

AN INSTRUMENT FOR CHLORINATING SMALL WATER SUPPLIES

BY
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A Thesis Submitted in Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

in

Sanitary Engineering

Engt

Approved:

Head of Department

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Virginia Polytechnic Institute

1950

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I INTRODUCTION

"And the men of the city said unto Elisha, Behold, I pray thee, the situation of this city is pleasant, as my lord seeth; but the water is naught, and the ground barren.

And he said, Bring me a new cruse, and put salt therein. And they brought it to him.

And he went forth unto the spring of the waters, and cast the salt in there, and said, Thus saith the Lord, I have healed these waters; there shall not be from thence any more death or barren land.

So the waters were healed unto this day, according to the saying of Elisha which he spake."

II Kings 2: 19 - 22

From antiquity to date man has been aware of the dangers of polluted water and has had some knowledge of effective methods of purification. References to filtration, exposure to sunlight, boiling and the use of coagulants to effect sterilization may be found in literature which probably dates back as far as 2000 B.C.

In spite of such knowledge, mankind through the ages has often been a victim of his own pollution. The epidemics of the middle ages and the rising incidence of typhoid fever and dysentery which accompanied the early growth of American cities offer verification of the correlation between disease and increasing contamination of water supplies.

The engineering profession, however, may take pride in the development and expansion of water works for the purification of public water supplies. On the basis of tonnage, the production of potable water, today, is America's leading industry. The purification of the water supplied the public has resulted in a marked reduction in the extent of water-borne diseases and anyone may use water from a public supply with great confidence. In addition to the high quality of public water supplies, the present low cost of the commodity is also note worthy.

Unfortunately, however, there are today millions of persons who do not enjoy the advantage of a public water supply of a city or town. These suburban and rural residents are often exposed to health hazards for which there is at present no economical and convenient remedy. Local health officials generally will testify to the inadequacy of many rural water supplies as far as safety is concerned. In rare instances some form of sterilization may be practical, but usually it is at best a makeshift.

True, there is commercially available equipment for chlorinating the small pressure water systems that are widely used in rural areas, but the cost of such equipment may run from two to four times as much as the cost of an entire water supply system. Consequently, it is beyond the means of the average property owner. The cost of this equipment has been verified by the attached quotations (Figs. 1 and 2) which were submitted recently by two of the leading manufacturers of such equipment.

In recognition of the need for protection of small private water supplies at moderate cost, the author has undertaken the development of an inexpensive device for the introduction of a sterilizing agent to the ordinary small pressure system found in rural and suburban homes as the object of this thesis. There is submitted with this thesis a working model of such an instrument, developed by the author. It is believed that this instrument is satisfactory for the purpose for which it was designed.

Current Quotations.

Mr. R. E. L. Gildea
Thornton Hall
University of Virginia
Charlottesville, Virginia

Dear Mr. Gildea:

We are pleased to acknowledge receipt of your sketch showing the layout of your existing water supply system, together with the engineering data sheet.

We would recommend the installation of [REDACTED] hypochlorinator equipped with auxiliary back-pressure valve for applying hypochlorite solution into the pump suction main at a point where there is a suction lift of five feet. It will not be necessary to have a separate water supply line to the hypochlorinator if the hypochlorite solution is applied against a negative head.

We can furnish you the following for the sum of THREE HUNDRED AND SIXTY-SIX DOLLARS (\$366.00) fob Newark, New Jersey, with full freight allowed to nearest shipping point and including supervision of the installation by a factory-trained engineer:

- One (1) [REDACTED] hypochlorinator
- One (1) Junior chlorine tester
- Four (4) gallons hypochlorite solution
- One (1) 20-gallon capacity crock

Our quotation is subject to the terms and conditions printed below.

We can make shipment within ten days after receipt of your formal purchase order. The attached Technical Publication [REDACTED] illustrates and describes the hypochlorinator.

Thanking you for your inquiry and trusting that we may have the pleasure of serving you, we are

APR: rmm

September 11, 1948

Professor R. E. L. Gildea
Thornton Hall
University of Virginia
Charlottesville, Virginia

Dear Sir:

Acknowledgment is made of your data sheet of September 8.

I would suggest that one of our [redacted] feeders be placed at the pump to inject hypo solution on the discharge side of the pump and that the little 1/8 hp motor with our unit be cross connected with the switch to the motor on your water pump so that both will start and stop simultaneously.

This unit is for a constant rate of flow which you should obtain from your water pump, which pumps at the rate of 250 gph. The price of this unit complete with accessories is \$250 freight allowed to Charlottesville, Virginia. Shipment can be made from Richmond stock subject to prior sale.

The hook-up of the unit would be according to the [redacted] bulletin which you have.

The price does not include container for the hypo-chlorite solution, which can be a crock, or pickle or molasses barrel, but cannot be metal.

In the event you order this unit, I would be glad to stop by and check the installation for you on my next trip through Charlottesville.

Thanking you for your consideration and trusting that we may be able to serve you, I am

Yours very truly,

[redacted]

II EXISTING DEVICES FOR CHLORINATION

(A) Commercial Devices. Commercial devices for the introduction of a sterilizing agent into small water supply systems are essentially diaphragm pumps having non corrosive parts at all points where there is contact with the sterilizing agent.

These devices are classified according to the method of feed control and the type of drive as follows:

- (1) Automatic - Water
- (2) Manual - Water
- (3) Automatic - Electric
- (4) Manual - Electric
- (5) Manual - Belt drive (Electric engine)
(Gasoline)

When classified as automatic, the feed is proportional either to the quantity of water delivered into the system, the number of revolutions of the prime mover driving the water system pump or the time interval during which water is pumped into the system. Devices controlling the feed on the basis of quantity of water are usually activated by means of a standard water meter which is directly connected to the solution feeder. Where the control is maintained on the basis of the number of revolutions of the prime mover the solution feeder is directly connected by means of a belt or gearing to the prime mover. Units operating on the basis of time interval of pumping are usually independently driven by an auxiliary electric motor which is controlled by a parallel connection to the pressure switch activating the main pump motor.

When classified for manual operation, the device itself must be

adjusted to deliver the sterilizing agent at a fairly constant rate on the basis of the quantity of water being pumped passed the point of introduction of the sterilizing agent. If classified for water power operation, the pump diaphragm may be activated by a device similar to that of a standard water meter or may be driven by means of a piston powered by back pressure existing in the water supply system.

The electric drive classification implies that the feeder unit is powered independently by means of a fractional horse power motor.

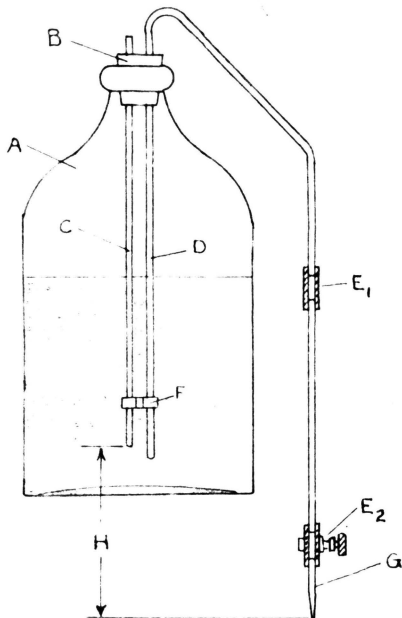
When classified as belt driven, the device is powered by means of a belt connection to the prime mover of the main pump.

(B) Emergency Devices. Many emergency devices have been developed for the introduction of a sterilizing agent, usually a hypochlorite, into a water supply system. These devices can often be constructed very economically of parts that are readily available. They all have certain defects however and due to the fact that they are difficult to control to the precision required and require constant maintenance and checking for stoppages, they cannot be considered for permanent installations.

Since such emergency devices illustrate some of the problems and possible solutions to the introduction of a sterilizing agent into a small water supply system and since they may properly be used by anyone having a dangerous water source and who yet finds the cost of a commercial unit prohibitive, several such devices will be illustrated

and described briefly.

Figs. 3, 4, and 5 are typical of such emergency devices.

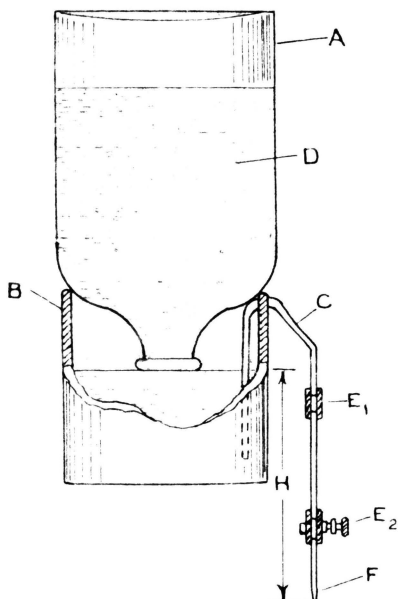


- A - Glass Carboy, 1 to 12 gallons
- B - 2 - hole rubber stopper
- C - Glass tube, lower end slightly above end of siphon tube
- D - Glass siphon tube
- E₁ - Rubber hose
- E₂ - Rubber hose and screw clamp
- F - Tube holder
- G - Glass tube orifice or medicine dropper
- H - Head on orifice

Note:

Rate of dosage may be varied by changing concentration of solution, by changing head "H", or by using different size orifice.

Fig. 3 - CARBOY SOLUTION FEEDER.

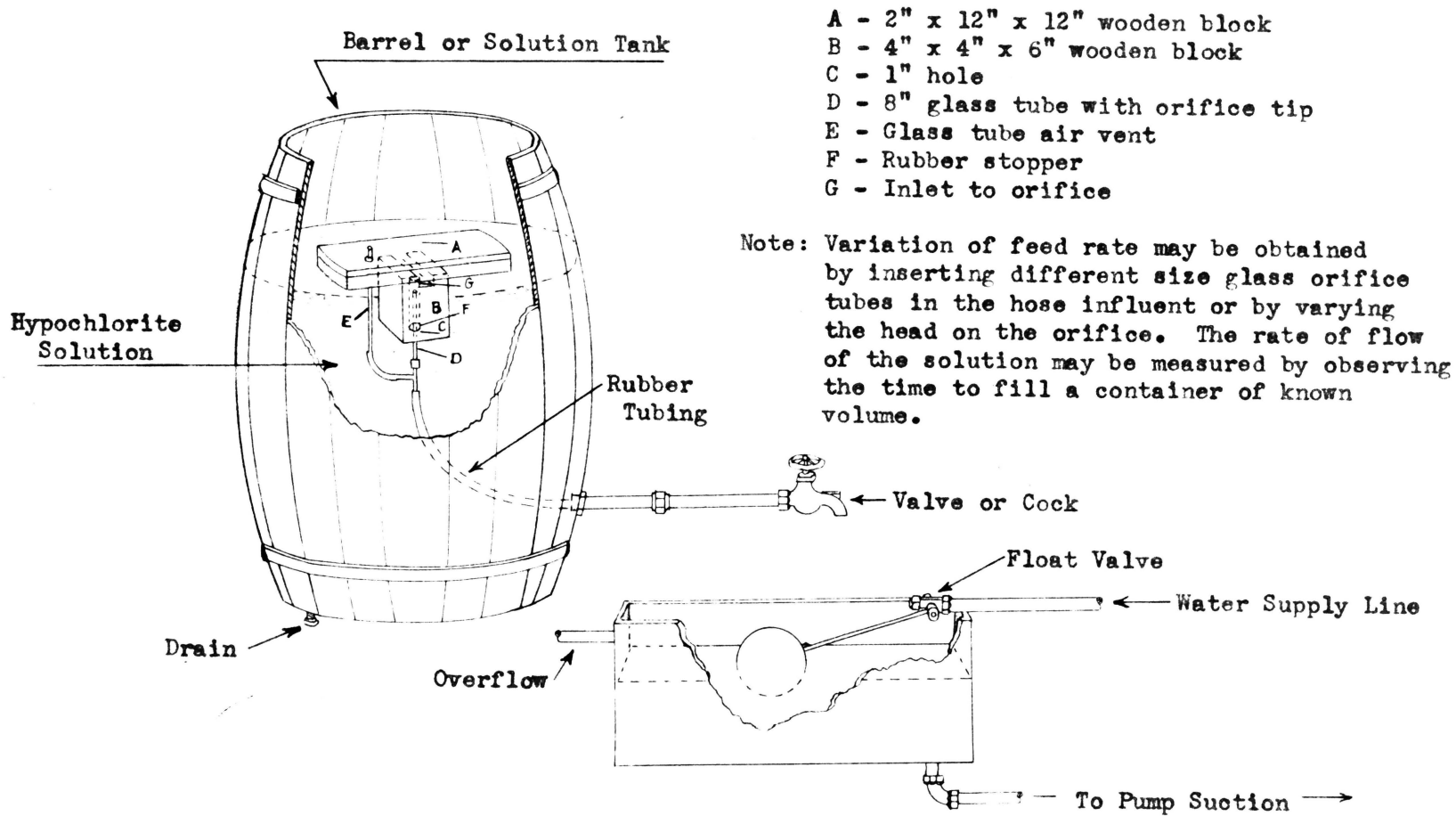


- A - Glass Carboy
- B - Crock
- C - Glass or rubber tube
- D - Hypochlorite solution
- E₁ - Rubber hose
- E₂ - Rubber hose and screw clamp
- F - Glass tube orifice or medicine dropper
- H - Head on orifice

Note:

Rate of dosage may be varied by changing concentration of solution, by changing head "H", or by using different size orifice. This apparatus will deliver solution at a constant rate.

Fig. 4 - INVERTED CARBOY SOLUTION FEEDER.



FLOATING ORIFICE FEEDER WITH PUMP SUCTION TANK.
Fig. 5.

III CHLORINE DEMAND RECOMMENDED DOSAGES AND CHLORINATOR CAPACITY

In approaching the problem of designing a pump to introduce a disinfecting agent into small water supplies, two questions immediately arise:

- (a) What disinfecting agent is to be used?
- (b) What is the required dosage of the chosen agent?

(A) Disinfecting Agent. In the author's opinion, the answer to the first question is relatively simple and is supplied by current literature on water sanitation practice. Since its introduction in this country in Jersey City in 1908, chlorine has proved to be the most economical and satisfactory sterilizing agent. It is readily obtainable in several forms ranging from the gaseous or "liquid" chlorine to the various hypochlorite solutions and hypochlorite powders. Since liquid hypochlorite solutions and hypochlorite powders are readily obtainable at the drug and grocery stores of most communities, these agents have been selected for the problem at hand. While either form is perfectly satisfactory for use with the apparatus presented, the author favors the use of liquid hypochlorites, since their use eliminates the necessity of preparing solutions and eliminates the problem of sludges which accompany the use of the powders. The trade names, Clorox, Purex, White Sail, BK, Rainbow, Zonite, etc. will be readily recognized and indicate that such liquid hypochlorites are available in any community.

(B) Required Dosage. The problem of ascertaining the required dosage is somewhat more difficult.

In order to destroy pathogenic and other bacteria by the use of chlorine and chlorine compounds, it is necessary that the organisms be exposed to adequate quantities of the disinfectant for a sufficient period of time. A further requirement is that the material be added uniformly to all portions of the water to be treated.

Chlorine is a very active chemical element which has a dual action. Namely, first, the reaction with and oxidation of organic matter, and, second, the disinfection and destruction of bacteria. Hence, it is necessary for sufficient chlorine to be added to react with the organic matter and still leave a residual to act as a disinfectant on the bacteria.

The reaction between chlorine and organic matter is very rapid initially, but gradually decreases. The rate of absorption being dependent upon the mineral and organic content, the pH, the temperature of the water and the chlorine concentration.

These ~~variable~~ do not admit of close control in the small system, hence the required dose must be predicated on tests for the amount of chlorine that has not been absorbed, that is, the amount which remains in the treated water as residual chlorine after a definite period of contact.

The amount of chlorine which reacts with the organic matter in water is known as the "chlorine demand" of the water. From this

definition, it may be seen that the chlorine demand represents the numerical difference between the dose of chlorine and the concentration of residual chlorine. For example, if a dose of one part per million gives a concentration of residual chlorine of 0.2 p.p.m. after a 10 minute reaction period, the 10 minute chlorine demand is 0.8 p.p.m. or the difference between 1.0 p.p.m. and 0.2 p.p.m.

Since the organic content and other elements vary, it is not practical to measure the chlorine demand directly although this may be done for any specific sample by laboratory test methods. Hence, the usual procedure is to add sufficient chlorine to give the desired concentration of residual chlorine as determined by the relatively simple orthotolidine test. (Directions for the orthotolidine test will be given as part of the operating procedure.) The standard procedure is to determine the residual chlorine concentration after a 10 minute reaction period.

The above principles may be illustrated by reference to the accompanying curves. Fig. 6.

CURVES SHOWING INFLUENCE OF THE CONTENT OF ORGANIC MATTER UPON THE RATE OF DISAPPEARANCE OF RESIDUAL CHLORINE.

Fig. 6

Residual Chlorine in p.p.m.

2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00

Reaction Time in Minutes

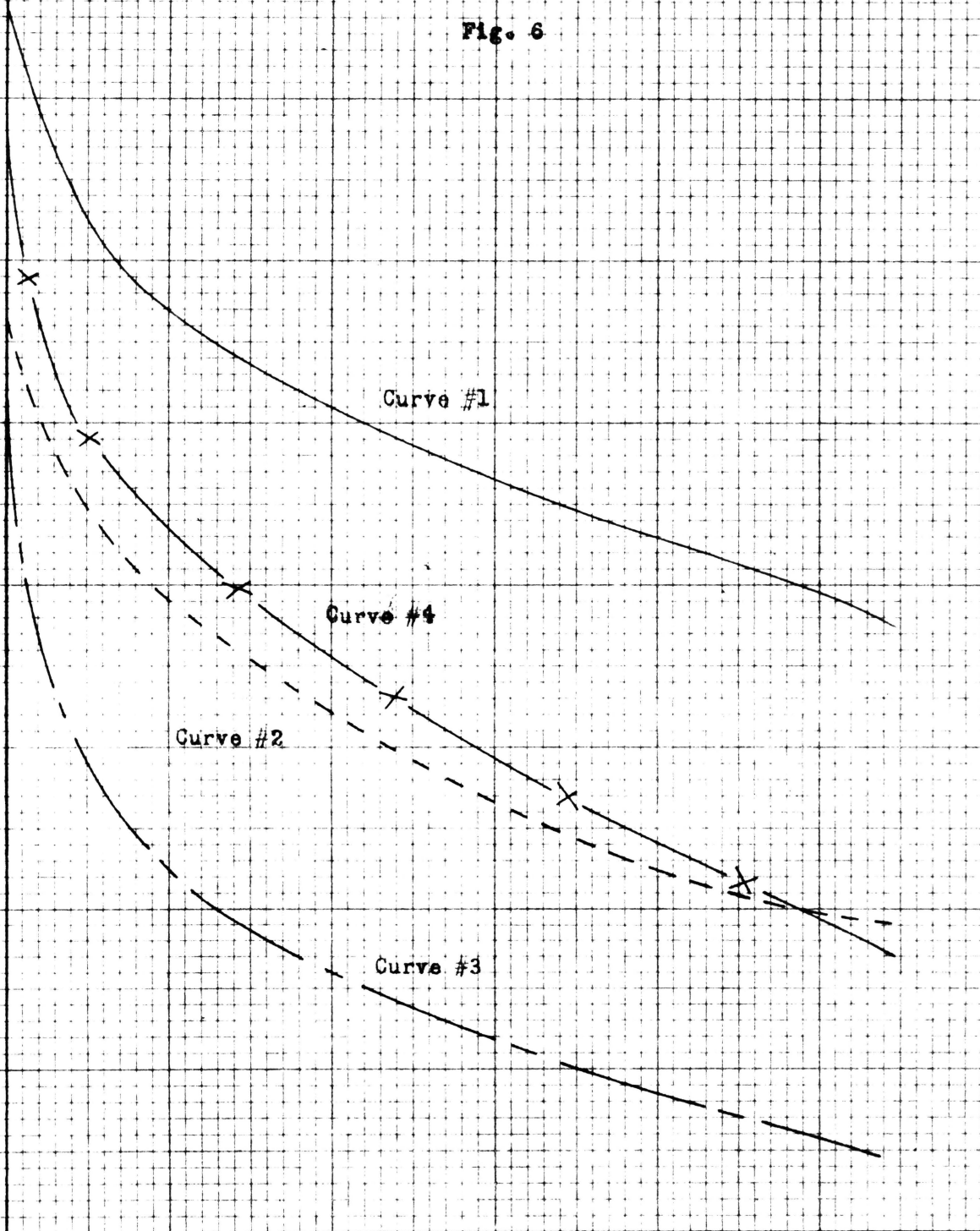
0 2 4 6 8 10

Curve #1

Curve #4

Curve #2

Curve #3



1918
50

The curves are based upon an assumed condition which makes it desirable that a water supply be chlorinated so as to produce a residual of 0.5 p.p.m. after a 10 minute reaction period.

Explanation of Curves. Curve No. 1 illustrates the results secured by a dose of 2.0 p.p.m. which produced a residual of 1.00 p.p.m. after the 10 minute reaction period. Here, the curve represents the effect of a higher than necessary dose, that is the dose was greater than the 10 minute demand plus the desired 0.5 p.p.m. residual.

Curve No. 2 shows the case where a dose of 1.5 p.p.m. when added to the same water produced a residual of 0.5 after the 10 minute reaction period. This represents the optimum condition since the dose was just equal to the demand of 1.0 p.p.m. plus the desired residual of 0.5 p.p.m.

Curve No. 3 represents a case where the same dose of 1.5 p.p.m. was added to a water having a higher organic content than in the previous illustrations. Here, the higher organic content leads to a more rapid decrease in the concentration of residual chlorine and it will be noted that only 0.15 p.p.m. of residual chlorine remained after the 10 minute reaction period rather than the required 0.5 p.p.m. Under such circumstances, the chlorine dose would have to be increased to approximately 2.0 p.p.m. to produce a residual of 0.5 p.p.m.

Curve No. 4 illustrates the conditions for the increased dose. From the "steepness" of this curve, it is evident that the higher chlorine demand is leading to a correspondingly more rapid disappearance of residual chlorine, but that in this case the dose was

sufficiently high to give a residual of 0.5 p.p.m. with a chlorine demand of 1.5 after a 10 minute reaction time.

Recommended Dose. On the basis of the above discussion and after a review of current literature the author finds current practice requires that all water supplies should be so dosed that a chlorine residual of from 0.1 to 0.2 p.p.m. be maintained at all times, and that if the source of supply is of doubtful quality or if emergency conditions obtain it is recommended that the residual be raised to 0.5 p.p.m.

Accordingly, it has been set as a specification requirement for the chlorinator to be designed that it be capable of dosing at controlled rates of from 0.1 p.p.m. to 5.0 p.p.m. This range should cover the extremes of operating conditions.

(C) Recommended Capacity of Chlorinator. Prior to the actual design of the pump to satisfy the requirements of this thesis problem, it is necessary to arrive at the chlorine concentrations to be handled by the pump and the rate of delivery of the pump that must be maintained to introduce a sufficient quantity of the chlorine solution to provide the desired chlorine residuals.

The small water supply systems for which this chlorinator is being designed normally have capacities of from 250 to 1000 gallons per hour, with most of the systems being of the smaller capacity.

To simplify the calculations involved, it will be assumed that the water to be treated is being pumped at the rate of 100 gallons per hour, and that the hypochlorite solution contains 1 percent of available

chlorine. Any required dosage may then be determined by a simple calculation as follows:

Case I

Required: The chlorinator delivery to provide a dose of 1 p.p.m.

Basic relation for calculation: 1 gallon of a 1 % chlorine solution will give a dose of 1.0 p.p.m. to 10,000 gallons of water. 1/100 gallon of 1% solution will give 1 p.p.m. to 100 gallons. Hence, 1/100 gallon of 1% solution must be delivered per hour.

128 ounces equals 1 gallon

Hence, 1.28 ounces of 1% solution must be delivered per hour to give a dose of 1 p.p.m.

Assuming a chlorine demand of 0.5 p.p.m. and a desired residual of 0.2 p.p.m. equals 0.7 p.p.m. dose.

(1.28 oz.) (0.7) equals .9896 oz. - say 1.0 oz. of a 1% solution must be delivered per hour to give the required dose.

We may say then that the chlorinator must be designed to deliver at approximately 1.0 ounce per hour per 100 gallons of water pumped.

Then for a 250 gallon per hour system which is the smallest usual commercial size, the chlorinator should be designed to discharge at a minimum rate of 2.5 ounces per hour of a solution containing 1% of available chlorine. The maximum rate requirement will be predicated upon the large 1000 gallon per hour system which would require a delivery of 10 ounces per hour.

Converting to milliliters which will be the unit used to demonstrate performance, 2.5 ounces per hour equals 75 milliliters per hour approximately, therefore:

Minimum discharge requirement equals 75 milliliters per hour.

Maximum discharge requirements equals 300 milliliters per hour.

These figures were adopted as criteria to control the design of the chlorinator.

Note (1): As is obvious, the calculations of the above example may be extended to cover any actual case of chlorine demand and delivery requirements merely by multiplying through by direct ratio conversion factors.

Note (2): To satisfy the previously set requirement of a dosing rate of 0.1 p.p.m. minimum, it is only necessary to work with a chlorine solution which has been diluted to a concentration of 1/10% of available chlorine

IV POSSIBLE TYPES OF PUMPS AND MATERIALS OF CONSTRUCTION

(A) Types of Pumps. Prior to starting the actual construction of the chlorinator, the author made a study of the types of pumps that might prove satisfactory for the problem at hand. As a result of this study it was decided to make a preliminary investigation of the following types:

(1) Diaphragm, (2) Plunger,

Rough working models were constructed of both types and as a result of preliminary work with these models, it was decided to restrict the investigation to the diaphragm type.

The diaphragm type was selected because it appeared to offer the following advantages:

1. Simplicity and relatively few moving parts.
2. Ruggedness.
3. Possibility of incorporating into the design inexpensive and commercially available parts and sub-assemblies.
4. Ease of servicing.
5. Long life of component part.

(B) Types of Materials. A preliminary investigation was also made of the possible types of materials that might be used in the construction of the chlorinator.

Because of the fact that all parts in contact with the chlorine solutions to be handled would be subject to corrosive action, the possible materials for such contact parts were:

1. Stainless steel
2. Plastic
3. Rubber

After some investigation, the author decided to use a plastic (lucite) for the pump head, valve casings and water line injector. Rubber was selected for valves, gaskets, valve retainers and connecting lines. Rubber impregnated cloth for the diaphragm. Stainless steel for the diaphragm actuating rod and diaphragm connector and valve retaining pins.

The basis of selection was as follows;

1. Resistance to corrosion
2. Durability
3. Cost
4. Ease of machining or casting
5. Visibility of moving parts.

V DESCRIPTION OF DIAPHRAM PUMP AND ACCESSORIES

Since a working model is being submitted here-with, it is believed that it will be unnecessary to submit accompanying detailed working drawings. The author also wishes to point out that since the completion of the final model, it appears that some additional refinements may be possible at slight cost and that the over-all dimensions may be reduced to give a more compact unit. A further study is proposed to cover possible modifications of the basic unit and an extension of the unit to other uses.

It is hoped that the accompanying photographs, Figs. 7, 8, 9, 10, 11, 12, 13, in conjunction with the working model, will clearly portray the details of construction and the principles of operation of the chlorinator and the accessories.

It is also the belief of the author that since this chlorinator can and should be produced commercially that there should be no requirement that the working drawings be published.

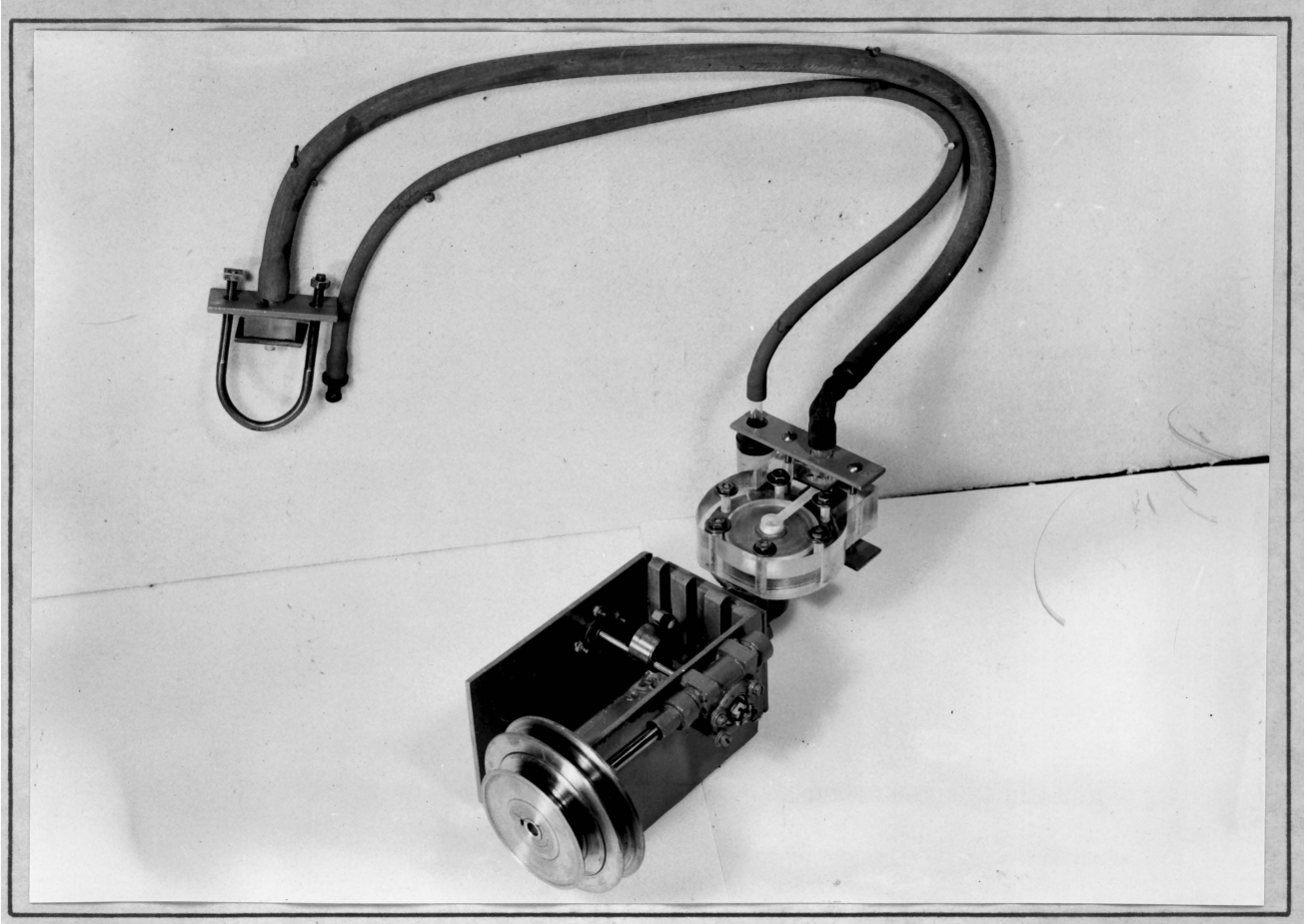


Fig. 7 THE WORKING MODEL

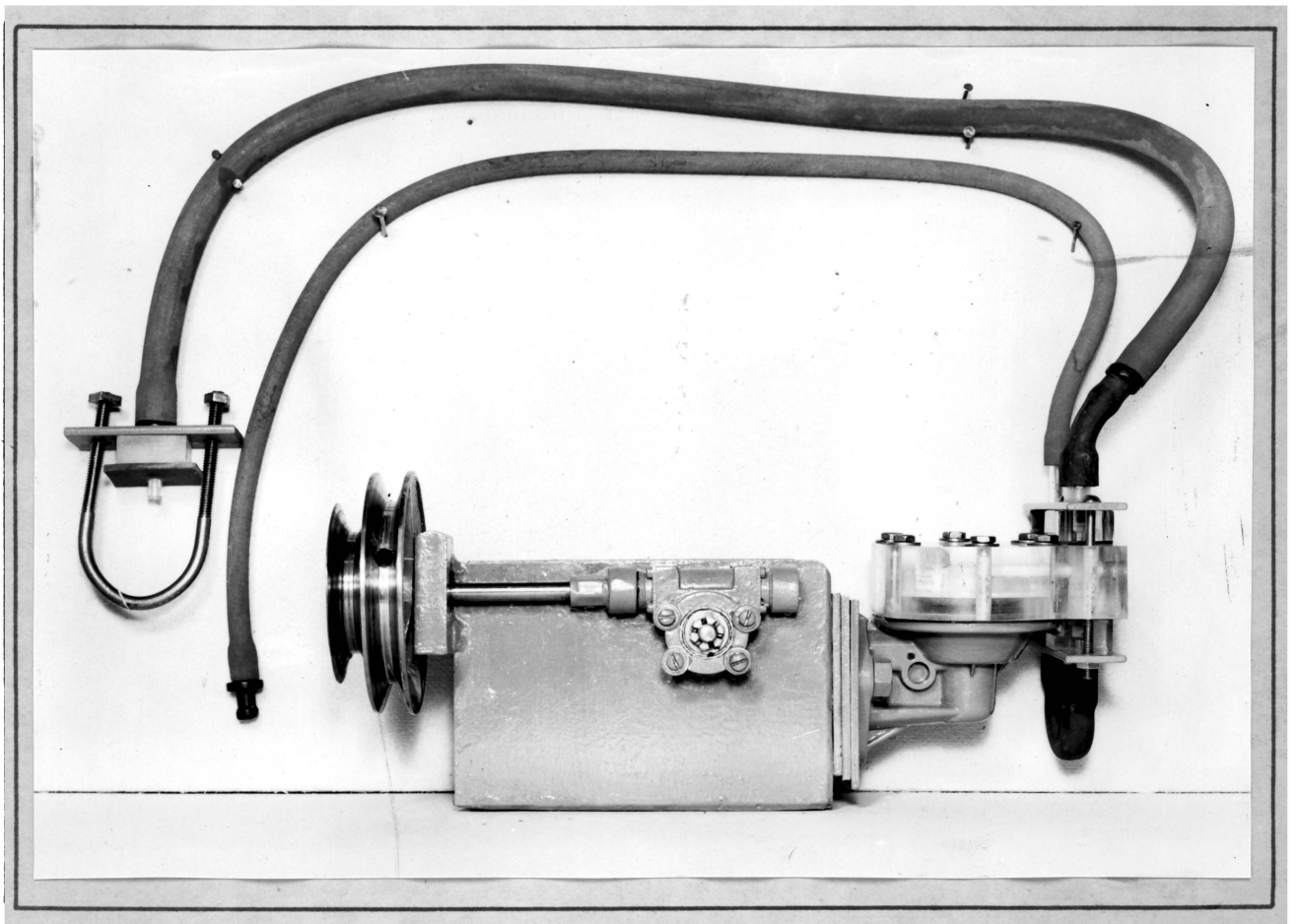


Fig. 8 ELEVATION VIEW (a)

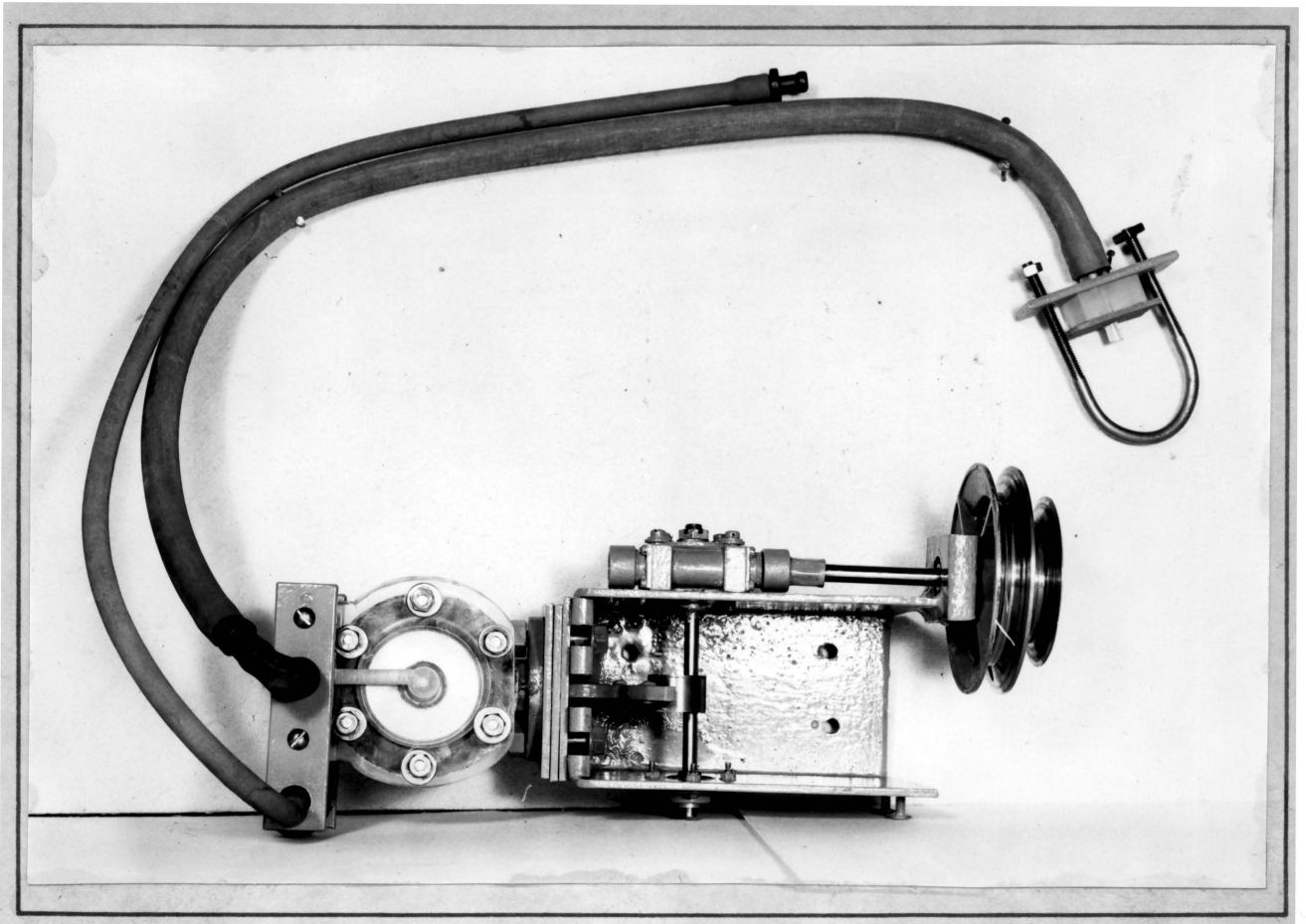


Fig. 9 TOP VIEW

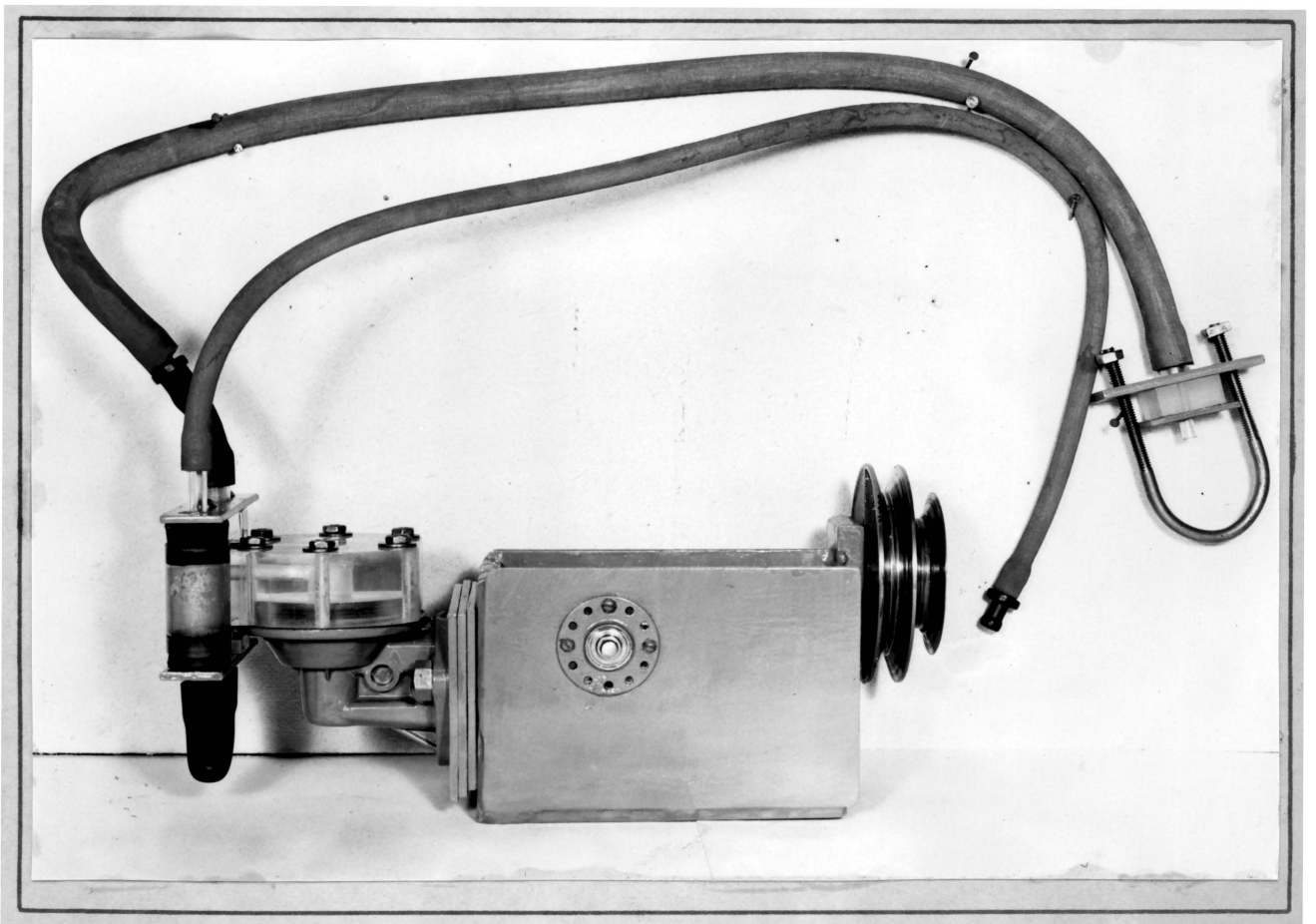


Fig. 10 ELEVATION VIEW (b)

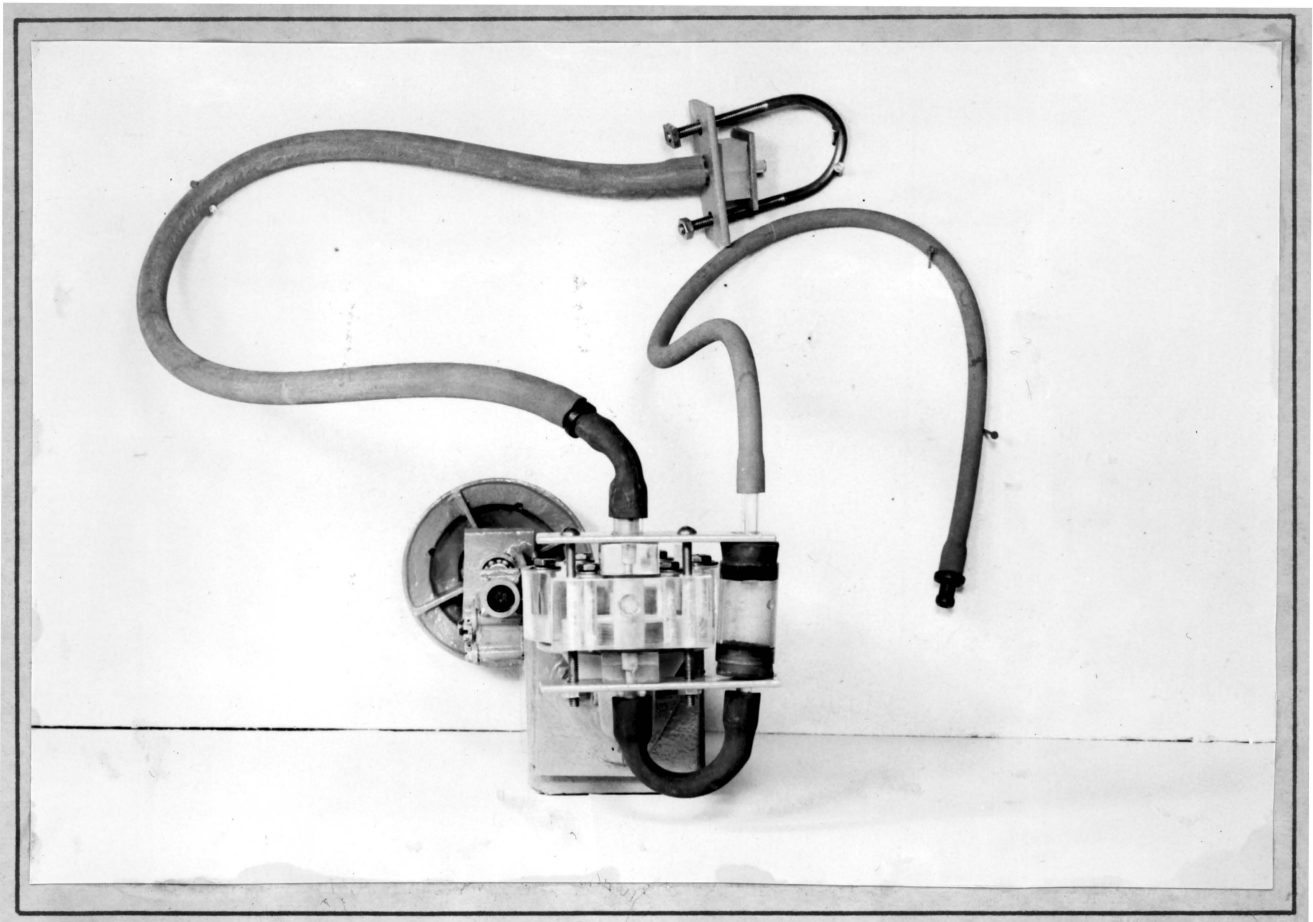


Fig. 11 END VIEW (a)

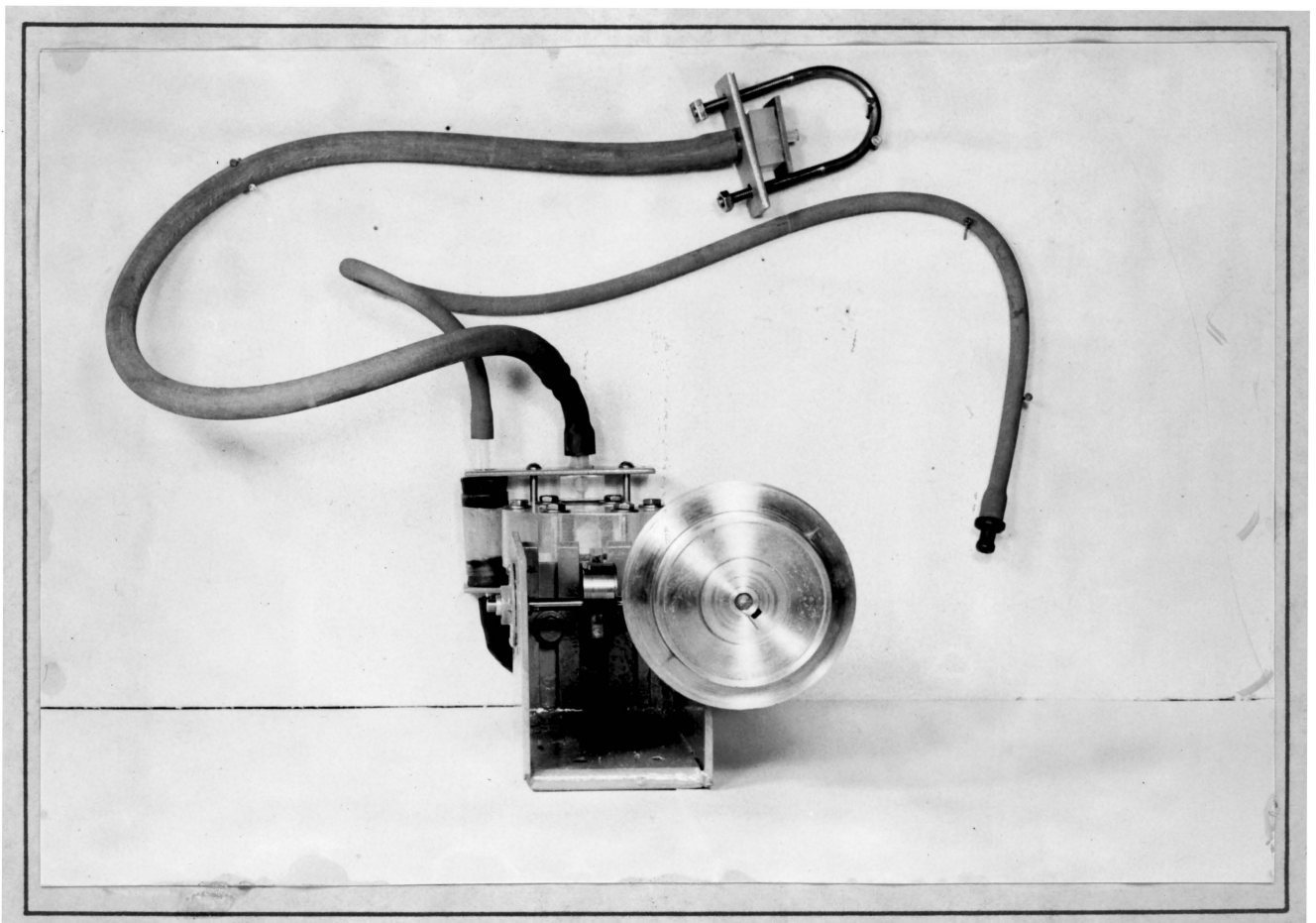


Fig. 12 END VIEW (b)

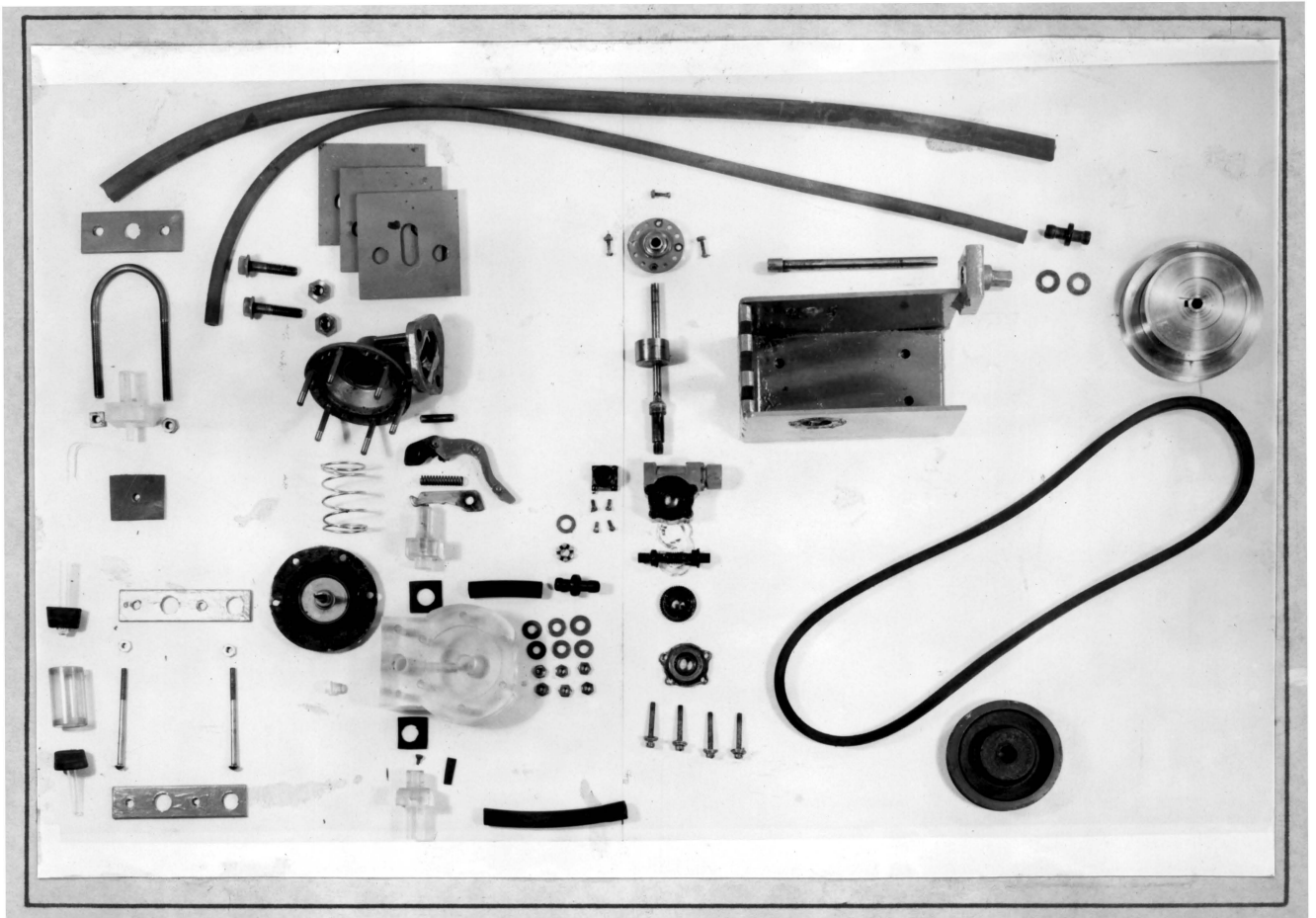


Fig. 13 COMPONENT PARTS OF WORKING MODEL

To clarify the photographic details, the following will describe the basic unit and accessories:

(1) Main Drive.

It is proposed to drive the chlorinator by a vee belt from a vee belt pulley bolted directly to the water pump drive pulley or fitted on the water pump shaft. In this way, the operation of the chlorinator will be entirely automatic and will be synchronized directly with the pump. Hence, the chlorine dose will be directly proportional to the amount of water pumped.

This method has a further advantage in that it accomplishes a 6 to 1 initial speed reduction which is the usual ratio of speed of pump motor (1725 RPM) to pump.

(2) Cam Shaft Reduction Gear.

The pulley driving the chlorinator drives a worm gear on the main drive shaft which in turn drives the cam shaft gear. The reduction gear system used accomplishes a 50 to 1 reduction so that the final actuating cam speed is only 5.6 R.P.M. approximately.

Note: Main drive and cam shaft bearings are standard ball bearings.

(3) Cam Throw.

The cam used is a one inch cam with a 1/4 inch offset which gives a throw of 1/2 inch. This throw is sufficient to cover the full range of travel of the diaphragm actuating lever.

(4) Chlorinator Body.

A standard automobile gasoline pump assembly was selected for the chlorinator body since this would provide a sub-assembly easily

procurable at low cost, and available as a repair or replacement part in any vicinity.

Note: The only modification to be made in this sub-assembly is to construct the diaphragm connecting rod and diaphragm clamping plates of stainless steel to provide ~~corrosion~~^{osion} resistance.

It is proposed that the diaphragm, connecting rod and clamping plates be furnished as a unit as a replacement or repair part.

(5) Chlorinator Head.

The chlorinator head has been fabricated from a plastic (Lucite) block. Plastic has been selected for this unit because of inherent corrosion resistance and economy. Although the head submitted with the working model has been machined from a solid block, the author has made a supplementary investigation of cast plastics and finds that the unit can be more economically produced by casting rather than machining. Hence, it is recommended that in the case of commercial production, the head be cast as a unit rather than machined.

It will be observed from the working model that the clear plastic head has the inherent advantage of making the moving parts visible at all times so that the operation of the chlorinator may be readily checked without the necessity of dismantling the assembly.

(6) Valve Casings and Valves.

The valve casings have also been fabricated of the plastic, "Lucite", by a machining process. The same comments as to casting to replace

machining and visibility apply to the valve bodies.

It will be noted that the valves have been designed as easily replaceable units and it is proposed that they be supplied as parts in an inexpensive repair and replacement kit.

Commercially available rubber poppet type tip valves have been selected because of economy, availability and demonstrated performance.

During the course of valve and casing design, it was found that the very small displacements of liquid and the small bore of the valve casings made it necessary to restrict the valve travel.

Consequently, a rubber valve retainer and a stainless steel retaining pin have been introduced in each valve casing. It will be noted that the retaining pin has been so positioned that the connecting rubber tubing will provide an effective seal against air or liquid leakage at the point of insertion of the retaining pin.

The valve bodies are seated on rubber gaskets and are clamped to provide a tight seal by means of two compression plates and two retaining bolts and nuts.

(7) Accessories.

(A) Sight glass. A sight glass has been designed of "Lucite" tubing, rubber end seals and glass tubing connections to provide a visible means of checking the chlorinator operation and by timing the drops of solution passing through the sight glass, the dosage rate may also be checked.

(B) Connecting Tubing. Standard commercially available rubber tubing has been used for all connections, i.e. solution reservoir to sight glass, sight glass to chlorinator, and chlorinator to water line injector.

Hose clamps may be used on all hose connections although these have been found unnecessary in test runs of the chlorinator.

(C) Water Line Injector. A water line injector has been designed in a form similar to the ordinary straddle cock. The injector proper has been fabricated of lucite. It is seated on a rubber gasket and is held in place by a single "U" bolt and clamping plate. The injector is to be installed in the main water line by drilling a single 1/4 inch hole at any convenient location.

(D) Accessory Valves. It has been thought advisable to install two auxiliary check valves. One in the discharge line and one as a foot valve in the suction line from the chlorine solution reservoir.

These valves serve a triple purpose. They relieve pressure on the main valve system, insure that all lines remain full of solution at all times and serve as a safety in the event that either main valve be held open at any time by a small particle.

The check valves selected are low cost, commercially available sub-assemblies of cast hard rubber bodies with rubber valves interchangeable with those used in the main valves.

These accessory valves are inserted and held by compression in the intake and discharge lines of the chlorinator.

(E) Lubrication. Due to the use of ball bearings and the relatively slow motion of all moving parts, only an occasional drop of oil on bearings and cam will be required.

(F) Finish. Metal parts have been finished with a corrosion and rust resistant rubber compound paint.

(G) Method of Installing Chlorinator. The chlorinator is to be fastened by bolts, wood screws or lag screws in any convenient location adjacent to the water pump pulley, the only restriction being that it be in alignment with the connecting pulley which is bolted to or fitted on the shaft of the water pump. Holes have been located in the chlorinator base to provide for mounting.

(H) Chlorine Solution Reservoir. It is proposed that the user furnish the chlorine solution reservoir which may consist of any one of the following: The container in which the hypochlorite is purchased, a glass bottle, earthenware crock or any other non-corrosive container.

VI METHODS OF VARYING DOSING RATE

It is believed that this chlorinator is extremely flexible in its provisions for varying the dosing rate. Any one of the following methods may be used:

- (a) The size of the take off pulley which provides the connection to the pump may be varied thereby changing the pump to chlorinator speed ratio.
- (b) The size of the chlorinator drive pulley may be varied to produce the same effect as in (a) above. (A two step pulley is submitted with the working model.)
- (c) The stroke of the diaphragm may be varied by inserting or removing the shims between the main frame and the chlorinator body. (Three 1/8 inch shims are furnished with the working model.)
- (d) Fine adjustment of the diaphragm stroke may be obtained by shifting the pump body vertically. This is accomplished in the working model by loosening the two body bolts and raising or lowering the chlorinator body in the slots provided in the main frame.
- (e) Finally, an almost infinite range of dosing variation may be accomplished merely by varying the concentration or dilution of the chlorine solution in the solution storage reservoir.

VII CALIBRATION AND PERFORMANCE CURVES

Figures 14, 15, 16 and 17 are typical of test data and performance curves which have been obtained with the working model. They are submitted to demonstrate that the minimum and maximum design requirements have been satisfied by the working model and further that the chlorinator is capable of functioning at a required constant rate of discharge.

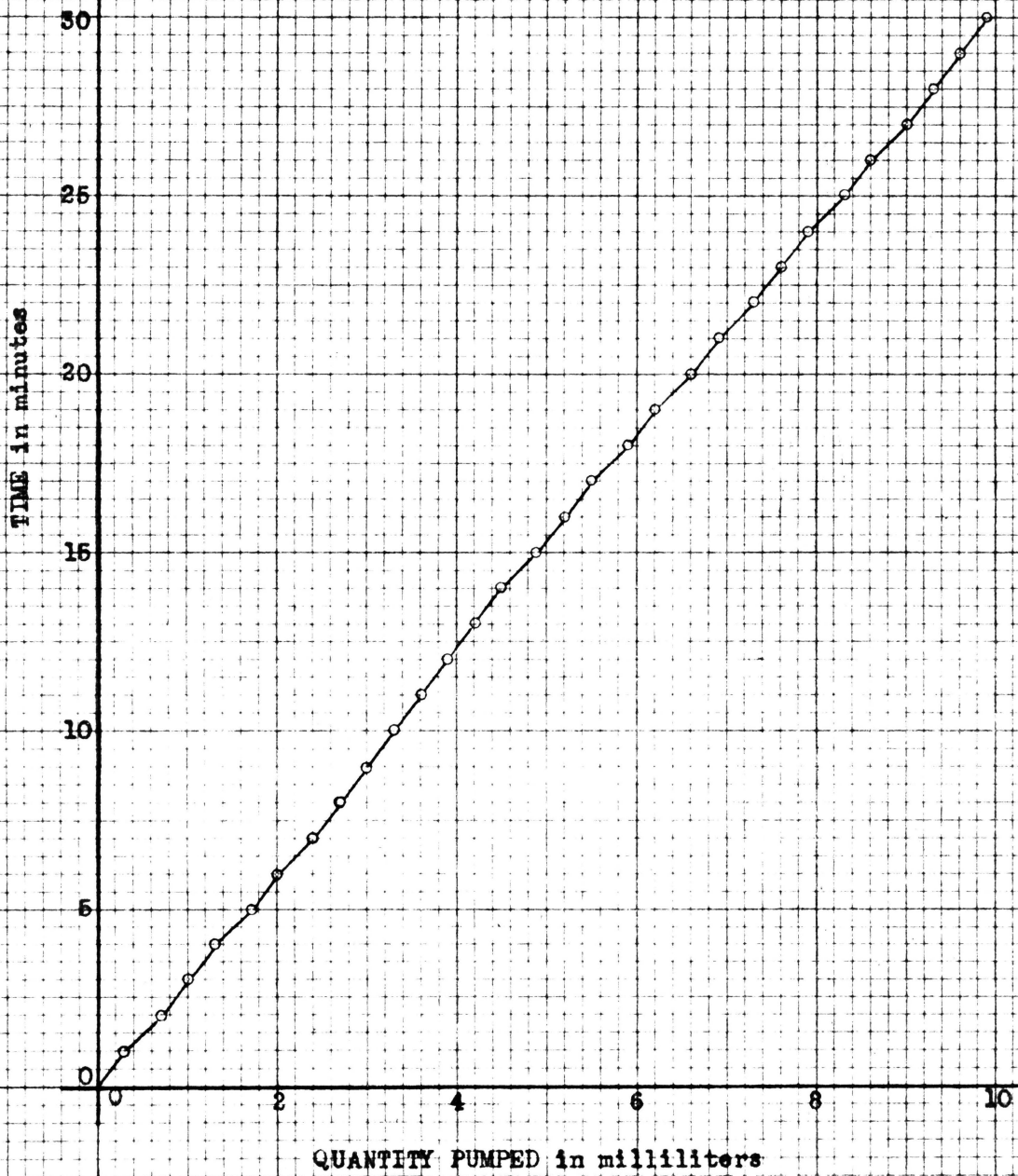
CHLORINATOR CALIBRATION TESTS.

| Time | Cumulative Quantities in Milliliters. | | | | | |
|------|---------------------------------------|----------|------|----------|-----|----------|
| | min. | Test No. | | Test No. | | Test No. |
| | | 1 | | 2 | | 3 |
| 0 | 0.0 | | 0.0 | | 0 | |
| 1 | 0.3 | | 3.0 | | 55 | |
| 2 | 0.7 | | 6.0 | | 111 | |
| 3 | 1.0 | | 8.5 | | 166 | |
| 4 | 1.3 | | 10.5 | | 222 | |
| 5 | 1.7 | | 13.5 | | 278 | |
| 6 | 2.0 | | 16.0 | | 333 | |
| 7 | 2.4 | | 19.0 | | 390 | |
| 8 | 2.7 | | 21.5 | | 444 | |
| 9 | 3.0 | | 24.0 | | 500 | |
| 10 | 3.3 | | 27.0 | | 556 | |
| 11 | 3.6 | | 29.5 | | 612 | |
| 12 | 3.9 | | 32.0 | | 669 | |
| 13 | 4.2 | | 35.0 | | 725 | |
| 14 | 4.5 | | 38.0 | | 781 | |
| 15 | 4.9 | | 41.0 | | 836 | |
| 16 | 5.2 | | 43.5 | | 893 | |
| 17 | 5.5 | | 46.5 | | | |
| 18 | 5.9 | | 49.0 | | | |
| 19 | 6.2 | | 52.0 | | | |
| 20 | 6.6 | | 56.0 | | | |
| 21 | 6.9 | | 57.5 | | | |
| 22 | 7.3 | | 60.0 | | | |
| 23 | 7.6 | | 63.0 | | | |
| 24 | 7.9 | | 65.0 | | | |
| 25 | 8.3 | | 68.0 | | | |
| 26 | 8.6 | | 70.5 | | | |
| 27 | 9.0 | | 73.0 | | | |
| 28 | 9.3 | | 76.0 | | | |
| 29 | 9.6 | | 79.0 | | | |
| 30 | 9.9 | | 82.0 | | | |

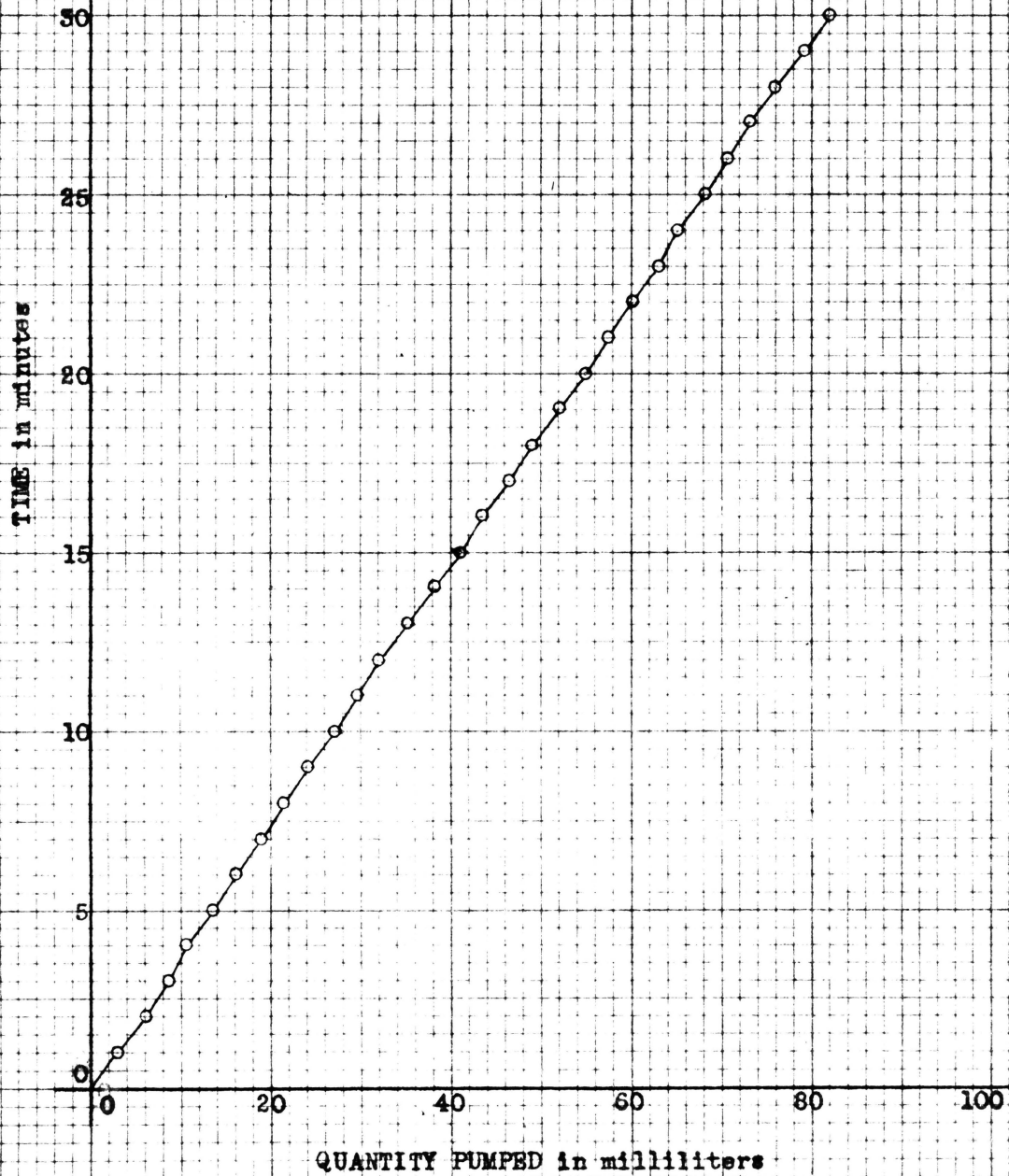
Notes:

1. These test runs are introduced to indicate the range and performance of the chlorinator.
2. Drive speed was 1725 R.P.M. with results reduced to the design drive speed of 287 R.P.M.
3. Test No. 3 was terminated after a 15 minute run since it was used only to demonstrate maximum capacity.

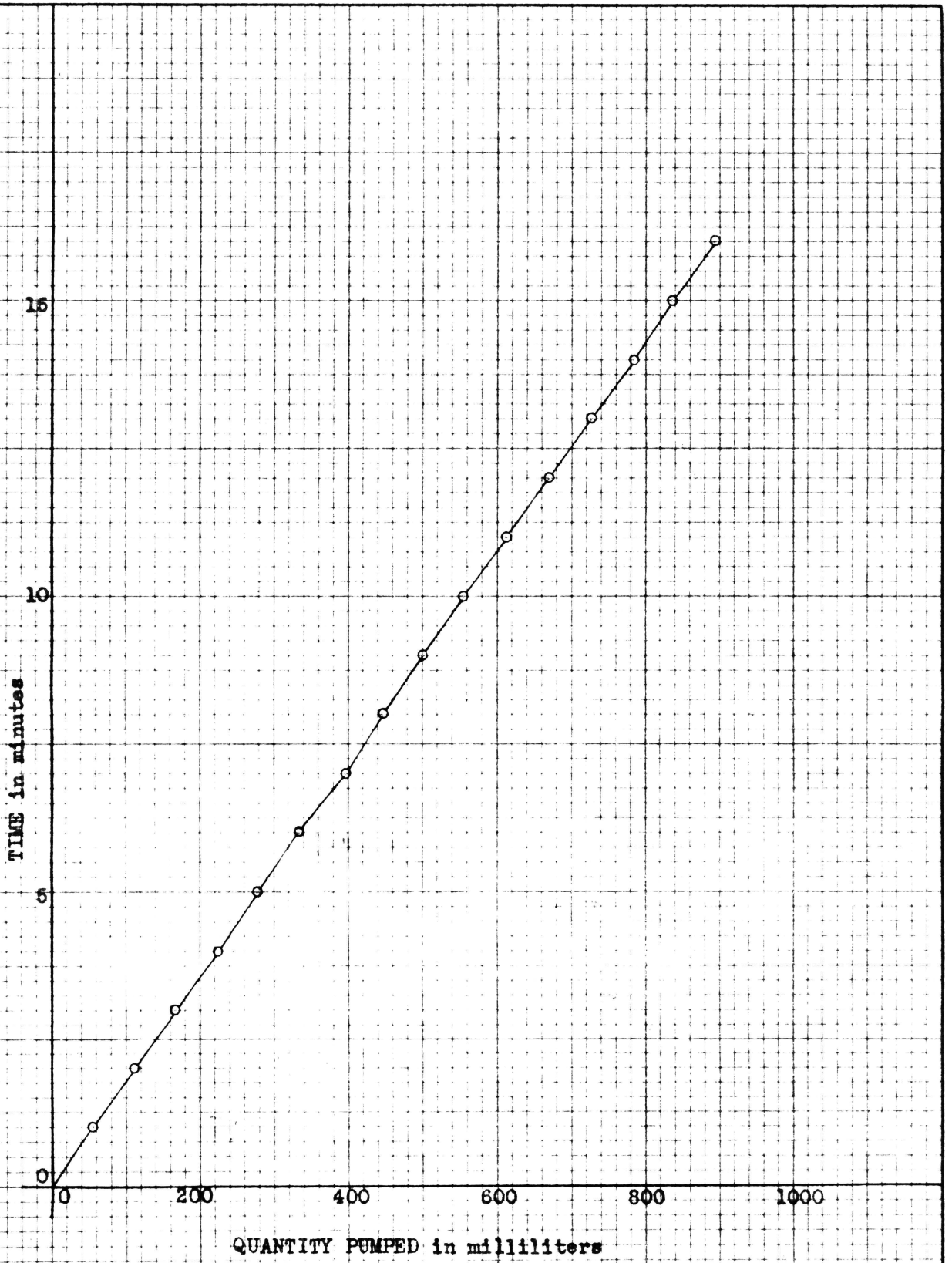
Fig. 14



CHLORINATOR CALIBRATION TEST
TEST No. 1
Fig. 15



CHLORINATOR CALIBRATION TEST
TEST No. 2
Fig. 16



CHLORINATOR CALIBRATION TEST
TEST No. 3
Fig. 17

VIII CONCLUSIONS

The author wishes to present the following conclusions which are the result of this study.

- (a) On the basis of submitted estimates predicated on current prices, it is believed that the chlorinator and accessories can be marketed at a profit for under twenty-five dollars. If this be true, the design fulfills the purpose of this study.
- (b) Actual performance of the working model demonstrates that a pump of this design is capable of delivering closely metered quantities at a constant rate and further that it is capable of handling very small quantities.
- (c) The author believes that the use of a clear plastic for the chlorinator head and main valve casing is a distinct advantage in that the operation of main components is visible at any time.
- (d) It is recommended that only the commercial liquid sodium hypochlorite solutions be used with this unit because of their economy and ease of preparation.
- (e) Work with the model has suggested other possible uses. It may be used as an injector of liquids into open or closed flow systems under either continuous or intermittent operation when used with a driving motor. It may be used for pipetting operations to deliver metered quantities and by a simple modification could be operated manually for such purpose.

- (f) The author believes that further study may lead to some refinement and improvement of the original design and such study is contemplated.
- (g) It is suggested that a simple and inexpensive residual chlorine test kit be supplied with the chlorinator is made commercially available.

IX ACKNOWLEDGEMENTS

The author wishes to express his appreciation and thanks to the following: Colonel R. B. H. Begg, Professor P. H. McCauley, and Professor J. A. Rives for continued help over the long period this study has been in progress. To Mr. Ralph Overbeck for aid and technical advice in the machine work involved in the production of the model. To Elizabeth M. Gildea for encouragement and the use of her kitchen and water works as a proving ground. To Mrs. E. J. Meyung for clerical assistance. And finally to my sons, Lee and Hugh, whose love of a working gadget has lightened the burden of this study. They have suggested unorthodox uses for the unit, and made the outcome of the study a sporting event.

X APPENDIX

The following information is appended in the hope that it will prove of interest. It is typical of information which should be provided in an instruction manual to accompany the chlorinator if it should be marketed. It has been abstracted from various sources.

Appendix (A) Recommended Solutions and Related Information.

- (1) Chloride of Lime. Chloride of lime, also known as "bleaching powder" or calcium hypochlorite is usually available in twelve ounce cans at grocery and drug stores.

Chloride of lime contains up to 33 to 37 per cent by weight of available chlorine.

- (2) H. T. H. and Perchloron. These two compounds are practically pure calcium hypochlorite. They are quite stable and it may be assumed that they contain 70% available chlorine by weight. Solutions of these compounds may be made up directly in the solution reservoir of the chlorinator.

One 3 3/4 pound can of either compound will make 30 gallons of solution containing 1% (10,000 p.p.m.) available chlorine.

- (3) Sodium Hypochlorite. Sodium hypochlorite also known as liquid bleach may be purchased from grocery and drug stores under various trade names. Zonite, sold in drug stores as a medicinal product contains 1% available chlorine by weight. Most solutions sold in grocery stores under a variety of names contain about 5% available chlorine by weight.

(4) Computing Required Doses of Chlorine or Chlorine Compounds.

Suggested procedure for computing chlorine doses is based upon simple tabulations. General formulae are given for computing tests under varying conditions when the tabulation may not be adequate.

Table I gives the weights of chloride of lime with assumed strength of 25% and also weights of H.T.H. or Perchloron with a strength of 70% of available chlorine by weight which are required to prepare a stated volume of 1% chlorine solution which strength is convenient for use with hypochlorite feeders.

Table No. 1. Illustrating Weight of Chloride of Lime, H.T.H. and Perchloron Required to Prepare Stated Volume of 1.0 Per Cent (0.01) Solution.

| Volume of Solution in Gallons | Weight of 25% Strength Chloride of Lime Required | | Weight of 70% Strength H.T.H. or Perchloron | |
|-------------------------------|--|--------|---|--------|
| | Pounds | Ounces | Pounds | Ounces |
| 1..... | 0 | 8 | 0 | 2 |
| 5..... | 1 | 12 | 0 | 10 |
| 10..... | 3 | 5 | 1 | 3 |
| 20..... | 6 | 7 | 2 | 6 |
| 30..... | 10 | 0 | 3(.75) | 9 |
| 40..... | 13 | 5 | 4 | 12 |
| 50..... | 18 | 5 | 5 | 15 |

Note: Weights are figured to the nearest ounce.

Table II gives the amount of the 1% solution so prepared which is required for the disinfection of the volumes of water noted.

The basic figure to keep in mind for the use of the 1% solution is that one gallon of the solution will provide a dose of 1 p.p.m.

to 10,000 gallons of water.

Sodium hypochlorite solutions need only be diluted to the desired strength. Household bleaches containing 1% to 5% available chlorine are suitable for treating small volumes of water.

The required volume of diluting water must be computed by including the volume of the stock solution as part of the final volume of the diluted solution. Thus, 5% strength solution diluted to 1% would require the use of 1 part of stock solution and 4 parts of water to give 5 parts of dilute solution of $1/5$ the original strength. Table No. 2 illustrates this fact.

TABLE NO. 2

Illustrating Volume of 1 per cent and 5 per cent Strength Hypochlorite Solution Required per 24 hours and Rates of Flow and Solution Needed to Provide a Dose of 1 p.p.m. When Treating Water Flowing at Rates of 1 to 20 gallons per minute.

| Rate of Flow of Treated Water | | | Total Quantity of 1 per cent solution Required per 24 hrs. | | Total Quantity of 5 per cent solution Required per 24 hrs. | | Time Required for Flow of 1 gallon | |
|-------------------------------|------------------|----------------------|--|-------|--|------|------------------------------------|----------|
| Gallons per minute | Gallons per hour | Gallons per 24 hours | | | | | 1% soln. | 5% soln. |
| | | | gals. | mls. | gals. | mls. | days | days |
| 1 | 60 | 1440 | 0.144 | 545 | 0.023 | 109 | 6.940 | 34.700 |
| 4 | 240 | 5760 | 0.576 | 2180 | 0.115 | 436 | 1.736 | 8.680 |
| 8 | 480 | 11520 | 1.152 | 4360 | 0.230 | 872 | .868 | 4.340 |
| 12 | 720 | 17280 | 1.728 | 6540 | 0.345 | 1308 | .578 | 2.890 |
| 16 | 960 | 23040 | 2.304 | 8720 | 0.461 | 1744 | .434 | 2.170 |
| 20 | 1200 | 28800 | 2.880 | 10900 | 0.574 | 2180 | .345 | 1.725 |

Table No. 3 may be used as a guide in preparing dilute solutions.

Table No. 3, Illustrating Volume of Stock Sodium Hypochlorite Solutions Needed to Prepare Stated Volume of Dilute Solution Containing 1.0 per cent Available Chlorine by Weight.

| Strength of Stock Sodium Hypochlorite Solution (See Label) | Volume of Dilute Solution to be Prepared (1.0 per cent available chlorine) | | | | | | | |
|--|--|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | 5 gallons | | 30 gallons | | 50 gallons | | 100 gallons | |
| | Vol. Dil. Water | Vol. Stock Sol. | Vol. Dil. Water | Vol. Stock Sol. | Vol. Dil. Water | Vol. Stock Sol. | Vol. Dil. Water | Vol. Stock Sol. |
| 1 | 0 | 5 | 0 | 30 | 0 | 50 | 0 | 100 |
| 2 | 2 1/2 | 2 1/2 | 15 | 15 | 25 | 25 | 50 | 50 |
| 3 | 3 1/3 | 1 2/3 | 20 | 10 | 34 | 16 | 66 2/3 | 33 1/3 |
| 4 | 3 3/4 | 1 1/4 | 22 1/2 | 7 1/2 | 37 1/2 | 12 1/2 | 75 | 25 |
| 5 | 4 | 1 | 24 | 6 | 40 | 10 | 80 | 20 |
| 10 | 4 1/2 | 1/2 | 27 | 3 | 45 | 5 | 90 | 10 |
| 15 | 4 2/3 | 1/3 | 28 | 2 | 46 2/3 | 3 1/3 | 93 1/3 | 6 2/3 |

Note: Add one part of 14% strength stock solution to 13 parts of water to give 14 parts of 1% solution

Formula:

Cases may arise where Tables 1 and 2 are of limited assistance in which case, the weight of chlorine compounds required for the disinfection of known volumes of water with desired doses of chlorine may be computed by the use of Formula No. 1.

(1) Pounds of Chlorine Compound (Powder) =

$$\frac{\text{Gal. water treated} \times \text{Desired Dose p.p.m.} \times 8.3}{\% \text{ strength of Compound} \times 1,000,000}$$

The per cent of chlorine compound should be expressed as a decimal.

The strength of the solution prepared in this way would be computed by Formula No. 2 as follows:

(2) Percent Strength of Solution =

$$\frac{\% \text{ Strength of Compound} \times \text{Pounds of Compound}}{\text{Gallons of Solution} \times 8.3}$$

In this case also the per cent strength of solution is expressed as a decimal.

It may be desirable to compute the gallons of solution required for specific conditions. Two formulae are available for this purpose.

(3) Gallons of Solution =

$$\frac{\text{Dose in p.p.m.} \times \text{Gallons of Water Treated}}{\% \text{ Strength Solution} \times 1,000,000}$$

Formula 3 gives gallons of solution required for a stated dose, the gallons of water to be treated and the per cent strength of solution.

Formula 4 gives the amount of water which is needed to prepare a solution of any desired strength when a given number of pounds of chlorine compound of known strength is used.

(4) Gallons of Solution =

$$\frac{\% \text{ Strength Compound} \times \text{Pounds of Compound}}{\% \text{ Strength of Solution} \times 8.3}$$

The weight of available chlorine in any given volume of solution of known strength may be computed by formula 5:

(5) Pounds of Available Chlorine =

$$\text{Gallons of Solution} \times \% \text{ Strength of Solution} \times 8.3$$

The dose of chlorine applied may be computed from gallons of solution used of known strength and the volume of water treated by using formula 6.

(6) Dose in p.p.m. =

$$\frac{\% \text{ Strength Solution} \times \text{Gallons Solution used} \times 1,000,000}{\text{Volume of Water Treated}}$$

Appendix (B) Procedure for Chlorine Demand Test

Reagents: (1) Standard Orthotolidine reagent
(2) Commercial "Zonite" solution which contains approximately 1% available chlorine by weight. (Unless this solution has been standardized, the results will be approximate.)

Equipment: One medicine dropper which will deliver 20 drops per milliliter. Ten 1-quart fruit jars marked at 500 ml. point. Ten 2-ounce bottles marked at 20 ml. point. Glass stirring rod.

Permanent color standards.

Procedure: Measurement of samples: Fill each jar to the 500 milliliter mark with the water under test.

Addition of Chlorine: While stirring constantly, add one drop of "Zonite" to water in the first fruit jar, two drops to that in the second jar, three drops to the third, etc. Each drop of "Zonite" represents a chlorine dose of 1.0 p.p.m.

Contact Time: Hold the samples for 10 minutes before testing. Do not allow the samples to be exposed to strong daylight during this period.

Examination of Samples: At the end of the contact time, remove a 20 milliliter portion of each sample, place it in a two ounce bottle, then add 1 milliliter of orthotolidine to each. Determine the residual chlorine by comparison with permanent standards or by means of a chlorine comparator.

Calculation: Subtract the parts per million of residual chlorine from the parts per million of chlorine added. These values are the chlorine demands expressed in parts per million of the sample at the respective dosages.

Appendix C: Determination of Residual Chlorine.
Orthotolidine Test - Drop Dilution Method.

Materials: Comparators or Nessler tubes. Medicine dropper that will deliver 20 drops per milliliter. Chlorine standards. Orthotolidine solution.

Reagents and Samples: Use 0.5 milliliters of orthotolidine in 10 or 15 milliliter comparator tubes. Use the same ratio for other volumes.

1. Fill the cell or tube to the mark with distilled water and mix thoroughly.
2. Add to the cell or tube one or more drops of the chlorinated water (mixing thoroughly after each drop) until an easily readable color is produced.
3. Compare color with regular chlorine color standards.

Contact Time: As chlorinated water with such concentration of chlorine contains only active chlorine, the color development will be rapid and may be read almost at once.

Calculation: The chlorine residual in the chlorinated water may be computed from the formula.

$$\text{Residual Chlorine (p.p.m.)} = \frac{\text{Volume of cell in ml.}}{\text{ml. of sample}} \times \text{chlorine}$$

Standard matched.

Example

$$\frac{(15) (\text{capacity of cell})}{1.50 (30 \text{ drops})} \times 0.20(\text{reading}) = 2.0 \text{ p.p.m.}$$

Note: The equipment needed to perform the residual chlorine test by this method is very simple and can be incorporated into an inexpensive test kit to be supplied with the chlorinator. It has a further advantage in that only one color standard need be supplied with the kit.

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