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Engineering and Geological Control and Research Division
Field Trip Report No. 3

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Bureau of Reclamation
Hydraulic Machinery Laboratory

Denver, Colorado

January 8, 1940.

Laboratory Report No. HM-12
Glendive Pumping Plant
Buffalo Rapids Project
Test Conducted by: G. J. Hornsby
Checked by: D. J. Hebert
Submitted by: G. J. Hornsby

Subject: Field acceptance test on pumping units Nos. 1 and 2 of the Glendive pumping plant - Buffalo Rapids project, Glendive, Montana - Specifications No. 1018-D.

I. THE TEST

1. Purpose of tests. The purpose of the tests was to determine whether or not the pumps met the conditions specified in the contract as to head, discharge, efficiency, cavitation, and general performance.

2. The pumping plant. The plant is located on the north bank of the Yellowstone River in Montana about thirty miles upstream from Glendive and about two miles downstream from the village of Fallon. It is a typical irrigation pumping plant consisting, at the time of test, of two installed units with provision for a third similar unit. The units are of the vertical type consisting of a 1,500-horsepower, 2,200 volt, 60-cycle, 400-r.p.m., synchronous motor direct-connected to a 36-inch single-suction, centrifugal, volute pump. The pumps are rated at 110 c.f.s. discharge at a dynamic head of 103 feet. The motor is rated at 95.7 percent efficiency at 100 percent power factor and full load, and the pump is rated at 89 percent efficiency at rated dynamic head and full discharge. The rated over-all efficiency of the unit is therefore, 85 percent.

The pumps each have individual suctions drawing through rack structures from a common inlet canal. The discharge of each pump is through a 36-inch gate valve, a short length of 36-inch steel pipe into the legs of a 3-way connection to a 7-foot diameter, concrete, common delivery pipe leading to the canal at the top of the hill. At the point where the delivery pipe discharges into the warped-wing transition to the canal, there is an 84-inch swing check, or flap valve, to prevent reversal of flow in case of emergency. The complete arrangement is shown on figure 1.

3. Test procedure. The horsepower input to the pump was measured by means of electrical test instruments connected as shown in the wiring diagram, figure 2. The motor field rheostat was adjusted so as to bring the power factor up to 100 percent as indicated by balanced readings on the two wattmeters and by the power factor meter on the switchboard. The power input as

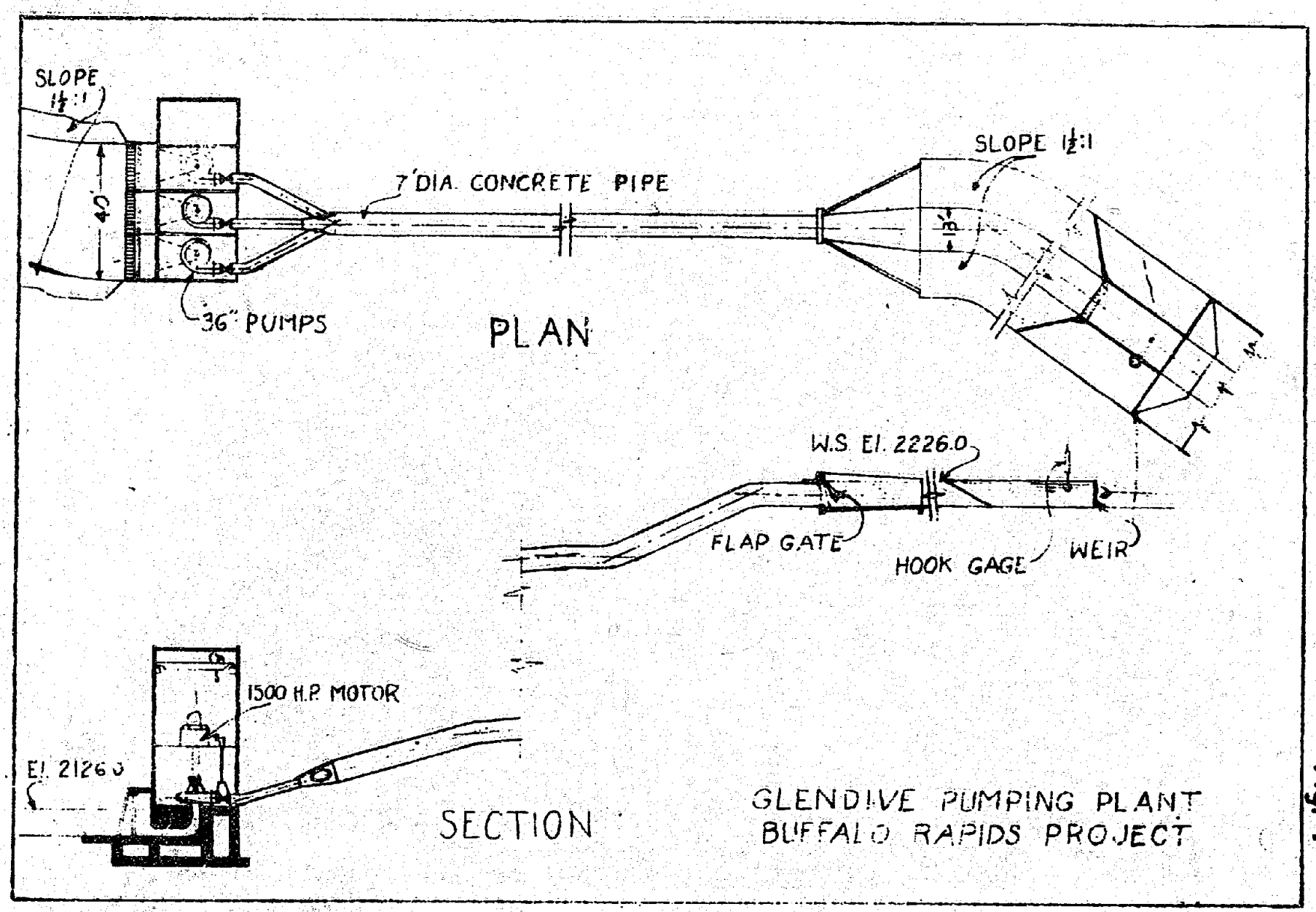
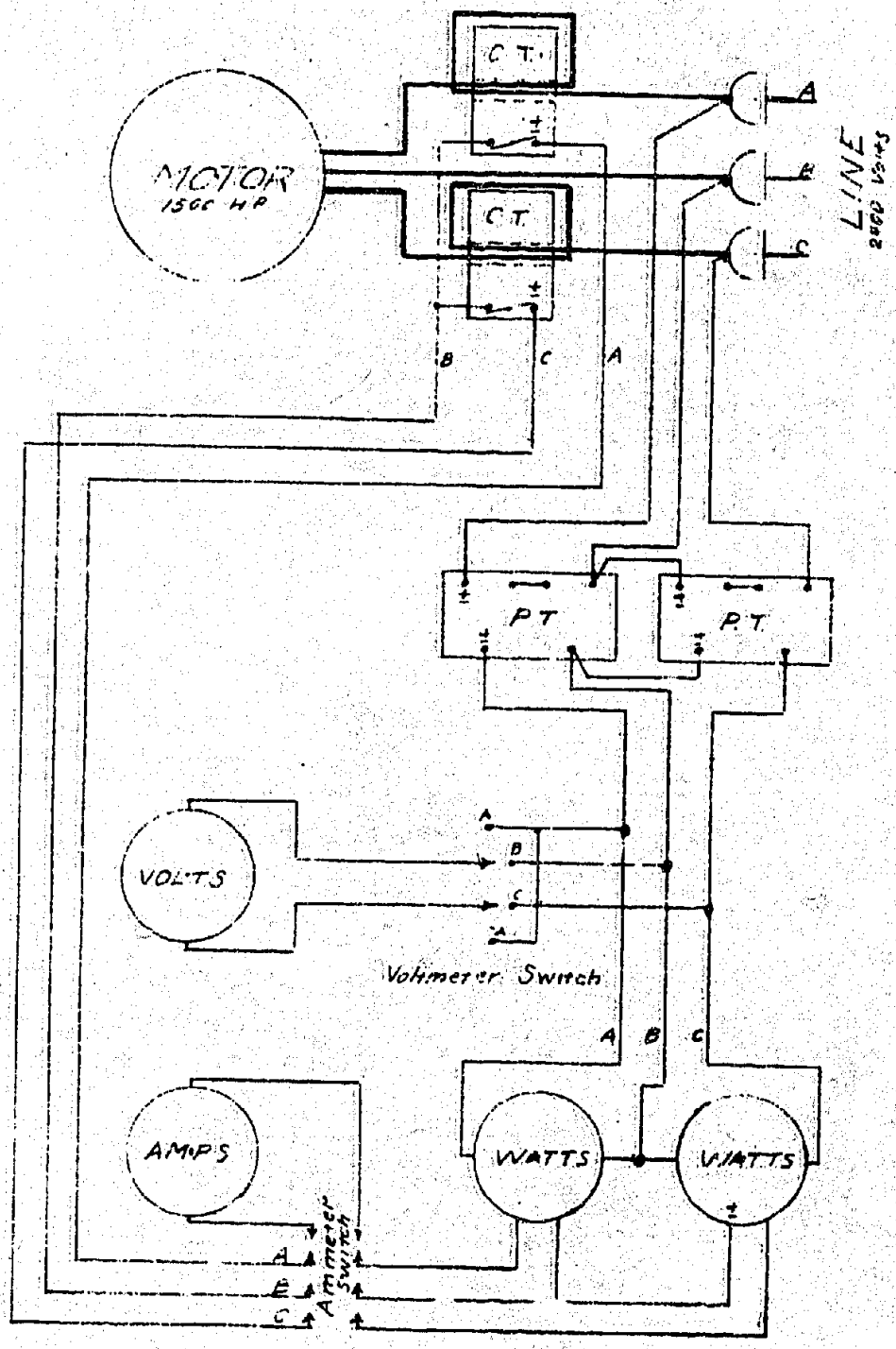

SLOPE 1½:1
40'
7' DIA. CONCRETE PIPE
36" PUMPS
PLAN
SLOPE 1½:1
W.S. El. 2226.0
FLAP GATE
HOOK GAGE
WEIR
1500 H.P. MOTOR
El. 2126.0
SECTION
GLENDIVE PUMPING PLANT
BUFFALO RAPIDS PROJECT

Fig. 1

Fig. 2



WIRING DIAGRAM
Glendive Pumping Plant
Buffalo Rapids Project

measured by the wattmeters was checked by means of an ammeter and a voltmeter, each of which could be switched from phase to phase of the motor leads. As a further check, the rotations of the watt-hour meter disk were counted for each run. The electrical input to the motors thus measured was multiplied by the motor efficiency to give the horsepower input to the pump. The dynamic head on the pump was measured by means of a mercury column on the discharge side and a water column on the suction side. A pressure-test gage was also connected on the pressure side to give a rough check on the mercury column. This check was not satisfactory due to extreme oscillations of the pointer caused by pounding in the pump casing. An attempt was made to damp the oscillations by throttling, but this was not successful. As the pressure was measured from the center line of the pump and the suction was measured from a point 2.75 feet below this line, the total dynamic head, H, was determined as follows:

$$H = 13.6\, h_d + h_s + 2.75 + \frac{(V_d^2 - V_s^2)}{(2g)}$$

where,

h_d = discharge pressure in feet of mercury,

h_s = suction pressure in feet of water,

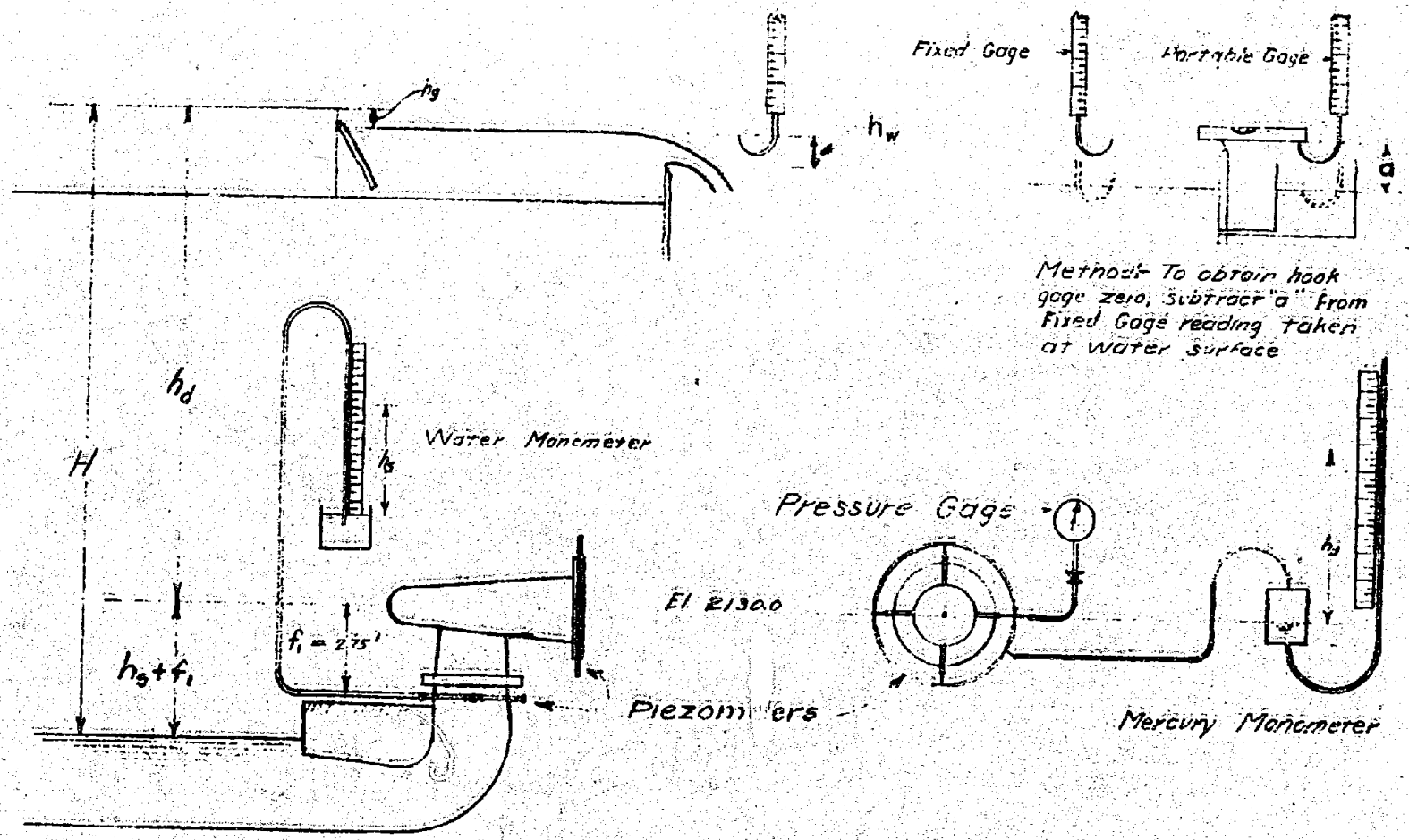
V_d = discharge velocity in feet per second, and

V_s = suction velocity in feet per second.

Of course the pipe areas in the plane of the piezometers at both the suction and discharge were carefully measured. The set-up is shown diagrammatically in figure 3.

The discharge was measured over a weir designed in strict accordance with Standards of Hydraulic Institute Code. The head over the weir was measured by means of a hook gage reading to thousandths of a foot. The hook gage zero was determined before and after each test by the method shown in figure 3. A head discharge curve, figure 4, was plotted according to the Hamilton Smith formula as shown on the curve sheet. The photograph, plate I, shows the measuring weir in operation.

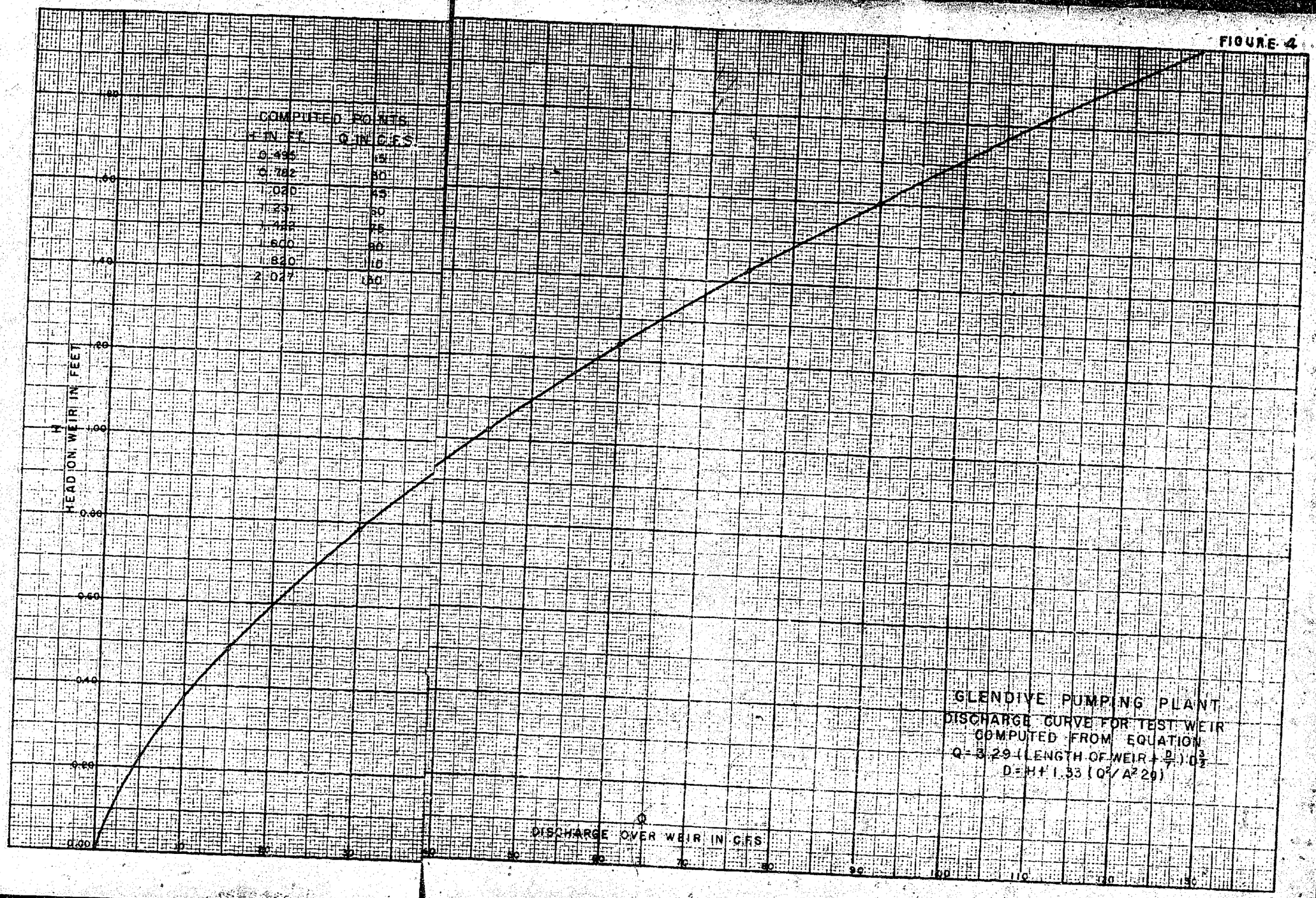
The canal seepage and leakage were determined by measuring the area of the water surface in the canal and observing the distance the water surface dropped in a measured period of time. The weir leakage alone was reckoned as slightly less than 0.1 second-foot.

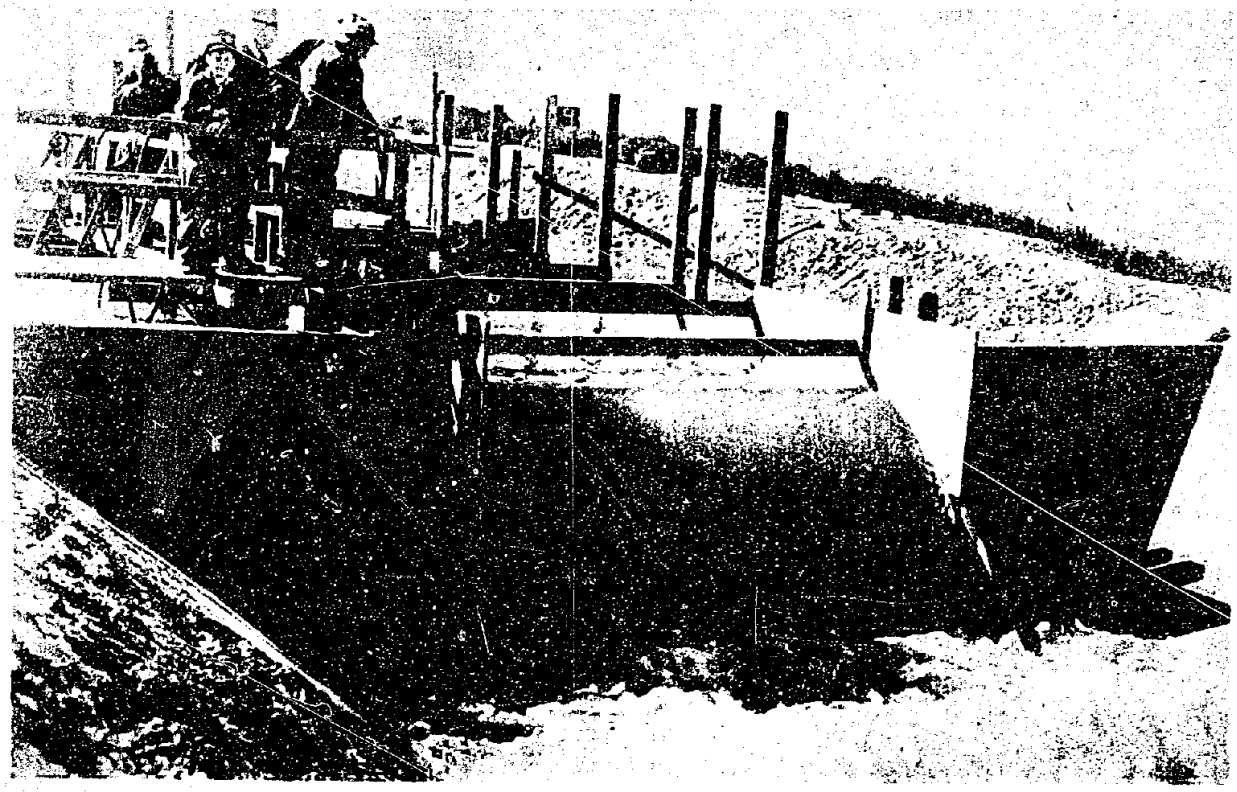


HEAD MEASUREMENTS
Glendive Pumping Plant
Buffalo Rapids Project

Fig. 3

FIGURE 4


COMPUTED POINTS
H IN FT. Q IN C.F.S.
0.495 15
0.782 30
1.020 45
1.237 60
1.442 75
1.600 90
1.820 110
2.027 130
HEAD ON WEIR IN FEET
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
DISCHARGE OVER WEIR IN CFS
0
10
20
30
40
50
60
70
80
90
100
110
120
130
GLENDIVE PUMPING PLANT
DISCHARGE CURVE FOR TEST WEIR
COMPUTED FROM EQUATION
Q = 3.29 (LENGTH OF WEIR + D/7) D^3/2
D = H + 1.33 (Q²/A² 2g)



Measuring Weir Glendine Pumping Plant

Plate I

Each test consisted of six runs. The first run was with valve fully opened for maximum discharge. For succeeding runs the valve was set for discharges of 95, 85, 55, 23, and 90 c.f.s. The full shut-off head was also determined. Each run consisted of the average of ten readings taken at one-minute intervals. The following readings were taken for each run:

A. Electrical:—

Ammeter, phases A, B, and C.
Voltmeter, phases A-B, B-C, C-A.
Wattmeters, 1 and 2.
Watthour meter, disk turns.
Motor r.p.m.

B. Hydraulic:—

Discharge manometer, mercury
Pressure-test gage.
Suction manometer, water.
Weir hook gage.
Flap-gate head-loss manometer, water.
Inlet staff gage.
Outlet staff gage.
Weir box staff gage.

C. Temperatures:—

Motor stator.
Motor room.
Pump room.
Water at pump inlet.
Water at weir box.

It is fully realized that some of these data are not essential to the test, but they are on file in the laboratory in case any question arises requiring their use.

4. Results of tests. The first, or trial test, on unit No. 1 was interrupted by a break in the canal at the discharge transition. The results of this test are, therefore, not plotted. Test No. 2, unit No. 1, was complete and the results are tabulated in table No. 1, and plotted on performance curve, figure 5. The results of test No. 1, unit No. 2, are tabulated in table No. 2, and plotted on performance curve, figure 6. The water temperature for all tests was between 10 and 11 degrees centigrade.

TABLE NO. 1

Unit No. 1 - Test No. 2

Run No.	Q	V_s	V_d	$\frac{V_d^2-V_s^2}{2g}$	H_s/f_1	H_d	Total head	WHP	BHP	Eff.
1	97.3	13.20	14.19	0.42	5.95	96.42	102.79	1135	1357	83.6
2	94.0	12.74	13.70	0.40	5.76	98.95	105.11	1121	1348	83.2
3	85.8	11.62	12.50	0.33	5.31	104.63	110.27	1074	1315	81.6
4	54.0	7.32	7.88	0.13	3.99	118.51	122.63	752	1075	70.0
5	24.5	3.32	3.57	0.03	2.80	126.79	129.62	361	848	42.6
6	92.2	12.50	13.45	0.38	5.62	99.95	105.95	1109	1349	82.3
7	Shut-off	--	--	--	3.41	131.93	135.34	--	713	--

TABLE NO. 2

Unit No. 2 - Test No. 1

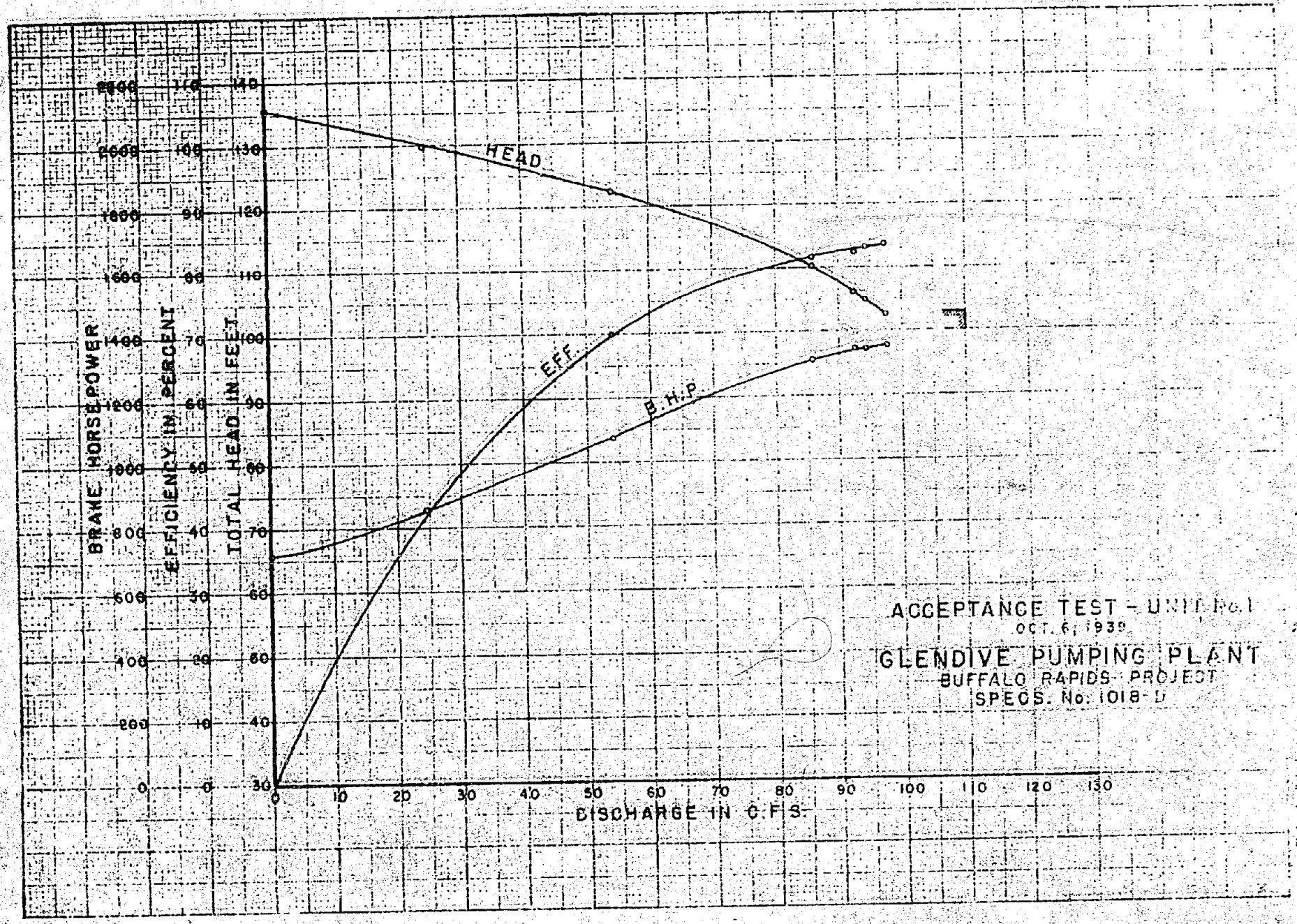
Run No.	Q	V_s	V_d	$\frac{V_d^2-V_s^2}{2g}$	H_s/f_1	H_d	Total head	WHP	BHP	Eff.
1	100.0	13.55	14.58	0.450	6.25	94.80	101.50	1152	1360	84.8
2	94.5	12.81	13.77	0.395	5.98	97.94	104.32	1119	1333	84.0
3	84.8	11.50	12.36	0.323	5.43	103.79	109.54	1054	1290	81.7
4	55.0	7.46	8.02	0.135	4.16	117.60	121.90	761	1080	70.5
5	23.5	3.18	3.43	0.026	3.69	126.90	130.62	348	847	41.1
6	89.5	12.12	13.05	0.362	5.58	100.35	106.29	1080	1325	81.6
7	Shut-off	0.0	0.0	0.0	3.38	130.83	134.21	0	713	0

TABLE NO. 3

Unit No. 2 - Test No. 1

Temperatures and Flap-Gate Losses

Run No.	Q c.f.s.	Temperatures, degrees C. Pump room	Motor room	Motor windings	Flap gate head loss in feet
1	100.0	15.0	16.0	31.5	0.366
2	94.5	15.0	19.5	40.0	0.327
3	84.8	14.5	20.0	44.5	0.281
4	55.0	14.0	20.0	49.0	0.119
5	23.5	14.0	20.0	51.0	0.020
6	89.5	14.0	20.0	52.5	0.308


HEAD
EFF.
B.H.P.
BRAKE HORSEPOWER
EFFICIENCY IN PERCENT
TOTAL HEAD IN FEET
DISCHARGE IN C.F.S.
ACCEPTANCE TEST - UNIT No. 1
OCT. 6, 1939
GLENDIVE PUMPING PLANT
BUFFALO RAPIDS PROJECT
SPECS. No. 1018-D

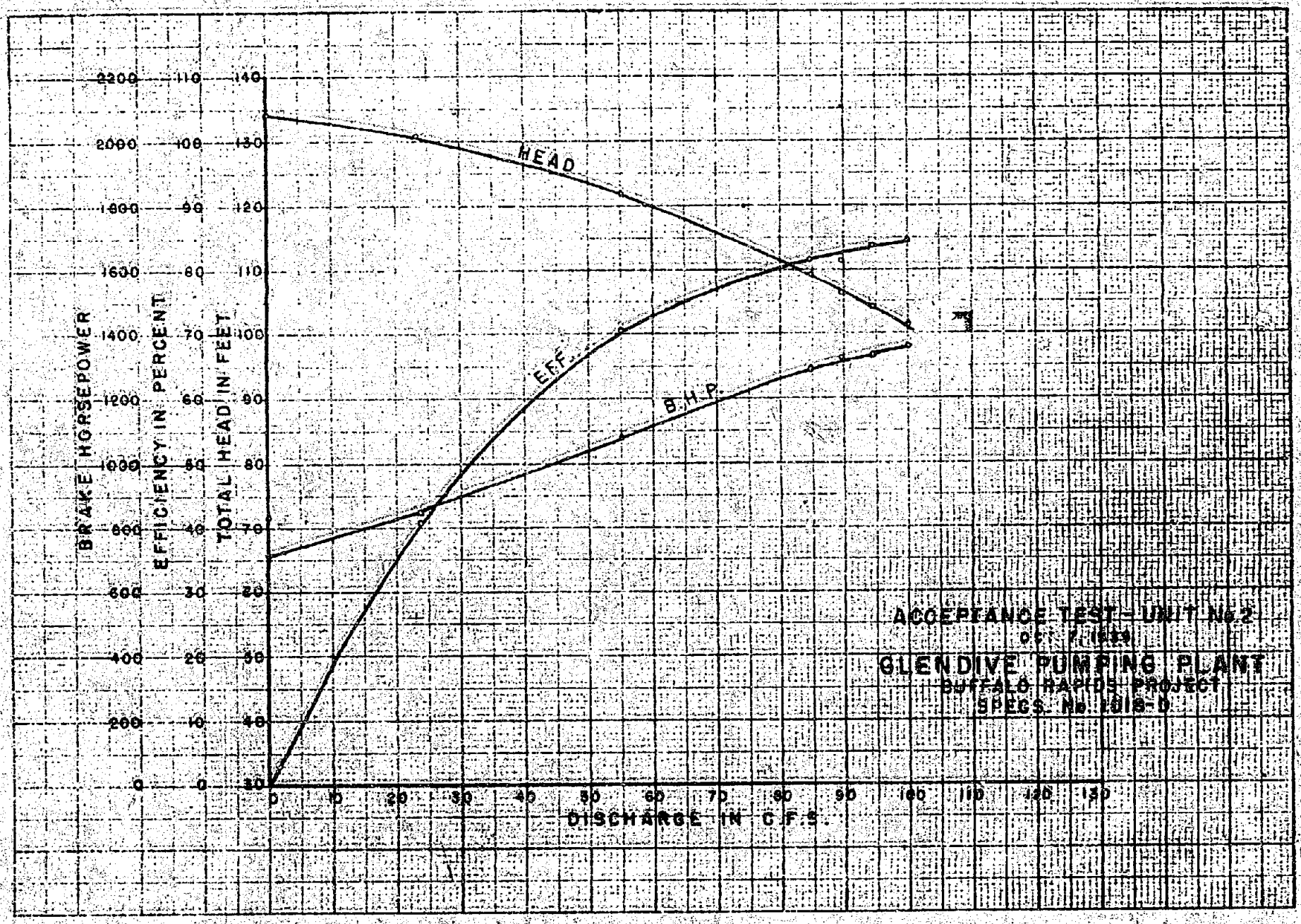

BRAKE HORSEPOWER
EFFICIENCY IN PERCENT
TOTAL HEAD IN FEET
DISCHARGE IN C.F.S.
HEAD
EFF.
B.H.P.
ACCEPTANCE TEST - UNIT No. 2
GLENDIVE PUMPING PLANT
BUFFALO RAPIDS PROJECT
SPECS. No. 1018-D

FIGURE 6

The motor performance was satisfactory in every way within the limits of these tests. There was no indication of undue heat in the windings or bearings. Noise and vibration were normal. Temperatures for unit No. 2, test No. 1, are shown in table No. 3.

The pump performance, from a mechanical point of view, was satisfactory. The bearings showed no evidence of overheating. The stuffing glands were kept full of grease and just tight enough to prevent leakage during the tests. The wear rings were examined and found to be in proper relationship. Hydraulically, however, the pumps did not perform as expected. The sound was as if stones about the size of a man's head were passing through the pump. The pounding was sufficient to cause the cover plate to move up and down causing an appreciable movement of the bearing support above the pump. This condition was alike apparent in both pumps at all discharges. This condition was so severe in the discharge line that the discharge pressure test gage readings were of no value in these tests.

II. NOTES ON TESTS

1. The three-branch transition. It will be seen from the test that, although the pumps are identical, unit No. 2 discharged about 2.7 c.f.s. more water than unit No. 1. This is due to the design of the connection between the 36-inch pump discharge pipes and the 84-inch conduit leading to the canal. The discharge pipe from unit No. 2 is coaxial with the conduit and there is gradual expansion from the smaller pipe to the conduit, the total expansion taking place within a distance of 10.5 feet. This affords considerable head recovery and eliminates loss due to sudden expansion. The discharge pipe from unit No. 1 (also unit No. 3) discharges into the side of this cone frustrum with sudden expansion. This sudden expansion and absence of head recovery account for the difference in discharge between the two units. It, therefore, appears that the design of the three-branch transition might be improved.

2. The outlet transition. Hydraulically, the outlet transition worked very satisfactorily. The leakage which occurred along the conduit and outlet transition was due generally to the nature of the soil on which the structure was built. The canal was first filled with water on September 26 and by October 5 the end of the outlet transition had settled 0.5 foot. As a result, the transition broke away from the conduit leaving a crack about an inch wide. Further settling stressed the steel in the conduit beyond the elastic limit causing several breaks in the top side along the horizontal section of the barrel.

3. Sealing water for the pump packing glands. It appears that pumping grease into the lantern rings in the packing gland will not afford effective sealing unless the grease can be supplied continuously. On the other hand, to supply sealing water to the lantern rings directly from the pump discharge line might cause undue wear on the bronze shaft sleeve due to silt in the water. A pressure-type filter inserted in the line leading from the pump discharge pipe to the lantern rings should give satisfactory results.

4. Heating. In order that the operator may be able to carry on such maintenance work as may be necessary during extremely cold weather, it is suggested that some means of heating the pumping plant building be provided.

III. LOG OF TRIP AND TESTS

9-23-39 - The test equipment having been shipped previously, I left Denver Municipal Airport at 1:10 p.m., by plane and arrived at Glendive by train at 12:35 a.m., having changed from plane to train at Billings, Montana.

9-24-39 - Contacted Mr. P. A. Jones, construction engineer in charge of the project, and Mr. Edwin Bean, chief clerk. Discussed the problem and made necessary arrangements for the tests.

9-25-39 - At 7:45 a.m. met the office personnel, had test equipment delivered to pumping plant. Made general inspection of the plant and canal. Opened up both pumps and checked runner clearances and piezometer holes. Inspected the delivery pipe from pumps to flap gate. Set up mercury manometer on unit No. 1. Got unit No. 2 ready to run. Installed flap gate.

9-26-39 - Started unit No. 2 at 4:25 a.m. at quarter gate and gradually reached full opening about noon. Pronounced rattling and pounding in pump at all discharges. Relay setting to prevent tripping at part load corrected. Found burned out hair spring in power-factor indicator. Examined transformer connections and found 2,400 volts as lowest possible secondary. Checked for leaks on manometers.

9-27-39 - Stopped unit No. 2 at 4:00 a.m. Water had reached Cracker Box Creek wasteway. Made final check and measurements on unit No. 1. Cleaned piezometers and

made all connection to manometers and pressure gages. Began connecting electrical instruments. Got weir partly installed. Got hook gages and pots ready to install. Riprapped canal at pump outlet transition to stop caving.

9-28-39 - Closed up pump No. 1. Spent most of day installing and connecting electrical instruments. Set up dead weight tester and tested pressure gage. Finished weir installation.

9-29-39 - Made voltmeter switch and finished electrical connections on unit No. 1. Adjusted weir crest. Ran unit No. 2 to wet down weir and canal. Set hook gages and pots. Leakage past weir about 0.10 cubic foot per second. Checked canal leakage.

9-30-39 - Checked weir gage zero, posted and instructed recorders. Started unit No. 1 at 10:30 a.m. Started testing at 11:15 a.m. At the end of run No. 2 (12:00 noon) break in canal caused shutdown. Testing was resumed at 1:30 p.m. and completed at 3:00 p.m. Discharge less than expected.

10-1-39 - Sunday, no testing. Work on test data. Repeat test necessary due to canal break and weir roughness.

10-2-39 - Weir had settled about 1/2 inch on west end. Reset weir crest. Changed manometers to read discharge and suction pressures separately. Installed manometer to show loss in flap gate. Installed borrowed power factor indicator on switchboard. Made ready for final test on unit No. 1 tomorrow.

10-3-39 - Posted and instructed recorders, checked instruments, and zeroed weir. Started unit No. 1 at 9:30 a.m. A few minutes later a serious break around discharge pipe started. Investigation revealed necessity of excavating and puddling backfill. This work continued all day and all night.

10-4-39 - Directed repair work all day. Drove over to Ed Bright's "sinking farm" in evening.

10-5-39 - Started test on unit No. 1 again when break started on opposite side of discharge pipe. More excavating and puddling. Transition has settled about 6 inches, breaking the barrel. Calking, grouting, and puddling continued all day and all night.

10-6-39 - Finally ran test, keeping about a dozen men checking leaks. Total leakage by test indicated about 0.3 c.f.s. due to seepage and weir leakage. Test results appear satisfactory. Transferred hydraulic and electrical test instruments to unit No. 2 in readiness for test tomorrow.

10-7-39 - Posted recorders and started testing about 7:00 a.m. on unit No. 2. Test proceeded without mishap. After test, gage zero had not changed appreciably. Canal leakage test showed about 0.25 c.f.s. from all sources.

10-8-39 - Sunday. Worked up some of data and found same complete. Visited Mr. P. A. Jones who had become ill due to exposure in repairing canal breaks.

10-9-39 - Dismantled test equipment and packed up ready to ship to Denver. Got wire asking when equipment could be shipped to Owyhee ditch. Replied, "CAN SHIP WHEN REQUIRED." Boarded train for Denver at 11:50 p.m.

10-10-39- Arrived at Denver Municipal Airport at 6:20 p.m. having been delayed about 8 hours in Billings due to grounded plane.

ACKNOWLEDGMENTS

It is here desired to express appreciation for the wholehearted cooperation of the staff at Glendive during these tests. Mr. Paul A. Jones, construction engineer in charge of the project, Mr. Ed. C. Bean, chief clerk, and Mr. Parley R. Neeley, associate engineer, rendered every possible assistance during the tests. Mr. Wm. S. Thompson, instrumentman, and his group of men rendered valuable assistance in taking care of the hydraulic measurements, and Mr. Joe Heitz, electrician, with his group of men, rendered valuable assistance in taking care of the electrical measurements. Especially valuable was the assistance rendered by Mr. Earl T. Walters, plant operator, in all phases of the tests.

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