UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

- - -

HYDRAULIC LABORATORY REPORT NO. 119

- - -

FIELD ACCEPTANCE TESTS
PUMPING PLANT "D", MODOC UNIT
TULE LAKE DIVISION - KLAMATH PROJECT

By

J. N. Bradley, Engineer

- - -

Denver, Colorado

January 21, 1943

HYD 119

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division

Laboratory Report No. 119
Hydraulic Laboratory
Compiled by: J. N. Bradley

Denver, Colorado
January 21, 1943

Reviewed by:

Subject: Field acceptance tests, on three pumping units furnished by the Morris Machine Works under specifications No. 1492-D, Pumping Plant "D" - Modoc Unit - Tule Lake Division, Klamath Project.

THE PUMPING PLANT AND ITS PURPOSE

In accordance with office letter of October 14, 1942, from Acting Chief Engineer to Superintendent, Klamath Falls, Oregon, acceptance tests were made together with a mechanical inspection of units 1, 2, and 3 at pumping plant "D", Tule Lake, California, during the period of October 21 to 30, inclusive, 1942.

The plant (figures 1A and 1B) is located on the west bank of Tule Lake, 5 miles west of the town of Tule Lake, California, and about 35 miles southeast of Klamath Falls, Oregon. Plant "D", although the largest, is one of a number of pumping plants which are used to control the level of Tule Lake. The lake, which at one time covered a vast area of swampy but very fertile land, has been gradually reduced and confined by dikes until it is now only a fraction of its original size and the reclaimed land resulting from the unwatering operations has been put under cultivation. This plant is necessary to insure against the water level overtopping the dikes during the wet season of the year. Plant "D" consists of three 450-horsepower units (figure 2). The pumps are of the vertical, single-suction type, measuring 24 inches in diameter at the suction throat and 30 inches at the discharge flange. They have a rated capacity of 50 second-feet each for a total pumping head of 64 feet and a speed of 600 r.p.m. (specifications

No. 1492-D), and were supplied by the Morris Machine Works. The pumps are directly connected to 2,300-volt, three-phase, 60-cycle synchronous motors which were supplied by the Electric Machinery Manufacturing Company. The motors are rated at 95 percent efficiency for unity power factor at full load. The pumps are rated at 87.0 percent efficiency when pumping 50 second-feet under a total pumping head of 64 feet, and the over-all efficiency of the units should therefore be 81.0 percent.

The pumps have individual suction tubes protected by single rack structures, which are supplied with water from a common unpaved intake canal (figure 1B). Each pump discharges through an expander from 30 to 36 inches in diameter, then through a short section of steel pipe to a reinforced concrete pipe. The three concrete pipes converge into a single three-barreled conduit, some 360 feet long, which conveys the water up an incline to a short section of open channel (figures 1E, 1F, and 2). To prevent the flow from reversing during a power outage, a 36-inch check gate is located at the outlet of each of the three conduits of the concrete barrel. These gates are also necessary during the priming operation. The short open channel section at the check gates serves as a transition to guide the water into a 5.75-foot horseshoe tunnel 6,700 feet in length. From this point on the flow is entirely due to the effect of gravity. The tunnel discharges into a trapezoidal canal from which the water can be routed to cultivated lands over the project for irrigation purposes or wasted into lower Klamath Lake and thence to the ocean via the Klamath River.

TEST SCHEDULE

To supply data for the efficiency determinations of the three units, the following measurements were taken:

(a) Measurement of quantity of water pumped.

(b) Determination of the total pumping head defined in specifications as "the difference between the energy of the water inside the trashracks and the elevation corresponding to the pressure head plus the average velocity head measured at the pump discharge pipe."

(c) Measurement of power input to motor.

The following were secondary considerations:

(d) Measurement of trashrack losses.

(e) Measurement of pipe line losses.

(f) Measurement of check gate losses.

MEASUREMENT OF DISCHARGE

The discharge was measured over an 8-foot rectangular suppressed weir specially constructed for these tests and designed to strict accordance with the Standards of Hydraulic Institute code. This weir was located in the trapezoidal canal approximately 400 feet downstream from the outlet of the horseshoe tunnel a mile and a half from the plant as the crow flies, or 13 miles by road (figure 2). It was estimated that 25 minutes were required for a given volume of water passing through the pumps to reach the weir. Therefore, head measurements at the weir were commenced 25 minutes after corresponding observations were made at the pumps. The head on the weir was measured by some twelve observations, over a period of 30 minutes, by a hook gage reading to thousandths of a foot (figure 3C). The gage zero was determined immediately before and after the tests and was found to have changed but slightly during the period. Leakage past the weir together with canal seepage upstream was insignificant. Photographs of the weir are shown as figures 1C and 1D, and a discharge curve for this weir, computed according to the Hamilton Smith formula, is shown on figure 4. Nine runs were made on unit 3, seven on unit 2, and eight on unit 1. The head on the weir, discharge, and condition under which each run was made are shown in columns 3, 4, and 59, respectively, of table 4.

DETERMINATION OF TOTAL PUMPING HEAD

The discharge head was observed from a mercury pot gage, connected in succession to four special taps, denoted as U.S.B.R. taps, located in the 30-inch pipe directly downstream from the pump (figure 3A). The suction head was taken as the difference between the center line of the pump and the energy of the water in the intake canal measured at gage 2 inside the trashracks (figure 3A). The total pumping head, H, was therefore determined as follows:

$$H = h_s + (13.56\, h_d - f) + \frac{V^2 d}{2g}$$

where

h_s = actual suction lift to ℄ pump in feet of water,

h_d = discharge pressure obtained from pot gage in feet of mercury,

$(13.56\, h_d - f)$ = discharge pressure in feet of water, corrected to read above ℄ of pump, and

$\frac{V^2 d}{2g}$ = velocity head at discharge taps in feet of water.

As a matter of interest the total pumping head was also determined from the manufacturer's suction and discharge taps located on the pump proper. The same mercury pot gage was employed to measure the discharge pressure but an additional mercury U tube (figure 3A) was required to observe the negative pressures at the suction throat of the pump. The method of computing the total pumping head in this case was as follows:

$$H_1 = (13.56 h_{s_1} + f_1) + (13.56 h_{d_1} - f) + \frac{(V^2{}_{d_1} - V^2{}_{s_1})}{2g}$$

where

h_{s_1} = suction pressure observed from manufacturer's suction tap in feet of mercury,

$(13.56h_{s_1} + f_1)$ = suction pressure in feet of water, corrected to ℄ of pump

h_{d_1} = discharge pressure from manufacturer's discharge tap in feet of mercury,

$(13.56h_{d_1} - f)$ = discharge pressure corrected to ℄ of pump in feet of water,

V_{d_1} = velocity at manufacturer's discharge tap in feet per second, and

V_{s_1} = velocity at manufacturer's suction tap in feet per second.

The total pumping heads as computed using the U.S.B.R. discharge taps and the actual suction lift are shown listed in column 14 of table 4, and the total pumping heads as obtained from the manufacturer's discharge and suction taps on the pump are listed in column 20 of the same table. It is interesting to note that the heads measured at the manufacturer's discharge taps are consistently 0.4 percent higher than those observed at the U.S.B.R. taps (columns 18 and 13, respectively, table 4); but the total pumping heads (columns 20 and 14) are consistently 1.4 percent lower than those obtained by the U.S.B.R. method. It is felt that this experience proves the point that accurate pressure readings cannot, as a rule, be obtained from suction taps located in close proximity to a rotating pump impeller. It can also be pointed out that only the loss in the pump proper was considered when measuring the head at the manufacturer's taps, while the loss in the suction tube was also included from the total pumping head as computed by the U.S.B.R. method.

MEASUREMENT OF POWER INPUT TO MOTOR

The power input to the motor was observed from two accurate test wattmeters which were calibrated before and after the test. These were connected in the main lines leading to the plant as shown on figure 5, through accurate test potential and current transformers. The power as measured included the energy to operate the exciter and current losses in the rheostat as per specifications. The exciter rheostat was adjusted so as to balance the readings on two wattmeters to obtain unity power factor. The coarseness of the rheostat, however, prohibited obtaining exactly duplicate readings on the two meters; these are shown tabulated in columns 42 and 43, table 4. The power input in kilowatts obtained by this means of measurement is shown in column 44.

As the panel instruments could not be read accurately, a sensitive voltmeter and ammeter were connected into the circuit as shown in figure 5. These were read several times during each run and the average readings are listed in columns 50 and 51. Normally the line voltage ranged from 2,400 to 2,500 at this plant. By shifting taps on the transformers in the switchyard, it was possible to reduce the voltage during the tests to the values shown in column 50 which were considered satisfactory. The voltage remained quite steady during the day, except for the noon hour, at which time it showed an increase of as much as 50 volts. The power in kilowatts as computed from the test voltmeter and ammeter is shown in column 52. In addition, readings of the panel voltmeters and ammeters are recorded in columns 53, 54, and 55. These can be recalibrated over the normal operating range by comparing the readings with the test instruments. Also, these readings may assist the operator in his attempt to operate the units at unity power factor.

As a third check on the power consumed, the rotations of the station watt-hour meter disk were timed during each run and the power in kilowatts obtained in this way is listed in column 57.

A comparison of the power input obtained by the three methods of measurement (colums 44,52, and 57) shows the results of the test voltmeter and ammeter combination to be as accurate as would be expected and the power input as obtained from the watt-hour meter to be consistently low by approximately 1.1 percent.

DETERMINATION OF EFFICIENCIES OF UNITS

Using the power input obtained from the test wattmeters and the total pumping head, as measured by the U.S.B.R. method, the over-all efficiencies of the units are listed in column 22 for the various conditions under which the runs were made. It can be noted from column 59 that runs were made at low, medium, and high levels in the open transition section immediately downstream from the check gates. Figure 1E shows a view of the open transition section and check gates with no flow. Figure 1F shows the transition during the high level with unit 1 in operation. The water level was controlled by regulation of the needles in the temporary check dam shown in the foreground. Gage 5 is shown on the left and gate 6 in the center of figure 1F. In some cases, the check gates were operating in their normal positions and in other cases they were lifted completely out of the water. Then in other runs the gates were actually blocked in a partially closed position to increase the head on the pump.

As a matter of interest, the over-all efficiencies were computed using the head measurements obtained from the manufacturer's taps on the pump. These are shown in column 23 and are consistently 1.4 percent lower than the efficiencies obtained by the former method of head measurement.

From the motor manufacturer's test curve (figure 6) the actual horsepower delivered to the pump shaft, designated as B.H.P., was obtained and this is shown tabulated in column 46. The actual pump efficiencies are listed in column 24. The extent of the pump characteristics obtained from these tests is shown plotted, by full lines, for units 1, 2, and 3 on figures 7, 8, and 9, respectively. The dotted curves were taken from Morris Machine Works print No. 32254 which was submitted by the manufacturer prior to delivery of the pumps. Unit 1 is one percent less than the over-all guaranteed efficiency, unit 2 exceeds the requirement by 1.3 percent, and unit 3 exactly meets the requirement for the rated head of 64 feet.

TRASHRACK LOSSES

The losses through the single trashrack structures were obtained from the difference in energy measured at gages 1 and 2 (figure 3A). These are quite small, amounting to an average of 0.012 foot of water or 1.6 $\frac{V^2}{2g}$, where V equals average velocity computed across the section at gage 2. The losses as measured for each run are tabulated in column 10 of table 4.

PIPE LINE LOSSES

Using gage 6, which consisted of a water tube connected to the air valves immediately upstream from the check gates (figures 1F and 3B), the total loss between this point and gage 3 was determined for the runs on units 1 and 2. The total energy at the U.S.B.R. taps was in this case computed using a velocity head correction factor $\alpha = 1.20$, which was based on experiments on single suction pumps. The corrected velocity heads are shown in column 25 (table 4) and the true total energy heads, expressed in elevation, are listed in column 27.

The velocity head correction at gage 6 was chosen as $\alpha = 1.03$ based on various sources, the most recent of which was an article written by Victor L. Streeter[1]. In this case the velocity distribution in the pipes in the vicinity of gage 6 was considered quite uniform. The corrected velocity heads at gage 6 are listed in column 30 and the total energy heads, expressed in feet of elevation, are shown in column 31.

---

[1] The Kinetic Energy and Momentum Correction Factors for Pipes and for Open Channels of Great Width, by Victor L. Streeter, Civil Engineering, April 1942, page 212.

The total losses measured between gages 3 and 6 for the various conditions of flow are tabulated in columns 32 and 33.

The expander and bend losses, as estimated for the two pipes, are summarized in column 34. Deducting the latter values from column 33, the resulting pipe losses (column 35) were obtained.

The friction factor "f", in the formula $h_f = f \frac{L}{D} \frac{V^2}{2g}$, for the combined length of concrete and steel pipe, ranges from 0.0138 to 0.0121 for Reynold's numbers ranging from 1,192,264 to 1,347,924 (columns 36 and 40, respectively). These figures would indicate exceptionally smooth concrete pipe.

CHECK GATE LOSSES

Two methods were used to measure the check gate losses, both of which showed comparable results. In the first case, the loss was considered as the difference in static head between gages 6 and 5 for runs in which the check gate swung free and a reading was visible on gage 6. In the second case, the tail-bay water surface at gage 5 was held as nearly constant as possible while the pressure at gage 3 was observed first for the check gate swinging free and then for it suspended above the water surface. The difference in pressure observed at gage 3 for the two conditions was considered as the check gate loss. The second method is not as reliable as the first. The check gate losses, in feet of water, are shown in column 38 (table 4) and these are expressed in velocity head in column 39, where V represents the velocity in the 36-inch conduit. The flap gate losses average $0.46 \frac{V^2}{2g}$ for the outside gates and $0.64 \frac{V^2}{2g}$ for the center gate. It so happens that the arms on the center gate were broken when the plant was first put in operation. The gate was repaired by welding and this may account for the difference in loss between this gate and the outer two.

TEMPERATURES

The following temperatures were measured during the four days of testing:

Table 1

AVERAGE TEMPERATURES - DEGREES C				
Location	Unit 1	Unit 2	Unit 3	
Water in forebay	5.9	5.0	6.6	7.2
Air in pump room	12.1	13.1	15.0	14.0
Air in motor room	23.5	23.1	25.0	27.2
Stator core	47.0	42.5	46.2	45.8
Oil in motor thrust bearing	47.4	47.9	52.7	52.0
Water at weir	5.0	4.8	5.8	5.0
Date	10-30	10-29	10-27	10-28
Time	8 a.m. to 4:45 p.m.	8 a.m. to 3:30 p.m.	10:30 a.m. to 4 p.m.	11 a.m. to 2:30 p.m.

Each pump was started the night before it was tested, thus providing at least 16 hours for the motors to warm up. It appears from the tabulation that all motors perform equally well from the standpoint of temperature. According to the operator this is not true in warm weather. The operator was alarmed that the motor on unit 3 ran considerably warmer than those of the other two units during the extreme heat of the past summer. Temperatures of the motor windings and cores were not measured during this period, therefore the actual extent of the heating is uncertain. The temperature of the armature windings, cores and mechanical parts in contact with insulation should not exceed 80 degrees C and the temperature of the field windings as determined by resistance should not exceed 100 degrees C. Apparent high motor temperatures during hot weather should be no cause for alarm unless the above limits are exceeded. It should also be mentioned that the motors can be operated at these limits without damage to the insulation. It is improbable that the temperature of unit 3 has ever reached this limit. The men on the project attribute the heating of unit 3 to poor ventilation of the building. The prevailing wind is from the south, thus air enters the plant through the large south door which is undoubtedly open during the summer months, and leaves through the windows of the east wall and the louvers of the west wall. Unit 3 is more or less deprived of this cross ventilation as the north wall is solid. It is questionable whether this is a valid explanation for the additional heating of unit 3, however, the heating does exist and an investigation should be made to determine the actual cause. If this is a ventilation problem, the facts should be made available. Each motor is cooled by two sets of fan blades which force air from the pump room through the motor and out into the motor room.

Table 2 is a copy of the operator's record showing hourly temperatures, in degrees Fahrenheit, for the oil in the main thrust bearings of the three motors during six of the warmest days of 1942. The highest oil temperature recorded was 152 degrees F for unit 3 which consistently operated from 15 to 20 degrees warmer than unit 1, and 5 degrees warmer than unit 2. Table 1 shows the average oil temperature of unit 3 to be a few degrees C higher than for the other two units when operating with outside air temperatures from 12 to 15 degrees C. These thrust bearing oil temperatures should not be confused with temperatures of the motor windings as the two may be entirely different.

The fact that the thrust bearing on unit 3 runs warmer than the other two, may indicate that this unit is slightly misalined. This, if true, could also account for the additional heating at the motor. It is, therefore, recommended that the alinement of unit 3 be checked and corrected if necessary. Then it is desired that a record be kept of the temperatures of the motor windings of the three units during the warmest days of 1943. Should the

TABLE 2

KLAMATH PROJECT - OREGON-CALIFORNIA
MODOC UNIT - TULE LAKE DIVISION

Temperatures of oil - Main thrust bearings
Pumping Plant "D"
Degrees F.

Time	July 1, 1942			July 2, 1942			July 3, 1942			July 23, 1942			July 24, 1942			July 25, 1942		
	Unit No.			Unit No.			Unit No.			Unit No.			Unit No.			Unit No.		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1 AM	128	134		130	136	148	136	140	148	120	130	140	128	134	143	127	133	142
2	124	132	140	126	132	144	134	139	146	122	128	140	126	134	142	126	130	140
3	124	130	144	124	131	143	130	136	145	120	130	140	126	133	140	124	129	139
4	125	130	144	121	128	142	125	134	144	120	130	140	124	130	140	122	127	137
5	124	130	143	119	126	140	123	132	142	120	126	140	124	130	140	120	125	136
6	123	130	143	116	126	140	121	130	140	120	126	138	122	130	140	120	125	136
7	121	130	141	115	124	138	120	130	140	118	126	138	121	129	140	119	125	135
8	121	130	142	116	126	139	120	129	140	120	128	140	120	127	140	119	124	136
9	122	130	143	122	130	140	121	130	140	120	130	144	121	130	144	120	130	140
10	125	132	144	124	132	141	124	132	140	122	131	144	122	133	144	123	130	140
11	127	134	144	126	133	143	126	133	140	124	132	142	123	134	143	122	130	140
12 M	129	136	144	128	134	143	128	135	143	124	134	140	125	134	142	124	131	140
1 PM	132	138	146	131	137	144	129	136	144	125	138	143	126	135	143	123	130	140
2	132	138	146	135	140	147	129	136	146	130	137	144	128	136	144	125	131	143
3	134	139	147	137	141	149	129	137	147	130	138	145			144	128	133	144
4	136	140	148	139	142	149	138	138	145	133	140	147	134	142	148	132	138	146
5	138	141	150	140	144	150	130	147	147	135	142	149	136	146	150	134	140	148
6	138	142	150	140	144	150	128	145	148	137	144	150	136	144	149	135	142	150
7	139	143	150	140	144	150	125	140	148	138	146	152	135	142	150	134	141	149
8	139	143	151	140	144	150	130	140	144	137	146	152	135	143	150	134	141	149
9	138	143	152	140	144	150	130	140	148	137	144	150	134	142	148	130	138	148
10	136	141	152	140	144	150	130	140	148	137	141	150	132	140	147	129	136	146
11	135	140	152	138	144	150	130	140	146	132	138	147	130	137	146	126	133	144
12PM	134	138	150	137	141	149	130	138	142	128	134	143	128	136	143	125	130	140
Air temp. of Tule Lake, Cal.	Max. 93° Min. 51°			93° 50°			92° 51°			94° 52°			93° 51°			92° 46°		

Note: Unit No. 3 operated with east half of floor plates removed to increase air circulation around motor. All doors, windows, and louvers in pumphouse open.

temperature of the motor on unit 3 continue to run considerably warmer than those on the other units, the records should be forwarded to the Denver office.

MECHANICAL INSPECTION OF PUMPS

Prior to testing, the inspection covers were removed from all three pumps and the inside pipe surfaces smoothed in the vicinity of the gage taps. The asphalt paint had peeled in spots immediately downstream from the pump but appeared to be in good condition further downstream. The pumps contain three-bladed bronze impellers with large water passages and all were found to be absolutely clean. In fact, there is some action produced by the tule growth that keeps the impeller surfaces highly polished and this does not appear to be abrasive luster. The clearances between impeller and pump cases were satisfactory for all three units. An attempt was made to adjust the packing glands so that all three impellers would turn with the same force for the tests. It was not possible to adjust unit 3 to turn with the same ease as units 1 and 2. The impeller and volute castings were rough in spots but in no case was this serious. The difference in shape and roughness between the three pumps, however, may account for the fact that unit 3 pumped two second-feet more water than unit 2, and two and one-half second-feet more than unit 1.

The suction tube of unit 3 was unwatered and found to be clean and smooth; however, a small offset of perhaps 0.5 inch is present at the point where the concrete joins the steel suction pipe. This was attributed to the slippage of a concrete form and is not serious as the corners have been rounded. The impeller, as observed from the suction tube, was highly polished but showed no signs of cavitation after seven months of continuous operation. The suction tubes of units 1 and 2 were not unwatered as it was not considered worth the necessary time and labor. Probing into tubes 1 and 2 with a rake indicated that no obstructions were present and this was also verified by the project construction superintendent and the operator, both of whom inspected the concrete work after its completion. The tube of unit 3 was supposedly the least desirable of the three.

The operator states that soon after the plant was set in operation the top pump bearing froze to the drive shaft on unit 3 and that the same bearing on the other two pumps ran hot. This particular bearing consists of two bronze sleeves; the center one, which has been shrunk on to the steel drive shaft, rotates inside the outer one making a bronze-to-bronze contact. Perhaps the proper clearances were not allowed for the additional bronze metal. According to the operator, the units were dismantled and an additional 0.016-inch clearance provided at each bearing. No further trouble has been experienced with these bearings.

INSPECTION OF MOTORS

Observed from the motor floor, units 1 and 2 perform without any noticeable vibration. Unit 3 does vibrate to some extent but not sufficient to be considered serious. This is undoubtedly a mechanical pulsation rather than the result of cavitation. The construction engineer stated that difficulty was encountered in alining the motor and pump on this unit. It appears that they may still be very slightly misalined. This, together with the fact that the thrust bearing runs warmer on unit 3 than on the other units, would suggest that a check of the alinement may prove beneficial.

No difficulties have been encountered with the motor starting equipment or any of the panel control units, except for the panel ammeters and voltmeters which are crude and not very reliable.

INVESTIGATION OF PRIMING EQUIPMENT

The priming equipment consists of a Victor Acme blower furnished by Roots-Connersville Blower Corporation, type R.F., size 5-2 L driven at a speed of 1,170 r.p.m. by a 15-horsepower General Electric motor. With the lake water surface at the present level, elevation 4,034.0 unit 1 primed in six minutes, unit 2 in four minutes, and unit 3 in five minutes. The time of priming, however, depended on the degree of seal obtained at the flap gates. The blower heated up considerably during the priming trials while the motor ran cool. Some difficulty was experienced with the ball valves in the air lines, however, which may account for a portion of the heating. The balls float in metal cups each of which had two 3/32-inch holes in the bottom for draining. It so happened that these holes were plugged with tule growth, the cups remaining continually full of water, causing the balls to float very close to the valve seats. It was believed that at times the balls seated before the priming operation was completed; therefore, larger holes were drilled in the retaining cups.

As it only requires a negative pressure of 1.65 pounds per square inch for priming, with the lake water surface at the present level of elevation 4,034.0, it is impossible to tell when a unit is primed from the combination pressure and vacuum gage located on each pump. The gage scales are too large to indicate these pressures. It was found that listening to the blower was the best means of discerning when a pump was primed. When the ball valve closes the blower commences to labor, producing a different tone. The relief valve opens soon afterward as a second warning but neither of these can be heard when a pump is running. Timing the priming operation is not reliable as the period is dependent on the air leakage due to variable seating of the flap gates, packing gland leakage, and other factors which vary with the period that a pump has been out of operation. For short periods of shut-down up to about 12 hours, the pumps will remain primed since a vent is not used in the discharge lines. For shut-down periods in excess of this amount it will be necessary to resort to the vacuum pump for priming.

To simplify the priming operation it is proposed that a vacuum gage reading to absolute zero or 26 inches of mercury be purchased for field installation in the 3-inch air header at the vacuum pump. Each pump should be primed separately and the procedure is outlined as follows: Open the 3-inch gate valve located in the air line directly below the Crispin valve (ball valve) of the pump to be primed. The corresponding valves on the two other units should be closed. The priming pump is then started which evacuates the air causing the water to enter the main pump and a portion of the discharge line. As the water level reaches the Crispin valve, the gage in the air line should register a vacuum of 6.5 inches of mercury with the lake level at 4,032.0 or 5.0 inches of mercury for the lake level at 4,034.0 feet. As the water level continues to rise, the ball in the Crispin valve floats into seating position after which the vacuum gage in the air line should rapidly register an increase in vacuum from 5.0 or 6.5 inches, depending on the lake level, to about 15 inches of mercury. At this point the 3-inch gate valve should be closed, the priming pump shut down and the main pump started. The relief valve in the air line should be adjusted to open at a vacuum of approximately 10 to 15 inches of mercury to prevent the priming pump from operating at full vacuum. There is no danger that the priming pump motor will become overloaded as the pump is motored to operate at complete vacuum. However, it will be found that the pump proper will heat considerably if run under this condition for any length of time.

Continue to utilize the combination gages connected to the main units to make certain that each unit is pumping water when on the line but ignore these gages so far as negative pressures are concerned as they are unreliable. It will be necessary to open the 3-inch gate valve and start the priming pump before the pressure condition in a pump can be observed. Now that the combination gages will be limited to pressure observations it may prove convenient to extend the gage lines so that the gages can be placed upstairs in the motor room.

FLAP GATE OPERATION

The check gates at the end of the concrete barrel provide the only means of sealing the units for priming. The "music note" rubber seals provided at the end of the pressure pipes are excellent with the exception of the joint. The rubber has evidently shrunk longitudinally leaving a crack from 1/4 to 3/8 inch where the two ends meet. Sufficient air enters through these cracks to drain the pipe lines overnight. It is suggested that these seals be cut to length and the ends vulcanized together at the factory for future installations.

The check gates together with the "music note" seals perform perfectly during starting and shut-down. As the pumps are started the gates swing open easily with a steady motion. On shut-down, the motion is again slow and steady in the opposite direction until the bottom of the gate approaches four inches of the seat. From here on the motion is quick, and the gate slams with sufficient impact to insure a good seal with the rubber.

The gate has one drawback, however, that was discovered while priming the pumps. After two days shut-down not one of the pumps could be primed until the gates were pushed against the rubber seals. In other words, these gates do not necessarily seal when hanging in their natural closed positions. The lower lips of the gates appeared to hang from 1/2 to 1/4 inch from the seats. It is therefore recommended that this type of gate, in future installations, be either counterbalanced to a greater extent or that the end of the pipe line and rubber seal be set at a flatter angle than shown in figure 3B. It is also suggested that the present gates be weighted so that sealing in their natural closed positions will be assured.

SHUT-DOWN CYCLE

An analysis of the hydraulic action in one of the pipe lines on shut-down is as follows: As the power is disconnected, the flow tends to reverse closing the check gate. During this short interval of time, a small volume of air may or may not enter the pipe previous to closure of the gate. As it is impossible for the water in the line to normally stand at a height greater than 29.2 feet above the intake surface, any trapped air expands as the water level in the pipe line rapidly falls. As the air expands and the pressure falls off to a value approaching absolute zero, the vapor pressure of water is reached and additional vapor is released from the water. This aids in filling the void space with gas and thus controls the rate at which the water level drops in the pipe line.

During this same period of time the pump slows down to a stop approximately 18 seconds after the switch is disengaged gradually reducing the pumping head to zero. It then reverses and spins in the opposite direction. During the interval from 10 seconds to 24 seconds after the circuit has been broken, the pump sets up a terrific clatter which is produced by cavitation. This action occurs while the pump is rotating slowly, stopping, and getting under way in the reverse direction. Twenty-four seconds after shut-down the noise abates and the pump coasts quietly in the reverse direction for approximately two minutes. It is evident from the complete characteristic curves obtained from the Grand Coulee pump experiments[2] that pumps of this type run with practically the same efficiency as turbines or pumps; therefore cavitation would be most severe during the period when the impeller was moving slowly or completely stopped. Quadrant IV (Figures 14 and 15 of

---

2 Centrifugal Pump Performance as Affected by Design Features, by R. T. Knapp, Transactions A.S.M.E., vol. 63, No. 3, page 251.

the above reference) shows typical pump characteristic curves during this reversal of speed for a constant head. In the case of the Modoc units the head is not constant after reversal.

Maximum reverse speeds were measured and are shown in table 3. The speed varied with the degree of submergence at the check gates. The speed was highest in cases where the unit tested was the only one running at the time, due to the fact that a small volume of air entered the discharge pipe prior to the closing of the check gate. This air allowed the water level in the pipe to fall off more rapidly than it would have had the air been absent. With two units operating a lesser quantity of air entered the pipe on shut-down, which is indicated by a lower speed. For three units running, the check gates were submerged; thus the air supply was eliminated, resulting in a still lower reverse speed of the pump.

Table 3

Maximum Reverse Speeds in R.P.M.

Unit	Speed	Condition
1	495	Units 2 and 3 operating
2	500	Units 1 and 3 operating
	577	Unit 1 shut down, unit 3 operating
	620	Units 1 and 3 shut down
3	515	Units 1 and 2 operating
	580	Units 1 and 2 shut down

ACKNOWLEDGEMENTS

It is desired to acknowledge and thank Messrs. B. E. Hayden, Project Superintendent, E. L. Stevens, Willard Smith, Frank Thompson, Luther McAnulty, and B. M. Mose for their friendly and helpful cooperation in the field, and Messrs. I. A. Winter, H. H. Plumb, Ralph Burkhardt, Wendal Morgan, D. J. Hebert, and J. A. Lindsey of the Denver office for their constructive assistance.

SUMMARY OF COMPUTATIONS

TABLE 4

ACCEPTANCE TESTS ON THREE PUMPS - MODOC UNIT "D", TULE LAKE, CALIFORNIA

HYDRAULIC DATA

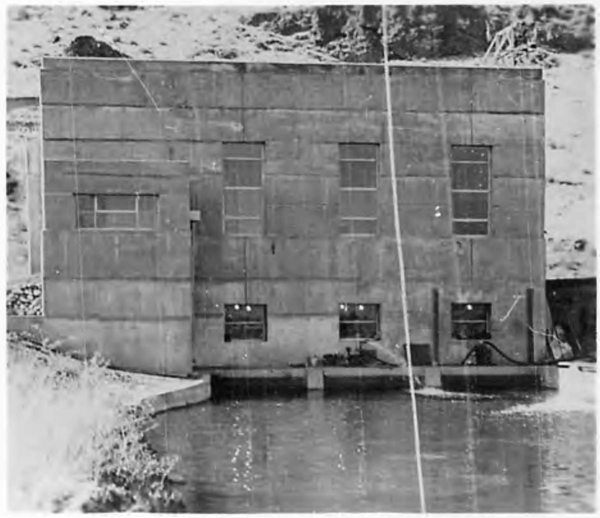
Test No. (1)	Date and unit No. (2)	Measuring weir: Head in feet (3)	Measuring weir: Discharge, second-feet (4)	Forebay: Water surface elevations, gage No. 1 (5)	Forebay: Water surface elevations, gage No. 2 (6)	Forebay: $\frac{V^2}{2g}$ (7)	Forebay: Energy elevation at gage No. 2 (8)	Trashrack losses: Loss in feet (9)	Trashrack losses: $\frac{Loss}{V^2/2g}$ (10)	U.S.B.R. taps: Actual suction lift in feet of water (11)	U.S.B.R. taps: $\frac{V_d^2}{2g}$ (12)	U.S.B.R. taps: $h_d \pm f$ (13)	U.S.B.R. taps: Total pumping head (14)	U.S.B.R. taps: WHP (15)	Manufacturer's taps: $h_s + f_1$ (16)	Manufacturer's taps: $\frac{V_s^2}{2g}$ (17)	Manufacturer's taps: $h_d \pm f$ (18)	Manufacturer's taps: $\frac{Vd_1^2}{2g}$ (19)	Manufacturer's taps: Total pumping head (20)	Manufacturer's taps: WHP (21)
					A=71.25 s.f.					A=4.936 s.f.					A=3.237 s.f.		A=4.508 s.f.			
1-1	10-27	1.547	52.25	4034.024	4033.989	0.0083	4033.997	0.027	3.25	2.541	1.744	58.74	63.02	373.57	4.33	4.040	59.14	2.088	61.52	364.68
1-2		1.551	52.50	4034.037	4034.014	0.0085	4034.022	0.015	1.76	2.516	1.760	58.36	62.64	373.09	4.44	4.090	58.80	2.110	61.26	364.87
1-3	3	1.551	52.50	4034.050	4034.028	0.0085	4034.036	0.014	1.65	2.502	1.760	58.23	62.49	372.20	4.21	4.090	58.65	2.110	60.88	362.61
1-4		1.549	52.40	4034.057	4034.043	0.0084	4034.051	0.006	0.71	2.487	1.754	58.30	62.54	371.79	4.13	4.075	58.67	2.099	60.82	361.58
1-5		1.512	50.50	4034.077	4034.060	0.0078	4034.068	0.009	1.15	2.470	1.628	61.66	65.76	376.75	4.15	3.784	61.91	1.950	64.23	367.99
1-6		1.520	50.95	4034.071	4034.055	0.0080	4034.063	0.008	1.00	2.475	1.656	61.10	65.23	377.06	4.14	3.852	61.47	1.985	63.74	368.44
1-7	10-28	1.545	52.20	4034.013	4033.996	0.0083	4034.004	0.009	1.08	2.534	1.740	58.58	62.85	372.22	5.14	4.045	59.02	2.085	62.20	368.37
1-8		1.523	51.10	4034.019	4034.002	0.0080	4034.010	0.009	1.08	2.528	1.666	60.17	64.37	373.19	5.52	3.876	60.59	1.996	64.23	372.38
1-9		1.511	50.45	4034.019	4033.993	0.0078	4034.001	0.018	2.31	2.537	1.624	61.31	65.47	374.74	5.53	3.779	61.66	1.945	65.16	372.95
										A=4.956 s.f.					A=3.237 s.f.		A=4.450 s.f.			
2-1	10-29	1.512	50.50	4034.036	4034.017	0.0078	4034.025	0.011	1.41	2.493	1.615	60.65	64.76	371.04	5.09	3.784	60.91	2.003	64.22	367.93
2-2		1.509	50.35	4034.043	4034.023	0.0077	4034.031	0.012	1.56	2.487	1.605	61.43	65.52	374.28	5.04	3.760	61.68	1.989	64.95	371.01
2-3	2	1.506	50.22	4034.047	4034.028	0.0077	4034.036	0.011	1.43	2.482	1.596	61.03	65.11	370.98	5.04	3.740	61.32	1.981	64.60	368.06
2-4		1.538	51.84	4034.062	4034.040	0.0083	4034.048	0.014	1.69	2.470	1.701	58.34	62.51	367.64	5.23	3.985	58.69	2.110	62.04	364.87
2-5		1.488	49.25	4034.027	4033.996	0.0074	4034.003	0.024	3.24	2.515	1.536	62.52	66.57	371.98	4.98	3.597	62.79	1.906	66.08	369.22
2-6		1.443	46.96	4033.988	4033.971	0.0068	4033.978	0.010	1.47	2.540	1.397	66.41	70.35	374.80	4.81	3.273	66.52	1.730	69.79	371.83
2-7		1.397	44.67	4033.935	4033.912	0.0062	4033.918	0.017	2.74	2.600	1.262	69.31	73.17	370.83	4.65	2.961	69.39	1.567	72.65	368.18
										A=4.929 s.f.					A=3.237 s.f.		A=4.547 s.f.			
3-1	10-30	1.502	50.00	4034.012	4034.000	0.0076	4034.008	0.004	0.53	2.470	1.599	60.13	64.20	364.19	4.74	3.711	60.24	1.881	63.15	358.22
3-2		1.500	49.85	4034.017	4033.998	0.0076	4034.006	0.011	1.45	2.472	1.589	59.96	64.02	362.08	4.77	3.687	60.13	1.867	63.08	356.75
3-3	1	1.484	49.04	4034.028	4034.017	0.0074	4034.024	0.004	0.54	2.454	1.540	61.32	65.31	363.36	4.66	3.568	61.52	1.810	64.42	358.41
3-4		1.483	49.00	4034.034	4034.022	0.0074	4034.029	0.005	0.68	2.449	1.536	61.60	65.59	364.62	4.67	3.564	61.71	1.807	64.62	359.23
3-5		1.468	48.20	4034.041	4034.025	0.0074	4034.032	0.009	1.22	2.446	1.487	62.57	66.50	363.66	4.63	3.447	62.82	1.747	65.75	359.54
3-6		1.435	46.60	4034.043	4034.018	0.0066	4034.025	0.018	2.73	2.453	1.388	65.06	68.90	364.26	4.35	3.224	65.18	1.634	67.97	359.34
3-7		1.420	45.80	4034.040	4034.021	0.0064	4034.027	0.012	1.88	2.450	1.342	66.63	70.42	365.92	4.27	3.113	66.71	1.576	69.44	360.81
3-8		1.520	51.00	4034.027	4034.006	0.0080	4034.014	0.013	1.60	2.464	1.666	58.31	62.44	361.29	4.88	3.857	58.65	1.957	61.63	356.59

Test No. (1)	Efficiencies, Over-all: U.S.B.R. taps (22)	Efficiencies, Over-all: Manufacturer's taps (23)	Pump efficiency U.S.B.R. taps (24)	Total energy at U.S.B.R. dis. taps: $\alpha_1 \frac{V_d^2}{2g}$ (α x col.12) (25)	Press. above C.L. pump, ft. (Col. 13 + col. 25) (26)	Total energy expressed in elevation (27)	Total energy at gage No. 6: Static water surface elevation at gage No. 6 (28)	$\frac{V^2}{2g}$ (29)	$\alpha \frac{V^2}{2g}$ (30)	Total energy at gage No. 6 in elevation (31)	Pipe, expander and bend loss: Total loss in feet (Col. 27 - col. 31) (32)	$\frac{Total\ loss}{V^2/2g}$ or $\frac{(Col.\ 32)}{(Col.\ 29)}$ (33)	Bend loss: $\frac{Bend\ loss}{V^2/2g}$ (Estimate) (34)	Pipe loss: $\frac{Pipe\ loss}{V^2/2g}$ (35)	"f": $f = \frac{h_f 2g}{V^2} \frac{D}{L}$ (36)	Gage No. 5: Static water surface elevation downstream from flap gates (37)	Flap gate loss in feet (38)	Flap gate loss: $\frac{Loss}{V^2/2g}$ (39)	R: $R = \frac{VD}{\nu}$ (40)	Actual lift: Intake to gage No. 5 - Ft. (Col. 37 - col. 8) (41)
	%	%	%	α=1.20	C.L.=4036.53		A=7.069		α=1.03				L=412.63 ft.→					ν=1.59x10^-5		
1-1	80.45	78.54	84.83	2.093	60.83	4097.36		0.849								4094.62	0.84	0.40		60.00
1-2	80.12	78.36	84.51	2.112	60.47	4097.00		0.858								4094.60		0.40		60.56
1-3	80.36	78.29	84.71	2.112	60.34	4096.87		0.858								4091.46				57.41
1-4	80.29	78.08	84.69	2.105	60.40	4096.93		0.854								4091.50				57.44
1-5	81.21	79.32	85.63	1.954	63.61	4100.14		0.793								4097.37	0.44	0.85		63.29
1-6	81.15	79.29	85.56	1.987	63.09	4099.62		0.808								4097.28		0.54		63.21
1-7	81.11	80.27	85.53	2.088	60.67	4097.20		0.848								4093.83		0.47		59.82
1-8	81.29	81.11	85.71	1.999	62.17	4098.70		0.812								4094.83		Avg.		60.81
1-9	81.45	81.07	85.89	1.949	63.26	4099.79		0.792								4094.80				60.78
					C.L.=4036.51								L=410.62 ft.→							
2-1	81.96	81.28	86.45	1.938	62.59	4099.10	4096.82	0.793	0.817	4097.64	1.46	1.841	26° bend 0.050	1.695	0.0124	4096.27	0.55	0.69	1,347,924	62.23
2-2	82.92	82.20	87.47	1.926	63.36	4099.87	4097.63	0.789	0.813	4098.44	1.43	1.812	17.5° bend 0.032	1.666	0.0122	4097.10	0.53	0.67	1,343,962	63.06
2-3	82.27	81.62	86.78	1.915	62.95	4099.46	4097.22	0.785	0.809	4098.03	1.43	1.822	3.5° bend 0.010	1.676	0.0122	4097.18	0.43	0.61	1,340,377	63.13
2-4	82.03	81.42	86.54	2.041	60.38	4096.89		0.783					5° bend 0.014			4093.27		0.61		59.21
2-5	82.84	82.28	87.40	1.843	64.36	4100.87	4098.69	0.755	0.778	4099.47	1.40	1.854	Expander 0.040	1.708	0.0125	4096.31		0.64	1,314,528	62.28
2-6	83.07	83.41	87.61	1.676	68.09	4104.60	4102.57	0.686	0.707	4103.28	1.32	1.924	Unit 2 0.146	1.778	0.0130	4096.03		Avg.	1,253,396	62.04
2-7	82.37	81.78	86.89	1.514	70.82	4107.33	4105.50	0.621	0.640	4106.14	1.19	1.916		1.770	0.0129	4096.00			1,192,264	62.06
					C.L.=4036.47								L=412.63 ft.→							
3-1	80.19	78.38	84.58	1.919	62.05	4098.52		0.778					0.146			4095.82	0.33	0.42		61.81
3-2	79.78	78.61	84.13	1.907	61.87	4098.34		0.773					+2-30° bends 0.100			4095.97		0.43		61.95
3-3	80.20	79.10	84.60	1.848	63.17	4099.64	4097.34	0.748	0.770	4098.11	1.53	2.045	+2-12.5° " 0.020	1.779	0.0129	4097.34	0.36	0.48	1,308,868	63.31
3-4	80.36	79.17	84.75	1.843	63.44	4099.91	4097.60	0.747	0.769	4098.37	1.54	2.062	Units 1 & 3 = 0.266	1.796	0.0131	4097.26	0.34	0.48	1,307,925	63.23
3-5	80.70	79.79	85.11	1.784	64.35	4100.82	4098.68	0.723	0.745	4099.42	1.40	1.936		1.670	0.0121	4096.56		0.45	1,286,415	62.52
3-6	80.91	79.82	85.35	1.666	66.73	4103.20	4101.11	0.676	0.696	4101.81	1.39	2.056		1.790	0.0130	4096.48		Avg.	1,243,774	62.44
3-7	81.34	80.20	85.80	1.610	68.24	4104.71	4102.63	0.653	0.673	4103.30	1.41	2.159		1.893	0.0138	4096.37			1,222,453	62.33
3-8	80.60	79.55	85.03	1.999	60.31	4096.78										4092.55				58.52

ELECTRICAL DATA

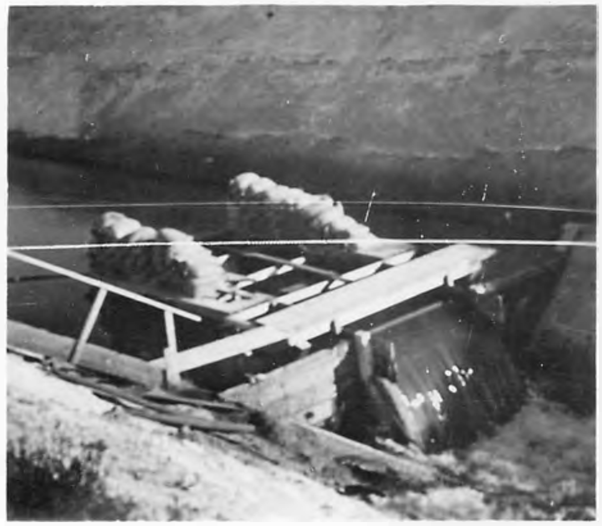
Test No. (1)	Test wattmeters, Corrected readings: A (42)	Test wattmeters, Corrected readings: B (43)	Power in kilowatts (44)	Horsepower: Motor input in horsepower (45)	Horsepower: Brake horsepower (46)	Test instruments, Voltmeter, Phases: 1-2 (47)	Phases: 2-3 (48)	Phases: 1-3 (49)	Voltmeter: Average (50)	Ammeter (51)	Power in kilowatts (52)	Panel instruments: Main panel voltmeter, average of 3 phases (53)	Panel instruments: Ammeter (54)	Main panel ammeter (55)	Watt-hour meter: Time in seconds (56)	Watt-hour meter: Power in kilowatts (57)	R.P.M. (58)	Condition at check gate (59)
													C-3		10 Rev.			
1-1	216.2	216.8	346.40	464.34	440.4	2,278	2,278	2,278	2,278	87.69	345.98	2,300	89.5	88	201.4	343.20		Medium level in canal, gate free.
1-2	217.1	217.1	347.36	465.64	441.5	2,334	2,336	2,336	2,335	85.20	344.57	2,370	87.8	86	201.8	342.52		Medium level in canal, gate held open.
1-3	215.8	216.1	345.52	463.17	439.4	2,302	2,302	2,302	2,302	86.19	343.64	2,325	88.3	88	202.0	342.18		Low level in canal, gate held open.
1-4	215.9	[illegible]	345.44	463.08	439.0	2,300	2,302	2,302	2,301	86.43	344.45	2,325	88.4	88	201.6	342.86		Low level in canal, gate free.
1-5	216.5	216.1	346.08	463.92	440.0	2,314	2,314	2,314	2,314	86.25	345.67	2,330	88.0	89	201.5	343.03		High level in canal, gate free.
1-6	216.8	216.5	346.64	464.67	440.7	2,312	2,310	2,312	2,311	86.35	347.63	2,331	89.0	87	201.1	343.71		High level in canal, gate held open.
1-7	214.3	213.6	342.32	458.88	436.3	2,290	2,294	2,296	2,293	85.98	341.46	2,317	88.0	88	204.4	338.16	603.0	Low level in canal, gate blocked.
1-8	213.8	214.3	342.48	459.09	435.4	2,314	2,316	2,316	2,315	85.23	341.74	2,340	87.1	87	205.9	338.99	603.0	Medium level in canal, gate blocked.
1-9	214.7	214.3	343.20	460.06	436.3	2,318	2,320	2,320	2,319	85.83	344.74	2,349	87.0	87	203.2	340.16	601.0	Medium level in canal, gate blocked.
													C-2					
2-1	208.9	213.2	337.68	452.66	429.2	2,298	2,298	2,302	2,299	83.34	331.85	2,325	78.0	85	207.7	332.79	601.0	Medium level in canal, gate free.
2-2	210.7	210.2	336.72	451.37	427.9	2,302	2,300	2,304	2,302	83.19	331.68	2,327	81.0	86	207.8	332.63	600.5	High level in canal, gate free
2-3	210.0	210.5	336.40	450.94	427.5	2,304	2,302	2,304	2,303	83.16	331.71	2,327	81.0	86	207.8	332.63	602.5	High level in canal, gate held open.
2-4	209.8	208.1	334.32	448.16	424.8	2,306	2,308	2,310	2,308	82.08	328.11	2,329	82.0	85	206.7	331.19	602.0	Low level in canal, gate free.
2-5	209.9	208.8	334.96	449.01	425.5	2,340	2,342	2,344	2,342	81.48	330.52	2,376	74.5	80	207.8	332.63	602.0	Low level in canal, gate blocked.
2-6	210.4	210.3	336.56	451.16	427.8	2,298	2,300	2,302	2,300	82.95	330.44	2,326	76.0	85	207.5	333.11	602.0	Medium level in canal, gate blocked.
2-7	209.0	210.8	335.84	450.18	426.8	2,310	2,310	2,312	2,311	82.56	330.46	2,333	76.0	85	208.1	332.15	603.0	Medium level in canal, gate blocked.
													C-1					
3-1	212.4	211.1	338.80	454.16	430.6	2,306	2,302	2,304	2,304	84.75	338.20	2,330	86.0	83	206.5	334.72	600.0	Medium level in canal, gate free.
3-2	211.0	212.2	338.56	453.84	430.4	2,306	2,304	2,306	2,305	84.90	338.94	2,328	86.0	84	206.8	334.25	600.0	Medium level in canal, gate held open.
3-3	210.9	211.6	338.00	453.09	429.5	2,300	2,300	2,302	2,301	85.05	338.95	2,326	86.0	84	206.8	334.25	602.0	High level in canal, gate held open.
3-4	211.2	211.9	338.48	453.73	430.2	2,298	2,298	2,300	2,299	84.90	338.06	2,325	86.0	84	206.6	334.56	601.0	High level in canal, gate free.
3-5	210.5	209.7	336.16	450.62	427.3	2,356	2,356	2,352	2,355	82.26	335.53	2,390	83.9	83	208.7	331.19	602.0	High level in canal, gate blocked.
3-6	208.8	211.0	335.84	450.19	426.8	2,312	2,312	2,314	2,313	83.82	335.79	2,350	85.0	83	208.8	331.03	601.0	High level in canal, gate blocked.
3-7	210.1	209.4	335.60	449.87	426.5	2,322	2,326	2,322	2,323	83.25	334.95	2,350	84.0	81	208.4	331.67	602.0	High level in canal, gate blocked.
3-8	209.7	208.3	334.40	448.26	424.9	2,328	2,330	2,330	2,329	83.07	335.09	2,359	84.0	81	209.4	330.08	600.0	Low level in canal, gate free.

A - Pump house looking north.

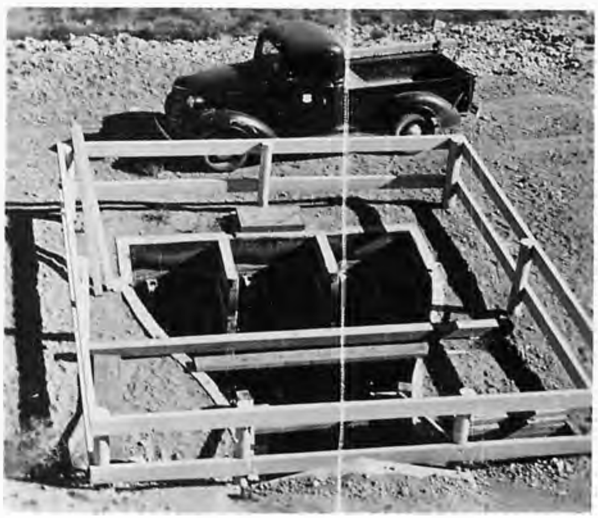


B - Pump house and intake channel

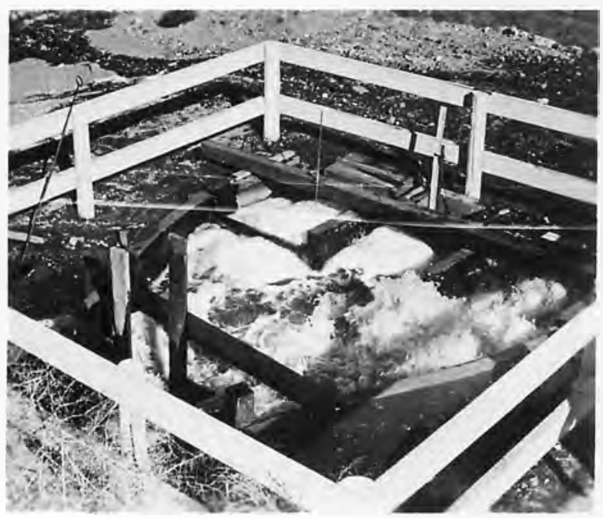
C - Weir structure in canal looking downstream.



D - Eight-foot measuring weir.



E - Open transition and 36-inch check gates.



F - Open transition showing gages and temporary needle dam. Unit No. 1 in operation.

FIGURE 1 - PHOTOGRAPHS TAKEN DURING ACCEPTANCE TESTS AT PUMPING PLANT "D"-MODOC UNIT - TULE LAKE, CALIFORNIA.

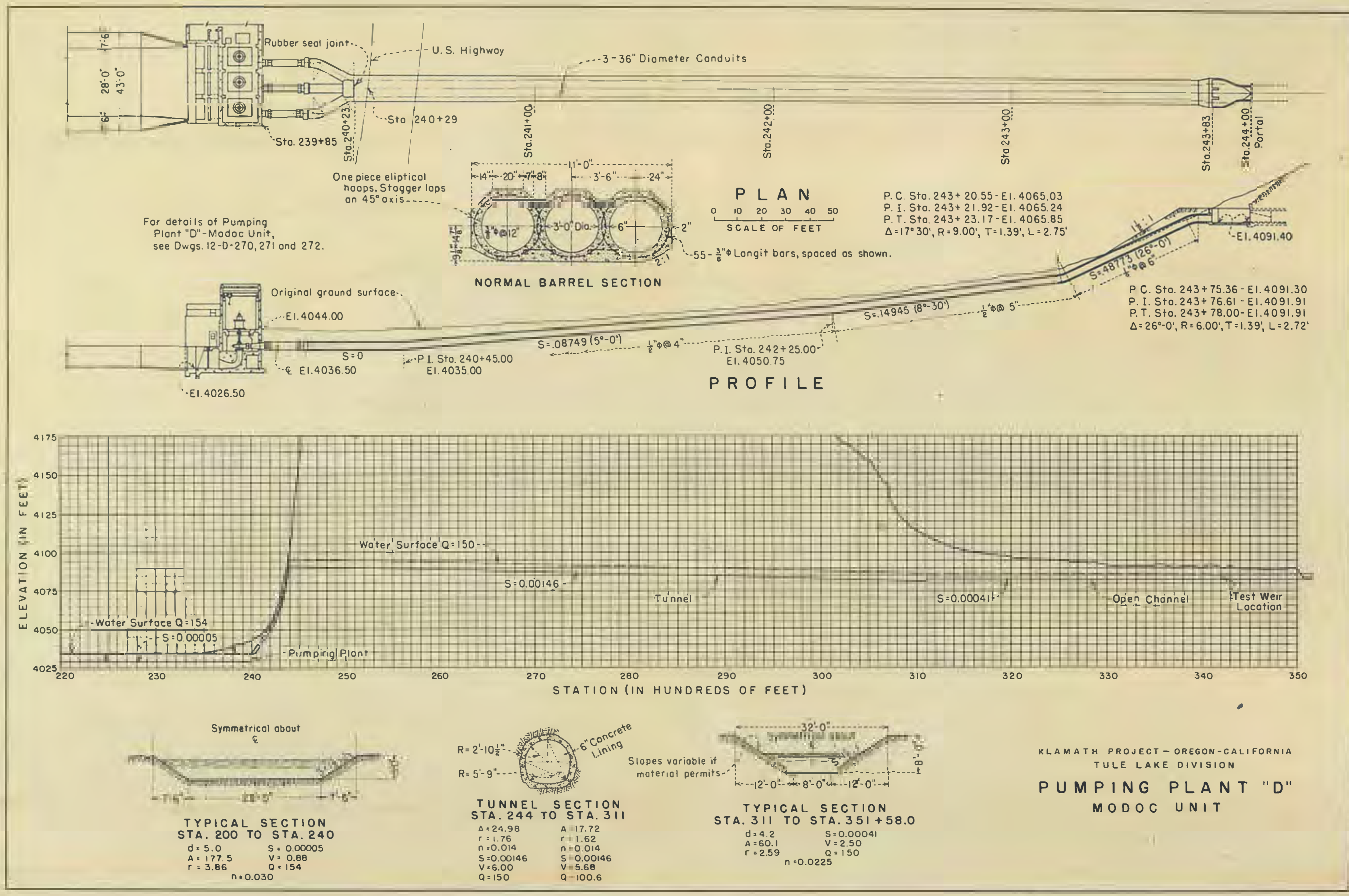
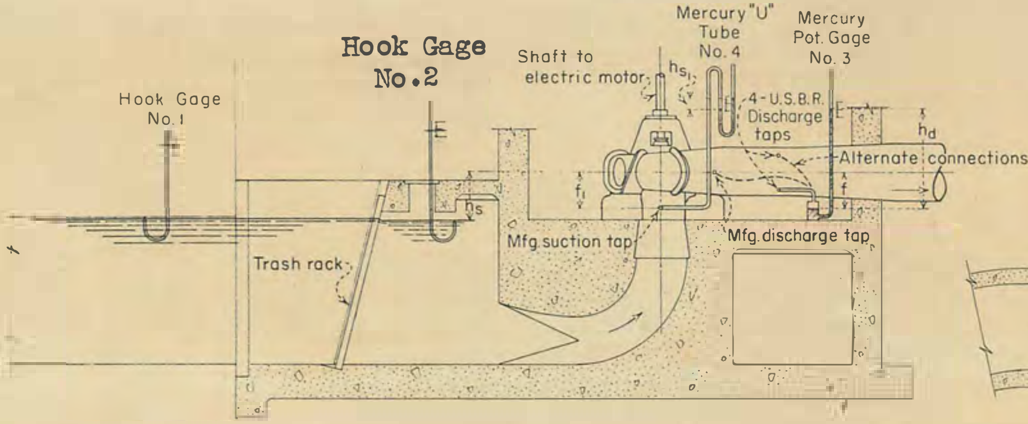
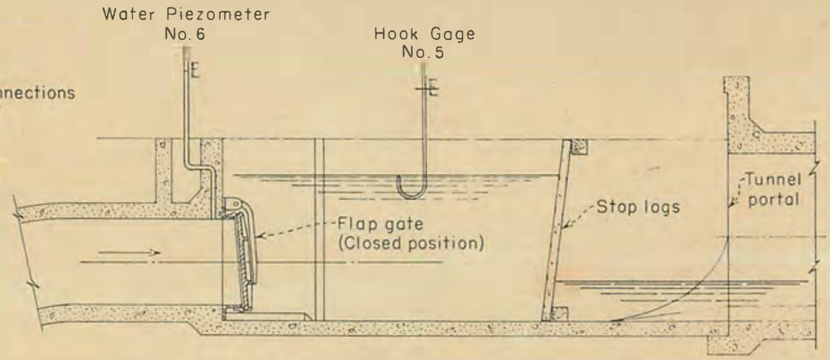

Rubber seal joint
U. S. Highway
3 - 36" Diameter Conduits
28'-0"
43'-0"
Sta. 239+85
Sta. 240+23
Sta 240+29
Sta. 241+00
Sta. 242+00
Sta. 243+00
Sta. 243+83
Sta. 244+00 Portal
One piece eliptical hoops, Stagger laps on 45° axis
For details of Pumping Plant "D"-Modoc Unit, see Dwgs. 12-D-270, 271 and 272.
11'-0"
3'-0" Dia.
55 - 3/8"φ Longit bars, spaced as shown.
NORMAL BARREL SECTION
PLAN
0 10 20 30 40 50
SCALE OF FEET
P. C. Sta. 243+ 20.55 - El. 4065.03
P. I. Sta. 243+ 21.92 - El. 4065.24
P. T. Sta. 243+ 23.17 - El. 4065.85
Δ=17°30', R=9.00', T=1.39', L=2.75'
El. 4091.40
P. C. Sta. 243+75.36 - El. 4091.30
P. I. Sta. 243+ 76.61 - El. 4091.91
P. T. Sta. 243+ 78.00 - El. 4091.91
Δ=26°-0', R=6.00', T=1.39', L=2.72'
Original ground surface
El. 4044.00
S=0
S=.08749 (5°-0')
S=.14945 (8°-30')
S=.48773 (26°-0')
1/2"φ@ 4"
1/2"φ@ 5"
P.I. Sta. 240+45.00 El. 4035.00
P. I. Sta. 242+25.00 El. 4050.75
℄ El. 4036.50
El. 4026.50
PROFILE
ELEVATION (IN FEET)
4175
4150
4125
4100
4075
4050
4025
Water Surface Q=150
S=0.00146
Tunnel
S=0.00041
Open Channel
Test Weir Location
Water Surface Q=154
S=0.00005
Pumping Plant
220 230 240 250 260 270 280 290 300 310 320 330 340 350
STATION (IN HUNDREDS OF FEET)
Symmetrical about ℄
TYPICAL SECTION
STA. 200 TO STA. 240
d = 5.0 S = 0.00005
A = 177.5 V = 0.88
r = 3.86 Q = 154
n = 0.030
R= 2'-10 1/2"
R= 5'-9"
6" Concrete Lining
TUNNEL SECTION
STA. 244 TO STA. 311
A=24.98 A=17.72
r=1.76 r=1.62
n=0.014 n=0.014
S=0.00146 S=0.00146
V=6.00 V=5.68
Q=150 Q=100.6
32'-0"
Slopes variable if material permits
12'-0" 8'-0" 12'-0"
8'-0"
TYPICAL SECTION
STA. 311 TO STA. 351+58.0
d=4.2 S=0.00041
A=60.1 V=2.50
r=2.59 Q=150
n=0.0225
KLAMATH PROJECT – OREGON-CALIFORNIA
TULE LAKE DIVISION
PUMPING PLANT "D"
MODOC UNIT

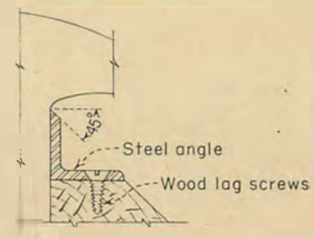
FIGURE 2



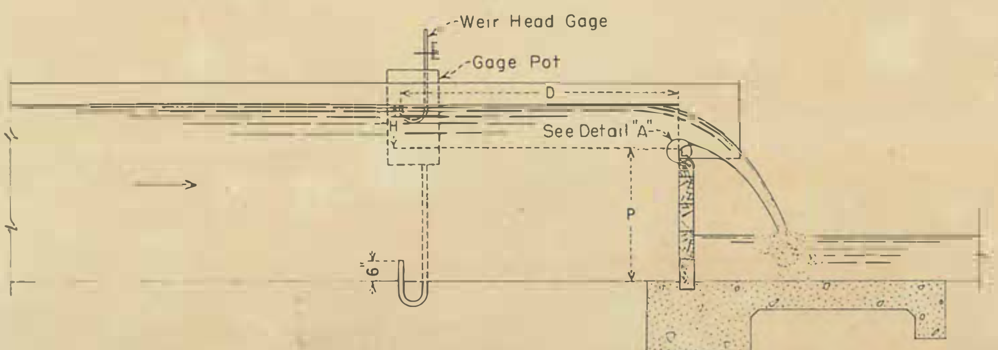
A-SECTION OF PUMP



B-SECTION OF TUNNEL TRANSITION



DETAIL "A"



C-SECTION OF WEIR

KLAMATH PROJECT - OREGON-CALIFORNIA
TULE LAKE DIVISION

PUMPING PLANT "D"
MODOC UNIT
GAGE LOCATIONS FOR PUMP
ACCEPTANCE TESTS

FIGURE 3

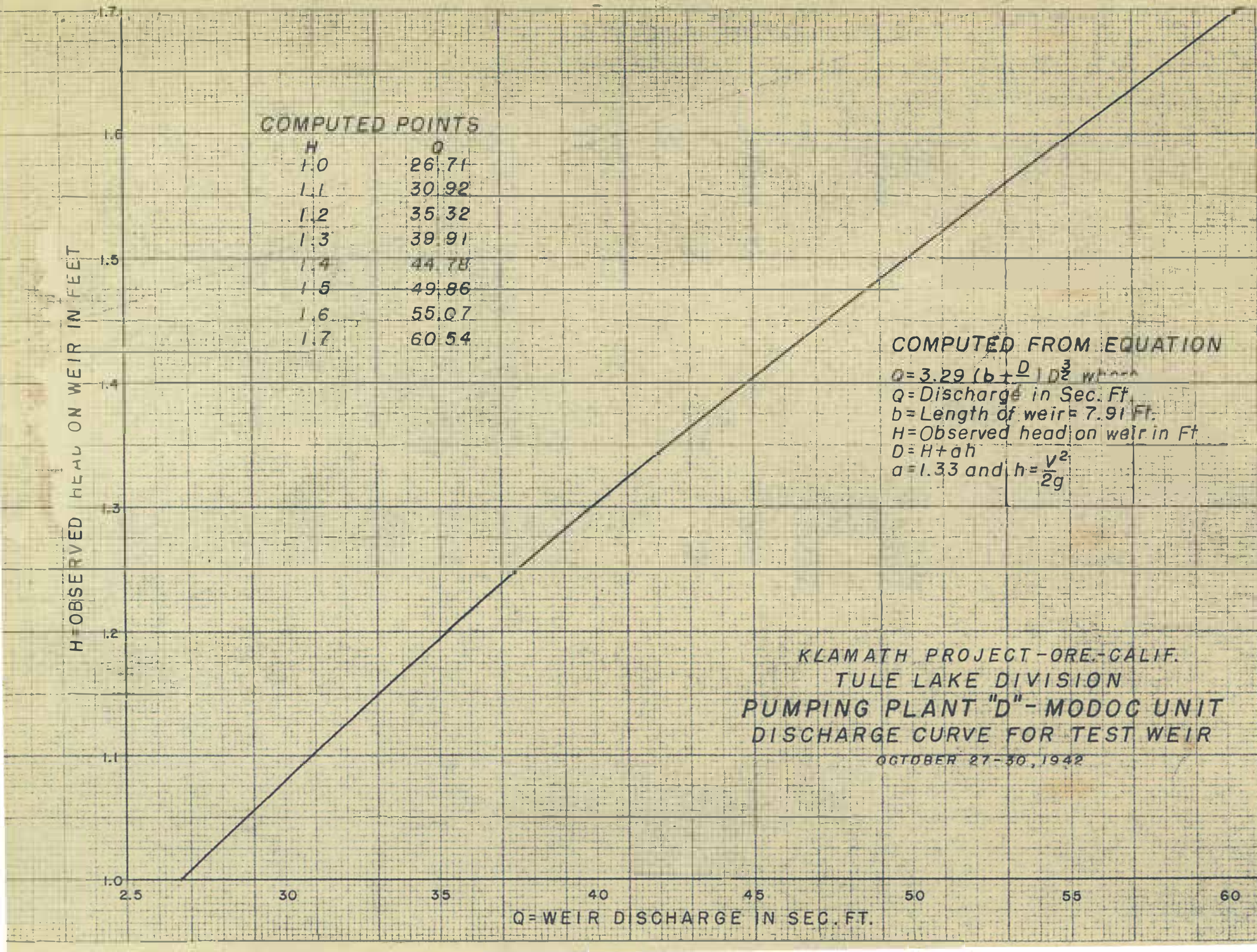
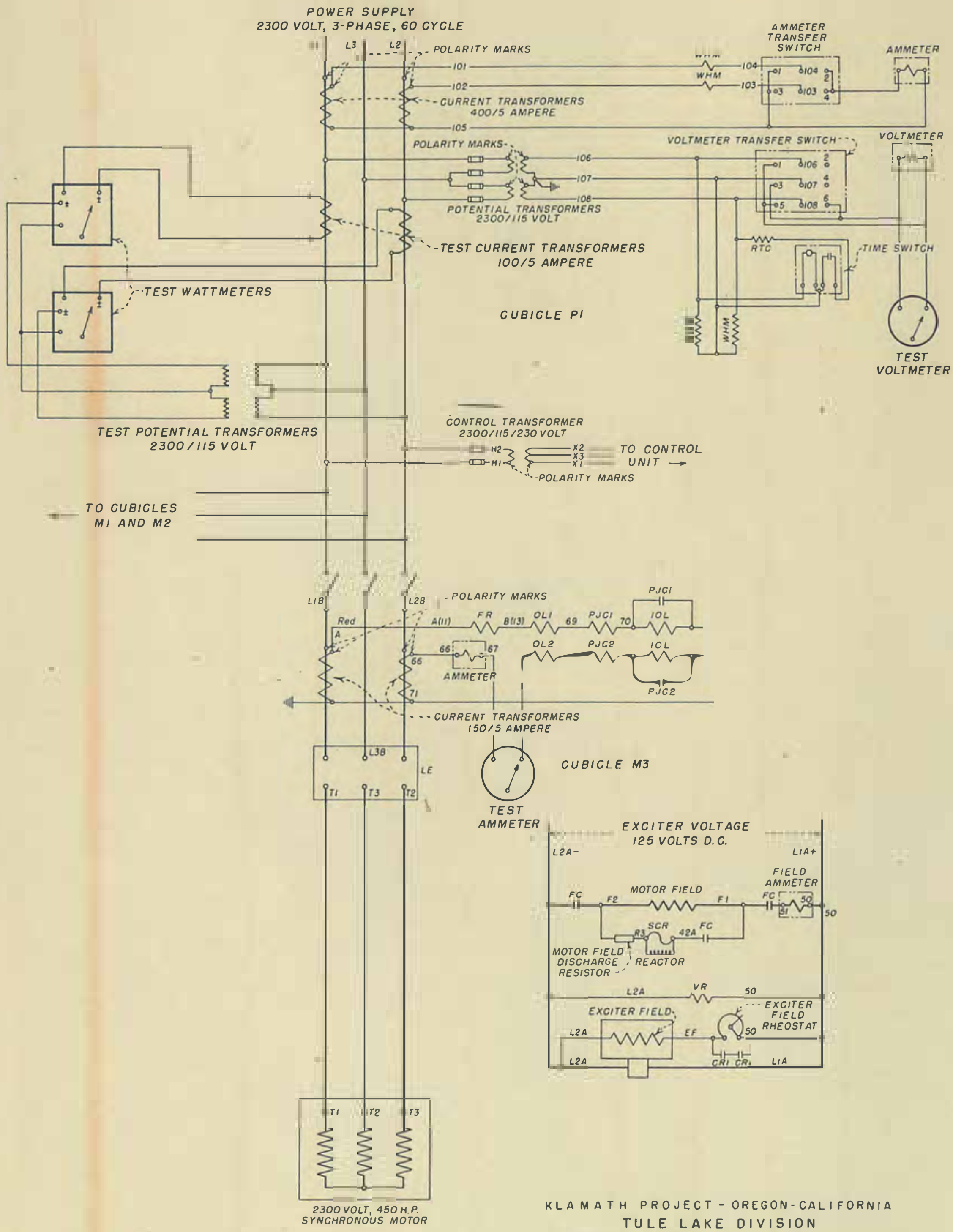

COMPUTED POINTS
H Q
1.0 26.71
1.1 30.92
1.2 35.32
1.3 39.91
1.4 44.78
1.5 49.86
1.6 55.07
1.7 60.54
COMPUTED FROM EQUATION
Q = Discharge in Sec. Ft.
b = Length of weir = 7.91 Ft.
H = Observed head on weir in Ft
D = H + ah
a = 1.33 and h = V²/2g
KLAMATH PROJECT - ORE.-CALIF.
TULE LAKE DIVISION
PUMPING PLANT "D" - MODOC UNIT
DISCHARGE CURVE FOR TEST WEIR
OCTOBER 27-30, 1942
H = OBSERVED HEAD ON WEIR IN FEET
Q = WEIR DISCHARGE IN SEC. FT.
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
2.5
30
35
40
45
50
55
60

FIGURE 4

FIGURE 5



KLAMATH PROJECT - OREGON-CALIFORNIA
TULE LAKE DIVISION

PUMPING PLANT "D"

MODOC UNIT
WIRING DIAGRAM
SHOWING CONNECTIONS TO
TEST INSTRUMENTS

J.A.L. 11-16-42

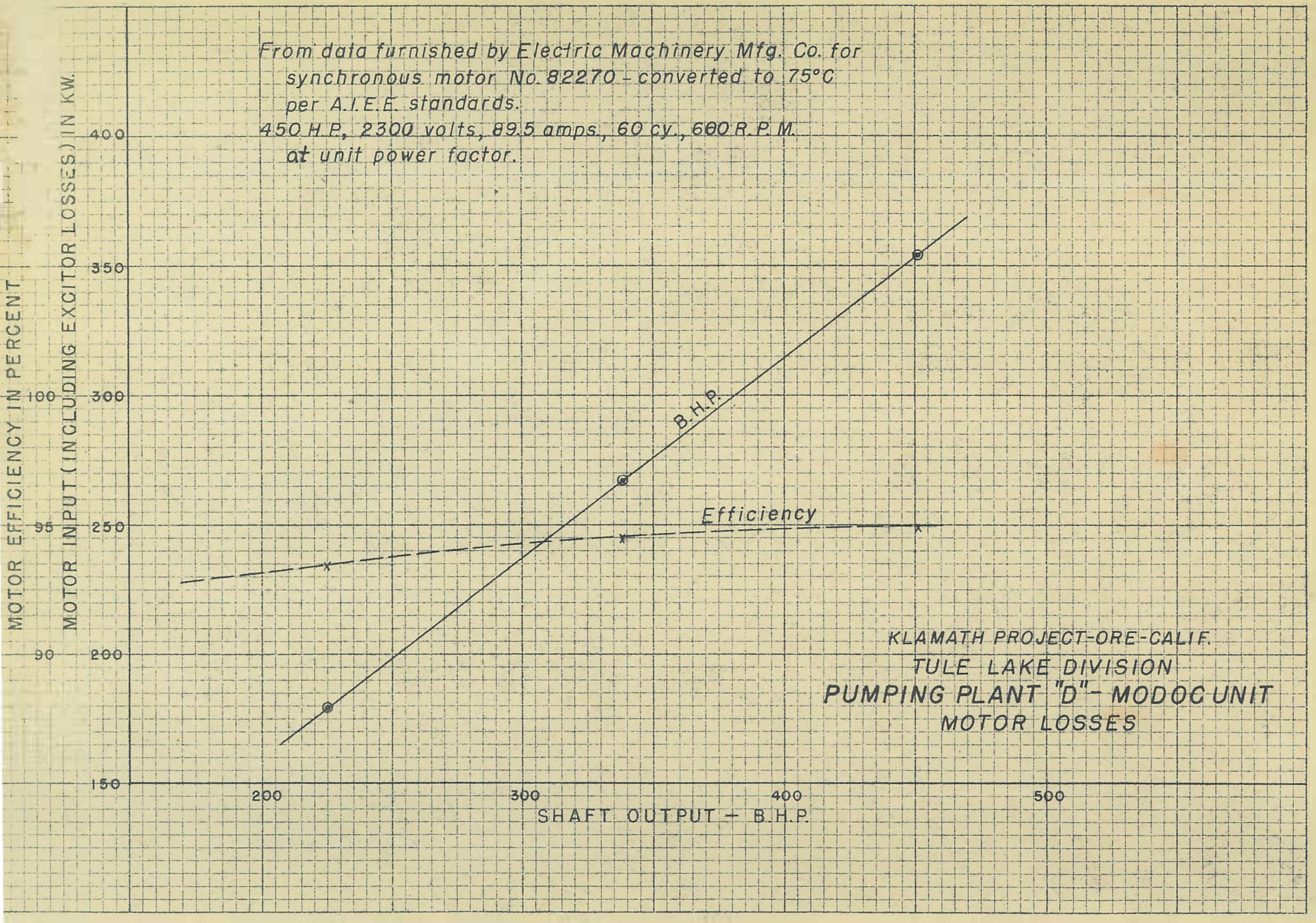

From data furnished by Electric Machinery Mfg. Co. for
synchronous motor No. 82270 - converted to 75°C
per A.I.E.E. standards.
450 H.P., 2300 volts, 89.5 amps., 60 cy., 600 R.P.M.
at unit power factor.
B.H.P.
Efficiency
MOTOR EFFICIENCY IN PERCENT
MOTOR INPUT (INCLUDING EXCITOR LOSSES) IN KW.
400
350
100
300
95
250
90
200
150
200
300
400
500
SHAFT OUTPUT - B.H.P.
KLAMATH PROJECT-ORE-CALIF.
TULE LAKE DIVISION
PUMPING PLANT "D" - MODOC UNIT
MOTOR LOSSES

FIGURE 6

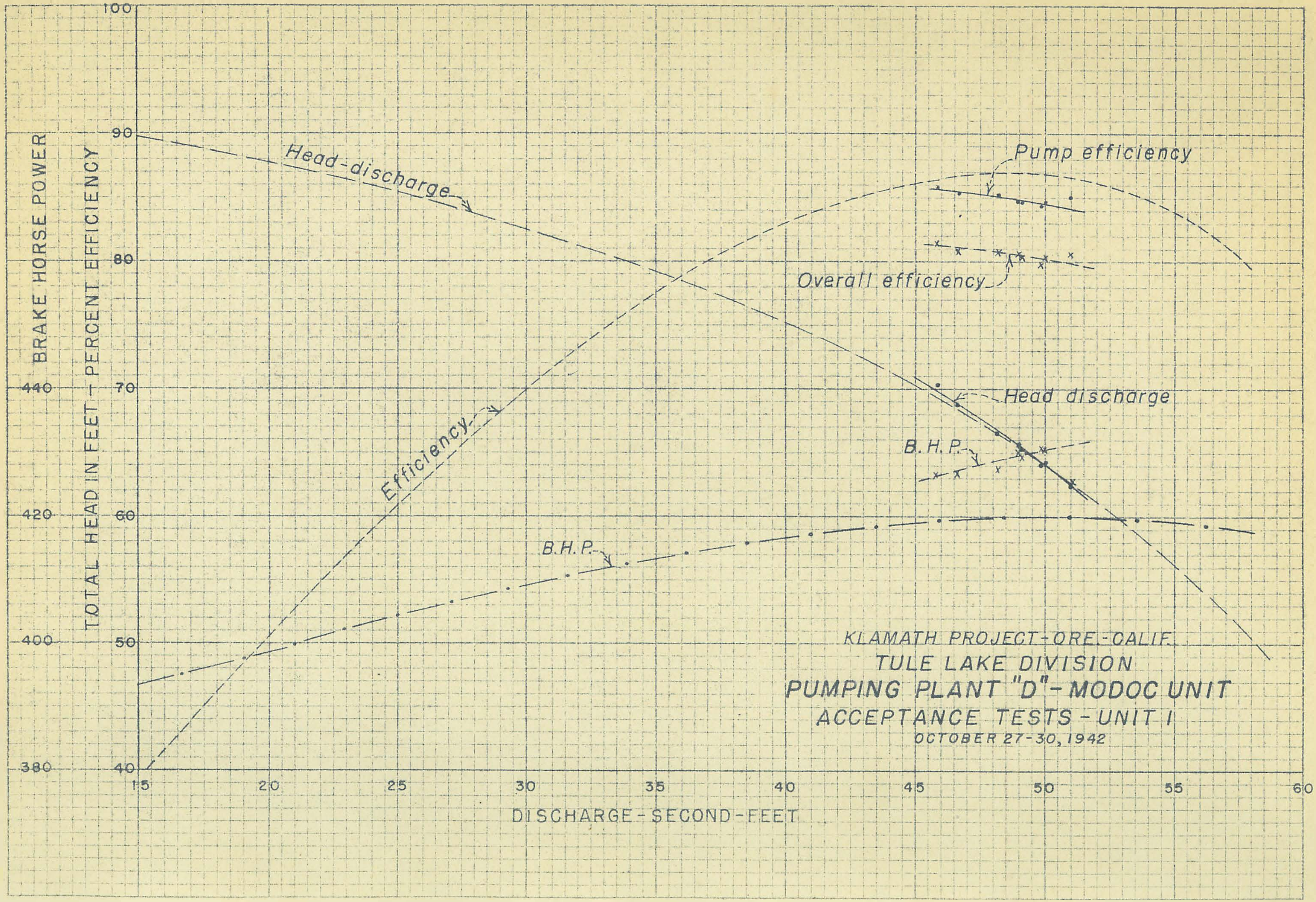
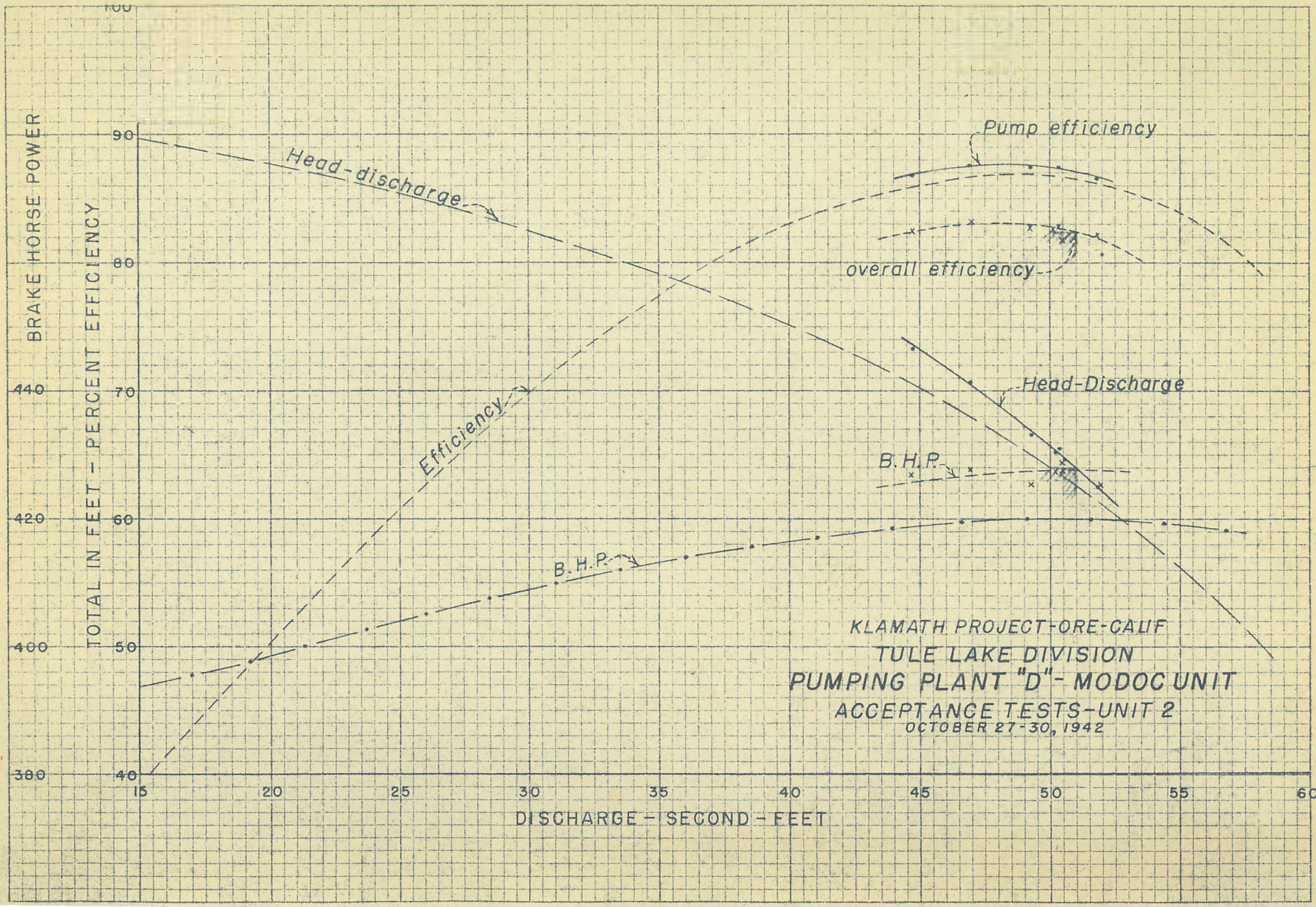

BRAKE HORSE POWER
TOTAL HEAD IN FEET - PERCENT EFFICIENCY
DISCHARGE - SECOND - FEET
Head-discharge
Pump efficiency
Overall efficiency
Head discharge
B. H. P.
Efficiency
B.H.P.
100
90
80
70
60
50
40
440
420
400
380
15
20
25
30
35
40
45
50
55
60
KLAMATH PROJECT - ORE. - CALIF.
TULE LAKE DIVISION
PUMPING PLANT "D" - MODOC UNIT
ACCEPTANCE TESTS - UNIT I
OCTOBER 27-30, 1942

FIGURE 7



BRAKE HORSE POWER
TOTAL IN FEET - PERCENT EFFICIENCY
DISCHARGE - SECOND - FEET
Head-discharge
Efficiency
B.H.P.
Pump efficiency
overall efficiency
Head-Discharge
B.H.P.
380
400
420
440
40
50
60
70
80
90
100
15
20
25
30
35
40
45
50
55
60
KLAMATH PROJECT-ORE-CALIF
TULE LAKE DIVISION
PUMPING PLANT "D"- MODOC UNIT
ACCEPTANCE TESTS-UNIT 2
OCTOBER 27-30, 1942

FIGURE 8

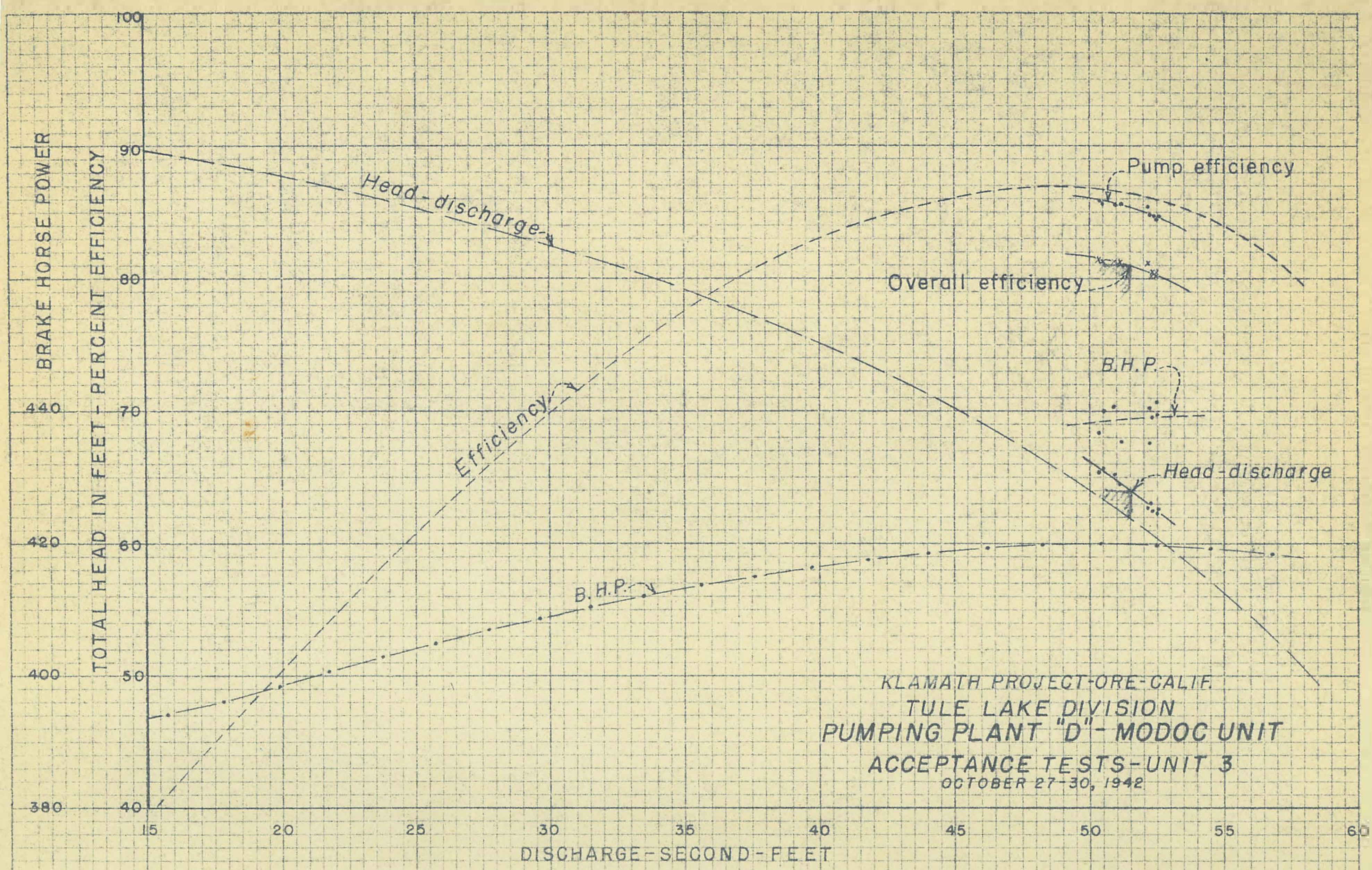

BRAKE HORSE POWER
TOTAL HEAD IN FEET - PERCENT EFFICIENCY
DISCHARGE-SECOND-FEET
Head-discharge
Pump efficiency
Overall efficiency
Efficiency
B.H.P.
Head-discharge
B.H.P.
100
90
80
70
60
50
40
440
420
400
380
15
20
25
30
35
40
45
50
55
60
KLAMATH PROJECT-ORE-CALIF.
TULE LAKE DIVISION
PUMPING PLANT "D"- MODOC UNIT
ACCEPTANCE TESTS-UNIT 3
OCTOBER 27-30, 1942

FIGURE 9