THE OPERATION OF CENTRIFUGAL PUMPS UNDER ABNORMAL CONDITIONS.

THESIS

by

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A Report Containing

A Description of the Experiment, the Original Data, Characteristic Curves, and a Discussion of the Results.

Experiment Performed Under the Direction of Dr. Robert T. Knapp

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INTRODUCTION

The common and widespread use of centrifugal pumps has caused a great deal of investigation to be carried on and a vast amount of knowledge accumulated regarding the normal operation of this type of apparatus. In a like manner, due to the rarity of the occasion on which a pump might operate under abnormal conditions, there has been little work done to determine the pump characteristics for this type of operation.

True, the abnormal conditions are very infrequent, but they may become of paramount importance where the pumps involved are worth tens of thousands of dollars and are depended upon to supply domestic water to millions of people. A little effort and money could well be spent to insure such a system against failure from these unknown factors.

Normal operation might be classed as positive rotation (of the impeller) and positive discharge. The three conditions of abnormal operation would then be positive rotation and negative discharge (water flowing backwards through the pump), negative rotation and positive discharge, and negative rotation and negative discharge. The first of these three conditions might occur if for some reason the head on the pump was suddenly increased, a condition arising from the sudden shutting down of a separate pump in series with the first, assuming that the check valves failed to function. To a lesser degree a similar situation would exist under regular shutting down operations (assuming as in the above that the valves failed to function), the energy of the rotating impeller serving to cause positive rotation for a limited time.

The second abnormal condition (negative rotation, positive discharge) might occur if for some reason the direction of rotation was reversed, and the operating head was low, or the reversed speed high. The third condition (negative rotation, negative discharge) would exist late in the shutting down operation after the energy of the rotating impeller had been dissipated (valves failing to function as before). In both cases of reversed flow the amount might be only that in the discharge pipe, or in the case in which the discharge was connected directly to an elevated tank or reservoir, the flow might be prolonged.

It is quite important to know what would happen in these unusual cases, especially in connection with the electrical apparatus. Will there be excessive power demand which might blow out circuit breakers, or will the motor act as a generator and put power back into the line? If so, at what voltage? And what might be the maximum speed expected? What torque would be necessary to start a pump through which water is already flowing, either in the positive or negative direction? What will be the duration of such conditions of the amount of water that has to be considered is only that in the discharge line? -----A complete investigation of these fields is necessary in order to answer the questions.

OBJECTS OF THE EXPERIMENTAL WORK.

With the questions which were raised in the introduction in mind, we attempted to determine the characteristics of a small centrifugal pump under all possible operating conditions, and to draw curves from the data thus collected which would be of use in solving these problems. Of course our pump is quite small, and the degree of variation of conditions limited by the laboratory equipment, but still the results should give a reasonable idea as to what might be expected with larger units, and cover the range of most of the abnormal fields which can be found in actual practice.

PROCEEDURE.

In order to secure abnormal conditions in the laboratory it was necessary to connect the pump to be tested in series with another larger pump which would serve as a source of supply. This supply pump had to be powerful enough to force water through the other pump under all operating conditions. This type of connection was also an advantage in that we were thus assured that there would always be a supply of water under pressure on the suction side of the test pump. In the cases where the total head across the pump was small this condition was quite essential.

To drive the test pump we used a three horse-power direct current, direct connected motor mounted on bearings so that the stator could rotate. By the use of a lever arm and spring balance we were able to read directly the force causing torque. To control the speed and hold it constant it was necessary to use water barrels in the armature circuit and a rheostat in the field circuit. After some experimenting it was found that the only way we could secure sufficient speed control was to have our driving motor separately excited from an adjustable voltage generator, leaving the above mentioned rheostats in their respective circuits. Even with this arrangement, due apparently to the characteristics of the motor, it was impossible to secure constant speeds for all conditions of operation above 1400 revolutions per minute.

The quantity and head were varied by valves on the output side of the pump. The quantity was measured by timing the flow into a tank and then weighing the water, the tank capacity being about 400 pounds. The head across the pump was measured by a constant volume mercury manometer. This type of manometer is especially convenient as one reading is sufficient to indicate the head.

In operation the proceedure was to weigh the empty measuring tank, and to adjust the regulation valve, then bring the motor to the proper speed. As quickly as possible we would read the head, read the scales measuring the force of the torque, and time the flow of water necessary to fill the weighing tank, after which the full tank was weighed. In general this cycle of operations took about four minutes.

EQUIPMENT.

The pump used in this experiment was manufactured by the Byron Jackson Company of Berkeley, California. The pump is number 115278, type VA 1 1/2 x 10, date 6-25-30.

To drive the pump we used a Continuous Current Motor, Shunt Wound, Number 347059, Type CVC 111, Form A 405. The normal speed was 1650, 115 volts, Open-HP 3, Amps. 23.9. The maker was the General Electric Co.

The Probator was of German make, Brevetê, number 10003.

For speed regulation we normally used a tachometer made by the Electric Tachometer Corp'n., Phil., Pa. The model was Tetco. The magneto number was 60071. The indicator was number 19815, model F, Millivoltmeter, made by Weston Electrical Instrument Co., Newark, N. J., Model 45.

This tachometer was very advantageous in that it was possible to place the indicator near the electrical controls so that the person adjusting the speed could read the instrument directly.

To measure pressures we used a manometer of our own make. It consisted of a mercury well connected to the lower end of a short glass tube by small cloth covered flexible rubber tube. The point of high pressure was connected to the top of the well, while the point of low pressure was connected to the top of the glass tube through another section of the flexible tubing. This glass tube was fixed to work over pulleys and slide up and down a board along side of a steel tape. At zero pressure the level of the mercury was brought to a scratch in the middle of the glass tube, the elevation of the mercury in the tube then being the same as in the well. This determined the zero reading. When there was any pressure across the system the level in the glass tube was maintained up to the scratch, and the height measured directly on the steel tape.

Plate I shows a diagram of the layout. There are also two pictures showing the set up as we used it. Plate II shows the wiring diagram and means of controlling speed. One of the two-pole double throw switches is for reversing the motor, the other is for cutting off the power input and loading the motor as a generator.

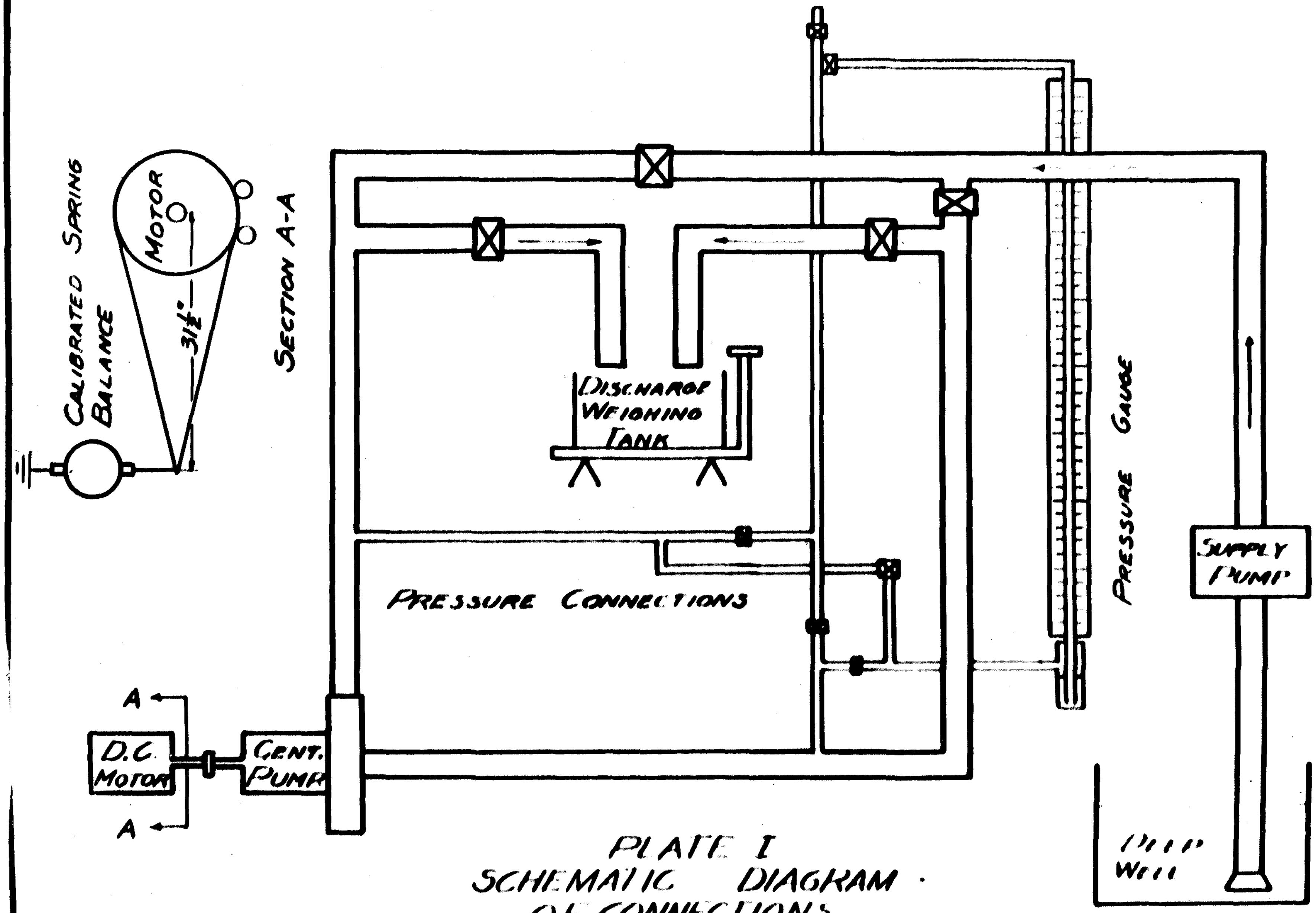


PLATE I
SCHEMATIC DIAGRAM
OF CONNECTIONS

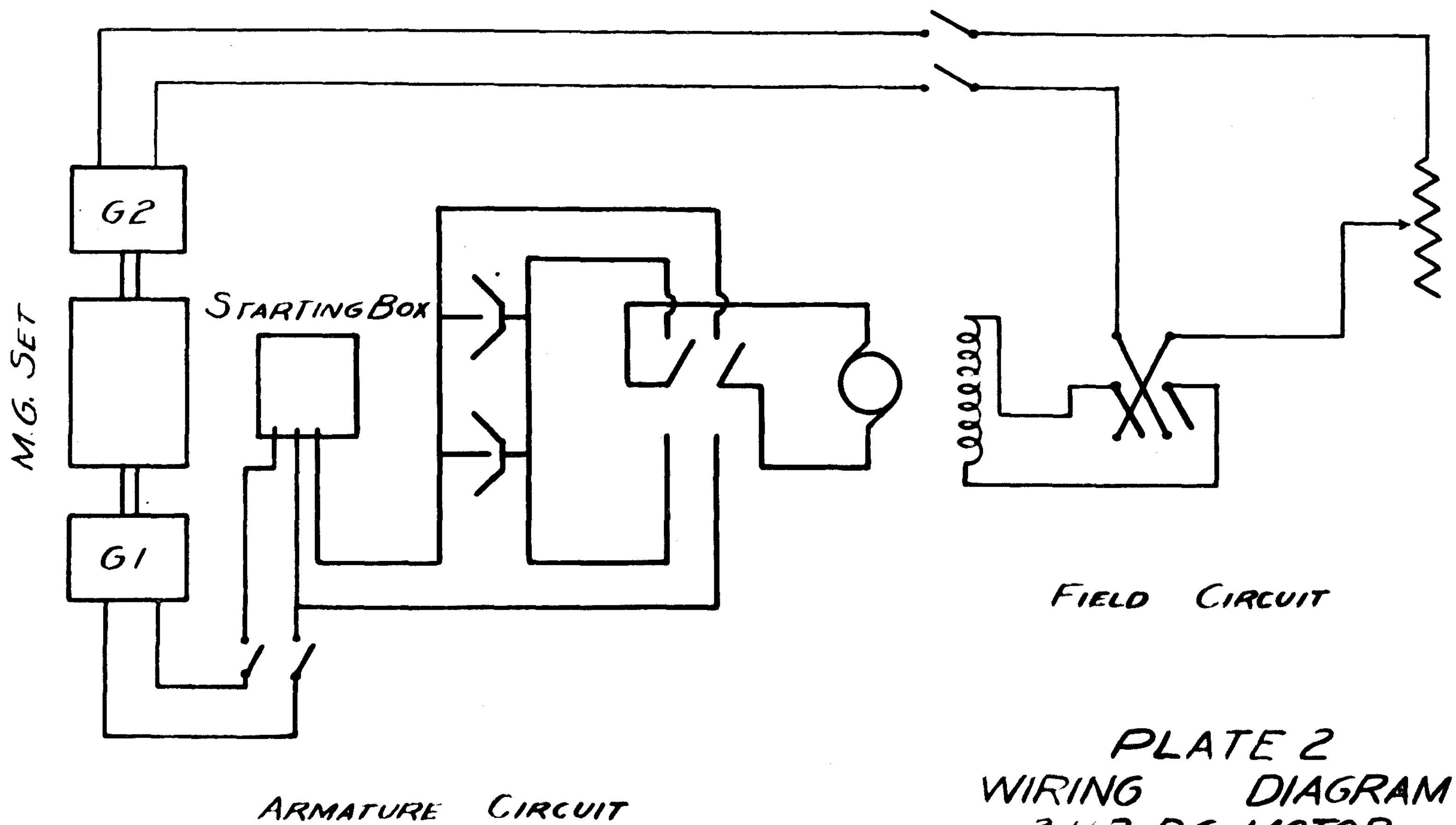
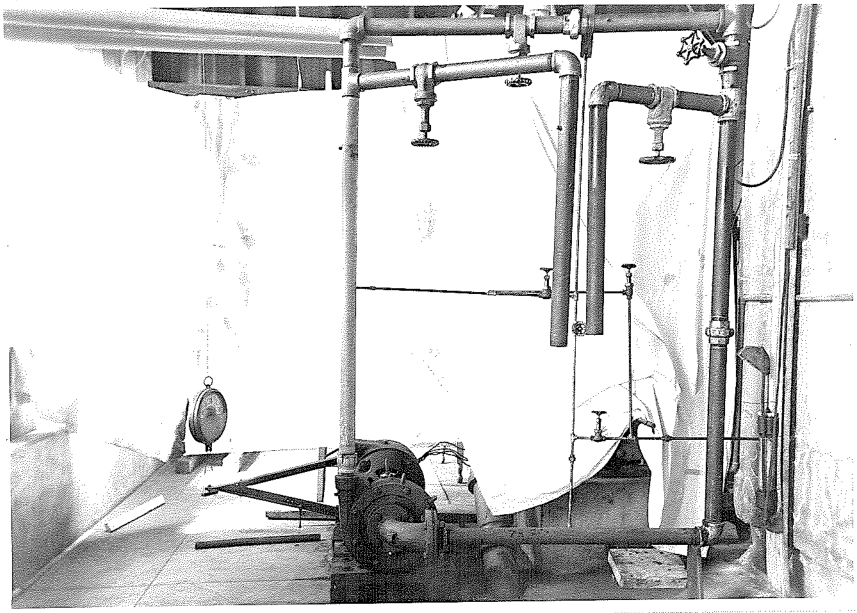
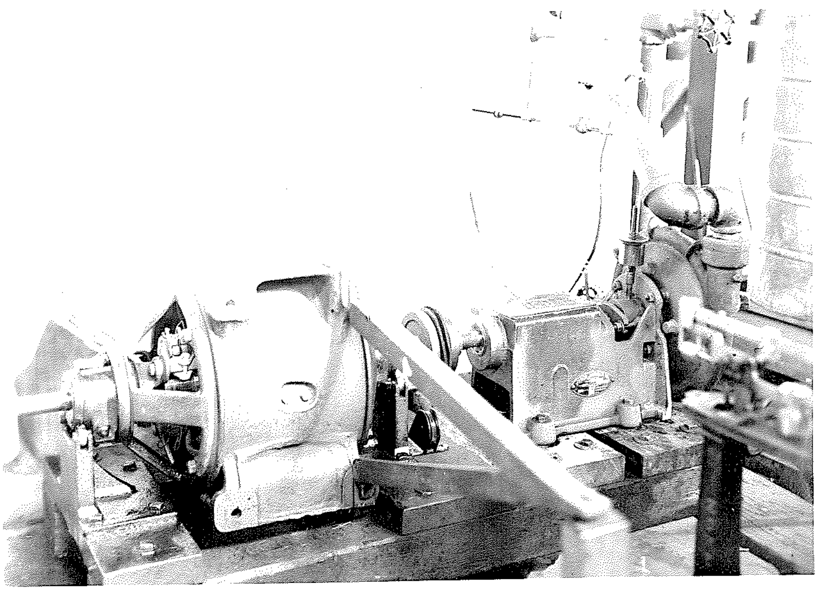


PLATE 2
WIRING DIAGRAM
3 H.P. D.C. MOTOR
SEPARATE EXCITATION

PICTURES OF APPARATUS.





ACCURACY AND ERRORS

The electric tachometer was not accurate at all speeds, so each time that we changed speeds we checked this instrument by the use of a probator, and thereafter on that particalar run we compensated for the error in the tachometer. On frequent occasions we would check the speed at both the beginning and the end of a reading in order to make sure that the speed had not changed during the time of the run. We found that there was a slight variation at times, but the amount was small, and we found it almost impossible to maintain absolutely constant speed for any long period of time. The high speeds were the most stable. Our probable error in speed was about one percent to about a half of one percent. Speed of course has a direct bearing on the quantity and head. This effect would be most noticeable at shut-off head, and probably for this reason our curves are less accurate in the region of zero quantity than in the regions of appreciable quantities.

The scales on which we measured the weight of water were quite sensitive and measured down to one half a pound. The error varies probably from about two percent at relatively low quantities to about one quarter of one percent for large quantities.

Occasionally we were able to secure a stop watch to measure the time necessary to fill the weighing tank, but most of the time we were forced to use the timing device on the probator, a combination revolution counter and stopwatch. Of course the watch was quite accurate, but the probator read directly only to seconds so that parts of seconds had to be estimated. Another difficulty was that the maximum time of the probator was only about sixty-five seconds, so that when the quantity of water flowing was small we were only able to measure the flow for a period limited by time and not by the capacity of the weighing tank as was the case when we had large quantities flowing. However, due to the type of the arrangement for changing the flow into and out of the weighing tank, our timing was not any more accurate than could be read on the probator. Probably the maximum error in timing was three fifths of a second. For the minimum period which we used this would be an error of less than four percent. For the maximum time the error would be one percent.

To both the suction and discharge sides of the test pump we attached fairly long (five or six feet) lengths of straight pipe, and from the centers (with respect to length) of these sections we attempted to take our head measurements so that we would not have turbulence as part of the head reading. Due to the length of these sections, however, it was hard to insert a tube at right angles to the pipe in such a fashion that it would end just flush with the inside surface of the pipe. The adjustment was made as good as possible under the circumstances, and the result seemed to indicate that the existing conditions were satisfactory. At low quantities there was practically no fluctuation in the level of the mercury in the manometer, and at high quantities the erratic fluctuations were seldom more than 0.10 feet. Of course under some of the unusual conditions we were operating with large quantities at very low heads so that head fluctuations would cause considerable error in the total head readings. In general no difficulty was experienced in determining a reasonable point in the range of fluctuations to consider as the average head reading.

The highest point on the manometer tube was equipped with a valve opening to the atmosphere so that we could frequently test the manometer tube system to make sure that there was no air present in the tubes.

The scale reading the torque force was rather sluggish, so each time that we read it we would jiggle it several times by hand and then take a reading which we considered to be a mean. The results of the various jigglings might vary as much as 0.10 pound. The error in reading was probably five percent or less. This is probably more accurate than the overall power reading due to the fact that we frequently had to tighten up the packing gland of the pump which in itself absorbed a considerable amount of power and could thus cause considerable variation in driving torque.

CALCULATIONS.

The calculations necessary to draw the curves are quite simple and routine. The empty and full weights of the measuring tank were subtracted giving the total quantity measured in pounds. This figure divided by the time of flow in seconds gave the quantity per unit time in pounds per second.

To the height of mercury in the constant volume manometer was added a correction factor of 0.15 feet of mercury. This constant was necessary to correct for the fact that the zero mark of the steel tape failed to coincide with the actual zero mark by 0.15 feet. The height of the mercury column (plus correction) was then multiplied by the density of mercury less one (the density of water), giving the head in feet of water. The reason for subtracting the density of water from the density of mercury before multiplying is to compensate for the fact that the manometer tube above the mercury and down to the point of low pressure reading is filled with water.

The scale measuring the force of the torque did not give accurate readings directly, so it was necessary to draw up a calibration curve. The actual force was found by the use of this rating scale and then a constant representing tare was subtracted. This gave the actual force that the motor was exerting on the lever arm at the point of bearing of the knife edge.

Sample calculations:-

Speed-	1000 R.P.M
Weight empty-	55 lbs
Weight full-	445 lbs
Time	60 Sec.
Torque scale reading-	8.6 lbs
Manometer reading-	3.85 in. of Hg.

Calculated

Quantity- Wt. full minus Wt. empty = 390#

Quantity per unit time- Quantity/time = 6.5 lbs/sec

Head in feet of water- (3.85 plus correction of 0.15) x (density of mercury minus one) = 4.00 x 12.56 = 50.25 feet.

Force of torque- from calibration curve, force = 1.95 pounds.

The correction to add to the head is due to the zero end of the tape being 0.15 feet above the true zero point. This correction is to be numerically added to head at all times unless there is a note to the contrary.

DESCRIPTION OF CURVES.

General.

In all curves the heads as plotted are in feet of water, and the quantities are in pounds per second. Pounds per second may be converted into gallons per minute by multiplying by the factor 7.19. Thus twenty-five pounds per second equals 179+ gallons per minute. Torque is measured in pounds at the end of a 31.5 lever arm.

In the first six figures the curves are all lines of constant speed.

Figure 1. Head Quantity, Positive Rotation.

On this figure, quantity to the right is positive, that is normal discharge, and head above the quantity coordinate represents normal positive pressure on the output side. The curves in the second quadrant represent water being forced back through the pump while it is still rotating in the normal direction, there being a large head loss across the pump. That is, the head is high on what is normally the discharge side, and low on the suction side. It can be noted that head increases very rapidly with an increase in quantity.

Curves in the lower right hand quadrant represent water being forced through the pump in excess of what it would normally carry. In this case the head is higher on the suction than on the discharge side.

The first quadrant indicates the normal pump characteristic range, showing normal positive discharge and positive head. It should be noted that this pump apparently has a slight rising characteristic.

This curve is probably the least accurate in the region of zero quantity.

Figure 2. Head-Quantity, Negative Rotation.

This curve is similar to the Quantity Head curve for positive rotation in that curves represent quantities and heads in the same direction. The curves show that a pump will deliver a relatively low quantity of water at fairly low head even if the pump is rotating backwards.

Under this condition, when the quantity is negative the pump will act as a turbine, the motor acting as a generator which must be loaded in order to keep the speed constant.

We have not been able to arrive at a definite conclusion as to why the curves crossed at the ends. Although this phenomonon appears incorrect, it apparently is correct judging from the way that such characteristics plotted on the composite curve.

Figure 3. Quantity Torque Curves, Positive Rotation.

As the title indicates, this curve is the relation between the quantity and the force producing the torque. This torque measure is in pounds at the end of a thirty one and one half inch arm.

The portion of the curves to the right of the dash line are in the region of negative head. The curve for six hundred revolutions per minute shows quite clearly that if more water is forced through the pump than it would normally deliver that the impeller begins to act as a turbine and deliver power to the shaft. If the quantity available was sufficient to carry the curves further out to the right it would probably be found that this condition would occur for all speeds.

The curves to the left of the dash line but still in the region of positive quantity show that at high speeds the force of the torque increases quite rapidly. Since horse power for any constant speed is the product of the measured force and a constant, the curve is also an indication of the variation of power.

To the left, in the region of negative quantity, the curves show that at first there is a decrease in power (for small quantities) and then that the power starts to increase quite rapidly. We did not have the equipment necessary to carry this curve out very far. The curves are quite steep at the ends, and it would be interesting to carry the curves out further and see what would happen.

There is a possibility that if the curves were carried out far enough to the right that the lower curves would cross the line and indicate a negative torque which would mean that the pump was acting as a turbine and that the motor was acting as a generator and delivering power.

Figure 4. Quantity Torque curves, Negative Rotation.

As in the previous set of curves the portion of the curves to the right of the dash line indicate negative head, that is, a higher head on what is normally the discharge side than on the suction side. This region represents water forced through the pump in the normal direction.

The portion between the dash line and zero quantity represents water being pumped in the normal direction by the negative rotation of the impeller.

The region of minus torque indicates that the pump is acting as a turbine. In this region it was necessary to put a water barrel load across the motor to absorb the generated power. In some cases the efficiency as a turbine was better than forty percent.

Figure 5. Head Torque Curves, Positive Rotation.

It might be said that this curve is a combination of figures 1 and 3. That is, there are only three parameters, so that having any two of the three curves, numbers 1,3, or 5, it is possible to derive the third.

The long sweeping part of the curves to the right and below the points of discontinuity represent positive quantities, the region above the points of discontinuity being the portion depicting negative quantity.

Figure 6. Head Torque Curves, Negative Rotation.

This curve is similar to those of figure 5. By having any two of the three curves numbers 2, 4, or 6 it is possible to derive the third.

The region to the right and below the dash line is the portion depicting positive quantity. From the dash line down to the point of zero head, the curves represent water being pumped in the positive direction. Below the zero head line represents water being forced through the pump.

Above and to the left of the dash line is negative quantity, the portion showing negative torque indicating that the pump is acting as a turbine and delivering power.

Figure 7. Composite Curve, Constant Head, Constant Torque.

This curve is drawn from data taken from the other curves which were taken from original data. In this case the abscissa represents variable speed, positive to the right and negative to the left. The ordinate represents quantity, positive upwards, and negative downwards. The solid curves are lines of constant head, as labeled, and the curves below the lines of zero head are positive head, while those above are negative head.

The short dash lines are lines of constant torque force. The region below $T = 0$ and in the region of negative rotation represents negative torque or power output. The remainder represents positive torque showing power input.

The line of zero head running from the origin up to the right theoretically should be a straight line for an infinite distance. However, due to cavitation this curve bends over towards the right until it approaches asymptotically a horizontal line, indicating that beyond a certain point increasing the speed will not increase the quantity of water pumped. The same is true of the line of zero head running from the origin up towards the left. The location of the points at which these curves begin to bend down towards the horizontal depends upon the head on the suction side of the pump. If we had not used positive pressures at the input side the curve would have bent over closer to the origin. This characteristic is obvious when one considers that the higher the pressure in the pump the higher must be the quantity of water flowing before cavitation occurs.

The curves labeled torque equals zero are plotted from experimental data. For positive rotation it was only possible to get a few readings, all of which were at relatively low speeds. In fact the power developed when water is forced through the pump in the positive direction is so small that in order to secure these readings we disconnected the motor entirely from the pump so that there would be no energy absorbed in rotating the motor. The long dash lines near the lines of T = 0 are estimated lines representing the true zero torque lines, the plotted lines being different from zero by the amount of torque necessary to overcome packing and bearing friction. Of course at constant torque, as speed increases, power increases. In all probability, once a fairly high speed is attained it takes relatively little increase in power to overcome the friction increase due to increased speed. Hence the curves would probably be approximately as shown, the two curves of experimental and expected T = 0 approaching each other as they receded from the origin until they are nearly parallel. Probably the two experimental curves should intersect the ordinate at points of equal torque. Our data is not accurate enough in this region to show whether this is true or not. If it were not true it might be due to the brushes of the motor allowing rotation in one direction more easily than in the other. Of course all of the other curves of constant torque include the item of torque necessary to overcome bearing and packing friction.

Figure 8. Sudden Power Shutoff, Constant Static head.

This curve is identical with number seven with the addition of the o---o---o---o curve. (A-A curve.) This curve represents what would happen if a pump were forcing water up into a reservoir and the power was suddenly shut off. It is assumed for the period of the calculation that the capacity of the upper reservoir is large enough that the amount of water flowing back down through the pump would not reduce the level of the water surface. Thus there is a constant static head.

Normally the water would be flowing up through the discharge pipe. As soon as the power was cut off the impeller would slow down and stop. The water would continue to flow in the positive direction for a very short period, then it would reverse direction and flow back down through the pipe, reversing the direction of rotation of the impeller and increasing its speed up to what would be run-away speed for that particular head. The head across the pump differs of course from the static head by an amount equal to the head lost due to pipe friction.

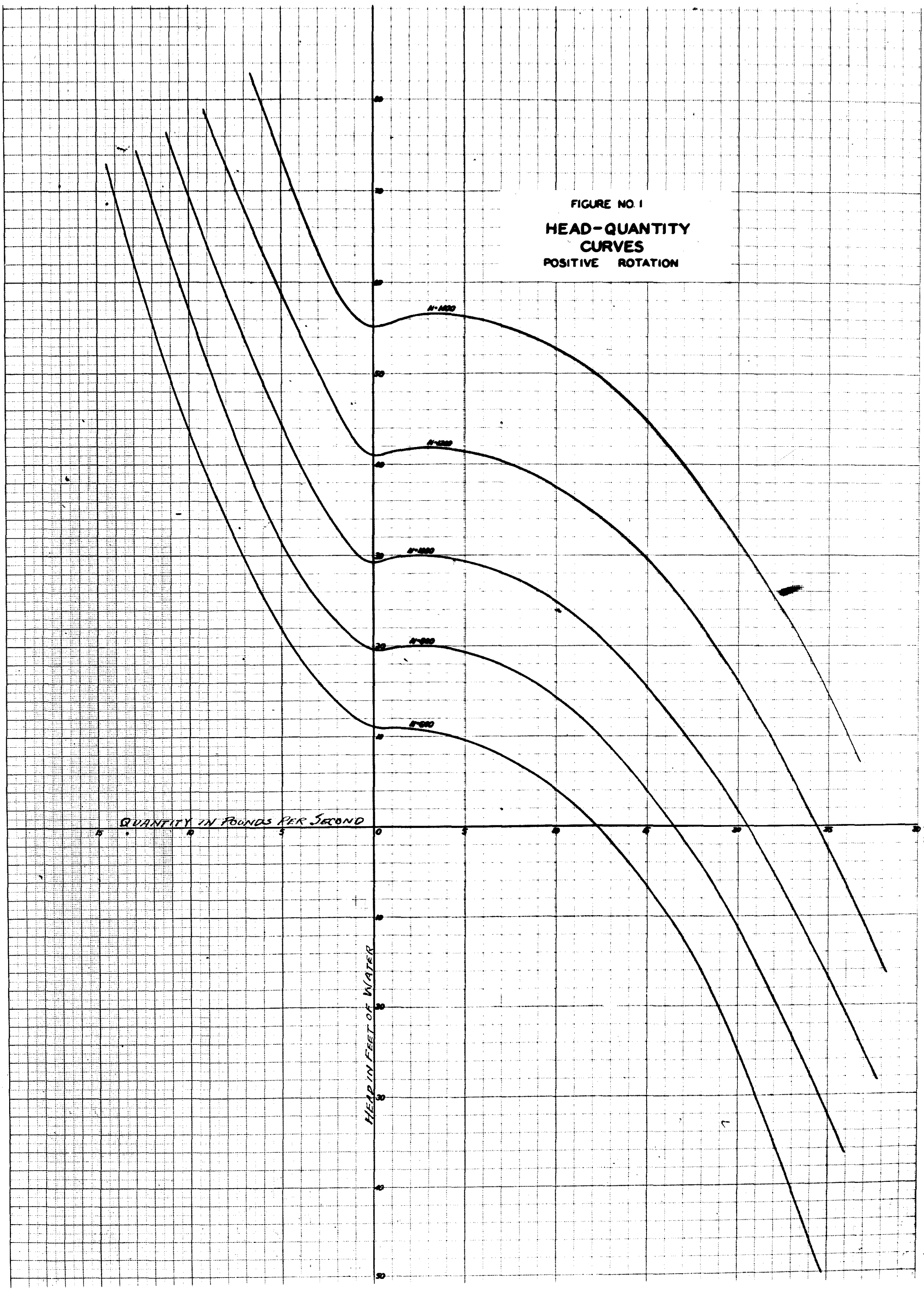


FIGURE NO. 1
HEAD-QUANTITY
CURVES
POSITIVE ROTATION
QUANTITY IN POUNDS PER SECOND
HEAD IN FEET OF WATER
15
10
5
0
5
10
15
20
25
30
60
50
40
30
20
10
10
20
30
40
50

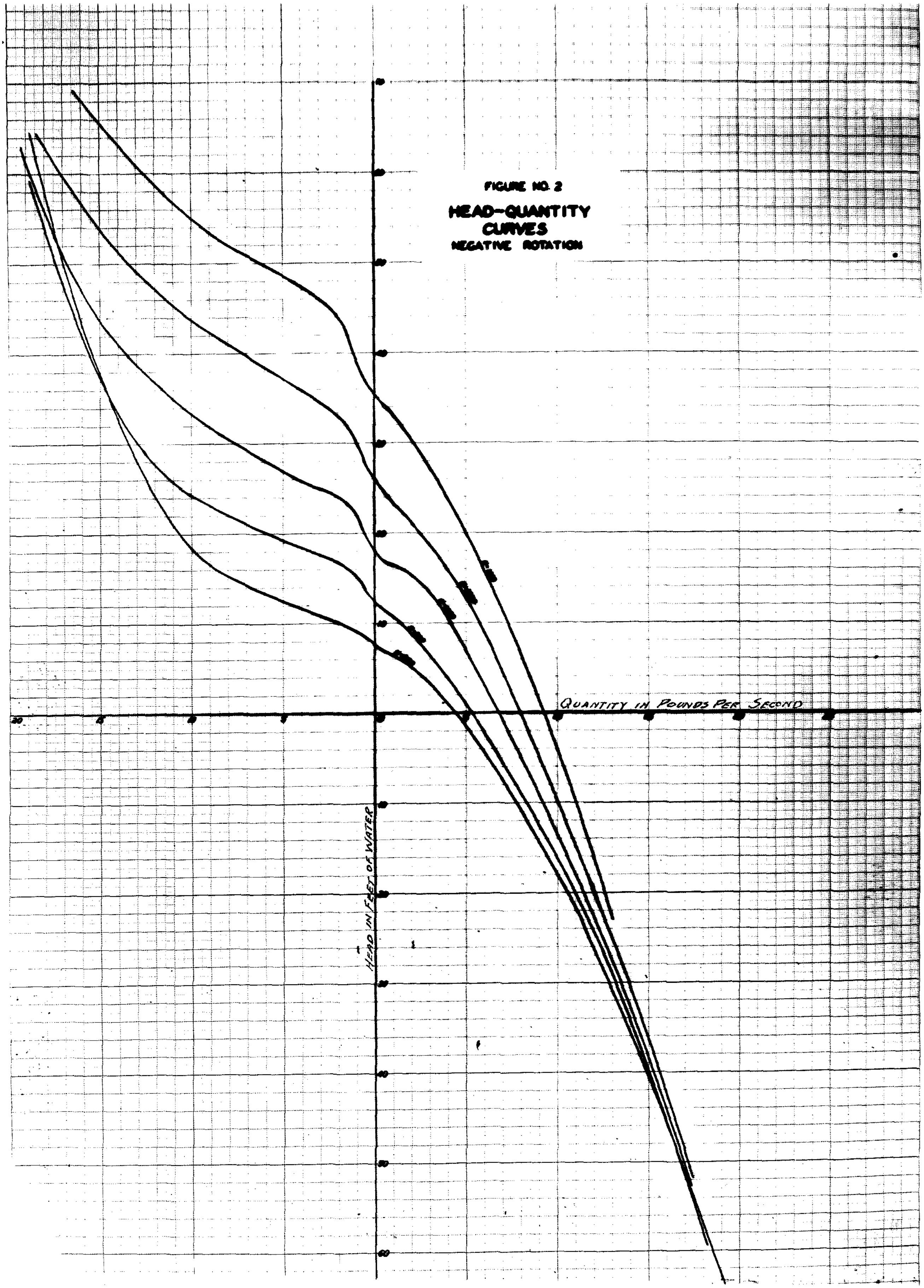


FIGURE NO. 2
HEAD-QUANTITY
CURVES
NEGATIVE ROTATION
QUANTITY IN POUNDS PER SECOND
HEAD IN FEET OF WATER

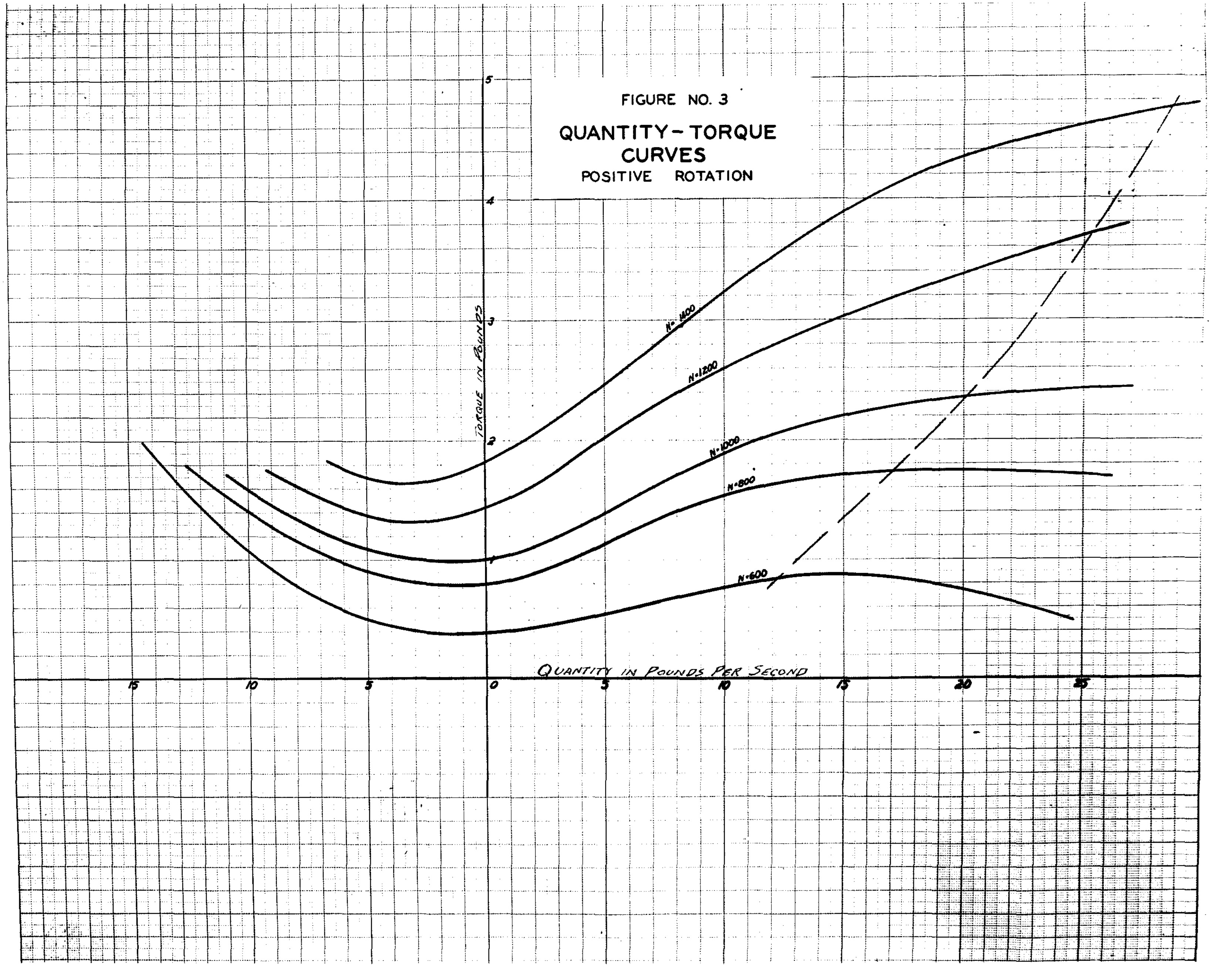


FIGURE NO. 3
QUANTITY - TORQUE CURVES
POSITIVE ROTATION
TORQUE IN POUNDS
QUANTITY IN POUNDS PER SECOND
N=1400
N=1200
N=1000
N=800
N=600
15
10
5
0
5
10
15
20
25
1
2
3
4
5

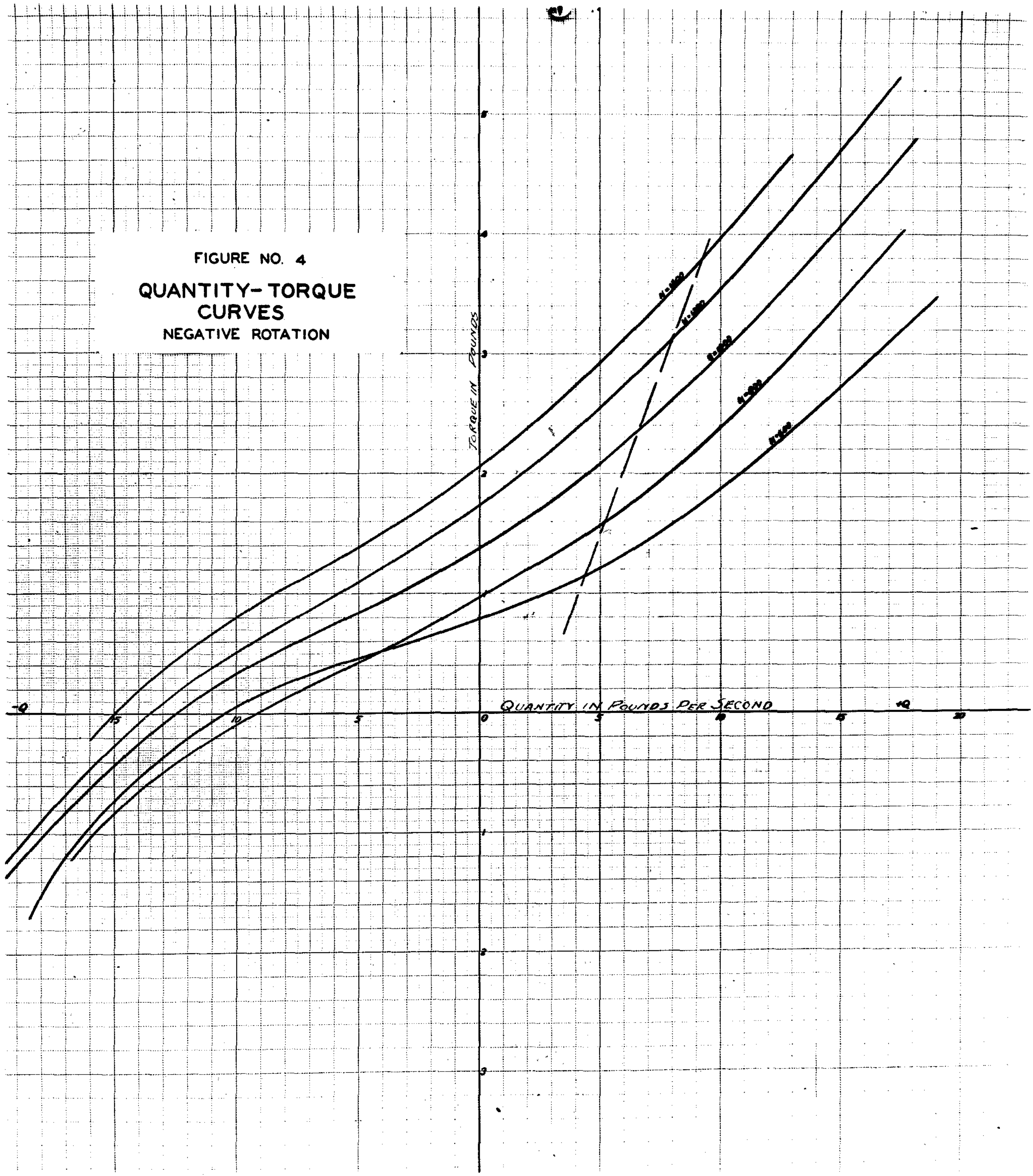


FIGURE NO. 4
QUANTITY-TORQUE CURVES
NEGATIVE ROTATION

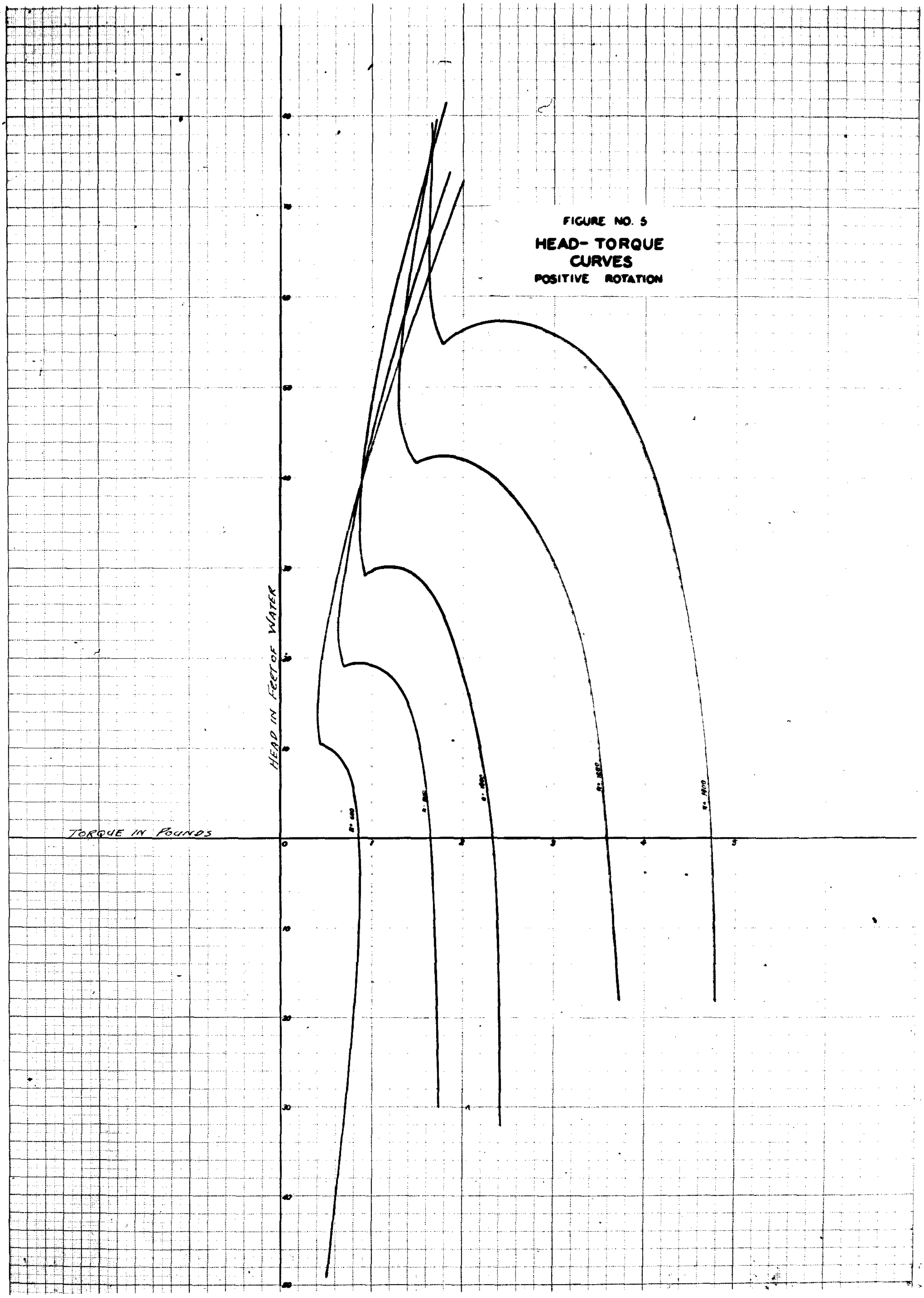


FIGURE NO. 5
HEAD- TORQUE
CURVES
POSITIVE ROTATION
HEAD IN FEET OF WATER
TORQUE IN POUNDS
0
1
2
3
4
5

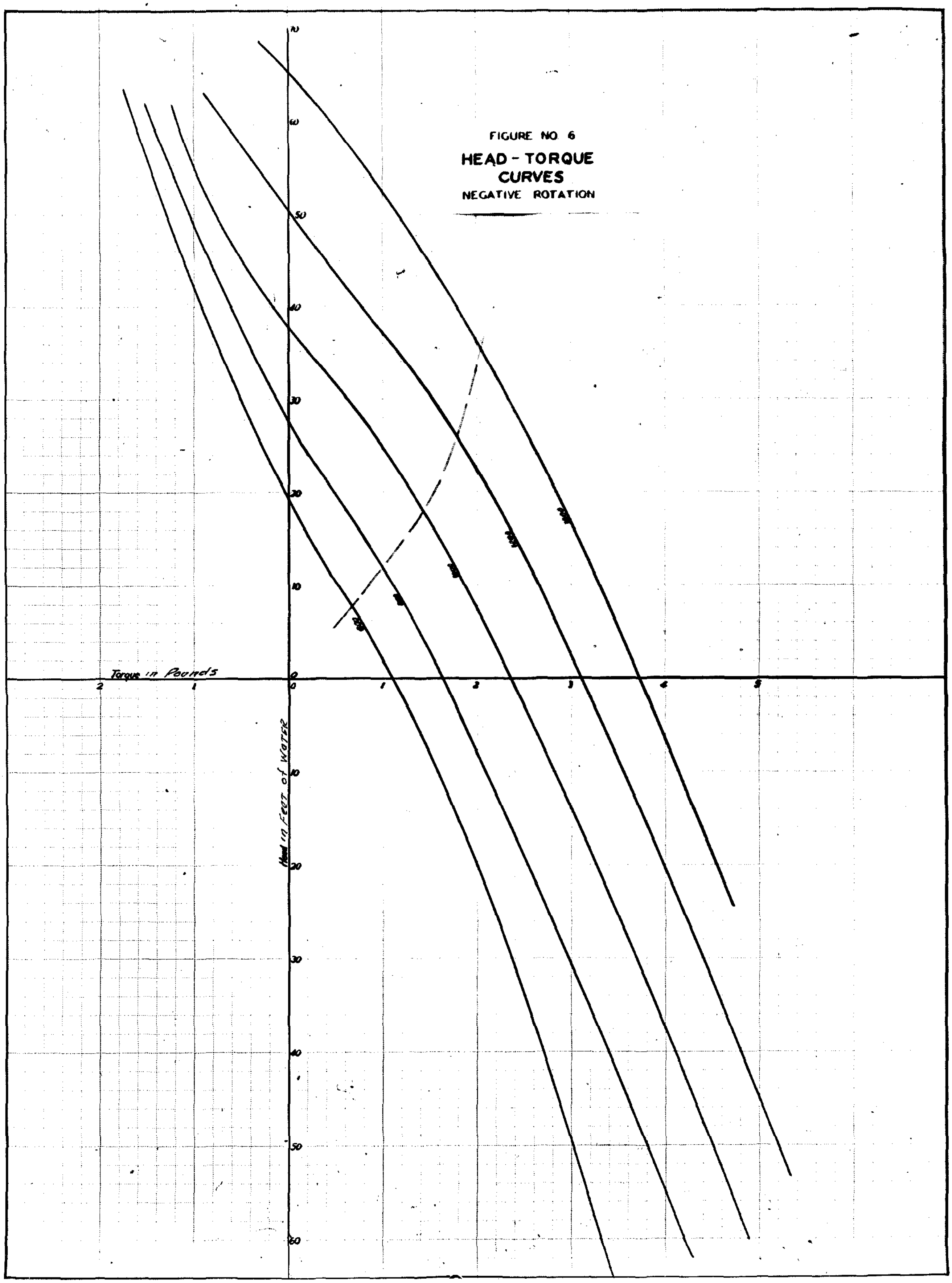


FIGURE NO. 6
HEAD - TORQUE
CURVES
NEGATIVE ROTATION
Torque in Pounds
Head in Feet of Water

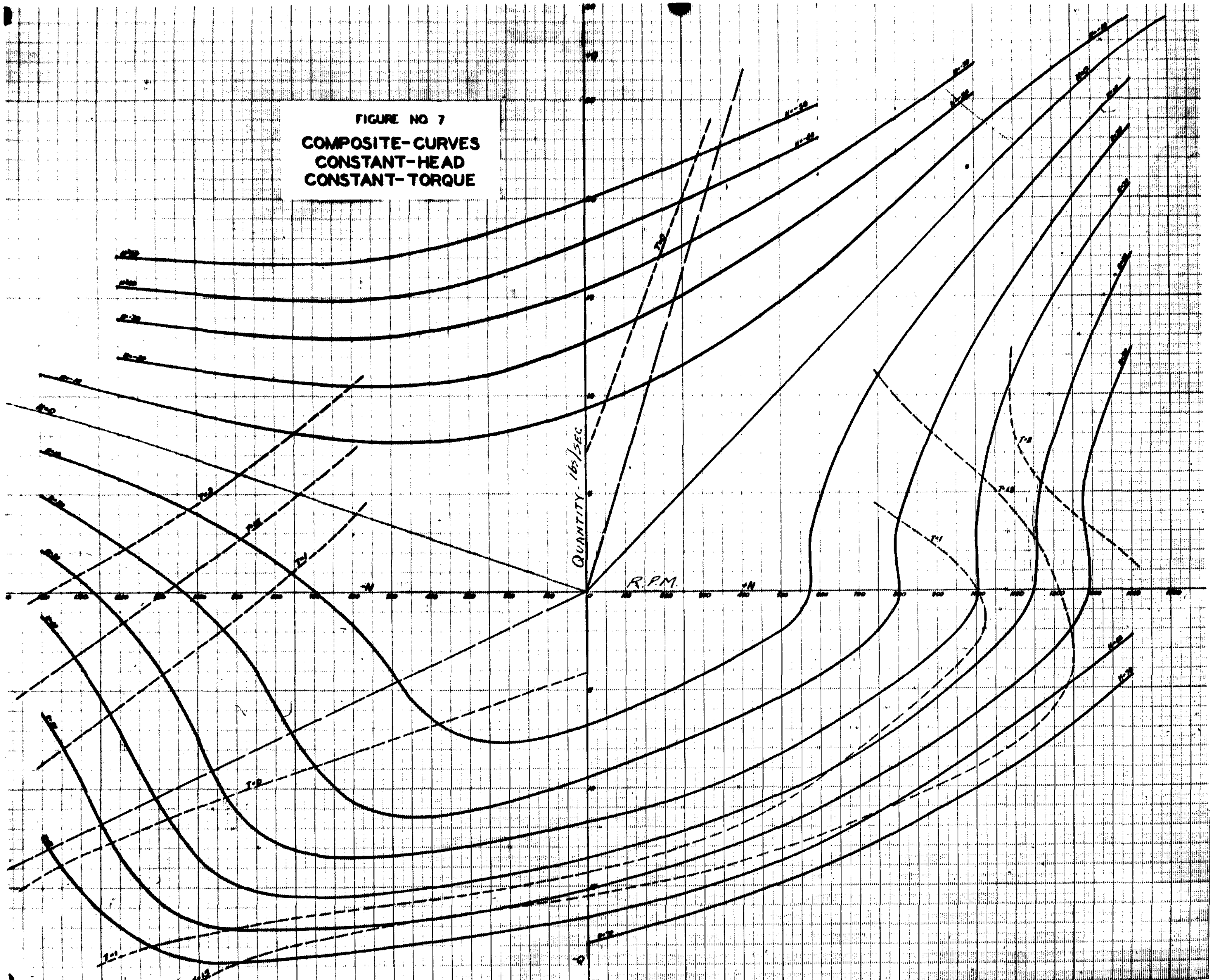


FIGURE NO. 7
COMPOSITE-CURVES
CONSTANT-HEAD
CONSTANT-TORQUE

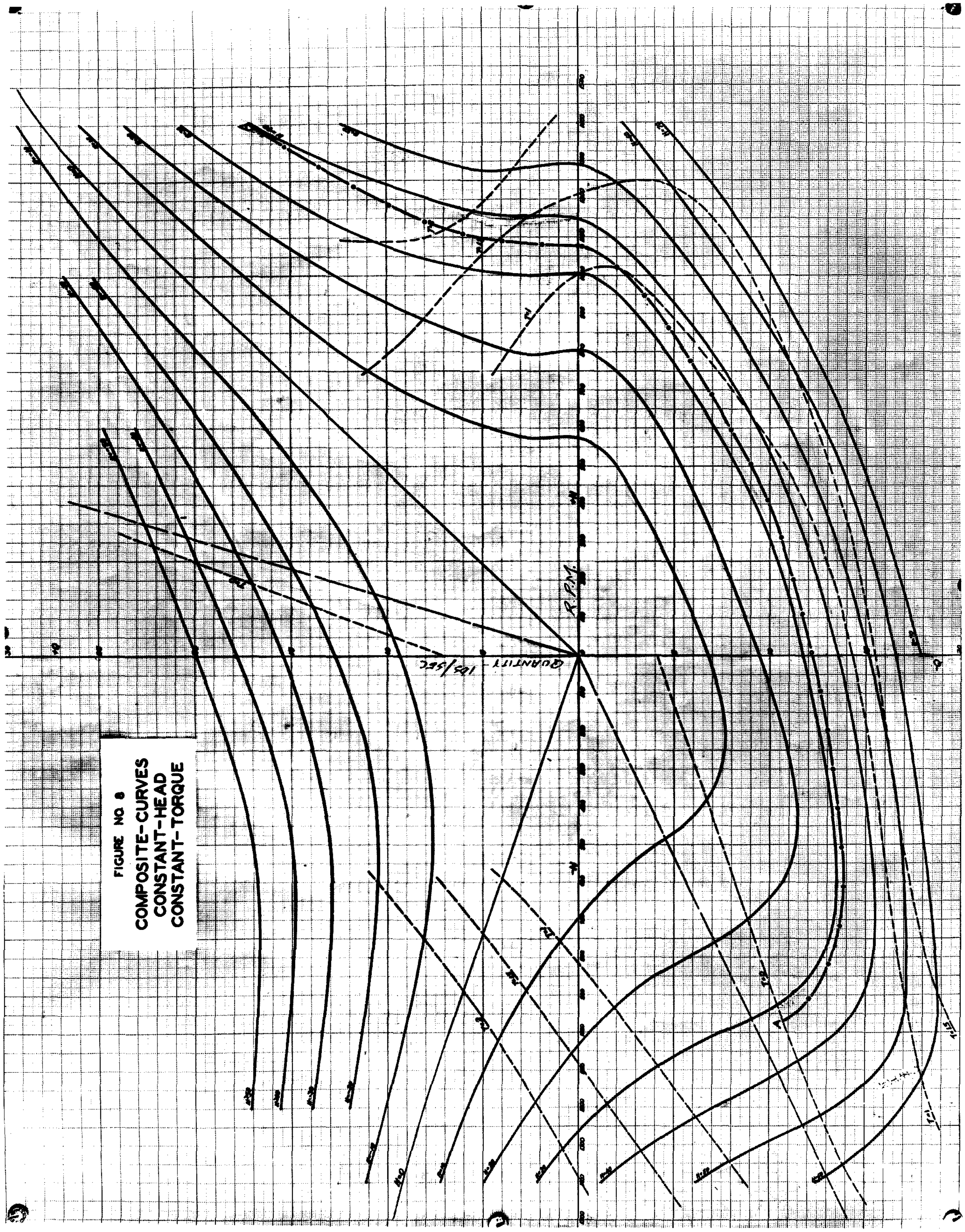


FIGURE NO. 8
COMPOSITE-CURVES
CONSTANT-HEAD
CONSTANT-TORQUE

DISCUSSION.

It is of interest to note that our composite curve agrees in general form with a curve of similar nature plotted by Dr. Robert Knapp from data taken from curves shown in an article in the June 2, 1931 issue of Power. The article referred to was by C. P. Kittrdge on some tests that he had run on centrifugal pumps under abnormal conditions, his tests being run in Germany some time last year. The scale of the diagrams in the magazine article was quite small so that the accuracy of the data taken from them is rather low, being only sufficient to show very general characteristics.

In general the accuracy of our experiments should be higher and the results of more value than those of Mr. Kittrdge due to the fact that we used a pump which required about four times as much power. The normal discharge of our pump was about the same as in the case of the earlier tests, but our head was four or five times as great. To be of value in determining the characteristics of very large pumps it would be necessary to use even much larger pumps and devise a system of securing more accurate readings.

Due to the system used by Mr. Kittrdge it would be impossible to compare our results directly except through the medium of a composite curve as shown in Figure 7.

To secure more accurate readings it would be necessary to use a larger measuring tank. Weighing the water discharged or measuring its volume directly is much more accurate than attempting to measure quantity by use of a weir or Venturi meter. An electrical timing device would be necessary to secure more accurate timing, and automatic speed control should be provided. The only way to get around the inaccuracy due to bearing friction is to use pumps large enough that this item will be small in comparison to the total power input or output. Packing glands always absorb some power, and this factor is never a constant due to the fact that they must be occasionally tightened, and then will wear loose again.

As previously mentioned we controlled the flow by opening and closing the outlet valves. At times we attempted to control by using the inlet valve. This system worked all right and gave the same results up to the point where cavitation began, but beyond this point the results were of no value to us in showing the desired characteristics.

Frequently we ran check tests which in nearly all cases gave identical readings. The only place where we encountered trouble was at shut off head. It was very difficult to secure duplicate readings at this point.

Our values for torque force should be considered as merely a good indication of what should be expected from the pump. As previously stated they are apt to be quite inaccurate due to the unknown and variable quantities of bearing and packing friction.

Although our motor was rated at 1650 r.p.m. we were unable to secure this speed under load. We tried all combinations of voltages, but still could not cover the entire range at any speed higher than 1400 revolutions per minute.

For shut off heads we ran the speed up as high as 1800 r. p. m. for positive rotation and 1700 for negative rotation. We also took a series of readings with the rotor blocked so that it could not turn in relation to the stator and measured the resisting torque force which prevented the motor from rotating on its supporting bearings.

The special curve in Figure 8 was calculated and plotted by Mr. Haynes who had also assisted in the regular computation work. This curve gives an idea of the type of problem that can be solved by using the date secured from tests such as we ran.

So far as we know Mr. Kittrdge is the only one other than ourselves who has run a series of tests on centrifugal pumps under these abnormal conditions.

APPENDIX.

DATA.

The following pages as indicated contain all of the original and calculated data. The head reading as taken must always have the correction of 0.15 added unless there is a note to the contrary under remarks. The last pages give the readings for shut-off head and for blocked rotor.

The tare in all cases is 6.80 pounds. The readings 625NQ to 630NQ, 825NQ to 831NQ, 1025NQ to 1035NQ, 1225NQ to 1234NQ, and 1425NQ to 1440NQ are calculated incorrectly with the tare taken as 6.60. In ploting these we corrected by the factor 0.20.

The reading numbers indicate the speed. That is, numbers in the eight hundreds represent a speed of 800 r.p.m., in the thousands, a speed of 1000 r.p.m., etc. A letter following a number indicates that the condition represented by that letter is negative. Thus 1223N means a speed of 1200 r.p.m. backwards. 1417NQ would mean a speed of 1400r.p.m., negative rotation, negative quantity. 1013 would be positive rotation, positive quantity, 1000 r.p.m..

Data.

Readings.						Calculations.				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water.	Torque Force, lbs.	Remarks.
600	.71	28			7.10			10.42	0.30	
1	.71	28	171	63.2	7.23	143	2.26	10.42	0.43	
2	.65	57.5	337	63.8	7.30	279.5	4.38	9.67	0.53	
3	.54	67.5	451.5	58.2	7.44	384	6.60	8.29	0.63	
4	.23	57.5	452	39.6	7.56	394.5	9.95	4.40	0.76	
5	.05	64	439	31.4	7.60	375	11.93	.63	0.80	No "C".
6	-.31	63	430	25.2	7.68	367	14.57	-5.40	0.87	
7	-1.01	63.5	427	20.6	7.62	363.5	17.63	-14.20	0.81	
8	-1.75	67	423	18.0	7.55	356	19.77	-23.50	0.75	
9	-2.64	64	412	16.0	7.44	348	21.72	-34.64	0.63	
610	-3.12	64	413	15.0	7.38	349	23.25	-40.70	0.57	
11	-3.59	60	417	14.8	7.32	357	24.13	-46.60	0.51	
12	-3.76	68.5	405	13.8	7.32	336.5	24.40	-48.74	0.51	
600 Q	0.86				7.25			12.31	0.45	
601 Q	0.86	49.5	126.5	62.6	7.18	77	1.23	12.31	0.38	
2	1.59	54.5	383.5	63.8	7.30	329	5.15	21.60	0.50	
3	1.14	58.5	241	62.4	7.21	182.5	2.93	15.82	0.40	
4	0.71				7.18			10.42	0.38	
5	2.68	58	446	45.4	7.60	388	8.55	35.16	0.80	
6	3.88	56.5	443.5	34.6	8.08	387	11.19	50.25	1.25	
7	3.01	57.5	450	42.4	7.74	392.5	9.26	39.30	0.93	
8	2.30	52	456	54.4	7.50	404	7.43	30.40	0.70	
9	4.15	59	447	33.0	8.19	388	11.75	53.65	1.35	
610 Q	4.85	56	434	29.0	8.49	378	13.03	62.44	1.63	
11	5.38	58	439	27.0	8.70	381	14.10	69.10	1.83	
12	5.65	59.5	442	26.4	8.85	382.5	14.50	72.50	1.98	
625 Q	2.46	51.5	449	51.6	7.39	397.5	7.71	32.8	0.58	
26	1.93	62.5	448.5	62.8	7.22	386	6.14	26.12	0.62	
27	1.55	56.5	370.5	63.8	7.12	314	4.92	21.36	0.51	
28	1.31	56	298.5	64	7.06	242.5	3.79	18.35	0.46	
29	1.04	56.5	211.5	64.2	7.04	155	2.41	14.95	0.42	
630 Q	0.88	211.5	292	63.6	7.03	80.5	1.27	12.94	0.41	
31	0.78	292	330	63.2	7.04	38	0.61	11.68	0.42	
32	0.74				7.03			11.17	0.41	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
600N	0.45				6.0		~~1.98~~	7.16	0.80	
1	0.30	54	141.5	63.4	5.89	87.5	1.38	5.28	0.41	
2	0.10	56.5	260	63.4	5.72	203.5	3.21	2.76	1.08	
3	-0.07	61	439.5	63.8	5.60	378.5	5.94	-0.88	1.20	No "C"
4	-0.47	58.5	455	58.4	5.37	396.5	6.80	-7.41	1.43	
5	-1.12	64	455	41.2	5.07	391	7.48	-15.58	1.75	
6	-2.14	61.5	436	29.8	4.57	374.5	12.57	-28.34	2.28	
7	-2.91	63	428	25.2	4.21	365	14.49	-38.05	2.63	
8	-3.54	62	425	22.6	3.92	363	16.07	-45.95	2.74	
9	-3.97	60	427	21.6	3.78	367	17.0	-51.40	3.06	
612N	-4.45	63	421	19.6	3.61	358	18.26	-57.45	3.24	
11	-4.83	66	421.5	18.8	3.44	355.5	18.40	-61.20	3.42	
12	-5.01	64	416	18.6	3.34	352	18.41	-69.50	3.47	
600NQ	0.42				6.05				0.75	
1	0.63	54	162	63	6.17	1.08	1.71	6.78	0.63	
2	0.82	53.5	384	63	6.35	330.5	5.25	7.41	0.45	
3	1.11	57	442.5	44.8	6.58	385.5	8.55	11.80	0.20	
4	1.54	55.5	444	35.4	6.86	388.5	10.48	15.44	0.05	
5	2.37	60	441	27.8	7.30	381	13.70	20.59	0.50	
6	3.04	62.5	428	23.8	7.54	365.5	15.35	30.01	0.80	
7	3.68	60.5	421	21.6	8.00	360.5	16.70	34.70	1.17	
8	4.25	43	419	21.2	8.30	376	17.72	47.74	1.45	
9NQ	4.81	57	426	20.0	8.55	364	18.45	54.90 → 61.40	1.70	
625NQ	0.46				6.14			7.67	0.45	
26	0.59	52	105	62.6	6.24	53	0.85	9.31	0.36	
27	0.66	58	205.5	64.2	6.30	147.5	2.30	10.19	0.30	
28	0.77	55	312.5	63.6	6.36	257.5	4.05	11.57	0.24	
29	0.90	59.5	435	63.6	6.47	375.5	5.90	13.20	0.08	
630NQ	1.04	57.5	430	48.8	6.65	372.5	8.04	14.47	0.05	

Data

	Readings					Calculations				
Reading Number	Head Reading	Weight Em	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
801	-2.18	46	398	14.6	8.63	352	24.11	-28.9	1.73	
2	-1.64	53	414	15.8	8.63	361	22.83	-22.7	1.73	
3	-0.72	58	417	18.2	8.66	359	19.72	-10.55	1.75	
4	-0.37	57	430	21	8.52	373	17.75	-6.15	1.61	
5	+0.73	54.5	440.5	33.8	8.44	386.	11.42	+10.67	1.54	
6	1.02	57	447	43	8.33	390	9.17	14.32	1.43	
7	1.27	61.5	456	60.2	8.17	394.5	6.55	17.37	1.21	
8	1.40	58	226	62.6	7.80	168	2.68	19.10	0.94	
9	1.71				7.85			23.0	0.98	
825	1.37				7.25			19.10	0.65	
26	1.38	33	101	62.6	7.35	68	1.08	19.20	0.75	
27	1.42	101	276	63.4	7.46	175	2.76	19.70	0.85	
28	1.37	56.5	302	63.2	7.52	245.5	3.88	19.10	0.88	
801Q	-5.45	51.5	438.5	31	8.66	387	12.49	-70.0	1.75	
2	-5.23	53.5	444.5	33.8	8.53	391	11.56	-67.3	1.62	
3	-4.62	61.0	432.5	35.4	8.33	371.5	10.50	-59.6	1.42	
4	-4.02	69.0	436	39.4	8.18	367	9.32	-52.0	1.28	
5	-3.43	62.5	444	47.6	7.97	381.5	8.02	-44.6	1.10	
6	-2.91	65	443	57.8	7.87	378	6.54	-38.07	1.00	
7	-2.28	64	352	62.0	7.70	288	4.65	-30.17	0.84	
8	-1.99	70.5	269	64	7.68	198.5	3.10	-26.58	0.82	
9	-1.36				7.68			-18.50	0.82	
810Q	-5.63	53.0	433	30.2	8.72	380	12.58	-72.30	1.80	
11	-4.93	56.5	446	35	8.51	389.5	11.13	-63.50	1.60	
12	-4.15	66.0	440.5	39.4	8.23	374.5	9.50	-53.67	1.35	
13	-3.43	67.0	443	47.8	8.05	376	7.87	-44.60	1.17	
14	-2.61	69	436	64	7.83	367	5.73	-34.33	0.97	
15	-1.90	82	272.5	64.6	7.68	190.5	2.95	-25.38	0.83	
825Q	-1.38				7.24			-14.22	0.69	
26	-1.46	52	104.5	63.6	7.22	52.5	0.83	-20.22	0.60	
27	-1.58	104.5	194.5	62.4	7.22	90	1.44	-21.73	0.60	
28	-1.45	194.5	248	62.8	7.22	53.5	0.85	-20.10	0.60	
29	-1.76	58	207.5	64.2	7.23	149.5	2.33	-24.0	0.61	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
830Q	-1.44	63.5	272	63.8	7.23	208.5	3.27	-26.26	.61	
31	-2.22	59.5	341.5	63.2	7.28	282	4.46	-24.77	0.68	
32	-2.50	58.5	405.5	64.2	7.32	347	5.40	-33.3	0.72	
33	-2.73	64.5	449.5	61.8	7.40	385	6.23	-36.2	0.80	
34	-3.05	54.5	453.5	55	7.44	394	7.16	-40.2	0.84	
801N	-4.28	52.5	421	21	2.88	368.5	17.54	-55.30	-4.04	
2	-3.42	66.5	428.5	21.4	3.07	362	16.42	-60.80	3.85	
3	-3.23	62.5	435.5	24.4	3.36	373	15.28	-42.11	3.54	
4	-2.72	61.0	433.5	26	3.63	372.5	14.32	-35.70	3.16	
5	-2.01	66	440	30.2	4.00	374.0	12.38	-26.77	2.88	
6	-1.44	54.5	434	35	4.33	374.5	10.85	-19.50	2.55	
7	-1.01	52	450	42	4.60	398	9.48	-14.20	2.17	
8	-0.53	68	446	47.2	4.90	378	7.68	-8.16	1.45	
9	+0.57	57	314	125	5.58	257	2.06	+8.67	1.27	
810N	+0.35	55	273	65.2	5.48	218	3.34	+5.40	1.38	
11	+0.82				5.85			11.81	1.00	
801NQ	-3.38	27	429	24.8	7.83	402	16.21	-44.0	0.47	
2	-2.86	58	432	25	7.70	374	14.46	-37.45	0.85	
3	-2.54	53	433	27.6	7.44	380	13.76	-33.44	0.54	
4	-4.24	52.5	428	20.8	8.33	375.5	18.05	-54.80	1.45	
5	-3.95	63	421.5	20.8	8.22	358.5	17.25	-51.15	1.32	
6	-3.73	65	417	21	8.12	352	16.76	-48.40	1.22	
7	-3.38	68	427	22.2	7.43	359	16.18	-44.00	1.06	
8	-2.18	52	431	30.6	7.38	379	12.64	-28.40	0.52	
9	-1.88	54	435	36	7.12	381	10.59	-25.13	0.26	
810NQ	-1.83	50.5	438	38.4	6.47	387.5	10.10	-24.50	0.11	
11	-1.57	66	438	47.0	6.71	372	7.42	-21.30	-0.16	
12	-1.35	58.5	426	63.7	6.52	367.5	5.81	-18.37	-0.34	
13	-1.10	70	317	125.2	6.22	247	1.48	-15.33	-0.63	
14	-0.84				5.47			-12.00	-0.88	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
825NQ	-0.86				5.91			-12.70	-0.80	
26	-0.99	52.5	94	64.6	5.97	41.5	0.642	-14.33	-0.73	
27	-1.15	94	196	64.6	6.05	102.0	1.58	-16.35	-0.55	
28	-1.26	58	257.5	63.8	6.14	199.5	3.13	-17.72	-0.45	
29	-1.35	59	353	63.6	6.25	294	4.62	-18.85	-0.35	
830 NQ	-1.44	60	434	64.8	6.32	374	5.77	-20.00	-0.28	
31	-1.55	60	442	54.0	6.42	382	7.08	-21.40	-0.18	
1000	2.13				7.61			28.25	0.80	
1	2.13	53	121.5	61.8	7.69	68.5	1.11	28.25	0.87	
2	2.16	121.5	288.5	62.4	7.82	167.5	2.68	28.61	1.00	
3	2.14	58	262.5	62.4	8.08	304.5	4.88	28.39	1.25	
4	2.02	61	447	53.4	8.30	416	7.80	26.85	1.45	
5	1.68	64	429	32.4	8.62	365	11.27	22.60	1.75	
6	1.22	66.5	431	26.2	8.96	364.5	13.91	16.81	2.08	
7	0.86	66	423	22.2	9.08	357	16.08	12.30	2.21	
8	0.31	61.5	396	18.0	9.17	334.5	18.60	5.40	2.30	
9	-0.12	58.5	417.5	17.0	9.25	359	21.12	-3.02	2.37	
1010	-0.65	63.5	417.5	15.0	9.27	354	23.60	-9.66	2.40	
11	-1.09	65.5	424.5	14.4	9.28	359	24.93	-15.20	2.41	
12	-1.70	66	393	12.6	9.30	327	25.95	-22.83	2.44	
13	-2.04	65	400	12.6	9.33	335	26.60	-27.13	2.45	
14	-2.27	63	389.5	12.2	9.28	326.5	26.77	-30.00	2.41	
15	-2.32	65	401	12.4	9.28	336	27.09	-30.87	2.41	
16	-1.70	61.5	401	13.2	9.32	339.5	25.71	-22.83	2.45	
17	-0.99	64.5	405	14.2	9.25	340.5	23.98	-13.94	2.37	
18	+1.01	65.0	439	26.0	8.88	374	19.70	+14.19	2.01	
1025	2.26				7.53			30.25	0.90	
26	2.39	52	211.5	63	7.91	159.5	2.53	31.50	1.27	
27	2.30	53	170.5	63.8	7.79	117.5	1.84	30.78	1.15	
28	2.30	57	240.5	62.4	7.90	183.5	2.94	30.78	1.26	
29	2.26	56.5	304	63.4	8.00	247.5	3.90	30.25	1.36	
1030	2.19	59.5	428	63.2	8.21	368.5	5.83	29.00	1.56	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
1001Q	2.21				7.95			29.25	1.08	
2	2.31	57	165	126.2	7.87	108	0.856	30.50	1.00	
3	2.79	59.5	394	125.8	7.90	334.5	2.66	36.55	1.03	
4	3.21	65	332	63.8	7.90	267	4.18	41.82	1.03	
5	3.65	60.5	423	63.2	7.95	362.5	5.74	47.35	1.08	
6	4.10	65.5	436	52.4	7.98	370.5	7.07	53.00	1.11	
7	4.63	65	441	44.4	8.14	376	8.47	59.65	1.21	
8	4.91	64.5	442.5	41.6	8.25	378	9.09	63.20	1.36	
9	5.16	65	438	38.8	8.30	373	9.62	66.35	1.40	
1010Q	5.30	64.5	432	37.4	8.35	367.5	9.82	68.10	1.45	
11	5.45	53.5	434	37.4	8.37	385	10.18	70.00	1.47	
12	5.54	65	436	36.2	8.43	371	10.25	71.10	1.53	
13	5.65	58.5	439.5	36.2	8.48	381	10.52	72.50	1.57	
14	5.82	59.5	437	35.2	8.55	377.5	10.72	74.60	1.65	
15	5.88	62	437.5	34.8	8.55	375.5	10.79	76.40	1.65	
16	5.90	60.5	441	35.0	8.56	380.5	10.88	75.60	1.66	
1025Q	4.60	52.5	441	45.8	7.92	388.5	8.48	59.7	1.27	
26	4.22	57.5	442.5	50.4	7.81	385	7.64	54.9	1.17	
27	3.83	57	444.5	61.0	7.69	387.5	6.36	50.0	1.06	
28	3.31	62.5	355.5	63.4	7.59	293	4.62	43.45	0.97	
29	2.85	66.5	267	63.6	7.52	200.5	3.15	37.70	0.90	
1030Q	2.62	57.5	202	63.4	7.49	144.5	2.27	34.80	0.88	
31	2.47	54.5	167.5	63.4	7.47	113	1.78	32.92	0.87	
32	2.33	56.5	133.5	63.6	7.48	77	1.21	31.15	0.88	
33	2.19	133.5	176.5	63.8	7.50	43	0.67	29.40	0.84	
34	2.16				7.58			29.04	1.05	
1000N	-4.55	51.5	414	20.0	2.11	362.5	18.10	-58.6	4.79	
1	-4.45	67	422.5	19.8	2.17	355.5	17.95	-57.40	4.72	
2	-4.62	66	423	19.6	2.10	357	18.20	-59.50	4.80	
3	-4.17	62	422	22.4	2.28	360	16.07	-53.85	4.60	
4	-3.68	67	428.5	21.8	2.49	361.5	16.58	-47.70	4.40	
5	-3.23	66.5	434	23.6	2.70	367.5	15.57	-42.05	4.18	
6	-2.63	65	423	25.2	2.98	358	14.20	-34.52	3.88	
7	-1.88	65.5	433	29.4	3.33	367.5	12.50	-25.12	3.53	

Data

Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head Feet of Water	Torque Force-lbs	Remarks
	Readings					**Calculations**				
1008N	-1.10	64.5	441	37	3.78	376.5	10.18	-15.31	3.05	
9	-0.45	64	440.5	44.6	4.10	376.5	8.44	-7.15	2.73	
1010N	+0.10	55	442	61.4	4.56	387	6.30	+12.5	2.26	No."C"
11	+0.33	61	386	63.2	4.75	325	5.14	+5.65	2.07	
12	0.88	61	338	64.2	5.11	277	4.31	+12.56	1.71	
13	1.18	60	135	63	5.32	75	1.19	+16.31	1.50	
14	1.34				5.42			18.33	1.40	
1000NQ	4.81	26	414	20.4	8.12	388	19.00	61.9	1.27	
1	4.75	55	417	19	8.12	362	19.02	61.17	1.27	
2	4.64	58	409	18.8	8.04	351	18.68	59.80	1.20	
3	4.37	61	410	19.6	7.91	349	17.80	56.36	1.08	
4	3.91	57	422	21.6	7.60	365	16.90	50.60	0.80	
5	3.27	57.5	430.5	25.6	7.15	373	14.57	42.55	0.35	
6	2.77	53	435	31.6	6.70	382	12.10	36.28	0.10	
7	2.36	59	446	46.8	6.22	387	8.27	31.14	0.58	
8	1.89	64.5	298.5	63.6	5.85	234	3.68	25.22	0.95	
9	1.80	52	172.5	63.2	5.67	120.5	1.91	24.12	1.13	
1010NQ	1.51	172.5	219	63.8	5.53	46.5	0.729	20.45	1.27	
11	1.35				5.46			18.46	1.58	
1025NQ	1.33				5.61			18.6	1.00	
26	1.52	51.5	96.5	61.8	5.68	45	0.73	21.0	0.41	
27	1.73	53	158.5	64.2	5.78	105.5	1.64	23.65	0.82	
28	1.80	56.5	229.	63.8	5.87	172.5	2.70	24.50	0.68	
29	1.96	59.5	331.	62.8	6.02	271.5	4.32	26.55	0.58	
1030NQ	2.09	53	439	63.8	6.18	386	6.05	28.20	0.42	
31	2.32	58	445	47.8	6.35	387	8.10	31.10	0.25	
32	2.57	61.5	436	36.2	6.58	374.5	10.34	34.20	0.02	
33	1.93	55.5	346.5	63.8	6.10	291	4.56	26.15	0.50	
34	1.97	61	349.5	63.4	6.09	288.5	4.55	26.70	0.49	
35	1.83	57	223	62.6	5.89	166	2.65	24.80	0.70	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
1201	3.22	26	204.5	61.4	8.61	178.5	2.91	42.0	1.72	
2	3.22	74.5	256	62.4	8.65	181.5	2.91	42.0	1.74	
3	3.20	74	347	60.8	8.83	273	4.49	41.70	1.93	
4	3.14	61	447	58.8	9.08	386	6.56	40.90	2.17	
5	3.14	60	438	57.8	9.08	378	6.54	41.00	2.17	
6	2.88	55.5	435	37.4	9.48	379.5	10.13	37.8	2.37	
7	2.72	52.5	433	33.0	9.65	380.5	11.51	35.7	2.72	
8	2.38	51.5	433.5	27.0	9.92	382	14.13	31.35	2.49	
9	1.97	57.5	410	21.0	10.15	352.5	16.79	26.25	3.20	
1210	1.56	59	400.5	18.6	10.25	341.5	18.35	21.10	3.30	
11	1.26	59.5	423	18.2	10.38	363.5	19.42	17.34	3.43	
12	0.90	64	425	17.0	10.40	361	21.21	12.81	3.45	
13	0.55	61	410	15.2	10.48	349	22.95	8.42	3.53	
14	2.28	52.5	425	24.8	10.00	372.5	15.00	30.20	3.06	
15	1.84	54	435	22.6	10.17	381	16.84	24.65	3.22	
16	1.59	66	426	20.6	10.17	360	17.46	21.50	3.22	
17	1.58	66	431	20.0	10.18	365	18.24	21.36	3.23	
18	2.18	53	437	24.4	10.11	384	15.73	28.40	3.17	
19	2.13	54	437	24.2	10.12	383	15.82	28.30	3.18	
1220	3.25	54.5	236	63.4	8.68	181.5	2.85	42.30	1.78	
21	3.19	59.5	360	62.8	8.84	300.5	4.78	41.60	1.92	
22	3.13	56	442.5	57.6	9.12	386.5	6.71	40.80	2.20	
23	2.69	57	437	33.8	9.64	380	11.23	35.40	2.71	
24	2.00	65	442.5	23.2	10.13	377.5	16.26	26.70	3.20	
25	1.88	65	418.5	18.0	10.38	353.5	19.62	16.34	3.43	
26	1.52	61.5	425	16.0	10.47	363.5	22.70	8.05	3.52	
1235	0.19	52	400	15	10.39	348	23.2	4.27	3.69	
36	0.90	70	424	16.8	10.32	354	21.06	13.19	3.62	
37	2.77	63	446	34.8	9.42	383	11.00	36.68	2.73	
38	3.17	61	414	64.6	8.69	353	5.46	41.65	2.02	
39	3.20	71	237.5	63.4	8.37	166.5	2.62	43.00	1.70	
1240	?3.34	52.5	223	65.4	8.40	170.5	2.61	43.85	1.74	

Data

Readings						Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
1225NQ	1.96				5.23			26.5	-1.40	
26	2.19	52	105.5	63.2	5.32	53.5	0.84	27.4	-1.30	
27	2.43	105.5	206	63.0	5.44	100.5	1.59	32.45	-1.16	
28	2.60	59	209.5	63.4	5.52	150.5	2.37	34.60	-1.01	
29	2.73	54.5	313	63.4	5.68	258.5	4.08	36.10	-0.45	
1230NQ	2.85	59.5	431	64.2	5.88	371.5	5.78	37.70	-0.70	
31	3.06	55	447	53.0	6.04	392	7.39	40.40	-0.56	
32	2.80	56.5	371.5	64.4	5.80	315	4.89	37.10	-0.80	
33	2.75	55.5	364.5	63.2	5.79	309	4.89	36.50	-0.81	
34	2.50	58.0	191	63.8	5.50	133	2.08	33.30	-1.10	
1400	4.25				8.61			54.40	1.75	
1	4.44	52	224	64.2	9.02	172	2.68	57.28	2.15	
2	4.23				8.63			54.60	1.76	
3	4.41	57	290	63.8	9.17	233	3.65	56.40	2.25	
4	4.31	66	431	63.6	9.45	365	5.74	55.60	2.57	
5	4.25	71	435.5	44.2	9.84	364.5	8.25	54.40	2.95	
6	4.00	68	445	33.8	10.31	377	11.15	51.80	3.40	
7	3.27	68.5	433.5	23.0	10.95	365	15.87	42.55	4.05	
8	2.30	54.5	408	17.4	11.20	353	20.30	30.40	4.36	
9	1.45	65.5	404.5	14.4	11.42	339	23.54	19.71	4.53	
1410	0.61	52	383	12.8	11.55	331	25.85	9.55	4.65	
11	0.05	54	383	11.6	11.60	329	28.37	0.63	4.72	No "C"
12	-0.45	37	380	11.6	11.65	343	29.58	-7.55	4.78	
13	-1.05	31	355	11.0	11.65	324	29.46	-14.83	4.78	
1425	4.28				8.58			55.6	1.42	
26	4.30	26	79.5	64.2	8.68	53.5	0.834	55.9	2.01	
27	4.35	79.5	183	63.4	8.78	103.5	1.63	56.5	2.12	
28	4.37	183	350	63.2	8.92	167	2.64	56.7	2.25	
29	4.39	65	332.5	63.6	9.18	267.5	4.20	57	2.50	
1430	4.37	66	423.5	63.8	9.38	357.5	5.60	56.7	2.69	
31	4.24	61	451	58	9.48	390	6.73	55.1	2.80	
32	4.22	65	445	47.8	9.73	380	7.95	54.9	3.03	
33	4.08	61	445	38.4	10.03	384	10.00	53.1	3.33	
34	3.84	57.5	436	31.4	10.37	378.5	12.05	50.1	3.67	

Data

	Readings					Calculations				
Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
1200N	1.93				5.02			25.74	1.80	
1	1.80	26	73	62.6	5.02	47.0	0.76	24.17	1.80	
2	1.48	57	192	62.4	4.77	135	2.16	20.09	2.06	
3	1.25	59	279	63.2	4.55	220	3.48	17.20	2.27	
4	1.05	57.5	329	63.4	4.35	271.5	4.28	14.69	2.47	
5	0.82	64	392.5	63.2	4.20	328.5	5.20	11.80	2.62	
6	0.60	63	435	63.4	4.08	372	5.87	9.04	2.75	
7	0.33	65.5	438	54.2	3.92	372.5	6.88	5.65	2.92	
8	0.10	63	446	50.2	3.80	383	7.64	1.26	3.04	No "C"
9	0.10	62	439	46.0	3.68	377	8.20	1.26	3.16	No "C"
1210N	0	61	440	47.9	3.72	379	8.00	0	3.13	No "C"
11	-0.31	68	446	41.8	3.54	378	9.05	-5.40	3.32	
12	-0.65	64	444	38.0	3.34	380	10.00	-9.66	3.53	
13	-1.06	63.5	441.5	34.6	3.18	378	10.91	-14.81	3.70	
14	-1.23	65.5	433	32.2	3.08	367.5	11.40	-16.45	3.83	
15	-1.44	67	431	30.6	2.94	364	11.90	-19.59	3.93	
16	-1.77	68	430	28.8	2.70	362	12.57	-23.35	4.17	
17	-3.60	62.5	425	22.0	1.81	362.5	16.48	-46.70	5.10	
18	-3.18	57.5	419	23.0	2.04	361.5	15.70	-41.40	4.86	
19	-2.61	65	427	24.8	2.34	362	14.60	-34.25	4.55	
1220N	-1.73	77	430	28.4	2.74	353	12.41	-23.20	4.13	
21	-2.18	56.5	426	27.0	2.63	367.5	13.67	-28.90	4.25	
22	-3.37	61	425.5	22.6	2.03	364.5	16.10	-43.85	4.85	
23	-3.97	65	417	20.2	1.68	352	17.42	-51.40	5.20	
24	-4.11	68.5	412	19.9	1.57	343.5	17.19	-51.90	5.33	
1201NQ	2.72	29	302.5	63.6	5.72	273.5	4.30	35.70	-1.15	
2	3.18	58.5	443.5	48	6.18	385	8.03	41.5	-0.68	
3	3.65	52	442	32.6	6.70	390	11.96	47.4	-0.17	
4	3.94	55.5	438	27.0	6.98	382.5	14.15	51.1	+0.11	
5	4.23	56	440	24.8	7.25	384	15.48	54.7	+0.39	
6	4.43	55	431	23.0	7.39	376	16.34	57.3	0.53	
7	4.58	56	427	22.2	7.50	371	16.70	59.1	0.65	
8	4.73	55	434.5	22.0	7.63	379.5	17.26	61.1	0.78	
9	4.80	65.5	433.5	20.6	7.70	368.5	17.85	61.9	0.84	
1210NQ	4.83	54	428	21.0	7.75	374	17.81	62.3	0.88	

Data

Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
	Readings					Calculations				
1241	3.22				8.03			42.32	1.38	
42	3.22	54.5	184.5	60.8	8.27	130	2.14	42.32	1.62	
43	3.22	56.5	301	63.6	8.46	244.5	3.84	42.32	1.78	
44	3.20	59.0	398.5	63.8	8.64	339.5	5.32	42.10	1.97	
45	3.07	65.0	443	50.0	8.98	374	7.54	40.44	2.30	
1201Q	3.19				8.38			41.58	1.50	
2	3.20	48	120	124.2	8.37	72	0.58	41.70	1.49	
3	3.61	52.5	303	125	8.28	250.5	2.00	46.85	1.40	
4	4.06	62	296.5	63.6	8.27	234.5	3.69	52.50	1.39	
5	4.55	60.5	381	64.2	8.30	320.5	4.99	58.60	1.41	
6	4.96	63	443	62.2	8.36	380	6.11	63.80	1.46	
7	4.96	66	441	61.8	8.37	375	6.07	63.80	1.47	
8	5.27	63.5	438	52.2	8.39	374.5	7.18	67.72	1.50	
9	5.47	64	436	50.6	8.48	382	7.55	70.20	1.58	
1210Q	5.64	59	441.5	48	8.52	382.5	7.97	72.37	1.62	
11	5.74	58.5	441.5	46.4	8.58	383	8.25	73.60	1.67	
12	5.89	57	436.5	45	8.59	379.5	8.43	75.50	1.68	
13	5.88	62.5	446	44.6	8.60	383.5	8.60	75.40	1.69	
14	6.01	62	433.5	42	8.61	371.5	8.85	77.00	1.70	
15	6.08	57	437.5	42	8.62	380.5	9.06	77.86	1.71	
16	6.12	63.5	436	40.8	8.62	372.5	9.13	78.40	1.71	
17	6.15	61	433	40.6	8.64	372	9.16	78.57	1.73	
18	6.15	59	436.5	41	8.66	377.5	9.21	78.57	1.75	
19	5.26	51	439	55.2	8.48	388	7.03	67.60	1.57	
1225Q	3.10				8.11			40.85	1.45	
26	3.20	26.5	75	63.8	8.02	48.5	0.76	42.10	1.36	
27	3.28	75	144.5	63.9	7.99	69.5	1.09	43.10	1.35	
28	3.46	144.5	254	64.[illegible]	7.93	[illegible]	1.70	45.35	1.28	
29	3.73	63.5	224	62.8	7.91	160.5	2.56	48.15	1.26	
1230Q	4.04	57.5	295.5	64.4	7.92	238	3.70	52.65	1.27	
31	4.26	62	349	63.4	7.91	287	4.52	55.40	1.26	
32	4.53	58.5	386	64.4	7.95	327.5	5.08	58.75	1.31	
33	4.89	61	438	60.0	8.07	377	6.28	63.32	1.42	
34	5.28	62	440.5	52.4	8.14	378.5	7.22	68.20	1.49	

Data

Reading Number	Head Reading	Weight Em.	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force-lbs	Remarks
	Readings					Calculations				
1400Q	6.35	57	446	61.4	8.48	389	6.33	81.4	1.80	
1	5.85	56	400	64	8.32	344	5.38	75.2	1.65	
2	5.01	55.5	254	62.8	8.25	198.5	3.16	64.6	1.60	
3	4.30	56	123	63.8	8.35	67	1.05	55.6	1.70	
4	4.24				8.50			54.8	1.85	
1425Q	4.32				8.63				1.96	
26	4.40	51	122	64.2	8.42	71	1.11	56.15	1.75	
27	4.65	122	237	63.2	8.34	115	1.82	57.15	1.74	
28	4.42	66	233	63	8.35	167	2.65	59.10	1.69	
29	5.57	59	349	63.8	8.34	290	4.54	63.70	1.68	
1430Q	6.20	63.5	442.5	64	8.41	379	5.92	71.90 → 79.80	1.76	
1400N	2.71				4.62			35.60	2.00	
1	2.14	50	214	63.4	4.16	164	2.59	28.4	2.48	
2	1.61	55.5	334	61.6	3.78	278.5	4.52	21.75	2.85	
3	0.90	59.5	456.5	59.6	3.38	397	6.66	12.82	3.25	
4	0.32	62	435.5	45.6	3.08	373.5	8.20	5.54	3.56	
5	-0.05	60	439	40.6	2.85	379	9.34	-0.63	3.83	No "C"
6	-0.37	52	435.5	36.8	2.63	383.5	10.41	-0.61	4.05	
7	-1.00	61	434.5	31.6	2.35	373.5	11.80	-14.10	4.34	
8	-1.70	51.5	431.5	24.2	2.03	380	13.01	-2290	4.67	
1400NQ	2.55				4.75			35.51	2.08	
1	2.75	50.5	43.5	63.4	4.45	43	0.68	36.02	1.86	
2	3.31	43.5	244	63.0	5.12	300.5	2.39	42.42	1.70	
3	3.58	59.5	364	63.0	5.40	304.5	4.84	46.45	1.40	
4	3.96	58	439.5	47.4	5.78	381.5	8.05	51.20	1.02	
5	4.48	62	443	33.2	6.20	381	11.48	57.15	0.70	
6	4.72	59	440	29.2	6.47	381	13.04	60.70	0.34	
7	5.01	55.5	431.5	25.2	6.78	376	14.91	64.45	-0.01	
8	5.24	60	424.5	22.8	7.04	364.5	16.90	67.35	0.23	
9	5.36	59.5	435	22.4	7.12	375.5	13.94	68.80	0.30	

Data

Reading Number	Head Reading	Weight Empty	Weight Full	Time	Torque Reading	Quantity	Quantity lbs/sec	Head-Feet of Water	Torque Force, lbs.	Remarks
Readings						Calculations				
1425NQ	4.99	26	432	29.2	6.56	406	13.9	64.6	0.08	
26NQ	3.86	56.5	443	57.8	5.64	386.5	6.69	50.4	0.95	
27	3.67	60	343.5	63.0	5.36	283.5	4.50	48.0	1.25	
28	3.50	56	225.5	63.6	5.14	169.5	2.67	45.95	1.46	
29	3.30	54.5	171.0	64.0	5.04	116.5	1.83	43.40	1.55	
1430NQ	2.66				4.78	45.5		35.30	1.81	
31	2.82	53.5	79	64.2	4.891	78.5	0.71	37.30	1.70	
32	3.06	110.5	184	64.2	4.95	116	1.22	40.40	1.65	
33	3.29	56	172	64.4	5.04	153	1.80	43.30	1.55	
34	3.42	55	208	63.6	5.12	192	2.41	44.90	1.49	
35	3.52	58	250	7.4	5.21	274	3.00	46.10	1.40	
36	3.63	55	329	62.8	5.38	379	4.36	47.40	1.20	
37	3.82	61.5	440.5	63.2	5.57	226.5	6.00	50.00	1.00	
38	3.56	50	276.5	63.4	5.17	117.5	3.57	46.60	1.42	
39	3.30	82.5	200	62.8	5.07		1.87	43.40	1.50	
1440NQ	2.67				4.79			35.40	1.80	
	ROTOR BLOCKED									
		+Q								
	4.51	48.5	401	16.6	5.25	352.5	21.2	58.9	-1.56	
	3.86	61	413.5	17.6	5.42	352.5	20.01	50.0	-1.40	
	2.88	67	426	20.6	5.77	359	17.4	37.7	-1.04	
	2.27	65	427	23.4	5.47	362	15.44	30.05	-0.85	
	1.65	68	432	27.6	6.10	364	13.18	22.22	-0.70	
	0.96	67	442.5	35.2	6.20	375.5	10.66	13.58	-0.60	
	0.30	68.5	447	59.6	6.37	378.5	6.35	5.27	-0.42	
	0.10	67	226	63.4	6.38	159	2.51	2.76	-0.41	
					6.40			0	—	

Data

Reading Number	Head Reading	Weight Em.	Weight Full	Time - Sec	Torque Reading	Quantity	Quantity lbs/Sec	Head-Feet of Water	Torque Force - lbs	Remarks
	Readings					Calculations				
	ROTOR BLOCKED -Q									
	5.21	34	424	22	8.45	370	17.72	67.0	2.08	
	4.62	71	414	21	8.80	343	16.32	59.6	1.43	
	4.04	52	427.5	24.2	8.55	375.5	15.51	52.3	1.67	
	3.48	65.5	426	24.8	8.30	360.5	14.53	45.2	1.45	
	2.67	64	438	29.2	7.75	374	12.80	35.1	0.94	
	2.01	64	444	34.4	7.45	380	11.04	26.8	0.64	
	1.28	66	449	43.0	7.05	383	8.92	17.6	0.24	
	0.63	63	456	63.0	6.80	343	6.55	9.44	0.00	
	0.18	62	312	63.2	6.78	250	3.96	3.77	-0.02	

Data

Shut Off Heads

Readings			Calculations			Readings			Calculations	
Speed R.P.M.	Head Reading	Torque Reading (+N)	Head-Feet of Water	Torque Force-lbs		Speed R.P.M.	Head Reading	Torque Reading (−N)	Head Ft. of Water	Torque Force-lbs
550	0.70	7.04	10.32	0.44		550	0.37	6.06	616	0.54
600	0.78	7.10	11.32	0.50		600	0.45	6.00	7.17	0.60
650	0.92	7.18	13.09	0.58		650	0.54	5.94	8.30	0.66
700	1.16	7.21	16.10	0.60		700	0.64	5.89	4.56	0.71
750	1.25	7.25	17.23	0.65		750	0.76	5.81	11.08	0.79
800	1.46	7.34	19.09	0.72		800	0.83	5.76	11.94	0.84
850	1.65	7.43	22.25	0.82		850	0.97	5.66	13.70	0.44
900	1.80	7.50	24.15	0.89		900	1.06	5.61	14.84	0.49
950	1.98	7.58	26.40	0.95		950	1.17	5.56	16.23	1.04
1000	2.17	7.68	28.80	1.06		1000	1.31	5.49	17.98	1.11
1050	2.38	7.79	31.4	1.15		1050	1.44	5.42	19.60	1.18
1100	2.60	7.89	34.2	1.25		1100	1.60	5.34	21.65	1.26
1150	2.87	8.03	37.6	1.39		1150	1.72	5.26.	23.15	1.34
1200	3.10	8.16	40.5	1.51		1200	1.88	516	25.15	1.44
1250	3.33	8.30	43.4	1.69		1250	2.03	509	27.05	1.51
1300	3.71	8.46	48.2	1.80		1300	2.21	496	29.80	1.64
1350	3.96	8.56	51.4	1.90		1350	2.40	484	31.70	1.77
1400	4.26	8.70	55.1	2.03		1400	2.57	473	33.85	1.87
1450	4.60	8.87	59.3	2.20		1450	2.80	460	36.7	2.02
1500	4.90	9.02	63.2	2.34		1500	3.00	446	39.2	2.17
1550	5.28	9.22	67.9	2.53		1550	3.17	436	41.4	2.27
1600	5.66	9.40	72.7	2.71		1600	3.40	421	44.2	2.43
1650	6.01	9.54	77.2	2.84		1650	3.64	406	47.3	2.57
1700	6.48	9.68	83.0	3.00		1700	3.92	386	50.8	2.78
1750	6.85	9.84	87.6	3.15						
1800	7.25	10.11	92.6	3.40						