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DESIGN OF NON-MECHANICAL CHLORINATOR FOR SMALL WATER SUPPLIES

by

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Eruditio et Religio

ROBERT PETER LALOR. Design of Non-mechanical Chlorinator for Small Water Supplies (Under the direction of Dr. P. Aarne Vesilind)

Numerous published designs of non-mechanical chlorinators for small community water supplies were studied and analyzed hydraulically. One widely accepted design was found to be theoretically and practically worthless. A design based on the siphon principle was found to give the desired constant discharge characteristic. The design is easily constructed of universally available materials at low cost.

Key words: Chlorination, Disinfection, Developing Countries

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OBJECTIVE

The objective of this study is the determination of an optimal design for a disinfection device to be used with small water supplies in developing countries. Analysis is on the basis of the following parameters:

AVAILABILITY OF MATERIALS
SIMPLICITY OF CONSTRUCTION AND MAINTENANCE
COST OF CONSTRUCTION AND MAINTENANCE
EFFECTIVENESS OF UNIT
VERSATILITY OF UNIT

The ideal device, then, would be a non-mechanical liquid feeder, simple to build and operate, constructed of easily available materials at low cost, and capable of proper disinfection over a wide range of foreseeable field conditions. An attempt is made here to select a design which conforms as closely as possible to the above criteria.

Although the thrust of the sutdy is directed toward the design of devices for rural, underdeveloped areas, it is obvious that such a unit can also be used for emergency chlorination in the developed countries. In the latter case, of course, there is much less constraint on available material. It should therefore be kept in mind that the subject of this study is easily adapted to disinfection of water supplies following disasters or any emergencies when existing treatment plants are not functioning.

INTRODUCTION

It is estimated that some 500 million human beings are afflicted with incapacitating water-borne or water associated illness each year. For ten million people, half of them infants, the affliction is fatal (1). This unfortunate attrition is centered, as might be expected, in the poorer, less developed nations of our world, which lack both the technological and financial resource to improve their own condition. In fact, a great deal of this suffering could be averted simply by the employment of the most rudimentary disinfection methods to rural community water supplies in underdeveloped areas. In this project, the development of one widely used type of disinfectant, chlorine, will be studied in the context of small, rural water supplies.

The expensive, technically sophisticated methods required in the handling of pure liquid chlorine obviously precludes any consideration of that form of treatment in the given context. Chlorine is available in other forms, however, which are both plentiful and inexpensive throughout the world. These include dry calcium and sodium hypochlorite and chloride of lime (bleaching powder). The use of dry materials results in some handling and application problems, but these are far from insurmountable. For example, chlorine compounds deteriorate with time and exposure to air and sunlight. Thorough studies have been made as to the extent of this decomposition, and simple measures to reduce loss of strength during storage are highly effective. A survey of proper handling techniques is included later in the report. The problems in applying the chlorine are not so easily solved, however. The determination of a suitable applicator comprises the major portion of this report.

The chlorine sources mentioned previously are highly soluble in water, but direct addition of some of these dry compounds to water results in a quantity of carbonate precipitate which is undesirable in a public water supply. This augments the considerable difficulties involved in "dry feeding" to the point that liquid feed chlorinators, which dose the water supply with a previously prepared stock solution of high chlorine concentration, are preferable. The precipitate formed when the stock solution is mixed is easily separated and discarded during the preparation.

REVIEW OF EXISTING DESIGNS

A number of supposedly effective designs of solution feed devices are found in the publications of various interested agencies. Practically all are variations on one of two basic design principles. The first, and by far the most widely used, principle is the basis for what is called the "float type" feeder. The second device is a "siphon type" feeder.

A. Float Type

The principle of operation of the float type solution feeder may be seen with reference to Figure 1. By maintaining orifice A at a constant distance below a wooden float (and hence a constant distance below the surface of the solution), a constant quantity of solution is supposed to pass through orifice A.

Obviously, this is true only if the tube D does not flow full--if the tube is full, the total static head at the shut off valve H is the depth of the liquid in the tank, not the distance between the orifice A and the surface. With the tube full, the discharge can be calculated by the orifice formula, with the flow being proportional to the square root of the static head. The velocity, and hence discharge, is obviously then a function of the elevation of water in the tank, and certainly not constant with changes in depth.

Some of the designs in question do attempt to restrict the flow at the influent orifice, allowing the solution to trickle through the partially empty tube at constant discharge. Such an orifice would have to be extremely small to satisfactorily regulate the flow. Proper dimensions could hardly be attained without the use of drawn glass tubing, and even were that feasible there would surely be problems with clogging. One such design, touted as being successful in the Sudan, is described in the abstract as being "constructed of local materials (2). Glass tees were suggested as the proper material for the influent orifice; but the tees, unfortunately, were not available in the Sudan.

A design widely publicized in the literature was first proposed in the N.Y. State Department of Health Bulletin no. 21 (3). It has been reprinted in the World Health Organization monograph by Wagner and Lanoix, "Water Supply for Rural Areas and Small Communities",(4) with the authors' comment that it is a "simple and reliable" device. This design is reproduced as Figure 1. No attempt is made to restrict flow at the influent orifice, which is specified 1/4" diameter. A valve is used at the outlet to regulate the flow. It is obvious that with such a large influent orifice the tube will flow full, and the discharge will be proportional to the square root of the elevation of the float. Because of the widespread acceptance of this particular design, however, it was decided toa ssemble a similar unit in strict conformance to the specifications.

The assembled apparatus consisted of a box, 2' -110" x 2' - 10" x 1'-6", with three walls and the floor made of plywood and the fourth wall of plexiglass. Inside, a 1/4" brass pipe with a 1/4" hole was connected to a 1/4" rubber tube. The tube, in turn, was connected to a 1/4" brass pipe passing through the container. The outside end of the pipe was connected to a shut-off valve.

The unit was tested over a range of static heads with a fixed constriction of the effluent orifice. The results are;

Effective Static Head	flow (cc/min)
18"	72
13"	50
10"	36
5"	17.5

The decrease in discharge of more than 75% from 18" to 5" of static head is far from satisfactory, especially since 36" is the suggested maximum of the tank!

It is readily apparent that the float type device is entirely unsatisfactory.

B. Siphon Type

The second type of simple chlorinator uses the siphon principle, and its applicability as a constant head feed device can be seen with the aid of Figure 2. As the solution is removed from the airtight vessel by siphon action through tube D, the pressure exerted by the gaseous phase at the top of the vessel is reduced. When the pressure in the container drops low enough, air enters through tube A. This controlled leakage of air into the container establishes a constant hydrostatic head H on the siphon, which is tehn translated to a constant discharge.

One such design was proposed by Mr. V.C. Lischer in a symposium on water supply in Southeast Asia, and published in Bulletin no. 21 of the N.Y. State Department of Health (3). His design is reproduced as Figure 6 Mr. Lischer mentioned that the rate of flow can be controlled in two ways. The first, of course, is adjustment of siphon head H. The second method suggested is "controlling the inflow of air through stopcock B .... The required flow is set by adjusting the stopcock opening." This second method might be theoretically correct but is not feasible, since air flow rate into the tank is quite small, and its adjustment therefore extremely difficult.

It can be concluded that the siphon type chlorinator, with rate of flow controlled by adjustment of siphon head, theoretically satisfies the requirements of this project.

Other Designs

Some designs have been suggested which utilize earthenware pots, filled with bleaching powder and immersed in a well. Zdravkov's "dosing cartridges (5) were found unsatisfactory due to blockage of the pores with calcium carbonate deposits (6). Further designs, proposed by Central Public Health Engineering Research Institute of India (6) must be rejected due to the complexity of charging them properly.

CONSTRUCTION AND USE OF SIPHON TYPE CHLORINATOR

Design

The siphon type device has been chosen as the unit which best meets the previously stated criteria. Obviously, the practicality of this design is limited by the availability of an airtight vessel. Many such vessels are available in smaller sizes--a little grease will convert a food jar with screw-on lid to air-tightness. Larger vessels are not as commonplace, but are available nonetheless in any area of the world. For our pruposes, we shall assume that the person constructing the unit has access only to equipment that would be found in a shop or garage in a central village of some developing nation-- i.e., rubber hoses, steel gasoline cans, washers, nuts and simple tools such as wrenches and drills. It should be noted that steel gas cans or drums, which are generally available in any locality, make excellent airtight containers. If available, the 55 gallon drum can provide disinfection runs of many weeks without refilling, and is ideal. The smaller 5 gallon (20 l.) jerry cans are probably more available, but need regular and frequent refilling.

Once an airtight vessel has been acquired, it must be tapped twice to give access to the siphon and air tubes. If some rubber stoppers are used, two holes can be drilled in the stopper and glass or metal rods inserted. In this report, however, it is assumed that no such supplies exist, and that the only available materials are those to be found in a small, rural garage or shop. The tapping of airtight metal cans and drums by elementary means is necessary.

A simple and inexpensive connection has been devised which maintains the airtight integrity of the container while permitting free flow of both air and solution through the appropriate tubes. A hole is first drilled or punched through the metal skin of the container. A hollow metal tube or nipple with outside surface threaded is then inserted into the hole. In construction of the test device, the tubes used were of a type commonly used in the manufacture of table lamps. These should be available in any locale which has electric service. Gaskets, washers, and nuts are placed as shown in Figure 3, and thus a snug, airtight fit is attained.

A five gallon steel jerry can was used as the container for testing of this siphon type design. It was tapped twice as shown in Figure 3, and rubber tubing was cut to proper lengths and attached. The completed apparatus is shown in Figure 4.

Flowing freely, the siphon will empty a jerry can or a container of similar size in a matter of minutes. The final touch for the chlorinator must therefore be a flow restrictor, which can stretch the chlorine run up to several days in length. It was found that a wooden plug with a V-notch, in Figure 5, was quite satisfactory. The flow can be readily regulated by altering the depth of insertion of the rod into the tubing. Additional (and more sensitive) control can be exercised by adjusting the elevation of the effluent orifice.

The device shown in Figure 4 was tested for constant head characteristics, with results as follows:

Effective depth of solution	Quantity of Solution left in can (liters)	Discharge (cc/min.)
9 3/4"	17	34
8 1/4	15	36
6"	12	35.5
4 1/2"	9	34
3"	7	35
3/4"	4	33

The variation in flow over the range of heads is no more than reasonable experimental error, and we can conclude that the siphon type device seems to work quite satisfactorily.

The jerry can device was tested by maintaining a discharge of 0.5% chlorine solution for 120 consecutive hours (5 days). No stoppage or blocking was observed.

Corrosion?

Use

The device should be filled with a previously prepared chlorine solution, siphoned out of the vessel in which it was prepared. In order that the device reach equilibrium flow as quickly as possible, it should be filled to the brim. In the case of a jerry can, the can should be tilted to reduce the amount of air left inside after filling.

Once it has been charged fully, the vessel should be tightly sealed. The siphon is started by blowing into the air tube, and should reach equilibrium flow in a short time (2-3 min.). The proper dose rate can then be determined by successively testing residuals, and adjusting the elevation of the siphon outlet relative to the container, until a proper discharge has been established.

Once this discharge has been determined, the corresponding siphon head should be measured or marked in some manner that will permit easy duplication--so long as the siphon head is maintained at that constant value and the unit is supplied with chlorine, the desired discharge (and disinfection) should be faithfully reproduced.

PREPARATION OF CHLORINE SOLUTION

As previously noted, there are certain difficulties involved in the handling and feeding of dry chlorine compounds. Those compounds considered to be universally available are:

a) Bleaching Powder
b) High Test Hypochlorite

Other commercially available laundry bleaches and cleaning solutions are also possible sources of chlorine, but their chlorine content is so low (1-3%), and their expense so high, that they cannot be considered within the context of this report. They may prove useful, however, for short term emergency treatment of contaminated water.

Difficulties involved in using bleaching powder or high test hypochlorite as the chlorine source are as follows:

Bleaching Powder

This compound, containing about 30% chlorine when fresh, undergoes rapid deterioration on exposure to air. The Central Public Health Engineering Research Institute of India ran tests on the extent of this deterioration (6). It was found that sufficient deterioration occurs so that the whole can of bleaching powder should be used at once in making up the stock solution. Caution must also be exercised in handling the solution, which is very sensitive to air and sunlight. It is obvious that containers both of powder and solution, should be sealed tightly at all times and stored in a dark place.

PREPARATION

For a 1% solution: to each 40 grams of powder add enough water to make one liter. Mix thoroughly and let stand for several hours. Siphon off the clear solution and discard the lime precipitate. Remember to keep the solution sealed and covered at all times.

High Test Hypochlorite

This compound contains 70% available chlorine. It is more stable than bleaching powder, so the whole can need not be used at once. Great care should be taken to use only clean, dry dippers or spoons when removing hypochlorite from a container which is to be reclosed. There is a possibility that contaminants (including water) inside the can will bring about spontaneous combustion of the contents if the can is left in hot sun (7).

PREPARATION

For a 1% solution: to each 15 grams of powder add one liter of solution. Mix thoroughly and let stand for several hours. Siphon off the clear solution and discard the calcium precipitate. Remember to keep the solution sealed and covered.

N.B. - A solution with 1% chlorine has the maximum practical concentration. Over 1% chlorine will be lost in the sediment.

REFERENCES

1. McJunkin, F.E., "Community Water Supply in Developing Countries", University of North Carolina, Chapel Hill, 1969.

2. "Water Supply and Sanitation in Developing Countries", AID-UNC/IPSED series Item No. 16, University of North Carolina, Chapel Hill, 1967.

3. Bulletin No. 21, New York State Department of Health.

4. Wagner, E.G., and Laxoix, J.N. "Water Supply for Rural Areas and Small Communities", World Health Organization, Geneva (Switzerland), 1959.

5. Zdravkov, M. "New Methods of Chlorinating Drinking Water", WHO/Env. San./124, Nov. 25, 1959.

6. "Disinfection for Small Community Water Supplies" , Central Public Health Engineering Research Institute, Nagpur (india).

7. Tolbert, Buzz, Technical Representative, Olin Mathieson Chemical Corporation, Chemicals Division, Charlotte, North Carolina.

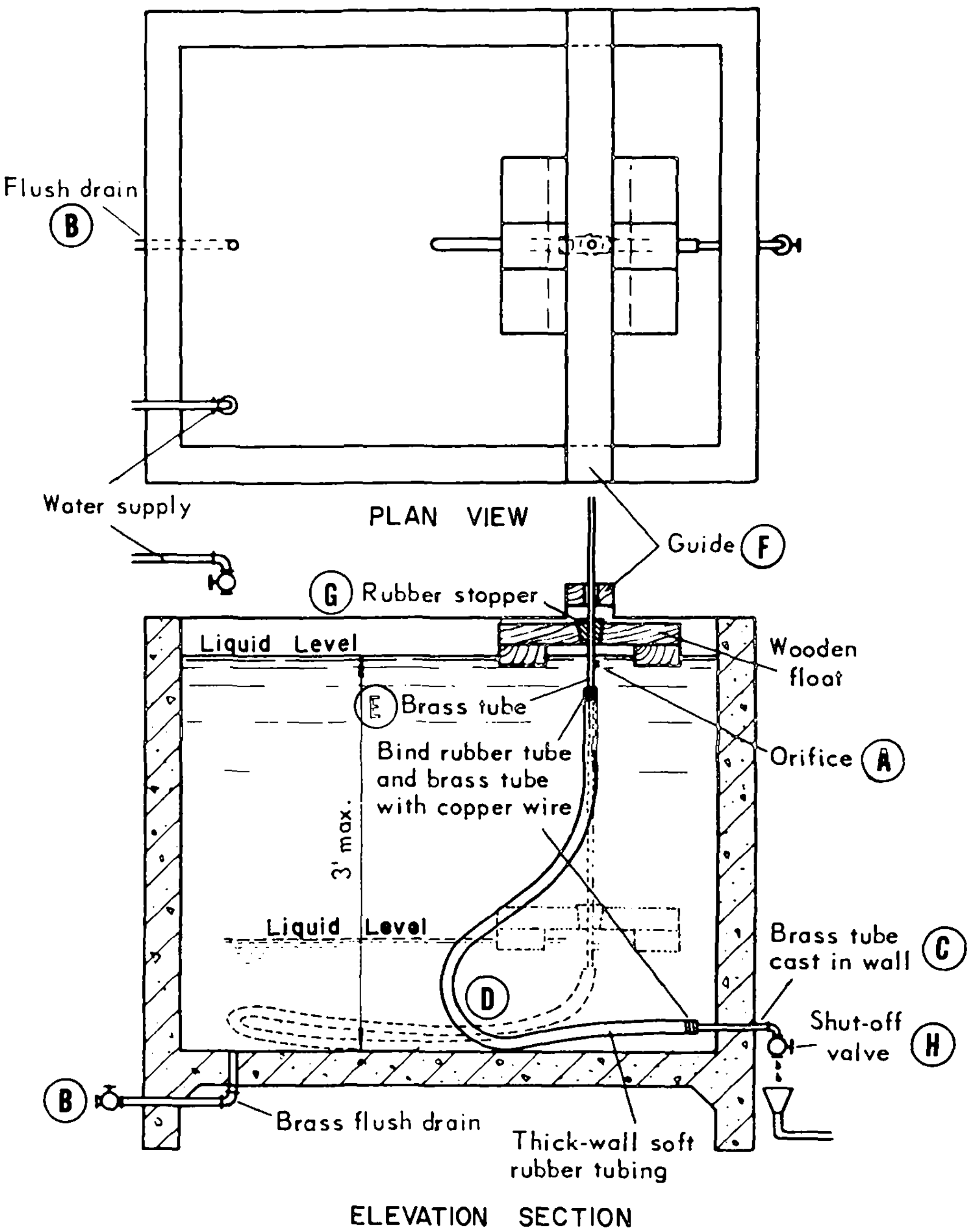

FIGURE I

FLOATING PLATFORM HYPOCHLORITE SOLUTION FEEDER

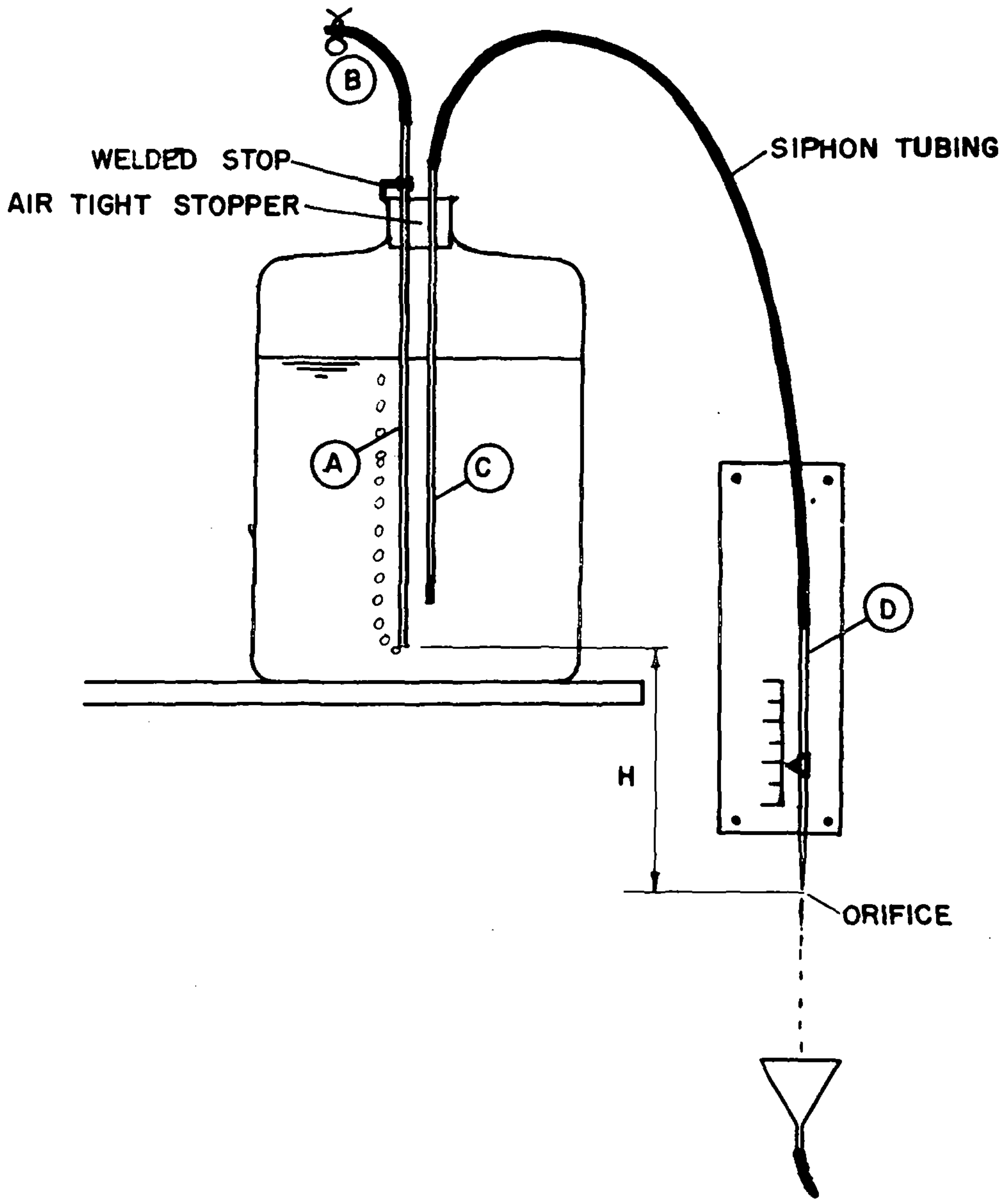

FIGURE 2 BOTTLE SOLUTION FEEDER
(Siphon Type)

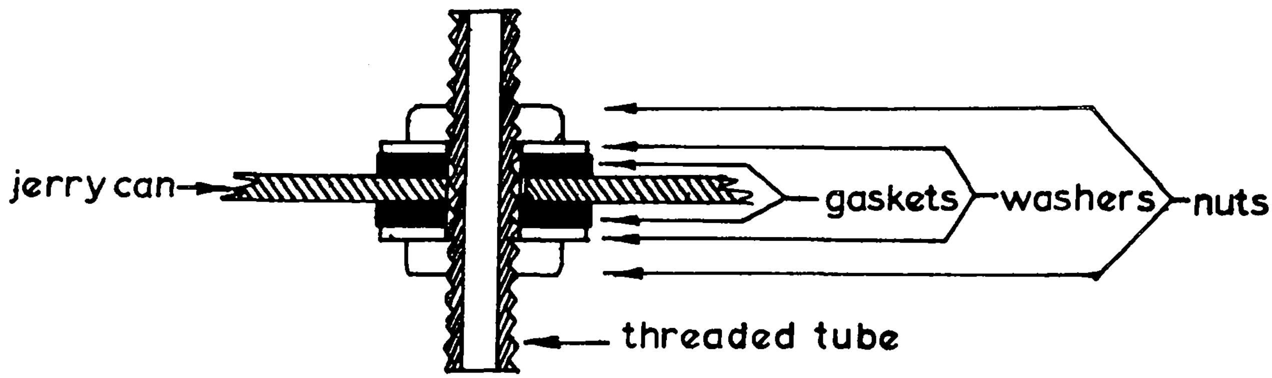

FIGURE 3. HOSE CONNECTION TO JERRY CAN

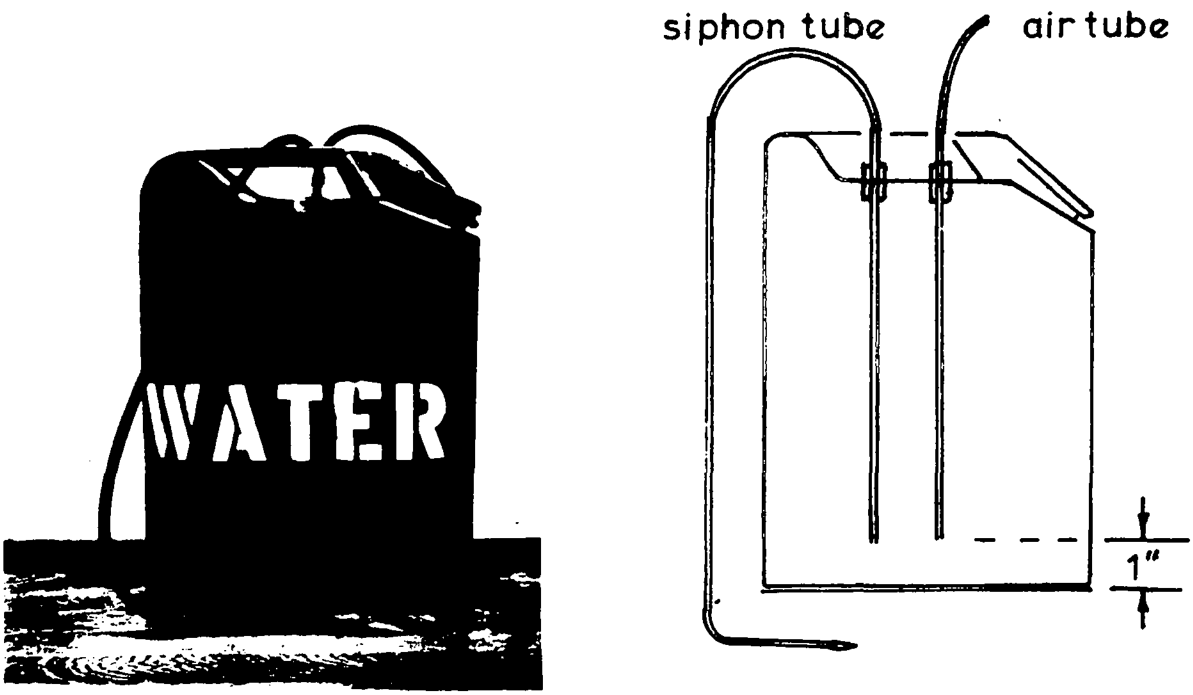

FIGURE 4. JERRY CAN CHLORINATOR

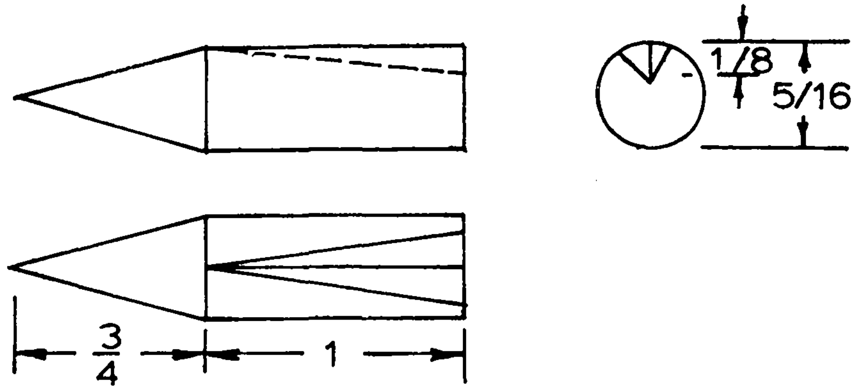

FIGURE 5. V-NOTCH FLOW RESTRICTOR PLUG