S A N I T A R Y

EVALUATION OF A WATER SYSTEM

SANITARY EVALUATION OF A WATER SYSTEM

by
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SYNOPSIS

Polluted water can be a carrier of many diseases. The pollution of the water can be detected by the multiple tube fermantation or the membrane filter techniques. Transmission of diseases can be prevented by filtration and disinfection.

Bacteriological Examination of the water by Membrane filter technique and the determination of the efficiency of disinfection by the orthotolidine method have been performed. The correct amount ofchlorine which should be added to the water was calculated from the break-point curve.

PART I

INTRODUCTION

Water is essential to all forms of life. Indeed, it is part of life itself, since the protoplasm of most living cells contains about 80-90 %, fatty tissue consists 30% water and bones 22%. (I)

In a normal man the percentage of water changes in accordance to age.

1-1,5 months embryo	97% of its weight is water
4 " "	91%
8 " "	82%
At birth	75%
2 months	70%
Adult	66%
Old age	60%

Any substantial deviation from the above percentages and the normal loss of three liters of water per day is disastrous.
Normal loss takes place by:

Kidneys	by urine	2000 gr/day
Intestines	by feces	100 gr/day
Epidermis	by evaporation or sweat	700 gr/day
Lungs	by evaporation	300 gr/day

In order the organism to continue its functions, this water must be replaced. The central nervous system regulates the demand for water. An average of three liters of water enters in the organism each day by:

a) Drinks : The average amount of water drunk by normal man is 1500 gr/day.

b) Foods : Almost all the foods contain a certain amount of water. Thus 33-45% of the weight of bread, 71-80% of patatos and 80-90% of vegetables is water. In this way by the foods 1000 gr. of water enters to the organism.

c) By oxidation of the hydrogen present in the foods. In this way 400 gr of water are formed daily.

Experiments made on pigeons have shown that although they can live 12 days without food, they will die if they are left 4 days without water (2:72). Man similarly can not live for long period without water, because water has several important duties in the continuation of life; it is used in the formation of cells; it regulates the chemical reactions within the organism, it transports different substances from one part of the organism to others or extract them, and it regulates the body temperature. (2:71; 3:11,16)

Man, however, does not use water only for drinking and culinary purposes. He uses it also for bathing, washing, heating and air conditioning, for agriculture, stock raising and gardens, for industrial processes, for water power and steam power, and for fire protection. In general it can be said that every activity of man involves some use of water. It is because of this, that man's search for pure water began in the prehistoric times.

WATER-BORN DISEASES

Water has long been the cause of epidemics. During the summer of 1849, 14,600 and in 1854, 10,675 deaths are attributed to Cholera in London. The reason for both these epidemics and of many others was contamination of the water supply (4:5).

At the beginning of the 20th century it was understood that water was a simple carrier of diseases. After that special treatment begun to be applied to water and nowdays in the European and most of the American countries the water born diseases are almost eliminated. However they continue to be an important problem for most underdeveloped countries.

Some of the diseases which can be transmitted by water are:

Enteric fever:

This includes both typhoid & paratyphoid fever, the first being caused by Salmonella typhosa and the second by Salmonella hirchfeldi, Salmonella paratyphi and Salmonella schottmuelleri. These bacteria are easily distinguished from one another (although they are similar in their morphology, staining reaction and cultural appearances, they differ in their biochemical and serological reactions) but the distinction was not made until 1896, prior to which date both typhoid and paratyphoid fever were described as enteric fever.

Enteric fever, that is both typhoid and paratyphoid, is contracted via the mouth by the medium of food, or water contaminated with typhoid or paratyphoid bacteria Fig.1 shows a diagram describing how enteric fever is spread.

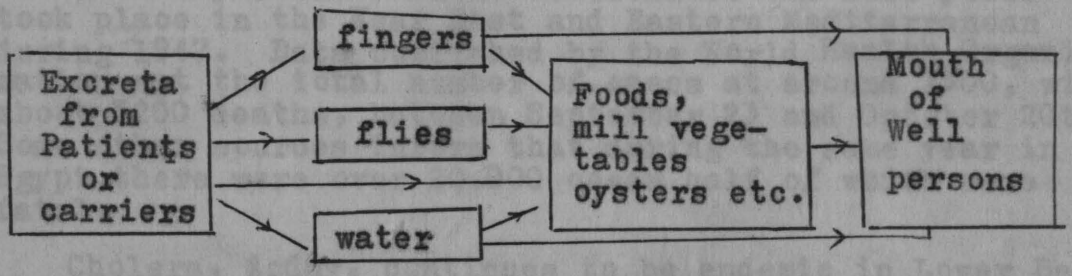


Fig. 1 Transmission of enteric fever (5)

a) Typhoid Fever :

Was a rather serious illness having mortality which varied from 10 to 20%, but now, by antibiotic therapy the fatality is reduced to 2-3%. The early symptoms are vague and varied, but common complaints are headache, lastitude, loss ofappetite, nausea, continued fever, constipation or diarrhoea, sore throat, pains in abdomen or back, nose-bleeding, shivering and enlargement of spleen. There is progressive increase in severity of the symptoms during the second and third week. Incubation period is variable and usually ranges from 1 to 3 weeks.

b) Paratyphoid fever :

Is milder, shorter in duration and much less fatal than typhoid fever. Many mild infections give no more than a transient diarrhoea. Paratyphoid bacilli may be found in feces, blood and urine. Incubation period 10 days. (5:8, 6:497, 558-564, 7:117, 201)

CHOLERA

This is essentially a water born disease and calamitous outbreaks arise from the infection of water. The etiologic agent is Vibrio cholerae. Severity differs greatly from place to place and within epidemics; mild cases show only diarrhoea. Death may occur within 24 hours. Fatality varies from 10 to 80%. The incubation period is from few hours to 5 days. It is characterized by severe diarrhoea, vomiting, abdominal and muscular pains, exhaustion and collapse due to endotoxins of the vibrios. There is no fever, the temperature being subnormal. Great damage is done by the excessive and rapid dehydration of the patient which is a consequence of the diarrhea.

Cholera is a classic example of what results from lack of sanitation, especially with respect to water supplies. The most important cholera outbreak of the last years took place in the Near East and Eastern Mediterranean during 1947. Data published by the World Health Organization set the total number of cases at around 7300, with about 3200 deaths, between September 23 and October 20th. Some other sources inform that during the same year in Egypt there were over 20.000 cases half of which were fatal.

Cholera, today, continues to be endemic in Lower Bengal and from here spreads from time to time to other parts of the globe. (6:571-2, 7:35, 9:410-1)

DYSENTERY

There are several kinds of dysentery. The most important are the Bacillary and the Amoebic dysentery.

a) Bacillary Dysentery:

It is caused by bacilli of the Shigella genus. The organism discovered by Shiga in 1896 during a frightful epidemic of dysentery in Japan with over 22.000 deaths. Because of that it is called Shigella dysenteriae. After Shiga's discovery many other kinds ("species") of dysentery bacilli were discovered by Flexner, Boyd, Sonne and others.

The Shigellas intestinal disturbances ranging from very mild diarrhea to severe and sometimes fatal dysentery with intense inflammation and ulceration of the large bowel, often with scar formation and stricture of the bowel after recovery. Abdominal pain and headache are from the usual characteristics. The incubation period is short (usually less than 4 days) and the on set sudden.

Bacillary dysentery has occurred very widely in armies and is often epidemic among civilians. The bacilli can appear in the excreta for several weeks after apparent recovery, but there appear to be no permanent carriers, and there is no immunization, either by an attack of the disease or by vaccination. The transmission is by pollution of the water or foods. (8:572-3, 5:9-10, 9:493)

b) Amoebic dysentery (Amoebiasis)

The disease is common in tropical countries, but appears in lighter form in other countries also. It is caused by the protozoon Endamoeba histolytica. Formerly it was thought that the infection was spread through food by food-handler carriers, but studies made during the Chicago epidemic in 1933, which involved 1,049 known cases and 98 deaths, indicate that the water carriage is more important than food contamination. Endamoeba histolytica forms cysts, which are present in the human excreta. The cysts are particularly resistant, and are chiefly responsible for the spread of the disease. In laboratory experiments Chang and Fair (7) found that the cysts survive in water for nearly three months at freezing temperatures about a month at 10°C, about ten days at 20°C and three days at 30°C.

The acute form of the disease is characterised by fever, diarrhoea (60-80 times in 24 hr) with passage of blood and mucus in the stools, emaciation and the development of liver abscesses. This acute form continue for 10-20 days and after that becomes chronic.

Amebiasis is only occasionally a direct cause of death. (6:575, 5:10, 10:394, 11:321)

WEIL'S DISEASE (Leptospiral Jaundice)

This disease is caused by leptospira icterohemorrhagiae, a spirochete sometimes present in excrementally contaminated water, mud and slime. It is capable of penetrating the skin. It is transmitted from animal to man through the urine of animals -usually rats, but also other rodents, dogs, cattle and occasionally other animals- as well as anything coming into contact with the skin of, or being ingested by, man. To become infected, therefore, it is not necessary to drink contaminated water. On the other hand communicability from man to man is negligible.

The typical symptoms are sudden shivering and headache with fever and collape, stiff neck, and some times is followed by jaundice and hemorrhage in skin and mucous membranes. The acute illness lasts from one to three weeks; relapses may occur.

If storage cisterns are accessible to rodents, spread of the disease by this means should always be kept in mind. (6:576, 5:17, 7:99, 9:407)

INFECTIOUS HEPATİSİS

This disease which is also known as "catarrhal Jaundice" is caused by the virus of infectious hepatitis. The virus is present in the blood and feces of an infected person.

An acute infection is characterized by a prodromal period, and a second phase commonly associated with jaundice. Prodromal symptoms include fever, anorexia, nausea with or without vomiting, fatigue, lassitude, headache and abdominal disconfort. Fever subsides after a few days, and clinically recognizable jaundice appears. The second phase is of variable duration, with occasional chronic impairment of liver functions. The incubation period is long and variable (10-40 days, commonly 25 days).

Infectious hepatitis is most common in rural areas and among children and young adults. Life-long immunity is believed to be conferred after attack. (6:579, 5:11, 7:84)

TULAREMIA

It is usually contracted by man from rabbits o possums, rodents, quails, skunks, and other animals. The symptoms are fever, pain and inflamation of the nack glands. The infection enters through a skin abrasion. The disease is also transmitted by insufficiently cooked rabbit, and by drinking contaminated water.

Turkey seems tohave had cases of tularemia since 1936. In 1954 a new epidemic took place, and it is assumed that it was water born because of its explosive beginning. There were 200 patients and all but two came from that part of the village in the south-west costal area of Turkey where the drinking water was from an open source. It is suggested that this source was polluted by rodents. (6:575, 5:18)

POLIOMYELITIS (Infantile Paralysis)

It is most common (75 to 80%) in children 15 years and under but not confined to childhood. In general in those areas where infection is highly prevalent, the occurrence of cases is usually limited to the lowest age-groups, indicating that the older members of the population have acquired an effective resistance or immunity. In temperate climates and in those communities where hygienic conditions are advanced, immunity is apparently acquired later and as a result clinical poliomyelitis is increasingly common in older age-groups in these areas.

The portal of entry of the virus is the mouth or the upper respiratory tract. The virus of poliomyelitis has been found in the pharyngeal passages and the intestinal tract of human beings and has been isolated from the secretion and excretions of these areas. Typical cases are characterized by sudden onset and febrile attack with nausea, headaches sometimes stiff neck, and muscular pains. In the vast majority of infections with the virus the disease is short and mild, usually passing unnoticed, unrecognized or confused with influenza. Complete recovery and presumably life-long immunity are the rule. In a relatively small percentage of cases the disease is severe. The principal and characterist damage is to nervous tissues, especially to those nerves which are in association with muscles. Muscular paralysis with resulting degeneration

sometimes occurs.

Transmission of Polio :

The virus leaves the body in the feces and -during the early stages of the disease- in oral and nasal secretions. Apparently animals do not harbor the virus in nature, nor is there any evidence that house flies and biting insects, are of importance in transmitting the disease. It appears to be transmitted ~~in the~~ mainly with feces and articles soiled with feces.

About the transmission of polio by water different scientists have different opinions. Thus although Taylor, Ehler and Steel (5,6) believe that it is theoretically possible for poliomyelitis to be spread by infected water there is practically no evidence of that.

On the other hand, Camp (I) and some others inform that the virus of poliomyelitis has been recovered from sewage and polluted waters and there is evidence that this disease is water born in some cases.

The theory of Camp is supported also by the cases of poliomyelitis, which appeared during the last few years in Istanbul, and most of which had fatal end. These cases are an other evidence, or at least enough stimulous in order to pay attention to this disease when we study the water born diseases. (1:77, 6:577, 5:13, 9:582)

Other water born diseases are :

Gastro-enteritis
Schistosome dermatitis
Echinococcosis, etc.

Except the diseases which are described above, and in which water is simply a vehicle of transmission, water may cause some other diseases due to the chemical substances, (and their concentrations) which it may contain. Some of these are :

Goiter - Caused by the absence of iodine from water
Methemoglobinemia (blue babies)- serious and occasionally fatal infant disease caused from the ingestion of nitrates (more than 70 ppm) found in some waters. The most acceptable hypothesis for the specificity of nitrate poisoning of infants is that the lower acidity in an infant's gastro-intestinal tract permits growth of nitrate-reducing

flora, which reduce nitrate to nitrite. Nitrite is absorbed by the blood, converting large quantities of hemoglobin to methemoglobin.

Lead poisoning - It may cause death

Argyria - A permanent blue- gray discoloration of the skin, eyes and mucous membrane, caused by silver.

Dental flurosis (mottled enamel) - is caused by the presence of fluorides in water in concentrations exceeding 0.5 ppm, while reduction of dental caries is achieved with law concentrations.

Intestinal derangements (1:94-99, 12:370)

A table giving the allowable concentrations of different substances and properties affecting potability is given in the appendix.

METHODS OF DETECTING POLLUTION OF WATER

Water to be used for public supply must be unpolluted. Pollution can be defined as the presence of any foreign substance (organic, inorganic, radiological or biological) which tends to degrade the water quality and constitute a hazard or reduce the usefulness of the water.

In cases when a water system constitutes a part of a city system, where all the necessary treatments are done, the most possible source of pollution after treatment, is a cross connection with a sewage, or in general a pollution by organic matter. This contamination may cause the diseases which are described in the previous section.

In this part, the methods for detecting pollution of organic or biological origin, and more specificly the detection of pathogenic organisms will be explained. Methods of determining other pollutants can be found in Standard Methods for the Examination of Water and Waste Water.

INDICATOR ORGANISM

The analytical procedures for pathogenic bacteria are very difficult and at the same time far from being reliable. Because of that the sanitary microbiologists rather than looking for the specific pathogens, they find an indicator -whose origin is in fecal matter- for fecal contamination, the coliform bacteria.

The coliform bacteria are members of the family Enterobacteriaceae. They include the genera Escherichia & Aerobacter. The genus Escherichia includes several species, the most important of which are Escherichia coli, Escherichia freundii and Escherichia inter-medium. The last two of these can live outside the body of the warm booded animals as well as in the intestinal tract. (9:468). The genus Aerobacter includes A. aerogenes and A. Cloacae (4:243)

The characteristics and the reactions of coliforms have been studied extensively and continue to be the subject of studies.

The size and shape of coliforms vary from forms almost coccal to long rods. Usually the rods are 2 to 3 μ in length and 0.5 μ in width.

In general coliforms are non-pathogenic but the Escherichia can be pathogenic if it passes into the blood stream. (13:560)

Investigations have shown that coliform organisms, principally of the Escherichia type, are present in the feces of all warm blooded animals (14:166). The only exception to this is reported by Foote (15) who could not isolate coliform in the feces of hebrivora, deer and elk. In cold blooded animals Escherichia may not be present. Studies have been made to determine the number and type of coliforms in fresh feces. The number of coliforms varied from five to fivehundred millions per gram of feces. Ninety-five percent of these are E.Coli, and a very small proportion are A.aerogenes. The rest are E.freundi and intermediate-aerogenes-cloacae (IAC) (14:167-170). Organisms of the intermediate-aerogenes cloacae group survive longer in water than E. Coli and are more resistant to chlorination. The relative survival times of the coliforms subgroups has been used to distinguish recent from less recent pollutions. Waters recently polluted show an E.Coli density greater than the IAC density, while waters polluted before some time have a higher concentration of IAC. (4:243)

In relatively uncontaminated soils, very few bacteria are present and these are mainly of the Aerobacter type. Winslow, Kligler, Konrich and others however have shown that coliform bacteria may be very abundant in soil which was previously polluted and in the dust of city streets. (4:243,5:31)

Coliforms can be found also on presumably uncontaminated plants, leaves and grasses, but their numbre is generally small and consists of Aerobacter Aerogenes, while E.coli organisms constitute a modest minority. (14:174,177)

Coliforms are classified according to the place where they live as "grain type", "soil type" and "fecal type", or more generally "fecal" and "nonfecal".

Data is lacking on the multiplication of non-fecal coliforms. Some investigators believe that the non-fecal coliforms not only survive on the soil, grasses and grains, but also multiply there. Others (Taylor (6)) however do not accept that multiplication can take place in this way.

The reason that coliform bacteria is used as an indicator is that experiments have shown that coliform organisms survive longer than any pathogenic organism. Thus the water which is free from coliforms should, in natural circumstances, also be free from disease producing organisms. On the other hand, the presence of coliform organisms is an indicator that the water has been polluted by fecal matter, and that pathogenic bacteria may be present. Gilcreas and Kelly, however have shown that at low temperatures and in salt water coliforms die more rapidly than other bacterias. (16)

The U.S. Public Health Service, in the Drinking Water Standarts of 1961 (17:941) limits the number of coliforms for potable water to less than one per 100 ml. The French consider water as unfit for drinking if it contains any E.coli per 100 ml of water (13:458). In Turkey the drinking water should not have any coliform bacteria in 100 ml., although it may contain as many as 50 aerobacter aerogenes per ml. (18,19:135, 20:29)

TESTS FOR PRESENCE OF MEMBERS OF COLİFORM GROUP

A) Multiple-Tube Fermentation Technique

This technique is separated into three parts, Presumptive, Confirmed and completed test.

I. Presumptive Test :

In the Presumptive test coliform organisms ferment lactose, forming a gas. Thus it is possible to detect the coliforms by adding a sample of water to a tube of lactose broth, a solution of beef extract, peptone and lactose disolved in water, containing a small inverted tube. The tube is incubated at 35 ± 0,5°C for 24 ±2 to 48 ±3 hr. As the coliforms metabolize the lactose under anaerobic conditions, acids are formed which depress the pH, force carbon dioxide out of the solution and assit in the production of hydrogen gas. These two gases are trapped in the inverted tube.

Thus if gas is absent from the inverted tube it means that no coliforms are present in the sample. The presence of gas however does not mean always that some coliforms are present since some other bacterias and aerobic sporeformers also can produce gas. In order to be sure that the positive results are not due to an interference of aerobic sporeformers an other test, the confirmed test is necessary.

II. Confirmed Test :

This test can be performed either by brilliant green lactose bile broth or by eosin methylene blue agar.

a) Brilliant green lactose bile broth:

A loopful sample from the lactose broth presumptive tube showing gas, is transferred to a fermentation tube containing brilliant green lactose bile broth, and this is incubated for 48 ±3 hr at 35 ± 0.5°C. Thi brilliant green lactose bile broth is a favourable medium for the growth of coliform organisms, while aerobic sporeformers can not grow beacuse the depressed surface tension prevents them from obtaining enough oxygen for

growth. The formation of gas in the inverted vial during the incubation confirms the presence of coliforms.

b) Eosin methylene blue agar:

A small sample from the lactose broth presumptive test is streaked on the surface of the eosin methylene blue agar plate and this plate is incubated at 35°C ± 0,5°C for 24 ± 2 hr.

The colonies developing on eosin methyelene blue agar may be described as:

1. Typical - nucleated, with or without metallic sheen. When these are developed the results of the confirmed test are considered positive.

2. Atypical - opaque, unnucleated mucoid after 24 hr. incubation pink. In this case identification is not possible, it is necessary to complete the test as described below, in section III.

3. Negative - all other are considered as negative.

The eosin methylene blue agar medium is quite popular because it has the ability to distinguish E. Coli and A.aerogenes. E.coli forms a small, raised, flat, dry colony with green metallic sheen. A.aerogenes forms a large moist convex colony with a dark center.

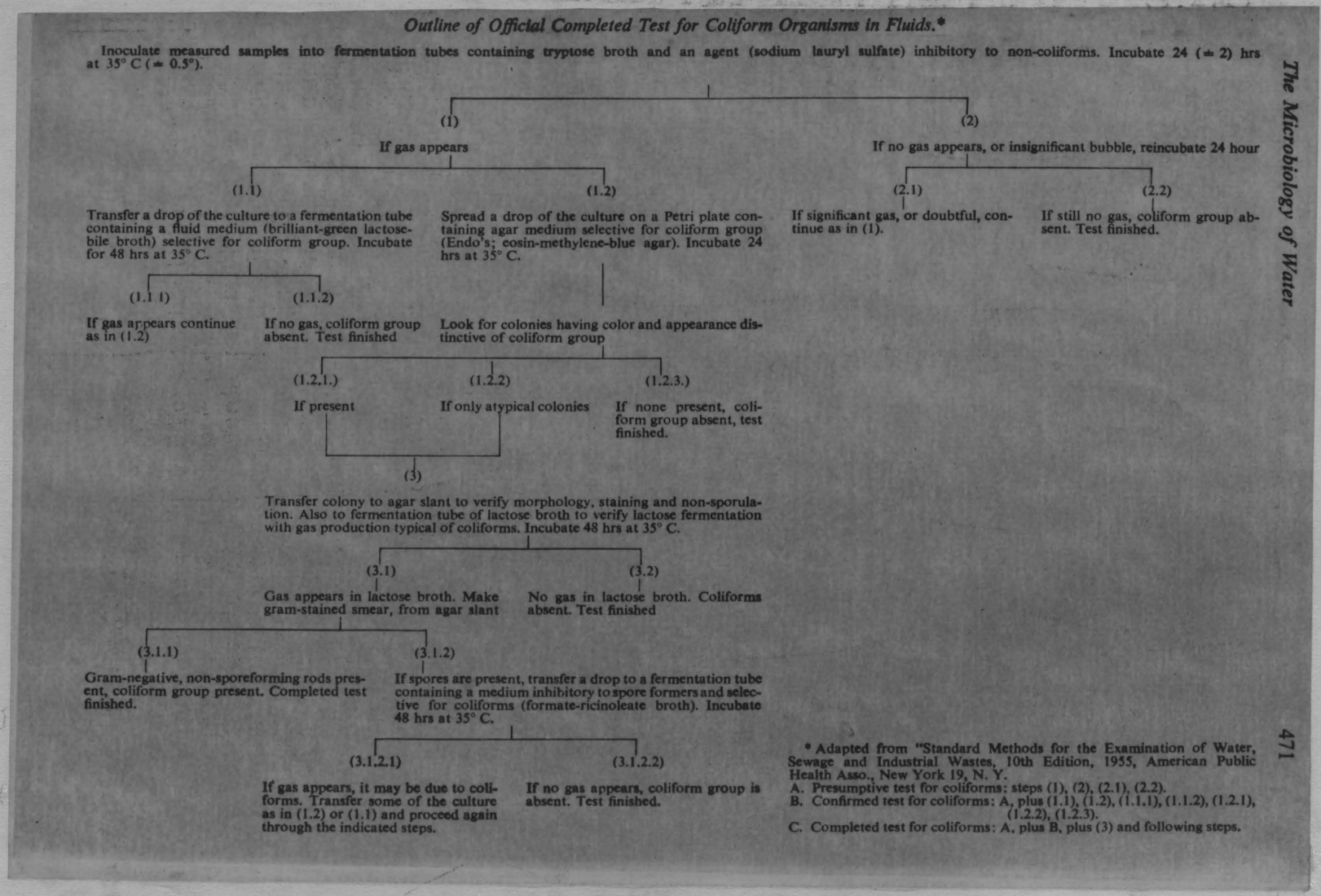
III. Completed Test :

If the brilliant green lactose bile broth tubes used for confirmed tests, give positive results, some eosin methylene blue (EMB) plates are streaked from each tube showing gas and they are incubated for 24 ± 2 hr at 35 ± 0.5°C. From each of EMB plates a coliform colony is taken and transfered to lactose broth fermentation tube. If the bacteria produce gas; the test is considered positive evidence for the peresence of coliforms. Sometimes the samples are also examined microscopically.

A schematic outline of the Multiple-Tube Fermentation tecnique is given on Chart 1, p.16

CHART 1- SCHEMATIC OUTLINE OF MULTIPLE-TUBE FERMENTATION TECHNIQUE (9:471)

CHART I- SCHEMATIC OUTLINE OF MULTIPLE-TUBE FERMENTATION TECHNIQUE (9:471)



ESTIMATION OF COLIFORM GROUP DENSITY - Most Probable Number (MPN)

While it is important to determine the presence of coliform bacteria, it is also essential to determine the number of coliforms in a water sample in order to evaluate the extent of contamination. For the enumeration of coliforms statistical method is used which is the "Most Probable Number" (MPN).

MPN is "that bacterial density, which if it had been actually present in the sample under examination, would more frequently than any other have given the observed analytical results" (22:257). This number is not exact, but nevertheless is useful.

To determine MPN, several fermentation tests using different dilutions are made on the same sample. For drinking water for example Standard Methods requires a minimum of five fermentation tubes each containing 10 ml or 100 ml of the water, on which the confirmed or the completed test must be employed.

Using the resulks of the test, the MPN can be determined by the following equation of Hoskins. (4:247,12:410) (23)

$$y = \frac{1}{a}\left[(1-e^{-N_1\lambda})^p(e^{-N_1\lambda})^q\right]\left[(1-e^{-N_2\lambda})^r(e^{-N_2\lambda})^s\right]\left[(1-e^{-N_3\lambda})^t(e^{-N_3\lambda})^u\right]$$

where N_1, N_2, N_3 : sizes of portinos examined, in milliliters.
p, r, t : number of portions of respective sizes giving positive tests for coliforms.
q, s, u : number of portions of respective sizes giving negative tests for coliform.
λ : concentrations of coliforms per milliliter.
y : probability of occurance of a particular result.
e : base of Naperian logarithms, 2.718
a : a constant for any particular set of conditions and therefore may be omitted in computation of .

The MPN is the mode of the curve given by the above equation. Therefore MPN is determined by finding the value of "λ" which when substituted in the equation will make "y" maximum. This value of "λ" is the MPN.

Standard Methods contains tables, prepared from the previous equation, which can be used to determine the MPN directly.

(10:244-250, 12:412-4,
21:154-6, 24:494-502)

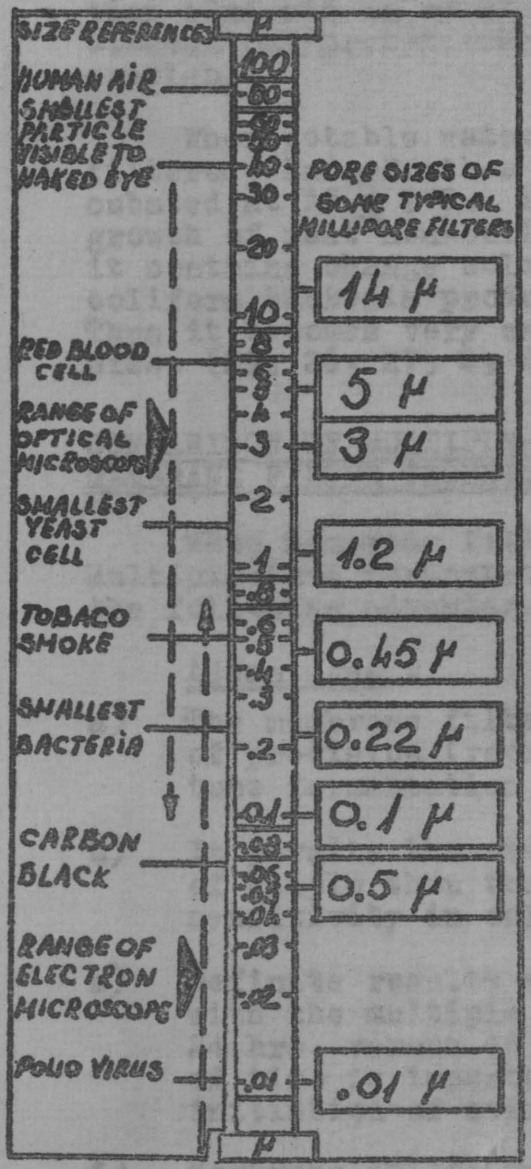
B) Membrane Filter Technique

The Membrane Filter was developed during World War II in Germany, and has been applied to the bacteriological examination of water. In 1960 this method was accepted as a "Standard Method".

Membrane filters are porous membranes composed of pure and biologically inert cellulose esters or similar polymeric materials. They are currently produced in more than twenty distinct pore sizes from 14 microns to 10 milli microns (0.01) in discs ranging from 13 mm to 293 mm indiameter. The pores occupy approximately 80% of the total filter volume. This permits high flow rates. For pore size and flow rates recommended, see Table I.

TABLE I

BASIC CHARACTERISTICS MF PORE SIZES AND FLOW RATES (26:2)



MF TYPE	PORE SIZE	RATE OF FLOW*	
		WATER	AIR
SC	8.0μ±1.4μ	850	55
SM	5.0μ±1.2μ	540	35
SS	3.0μ±0.9μ	400	20
RA	1.2μ±0.3μ	300	15
AA	0.80μ±.05μ	212	11
DA	0.65μ±.03μ	150	10
HA	0.45μ±.02μ	64	4.5
PH	0.30μ±.02μ	40	3.7
GS	0.22μ±.02μ	21	2.5
VC	100mμ±8mμ	2.0	.49
VM	50mμ±3mμ	1.0	.31
VF	10mμ±2mμ	0.2	.22

*Water flow rates are given in ml/min per cm^2 of filter area at 25°C with a pressure differential of 70cmHg. Air flow rates are given in l/min per cm^2 of filter area at 25°C with a pressure differential of 70cmHg.

When fluids are passed through the filter, all particles, bacteria and cells larger than the pores are retained on the filter surface and lie in a plane where they can be readily examined. Each organism thus retained on the membrane Filter may then be developed into a visible bacterial colony by superimposing the filter on an absorbent pad saturated with liquid nutrient medium and incubating at approximately body temperature for 18-24 hours. With variation in such factors as culture media, incubation time and in combination with different cultural and biochemical procedures, many different kinds of tests are available.

When potable water is tested samples of 100 ml are filtered, Endo-Broth-a nutrient medium- is added and incubated at 35 ± 1°C. The Endo-Broth suppresses the growth of most non-coliform colonies, and the dyes which it contains change color when the growing colonies of coliform bacteria produce acid by fermenting the lactose. Thus it becomes very easy to identify the coliforms colonies. (25, 26, 27, 6, 4:250, 24:508,28)

COMPARISON OF MULTIPLE-TUBE FERMANTATION TECHNIQUE and MEMBRANE FILTER TECHNIQUE

When Membrane filter technique is compared with Multiple Tube Fermentation technique we see that it has the following advantages and disadvantages.

Advantages :

a) The membrane filter technique has a higher degree of precision (reproducibility) than the multiple tube fermentation test.

b) It permits the examination of much larger volumes of sample than the multiple-tube test, with increased sensitivity in coliform detection.

c) Definite results are obtained in a shorter time than with the multiple tube procedure (approximately 24 hrs. versus 48 to 96 hr for MPN). The reduction of time is important consideration for the prompt initiation of corrective treatments.

d) Membrane filter method provides a direct enumeration of the bacterial density as opposed to a satistical estimate.

e) The membrane filter method can be used in the field preventing undesirable changes in coliform content of the samples which can result in a stored sample. This field examination uses ~~a~~ Field Monitors (Fig.2)

which consist of plastic filter holders, between which a membrane filter disc is sealed tightly. A cellulose pad is placed beneath the filter to support and to distribute fluid flow over the entire filter surface. The effective filtration area of Millipore Field Monitor is 9.0 square centimeters. It is advisable to incubate the Field Monitors in a field incubator directly after sampling. Monitors containing Endo Broth, however, can be mailed to the laboratory if shipping delays are not in excess of 48 hrs. and temperatures do not exceed 42°C.

c Disadvantages :

a) Waters with turbidity due to algae or other materials may cause clogging.- Millipore filters especially are easily clogged by liquid-borne particles which approximate the Millipore filter pore size and by stable gels.- This precludes the testing of a required size sample and thus it is not possible to obtain reliable results.

b) In waters with a high density of noncoliform organisms the ratio of membrane filter density estimates, will be excessively low when compared to MPN estimates. This may be due to the effects of noncoliform organisms on coliforms.

In general the MPN and the membrane filters do not give the same results, nor has a relationship between the two methods been established. (4:251, 24:508-9, 27:22-23)

An other tentative method for detecting pollution of a water supply by pathogenic organisms is the use of enterococci as indicator. The presence of enterococci in water may accurately indicate fecal contamination since these are normal enteric inhabitants in man and other warm blooded animals.

Monitor showing its construction.

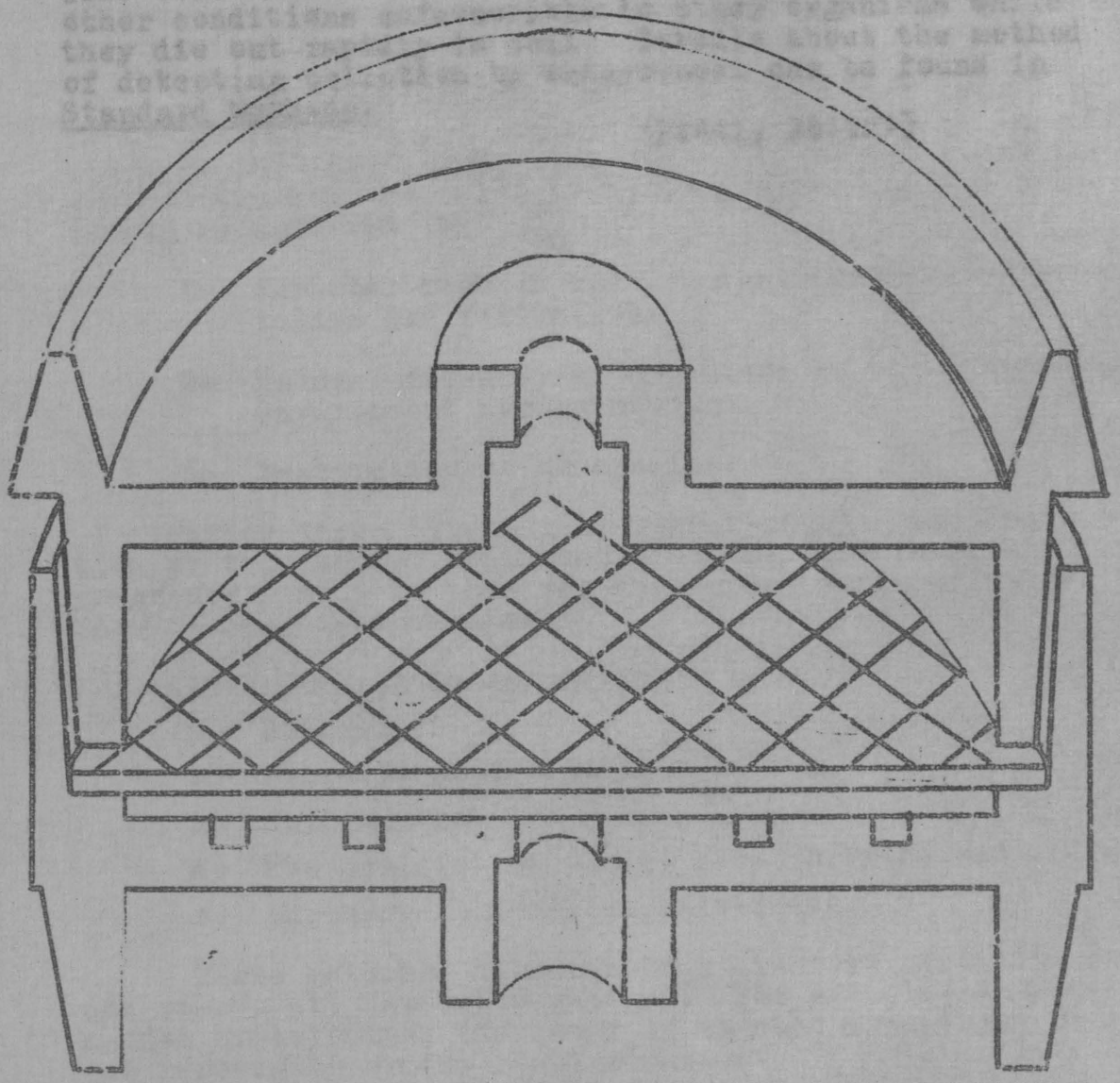


Fig 2. Cross sectional view of field Monitor showing its construction.

Enterococci are seldom found in areas not associated with fecal pollution of either humans or animals. An other characteristic of enterococci is that they have wide tolerance of to heat, cold, pH as high as 9,6 and other conditions unfavourable to other organisms while they die out rapidly in soil. Details about the method of detecting pollution by enterococci can be found in Standard Methods.

(9:441, 24:523)

DISINFECTION

The existence of pathogenic organisms and of other undesired substances in the water, forces people to treat water before using it.

The earliest recorded knowledge of water treatment is in the Sanskrit medical lore and Egyptian wall inscriptions dating about 2000 B.C. (4:1). In modern times the destruction and removal of undesired organisms and substances is achieved by:

1- Physical removal through coagulation, sedimentation and filtration.

2- Natural die-away of organisms in an unfavourable environment during storage.

3- Destruction by chemicals.

After these treatments, disinfection - the destruction of the harmful, pathogenic organisms - is still necessary. Only in this way the transmission of water born diseases is prevented.

Disinfection is accomplished by

a) Heating
b) Ultraviolet irridation
c) Chlorination
d) The addition of ozone, lime, bromine and iodide
e) Exposure to coloidal silver etc.

These methods, although they are very effective do not remove all harmful organisms. For example, Endamoeba histolytica, the cause of amoebic dysentery, is not removed by ordinary chlorination.

From the methods mentioned above the most common one is chlorination, which will be discussed in more details.

CHLORINATION

Chlorination is a method of disinfection which has been practiced since about 1850 in emergencies and which after 1904 became common practice in England, and later in other countries.

Chlorine gains its characteristic as disinfectant by the fact that it is toxic, but at the same time the concentration in which is used for the killing of pathogenic organisms in water, does not have any effect on man. Experiments have shown that 50 mg/l can be ingested safely by human beings while in disinfected water the concentration is usually less than 1 mg/l when it reaches the consumer.

Chemistry of Chlorination :

Atomic Chlorine can exist in any one of several oxidation states. Some of the compounds in which chlorine exist in different oxidation states are listed below.

Compound	Chlorine Valence
ClO_2	+ 4
$NaClO_2$	+ 3
HOCl	+ 1
Cl_2	+ 0
NaCl	- 1

The higher the oxidation level, the more powerful is the oxidizing power of the chlorine compound. However with the exception of chlorides, little difference in bacterial efficiency is noted between the oxidation levels. (29:157-8)

When chlorine is added to water we have

Hypochlorite ion (OCl) and

Hypochlorous acid (HOCl) formed.

The reactions are :

I. When chlorine gas is added

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-$$

and $$HOCl \rightleftharpoons H^+ + OCl^-$$

II. When hypochlorites are added to the water, they ionize first to form hypochlorite ion,

and then this ion establishes an equlibrium with hydrogen ion in accordance with the equations.

$$Ca(OCl)_2 + H_2O \rightleftarrows Ca^{++} + H_2O + 2OCl^-$$
$$OCl^- + H^+ \rightleftarrows HOCl$$

The amounts of OCl^- ions and HOCl in the solution depend upon the pH, thus OCl^- predominates at higher pH while hypoclorour acid (HOCl) predominates at lower (see Fig. 3)

Relating this with the fact that disinfection efficiency of chlorine decreases noticeably with increase of pH, it can be assumed that HOCl is the effective agent in disinfection with chlorine.

The reaction of HOCl with NH_3 in the water forms chloramines according to the following reactions :

$NH_3 + HOCl \longrightarrow NH_2Cl + H_2O \rightarrow$ monochloramine
$NH_3 + 2HOCl \longrightarrow NHCl_2 + 2H_2O \rightarrow$ dichloramine
$NH_3 + 3HOCl \longrightarrow NCl_3 + 3H_2O \rightarrow$ trichloramine (30:248)

The first two of these have significant disinfecting power. Monochloramine is formed at pH values above 7,5 dichloramine at pH values from 5 to 6.5 and trichloramines at lower pH values (31:1000). These properties are some times used for differentiating between monochloramine and dichloramine.

The hypochlorous acid and hypochlorite ion are refered as "free chlorine residuals" while the chloramines are called "combine chlorine residuals".

Chlorine combines also with other materials such as iron, manganese and organic compounds. These creat a demand, but do not produce any disinfection.

The reactions which take place when chlorine is added to the water can be summarised by the "break-point curve" shown on Fig.4.

Thus the chlorine added initially (between A-B) reacts with reducing agents (hydrogen sulfide, nitrites, ferrous ions etc.) present, it is reduced to chlorides and no residual chlorine remains. No disinfection can occur in the absence of residual chlorine. After the chloramine

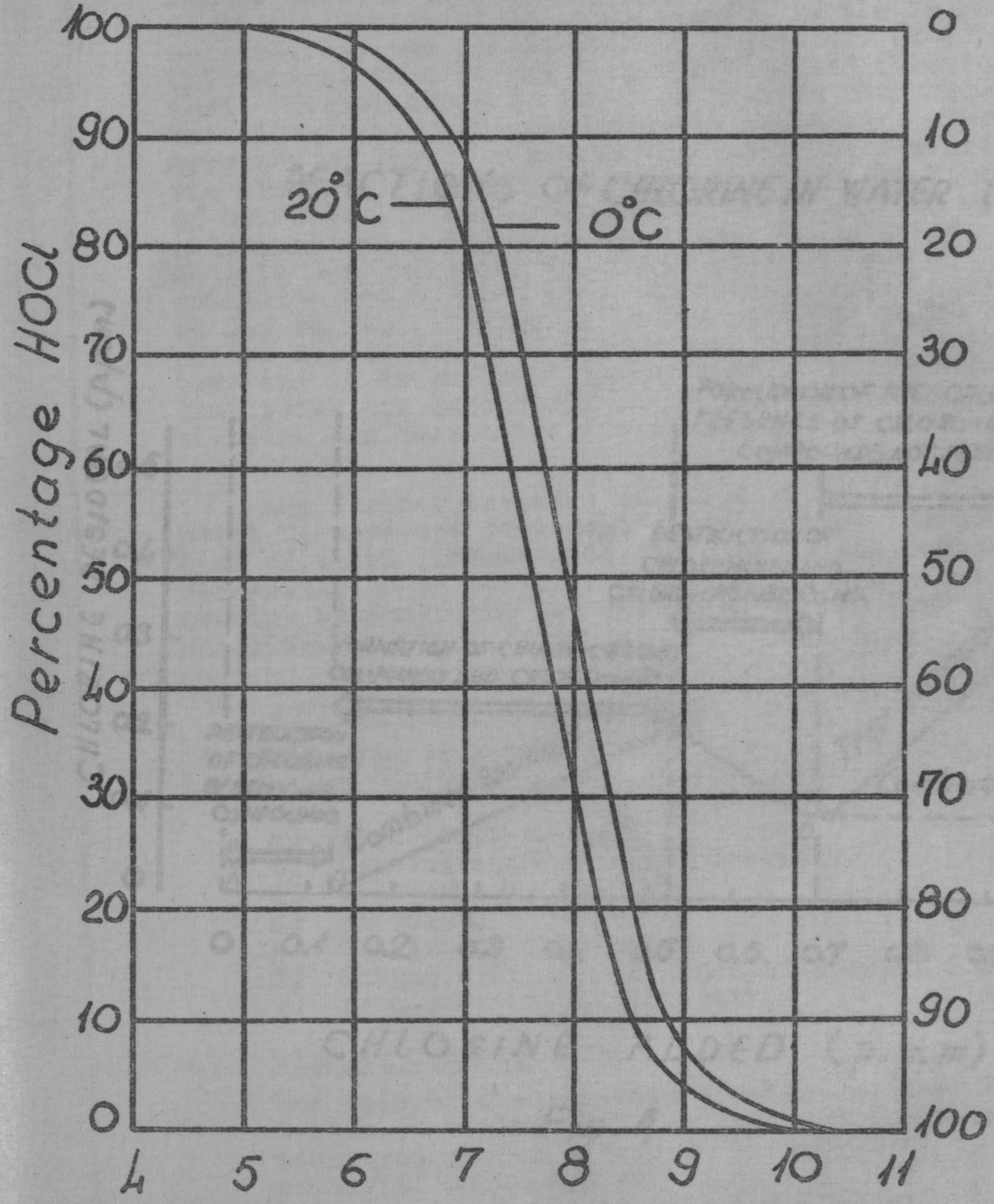


Fig. 3. Relationship between HOCl, OCl^-, and pH at 0 and 20°C. (4:467)

REACTIONS OF CHLORINE IN WATER (33:139)

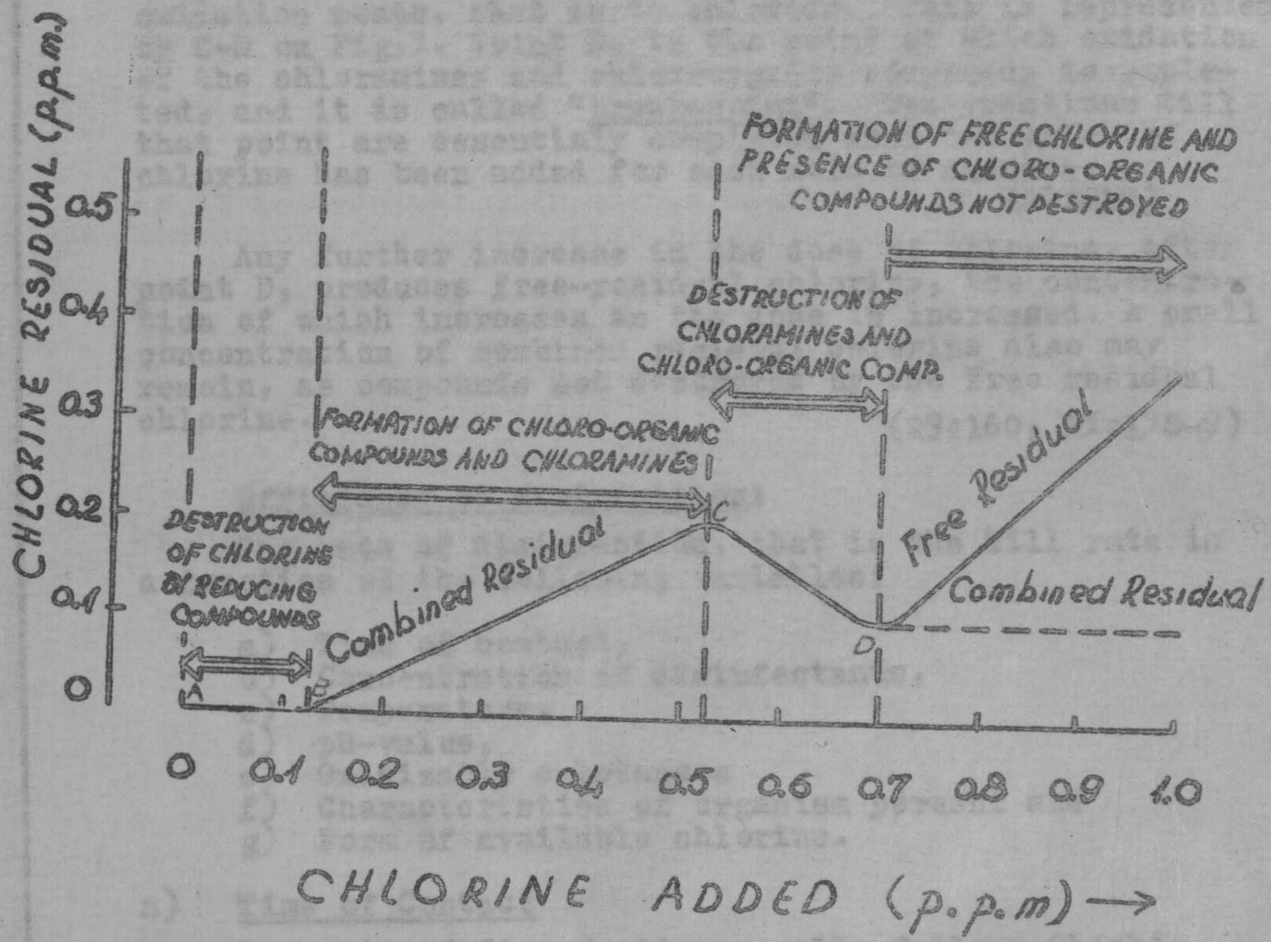


Fig. 4

demand exerted by reducing agents has been met (point B) further addition of Chlorine results in the formation of chloramines, and chloro-organic compounds. (B-C) Chloramines thus formed impart a combined chlorine residual. Higher doses of chlorine lead to the oxidation of the chloramines and chloroorganic compounds. The destruction of this chloramine fraction, which decreases the chlorine residual, is accompanied by the formation of oxidized nitrogen compounds such as nitrous oxide, nitrogen, and nitrogentrichloride. The decrease of residual is the reduction of atomic chlorine to its lowest oxidation state, that is to chloride. This is represented by C-D on Fig.3. Point D, is the point at which oxidation of the chloramines and chloroorganic compounds is completed, and it is called "break-point". The reactions till that point are essentialy completed when two moles of chlorine has been added for each mole of ammonia. (30:252)

Any further increase in the dose of chlorine, after point D, produces free-residual chlorine, the concentration of which increases as the dose is increased. A small concentration of combined residual chlorine also may remain, as compounds not destroyed by the free residual chlorine. (29:160, 33:138-9)

Efficiency of disinfection:

The rate of disinfection, that is the kill rate is a function of the following variables:

a) Time of contact,
b) Concentration of disinfectants,
c) Temperature,
d) pH-value,
e) Oxidizable substances
f) Characteristics of organism present and
g) Form of available chlorine.

a) Time of Contact

The rate of disinfection usually follows Chick's law which states that the number of organisms destroyed per unit time is proportional to the number of organisms remaining.
This law is expressed with the following equation:

$$dy/dt = K(No-y)$$

where
y : the organisms destroyed
No : initial number of organisms
k : rate constant (unit (t^{-1}))
t : time of contact.

Integration betweenn the limits y = 0 at t = 0 and y = y at t = t gives:

$$\ln \frac{No-y}{No} = \ln \frac{N}{No} = -kt$$

which can be expressed also as

$$\frac{N}{No} = e^{-kt}$$

or

$$t = \frac{-1}{k} \ln \frac{No}{N}$$

where N : number of organisms remaining (34:477)

As it is understood from this equation is practically impossible the destruction of all organisms.

Although this is the case for most disinfectants, chlorine does not follow Chick's Law. Instead, the rate of kill of chlorine has been found to be expressed by the relationship

$$\frac{dN}{dt} = -kNt \qquad (1)$$

or its integral

$$\int_{N1}^{N2} \frac{dN}{N} = -k \int_{0}^{t} t\,dt$$

$$\ln \frac{N2}{N1} = -\frac{kt^2}{2}$$

$$t^2 = \frac{2}{k} \ln \frac{N1}{N2} \qquad (2)$$

Where

dN/dt : time rate of kill
N : number of living organisms
N1 : " " " " initially
N2 : " " " " at time t
k : rate constant

(29:160)

The rate constant k, can be determined experimentally from a semi logarithmic plot of the percent surviving versus the square of the contact time. (29:162)

b) Concentration of disinfectant:

Changes in efficiency, with concentration of the disinfectant can be expressed by the equation

$$c^n t : \text{Constant}$$

where t : time required to kill a given percentage of microorganisms
c : concentration of disinfectant
n : coefficient of dilution

The value of "n" can be determined by plotting contact time as a function of concentration on a log-log paper. The slope of this streight line is -1/n

Within the pH range of 7 to 10, and for the organism Escherichia coli, the value of the coefficient of dilution, n, is approximately 1.3 for both free available and combined available chlorine residuals (29:148,161:34:479)

c) Temperature :

The variation of the rate of disinfection is expressed by the Van't Hoff- Arrhenius equation

$$\log \left(\frac{t1}{t2}\right) = \frac{E\,(T2-T1)}{2.303\ RT1T2} \qquad (4)$$

where T2,T1 : temperatures (in degrees Kelwin) between which the rates are to be compared.

t1,t2 : times required for equal percentage of kill to be effected at these temperatures and at a fixed concentration of disinfectant.

E : activation energy (calories)

R : gas constant (≈1.99 cal per degree C.)

Using this they found the effect of temperature on the rate constant, k, of the equation of time of contact (see eq. 1 and 2) which is expressed by the empirical relationship

$$k = Ce^{-(\Delta Ha/RT_a)}$$

where C : constant
ΔHa : energy of activation (E in equat.4)
R : gas constant, 1.99 cal/°C
T_A : absolute temperature °K

A plot of log k versus (1/TA) enables us to evaluate both the constant C and the energy of activation, ΔHa. Values of ΔHa and C (when chlorine is the disinfectant) are listed in Table 2. These values which are specific for the organism Escherichia coli, are based on limited data and therefore, must be used with caution (34:480, 29:148:9)

TABLE 2.

VARIATION OF THE ENERGY OF ACTIVATION AND THE CONSTANT IN EQUATION $k : Ce^{-(\Delta Ha/RTa)}$ WITH pH* (29:162)

	pH	Ha (calories)	C
Free Available Chlorine	7.0	8200	8.16×10^5
	8.5	6400	1.40×10^4
	9.8	12000	2.60×10^6
Combined Available Chlorine	7.0	12000	8.95×10^6
	8.5	14000	1.00×10^7
	9.5	20000	1.45×10^{10}

* Esch. coli was used as the test organism.

d) pH Value :

Chlorination is more effective at low pH. For equal concentrations of chlorine added, other conditions being equal, 150 times as much chlorine must be added at a pH of 10 than at pH of 5 to produce the same killing effect (12:530)

e) Oxidizable Substances :

Chlorine is primarily an oxidizing agent, hence oxidizable substances reduce chlorine and weaken its bactericidal effect (12:530)

f) Forms of Available Chlorine

Free available chlorine is more effective bactericide than combined available chlorine. To obtain the same kill with the same amount of free available chlorine and combined available chlorine, under the same conditions requires approximately 100 times the exposure period of the first for the second. It is because of that, that the recomended minimum concentration of combined available chlorine residual is higher than the minimum concentration of free available chlorine residual (see table 3) (37:158-9)

TABLE 3.

RECOMMENDED MINIMUM CONCENTRATIONS OF FREE RESIDUAL CHLORINE VERSUS COMBINED-RESIDUAL CHLORINE TO ENSURE EFFECTIVE DISINFECTION

pH value	Minimum concentration of free residual chlorine p.p.m.		Minimum concentration of combined residual chlorine p.p.m.	
	U.S.A.* (disinfection period at least 10 min.)	Turkey+ (For disinfection period see table 4)	U.S.A.* (disinfection period at least 60 min.)	Turkey+ (For disinfection period see table 4)
6.0-7.0	0.2	0.2	1.0	1.0
7.0-8.0	0.2	0.3	1.5	1.5
8.0-9.0	0.4	0.4	1.8	2.0
9.0-10.0	0.8	0.4	not recommended	2.0
10.0+	0.8 (with longer contact)	0.4	" "	2.0

* From Manual of instruction of water treatment plant operators of New York Department of health. (33:142)

+ This values will be applied in Turkey after March 1, 1968 (37)

TABLE 4.

DISINFECTION PERIODS ACCORDING TO TURKISH LAWS (37)

Category of Water	Minimum Contact period (minutes)	
	When free residual chlorine is formed	When combined residual chlorine is formed
Drinking Water which is treated only by chlorination	10	30
Drinking Water which is treated by chlorination, filtration, coagulation and other similar treatments	30	60

BACTERICIDAL EFFECT OF CHLORINE

The manner in which chlorine and chlorine compounds effect their killing action upon bacteria has received much study, but little has been learned about the mechanism. Some of the hypotheses that have been advanced to explain the bactericidal effect of chlorine are :

1) Effect of nascent oxygen:

This assumes that the decomposition of HOCl releases nascent oxygen which oxidizes the organic matter of which the bacteria is composed. This hypothesis is absolete, and has lost support because chloramines contain no oxygen.

2) Effect of direct chlorination resulting from the reaction of free chlorine with the bacterial protoplasm.

3) The fact that toxic substances are formed by the reaction of the chlorine with substances in the bacterial cell wall.

4) The fact that it inhibits a key enzymatic process.

None of these hypotheses has been generally accepted (12:529-30;31:1000)

Chlorine Demand

The chlorine demand of water, that is the amount which is required to kill pathogenic bacteria, is the difference between the amount of chlorine added and the amount of free, combined or total available chlorine remaining in the water at the end of the contact period.

The minimum chlorine residual, according to the New York State Department of Health (seet Table 3) is 0.2 mg/l. According to the Standard Methods the smallest amount considered significant is 0.1 mg/l. (24:103).

The chlorine demand can be determined in the following way :

A break-point curve is dawn for the water in consideration, by preparing different solutions in which the concentration of chlorine varies from 0.1 mg/l to 1.0 mg/l or more. After a period of time equal to the contact period the chlorine residual is determined. The initial concentration of the solution, giving the required chlorine residual, is equal to the chlorine demand.

Determination of Residual Chlorine :

In the 11th edition of Standard Methods, the following methods for the determination of residual chlorine are recomended.

a)	Iodometric method	Standard Methods
b)	Orthotolidine method	
c)	Orthotolidine flash method	
d)	Orthotolidine - Arsenite method	
e)	Drop dilution method	
f)	Amperometric titration method	
g)	Differential amperometric titration	Tentative Methods
h)	Palin method	

The first two of these methods determine total chlorine residual, while the others differentiate between free and combined chlorine residual. The last two which are tentative methods, differentiate between chloramines and dichloramines.

Methods of measuring chlorine residuals depend upon the oxidizing power of chlorine; consequently any other oxidizing agent present may interfere with the test. Manganese in valence above two and nitrites are the most common interferences.

Details for the above mentioned methods can be found in Standard Methods, however some explanations for some of them will be given in the following lines.

a) Iodometric Method

This method depends on the fact that chlorine will liberate free iodine from potassium iodide solution, when its pH is 8 or less. The liberated iodine is titrated with 0.I.N standard thiosulfate solution, using starch as indicator. The end point of the titration is indicated by the disappearance of the blue color, which iodine products in the presence of starch. The reactions which take place are :

$$Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$$

(I_2 + starch $\rightarrow$ blue color)

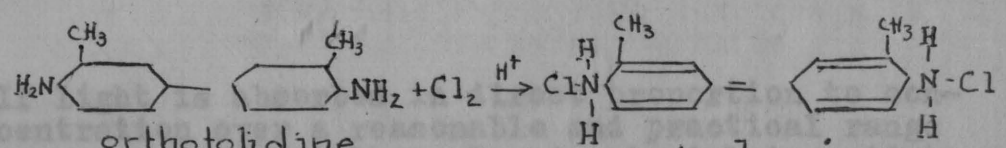
$$I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2NaI$$

$$I_2 + 2S_2O_3 \longrightarrow S_4O_6^{=} + 2I^-$$

This method is used in determining chlorine residuals of more than one mg/l.

b) Orthotolidine Method

This method depends on the fact that orthotolidine, which is an organic aromatic compound, is oxidized in acid solution by chlorine, chloramines or other oxidizing agents to produce a yellow colored compound, holoquinone. The reaction is represented as:



(30:254)

This yellow holoquinone color developed obeys Beer's Law* over a considerable chlorine range.

The reaction between orthotolidine and chloramines is slow. For this reason it is recommended that the sample be warmed to 20°C and a contact period of 3 to 5 min. provided before reading the residual chlorine.

The following substances may cause interferences to the orthotolidine test : Nitrite, ferric compounds, manganic compounds, organic iron compounds, lignocellulose and algae.

c) Orthotolidine Flast test method

Makes use of the fact that free chlorine reacts almost instanteneously with orthotolidine even at 0°C while combined chlorine needs some time and higher temperature. It is a qualitative technique. It is affected by colloidal-manganese dioxide.

d) Orthotolidine-Arsenite (OTA) test

This method is based on the fact that free chlorine residuals react instaneously with orthotolidine, to produce the yellow holoquinone while chloramines react more slowly. In the simpliest way of determination two test are performed. Total residual is measured in the usual way with the reading made after 5 min. so that full color to be developed. A second test is made in order to obtain free residual. In this 5 sec. after the orthotolidine a much stronger reducing agent - sodium arsenite solution - is added. This reduces the chloramines instanteneously. Thus the color developed is only due to free chlorine residual.

Knowing total and free residual chlorine combined chlorine can be determined by the equation:

Combined residual Chlorine : Total residual chlorine - Free residual chlorine.

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* If light is absorbed in direct proportion to concentration over a reasonable and practical range of concentration, the colored material is said to conform to Beer's Law (30:50)

e) Drop-dilution method

The Drop-dilution method is a rapid field method applied especially when chlorine concentrations are greater than 10 mg/l.

f) Amperometric titration method

Amperometric titration method is the most accurate method in the determination of free or combined chlorine. The titration procedure requires the use of internal indicators or electrometric devices, employing a suitable electrode system to show when reactions are completed. In the titration, a titrating agent Phenylarseneoxide (C_6H_5AsO) is usually used as a reducing agent. Free available chlorine is determined by titration at pH between 6.0 and 7.5. A range in which the combined chlorine does not react. The combined chlorine is titrated in the presence of the proper amount of potassium iodide in the pH range 3.5 to 4.5.

The amperometric titration method is usually uneffected by the presence of various oxidizing agents, temperature variations, turbidity and color which interfere with the accuracy of the other methods. (30:253-5,24:81-98)

CHARACTERISTICS OF CHLORINE

Some important characteristics of the chlorine affecting its use and handling are

1) Color : of gas : greenish-yellow
of liquid; amber

2) Odor : typical penetrating

3) Weight: of gas at room temperature about 2.5 times that of air; of liquid 1.5 times that of water

4) Solubility : Solubility of chlorine in water is low (abbut 7300 mg/l at 68°F and pressure of 1 atm.) and it is affected by the temperature as shown in Fig.5. Below 49.2°F chlorine combines with water to form solid chlorine

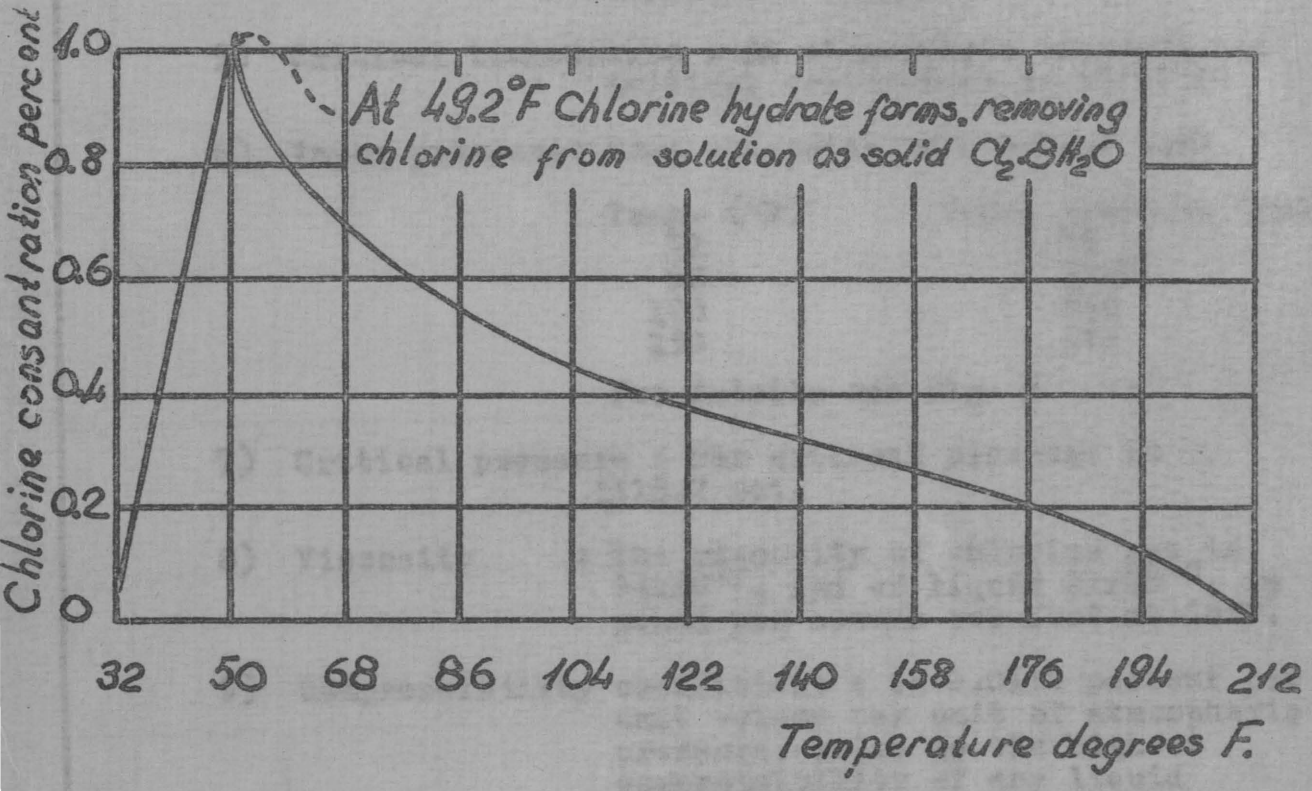


Fig. 5.- SOLUBILITY OF CHLORINE IN WATER (31: 1002)

hydrate, called "chlorine ice". This interferes with the proper operation of the feeding equipment, thus water which comes into contact with the chlorine gas should be kept above 49.2°F.

5) Critical temperature : At atmospheric pressure the critical temperature is 291.2°F.

6) Vapor pressure: Some characteristic values are:

Temp. (°F)	Vapor pressure (psi)
32	39
68	81.9
100	140
150	270

For details see Fig. 6

7) Critical pressure : The critical pressure is 1,118.7 psi.

8) Viscosity : The viscosity of chlorine gas is 94×10^{-7}, and of liquid 23×10^{-5}, in pound per second per foot at 68°F.

9) Compressibility coefficient : is 0.0118 percent per unit volume per unit of atmospheric pressure, which is the highest compressibility of any liquid element and results in rapid increase in pressure with rise in temperature.

10) Ratio of volume of gas to volume of liquid at 32°F and pressure 776 mmHg is 462; or one lb. of liquid forms about 5 cub.ft.gas.

11) Toxicity : This is the main characteristic of chlorine which renders it disinfectant.

12) Other properties : The dry gas is highly corrosive to metals at temperatures above 300°F, and it may become corrosive at 195°F (steel burns brightly in dry chlorine at temperatures above 194°F). At lower temperatures it does not react with metals.

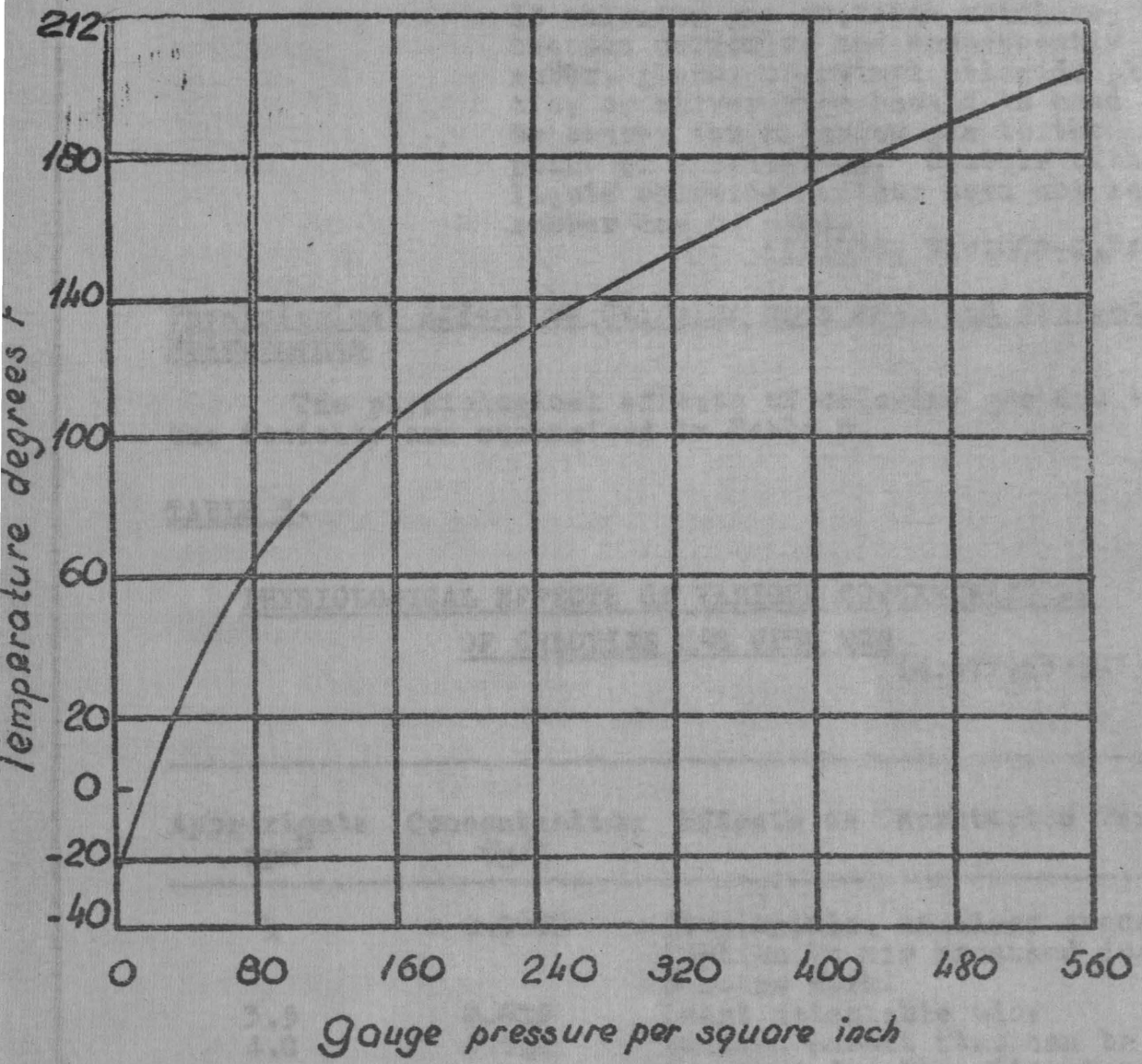


Fig. 6.-VAPOR PRESSURE OF LIQUID CHLORINE (31:1002)

If chlorine gas contains moisture, it becomes corrosive and consequently rubber, glass, polyvinyl chloride plastic, or silver pipe should be used to be convey the chlorine gas to the point of application. However with liquid chlorine neither hard nor soft rubber may be used. (12:535, 31:1000-2,34)

Physiological Effect of Chlorine upon Men, and Protective Measurments :

The physiological effects of chlorine gas due to the toxicity are summarized in Table 5.

TABLE 5.

PHYSIOLOGICAL EFFECTS OF VARIOUS CONCENTRATIONS OF CHLORINE GAS UPON MEN (4:473,13:207)

Approximate ppm*	Concentration mg/l	Effects on Unprotected Persons
1	0.0029	Permissible, harmless concentration in air breathed during 8 hours work.
3.5	0.010	Least detectable odor
4.0	0.012	Maximum amount that can be breathed for 1hr without serious disturbances.
15.1	0.044	Least amount required to cause irritation of throat
30.2	0.088	Least amount required to cause coughing
40-60	0.12-0.17	Amount dangerous even in short period of exposure
1000	2.9	Quickly fatal

* Parts of chlorine gas per million parts of air, by volume.

Chlorine is particularly irritating to persons suffering from asthma or certain types of chronic bronchitis. Therefore such persons should take care not to expose themselves to chlorine. Chlorine gas in the atmosphere causes coughing, difficulty in breathing and bronchial catarrh.

As the condition of the patient deteriorates, the successive stages observed are as follows: - difficulty in breathing (asthma) - fairly rapid breathing - irritation of the throat and larynx - expectoration of mucus frothing at the lips and nostrils - cyanosis (face blue) - very rapid breathing - red or pink sputum (+saliva) - loss of consciousness.

These characteristics of chlorine make necessary to ventilate the places where chlorine is used. Equipment should be available to change the air twice a minute in the chlorine storage room or chlorinator room.

CHLORINATORS

Chlorinators are instruments by which chlorine is fed to the water. They can be classified on the basis of :

A) State of Chlorine

B) Type of Solution feed

C) Method of applying vacuum to solution feed

D) Type of control

According to these we have :

I) Dry (or Direct) feeders

Dry feeders introduce chlorine gas directly in the water through a diffuser. Dry feeders find application chiefly as emergency equipment and on small installations.

II) Solution feeders

The chlorine gas is dissolved in a relatively small amount of water and the controlled solution is conveyed to the point of application. They are prefered and widely used because of greater capacity, greater flexibility of control and installation and greater adaptability to widely varying requirements.

III) Hypochlorinators or hypochlorite feeders

They are devices which feed the solution of hypochlorite at a constant rate to the water which is to be treated. Variable speed hypochlorinators are available.

Details about the chlorinators, the way of opperation, and their diagrams can be found in the Appendix.

PART II

THE WATER SYSTEM OF ROBERT COLLEGE
and
ITS EVALUATION

The water system of Robert College has continuously changed and improved with the growth of the Robert College Community. In the beginning each building obtained its water from cisterns which were filled with rain water. Latter, water from the city distribution system was utilized and pumped uphill to a tank from where it was distributed. Despite the changes and improvements the system was inadequate. During the academic year 1964-65 an infectious hepatitis epidemic, which was attributed to pollution of the water, swept the campus.

Further changes were made on the water system after the 1964-65 epidemic but no evaluation of the system has been made.

Description of the present system:

The Robert College water system which serves approximately 1450 persons, obtains its water from the city at the Bebek Gate. The two systems are connected by a cistern. In the cistern the water is chlorinated by a Permodid hypochlorite chlorinator. The Permodid chlorinator feeds a constant rate of hypochlorite independent of the quantity of water being treated. The water thus stored and chlorinated is pumped to the storage reservoir and distribution system. Two pumps are used. Although the pumps can be used in parallel, normally one is used in stand by.

The water from the pumphouse is pumped to the Administration Building and there the system separates. One pipe serves the power house and the infirmary and the other conducts water to a storage tank at the southwest corner of the campus. From the tank the water is distributed to the other buildings.

The water of the cisterns, which exist in most buildings, can be used also,

Details of the distribution system can be seen on the "General Map of Robert College" which is included in the Appendix.

Consumption of Water

From the data obtained between October 11 and November 24 it was found that the average daily consumption was 320 m^3/day with a maximum daily consumption of 461 m^3/day and minimum of 182 m^3/day. The average of October was 322 m^3/day and of November 319 m^3/day.

The variation of consumption based on water pumped within the above period was very irregular and no regular pattern of pumping was observed. (Fig. 7)

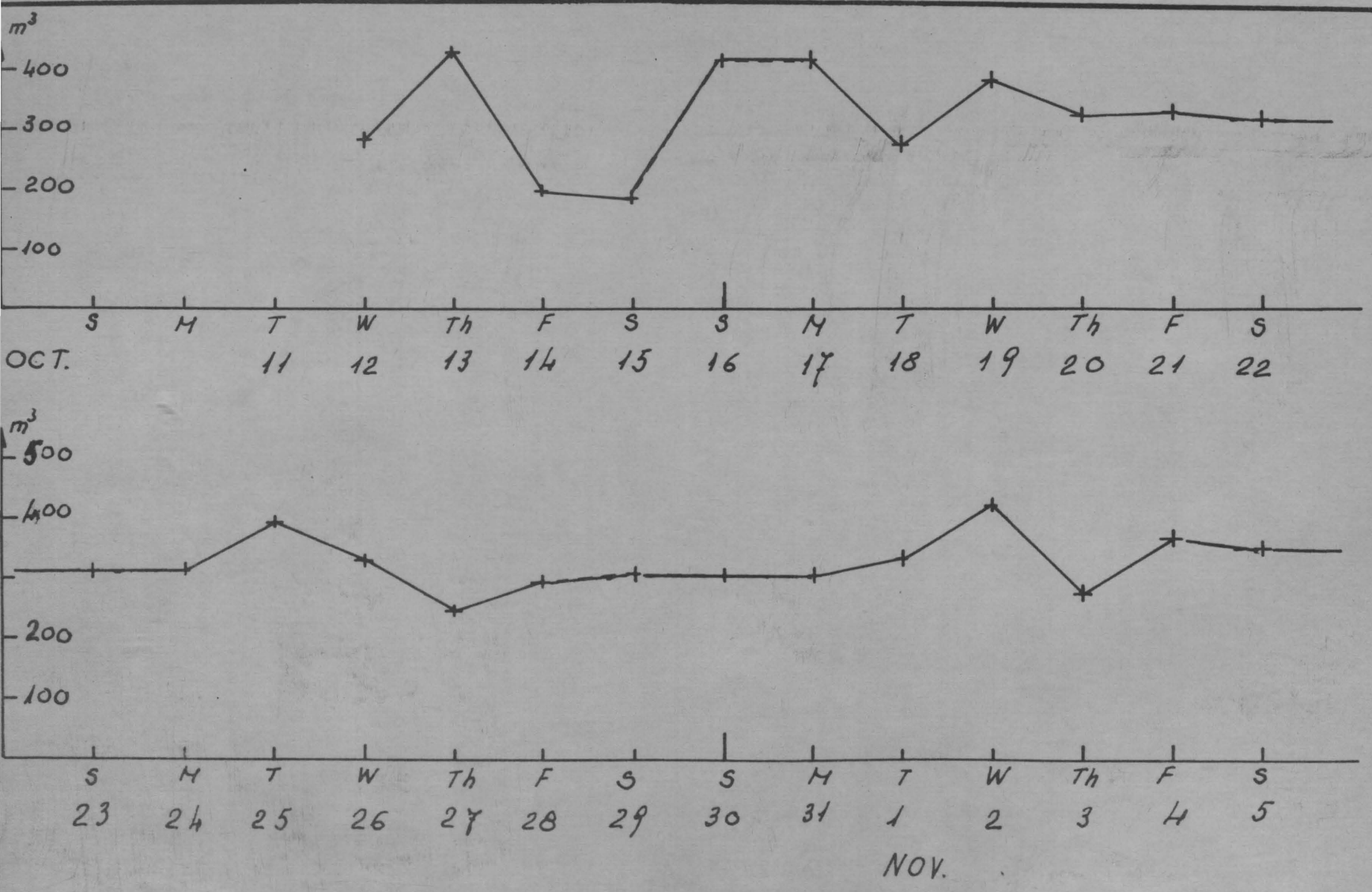


Fig 7.— DATA RELATED TO THE WATER DEMAND OF ROBERT COLLEGE

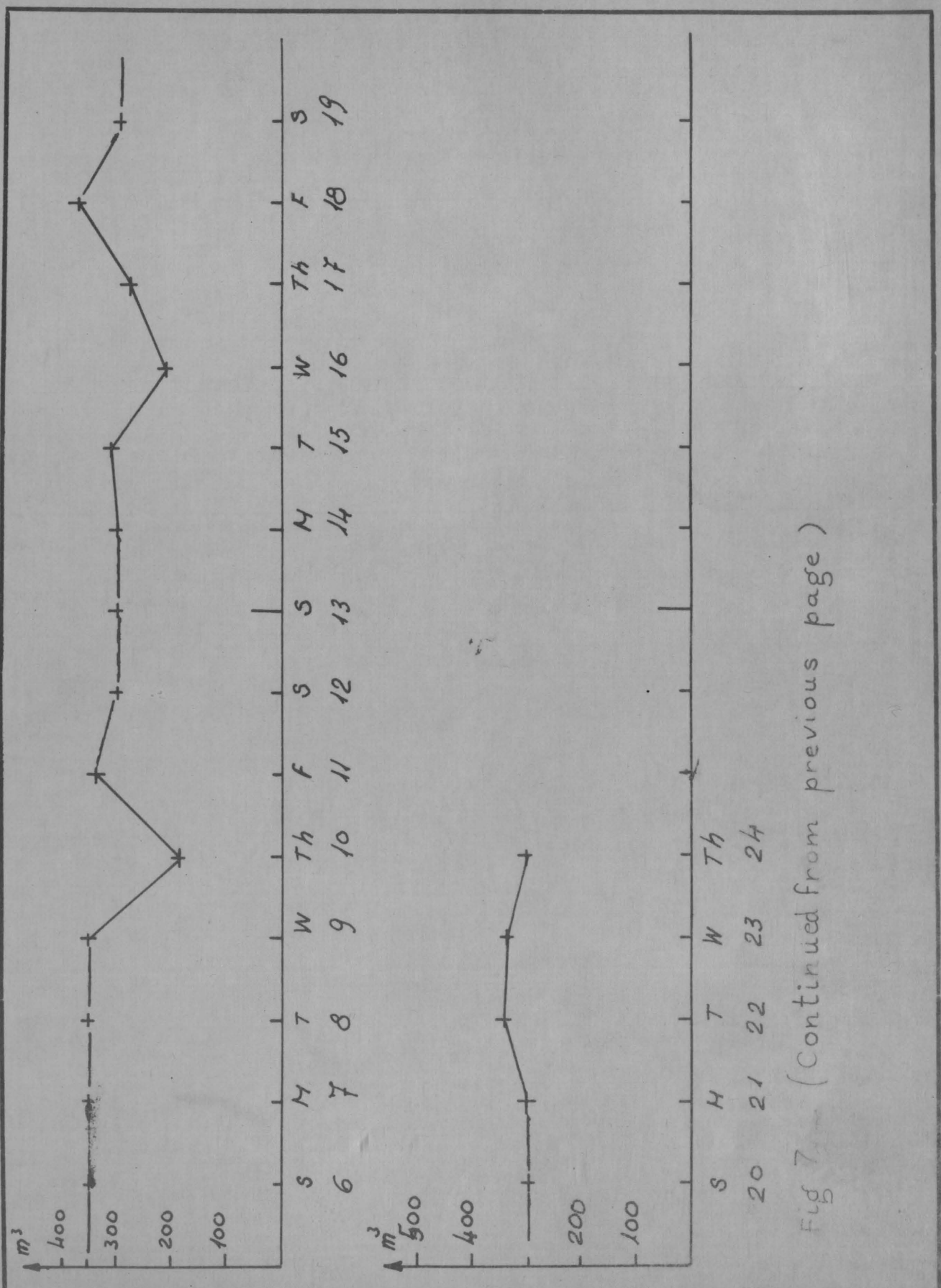


Fig 7 (Continued from previous page)

TESTS

A) BACTERİOLOGICAL EXAMINATION OF WATER BY MEMBRANE FILTER TECHNIQUE

Bacteriological quality is necessary factor in determining whether a water is potable. Potable water is free from pathogenic organisms.

Various methods for the bacteriological examination of water have been previously discussed. In this study the bacteriological evaluation was made by using the membrane filter technique and Millipore Field Monitors.

The apparatus and materials used included:

1. Millipore Field Monitors,
2. Endobroth, Difco Laboratories,
3. A furnace as an incubator
4. A 50 cc. syringe
5. A glass cup

PROCEDURE

Samples from selected points on Robert College Campus (see Appendix) were taken in accordance with the following procedure :

1. The water was allowed to run for five minutes before the sample was taken.

2. The cup in which the water was to be collected was rinsed thoroughly with the water to be tested.

3. The cup was filled with water.

4. The plug from the bottom of the Field monitor was removed and the filter was fixed on the syringe.

5. The plug from the top hole was removed.

6. One hundred cc of water were filtered by drawing the syringe plunger back very slowly. If the filter in the Monitor became wet before the Monitor was completely filled an "air lock" developed and filtration was impossible.

7. The Monitor was removed from the syringe, and was shaken, to be sure that no water droplets remained in the bottom hole.

8. Eight tenth's of a milliliter of Endo-Broth was poured through the bottom hole of the Monitor on the absorbent pad. The broth was added from the bottom since it is somewhat toxic if applied to the surface.

9. The plugs where replaced on the monitor.

10. The monitor was incubated in an inverted position at 37°C for 24 hrs. Recommended temperature for incubation is 35°C ± 1°C.

11. The number of Coliform colonies noted by a sheen were counted.

RESULTS and DISCUSSION

Tests for the bacteriological evaluation of the water system were conducted during a four month period. The results obtained from these tests are summarised as follow.

The samples from the fountain to the north of the football field and from the drinking fountain of Anderson Hall had atypical colonies which might indicate the presence of coliform bacteria.

The samples from Hamlin Hall had excessive solids. This water would be deemed unfit for human consumption under the United States Public Health Standards.

During the laboratory portion of the project several difficulties were encountered which might affect the validity of the tests.

The quantity of Endomedia used was 2.0 ml. per monitor. (The media was packed in sterilized containers of 2 ml.) This tended to flood the disk and could have washed the organisms to the upper surface of the Monitor where they would not be observed. On opening these monitors after incubation, for counting, excess liquid was always present. The larger quantity of Endomedia could be toxic and prohibit the formation of the metalic sheen. The volume added after February 13 was approximately 0.8 ml. This quantity only soaked the pad behind the filter and this would not wash off the organisms which had been cultured on the pad. Samples of sewage were used to check the media and the validity of the tests.Early samples gave positive results, when a sewage sample was used. However samples run on February 21 and March 22 did not give positive results. However this can be due to the fact that large quantities of coliform organisms can inhibit the formation of coliform colonies.

The media is known to detoriate with age even when stending in sterilised viles. The media was manufactured in February of 1964 and had passed the normal expitation date by February 1967.

Another difficulty encountered was that a regular incubator was not available. A furnace in the soils laboratory had to be used and the temperature could not be maintained at 35° ± 1°C. A variation of as much as 5°C was detected.

The other means to check the filter would be the multiple tube fermantation technique. Attempts were made to prepare lactose-broth, but no commercial beef-extract was available in Istanbul. Beef-extract was prepared by cooking a beef for 30 min in "bain-marie" (a boiling water within which a closed jar containing the beef was placed). The lactose broth prepared from this extract had a pH 4.5 which was below the optimum pH of 6.9. This low pH would inhibited the growth of the bacteria. In future experiments a buffer should be used in the lactose broth to maintain the pH at 6.9.

DETERMINATION OF RESIDUAL CHLORINE

In order to eliminate any danger of pollution of the water a chlorine residual of approximately 0.4 mg/l should be maintained in the distribution system (Minimum values required in Table 3). Orthotolidine was used to determine the residual.

REAGENTS and INSTRUMENTS

Orthotolidine reagent,

is prepared by dissolving 1.35 g. orthotolidine dihydrochloride in 500 ml. distilled water. This solution was added with constant stirring, to a mixture of 350 ml distilled water and 150 ml concentrated HCL and stored in an amber bottle.

Color comparator

A color comparator for chlorine was used. The comparator was of Permodid P-777 type, and its range was from 0.1 to 3.0 mg/l.

PROCEDURE

Samples of water were tested for the determination of residual chlorine on the day and/or the following days of chlorination. In a 20 ml sample of water one ml of orthotolidine reagent was added, and after mixing, it was placed in the color comparator from which the residual chlorine was read.

If no chlorine had been added, no residual chlorine test was conducted.

RESULTS and DISCUSSION

As it is seen in the data (Appendix p. 72) only four of the samples examined within four months show a chlorine residual. However none of the positive samples contained the minimum of 0.2 mg/L required by the Turkish Standards (20). This shows that the chlorination was not properly accomplished.

DETERMINATION OF THE AVAILABLE CHLORINE PRESENT IN THE HYPOCHLORITE SOLUTION USED FOR CHLORINATING THE WATER BY SODIUM ARSENITE METHOD

In the determination of the available chlorine, present in the hypochlorite solution, the sodium Arsenite method given by Snell, in Commercial Methods of Analysis (41:136-7) was used.

Results

The average of the results obtained from the three tests (for data see appendix p. 73) was 4.8% available chlorine in the hypochlorite solution.

DETERMINATION OF BREAK POINT and BREAK POINT CURVE

In order to calculate the chlorine demand, the break point curve for the water of Robert College was determined. The procedure used was that given in Standard Methods.

Apparatus

1. Color comparator : A type permodid P-777 with a range 0.1-3.0 mg/l comparator was used.
2. Six one liter graduated cylinders
3. Thermometer
4. Dropper
5. Lamp for heating the samples.

Procedure

1. A hypochlorite solution used for chlorinating the water. This was diluted by adding 3 units of water to 1 unit of hypochlorite solution.
2. The graduated cylinders were filled to the 1000 ml mark with the water being tested.
3. While stiring constantly 0.6 mg of the diluted chlorine solution was added to the first graduate cylinder, 1.2 mg to the second, 1.8 mg to the third etc.
4. A contact period of 15, 30, 45 and 60 min. was used.
5. At the end of the contact period a 20 ml portion, from each sample was removed, and 1 ml. of orthotolidine reagent was added. After 5 min. total residual chlorine was determined by the color comparator.

In order to investigate the effect of temperatures, 20 ml portions of the above samples were separated and heated to 20°C and to 36°C respectively. The chlorine residual was then determined.

Points near the break point were examined more carefully by mixing different solutions, and thus concentrations, like 1.9, 2.1, 2.2 mg/l which were not possible to examined otherwise were obtained.

To check the procedure samples which had contact period of 60 minutes were mixed with water, and the residual of these was determined and checked with the value of the unmixed. For example, one portion of the solution where 2.4 mg chlorine was added, was mixed with one portion of water, and the residual of this was compared with the residual of the solution where only 1.2 mg chlorine was added at the beginning. Both showed the same Chlorine residual.

RESULTS

The results of this experiment are summarized on Table 6.

TABLE 6 - BREAK POINT FOR DIFFERENT TEMPERATURES AND CONTACT PERIODS

Contact Period min.	Temperature	Chlorine added corresponding to Break point mg/l *	Residual Chlorine Corresponding to Break point mg/l
15	10	1.8 - 2.1	0.8
30	12	1.2 - 1.5	0.4
45	13	1.8 - 2.1	0.8
60	14	2.0	0.7
60	20	1.8 - 2.1	0.8
60	36	1.8 - 2.1	0.7

* When it wasn't possible to determine exactly the chlorine added which was corresponding to break point two values, for which the same residual chlorine was obtained as chlorine added and between which the break points occured were given.

The break point curves obtained can be seen on Fig. 8-13.

DISCUSSION

The data indicates that the break point occurs some where between 1.8 - 2.1 mg/L of applied chlorine, and more detailed investigation has shown that for a contact period of 60 min. at 14°C the break point occured when 2.0 mg/l chlorine was added. This means that to each 24 m^3 of water 1 liter of the hypochlorite solution containing 4.8% available chlorine should be added.

A point which should be noted here, is that the characteristics of the water are changing from day to day, and thus a different break-point curve and break-point will be obtained each day.

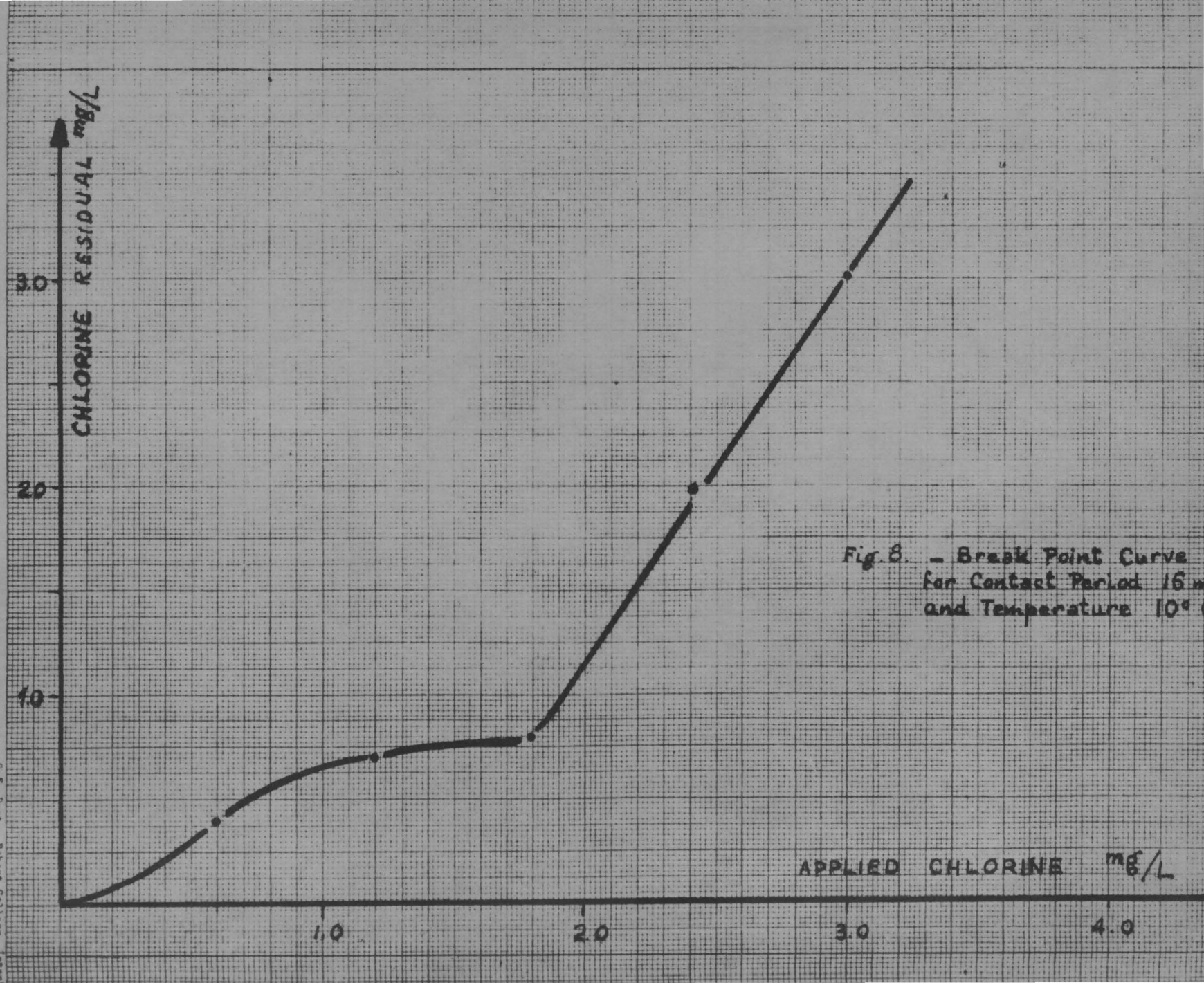


Fig. 8. – Break Point Curve
for Contact Period 16 m
and Temperature 10°

Fig. 9 – Break Point Curve
for Contact Period 30
min. and Temperature 12°

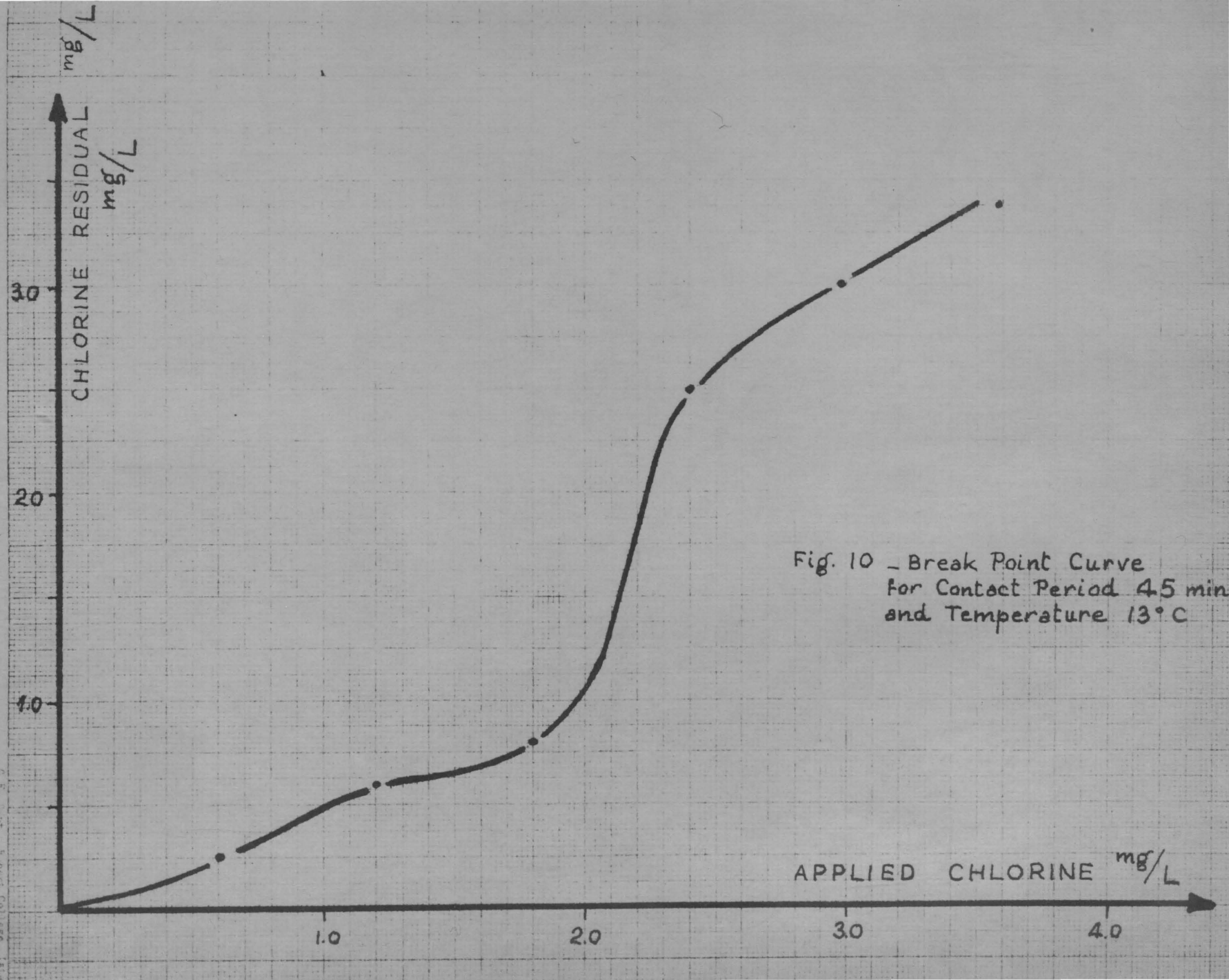


Fig. 10 _ Break Point Curve for Contact Period 45 min and Temperature 13° C

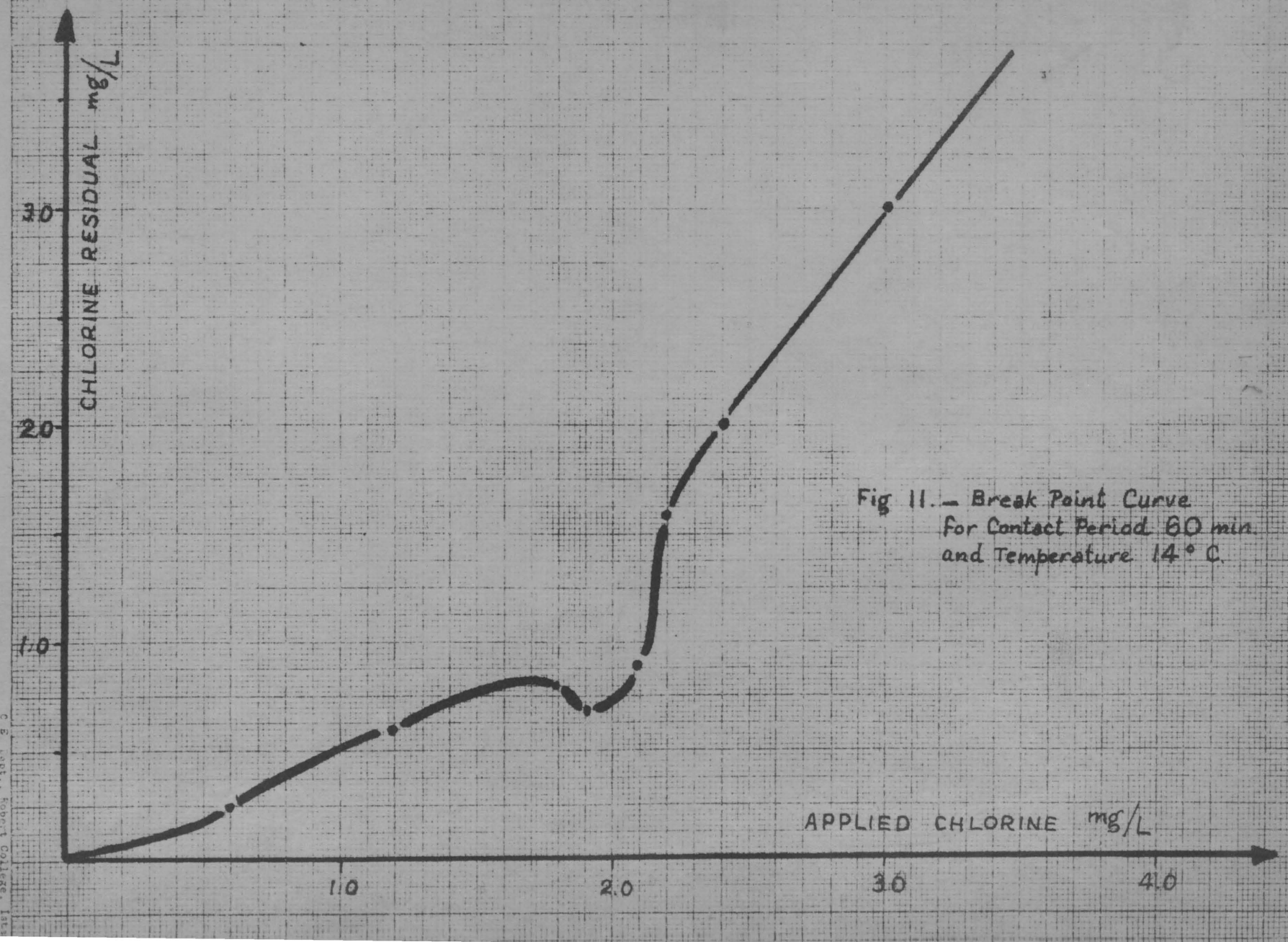


Fig 11.— Break Point Curve
For Contact Period 60 min.
and Temperature 14° C.

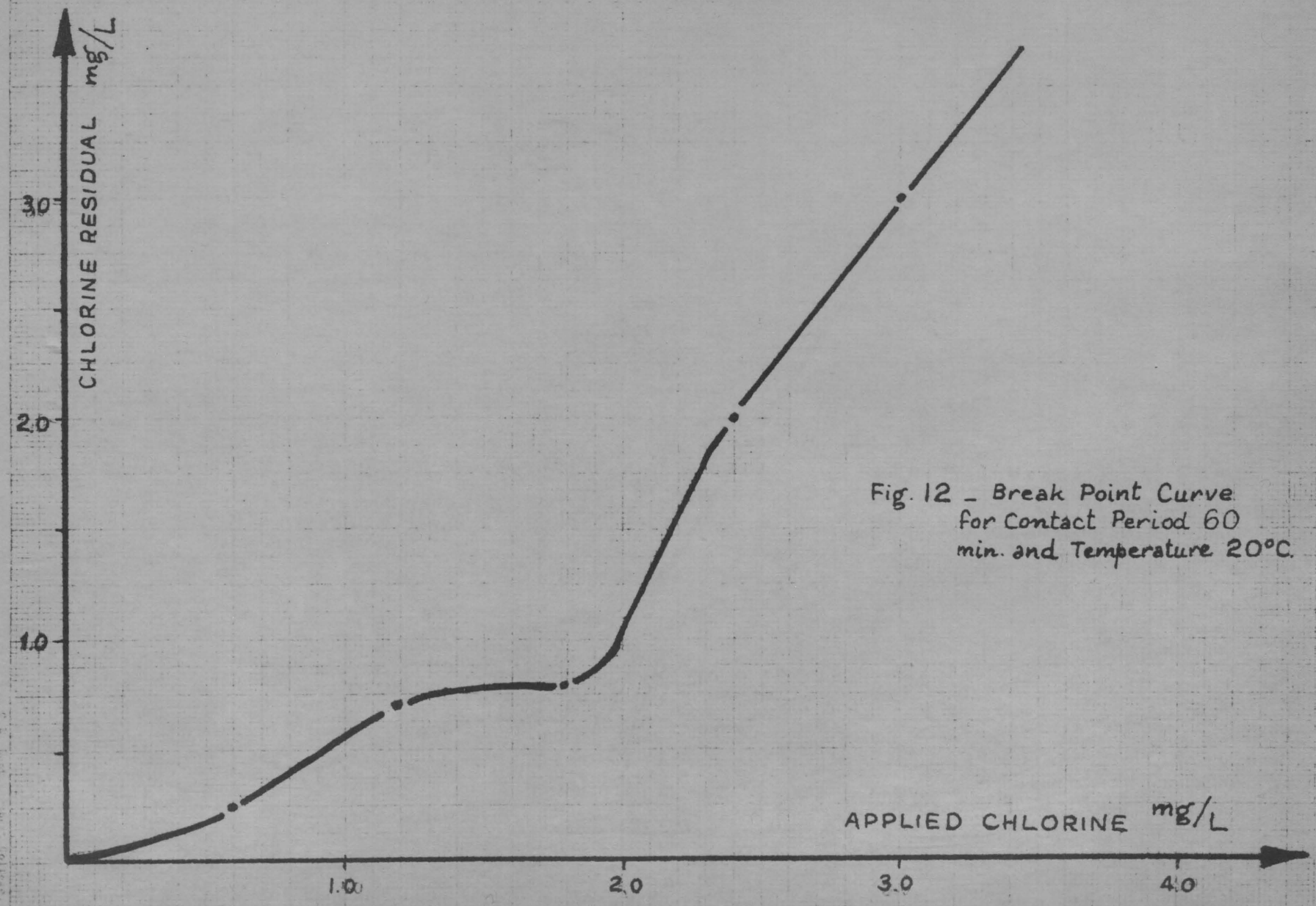


Fig. 12 _ Break Point Curve for Contact Period 60 min. and Temperature 20°C.

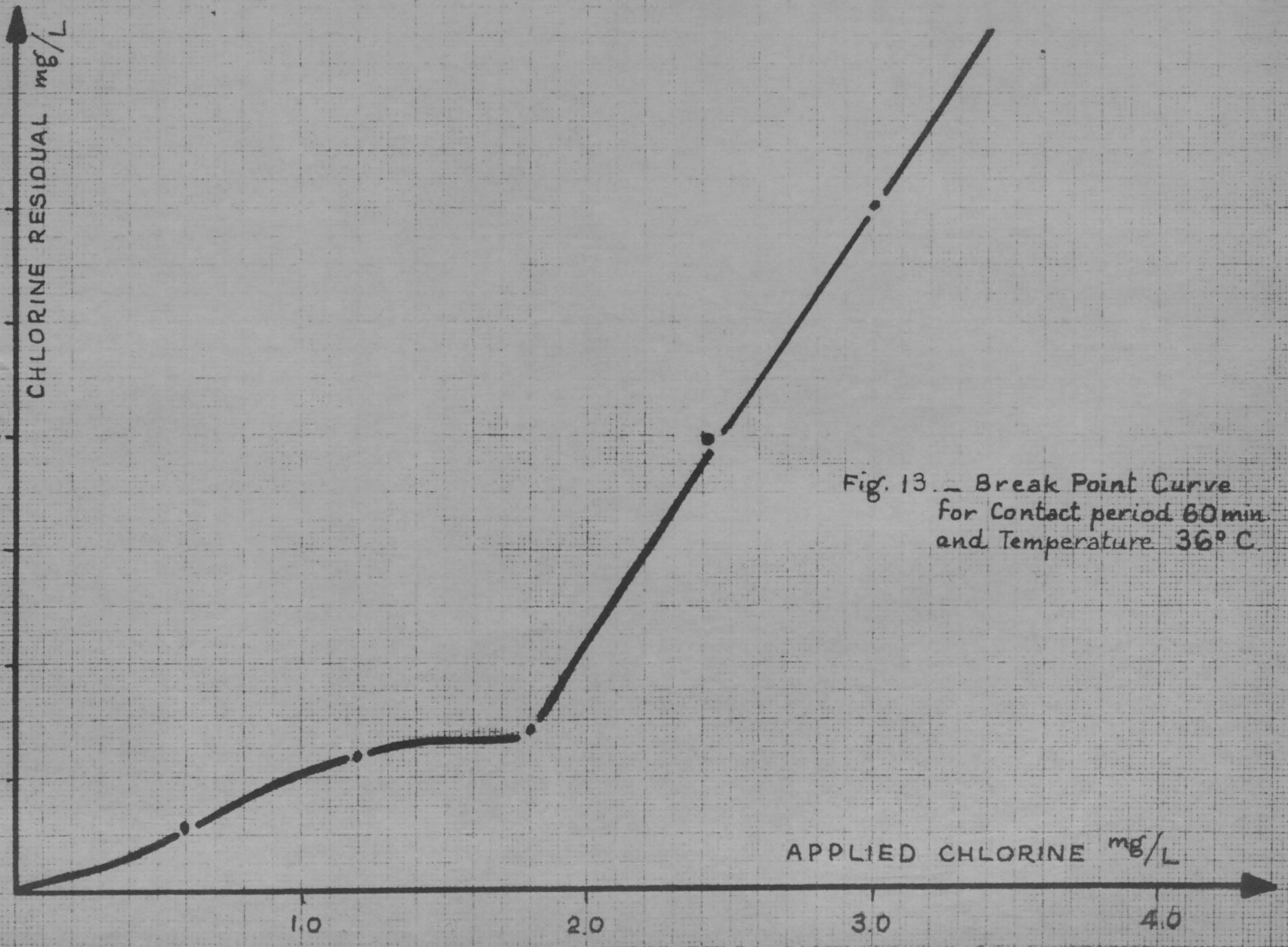


Fig. 13 – Break Point Curve for Contact period 60 min. and Temperature 36° C.

GENERAL DISCUSSION AND CONCLUSION

The water distribution system of Istanbul delivers water which is considered unfit for human consumption without further treatment. Several institutions now practice rechlorination as disinfection method.

Robert College, after an epidemic of infectious hepatitis, installed a chlorinator and made improvements to its distribution system. The installation of the chlorinator has not been a total success as it was in use only 25 out of 158 days. On the other days chlorine was added by pail or none was added. However when the chlorinator was operating 1.95 mg/l of chlorine was added, and when chlorine was added by pail only about 0.75 mg/l of chlorine had been applied. Tests indicated that at least 2 mg/l of chlorine dosage was necessary to obtain an adequate residual.

Test carried out on the distribution system indicated that over a period of 160 days there was at no time adequate chlorine to meet the minimum recommended by the Turkish Standards

The bacteriological examination using the Millipore filter indicated that the drinking fountain on the first floor of Anderson Hall although it has a sign "drinking water" delivered water of questionable bacteriological quality. Steps should be taken in this building to ensure a separate water system containing only potable water.

The water of the drinking fountain at Hamlin Hall near the cafeteria exit contains more suspended solids than are permitted in drinking water. The system should be cleaned.

The overall condition of the College water system would indicate that the following steps should be taken to avoid the break of a new epidemic:

1. The label of "drinking water" shouldbe removed immediately from the drinking fountain of Anderson Hall, and this water should not be used until more tests can demonstrate that this water is suitable for human consumption.

2. The pump house should have at least two chlorinators, from which one should be auxiliary. Thus when, for any reason, one chlorinator can not be used, the chlorination can be continued by the other.

3. A residual chlorine of 0.2 mg/l should be maintained throughout the system. Routine test should be made throughout the College System to make sure that the residual is maintained.

4. Records should be maintained showing the quantity of chlorine added and the quantity of water consumed per day.

5. Bacteriological examination should be carried out at various sampling points at least twice a month and any point giving a positive sample should be immediately reexamined and corrective measures taken to eliminate the source of pollution.

6. In order to make even an evaluation of a water system a laboratory and the necessary supplies must be available.

APPENDIX

DATA RELATED TO THE WATER DEMAND OF ROBERT COLLEGE

Date	Reading of Meter	Time interval (days)	Amount of Water Used (m^3)
Tuesd., Octob. 11, 1966	038891	-	
			280
Wednesd. " 12, "	039171	1	
			424
Thursd. " 13, "	039595	1	
			195
Friday " 14, "	039790	1	
			183
Saturd. " 15, "	039973	1	
			931*
Monday " 17, "	040904	2	
			276
Tuesd., " 18, "	041180	1	
			380
Wednesd. " 19, "	041560	1	
			320
Thursd. " 20, "	041880	1	
			330
Friday " 21, "	042210	1	
			940
Monday " 24, "	043150	3	
			390
Tuesd. " 25, "	043540	1	
			330
Wednesd. " 26, "	043870	1	
			244
Thursd. " 27, "	044114	1	
			296
Friday " 28, "	044410	1	
			917
Monday " 31, "	045327	3	
			333
Tuesd. Novemb. 1, "	045660	1	
			422
Wednesd. " 2, "	046082	1	
			274
Thursday " 3, "	046356	1	
			370
Friday " 4, "	046726	1	
			1762
Wednesd. " 9, "	048488	5	
			182**
Thursd. " 10, "	048670	1	
			340
Friday " 11, "	049010	1	
			925
Monday " 14, "	049935	3	
			312
Tuesday " 15, "	050247	1	
			215
Wednesd. " 16, "	050462	1	
			280
Thursd. " 17, "	050742	1	

Date	Reading of Meter	Time interval (days)	Amount of Water Used (m^3)
Friday Novemb.18,1966	051115	1	373
Monday " 21, "	052005	3	890
Tuesd. " 22, "	052345	1	340
Wednesd. " 23, "	052684	1	339
Thursd. " 24, "	052988	1	304
	Summation:	44	14097

Calculations and Results

Average daily demand : $\frac{14097}{44}$: 320 m^3/day

Max. " " : $\frac{931}{2}$: 461 m^3/day (on Octob.15-17)

Min. " " : 182 m^3/day (on Nov. 10)

Average of October : $\frac{6436}{20}$: 322 m^3/day

Average of November : $\frac{7661}{24}$: 319 m^3/day

DATA OF BACTERIOLOGICAL EXAMINATION OF R.C. WATER BY MILLIPORE FIELD MONITORS
(samples of 100ml. were used)

Date of taking the sample	Place from where sample was taken	Results	Notes
Nov.24,1966	Polluted water	+	This test was made to check if filters are working
Nov.29,1966	Perkin's Hall, W.C of 2nd floor	-	
"	Anderson Hall, Drinking Fountain at 1st floor	?	3 large colonies and some smaller were noticed, but the characteristic sheen color disapeared after some hours.
"	Hamlin Hall, Cafeteria	-	
"	Hamlin Hall, drinking fountain at the left of the exit of cafeteria	-	Plenty of suspended solids
Decemb.1,1966	Anderson Hall, Drinking Fountain at 1st floor	?	4 large colonies and certain smaller. Sheen color disapeared when it was removed from incubator and dried.
"	Library Building, drinking fountain	-	
"	Administration Building W.C.next to the post office	-	

Date of taking the sample	Place from where sample was taken	Results	Notes
December 5,66	Hamlin Hall, Cafeteria	-	
"	Hamlin Hall, Drinking fountain at the left of the exit of cafeteria	-	Too many solids
"	Washburn Hall, WC of basement	-	
Dec. 14,1966	Perkin's Hall, WC of 2nd floor	-	
"	Perkin's Hall, drinking fountain at the coridor of second floor	-	
" 20,1966	Fountain at the South of Footboal Field	-	Some colonies of white color.
"	Water tank, South west of campus	-	
Jan. 16,1967	Perkin's Hall, Drinking Fountain of 3rd floor.	-	
"	Library Building drinking fountain	-	Water too hot, almost impossible todrink it.
"	Gym, Shower Room	-	
"	Anderson Hall, Drinking Fountain	-	
February 8,1967	Hamlin Hall, cafeteria	-	
"	Perkin's Hall,W.C. 2nd floor	-	
Feb. 13,1967	" " " "	-	
Feb. 20,1967	" " " "	-	

Date of taking the sample	Place from where sample was taken	Results	Notes
Feb.20,1967	Anderson Hall, Drinking Fountain	?	Coliform like colonies but color become almost black some hours after it was removed from the incubator.
"	Library Building, Drinking Fountain	-	
"	Hamlin Hall, drinking fountain at the left of exit of cafeteria	-	Some solids present in water,
Feb.21,1967	Polluted water	-	This was done in order to check the procedure followed. The fact that not any colony was present, proved that something was wrong in the procedure.
	" "	-	
March 22,1967	" "	-	"

- : Not coliform present
+ : Coliforms present

DATA ABOUT CLORINATION

(Data from pumphouse, related to periods of Chorination and Non Chlorination)

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		OCTOBER 1966				
	C10	C11	C12	C13	C14	C15
C16	A17	A18	A19	A20	A21	A22
A23	A24	A25	A26	A27	A28	A29
A30	C31					
		NOVEMBER 1966				
		C1	C2	C3	C4	C5
C6	C7	C8	C9	C10	C11	C12
C13	C14	C15	C16	C17	C18	H19
H20	H21	H22	H23	H24	H25	H26
H27	H28	H29	H30			
		DECEMBER 1966				
				H1	H2	H3
H4	H5	H6	H7	H8	H9	H10
H11	H12	H13	H14	H15	H16	H17
D18	D19	D20	D21	D22	D23	D24
D25	D26	D27	D28	D29	D30	D31
		JANUARY 1966				
D1	D2	D3	D4	D5	D6	D7
D8	D9	D10	D11	D12	D13	D14
D15	D16	D17	D18	D19	D20	D21
D22	D23	H24	H25	H26	H27	H28
H29	H30	H31				
		FEBRUARY 1966				
			H1	H2	H3	H4
H5	H6	H7	H8	H9	H10	H11
H12	H13	H14	H15	H16	H17	H18
H19	H20	H21	H22	H23	A24	A25
A26	H27	H28				

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
			MARCH 1966			
			H1	H2	H3	H4
H5	H6	H7	H8	H9	H10	H11
H12	H13	H14	H15	H16	H17	H18
H19						

C : Chorinator operating. Applied chlorine ≈ 1.95 mg/l

D : Chlorinator although not operating properly chlorination by chlorinator - deficient chlorination

H : Chorinator not operating - chlorination by hand applied chlorine ≈ 0.75 mg/l

A : Not any chlorination.

Results

Appropriate chlorination with chlorinator	25 days
Chlorination with non properly operating chlorinator	37 days
Chlorination by hand	81 days
Not any chlorination	17 days
	160 days

Notes

1. Chlorinator didn't come back from the repair till March 19.
2. When chlorinator is operating 375-400 liters of hypochlorite are consumed per month (Information obtained from Permodid, the firm from where Robert College buys the hypochlorite solution)
3. When chlorination is done by hand 5-7 liters of hypochorite are added to the water per day (Informations obtained from the operator).

CHLORINE RESIDUAL BY ORTHOTOLIDINE TEST

Date	Place	Clorine* Residual mg/l	Notes
October 31,1966	Perkin's Hall	0.0	
Novemb. 1,1966	" "	0.0	
" "	Water Tank	0.0	
Novemb. 4,1966	Perkin's Hall	0.0	
" 9,1966	" "	0.0	
" 10,1966	" "	0.0	
" 15,1966	" "	~0.05	Approximate value
	Library Building	0.0	
	Hamlin Hall	0.0	
	Washburn Hall, Darkroom	0.0	
Novem. 16,1966	Perkin's Hall	~0.1	
" 16,1966	Library Building	~0.05	Very slight amount
"	Hamlin Hall	0.0	
"	Anderson Hall	0.0	
Novem. 17,1966	Perkin's Hall	0.0	
"	Water Tank	0.15	
Novem. 25,1966	Perkin's Hall	0.0	Although odor of chlorine existed in the water not any residual found
"	Water Tank	0.0	
"	Library Building	0.0	
"	Hamlin Hall	0.0	
"	Washburn Hall	0.0	
"	Anderson Hall	0.0	
Dec. 20,1966	Perkin's Hall	0.0	
"	Water Tank	0.0	
Dec. 21,1966	Perkin's Hall	0.0	
Jan. 23,1967	" "	0.0	
Feb. 6,1967	" "	0.0	
Feb. 8,1967	" "	0.0	
Feb. 14,1967	" "	0.0	
Feb. 15,1967	" "	0.0	
Feb. 24,1967	" "	0.0	
Feb. 27,1967	" "	0.0	
"	Water Tank	0.0	
March 3,1967	Perkin's Hall	0.0	

* The values are determined by Comparator, Type Permodid P-777 which had range: 0.1, 0.2, 0.4, 0.5, 0.7, 0.9, 1, 2, 3 mg/L

DATA AND CALCULATIONS OF THE TEST MADE FOR DETERMİNATİON OF AVAILABLE CHLORINE (BYSODIUM ARSENITE METHOD) PRESENT IN THE HYPOCHRORITE SOLUTION USED FOR CHLORINATING THE WATER

Data

1st test : Sodyum Arsenite used for titration : 27.2 ml.
2nd " " " " " " : 27.1 "
3rd " " " " " " : 26.9 "
Normality of sodyum Arsenite : 0.05

Calculation

The percent of available chlorine is to be calculated by

$$\% \text{ Available Chlorine} : (\text{Ml of Sodyum Arsenite solution}) \times \text{Normality} \times 0.03546 \times \text{aliquot} \times \frac{100}{\text{weight of sample}}$$

For the first test.

27.2 x 0.05 x 0.03546 x 1 x 100 : 4.8 %

For the second test.

27.1 x 0.05 x 0.03546 x 1 x 100 : 4.8 %

For the third test.

26.9 x 0.05 x 0.03546 x 1 x 100 : 4.7 %

Average : 4.8% of available chlorine exist in the hypochlorite solution.

DATA FOR BREAK POINT CURVE

Concentration of chlorine in the hypochlorite solution used : 48 %

Dilution : 1 portion of the hypochlorite solution + 3 portions water.

Volume of sample : 1000 ml.

Chlorine solution added drops	mg	Residual Chlorine mg/L					
Temperature °C		10°	12	13	14	20	36
Contact periods (min)		15	30	45	60	60	60
1	0.6*	0.4	0.3	0.25	0.25	0.25	0.3
2	1.2	0.7	0.5	0.6	0.6	0.7	0.6
3	1.8	0.8	0.8	0.8	0.8	0.8	0.7
4	2.4	2.0	2.0	2.5	2.0	2.0	2.0
5	3.0	3.0	-3.0	3.0	3.0	3.0	3.0
6	3.6	+3.0	3.0	+3.0	+3.0	+3.0	+3.0
	1.9				0.7		
	2.1				0.9		
	2.2				1.6		

* The way in which drops are converted to mg is given on next page.

CALCULATIONS FOR CONVERTION OF DROPS OF CHLORINE TO mg.

Hypochlorite solution used contained 4.8% available chlorine

$\therefore$ Available chlorine in 1 liter of hypochlorite - 48gr.

Solution is diluted by adding 3 portions of water

$\therefore$ Available chlorine in one liter diluted hypoclorite solution : 12 gr.

$\therefore$ Available chlorine in 1 ml. diluted hypochlorite solution : 12 mg.

1 ml is 20 drops.

$\therefore$ Available chlorine per drop of hypochlorite: $\frac{12}{20}$:0.6mg

Given that the chlorine solution was added to 1000 ml. of water, automatically the amount added can be expressed as mg/L.

DOSAGE OF CHLORINE IN WATER EXPRESSED AS mg/L

a) When hypochlorite is added by hand 5 liters of 4.8 % chlorine solution is added per day (see p.73) 5x48 = 240 gr. chlorine added par day
Average water consumption per day: 320 m3 (see p.66)
$\therefore \frac{240000}{320000} = 0.75$ mg/L are added

b) When hypochlorite is added by chlorinator 375-400 liters of 4.8% chlorine solution is added per month or approximately 13 lit. per day.
$\therefore$ 13x48 : 624 gr. chlorine is added per day
Average water consumption per day 320 m3
$\therefore \frac{624000}{320000} = 1.95$ mg/L

OTHER CHARACTERISTICS OF R.C. WATER

In order to have a better idea about the quality of the water, pH, alkalinity and hardness was determined, but beaause it didn't have direct relation with the purpose of this study they are not included in the main part.

The results are as follow:
Alkalinity : 108 mg/L as CaCO3
Hardness : 128 mg/L " "
pH : 7.8

ALLOWABLE CONCENTRATIONS OF CHEMICAL SUBSTANCES AND PROPERTIES AFFECTING POTABILITY

Substance or Property	W H O*		FRANCE **	
	Max. Acceptable	Max. Allowable	Max. Acceptable	Max. Allowable
Lead (as Pb)	-	0.05 mg/L		0.1 mg/L
Selenium (as Se)	-	0.01 "		0.05 "
Arsenic (as As)	-	0.05 "		0.05 "
Chromium (as hexavalent)	-	0.05 "	(	Less than the minimum quantity detectable by analysis.
Cyanide (as CN)	-	0.2 "	(	
Cadmium	-	0.01 "		
Barium	-	1.0 "		
Iron (Fe)	0.3 mg/l	1.0 "	0.1 mg/l (	Total of 0,3 mg/l comprising 0.2 Fe and 0.1 Mn
Manganese (Mn)	0.1 "	0.5 "	0.05 " (	
Copper (Cu)	1.0 "	1.5 "		1.0 mg/l
Zinc (Zn)	5.0 "	15 "		5.0 "
Calcium (Ca)	75 "	200 "		
Magnesium (Mg)	50 "	150 "	125mg/l	
Sulfate (SO_4)	200 "	400 "	250 "	
Chloride (Cl)	200 "	600 "	250 "	
pH range	7.0-8.5	Less than 6.5 or greater than 9.2		
Magnesium + sodium sulfate	500 mg/l	1000 mg/l		
Phenolic Substances (as phenol).	0.001 "	0.002 "		0.0
Carbon Chloroform extract (CCEi organic pollutants).	0.2 mg/l	0.5 mg/l		
Alkyl benzyl sulfonates (ABS, surfactants)	0.5 mg/l	1.0 mg/l		
Color	5 units (platinium cobalt)	50 units (platinium cobalt scale)	5 units (platinium cobalt)	20 (platinium cobalt)

Substance or Property	W H O ※		France ※※	
	Max. Acceptable	Max. Allowable	Max. Acceptable	Max. Allowable
Turbidity	5 units (of turbidity)	25 units (of turbidity)		
Taste	unobjectionable	-		unobjectionable
Odor	"	-		"
Total solids	500 mg/l	1500 mg/l		
Total mineral content				2000 mg/l

※ From order issued by the Ministry of Health and Population on 10th August 1961, and Brochure No. 1106 (13 : 458-60)

※※ From World Health Organization, International Standards for Drinking Water 1963 (33:173,4)
Exactly the same values are given also by the Drinking Water of Turkish Standards, 1965 (20:28)

TYPES AND OPERATION OF CHLORINATORS (from Riehl, Water Supply and Treatment (39)

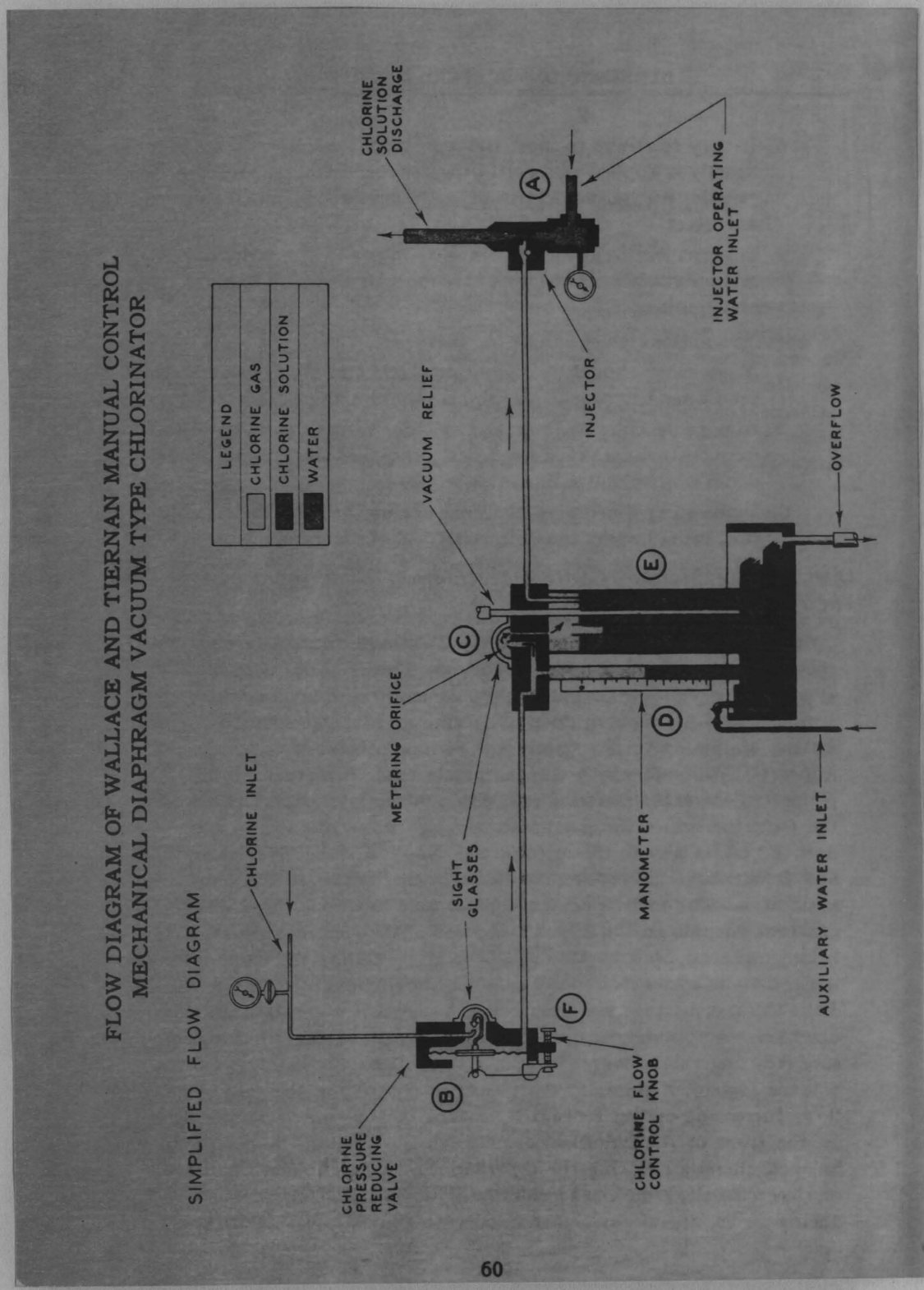
6. Is very corrosive to most common metals when wet. Since it usually is applied dissolved in water it must be measured and carried through non-corrosive materials such as glass, rubber, and silver.
7. Is extremely irritating to the membranes in the nose, throat, and lungs. Therefore, great care must be exercised in handling and applying it.

Some precautions which should be observed:

1. A gas mask should be readily available and always should be used when entering an atmosphere containing chlorine gas.
2. Apparatus, chlorine lines, and cylinder valves should be tested frequently for leaks. (Ammonia fumes and chlorine produce a dense white cloud assimilating smoke.)
3. Never stoop down when the smell of chlorine is noticed as chlorine, being heavier than air, collects at the lower levels.

Operation of Manual Control Mechanical Diaphragm Vacuum Type Chlorinator

In the Manual Control Series A-677 Chlorinator, the chlorine gas is metered and controlled under a vacuum developed by an aspirator type injector (A). The gas enters the chlorinator through an adjustable spring loaded, diaphragm operated pressure reducing valve (B). The setting of this valve determines the vacuum ahead of the metering orifice (C), through which the gas passes next. A manometer (D) is connected across the metering orifice to indicate rate of gas flow. From the metering orifice the gas passes through a meter vacuum control unit (E) on its way to the injector (A), where it is dissolved in water and from which the resultant solution is discharged to the point of application. The meter vacuum control unit functions to maintain a constant vacuum on the downstream side of the metering orifice. This is accomplished by the simple expedient of adding makeup water, under definite hydraulic conditions, to positively limit injector vacuum. Thus the downstream metering orifice vacuum is a constant and the upstream vacuum depends on the spring tension on the chlorine pressure reducing valve diaphragm. Since this valve is, in essence, a force balance system, it provides the means of controlling the rate of gas flow. Increasing spring tension by means of the control handle (F) on the front of the chlorinator increases the vacuum necessary for balance, thereby reducing the differential across the metering orifice, and, as a result, reduces the chlorine flow. The chlorine pressure reducing valve, therefore, acts not only to reduce pressure to below


FLOW DIAGRAM OF WALLACE AND TIERNAN MANUAL CONTROL
MECHANICAL DIAPHRAGM VACUUM TYPE CHLORINATOR
SIMPLIFIED FLOW DIAGRAM
LEGEND
CHLORINE GAS
CHLORINE SOLUTION
WATER
CHLORINE SOLUTION DISCHARGE
INJECTOR OPERATING WATER INLET
INJECTOR
VACUUM RELIEF
OVERFLOW
METERING ORIFICE
SIGHT GLASSES
MANOMETER
AUXILIARY WATER INLET
CHLORINE INLET
CHLORINE PRESSURE REDUCING VALVE
CHLORINE FLOW CONTROL KNOB
A
B
C
D
E
F

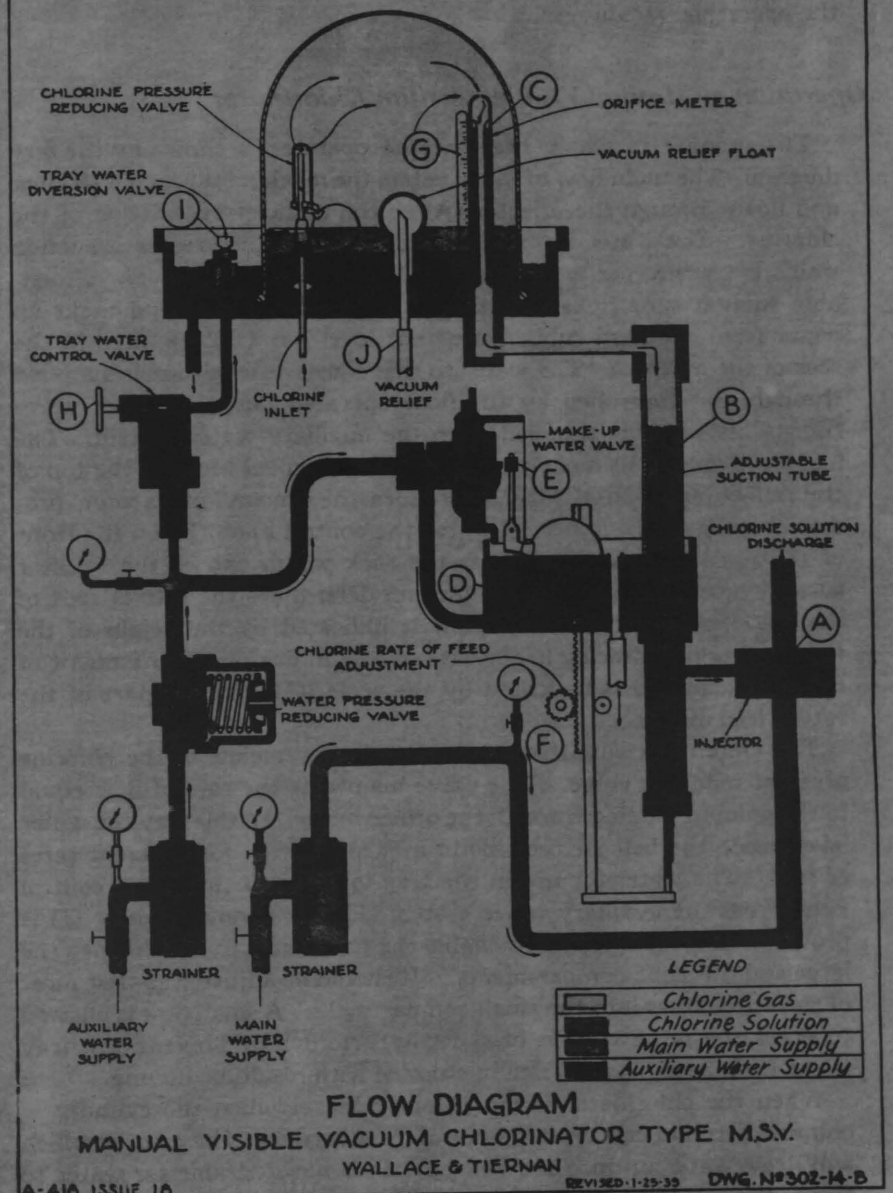
atmospheric but also as an adjustable flow control valve and as a shut-off valve in the event that injector water supply failure destroys the operating vacuum.

Operation of Manual Visible Vacuum Chlorinator

The manner in which the machine operates is shown by the flow diagram. The main flow of water enters the machine through a strainer and flows through the injector (A) to the point of application of the chlorine. The water flowing through the injector creates a suction which is transmitted to the adjustable suction tube (B). The adjustable suction tube pulls gas through the orifice meter and make-up water from the hard rubber, constant level box (D) mounted in the rear of the machine. The water to this constant level box is supplied through and controlled by the float operated make-up water valve (E). This water is supplied from the auxiliary water system. The height to which this make-up water must be pulled to reach the top of the adjustable suction tube determines the amount of vacuum produced in the orifice meter. Turning the control knob (F) on the front of the machine raises or lowers the rack which carries the injector suction tube. This adjustable vacuum determines the rate of feed of the chlorinator. The chlorine flow is indicated by the height of the water column appearing in the rate of feed indicator. The amount of chlorine being fed is indicated by the scale (G) which is part of the rate of feed indicator.

The chlorine is admitted to the bell jar by means of the chlorine pressure reducing valve. This valve maintains the rate of flow equal to the amount passing through the orifice meter. In this way the water level inside the bell jar remains in a fixed position for different rates of feed. The water for use in the tray is supplied through a control valve from the auxiliary water system (H). A diversion valve (I) is provided in the tray itself to enable the tray water to be split into the large and the small compartments. It should be adjusted so that most of the water flows into the small compartment. A small flow is allowed to enter the large section of the tray in order to prevent the tray water from becoming too rich in chlorine with resultant fuming.

When the chlorinator is out of operation or when the cylinder of chlorine becomes empty, it is natural for a vacuum to be created which will draw water up into the bell jar. It is not desirable for water to rise in the bell jar more than an inch above the normal operating level. For this reason a vacuum relief (J) is provided which will admit air to the bell jar when this water level rises above normal. This device



FLOW DIAGRAM

MANUAL VISIBLE VACUUM CHLORINATOR TYPE M.S.V.

WALLACE & TIERNAN

A-416 ISSUE 18 REVISED-1-25-39 DWG. N°302-14-B

has a further function of discharging excess chlorine outside the building if conditions were such that a pressure of chlorine was built up under the bell jar.

Operation of V-Notch Chlorinator

In the Series A-711 chlorinator, the chlorine gas is metered under a vacuum developed by an aspirator type injector (A). The gas enters the chlorinator through a spring loaded diaphragm operated pressure reducing valve (B). This valve maintains the proper operating vacuum ahead of the V-notch Variable-Orifice.

The gas next flows through a rotameter rate of feed indicator (C) and then through the V-notch Variable-Orifice (D). After leaving the orifice, the gas passes through a vacuum differential valve (E), which maintains a constant differential across the V-notch, and then to the injector where it is dissolved in water. The resultant solution is discharged from the injector to the point of application.

With the vacuum differential across the V-notch Orifice (D) maintained at a constant value under all conditions, the feed rate is adjusted by changing the area of the V-notch Variable Orifice (D). This is accomplished by positioning the V-notch plug within its ring.

The chlorine pressure reducing valve, which regulates the vacuum ahead of the metering orifice, also shuts off the chlorine if interruption of the injector water supply should destroy the operating vacuum.

The injector water supply is turned off or on by a three-way pilot valve (F) which controls a spring loaded diaphragm actuator. Thus, starting or stopping the chlorinator is a simple matter of positioning the three-way pilot valve.

Intermittent start-stop or program operation is obtained by interrupting the injector water supply. The injector shut-off pilot valve is equipped with a three-way solenoid valve which functions in place of the manual pilot valve to start or stop the chlorinator in synchronism with a program timer or other equipment operating circuit.

Automatic operation is accomplished by positioning the V-notch plug to change the size of the orifice and thereby adjust the feed rate. The operation of auxiliary equipment for automatically positioning the plug is described in other catalog files.

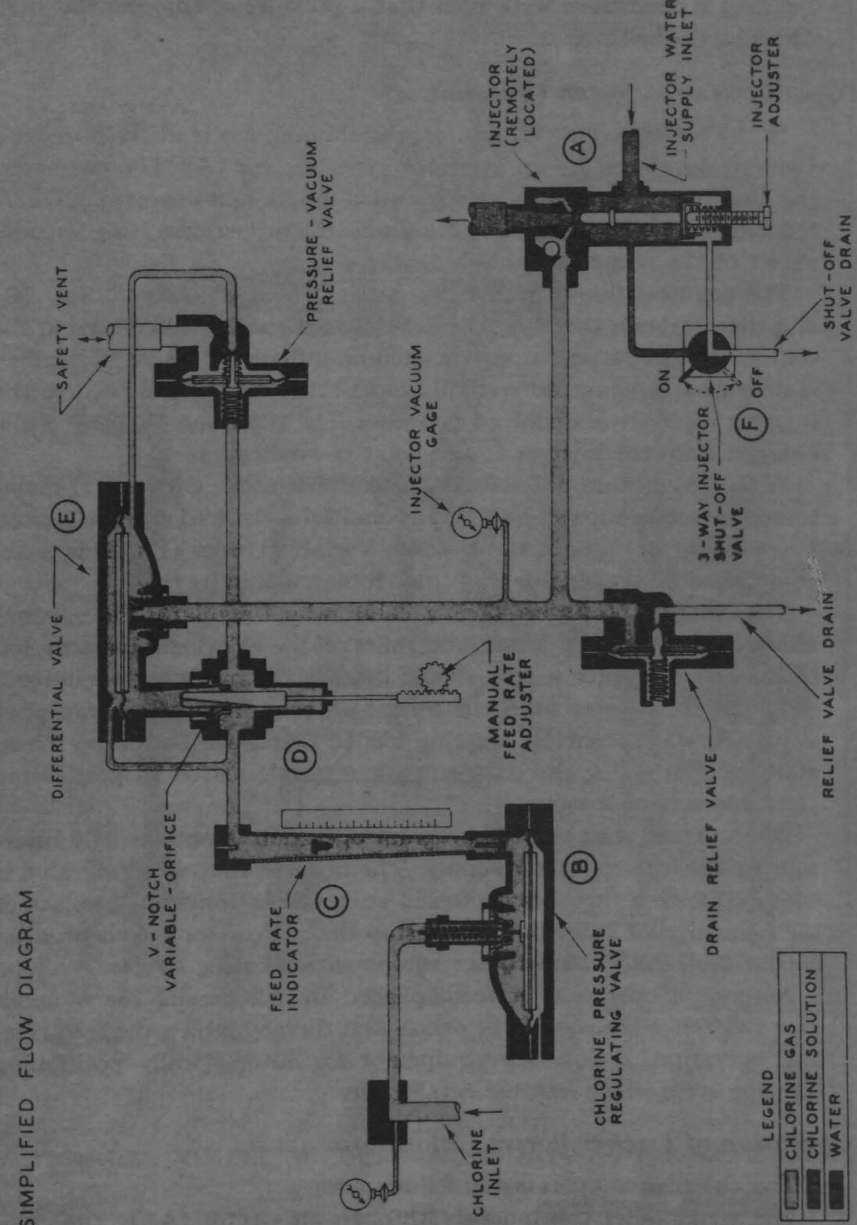
Operation of Fischer Porter Chlorinator

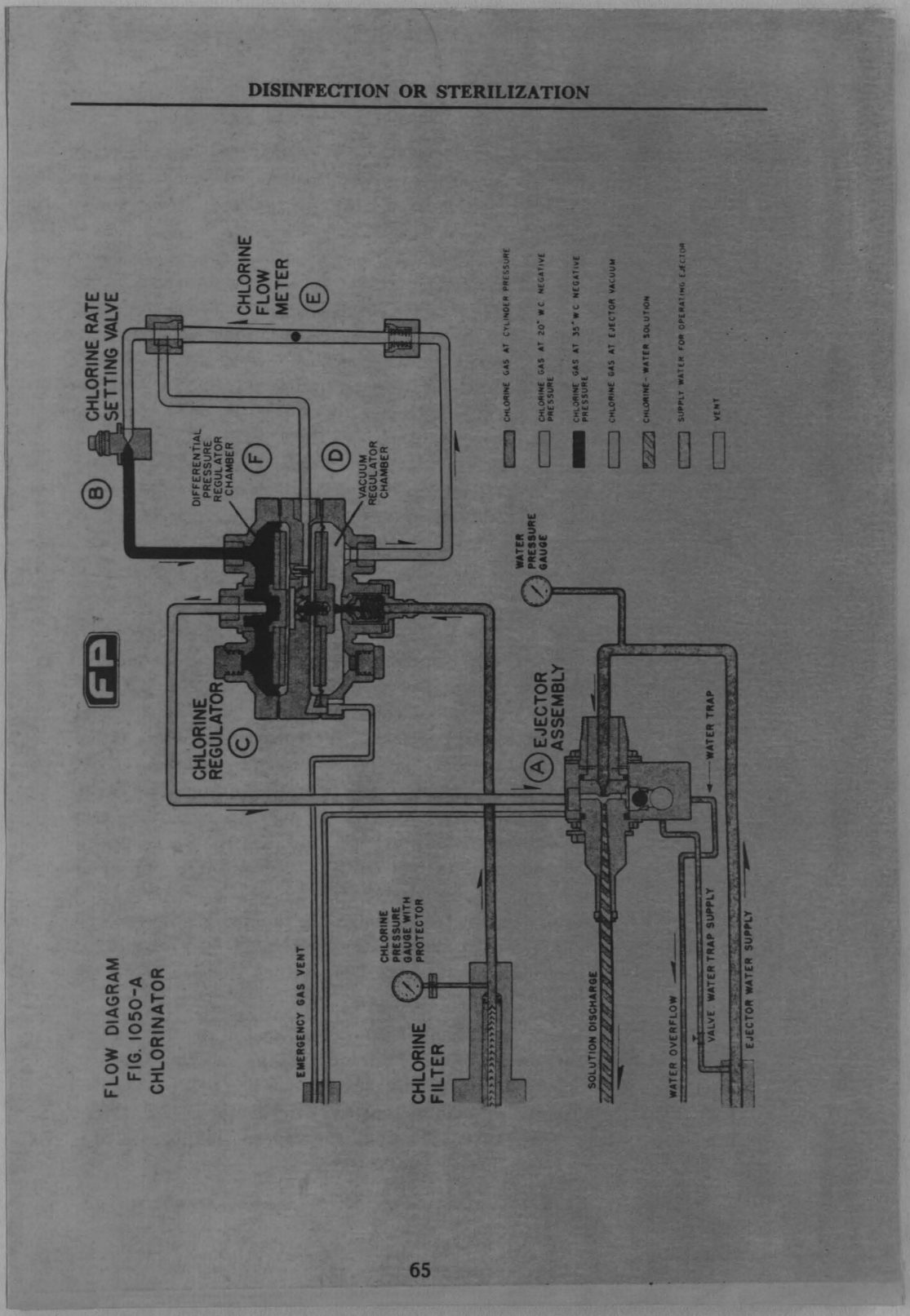
The chlorinator operates as follows:

The water flows continuously through an ejector (A) in the chlorinator, and is mixed with chlorine gas entering the ejector at a regulated flow rate.

FLOW DIAGRAM FOR WALLACE AND TIERNAN V-NOTCH CHLORINATOR

SIMPLIFIED FLOW DIAGRAM





FLOW DIAGRAM
FIG. 1050-A
CHLORINATOR

With the chlorinator set for start-up, the external water supply valve is open, the chlorine rate valve (B) is almost closed, and the chlorine shut-off valve is about to be opened to allow chlorine gas to enter the chlorinator.

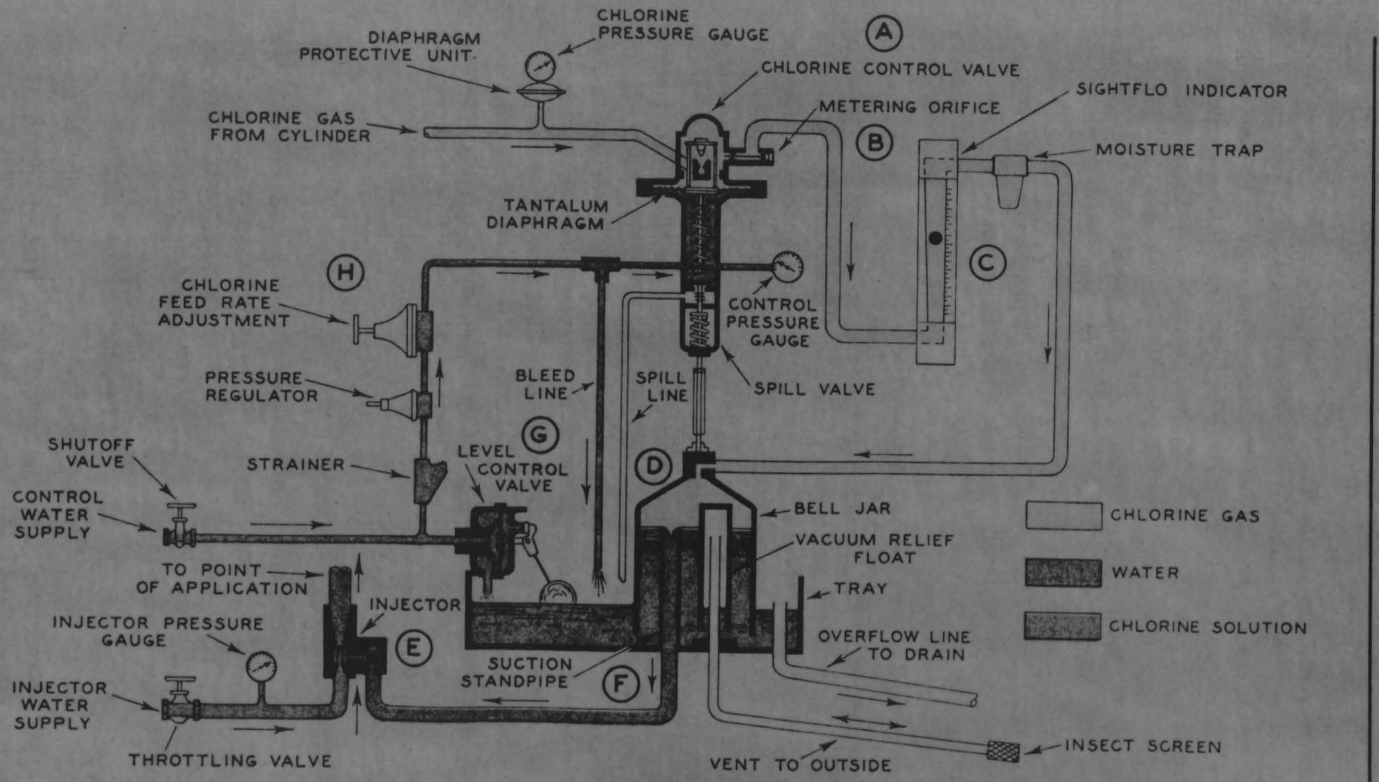
Water, under pressure*, flowing through the ejector, creates a vacuum extending to the chlorine regulator (C). The pressure of the incoming chlorine gas is reduced to 20″ water column negative pressure by the vacuum regulator (D). Flow of gas is metered at this reduced pressure in the chlorine flow meter (E) located in the front of the cabinet. This gas flow rate is adjusted by the chlorine rate setting valve (B) which is in parallel with the differential pressure regulator (F). The differential pressure regulator (F) throttles the flow of gas to maintain a constant differential pressure across the rate valve (B), thereby maintaining a constant gas flow for a given rate valve setting. Gas flows to the ejector (A) where it is mixed with water and the resulting solution is discharged to the point of application.

Operation of Chlorinizer

Flow Path: Dry chlorine gas from the cylinder enters the upper chamber of the chlorine control valve (A) in which pressure is reduced and maintained constant regardless of variations in cylinder gas pressure. Chlorine leaving the control valve passes through the metering orifice (B) at a constant rate because of the constant pressure differential established across the orifice. The system from metering orifice to injector is entirely under vacuum. Gas is drawn through the Sight-flo Indicator (C) (where it is metered) through the moisture trap (which maintains dry conditions in the vital control parts during shutdown periods) and into the bell jar (D). The injector (E) which produces the operating vacuum draws chlorine gas, together with a small quantity of makeup water, through the suction standpipe (F). The makeup water satisfies excess injector capacity at feed rates below maximum. The thoroughly mixed solution is then discharged to the point of application.

Maintaining Vacuum Conditions: The height of the suction standpipe under the bell jar limits and maintains the vacuum constant. The difference in elevations between the water in the bell jar and the tray shows the amount of vacuum created. Tray water is maintained at a constant level by means of a pilot-operated, diaphragm-type control valve (G).

* In most installations a pressure ratio of 3 to 1 (in absolute psi units) is recommended.



FLOW DIAGRAM, MODEL DVS CHLORINIZER

FLOW DIAGRAM B-I-F INDUSTRIES CHLORINIZER

Chlorine Rate Control: Since the metering orifice size is fixed and the downstream vacuum is constant, the rate of chlorine feed is determined by the reduced and compensated pressure of the gas in the chlorine control valve upper chamber. Any change in the water pressure imposed on the lower side of the control valve diaphragm will cause a corresponding change in the chlorine gas pressure in the upper valve chamber, and a change in the rate of chlorine feed. In manual and semi-automatic Chlorinizers, the water pressure in the lower valve chamber is determined by the setting of the rate setting knob (H) located at the front of the panel. In the program-operated Chlorinizer, this pressure is automatically governed by a Program Controller, and in an automatic proportional Chlorinizer by a Pneumatic Converter.

Operation of Chlorine Control Apparatus

The manner in which the machine operates is indicated by the flow diagram. The chlorine gas enters at (K) and flows into the Chlorine Gas Regulating Valve (No. 40 or No. 50). Water enters at (A), one line supplying the Reservoir (9) and another line supplying water through Water Pressure Regulator (20) to the Ejector (7). The Ejector (7) creates the necessary vacuum to pull water up into the Absorption Tower (8) and maintains a vacuum or suction head sufficient to operate the Chlorine Gas Regulating Valve (No. 40 or No. 50), and pull the chlorine gas through that valve, through the Gas Throttling Valve (T), up through the Rota-Meter (O), and down to the Absorption Tower (8) where it mixes with the water. This mixture is then lifted by this head into the Ejector (7) and flows from there through the Solution line (18) to the Point of Application (Z) in a main or sewer. Vent from Absorption Tower is indicated by line (8B). All gas in this apparatus is under constant suction head, the quantity fed being controlled by Gas Throttling Valve (T).

How Chlorine Kills Bacteria

The effect of chlorine on organisms in water and sewage has been the subject of considerable controversy. It was believed originally that nascent oxygen, produced by the reaction of chlorine with water, accomplished the destruction of bacteria. The following reactions illustrate what is supposed to take place:

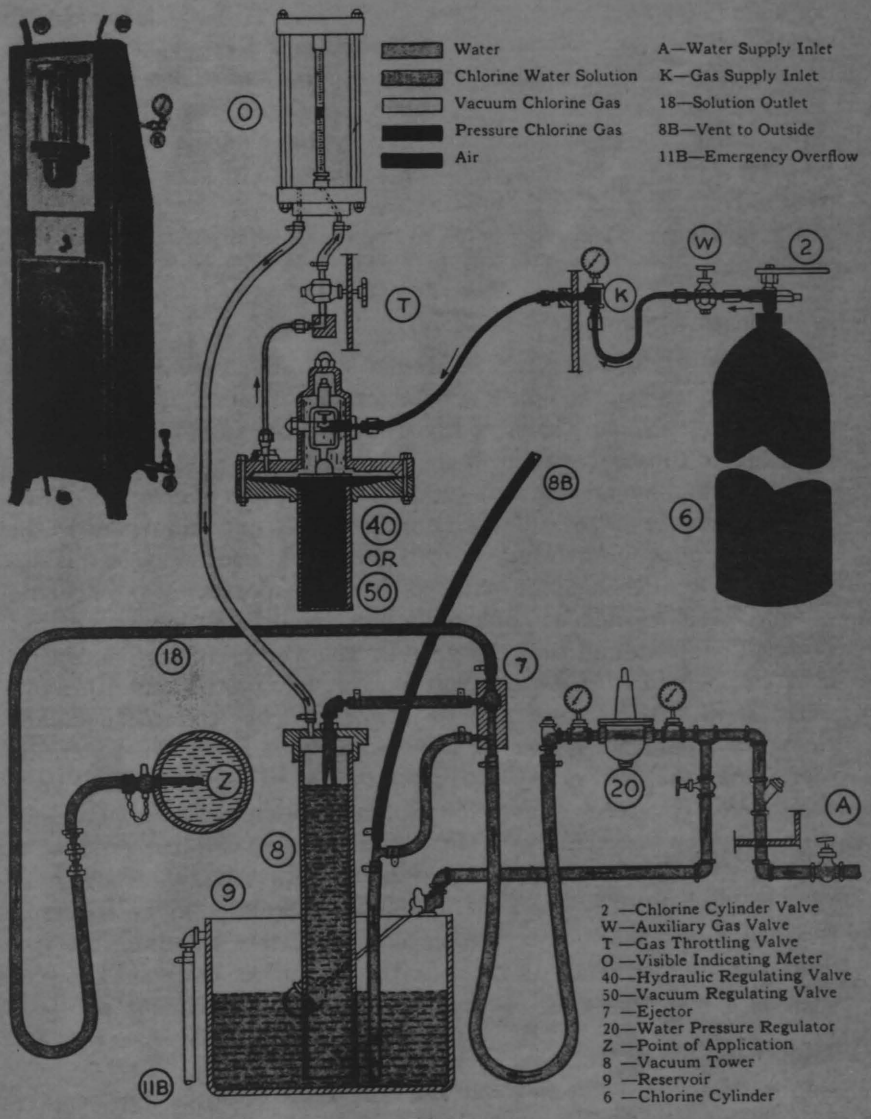
$$H_2O + Cl_2 \rightleftarrows HCl + HOCl$$
$$HOCl \rightarrow HCl + O$$

Explanation of reaction: Chlorine unites with water to form hypochlorous acid which, being unstable, breaks up into nascent oxygen and

DISINFECTION OR STERILIZATION

CHLORINE CONTROL APPARATUS

(Everson Manufacturing Co.)



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