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WASTEWATER TREATMENT PLANT CONTROL

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RESEARCH REPORT

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PREFACE

This report is the result of investigation of the feasibility of increasing the use of automatic controls at the Florida Technological University Wastewater Treatment Plant. This investigation was to include a literature search and visits to wastewater treatment plants. During the writers course of study, he was privileged to make a series of tests of a residual chlorine analyzer which was made in the school shop. Since this work was closely related to automatic controls the data are included in this report.

The writer is deeply indebted to many people for their assistance in this endeavor. Dr. Yousef A. Yousef allowed free use of the laboratory and gave much encouragement. Mr. Dan Abbott and Mr. Bob Elgin spent hours of their time explaining the operation of the FTU wastewater treatment plant. Mr. Tom Crumley explained the operation of the Disney World wastewater treatment plant. Mr. Joe Haibach constructed the residual chlorine analyzer. Adams Jewelry provided the gold wire for the residual chlorine analyzer. To these, and others who have helped, the writer wishes to express his sincere thanks.

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I. INTRODUCTION

The basic purpose of a wastewater treatment plant is to separate dissolved and suspended solids from the water. These solids include organic nutrients and bacteria and may include pathogenic organisms. After separation, these solids are reduced in volume as much as possible and disposed of in a sanitary manner.

In a typical activated sludge wastewater treatment plant the separation of solids and their reduction in volume is accomplished with the aid of aerobic bacteria. These bacteria use the dissolved and suspended solids as food by the process of assimilation. Then by a process of aggregation or flocculation the individual microorganisms gather together into masses or matrices usually of the order of 100 times the size of the individual bacteria cells.¹ These masses are then separated from the water by the process of sedimentation.

Some of the resulting sludge (containing bacteria and settled solids) is returned to the aeration tank where the bacteria continue to assimilate dissolved and suspended nutrients. The remainder of the sludge is wasted to the digester where bacteria feed on remaining nutrients and on each other. In the digester, further separation of liquid and solid takes place by sedimentation. The liquid is

¹A. A. Kalinske, "Effect of Dissolved Oxygen and Substrate Concentration on the Uptake Rate of Microbial Suspensions," Journal of the Water Pollution Control Federation, XLIII (January, 1971), 73.

returned to the input of the plant and the solids are spread on drying beds.

The bacteria used in these processes require oxygen for respiration and the amount of oxygen dissolved in the water is a critical parameter that must be carefully controlled. If there is too much oxygen the bacteria will consume the nutrients in the influent wastewater too quickly and then start destroying each other. If there is too little oxygen the aerobic bacteria will die and the efficiency of separation of dissolved and suspended solids from the water will be impaired.

The dissolved oxygen concentration can be controlled by controlling the rate of air flow through the diffusers in the bottom of the tanks. The dissolved oxygen concentration must be measured in each tank in order to properly control the air flow rate.

The food to microorganism ratio or loading factor is an important parameter and must be carefully controlled. If there is too much food in the influent for the bacteria in the system to consume during the aeration time, excess nutrients will be found in the effluent. If there is not enough food in the influent for the number of bacteria present, the bacteria will begin to destroy each other and the efficiency of solid separation will be impaired.

This loading factor can be controlled by adjusting the amount of sludge wasted and the amount of sludge returned to the aeration tank. One method of accomplishing this maintains a constant mixed

liquor suspended solids (MLSS) level in the aeration tank.¹ This requires measurement of the MLSS level.

The level of the sludge blanket in the clarifier is an important parameter that must be controlled. If too much sludge is allowed to accumulate in the clarifier, anaerobic conditions will develop, gas will form and sludge will float to the surface and be carried over the weirs.² If too much sludge is removed from the clarifier, the sludge will become too thin, the digester may be overloaded hydraulically and it will not be possible to maintain the desired loading factor in the aeration tank. The level of the sludge blanket can be controlled by adjusting the sludge wasting rate. The need for adjustment is determined by measuring the level of the sludge blanket.

Chlorination of the effluent is required to prevent pathogenic organisms from escaping to the environment. The chlorine feed rate can be controlled to maintain a specified residual chlorine level in the effluent from the chlorine contact tank. X1

¹Larry F. Walker, "Hydraulically Controlling Solids Retention Time in the Activated Sludge Process," Journal of the Water Pollution Control Federation, XLIII (January, 1971), 30.

²D. M. Pierce, and others, Operation of Wastewater Treatment Plants, (Washington, D. C.: Water Pollution Control Federation, 1961), p. 35.

II. LITERATURE SEARCH

Instrumentation

The magnetic flow meter is ideally suited to the measurement of wastewater and sludge flows. Some of its advantages are: no head loss, suspended solids do not affect it, it has an electronic output linear with respect to flow, it can measure wide ranges of flow with good accuracy, and installation is simple.¹

Liquid level in wet wells and other open tanks can be measured by a bubble tube, or diaphragm box connected to an air pressure gauge, or by a float and cable device.²

Electrical conductivity of wastewater is easily measured and may be used to indicate changes in the quality of the wastewater.³ Conductivity measurements may also be used to indicate the efficiency of phosphate removal in a wastewater treatment plant.⁴

Measurement of pH at all stages of treatment can be made by pH sensors.⁵ The pH of the effluent from the sedimentation tank

¹Russell H. Babcock, Instrumentation and Control in Water Supply and Wastewater Disposal, reprinted from the pages of Water and Wastes Engineering, (Reuben H. Donnelley Corporation, 1968), pp. 6-8.

²Ibid., 14-16.

³Ibid., 20.

⁴Joseph L. Pavoni and Wayne F. Echelberger, Jr., "Coagulation Control Using Electrical Conductivity," Water and Sewage Works, CXVIII (January, 1971), 19-20.

⁵Charles W. Heckroth, ed., "Mini-Computer Will Close Franklin Loops," Water and Wastes Engineering, VIII (June, 1971), 35.

should be between 6.5 and 7.5.¹ If the pH is over 9.5 sludge cannot be sufficiently separated from effluent in the settling tank.² The pH should be below seven for effective inactivation of virus by chlorine.³ A slowly dropping pH in a digester indicates a tendency toward upset.⁴ Excessive acid in a digester causes frothing and reduces the efficiency of supernatant separation.⁵ These examples show the importance of pH measurement.

Proper maintenance of pH measuring equipment is very important in a wastewater treatment plant because of the nature of the materials in the process. The electrodes should be cleaned about once every eight hours.⁶

Residual chlorine in the effluent can be measured by an amperometric cell. A solution of potassium iodide and a buffer must be added to the sample being measured. The combined chlorine reacts with the potassium iodide to produce free iodine which is measured

¹John W. Saucier, "How to Operate 'Package' Wastewater Treatment Plants," American City, LXXXIII (September, 1968), 92-97.

²L. Lijklema, "Factors Affecting pH Change in Alkaline Wastewater Treatment - II Carbon Dioxide Production," Water Research, V (April, 1971), 123.

³Vincent P. Olivieri, Thomas K. Donovan and Kazuyoshi Kawata, "Inactivation of Virus in Sewage," Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, XCVII [SA 5 No. 8419] (October, 1971), 661-73.

⁴J. Salvatorelli, "Value of Instrumentation in Wastewater Treatment," Journal of the Water Pollution Control Federation, XL (January, 1968), 101.

⁵L. A. McDowell, "Odor-Prevention Insurance," American City, LXXXVI (February, 1971), 54-58.

⁶Babcock, Instrumentation and Control, p. 24.

by the cell.¹ A cell has been developed which automatically cleans itself and adds the proper amount of buffer and potassium iodide solutions to the sample.² The cell uses gold and copper electrodes. The reagent bottles must be refilled once a week. A unit being tested at a Philadelphia area sewage treatment plant required no recalibration after one year of continuous operation.³

Dissolved oxygen in wastewater can be measured with a probe using platinum and silver electrodes covered by a Teflon membrane. The cell is filled with potassium chloride solution.⁴ A similar probe using a gold and silver electrode system has also been developed.⁵ This instrument has been compared with the Winkler method for determining dissolved oxygen in wastewater and the results agreed within 0.1 mg per liter.⁶ Using this instrument an analyst can obtain oxygen uptake profiles and dissolved oxygen values of an entire

¹Ibid., 25-27.

²N. K. Stenberg, "Chlorine Residual Analyzer/Monitor Challenges Need for Simplicity, Accuracy, Reliability," Water and Wastes Engineering, VII (December, 1970), 41-42.

³Thurber G. Zeh, Jr., "Improvements in Chlorine Residual Analyzers," Presented at the 32nd International Water Conference of the Engineers' Society of Western Pennsylvania at the William Penn Hotel, Pittsburgh, Pennsylvania, Thursday, Nov. 4, 1971.

⁴Babcock, Instrumentation and Control, p. 27-28.

⁵Instructions for YSI Model 54 Oxygen Meter, Yellow Springs Instrument Co., Yellow Springs, Ohio 45387.

⁶Jeremiah F. Reynolds, "Comparison Studies of Winkler vs. Oxygen Sensor," Water Pollution Control Federation Journal, XLI (December, 1969), 2002-2009.

system in minutes.¹ The dissolved oxygen probe is reliable if given weekly servicing. It can be self cleaned by a jet of water directed against the sensing membrane.²

Sludge level in the clarifier can be electronically measured and automatically controlled.³ The suspended solids concentration in the aeration tank can be electronically measured and controlled.⁴ The suspended solids concentration in the effluent from the plant can be measured by a turbidity meter.⁵

Control

Flow can be controlled either by valves or by variable speed pumps. Valves can be operated by pneumatic, electric or hydraulic operators. Valve position can be sensed and compared to the desired position and the result used to control the valve operator.⁶

A small wastewater treatment plant (0.175 mgd) has been in operation with automatic controls for more than a year.⁷ The

¹Jeremiah F. Reynolds, "Activated Sludge System: Control and Analysis," Water and Sewage Works, CXVII (July, 1970), 251-259.

²Jon W. Nauman and Robert L. Cory, "Cost of Patuxent River Quality Monitoring," Journal of American Water Works Association, LXII (December, 1970), 796.

³"Activated Sludge Process Automated," Water and Sewage Works, CXVII (May, 1970), 160-161.

⁴"Automatic System for Sewage Disposal Patented," Civil Engineering, XLI (September, 1971), 114.

⁵Babcock, Instrumentation and Control, p. 81.

⁶Ibid., 62.

⁷Ralph Stone and E. T. Conrad, "Automatic Water and Waste Treatment Plants in Operation," Civil Engineering, XL (May, 1970), 37-40.

automatic controls cost 7.9 per cent of the total cost of the sewage treatment system. The total cost for controls was \$24,110.¹

A computer can be used to tie the instrumentation and control elements together to achieve more efficient operation. Some typical computer functions that can be implemented are:

1. Scan process sensing instruments, check for instrument malfunction, store data.
2. Process data by smoothing, curve fitting, integration, differentiation and statistical analysis.
3. Monitor and report status of process equipment, for example: on-off condition of pumps, valves, motors, compressors, etc.
4. Compare process variables against high-low limits and sound alarms.
5. Prepare operating log and display information to operator.
6. Furnish operator operating guidance upon request, such as instructions in case of upset or set points to improve operation.
7. Furnish data for other computers or provide reduced operating data to higher management.
8. Using a dynamic math model stored in memory, take control action based on input data.²

A computer control system has been implemented at Franklin, Ohio.³

¹Stone and Conrad, "Automatic Water and Waste Treatment Plants in Operation," 37-40.

²John F. Andrews, "Control of Wastewater Treatment Plants - The Engineer as an Operator," Water and Sewage Works, CXVIII (January, 1971), 26-32.

³Heckroth, "Mini-Computer Will Close Franklin Loops," 35.

III. LABORATORY RESEARCH WITH RESIDUAL CHLORINE ANALYZER

Objective

The objective of this research was to make an amperometric cell and demonstrate its use in the measurement of residual chlorine in water.

Theory

The concentration of the electroactive constituent of a solution can be measured by determining the current flowing between two electrodes in the solution.¹ An amperometric cell for measuring residual chlorine can be made with gold and copper electrodes.² One electrode is made small so that it is easily polarized.¹ Chlorine in the solution will depolarize this electrode permitting current to flow.

The measured output voltage of the cell also is an indicator of the residual chlorine concentration as shown by the following experimental data.

¹Russell H. Babcock, Instrumentation and Control in Water Supply and Wastewater Disposal, reprinted from the pages of Water and Wastes Engineering, (Reuben H. Donnelley Corporation, 1968), pp. 25-27.

²N. K. Stenberg, "Chlorine Residual Analyzer/Monitor Challenges Need for Simplicity, Accuracy, Reliability," Water and Wastes Engineering, VII (December, 1970), 41-42.

Procedure

An amperometric cell as shown in Figure 1 was constructed in the shop and used to make the following measurements:

Preliminary Tests

Chlorine solutions of various strengths as shown in Table 1 were made by diluting Chlorox with distilled water. Each sample size was 500 ml. The prepared chlorine solutions were poured into the sample inlet in turn starting with the weakest solution. The reading of the vacuum tube voltmeter was recorded as each solution passed through the cell. The results were plotted in Figures 2 and 3 (see Appendix).

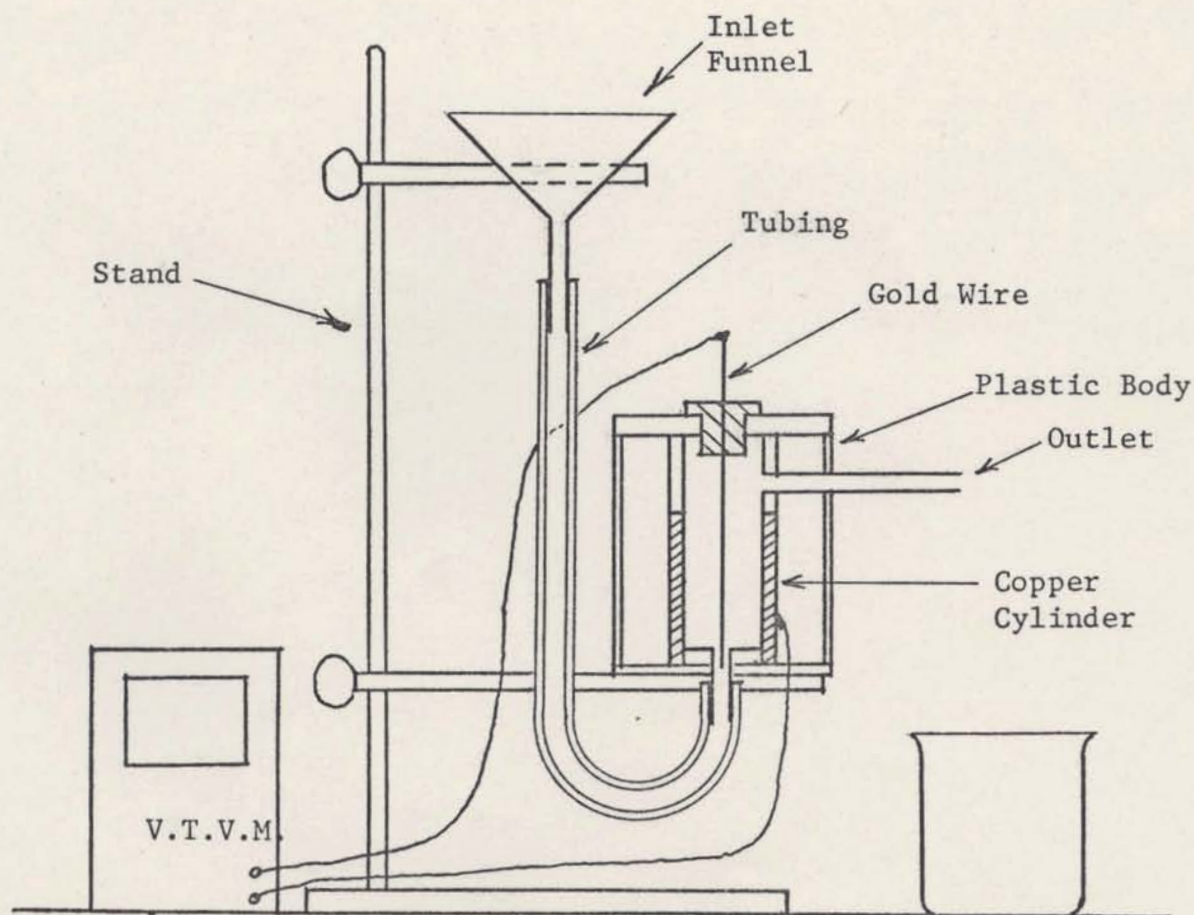


Fig. 1.--Amperometric Cell.

TABLE 1

FIRST PRELIMINARY MEASUREMENTS

Chlorine concentration milligrams per liter	Meter reading in volts
0.0	0.08
0.5	0.13
1.0	0.34
2.0	0.40
5.0	0.48
10.0	0.51

During this first set of measurements, water leaked into the space between the copper cylinder and the outer case, thus making contact with the area where the lead wire was soldered to the copper cylinder. The presence of solder, residual flux, etc may have contaminated the water enough to change the cell characteristics.

The amperometric cell was modified by adding a gasket to control leakage and another test was made with chlorine solutions as described before. The results were recorded in Table 2 and plotted in Figures 4 and 5.

TABLE 2

SECOND PRELIMINARY MEASUREMENTS

Chlorine concentration milligrams per liter	Meter reading volts
0.0	0.105
0.2	0.360
0.5	0.385
1.0	0.420
2.0	0.480
5.0	0.540

During this second set of measurements the discovery was made that the output of the cell changed as the rate of flow of water through the cell changed. This rate of flow must be carefully controlled to obtain repeatable readings. The flow rate can be controlled by maintaining a constant head at the input to the cell.

Control Test

The inside of the copper cylinder was cleaned with fine sandpaper until it was shiny. The cell was washed and then flushed with deionized water. Another test was made with chlorine solutions as described before except, dilutions were made with deionized water instead of distilled water. The results were recorded in Table 3 and plotted in Figures 6 and 7.

TABLE 3

CONTROL MEASUREMENTS

Chlorine concentration milligrams per liter	Meter reading in volts	pH
0.0	0.02	6.85
0.08	0.076	6.90
0.16	0.125	6.90
0.40	0.35	6.90
0.80	0.39	6.90
1.60	0.42	6.90
4.00	0.48	7.15

The strengths of the chlorine solutions were checked with an Enslow Chlorimeter. The pH measurements were made with a Corning pH meter Model 10.

Salt Test

The cell was again washed and flushed with deionized water. Another set of measurements with chlorine solutions was made as before except sodium chloride was added to produce a concentration of 330 milligrams per liter. The results were recorded in Table 4 and plotted in Figures 8 and 9.

TABLE 4
SALT INTERFERENCE MEASUREMENTS

Chlorine concentration milligrams per liter	Meter reading in volts	pH
0.0	0.085	7.0
0.08	0.11	7.0
0.16	0.14	7.0
0.32	0.30	7.0
0.80	0.43	6.95
1.60	0.47	6.95
4.00	0.53	6.95

Ammonia Test

After washing and flushing the cell with deionized water, another set of chlorine measurements was attempted with ammonium hydroxide added to each sample to produce a concentration of 10.5 mg/l. The results were recorded in Table 5.

TABLE 5
AMMONIA INTERFERENCE MEASUREMENTS

Chlorine concentration milligrams per liter	Meter reading in volts	pH
0.0	0.025	10.15
0.1	0.012	10.20
0.2	0.002	10.15
0.4	-0.006	10.20
1.0	-0.011	10.10
2.0	-0.026	10.15
5.0	-0.023	10.20

Buffered Ammonia Test

A liter of phosphate buffer solution with pH 6.865 was prepared according to the formula in Standard Methods.¹ A solution of potassium iodide was prepared by dissolving one half gram of KI in 10 ml of deionized water. Chlorine solutions with NH_4OH were made as before except that 50 ml of buffer solution was included in each sample and one ml of KI solution was added to each sample just before pouring the sample through the cell. The results were recorded in Table 6 and plotted in Figures 10 and 11.

Acid Ammonia Test

Another set of chlorine solutions with NH_4OH was made as before except that three ml of 0.34 N Acetic acid were included in

¹Michael J. Taras, and others, ed., Standard Methods for the Examination of Water and Wastewater, (13th ed.; New York: American Public Health Association, 1971), p. 278.

TABLE 6

AMMONIA INTERFERENCE MEASUREMENTS WITH BUFFER
SOLUTION AND POTASSIUM IODIDE ADDED

Chlorine concentration milligrams per liter	Meter reading in volts	pH
0.0	0.16	7.09
0.1	0.26	7.15
0.2	0.40	7.15
0.4	0.49	7.18
1.0	0.56	7.17
2.0	0.56	7.16

each sample. Two ml of KI solution were added to each sample just before purging the sample through the cell. The results were recorded in Table 7 and plotted in Figures 12 and 13.

TABLE 7

AMMONIA INTERFERENCE MEASUREMENTS WITH SOLUTION
pH ADJUSTED TO FOUR AND POTASSIUM IODIDE ADDED

Chlorine concentration milligrams per liter	Meter reading in volts	pH
0.0	0.16	4.10
0.1	0.31	4.05
0.2	0.42	4.00
0.4	0.54	4.00
1.0	0.58	4.00
2.0	0.60	4.00

Results and Conclusions

The first set of measurements is not considered to be accurate because of the leakage and contamination problems described earlier. However, these measurements were encouraging to the writer at the time because the output voltage of the cell did increase as the chlorine concentration increased. This proved that the cell would work.

One might expect the second and third sets of measurements (Tables 2 and 3--Figures 4, 5, 6, and 7) to agree with each other because the conditions of measurement were similar. They do agree within ten per cent over a chlorine residual concentration range of ten to one. The differences evident at concentrations below 0.4 mg per liter were probably caused by a difference in the input impedances of the vacuum tube voltmeters used. The HP 410 C used for the second set of measurements has an input impedance of 100 megohms but the HP 425 A used for the third set of measurements has an input impedance of one megohm. The internal impedance of the cell increases as the chlorine concentration decreases. If the impedance of the measuring instrument is too low the output voltage versus chlorine concentration curve will be nonlinear.

A comparison of the third and fourth sets of measurements (Tables 3 and 4--Figures 6, 7, 8, and 9) indicates the effect of adding sodium chloride to the water. The dissolved salt lowers the internal impedance of the cell thus causing output voltage readings to be slightly higher than normal. The readings agreed within ten per cent above 0.2 mg per liter. Below this concentration the sensitivity of the cell to small changes in chlorine concentration was degraded.

The fifth set of measurements (Table 5) shows that the cell cannot be used to measure combined chlorine without modification of experimental parameters.

The sixth set of measurements (Table 6--Figures 10 and 11) indicated that the cell could be used to measure combined chlorine if the sample were properly buffered and potassium iodide added. Chlorine liberates free iodine from potassium iodide solutions if the pH is eight or less.¹ The cell then measures the free iodine.

Again, the addition of salts to the solutions decreased the internal impedance of the cell causing higher voltage readings for given chlorine concentrations.

The seventh set of measurements (Table 7--Figures 12 and 13) showed the effect of lowering the pH to four. Figure 12 is nearly linear over a wider range than Figure 10.

This research has demonstrated that the amperometric cell can be used to measure the residual chlorine concentration in water.

¹Standard Methods, p. 110.

IV. VISITS TO WASTEWATER TREATMENT PLANTS

Disney World

The wastewater treatment plant at Disney World is an activated sludge plant using extended aeration. The influent passes through a magnetic flow meter which has not been working for several months because it was damaged by lightning. The wastewater then flows through a grit chamber where the grit settles to the bottom and is removed by a mechanical conveyer. The grit is hauled away in trucks and buried.

The wastewater passes through a comminuter, which grinds the solids into smaller pieces, to a wet well. The wastewater is pumped from the wet well to the aeration tanks where it is mixed with air and sludge from the clarifier.

After aeration the wastewater flows to the clarifier where the heavier solids settle to the bottom and the lighter solids rise to the surface where they are removed by a skimmer. The clear water flows over weirs to the chlorination tank. The sludge is mechanically removed from the bottom of the clarifier and a portion of it is returned to the aeration tanks. The remainder is wasted to the aerobic digesters. The percentage of sludge to be returned to the aeration tanks is determined by the indications of a radiation absorption type sludge density meter,¹ in the return sludge line and manually determined suspended solids level in the aeration tank.

¹Manufactured by the Ohmart Company, Cincinnati, Ohio.

As the plant was originally designed the effluent from the clarifier was pumped through mixed media filters, containing coal and sand, before flowing to the chlorination tank. However, when attempts were made to back flush these filters structural failure permitted the filter tanks to separate from their concrete bases.

A chlorine residual analyzer¹ was used to automatically control the chlorination process until it failed several months ago. Chlorine residual is checked by wet chemical methods and chlorination rate is manually controlled to maintain a residual of about 0.75 ppm chlorine in the effluent.

A portion of the effluent from the chlorine contact tank is pumped to the incinerator where it is used in the wet scrubbers to prevent air pollution. The remainder of the effluent is disposed of by land spreading.

Dissolved oxygen meters are used to determine dissolved oxygen levels throughout the plant. Air flow rates are manually controlled to maintain a dissolved oxygen level of about two ppm.

The influent to the plant contains about 310 mg/l BOD. It is estimated that the plant receives about 2600 pounds of BOD per day. The aeration tanks contain about three pounds of mixed liquor suspended solids for each pound of BOD input per day. The plant achieves 95 to 97 per cent BOD removal and 90 to 92 per cent removal of suspended solids.

A small computer was installed in the control room to control flow rates throughout the plant by means of pneumatically

¹Wallace and Tiernan

operated valves. This computer is not being used at present because the influent flow meter is not working.

Florida Technological University

Wastewater enters the plant through a comminuter which grinds the incoming material into pieces small enough to avoid damage to the pumps. Immediately following the comminuter is a Parshall flume which measures the rate of flow of the wastewater. The rate of flow is electrically telemetered to a chart recorder in the control room which records rate of flow versus time continuously. After passing through the Parshall flume the wastewater flows into a wet well. From the wet well it is pumped to the contact tank by pumps which are automatically controlled by the level of water in the wet well.

The wastewater is kept in the contact tank for about three to four and one-half hours while it is mixed with air and sludge from the reaeration tank. The wastewater then flows into the clarifier where it is retained for two and one-half to 4.3 hours. The heavier solids settle to the bottom of the clarifier and the lighter solids (for example, grease and ash) rise to the surface where they are removed by the skimmer. The clear water flows over weirs to the chlorination tank. The sludge is mechanically removed from the bottom of the clarifier by scrapers and pumped to the reaeration tank where it is kept for about three to four and one-half hours while being mixed with air.

In the chlorination tank the water is mixed with a solution of chlorine dissolved in water. The amount of chlorine added is controlled

manually to maintain a chlorine residual of two ppm in the effluent. From the chlorination tank the water flows to the oxidation pond.

After several weeks retention in the oxidation pond the water is pumped to sprinklers for land spreading.

Samples are taken periodically from all parts of the plant to determine dissolved oxygen and dissolved and suspended solids. When the dissolved and suspended solids in the reaeration tank exceed about 2000 ppm the sludge is wasted to the digester. In the digester the sludge is mixed with more air and biodegradation of the organic material continues. After 10 to 30 days in the digester the sludge is spread on drying beds. Samples are taken periodically from the digester to determine the percentage of volatile solids. This measurement is used as an indicator to determine retention time in the digester. Supernatant from the digester is returned to the wet well.

The rates of air flow into the contact tank, the reaeration tank and the digester are manually controlled by valves at each tank. These valves are set to maintain the dissolved oxygen in the contact tank between two to five ppm, in the reaeration tank between 1.5 to two ppm and in the digester about one ppm.

V. RECOMMENDATIONS FOR FLORIDA TECHNOLOGICAL
UNIVERSITY WASTEWATER TREATMENT PLANT

Short Term Improvements

The treatment plant operators should become familiar with the dissolved oxygen measuring instrument¹ presently owned by the school (used in the Environmental Engineering instructional program) and use it to make some of the dissolved oxygen measurements required for normal operation of the plant. A survey of the dissolved oxygen conditions throughout the volume of each tank in the treatment plant should be made, using the dissolved oxygen probe, to determine possible critical areas that should be monitored on a continuous basis.

A dissolved oxygen measuring instrument similar to the one presently owned by the school should be purchased for the exclusive use of the wastewater treatment plant operators. This would avoid the time consuming wet chemical oxygen determinations.

Long Term Planning

An automatic sludge level control system² (for example, Keene Corporation Model 8100) should be installed in the clarifier to assist in maintaining the sludge blanket at or below a fixed height by controlling the sludge wasting cycle. The instrument to perform this function would cost about \$ 1200.

¹Model 54 Oxygen Meter, Yellow Springs Instrument Company, Yellow Springs, Ohio 45387.

²"Activated Sludge Process Automated," Water and Sewage Works, CXVII (May, 1970), 160-161.

A mixed liquor suspended solids analyzer¹ (for example Keene Corporation Model 8200) should be installed in the contact tank and used to assist in maintaining an optimum suspended solids concentration by controlling the sludge return rate. The instrument to perform this function would cost about \$ 3500.

A turbidity measuring probe should be installed in the chlorine contact tank at a point near the effluent weir.

A residual chlorine analyzer and monitor² (for example Capital Controls Company Model 872) should be installed at the chlorine contact tank to maintain a constant chlorine residual by controlling the chlorine feed rate. The instrument to perform this function would cost about \$1700. A small sample pump and strainer would also be required to pump the water to the analyzer and remove suspended solids.

Dissolved oxygen probes³ should be installed in the wet well, the contact tank, the clarifier, the aeration tank and the digester. These instruments cost about \$500 each.

Probes for measuring pH should be installed in the wet well, the contact tank, the clarifier and the digester. A magnetic flow meter should be installed in the return sludge line. Data from each of

¹"Automatic System for Sewage Disposal Patented," Civil Engineering, XLI (September, 1971), 114.

²N. K. Stenberg, "Chlorine Residual Analyzer/Monitor Challenges Need for Simplicity, Accuracy, Reliability," Water and Wastes Engineering, VII (December, 1970), 41-42.

³Frank J. Humenik and George P. Hanna, Jr., "Algal-Bacterial Symbiosis for Removal and Conservation of Wastewater Nutrients," Journal of the Water Pollution Control Federation, XLIII (April, 1971), 580.

the above mentioned instruments, together with clarifier torque, sludge pump load, chlorinator ejector pressure, chlorine cylinder weight, influent flow rate, wet well level, and status of all electric motors should be digitized and transmitted over a data link to the computer center. The IBM 1130 computer could be used on a time sharing basis to process these signals, compute desired corrective actions, send control signals back over the data link to the plant and sound alarms in case of malfunction. Some of the parameters that could be controlled through computer assistance are: return sludge flow rate, waste sludge flow rate, air flow to each tank, chlorine feed rate, and pH adjustment.¹

The installation of this proposed automatic control system must not be expected to replace well qualified operators at the wastewater treatment plant. The automatic control system is intended to help the operator produce an effluent of consistently high quality, not to replace the operator. Skilled personnel will be required to maintain the instrumentation. If these skilled personnel are not available, the automatic system will fail.

¹John F. Andrews, "Control of Wastewater Treatment Plants - The Engineer as an Operator," Water and Sewage Works, CXVIII (January, 1971), 26-32.

¹Charles W. Heckroth, Ed., "Mini-Computer Will Close Franklin Loops," Water and Wastes Engineering, VIII (June, 1971), 35.

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APPENDIX

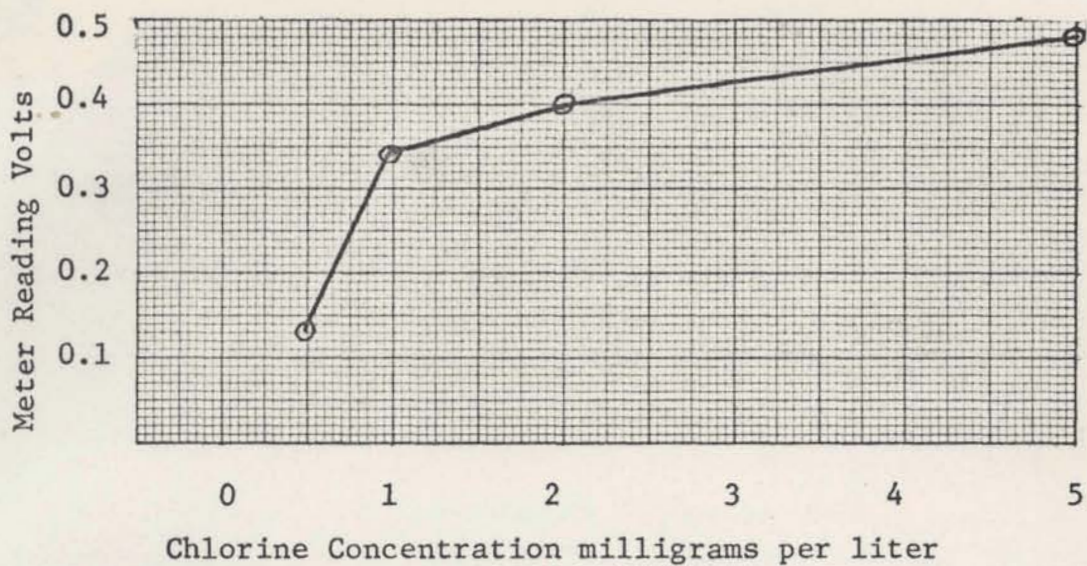


Fig. 2.--Preliminary Measurements

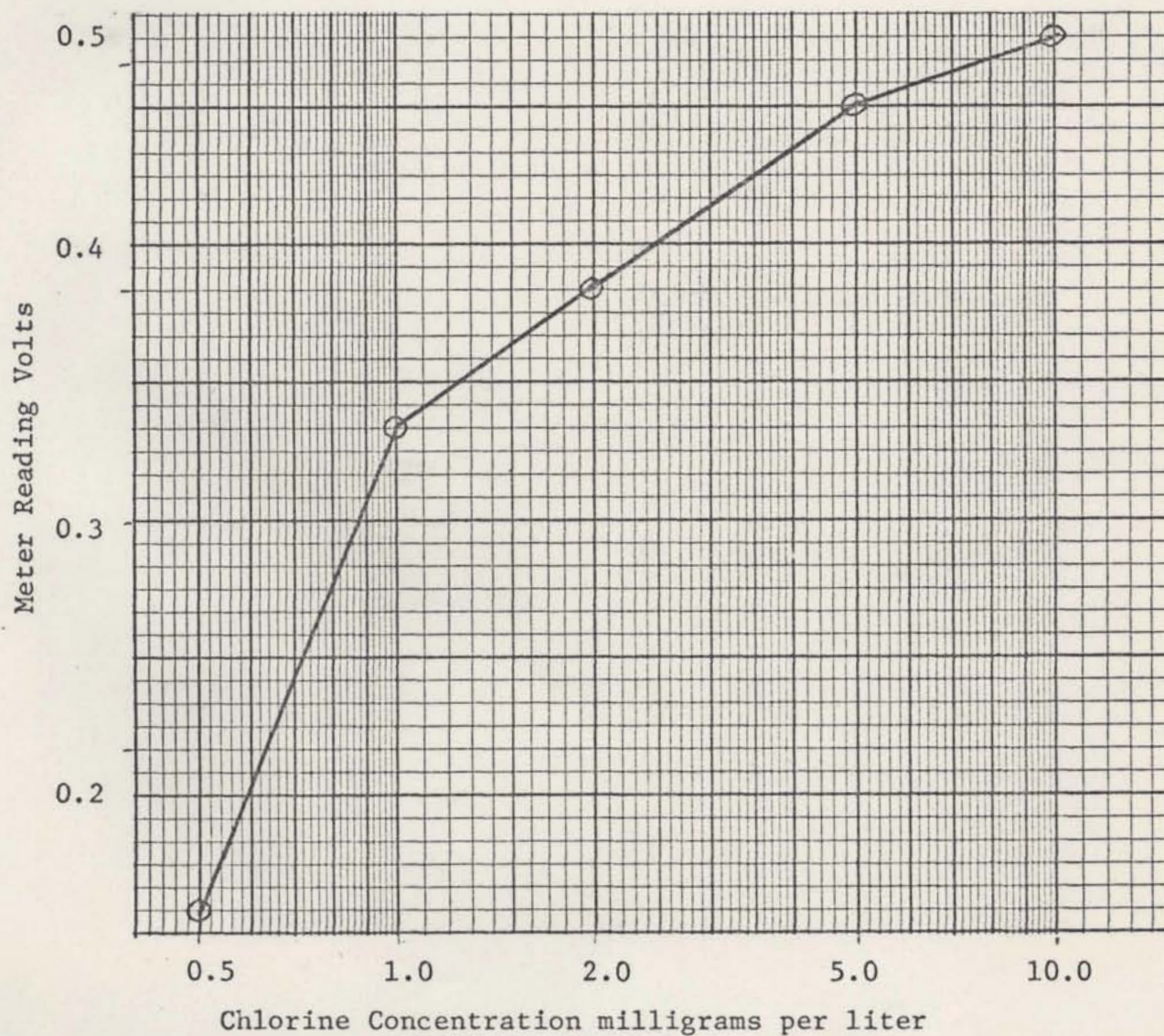


Fig. 3.--Preliminary Measurements

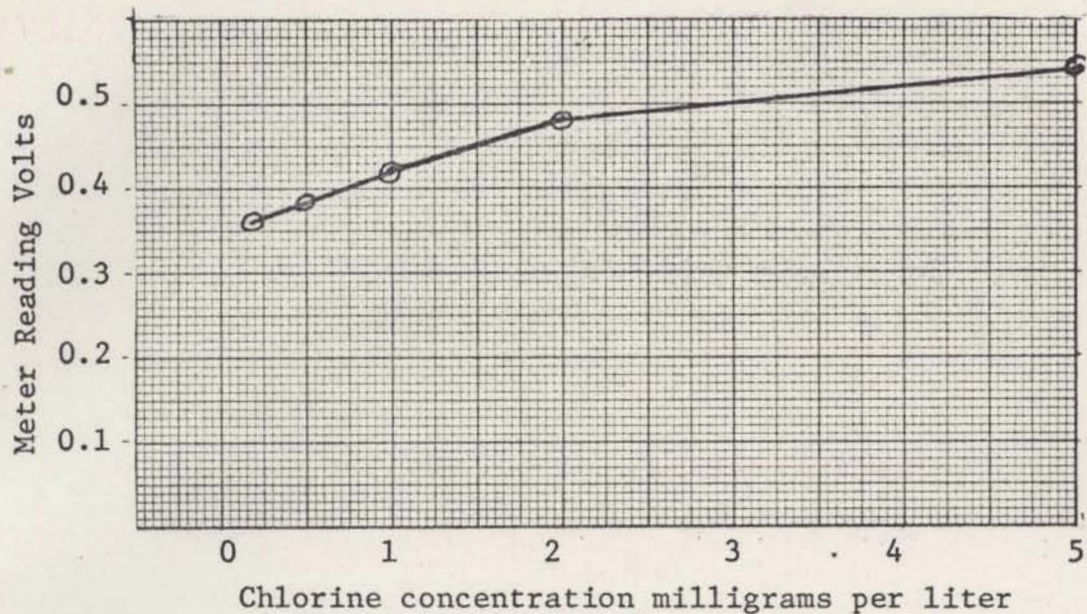


Fig. 4.--Preliminary Measurements

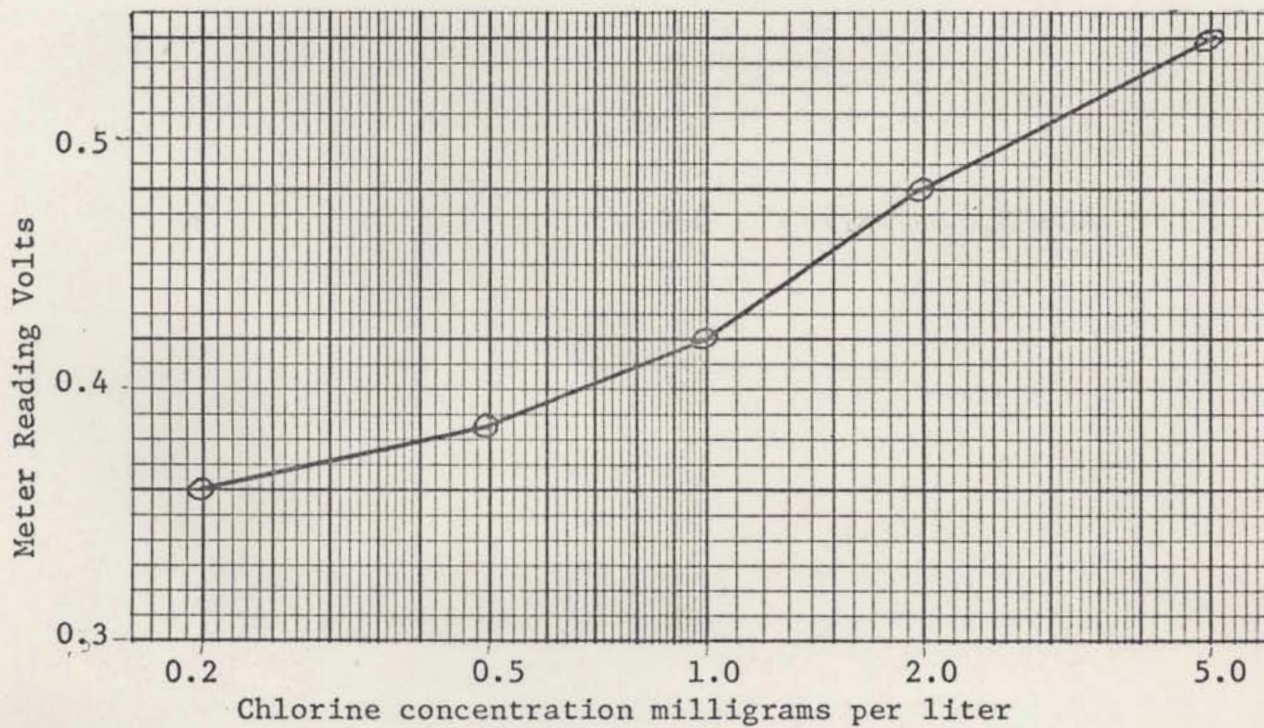


Fig. 5.--Preliminary Measurements

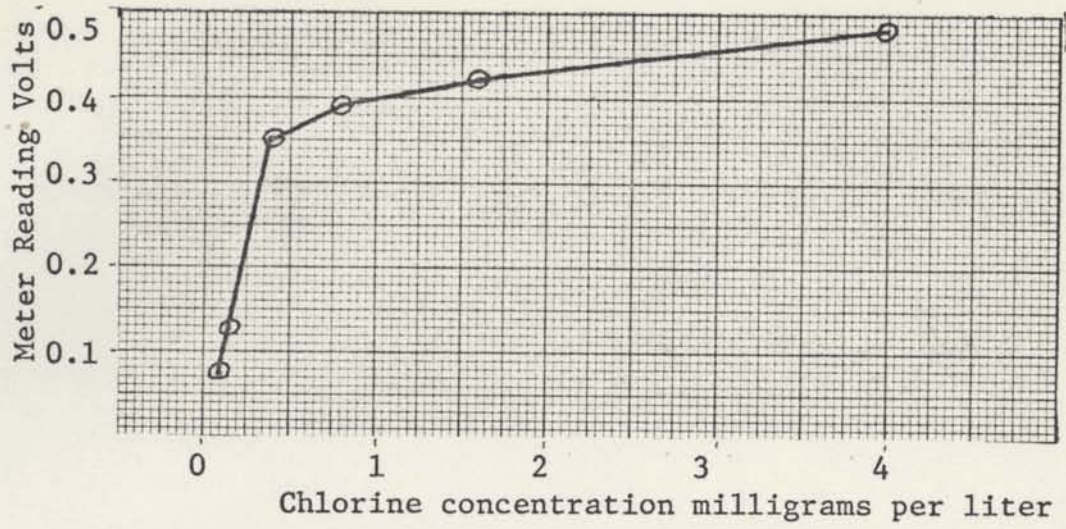


Fig. 6.--Control Measurements

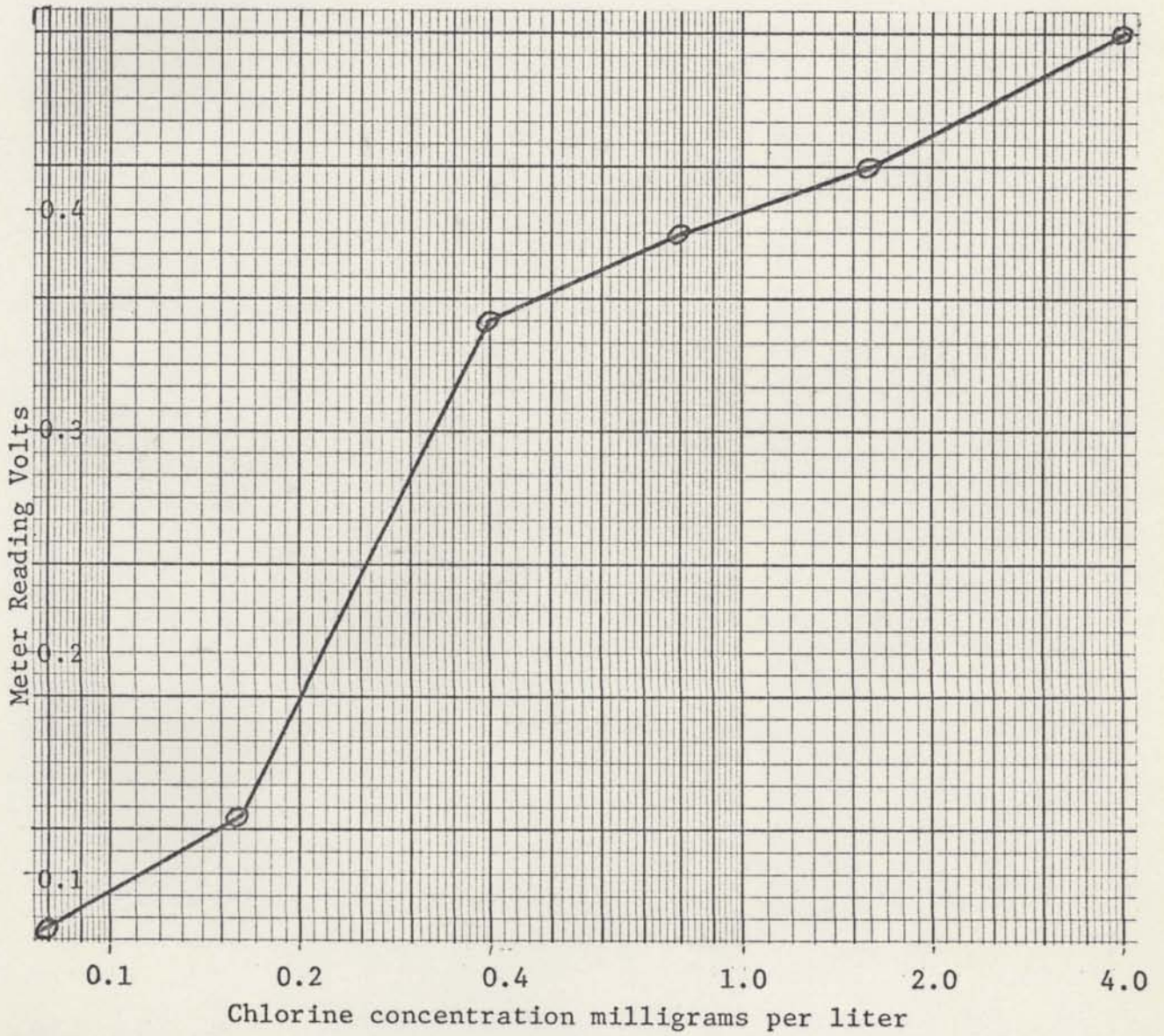


Fig. 7.--Control Measurements

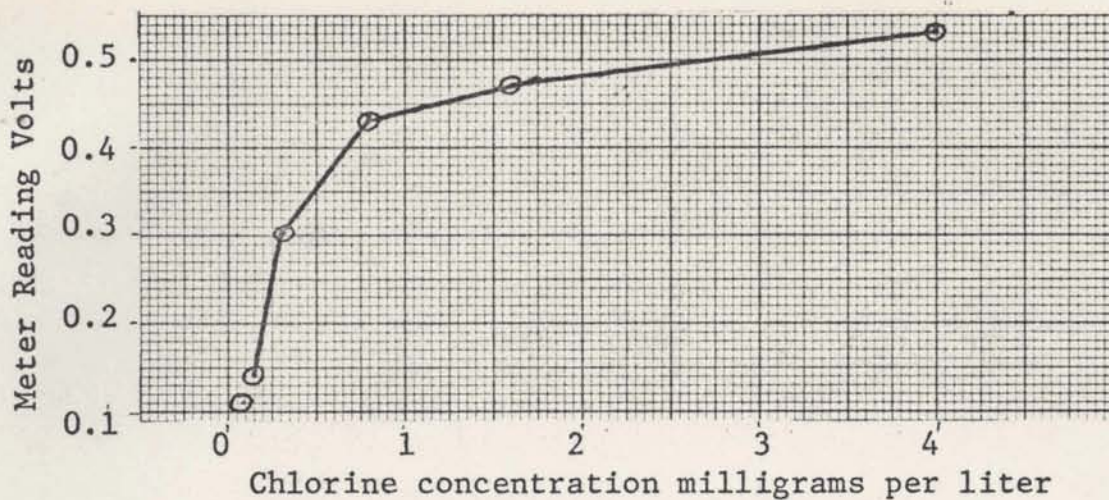


Fig. 8.--Salt Interference Measurements

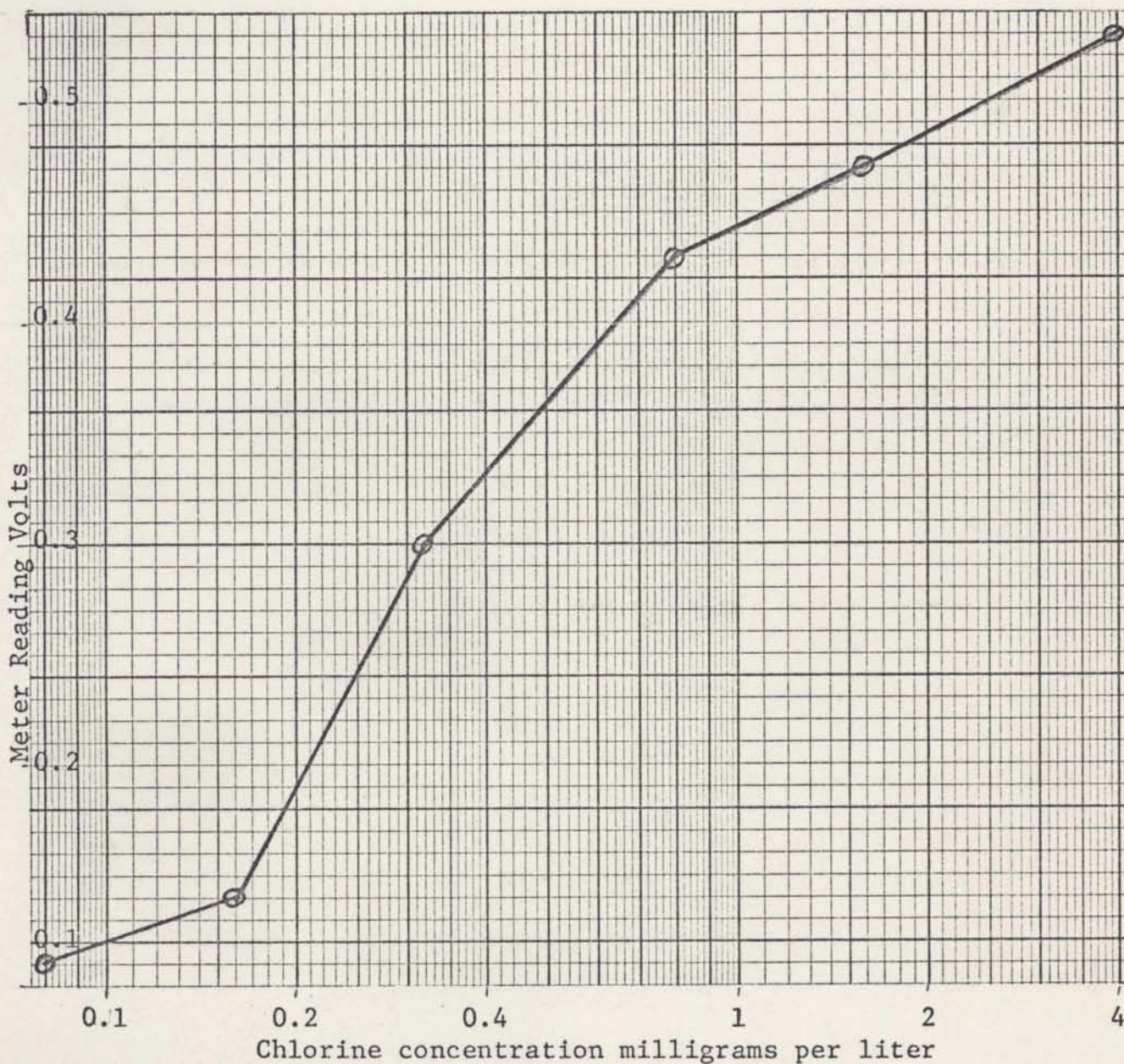


Fig. 9.--Salt Interference Measurements

