RESULTS OF THE TESTING OF A 12-INCH, STAINLESS STEEL, TWO-STAGE, DEEP-WELL, TURBINE PUMP

FOR

BECHTEL CORPORATION,
Twenty Two Bush Street
SAN FRANCISCO, CALIFORNIA

CIVIL ENGINEERING DEPARTMENT

Engineering Research Center
Foothills Campus
Colorado State University
Fort Collins, Colorado

June 1967

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James F. Ruff
and
Morris M. Skinner

Colorado State University
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PREFACE

The Engineering Research Center at Colorado State University is located between two lakes, Horsetooth Reservoir of the Colorado Big Thompson Project, and College Lake. The laboratories of the Center were strategically placed to utilize the high head, 250 feet, available from the reservoir and the storage capacity of the lakes. The Center is the focal point for research and graduate education.

There are five principal parts to the Center: the offices for staff and graduate students, the hydraulics laboratory, the fluid dynamics laboratory, the hydromechanical laboratory and the outdoor hydraulics - hydrology laboratory. The research activities of the center are in fluid mechanics, hydraulics, hydrology, ground-water, soil mechanics, hydro-biology, geomorphology and environmental engineering.

The hydraulics laboratory includes 50,000 square feet of floor space in which basic and applied research activities are undertaken. The floor of the laboratory is constructed over a large sump system, having one acre-foot capacity, which permits recirculation of water through the various research facilities. Generally, pumps are used for recirculation but the high head and large flow capacity from the reservoir can also be utilized. A volumetrically calibrated sump is located in the laboratory and is used for special studies. The calibrated sump has a capacity of 12,000 gallons.

The Center includes well equipped machine and woodwork shops. All research facilities of the Center are constructed on site and in the case of this study, necessary metal work and welding were accomplished by personnel in the shops.

TABLE OF CONTENTS

LIST OF FIGURES

RESULTS OF THE TESTING OF A 12-INCH, STAINLESS STEEL, TWO-STAGE, DEEP-WELL, TURBINE PUMP

by

James F. Ruff[(1)] and Morris M. Skinner[(2)]

Introduction

The purpose of this study was to establish head-capacity, efficiency, and horsepower curves for a 12-inch stainless steel, two-stage, deep-well, turbine pump utilizing certain impeller types, and sump configurations. Three types of impellers were tested and two sump configurations used.

1. "Standard Impeller - polyethylene type wear rings" with sump boundary located 24 inches from centerline of pump. (A Runs).

2. "Standard Impellers - polyethylene type wear rings" with sump boundary located 11 inches from centerline of pump. (B Runs).

3. "Polished Impellers - cast iron wear rings" with sump boundary located 24 inches from centerline of pump. (C Runs).

4. "Oversize Impellers - cast iron wear rings" with sump boundary located 24 inches from centerline of pump. (D Runs).

5. "Standard Impellers - cast iron wear rings" with sump boundary located 24 inches from centerline of pump. (E Runs).

6. "Standard Impellers - cast iron wear rings" with sump boundary located 11 inches from centerline of pump. (F Runs).

7. "Standard Impellers - cast iron wear rings" with impellers lowered to 0.093 inches clearance from bottom of bowls and with sump boundary located 11 inches from centerline of pump. (G Runs).

8. "Standard Impellers - polyethylene type wear rings" with sump boundary located 24 inches from centerline of pump. (H Runs).

9. "Standard Impellers - polyethylene type wear rings" with sump boundary located 24 inches from centerline of pump and performance measurements made after 8 hours of continuous operation. (I Runs).

The "Standard Impellers" refer to that impeller type in use, prior to this test, at Bingham Canyon precipitation plant of Kennecott Copper Corporation. The impeller is 14.250 inches in diameter. A photograph of the impeller is shown in Fig. 1.

The "polished impellers" refer to a slight modification of the standard impeller design in that the radius of curvature of each vane was decreased in order to provide a slightly larger exit port area. The increased port area was approximately 0.25 square inches larger. In addition, some effort was made to decrease the roughness of the interior of the ports by grinding.

The "oversize impellers" were 14.700 inches in diameter. The thickness of the web was somewhat greater than in the standard impeller. A photograph of the oversize impeller is shown in Fig. 1.

Either cast iron or polyethylene type wear rings were installed. Cast iron wear rings were used in Runs C, D, E, F, and G; Polyethylene type wear rings were used in Runs A, B, H, and I.

The sump boundary was simulated by placing a sheet metal box, open on one end, as shown in Fig. 2. The spacing between the back side of the sheet metal box and the centerline of the pump was adjusted to either 24 inches (configuration A) or 11 inches (configuration B). In configuration B, the sump boundary was placed directly against the outer edge of the bowls.

Certain additional qualitative information was recorded during the course of the investigation:

1. Approach velocities in the sump area immediately in front of the pump intake.

2. Water surface stability and possible vortex formation in the sump.

Test facility - A schematic diagram of the test facility is shown in Fig. 3. Photographs of the facility are shown in Fig. 4. The sump configurations used are shown in Fig. 2.

The pressure head on the pump was established by measuring the pressure at a point 20 feet downstream from the face of the flange on the discharge elbow of the pump. This location is shown in Fig. 3. The pressure was measured with a mercury manometer and checked with a calibrated

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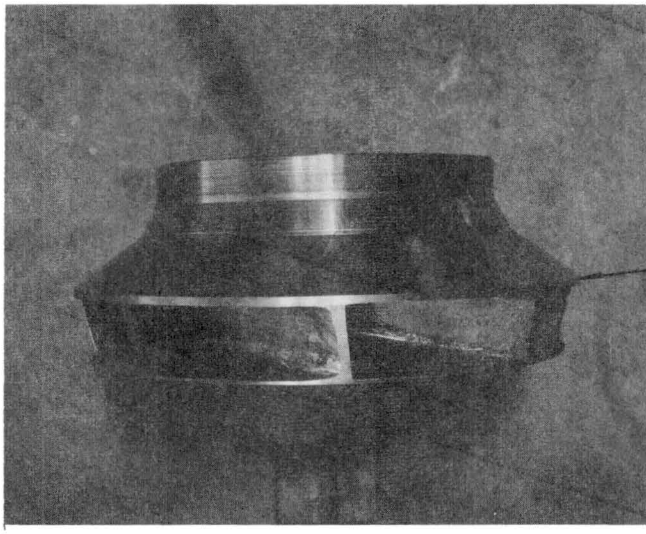
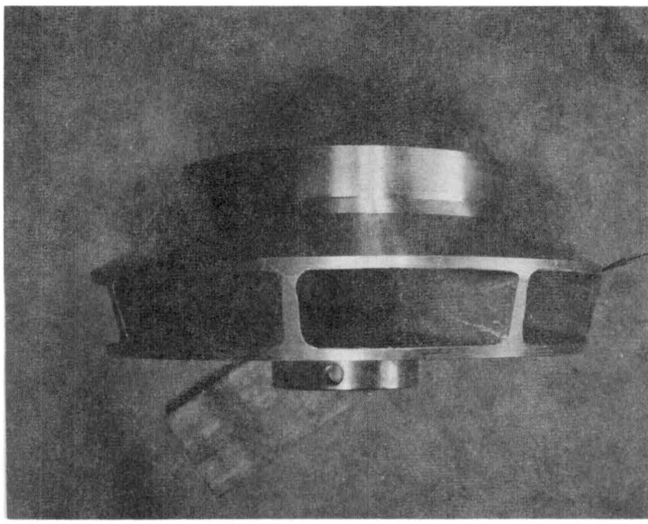


O.D. = 14.250"

Photo - A



O.D. = 14.700"

Photo - B

Fig. 1 "Standard Impeller" (Photo A); "Oversize Impeller" (Photo B)

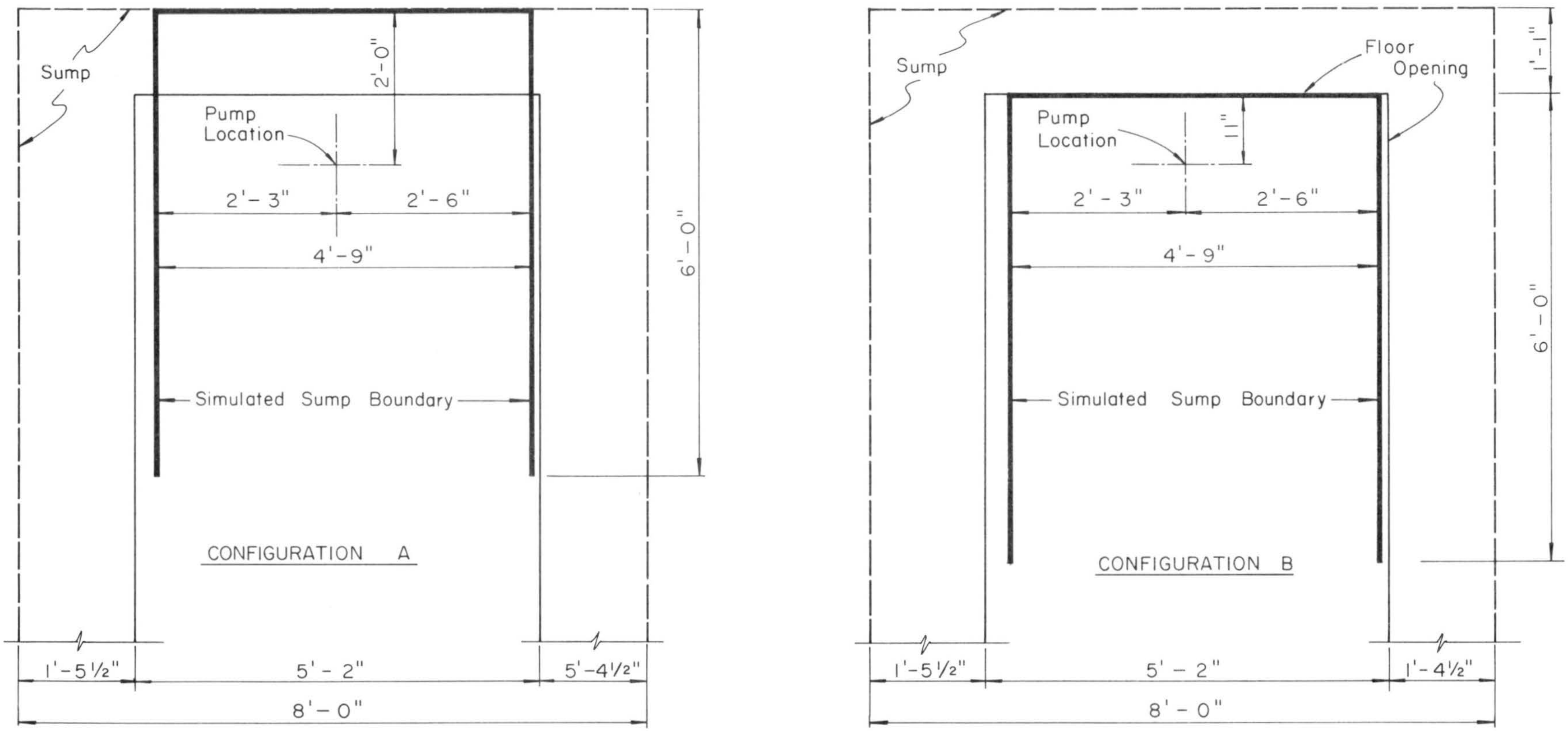


Figure 2 Plan View of Sump Configuration

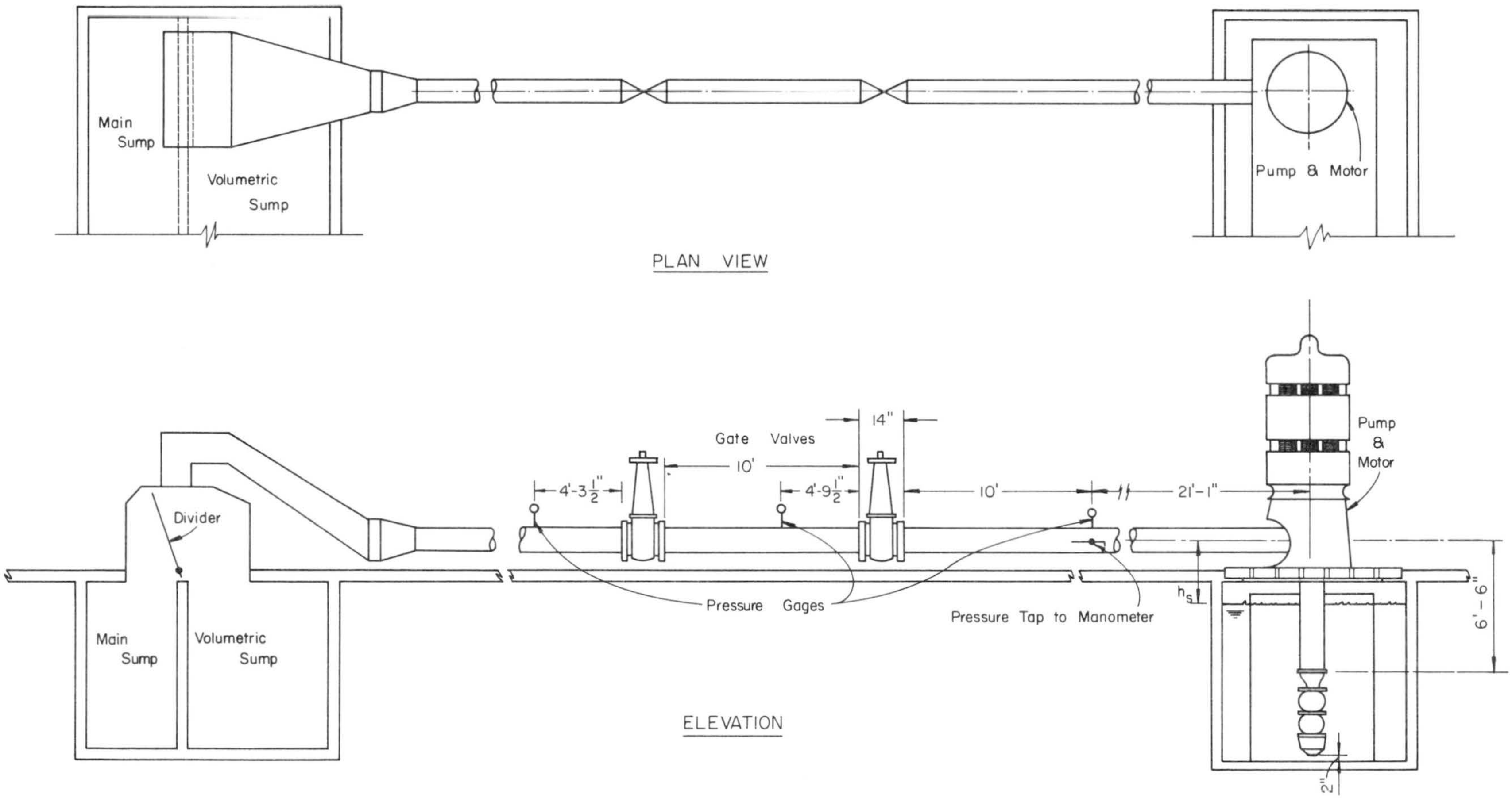


Figure 3 Schematic Drawing of Test Facility

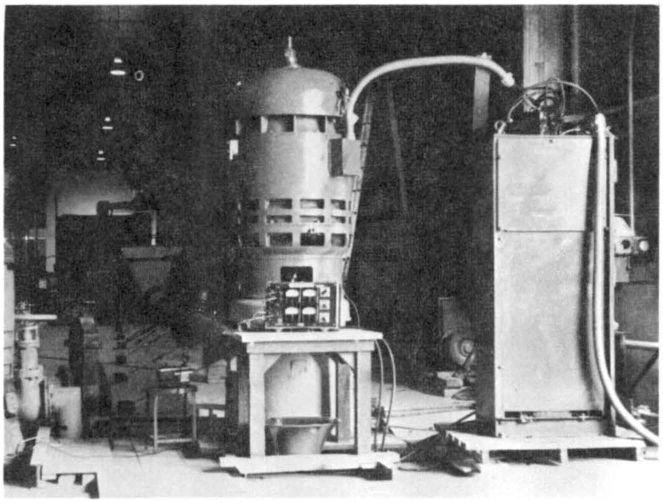


Photo 1 - Over-all view of pump test layout

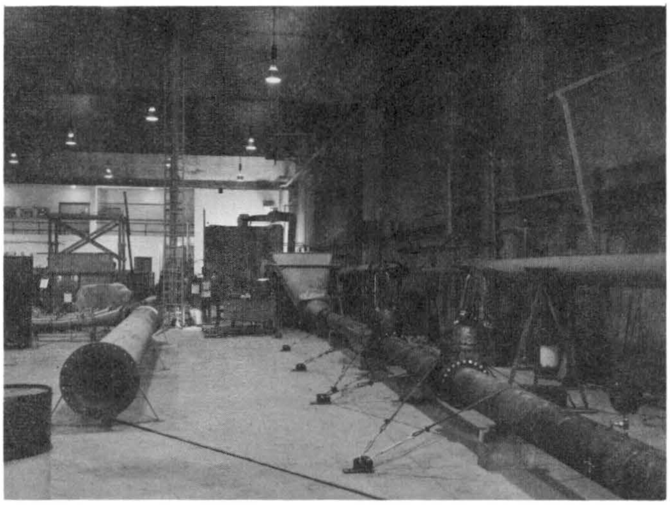


Photo 2 - Control valves, manometer pressure taps, and mercury manometer in background

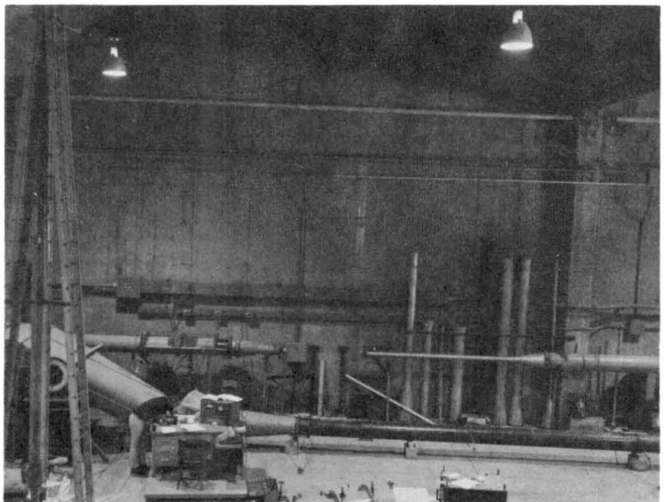


Photo 3 - Lower end of test facility with divider box into sump and manometer on far left

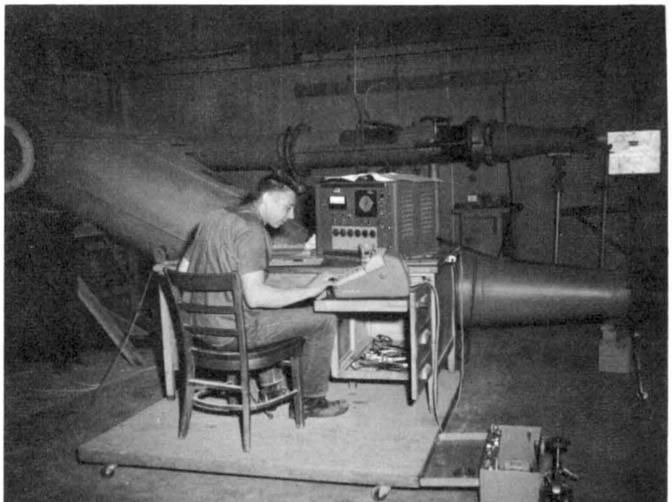


Photo 4 - Electric timer and actuator for divider box at calibrated sump

Fig. 4 Photographs of Test Facility

Bourdon pressure gage. Pressure gages were also installed at locations downstream from the valves as indicated in Fig. 3 to establish the back pressure on the control valves.

The water level in the sump was measured with a point gage and referenced to the centerline of the pump discharge pipeline. The distance between the pipe centerline and the water surface, denoted, h_s, is shown in Fig. 3. During the actual test runs the level in the main sump decreased on the order of 0.2 of a foot. This decrease was the result of diverting the flow from the main sump system into the volumetrically calibrated sump.

The flow was diverted into a volumetrically calibrated sump as shown in Fig. 3. The divider operated hydraulically and was activated by a push button which also started a clock to time the diversion period. A push button also activated the return cycle of the divider and stopped the clock. The discharge was determined from the difference between the initial and final volumes and the time interval recorded on the clock.

The power input to the motor was measured with a Westinghouse Industrial Analyzer. The nomenclature for this instrument and others described hereinafter are given in Appendix A. The analyzer measured line to line voltages, the line currents, power factor, and power input in watts. Potential transformers and current coils were used to reduce the voltages and amperages to values compatible with the analyzer. The polyphase voltmeter in the power line was read and used as a check for the analyzer. The calibration of the analyzer was checked upon completion of the tests.

The motor speed was determined using a magnetic transducer, a 60-tooth gear attached to the motor shaft, and an electronic counter. By using a 60-tooth gear, a direct reading of the motor's rpm was determined from the counter. A strobotac was also used as a check on the pump speed.

Test Procedure

The general test procedure consisted of adjusting the control valves to give a certain head on the pump and a corresponding discharge. The first test point was always near the maximum capacity of the pump. The head was then increased between successive points until the maximum head at shut-off was achieved. Complete shut-off was not required for all tests.

The initial volume in the sump was recorded and then the flow discharging from the pump was diverted into the calibrated sump for a period of time ranging from about two minutes (minimum) to about five minutes (maximum). During this diversion time, the instruments were read and recorded. At the end of the time interval, the flow was diverted back to the main sump system for recirculation to the pump intake. (See Preface for sump capacities)

For the first series of test runs (A Runs), the velocities at the entrance to the sump were measured with an Ott current meter. The meter was located at the entrance to the simulated sump boundary, mid-way between the sides, and one foot above the floor of the sump. Other miscellaneous items recorded during the course of the tests included barometric pressure, motor temperature, and motor vibrations.

Results

The pump speeds for the series of tests varied between 1769 rpm and 1789 rpm. Correction factors were applied to the values of discharge, head, and power to relate these values to a pump speed of 1770 rpm. The correction factors are a function of the ratio of 1770 rpm to the actual speed of the pump, n, in rpm to a certain power. Discharge is a function of the ratio to the first power:

$$Q = f\left[\left(\frac{1770}{n}\right)\right].$$

The head is a function of the ratio to the second power:

$$H = f\left[\left(\frac{1770}{n}\right)^2\right].$$

The power is a function of the ratio to the third power:

$$P = f\left[\left(\frac{1770}{n}\right)^3\right].$$

The basic data and calculated values for the pump tests are listed in the table in Appendix B. Definitions and calculation procedures for each entry in the table are defined as follows:

1. h_s - the distance in feet from the water level in the sump to the centerline of the discharge pipe.

2. $\frac{V^2}{2g}$ - the velocity head in the discharge pipe expressed in feet.

3. h_ℓ - head loss in the 20 feet of 12-inch pipeline between discharge side of the pump and the manometer pressure tap.

4. h_p - pressure head measured at the centerline of discharge pipe 20-feet downstream from the pump. Measurements were made with a mercury manometer and converted to feet of water.

5. H - total head equaling the sum of

$$h_s + \frac{V^2}{2g} + h_\ell + h_p .$$

6. Q - discharge measured in the volumetrically calibrated sump (gallons per minute).

7. Speed - speed of pump shaft, in rpm, measured with an electronic counter.

8. Q (corrected) - measured discharge corrected to a pump speed of 1770 rpm.

9. H (corrected) - total measured head, H , corrected to a pump speed of 1770.

10. Water horsepower (corrected) - Q (corrected) multiplied by the specific weight of water at $80^{o}F$ ($62.2\ \#/ft^3$) multiplied by H (corrected) and divided by 550.

11. Brake horsepower - power input to the electric motor (watts) multiplied by the efficiency of the electrical motor for that particular load divided by 746.

12. Over-all efficiency - the ratio of water horsepower (corrected) to brake horsepower.

The head-capacity, efficiency, and horsepower curves are given in Appendix C for each series of runs. The curves are related to a pump speed of 1770 rpm.

Approach velocities, measured with the Ott current meter, are given in Appendix D. Maximum approach velocity was 0.51 feet per second. The water surface was quite stable throughout all tests and no visible vortex formation was evident.

Barometric pressures, motor temperatures, and vibrations are listed in Appendix D. The barometric pressure was the pressure recorded at the Colorado State University Weather Station at 8:00 A.M., on the dates given, and corrected to the elevation at the test facility. The vibrations recorded were the peak-to-peak horizontal displacements in thousands of an inch of the motor measured in the plane formed by the pump, motor, and pipeline.

Acknowledgments

Thanks are extended to representatives of Bechtel Corporation, Kennecott Copper Corporation, and Layne Bowler Pump Manufacturing Company for their cooperation during the entire testing period.

Mr. J. R. Schmiedel, Project Engineer, and Mr. W. R. Heinke, Project Superintendent, Bechtel Corporation, San Francisco, California; Mr. W. D. Southard, Project Engineer, and Mr. D. W. Early, Maintenance Engineer, Kennecott Copper Corporation, Salt Lake City, Utah; and Mr. P. T. Roach, Test Engineer, Layne Bowler Pump Manufacturing Corporation, Memphis, Tennessee.

A great deal of the success of this pump test must be attributed to the Shop Superintendent, Mr. Ralph Asmus, and his entire crew for their usual efficiency, capability, and enthusiasm.

APPENDIX A - INSTRUMENTATION

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1. Westinghouse Industrial Analyzer - Type TA
   Serial No. 2287382 - NBS 114461

   a. Ammeter 5-25-125 amps
   b. Voltmeter 115-230-575 volts
   c. Wattmeter (calibrated by Ball Brothers - Standards Laboratory, Boulder, Colorado June 1967, and verified to be $\pm$ 1% accuracy
   d. Power factor

2. Current Transformers

Weston Model 461	#10507	#13517
Type	1	1
Capacity V-A	5	5
Frequency	25-133	25-133
Line Volts	2500	2500

3. Westinghouse Potential Transformers
   2400-120 Volts

4. Strobotac - General Radio Model 1531 A

5. Ott Meter - #12460 W/P 2-3

6. Electro-Tec Magnetic Transducer

7. Hewlett-Packard Electronic Counter
   Model 521 A

8. Westinghouse Polyphase Wattmeter
   Meter constant = $\frac{2}{3}$ WH/rev.

APPENDIX B - TABLE

PUMP PERFORMANCE DATA

PUMP PERFORMANCE DATA

Run	h_s (Feet	$\frac{V^2}{2g}$ (Feet)	h_ℓ (Feet)	h_p (Feet)	H (Feet)	Q (gpm)	Speed (rpm)	Q Corrected (gpm)	H Corrected (Feet)	Water Horsepower Corrected	Brake Horsepower	Over-all Efficiency (Percent)
A-1	4.46	2.33	0.68	271.40	278.87	4317.09	1772	4312.35	278.26	302.37	380.4	79.5
A-2	4.47	2.14	0.62	282.19	289.42	4133.62	1772	4129.08	288.78	300.47	376.9	79.7
A-3	4.46	2.04	0.59	286.33	293.42	4038.26	1770	4038.26	293.42	298.58	373.9	79.9
A-4	4.46	1.74	0.51	299.78	306.49	3722.45	1769	3724.68	306.86	288.01	366.4	78.6
A-5	4.45	1.64	0.48	303.38	309.95	3626.11	1769	3628.29	310.32	283.72	361.9	78.4
A-6	4.46	1.28	0.37	316.55	322.66	3194.42	1769	3196.34	323.05	260.19	345.4	75.3
A-7	4.43	0.68	0.21	331.15	336.47	2335.03	1773	2331.07	335.33	196.97	304.5	64.7
A-8	4.38	0.85	0.26	327.01	332.50	2601.03	1774	2595.06	330.98	216.43	317.6	68.1
A-9	4.33	0.42	0.13	338.55	343.43	1835.51	1774	1831.30	342.64	158.64	279.9	56.5
A-10	4.22	0.25	0.08	343.51	348.06	1414.66	1775	1410.71	346.12	123.04	261.4	47.1
A-11	4.21	0.14	0.05	348.19	352.59	1053.30	1776	1049.73	350.21	92.64	248.9	37.2
A-12	4.18	0.06	0.03	353.90	358.17	718.89	1777	716.03	355.33	64.11	237.9	26.9
A-13	4.12	0.00	0.00	365.98	370.10	0	1779	0	366.36	0	214.0	0
A-14	4.44	2.75	0.78	244.44	252.41	4685.15	1772	4680.00	251.86	297.02	377.9	78.6
A-15	4.43	2.83	0.81	206.14	214.21	4755.74	1772	4750.51	213.74	255.86	355.5	72.0
B-1	4.34	1.89	0.55	290. *	296.78	3888.03	1775	3877.17	295.13	288.34	370.4	77.8
B-2	4.09	2.16	0.62	280. *	286.87	4151.34	1771	4148.85	286.53	299.55	374.4	80.0
B-3	4.08	1.67	0.49	300. *	306.24	3648.94	1772	3644.93	305.57	280.66	360.9	77.8

* h_p measured with Bourdon gage

PUMP PERFORMANCE DATA - Continued

Run	h_s (Feet)	$\frac{V^2}{2g}$ (Feet)	h_ℓ (Feet)	h_p (Feet)	H (Feet)	Q (gpm)	Speed (rpm)	Q Corrected (gpm)	H Corrected (Feet)	Water Horsepower Corrected	Brake Horsepower	Over-all Efficiency (Percent)
C-1	3.86	2.51	0.72	218.50	225.59	4473.83	1778	4453.79	223.58	250.92	369.4	67.9
C-2	3.84	2.51	0.72	230.32	237.39	4475.18	1777	4457.35	235.51	264.52	382.9	69.1
C-3	3.82	2.51	0.72	245.25	252.30	4478.82	1776	4463.64	250.60	281.87	391.4	72.0
C-4	3.85	2.50	0.72	262.64	269.71	4466.52	1775	4454.05	268.21	301.03	411.3	73.2
C-5	3.82	2.43	0.70	280.97	287.92	4409.77	1774	4399.65	286.60	317.74	416.3	76.3
C-6	3.81	2.30	0.67	293.33	300.11	4289.31	1774	4279.47	298.74	322.15	416.3	77.4
C-7	3.85	2.06	0.60	306.82	313.33	4054.25	1774	4044.95	311.90	317.91	410.9	77.4
C-8	3.84	1.72	0.50	321.81	327.87	3706.39	1775	3696.04	326.04	303.66	395.9	76.7
C-9	3.85	1.50	0.43	330.27	336.05	3463.79	1776	3452.05	333.78	290.34	387.9	74.8
C-10	3.78	0.00	0.00	375.62	379.40	0	1788	0	371.78	0	218.5	0
C-11	3.78	0.45	0.14	349.62	353.99	1900.27	1783	1886.50	348.86	165.84	300.0	55.3
C-12	3.83	2.30	0.67	301.41	308.21	4288.29	1775	4276.32	306.49	330.26	416.3	79.3
D-1	3.69	2.29	0.67	237.65	244.30	4283.68	1778	4264.49	242.12	260.18	391.9	66.4
D-2	3.74	2.29	0.67	254.35	261.05	4281.93	1776	4267.42	259.29	278.82	396.3	70.4
D-3	3.70	2.28	0.66	269.43	276.07	4267.21	1775	4255.30	274.53	294.37	401.4	73.3
D-4	3.72	2.25	0.66	283.01	289.64	4239.76	1774	4230.03	288.31	307.31	408.8	75.2
D-5	3.74	1.92	0.56	308.27	314.49	3914.74	1775	3903.81	312.74	307.64	406.4	75.7
D-6	3.70	1.63	0.47	322.93	328.73	3604.51	1775	3594.45	326.90	296.09	393.9	75.2

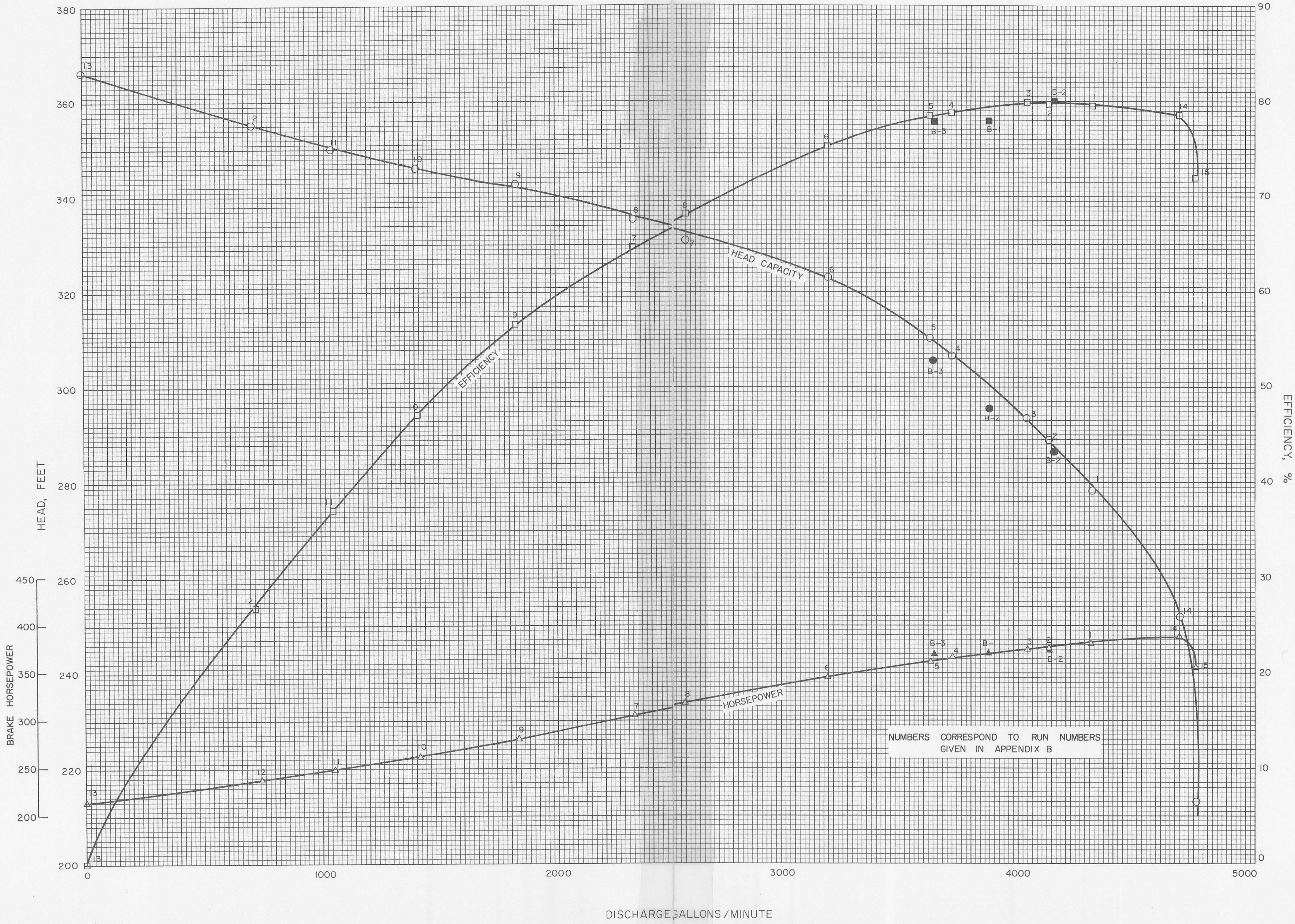
PUMP PERFORMANCE DATA - Continued

Run	h_s (Feet)	$\frac{V^2}{2g}$ (Feet)	h_ℓ (Feet)	h_p (Feet)	H (Feet)	Q (gpm)	Speed (rpm)	Q Corrected (gpm)	H Corrected (Feet)	Water Horsepower Corrected	Brake Horsepower	Over-all Efficiency (Percent)
D-7	3.70	1.30	0.38	336.65	339.03	3227.60	1775	3218.59	337.14	273.43	396.3	69.0
D-8	3.71	2.20	0.63	291.56	298.10	4192.04	1774	4182.42	296.74	312.74	411.3	76.0
E-1	4.19	2.79	0.79	210.49	218.26	4723.20	1780	4696.43	215.80	255.38	377.9	67.6
E-2	3.88	2.76	0.79	232.49	239.92	4700.23	1779	4676.38	237.50	279.86	370.9	75.5
E-3	4.22	2.61	0.75	253.54	261.12	4564.99	1778	4544.54	258.79	296.35	374.4	79.2
E-4	4.14	2.33	0.67	269.84	276.98	4311.85	1778	4292.53	274.51	296.92	372.9	79.6
E-5	3.88	1.93	0.57	287.62	294.00	3927.37	1779	3907.44	291.03	286.55	368.4	77.8
E-6	3.87	1.64	0.48	300.05	306.04	3613.84	1779	3595.50	302.95	274.48	357.0	76.9
E-7	3.86	0.95	0.28	321.91	327.00	2749.19	1782	2730.62	322.61	221.98	324.6	68.4
E-8	3.86	0.15	0.06	344.53	348.60	1164.64	1787	1153.57	342.00	99.41	252.4	39.4
E-9	3.85	0.00	0.00	365.30	369.15	0	1789	0	361.38	0	208.5	0
E-10	3.86	2.15	0.63	278.87	285.51	4147.71	1778	4129.13	282.96	294.41	370.9	79.4
F-1	3.83	2.29	0.67	271.26	278.05	4277.74	1778	4258.58	275.57	295.71	373.4	79.2
F-2	3.83	2.13	0.62	278.93	285.51	4122.20	1778	4103.73	282.96	292.60	370.9	78.9
F-3	3.80	1.89	0.55	289.25	295.49	3888.02	1778	3870.60	292.85	285.63	363.9	78.5

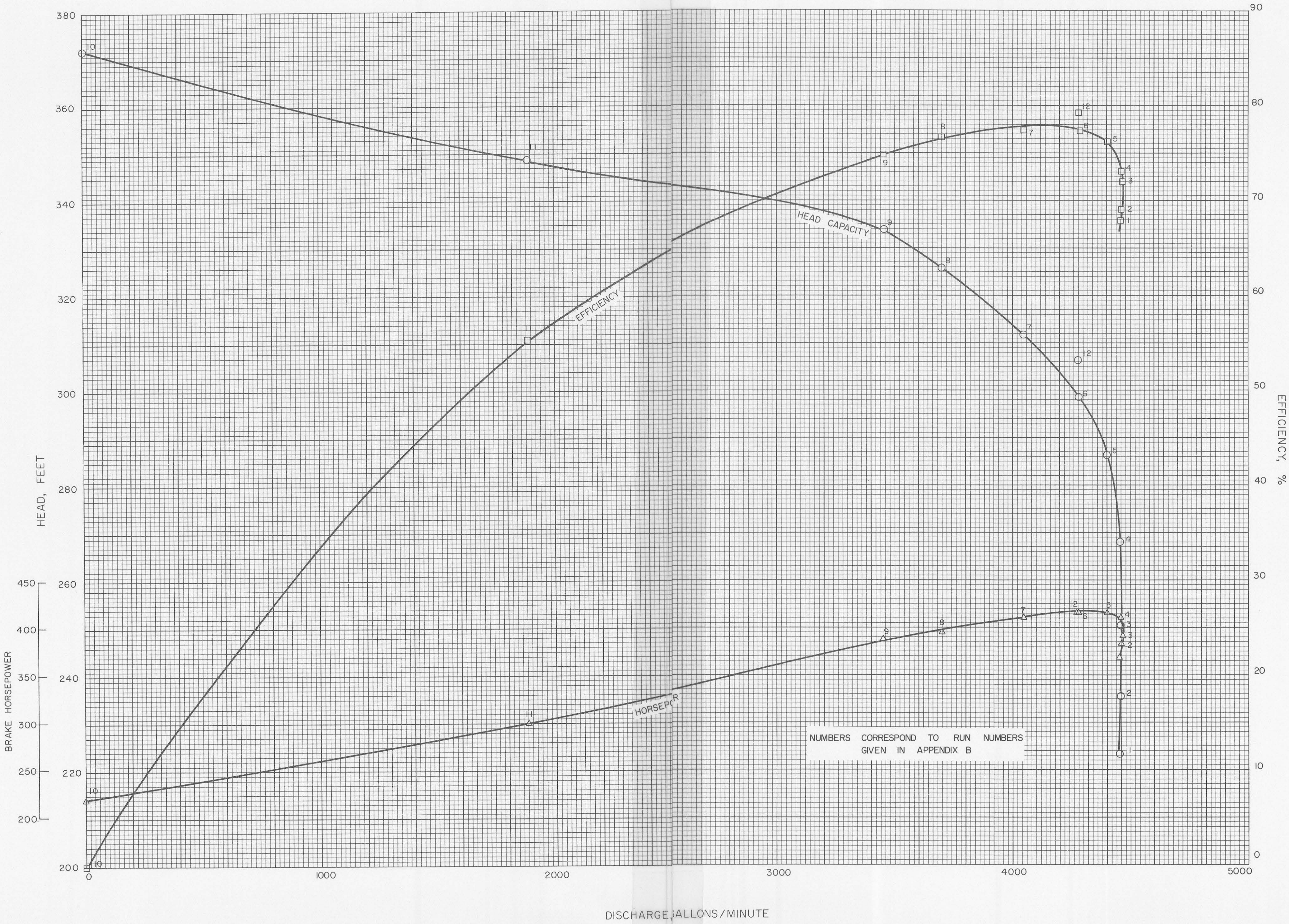
PUMP PERFORMANCE DATA - Cont'd.

Run	h_s (Feet)	$\frac{V^2}{2g}$ (Feet)	h_ℓ (Feet)	h_p (Feet)	H (Feet)	Q (gpm)	Speed (rpm)	Q Corrected (Feet)	H Corrected (Feet)	Water Horsepower Corrected	Brake Horsepower	Over-all Efficiency (Percent)
G-1	3.81	1.97	0.57	287.15	293.50	3962.54	1778	3944.79	290.88	289.14	365.9	79.0
G-2	3.80	1.72	0.51	297.27	303.30	3707.38	1778	3690.77	300.59	279.55	361.9	77.2
H-1	4.00	2.79	0.79	238.19	245.77	4720.35	1779	4696.40	243.29	287.91	378.9	76.0
H-2	3.71	2.62	0.75	256.53	263.61	4572.84	1777	4554.62	261.52	300.15	381.4	78.7
H-3	3.72	2.35	0.68	271.06	277.81	4330.71	1777	4313.46	275.61	299.57	380.4	78.8
H-4	3.72	2.16	0.63	280.43	286.94	4152.84	1778	4134.24	284.38	296.26	375.4	78.9
H-5	3.72	1.91	0.56	291.22	297.41	3909.06	1778	3891.55	294.76	289.05	370.9	77.9
H-6	3.71	1.64	0.48	302.50	308.33	3615.20	1779	3596.86	305.22	276.64	361.9	76.4
H-7	3.73	0.97	0.29	323.20	328.19	2782.07	1782	2763.28	323.79	225.46	326.5	69.1
H-8	3.72	0.52	0.16	335.15	339.55	2042.52	1784	2026.51	334.24	170.68	290.0	58.9
H-9	3.71	0.13	0.50	347.78	352.12	1021.80	1787	1012.08	345.45	88.10	247.4	35.6
H-10	3.81	0.00	0.00	365.64	369.45	0	1789	0	361.67	0	211.0	0
H-11	3.70	1.76	0.52	297.74	303.72	3753.35	1779	3734.31	300.65	282.91	363.9	77.7
I-1	3.73	2.78	0.79	231.40	238.70	4711.62	1778	4690.51	236.57	279.61	368.4	75.9
I-2	3.74	2.63	0.75	255.24	262.36	4581.74	1777	4563.49	260.28	299.30	380.4	78.7
I-3	3.73	2.30	0.66	273.09	279.78	4290.81	1777	4273.72	277.56	298.91	375.4	79.6
I-4	3.74	1.93	0.57	290.27	296.51	3932.85	1778	3915.23	293.87	289.93	370.4	78.3
I-5	3.72	1.68	0.49	301.00	306.89	3664.94	1778	3648.52	304.15	279.63	361.4	77.4

APPENDIX C - PUMP PERFORMANCE CURVES

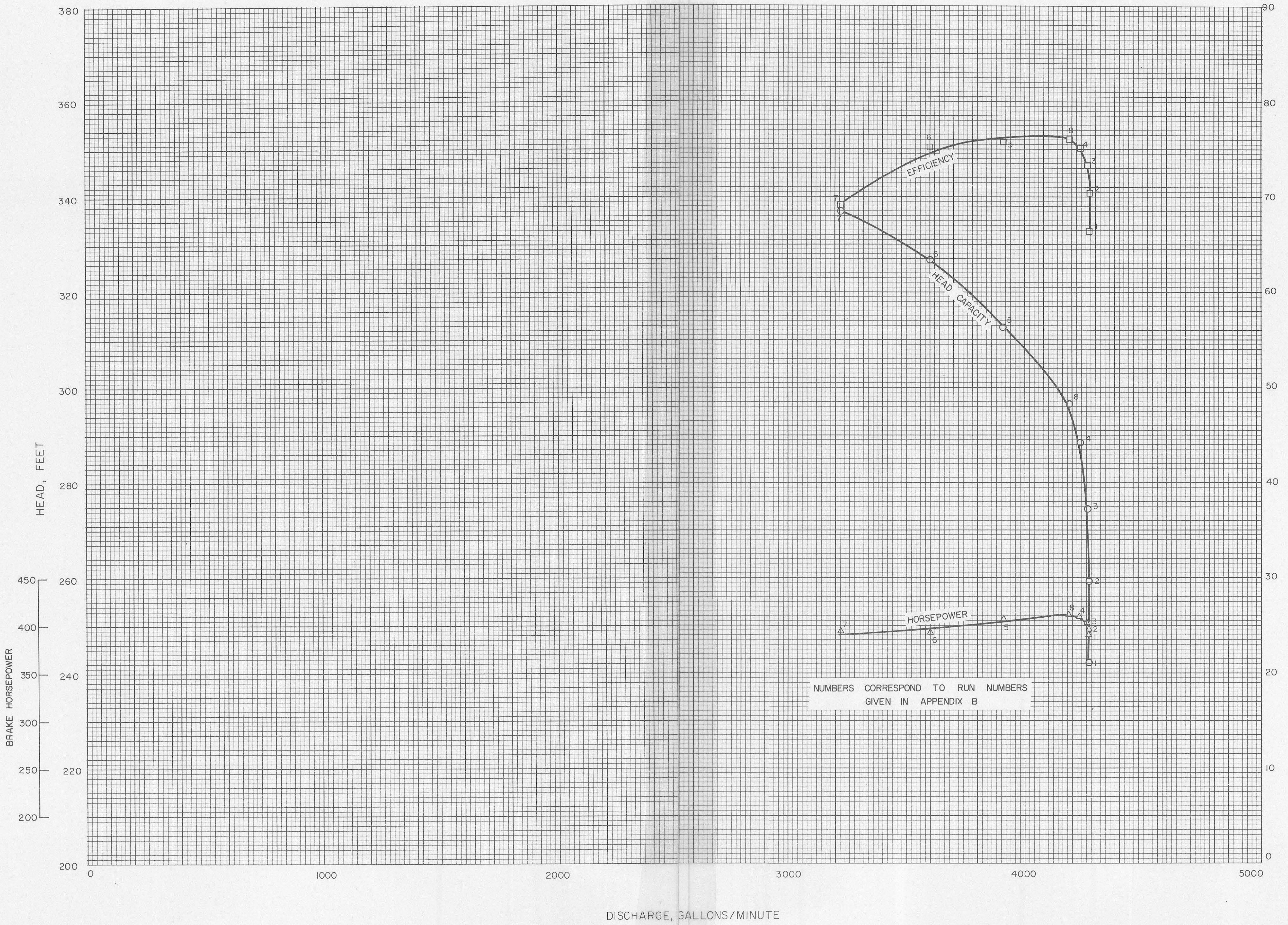


Performance Curves for a 12 inch, Stainless Steel, Two-stage, Deep-Well, Turbine Pump for Runs A and B
Corrected for a Speed of 1770 RPM

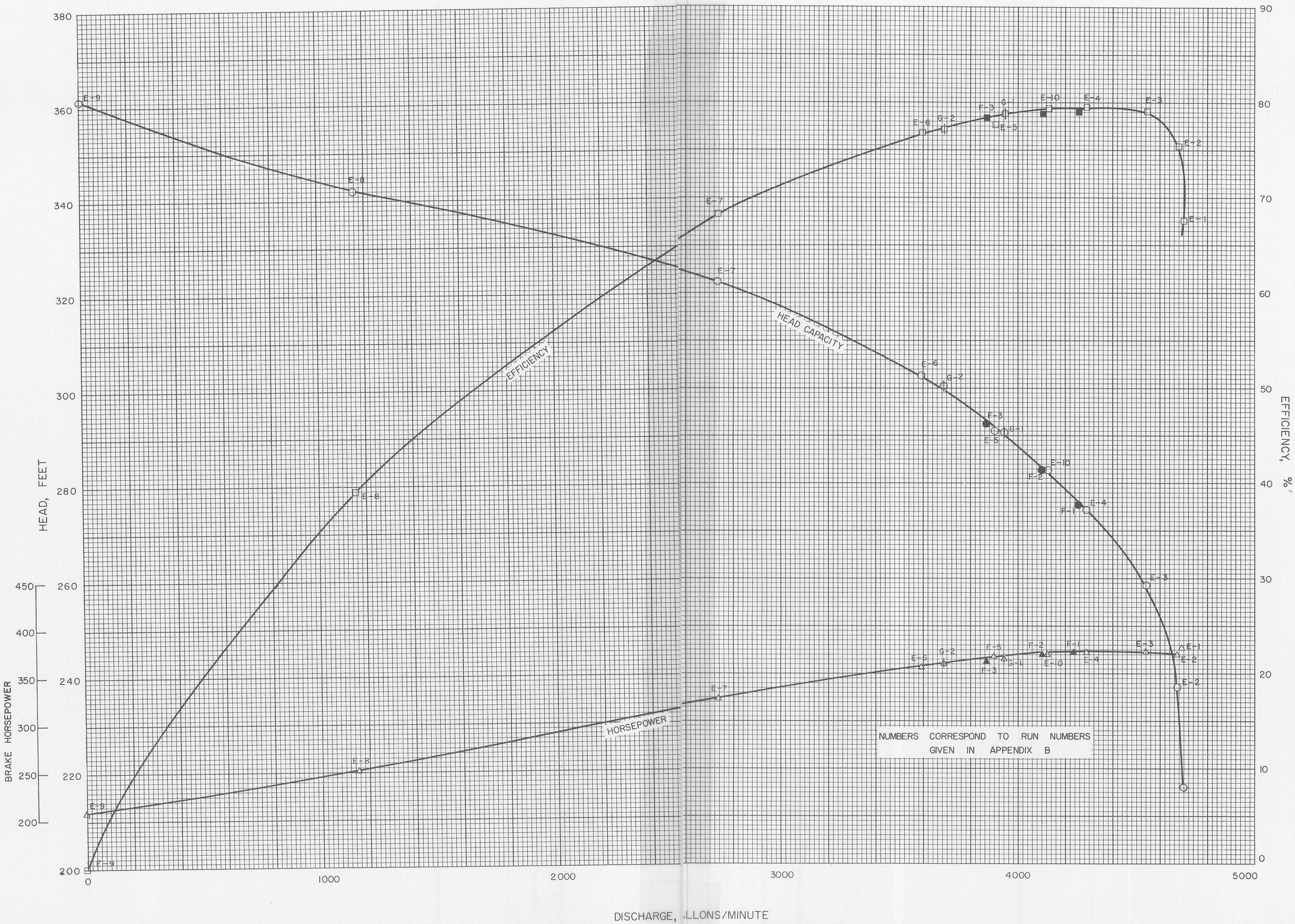


Performance Curves for a 12 inch, Stainless Steel, Two-Stage, Deep-Well, Turbine Pump for Run C

Corrected for a Speed of 1770 RPM

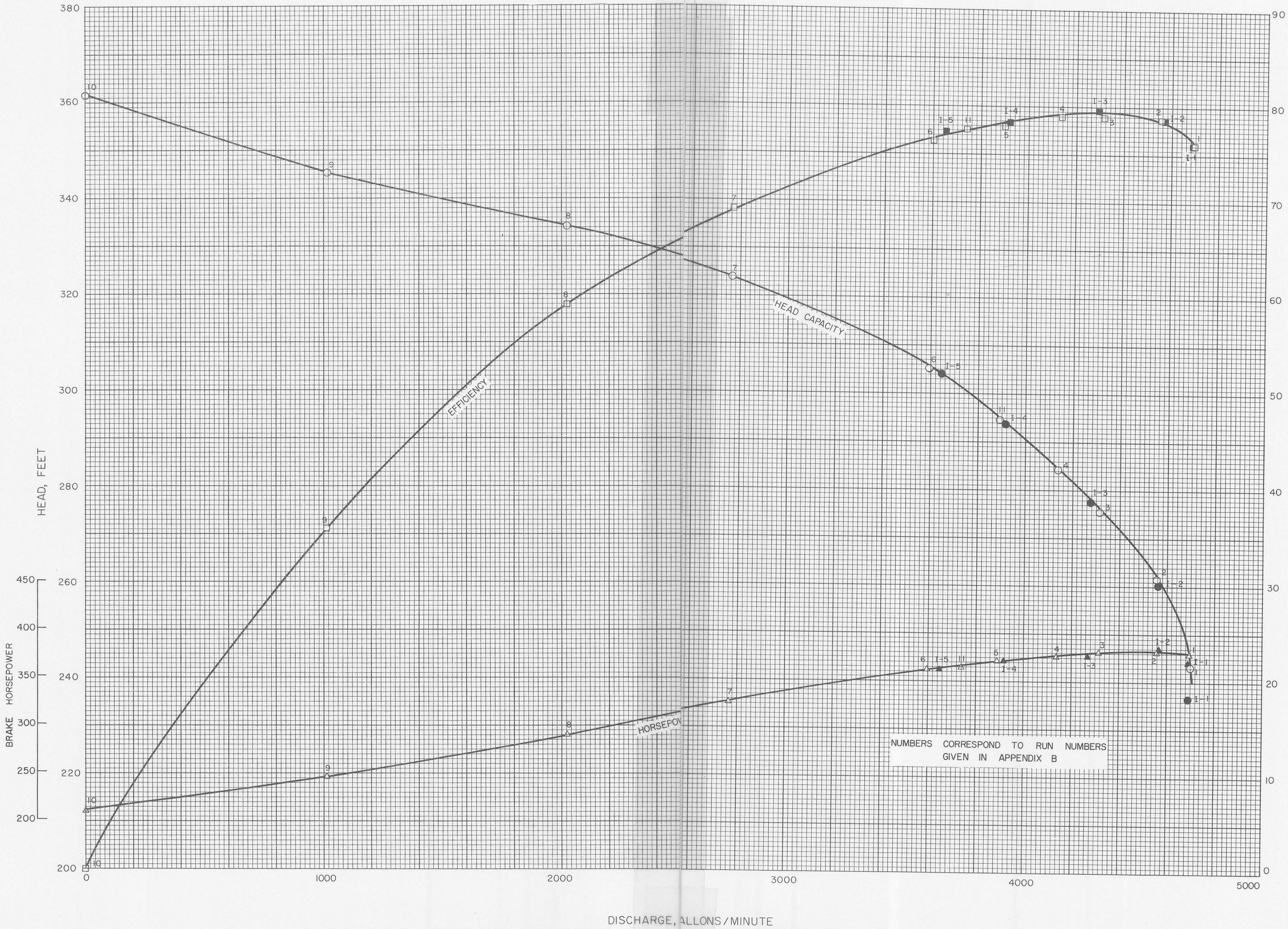


Performance Curves for a 12 inch, Stainless Steel, wo-Stage, Deep-Well, Turbine Pump for Run D
Corrected for a beed of 1770 RPM

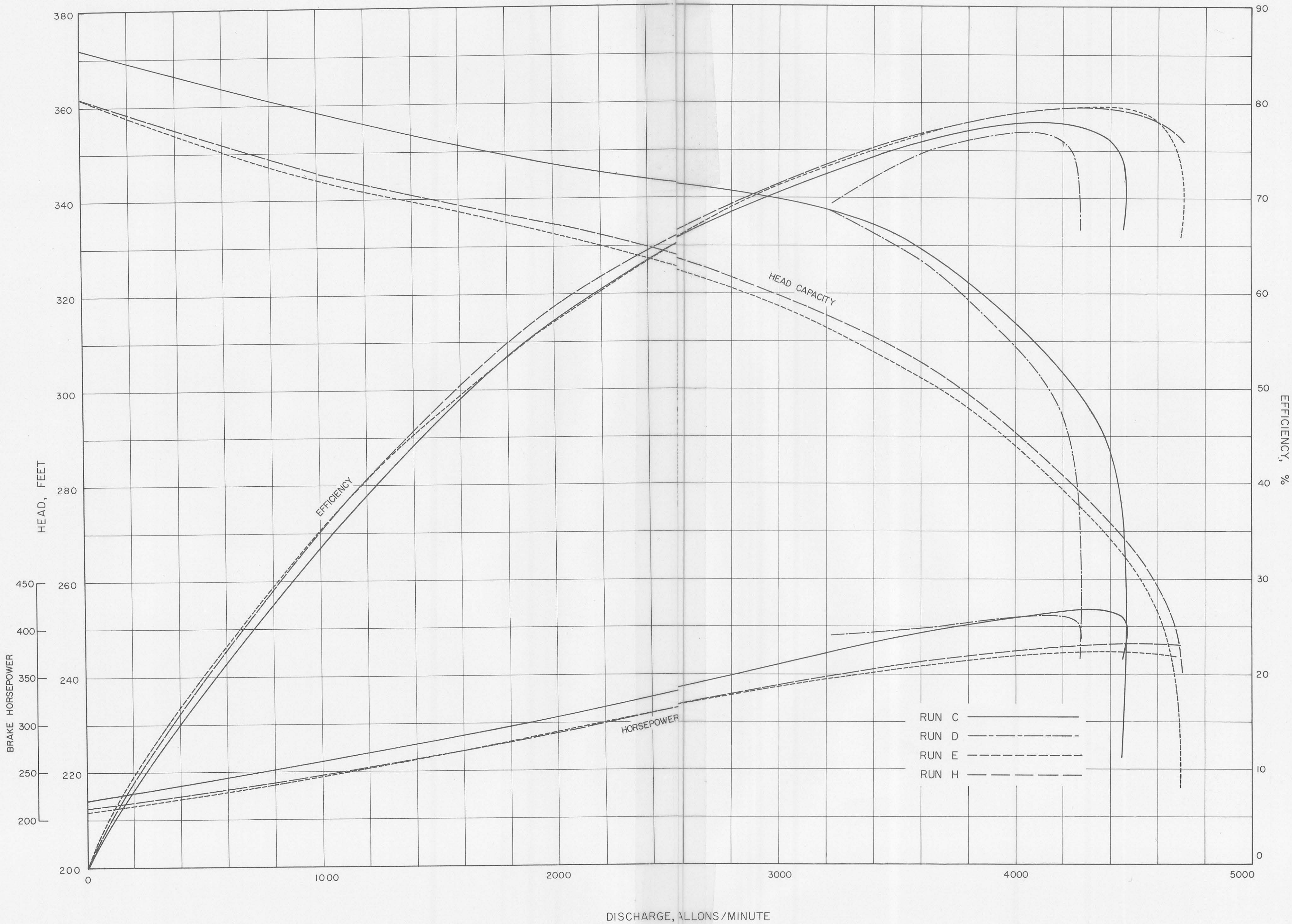


Performance Curves for a 12 inch, Stainless Steel, o-Stage, Deep-Well, Turbine Pump for Runs E, F, & G

Corrected for a eed of 1770 RPM



Performance Curves for a 12 inch, Stainless Steel, Two-age, Deep-Well, Turbine Pump for Run H Corrected
for a Speed of 1770PM



Comparison of Performance urves for Runs C, D, E, & H

APPENDIX D - MISCELLANEOUS DATA

1. Velocity measurements at the entrance to the simulated sump boundary - (measurements made with Ott meter # 12460).

Run No.	Velocity (ft/second)
A-1	0.51
A-2	0.36
A-3	0.34
A-4	0.21
A-5	0.19
A-6	----

2. Barometric pressure (inches of mercury corrected to elevation of test stand).

Date	Pressure (in. of Hg)
20 May '67	25.120
21 May '67	25.060
22 May '67	24.955
23 May '67	24.851
24 May '67	24.742
25 May '67	24.706

3. Motor temperatures and vibratory displacement

Run No.	Motor Temperature °F	Motor Vibrations Peak-peak absolute displacement in thousands of an inch
A - 1	77	--
A - 2	83	--
A - 3	88	--
A - 4	90	--
A - 5	90	--
A - 6	90	--
A - 7	90	--
A - 8	86	--
A - 9	83	--
A - 10	84	--
A - 11	81	--
A - 12	81	--
A - 13	--	--
A - 14	80	--
A - 15	81	--
B - 1	79	--
B - 2	83	--
B - 3	85	--

3. (Continued)

Run No.	Motor Temperature °F	Motor Vibrations Peak-peak absolute displacement in thousands of an inch
C - 1	89	4
C - 2	92	5
C - 3	92	5
C - 4	93	4
C - 5	94	3
C - 6	95	4
C - 7	96	4
C - 8	97	4
C - 9	97	5
C - 10	96	4
C - 11	96	3
C - 12	96	3
D - 1	80	4
D - 2	89	6
D - 3	92	6
D - 4	96	4
D - 5	100	4
D - 6	100	2
D - 7	101	3
D - 8	102	3
E - 1	84	6
E - 2	90	6
E - 3	96	4
E - 4	98	4
E - 5	100	6
E - 6	102	4
E - 7	102	4
E - 8	100	2
E - 9	98	4
E - 10	96	4
F - 1	100	4
F - 2	102	4
F - 3	102	4
G - 1	108	4
G - 2	108	4
H - 1	82	--
H - 2	89	4
H - 3	94	6
H - 4	98	4
H - 5	102	3
H - 6	103	3
H - 7	103	4
H - 8	103	4
H - 9	99	3
H - 10	99	3
H - 11	99	3

3. (Continued)

Run No.	Motor Temperature °F	Motor Vibrations Peak-peak absolute displacement in thousands of an inch
I - 1	105	6
I - 2	105	6
I - 3	105	4
I - 4	106	4
I - 5	107	4