CLEAN WATER

EDISON WATER QUALITY LABORATORY VESSEL POLLUTION REPORT NO. 1

EVALUATION OF MACERATOR-CHLORINATORS

SEPTEMBER 1971

ENVIRONMENTAL PROTECTION AGENCY

EVALUATION OF

MACERATOR-CHLORINATORS

Edison Water Quality Laboratory
Environmental Protection Agency
Edison, New Jersey 08817
September, 1971

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INTRODUCTION

Marine sanitation devices available to the boatowner include holding tanks, chemical recirculating systems, incinerating toilets and the macerator-chlorinator. The macerator-chlorinator is a flow-through device readily available in the marine supply market. The purpose of this investigation was to characterize the effluent resulting from treatment with the macerator-chlorinator unit. An attempt was also made to estimate the relative percent reduction of pollutants achieved by this treatment system.

CONCLUSIONS

1. The macerator-chlorinator does not meet the effluent standards proposed by the Federal government. Floating and settleable solids were evident in effluent samples collected. Total coliform densities were generally greater than 240 per 100 ml, and Suspended Solids and Biochemical Oxygen Demand (BOD_5) exceeded the proposed limit of 150 and 100 mg/l respectively.

2. Effluent data exhibited a high degree of variance, undoubtedly due to the many operational variables inherent in this type of treatment system.

BOD_5	500 - 2,600 mg/l
COD	3,100 - 14,000 mg/l
TOC	400 - 2,200 mg/l
MPN	<2 to >240,000/100 ml
Suspended Solids	1,500 - 9,800 mg/l
Settleable Solids	60 - 560 mg/l

3. Based on limited influent and effluent data collected during this study, a comparison of mean values for the test runs indicated that relative percent reductions of the various pollutants were: total coliform - 99 and greater percent; BOD - 38 to 72 percent; COD - 24 to 58 percent; TOC - 32 to 53 percent; and suspended solids - 15 to 59 percent. One test run showed no reduction in suspended solids and TOC.

4. The macerator-chlorinator does not sufficiently reduce particle size to allow effective treatment and disinfection. Disinfection, in particular, is less effective due to the masking effect caused by the large fecal particles.

5. Chlorine dosage rates vary widely with each flush and also with the type of disinfection system used. Adequate control of such dosages, which would insure that the proper amounts of chlorine per flush were added, is limited.

6. Injection of less than 300 ml of 6% sodium hypochlorite solution may not be sufficient to provide proper treatment. A stronger solution (15%), or use of HTH tablets (70% available chlorine) with an improved dose control, may give greater reduction of pollutants.

7. The chlorine demand of carbonaceous and nitrogenous substances in the waste will significantly reduce the amount of chlorine available for disinfection. The chemistry of chlorine reacting with these substances requires further study. In addition, discharges containing chlorine reaction products and non-reacted free available chlorine may have a detrimental effect on the waters receiving these wastes.

RECOMMENDATIONS

1. Manufacturers of the macerator-chlorinator should modify their units to provide the optimum treatment possible under varying field conditions. Improvements may include: (1) greater efficiency in particle size reduction; (2) higher feed rates of stronger disinfectant needed to destroy bacteria and reduce organic substances; and (3) a controlled dosage of disinfectant with each flush.

2. New models developed by the manufacturers should be tested at the Edison Laboratory. An experimentation program should also be conducted to access the possibilities of improving the maceration-chlorination treatment concept by combining the most effective features of each unit.

3. An investigation should be made into the chemistry of the chlorine reaction with carbonaceous and nitrogenous substances. In addition, the potential detrimental effect on the environment of chlorine reaction products and non-reacted free available chlorine in the discharge should be considered.

TEST PROCEDURE

Two macerator-chlorinator units---Raritan Electro-Chemical and Wilcox-Crittenden Model 6006---were installed at the Edison Laboratory, as shown in Figures 1 and 2. The Raritan unit including PHE marine electric toilet, electric chemical chlorinator and automatic chlorinator timer ACT-1 was purchased at a cost of $270.00. The Wilcox-Crittenden was purchased at a cost of $136.50. Diagrams of the individual units and the manufacturers installation and operational instructions are contained in Appendix I.

Each unit with its own marine toilet was installed according to manufacturer's instructions. Human waste was provided by participating Edison Laboratory personnel. Operation of the macerator-chlorinator units was controlled by the test team. Test runs were conducted to simulate as closely as possible normal and peak loading conditions as outlined by the National Sanitation Foundation, Standard No. 23, "Watercraft Sewage Disposal Devices". A copy of this procedure is contained in Appendix II. The test sequence for normal conditions include fecal precharge before testing and four fecal charges at 30 minute intervals. Peak conditions required fecal precharge and four fecal test charges at 10 minute intervals.

In tests on the Raritan unit, a commercially available solution of household bleach (Purex - 6% sodium hypochlorite solution) was used as recommended by the manufacturer. Tests on the Wilcox-Crittenden unit were made using the recommended HTH tablets (70% calcium hypochlorite). Since the intent of the experiment was to operate the units as close to actual field conditions as possible, no control was made of operational

variables, i.e., chlorine dose, available chlorine in purchased products, toilet paper usage, feces size, etc. Flush volume was set at one gallon for both units. Sea water taken near Sandy Hook, New Jersey served as the flush water.

To operate the Raritan unit, a single button was pushed which activated the timing control, started the macerator motor and at the same time engaged the pump which flushed the toilet. Upon releasing the button, the pump flushing the toilet stopped while the macerator-chlorinator unit continued operation until its 60-second time cycle was up. The Wilcox-Crittenden unit employed an activating time switch separate from the flush control of the marine toilet. A user would first activate the macerator motor by setting the timer switch at the desired time cycle (60 seconds for our tests), and then push the button to flush the toilet, holding it down for a set amount of time to flush the bowl clean.

Prior to actual testing, runs were made using tap water to familiarize the test team with mechanical operation. The approximate volume of liquid retained in the units was also determined. This volume and the effluent flushing volume was used to establish the precharge loading. Precharge for both units included two fecal flushes at a 10 minute interval.

During the test sequence samples were collected in sterilized containers, as shown in Figure 3. Full flush volumes of approximately one gallon were collected for analytical testing in the laboratory. Parameters for each test flush included: five day Biochemical Oxygen Demand (BOD_5), chemical oxygen demand (COD), total organic carbon (TOC), suspended solids, settleable solids, total chlorine residual, and total coliform (blended and unblended).

Chlorine in each sample was immediately neutralized with sodium thiosulfate. Laboratory tests were performed in accordance with Standard Methods for the Examination of Water and Wastewater, 13th Edition. The MPN procedure was used for bacteriological analyses. This method was used after the first test run in lieu of the membrane filter (MF) because of filtration interference caused by high solids in the effluent samples. Chlorine residuals were determined by the Iodiometric Method.

An attempt was made to characterize the raw waste being treated by the test units. The Raritan unit was disassembled and cleaned and waste passed through the unit without injection of chlorine. Laboratory tests were run on this macerated sample to determine influent concentrations and also to provide some basis for estimating the relative degree of treatment effected by chlorination.

DISCUSSION OF RESULTS

Results of the study indicate that under the test conditions described earlier, effluent from the macerator-chlorinator does not meet the proposed Federal standards. Floating and settleable solids were visibly evident to varying degrees in generally all the samples collected. Total coliform levels were, in the majority of samples examined—about 50% greater for unblended and 76% for blended—greater than 240/100 ml. Suspended solids and BOD_5 were higher than the proposed limit of 150 and 100 mg/l, respectively. Table I summarizes the results of each test run. Table II presents mean values for each parameter. All data resulting from the study are contained in Appendix III. The data shows a wide range of values for each parameter examined,

TABLE I

SUMMARY, TEST RESULTS
RANGE OF VALUES
MACERATOR-CHLORINATORS

Test Run	Date	Settleable Solids ml/l	Suspended Solids mg/l	BOD mg/l	COD mg/l	TOC mg/l	Total Coliform Unblended per 100 ml	Total Coliform Blended per 100 ml
1	8/17/71	160-300	1760-5670	780-1660	4120-8620	500-1080	10-6200	160-30,000
2	8/18/71	240-420	2620-5650	940-1270	4280-8250	530-1250	5->24,000	9200->24,000
3	8/19/71	60-400	3310-4720	1060-1440	5850-7150	690-875	2->240,000	3500->240,000
4	8/26/71	150-340	3940-5960	1080-1540	5800-7300	620-900	<2-11,000	4-240,000
				RARITAN				
1	8/23/71	100-240	1510-3300	540-1130	3120-10600	440-970	<2->240,000	<2->240,000
2	8/24/71	100-270	3240-4820	660-1200	2980-6650	560-820	<2-2800	<2->240,000
3	8/25/71	175-560	4030-9790	1130-2630	6120-13900	690-2250	<2	<2
				WILCOX-CRITTENDEN				
1	8/20/71	200-300	3300-6880	1570-4700	9380-16300	1020-1560	$>24 \times 10^7$	$>24 \times 10^8$
				INFLUENT				

TABLE II

SUMMARY, TEST RESULTS
MEAN VALUES
MACERATOR-CHLORINATOR

	Test	Date	Settleable Solids ml/l MEAN	Suspended Solids mg/l MEAN	BOD mg/l MEAN	COD mg/l MEAN	TOC mg/l MEAN
RARITAN	1	8/17/71	200	3930	1210	6810	810
	2	8/18/71	320	4500	1160	6620	940
	3	8/19/71	260	4000	1220	6670	800
	4	8/26/71	280	5060	1280	6640	730
Wilcox-Crittenden	1	8/23/71	150	2450	800	5240	650
	2	8/24/71	160	4200	1000	5480	670
	3	8/25/71	380	6810	1770	9620	1550
Influent	1	8/20/71	240	5970	2840	12560	1390

indicating the effect of operational variability on the treatment process.

Total coliform levels are generally considered the most important parameter measured. The data shows that the macerator-chlorinator can result in 99 and greater percent reduction; however, coliform levels were not consistently reduced below 240 per 100 ml. Effective bacteria kill, or lack of kill, depends upon: (1) the ability of the macerator unit to reduce the feces of each flush to particles that can be penetrated by the disinfectant; (2) sufficient quantities of available chlorine in the disinfectant; and (3) contact time.

The amount of chlorine added with each flush is dependant upon the operation of the unit. The Raritan siphons the sodium hypochlorite from the bleach container through a vortex produced by the macerator motor. Observations during the test indicate that this vortex can be broken during flushing action of the toilet. The Wilcox-Crittenden unit which uses HTH tablets introduces chlorine into the unit chambers by simple action of flush water on the tablets. In each unit, control is limited.

Disinfectant injected into the Raritan unit during operation was measured generally below 300 ml ranging from 80 to 330 ml. Such amounts of chlorine solution recommended for use appear insufficient to result in complete or near complete coliform kill. This was also found in the New York State study, "Evaluation of Marine Toilet Chlorination Units", which showed that 300 ml of 5.25% sodium hypochlorite was inadequate.

An EPA study in 1968, "Evaluation of Macerator-Chlorinators on U.S. Coast Guard Vessels", concluded that 15% sodium hypochlorite, at a 250 ml dosage rate, provided improved disinfection capacity in the unit being evaluated. Data from this earlier survey tends to confirm that higher amounts of available chlorine are needed to improve treatment by these units. The use of HTH tablets, with its 70% available chlorine, would appear to have enough disinfection power to produce the bacterial kills desired. However, effluent from the Wilcox-Crittenden unit also showed coliform counts as high as those from the Raritan unit. It is possible that contact time between the tablets and waste liquid is not sufficient to permit the release of adequate quantities of chlorine into solution. Observations during the test runs on the Wilcox-Crittenden indicated that as the HTH tablets dissolve, a cake formed which reduced the surface area of contact and restricted the flushing action of the liquid over the chlorine tablets.

The reduction of particle size to permit the chlorine to efficiently act is of extreme importance and may present a serious drawback with these units. This problem was also reported during the 1968 EPA study, referenced earlier. Reduction in particle size to less than 2 mm in diameter was recommended as a result of that study.

Coliform levels on unblended and blended samples show significant differences, with the latter exhibiting higher bacteria levels. The data suggests that a bacteriostatic, rather than a bactericidal effect is taking place. Periodic observations of the effluents indicated that particles

greater than 2 mm were evident. This observation was more prevalent in the effluents from the Raritan unit, indicating that the joker valve arrangement is less effective than the screen and baffle arrangement of the Wilcox-Crittenden unit in controlling discharge from the macerator chamber.

During these experiments, where time of contact was 10 minutes or greater, reduction of coliform by chlorine did not appear to be a function of detention time (time elapsed between flushes) in the macerator-chlorinator. Coliform kill, however, will vary when contact times are less than 10 minutes, particularly around two minutes. The New York State study showed this by reporting that 99% bacterial kill was evidenced in the early phases of chlorination and that holding time in the units tested did not improve disinfection. This indicates that an initial rapid "kill" occurs; however, with further detention, the chlorine demand of the carbonaceous and nitrogenous substances in the waste reduces the effectiveness of disinfection. The reaction rate of chlorine with the waste will depend upon: (1) temperature; (2) pH; (3) concentration of ammonia and organic nitrogen; (4) amounts of excess available chlorine; and (5) amounts of carbonaceous substances. The chemistry of these reactions requires further study. In addition, the toxic effects on the environment of discharges containing chlorine reaction products should be investigated. The presence in the discharge of non-reacted free available chlorine may also be detrimental to the aquatic community. This, too, should be investigated.

The other parameters of importance to this study are suspended solids and oxygen demanding substances measured as BOD, COD and TOC. It must be noted that the estimate of relative reduction of these pollutants is based on the limited influent data collected during this study. Comparisons of

influent and effluent are made based upon mean values for each set of data (test runs).

Results of five influent samples tested showed that BOD_5 averaged 2,800 mg/l; COD 12,600 mg/l; and TOC 1,400 mg/l. It is theorized that the low TOC values are due to sample injection errors resulting from high solids concentrations in the influent.

Suspended solids in the effluents collected during the test runs ranged from 1,500 to 9,800 mg/l. Mean values were generally in the 4,000-5,000 mg/l range. Effluent and influent data indicate that percent removals for the macerator-chlorinators tested varied from 15% to 59%. Four runs showed percent reductions around 30%. One run, the first for the Wilcox-Crittenden, showed a 59% reduction of suspended solids. The third test run on the Wilcox-Crittenden unit showed zero percent reduction.

Effluent BOD_5 for all runs showed a wide range, varying from 540 mg/l to 2,600 mg/l. Based upon mean values for each run, percent removals were in the order of 60%. The first run for the Wilcox-Crittenden showed a 72% reduction of BOD_5. COD of the effluents were in the neighborhood of 6,600 mg/l for the Raritan unit and 5,200-5,500 mg/l for the Wilcox-Crittenden unit. Percent reductions ranged from 24% to 58% and were generally on the order of 50%. TOC, following a similar pattern as both BOD and COD, showed reductions which varied from 32% to 53%. The last run on the Wilcox-Crittenden unit showed zero percent reduction in TOC.

Percent removals for the Wilcox-Crittenden unit were generally higher than the Raritan unit. The results, however, again as with suspended solids, showed a decrease in percent removals by test run for BOD, COD and TOC. Observations of the unit after testing indicates that this may be caused by: (1) solids buildup in the macerator chamber; (2) matting

of solids on the macerator screen; (3) caking of HTH tablets; and (4) evidence of short-circuiting.

Visual observations made during testing noted the color and odor in the effluent samples. Color varied from a milky white to brown. In general, discharges from the Wilcox-Crittenden unit were milky white to yellowish tan. The discharge from the Raritan unit was much darker in color, ranging from milky grey to brown. In addition, the discharges from both units contained noticeable odors of chlorine. The Wilcox-Crittenden unit displayed a much stronger chlorine odor.

Figure 1

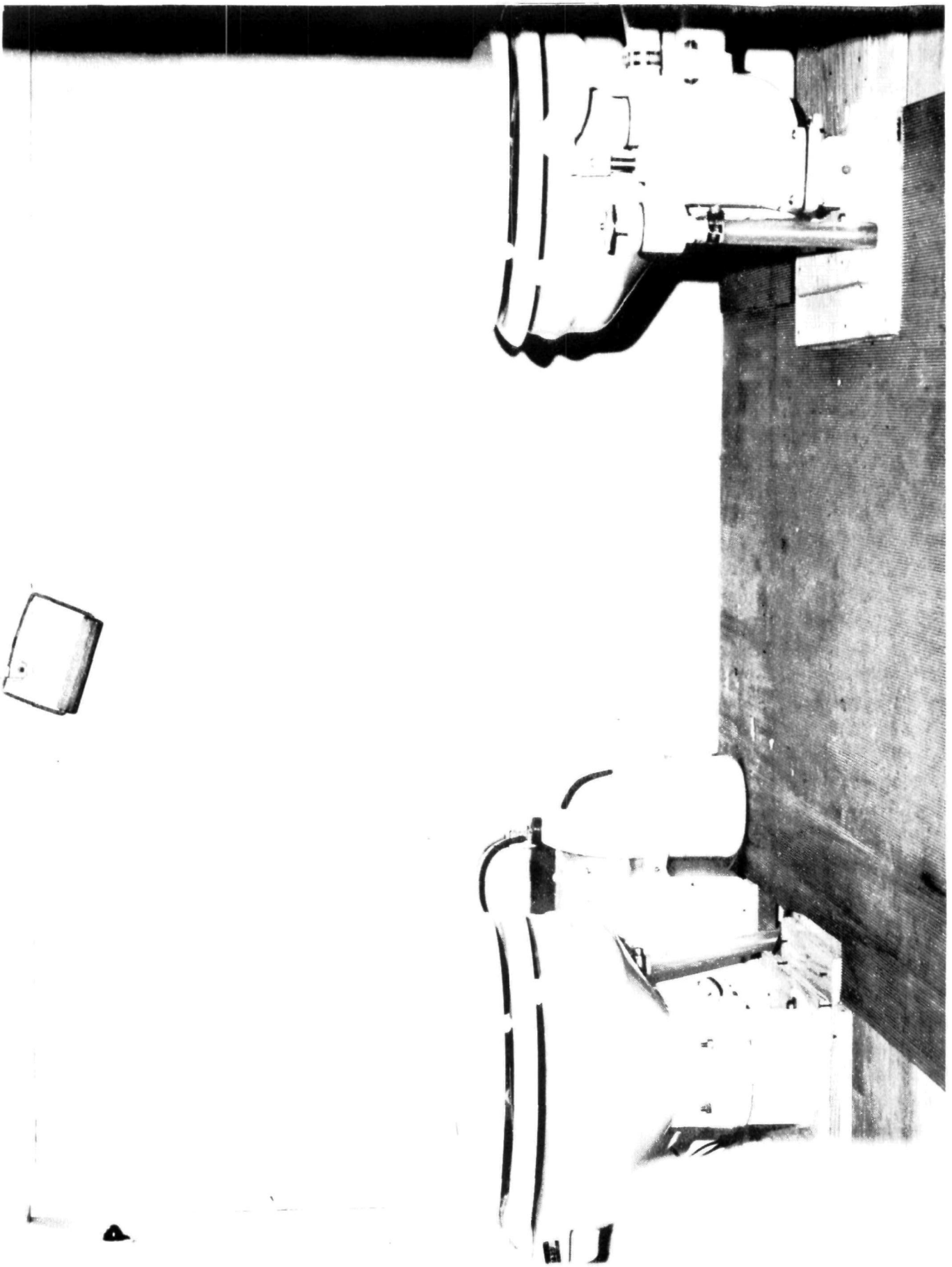


Figure 2

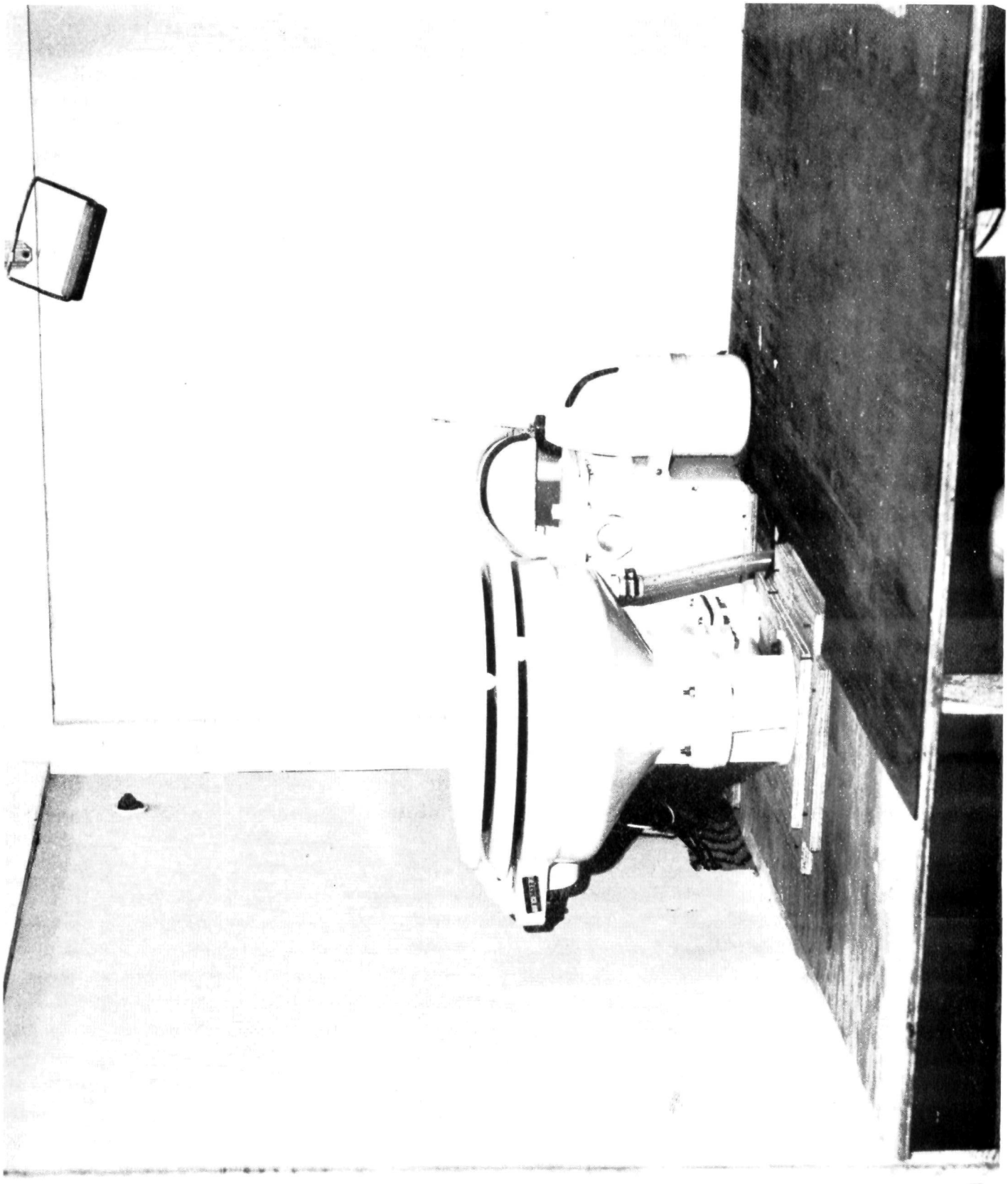
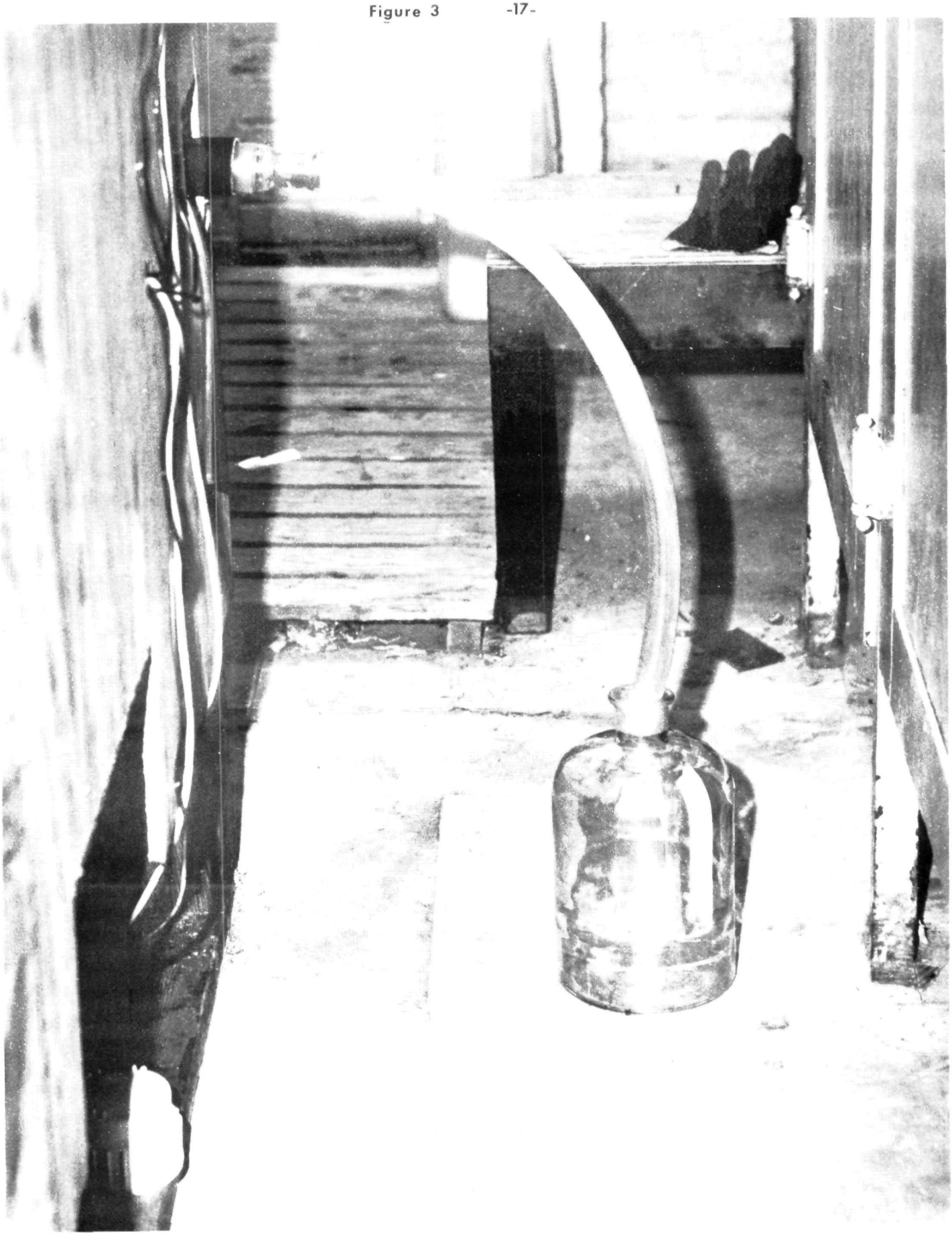


Figure 3



Appendix I

Installation and Operating Instructions for Raritan Electro-Chemical and Wilcox-Crittenden Unit

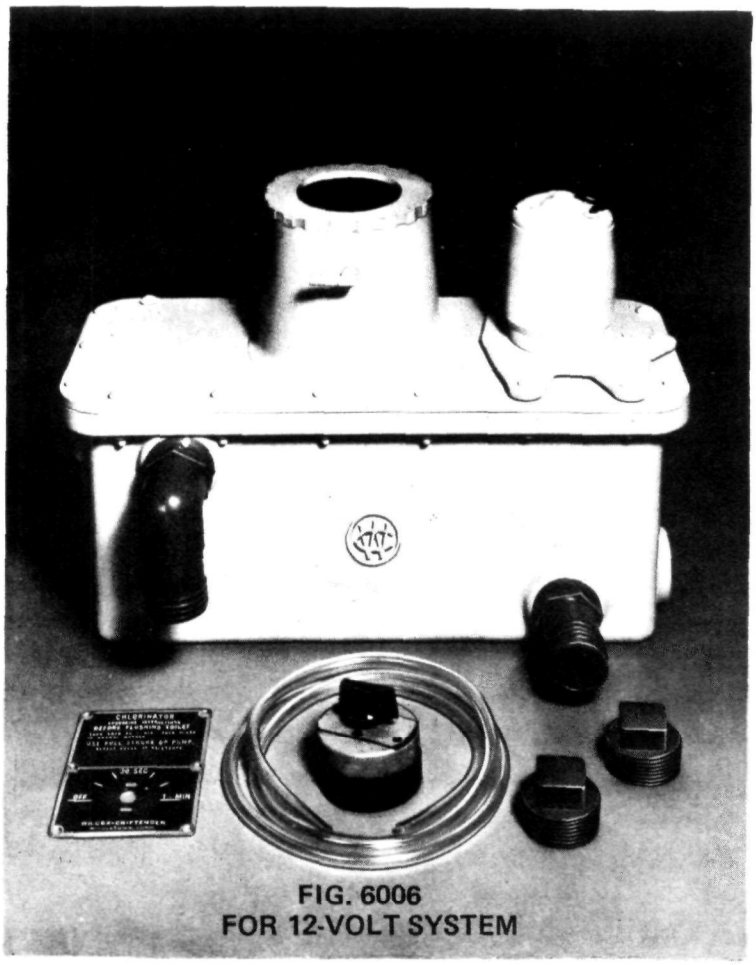


FIG. 6006
FOR 12-VOLT SYSTEM

THE MACERATOR CHLORINATOR

FOR USE WITH ALL MARINE TOILETS

IMPORTANT

- Existing above-waterline or below-waterline discharge thru-hull fittings may be used to complete the installation of this unit on your boat.
- However, IN NO CASE should the MACERATOR/CHLORINATOR be installed below the waterline.

Installation Instructions

WARNING

- When winterizing, make certain Macerator/Chlorinator Tank is flushed clear of waste, and all H.T.H.® Tablets are dissolved or removed from pill chamber.
- If there is danger of freezing, remove entire unit from boat and drain, or remove cover assembly and pump out remaining water.

DO NOT USE ANTI-FREEZE SOLUTIONS, LUBRICANTS, ETC., WHILE PILLS ARE IN CHAMBER.

- Recommissioning procedure will be the same as outlined in Steps 13, 14, 15 and 16 on back page of this folder.

WILCOX-CRITTENDEN
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GW
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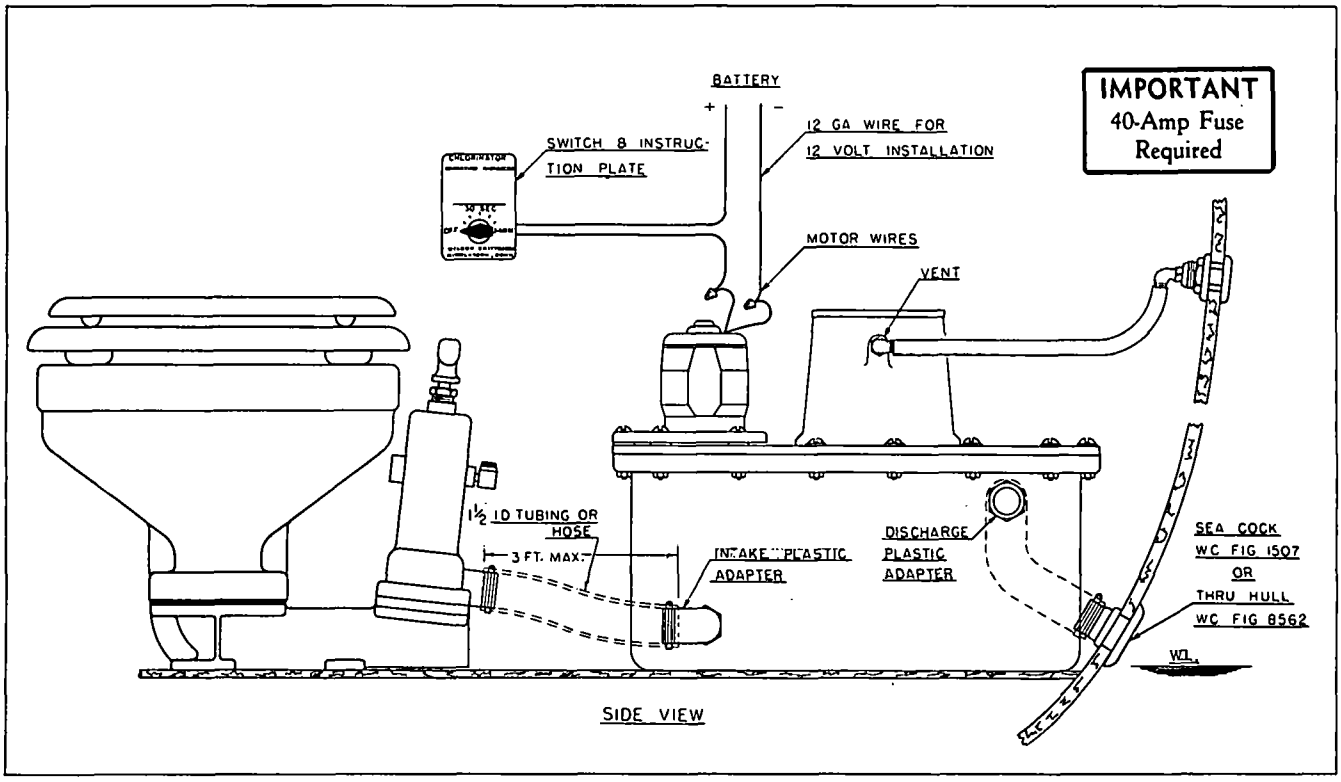


MACERATOR/CHLORINATOR INSTALLATION

1. Pump the closet dry, then close all Seacocks connected to it.

2. The Macerator/Chlorinator can be installed in any convenient location, at or above the waterline, and within three feet of the closet in compliance with American Boat & Yacht Council recommendations. Typical installations are illustrated above, and on next page.

3. Disconnect the existing Discharge Hose from the closet.

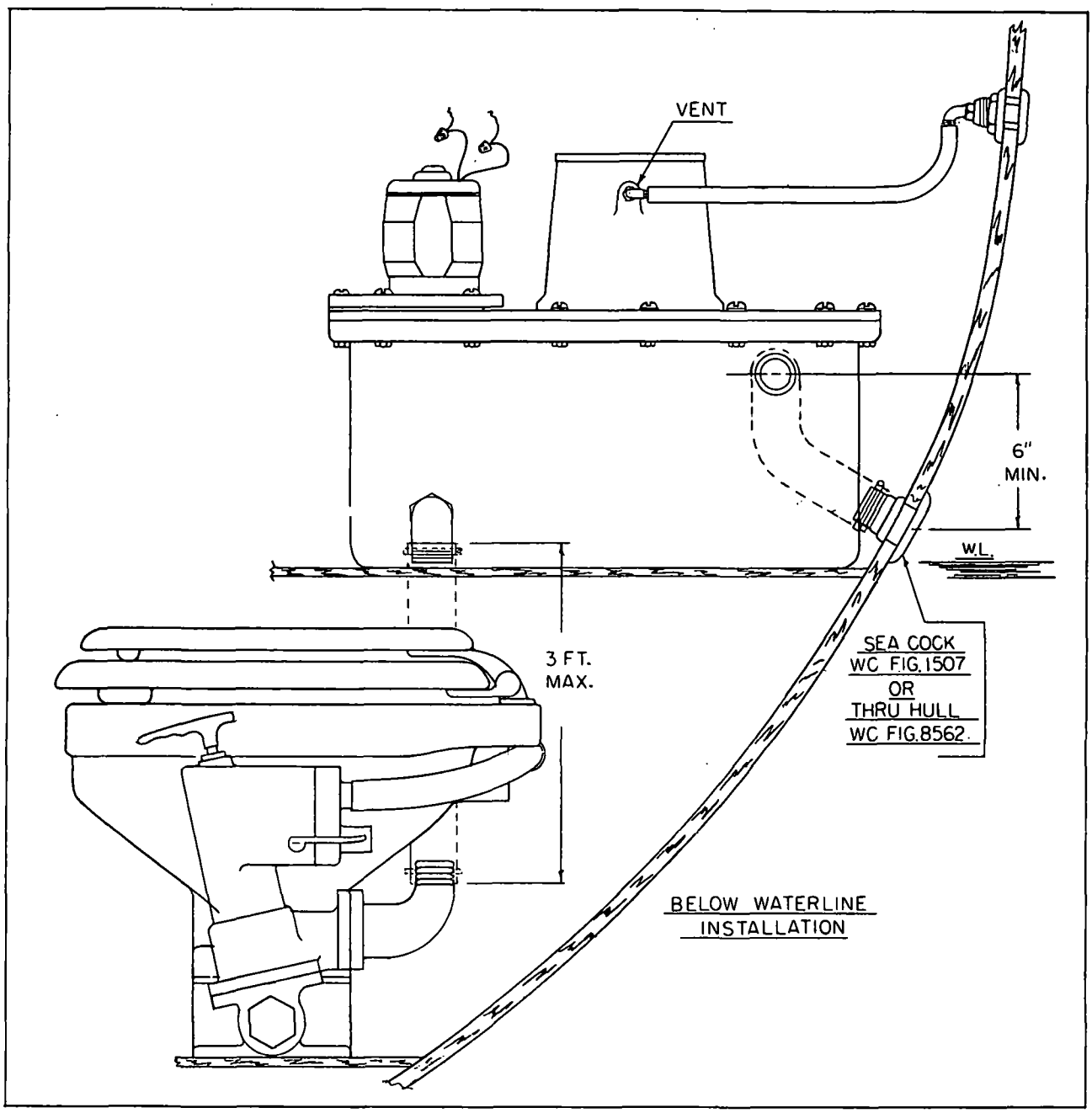
4. Install either the curved or straight Plastic Adapter supplied into one of the lower intake holes on either side of the Macerator/Chlorinator Tank **at the motor end.** Use whichever Adapter lends itself best to the installation.

   (Note: Pipe Dope should be used, and care should be taken not to overtighten Plastic Fittings.)

5. Install the remaining Plastic Adapter into one of the upper discharge holes located on either side of the Tank.

6. Two Plastic Pipe Plugs are supplied to plug the two unused openings in the Tank.

7. Two blind holes – one at either end of the Tank – can be drilled and tapped through to provide for end installation of intake and discharge Adapters, if desired.



(CONTINUED)

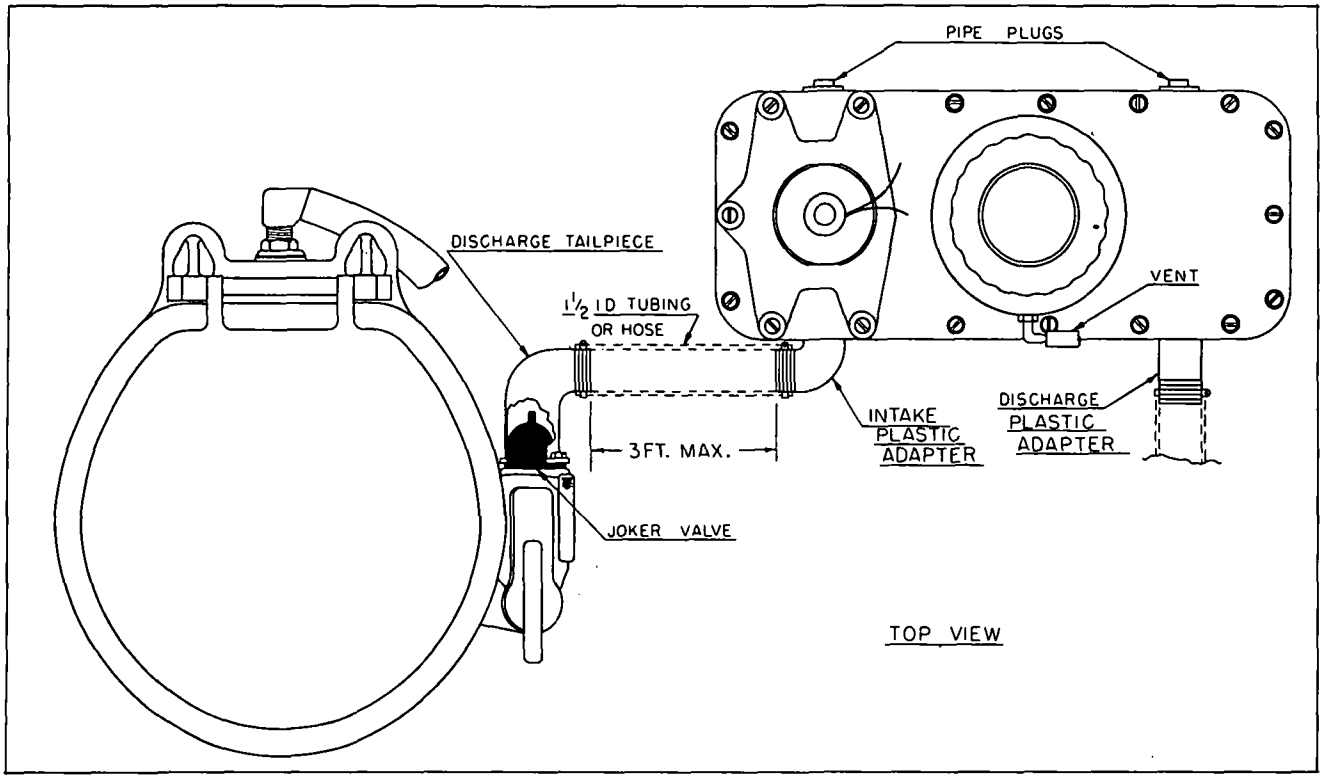
8. Connect the discharge adapter on the Tank to a 1½" Thru-Hull or Seacock, using 1½" I.D. Hose and Clamps. (Hose is not supplied.)

9. Connect the Intake Adapter on the Tank to the Closet. Use 1½" I.D. Hose and Clamps.

10. Secure the Macerator/Chlorinator with blockings or straps (not supplied). Note: **Do not drill holes in Tank.**

11. Install Thru-Hull Vent well above waterline and connect to Pill Chamber with Plastic Tubing supplied, as illustrated.

12. Assemble Timer Switch and Instruction Plate and mount on wall near the Closet. Connect wiring as shown in Installation Sketch, **using 12 gauge wire.**



(CONTINUED)

13. Remove cover of Pill Chamber.

14. Open all Seacocks and pump Closet until Macerator is filled with water.

15. Fill Pill Chamber with H.T.H. ®* Tablets. **Do not fill beyond vent hole.**

    (Note: H.T.H. ®* Tablets can be purchased at any swimming pool supply house, as well as most drug stores.)

16. Replace cover on Pill Chamber, making sure "O" Ring Gasket is firmly seated. The Macerator/Chlorinator is now ready for use.

* H.T.H. is a trademark of Olin Mathieson Chemical Corporation

(Due to the varying state and local laws applying to the use of marine toilets with anti-pollution devices, Wilcox-Crittenden assumes no responsibility or liability for the sale and/or use of the Fig. 6006 Chlorinator in those areas where it is found that its use does not comply with state or local requirements.)

NOTE: OWNERS OF THE EARLIER STYLE OF W-C CHLORINATOR, FIG. 6000, WHICH OPERATED WITH CLOROX, MAY READILY CONVERT TO THE NEW CHLORINATOR BY DISCARDING THE OLD COVER AND MOTOR, AND REPLACING THEM WITH THE NEW W-C CHLORINATOR CONVERSION UNIT. ORDER THIS BY SPECIFYING FIG. 6006-C.

WILCOX-CRITTENDEN GW A GULF + WESTERN COMPANY

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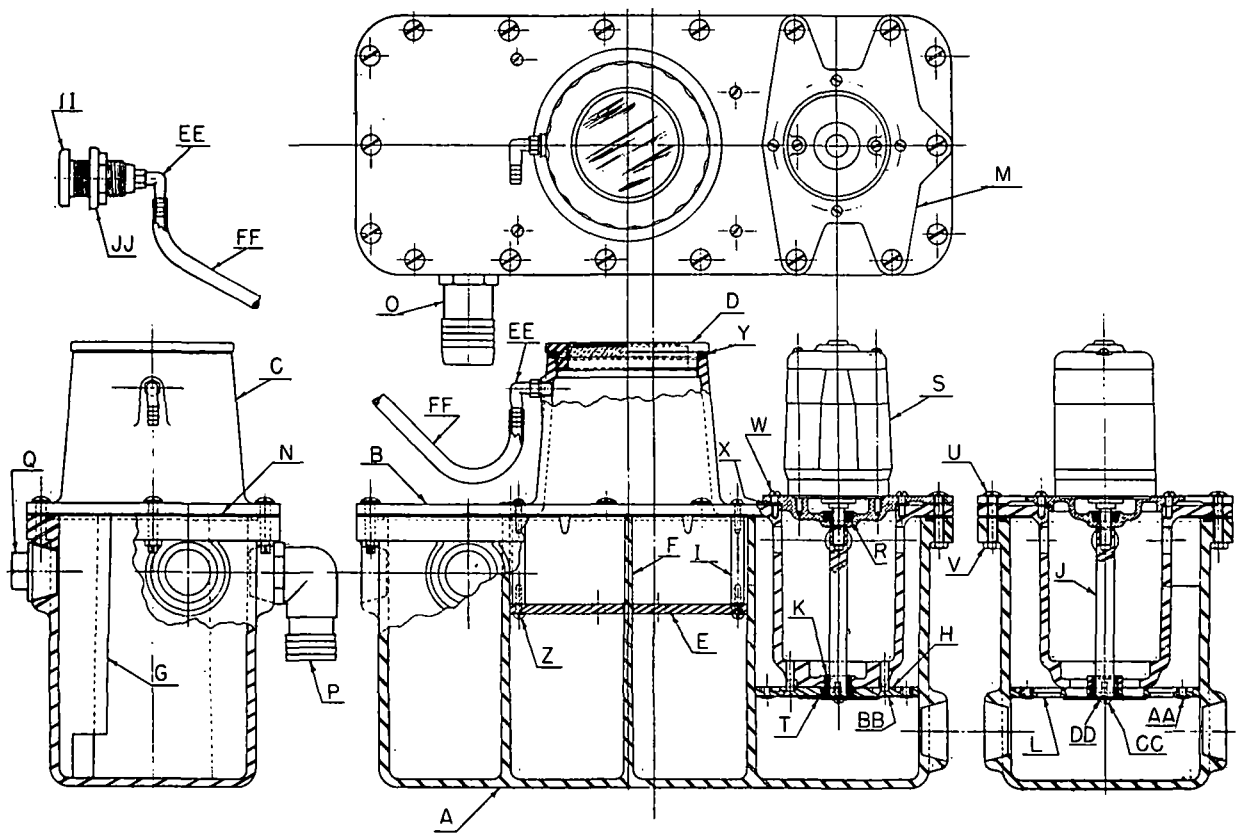
MACERATOR/CHLORINATOR

PARTS LIST

(FOR USE WITH FIG. 6006 UNIT)



Dwg. Ref.	*Quantity Per Unit*	*PART NAME*
A	1	Chlorinator Tank
B	1	Tank Cover
C	1	Pill Box
D	1	Pill Box Cover
E	1	Pill Box Tray
F	1	Pill Box Tray Baffle
G	1	Tank Baffle
H	1	Chopper Plate Baffle
I	4	Pill Box Tray Posts
J	1	Chopper Shaft
K	1	Chopper Shaft Bearing
L	1	Chopper Plate Baffle Screen
M	1	Motor Mounting Bracket
N	1	Tank Cover Gasket
O	1	Hose Adapter—Straight
P	1	Hose Adapter—90° Elbow
Q	2	Pipe Plugs
R	1	Shaft Seal
S	1	Chopper Motor

Dwg. Ref.	*Quantity Per Unit*	*PART NAME*
T	1	Chopper Blade
U	18	Tank Cover Screws
V	18	Tank Cover Nuts
W	4	Motor Mounting Bracket Screws
X	1	Motor Mounting Bracket Gasket
Y	1	Pill Box Cover Gasket
Z	9	Pill Box Tray Screws
AA	12	Chopper Baffle Plate Screen Fasteners
BB	2	Chopper Baffle Plate Screws
CC	1	Chopper Blade Screw
DD	1	Chopper Blade Washer
EE	2	Vent Hose Adapters
FF	1	Vent Hose
GG	1	Chopper Motor Timer (not illustrated)
HH	1	Timer Mounting and Instruction Plate (not illustrated)
II	1	Vent Thru-Hull Connection
JJ	1	Vent Thru-Hull Connection Nut

WILCOX-CRITTENDEN

A GULF + WESTERN *PRECISION ENGINEERING* COMPANY

MIDDLETOWN, CONNECTICUT 06457

RARITAN

Electro-Chemical Chlorinator

INSTALLATION AND MAINTENANCE INSTRUCTIONS

Parts and Exchange Unit Lists

The Raritan Electro-Chemical Chlorinator is a miniature sewage treatment plant for on-board use. It utilizes the macerator/chlorinator principle and works well with most marine toilets except the jet types. The latter's use of large volumes of flush water is incompatible with the chlorinator's compact design.

The chlorinator uses readily available household type 5 3/4% sodium hypochlorite solution (such as "Clorox") as a decontaminating agent to both destroy bacteria and sharply reduce the B.O.D. of waste material.

INSTALLATION

The Chlorinator should be located as close to the head as possible, preferably within 3 feet. It can be placed a reasonable distance above or below the head; but the longer the hose between toilet and chlorinator, the more pumping action will be required to clear the line of sewage. The dilution caused by this additional water will adversely affect the chlorinator's decontaminating ability. Where the length of connecting hose exceeds three feet, the chlorinator must be operated for a longer period of time.

The "Clorox" bottle *must* be located on the same level as the macerator/chlorinator. It should be secured to the box with the strap and screws provided (Figure 4). Replace the bottle cap with the syphon (see Part # 2017) provided. Syphon length and cap size varies according to bottle size. The 1/2 gallon size is normally furnished as standard. NOTE: If the syphon cap fits the bottle, you have the correct length.

Secure the base of the chlorinator to the deck. It should be nested within a box frame for side support, similar to the method recommended for installing storage batteries. Leave enough room to allow bottles to be changed easily. Since the chlorinator motor will turn at very high speed, use a 1" thick foam rubber pad around and under the chlorinator to deaden sound.

Connect the chlorinator inlet (motor end) to the head discharge with a 1½" I.D. neoprene or plastic hose. If it must be bent around a sharp corner, use a standard auto radiator hose of the type with the desired curve molded in (not the "flexible" type with annular corrugations). A single hose is preferable to plumbing "ells".

Do not use a vented loop or "swan's neck" between the head and the chlorinator.

Where a loop must be used, as in certain sailing craft, install it between the outlet of the chlorinator and the discharge sea cock. Secure all hoses with a good grade clamp.

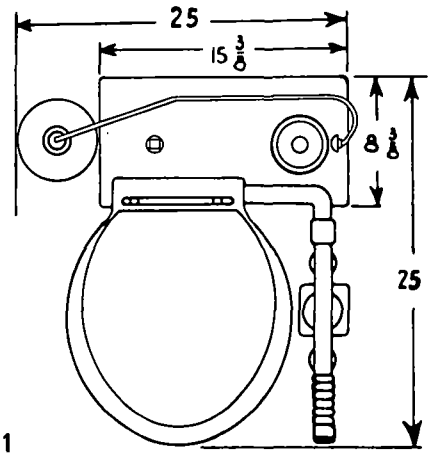


Figure 1

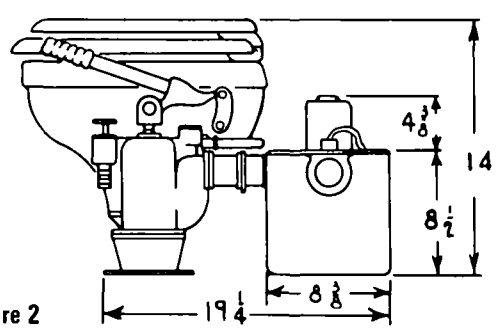


Figure 2

One possible installation of the Raritan Model PH Hand Toilet and Electro-Chemical Chlorinator.

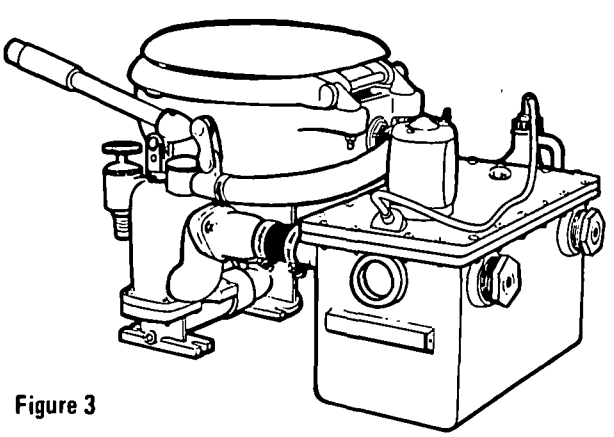
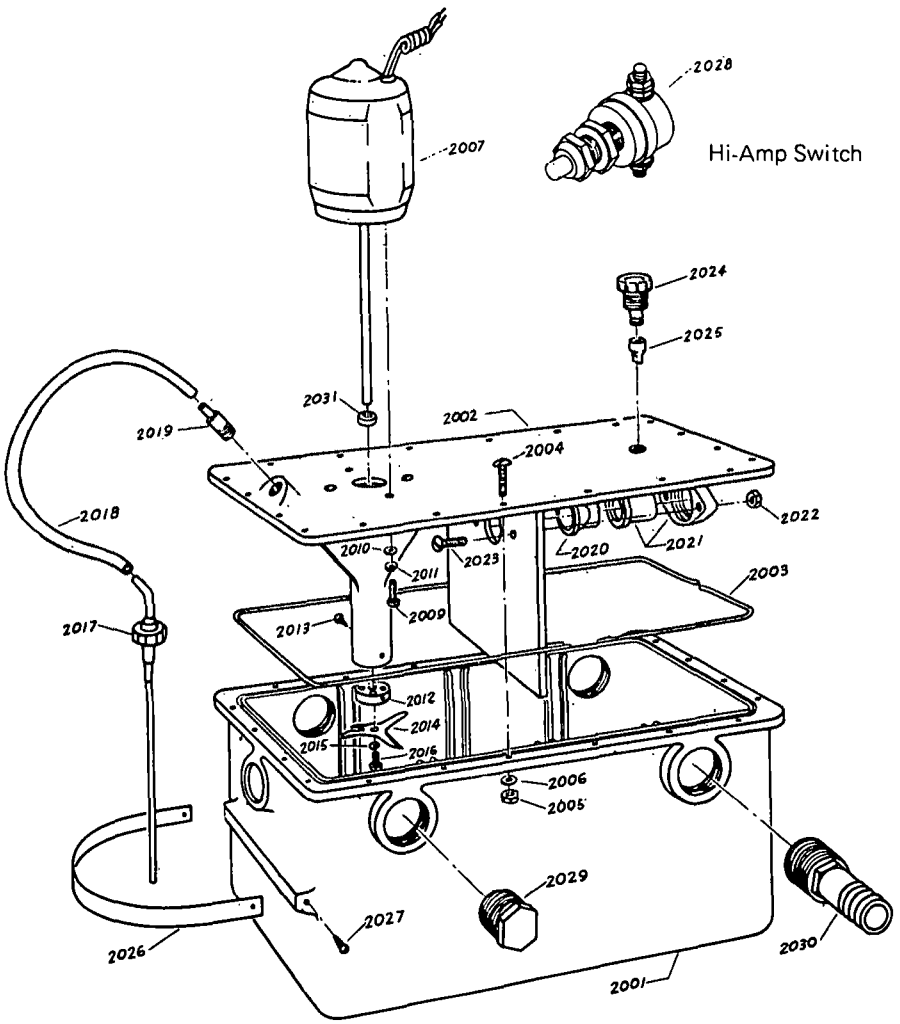


Figure 3

RARITAN ELECTRO CHEMICAL CHLORINATOR
MODEL NO. 2000



DIMENSIONS: HEIGHT 12-7/8"
DEPTH 8-3/8"
WIDTH 15-3/8"

Figure 4

INLET-OUTLET COMBINATIONS

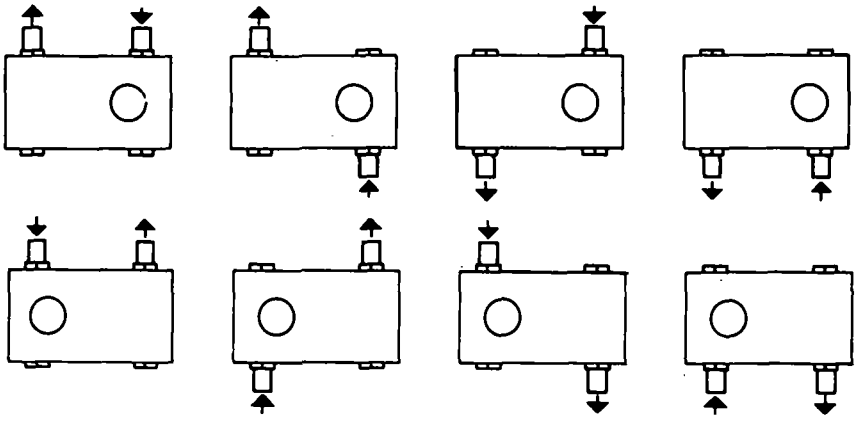


Figure 5

The discharge must always be located at the opposite end of the box. If the hose connections are reversed, the chlorinator will clog and the chlorinator box may be damaged.

If the chlorinator is used with an electric toilet, make it a practice to flush the toilet first, then operate the chlorinator. It is advisable to use 2 circuits, separately fused to avoid high battery loads and voltage drop. Use the following table as a guide to proper wire sizes and fuse capacities.

MINIMUM SIZES FOR SPECIFIC VOLTAGES

	12VDC	32VDC	115VAC/DC
Distance from battery is less than 15 feet; use wire at least	10 gauge	12 gauge	14 gauge
Distance from battery is more than 15 feet; use wire at least	8 gauge	10 gauge	14 gauge
Fuses (or circuit breakers)	40 amps	20 amps.	10 amps.

NOTE: In computing "distance from batteries", include all the wiring from the battery to the switch, the chlorinator and back to the battery to allow for both circuit legs. If a relay is used to supplement the switch (as in 115VDC) ignore wire length between switch and relay.

A Raritan "Hi-Amp" on-off switch is included with each chlorinator for your protection. It is best to use a DC-rated relay (not supplied) when 115VDC is being used. (AC current needs no relay.)

In some areas, anti-pollution laws require the use of timer switches. We recommend the Raritan 60 Second Timer with adjustable intervals. The timing switch interval is normally set so the macerator will be operated long enough to thoroughly perform its function when handling solids. By far the greatest use of the head is for fluids only, which require less "Clorox" and maceration for adequate decontamination. Read the portion of the instruction manual under "Operation" for more details.

OPERATION

Be sure that the "Clorox" bottle is in place. Make a visual inspection to see that the bottle cap has been replaced with the special "syphon" cap and that the small plastic tube (Part # 2018) connects the syphon to the fitting on the chlorinator box. Finally, make sure that both the inlet and outlet seacocks are open. If the latter is closed, the chlorinator will clog and may rupture under the pressure that will develop.

When the head is flushed, sewage is forced through the connecting hose and enters the chlorinator maceration chamber. A high speed beater macerates the waste into a suspended solution. The beater speed creates a strong vortex and suction. This draws the "Clorox" from the bottle, past the syphon check valve, and into the macerator chamber.

When solids (feces and paper) are flushed, the push button switch should be held down for a full 60 seconds. This permits the action to proceed until the solids are reduced to a finely divided slurry and insures an adequate quantity of "Clorox" has been added to the mixture. Active chlorine in the Clorox destroys the bacteria. At the same time, residual chlorine reduces and decomposes the fine solids into harmless gases.

Maceration's prime purpose is to reduce the size of particles so they are exposed to immediate attack by the chlorine. If the chlorinator is shut off too soon, the macerator will not have enough time to act, and an inadequate amount of chlorine will be withdrawn from the bottle. If this condition persists, the chlorinator will eventually clog. The same thing will happen if the supply of "Clorox" is not replenished when empty.

PROPERLY USED, THE CHLORINATOR WILL NEVER REQUIRE CLEANING OUT!

The extent of decontamination depends on three factors: thorough maceration; an adequate quantity of chlorine and enough time for the reaction to be complete. This requires at least twenty minutes. In the chlorinator, the necessary retention time is provided by a tank partition. The first section holds four average flushes. Any flush after that moves some of the processed effluent into the second section and is again held. Thus, retention time is automatically provided by chlorinator design.

Maceration is required, even when only fluids (urine) are flushed. The tank's residual chlorine is circulated to complete decomposition of previous flushes, particularly paper decomposition. It requires almost as much chlorine to decompose paper as solid wastes.

We have explained the chlorination action in detail to emphasize that "skimping" on maceration and chlorination time is self-defeating, and causes eventual malfunction.

OPERATING HINTS

DO NOT operate an electric toilet simultaneously with the chlorinator. Flush the toilet first, then operate the chlorinator.

DO NOT use undersize wiring, particularly in 12-Volt models. The resulting low voltage reduces maceration speed and slows decomposition. If voltage is less than 11.5 volts, measured at the terminals while the motor is running, correct the cause. Check batteries, wiring, fuses, connections and the switch. Low voltage also reduces beater vortex suction resulting in too skimpy ' Clorox" intake and eventual clogging.

DO NOT fail to replenish "Clorox" as required. Neglect will result in clogging, and obnoxious odors emitted by the discharge sea cock.

DO NOT allow certain things to be flushed down the toilet, such as sanitary napkins, tampons, and "wet strength" paper towels. Ordinary cigarette butts are easily flushed but require extra chlorine to decompose. Filter tip cigarettes, especially those with plastic inserts and cigars with plastic mouth pieces, *must not be thrown* down the toilet. Cellophane, pliofilm, and rubber products are almost impossible to macerate.

DO NOT run the macerator when the tank is empty. It requires liquid in the tank for bearing lubrication.

DO NOT fail to brief landlubber guests on the proper usage of the head. Avoid the greater embarrassment of having to explain what happened.

DO NOT fail to flush the toilet 3 times when the boat will be left unattended for 3 days or more.

DO NOT attempt any repairs until you have thoroughly studied the instruction manual. Check the terms of our Warranty and Factory Exchange Policy.

DO NOT "sweeten" the toilet by pouring "Pine Oil", "Mr. Clean" or any other kerosene based products in it.

DO NOT winterize with denatured alcohol.

DO NOT neglect to fill in and return our guarantee card.

MAINTENANCE

Very little maintenance is required. The most important care needed is to replenish the "Clorox" supply as depleted. Always carry a spare bottle on board. If little or no "Clorox" is consumed, motor voltage is probably too low to develop adequate suction. Check causes under "Operation". Also check the "syphon" valve to see that it is working. It should pass liquid one way; *from* the bottle only.

For your convenience, make sure you have the manufacturer's toilet instruction manual on board. The functioning of any toilet and its connected Raritan chlorinator are closely associated.

WINTER STORAGE

Winterize the toilet according to the manufacturer's instructions. If you do not have their manual, send for the Raritan Marine Toilet Operating and Maintenance Manual. It contains useful hints that apply to all marine heads.

After the toilet has been winterized, winterize the chlorinator. Pour at least three quarts of permanent antifreeze (ethylene glycol) – not the anti-leak brands – into the toilet bowl and pump into the chlorinator. Leave it there until recommissioning in the spring when it will be discharged as the head is normally used. *Never use alcohol or kerosene.*

RECOMMISSIONING

When recommissioning in the spring, flush the toilet the equivalent of at least 10 normal flushes to expel *all* the anti-freeze.

WARNING

It is VERY IMPORTANT to do this *BEFORE* connecting the "Clorox" bottle. The chemical reaction between sodium hypochlorite and ethylene glycol can generate heat.

Appendix II

Operation Under Loading Conditions—National Sanitation Foundation, Standard No. 23, "Watercraft Sewage Disposal Device"

4.05 OPERATION UNDER LOAD CONDITIONS: Treatment and discharge devices shall, when installed and operated in accordance with manufacturer's instruction, be capable of producing an effluent meeting the microbiological and chemical/physical requirements of this Standard throughout the testing period of two hours operations at normal load conditions after initial discharge, followed by 20 minutes of operation at peak conditions, and then an additional two hours at normal load conditions.

4.051* NORMAL LOAD CONDITIONS*:

The device shall be placed in service and used (flushed) at a frequency of ½ hour. When discharge of effluent is evident, the normal loading shall continue for a period of two hours, at which time the Peak Load conditions (Item 4.052), shall be applied.

4.052* PEAK LOAD CONDITIONS*:

Single Head Units: The minimum time between uses (flushes) under peak load conditions shall be considered to be five (5) minutes over a 20 minute period.

Multiple Head Units: Peak load conditions for multiple head units shall be considered simultaneous uses (flushes) of all units possible at five (5) minute intervals over a twenty (20) minute period.

Appendix III

Lab Test Results

LAB TEST RESULTS

RARITAN UNIT

Date	Sample No.	Holding Time (between flush)	ML-Inj. Disinfectant	Total Chlorine Residual	Settleable Solids ml/l	Suspended Solids mg/l	BOD mg/l	TOC mg/l	COD mg/l	Unblended T-Coliform per/100 ml	Blended T-Coliform per/100 ml
8/17/71	1	0 min.	410	200	160	1755	780	500	4200	10	5400
	2	12 min.	420	180	-	8750[1]	1820[1]	890[1]	11,575[1]	4900	5400
	3	26 min.	430	380	300	4680	1660	1050	6900	3000	7000
	4	38 min.	390	420	220	4420	1210	530	8300	20	<200
	5	69 min.	200	180	180	4590	1550	1080	8620	1400	<1600
	6	99 min.	260	200	140	5670	1350	985	8400	6200	25,000
	7	129 min.	200	140	170	3270	1120	590	7100	4500	30,000
	8	159 min.	260	100	260	3130	803	935	4120	20	160
8/18/71	1	0 min.	250	180	238	2620	940	530	4280	5	9200
	2	30 min.	330	100	420	5390	1210	1250	6650	>24,000	>24,000
	3	60 min.	230	40	410	5650	1200	1060	7150	9200	>24,000
	4	90 min.	230	80	370	4720	1270	1030	8520	5400	>24,000
	5	120 min.	160	140	280	4110	1230	906	7650	16,000	>24,000
	6	130 min.	200	140	360	4980	1140	970	5950	540	9200
	7	140 min.	80	40	300	3680	1060	810	6250	2	2400
	8	150 min.	210	40	240	4820	1270	970	6550	16,000	>24,000

LAB TEST RESULTS

RARITAN UNIT

Date	Sample No.	Holding Time (between flush)	ML-Inj. Disinfectant	Total Chlorine Residual	Settleable Solids ml/l	Suspended Solids mg/l	BOD mg/l	TOC mg/l	COD mg/l	Unblended T-Coliform per/100 ml	Blended T-Coliform per/100 ml
8/19/71	1	0 min.	320	240	250	3380	1150	690	5850	11	>240,000
	2	30 min.	280	200	280	3700	1300	810	7150	3500	54,000
	3	62 min.	270	320	280	3310	1160	875	6150	220	5400
	4	92 min.	280	220	60	4720	1440	780	6950	<2	3500
	5	122 min.	260	140	280	4720	1060	875	6850	>240,000	>240,000
	6	152 min.	270	180	400	4190	1220	750	7050	54,000	>240,000
8/26/71	1	0 min.	310	400	325	4800	1430	750	7300	8	240,000
	2	30 min.	220	240	150	3940	1080	690	6050	11,000	7,900
	3	58 min.	248	300	285	5100	1150	625	7250	<2	4
	4	88 min.	210	240	295	5960	1180	690	5800	1300	4900
	5	99 min.	160	280	335	5500	1540	900	6800	20	27

LAB TEST RESULTS

WILCOX-CRITTENDEN

Date	Sample No.	Holding Time (between flush)	Total Chlorine Residual	Settleable Solids ml/l	Suspended Solids mg/l	TOC mg/l	BOD mg/l	COD mg/l	Unblended T-Coliform per/100 ml	Blended T-Coliform per/100 ml
8/23/71	1	0 min.	240	100	2100	560	783	4000	17	7
	2	10 min.	480	100	1510	470	540	3850	4900	54,000
	3	40 min.	1100	240	1540	595	716	4220	>240,000	>240,000
	4	65 min.	700	100	2710	875	933	5700	>240,000	>240,000
	5	95 min.	640	175	2720	655	913	5180	24,000	>240,000
	6	125 min.	480	200	3250	970	1133	10,600	790	1100
	7	245 min.	1240	150	3300	440	590	3120	<2	<2
8/24/71	1	0 min.	540	100	4100	815	1200	6650	23	24,000
	2	12 min.	380	340	5820[1]	1250[1]	2600[1]	14,200[1]	7	8
	3	25 min.	540	-	5910[1]	1440[1]	1500[1]	8000[1]	<2	<2
	4	70 min.	740	150	7660[1]	900[1]	1940[1]	10,400[1]	23	24
	5	90 min.	760	100	9310[1]	1030[1]	1980[1]	9680[1]	79	350
	6	120 min.	720	270	4640	565	1080	5950	2800	54,000
	7	150 min.	440	160	4820	750	1060	6350	<2	42
	8	285 min.	1400	25	3240	565	660	2980	<2	<2

LAB TEST RESULTS

WILCOX-CRITTENDEN

Date	Sample No.	Holding Time (between flush)	Total Chlorine Residual	Settleable Solids ml/l	Suspended Solids mg/l	TOC mg/l	BOD mg/l	COD mg/l	Unblended T-Coliform per/100 ml	Blended T-Coliform per/100 ml
8/25/71	1	0 min.	-	-	-	-	-	-	-	-
	2	30 min.	720	325	4030	690	1130	6120	$<2^2$	$<2^2$
	3	50 min.	700	175	9200	1560	1130	11,520	$<2^2$	$<2^2$
	4	80 min.	680	320	4410	1250	1360	8050	$<2^2$	$<2^2$
	5	110 min.	280	510	6640	2000	2630	8500	$<2^2$	$<2^2$
	6	135 min.	480	560	9790	2600	2600	13,900	$<2^2$	$<2^2$

LAB TEST RESULTS

INFLUENT

Date	Sample No.	Holding Time (between flush)	Settleable Solids ml/l	Suspended Solids mg/l	BOD mg/l	TOC mg/l	COD mg/l	Unblended T-Coliform per/100 ml	Blended T-Coliform per/100 ml
8/20/71	1	0 min.	200	6600	2370	1020	9380	$>24 \times 10^7$	$>24 \times 10^8$
	2	30 min.	240	6540	4700	1340	10,100	$>24 \times 10^7$	$>24 \times 10^8$
	3	60 min.	230	3300	3420	1500	15,600	$>24 \times 10^7$	16×10^8
	4	90 min.	300	6880	2140	1500	16,300	$>24 \times 10^7$	$>24 \times 10^8$
	5	120 min.	230	6520	1570	1560	11,500	$>24 \times 10^7$	54×10^7
8/20/71	Flush Water[3]	Taken - 8/13	<0.1	93	-	2.5	141	2	
8/25/71	Flush Water[3]	Taken - 8/29	<0.1	113	2.3	2.5	153	79	

[1]Data not included in summary calculations and discussions due to operational difficulties encountered during test.

[2]It is suspected that the amount of Sodium Thiosulfate in the sterile sample jar was of an insufficient quantity to neutralize the chlorine in the sample.

[3]Flush water taken from Atlantic Ocean off Sandy Hook, New Jersey.