

A COMPARISON OF THE
EAST LANSING, MICH.
ZEOLITE WATER
TREATMENT PLANTS

MICHIGAN STATE COLLEGE
THESIS FOR DEGREE OF B.S.

NILS R. HAMMARSKJOLD

1941

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A COMPARISON OF THE
EAST LANSING, MICHIGAN
ZEOLITE WATER TREATMENT PLANTS

A Comparison of the
East Lansing, Michigan
Zeolite Water Treatment Plants

A Thesis Submitted to

The Faculty of
MICHIGAN STATE COLLEGE
of
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by

Nils Reinhold Hammarskjold

Candidate for the Degree of

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PREFACE

This comparison of the two water treatment plants was undertaken for two reasons. They were (1) a desire to aid, in some small way, the City of East Lansing in its efforts to supply a pure and soft water to the consumers more effeciently and economically than before, and (2) a means by which the author could, on his own, solve some of the problems encountered in the zeolite type of water softening plant.

If this thesis should add one grain of knowledge to the ever-mounting heap being built, it will not have failed in its purpose. Of necessity, the whole field of water-softening in East Lansing could not be covered in any great detail, due to the limited time available.

The author is greatly indebted to Professor Frank R. Theroux for the valuable aid and counsel which was freely given, and is also grateful to the officials of the City of East Lansing for their cooperation and permission to carry out the necessary tests in the water plants.

N. R. H.

East Lansing, Michigan
May, 1941

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A Comparison of the
East Lansing, Michigan
Zeolite Water Treatment Plants

Part I

General Considerations

1. Early Water Supplies. The first well of which we have any records seems to be a drilled well, 6 inches diameter and 362 feet deep. It was located between Grand River and Oakhill Avenues. Water was more than ample for the needs of that time, as in November, 1909, the well was pumped only an average of five hours a day.

The well was first put into operation on October 20, 1909 and it was noted that the drawdown was very little, 17 feet being measured once. No well log was kept at the time of drilling, and no exhaustibility tests were thought necessary. Knecht and McKenna, in their investigation*, wanted to make a 24 hour drawdown test, but were not granted permission to do so by the city officials. They were forced to conclude that the supply was inexhaustible because

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* Knecht, J. W., and McKenna, P. G., "An Investigation of the Water Supply of East Lansing, Michigan", pp. 1-8 unpublished B. S. Thesis, M. S. C., 1910.

of the little drawdown, and the high level of the water maintained in the well.

This 6 inch well was pumped by a gasoline driven double-acting reciprocating pump, with a 5 inch by 12 inch cylinder. On a capacity test run by Knecht and McKenna, the pump delivered 63 g.p.m., with a pump and motor efficiency of 41.4 percent. Cost of water delivered was 5.03 cents per 1,000 gallons, with electric rate for the motor at 0.5 cents per K.W.H. This well serviced 90 connections, of which 60 were metered.

In addition to the city-owned supply just described, we also find mention of the water system known only as "Chase's", which was connected to 25 residences. Only two connections were not metered. The well was 3 inch bored, and was 80 feet deep. The maximum rate it could be pumped was 60 g.p.m., but the electric motor and pump were capable of delivering only 40 g.p.m. The Chase system was worth about \$1,750. Water cost was 6 cents per 1,000 gallons. Mr. Chase, in an estimate, stated that the average rate of use was 6,000 - 7,000 per connection per month. An emergency connection existed between Chase's supply system and the city mains. No mention can be found of the final fate of Chase's system, but it must have been taken over by the city later on.

The next time reference is made to the city well, was in 1923 in an investigation by L. M. Z. Van Noppen.* The

* Van Noppen, L. M. Z., "An Analysis of East Lansing's Water Supply System, and Recommendations for Enlargement.", pp. 1-2, unpublished B. S. Thesis, M. S. C., 1923

drawdown was now at least 30 feet, as evidenced by the failure of a hand pump to work. The reciprocating pump was still on the job, driven by an electric motor. An auxiliary gas-engine was also ready at all times to stand by in case of power being shut off. The pump was in operation 24 hours a day, and delivered a maximum of 125 g.p.m. The elevated tank of 10,000 gallon capacity had to be filled every other day from the college supply. Things were in a critical state, and the city was not "getting by", as they had to depend on the college for help in supplying enough water.

Evidently something was done about ~~the~~ situation quickly, because in 1925, three wells were in existence. The original 6 inch well, which now delivered only 60 g.p.m. was being used as a standby only. Miller and Slack* mention a new well on the site of the old well. They state that it was 12 inch diameter, 430 feet deep, and operated by a 9 3/4 inch Downie deep well pump at a rate of 250 g.p.m. This is still standing, but not operated.

Another well was drilled at this same time (1925) on the site of the present East plant, on Orchard Street. It is a 12 inch well, 420 feet deep, and was operated by a 10 inch American Well Pump at 250 g.p.m.

2. Present Water Supplies.

The three wells mentioned

* Miller, C. H., and Slack, P. H., "East Lansing's Fire Protection", pp. 1 - 2, unpublished B. S. Thesis, M. S. C. 1925.

in the previous article (the 6 inch and 12 inch at Oakhill Street, and the 12 inch at Orchard Street) served the city until 1935 very adequately. When the new softening plant was put up at Chittenden Drive and Orchard Street, the American well pump which had been in service since 1925 was replaced by a Byron Jackson deep well turbine pump. This pump (now called Pump #1) is located inside the present East treatment plant.

The two wells at the Oakhill plant were discontinued. To replace them, another well was drilled in 1935 at the same time the treatment plant was constructed. This well draws from about the same water vein as does the Well #1. The rock samples encountered in the drilling are to be seen hanging just inside the East plant front door. From these, the character of the substrata may be studied for future plant extensions.

This well (called # 2 in the records) is located in the street circle at the intersection of Beech and Orchard Streets. The driving unit is a ⁶⁰ H.P. Induction motor operating at 1,765 r.p.m. Rate of delivery may be adjusted by means of a nut at the top of the impeller shaft. Delivery is by means of a 12 inch main to the East plant, underground. The well is a 12 inch diameter, and is 392 feet deep.

Before the West treatment plant, out on Saginaw Street near Grand River, was built, it was necessary to secure a well which would deliver the water necessary. Quite a bit of difficulty was encountered, and the only way the yield could

be increased was to dynamite the well. This was quite successful, but the well is still a little short of good on delivery.

The West well, put into service late in 1939, is pumped by a Layne well pump (deep well turbine), and is powered with a 50 H.P. Induction motor, operating at 1,770 r.p.m. The well is 410 feet deep, and 12 inches in diameter.

3. Growth of East Lansing. To be able to predict closely what the life of a water supply system should be, it is necessary to determine what the future water demands will be. Population growth trends must be studied closely, and then future approximations made, with that as a basis.

East Lansing is a hard city to do this with, because the population is dependent upon two variables: (1) the growth of the city itself, due to the influences from Lansing industries, and the proximity of the college, and (2) the growth of the college, with an increased number of students living "off campus" in fraternity houses, sororities, and rooming houses as a natural result.

The men and women housing directors for the college, (Mr. Ron Heath and Miss Mabel Petersen, respectively), were consulted for approximate figures on the number of men and women students living off-campus. The women have numbered from 211 in 1934 to a high of only 343 in 1939, as the college building program has kept pace with the increased enrollment of women. Men numbered about 500 in the

fraternity houses, while an additional 1,700 to 2,200 live in rooming houses. A recent estimate is 250 women, 500 men in fraternities, and 1,700 men in private homes, giving a total of 2,450.

Figure 2 shows the population trends. The "U. S. Census" figures are plotted. The dotted line above, called "U. S. Census and Assumed College Off-Campus Students" shows the total consuming population. This, of course, is only an estimate, and it should not be used too closely, even though it gives good results. The prediction of "Water Users" is quite conservative. The tendency always is to over-estimate when drawing such a line, and this has been corrected for over-zealous estimation. Future records will determine the accuracy of this prediction.

4. Past Water Demands. In order to predict with any degree of accuracy the future demands of East Lansing, it is first necessary to dig into all the old available records to find out what the past water demands have been. Such data was very scarce, and it was found necessary to depend upon three previous theses (listed in the footnotes for the previous pages) for data. The accuracy is limited, as the authors of these theses depended upon estimates for the larger part. Their estimates have weight, though, because they each were in close contact with the operators of the plant back in 1910, 1923 and 1925 respectively.

Computations follow for each period:

1910:

City Well

Pumped average of 19,000 gal./day = 570,000 gal./mon.

Chase's Well

Estimate of 6,500 gal./connection/mon.
for 25 connections. = 160,000 gal./mon.

Total =- 830,000 gal./mon.

1923:

Pumped 24 hours a day
@ 125 g.p.m. = 180,000 g.p.d. = 5,400,000 gal./mon.

Add 15 tank fillings @ 10,000 gal. = 150,000

Total = 5,550,000 gal./mon.

1925: (Based on Data gathered in 1923)

Pumped 240,000 g.p.d. =- 6,019,000 gal./mon.

Since the operation of the East plant, meter reading records have been kept, and the totals follow:

Table I

Year	Water Metered from Plant (Thousands of Gallons)		
	Total for Year	Percent of 1935	Monthly Average
1936	125,050	100	11,368
1936	161,920	128	13,493
1937	148,400	119	12,367
1938	179,190	143	14,993
1939	204,970	164	17,061
1940*	219,416	175	18,285

* both East and West Plants operating.

If we take these monthly averages and divide them by 30 times the estimated population, we obtain the consumption of water in gallons per capita[[]per day. We do this so that we may plot in Figure 1 the corresponding values of (G = gal./cap./day) and p = population in thousands, to find the equation of a curve for East Lansing.

$$\frac{1910}{(P = 0.85) \quad \frac{830,000}{30 \times 850} = 32.5 \text{ gal./cap./day}}$$

$$\frac{1923}{(P = 4.139) \quad \frac{5,550,000}{30 \times 4139} = 43.5 \text{ gal./cap./day}}$$

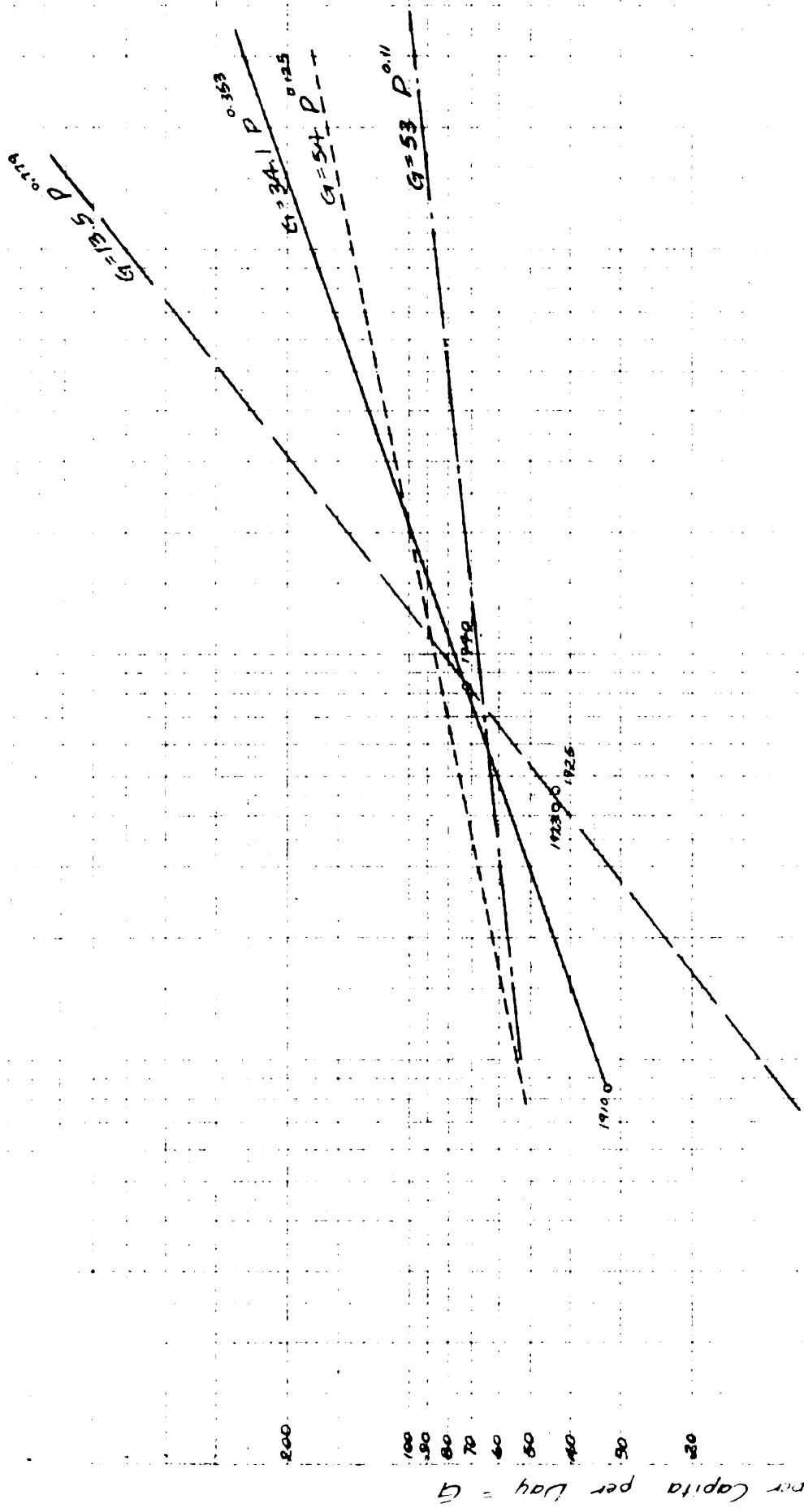
$$\frac{1925}{(P = 4.639) \quad \frac{6,019,000}{30 \times 4639} = 43.5 \text{ gal./cap./day}}$$

$$\frac{1940}{(P = 8.306) \quad \frac{18,285,000}{30 \times 8306} = 73.1 \text{ gal./cap./day}}$$

After plotting these values of G and P on logarithmic graph paper in Figure 1, we draw two curves which may apply. The long dashed curve $G = 13.5 P^{0.779}$ considers the 1923, 1925, and 1940 values as correct, but gives us a curve which is way too high. The heavy lined curve $G = 34.1 P^{0.353}$ considers the 1910 and 1940 values as indicative of the trend, and gives a more reasonable curve.

C. H. Copen, Jr., in his studies* of water consumption in American cities found that two curves seem to apply. They

* Copen, C.H., Jr., Jour. A.W.W.A., Vol. XXIX, No. 2, p. 201, February, 1937



- $G = 34.1 P^{0.353}$ - East Lansing Trend
- $G = 13.5 P^{0.779}$ - " (too high)
- * $G = 54 P^{0.125}$ - Well-metered Average System
- * $G = 53 P^{0.11}$ - Completely-metered Low-waste System

- Fig. 1 -
CURVES FOR ESTIMATING
PER CAPITA WATER CONSUMPTION

* C.H. Copen, Jr., Jour. A.W.W.A.,
 Vol. XXIX, No. 2, p. 201,
 February, 1937.

Population in Thousands = P

have been plotted on the same paper as the East Lansing values, and show good resemblances. The East Lansing curve $G = 34.1 P^{0.353}$ is a trifle high, and probably should be corrected so that a line parallel to $G = 54 P^{0.125}$ would pass through the 1940 plotted point. This would give a more conservative value, which is in keeping with the non-industrial character of the city. .

5. Future Water Demands. Figure 2 is then related to Figure 1 in the prediction of future water consumption, we are able to note. Average Monthly consumption values for 1910, 1923, 1925 and Table I are plotted in a "water demand curve", on Figure 2. Prediction based on $G = 34.1 P^{0.353}$ is made by converting the population curve values (given in Figure 2) by means of the curve in Figure 1 to gallons per capita per day values, (G), and then multiplying them out so as to be in terms of monthly averages.

Table II shows some interesting things concerning monthly flow records. It was made up from the records kept since 1935, in an attempt to determine which months are the peak months, and which are the more nearly average. July is by far the heaviest month of all, the maximum of 149.1 percent being recorded in 1939.

By means of this Table II, it is possible, by estimating from Figure 2 the millions of gallons average monthly consumption for a definite year in the future, to predict what the consumption for each month of that year will be.

-Fig. 2-

East Lansing, Michigan

PREDICTION OF
FUTURE WATER CONSUMPTION

May, 1941

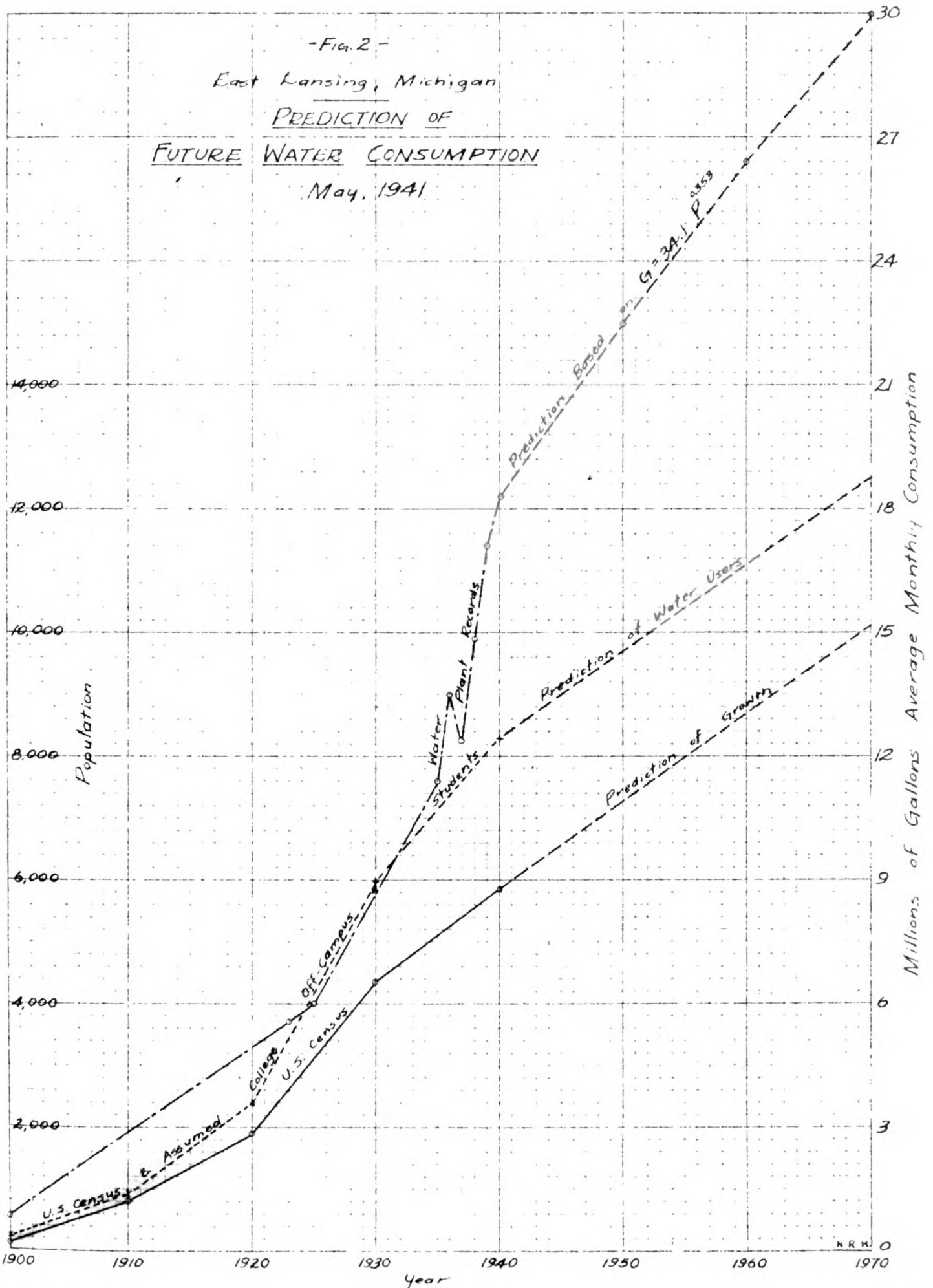


Table II
Consumption of Water as Shown By
Monthly Flow Records
1935 - 1940

Month	Percent of Monthly Average			Month	Percent of Monthly Average		
	Aver.	Max.	Min.		Aver.	Max.	Min.
Jan.	89.6	96.6	78.8	July*	132.4	149.1	112.4
Feb.	88.2	106.6	76.4	August*	117.0	126.3	96.0
Mar.	91.4	110.0	80.6	Sept.	104.2	122.0	88.7
April	87.8	102.8	79.0	Oct.	103.8	117.7	83.9
May	100.7	117.1	86.3	Nov.	99.2	116.2	82.1
June	106.0	125.7	87.9	Dec.	95.6	113.0	78.3

* Indicates water by-passed in summers of 1938-39, due to high sprinkling loads.

For instance, suppose we want to know what the consumption in 1950 will be. Looking on Figure 2, we find that the average monthly consumption will be 22,500,000 gallons. Then we may estimate that in January, we will pump 89.6 percent, or 20,200,000 gallons, in February, 88.2 percent, or 19,820,000 gallons, and so on. It gives us some sort of a yardstick by which we may gauge our future needs. The highest maximum ever encountered was 144.1 percent, and this could be 33,750,000 gallons, which could possibly occur during the year, especially in a summer with heavy lawn sprinkling.

Table III, which follows, is really what we have been striving for: a prediction of future water needs in East

Lansing. In brief, this is how it was made up:

- (1) Population for year desired is obtained from the "Prediction of water users" curve of Figure 2.
- (2) This "P" is looked up on the curve $G = 34.1 P^{0.353}$ and a value of "G" obtained from Figure 1.
- (3) This G times the population equals the total daily demand.
- (4) The daily demand is multiplied by 30 to get the average monthly demand.
- (5) This monthly demand is converted to maximum possible demand by taking 150% for the maximum.

It is for this monthly maximum that we must be prepared to handle, and for which we shall check our plant capacities

Table III

Estimated Future Water Consumption

Item	1940	1950	1960	1970
Estimated Population	8,300	9,700	11,000	12,500
$G = 34.1 P^{0.353}$ gal./cap/ day	73.1	77	80	83
Tot. Daily Consump. (Thous. of Gallons)	609	750	880	1,000
Av. Monthly Consump. (Thous. of Gallons)	18,285	22,500	26,400	30,000
Max. Monthly Consump. (Thous. of Gallons)*	25,000	33,750	39,600	45,000

* On the basis that the maximum = 150% of the monthly average.

later in this thesis.

6. Adequacy of Design. The East water plant has a maximum softening capacity of 1,000,000 g.p.d. using both wells, with one throttled down to avoid over-running of the zeolite sand. The West plant has a softening capacity of 1,400,000 g.p.d., but the present well can supply only enough to deliver 600,000 g.p.d. of softened water.

Therefore the present softening capacity is equal to 1,600,000 g.p.d., or 48,000,000 g.p. month. This is enough to take care of the average needs, but a protracted dry spell will cause the plants to deliver not nearly anywhere the needed quantity.

In 1940 summer months, the softening facilities were severely taxed to supply the water needs. In 1941, there will be even greater demands. To keep up with the demands, the city should drill another well to utilize the West plant to its full capacity. If this were done, the softening rate could jump 50 percent, to a value of 2,400,000 g.p.d. or 77,000,000 g.p. month.

This should be fairly adequate up until 1950 to take care of monthly demands, and most of the dry-spell runs on the supply which could occur in the early forties. Difficulty would be encountered, however, in the late forties, as a sufficient reserve could not be maintained, due to heavy consumption.

Part II

Pumping Efficiency Tests

7. Introduction. These tests are quite important to the economical operation of a plant. The main purpose of the tests is to determine with what efficiency the pumps are converting electrical energy purchased to useful work in pumping up water for the softening tanks to process.

If the efficiency of a pump is very much lower than the rating guaranteed, then quite a bit of power is being wasted. In the pressure type of zeolite plant, power cost is a considerable item, and should be kept as low as possible. It is toward better efficiencies that we are looking, and we will investigate what conditions exist in the present pumping arrangements.

8. Notes on Electric Meters. This is a brief summary of the use of the necessary formulae in making efficiency tests on pumps.

K = Disc Constant of the Meter

■ Watt Hours per Revolution

$$\text{Kilowatts} = \frac{(\text{Rev. / sec}) \times 3600 \text{ sec./hour}}{(1,000 \text{ watts/KW})}$$

$$= 3.6 \text{ K } \frac{R}{t}$$

where R = Revolution

t = time in seconds

K.W. = 1.341 H.P.

$$\begin{aligned}\text{Horsepower} &= (3.6) (1.341) K \frac{R}{f} \\ &= 4.826 K \frac{R}{f}\end{aligned}$$

M = the product of the current transformer ratio and the potential transformer ratio. This is sometimes required in the formula as $KW = 3.6 KM \frac{R}{f}$, but this is usually included in the disc constant. Before using a K for any meter, it is well to check on this fact of using M or not. Here at East Lansing we do not use M separately.

9. East Plant - Pump #1 Tests. Several tests were made on the pump, to determine as closely as possible the average efficiency, for different conditions of flow.

As is the case in well #2 also, there is no means provided for measurement of the distance down to the water surface in the well column. From previous tests run on this well when there was an altitude tube and gauge, readings of 85 to 90 feet were encountered. We shall use 90 feet in these tests, as the pump had been in operation long enough to stabilize the drawdown reasonably well.

Electric meter-disc revolutions were counted, to determine the KW of current used, and then the actual Horsepower used to raise the water, as compared with the theoretical. Efficiency is equal to the theoretical H. P. divided by the actual H. P.

Gage readings noted under computation of head are those

taken from the gage at the base of the pump.

Test results follow:

(a) May 14, 1941 Test (all soften):

Electric Meter - 110 disc revolution in 778 seconds.

$$\frac{R}{f} = \frac{110}{778}$$

Flow when all the tanks were softening was
760,000 g.p.d. This gives a pumping

$$Q = \frac{760,000}{1440} = 528 \text{ g.p.m.}$$

Head Computations:

$$\text{Well} - 55 \frac{7}{8} / \text{sq. in.} \times 2.31 \text{ ft.} = 127 \text{ ft.}$$

Depth to water	90
	217 ft.

Theor. H. P. Needed

$$= \frac{Qwh}{33,000} = \frac{528 \times 8.34 \times 217}{33,000} = 29.0 \text{ H.P.}$$

$$\begin{aligned} \text{Actual H.P.} &= 4.826 \text{ K } \frac{R}{f} = 4.826 \times 80 \times \frac{110}{778} \\ &= 54.6 \text{ H.P.} \end{aligned}$$

$$\text{Efficiency} = \frac{29.0}{54.6} = 53.0 \%$$

(b) May 15, 1941 Test (#3 Wash last half):

Electric Meter - 70 revolutions in 537 seconds

$$\frac{R}{f} = \frac{70}{537}$$

Flow when all tanks softening (after 15 min. of
operation to stabilize drawdown) was 875,000 g.p.d.
This gives a pumping $Q = \frac{875,000}{1440} = 607 \text{ g.p.m.}$

Head Computations:

$$\text{Well} - 53\#/\text{sq. in.} \times 2.31 \text{ ft.} = 122.5 \text{ ft.}$$

$$\text{Depth to Water} \quad \quad \quad 90$$

$$\text{Dynamic Head} \quad \quad \quad \underline{212.5 \text{ ft.}}$$

Theor. H. P. Needed

$$= \frac{60\cancel{7} \times 8.34 \times 212.5}{33,000} = 32.6 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{70}{537} = 50.3 \text{ H.P.}$$

$$\text{Efficiency} = \frac{32.6}{50.3} = 64.9\%$$

This is rather high, and is probably due to the little time of operation before making the test. Probably the depth to water allowance was too great in this case.

(c) May 16, 1941 Test (#3 tank ^hrising):

Electric Meter - 70 disc revolutions in 556 seconds

$$\frac{R}{L} = \frac{70}{556}$$

Flow when all tanks were softening was 760,000 gp.d.

$$\text{This gives a pumping } Q = \frac{760,000}{1440} = 528 \text{ g.p.m.}$$

Head Computations:

$$\text{Well} - 54\#/\text{sq. in.} \times 2.31 \text{ ft.} = 124.9 \text{ ft.}$$

$$\text{Depth to Water} \quad \quad \quad 90$$

$$\text{Dynamic Head} \quad \quad \quad \underline{214.9 \text{ ft.}}$$

$$\text{Theor. H.P.} = \frac{528 \times 8.34 \times 214.9}{33,000} = 28.7 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{70}{556} = 48.6 \text{ H.P.}$$

$$\text{Efficiency} = \frac{28.7}{48.6} = 59.0\%$$

(d) May 18, 1941 Test (all soften):

Electric Meter - 80 disc revolutions in 570 seconds

$$\frac{R}{T} = \frac{80}{570}$$

Flow when all the tanks were softening was 750,000 g.p.d.

$$\text{This gives a pumping } Q = \frac{750,000}{1440} = 520 \text{ g.p.m.}$$

Head Computations :

$$\text{Well} - 55\frac{1}{2}/\text{sq. in} \times 2.31 \text{ ft.} = 127 \text{ ft.}$$

$$\begin{array}{r} \text{Depth to Water} \\ \hline 90 \\ \text{Dynamic Head} \quad \quad \quad 217 \text{ ft.} \end{array}$$

Theor. H.P. Needed

$$= \frac{520 \times 8.34 \times 2.7}{33,000} = 28.5 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{80}{570} = 54.1 \text{ H.P.}$$

$$\text{Effeciency} = \frac{28.5}{54.1} = 53.6 \%$$

Summarizing these effeciencies as follows:

<u>Flow in g.p.m.</u>	<u>Effeciency</u>
520	52.6%
528	53.0%
528	59.0%
607	64.9%

We can see that there is alittle trend towards greater effeciencies in the greater flows. The only way to prove this would be to inset a drop tube with an altitude gage and connection for a tire pump so that the exact depth down to water may bemeasured. On the basis of these four tests, we may say that the average effeciency lies at about 54 percent,

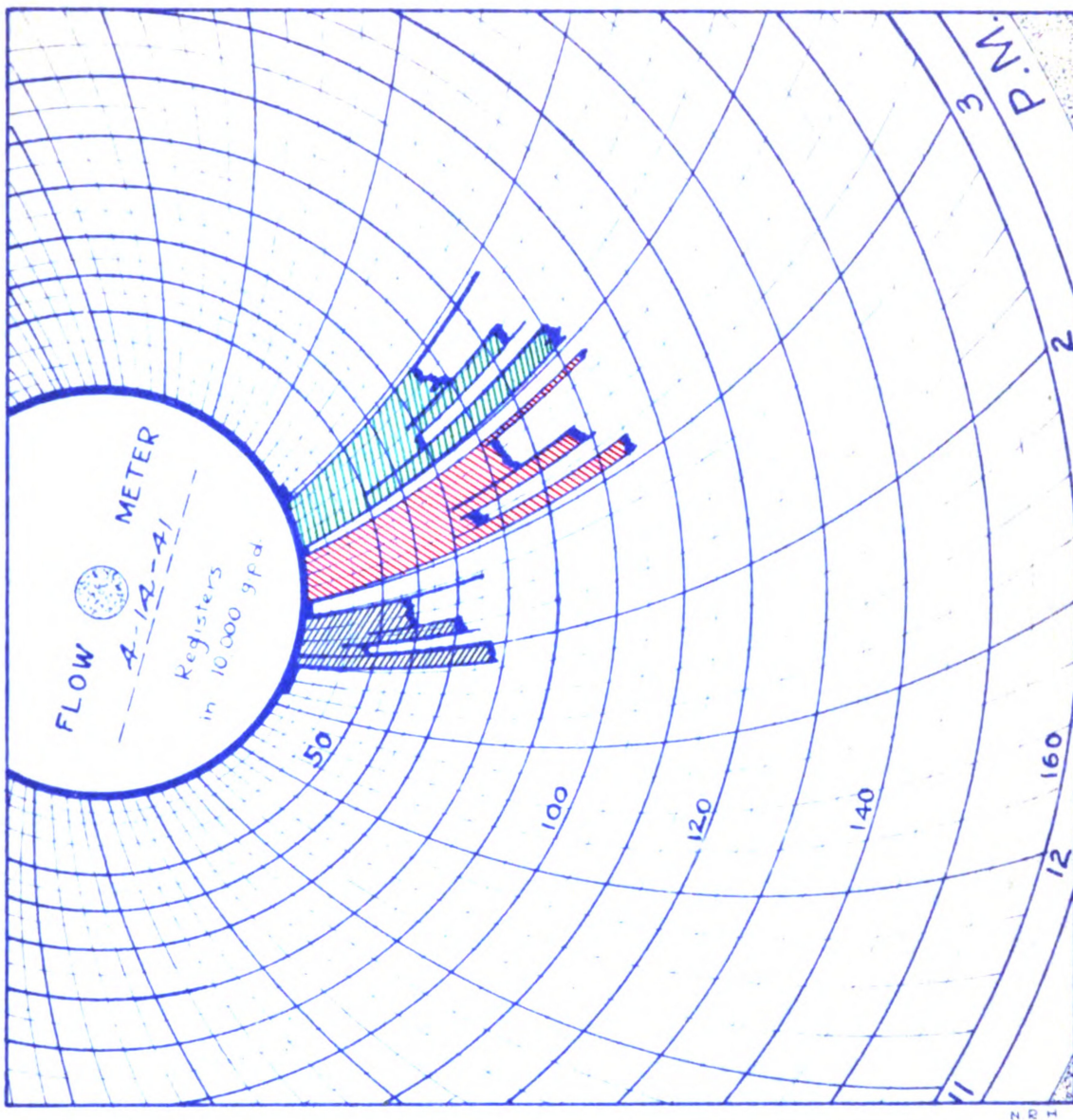
As this is a constant setting pump, the only way to change the setting is to pull the whole well, which is quite a lengthy and tiresome job. To make several different settings, to determine the maximum pumping efficiency would take several weeks, to get accurate results. The cost of pulling the well might offset any power savings which could result.

To compare the change which slight adjustments of the height of the impeller vanes make on the efficiency of the pump, note the results of the tests on Pump #2, which follow this discussion.

If ever another power head were installed on this well, it would be wise to make provision to obtain a motor which is made so that impeller adjustments are possible.

10. East Plant #2 Tests. It would be well to state briefly how these tests were made. Pump # 2 is on the well north of the plant, at Beech and Orchard Streets circle. By changing the setting of the bolt on the motor end of the impeller shaft, it is possible to change the clearance between the impeller vanes and the impeller bowls. By lowering the vanes completely down so that they rest on the bowls, we can obtain a starting point for the counting of the notches, as we pull the impeller vanes higher up.

The smaller the clearance between the vanes and the bowls (smaller corresponding number of notches up from the bottom) the greater the flow from the well. Nine notches



-FIG. 3-

PORTION OF EAST PLANT FLOW CHART
showing effects of changing the impeller setting.

-NOTCHES

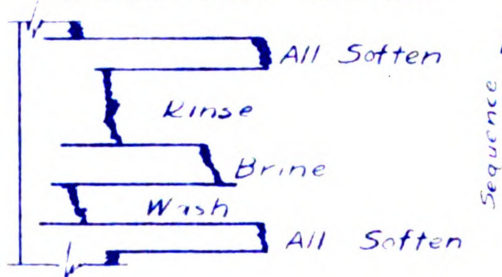
UP-

11

9

16

-SOFTENING CYCLE-



up will cause the pump to deliver more water than eleven or sixteen, as we have tested.

There is an efficiency consideration to be dealt with however, A pump setting of nine notches may deliver more water than eleven, but may do so less cheaply or less efficiently than does it under a smaller flow. It is to determine roughly the relative pumping efficiencies that we have tested the various settings. From these efficiency values we may be able to judge approximately what pump setting is best for use for long periods of time.

The electric meter disc revolutions were counted, as this is the most accurate means we have of determining the power consumed by the motor to pump the water. Each revolution is 80 watt-hours of current.

The depth to water could not be measured exactly, as there is no inside drop tube provided to test the altitude in the well column. Readings of previous tests have been used, and average 75 feet. The gage readings noted are those which were read in the plant at the point of entering the plant. The sum of these two readings, converted into feet, give the dynamic pumping head for the measured flow.

Test results are figured below:

Note: All these tests were made on April 14, 1941

(a) Impeller Vane @ 16 notches up from the bowl:

Electric Meter - 10 disc revolutions in 64 seconds

$$\frac{R}{T} = \frac{10}{64}$$

From April 14, 1941 chart, flow when all tanks softening was 775,000 g.p.d. This gives a pumping

$$Q = \frac{775,000}{14440} = 538 \text{ g.p.m.}$$

Head Computations:

$$\text{Well} - 48\text{#/sq. in.} \times 2.31 \text{ ft.} = 111 \text{ ft.}$$

$$\text{Depth to Water} \quad \quad \quad 75$$

$$\text{Dynamic Head} \quad \quad \quad \underline{186 \text{ ft.}}$$

$$\text{Theor. H.P. Needed} = \frac{538 \times 8.34 \times 186}{33,000}$$

$$= 25.2 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{10}{64} = 60.4 \text{ H.P.}$$

$$\text{Efficiency} = \frac{25.2}{60.4} = 41.8\%$$

(b) Impeller Vane @ Nine notches up from bowl:

Electric Meter - 10 disc revolutions in 48 seconds

From the April 14, 1941 chart, we can read that the all soften pumping rate was 1,050,000 g.p.d.

$$\text{Then the pumping } Q = \frac{1,050,000}{1440} = 729 \text{ g.p.m.}$$

Head Computations:

$$\text{Well} - 53\text{#/sq. in.} \times 2.31 \text{ ft.} = 122 \text{ ft.}$$

$$\text{Depth to Water} \quad \quad \quad 75$$

$$\text{Dynamic Head} \quad \quad \quad \underline{197 \text{ ft}}$$

$$\text{Theor. H.P. Needed} = \frac{729 \times 8.34 \times 197}{33,000} = 36.3 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{10}{48} = 80.4 \text{ H.P.}$$

$$\text{Effeciency} = \frac{36.3}{80.4} = 45.1\%$$

(c) Impeller Vane @ 11 notches up from the bowl:

Electric Meter - 10 disc revolutions in 53 seconds

$$\frac{R}{f} = \frac{10}{53}$$

From April 14, 1941 chart, we can see that the all softening pumping rate was 1,020,000 g.p.d.

$$\text{Then pumping } Q = \frac{1,020,000}{1440} = 708 \text{ g.p.m.}$$

Head Computations:

$$\text{Well} - 54\text{#/sq. in.} \times 2.31 \text{ ft.} = 125 \text{ ft.}$$

$$\begin{array}{rcl} \text{Depth to Water} & & 75 \\ \text{Dynamic Head} & & \hline & & 200 \text{ ft.} \end{array}$$

$$\text{Theor. H.P. Needed} = \frac{708 \times 8.34 \times 200}{33,000} = 35.8 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 80 \times \frac{10}{53} = 72.8 \text{ H.P.}$$

$$\text{Effeciency} = \frac{35.8}{72.8} = 49.2\%$$

We may tabulate the data obtained as follows:

<u>#Notches</u>	<u>Flow in g.p.m.</u>	<u>Effeciency</u>
9	729	45.1%
11	708	49.2%
16	538	41.8%

Inspection of this shows that the highest effeciency and almost the highest flow occurs with the setting at 11 notches.

The effeciency curves flattens out near 49.2 percent, so it is more economical to pump only 708 g.p.m. with an effeciency of 49.2 percent than it is to pump 729 g.p.m. with only 45.1 percent.



The value of effeciency tests may be readily perceived here.

11. West Plant - Pump Tests. The only new item encountered in conducting the effeciency tests on this well is that of measuring the height of lift of water being pumped. Figure 4 shows briefly the main items of consideration.

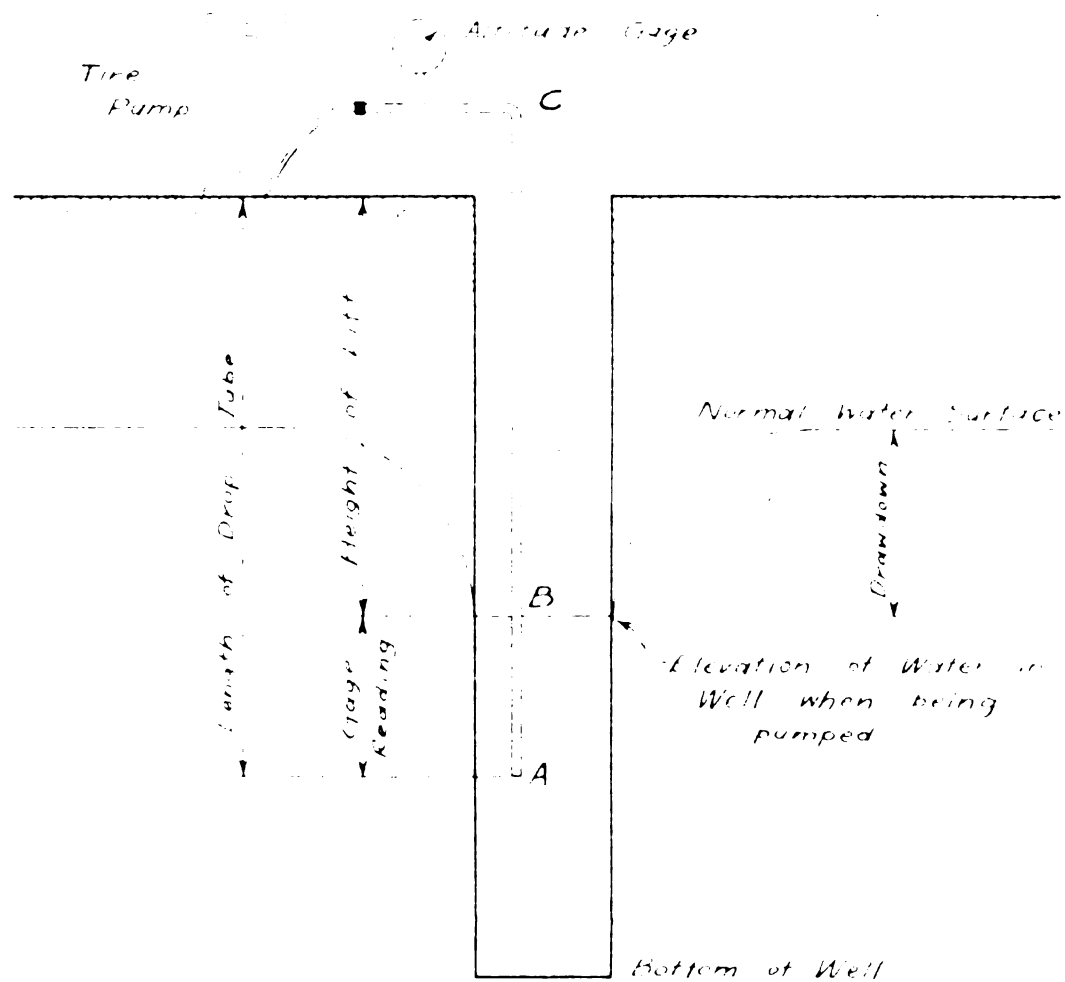
A tire pump is attached to the upper end of the drop tube and pumped ~~till~~ a constant reading is obtained on the altitude gage. This gage reading (in feet) is the height (AB) of the column of water in the well when being pumped and the bottom of the drop tube (A). If this gage reading is subtracted from the known length of the drop tube (AC), the height of the ligt in the well has been computed. (BC).

$$BC = AC - AB$$

With this depth down to the water known, the effeciency may be computed more exactly than was possible with wells # 1 and # 2 at the East Plant.

This depth may also be used when making well capacity tests for exhaustion. The Normal ground water surface is uncovered when the pump has been shut off for quite a long period. Then the pump is started up, and at certain regular time intervals, the depth down to the water is measured. From a set of these readings it is possible to determine how fast the water elevation in the well drops when being pumped.

Details of the pump tests ran are tabulated below.



- FIG 4 -

METHOD OF FINDING HEIGHT OF LIFT
IN A WELL

(a) November, 1940

Water Meter Readings

	Tank #1	#2	#3	#4	Plant
Stop	5,592,200	806,500	7,042,000	15,186,500	110,926,000
Start	5,590,000	804,800	7,039,600	15,186,000	110,920,000
Diff.	2,200	1,700	2,400	500	6,000
Stop	4:52:37	4:51:09	4:51:14	4:53:07	4:54:04
Start	4:38:20	4:36:11	4:37:12	4:43:20	4:41:37
Diff.	14:17	14:58	14:02	9:47	12:27
G.P.M.	154	113	171	51	481
				Sum Tanks #1-4	489 gpm
				Average	485

Gage Readings	Start	Stop	Average
Pump(#/sq.in.)	52.8	53	52.9
Altitude (ft.)	80	75	77.5

	Trial #1	Trial #2
Electric Meter		
Stop	4:44:56	4:49:41
Start	4:43:21	4:48:05
t for 20 rev.	1:35	1:36
Average t - 20 rev. in 1 ^m	35.5 ^s	= 95.5 sec.

(K = 53 1/3 for Meter at the West Plant)

$$\frac{R}{f} = \frac{20}{95.5}$$

Head Computaions:

Length of Air tube	210 ft.
Less Altitude Reading	77½ ft.
Depth to Water	132.50 ft.
Altitude gage to pressure gage (13½m.)	1.08
Pressure gage 52.9#/sq.in x 2.31 ft.	122.00
Loss in 200' of 8" pipe @ 5'/1000	1.00
Dynamic Head	256.58 ft.

$$\text{Theor. H.P.} = \frac{485 \times 8.34 \times 256.58}{33,000} = 31.4 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 53 \frac{1}{3} \times \frac{20}{53.9} = 53.9 \text{ H.P.}$$

$$\text{Effeciency} = \frac{31.4}{53.9} = 58.4\%$$

(b) May 15, 1941

Water Meter Readings

	Tank #1	#2	#3	#4	Plant
Stop	1,431,200	6,803,500	5,712,300	23,533,200	174,131,000
Start	1,429,000	6,810,500	5,710,400	23,532,500	174,124,000
Diff.	2,2000	2,000	1,9000	700	7,000
Stop	4:59:28	4:59:52	5:01:58	5:03:40	5:04:42
Start	4:44:47	4:45:22	4:46:26	4:47:25	4:48:57
Diff.	14:41	14:30	15:32	16:15	15:45
	14:68	14:50	15:53	16.25	15.75
G.P.M.	150	138	122	43	444

Sum Tanks #1-4 453

Average 447

Gage Readings	Start	Stop	Average
Pump (#/sq.in.)	86	85	85.5
Altitude (ft.)	78	80	79.0

Electric Meter -

Stop 4:56:40

Start 4:50:55

t for 70 rev. 5:45 = 345 sec.

$$\frac{R}{f} = \frac{70}{345}$$



Head Computations:

Length of Air tube	210 ft.	
Less Altitude Reading	<u>79</u>	
Depth to Water		131.00 ft.
Altitude Gage to Pressure Gage (13 $\frac{1}{2}$ in.)		1.08
Pressure Gage 53 $\frac{1}{2}$ #/sq.in. x 2.31 ft.		123.00
Loss in 200' of 8" pipe @ 5'/1000'		<u>1.00</u>
Dynamic Head		256.08 ft.

$$\text{Theor. H.P.} = \frac{447 \times 8.34 \times 256.08}{33,000} = 28.9 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 53\frac{1}{3} \times \frac{70}{345} = 52.1 \text{ H.P.}$$

$$\text{Effeciency} = \frac{28.9}{52.1} = 55.4\%$$

(c) May 18, 1941

Water Meter Readings

	Tank #1	#2	#3	#4	Plant
Stop	1,776,300	7,140,900	6,037,600	23,735,000	175,210,000
Start	1,774,300	7,139,000	6,035,900	23,734,100	175,234,000
Diff.	2,000	1,900	1,700	900	6,000
Stop	4:25:25	4:25:50	4:26:10	4:26:50	4:29:06
Start	4:10:37	4:11:20	4:12:25	4:13:32	4:14:48
Diff.	14:48	14:30	13:45	13:18	14:18
G.P.M.	135	131	124	67	421 gpm.

Sum Tanks #1-4 457 "

Average 439 "

Gage Readings	Start	Stop	Average
Pump(#/sq.in.)	85	85	85
Altitude	81	83	82

Electric Meter -	Trial #1	Trial #2
Stop	4:23:17	4:31:15
Start	4:18:23	4:28:00
60 rev. in	4:54	40 rev. 3:15 in

$$\frac{R}{f} = \frac{60}{294} \qquad \frac{R}{f} = \frac{40}{195}$$

$$\text{Average} \quad \frac{R}{f} = \frac{10}{49}$$

Head Computations:

Length of Air tube	210 ft.
Altitude Reading	<u>82</u>
Depth to Water	128.00 ft.
Altitude gage to Pressure gage (13 $\frac{1}{2}$ in.)	1.08
Pressure Gage 53 $\frac{1}{2}$ /sq.in. x 2.31 ft.	122.50
Loss in 200' of 8" pipe @ 4'/1000'	<u>0.80</u>
Dynamic Head	251.38 ft.

$$\text{Theor. Required H.P.} = \frac{439 \times 8.34 \times 251.38}{33,000} = 27.8 \text{ H.P.}$$

$$\text{Actual H.P.} = 4.826 \times 53\frac{1}{2} \times \frac{10}{49} = 52.5 \text{ H.P.}$$

$$\text{Effeciency} = \frac{27.8}{52.5} = 53.0\%$$

12. Summary of Tests. Results of the test are repeated here:

Flow in G. P. M.	Effeciency
439	53.0%
447	55.4%
485	58.4%

Here again we notice a tendency to exist that as the flow increases, so does the effeciency. To find the highest effeciency would require more readings on both sides of the peak effeciency to establish a definite peak.

This pump is operating quite well, as average deep well pumping effeciencies of 50-55 percent are in the common class. When new, this pump operated at 62 percent, and the present dropping off may be due to need for adjustments.

Part III

Power Consumption

13. Electric Rate Schedules. In years to come, when these results are referred to for cost data, it will help to have the method of computing power costs available. It will also aid in following the computations listed in this thesis.

Rate No. 5 - Regular Primary Power Rate

Used at the East Plant, Pumps #1 and #2

Second Metering

Any power user in the City of Lansing or East Lansing, Michigan, or in the vicinity thereof, with a demand load of 50 kilowatts or over, using city owned transformers.

Rate Charges

Primary Metering

Demand Charge

Transformer installation owned by the Board of Water and Light.

\$2.75 per kilowatt per month for the first 100 kilowatts of maximum demand.

\$1.75 per kilowatt per month for the next 4900 kilowatts of maximum demand.

Energy Charge

Plus the Following:

1.05 cents per kilowatt hour for the first 100,000 kilowatts hours used per month

0.75 cents per kilowatt hour for the next 900,000 kilowatt hours used per month.

Secondary Metering

Discount:

The above primary rate metered, plus $8\frac{1}{2}\%$
A discount of 5% will be allowed on above rates if bills are paid on or before last discount day shown on bill.

Monthly Maximum Demand

The maximum demand will be obtained by the use of a demand meter or demand indicator attached to the meter, which registers the maximum demand for a period of 15 minutes; or at the option of the Board, the maximum demand will be considered

as 75% of the connected load in kilowatts.

Rate No. 4

(Used at the West Plant)

Optional Commercial Lighting and Miscellaneous Power Service.

Rate Charge

6 $\frac{1}{4}$ cents per kilowatt hour for the first 25 hours used per month per meter.

5 cents per kilowatt hour for the next 25 kilowatt hour used per month per meter.

3 $\frac{3}{4}$ cents per kilowatt hour for the next 150 kilowatt hours used per month per meter.

2 $\frac{1}{2}$ cents per kilowatt hour for all over 500 kilowatt hours used per month per meter.

Discount

A discount of 20% of the above rate will be allowed on all bills that are paid on or before the last discount day shown on bill.

14. East Plant - Pump #1

(Based on the 30-day month April 21, through May 20, 1941)

Water Metered:

May 20 622,900,000 gal.

April 21 613,000,000 "
9,900,000 gal.

Power Consumed:

May 20 104,138 KWH

April 21 88,845
15,293 KWH

Cost of Power (Rate No. 5

60 KW Demand @ \$2.75 \$165.00

15,293 KWH @ \$.0105 \$160.58

Plus 8 $\frac{1}{2}$ % \$325.58
27.67

Gross \$353.25

Less 5% Discount 17.66

Net \$335.59

$$\text{Pumping cost per 1,000 gal.} = \frac{335.59}{9,900} = \$0.0339$$

KWH per million gal. =

$$\frac{15,293}{9,900} = 1,543 \text{ KWH}$$

The demand indicator on the electric meter shows that pump #1 has a ^{42.5} KW demand. This is less than the 60 KW demand that the plant is being billed for. The lighting board may bill one of two ways, whichever is the largest.

One way is to bill maximum demand. This would be 42.5 KW in the case of this well alone. The other is to consider it as 75 percent of the connected load in KW. It is for the whole plant as follows:

Well #1	50 H.P. Motor
Well #2	60 H.P. Motor
Lights, etc.	<u>1 H.P. Motor</u>
	111 H.P.

$$\begin{aligned} \text{In KW, this} &= 111 \text{ H.P.} \times .746 \text{ KW/H.P.} \\ &= 82.806 \text{ KW} \\ 75\% \times 82.806 &= 62.1 \text{ KW.} \end{aligned}$$

The meter is 150 amp., 480 volts - so it will roughly take care of 72.0 KW. Then 75% of 72 KW. is equal to 54 KW. Which checks approxiamtely.

When the whole plant is being billed on a 60 KW. demand, the city is getting a saving of $2 \times \$2.75 = \5.50 a month. But if Well #1 were being operated continuously and alone, power costs could be reduced by \$17.00 a month. This is out of the question, however, as both wells must be in operation

at the same time. The advantages balance the ~~dis~~advantages over the year, and make the costs still quite reasonable.

15. East Plant - Pump #2

(A) Impeller vane 16 notches up from the bottom:

Based on the 7-day period April 7 through April 14, 1941.)

Water Metered:

April 14	610,780,000 gal.
April 7	<u>608,550,000</u>
	2,230,000 gal.

To get this on a 30 day basis, to compare with Pump #1, we will correct it to 30 days.

$$2,230,000 \times \frac{30}{7} = 9,557,000 \text{ gal.}$$

Power Consumed:

April 14	85,420 KWH
April 7	<u>81,680</u>
	3,740 KWH

Correcting this for 30 days to figure the power costs on a monthly basis, we obtain $3,740 \times \frac{30}{7} = 16,030 \text{ KWH}$

Cost of Power (Rate No. 5)

60 KW Demand @ \$2.75	\$165.00
16,030 KWH @ \$.0105	<u>\$168.32</u>
	\$333.32
Plus 8½%	<u>28.33</u>
Gross	\$361.55
Less 5% Discount	<u>18.08</u>
Net	\$343.47

Pumping cost per 1,000 gal. $\frac{343.47}{9,557} = 0.0359$

KWH per million gal. $= \frac{16,030}{9557} = 1,679 \text{ KWH}$

(b) Impeller vane @ 11 notches up:

Based on the $4\frac{1}{2}$ day period from 4:30 p.m.

April 14 to 8:00 a.m. April 19, 1941

Water Metered:

April 19	612,020,000 gal.
April 14	<u>610,840,000</u>
	1,180,000 gal.

To correct this for a 30-day period, we will multiply

$\frac{30}{4\frac{1}{2}} \times 1,180,000 \text{ gal.} = 7,867,000 \text{ gal.}$

Power Consumed:

April 19	87,340 KWH
April 14	<u>85,513</u>
	1,827 KWH

$1,827 \times \frac{30}{4\frac{1}{2}} = 12,200 \text{ KWH}$

Cost of Power (Rate No. 5)

60 KW Demand @ \$2.75	\$165.00
12,200 KWH @ \$.0105	<u>128.10</u>
	\$ 293 .10
Plus $8\frac{1}{2}\%$	<u>24 .91</u>
	\$ 318.01
Less 5% Discount	<u>15.90</u>
Net	\$302.11

$$\text{Pumping cost per 1,000 gal.} = \frac{\$302.11}{7,867} = \$0.0384$$

$$\text{KWH per million gallons} = \frac{12,200}{7,867} = 1,550 \text{ KWH}$$

The maximum demand read on this pump was 68.5 KWH, so the City of East Lansing is saving 8.5 KW. x 12.75 = \$23.38 a month on this pump operation. This makes up for the low demand on the Well #1.

16. West Plant.

Based on the 30-day month - April 21 through May 20, 1941.

Watered Metered:

May 20	175,832,000 gal.
April 21	<u>166,007,000</u>
	9,825,000 gal.

Power Consumed:

May 20	88,001 KWH	17,092 KWH
April 21	<u>70,909</u>	<u>500</u> Stepped Charges
	17,092 KWH	16,592 KWH @ 2½¢

Cost of Power (Rate No. 4)

25 KWH @ 6¼¢	\$1.5625
25 KWH @ 5¢	1.2500
450 KWH @ 3 3/4 ¢	16.8750
16,542 KWH @ 2½¢	<u>414.8000</u>
	434.4875
Less 20%	<u>86.8975</u>
Net Power Cost	347.5900

$$\text{Pumping cost per 1,000 gal.} = \frac{\$347.59}{9,825} = \$.0354$$

$$\text{KWH per million gal.} = \frac{17,092}{9,825} = 1,739 \text{ KWH}$$

If another well was installed at the West Plant, pumping costs based on the same power rate as at the East Plant would be figured on Rate No. 5, with secondary metering. Based on the same 60 KW power demand, power cost would be:

60 KWH demand @ 2.75	=	\$165.00
17,092 KWH @ \$.0105		<u>179.46</u>
Plus 8½%		<u>\$344.46</u>
		<u>29.28</u>
Gross		<u>\$373.74</u>
Less 5% Discount		<u>18.69</u>
Net		\$355.05

We can see that the present power rate is cheapest under conditions of usage maintained now. It would not be advantageous to change over unless another pump demanded it, due to increased power consumption. An additional pump would mean more power used, and the advantage of the cheaper power rate would be felt, as enough current could be used to affect some saving.

The pumping cost per 1,000 gal. based on a 60 KW demand would be $\frac{355.05}{9,825} = \$.0362$, a 2.3% increase

over the present cost.

17. Summary of the Tests.

The results and costs of power

per 1,000 gallons delivered are very interesting. The differences between the various pumps shows up very markedly when tabulated:

Pump	Av. Soft. Rate g.p.m.	Water* Metered thous. gal.	Pump. Costs per 1,000 gal.	KWH per million gallon	Remarks
East #1	473	9,900	\$.0339	1,543	-- -- --
East #2 (16)	455	9,557	.0359	1,679	16 notches
East #2 (11)	618	7,867	.0384	1,550	11 notches
West	-	9,825	.0354	1,739	-- -- --

* On a 30-day basis (computed)

The West well takes more K.W.H. of power to pump a million gallons of water than does either of the wells as the East plant, regardless of setting. Due however to a different way of billing the power, it does it cheaper than well #2 at either setting. Of all three pumps, East #1 does the best job of pumping for the best amount. The records on this well are quite accurate, as they cover a full 30-day month,

In all fairness to East well #2, it should be said that records over a longer period of time might show that the tests here are on the high side. The only factor we have to judge the relative merits really is the K.W.H. per million gallons, which shows that this well #2 pump does quite a good job.

The 16 notch setting on pump #2 does not cost as much to pump a 1,000 gallons, as does the 11 notch setting, but it takes more K.W.H. to do the same job. This seeming contradiction is due to the method of demand billing, and also to the fact that the pumping costs for 11 notches was not figured for as many million gallons as was the 16. In

this case, the demand billing shoots the cost up.

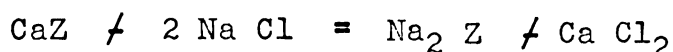
Reference is made to the efficiency of 16 notches as against 11 notches again. 16 was 41.8%, while 11 was 49.2%. Therefore, it should be seen that, if the tests were made on the basis of, cost of the same number of million gallons pumped in a month, the 11 notch well would eventually show up as the cheapest and more efficient setting of the two settings tested.

Part IV

Salt Consumption

18. Introduction. As has been previously stated, salt costs rank on about the same level as do power costs. We shall try to analyse the reasons for this, and arrive at some definite cost figures.

When the exchange capacity of the Zeolite has been used up, the zeolites are in the form of calcium and magnesium zeolites. They are changed back to sodium zeolites by the addition of a sodium chloride brine through the zeolite bed. The reactions are shown by these equations:



The excess salt, and the Calcium and magnesium chlorides are then washed out of the zeolite bed before it is put into softening service again.

The brine is stored in a large underground tank, which is kept quite full of salt, covered with water. The solution is saturated, and contains, at the temperature common, 19.6 lbs. of salt per cubic foot of brine. The brine is drawn into the softener by a hydraulic injector, which gives the brine a dilution of about 5 to 1.

There have been many schemes devised for the saving of salt which otherwise would be wasted. A patent, U. S. 1,510,569 has been granted on the following process:

Separate out the less-contaminated portions which were wasted at the end of the bring period. The first one-quarter or one-half of the brine used does the greatest job of regenerating, as chemical reactions proceed faster then. If the last three-quarters or one-half of the brine is reused, an economy will result.*

This plan was tried at the East plant, and was one of the main design features. Tests and investigations proved however that the cost of recovering the brine did not merit the brine saved.

Another system for reduction of the salt consumption does it without mechanical brine recovery systems**. The method in brief is this: (1) Reduce the rated softening capacity of the zeolite sand per cubic foot; and (2) compensate for this by using more cubic feet in the bed, to get the same volume of the softened water.

An example will illustrate the method. With a good gel zeolite, the exchange capacity is about 12,000 gallons per cubic foot, with the salt used for regeneration about 0.45 lbs.

* Hoover, C.P., "Present Status of Munciple Water Softening", Jour. A. W. W. A., Vol. XXV, No. 2, p. 186, February, 1933.

** Behoman, A.S., "Progress in Munciple Zeolite Water Softening", Jour. A. W. W. A., Vol. XXVI, No. 5, p. 625, May, 1934.

per Kg, of hardness. Reducing the rated capacity down to 9,000 to 10,000 gal./cu. ft., we find that the salt consumption is down to 0.30 lbs./kg. hardness. For a salt saving of 33 1/3 percent, the decrease in the exchange capacity per cubic foot is equal to 20 to 25 percent.

Results of the tests run at both plants follow:

19. East Plant - Well #18

Drawdown in small brine tank = 18 3/4 inches per
regeneration.

5 ft. x 1.5 ft. x $\frac{18 \frac{3}{4}"}{12"} \times 19.6 \frac{\text{#}}{\text{cu. ft.}} = 230 \text{ lbs.}$
salt
per regeneration of tanks 1-5

12" of big tank = 888 lbs. salt per regeneration tank
6

(For the 30-day month April 20, through May 19, 1941)

Water Metered:

May 19	622,810,000 gal.
April 20	<u>612,460,000</u>
	10,350,000 gal.

Salt Consumption:

460 Regenerations (tank 1-5) @ 230 lbs. salt
= 105,800 lbs.

17	"	(" 6)	
		@ 888 lbs.	<u>15,096 lbs.</u>
			120,896 lbs.

Salt used per 1,000 gallons delivered

= $\frac{120,896}{10,350}$ = 11.68 lbs.

Cost of salt per 1,000 gal. = $\frac{11.68 \text{ lbs.} @ \$6.70 \text{ ton}}{2,000 \text{ lbs.}}$

= \$.0391

(Average Softening Rate 473 g.p.m.)

20. East Plant - Well #2

(a) Impeller vane @ 16 notches up:

(For the 8 day period April 6 through 13, 1941)

Water Metered:

April 13 610,630,000 gal.

April 6 607,940,000

2,690,000 gal.

Salt Consumption:

118 Regenerations (tank 1-5)

@ 230 lbs. salt = 37,140 lbs.

5 Regenerations (tank 6)

@ 888 lbs. salt = 44,440
41,580 lbs.

Salt used per 1,000 gallons delivered -

41,580
2,690 = 15.46 lbs.

Cost of salt per 1,000 gal. = $\frac{15.46 \text{ lbs.} @ \$6.70 \text{ ton}}{2,000 \text{ lbs.}}$

= \$.0518*

(Average Softening Rate = 455 g.p.m.)

*Records for March 1941, indicate that this is rather high.

92,520 lbs. = 10.01 lbs.
9,230 thous. gal.

$\frac{10.01 \times 6.70}{2,000} = $.0336$, which is a more reasonable

value. The short test period magnifies any errors which may have occurred.

(b) Impeller vane @ 11 notches up:

(For the 4 day period April 15 through 18, 1941)

Water Metered:

April 18 612,010,000 gal.

April 13 610,990,000

1,020,000 gal.

Salt Consumption:

32* Regeneration (tanks 1-5)

@ 230 lbs. salt = 7,360 lbs.

2 Regenerations (tank 6)

@ 883 lbs. salt = 1,776

9,136 lbs.

Salt used per gallons delivered = $\frac{9,136}{1,020} = 8.95 \text{ lbs.}$

Cost of salt per 1,000 gal = $\frac{8.95 \text{ lbs.} \times 16.70 \text{ ton}}{2,000 \text{ lbs.}}$

= 0.0300

(Average Softening Rate = 618 g.p.m.)

* 3 Regenerations skipped April 15, 1941. Salt is figured in though, just as if the regenerations had occurred.

21. West Plant.

Drawdown in brine tank is 25 inches per regeneration.

2 ft. x 9 ft. x $\frac{25"}{12"} \times 19.6\#/\text{cu.lb.}$ salt per regeneration
of tanks #1-3

(For the 30-day month April through May, 1941)

Water Metered:

May 19 175,744,000 gal.

April 20 165,604,000

10,140,000 gal.

Salt Consumption:

128 Regenerations @ 735 lbs. salt = 94,080 lbs.

Salt used per 1,000 gallons delivered = $\frac{94,080}{10,140} = 9.28$ lbs.

Cost of salt per 1,000 gal.

@ \$6.70 / ton = $\frac{9.28 \text{ lbs.} @ \$6.70 \text{ ton}}{2,000 \text{ lbs.}}$

= \$.0312

23. Summary of Tests.

Reviewing the results we have obtained, they may briefly be tabulated thus:

Well	Av. Soft. Rate	lbs. Salt	Cost of Salt	Remarks
East #1	473	11.68	\$.0391	* - -
East #2 (16)	455	10.01	.0336*	16 notches
East #2 (11)	618	8.95	.0300	11 notches
West	-	9.28	.0312	- - -

* Based March, 1941 Records, not on the test run April 6 through 13, 1941.

The values for the first two tests (East #1, and East #2, 16 notches) are quite common to the average operating conditions at the plant. They are very near in value to what has been experienced before. It is for about these flows that the softening cycle of 50 minutes has been set for.

It would be dangerous to maintain the flow of 618 g.p.m.

on the East #2 set at only 9 or 11 notches, as the tanks stand a very good chance of being overrun. The saving in salt which would result from continuous operation at this rate would not pay for the damage which could result in the running over of the zeolite. Repeated extra brinings would have to be made to assure the good condition of the tanks.

It is not considered good practice to run the tanks "to the limit" of their softening capacity because it takes excessive amounts of salt to "recharge" them again. The plant operator watched the tanks closely in the East plant while working the East #2 11 notches test, because of the danger of over-running many times. The test was run only long enough to get semi-complete data, enough for a good calculation of salt and power costs.

The West plant, on the other hand, is more economical on salt than the East plant. This is because this plant is not on a time cycle, but instead, on a definite "gallongage" cycle. This is based on the fact that each tank, as soon as the meter registers the total amount the tank is set to soften, automatically regenerates itself. This results in an economy, because the regenerations can come independently of time. The zeolite is regenerated only when it needs it.

A time cycle is not so flexible as a rate cycle (gallongage), because if the rate fluctuates, the same time cycle continues regardless of whether twice as much water is passing through, or only half the average computed amount.

23. Notes on a Brine Well. Near the ocean, enterprising waterworks engineers have used sea water (after purification for bacteria) to regenerate their zeolite beds. Here in Michigan, we are quite a distance from the ocean, measured along the earth's surface. But if we go straight down, we are not very far from brine deposits, comparatively speaking.

Investigation into the depth of salt brines in the vicinity of East Lansing brought forth some interesting information. Advice and information were obtained from R. A. Smith, and O. F. Poindexter of the Geological Survey Division, Michigan Department of Conservation as to the availability of salt in this region.

The facts brought out were:

(1) The Marshall Formation, 760 to 815 feet down in Ingham County, bears salt water. Typical results of well tests have been, for Marshall Brines:

<u>Location</u>	Calcium Chloride	Magnesium Chloride	Sodium Chloride
Gratiot Co.	2.21	0.87	7.97
Midland Co.	12.50	2.77	10.50
Midland Co.	9.71	3.45	10.98

(2) The next formation that bears salt water also has a high percentage of Magnesium and calcium, which renders it unfit for softener regeneration, because the reactions could never go to completion. This formation is at 2,200 feet. A typical analysis shows:

Calcium Carbonate	103,860 p.p.m.
Sodium Chloride	220,240 "
Magnesium Carbonate	80,560 "

(3) The Salina formation, 3,600 feet down is quite high in sodium, and low in Magnesium and Calcium, the undesirable elements. Of all the brines "near the surface" this would be the most promising and the most useful. It is almost saturated with Sodium chloride (sat. @ 270,000 p.p.m.). An analysis shows the following constituents:

Sodium Chloride	247,400 p.p.m.
Magnesium Chloride	2,015 "
Calcium Sulfate	5,660 "

(4) Cost of such a well into the Salina (8" or 12") would be about \$15,000 to \$20,000. The pumping head on the brine would be very low, but the difficulty of getting the brine to both plants would have to overcome in some manner.

\$20,000 would buy a large amount of salt, but might be an economical method of getting a brine if large quantities were used yearly. A city ten times the size of East Lansing, using zeolite for softening, might put down a salt well to a great advantage. The scheme does not seem practical for East Lansing.



Part V

Chemical Consumption

24. Uses of Chemicals. At the present time, only two chemicals are in use: caustic soda is used at each plant for the purpose of reducing the corrosiveness of the treated water. The cost may be apportioned equally for each plant, as it really is an item to be charged to maintenance of its delivery mains, necessary to reduce complaints of "red water". The permanganate is used solely for the regeneration of the iron - removed tanks at the plants.

25. Caustic Soda Used. The rate of application of the caustic soda should be proportional to the rate of delivery of water. It has been approximately proportional, and for the purposes of this paper, will be considered as such.

Costs (based on the 30-day month from April 20 through May 14, 1941) are as follows:

Water Metered (previously computed under Power Consumption):

East Plant	10,350,000 gal.
West Plant	<u>10,140,000</u>
Total	20,490,000 gal.

Caustic Soda:

East Plant	13 applications @ 175#each	= 2,275 lbs.
West Plant	30 " @ 60# each	= 1,800 lbs.



Total 4,075 lbs.

Caustic Soda used per 1,000 gallons delivered

$$= \frac{4075}{20,490} = 0.199 \text{ lbs.}$$

Cost of Caustic Soda per 1,000 gal. = .199 lbs. @ \$0.08

= \$.0159 at each plant.

26. Potassium Permanganate Used.

(a) East Plant - The iron removal tank (#7) is regenerated once every month at least, or at every 1,080,000 gal. passing through it. About 3/20 of the total plant flow passes through this tank. Computing on this basis, we find that each regeneration takes 18 lbs. @ \$0.20 a lb. for a monthly cost of \$3.60. Getting this into a cost basis for 1,000 gallons, we find (for the same month as used for caustic soda) that $\frac{\$3.60}{10,350} = \0.000348 (East Plant).

(b) West Plant - Figuring on the same basis as we did for the East Plant, we find that about 3/20 of the total flow passes through the iron-removal tank (#4). Design capacity is 1,300,000 gal. It is regenerated once a month. It takes 23# more than does the #7 tank.

23 lbs. x \$0.20 per lb. = \$4.60 per month

$$\frac{\$4.60}{10,140} = \$0.000453 \text{ per 1,000 gal.}$$

27. Summary of Costs. We find that the cost of caustic soda is quite a lot more than the iron, but very much less

than either power or salt. The results may be tabulated as follows:

Costs per 1,000 gal.		
Plant	Caustic Soda	Potass. Permanganate
East	\$.0159	\$.000348
West	.0159	.000453

There are no significant differences between the two plants, as far as the chemicals are concerned.

Part VI

Cost of Treatment

28. Fixed Charges. The East plant, completely equipped cost \$21,000. The West plant completely equipped, cost \$64,000, including total construction costs and engineering costs.

The fixed charges will be based on a 4% interest on the money invested, and a $3\frac{1}{2}\%$ general average depreciation value common to waterworks. The fixed charges are then computed on the basis of 1940 pumping values.

$$(a) \text{ East Plant } \frac{\$21,000 \times 7\frac{1}{2}\%}{86,051 \text{ thous. gal.}} = \$0.0185$$

$$(b) \text{ West Plant } \frac{\$44,800 \times 7\frac{1}{2}\%}{133,365 \text{ thous. gal.}} = \$0.0251$$

29. Labor Charges. If a man worked full time at supervising the plants, (half of his time at each plant), he could ~~ably~~ do all the maintenance work necessary. For the purpose of this thesis, we will hire just one man, at \$1,800 per year for maintenance.

Then the cost to each plant per 1,000 gallons would be

$$\frac{\frac{1}{2} \times \$1800}{219,416 \text{ thous. gal.}} = \$0.00410$$

30. Miscellaneous. To take care of items, as small pump repairs, pipe repairs, charts, tools, and other costs, let us assume \$.00100 per 1,000 gallons per plant to be on the safe side.

31. Conclusions. Because the softening plants operate on units, we must consider total costs in each case. Naming the various combinations is by referring to the pump and well number.

It is surprising how little difference there is in the cost of treating water between East #1 and the West Plant. Wide differences are apparent in the cost of fixed charges, power and salt, but the differences are compensating: They make up for each other.

East #2 well delivers the water more cheaply than does East Well #1 and West. The 9-notch setting though might prove too expensive, if the zeolite were over-run too many times, due to the little excess softening capacity remaining, when the tank has softened its quota.

Further detailed cost studies should be made, under longer periods of time for well #2, East, to get more significant data. The power costs and the salt costs are the ones which should be watched more closely. There is a great deal more work which may be done. It is hoped that this thesis will point out what should be done, and that the City Officials will be able to benefit by this study.

Table IV

Summary of Treatment Costs

(Costs per 1,000 gal. Based on 1940 Yearly Flow)

(From Each Plant)

Item	East #1	East #2 16 note.	East #2 11 note.	West
Fixed Charges (7½%)	\$.01850	\$.01850	\$.01850	\$.02510
Power	.03390	.03590	.03840	.03540
Salt	.03910	.03360*	.03000	.03120
Chemicals-				
Soda Caustic	.01590	.01590	.01590	.01590
Potass. Perm.	.00035	.00035	.00035	.00045
Labor Charges	.00410	.00410	.00410	.00410
Miscellaneous	.00100	.00100	.00100	.00100
Total	\$.11285	\$.10935	\$.10825	\$.11315
% of West Plant	99.5%	96.4%	95.5%	100%

* Based on March 1941 Records, not on the test run April 6 through 13, 1941.

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