<u>An Investigation of the Purification System</u>

<u>Of The</u>

<u>New University Club Swimming Pool</u>

<u>And An</u>

<u>Attempt To Increase The Efficiency of Operation</u>

****

<u>A   THESIS</u>

****

<u>Submitted in Partial Requirements</u>

<u>For the Degree Of</u>

<u>Bachelor Of Science</u>

<u>From the</u>

<u>Massachusetts Institute of Technology</u>

Author

Approved By

The authors wish to thank Professor Tyler for the assistance and recomendations rendered to them during the work on this thesis.

156115

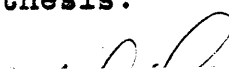## TABLE OF CONTENTS

INTRODUCTION

The sanitation of swimming pools, while not the most important subject in the field of sanitary science, is, nevertheless, a most important, and at the same time, vital subject for our consideration. When we consider the millions of persons who use daily during the summer every available swimming pool and shower in the country, the importance of these institutions becomes only too apparent.

These pools afford excellent opportunities for the possible infection of millions of bathers. Water can act as a transmissable medium for any communicable disease. As a source of infection for intestinal diseases, such as typhoid and dysentery; eye and ear infections; for venereal contagion; for infections of the respiratory system, such as grippe, colds, pneumonia, sinus infections, acute otitis media, and some protozoan diseases, the swimming pool is one of the most dangerous menaces. For this reason it is most urgent and necessary that persons having any contagious diseases be kept from entering or using these highly contaminable public places.

Swimming pools have so grown in number and popularity during the past decade that innumerable state laws have been passed regulating and controlling their operation. A great majority of the states have passed and have in operation regulations governing the use and care of swimming pools. These regulations deal with the allowable quality and purity of the water in the pool, with the amount of water necessary per bather, with pre-showers and other pre-washing regula-

tions, sterilization of bathing suits and purification of water. These laws give the control of the swimming pools into the hands of the various State Boards of Health, and make compliance with the regulations mandatory and binding upon the various swimming pool operators.

Relative to the number of people using a pool, the committee on bathing places has estimated that the total number should not exceed twenty for each thousand gallons, and during disinfection periods, seven to each thousand gallons. The prevalent opinion is that this number may be safely raised to thirty or even forty per thousand gallons, since these latter figures are used in all the large natatoria in Chicago. Observations at one pool for four seasons where the bathing load often reached ninety to a hundred per thousand gallons showed only one otitis and one derm-otitis infection whose possible etiology might be traced to the swimming waters. During the course of the experiments at the University Club, the total number of persons in swimming varied between 14 and 50 per day, which is less than one per thousand gallons of water. With this low bathing load one cannot deduce much in regards to the effect on the pool under maximum load.

The swimmer is considered of first hygienic importance. With him in a hygienic state the problem is materially simplified. Ex-periments made by Bengt Norman Bengston, M. D., concern the impor-tance, bacteriologically, of supervised showers before swimming, a point, by the way, usually overlooked by most pool caretakers.

An individual was placed in a sterile pan and washed from head

to foot. Total bacterial counts were made of the washings before and after the subject had a thorough soap shower. High, low, and average counts are listed of ten individuals. The results are tabulated in Table I.

In order to make the results as average as possible, subjects from various occupations were used: laborers, mechanics, a student, a life guard, chauffeurs, etc.

It has long been conceded that a shower prior to swimming is essential to pool hygiene, and yet it is very common to have even the more intelligent class of men enter the pool without taking a preliminary shower. Again many of the swimmers have only a perfunctory wetting before entering the pool.

Using the difference in count in A and B Series No. 1, and with a tank as at the University Club with 84,000 gallons of water capacity, it can be seen that the bacterial count would be increased some 50 per cubic centimetre per person over the usual count coincident with a swimming day.

Thus, careful supervision at the shower room of the pool would decidedly lower the bacterial count of their waters.

The University Club insists that its patrons wear a loin cloth, which is made of light washable cotton. It also should be insisted that the patrons should not don the loin cloths until after the shower. The importance of this can be appreciated by referring to Series No. 2, where it isshown that one swimmer may pollute the water to the extent of 9,000,000,000 bacteria, mostly B. coli.

Rubber caps are of greater value than is head washing as is demonstrated in Series No. 3. At the University Club the wearing of rubber caps is entirely optional, but judging by observation, very few choose to wear any headgear.

The attendant at the pool should watch vigilantly for any pustulations and should bar such persons so affected from the pool; for it is well known from past bacteriological investigations of similar conditions a small suppurative lesion could easily transmit billions of organisms to the water, and particularly the type that would tend to pathogenicity.

It has been the practice at some pools to advocate showers after swimming merely as a preventation against any bacterial infection that might result from the water. The mechanical lowering of the film of bacteria on the recent swimmer by washing with water, or with soap and water, lessens that persons changes for any infection whose source might be the swimming pool.

TABLE A.

SERIES I.		ENTIRE BODY	
A. Count before Shower		B. Count after Shower	
High Count	46,000,000,000	12,010,000,000	
Low Count	1,150,000,000	3,800,000	
Average of ten . .	17,529,000,000	2,771,560,000	

SERIES II.   PERINEALAND PUBLIC REGIONS

A. Before Shower		B. After Shower
High Count	28,220,000,000	1,968,000,000
Low Count	1,790,000	2,000,000
Average of ten . .	9,788,923,000	553,824,000

SERIES III-A   HEAD AND NECK

A. Before Shower		B. After Shower
High Count	12,000,000,000	270,000,000
Low Count	330,000	60,000
Average of ten . .	1,919,035,600	44,749,000

SERIES III-B   HEAD AND NECK

Subject wearing Rubber-Caps.

A. Before Shower with Cap on.		B. After Shower
High Count	721,000	809,000
Low Count	22,000	13,200
Average of ten . .	404,420	286,300

SERIES IV.   COMPARISON OF SUITS

A. Private Suits		B. Pool Suits
High Count	1,980	390
Low Count	802	32
Average of ten . .	1,100	106

THESIS

    The particular pool in which we ran this thesis was situated in the new University Club of Boston. At the present time it has been in operation only a few months, the building having been erected in the year of 1926. The pool has a capacity of approximately 84,000 gallons. Its maximum depth is at a point 5 yards from the deeper end. This maximum depth comes directly under the end of the diving board. Toward this low point the bottom slopes from both ends. The 2 outlet pipes are situated about 18 inches from the sides of the pool on this line of maximum depth. The total length of the pool is 75 ft. and the width is 25 ft. There are six inlet pipes situated at the 5 , 35 and 65 ft. marks along the both sides of the tank. These are placed at a depth of 2ft-6 inches from the top of the scum drains. This provides for an even distribution of the purified water, and prevents any portion of the water from becoming stagnant and not going through the purification system.

    The entire pool is made of reinforced concrete and surfaced with white tile. There are three showers, a lavatory and a drinking fountain in the tank room.

    The water in the pool is very seldom changed; in fact, at the present time, the same water that was originally put in is still there, with the small exception of what little goes over into the scum drains. This loss is supplied from the city mains and is heated, if necessary, to bring it up to the temperature of the pool

water, and is then sent through the filters to the tank. It is easily seen that in using water for such a long period of time, it is absolutely necessary to purify it in some manner.

This purification is obtained by circulating the water by means of a centrifugal pump through a set of pressure filters, passing it then through a chlorinator and back into the tank.

The filters are of steel construction, designed for 100 lbs. water working pressure. Shell plates are of mild tank steel and a factor of safety of four is utilized in computing thicknesses and methods of riveting. Before shipment, each tank is subjected to and made tight under a hydrostatic test pressure of 150 pounds per square inch. Top and bottom heads are made of flange steel and are dished to a radius equal to the diameter of the filter shell. A cast iron elliptical manhole frame having 10" by 14" clear opening is riveted to the shell plate at proper location to permit access to the interior of the filter. This manhole is provided with a cast iron cover which is secured to the frame with steel stud bolts having hexagon nuts. A filling hole with cast iron cover is provided in the top head. Before shipment, each tank is painted inside with an approved rust resisting paint and outside with black asphaltum paint.

The filtering material consists of a bed of selected silica sand superimposed on a graded bed of hard filter gravel. The underdrainage system, which consists of a centrally located manifold with galvanized perforated strainer pipes placed on 6" centers, is designed to secure uniform withdrawal of filtered water and effective distri-

tribution of wash water.   A cinder concrete·fill is placed with-
in each filter, beneath the underdrainage system, before shipment.
A circular baffle plate is located under the inlet pipe to pro-
vide for distribution of the raw water over the filter bed.

The five-way central controlling valve, with which each fil-
ter is equipped, is constructed of first quality valve bronze thru-
out.   The tapered plug is hand ground to insure a tight and working
fit in the valve seat.   The simplicity of the valve is apparent
as the attendant need only move the valve lever to bring the pointer
to the location on the dial indicating the desired function whereas
with a series of small valves, filter, several valves must be open-
ed and closed to accomplish the same purpose.   A sight trap with
glass for the drain connection is used with filter.

A coagulator is used with the installation.   The function of the
coagulator is to dissolve and proportionately feed into the incoming
raw water-minute quantities of crystal alum which, when combined with
the impurities and suspended matter, coagulates them and forms a prac-
tically impervious gelatinous mass on the upper surface of the filter
bed.   The coagulator consists of a cast iron chemical containing
chamber with a bronze removable filling plug in the top head; a cast
iron differential tube for insertion in the raw water supply main and
brass piping to connect the differential tube with the chemical chamber.
A similar device could be furnished for feeding a solution of soda when
filtering water having insufficient alkalinity to secure a coagulant re-
action.

Washing of the filter is accomplished under the high velocity principle without the aid of air or mechanical agitation. The flow of either raw or filtered water is reversed through the filter bed at a rate of twelve to fifteen gallons per square foot of filtering area per minute, and the collected impurities and suspended matter are carried to drain with the waste wash water.

The process of coagulation is based on the fact that soluble salts of aluminum, iron (inboth the ferrous and ferric state), zinc, copper, and some other metals react with the solutions of the hydroxids, carbonates, and bicarbonates of the alkalis and the alkaline earths to form gelatinous precipitates of the hydroxids of the metals. For economic reasons and because of the poisonous quality of the salts of some of the other metals, sulphate of aluminum or sulphate of iron are most generally used, the requred concentrations of hydroxyl ions being supplied by the salts of the alkaline earths quantities, by the addition of hydrated lime or soda ash.

When sulphate of aluminum is added to water, the precipitate takes the form of small flakes about the size of a pin head, and white in color. Due to their gelatinous form, these flakes sink very slowly. As is commonly the case with reactions between solutions in water, the precipitate tends to form about the particles of silt, bacteria, etc., present, and in traveling through the water, more silt becomes attached to the flakes of coagulum and these unite, one with the other, until quite sizable masses are formed, which either settle to the bottom of the sedimentation basins or are caught on the filter sand, being too

large to pass through the interstices between the grains. Such

of the coagulum as is carried over the filters forms a gelatinous

coating over the surface of, and in the upper part of the filter

sand, which constitutes the real filtering medium.   The portion

of the coagulum which is carried over on the filters forms over

the sand a film or layer of gelatinous substance perforated by

very fine pores, through which water readily passed, but which are

impenetrable to fine suspended matter or even to matter in pseudo-

solution.   This film also has an absorptive action on the water

passing through it removing colors, odors, and tastes.

Aluminum sulphate $(Al_2(SO_4)_3 \cdot 18H_2O$ commonly filter alum, in its

purest commercial form consists of small lumps ($\frac{1}{2}$ to $2\frac{1}{2}$ inches in

size) hard, having a greasy feel and an opaque, greenish-white

color.   It should contain 51% aluminum sulphate and 49% hydration,

but owing to the process of manufacture the composition may vary,

and some of the authorities assign to the commercial product the

formula $Al_2(SO_4)_3 \cdot 16H_2O$ Theoretically it should contain 15.3%

of water soluble alumina Al O, but it is generally specified to con-

tain not less than 17%, being known as basic. aluminum sulphate.   It

should contain more than 0.5% matter insoluble in cold distilled water.

Impure alum generally has a brownish tinge.

Alum and Alkalinity Equation

$$Al_2(SO_4)_3 + 3CaCO_3 \cdot H_2CO_3 \longrightarrow Al_2(OH)_6 + 3CaSO_4 + 6CO_2$$
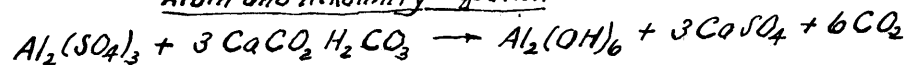
Calcium sulphate remains in solution, causing permanent hardness.

The increase in permanent hardness is 10.4 p.p.m. or about 0.6 grains

per gallon for each grain per gallon of aluminum sulphate used.   Car-

bonic acid (CO2) is an objectionable by-product, especially in waters of low alkalinity, owing to its corrosive action. If sufficient alkalinity, natural or otherwise, is not present to react with the aluminum sulphate, basic sulphates will form. Some of these are soluble, so that no coagulation may appear.

INLET

ALUM TANK.

Control Valve

Sight Trap

Manhole.

Sample Faucet

Waste.
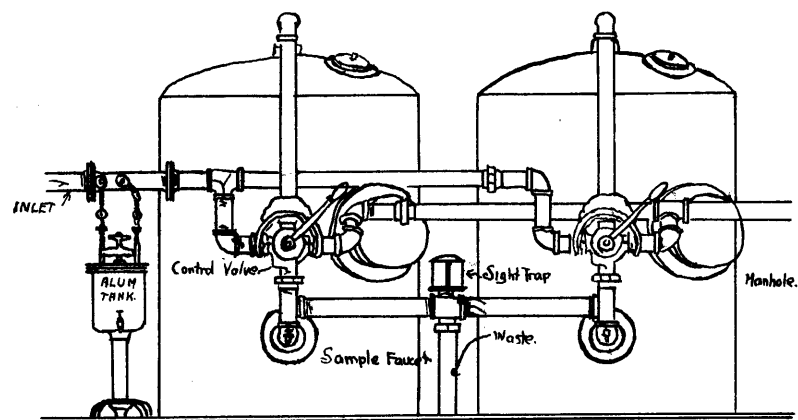
FRONT ELEVATION OF FILTERS
AT
THE NEW UNIVERSITY CLUB OF
BOSTON.

Baffle Plate.

Filtering Surface

SAND

Manifold and Laterals   GRAVEL

Concrete Fill
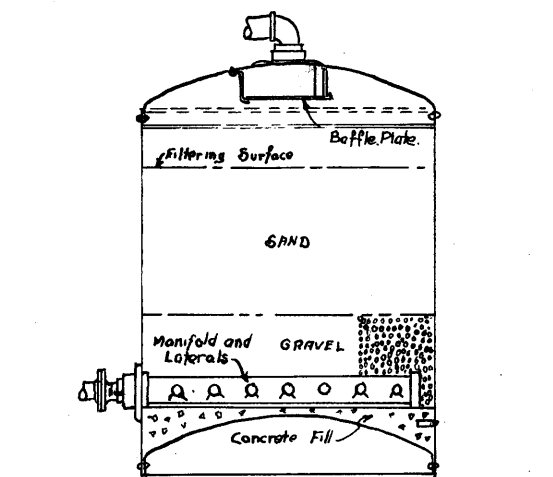
CROSS SECTION OF
FILTER

ALUM POT USED
AND CONNECTIONS.
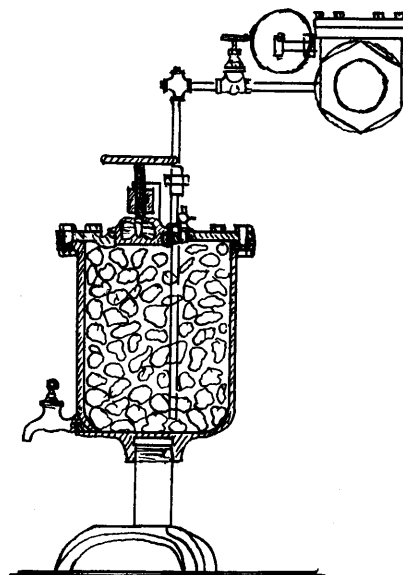
CHLORINATOR

Chlorine gas liquified by pressure is now used at the University Club pool for sterilizing the water. Its germ-icidal effect results from the same cause as does that of chlorid of lime, namely, by the liberation of nascent oxygen. The reaction is: -
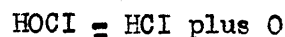
CI-2 plus H-2-O = HOCI plus HCI

HOCI = HCI plus O
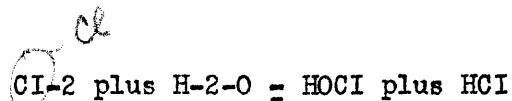
The hydrochloric acid formed reacts with the carbonates and bicarbonates of the water to form chlorids and carbonic acid. As the gas is essentially 100 per cent "available chlorine" only about a third as much is required as a bleach. The commercial gas is 99.8 per cent pure chlorine and is pur-chased in steel cylinders 8 inches in diameter and 60 inches high, holding 100 pounds of chlorine. The pressure in the cylinders ranges from 50 to 100 lbs. per square inch, varying with the temperature.

The usual dosage is from .25 to .50 part per million or 2 to 4 pounds per million gallons. Sometimes in a polluted or suspicious water, as much as 1.0 part per million is used, but this generally causes a noticeable taste. The dosage is effected by the presence of organic matter or oxidizable salts and by the hydrogen ion concentration, as might be expected from the fact that oxidation results more quickly in the presence of free car-bonic acid.

The principle involved in the construction of the apparatus now being used for the application of chlorine gas is that of maintaining by means of suitable pressure reducing valves a constant drop in pressure across an orifice. The apparatus consists essentially of a reducing pressure valve in the pipe leading from the supply tank, a second regulating valve following the first valve, an orifice plate and an absorption tank. The first valve reduces the initial pressure of the gas coming to the supply tank to about 15 pounds per square inch. The gas then passes through the second adjustable reducing pressure valve by which any desired pressure may be maintained over the orifice plate in the pipe line. Between the second regulating valve and the orifice plate there is a branch pipe line to which a chlorine pressure gage is attached. This gage is caliberated in pounds per hour, and thus serves to indicate the rate of discharge of the gas for any given setting of the second regulating valve.

After passing the orifice plate, the gas is conducted to the bottom of an absorption tower. Water admitted at the top of the tower flows down in such a manner as to offer a large surface for the absorption of the ascending gas. The chlorine solution thus produced is conducted to the water to be treated.

The attached diagram of the chlorinator will serve to give an idea of the operation. The liquid chlorine is in the cylinder (a), equipped with the cylinder valve (b). Connection to the apparatus is made by the special coupling (c), which includes an auxiliary valve, and by flexible tubing of non-corrosive metal to the compensation (d),

which maintains a constant pressure of gas on the apparatus
for any setting of the valve.   The chlorine control valve
(e) enables the operator to adjust the rate of flow of the
chlorine to the desired amount as indicated by the volumeter
(g).   The gage (f) indicates the tank pressure.   The volumeter
is immersed in the solution jar (h) which receives an auxiliary
supply of water from the connection (j) to dissolve the chlorine.
The chlorine then flows to the point of application through the
flexible tube (m).   An important feature is the check valve (i)
which prevents water and moisture from backing into the compen-
sation where it would cause serious trouble by clogging and
corrosion.   The auxiliary water supply is provided with a press-
ure reducing valve (k) and gage (e), and a water seal (n) pre-
vents the entrance of air where the solution discharges into a
pump suction.   The auxiliary pressure should be at least 15
pounds and the rate of flow 20 gallons per hour.   The auxiliary
pressure is greater than the pressure in the pipe from the filter
apparatus and a check valve prevents the water from the effluent
pipe from backing into the apparatus in event of failure of the
auxiliary pressure.
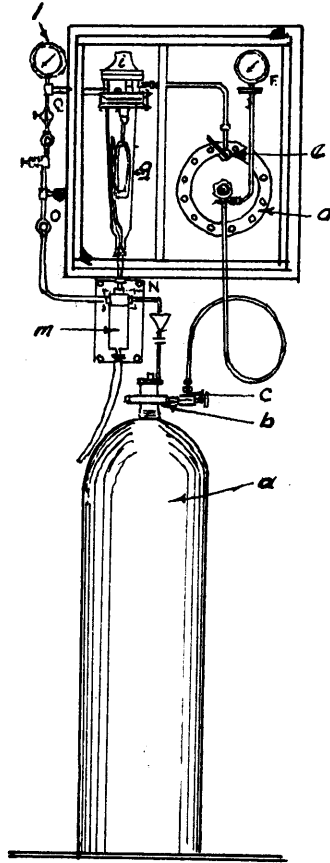
CHLORINATOR AS USED
AT THE UNIVERSITY CLUB

SCUM DRAINS

The scum gutters at the University Club pool are cast so that the lip of the water channel fits the hand and provides an excellent hand-hold, while the channel itself forms an expectoration and overflow trough, and a passage through which all surface wastes and dust may be carried away to the sewer. The scum gutters extend around the whole pool, but due to faulty construction some of the drains fail to emply quickly and completely, because the slope of the gutter in these cases is away from instead of towards the drain. This is particularly true at the corners of the pool where water remains until it evaporates. The objection to these conditions is that every now and then a wave comes along, strikes the wall, overflows the gutter, and carries back a part of the contents into the pool. But even here the scum gutter gets rid of a lot of dangerous wastes from the bodies of the bathers.

Much of the material discharged from the noses and throats of the patrons of the pool will float, and will collect at the point where the dust gathers. The sooner such material goes down the sewer, the better, for it is potentially dangerous. Bathers should be requested to spit in the scum gutter, but the man who is in the middle of the pool must spit somewhere when he takes aboard too much water, and he can't take the time to come clear over to the edge in such an emergency.

Dust and collections of floating material may be flushed away merely by raising the water level and letting the overflow carry it into the scum gutter and so on to the sewer.

DISCUSSION OF pH AND ITS EFFECT ON CORROSION

According to the generally accepted theory of corrosion to-day, the principle factors causing this phenomena are oxygen content, hydrogen ion concentration, the temperature, the presence of protecting films over the metal in question, the surface of the carroding liquid exposed to the air, light, and many other minor factors. The main factors, however, are the oxygen content, and what is closely allied, the surface of the water exposed to the air; also the hydrogen ion concentration, or in other words, the pH value and the temperature. The explanation of this is as follows: -

Iron or any metal, for that matter, when it is submerged in a liquid tends to go into solution; that is, to give off the ion corresponding to the metal immersed. If this metal is iron, as in iron pipe, Fe-plus-plus ions are given off. This leaves the metal body charged negatively or with a lack of the positive charges, which were taken off with the ions. The attraction between unlike charges will tend to pull the Fe-plus-plus ions back to the metal, unless there is some other positive ion which will come back easier to supply the dearth of positive charges. In corrosion, it is usually the case that the ion that is present and which will come back much more easily, due to its place in the electrochemical series, as the hydrogen H-plus. So, we see that if we have a large concentration of H ions, this proceedure of iron going into solution and its place being taken by hydrogen, will go on very rapidly. The curve for the rate of corrosion, plotted against the pH value, is given.later. (Curve No. 1). Here it can be seen that temperature has a very large effect and that the curve

is divided into three parts, namely, the alkaline zone, the ~~mental~~ neutral
zone, and the acid zone. As the pH descreases the effect of this
factor increases, so that as we get more toward the acid zone, the
effect of this increase in hydrogen ion concentration increases to
a very large extent.

The following table showing the relative effects of the im-
portant factors influencing corrosion, are the alkaline zone, the
neutral ~~mental~~ zone, and the acid zone.

So far we have not shown where the oxygen comes into the pic-
ture as a most important factor in increasing corrosion. When the
hydrogen ion is attracted to the metal in question, it gives up its
positive charge and clings to the metal as a thin film of hydrogen.
This prevents further iron from going into solution and so decreases
the rate of corrosion. However, if oxygen is present, this sub-
stance will unite with the hydrogen film to form water H_2O, leaving
the iron free to go into solution. Thus, the oxygen plays a very
important part in the speed of the reaction, especially in water of
a high pH value.

Let us now see how these factors could affect our particular
problem at the University Club. In the first place, we have a warm
water to deal with. The temperature of the water is kept to a rather
high point continually, due to its position in the heated building.
The pool itself serves as a good aerator, exposing a large surface of
water, which is being continually broken up by the swimmers plunging
into it. Thus, it is easily seen that the oxygen concentration is
fairly high. The pH, however, is lowered by the addition of alum to

a water whose alkalinity has already been all used up. According-
ing to tests, as shown in table, this value was 4.5 to 5.0 at
first, after the water had been continually fed alum for a period
of months, and stayed there until we started to add soda ash. So
we can take about 4.5 to 5.0 as a minimum value of pH to be obtained
in an excessively treated alum water. This value, as seen on the
chart, is just at the later part of the neutral zone.

After treating the water with soda ash for several days to bring
up the alkalinity, we increased the pH value to nearly 8.0. According-
ing to the curve, it is seen that even at 40°C, which is 104°F, and
much higher than the value obtained in the pool, there is practically
no reduction in corrosion due to such a decrease of pH.

Since oxygen content and other factors, although they may be
excessive, cannot be altered, and since it is impossible to increase
the pH value enough to get it completely out of the neutral zone and
still have a good water, the effect of the low pH as obtained by the
addition of excessive amounts of aluminum sulphate on the corrosions
of the piping system, is negligible.

The pipes outer surfaces have, it is true, corroded to a very
large extent but this is due to the chlorine which has escaped from
the chlorinator and not the low pH of the water in the system.

TABLE B.

Relative importance of the important factors affecting the corrosion of steel.

ALKALINE ZONE	NEUTRAL ZONE	ACID ZONE
pH 7-10	pH between 4.3 to 10.0	pH less than 4.3
Protective coatings	Oxygen Concentration	pH value
Oxygen centration	Protective coatings	Hydrogen over voltage
Composition of metal	pH value	Composition of metal
pH value	Composition of metal	Oxygen concentration
Hydrogen over voltage	Hydrogen over voltage	Protective coatings.
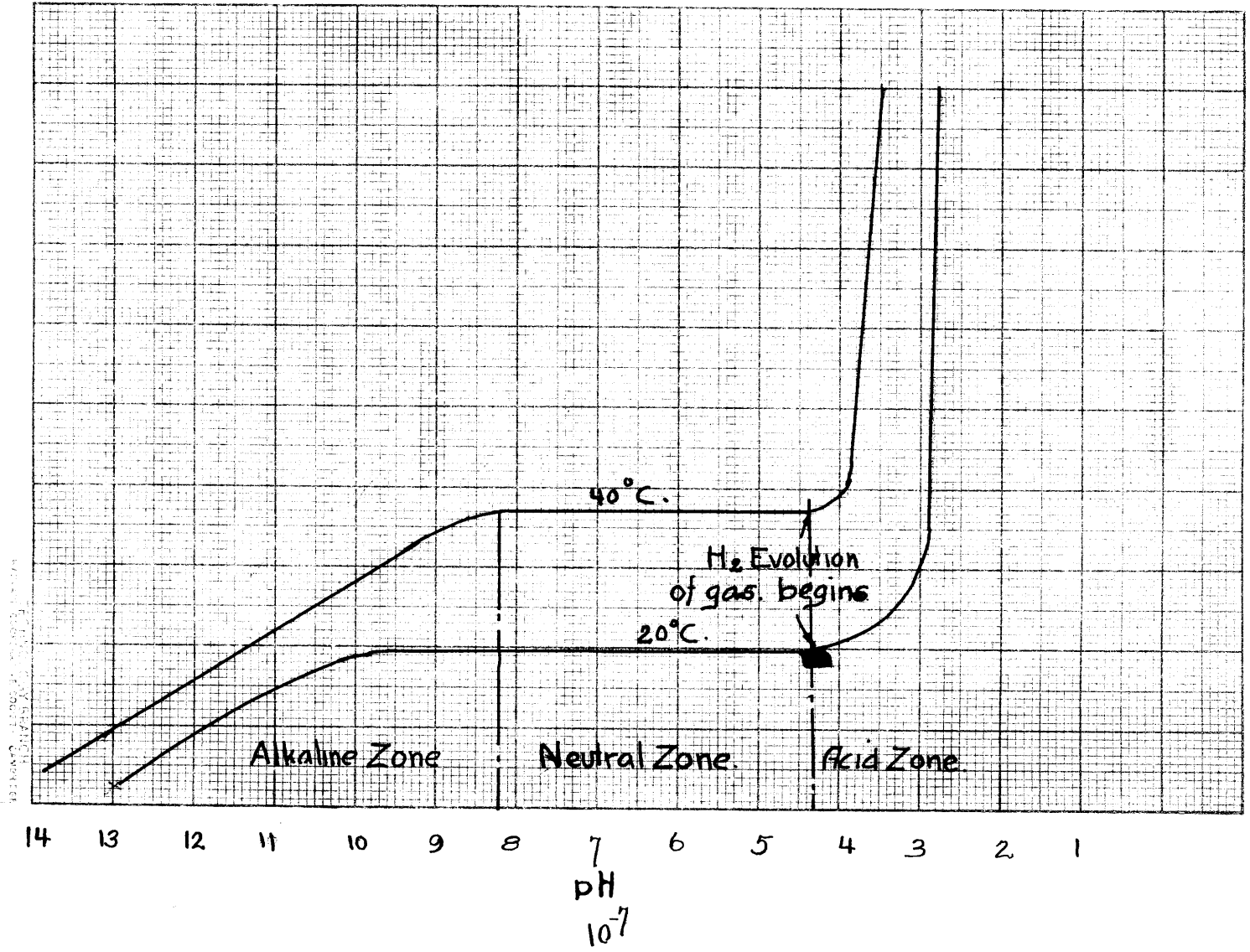
PROCEDURES

Bacteriological

Bacteriological tests were made on all samples for total count at $37^{\circ}C$ and $20^{\circ}C$ on nutrient agar and for gas formers in 10cc samples of water inoculated into fermentation.tubes with 30cc of lactose broth.

pH

The pH of the water was determined colorimetrically by the use of the LaMotte colorimetric apparatus.

Chemical

All the chemical tests were performed according to procedures outlined in Standard methods, which are as follows: -

ALKALINITY

The alkalinity of a natural water represents its content of carbonate, bicarbonate, borate, silicate, phosphate, and hydroxide. Alkalinity is determined by neutralization with standard sulfuric acid or potassium bisulfate in the presence of phenolphthalein and either methyl orange, erythrosine, or lacmoid as indicators. Methyl orange may be used except in waters containg aluminum sulfate or iron sulfate. The alkalinity of carbonates in the presence of phenolphthalein is different from that in the presence of methyl orange, partly because of loss of carbon dioxide and partly because of defects in phenolphthalein as an indicator in such conditions.

Add 4 drops of phenolphthalein indicator to 50 or 100 cc. of the

sample in a white porcelain casserole or an Erlenmeyer flask over a white surface. If the solution becomes colored, hydroxide or normal carbonate is present. Add N/50 sulfuric acid from a burette until the coloration disappears.

The phenolphthalein alkalinity in parts per million of calcium carbonate is equal to the number of cubic centimeters of N/50 sulfuric acid used multiplied by 20 if 50 cc. of the sample was used, or by 10 if 100 cc. was used.

ACIDITY

Waters may have an acid reaction because of the presence of free carbon dioxide, mineral acids, or some of their salts, especially those of iron and aluminum.

Reagents.-- 1. N/50 sodium carbonate. Dissolve 1.06 grams of anhydrous sodium carbonate in 1 liter of boiled distilled water that has been cooled in an atmosphere free from carbon dioxide. Preserve this solution in bottles of resistant glass protected from the air by tubes filled with soda-lime. One cc, is equivalent to 1 mg. of $CaCO_3$.

2. Phenolphthalein indicator.

Procedure. -- Add 4 drops of phenolphthalein indicator to 50 or 100 cc. of the sample in a white porcelain casserole or an Erlenmeyer flask over a white surface. Add N/50 sodium carbonate until the solution turns pink. The total acidity in parts per million of calcium carbonate is equal to the number of cubic cen-

timeters of N/50 sodium carbonate used multiplied by 20 if 50

cc. of the sample was used, or by 10 if 100 cc. was used.

TOTAL HARDNESS BY SODA REAGENT METHOD

Add standard sulfuric acid to 200 cc. of the sample until

the alkalinity is neutralized.   Then apply the non-carbonate

hardness method.   This method gives fairly satisfactory esti-

mates of total hardness of hard waters.

NON-CARBONATE HARDNESS BY SODA REAGENT METHOD

The use of soda reagent does not avoid entirely the error

due to solubility of the salts of calcium and magnesium; con-

sequently, if much depends on the results, as in water soften-

ing, gravimetric determinations of the calcium and magnesium that

remain in solution should be made and a correction should be

applied for those amounts.

Reagent.— Prepare soda reagent from equal parts of sodium hydrox-

ide and sodium carbonate.   It should be approximately tenth normal.

Procedure.— Measure 200 cc. of the sample and 200 cc. of distilled

water into 500 cc. Jena or similar glass Erlenmeyer flasks.   Treat

the contents of each flask in the following manner.   Boil 15 min-

utes to expel free carbon dioxide.   Add 25 cc. of soda reagent.

Boil 10 minutes, cool, rinse into 200 cc. graduated flasks, and di-

lute to 200 cc. with boiled distilled water.   Filter, rejecting the

first 50 cc. and titrate 50 cc. of each filtrate with N/50 sulfuric

acid in the presence of methyl orange or erythrosine indicator.   The

non-carbonate hardness in parts per million of calcium carbonate is

to 20 times the difference between the number of cubic centi-
meters of sulfuric acid required for the soda reagent in dis-
tilled water and the number of cubic centimeters of N/50 sul-
furic acid required for the soda reagent in the sample.

Water naturally containing bicarbonate and carbonate in
excess of calcium and magnesium requires a larger amount of acid
to neutralize the sample after it has been treated than is re-
quired to neutralize the volume of soda reagent originally added.

RESULTS

Experiments were conducted to determine the efficiency of the plant as a whole and the relative efficiency of the various parts. At the beginning of these determinations it was found that we were dealing with an acid water caused by the addition of excessive amounts of alum to a water whose alkalinity had been all used up. Bacteriological tests were performed on samples taken from the pool and invariably sterile plates were obtained at the end of 48 hours. The plates were then thrown out.

These results seemed to indicate that either one or two factors were responsible for the apparent complete germicidal action in the system. The acidity of the water and the addition of excess chlorine were the two possible causes and to determine the actual cause we shut the chlorinator off and ran bacteriological tests on the pool. Again sterile plates were obtained. The acidity and pH of the water was then determined and we found that the pH varied between 4.8 and 5.1, and the acidity was approximately 33ppm. According to all the information that could be obtained on the subject, these conditions were not sufficient to cause complete destruction of the bacteria as our results indicated. By mere chance plates that had been previously counted as sterile were left in the incubator for another day. The plates were then noticed and it was found that colonies had developed in the additional incubation period. The rate of

growth was then determined for a sample from pool. The acidity
of the pool at this time was found to be 40ppm and the pH was
equal to 4.8.

The results of this particular test are shown in Table IV.
Here the preponderance of organisms that grow at 20°C is indicated.
This would indicate that most of the organisms were soil organisms
and spore-formers. The fact that no gas producers were present
points fairly conclusively to the complete elimination of all gas
formers, due to the acid condition of the water, but other organisms,
especially spore-formers are merely inhibited. Since soil organisms
are non-pathagenitic and as a rule harmless, we might say that the
inhibition action of the acidity in the water was desirable.

The pH, hardness and acidity of all samples were determined.
Table VII shows the variation in these factors during a test per-
formed for 7 days on the system as a whole. The alum pot was turned
on for one-half an hour a day and the chlorinator was run at the rate
of 60 bubbles per minute. The increase in acidity may be accounted
for by the fact that more alum was added daily. This conclusion,
however, is not justified because alum will not cause an acidity much
over 20ppm. The trouble seems to be in the titration procedure, which
was performed with an N/50 solution of sodium carbonate in the presence
of phenolphthalun. This is the procedure recommended by Standard
methods, for the determination of acidity in water, but is not suit-
able for a water in which the acidity is due to aluminum sulphate be-
cause of the alkaline hydrolysis that takes place and which consequently

gives a variable end point. Again the gradual increase in hardness is extremely hard to account for since theoretically there is no reaction taking place which will cause the increase in hardness and nothing is added to cause such an increase, since alum does not effect the hardness. The results tabulated in Table VIII for hardness when alum pot is turned off are constant as they should be, and they seem to indicate that the alum pot was responsible for the increase in hardness in Table VII.

Soda ash was then added to bring up the alkalinity . A total of one hundred and twelve pounds were added to bring the alkalinity up to 22ppm and the pH to 8.0. Tests were then run to determine the distribution of bacteria in the pool. Samples were taken at five yard intervals along each side of the pool. The results are tabulated in Table I and show a fairly even distribution of bacteria in the pool, which would indicate that one sample was representative of the pool.

The daily variation of bacteria in the pool was then determined and Table Ii gives the results of the bacteriological analysis at hourly periods from 9 A.M. to 9 P.M. The counts increase gradually up to 6 P.M. and then fall off again. These results coincide with the variation in the number of swimmers and the time of taking swim. All the tests showed the presence of B coli in 10 cc. quantities.

The essential nature of the chlorinator is demonstrated in Table III, where it is clearly illustrated that the factors are incapable of proper purification from a sanitary point of view. During the

week that this test was run the alum pot was allowed to run for one-half hour each day. The filters were not washed during the entire week, although a thorough washing was given at the start of the test. The presence of B coli w as demonstrated in all s amples taken.

Table IV gives a comprehensive idea of the efficiency of the filters. The filters were washed before starting the determinations and the pressure taken from a water gauge inserted in the influent pipe of the alum pot. The pressure read after washing was ten pounds. The alum pot was then filled and allowed to run for two hours, smples of the filter effluent being tested every fifteen minutes. The count of bacteria in the pool before starting alum pot serves as an indication of the working basis for computing the efficiency. The efficiency of the washed filter before alum was added is according to this test a little over 50%. The addition of alum serves to bring up the efficiency as measured by bacteria removal to approximately 85%. The two hour run caused an approximate total reduction of 14% of the bacteria in the pool as indicated by tests, but this result cannot be taken with too much weight, because only our sample was used and the sample was taken from the surface at the deeper end of the pool.

The chemical tests for the particular run are tabulated in Table IX. The first ample of the filter effluent shows a decided drop in pH from 8.0 to 7.2 and in alkalinity from 22ppm to 8ppm. This may be accounted for by the fact that a more concentrated solution of

alum would be injected into the system at the beginning. The
pH and the alkalinity from this point on show a slight decrease
which might be expected. The increase in hardness is not en-
tirely to be expected since the reaction between soda ash, which
forms the alkalinity in the water and aluminum sulphate does not
form products that would effect the hardness. This increase,
however, is merely temporary as is shown by Table and tapers off
again to almost the starting point.

In a similar experiment the results were practically the
same as shown by Tables VI and X.

PRESSURES. During the two hour runs the pressure readings
were taken from the préssure gauge at fifteen minute intervals.
The results of these readings are tabulated in Table XI. We
assumed that the initial reading after washing filters was the
minimum pressure for the system. This reading was 10 pounds. We
found that bacterial efficiency was greatest when pressure, as shown
by gauge, was 11 pounds or greater. These results are shown in
Table V and Table VI. In Table V the preliminary reading of the
gauge was 10 pounds and the final reading 10.8 pounds. In Table
VI the starting pressure was 11.1 and the final pressure reading was
12.0 pounds. Of the two runs, the run as indicated by Table VI,
shows the greatest efficiency in bacteria removal.

CONCLUSIONS AND RECOMMENDATIONS

By the results of the various experiments conducted at
the New University Club swimming pool, it is quite evident
that the pressure filters, as operated, merely act as strain-
ers with only a limited bacteria removal.

To remedy these conditions three possible solutions have
been devised as follows: -

1. To use the alum pot both as an alkaline pot and an
alum pot. The pot to be filled with soda ash the first day
and allow to run until the soda ash has been completely in-
troduced into the system and on the second day to fill the pot
with alum and carry on the same procedure as with the soda pot.
This procedure is somewhat better than the system now in use in
that it insures a fairly constant alkalinity which is desirable,
but it has the same disadvantageous feature as the present system
in that there is no facilities provided for a proper retention
period to allow the formation of *floc* -

2. The second suggestion is to use one of the filters as a
coagulation basin. This might be done by ripping out the sand
and gravel inside the filter. This has some disadvantages among
which might be included increase in time necessary to filter the
contents of the pool. The time of detention too, as shown on the
next page, is to our belief too small to make this procedure worth
while.

3. The third suggestion is to our minds the best plan. It

concerns the installation of an alkalinity pot.   Let us consider

the introduction of this pot connected up in parallel with the

present alum pot as illustrated by the following sketch.
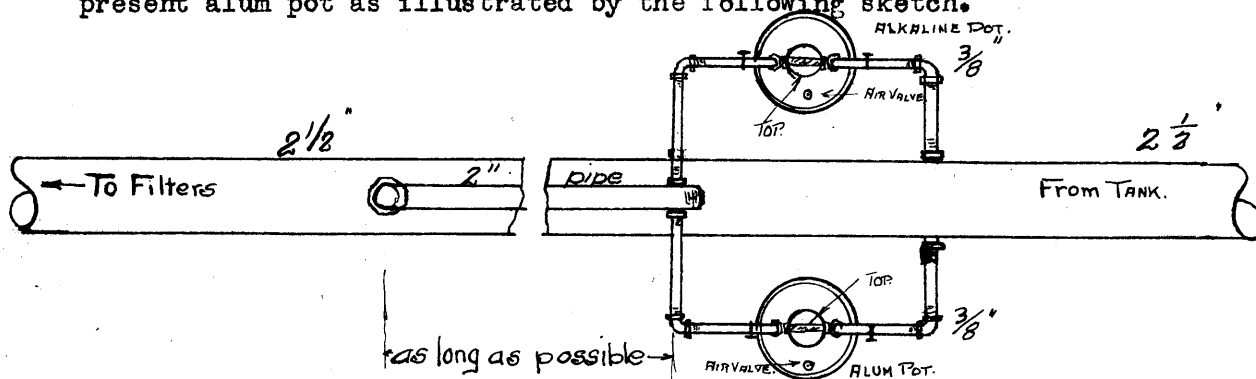
With the above arrangement of pipes, we will get the following

chemical reaction taking place.

$$3H_2O \text{ plus } AL_2(SO_4)_3 + 3\ Na_2CO_3 = AL_2(OH)_6 + 3\ Na_2SO_4 + 3CO_2$$
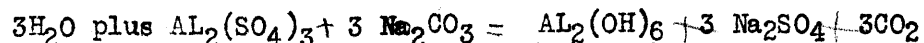
From data obtained by taking half hourly analyses of the water

with the alum pot turned on, it is apparent that we are getting a

concentrated solution of alum using a 3/8 of an inch pipe.   In order

to form a satisfactory "blac", it is necessary to have 342.2 parts of

$Al_2(SO_4)_3$ for every 318 parts of Na_2CO_3.   If it is much preferable

to have an excess of Na_2CO_3 rather than an excess of $Al_2(SO_4)_3$ in the

water, we will be on the safe side if we use one part of Na_2CO_3 for

one part of $Al_2(SO_4)_3$.

The above conditions can be satisfied if the pots are connected

up as shown in the above sketch, that is, both lead pipes being the

same size.   With this apparatus, we are getting a stream of a strong

solution of Na_2CO_3 striking a strong solution of alum.   Under similar

conditions in test takes, we found that the time of precipitation was

decreased to a very large extent.

For instance, a strong solution of Na_2Co_3 <u>mixed</u> with a <u>strong</u>
solution of $Al_2(SO_4)_3$ gave a precipitation almost immediately, where-
as a weaker solution took a much longer time to form and even then
the formation was only slightly noticeable. A strong solution of
alum mixed with a weak solution of the soda ash was also very slow
in forming.

• By our method of adding both solutions at the same time, we
hope to get a formation of floc of much greater amount than if
either the soda ash or the alum were added first.

In water supply filtering plants, where coagulation is used,
a detention period of at least 2 hours is required for good design,
while one plant at Providence designed by Allen Hazen, has a period
of over 4 days. A value commonly used is six hours. It is easily
seen that while a concentration of chemicals, which would give a
good floc in this time, would be hoplessly inadequate in pressure
filters where the water goes from the alum pot to the filters in a
very few seconds, and where it takes approximately only 15 minutes
to go through the filters itself.

$$3 \, gal/\square'/min = 3 \times \frac{1}{7.48} = 0.40 \, cu \, ft./\square'/min$$

$$\text{Effective depth} = 5'$$

$$\text{So time thru filters} = \frac{5}{0.4} = 12.5 \, \frac{min}{}$$

So it is evident that whatever flocculation takes place must take
place in 15 minutes, unless you count on floc which may be brought
back from the swimming pool, which is ~~very~~ hardly to be counted on.

We also recommend that daily washing of the filters be eliminated. This washing in a system where it is so difficult to form Aluminum, Hydroxid coating over the filter is very harmful. We would recommend that this washing be carried on weekly as for instance, Saturday evening or Sunday morning.

Respectfully submitted-

TABLE I.

TABLE SHOWING BACTERIAL DISTRIBUTION IN POOL

Bacteria per Cubic Centimetre

Sample	Nutrient Agar at 37°	Nutrient Agar at 20 C.	Gas Producers in 10 cc.
1	935	710	plus
2	910	715	plus
3	865	750	plus
4	790	745	plus
5	895	725	minus
6	1015	675	plus
7	950	700	minus
8	835	665	minus
9	945	610	plus
10	860	720	plus
11	780	695	minus
12	885	735	plus
13	825	725	minus

TABLE II.

TABLE SHOWING THE DAILY VARIATION IN BACTERIA IN THE POOL

		Nutrient Agar 37° C.	Nutrient Agar at 20 C.	Gas Producers in 10 cc.
*1	9 A.M.	5000	3975	plus
	10 A.M.	4125	3450	plus
	11 A.M.	4050	3635	plus
	12 A.M.	5525	4115	plus
	1 P.M.	6725	4895	plus
	2 P.M.	6230	5330	plus
	3 P.M.	8950	6995	plus
	4 P.M.	7935	6750	plus
	5 P.M.	9165	8885	plus
	6 P.M.	10650	8725	plus
	7 P.M.	9375	8330	plus
	8 P.M.	8450	6325	plus
*2	9 P.M.	6225	5765	plus

*1 Pumps turned on.

*2 Pumps shut down.

TABLE III.

TABLE SHOWING BACTERIAL COUNTS IN POOL WITH CHLORINATOR TURNED

OFF.

	Nutrient Agar 37° C.	Nutrient Agar at 20 C.	Gas Producers in 10 cc.
1 day	4600	3750	plus
2 "	6350	6000	plus
3 "	7850	6550	plus
4 "	11200	8400	plus
5 "	15300	14150	plus
6 "	19600	17200	plus
7 "	23950	16850	plus

TABLE IV.

TABLE SHOWING THE RATE OF GROWTH OF BACTERIA IN SAMPLE FROM POOL

WITH ACIDITY OF 40ppm and pH of 4.8

	Nutrient Agar at 37° C.	Nutrient Agar at 20 C.	Gas Producers in 10 cc.
1 day	0	0	0
2 "	3	2	0
3 "	95	145	0
4 "	175	265	0

TABLE V.

BACTERIOLOGICAL RESULTS

Bacteriological tests of the water were made before the alum pot was turned on both from the pool and from the filter effluent. The alum pot was filled with alum and allowed to run for two hours samples of the filter effluent being tested every fifteen minutes.

SAMPLE OF	TIME TAKEN	BACTERIA/ c.c. At 37 C.	At 20 C.
POOL	BEFORE ADDITION OF ALUM	1400	1125
FILTER EFFLUENT	BEFORE ADDITION OF ALUM	620	550
FILTER EFFLUENT	AFTER ADDITION OF ALUM (15 min.)	570	435
FILTER EFFLUENT	AFTER - 30 min.	530	415
" "	" 45 min.	425	330
" "	" 60 min.	385	220
" "	" 75 min.	395	345
" "	" 90 min.	265	210
" "	" 105 min.	270	225
" "	" 120 min.	210	175
POOL	AFTER SHUTTING OF ALUM POT	1275	1145

TABLE VI.

BACTERIOLOGICAL RESULTS

Bacteriological tests of the water were made before the alum pot was turned on both from the pool and from the filter effluent.   The alum pot was filled with alum and allowed to run for two hours samples of the filter effluent being tested every fifteen minutes.

SAMPLE OF	TIME TAKEN	BACTERIA/c.c. At 37 C.	At 20 C.
POOL	BEFORE ADDITION OF ALUM	3,200	2700
FILTER EFFLUENT	BEFORE ADDITION OF ALUM	1,400	1150
FILTER EFFLUENT	AFTER ADDITION OF ALUM (15 min.)	950	900
FILTER EFFLUENT	AFTER - 30 min.	825	840
" "	" - 45 min.	810	720
" "	" - 60 min.	540	430
" "	" - 75 min.	450	410
" "	" - 90 min.	475	300
" "	" - 105 min.	390	250
" "	" - 120 min.	360	200
POOL	AFTER SHUTTING OFF ALUM POT	2950	1900

TABLE VII.

CHEMICAL ANALYSIS.

Table showing the variation in pH, Acidity and Hardness during the course of a week with the system operating in prescribed way.

SAMPLE	pH	ACIDITY	HARDNESS
1 Day	5.1	27ppm	185ppm
2 "	5.0	30ppm	190 "
3 "	5.0	32ppm	195 "
4 "	4.9	35ppm	205 "
5 "	4.8	38ppm	215 "
6 "	4.8	40ppm	225 "
7 "	4.8	41ppm	230 "

TABLE VIII.

CHEMICAL ANALYSIS.

Table showing the variation in pH, Acidity and Hardness during a period of a week when Alum pot was shut off and Chlorinator operating.

SAMPLE	pH	ACIDITY	HARDNESS
1 Day	5.0	37.5ppm	185ppm
2 "	5.1	37.0ppm	" "
3 "	5.1	37.5ppm	"
4 "	5.2	37.5ppm	"
5 "	5.2	37.5ppm	"
6 "	5.2	37.5ppm	"
7 "	5.2	37.0ppm	"

TABLE IX.

CHEMICAL ANALYSIS.

Table showing the variation in pH, Hardness and Alkalinity during a two hour run with alum pot open.

SAMPLE	pH	ALKALINITY	HARDNESS
POOL-BEFORE	8.0	22ppm	35ppm
FILTER-AFTER (15-min.)	7.2	8ppm	45ppm
FILTER-AFTER (30-min.)	7.0	8ppm	45ppm
FILTER-AFTER (45-min.)	6.8	8ppm	40ppm
FILTER-AFTER (60-min.)	6.8	7ppm	40ppm
FILTER-AFTER (75-min.)	6.8	7ppm	40ppm
FILTER-AFTER (90-min.)	6.6	6ppm	40ppm
FILTER-AFTER (105-min.)	6.6	6ppm	40ppm
FILTER-AFTER (120-min.)	6.6	6ppm	38ppm
POOL-AFTER	7.8	18ppm	38ppm

TABLE X.

CHEMICAL ANALYSIS.

Table showing the variation in pH, Alkalinity and Hardness during a two hour run with alum pot open.

SAMPLE	pH	ALKALINITY	HARDNESS
POOL-BEFORE	7.5	17ppm	55ppm
FILTER-AFTER (15-min.)	6.7	10ppm	60ppm
FILTER-AFTER (30-min.)	6.6	8ppm	65ppm
FILTER-AFTER (45-min.)	6.6	7.5ppm	65ppm
FILTER-AFTER (60-min.)	6.5	7.5ppm	65ppm
FILTER-AFTER (75-min.)	6.5	7ppm	60ppm
FILTER-AFTER (90-min.)	6.4	6.5ppm	60ppm
FILTER-AFTER (105-min.)	6.4	6.5ppm	60ppm
FILTER-AFTER (120-min.)	6.4	6ppm	60ppm
POOL-AFTER	7.3	15ppm	60ppm

TABLE XI

Table showing the increase in pressure during a two hour period when the alum pot was allowed to run.

SERIES I.		SERIES II.	
Time	Pressure	Time	Pressure
0 Min.	10.0 lbs.	0 Min.	11.1 lbs.
15 "	10.1 "	15 "	11.1 "
30 "	10.2 "	30 "	11.3 "
45 "	10.3 "	45 "	11.5 "
60 "	10.4 "	60 "	11.6 "
75 "	10.5 "	75 "	11.7 "
90 "	10.6 "	90 "	11.9 "
105 "	10.8 "	105 "	11.9 "
120 "	10.8 "	120 "	12.0 "

BIBLIOGRAPHY

Municipal and County Engineering--Vol.66,1924

The Nation's Health--April 15,1927

Standard Methods of Water Analysis--A.P.H.A. 1920

Water Purification--J.W.Ellms

Water Purification plants and their Operation--Stein

Air,Food,and Water--Woodman

Elements of Water Bacteriology--Prescott and Winslow

Journal American Water Works Association-VOl.II,1924
        (pages598-604,873-880,881-886,887-895)
Journal American Water Works Association-Vol.14,1925

        (pages 440-441,442-447)

Journal American Water Works Association-Vol.12,1924
        (pages 272-281)

Journal American Water Works Association-Vol.8,1921
        (pages 397-401,426-432,603-615)

Study of the Sanitation of aSwimming Pool-G.T.Lane 1913

Corrosion,Causes and Prevention--Speller