

III EXPERIMENTAL INVESTIGATION

The experiments will be performed on surface water taken from Klong Prapa at the intake to Samsen Waterworks and ground water from a well within Chulalongkorn University campus.

The research will be divided into two parts:

- a. Coagulation by chemical means using aluminum sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$, as the coagulant
- b. Coagulation by electrical means

Experiments on both methods were conducted at the Department of Sanitary Engineering Laboratory, Chulalongkorn University.

Design of Experiments

1. Coagulation by Chemical Means

Water Sampling and Method of Analysis

The sources of natural waters used in this project research were taken from Klong Prapa at the intake to Samsen Water Works except one sample, which was taken from a well at Chulalongkorn University. The physical and chemical characteristics of both surface water and ground water were initially analyzed for pH, turbidity, color, alkalinity, total hardness, total solids, chloride, fluoride and also total iron content. Analysis of the samples was determined according to Standard Methods(1971) of Water and Waste Water except color, turbidity, fluoride and total iron content of raw and treated waters were determined by the use of a Delta Scientific Company photometric analyzer, model 260.

Color and turbidity were measured in unit of percentage of light transmission.



Jar Test Procedure

There is no precise standard procedure for the jar test because of varieties of composition of raw water sources. Therefore, various conditions must be tested to determine the most suitable technique for a particular water. Jar tests were carried out by the use of a Phipps and Bird laboratory stirrer shown in Fig.7 with a variable stirrer speed ranging from 0 to 100 rpm. One litre of colored and turbid water was filled in each of six one-litre beakers. Alum, $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ was added into the water in the beakers after the water had been well stirred at 100 rpm for one minute. After that the test was carried out into steps as follow:

1. Determination of Mixing Conditions

Since the mixing conditions were important factors in the coagulation process, the optimum mixing speed and time would be determined.

a. Determination of Fast Mixing Speed and Fast Mixing Time

Fast mixing speed and fast mixing time were essential to the dispersion of the coagulant ($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$) into the suspension. The optimum conditions could be determined by varying the stirrer speed from 60,80 to 100 rpm for the period of 20,40,60,80,100 seconds while maintaining a slow mixing speed at 40 rpm for one minute, with a 40 mg/l. $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$

dosage. The results are shown in Fig.13.

b. Determination of Slow Mixing Speed and Slow Mixing Time

The processes of slow mixing speed and slow mixing time could be obtained by varying the stirrer speed from 20,40,60 80 to 100 rpm for 1,2,3,4,5 minutes, at the specified fast mixing condition obtained from part a, at 40 mg/l. $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$. The conditions were used for floc agglomeration. The results are shown in Fig.14.

2. Total Settling Time by the Jar Test

The settling time required for the determination of final turbidity in the treated water was estimated by pipetting the residual supernatant from the center of the bulk of the liquid, about 5 centimetres from the bottom of the beakers After 1,5,10,15,20 and 30 minutes of settling. The results are shown in Fig.15. Final residual color and turbidity after 15 minutes were stable and slight reduction in turbidity proceeded afterwards.

3. Chemical Utilized in the Chemical Coagulation process

Liquid alum ($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$) produced from the Department of Science, Ministry of Industry, was selected as the chemical coagulant in this study. The concentration, specific gravity and production cost of alum are shown in Table 1 :

$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$	% Al_2O_3	Sp.Gr.of $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ at			Cost
		Various Temperatures			
		25 °C	28 °C	30 °C	B/ton
50.0	7.67	1.3004	1.2989	1.2978	1380

Table 1. Concentration and Specific gravity of Liquid Alum at Various Temperatures and Production Cost Estimated by the Department of Science, Ministry of Industry.

4. Determination of Optimum Alum Dosage

One-litre of raw water was added into each of the six one-litre beakers. The stirrers were switched on at the fast speed, 100 rpm. After one minute, a number of aluminium sulfate dosages were added simultaneously to each of the six beakers. The experiment was proceeded as described in the Jar Test procedure. Final residual color, turbidity, pH, alkalinity were determined and plotted against the aluminium sulfate dosage, expressed as mg/l. $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ as shown in Fig.16. The dosage of aluminium sulfate which gave minimum residual color and turbidity was selected in the determination of the optimum pH range for aluminium sulfate coagulation.

5. Determination of Optimum pH Range for Alum Coagulation

The samples of water were adjusted to different pH values through the use of sulfuric acid (H_2SO_4) and calcium hydroxide ($Ca(OH)_2$) prior to the addition of alum. The method just described in 4 was used in determining the optimum pH range for alum coagulation.

2. Coagulation by Electrical Means

SUWAN(1971) developed an electrical method to coagulate colloidal and suspended matter in natural waters. The method could also be applied to domestic or industrial wastes by the transfer of electrical energy into the liquid mass.

A pilot plant-scale electrical apparatus consisted of an electrically insulated column having an outside diameter of 16 centimetres and height of 56.5 centimetres. Inside at the upper part of the column there were a couple of copper-nickel-alloy plates, between the plates there existed dielectric materials. These copper-nickel-alloy plates might be considered as a capacitor energy storage bank and functioned as a transducer (transform one form of energy to another form, for example, electrical energy to mechanical energy). Under these plates there was a corrugated special alloy diaphragm usually made of copper alloy. Before applying an alternate-voltage source of 220 V 50 cycle to the electrical treatment column (may be called electrical coagulator). The alternate-voltage source had to pass through the primary of an isolation 220/220 volts transformer,

to prevent an electrical shock induced at the overflowed outlet of the tank. The electrical column was fed to a complex wave generator which consisted of a transformer and electronic circuits which stepped up the voltage to about 400-500 volts. The A.C. supply was assumed to be sinusoidal wave form and transformed by the complex wave generator to complex waves which were the combination of fundamental and harmonic waves of different amplitudes and phase shifts. The electrical energy generated from the wave generator induced electrical field lines perpendicular to the corrugated diaphragm into the liquid mass.

To operate the unit, raw water were pumped through the column at lower part. The raw water flowed towards the corrugated diaphragm before overflowed to the perspex settling column. The diagram of the process and detailed of settling column were shown in Fig.8 and Fig.9 respectively.

The samples of surface water and ground water were used as the sources of raw waters supply in this study. The physical and chemical characteristics were determined.

In this study the power supply was fixed while the effluent overflowed rates were varied and vice versa, in order to determine optimum conditions. After the settling column was filled with the effluent overflow until reaching the free board. Color and turbidity of final clari-fied water at various depths were measured in order to determine maximum color and turbidity reduction at a specified optimum settling time. It was impossible

to measure simul-taneously percentage of light transmission of final clarified water at various depths in a short interval of time, fortunately percentage of light transmission of treated waters at various depths were little different. Therefore, a reference sampling point at level at 130 centimetres from the bottom of settling column was selected.

Effect of Mixing on Electrical Coagulation

Effect of mixing on electrical coagulation could be determined as follow:

A one-litre treated water containing flocs from the effluent line of the column were drawn to each six one-litre beakers. Simultaneously the treated waters were stirred at various speed, for example 0 to 100 rpm for one minute and allow to settle from 1 to 120 minutes. Color and turbidity after 1 to 120 minutes were measured to determine optimum total settling time at specified power supply and effluent overflowed rate.

Materials and Equipment Utilized

In performing chemical coagulation the Phipp and Bird laboratory stirrers were used. The equipment was shown in Fig. 7.

While materials and equipments used in electrical coagulation were :

- a. An isolation transformer
- b. A complex wave generator
- c. An electrical treatment column

- d. A wattmeter
- e. A perspex settling column
- f. A PVC tank

which were shown in Fig.10, Fig.11 and Fig.12.

Procedure and Analytical Methods

Physical and chemical analysis of raw waters characteristics were determined according to Standard Method (1971) except color, turbidity, fluoride and total iron content were determined by the use of a Delta Scientific Company photometric analyzer, model 260. The procedure for the determination were as follows:

Test No. 260-23, 26 ----- COLOR AND TURBIDITY OF WATER

1. Fill one No. 260-T Square 26 mm Test cell with the sample to be tested.
2. Fill another test cell with colorless or turbidity-free distilled water, for use as a blank.
3. Turn the Analyzer on, and rotate the filter selector to No 440.
4. Insert the test cell containing the blank into the Analyzer, making certain that one of the frosted sides faces to the front. Adjust the meter needle to a reading of 100.
5. Replace the blank with the test cell containing the sample and read the meter, then determine the color and turbidity in the unit of percent transmission.

Test No. 260-13 -----FLUORIDE

The Reagents and Accessories required are as follows:

R-68 Fluoride Standard, 1.00 ppm

R-69 Sodium Arsenite, 0.5%

R-67 SPADNS Reagent

2 105-A Flask, Erlenmeyer, 125 ml

1 103-A Cylinder, Graduated, 50 ml

1 110-A Pipette, Mohr Measuring, 5ml in 1/10 ml

1. Using a clean, dry cylinder, measure 25 ml of No. R-68 1.00 ppm Fluoride Standard into a No. 105-A 125 ml Erlenmeyer flask. Mark the flask for identification.
2. Rinse the cylinder used in Step 1 with sample and measure



25 ml of sample into another 125 ml Erlenmeyer flask. Add 3 drops of No. R-69 Sodium Arsenite, 0.5% and mix to remove any chlorine present.

Note: The Fluoride Standard should be close to or at the same temperature as the water being tested. Let stand or hold both flasks under running tap water until the temperature is the same.

3. Add 5.0 ml of No. R-67 SPADNS Reagent to each flask, and mix the contents of each flask by swirling.
4. Turn the Analyzer on, and rotate the filter selector to No. 570.
5. Pour the treated Standard into a dry, clean No. 260-T Square 26 mm Test Cell, and mark the cell for identification. This Standard may be used for 1 hour after preparation.
6. Pour the treated sample into another clean, marked test cell.
7. Insert the test cell containing the Standard into the Analyzer so that one of the frosted surfaces of the cell faces the front. Set the meter needle to the scale value equivalent to 1.00 ppm Fluoride. This number is shown on the Fluoride Graph.
8. Remove the test cell containing the Standard. Immediately insert the test cell containing the treated sample and read the meter.
9. Refer to the graph to convert the meter reading to ppm Fluoride in the sample. The Model 260 Photometric Analyzer is calibrated from 0-2 ppm Fluoride. If necessary expand the range as described in the Introduction.

Test No. 260-14 --- IRON

The Reagents and Accessories requires are as follows:

- R-101 Ammonium Acetate Buffer
- R-39 Hydrochloric Acid, Concentrated
- R-100 Hydroxylamine Reagent
- R-36 Iron Reagent Powder
- R-102 Phenanthroline, 0.1%
- 2 103-A Cylinder, Graduated, 50 ml
- 2 105-A Flask, Erlenmeyer, 125 ml
- 2 107-A Flask, Volumetric, 50 ml
- 2 110-A Pipette, Mohr Measuring, 5 ml in 1/10 ml
- 112-A Scoop

Procedure - This is based on the standard A.P.H.A. method, 12th edition, using Phenanthroline, Where the sample is TREATED TO REMOVE INTERFERING SUBSTANCES. The calibration graph is used.

1. For total Iron, mix the sample thoroughly and measure 50 ml of mixed sample into a 125 ml Erlenmeyer flask.
2. Simultaneously prepare a reagent blank by adding 50 ml of distilled water to a second 125 ml Erlenmeyer flask.
3. To each flask, add 2 ml of No R-39 Hydrochloric Acid, Concentrated, and 1 ml of No. R-100 Hydroxylamine Reagent.
4. Heat both flasks to boiling on a hot plate and reduce the volume to approximately 20 ml
5. Cool to room temperature and transfer each to No. 107-A 50 ml Volumetric Flasks.

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6. To each, add 10 ml of No. R-101 Ammonium Acetate Buffer and 3ml of No. R-102 Phenanthroline, 0.1%
7. Dilute each flask to volume with distilled water, and mix. Let stand for five minutes.
8. Turn on the Analyzer and rotate filter selector to No. 520.
9. Fill one No. 260-T Square 26 mm Test Cell with untreated filtered sample.
10. Insert the test cell containing the blank into the Analyzer, making certain that one of the frosted sides faces to the front. Adjust the meter needle to 100.
11. Replace the blank with the test cell containing the treated sample, and read the meter.
12. Refer to the graph for Iron to convert the meter reading to ppm Iron (Fe).
13. The Model 260 Water Analyzer is calibrated from 0 to 5 ppm Iron(Fe). If necessary expand range as described in the Introduction, The results are reported in ppm Iron, either Total or Dissolved. Total Iron is obtained with mixed, unfiltered sample.

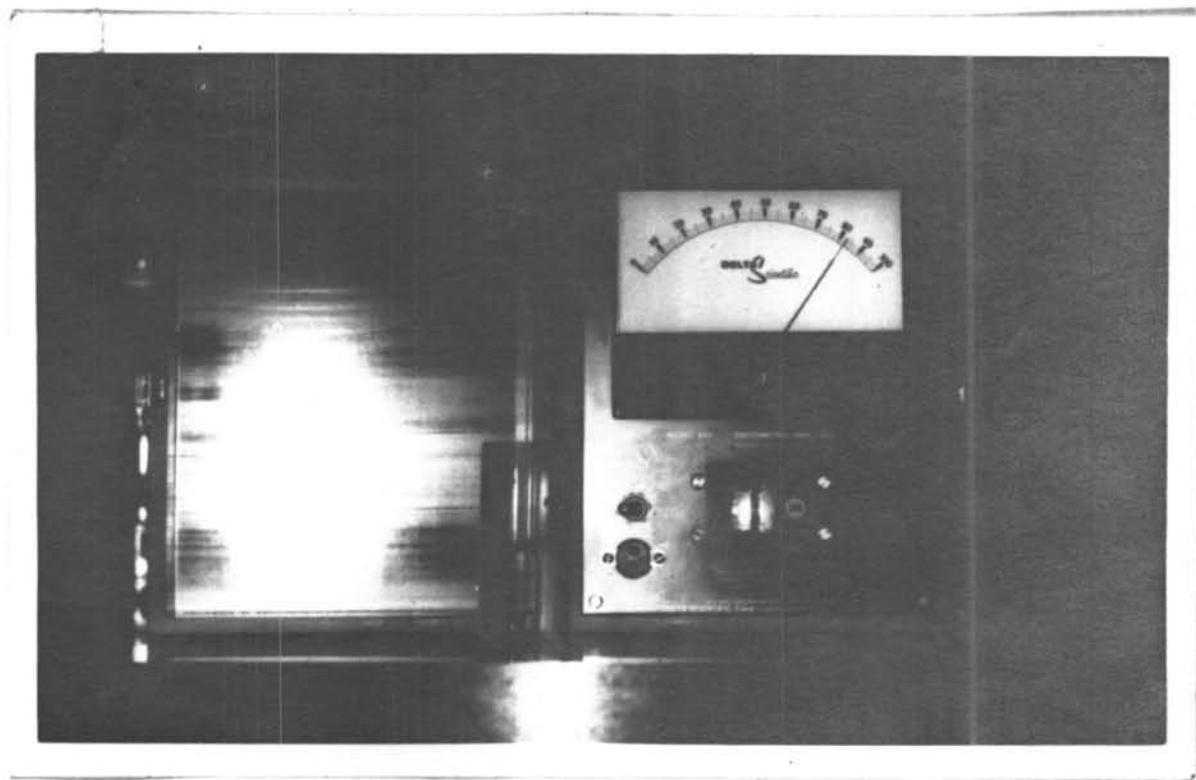


Fig.6- Delta Photometric Analyzer, Model 260

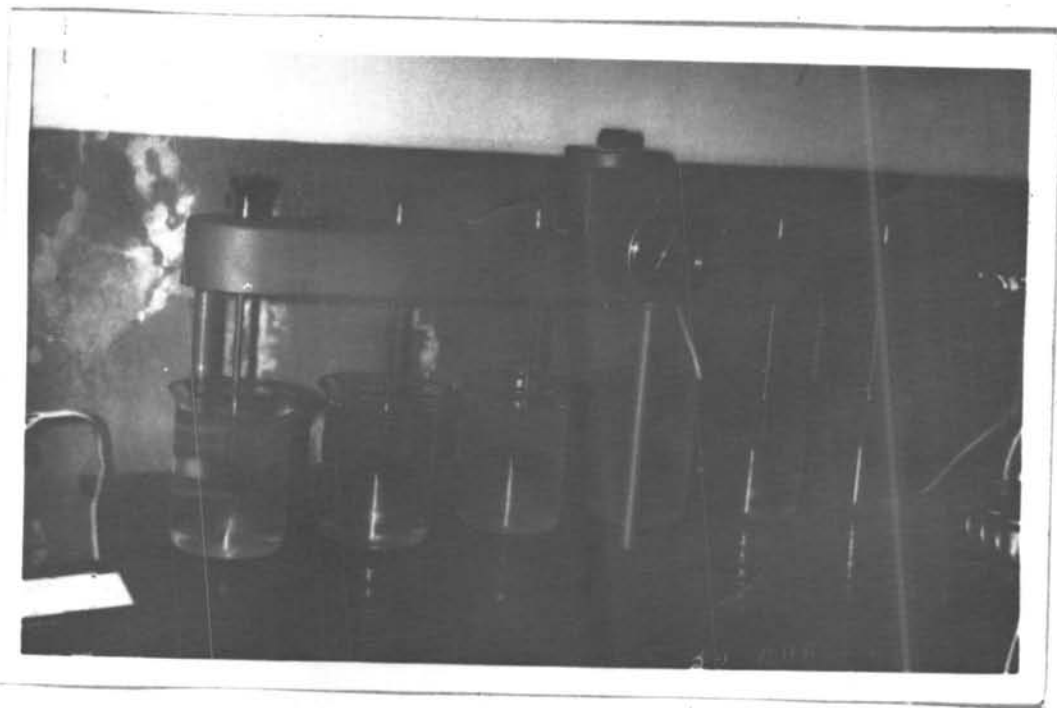


Fig.7- The Jar Test Performed by the Phipp and Bird Laboratory Stirrer

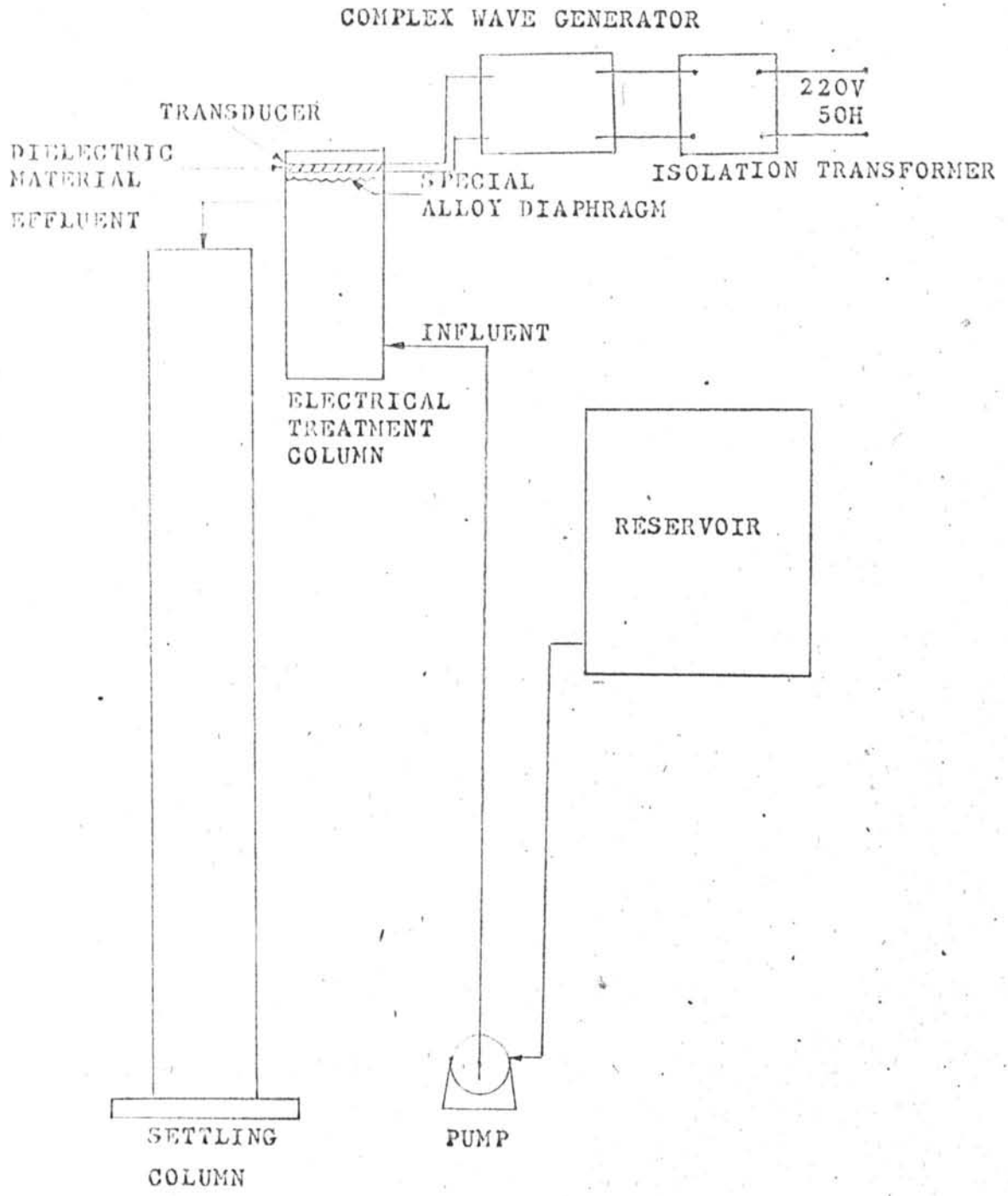


Fig.8-Schematic Diagram of Electrical Coagulation Process

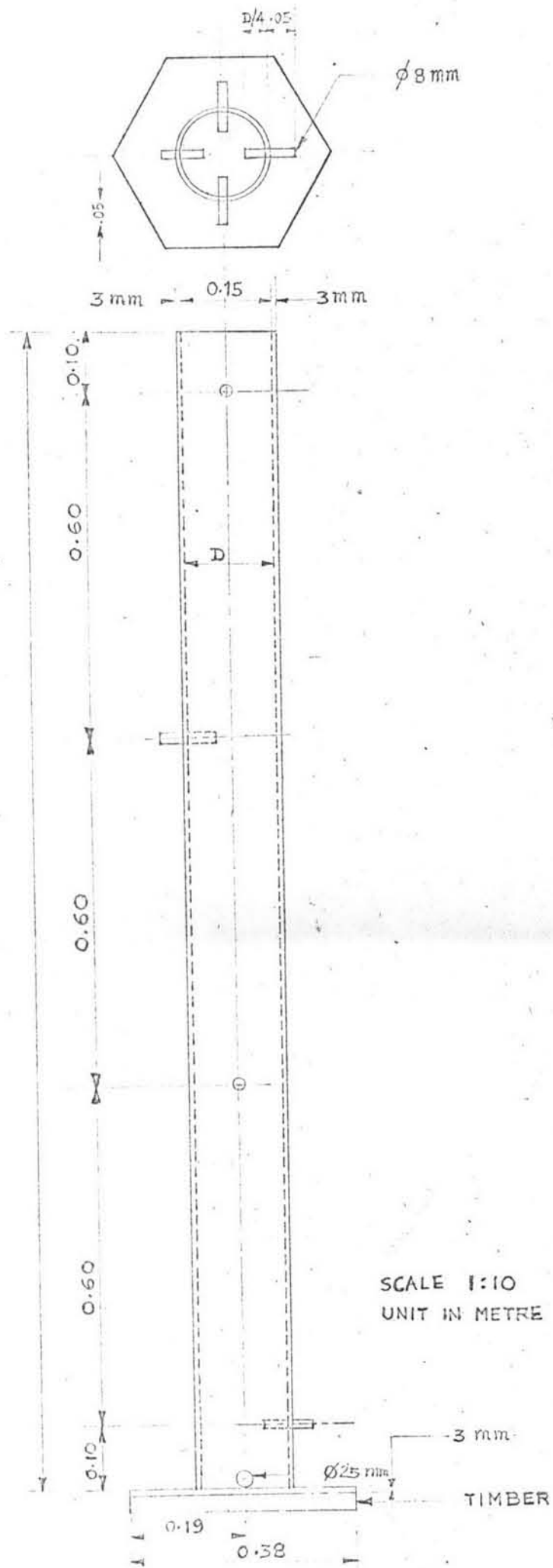


Fig.8 PERSPEX SETTLING COLUMN

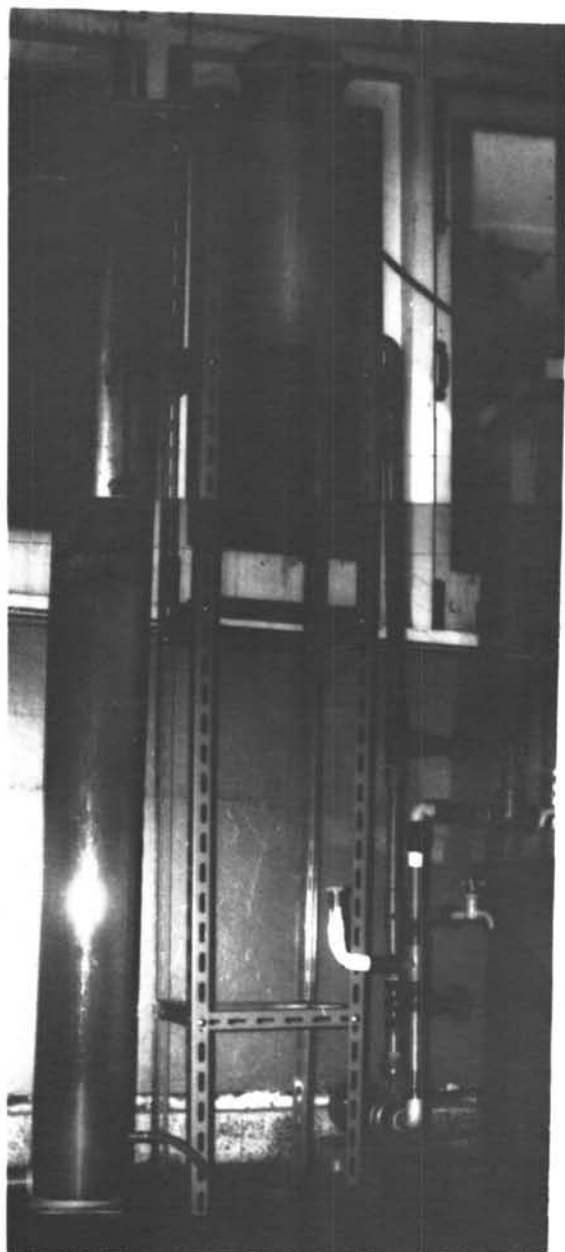


Fig.10- Apparatuses Used for Electrical Coagulation Including Reservoir, Electrical Column, Perspex Settling Column

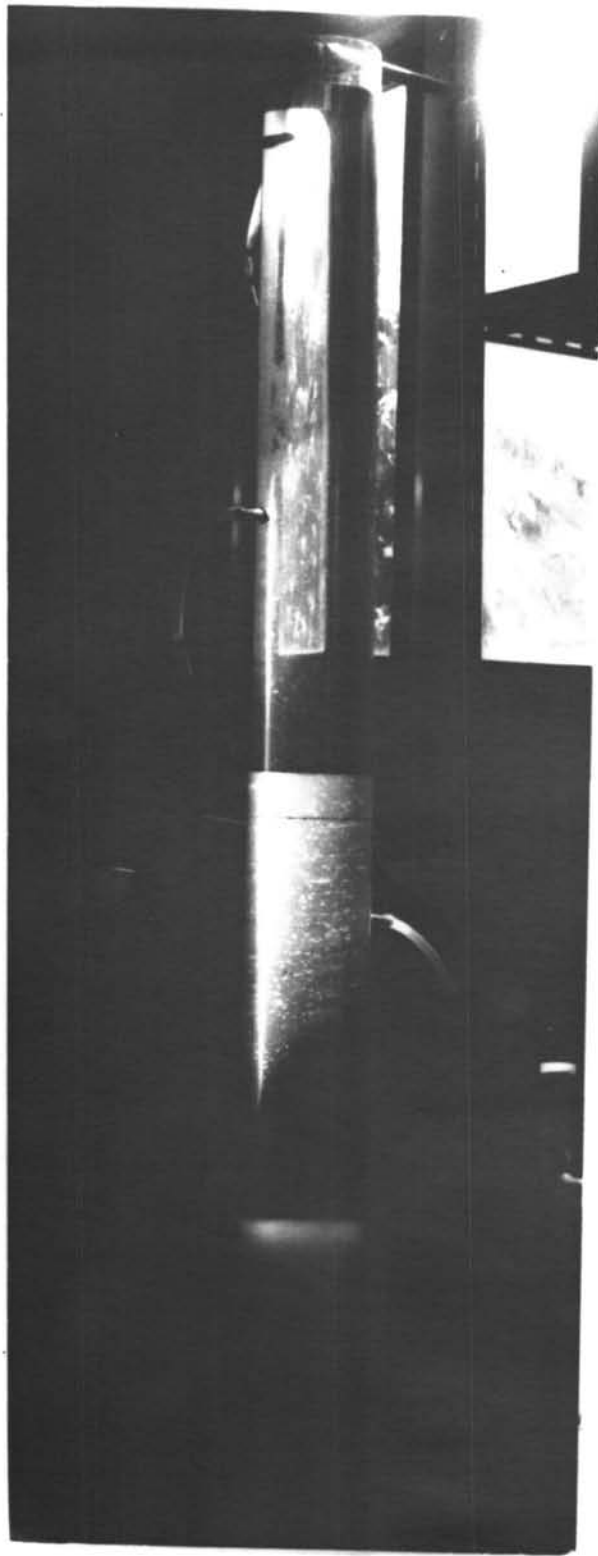
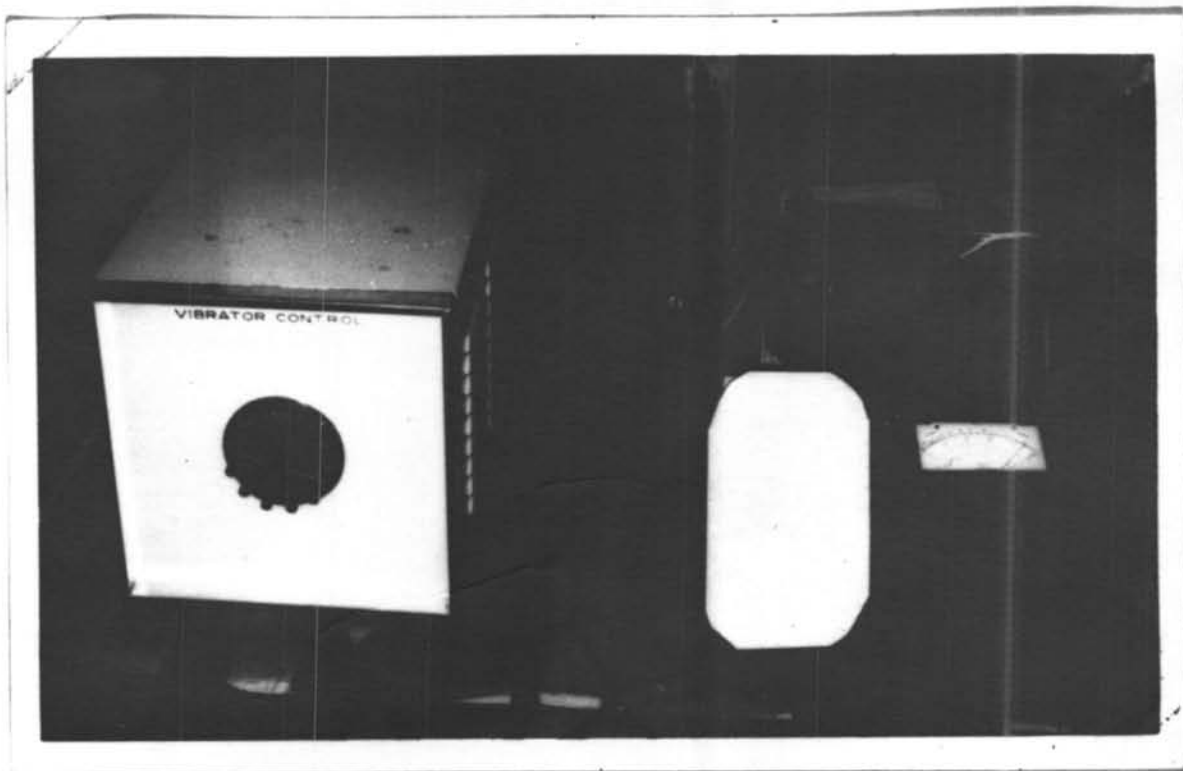


Fig.11- Perspex Settling Column Contained Treated Water



**Fig.12- A Complex Wave Generator, An Isolation
Transformer, A Wattmeter**