PROCEEDINGS

OF THE

TWENTY-NINTH ANNUAL CONVENTION

OF THE

AMERICAN WATER WORKS ASSOCIATION

HELD AT

MILWAUKEE, WIS., JUNE 7-12, 1909

PUBLISHED BY THE SECRETARY

10947
2/5/11

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its Proceedings

DESCRIPTION OF THE PROCESS AND PLANT OF THE JERSEY CITY WATER SUPPLY COMPANY FOR THE STERILIZATION OF THE WATER OF THE BOONTON RESERVOIR.

BY GEORGE W. FULLER

The purpose of this paper is to outline the more important technical details of the process adopted at the Boonton reservoir of the Jersey City Water Supply Company, to destroy objectionable bacteria under the conditions stated by Dr. Leal; and also to describe the plant designed by Hering & Fuller for this sterilizing process and the results of the operation of which since September 26, 1908, will be given in the paper of Mr. Johnson. .

NATURE OF PROCESS

This process is essentially one of oxidation by which the objectionable bacteria in the water under treatment are destroyed. It is also spoken of as a "sterilization process," a name which is quite appropriate from a practical viewpoint, although not absolutely correct theoretically speaking. As a matter of convenience the plant designed for the Jersey City Water Supply Company, to be used at the Boonton reservoir for the purpose above stated, is generally spoken of as a "sterilization plant."

AGENT OR CHEMICAL USED

For the purpose of securing the oxidation and sterilization above mentioned the Boonton reservoir water is treated with a minute dose of bleaching powder of a high degree of purity. This compound, commonly spoken of as hypochlorite of lime, is in reality a mixed salt of calcium containing about equivalent proportions of chloride of calcium and hypochlorite of calcium. This compound is acted upon by the moisture in the atmosphere and hence is transported for the trade in tight metal drums to preserve its initial strength so far as practicable. Ordinarily this compound contains some 35 per cent of available chlorine and some 40 to 44 per cent of lime. The remainder is made up of water, part of which is combined with the chemical and part of it is uncombined water in the form of moisture, together with several impurities coming for the most part from the slaked lime used in preparing this salt.

COMPOSITION OF APPLIED CHEMICAL IN WATER.

When this applied chemical is dissolved in the water it no longer exists as a mixed salt of calcium, but appears in the form of two salts of calcium, namely, calcium chloride and calcium hypochlorite. The former of these salts remains inert and ineffective as applied to natural waters, and it is the second salt (hypochlorite of calcium) which alone serves as an oxidation and sterilization agent.

EFFECT OF CARBONIC ACID UPON HYPOCHLORITE OF CALCIUM

When the active portion of the applied chemical, that is, the hypochlorite of calcium, is added to any ordinary natural water such as that in the Boonton reservoir, the free corbonic acid or half-bound carbonic acid in the water combines with it and there is formed calcium carbonate, and at the same time free oxychloride, known technically as hypochlorous acid, is released in the water. This latter compound is spoken of by chemists as an acid, but it is an extremely inert acid, as is shown by the fact that in the atmosphere the applied chemical is decomposed by the very weak carbonic acid contained in the air and there is set free hypochlorous acid in the manner corresponding to that taking place in the treatment of the reservoir water, as above mentioned. This oxychloride or oxy-acid is so unstable that in its pure state it is said to be unknown.

NATURE OF OXYCHLORIDE OR HYPOCHLOROUS ACID

While oxychloride of hydrogen or hypochlorous acid is an extremely weak acid it is a fact well known to chemists that it is a powerful oxidizing agent. It effects oxidation in the presence of oxidizable substances by virtue of the liberation of nascent oxygen in consequence of its instability as a chemical compound. At this point it may be mentioned that this treatment is in no sense a chlorine treatment such as is sometimes spoken of and largely because of the use of the same commercial product in bleaching operations. In bleaching the commercial product is treated with strong acids which do break up the chemical and release free chlorine. Even free chlorine is not of itself an oxidizing agent, but in the presence of water it combines with hydrogen and thus sets free oxygen in an atomic or nascent state.

The weak carbonic acid, the only free acid in the Boonton reservoir water, or other natural water, is entirely incapable of releasing the free chlorine; but instead there is produced hypochlorous acid, as above stated, and it is this weak and unstable oxy-acid or oxychloride which gives up its oxygen to form a powerful oxidizing agent. Hypochlorous acid is not a poison. The chlorine of this compound combines with the alkalinity of the water, forming calcium chloride.

ATOMIC OR NASCENT OXYGEN

The Boonton reservoir water is ordinarily well supplied with atmospheric oxygen and in fact during the colder portions of the year is doubtless saturated with atmospheric oxygen. It is to be pointed out here that the oxygen resulting from the application of chemical in this process is not ordinary atmospheric oxygen. On the contrary it is in the most active state and in what chemists speak of as a "nascent state" or "atomic state." In this form at the instant of its liberation from the applied chemical it is by no means the inert agent of ordinary atmospheric oxygen, but in a far more active stage and capable of oxidizing substances which are quite unaffected by the oxygen of the atmosphere as ordinarily present, either in the atmosphere or in natural waters.

The expression "potential oxygen" has been used on this work to indicate the strength or quantity of oxygen which could be produced from the applied chemical. It is a much more rational expression than the "available chlorine" of the industrial chemists because as applied to water no chlorine as such becomes available.

SIMILARITY OF RECOMMENDED TREATMENT TO THE SO-CALLED OZONE TREATMENT

The word "ozone" means a modified form of oxygen capable of far more intense oxidation than the ordinary atmospheric oxygen. It is produced by nature under certain atmospheric conditions and by certain processes in the laboratory, and in recent years its production on a large scale through the aid of electricity has constituted one of the most interesting lines of investigation as regards water purification. Difficulties in securing its uniform production in a reliable manner has been and still is a serious draw-back to its use as an oxidizing and sterilization agent in the field of water purification. For that reason another process was recommended in this case for securing the same working agent by other and cheaper means and in such a manner as to put the control of the treatment within the reach of the operators of the plant at all times.

COMPOSITION OF THE BOONTON RESERVOIR WATER WITH REFERENCE TO ITS OXIDIZABILITY

The principal substances or compounds in the water of the Boonton reservoir which are capable of oxidation under favorable conditions are those substances generally spoken of as organic matter. Some of this organic matter is dead, disintegrating and partially dissolved, and some of it is living organic matter comprising the bodies of various small micro-organisms, notably bacteria and certain forms of algæ, diatoms and the like.

There are also some mineral substances or compounds in the reservoir water which are not in an oxidized form, but which can be oxidized under certain conditions. They are present in very minute traces, such, for instance, as nitrogen in the form of nitrites. Another compound which is capable of passing to a more highly oxidized form is that of nitrogen in the form of free ammonia, as spoken of by the analyst, and which exists in water, for the most part, in the form of ammonium carbonate.

While it is true that the substances last mentioned are present in very minute quantities in the reservoir water, it is also true that the dose of applied chemical in this process is also very minute as regards the quantity of "potential oxygen" which it possesses. By potential oxygen is here meant the content of the applied chemical as to the amount of oxygen which it can yield under conditions of complete decomposition under conditions obtained with a natural water such as that in the Boonton reservoir.

In speaking of the oxidizability of certain constituents of the reservoir water on the one hand, and of the potential oxygen applied in the course of the treatment on the other hand, it is to be clearly borne in mind that the quantities are very minute, dealing with fractions of one part of the substance in question in one million parts of water; or, stating it in another form, they are present as very small fractions of one grain to a gallon of water. The significance of these dilutions has a substantial bearing upon the understanding of the practicability and merit of the process in question.

CLASSES OF DEAD ORGANIC MATTER

It is ordinarily said that dead organic matter is present in water either in a dissolved or suspended form. Where particles of disintegrated leaves or twigs are present, and of a size to be visible as suspended matter when viewed by the naked eye, there is no opportunity for mistaking what is meant by that class of suspended organic matter. This class, of course, is more or less present in mixtures with mineral substances resulting from the soil washings of the water shed during rain storms.

As regards organic matter in solution, that is an expression which is not plainly understood by most people. In fact, it is a difficult one to state with precision from the viewpoint of the modern theoretical chemist. For the purposes at hand, however, it may be said that a large proportion of the so-called dissolved organic matter which gives, for instance, the so-called color or vegetable stain to the Boonton water, is not truly in solution in the full chemical sense, but as a matter of fact is in a colloidal state. This colloidal state is an intermediate one between the true solution and the suspension state. It really means that the colloidal particles are in an exceedingly fine state of subdivision and are truly in suspension and not in solution. This is indicated by the inability of large portions of this vegetable stain or color to pass through a dialyzer or parchment, and which is a test of the conditions of substances as to whether they are in a true solution or in a semi-soluble or colloidal state. In the reservoir water organic matter is present in the dissolved, colloidal and suspended forms.

This rough description of organic matters in the reservoir water, such as result for instance from the decomposition of leaves, is of importance in showing the relative amounts of oxidizability of the constituents of the water, because dissolved organic matters, generally speaking, consume potential oxygen more readily than colloidal or suspended organic matter, other things being equal.

CLASSES OF LIVING ORGANIC MATTER

Taking the bacteria as the form of living organic matter of most significance in this problem, it may be stated that bacteria, from the standpoint of readiness of oxidation, may be divided into several classes. The first of these, in which presumably the majority of bacteria are ordinarily present in waters, is the normal or vegetative state in which the cells are found with the tiny bits of protoplasm surrounded by a membrane. As is well known it is in this form that the bacteria are most readily destroyed by oxidation and other forms of sterilization.

A form in which bacteria sometimes occurs and in which it is very difficult to destroy them by oxidation and other means of sterilization, is that known as the "spore" form. When in this condition the normal bacterial cell has practically given place to a small kernel or substance much smaller than the normal cell and within which kernel the protoplasm or essence of life is contained in a thick membrane or sheath, much thicker than the membrane of the ordinary vegetative bacteria. Indeed this membrane is sufficient to protect it from destruction under a great variety of conditions. In practical sterilization it is found that even boiling temperatures of water destroy some of these "spore" forms of bacteria with great difficulty.

Fortunately in the problem at hand the importance of this bacterial condition is comparatively slight and almost negligible for the reason that the specific germs of intestinal diseases, such as typhoid fever, Asiatic cholera, etc., do not form spores and the same is true of B. coli and the majority of the bacteria which dominate the intestinal tract of man and domestic animals.

To obtain a clearer conception of the conditions which actually obtain in a natural water such as that of the Boonton reservoir, especially from the standpoint of destroying all bacteria, it is also to be pointed out that the vegetative bacteria, or the normal bacterial cells, may to a *slight* extent be present in water in the interior of tiny masses of suspended matter, the surfaces of which particles may become sterilized without necessarily having the active oxidizing and sterilizing agent penetrate fully within such suspended particles.

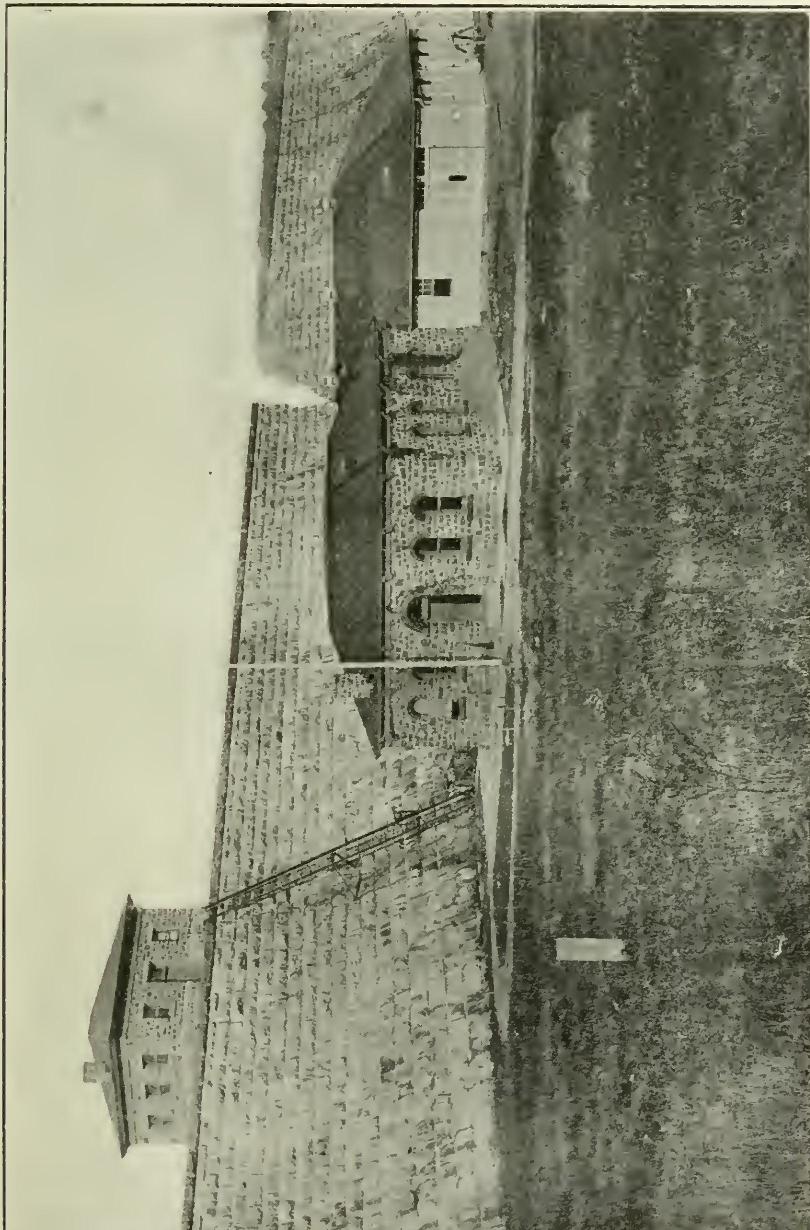
Bacteria in spore form or contained within particles of suspended matter are not killed *entirely* in this process. In making the above statements, it is not to be inferred that the recommended process suffers in efficiency as to destruction of objectionable vegetative bacteria. On the contrary it confirms the reliability of its normal action and furthermore explains the few residual bacteria which are in the water treated by the process just as they are in the effluents of filters.

LOCATION OF PLANT

This plant was built at the large impounding reservoir on the Rockaway River, a tributary of the Passaic, at Boonton, N. J., about 25 miles west of New York City. It is located below the main Boontön dam immediately adjoining the so-called lower gate house, the western end of which is about 30 ft. east of the down-stream face of the dam, measured at ground level. This gate house is located towards the southern end of the dam, the spillway of which is at the northern end. From the upper gate house, built within the dam, to this lower gate house in question there are four 48-in. steel pipe lines conveying water in desired quantities to the gate house which is located at the head of the concrete aqueduct leading towards Jersey City.

The elevation of the spillway of the dam is approximately 305 and the center line of these 48-in. pipes is at elevation 257.25.

The sterilization and oxidation plant was designed to permit the commercial product known as "high grade bleaching powder" or hypochlorite of lime to be dissolved in a convenient manner in tanks located adjoining the lower gate house, whence the solution is pumped with suitable devices into grids of perfo-



BOONTON DAM, UPPER AND LOWER GATE HOUSES AND STERILIZATION PLANT rated pipe placed in the mouth of the several 48-in. pipe lines conveying water from the reservoir to the head of the Jersey City aqueduct.

GENERAL ARRANGEMENTS AND DIMENSIONS OF THE STERILIZATION PLANT

Before taking up the individual details of the works as built, it will be convenient to state in outline the different parts of which the plant consists, as follows:

(*a*) A store-room with a floor area of about 20 by 33 ft.; a main operating room about 30 by 33 ft.; an engine room about 8 by 16 ft.; and a boiler room about 10 by 33 ft.

(*b*) Three dissolving tanks, each 6 ft. in diameter and about 3 ft. deep and placed within the respective solution or mixing tanks, all of which are built of concrete.

(*c*) Three solution tanks, each of a capacity of 1400 cu. ft.

(*d*) Water supply, comprising two 3-in. pipe lines connecting with the 48-in. lines coming from the reservoir, with water under a static pressure of about 15 lb.

(*e*) Stirring devices, consisting of revolving rakes in the dissolving tanks for getting the chemical into solution and also in the solution tanks for keeping the solution mixed so as to be of a uniform strength.

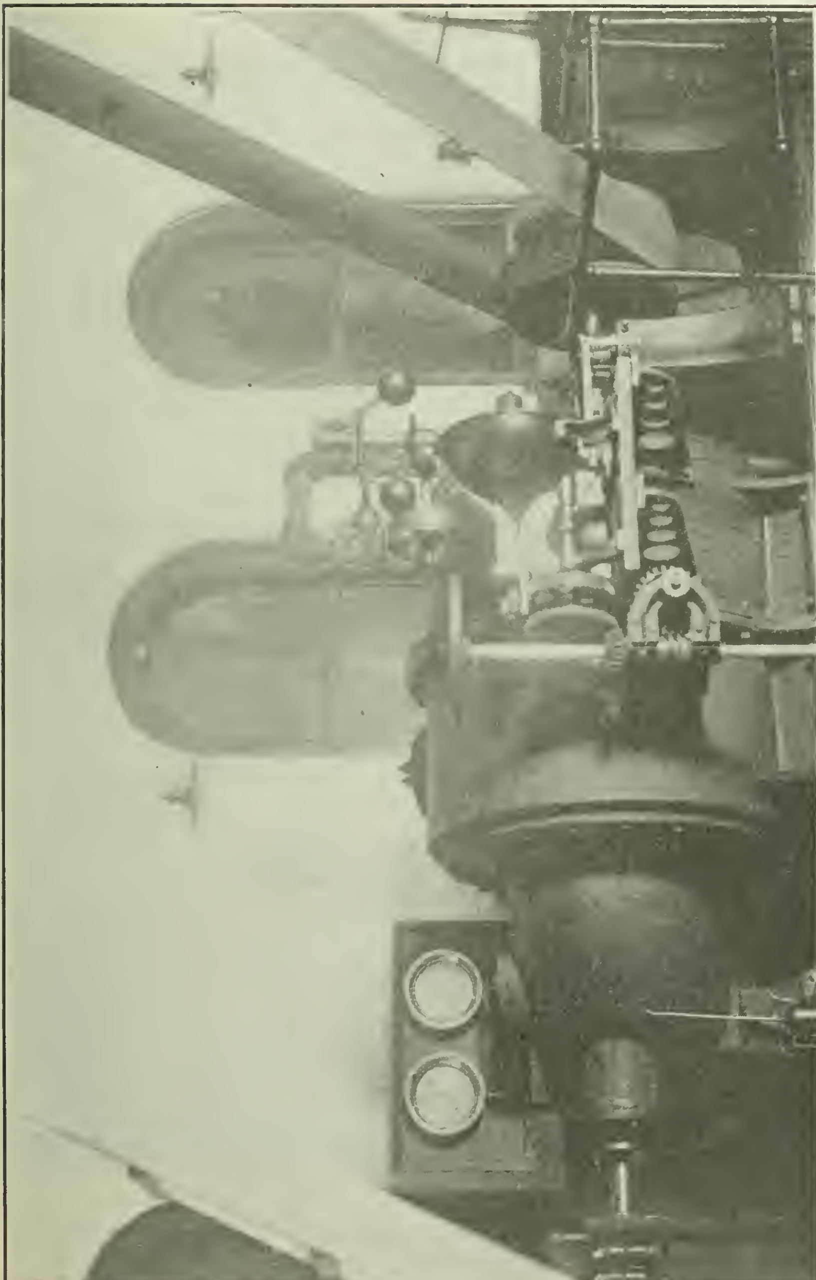
(*f*) Depth recorders by which a continuous automatic record is secured of the level of the liquid in each of the solution tanks.

(*g*) Pumping devices, consisting of two belt-driven 2-in. turbine pumps for delivering the chemical solution from the solution tanks to the orifice tanks.

(*h*) Power equipment, comprising two small boilers and two small engines for driving the shafting to which are belted the pumps and stirring devices, and which temporary steam plant was later replaced by water wheels driven by the water going to Jersey City.

(*i*) Two orifice tanks into which the chemical solution is pumped so as to maintain a fixed depth or head of solution above an orifice, the opening of which is to be adjusted to give the required volume of solution to give the prescribed dose.

(*j*) An alarm system by which a gong is rung with the aid of floats in the orifice tanks to call the immediate attention of the



WATER WHEEL

operators to any lowering of the solution level in the orifice tanks and thus guard against an underdose of solution.

(*k*) A set of perforated pipes or grids placed in the mouth of each of the 48-in. pipe lines coming from the reservoir to the lower gate house and through which grids the chemical solution is to be applied to each of the main pipe lines in service.

(*l*) A general system of pipes and drains for getting the water to the dissolving and solution tanks, connections from these various tanks through the pumps to the orifice tanks, and from the orifice tanks to the point of application through the grids just mentioned.

(*m*) A small laboratory is provided whereby the operators may make suitable tests to regulate properly the prescribed dose of chemical.

(*n*) Miscellaneous appurtenances, such as arrangements for heating, lighting etc.

All of the additional works built outside of the gate house, including the various tanks, pipes, pumps, etc., are included within and beneath a one-story wooden building approximately 33 by 67 ft. in size. This superstructure covers a concrete floor built around and above the various main tanks between which is a pipe gallery. The floor of the boiler, engine and store rooms rest upon an earth fill.

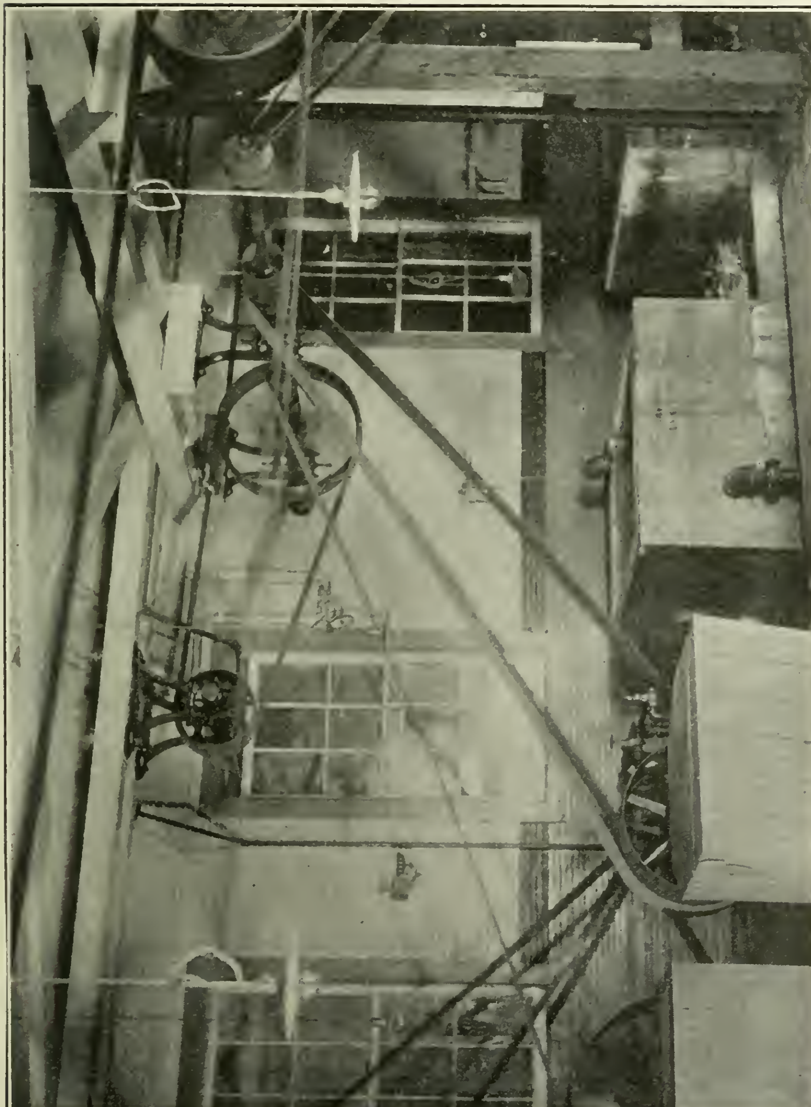
From the figures and plans will be noted the more essential details of each of the above-mentioned parts of the plant, but the more important of these details, such as to allow a good understanding to be obtained as to the nature of the plant, are taken up seriatim, as follows:

CAPACITY OF STOREROOM

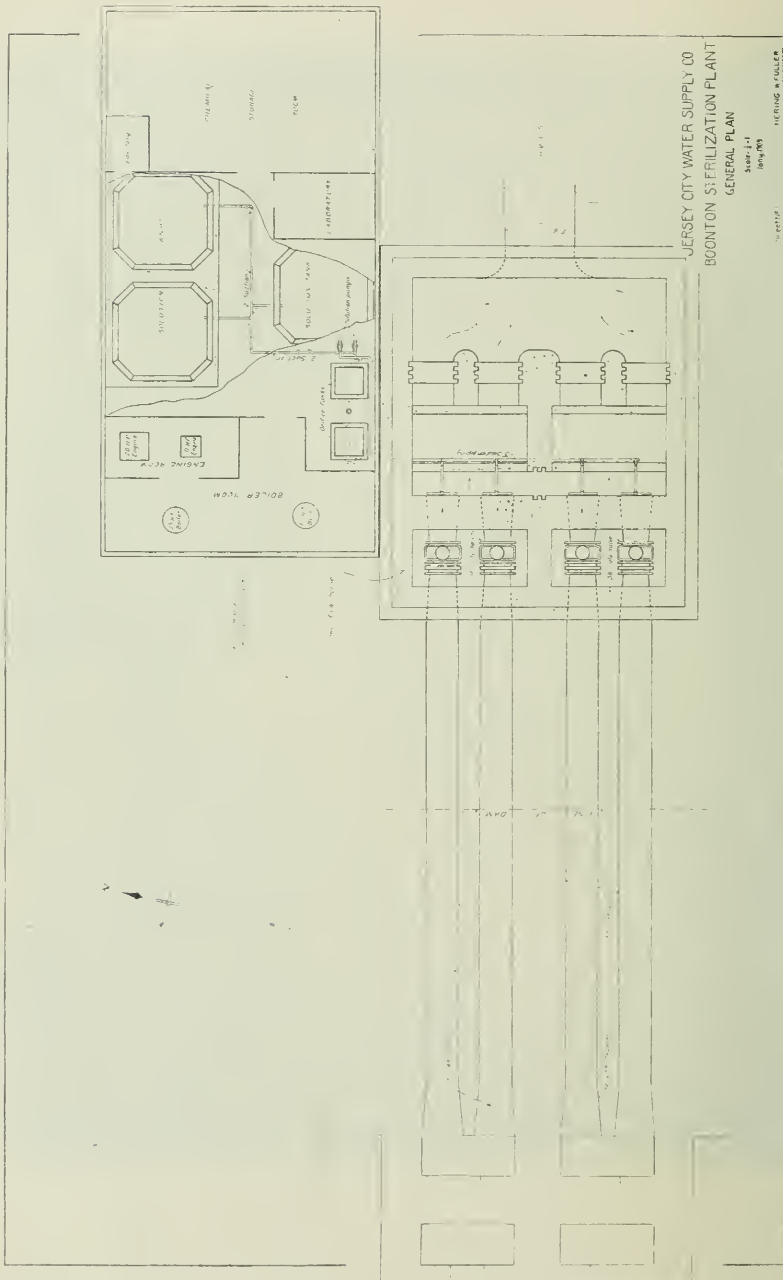
The store room has a capacity of three carloads of bleaching powder, corresponding to 120 drums, or approximately 90,000 pounds. This quantity is more than ample to tide over any interruptions in the delivery of this product, as it would provide for over a year's continuous operation with the present volume of water (40 million gallons daily), according to the present dose applied.

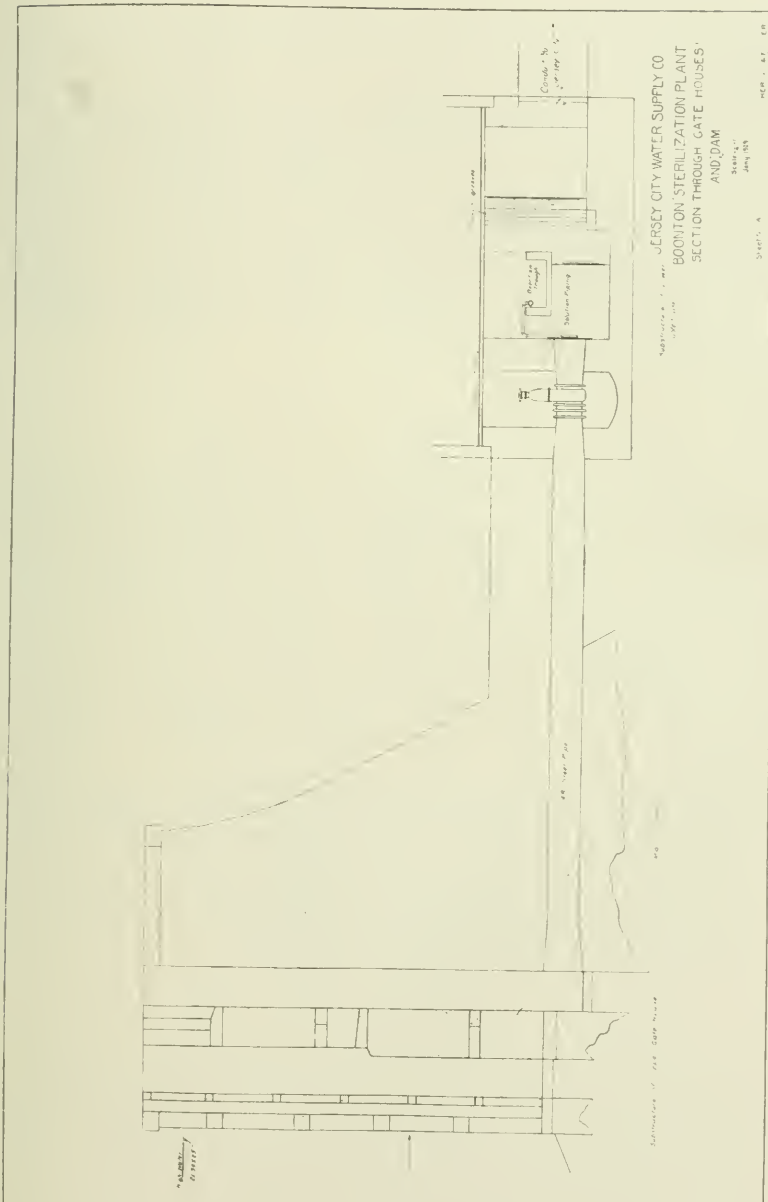
DISSOLVING TANKS

The dissolving tanks, 6 ft. in diameter and 3.5 ft. in gross depth, are built of reinforced concrete with their tops forming a



ORIFICE TANKS


JERSEY CITY WATER SUPPLY CO
BOONTON STERILIZATION PLANT
GENERAL PLAN
HERING & FULLER ENGINEERS
ENGINE ROOM
BOILER ROOM
LABORATORY


JERSEY CITY WATER SUPPLY CO
BOONTON STERILIZATION PLANT
SECTION THROUGH GATE HOUSES
AND DAM

portion of the floor of the main operating room of the building housing this plant. They are located within the respective solution tanks. Over a portion of the top of the dissolving tanks is a grating made of 2-in. by ⅜-in. steel bars, spaced on 3-in. centers, through which the dry chemical is dumped.

A 2-in. supply pipe enters the dissolving tanks near the flow line which is 2.5 ft. above the bottom. The center of the 6-in. overflow pipe taking the bleach and water into the solution tank is 18 in. above the bottom. At the bottom is a 4-in. blow-off pipe by which sludge or accumulated solid matter may be removed from these tanks after the soluble matters have been extracted so far as practicable.

SOLUTION AND MIXING TANKS

These are the large tanks into which the solution of chemical is discharged from the dissolving tanks, for purposes of more complete solution as well as complete and uniform mixing with the aid of stirrers. These tanks, of which there are three, are each 11 ft. 3 in. deep, 11 ft. wide at the bottom and 12 ft. 4 in. wide at the top.

They are covered with a concrete deck which serves as a floor of a part of the main room, and in this floor over each tank is a manhole, as shown.

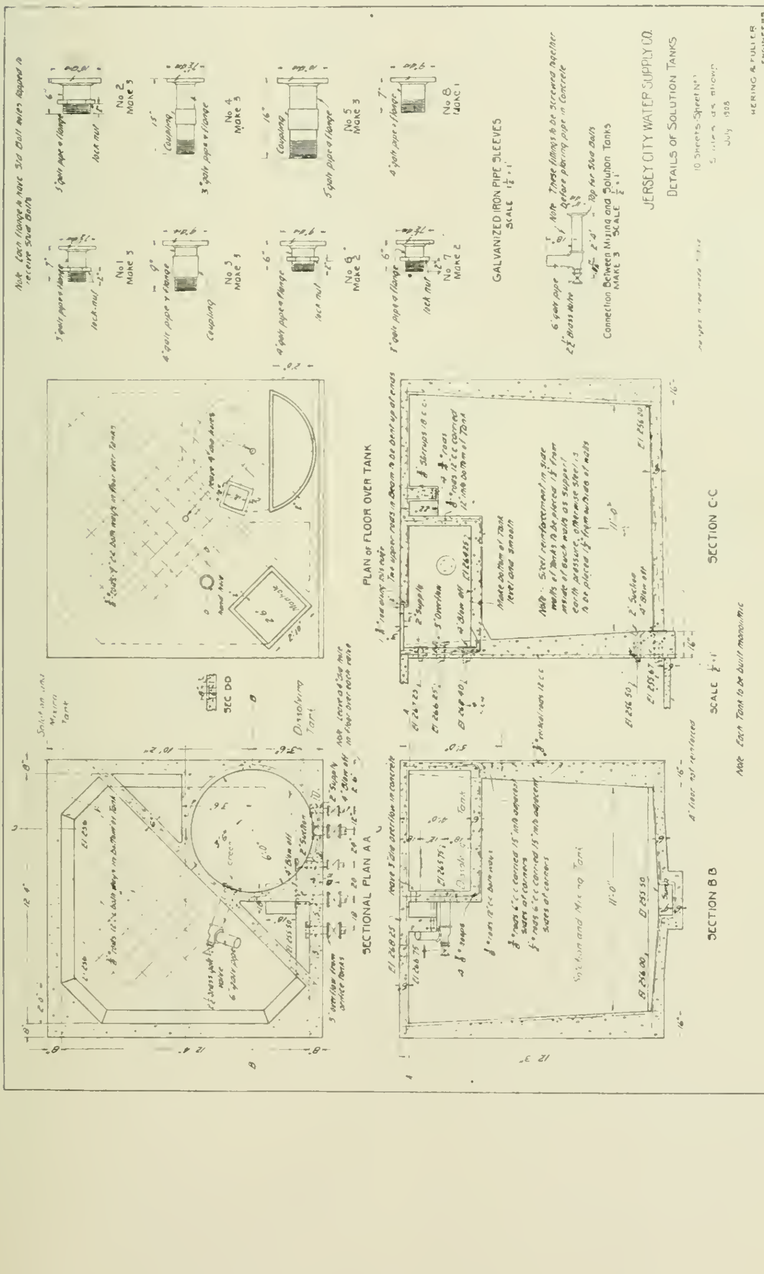
The bottom of these tanks slope to a sump and a 4-in. blow-off pipe from th lowest point provides drainage into a 32-in. steel overflow pipe extending from the adjoining gate house to the stream bed of the Rockaway River below.

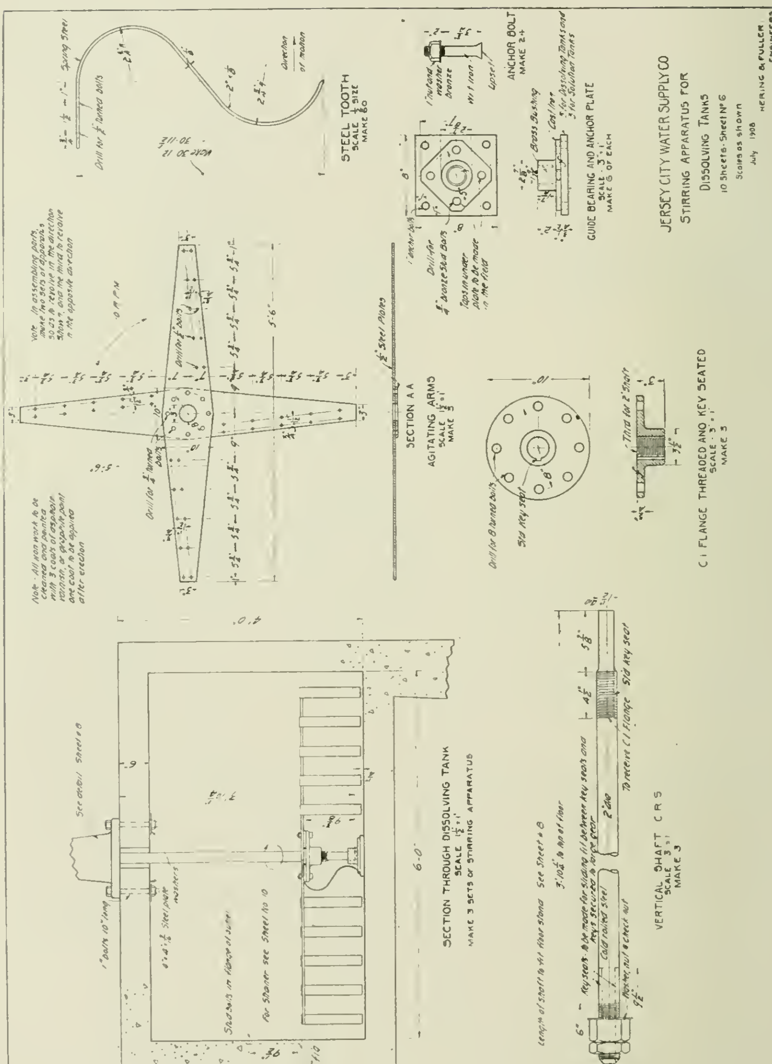
A 2-in. suction pipe leads from just above the bottom of these tanks to the turbine solution pumps.

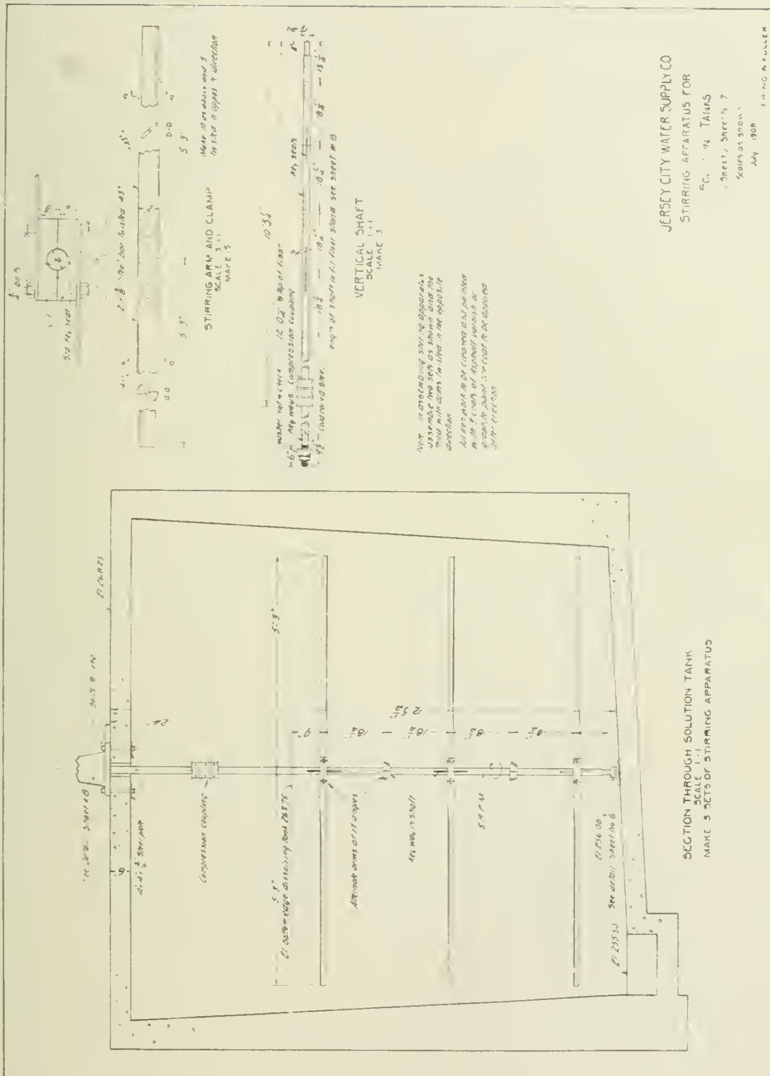
STIRRING DEVICES

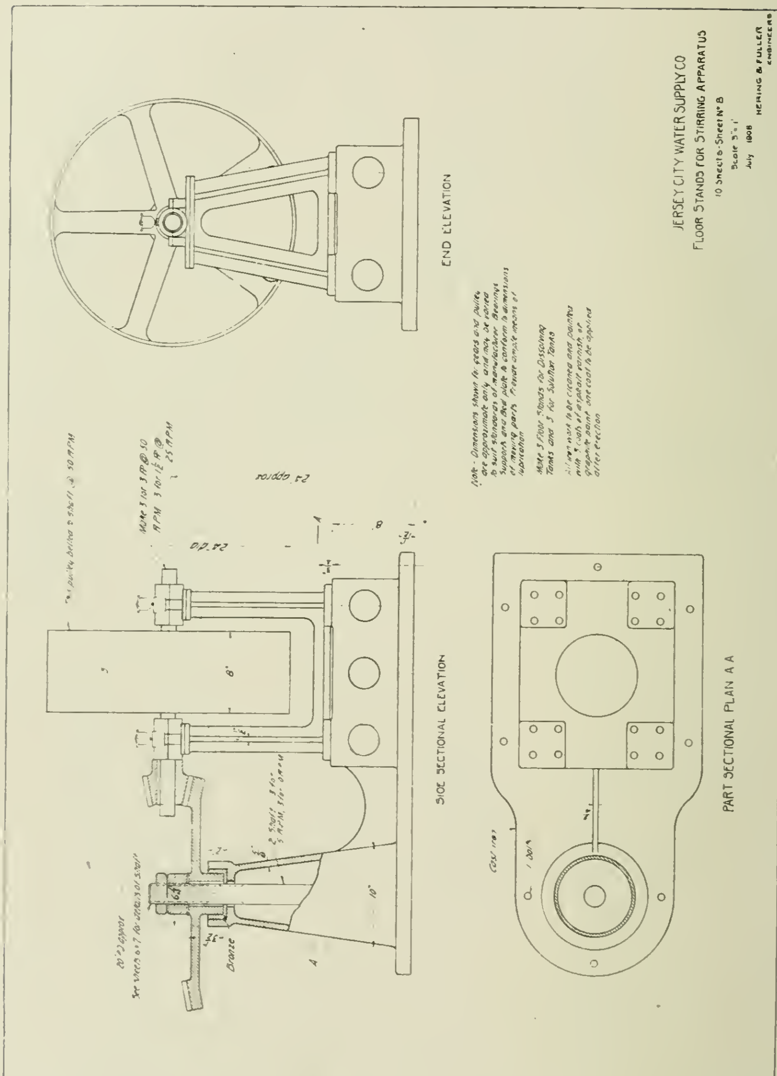
Belt-driven rakes with suitable teeth attached thereto revolve in the dissolving tanks and revolving paddles similarly operated in the solution tanks facilitate solution of the chemical and the maintaining of a solution of uniform strength.

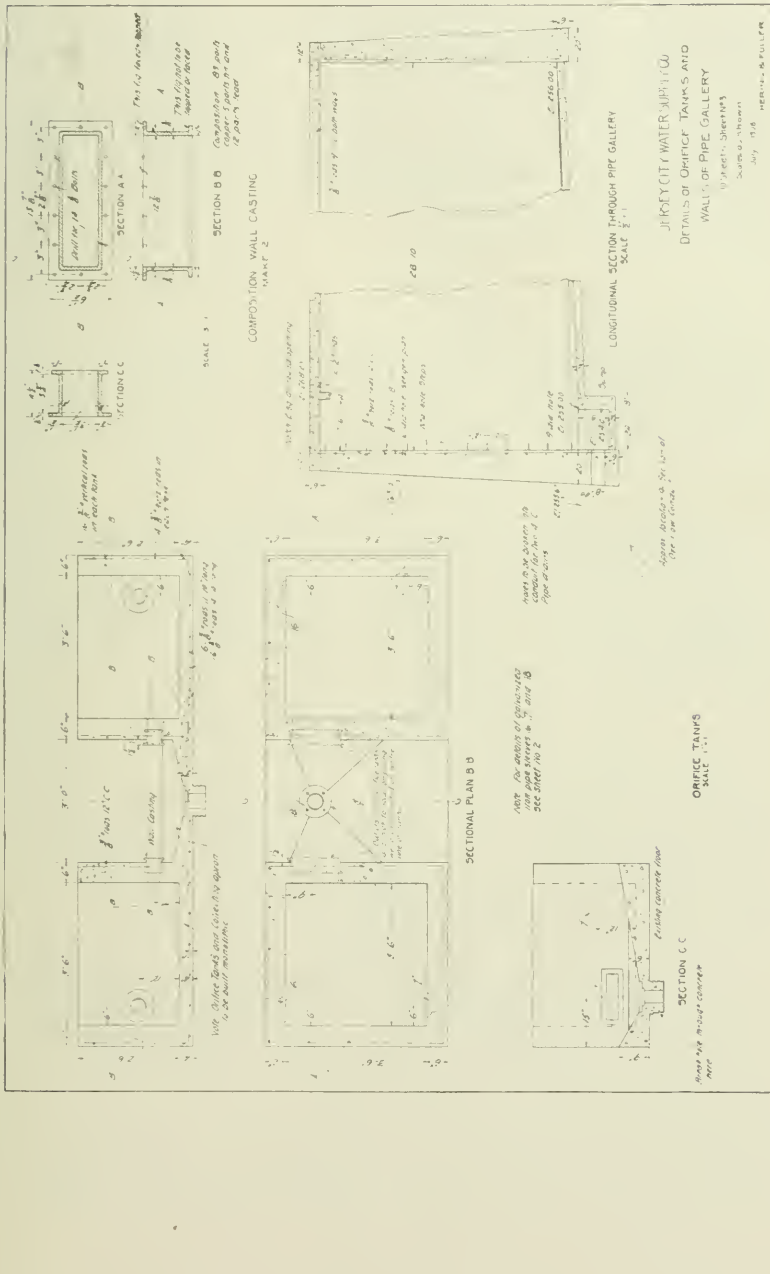
Wooden covers protect the floor stands for these devices from rust so far as practicable.


JERSEY CITY WATER SUPPLY CO.
DETAILS OF SOLUTION TANKS
GALVANIZED IRON PIPE SLEEVES
Connection Between Mixing and Solution Tanks
PLAN OF FLOOR OVER TANK
SECTIONAL PLAN AA
SECTION BB
SECTION C-C
SEC DD
Dissolving Tank
HERING & FULLER ENGINEERS
Note Each Tank to be built monolithic


STEEL TOOTH
ANCHOR BOLT
GUIDE BEARING AND ANCHOR PLATE
JERSEY CITY WATER SUPPLY CO
STIRRING APPARATUS FOR
DISSOLVING TANKS
July 1908
HERING & FULLER ENGINEERS
SECTION A A
AGITATING ARMS
C I FLANGE THREADED AND KEY SEATED
SECTION THROUGH DISSOLVING TANK
MAKE 3 SETS OF STIRRING APPARATUS
VERTICAL SHAFT C R S


STIRRING ARM AND CLAMP
VERTICAL SHAFT
JERSEY CITY WATER SUPPLY CO
STIRRING APPARATUS FOR
SECTION THROUGH SOLUTION TANK
MAKE 3 SETS OF STIRRING APPARATUS


END ELEVATION
SIDE SECTIONAL ELEVATION
PART SECTIONAL PLAN A A
JERSEY CITY WATER SUPPLY CO
FLOOR STANDS FOR STIRRING APPARATUS
HERING & FULLER
ENGINEERS


JERSEY CITY WATER SUPPLY CO
DETAILS OF ORIFICE TANKS AND
WALLS OF PIPE GALLERY
LONGITUDINAL SECTION THROUGH PIPE GALLERY
COMPOSITION WALL CASTING
SECTION A A
SECTION B B
SECTION C C
SECTIONAL PLAN B B
ORIFICE TANKS
HERING & FULLER

DEPTH RECORDERS

In each of the three solution tanks are float pipes in which copper floats are placed to actuate a self-recording depth recorder of the standard type. The dials are 12 in. in diameter, which is the size of the chart upon which is recorded continuously the depth of solution in tanks. Glass sight tubes are also attached to the sides of the solution tanks so that by entering the pipe gallery the level of the solution in each tank may be noted by the level in the glass tube.

PUMPS

The belt-driven turbine pumps have 2-in. connections and have a nominal capacity of 25 gallons per minute. They are built of special bronze. One pump is to be used at a time, the other being in reserve.

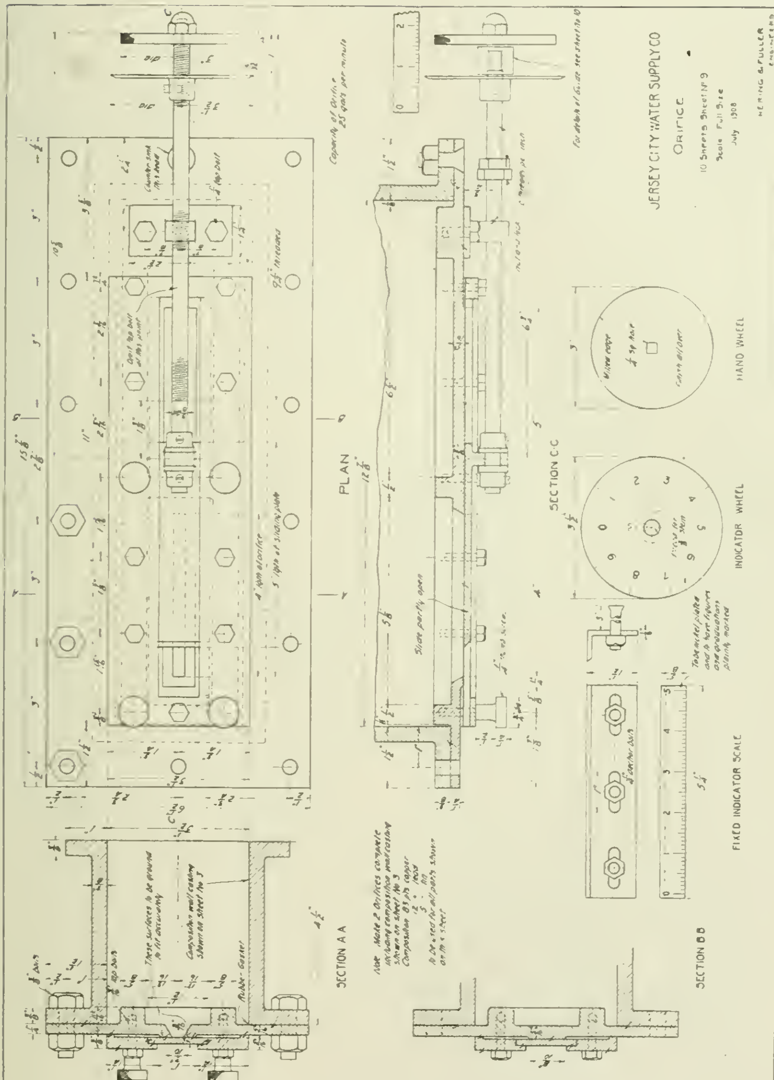
POWER EQUIPMENT

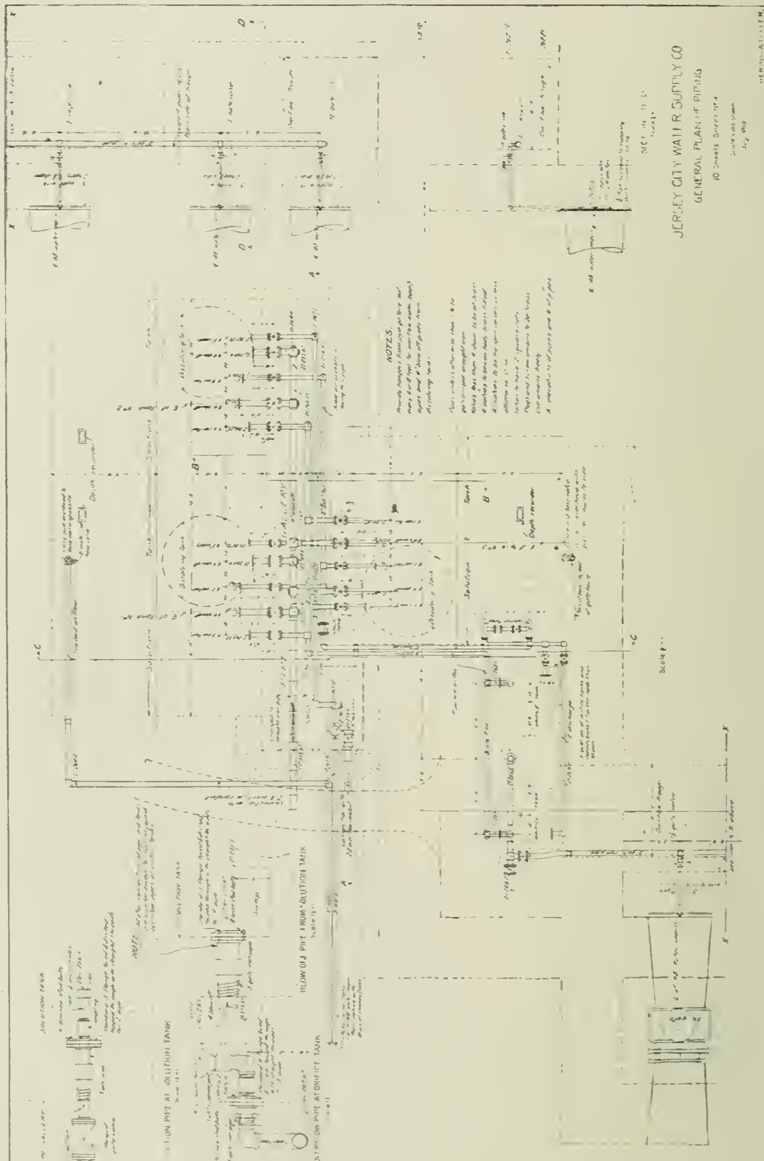
Water coming from the reservoir to the lower gate house on its way to Jersey City drives a 30-h.p. horizontal turbine wheel to develop power needed for pumping and stirring the solutions. Temporarily two vertical boilers of 12 and 15 h.p. and two small engines of 10 and 20 h.p. were used.

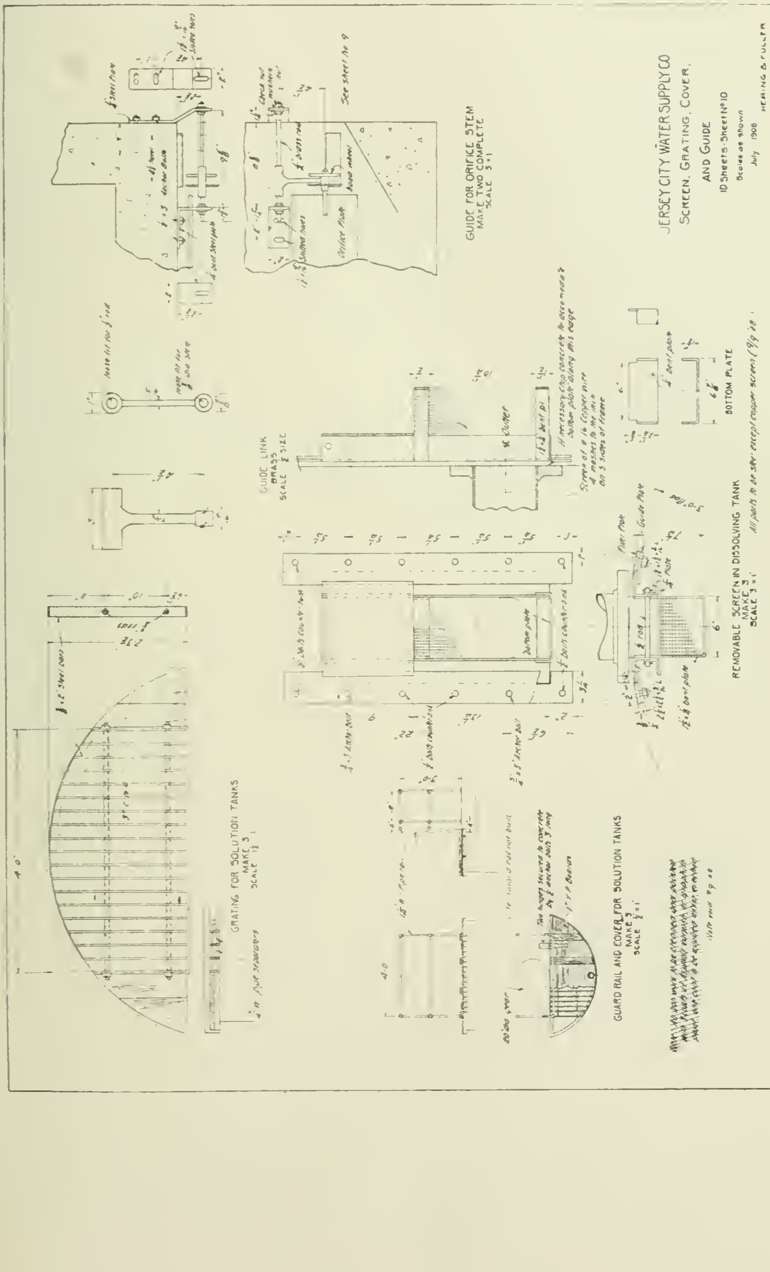
ORIFICE TANKS AND APPURTENANCES

There are two concrete orifice tanks, 3 ft. 6 in. square in plan, and 2 ft. 6 in. deep. The delivery pipe from the pump discharges into either one of these orifice tanks as desired. An excess of solution is always pumped to them, which excess flows back to the solution tank through a 3-in. overflow pipe.

Each tank is provided with an outlet in the shape of an adjustable orifice which is made of a special composition of copper, lead and tin and is arranged so that with the aid of a fine micrometer screw a cover is moved backwards and forwards over a slot, thus permitting the use of an area of orifice found to give the desired volume of solution under a constant head. As already explained the excess volume of solution is taken care of by means of an overflow pipe, thus preventing an excessive head upon the orifice; and any deficiencies in head or depth


JERSEY CITY WATER SUPPLY CO
ORIFICE
10 Sheets Sheet No 9
Scale Full Size
July 1908
HERING & FULLER
ENGINEERS
PLAN
SECTION C-C
HAND WHEEL
INDICATOR WHEEL
FIXED INDICATOR SCALE
SECTION A A
SECTION B B


JERSEY CITY WATER SUPPLY CO
GENERAL PLAN OF PIPING
NOTES.


JERSEY CITY WATER SUPPLY CO
SCREEN, GRATING, COVER,
AND GUIDE
10 Sheets - Sheet No 10
Scales as shown
July 1908
HERING & FULLER
ENGINEERS
GUIDE FOR ORIFICE STEM
MAKE TWO COMPLETE
GUIDE LINK
BRASS
REMOVABLE SCREEN IN DISSOLVING TANK
MAKE 3
BOTTOM PLATE
GRATING FOR SOLUTION TANKS
MAKE 3
GUARD RAIL AND COVER FOR SOLUTION TANKS
MAKE 3
Orifice Plate
Bottom plate

of liquid over the orifice are indicated almost instantly by a copper float adjusted so as to ring an alarm gong.

Only one device is used at a time, so that as in all other features, the plant is built in duplicate.

PIPING FOR APPLICATION OF SOLUTION TO RAW WATER

The prescribed volume of solution of known strength flows by gravity from the orifice tanks through a 3-in. galvanized iron pipe line into the screen chamber located beneath the floor of the lower gate house. This main pipe branches into 4 lines, each 1.5 in. in diameter and extending to a grid fastened over the mouth of each of the four 48-in. mains coming from the reservoir. The grids are made up of 1-in. pipe drilled with twelve $\frac{1}{4}$-in. openings pointed downward. The grids are fastened in place by $\frac{3}{4}$-in. wrought iron bars bolted to the masonry.

The solution and the water treated are well mixed before entering the concrete aqueduct.