CHAPTER IV

DISCUSSION

The electrical energy is transformed to complex wave form and transfer to the iron bearing water in the electric field column. The frequency of the wave is controlled by the applied wattage. The wave which has a very high frequency will create electrophydraulic effect which can oxidize Fe^{+2} to Fe^{+3} by losing one of the outer shell electron and disperse the surrounding water. Then Fe^{+3} will hydrolize to form a colloidal particle of $Fe(OH)_3(s)$. The hydrolysis of Fe^{+2} to Fe^{+3} are as follow:-

$$2Fe^{+2} + \text{energy} \longrightarrow 2Fe^{+3} + 2e$$

$$2Fe^{+3} + 6OH^{-} \longrightarrow 2Fe(OH)_3$$

$$6H_2O + 6e \longrightarrow 3H_2 + 6OH^{-}$$

$$2Fe^{+2} + 6H_2O + 4e + \text{energy} \longrightarrow 2Fe(OH)_3 + 3H_2$$

Iron is the element belonging to the subgroup VIIA in the periodic table. In this group there are four elements, Fe, Ni, Co and Al. All of these elements can be hydrolized and precipitated in floc form but it is different in colour. The hydrous form of Al and Ni are white, Co is grey and Fe is Red-Brown.

The precipitate in the ground water and synthetic water after passing through the electric field column is red-brown in colour. It can be conclude that the iron is removed in the form of $Fe(OH)_3(s)$.

5.1 Flow Rate and Percentage of Iron Removal

From the experiment, the percentage of iron removal is affected by the flow rate. As shown in fig.27 and table VI, the percentage of iron removal at each energy use is decreased with increasing of flow rate. It is because at high flow rate the detention time in the electric field column is short, so less amount of energy was transferred to the water. The amount of dissolved iron oxidized by the electric field will be less than the amount of dissolved iron oxidized in a low flow rate. In table VI at an energy use of 40 watts and flow rate of 3 l/min or a detention time of 3.3 min the percentage of iron removal is 95% and when the flow rate is increased to 4 l/min or the detention time of 2.5 min the percentage of iron removal is dropped to 65%.

Table VI Detention Time and Flow Rate

Flow Rate l/min	Detention time,min.	%Fe Removal	Remark
3	3.33	95	influent alk. = 380 ppm. energy use = 40 watts.
4	2.5	65	
5	2.0	63	

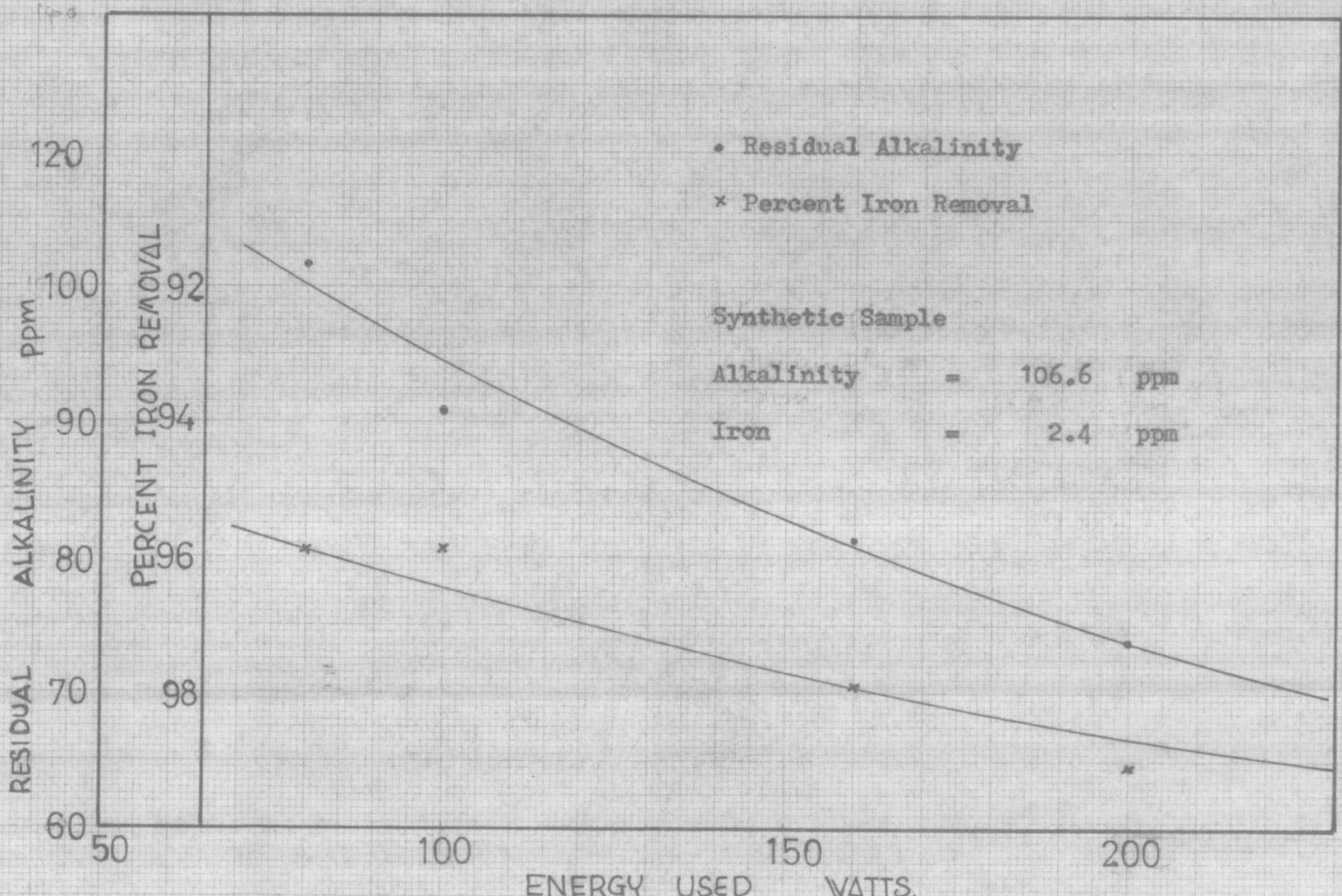

Fig. 28 Relation of Energy Used, Residual Alkalinity and Percent Iron Removal

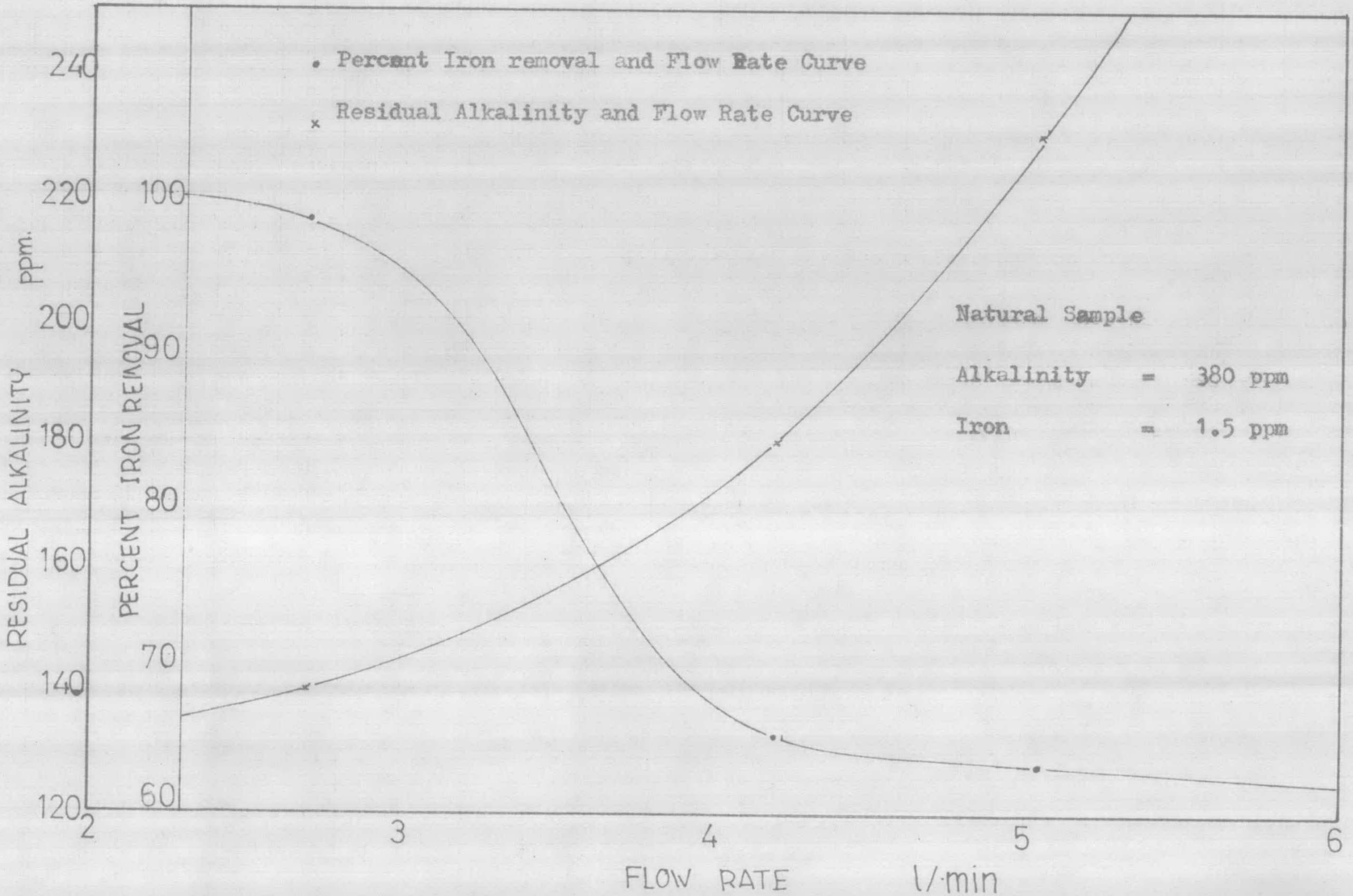

Fig. 27 Relation of Flow Rate, Residual Alkalinity and Percent Iron Removal

5.2 Energy Use and Percentage of Iron Removal

The percentage of iron removal is also varied with energy used. The amount of ferrous iron oxidized to ferric iron is increased with the increasing energy. It is because the increased transformed energy will increase the energy to split out the protective shell of water surrounding the dissolved iron (Fe^{+2}), and will lose one of the outer shell electron of Fe^{+2} to form Fe^{+3}. As shown in fig.28 and in the

Table VII. Power Supplied and Percentage of Iron Removal

Power Supplied watts	% Fe Removal	Flow Rate l/min	Remark
80	95	0.698	Syn. Sample
160	98	0.698	"
20	82	0.698	Nat. Sample
40	90	0.698	"

table VII at the same flow rate of 0.698 l/min and the energy use of 80 watts, the percentage of iron removal is 95%. When increased the energy use to 160 watts, the percentage of iron removal is increased to 98%.

5.3 Alkalinity and Percentage of Iron Removal

The iron is removed by forming complex with alkalinity in the water, as the following equations:-

$$Fe^{+3} + 3OH^{-} \longrightarrow Fe(OH)_3$$

The amount of alkalinity removal depends on the amount of iron removal which depends on the flow rate and the energy use.

The residual alkalinity increases with the flow rate and decreases with the percentage of iron removal. As shown in fig.27. The residual alkalinity is also depended on the energy use as shown in fig.28. The energy use increases with the percentage of iron removal as discussed in section 4.2, so more alkalinity is removed or less residual alkalinity is left.

Table VIII. Alkalinity and Percentage of Iron Removal

Alk.ppm	Residual alk.ppm	% Fe Removal	Flow Rate l/min	Alk./ppm Fe	Remark
380	145	95.00	3	164.9	Energy used= 60watts
380	172	66.5	4	208.6	
380	225	62.5	5	160.0	
380	190	72	3	175.9	Energy used= 40watts
380	220	64.0	4	166.6	
380	270	61.5	5	119.2	
		Average		165.86	

In table VIII at an energy use of 60 watts and the flow rate of 3 l/min the percentage of iron removal is 95% and the residual alkalinity is 145 ppm. When the flow rate is increased to 5 l/min the percentage of iron removal is decreased to 62.5% and the residual alkalinity is increased to 225 ppm. When the energy use is decreased to 40 watts, at the flow rate of 3 l/min the percentage of iron removal is decreased to 72% and the residual alkalinity increased to 190 ppm.

5.4 pH

The range of the influent ground water pH is 6.35 to 7.1 with average of 6.72 and the effluent ground water pH is 6.5 to 7.2 with average of 6.87. Table IX shows the fluctuation of influent ground water pH and effluent ground water pH. It shows that the effluent ground water pH is slightly changed from the influent ground water pH.

Table XI. Fluctuation of pH in the influent and the effluent of the ground water

Flow Rate 1/min	Inf. pH	eff. pH	Remark
1.50	6.35	6.5	Energy Use
2.31	6.35	6.55	= 20 watts
2.85	6.35	6.55	
3.18	6.35	6.45	
2.40	7.1	7.3	Energy Use
3.12	7.1	7.2	= 40 watts
4.80	7.1	7.1	
2.7	7.1	7.05	Energy Use
4.2	7.1	6.8	= 60 watts
5.04	7.1	7.2	
average	6.73	6.57	

5.5 Temperature

The influent temperature and effluent temperature of ground water are shown in table X. The temperature change was varied directly with power input and varied indirectly with flow. In fig.X at a flow rate of 3 l/min for the energy use of 40 watts the effluent temperature is 37.2°C and when increases the energy use to 60 watts the effluent temperature is raised to 38.4°C. It is because the heat is created in the electric field column by energy loss. The energy loss can be computed by the following equation:-

$$\text{energy loss} = I^2R$$

Where R = resistance of water

I = the current.

The energy loss will increase directly with the current which increase directly with the wattage. This energy loss will be transformed into heat energy and provide a high temperature in water. The conductivity or resistance of the water will affect the effluent water temperature. Low conductivity or high resistance will raise the effluent water temperature. As shown in table X at flow rate of 2 l/min the effluent temperature of the water which has 3.34 m℧ conductivity and 20 watts energy use, is 39.5°C which is higher than the effluent temperature of the water which has 3.96 m℧ conductivity and 40 watts energy use.

The fluctuation of temperature of the effluent is also based upon the detention time in the column. As shown in table.X the high detention time give a high effluent temperature, as at the fixed energy use of 20 watts, detention time of 5 min, the effluent temperature is 38°C. When the detention time is decreased to 2.5 min the effluent temperature is decreased to 35.5°C. It is because at high flow rate there will be more water to absorb a certain amount of heat.

Table X Relation of Flow Rate, Energy Use and Effluent Temperature

Flow Rate 1/min	Detention time,min	Temperature °C			Remark
		Energy Use = 20watts Cend.3.34	Energy Use =40 watts Cend.3.96	Energy Use =60 watts Cend.3.96	
2	5	39.5	37.2	38.4	
2.5	4	36.5	36.3	38.1	
3	3.33	33.5	35.5	37.8	
3.5	2.85	30.0	34.7	37.6	
4	2.85	-	33.8	37.3	
4.5	2.22	-	33.0	37.1	
5	2	-	32.2	36.8	

The heat developed in the process will remove some temporary hardness in the influent water. The reason is that the heat which is created by the energy lost in the electric field column will cause the temporary hardness to precipitate as shown by the following equation.

$$Ca^{+2} + 2HCO_3^- \rightleftharpoons CaCO_3 + H_2O + CO_2$$

In the table XI the temperaly hardness is removed up to 13.2%, when the effluent temperature is raised to 48°C. It is also shown that the temporary hardness at about 5 - 13 % can be removed when the efflunet temperature is raised above 32°C.

Table XI. Effluent Temperature and Percentage of Hardness removal

Eff. Temp. °C	Eff. Hardness ppm	% Hardness Removal	Remark
48	330	13.2	inf. hardness = 380 ppm
43	370	5.3	inf. temp. = 28°C.
40	350	7.9	
32	380	0.0	

5.6 Applications

In order to apply this method in removing the iron contents in the ground water. A most economical method must be determined. In fig.29 the relationship of flow rate, percentage of iron removal energy use, and cost of energy use are plotted. These curves can be used to find our the most economical flow rate and wattage for any percentage of iron removal.

For a ground water in which the iron must be removed for 82%, the most economical flow rate and wattage can be read from the fig.29 to be 2.7 l/min and 40 watts of energy use respectively with a cost of 0 185 ฿/cu.m.

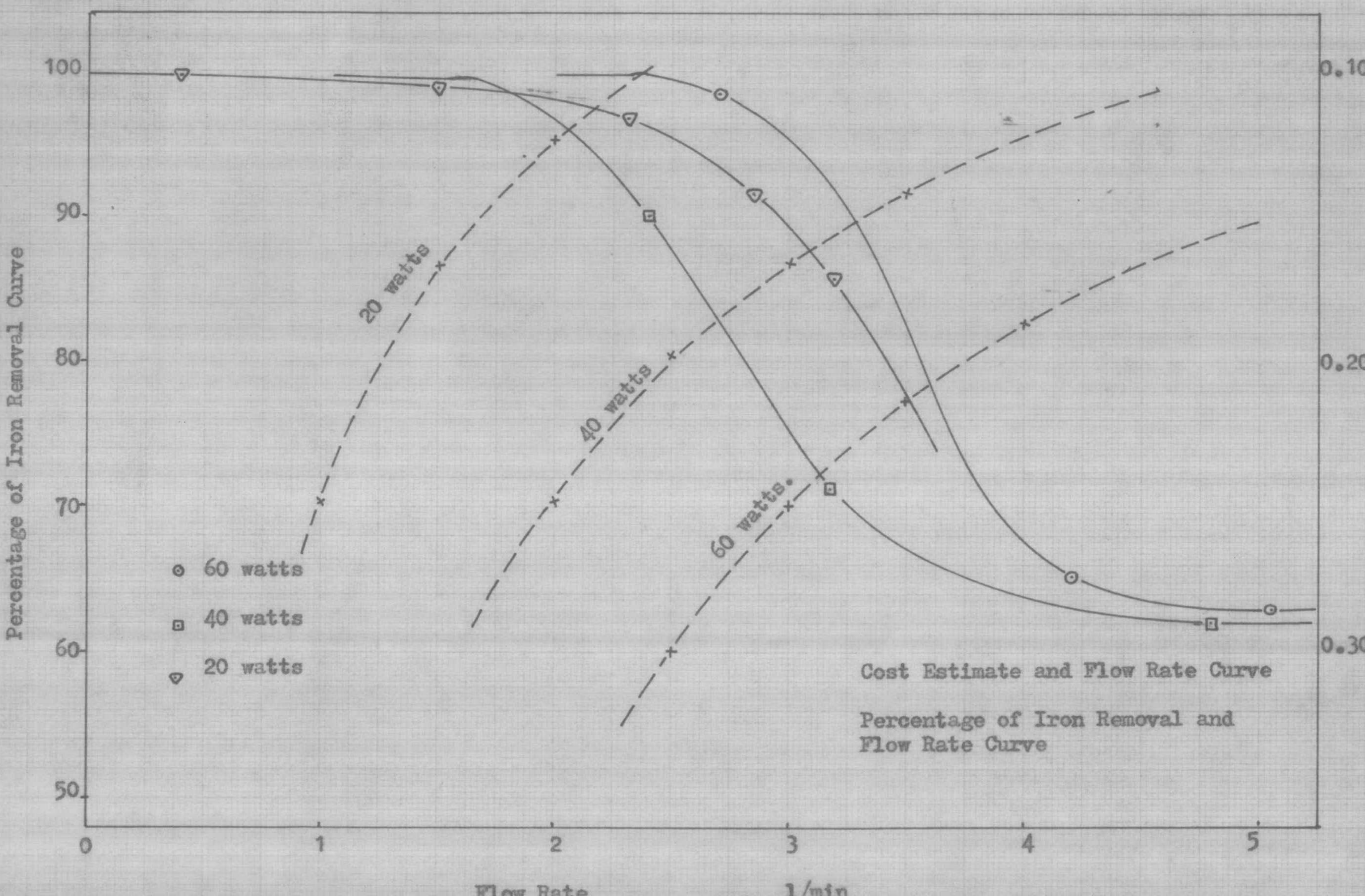

Fig. 29 Flow Rate and Percentage of Iron Removal and Estimated Cost Curve.