vent Line Assembly into Tank

length of hose to form a dip pipe. Joints with fittings are made up with a standard hose clamp supplemented with plastic tape to insure an air-tight seal.

SECTION VI

TESTING PROGRAM

During the course of the work the question arose as to whether a corrugated tank would merit the added expense required for its fabrication. Both a plain and corrugated tank were therefore fabricated and included in the tests to be described below. Also included were tests in which the containers were used as a simple collection basin and some where they were used as a reservoir in a recirculating sanitary system. The overall program involved four types of tests:

1. Application tests
2. Immersion tests
3. Performance tests
4. Rocking tests

Application Tests

The application tests were designed to demonstrate the advantages of a flexible holding tank for use in a small pleasure craft. The test facility consisted of a composite boat section, the elements of a sanitary system, and a sewage discharge pump.

The simulated boat section is shown in Fig. 10. It provides five typical locations where a holding tank might be installed in a 22-28 foot pleasure boat. The reader should understand that these spaces do not necessarily exist in the same cross-section (as they do in the mock-up) but wherever located they undoubtedly would be accessible to the boat's toilet. The spaces, which represent typical ones found in actual boats, include:

1. The wedge-shaped space under the toilet
2. A wedge-shaped space in the deep keel
3. The shape offered by a shallow keel
4. An askew shape in the rope locker, and
5. An open space found in a typical motor chamber

The mock-up boat section (full size) was made of plywood. It was designed to tilt 15° to the right or left of vertical and thus simulate

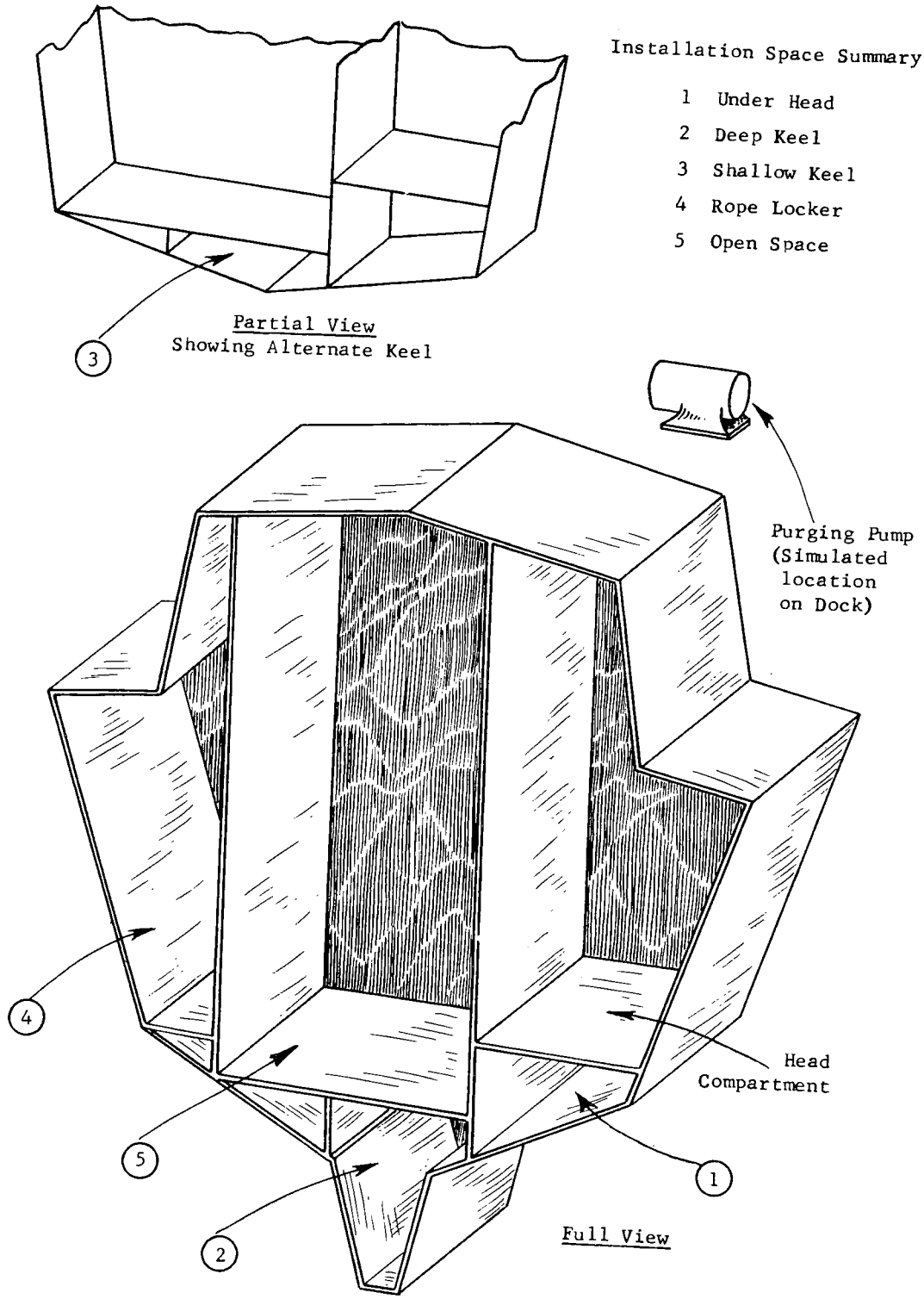


Figure 10. Mock Up Boat Section

extremes a boat might assume in a rough sea. The center area is logically a cabin interior, except when used as we did to represent open space in a motor chamber. The deep and shallow keel spaces (2 & 3) were designed to replace one another and thus simulate a sailing boat and motor cruiser, respectively. Space similar to that represented by 1 and 3 in the mock-up is often found under bunk beds in a variety of crafts.

The discharge pump was located at a height typical for a dock used for medium sized pleasurecraft at low tide. The pump[1] selected for the test was designed to pull a suction head of 20 feet and thus would be suitable for practically any condition imaginable in a lake or seashore marina. Sea water was furnished along side the hull in a 55 gallon drum.

The toilet[2] used on the mock-up was a standard hand-pumped marine type found typically on small pleasurecraft. Many are now equipped with electric pumps, but the operation is essentially unchanged.

The object of the application test was to determine the ease and/or problems encountered in installing a flexible holding tank aboard a small pleasurecraft and to check its operation for any malfunctions, deficiencies, etc. A qualified mechanic with a normal variety of handyman tools and the necessary supply of hose and fittings was assigned the task of installing the tanks into each of the assigned spaces. The actual installation, aside from the tedious and time-consuming tasks of rounding up tools and materials, required from two to three hours at each location. Obviously this could vary considerably depending on such factors as the remoteness of the tank's location to the boat's toilet. The task consisted of the following:

1. Cutting feed-through holes for hose and vent lines in bulkheads and decking

2. Providing arm-size access openings through bulkheads and/or decking - one being large enough (an 8 in. square) to insert the flexible holding tank.

3. Installing supporting walls to contain the tank on all sides where unsupported heights were deemed excessive. Existing bulkheads, decking, ribbing and hull are used to the fullest extent possible here. A basket, formed of expanded metal, was fabricated for containing the tank in the open motor space.

1. Series M8000 diaphragm pump manufactured by Mansfield Sanitary, Inc. A similar pump, Model 204 EC, is available from ITT, Marlow Pump Div.

2. Groco Model EB, hand operated

4. Connecting the holding tank and discharge line into the sanitary system.

5. Closing the exposed access opening.

Photographs were taken of each installation as it was pumped full by the hand-operated toilet pump, tilted at various stages and emptied by the discharge pump. Pictures accumulated during this procedure are reproduced in the Appendix. Fig. 11 is an enlargement of a typical installation.

Generally speaking, no difficulty was encountered with filling and emptying the tanks in any of the locations designated nor at any degree of boat tilt. The perforated dip pipe was found to be essential for insuring complete discharge of the tank. The need to install the vent line at the highest point in each setup was also demonstrated. By watching for water rising in this line (which consisted of transparent Tygon tubing), one could tell when the tank was nearly filled. Due to the inherent flexibility of the holding tank, however, numerous flushes were always possible even after water was first noticed in the vent line.

The amount of water contained by the two test tanks when filled at the various installation locations is summarized in the following table.

Location Number	Filled Capacity (gal.) Corrugated Tank	Plain Tank
① Under head	8.2	6.8
② Deep keel	14.0	13.6
③ Shallow keel	7.3	7.3
④ Rope locker	15.7	12.8
⑤ Motor chamber - basket	18.0	18.4

Approximately 2 to 4 quarts were left in the system after purging, but this amount could readily be contained in the noncollapsible hose used in the respective hook-ups. By visual examination it was noted that the container itself was literally wrung dry during the clean-out procedure.

The corrugated tank was far simpler to handle than the plain tank. Because of the pleated design, it tended to lay flat and expand on filling as it was expected to do. The corrugations provided a circumferential rigidity which aided in positioning it through blind access openings. The plain tank behaved in exactly the opposite manner. It was very difficult to identify the lower corners of the

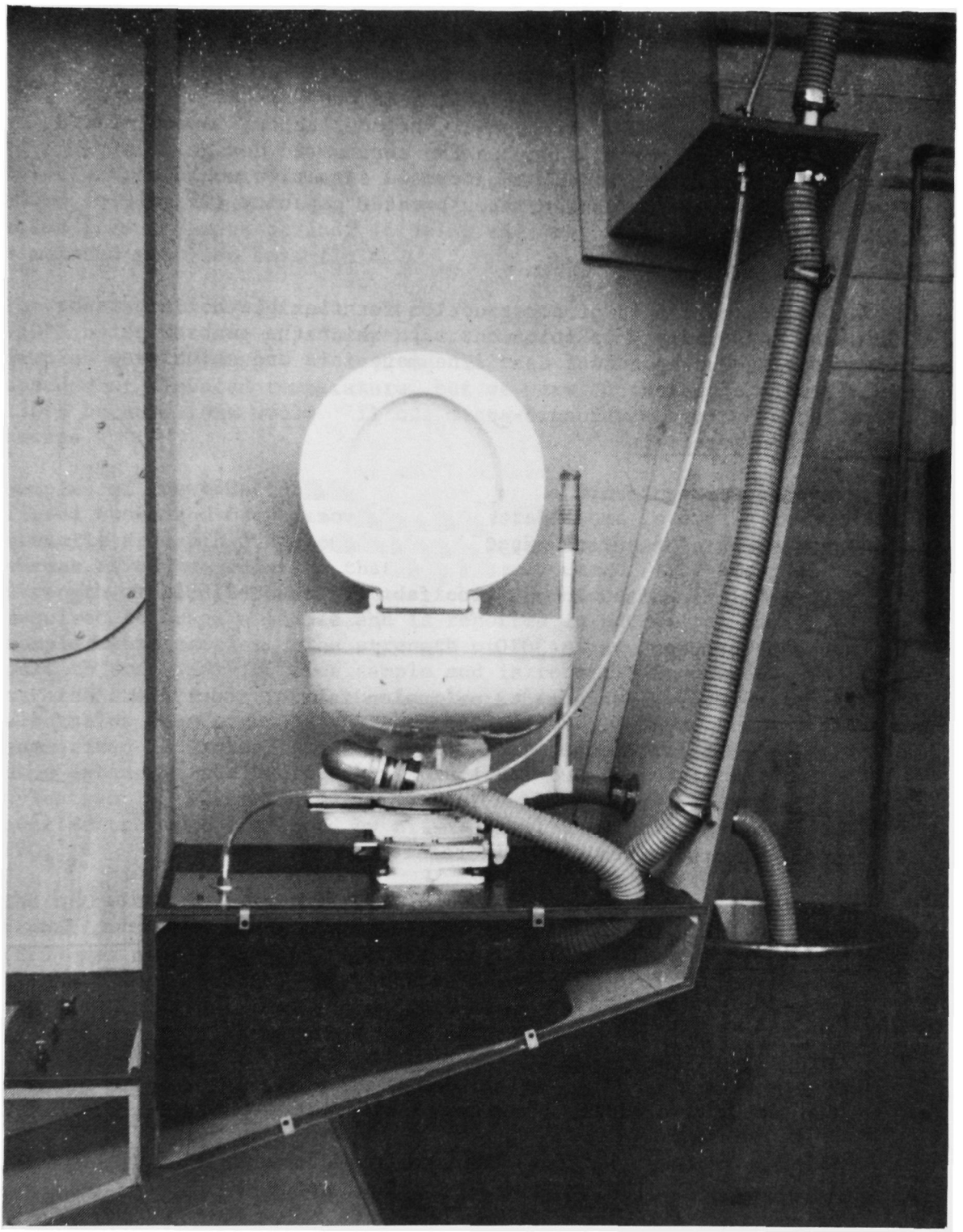


Fig. 11 - Installed tank on mock-up boat section

tank to position it in a blind hole and to tell if the bottom surface was spread out fully or not. Often a part of the bag was turned under itself and/or folds existed which never opened up fully on filling. Nevertheless it must be acknowledged that this problem was of no real significance - whether folded grotesquely or not, the plain container usually filled to the same capacity as the corrugated design. Only when filled to the maximum in an unrestricted situation would the corrugated tank provide a substantially greater capacity (25 gal.)

Immersion Tests

Several candidate materials of construction for flexible holding tanks were immersed in a variety of solutions with which the tanks might come into contact during actual use. The materials and solutions involved are listed below:

Construction Materials

1. Urethane impregnated 8 oz. nylon fabric, Code 5408*
2. Thermoplastic polyurethane, Code E-9
3. Neoprene impregnated 2 oz. nylon fabric, Code T-71595
4. Neoprene compound, Code 3070
5. Nitrile rubber impregnated 2 oz. nylon fabric, Code 5200
6. Nitrile rubber compound, Code 3010
7. Urethane impregnated 5 oz. nylon fabric, Exptl. 2195
8. Axial cut strip from flexible reinforced PVC hose.

*Code numbers assigned by Uniroyal Plastics and Industrial Products Co., Mishawaka, Ind

Test Solutions

1. Water
2. Sewage
3. "Vanish" bowl cleaner, 1 cup per 3 gals. of water
4. Thetford Engineering Corp. odor control chemical "Aqua-Kem', 4 fluid oz. per 10 gals. of water
5. Monogram Industries 'T-5' treatment chemical for recirculating systems, 5 oz. per 4 gals. of water

6. Fed. Spec. TT-S-735 hydrocarbon type III test fluid (gasoline)

7. Commercial diesel fuel

8. Commercial lubricating oil

Solutions 3, 4, 5 and 6 were renewed every other week. Toluene was added to solution 6 on the off week to replace the amount that evaporated in a one-week period, it being the most volatile portion of the simulated gasoline test fluid.

The test solutions were contained in battery jars and maintained at 130°F by submerging in a temperature controlled water bath. Racked samples were submerged in turn in the test solutions. Degradation is speeded at elevated temperature, but we were advised not to exceed 130°F because this would kill off micro-organism activity in the raw sewage.

Samples of the construction materials were immersed in the solutions listed above and were removed at pre-established intervals and tested (tensile strength and elongation at break) in order to determine the extent of any degradation that may have occurred. The tensile strength of an elastomer without fabric reinforcement is the pull required to break a sample and is reported in pounds per sq in. of sample cross-section. The strength of an impregnated fabric is the pull to break a 1 in. wide sample and is reported in pounds. The stretch characteristic of the samples is reported as per cent elongation when stressed to its breaking point. These results are summarized in Tables I and II. All of the elastomers swelled to some extent in the hydrocarbon solutions, but the elastomer-coated nylon samples were relatively stable in this regard. Neoprene swelled the most, followed by nitrile rubber, polyurethane and finally PVC.

The nitrile rubber sample (3010) displayed the greatest overall stability in contact with the varied test solutions. Polyurethane (E-9) was nearly as good, but the test results on this material were slightly more erratic. Unsupported Neoprene (3070) was noticeably degraded in diesel fuel and suffered some loss in physical strength by exposure to all the other test solutions except gasoline. The PVC sample cut from a flexible hose was only slightly affected by the various aqueous solutions but became quite stiff on exposure to the hydrocarbon fluids.

The several coated nylon samples were affected to a lesser extent by exposure to the test solutions. "Vanish" bowl cleaner solution appears to downgrade coated nylon slightly. Also, all of the aqueous solutions caused the nitrile rubber-coated nylon to blister (noticed on samples immersed for only one week), but the condition did not worsen with time. Lining a tank with a thin sheet of elastomer should therefore be sufficient to protect the nylon thoroughly in the final tank

TABLE I

TENSILE STRENGTH* AND (ELONGATION)** OF CANDIDATE IMPREGNATED FABRICS

Material Code	Aging Period	Water	Aqua Chem	T-5	Vanish	Gasoline	Lub Oil	Diesel Fuel	Sewage
5200	Unaged	←		93(28)					→
	1 Wk.	106 (34)	114 (38)	109 (36)	113 (39)	117 (36)	118 (35)	116 (36)	105 (34)
	3 Wks.	95 (62)	86 (54)	95 (58)	110 (47)	112 (36)	93 (54)	85 (48)	89 (54)
	8 Wks.	83 (64)	61 (47)	86 (51)	92 (43)	94 (56)	90 (60)	92 (51)	101 (63)
	3 Mos.	88 (30)	86 (25)	89 (30)	90 (35)	73 (24)	94 (29)	88 (25)	92 (26)
5408	Unaged	←		323(44)					→
	1 Wk.	496 (46)	490 (49)	460 (46)	503 (49)	513 (48)	444 (36)	500 (49)	475 (48)
	3 Wks.	495 (48)	500 (46)	510 (48)	505 (47)	500 (40)	500 (46)	538 (46)	465 (45)
	8 Wks.	510 (51)	515 (53)	500 (48)	505 (48)	490 (46)	495 (49)	521 (46)	510 (52)
	3 Mos.	473 (44)	518 (48)	518 (49)	490 (48)	481 (43)	483 (45)	505 (45)	520 (49)
2195	Unaged	←		255(38)					→
	1 Wk.	288 (34)	270 (34)	270 (33)	260 (31)	295 (31)	294 (36)	294 (33)	279 (34)
	3 Wks.	250 (50)	255 (50)	234 (50)	260 (50)	274 (50)	261 (50)	264 (48)	289 (41)
	8 Wks.	230 (50)	253 (55)	243 (55)	115 (50)	260 (53)	228 (53)	220 (48)	248 (46)
	3 Mos.	246 (31)	222 (30)	173 (36)	96 (30)	258 (29)	253 (29)	239 (26)	258 (31)
71595	Unaged	←		68(25)					→
	1 Wk.	93 (31)	77 (33)	85 (33)	98 (33)	99 (30)	94 (30)	73 (26)	76 (33)
	3 Wks.	80 (33)	94 (35)	86 (36)	108 (36)	103 (33)	94 (31)	101 (31)	81 (35)
	8 Wks.	69 (41)	86 (36)	85 (42)	151 (35)	87 (39)	94 (35)	82 (31)	85 (39)
	3 Mos.	92 (32)	100 (33)	89 (30)	72 (30)	84 (34)	76 (26)	71 (26)	80 (31)

* Given in lbs /in. width of sample

** Given as % at break of unstressed length

TABLE II

TENSILE STRENGTH* AND (ELONGATION)** OF CANDIDATE LINER ELASTOMERS

Material Code	Aging Period	Water	Aqua Chem	T-5	Vanish	Gasoline	Lub Oil	Diesel Fuel	Sewage
3010	Unaged	← 1,790(360) →							
	1 Wk.	1,690 (330)	1,565 (330)	1,695 (345)	1,570 (317)	1,735 (365)	1,995 (365)	1,715 (335)	1,735 (337)
	3 Wks.	1,700 (305)	1,765 (315)	1,575 (305)	1,675 (305)	2,023 (340)	2,054 (330)	1,830 (330)	1,560 (290)
	8 Wks.	1,553 (275)	1,765 (300)	1,590 (300)	1,643 (280)	1,943 (320)	2,068 (300)	1,840 (330)	1,790 (300)
	3 Mos.	1,922 (325)	1,687 (310)	1,582 (310)	1,422 (280)	1,845 (315)	2,092 (325)	1,740 (335)	1,800 (315)
3070	Unaged	← 2,421(655) →							
	1 Wk.	2,385 (630)	2,400 (610)	2,415 (615)	2,585 (655)	2,505 (640)	2,470 (650)	1,028 (460)	1,965 (540)
	3 Wks.	1,941 (515)	2,058 (540)	2,090 (530)	2,155 (545)	2,585 (650)	2,260 (595)	760 (450)	1,935 (520)
	8 Wks.	1,800 (460)	1,695 (455)	1,650 (465)	2,240 (530)	2,235 (640)	1,985 (590)	640 (475)	1,840 (470)
	3 Mos.	1,467 (410)	1,320 (390)	1,150 (405)	2,117 (500)	2,205 (650)	1,802 (560)	235 (395)	1,590 (435)
E 9	Unaged	← 4,555(455) →							
	1 Wk.	4,560 (485)	4,765 (480)	4,040 (455)	4,505 (462)	4,715 (495)	4,725 (490)	3,560 (437)	4,945 (495)
	3 Wks.	6,270 (565)	6,010 (540)	5,175 (500)	3,200 (380)	4,315 (435)	3,930 (330)	4,125 (425)	5,750 (535)
	8 Wks.	5,725 (550)	4,875 (500)	4,138 (485)	5,540 (520)	2,930 (305)	4,888 (470)	4,810 (560)	6,225 (585)
	3 Mos.	4,800 (485)	4,180 (432)	3,225 (400)	5,045 (495)	4,515 (480)	5,005 (475)	2,980 (410)	4,725 (470)
PVC	Unaged	← 39(181) →							
	1 Wk.	36 (145)	39 (165)	38 (188)	40 (170)	51 (11)	45 (59)	51 (39)	37 (162)
	3 Wks.	38 (135)	38 (158)	33 (157)	37 (167)	63 (6)	48 (34)	49 (14)	38 (180)
	8 Wks.	40 (132)	37 (177)	33 (118)	38 (155)	28 (5)	50 (5)	58 (5)	39 (136)
	3 Mos.	32 (242)	31 (230)	33 (246)	38 (268)	69 (18)	52 (28)	59 (27)	39 (280)

* Given in lbs/sq in. of original cross section.

** Given as % at break of unstressed length

design. Our prototype tanks, for example, have not blistered.

In summary, all of the materials tested except PVC probably could be used to make a satisfactory flexible holding tank for sewage. The selection of nitrile rubber coated nylon for fabricating the prototype tanks in any event was proven to be acceptable and as good probably as any other selection that could have been made.

Use Tests

Actual use tests were conducted on the flexible holding tank by constructing a room for the purpose in the shop area of the Uniroyal Research Center. The plain holding tank was used for this purpose because it incorporated an access opening that permitted examination of its interior at the conclusion of the testing program. The set-up also included the Groco toilet used for the application tests previously described and the required fluid transfer line fittings and hose. The room was 6 x 6 x 8 feet in size and incorporated a small ceiling fan that was connected in common to the light switch. The tank vent was terminated outside of the room.

Testing cycles were of relatively short duration because of the large number of persons who chose to use the facility. A record was maintained of the type of hookup used, treatment chemicals applied, and the number of uses involved. This information is summarized in Table III.

The plain holding tank had a capacity of 18 gals. Used simply as a holding tank, an average of 38 flushes were accomodated (approximately 1/2 gallon per flush). Used as a reservoir in a recirculating set up, however, facilitated approximately 133 uses or 3-1/2 times as many.

At no time was it found necessary to use the activated charcoal to filter odors at the end of the vent line. This line terminated outside the toilet room in the large shop area and odors were never detected there. When used simply to collect waste products, the holding tank was treated with four fluid oz of Thetford Engineering Co.'s Aqua-Kem deodorizer. In a recirculating system, the tank was precharged with from 6 to 10 gals. of water and 7-1/2 to 12-1/2 dry oz of Monogram Industries T-5 sewage treatment chemical. The odor of the T-5 chemical was dominant at all times but near the end of each recirculating trial, it had changed sufficiently to become objectionable. The smell seemed to emanate mainly from the toilet (during flushing), however, rather than from the vent. For the simulated use tests above, an open mesh fabric bag was fastened to the toilet discharge line inside the holding tank. It was placed there to hold the solids and prevent them from being recirculated until completely dissolved by the T-5 chemical. At the end of each use cycle, the tank was discharged into the building sewer. Also, following each sequence the system was cleaned by filling with fresh water (to which a half can of Vanish bowl cleaner was added), circulating the solution for several minutes and pumping

TABLE III

SANITARY SYSTEM USE TEST SUMMARY

Type Hook up	Initial Water Charge Gallons (1)	Initial T-5 Charge Oz.	Uses each day following date activated																Total Uses	Comments
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
recirculating	10	12½	3	18	19	13	14	-	-	3	7	9	11	15	-	-	9	5	136	Odor complaints after 8th day (2)
collection	-	(4)	1	10	18	5													34	
collection	-	(4)	9	11	15	8													43	
recirculating	8	10	7	15	12	16	-	10	18	20	15	5	-	-	10	9	7		137	(3)
recirculating	6	7½	10	15	22	-	-	5	12	15	11	9	-	-	15				114	(3)
recirculating	6	7½	10	10	12	10	-	-	22	10	20	15	10	-	-	-	10	6		(3)

(1) Maximum capacity, approximately 18 gals.
(2) Filter bag partially filled with paper after flushing system
(3) Complaints on odor always came near end of run
(4) Four oz of Thetford Engineering Corp. odor control chemical "Aqua Kem" used on these tests

NOTE: Cleaning involved two flushes with fresh water. One cup of Vanish bowl cleaner was added to 1st flush

out a second time. It was noted at the end of the program that all organic material had dissolved and had been removed. The fabric filter, however, was still filled with a paper slurry which had never dissolved. On the basis of these tests, the use of a filter bag is not recommended.

The holding tank itself remained in excellent condition throughout the test.

Photographs of this set-up are included in the Appendix.

Rocking Tests

The rocking test facility consisted of a platform mounted on bearings which could be oscillated via a motor through a simple rocker arm linkage. Both the frequency and amplitude of the rocking action were adjustable. Tests were conducted by fastening a simulated boat section to the platform, installing a flexible tank in the section and then rocking the asembly while periodically varying the water level in the tank. Figure 12 show the set-up with a deep keel section used to hold the flexible test container.

As noted during the tests, very little destructive action is generated with a normal rocking motion. A flexible tank tends to open only to the extent that is necessary to contain the fluid being held and thus tends to dampen sloshing which can be serious in a rigid container. When a partially filled flexible tank is rocked, it tends to fold and unfold from side to side to accomodate the change in water surface level. Also, no appreciable rubbing action is produced as the flexible tank unfolds against the confining walls and then alternately pulls away.

An attempt was made in one test to aggravate the conditions imposed by the rocking test facility. Sand was purposely stuck to the painted surface of the boat section involved and both water and some additional loose sand was scattered throughout the structure to promote slippage and wear. This test was stopped after six weeks, however, when visible signs of wear still failed to materialize.

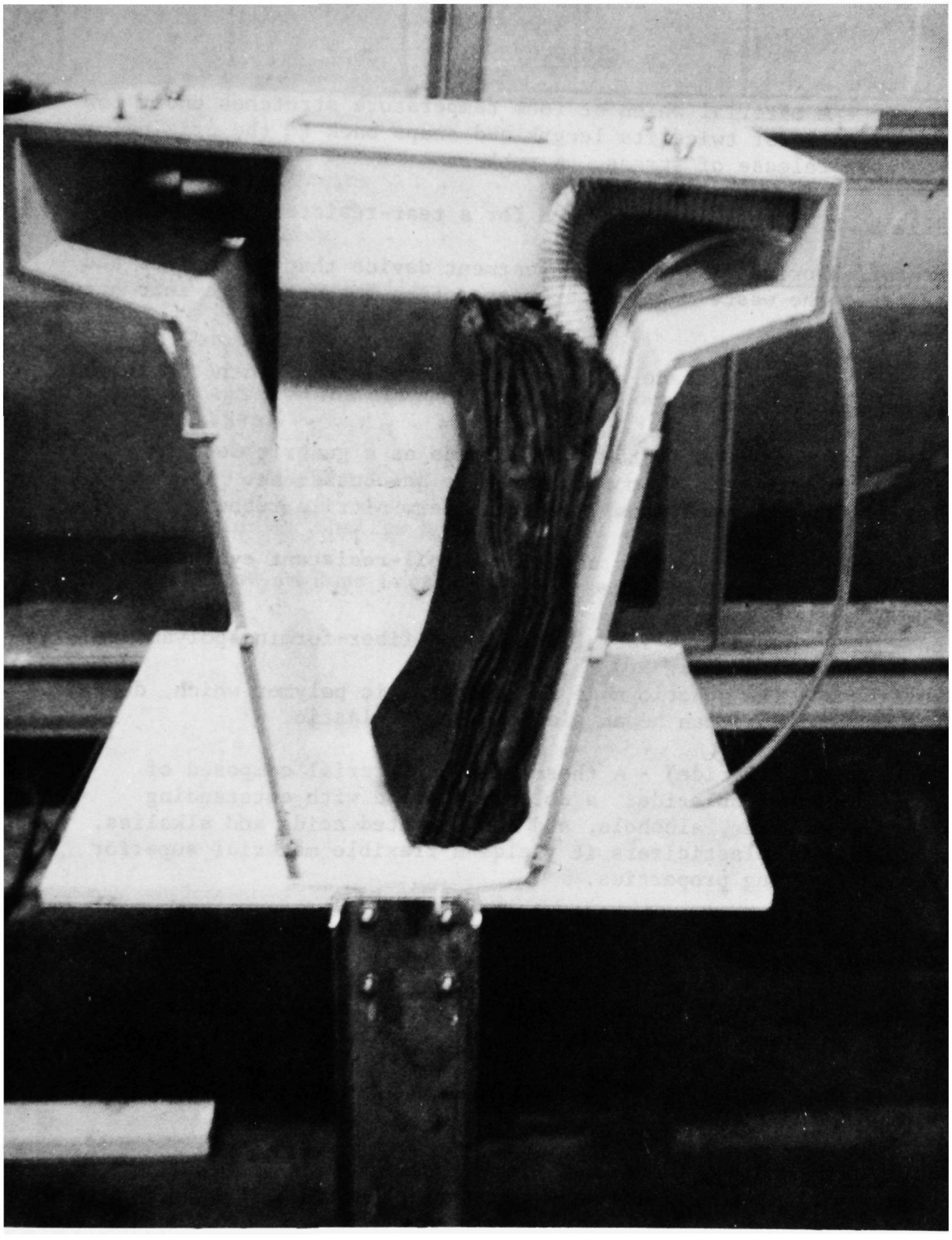


Fig. 12 - Deep keel section on rocking test platform

SECTION VII

GLOSSARY

Elastomer - A material which at room temperature stretches under low stress to at least twice its length and snaps back to the original length upon release of stress. A rubber.

Fiberthin® - Uniroyal's trade name for a tear-resistant nylon fabric.

Macerator/chlorinator - a waste treatment device that pulverizes and chlorinates the waste material in preparation for discharge into natural waters.

Neoprene® - Dupont's trade name for an oil-resistant synthetic rubber based on chloroprene.

NBR - Letter code used in the rubber trade as a generic designation for synthetic rubbers made from acrylonitrile and butadiene. In this report it is used synonymously with the term nitrile rubber.

Nitrile rubber - The generic name for an oil-resistant synthetic rubber based on acrylonitrile.

Nylon - The generic name for all synthetic fiber-forming polyamides.

Polyurethane - The generic name for a synthetic polymer which, depending on its composition, can be an elastomer or a plastic.

PVC (polyvinyl chloride) - A thermoplastic material composed of polymers of vinyl chloride: a colorless solid with outstanding resistance to water, alcohols, and concentrated acids and alkalies. Compounded with plasticizers it yields a flexible material superior to rubber in aging properties.

Thermoplastic - Capable of being repeatedly softened by heat and hardened by cooling.

Self-contained Toilet - A toilet which has a build-in reservoir and does not require external connections to dispose of sanitary wastes.

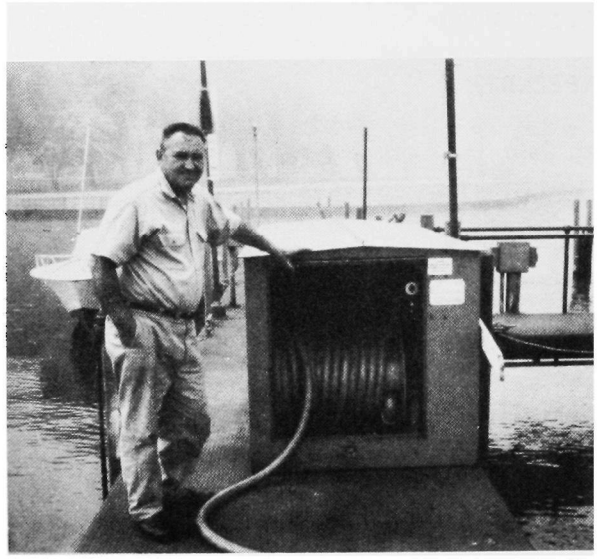
Tygon - A trade name for a transparent, flexible plastic which is highly resistant to chemicals.

Uniroyal Compound No. - A number used to designate a particular rubber or plastic material in the Uniroyal plant in Mishawaka, Indiana.

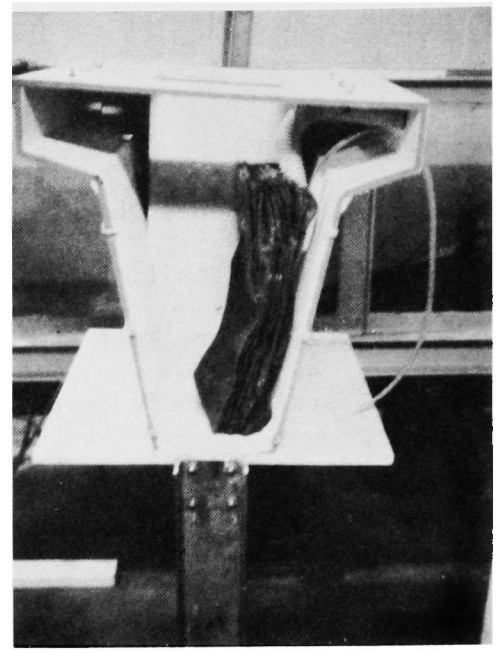
Uniroyal Style No. - A number used to designate a particular fabric in the Uniroyal plant in Mishawaka, Indiana.

SECTION VIII

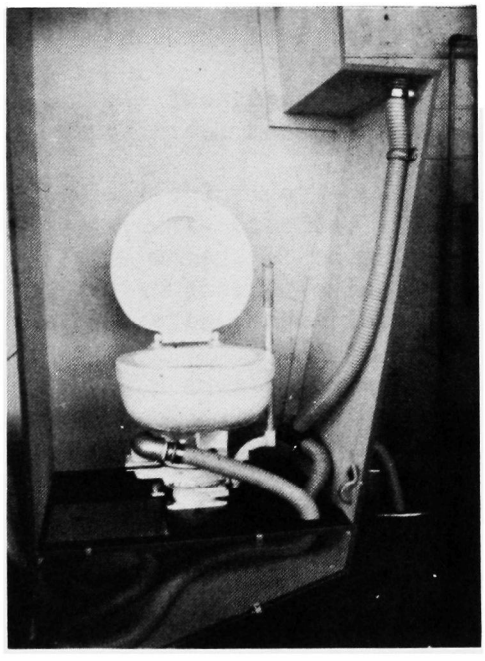
APPENDIX



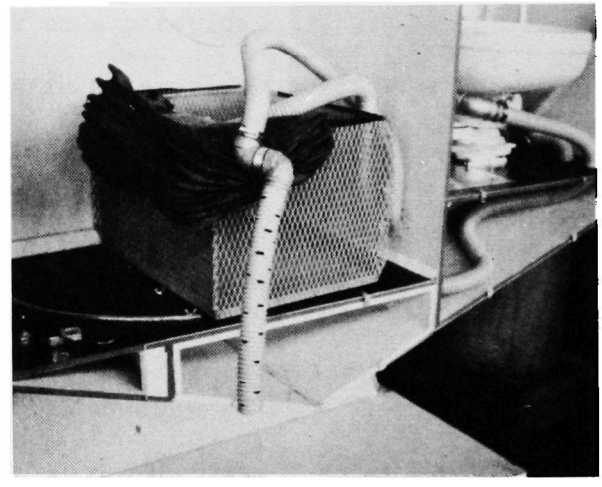
City of Chicago Pump out Equipment



Rocking Test Stand

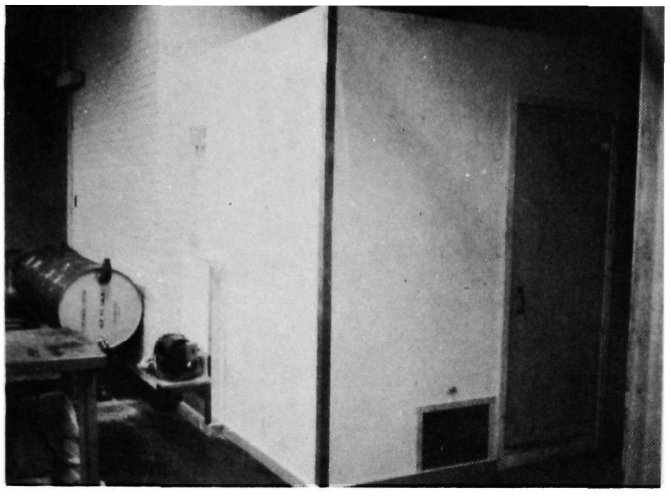


Recirculating Hook Up

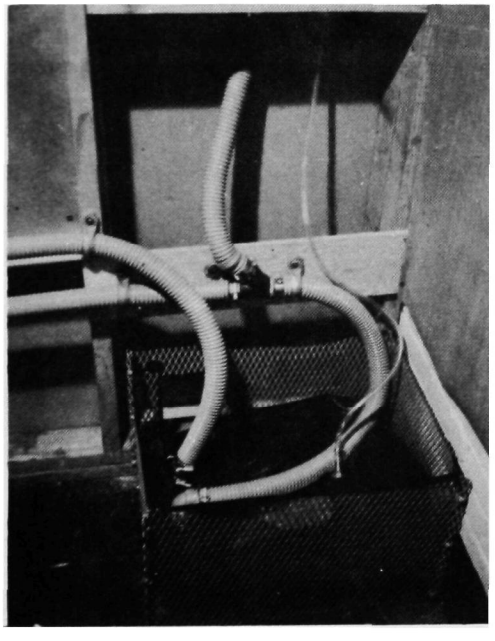


Dip Pipe and Swivel Fitting

Miscellaneous Photos



Test Room



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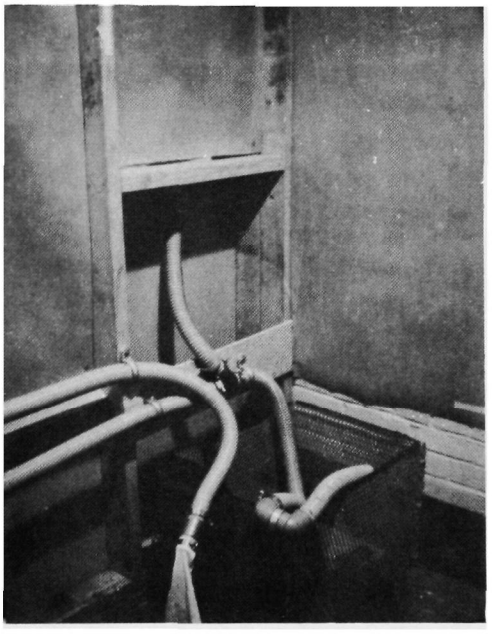
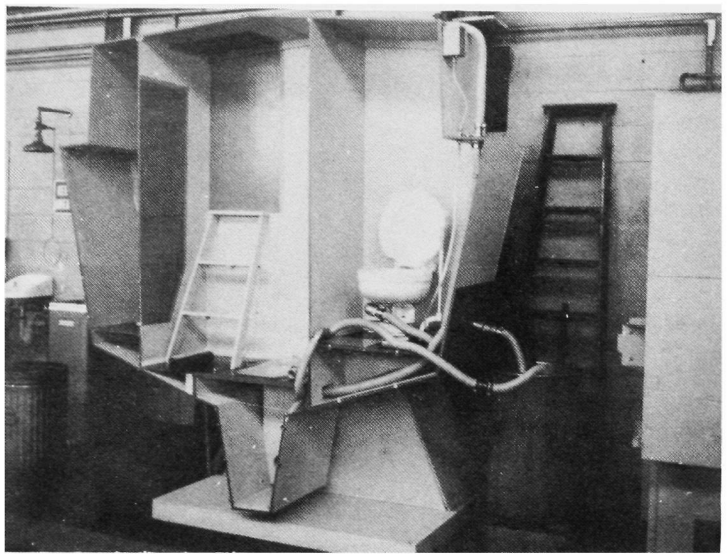
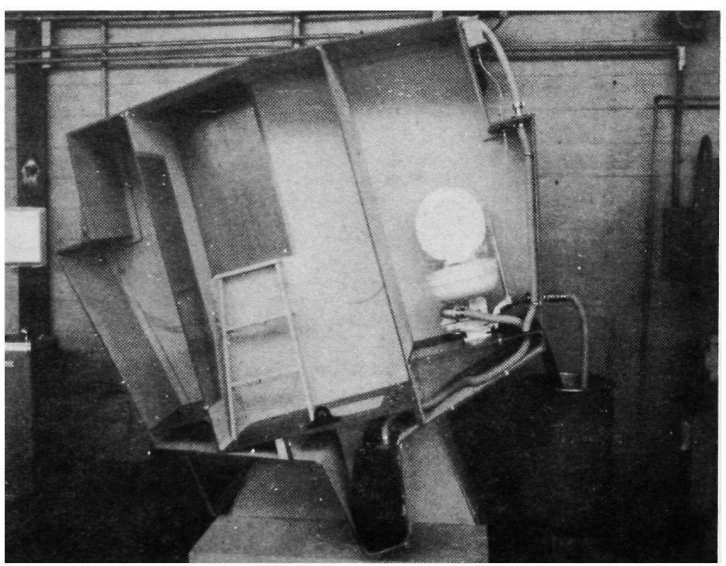
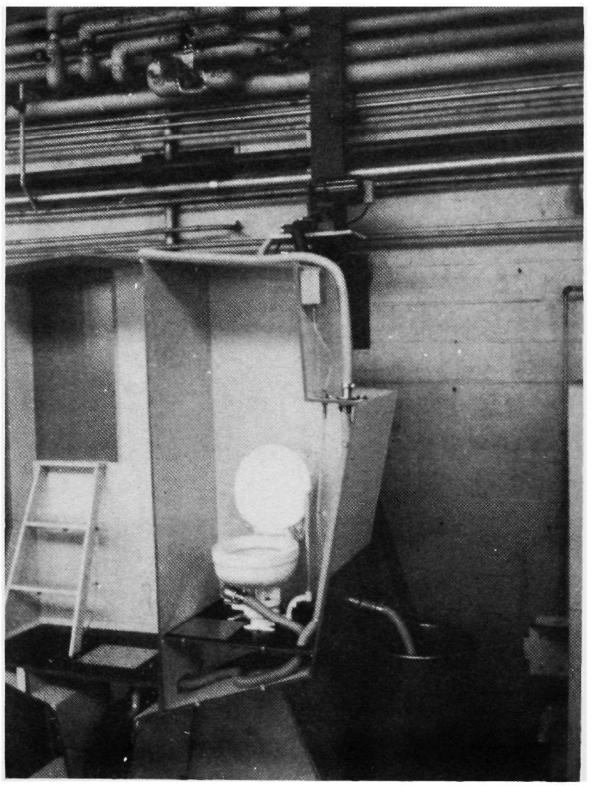


Dip Pipe and Filter Bag

Use Test Facility





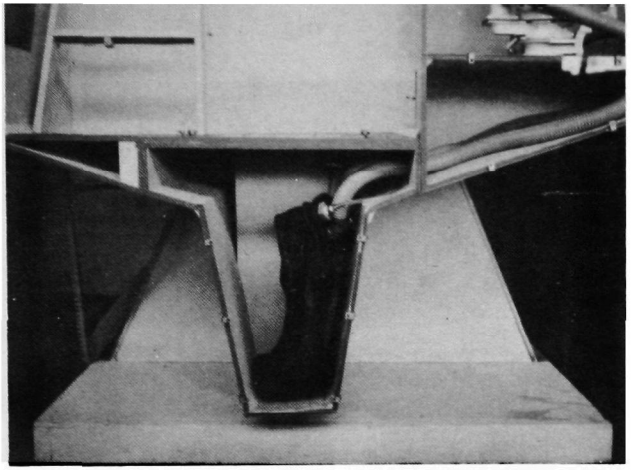


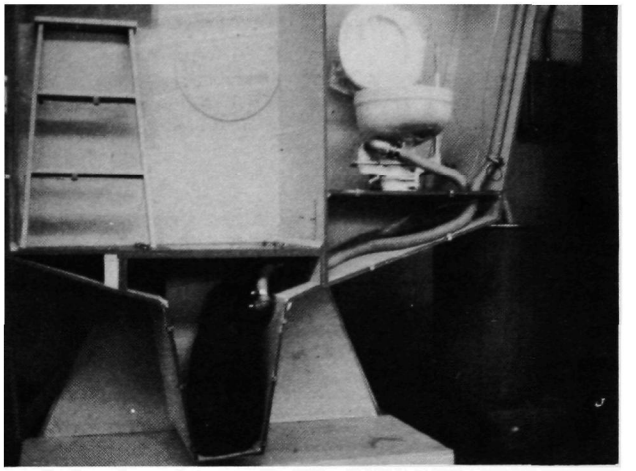
Applications Test Facility

(3 Views)

Corrugated Tank

Plain Tank





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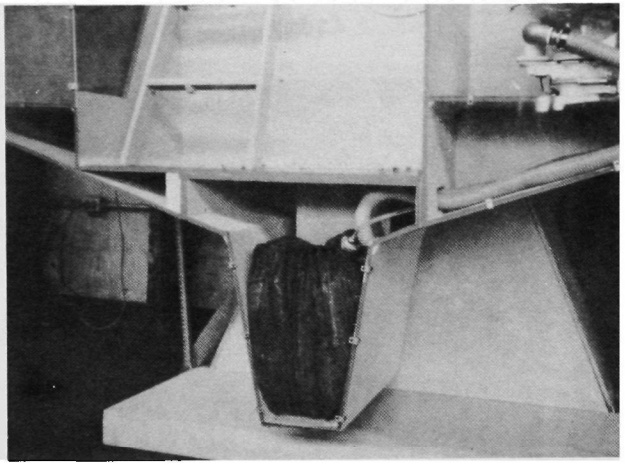
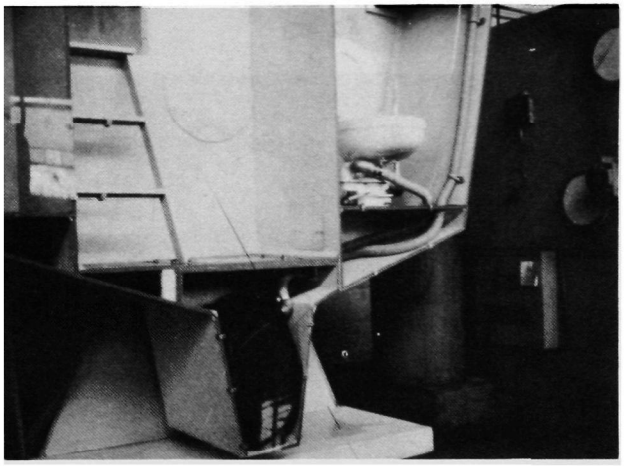




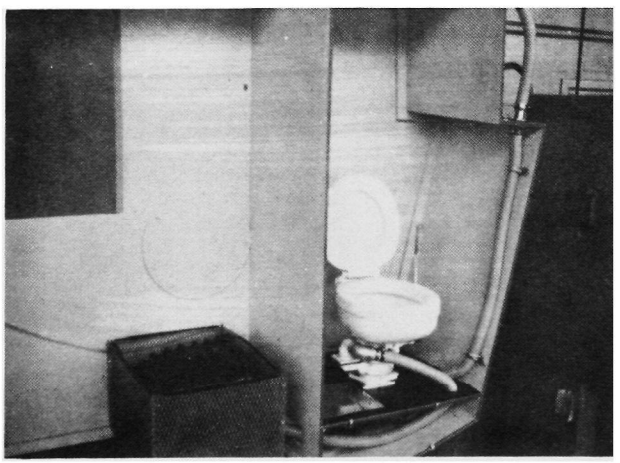
Full

Installation in Deep Keel

Full

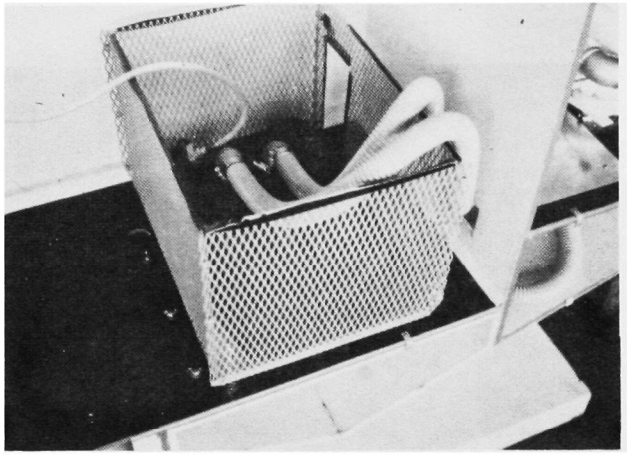
Installed on Edge

Empty



Full

Installed Flat



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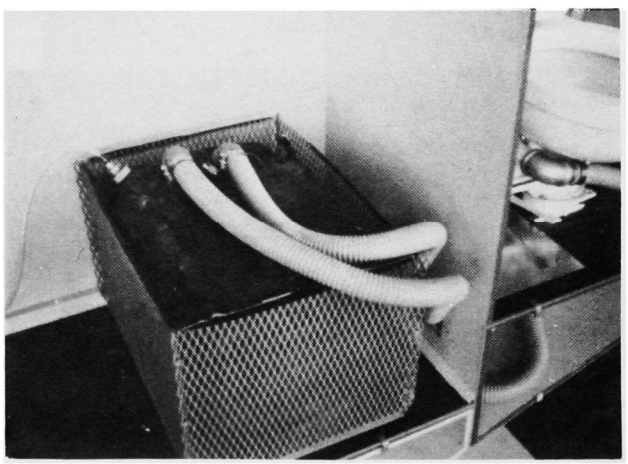
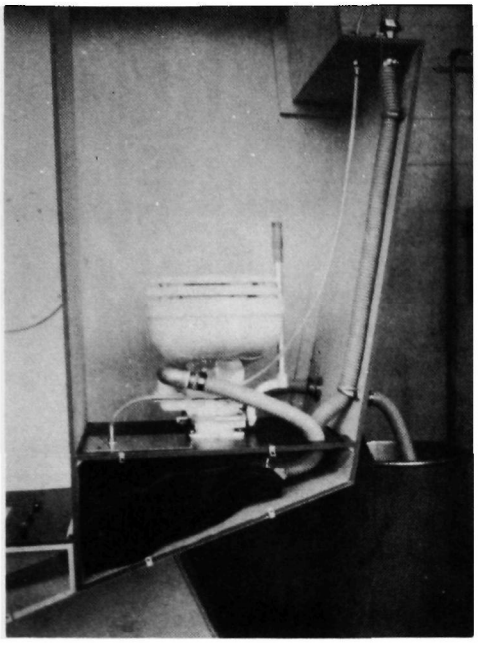


Full

Corrugated Tank Installation
in Motor Room Open Space - In Basket

Plain Tank



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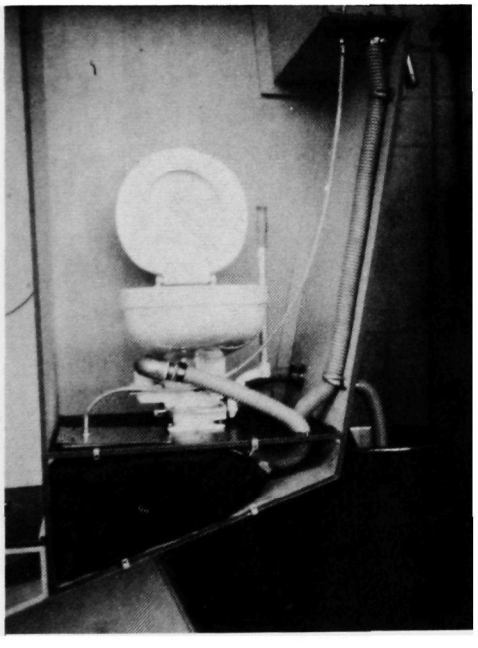
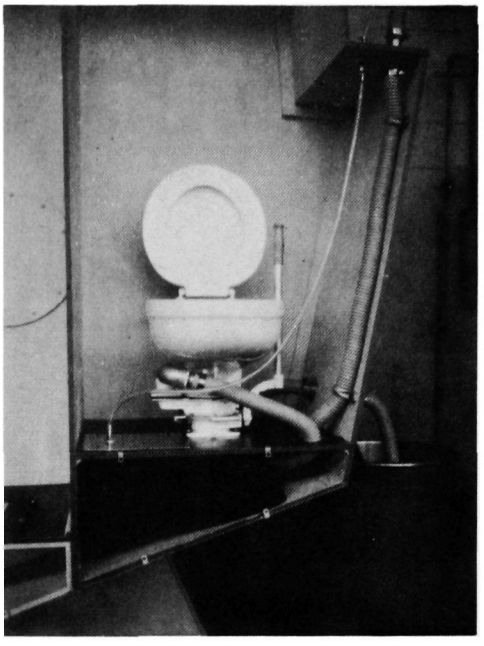


Full

Corrugated Tank



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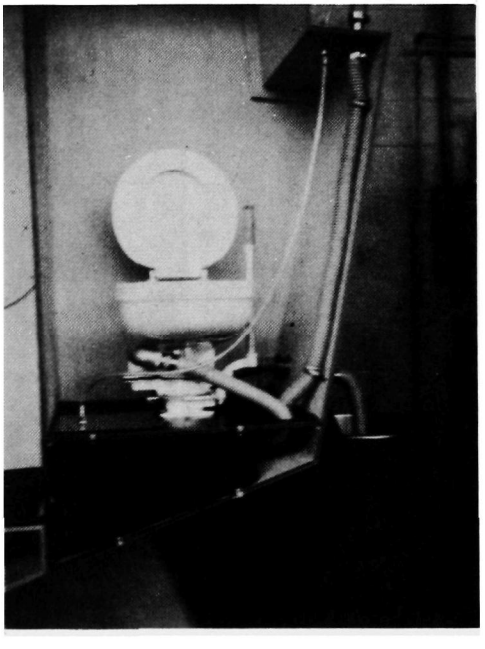
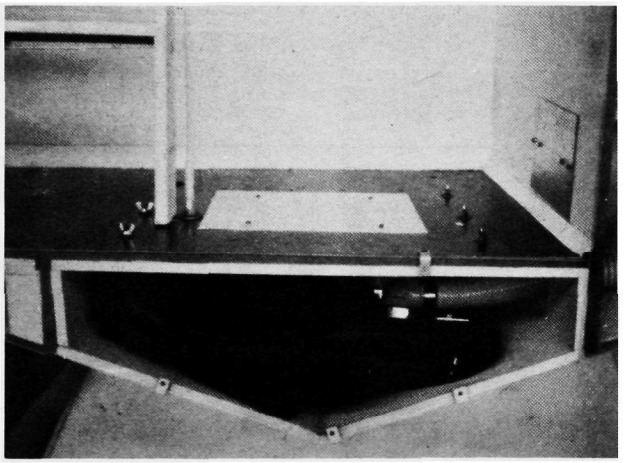


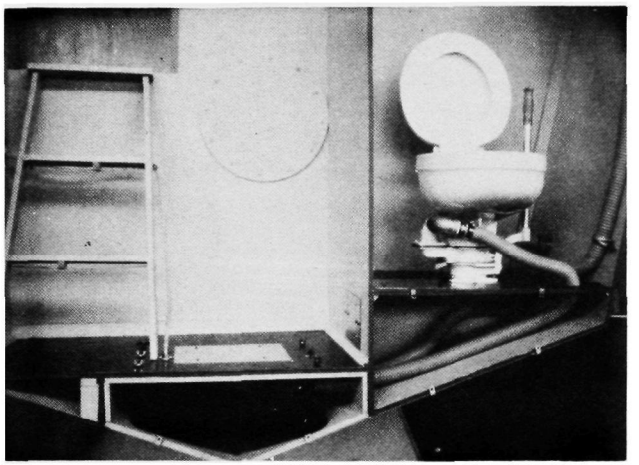
Full

Tank Installation - Under Closet

Plain Tank

Corrugated Tank





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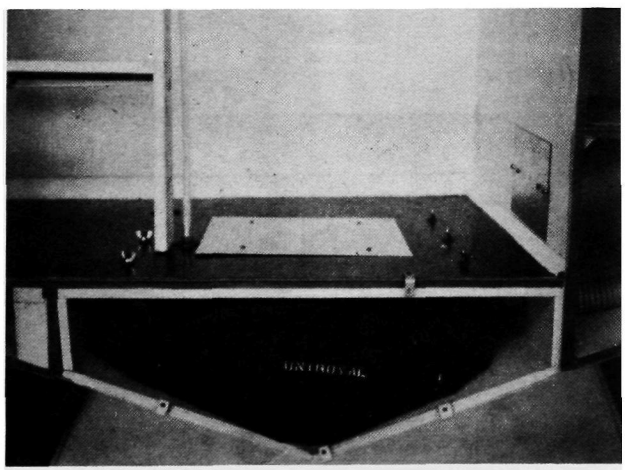
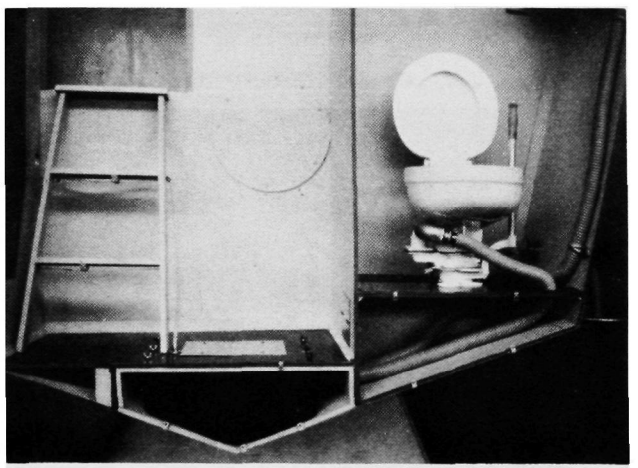


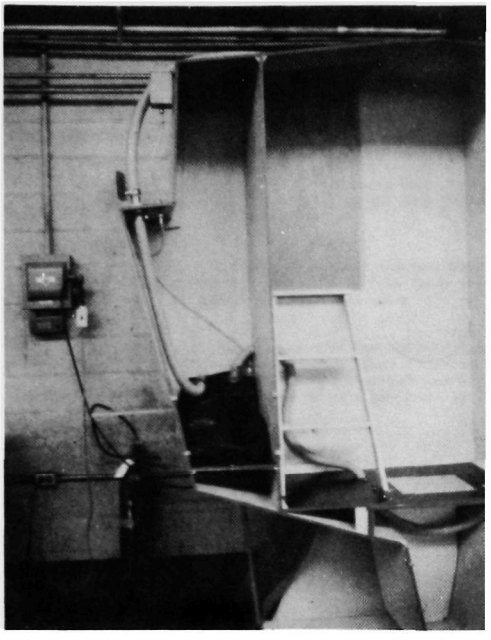


Full

Full

Installation in Shallow Keel

Plain Tank



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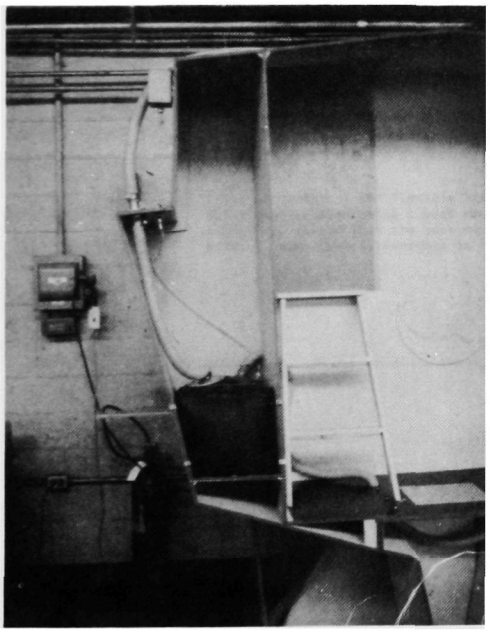
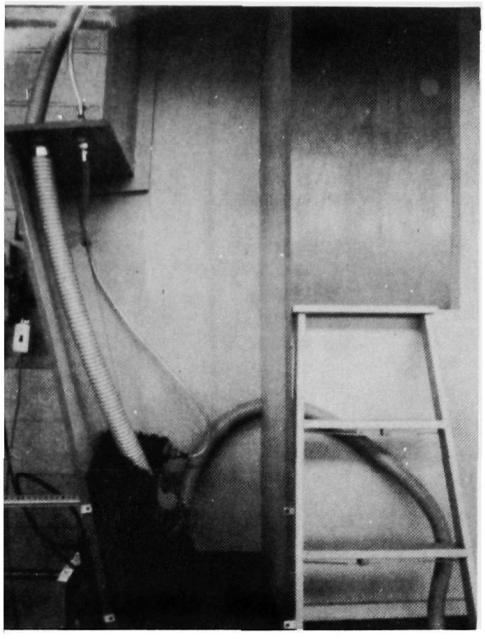


Full

Corrugated Tank



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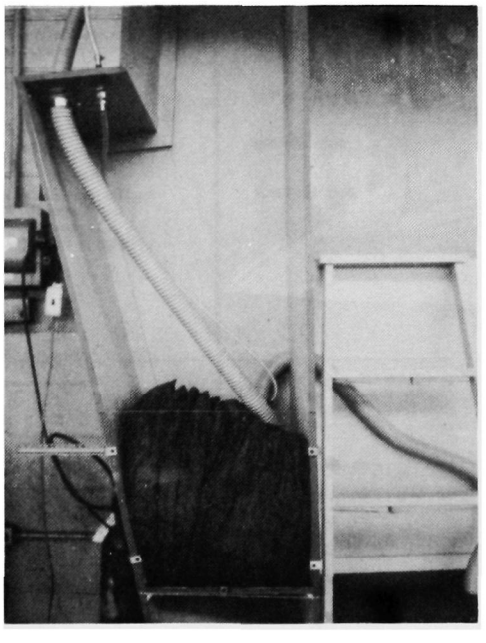

Full

Installation in Rope Locker

BIBLIOGRAPHIC:

Uniroyal, Inc. Flexible Holding Tank for Pleasurecraft Sanitary System, Final Report FWQA Contract #14-12-506, August 1970

ACCESSION NO.

ABSTRACT

The purpose of this effort was to develop a flexible holding tank to collect waste products in small pleasurecraft. Its use is primarily proposed as a convenient means for modifying existing craft so as to comply with existing and proposed new legislation on the subject of water pollution.

A survey delineated numerous locations where a flexible tank could be located in the various craft under consideration and a corrugated design was conceived which will conform to most of these.

The placement of the flexible tank in several locations was successfully demonstrated using a boat mock-up. Performance tests, also conducted, showed that the tank could be used both as a simple holding tank or as a reservoir in a recirculating sanitary system.

KEY WORDS:

SANITARY SYSTEM

WATER POLLUTION

HOLDING TANK

FLEXIBLE TANK

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1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM

5 Organization

Uniroyal, Inc., Research Center, Wayne, N. J. 07470

6 Title

Sanitary Holding Tank for Pleasurecraft

10 Author(s)	11 Date	12 Pages	15 Contract Number
Mark W. Olson	August 1970	45	FWQA 14-12-506
	16 Project Number	21 Note	
	1502DGR06/70		

22 Citation

23 Descriptors (Starred First)

25 Identifiers (Starred First)

27 Abstract

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Abstractor Mark W. Olson

Institution Uniroyal, Inc.

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