The CTI 8 Chlorinator

THE CTI 8 CHLORINATOR

AN INSTRUMENT FOR DISINFECTING DRINKING WATER IN GRAVITY FED SYSTEMS

MANUAL OF INFORMATION, MAINTENANCE & OPERATION

By

Fred Jacob and Charles Taflin

Compatible Technology International (CTI)

The CTI 8 is a device for disinfecting drinking water in gravity-fed water systems. It is low-cost, non-electrical, and requires minimal maintenance. The CTI 8 is capable of delivering a constant and appropriate dose of chlorine to control disease-causing organisms in small community water systems.

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CTI CONTACT INFORMATION

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PART I: OVERVIEW OF THE CHLORINATOR

1. CTI (Compatible Technology International)

CTI is a not for profit Non Governmental Organization (NGO) headquartered in St. Paul, Minnesota, USA. This volunteer organization has a history of twenty-five years working in appropriate technology devices for use in developing countries. The mission of CTI is inventing and sharing simple and sustainable food and water technologies to empower people to improve their living conditions.

Currently CTI supports projects in ten countries worldwide including Africa, the Caribbean, Central America, and India. The projects include water treatment, solar devices for cooking, roasting, and drying food, grinders for milling grains and nuts, efficient wood-saving cook stoves, and devices for post-harvest food production.

In 2001, having received funding from the Lilly Family Foundation, CTI initiated a pilot chlorinator project in Nicaragua, Central America. Cooperation between CTI and the Water Ministry, specifically the Maintenance and Operation Division (UNOM), resulted in technicians from UNOM learning the chlorinator construction and operation. This trained them to supervise community level workshops, and twenty-one chlorinators are currently installed in gravity fed water systems in the northern Matagalpa and Jinotega Departments. The results from a pilot project of one year, and the data from the twenty one systems operating for three years were encouraging in that the chlorinator functioned as designed in delivering a constant flow of chlorine within the standards set by international and national water agencies. Tests have shown that the chlorine dosage for the chlorinator is adjustable, basic costs are acceptable, maintenance is minimal, and community acceptance is very high.

2. CONTAMINATED WATER RELATED TO ILLNESS

Statistics show that diarrhea due to contaminated water is one of the major causes of morbidity and mortality in children under the age of five years in developing countries. UNICEF states, "Every day diarrhoeal (sic) diseases cause some 6,000 deaths worldwide, mostly among children under five (years of age). More than 2.2 million people, primarily in developing countries, die each year from diseases caused by polluted water."[1]

3. DISINFECTING GRAVITY FED, RURAL DRINKING WATER THROUGH CHLORINATION

The **CTI 8 Chlorinator** is an inexpensive, low-maintenance, non-electrical, appropriate technology instrument. It is capable of delivering a controlled dosage of chlorine to water sufficient to inactivate most of the pathogens (disease-causing organisms) found in water systems. The CTI 8 accomplishes disinfection by directing water flow over solid chlorine tablets placed in a simple configuration of PVC pipe.

[1] UN Department of Public Information "A "Framework for Action on Water and Sanitation", 2003

The chlorinator is constructed of 3-inch (75 mm) and 4-inch (100 mm) schedule-40 PVC pipe and fittings, and ¼-inch (6 mm) sheet PVC using chlorine in the form of solid tablets approximately 2 ½ inches (6.35 cm) in diameter. Experience demonstrates that the CTI 8 can be built in three hours or less using basic hand tools. Detailed instructions for construction, installation, and maintenance are explained further on in this manual.

Developing the CTI 8 involved three years of research plus three additional years of field-testing in twenty-one rural water systems in Nicaragua. There are also two chlorinators installed in Guatemala serving in total, approximately 7,000 inhabitants. The data gathered from testing these twenty-three systems demonstrate that properly constructed and with appropriate chlorine tablets being used, the CTI 8 Chlorinator is capable of delivering constant and appropriate doses of chlorine in low to medium flow water systems.

4. THE USE OF CHLORINE

Chlorine has been chosen as the method to disinfect drinking water in the CTI 8 because it is efficient, widely available, and cost effective even in rural areas of developing countries. Chlorine has the advantage of leaving a residual in the distribution system that provides long-term protection from bacterial contamination. Chlorine is currently the only practical method of disinfection that will accomplish this, given the criteria of creating a low cost, widely available, and effective method of drinking water disinfection.

Because chlorine is a potentially toxic oxidant, it must be handled properly and the chlorinated water must be tested frequently to insure that the required dose is not exceeded.

5. CRITERIA FOR INSTALLATION / TECHNICAL INFORMATION

The CTI 8 chlorinator is intended for use in small to medium flow (2 to 20 gallons per minute/.13 to 1.3 liters per second), enclosed, gravity fed, potable water systems in rural areas. Precise details and measurements for constructing, installing, and maintaining the CTI 8 are found in Part II of this Manual.

A. TECHNICAL CRITERIA

- **First, it must be determined whether the candidate system is appropriate for the installation of a CTI8.** A checklist in Part II, #6 of this manual will aid in this determination.
- **Before a community installs a chlorinator, it is recommended that designated community representatives participate in a training workshop.** In Central America, the workshop is led by a Water Ministry technician familiar with the construction, installation, and maintenance of the CTI 8, chlorine residual monitoring, and recording of data. The purpose of the workshop is to familiarize the community with all necessary installation, operation, and maintenance procedures.
- **A single CTI 8 chlorinator is capable of treating a gravity-fed water system having a flow between 2 and 20 gallons per minute (gpm).** If the required

chlorine dose is very low, the maximum flow the CTI 8 could treat could be higher than 20 gpm.

- **The candidate water system should have an enclosed water source and an enclosed delivery system.** The chlorinator is designed for use in enclosed systems with a minimal amount of organic matter present. If an open source and / or open delivery system are used, the water may contain excessive amounts of impurities that may make treatment by simple chlorination ineffective.
  Open sources require pretreatment, such as a settling tank or sand filtration before passing through the chlorinator. CTI's partners from the Water Ministries in Nicaragua and Guatemala are currently testing the chlorinator in eight open systems that have been pre-filtered with rock, gravel, and sand; as of this writing, there are not sufficient data yet from these systems to draw conclusions as to the chlorinator's effectiveness in open systems.
- **The chlorinator must be located where there is zero water pressure (piezometric pressure) in the pipe.** Zero pressure will normally be found where the water empties into the holding tank from the delivery tube. If there is a water pressure larger than zero where the chlorinator is installed, water will rise in the tablet tube, submerging many chlorine tablets and the amount of chlorine in the water becomes difficult to control.
- **A device for measurement of chlorine residual should be available in each community that is installing a chlorinator.** The correct chlorine dosage is determined by measuring ***residual chlorine*** in the water. It is most effective to measure the chlorine residual at the chlorinator and at one or two points of use in the distribution system. A simple and inexpensive color comparator or colorimeter is a reliable method of measuring chlorine and is recommended for this purpose. In Central America it is required that each chlorinator installed is accompanied by a chlorine color comparator. In all twenty three cases where there is a chlorinator installed, the community water committee has been trained to take the chlorine samples and note the results in a notebook that reflects the data for all of the samples.
- **The chlorinator should be installed at a location accessible for maintenance and monitoring purposes.** CTI recommends the chlorinator be monitored daily during the first thirty days and at least weekly after that, especially during the first three months. Even though maintenance is minimal, experience has shown that this level of monitoring is important to insure optimum functioning.
- **Correct installation is a critical component of a properly functioning chlorinator.** A qualified water technician or person well trained in the installation of the apparatus should assist the community to insure that the CTI 8 is accurately installed**.** The main body of the chlorinator must be installed level, plumb, and be enclosed for protection. The protection enclosure needs to include access to the chlorinator for maintenance purposes. In field tests in Nicaragua and Guatemala block, brick, and poured concrete have been used to create a protective box, with a hinged and locked access panel made of galvanized steel, wood, or concrete.

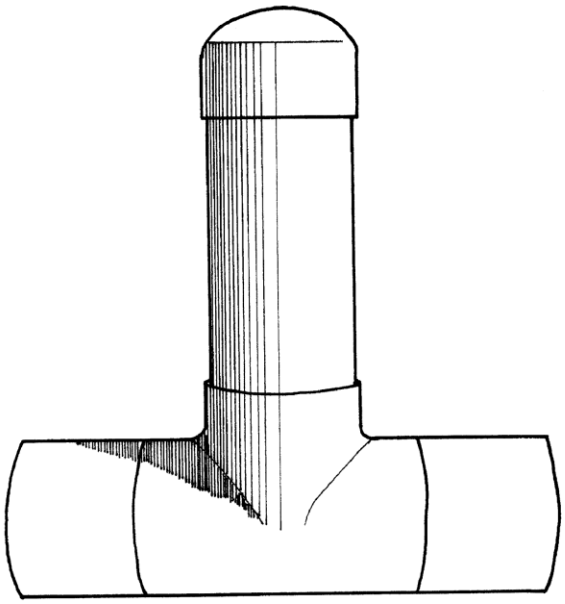
B. NON-TECHNICAL CRITERIA

- **The motivation of the water users in the maintenance of the CTI 8 is vital for a community to fully benefit from a chlorinator.** Often a Water Committee is either identified or formed at the community level and might include a coordinator, treasurer, technician or more. The CTI 8 chlorinator is a simple and reliable device yet it does require vigilance, training, and basic skills to operate properly. The device will work satisfactorily with proper attention, but may fail without adequate monitoring and maintenance.
- **Long term functioning of the chlorinator is enhanced if the community maintains a monetary fund for repairs and purchases.** In Nicaragua and Guatemala where chlorinators have been installed, community leaders collect a small monthly fee from each household to maintain a fund for purchasing chlorine tablets and for system maintenance. This fund makes available financing for the purchase of chlorine tablets and repair of the chlorinator as well as for upkeep of the entire water system. Based on costs obtained from twenty-three systems installed in Nicaragua, a CTI 8 chlorinator can be built and installed for less than $100.00 US. A typical Nicaraguan community of 200 people has operational costs between $5 and $10 US monthly. Factors such as temperature, level of contamination, and water flow will affect the quantity of chlorine needed and consequently affect the operating cost.
- **Weekly visits by trained supervisors during the first ninety days of operation are crucial.** Three years of experience in chlorinator installation and start up has led researchers to the conclusion that supervision during the first three months is a critical time to assure maximum performance of the CTI 8. This supervision monitors chlorinator functioning and insures that the community fully understands the calibration of chlorine dosage, the maintenance procedures, and recording the residual chlorine results.

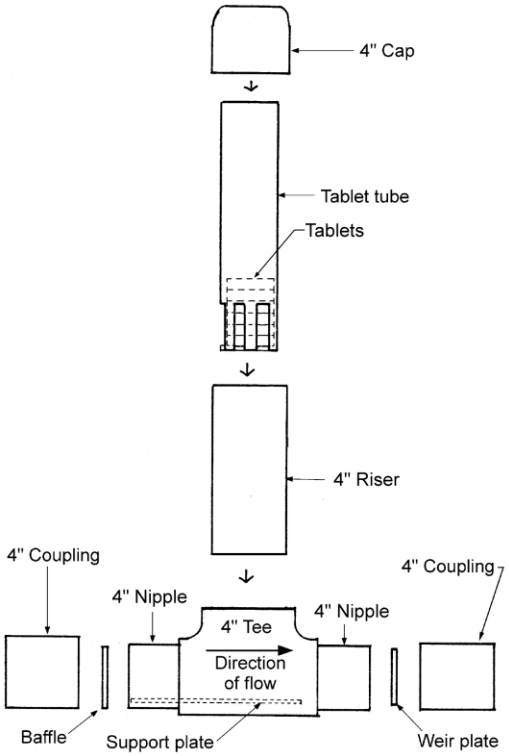
PART II: CONSTRUCTING AND OPERATING THE CHLORINATOR

1. THE CHLORINATOR

The chlorinator is shown in Figure 1. It is built entirely from schedule 40 PVC pipe, fittings, and ¼-inch (6 mm) sheet PVC. The parts are easily constructed with simple tools and assembled with standard PVC cement and stainless-steel screws or PVC pegs. The body of the unit is a 4-inch (100 mm) PVC tee, with a 9-cm nipple and coupling on each end. A 4-inch (100 mm) riser, 30-cm long, is fitted into the branch of the tee, and is closed on top by a cap.



CTI 8 Chlorinator
Fully Assembled



Exploded View

Figure 1

A tube containing the chlorine tablets is placed inside the riser. Inside the tee a ¼-inch (6 mm) plate supports the tablet tube. On the inlet end of the tee, between the nipple and the

coupling is a baffle that directs the water flow. At the outlet end is a weir plate that regulates the depth of flow through the chlorinator.
The support plate, inlet baffle, and weir plate are shown in Figure 2. These, and all other flat parts, are cut from ¼" (6 mm) sheet PVC.

Dimensions for constructing the parts are shown on the included figures. To simplify the fabrication of the chlorinator, full-size templates for most of the flat parts are included at the back of this manual.

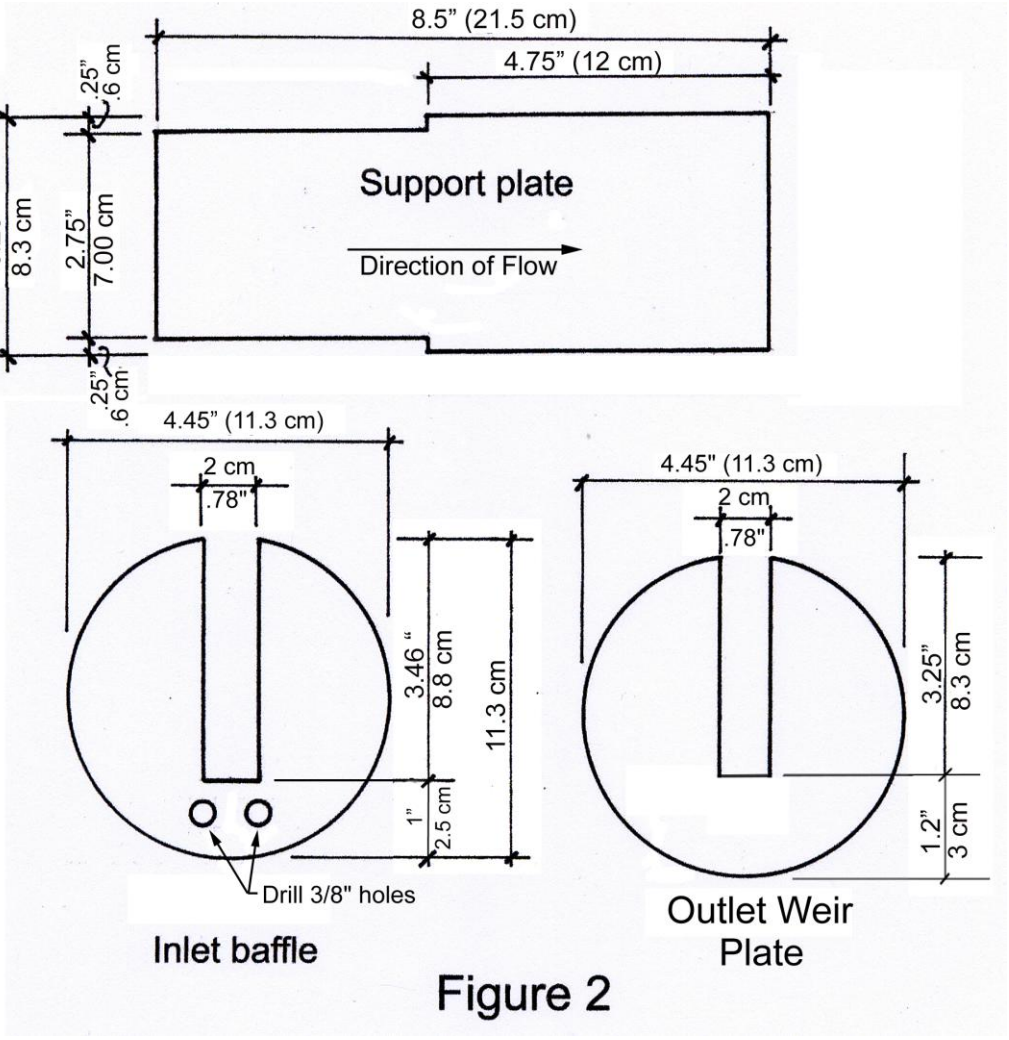


Figure 2

The tablet tube, shown in Figure 3, consists of a 3-inch (75 mm) pipe section that is slotted at the lower end. A circular plate is cemented to the bottom and secured with stainless steel sheet metal screws. Chlorine tablets are stacked in the tube before it is placed in the riser. The CTI 8 has been successfully tested with two types of chlorine tablets, calcium hypochlorite and trichloro-s-triazinetrione. Both contain approximately 70% available chlorine and are intended for use in potable water. Each tablet is approximately 2 ½ inches (6.35 cm) in diameter and weighs approximately 140 grams.

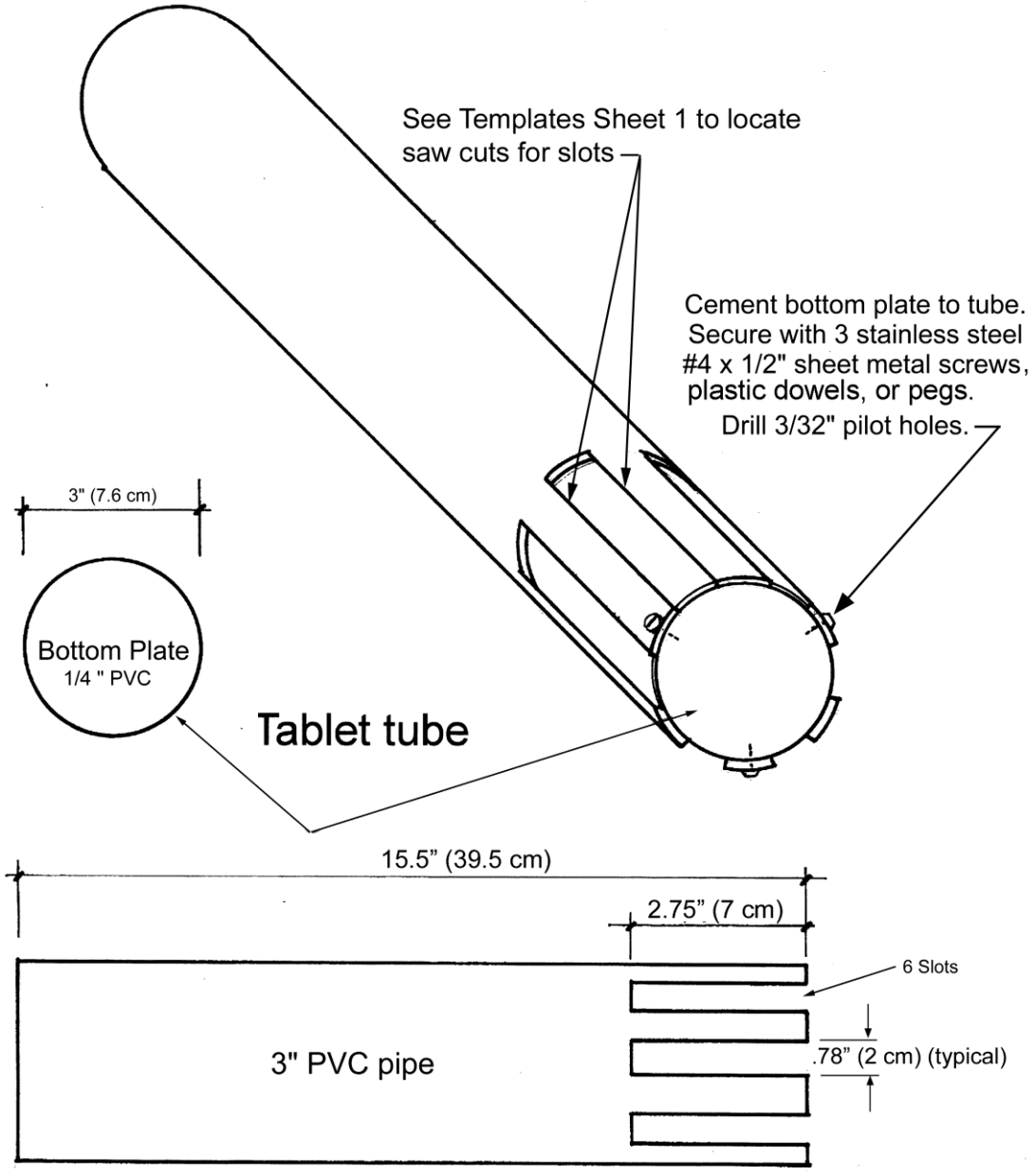


Figure 3

2. Installation

The chlorinator should be assembled as shown in Figure 4. For ease of maintenance and part replacement the tee, nipples, couplings, riser, cap, baffle and weir should not be cemented together unless necessary because of excess leakage or other operational problems. The best location for the chlorinator is on the inlet to a reservoir. The reservoir will provide a buffer for chlorine dose variations and also will provide contact time for the chlorine to work. The unit should be installed with the tee level and the riser vertical.

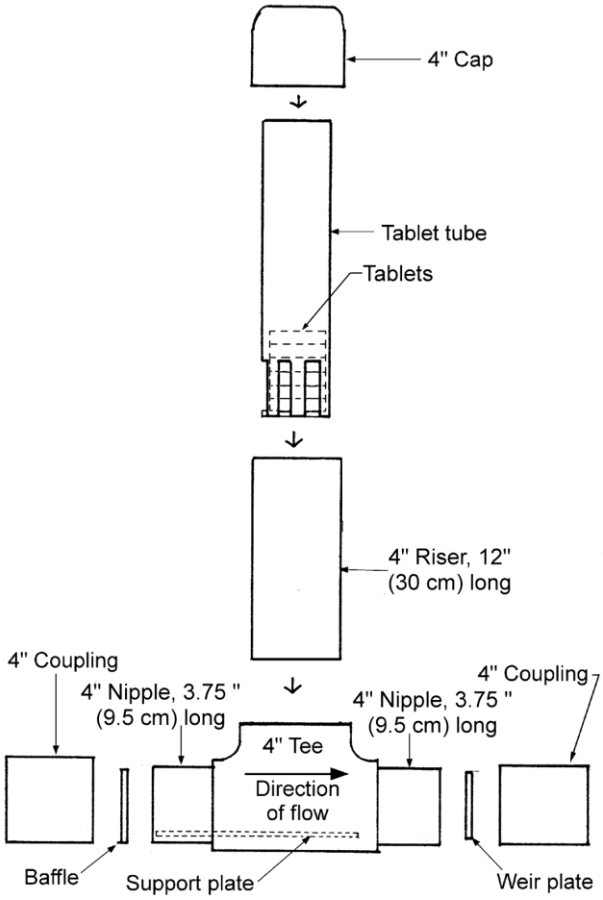


Figure 4
Exploded View

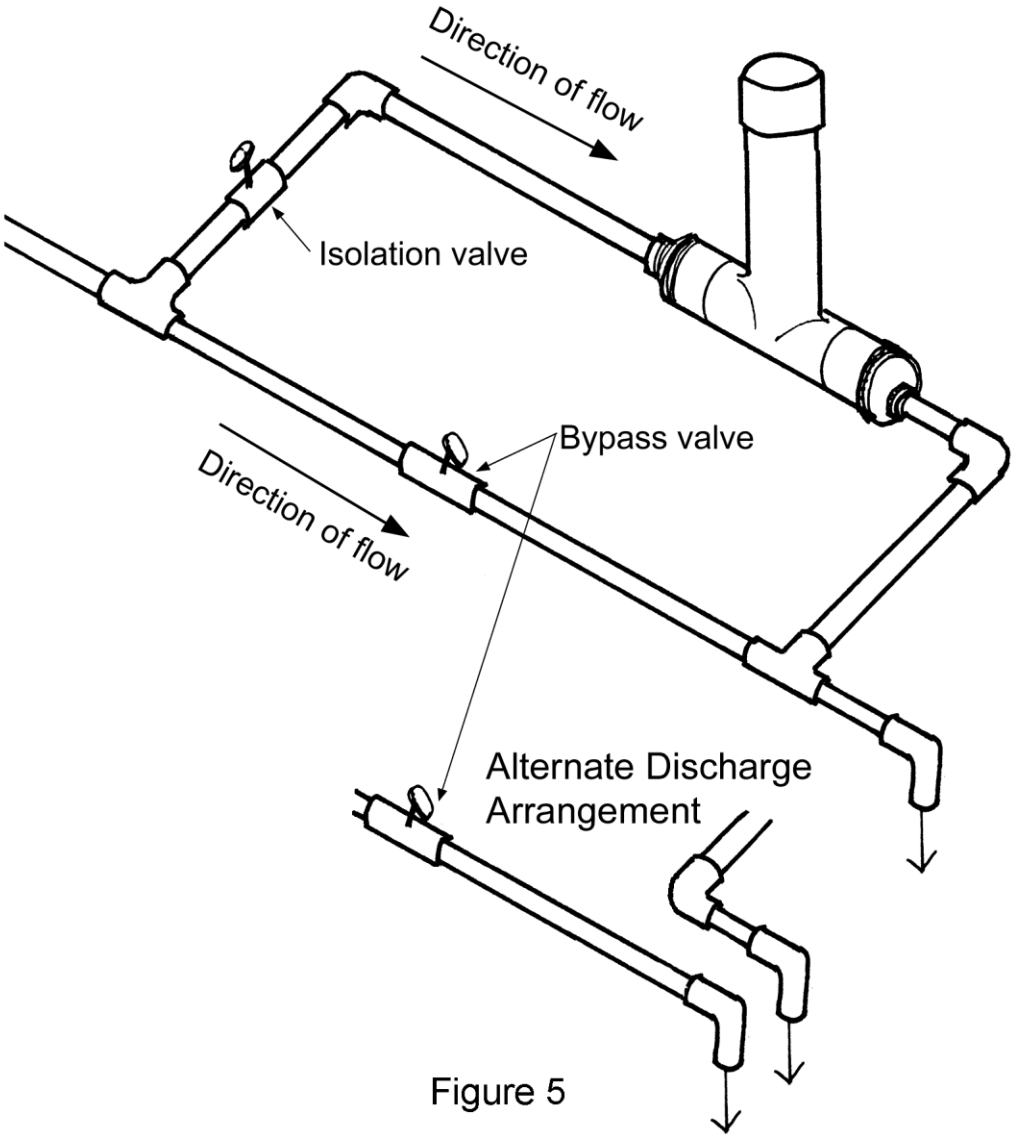


Figure 5

It should be installed as shown in Figure 5, so that a portion of the flow can bypass the chlorinator. A valve should be installed on the bypass pipe and another valve on the pipe to the chlorinator.

If the influent flow is much greater than the needs of the community, it may be advisable to install another valve upstream of the assembly shown in Figure 5 that may be adjusted to restrict the flow to the reservoir. The valves used should be of the type that will not restrict the flow very much, such as ball valves or gate valves.

During operation it will be necessary to take samples downstream of the chlorinator to check the chlorine residual. The sample must be drawn after the chlorinated flow has merged with the bypassed flow. A sample tap may be installed for this purpose.

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Two alternative piping arrangements are shown in Figure 5. The first, where the bypassed flow and the chlorinated flow are combined in a tee, is convenient for sampling the combined flow for chlorine testing. The other arrangement, where the two flows discharge separately, is applicable for tank-top installations and will permit a higher total flow. In this arrangement the discharge pipes should be close together to allow a sample to be taken from both simultaneously with a single container.

3. Operation

In operation, the water flows by gravity through the chlorinator, entering through the inlet baffle and exiting through the weir plate. The baffle directs most of the flow toward the center of the unit and directs a small portion of the flow under the support plate. The portion of the flow above the plate encounters the chlorine tablets in the tablet tube. The weir plate controls the level of water in the unit. The higher the flow, the higher the water level and the more tablet surface is exposed to the water. The dose should remain relatively constant regardless of the rate of flow. A cutaway view of the assembled chlorinator is shown in Figure 6.

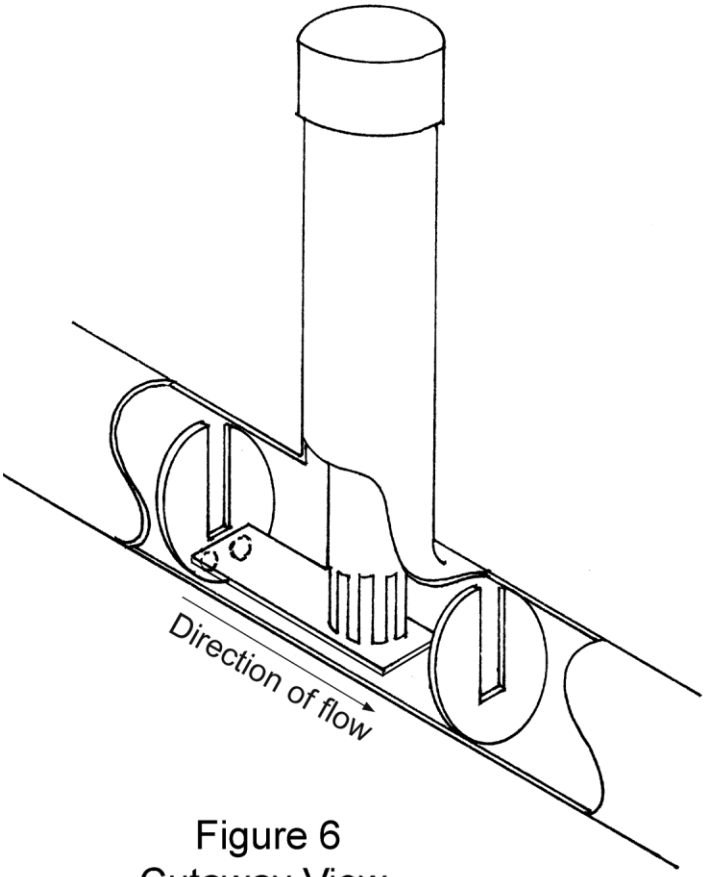


Figure 6
Cutaway View

The chlorine dose should be sufficient to satisfy the chlorine demand and provide a residual level in the distribution system. If the chlorinator adds more chlorine to the water than is needed for these purposes, the chlorine dose can be controlled in two ways:

1. **By the amount of water bypassing the chlorinator.** To increase or decrease the dose the bypass valve may be adjusted to divert more or less water through the chlorinator. During operation the bypass valve will normally be partially or completely closed for flow control and the isolation valve will be wide open.

2. **By the use of spacer discs.** Figure 7 is a diagram of a spacer disc. One or more discs may be placed in the tablet tube under the tablet stack to raise the tablets so that less tablet surface will be submerged. Caution: The spacer discs must not raise the tablets so much that they will be completely out of the water at minimum flow. Normally only one spacer disc may be used at a flow of 2 gpm (.13 liters/sec), but at higher flows more than one may be used.

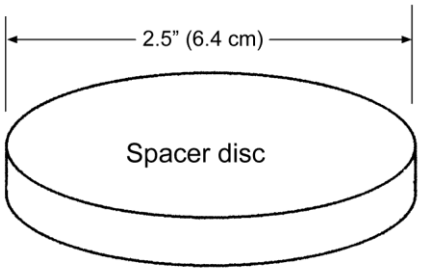


Figure 7

4. Maintenance

The chlorinator must be checked periodically to make sure that the tablets are not hanging up in the tube and to add new tablets as needed. The rate of tablet usage will vary according to flow rate and the chlorine demand of the water. For estimating purposes the following may be used: If total flow is 5 gpm (.32 liters/sec) and the chlorine dose is 1 mg/l, approximately two 140-gram tablets will be used each week.

When the tube is replaced after maintenance it should be turned to present a new face to the flow.

During use the chlorinator may accumulate deposits from the water or the tablets, therefore it should be cleaned periodically by closing the isolation valve and disassembling the chlorinator as necessary for cleaning.

5. Tools and Materials

To construct one CTI 8 chlorinator complete, the following are required:

Materials:

Item	Quantity
PVC Tee, 4"x 4" (100 x 100 mm), Schedule 40	1
PVC Pipe, 4" (100 mm), Schedule 40	21" (54 cm)
PVC couplings, 4" (100 mm), Schedule 40	2
PVC cap, 4" (100 mm), Schedule 40	1
PVC Pipe, 3" (75 mm), Schedule 40	17 (43 cm)"
Sheet PVC, ¼" (6 mm)	1.3 sq.ft. (.12 sq. m)
PVC cement	Small container
Sheet metal screws, #4 x ½", stainless steel	11

Tools:

Handsaw or equivalent
Coping saw, saber saw, or equivalent
Wood rasp or coarse file
Sandpaper
Drill
Drill bits 3/8" & 3/32"
Wood chisel
Screwdriver
Spirit level (for installation)

6. Installation Check List

The following check list may be used to determine whether a water system is suitable for the installation of a CTI 8 chlorinator.

- **Type of supply:** Gravity; i.e. the water flows to the reservoir by gravity, rather than delivered by pump, under pressure.
- **Water quality:** Clear, not cloudy. Cloudy water may need to be filtered before chlorination for the chlorine to be effective. As a general rule, water should be filtered before being chlorinated if the turbidity is greater than 10 units or the suspended solids concentration is higher than 10 mg/l.
- **Water flow:** The flow through the chlorinator needs to be between 2 and 10 gpm (.13 and .63 liters/sec). For an average ground water supply the maximum flow that one chlorinator can treat (including bypassed flow) is about 20 gpm (about 1.3 liters/sec).

- **Reservoir:** The tank at which the chlorinator is to be installed should have the following characteristics:
    - The influent pipe (where the chlorinator will be installed) should enter the tank above the high water level.
    - A hatch for maintenance is needed.
    - A drain for cleaning and draining should be located at the bottom of the tank.
    - The tank should be in an accessible location.
- **Water pressure:** The pressure in the influent pipe where the chlorinator is to be installed must be essentially zero. The pipe must be level or slope slightly downhill to the tank.
- **Operation and maintenance personnel:** Local people with responsibility for the system must be available to service the system and make the required tests.
- **Chlorine testing:** A simple chlorine test kit must be available locally, and responsible people trained in its use.

7. Notes from the Field

The following successful practices have been observed in Nicaragua and Guatemala.

- In a few installations the chlorinator has been installed on top of the tank. This required re-routing the influent pipe to run on top of the tank to the chlorinator. A hole was drilled through the tank top for the combined chlorinator effluent and bypass flow. Two of these installations may be seen on Photo Sheet 4. This arrangement seems to work extremely well.
- In some cases the pressure in the reservoir influent pipe was too low to raise the water to the top of the tank, so the chlorinator could not be located there. The chlorinator was instead installed inside the tank, below or near an access opening for servicing. When this is done, it is absolutely necessary that a tank overflow pipe be located below the level of the chlorinator to preclude the possibility of the chlorinator being submerged. The overflow pipe should be larger in diameter than the influent pipe and must be checked routinely to ensure that it has not become blocked.
- In one installation the operator needed to raise the tablet stack, but didn't have a plastic spacer disc on hand. He placed a small stone under the tablets instead. As a stopgap measure it served the purpose.
- Before a chlorinator is installed in any community a training workshop is always held as mentioned in Part I-5-A. During these workshops, usually held in the community itself, many residents besides the water committee often attend. All attendees are given an opportunity for some "hands-on" familiarization through practice disassembly and assembly of the chlorinator. This has been shown to aid in community acceptance of chlorination, and gives the entire community a sense of ownership in the device.

- In some installations small PVC pegs have been used to assemble the chlorinator in place of the stainless-steel screws shown on the drawings. The pegs are made in the field from scrap PVC and are cemented in place.
- Setting the chlorinator in sand has proven useful for leveling the chlorinator.

8. Acknowledgments

The initial development of the CTI 8 chlorinator was done at the treatment plant of the St. Paul Regional Water Utility. Thanks is due to the General Manager and his staff who recognized the potential usefulness of this device and provided plant space and staff time for the project. Special thanks is due to the treatment plant and laboratory personnel that set up the test site, assisted with the monitoring and testing, and provided useful insights into the design of the unit.

The field-testing was done in rural communities near Matagalpa, Nicaragua. Employees of the Operation and Maintenance Unit (UNOM) of the Matagalpa office of the Water Ministry (ENACAL) constructed the chlorinators. UNOM technicians selected the test communities and provided direction, technical support, and training in operational procedures. The Health Ministry (MINSA) established monitoring parameters and generously provided chlorine monitoring equipment and supplies and for the field test. The successful outcome of the field test is largely due to the cooperative efforts of these people. The enthusiastic participation of Ivan Lira of UNOM and Sergio Romero of MINSA has been crucial to the success of the field test.

Sue Britt, CTI volunteer, did the drawings for most of the figures in the manual.

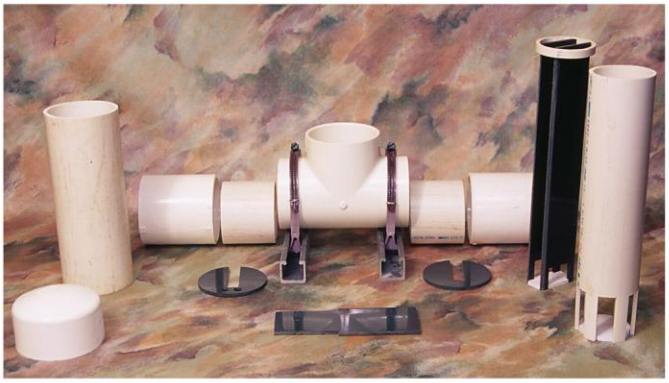
Teresa Yamana, while an engineering student at the Massachusetts Institute of Technology, contributed considerable time and effort to the chlorinator project both in Nicaragua and at the Institute. Her contributions are much appreciated.

Circles Robinson edited the Spanish translation of the manual.

9. Photos

Photo Sheet 1

The CTI 8 Chlorinator, fully assembled



The CTI 8 Chlorinator disassembled

Fabricating the CTI 8

Assembling the chlorinators and appurtenant fittings

Photos by Charles Taflin

Photo Sheet 2

Field installation

First test site:
Chilamate, Nicaragua

Building a brick housing
for the CTI 8 chlorinator
and control valves

The chlorinator in
the completed housing

Photos by Charles Taflin

Photo Sheet 3

Tank-top installation with alternate (2-pipe) discharge arrangement (See Figure 6)

Photo by Jenni Amundson

Washing the chlorinator parts

Photo by Teresa Yamana

Test site: Jucuapa, Nicaragua
Choosing a location for the chlorinator

Photo by Fred Jacob

Photo Sheet 4

Chlorinator demonstration: Limares, Guatemala

Tank-top chlorinator installation: Limares, Guatemala

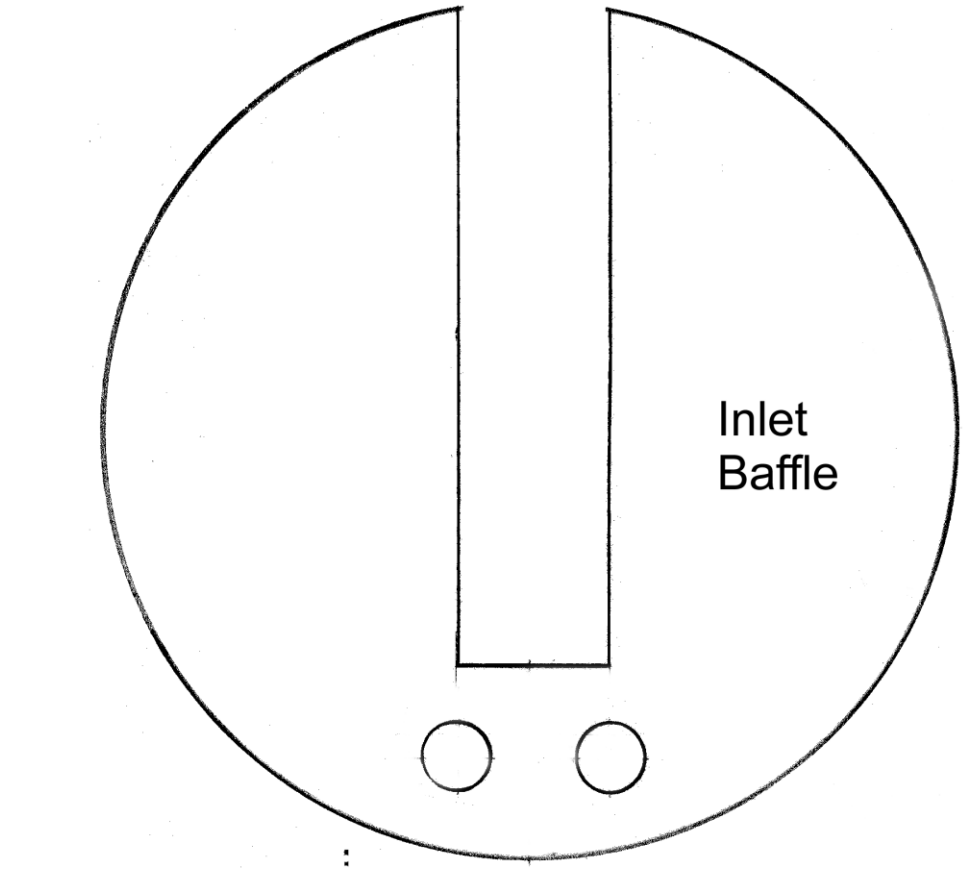
Photos by Charles Taflin

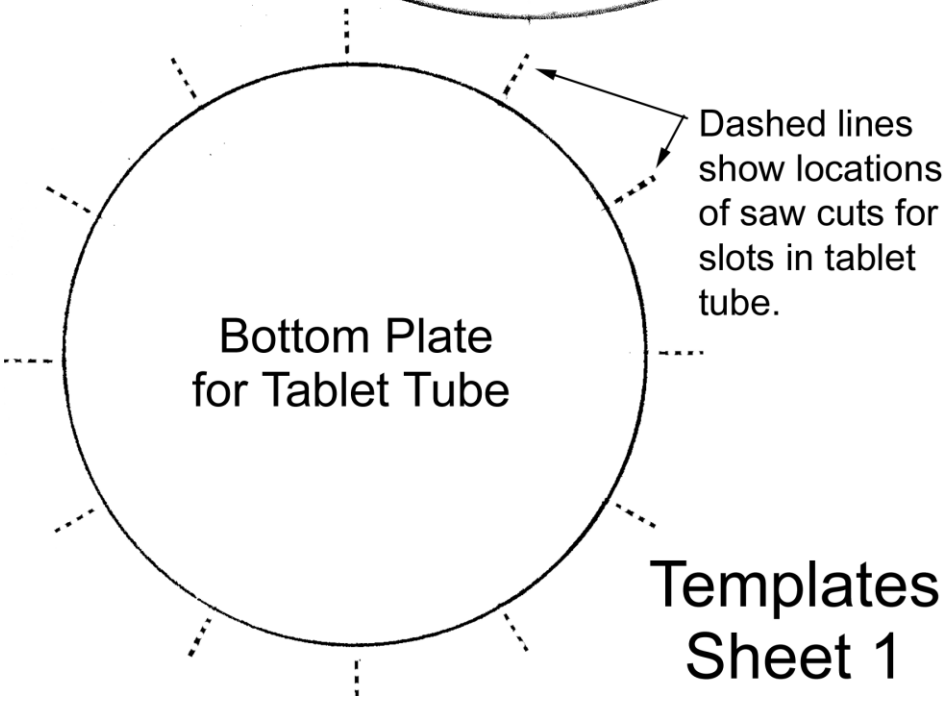
Tank inlet pipe re-routed to top of tank, Juvieroto, Nicaragua

Tank-top installation: Juvieroto, Nicaragua

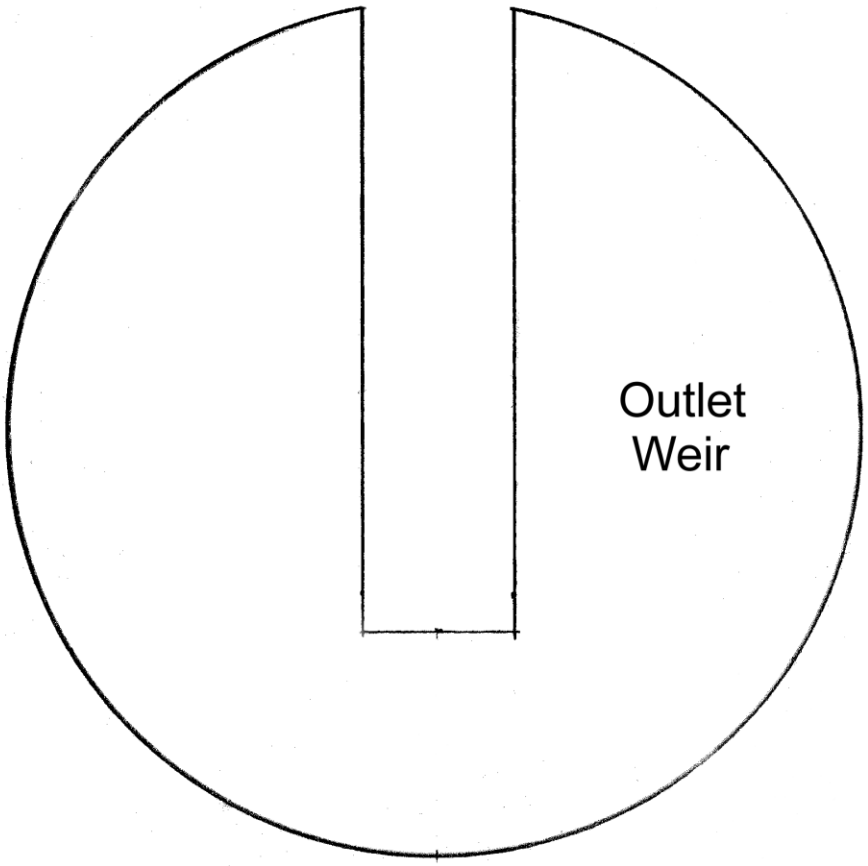
Photos by Harry Jebens

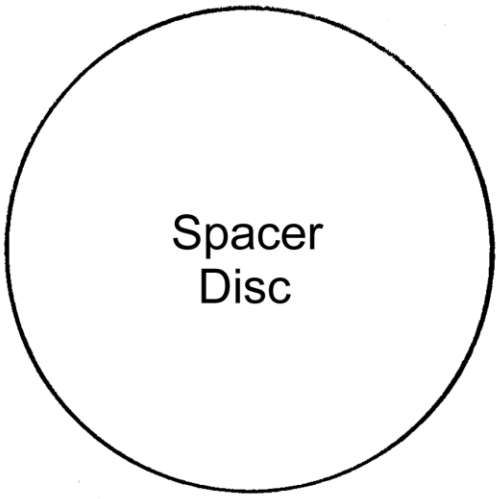
10. Templates



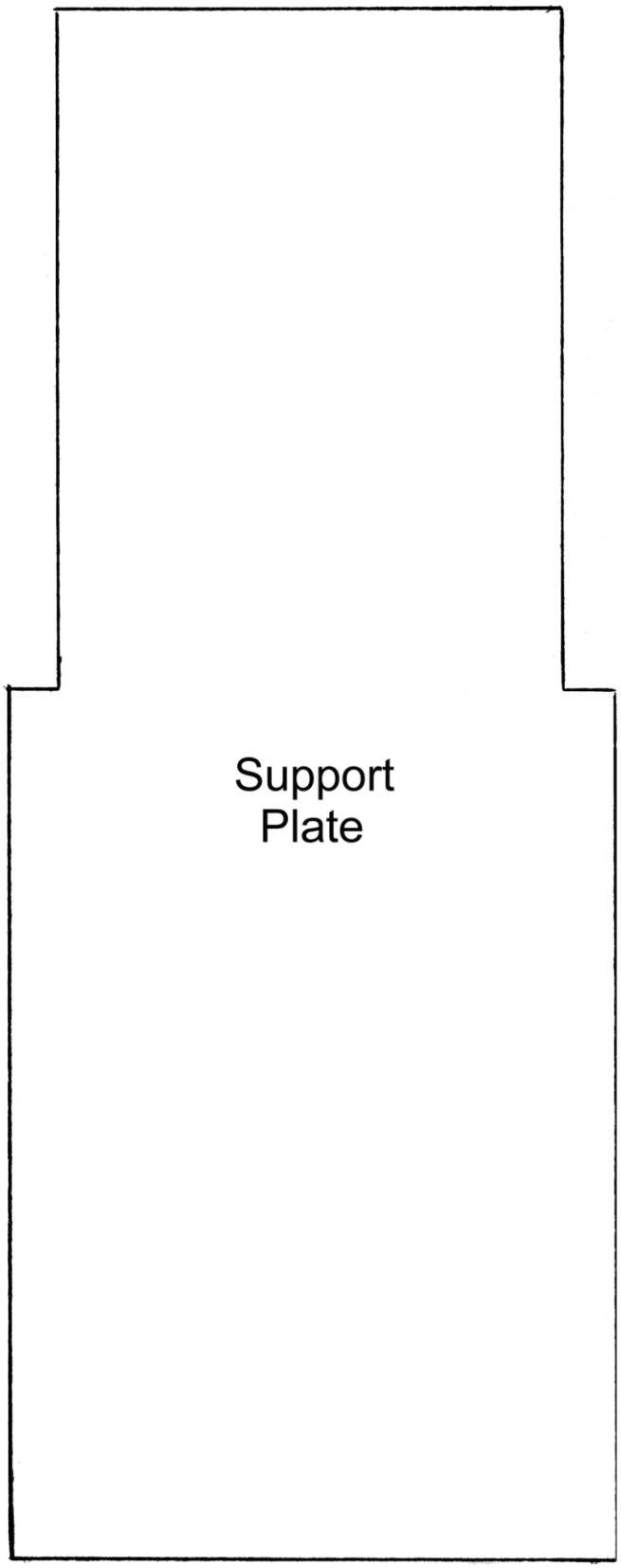


Templates
Sheet 1





Templates
Sheet 2



Templates
Sheet 3