EFFICIENCY STUDIES AT THE HIGHLAND PARK PUMPING STATION

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
William N. Rieger
1941

ACKNOWLEDGEMENTS

I wish to express my appreciation to Mr. Lyle Whitsitt, Highland Park City Engineer, Mr. George Golden, Water Works Superintendent, Mr. Irving Dahljelm, Chemist in charge of the Filter Plant, and the Pump House Operators for their cooperation in carrying out the work connected with this thesis. I also wish to thank Prof. Frank R. Theroux, of the Michigan State College Civil Engineering Department, for valuable guidance and assistance.

TABLE OF CONTENTS

Efficiency Studies
at the
Highland Park Pumping Station

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

William N. Rieger

Candidate for the Degree of

Bachelor of Science

June 1941

THESIS

It is the aim of every public water department to deliver water to the consumer at the lowest possible cost. To accomplish this aim, it is essential that the most efficient equipment obtainable be used.

Today, more and more public water departments realize that, under most conditions, motor-driven centrifugal pumps are able to furnish the necessary water more economically than any other type of pumping equipment. Some of the larger centrifugal pumps of modern design are able to attain efficiencies as high as ninety per cent.

It seems to be a rather general practice for water departments using the motor-driven centrifugals to forget all about the efficiency of the pumps, once they are installed or to assume that they are going to maintain their efficiency indefinitely.

When new pumps are installed, acceptance tests are made to determine whether or not the pumps will accomplish what the specifications called for. In many cases these are the only tests ever made on the pumps, or <u>ever intended to be made.</u> To illustrate this point, let me give an example of what was done at the Highland Park Pumping Station. Before giving the example, however, I want to say that I am not making a criticism of the Highland Park Water Department specifically, but am making the criticism of water departments in general, because similar things have been done at other plants.

The pumps at the above mentioned station are set on a concrete base about six inches above the floor level. The intakes for the pumps extend vertically downward below the center of the pumps. When first installed the concrete bases were not filled in solid, but there was an open space allowing access to the discharge line where it extends thro the floor. When the original tests were made, a hole was tapped in the flange which is situated just above the floor level in the intake line, but below the top level of the concrete base, to which a mercury U-tube gage could be connected for the tests. After the tests were completed the base was filled in with concrete, completely covering this flange, thus indicating that no tests in the future were contemplated.

When you buy a new automobile, the dealer tells you that you will get 25 miles per gallon of gasoline, so you try it out and find out for yourself that you do get 25 miles per gallon. Yet, do you assume from this test that after the automobile is two or more years old, it will still go 25 miles on a gallon of gasoline? The wise motorist will make an occasional check of his gasoline mileage, and when it decreases a considerable amount he concludes that something is wrong, and that he will save money by having it repaired, or by getting a new automobile. The same reasoning can, and should be, applied to pumps.

Certainly, we cannot expect pumps to maintain the initial efficiency year after year. As any other piece of equipment, they too, become worn and become less efficient.

Every water department should make a practice of making periodical tests on its pumps and when there is a considerable drop in efficiency, necessary action should be taken to correct this condition of inefficiency.

It will be my purpose to make a check on the efficiency of the pumps at the Highland Park Davison Ave. Pump Station, and to suggest improvements where needed.

GENERAL LAYOUT OF HIGHLAND PARK WATER SYSTEM

The Highland Park water supply is taken from Lake St. Clair at a point about ½ mile from the shore, near Seven Mile Road and Lake Shore Drive.

A Pumping station equipped with three 8 MGD and three 10 MGD centrifugal pumps takes the water from the lake through a 30" cast iron pipe line and delivers it to the Filter Plant, located at Davison and Dequindre Avenues - a distance of fourteen miles.

In front of the filter plant the 30" lake line divides into two 30" lines, one of which leads to the open storage reservoir, and the other of which enters the pump house. (see print No. 1) The system is so arranged that the amount of water being used at the time goes into the pump house line, while the excess goes into the storage reservoir thro the other 30" line.

The water which enters the pump house is disposed of in two ways. Part of it is pumped directly from the 30" line to the Ford Motor Plant by pumps No. 7 and No. 8. The remainder goes through the filtration process and thence into the city mains.

The water which goes thro the filter plant flows under the influence of the head furnished by the Grosse Pointe pumps. Just before leaving the pump house chlorine and alum are added - about 1.5 to 2.0 ppm of chlorine being used to give more efficient operation of the filter beds.

After the chlorine and alum are added, the water passes thro a baffled mixing chamber and then into the coagulating basin, where sedimentation takes place. From the coagulating basin the water goes into the filters. Before entering the filters powdered activated carbon is added for removing odors and tastes.

The filter plant consists of sixteen units, each having an area of 0.007853 acres, with a gravel bed of about 18 to 24 inches, and sand layer of about 30 inches. The filters are operated at a rate of 1 MGD per unit, which is equivalent to about 125 MGD per acre of filter area.

From the filters the water goes into the clear well, which has a capacity of 3 M.G., and is located directly beneath the filter plant. After final chlorination, to insure a residual of 0.2 ppm, the water is led by a 42" pipe line to the pump house whence it is pumped into the distribution system.

The pump house is equipped with nine centrifugal pumps, arranged as shown on Print No.2. Pumps No. 3, 4, 5, 6, and 9 are ordinarily used to pump the filtered water.

Pump Room Layout

Main Panel Board

Pumps

Starting Switch

All pumps are single stage, double suction pumps equipped with 440 volt, 3 phase, 60 cycle, General Electric Motors. With the exception of pump No. 9, all are the Rees Roturbo type, manufactured by the Manistee Iron Works Co., Manistee, Michigan. Pump No. 9 is a Worthington pump, manufactured by the Worthington Pump and Machinery Corporation of Harrison, New Jersey. Details of the various pumps are given in Table 1.

Two 24" feeder lines lead from the pump station to the distribution system. One of these enters the system at Davison and Oakland Avenues, and the other at Oakland and McLean.

A 250,000 gallon elevated storage tank, with a 30" riser pipe, maintaining a 125' head is connected into the system just outside the pump station. The purpose of this tank is to prevent surging and to maintain a more or less constant pressure in the distribution system.

The aforementioned open storage reservoir is of reinforced concrete construction with dimensions of 1380' x 250' x 14'-6" and a capacity of 48 M.G. It is divided into two parts, so that half of it may be cleaned without disrupting service. As stated before, if more water is pumped from the lake than is being used at present the excess goes into the reservoir. If, however, an insufficient amount is being pumped from the lake, the difference can be made up from the reservoir supply. With the reservoir full, water will flow by gravity thro the filter plant, unless the filters are operating at a rate greater than 8 MGD. In such a case, the water is pumped by pumps

Table 1

PUMP NO.	RATED CAPACITY MGD	RATED HEAD FT	MOTOR HP	MOTOR RPM
1	5	100	100	1150
2	5	100	100	1150
3	5	120	150	1200
4	5	120	150	1200
5	5	125	150	1200
6	5	125	150	1200
7	11		60	680-720
8	6		40	680-720
9	3	135	85	1800

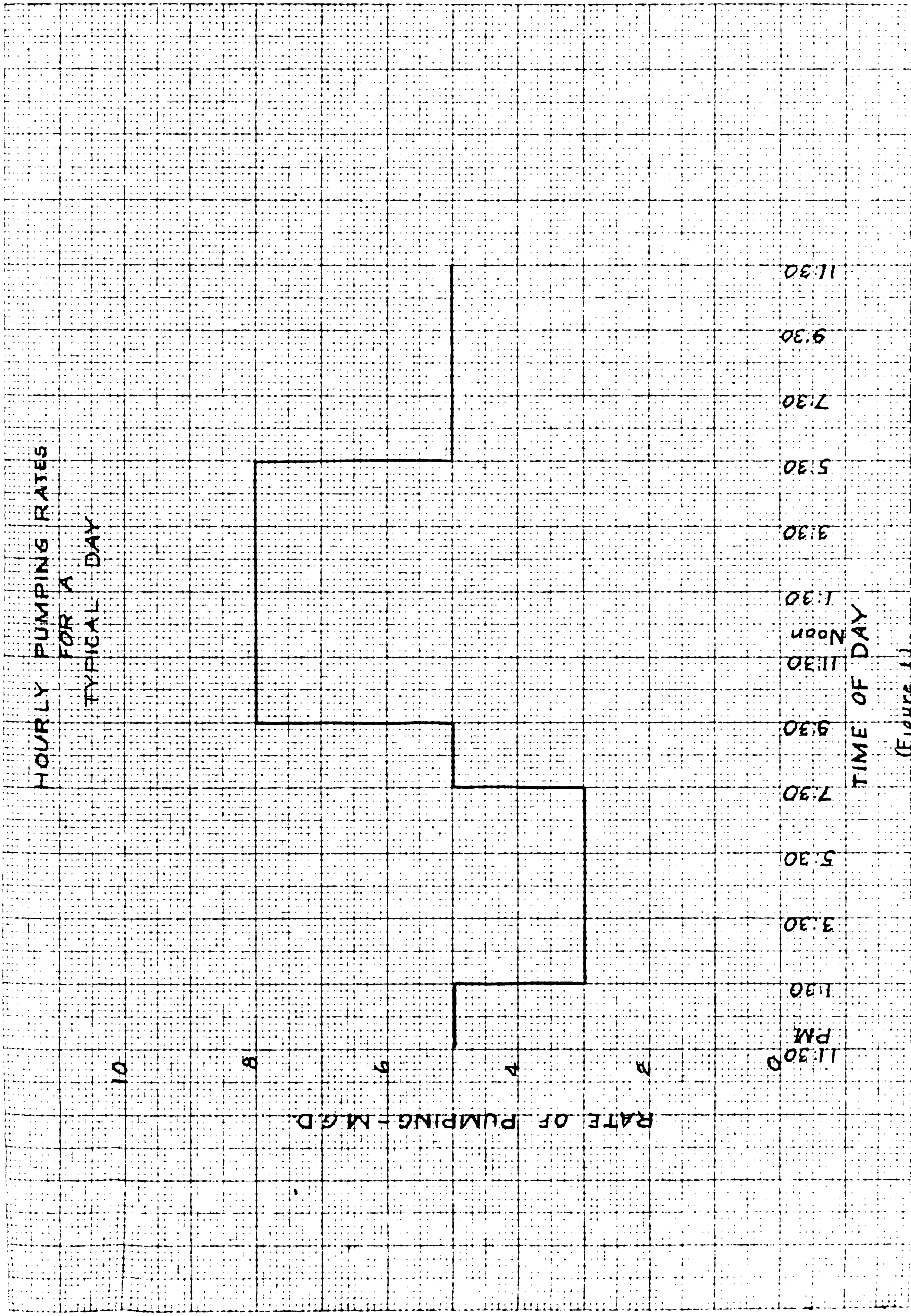
7 and 8, through a 54" concrete conduit leading from the reservoir. The piping is so arranged that these pumps can pump to the Ford Motor Co. and to the filter plant at the same time.

PUMPS IN GENERAL

In any water supply pumping station, two items are of primary importance, namely, quantity and variability. Pumping units must be provided to satisfy the maximum demand and the units must be of such size that the pumping rates can be varied to conform with the rates of consumption.

It is a well known fact that pumps operate most efficiently under the conditions for which they were designed. Operating pumps at rates greater or less than that for which they were designed, results in a considerable decrease in efficiency, as will be seen in the test results which will be given later. Therefore, it will be seen that maximum efficiency results if units of such size are provided that they can operate at rated capacity and supply the demand under the various conditions.

Consumption rates vary from hour to hour, from day to day, and from month to month. The reasons for these variations will not be discussed here but typical values will be given to show that such variations do exist and that they are of considerable amount. Figure 1 shows the hourly pumping rates for a typical day, while Tables 2 and 3 show the daily and monthly variations, respectively.


HOURLY PUMPING RATES
FOR A
TYPICAL DAY
RATE OF PUMPING - M.G.D.
0
2
4
6
8
10
TIME OF DAY
11:30 PM.
1:30
3:30
5:30
7:30
9:30
11:30
Noon
1:30
3:30
5:30
7:30
9:30
11:30

(Figure 1)

Table 2

DAILY PUMPING RECORDS
FOR THE MONTH
OF
JANUARY, 1939

DATE		GROSSE PTE. PUMP HOUSE	HIGHLAND PK. PUMP HOUSE	FILTERED	FORD
S.	1	6,827,000	5,180,000	4,470,000	710,000
M.	2	5,887,000	5,280,000	4,550,000	730,000
T.	3	7,112,000	7,100,000	6,100,000	1,000,000
W.	4	7,298,000	7,150,000	6,090,000	1,060,000
Th.	5	7,271,000	7,090,000	6,130,000	960,000
F.	6	7,274,000	7,130,000	6,190,000	940,000
S.	7	7,280,000	6,240,000	5,350,000	890,000
S.	8	7,253,000	5,130,000	4,400,000	730,000
M.	9	7,205,000	6,770,000	6,020,000	750,000
T.	10	7,107,000	6,760,000	6,140,000	620,000
W.	11	7,146,000	7,100,000	6,210,000	890,000
Th.	12	7,236,000	6,850,000	5,940,000	910,000
F.	13	7,438,000	6,320,000	5,410,000	910,000
S.	14	7,712,000	5,920,000	5,040,000	880,000
S.	15	5,132,000	5,040,000	4,340,000	700,000
M.	16	7,854,000	6,680,000	5,850,000	830,000
T.	17	7,094,000	7,390,000	6,470,000	920,000
W.	18	7,082,000	7,800,000	6,690,000	1,110,000
Th.	19	7,053,000	7,060,000	6,010,000	1,050,000
F.	20	7,092,000	6,620,000	5,910,000	710,000
S.	21	7,079,000	6,030,000	5,280,000	750,000
S.	22	6,666,000	5,320,000	4,650,000	670,000
M.	23	4,311,000	6,790,000	5,890,000	900,000
T.	24	8,099,000	7,100,000	6,060,000	1,040,000
W.	25	5,158,000	7,130,000	6,130,000	1,000,000
Th.	26	7,791,000	7,160,000	6,150,000	1,010,000
F.	27	13,041,000	6,920,000	5,990,000	930,000
S.	28	8,014,000	6,330,000	5,510,000	820,000
S.	29	7,698,000	5,480,000	4,750,000	730,000
M.	30	6,982,000	7,660,000	6,570,000	1,090,000
T.	31	8,707,000	9,000,000	7,720,000	1,280,000
		224,999,000	205,530,000	178,010,000	27,520,000

	G.P.P.H.	H.P.P.H.
Daily Average	7,258,000	6,630,000
Max. Daily	13,041,000	9,000,000
Min. Daily	4,311,000	5,040,000
Electric Cost	$ 1,571.63	$ 1,219.09
Electric Cost per M.G.	$ 6.98	$ 5.09

	GPPH.	per MG
January	224,999	$5.09
February	205,534	6.80
March	215,708	7.02
April	205,045	6.13
May	223,141	6.00
June	218,246	7.33
July	278,311	5.33
August	252,961	6.31
September	228,163	6.20
October	217,122	6.40
November	186.109	6.48
December	199,092	5.99

January	209,316	$6.15
February	199,975	6.03
March	204,799	5.90
April	199,064	6.15
May	213,408	6.02
June	229,581	6.34
July	251,243	6.48
August	245,962	6.78
September	227,329	6.07
October	233,283	5.99
November	236,855	6.88
December	246,600	6.79

Since the pumping station is equipped with four 5 MGD pumps and a 3 MGD pump, we may conclude by referring to Figure 1 that the sizes of the pumping units are satisfactory with respect to variability.

Maximum pumping rates to be provided are dependent upon two things, first, the maximum ordinary consumption, and second, fire demand.

I am going to assume a maximum ordinary demand of 10,000 GPM. The fire demand for a city of 50,000 population, which is approximately the population of Highland Park, is 6,500 GPM, based on a table compiled by the National Board of Fire Underwriters.[1] This gives a total maximum demand of 16,500 GPM. The plant is equipped with four 3,420 GPM and one 1,840 GPM pumps, having a total output of 15,520 GPM, and two 3,400 GPM pumps (1 & 2) which can also be put on the line, thus giving a maximum output of 22,320 GPM, which is certainly an ample amount to take care of any conditions which might arise.

[1] Bulletin No. 116, National Board of Fire Underwriters, "Water Supply for Municipal Fire Fighting", Jan. 15, 1941.

METHODS OF TESTING PUMPS

The acceptance tests on pumps are usually made to a considerable degree of accuracy in order to be sure that the pumps come up to the guarranteed standards. Subsequent tests are usually run merely as a check to see whether or not there has been any considerable loss in performance.

In making pump tests three things must be measured: the head pumped against, the power input into the motor, and the amount of water pumped.

The head pumped against consists of the pressure on the discharge side of the pump, the suction lift, and the frictional loss in the intake line. The discharge head is measured by means of a pressure gage placed on the discharge side of the pump. The suction head is usually determined by attaching a mercury U-tube on the intake side of the pump, in which case the frictional loss in the line is included in the U-tube reading. In this case the total head is equal to the discharge head plus the suction head measured by the U-tube and the difference in elevation of the pressure gage and the point where the U-tube is connected into the intake line.

Under certain conditions it is possible to connect one side of the U-tube to the pressure side of the pump and the other side to the intake side of the pump, in which case the total head pumped against is registered by the U-tube.

Often it is inconvenient to connect a U-tube to the intake side of the pump. In such a case, the discharge pressure is measured in the usual way and the suction head is determined by measuring from the water surface from which the water is being pumped to the center of the pump and arbitrarily adding a foot or two for frictional losses in the intake line. The frictional losses can be estimated quite accurately by taking into consideration the amount of pipe and the number of fittings through which the water flows and the velocity of the water through them. In this case the total head pumped against is the sum of the discharge head, the difference in elevation of the water surface and the center of the pump, and the estimated frictional loss. This latter method is the one which was used in making the present tests.

The power input into the motor is measured by one of two methods. The first method, commonly called the disc constant method, involves the use of a kilowatt-hour meter. In this method it is necessary to count the number of revolutions of the meter disc during a period of time. The horsepower is then computed from the formula,

$$\text{H.P.} = \frac{R \times K \times M}{.2072 \times t}$$

where, R is the number of revolutions of the disc, t is the time in seconds for this number of revolutions, K is the disc constant, and M is a multiplying factor obtained by multiplying the current transformer ratio by the potential transformer ratio. The factors K and M are usually given on the name plate of the meter but if they are not given they can be obtained from the manufacturer.

The second method of measuring power input involves the use of a kilowatt, or watt meter. In this case the rate of kilowatt consumption is given by the meter. To obtain the horsepower input it is necessary only to divide the kilowatt input by 0.746, since 1 H.P. = 0.746 KW. In equation form,

$$H.P. = \frac{KW}{0.746}$$

This second method is the one which was used in making our tests.

The amount of water pumped can also be measured in one of several ways. Perhaps the simplest, and the one used in our tests, is the use of Venturi meters. In important tests Venturi meters should first be checked before relying on their results.

A frequently used method of measuring the amount of water pumped involves the use of weirs. In this case the water pumped is run over a weir, and by measuring the depth over the weir and the size of the notch the flow can be calcuated by using one of the weir formulae. One of the most used is King's formula,

$$Q = 3.34LH^{1.47} \left(1+.56\frac{H^2}{D^2}\right)$$

in which Q = flow in c.f.s. (cubic feet per second)

L = length of the weir, in feet corrected for end contractions

H = head on the weir, in feet

D = area of channel divided by L

This method of measuring the flow was used in making the acceptance tests on several of the present pumps.

Still another method of measuring the rate of pumping is to pump the water into a tank of known dimension and measuring the depth of water pumped in a specific time.

After the total head pumped against, the power input and the pump discharge have been determined the "wire to water" efficiency of the unit can be computed. "Wire to water" efficiency means the combined efficiency of the pump and the motor.

By definition, efficiency is the ratio of the work gotten out of a machine to the amount of work put into it. Or, in our case, it would be the ratio of the horsepower output to horsepower input. In equation form,

$$E = \frac{WHP}{BHP} \times 100$$

where, E = efficiency in per cent

WHP = water horsepower = horsepower output

BHP = brake horsepower = horsepower input.

Water horsepower can be computed from the formula,

$$WHP = \frac{GPM \times head}{3960}$$

where, GPM = gallons pumped per minute

and, head = total head pumped against expressed in feet of water.

By taking a series of readings on each pump at different rates of discharge enough data is obtained to plot the characteristic curves of the pump. This has been done in our case and the present curves have been compared with the original curves, where these curves have been available, in order to show the difference between the pump performance when the pump was installed and the present performance.

In comparing the efficiencies of old and new pumps, the difference in efficiency of the two pumps is often referred to as the improvement. This, however, is incorrect. The improvement is the difference in efficiencies divided by the efficiency of the new pump. For example, if a pump whose efficiency is 60% is replaced by one whose efficiency is 80%, the improvement, or power saving, is $\frac{.80-.60}{.80}$ or 25%.

Figure 2 gives an easy way of obtaining the power saving without doing any computing. Run a straightedge through the efficiency of the new pump in Column A and of the old pump in Column B, and read the improvement in Column C.

TEST RESULTS

Pumps No. 1 & No. 2 Tested: May 13, 1941

The present tests on these pumps were made under very unfavorable conditions. They were pumping raw water from the lake line and discharging through a six inch line with four openings which is much too small to handle the required amount of water.

The results obtained show a very low efficiency, but it must be remembered that the pumps were not opened up to full capacity.

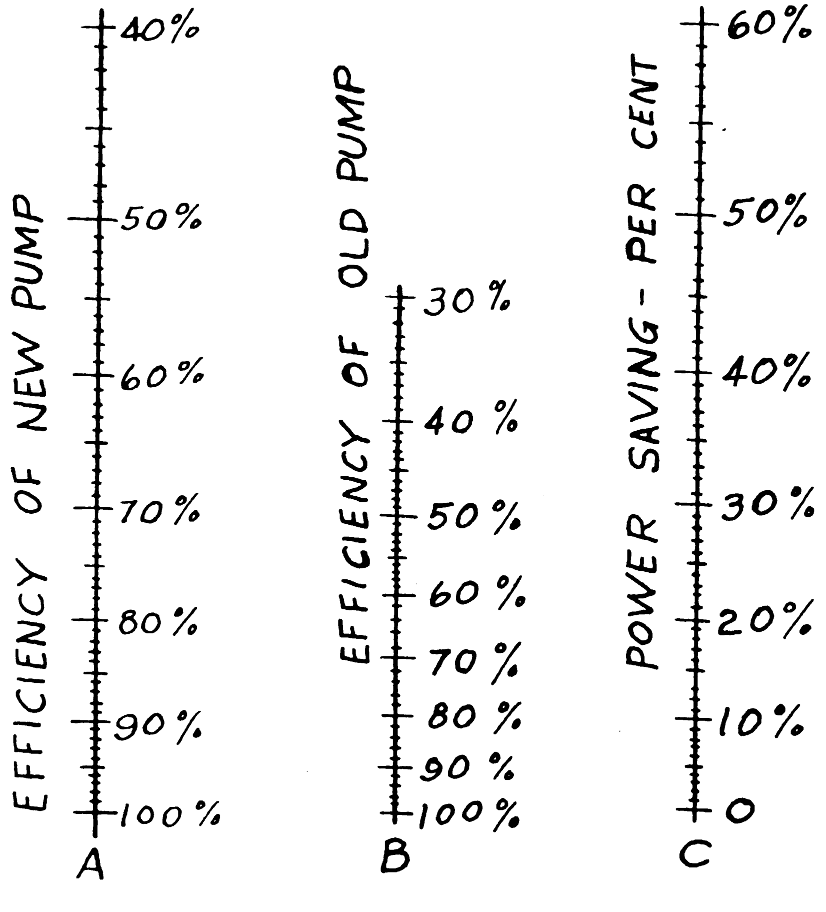
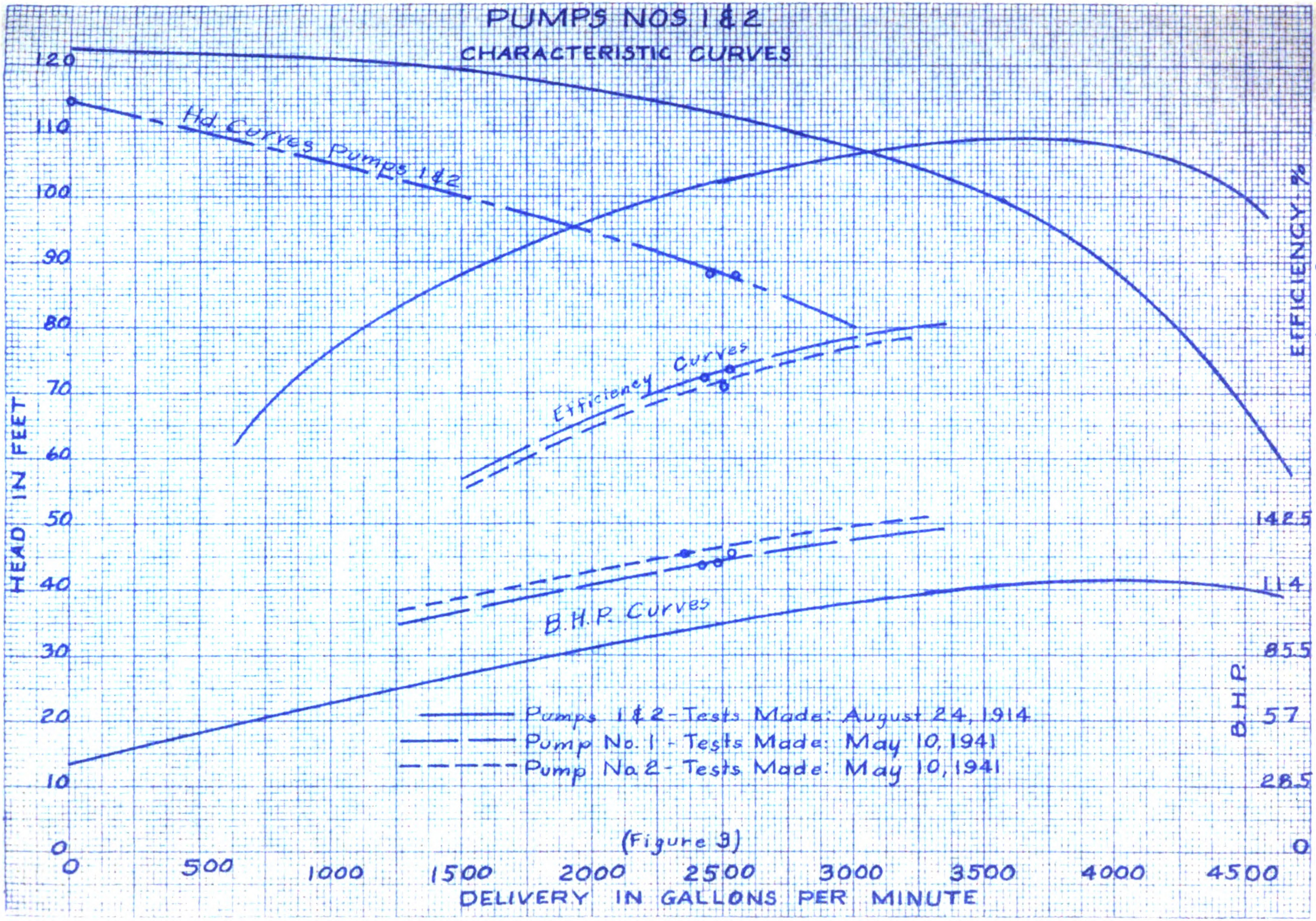

EFFICIENCY OF NEW PUMP
40%
50%
60%
70%
80%
90%
100%
A
EFFICIENCY OF OLD PUMP
30%
40%
50%
60%
70%
80%
90%
100%
B
POWER SAVING - PER CENT
60%
50%
40%
30%
20%
10%
0
C

FIGURE 2

TEST RESULTS

TRIAL NO	SUCTION HEAD FT	DISCHARGE HEAD Lbs per sq. in.	DISCHARGE HEAD Ft of water	TOTAL HEAD	DISCHARGE MGD	DISCHARGE GPM	KW	BHP	WHP	EFFICIENCY %
PUMP NO. 1										
Shutoff	7	53	122	115						
1	7	41	95	88	3.5	2430	95	127	54	42.5
2	7	41	95	88	3.64	2530	97	129	56.2	43.6
PUMP NO. 2										
1	7	42	97	90	3.4	2360	97	129	53.6	41.3
2	7	40	92	85	3.6	2500	98	131.5	53.9	41.0


PUMPS NOS 1 & 2
CHARACTERISTIC CURVES
Hd. Curves Pumps 1 & 2
Efficiency Curves
B.H.P. Curves
Pumps 1 & 2 - Tests Made: August 24, 1914
Pump No. 1 - Tests Made: May 10, 1941
Pump No. 2 - Tests Made: May 10, 1941
HEAD IN FEET
EFFICIENCY %
B.H.P.
DELIVERY IN GALLONS PER MINUTE
0
500
1000
1500
2000
2500
3000
3500
4000
4500
10
20
30
40
50
60
70
80
90
100
110
120
28.5
57
85.5
114
142.5

(Figure 3)

Since these pumps are very seldom used - usually about once a year - their low efficiency is not of much consequence. However, should conditions become such that the pumps would be needed more often, I would suggest that another set of test be made under more favorable conditions, if possible. Referring to Figure 2, it can be seen that by replacing these pumps with pumps whose efficiencies would be 80% would result in a power saving of approximately 45%.

Pump No. 3 Tested: May 17, 1941

Referring to Figure 4, we see that the present curves correspond quite closely to the test curves of January 12, 1917. There is a slight drop in efficiency which is to be expected, since the pump has been in operation for over 24 years.

Let us, however, examine the savings in power cost which could be expected if a pump of modern design were installed. A modern pump of this size may be expected to give a "wire to water" efficiency of 80%[1]. At this rate pump No. 3 has an efficiency of about 64%. If a pump of 80% efficiency were installed the savings in power cost would be 20%. Referring to the column in Table 3 which gives the electric cost per M.G., we will assume a value of $6.00 per M.G. The saving in cost per M.G. would be 20% of $6.00, or

[1]Beckwith, H. E. "Simple Method for Checking Pump Efficiencies", Water Works & Sewerage, Vol. 86, p. 445.

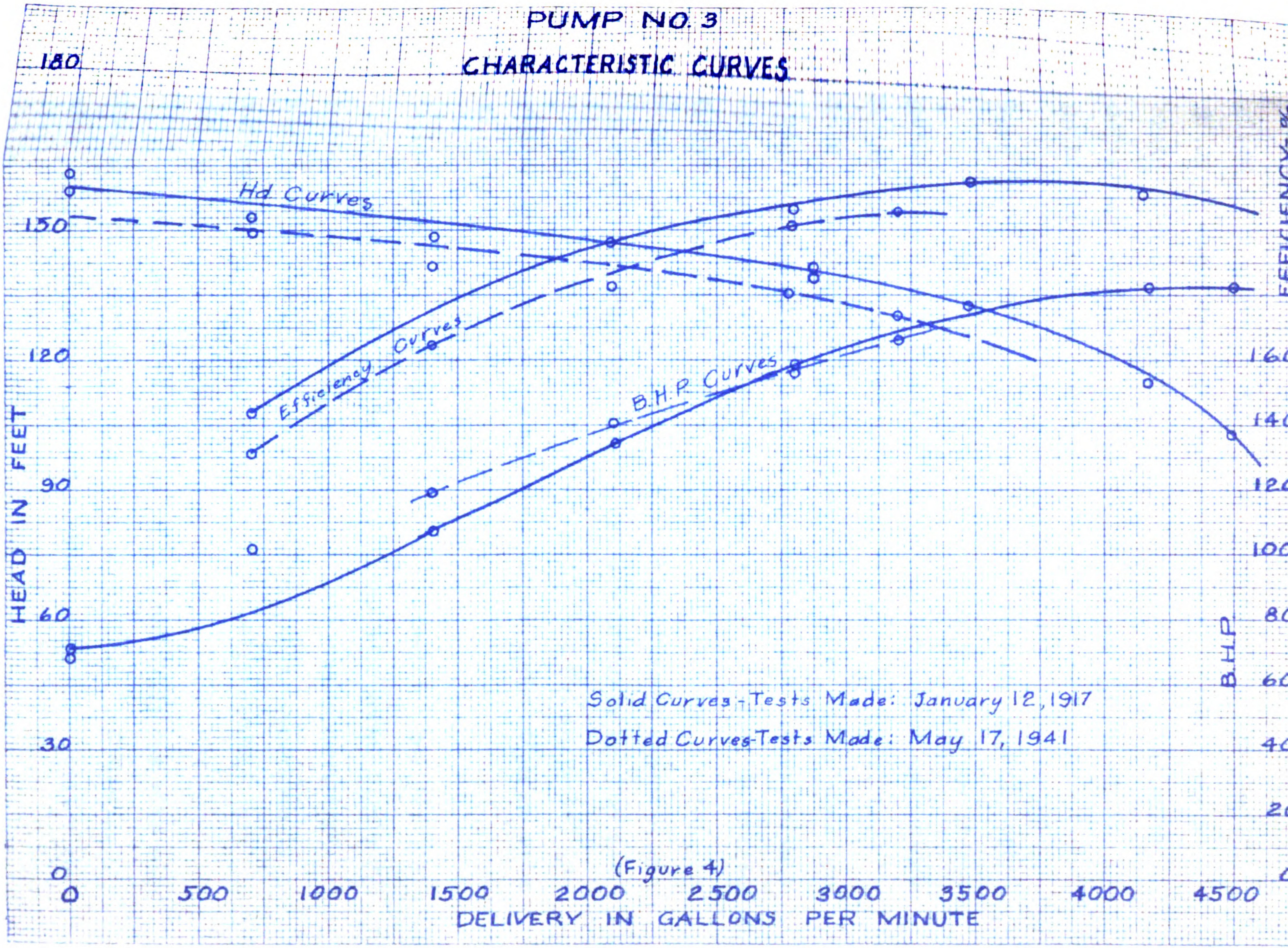
PUMP NO. 3
TEST RESULTS

TRIAL NO	SUCTION HEAD FT	DISCHARGE HEAD Lbs per sq. in.	DISCHARGE HEAD Ft of water	TOTAL HEAD	DISCHARGE MGD	DISCHARGE GPM	KW	BHP	WHP	EFFICIENCY %
Shutoff	18	62	143	161			52	69.6		
1	18	57	132	150	1	694	77	103	26.3	26
2	18	54	125	143	2	1388	90	120.5	50.1	42
3	18	51½	119	137	3	2083	105	140.7	72.1	51
4	18	51	118	136	4	2776	117	156.8	95.2	61
5	18	48½	112	130	4.6	3192	125	167.3	104.9	63

PUMP NO. 9
CHARACTERISTIC CURVES

PUMP NO. 3

CHARACTERISTIC CURVES



(Figure 4)

$1.20. The question now arises as to whether a saving of $1.20 in power costs per M.G. pumped would justify the purchase of a modern pump. That is a question for the water department officials to answer. My purpose is merely to point out the possibilities.

Pump No. 4 Tested: May 16, 1941

A study of the test curves shows the tendancy of the present curves to follow the slopes of the curves determined by the tests of January 12, 1917. It will be noted, however, that the present efficiency curve runs higher than the original, and the BHP curve runs lower. This indicates that there is an error in measuring the amount of water delivered. Judging from these curves, I w ould say that the Venturi meter (meter No. 2) through which this flow was measured was in error. It registers high - and considerably so. My recommendation is that this meter be checked and corrected immediately. An erroneous meter is little better than no meter at all.

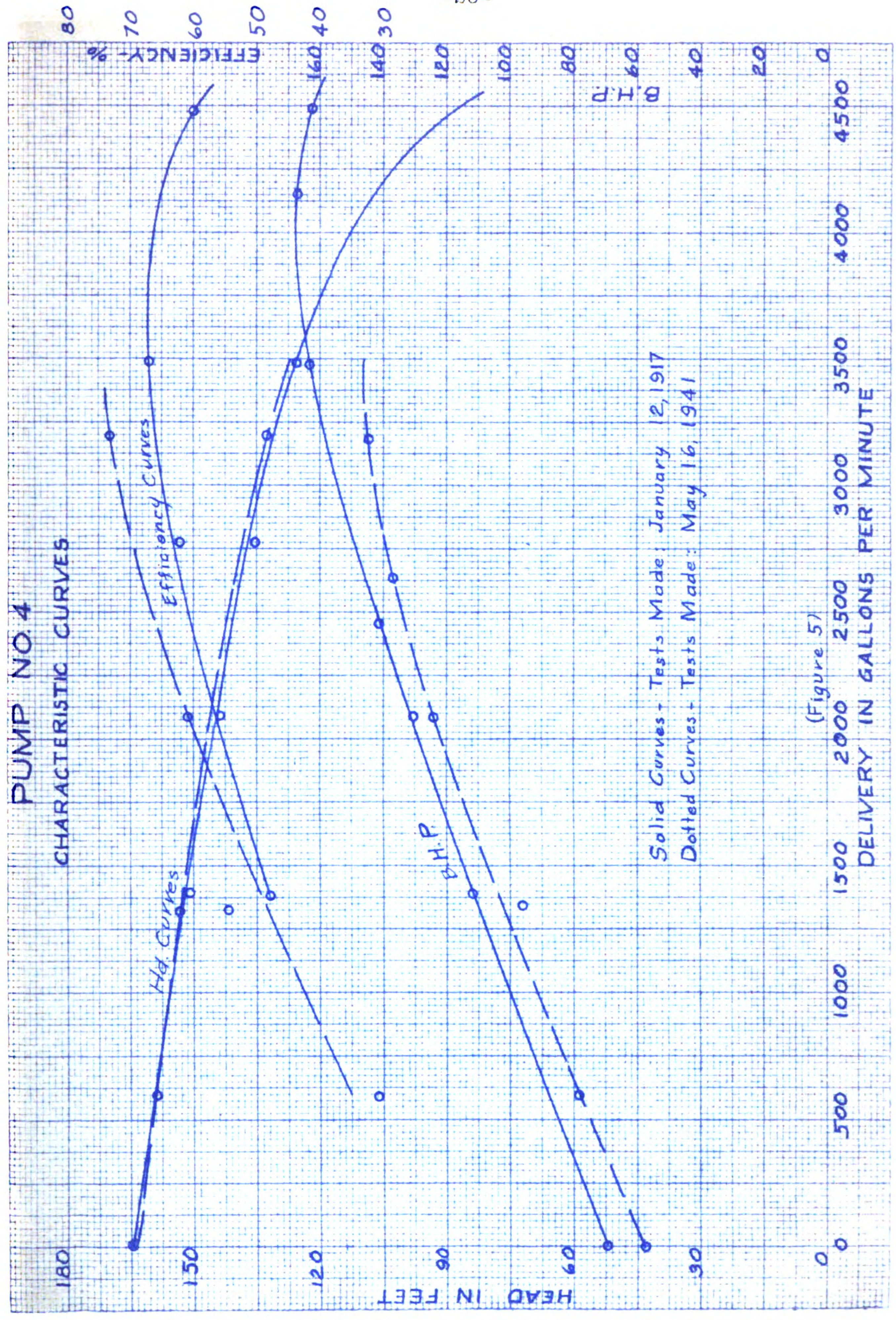
Pump No. 5 Tested: May 10, 1941

The original tests on this pump were made on July 27, 1920, It will be noted on Figure 6 that the maximum efficiency attained by pump No. 3 was 68%. This comparison is indicative of the improvement of pump design between 1917 and 1920.

The present efficiency is comparatively low with respect to the original. My recommendation is that another test be run on this pump, and if the results are similar to

PUMP NO. 4
TEST RESULTS

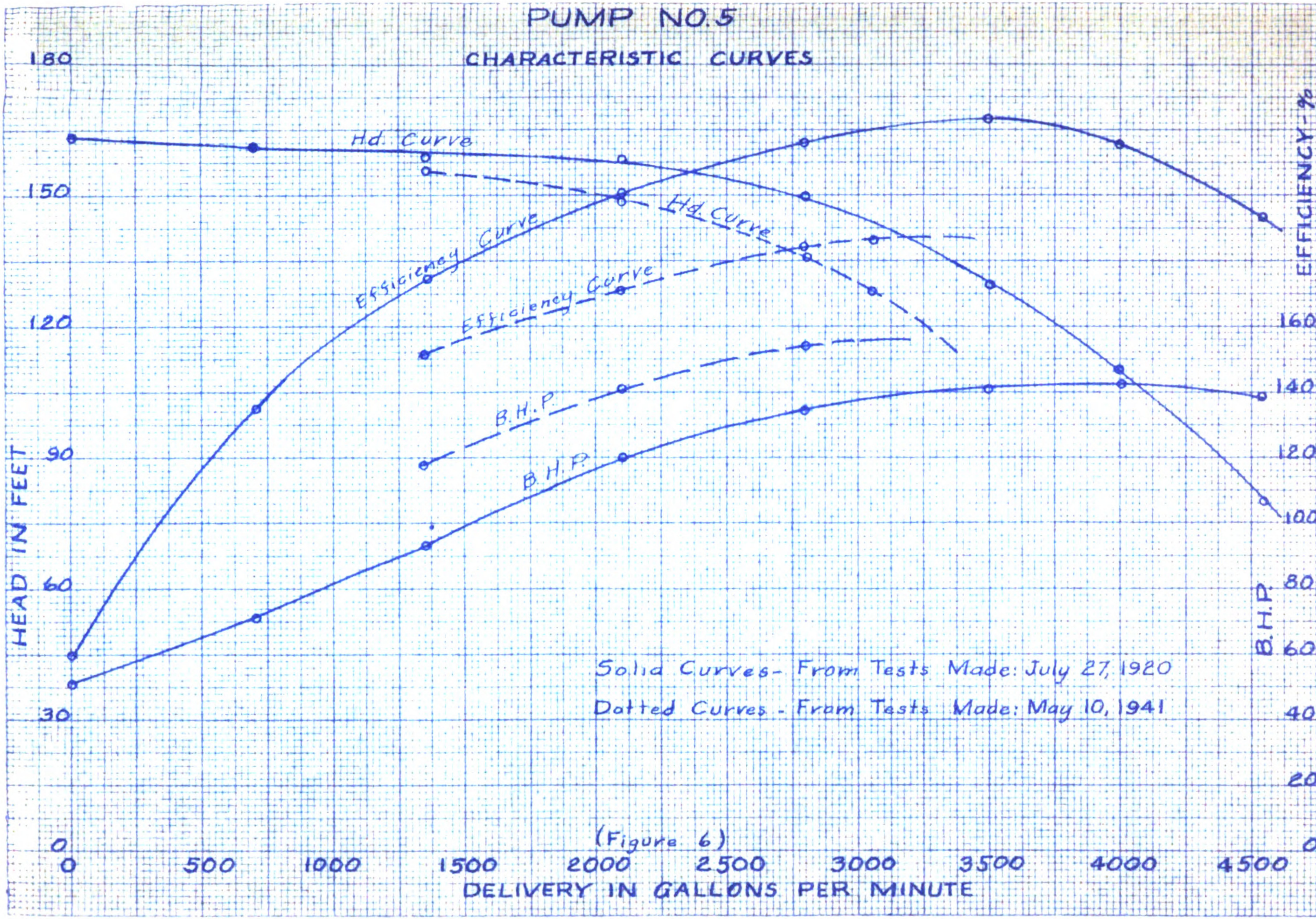
TRIAL NO	SUCTION HEAD FT	DISCHARGE HEAD Lbs per sq. in.	DISCHARGE HEAD Ft of water	TOTAL HEAD	DISCHARGE MGD	DISCHARGE GPM	KW	BHP	WHP	EFFICIENCY %
Shutoff	19	63	145	164			43	57.6		
1	19	61	141	160	.85	590	57	76.4	23.8	31
2	19	58	134	153	1.9	1318	73	97.8	53.3	55.
3	19	55	127	146	3	2083	93	124.7	76.8	61.5
4	19	52	120	139	3.8	2635	102	136.7	92.5	67.5
5	19	49	113	132	4.6	3192	108	144.8	106.4	73.5


PUMP NO 4
CHARACTERISTIC CURVES
EFFICIENCY - %
B.H.P.
Efficiency Curves
Hd. Curves
B.H.P.
Solid Curves - Tests Made: January 12, 1917
Dotted Curves - Tests Made: May 16, 1941
HEAD IN FEET
DELIVERY IN GALLONS PER MINUTE

(Figure 5)

PUMP NO. 5
TEST RESULTS

TRIAL NO	SUCTION HEAD FT	DISCHARGE HEAD		TOTAL HEAD	DISCHARGE		KW	BHP	WHP	EFFICIENCY %
		Lbs per sq. in.	Ft of water		MGD	GPM				
1	20	59	137	157	2	1388	89	119.2	54.8	46
2	20	56	129	149	3	2083	105	141	78.5	55.5
3	20	50	116	136	4	2776	115	154	95.8	62
4	20	47	109	129	4.4	3056	117	156.8	99.5	63.5


PUMP NO.5
CHARACTERISTIC CURVES
Hd. Curve
Hd. Curve
Efficiency Curve
Efficiency Curve
B.H.P.
B.H.P.
Solid Curves - From Tests Made: July 27, 1920
Dotted Curves - From Tests Made: May 10, 1941
HEAD IN FEET
EFFICIENCY-%
B.H.P.
DELIVERY IN GALLONS PER MINUTE
0
500
1000
1500
2000
2500
3000
3500
4000
4500
180
150
120
90
60
30
0
90
80
70
60
50
40
30
160
140
120
100
80
60
40
20
0

(Figure 6)

those of the present test, then an investigation should be made as to the cause of this decrease in efficiency. There is a possibility that the impeller may be badly worn, or that the motor needs repairing. In any case, the possibility of increasing the efficiency 10% to 15% is certainly worth an investigation.

Pump No. 6 Tested: May 10, 1941

No comparison has been made between the present test results and the original tests. I was unable to get the curves for this particular pump because I could not find its serial number. If the department wishes to make the comparison, the original curve may be obtained by writing to the manufacturer, and giving the serial number of the pump, if it can be located.

Pumps No. 7 & No. 8

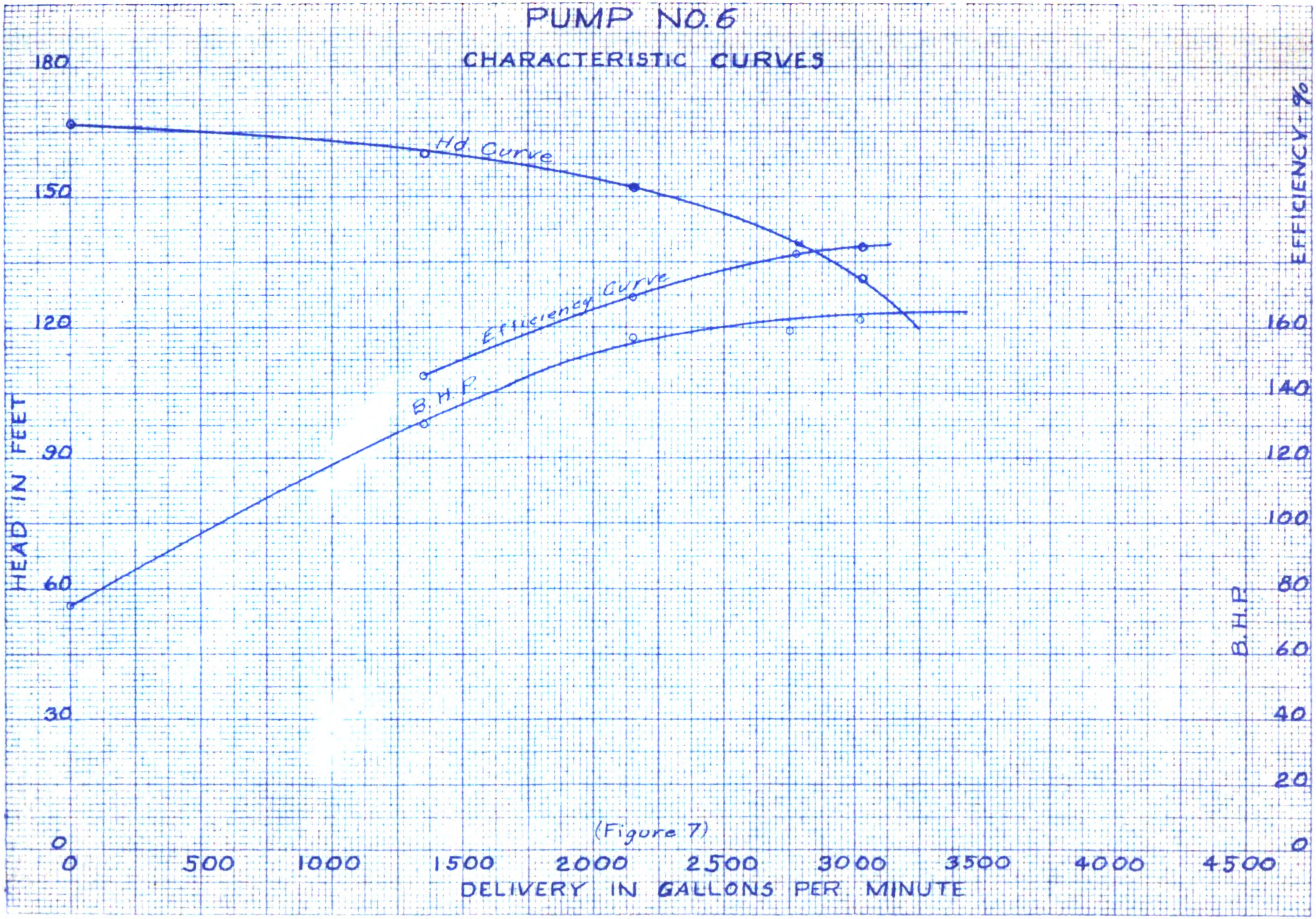
No tests were run on these pumps because of the difficulty which would be encountered in obtaining a constant flow.

Pump No. 9

We went through the procedure of running a test on this pump, but when it came to making the computations I discovered that I had been reading an ammeter instead of a kilowatt meter. Upon further investigation I found that these are no means for measuring the power input to this pump. If the power factor of the motor were known, the power input could be computed from the voltage and

PUMP NO. 6
TEST RESULTS

TRIAL NO	SUCTION HEAD FT	DISCHARGE HEAD Lbs per sq. in.	DISCHARGE HEAD Ft of water	TOTAL HEAD	DISCHARGE MGD	DISCHARGE GPM	KW	BHP	WHP	EFFICIENCY %
Shutoff	20	63	146	166			56	75		
1	20	60.5	140	160	2	1388	97	130	57	43
2	20	57	132	152	3.1	2151	113	151.4	82.5	54.5
3	20	51.5	119	139	4	2776	119	159.4	97.4	61
4	20	48	111	131	4.39	3023	121	162.2	100	61.5


PUMP NO.6
CHARACTERISTIC CURVES
Hd. Curve
Efficiency Curve
B.H.P.
HEAD IN FEET
180
150
120
90
60
30
0
EFFICIENCY - %
80
70
60
50
40
B.H.P.
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
DELIVERY IN GALLONS PER MINUTE

(Figure 7)

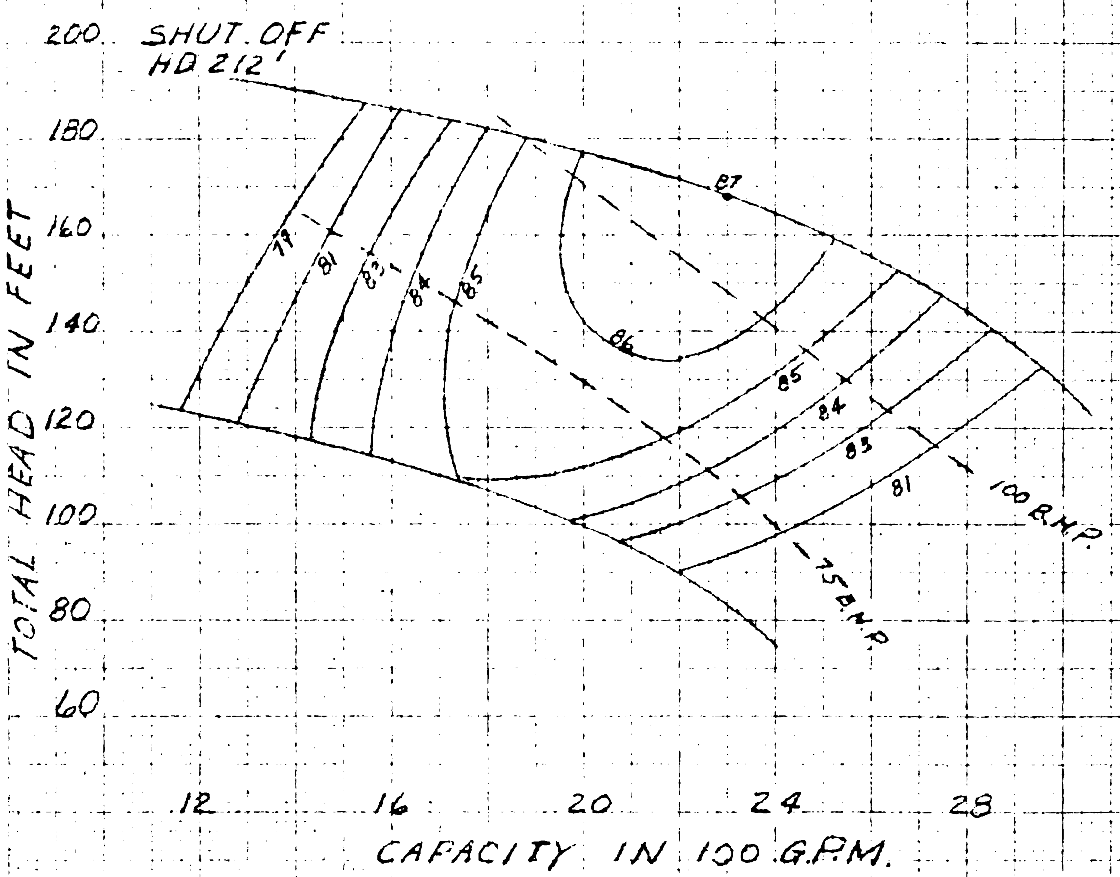


Figure 5

Q No.	WORTHINGTON PUMP AND MACHINERY CORPORATION	DATE
ORDER No.		E
APPR.	SUBJECT	

amperage. However, the power factor would also vary with the load, so at best, this method would be very crude.

I have included the general efficiency curves for this particular type of pump so that if the department wishes to make a test, the results may be compared with the design efficiency.

If the department feels that it is not necessary to have a kilowatt meter installed on this pump, a meter can be borrowed from any electric company so that tests can be made.

CONCLUSION

It is my hope that the test results here given will bring about the realization that occasional check-ups on equipment are essential to economy of operation.

I believe that pumps should be tested at least once a year. Some one man in the department should be put in charge of this work, and it should be his duty to supervise the tests, draw up the conclusions, and make recommendations for improvements. This work would take up but several days time each year, and I am convinced that the benefits derived therefrom would more than pay for this time.

BIBLIOGRAPHY

Babbit & Doland, "Water Supply Engineering", McGraw-Hill Book Co., 1939.

Schoder & Dawson, "Hydraulics", Chapter XVIII, McGraw-Hill Book Co., 1934.

Pickels, George W., "Drainage and Flood-Control Engineering", Chapter X, McGraw-Hill Book Co., 1925.

Peerless Pump Division, "Catalog P-126", pp. 38-40.

National Board of Fire Underwriters, Bulletin 116, "Water Supply For Municipal Fire Fighting", Jan. 15, 1941.

Schaphorst, W. F., "How To Compare Pump Efficiencies", Water Works & Sewerage, Jan., 1941, p. 43.

Beckwith, H. E., "Simple Method For Checking Pump Efficiencies", Water Works & Sewerage, Vol. 86, p. 445.

Angus, R. W., "An Improved Technique for Centrifugal-Pump Efficiency Measurements", Transactions of the ASME, Vol. 63, No.1, p,13.