Water Measurement File

LABORATORY TESTS AND INSPECTION OF THE MEASURE-RITE OPEN-FLOW PROPELLER METERS

OCTOBER AND NOVEMBER 1966

PAP 226

LABORATORY TESTS AND INSPECTION OF TWO MEASURE-RITE OPEN-FLOW PROPELLER METERS

October and November 1966

Purpose

These studies were made to determine the accuracy of the flow rate indicated by two Measure-Rite meters that had been used for the "study of the use of water on Federal irrigation projects" in the Angostura Unit, Missouri River Basin Project, South Dakota.

Background

In his travel report to Chief Engineer, Subject: Report of trip to Region 6 projects, May 24 to June 6, 1964, Mr. S. T. Larsen, Irrigation Operations Division, Denver, Colorado, noted that project personnel had experienced difficulty in accurately measuring water with their Measure-Rite meters installed in metergate structures. In one case, the project reported that an 18-inch Measure-Rite propeller meter had indicated 1.5 cfs while at the same time a Clausen weir rule indicated 2.7 cfs and a metergate indicated 3.5 cfs. Because of the disagreement among the flow measurements, the Angostura Field Section, Oral, South Dakota, requested that two 18-inch Measure-Rite open-flow propeller meters be examined and tested by the Hydraulics Branch in the Denver Office.

Investigation

Previous field use of meters.--Two meters were shipped to the Hydraulics Branch from the Angostura Unit. They were 18-inch Measure-Rite open-flow propeller meters, Head No. GI4505.18, Shaft No. 8326036 and Head No. GI4505.19, Shaft No. 8326037. For the purpose of this discussion, these meters will be called Meters No. 36 and 37, respectively. Meter No. 36, according to a statement furnished by project personnel, had been used in the field for 680 hours, had been dry three times, and had registered about 70 percent of the rates indicated by a metergate and a Clausen weir rule. When the meter was received, the totalizer read 139.5 acre-feet. Assuming that this volume of water was measured in 680 hours, the average flow rate was about 2.5 cfs. Meter No. 37 was used 210 hours in the field, was dry once, and registered about 115 percent of that measured by the other two methods. The register of this meter read 88.9 acre-feet when received. Assuming that this volume corresponds to the 210 hours of operation, the average rate of flow past the meter was about 5.2 cfs.

Laboratory installation.--In the laboratory the meters, one at a time, were installed in a typical Angostura 18-inch turnout, Figure 1.

Water was pumped from the laboratory supply through two right-angle bends and a 12-inch gate valve to a 20-foot-long, 12-inch-diameter approach pipe. Then the water passed through a transition section, and 8 feet of 18-inch steel delivery pipe were connected to an 8- by 10- by 3-foot box shown in Figure 2A. Stop planks and a control well were used in the field turnout and in the laboratory installation to maintain submergence above the top of the delivery pipe. The control well and angle iron stop plank slots are shown in Figure 2B. Figure 3 shows stop planks in place to maintain the minimum 9-inch head measured above the top of the 18-inch pipe. The transition from the end of the control well to the canal and the canal shape itself, as shown in Figure 1, were not reproduced in the laboratory installation. This omission would not affect the results obtained.

Laboratory measurements.--True flow rates through the laboratory turnout were measured before the flow entered the turnout using calibrated Venturi meters that are a permanent part of the hydraulic laboratory equipment. The Venturi meters measure discharges within an accuracy of $\pm$ 1 percent. The differential pressure across the Venturi meter used to indicate the discharge was read and averaged during each run made to test the propeller meters.

To obtain discharge values from the indications on the propeller meter for comparison with the Venturi meter values, the totalizer was read in acre-feet at the beginning and end of a time interval measured in seconds. The time interval and the difference between totalizer readings was used to compute the cfs rates. Each data point plotted in Figure 4 is laboratory Venturi meter discharge versus meter registration. Meter registration is defined as indicated propeller meter discharge in percent of laboratory Venturi discharge. The four curves are calibrations of the propeller meters. Two of the curves are for Meter No. 37 before removing sediment from the propeller shaft housing, one is for Meter No. 37 after removing sediment, and one curve is for Meter No. 36 after removing sediment.

Calibration of Meter No. 37.--Meter No. 37 was installed and calibrated as received from the field. The first test was made for a laboratory discharge rate of 1 cfs; the rate was then increased in increments up to 5 cfs. The data for this calibration are plotted as open triangles in Figure 4. These data show much scatter about the dashed line labeled Curve A. To further define and verify the previous calibration data, additional data were obtained with the discharge decreasing in increments. These data are plotted as solid squares, Figure 4, and have much less scatter. However, the propeller ceased to rotate at 1.8 cfs rather than at 1 cfs as shown

in Curve A of Figure 4. Because of the decrease in data scatter and the higher discharge required to start propeller rotation, these data were considered a separate calibration and the curve was designated Curve B.

Inspection of pivot bearing, Meter No. 37.--After obtaining the data for Curve B, the propeller was turned by hand. The bearing sounded noisy. The mechanical parts and the inside wall of the propeller shaft housing, Figure 5, were repeatedly flushed with clear water which was caught in a container. A total of 14.5 grams dry weight of silty clay sediment was removed. This was after the meter had delivered 6.7 acre-feet of clean laboratory water. The dry sediment cake is shown in Figure 6A.

The propeller housing was removed from the register shaft housing, Figure 5, and the jewel pivot bearings and the brass bearing plate were inspected. The jewel on the propeller side of the brass-bearing plate showed considerable wear and fracturing. Enough of the jewel was missing (shown magnified nine times in Figure 7A) to allow the sediment around the thrust ball to wear the brass bearing plate around the periphery of the jewel. The jewel bearing on the register side, Figure 7B, was in better condition and the brass was not being worn. The thin part of the brass bearing plate shown in Figure 5 had circular scoring or groovelike wear on the propeller shaft side. This scoring may have been caused either by sediment grinding between the magnet and the bearing plate or by direct contact of the magnet on the plate as the jewel wore away, decreasing the gap between the magnet and plate.

Recalibration of Meter No. 37.--After removing the sediment and reassembling and installing the meter in the laboratory facilities, the meter was calibrated over the full discharge range. These data, obtained as previously discussed, are shown as open circles and the calibration is identified as Curve C in Figure 4.

Inspection of pivot bearings, Meter No. 36.--Before calibrating Meter No. 36, the shaft housing was repeatedly flushed with clean water. A total of 0.3 grams dry weight of sandy sediment was removed. The sediment did not form a cake upon drying, Figure 6B. The jewel pivot bearings were inspected and each was found to be worn and each was fractured, Figures 8A and 8B; the jewel on the register side of the meter was damaged less than the other three inspected bearings. Calibration data were obtained as previously described and the calibration of Meter No. 36 is shown as Curve D, Figure 4.

Discussion of Results

Company specifications, test records, and laboratory performance.--The Badger Manufacturing Company states an accuracy for their Measure-Rite meters as ± 2 percent of actual flow within the normal range from about 1 to 10 cfs for the 18-inch meters. The company test records obtained before field use for the same two meters tested in the Bureau's laboratory are included in the appendix of this memorandum.

The laboratory calibration Curves C and D in Figure 4 show that Meter No. 36 had ± 2.5 percent accuracy from 2 to 10 cfs and Meter No. 37 had this accuracy from about 1.4 to 2 cfs. In Tables 1 and 2, the laboratory registration data are compared with the company meter test record data. These tables show that during the laboratory test, the propellers of both meters would not turn at the lowest discharge used by the company for their meter tests. Table 2 shows that the difference between laboratory and the company registration for Meter No. 36 was within 2 percent for discharges equal to and greater than 4.6 cfs. Table 1 shows a difference between laboratory and company calibrations for Meter No. 37 ranging to 11 percent for discharges equal to and greater than 4.6 cfs.

Effects of worn bearings.--It is usually expected that wearing of bearings would cause a propeller meter to slow down. Comparing the company meter registration before field use with the laboratory registration after field use (Columns 2 and 3 of Table 1) indicates that the propeller speeded up after the bearings were damaged. Two possible causes for this increase in propeller speed come to mind. (There may be others.) The gears may have been changed without record after the company meters had been tested. Another possibility is that some part of the meter was overtightened or out of adjustment during the company record test, then subsequently loosened by operation or wear during field use.

Effects of turnout geometry.--Previous laboratory studies indicate that the large differences between discharges measured by the Measure-Rite meters and the other measuring methods used at the Angostura Unit probably cannot be caused by the stop planks. Also, the data of the calibration curves in Figure 4 did not indicate metering errors as large as those experienced in the field. A copy of the Report No. Hyd-545 "Investigations of the Turnout Geometry on the Registration Accuracy of a Propeller-type Open Flow Meter" is included in the appendix. Comparison of the farm turnout in Figure 1B of Hyd-545 and the Angostura farm turnout, Figure 1 of this memorandum, shows that they are similar in that the flow is abruptly forced upward by vertical walls or stop planks. For the

Hyd-545 farm turnout, the vertical wall was at a distance equal to 1-1/2 outlet diameters downstream of the pipe exit and the vertical rise was equal to 2 diameters. For the Angostura farm turnout, the stop plank slot was 1 diameter downstream and maximum height of planks needed to maintain the 9-inch submergence head on top of the pipe exit was equal to about 1-1/3 diameters for flow of 1 cfs. The differences in geometry between the Angostura and the Hyd-545 farm turnouts were not considered to be a major contributor to the large differences between discharges measured with the Measure-Rite meters and measurements obtained with the Clausen weir rule or metergates.

Conclusions

Based on the studies and investigations of these two meters, the following was concluded:

1. Results of these and the previous studies described in the enclosed copy of Report No. Hyd-545 indicate that the stop planks should not contribute errors of discharge of the magnitude experienced in the field.

2. As shown by Curve A (triangular data points) in Figure 4, the sediment found in the propeller shaft housing caused scatter in the measured discharge values.

3. The presence of sediment may have caused erratic measurements during field use of the meter.

4. As shown in Curve D, Figure 4, Meter No. 36 had registered the discharge with an accuracy of $\pm$ 2.5 percent of a calibrated Venturi meter flow, from 2 to 10 cfs, after removing sediment from the propeller shaft housing and using clean laboratory water.

5. As shown in Curve C, Figure 4, Meter No. 37 registered the discharge with an accuracy of $\pm$ 2.5 percent of a calibrated Venturi meter flow, from 1.4 to 2 cfs, after removing sediment from the propeller shaft housing and using clean laboratory water. Differences ranging to 8 percent were measured for discharges larger than 2.0 cfs.

6. The jewel pivot bearing, Figures 5, 7, and 8, was badly fractured and in some cases enough of the jewel was missing to cause wear on the brass bearing plate. The fracturing was probably caused by the impact of the propeller shaft on the jewel caused by surges in the flow or by forces delivered while attaching and removing propellers, rather than by sediment grinding.

Table 1

METER NO. 37

Comparison of Company and Laboratory Flow Registration for 18-inch Measure-Rite Propeller Meter No. Head GI 4805.19-- Shaft 8326037 After 210 Hours Field Operation

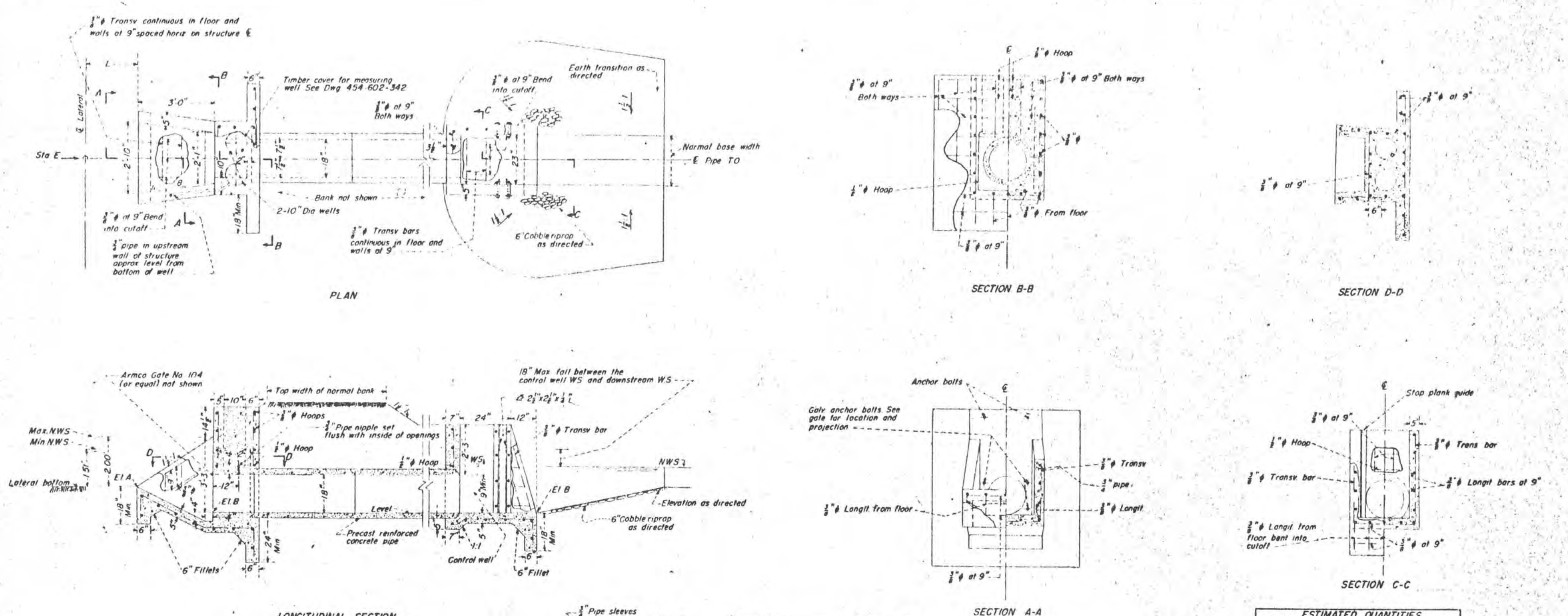
(1)	(2)	(3)	(4)
Discharge, cfs	Company meter registration, percent	Laboratory meter registration, percent	Difference of registrations
9.50	99.0	106.4	7.4
4.60	97.3	108.0	10.7
0.96	96.3	Propeller would not turn	-

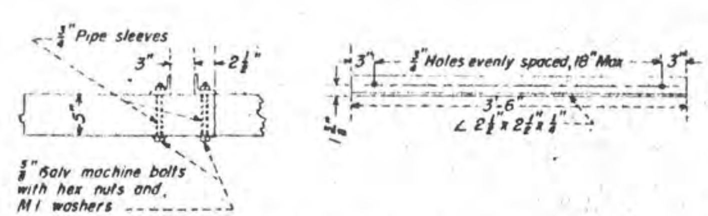
Table 2

METER NO. 36

Comparison of Company and Laboratory Flow Registration for 18-inch Measure-Rite Propeller Meter No. Head GI 4805.18-- Shaft 8326036 After 680 Hours Field Operation

(1)	(2)	(3)	(4)
Discharge, cfs	Company meter registration, percent	Laboratory meter registration, percent	Difference of registrations
10.0	102.3	102.3	0.0
4.6	100.0	102.0	2.0
0.95	99.3	Propeller would not turn	-





DETAIL OF STOP PLANK GUIDES

SCALE OF FEET

ESTIMATED QUANTITIES	
Concrete	2.2 cu yds
Reinforcement steel	130 lbs

DATA FOR TURNOUTS

LAT	STA E	EL A	EL B	TURNOUT DIRECTION	LENGTH PCP	L	
5.5A	23+20	3125.75	3124.50	Rt	24'	2.0'	
5.5A	23+20	3125.75	3124.50	Lt	8'	2.0'	
7.2	32+33.3	3142.39	3141.14	Rt	8'	3.0'	
7.2	72+25	3127.67	3126.42	Rt	8'	2.5'	
10.6	29+00	3120.52	3119.27	Lt	8'	2.5'	
10.6	37+50	3120.22	3118.97	Rt	8'	2.5'	
11.4	29+50	3119.08	3117.83	Lt	24'	2.0'	
13.8	47+50	3089.81	3088.56	Rt	8'	3.0'	
15.8	36+50	3102.04	3100.79	Lt	8'	3.0'	
15.8	46+67.5	3074.84	3073.59	Rt	8'	3.0'	
15.8	101+0	3042.89	3041.64	Lt	76'	2.0'	Refer Dwg 454-622-95
15.8	105+00	3041.69	3040.44	Lt	72'	2.0'	Refer Dwg 454-622-95
17.6	0+60	3118.58	3117.33	Lt	8'	2.5'	
19.1	1+20	3115.29	3114.04	Rt	24'	2.5'	
19.1	5+00	3115.11	3113.86	Lt	8'	2.5'	

NOTES

Place outer layer of reinforcement bars 2" from formed or floated surfaces and 2 1/2" from foundation surfaces, unless otherwise shown

Lap all bars 34 diameters at splices

If roadway is required along bank, provide a minimum cover of 18" on top of pipe

Discharges are assumed to be according to water measurement tables for the Calco Meter Gage.

Ratings may be made to certify discharge tables

Place entire structure on undisturbed natural foundation or thoroughly compacted fill

Height of gate frame 5

All reinforced precast concrete pipe shall conform with requirements of ASTM designation C-76-41 for standard strength reinforced concrete culvert pipe

Provide stop planks for each turnout as follows:

4-2" x 6" x 1'-10" S2E
2-2" x 4" x 1'-10" S2E

AS BUILT BY 622 LTR 8-25-53

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
CHEYENNE DIVISION-S DAK
ANGOSTURA UNIT

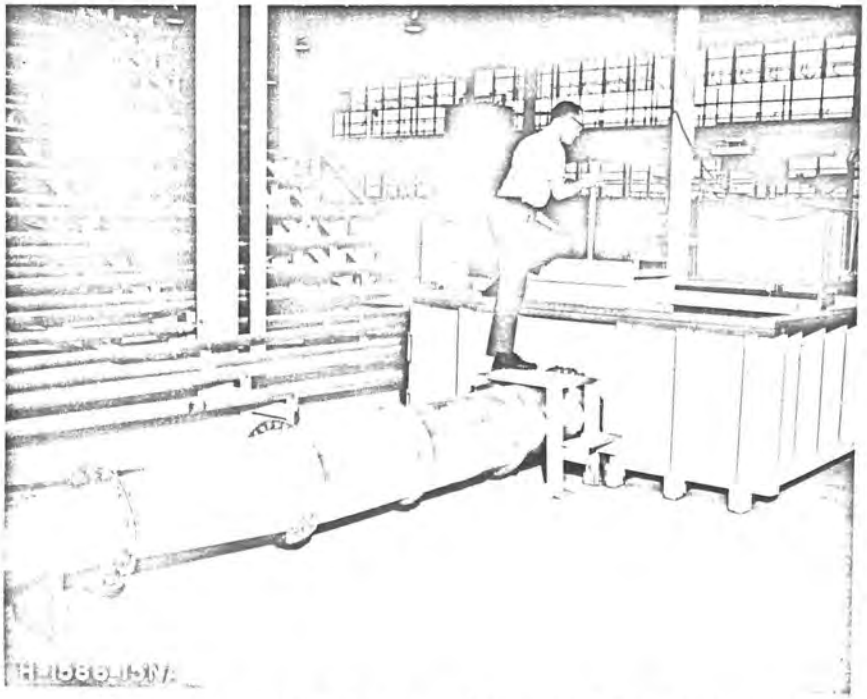
18" TURNOUT

LATERAL DEPTHS 1.51' TO 2.00'

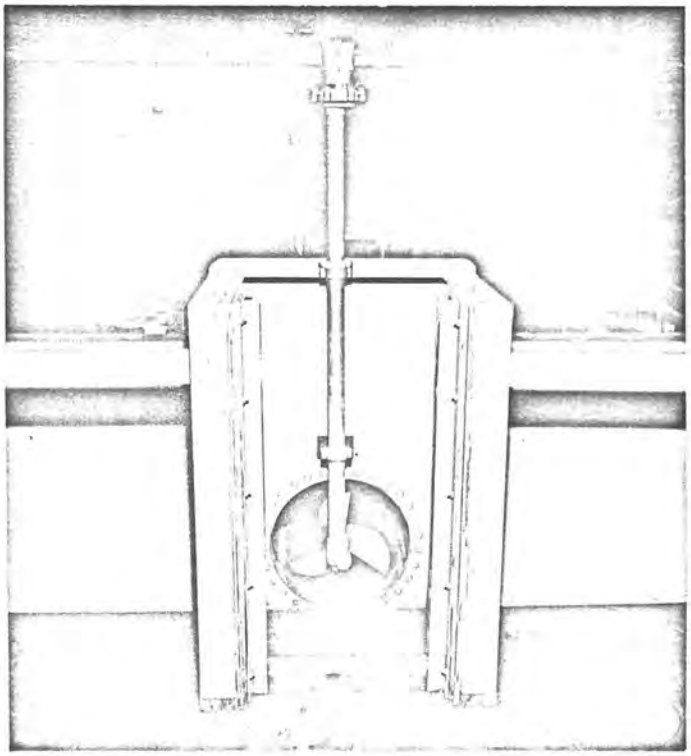
DRAWN F.C.A. SUBMITTED Arthur H. Johnson
TRACED R.W.A. RECOMMENDED Franklin M. McDeott
CHECKED [illegible] APPROVED C. Anderson, REGIONAL ENGINEER

HURON, S DAKOTA 12-12-50 454-602-346

Figure 2

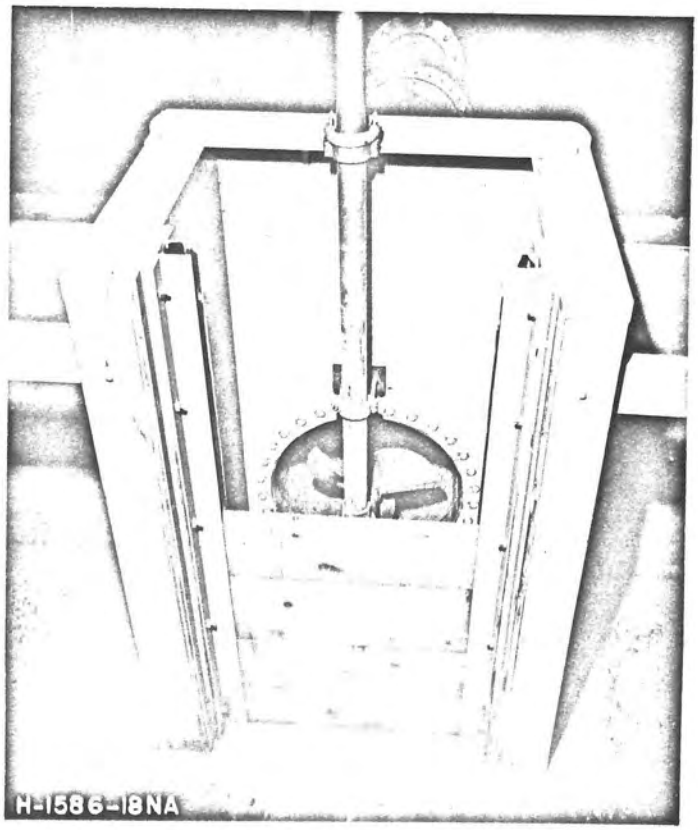


A. Laboratory installation for testing Measure-Rite meters showing the expansion from 12-inch laboratory pipe to the 8-foot-long, 18-inch delivery pipe.



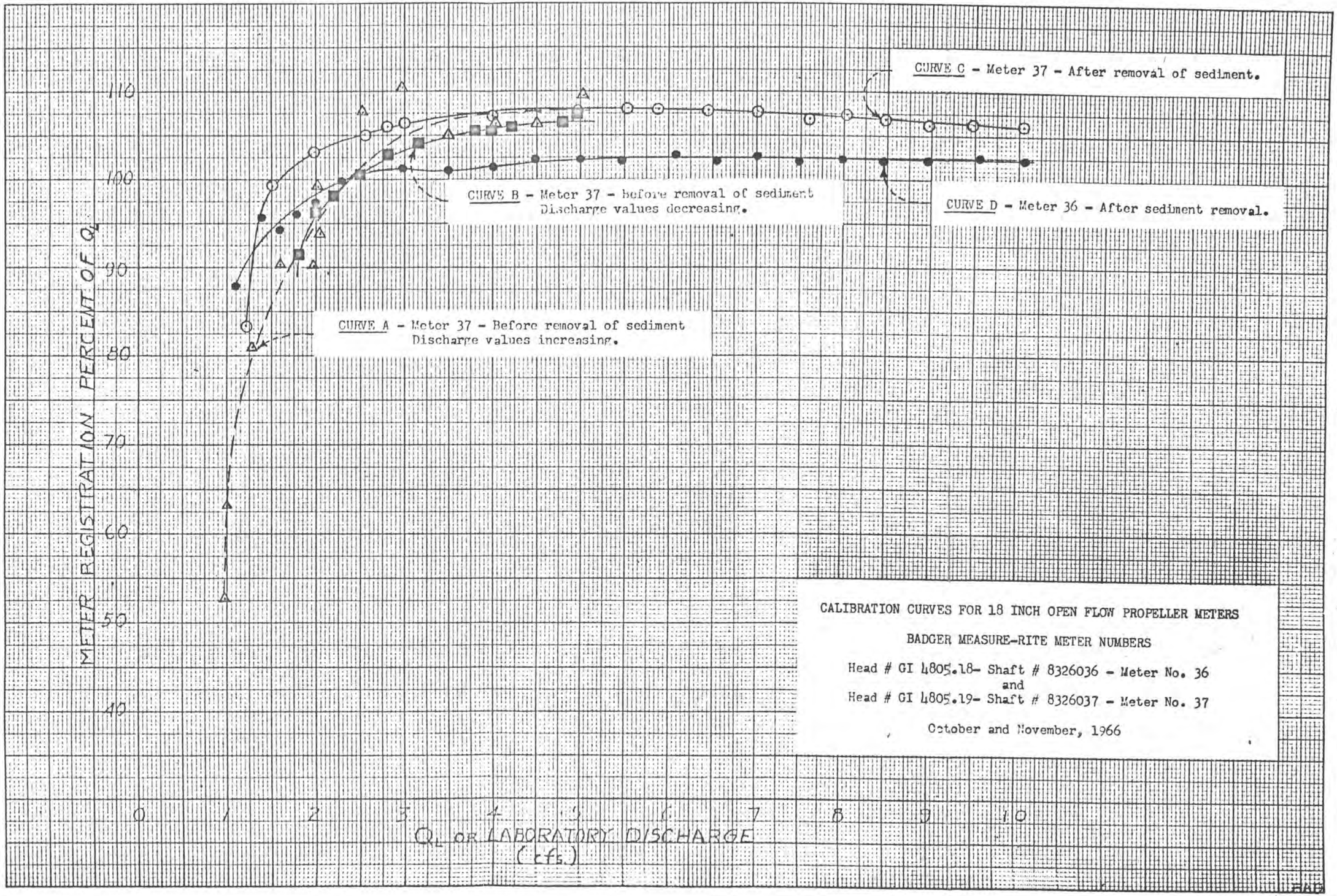
B. Looking upstream at Measure-Rite meter in the 18-inch delivery pipe. One stop plank in place across end of control well.

Figure 3



Upstream view of Measure-Rite meter in 18-inch delivery pipe. Stop planks installed to maintain minimum 9-inch head on delivery pipe.

FIGURE 4



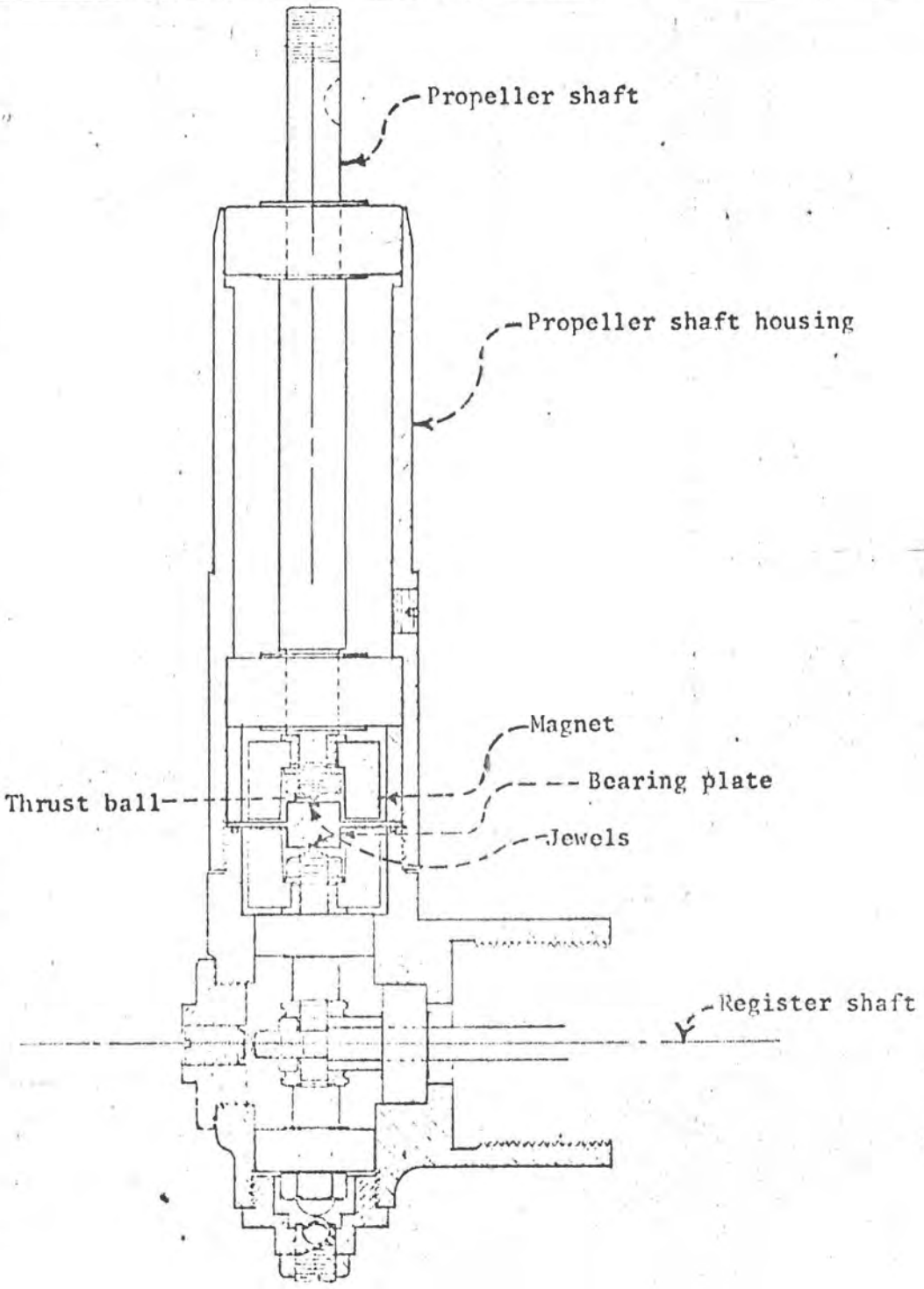
CALIBRATION CURVES FOR 18 INCH OPEN FLOW PROPELLER METERS

BADGER MEASURE-RITE METER NUMBERS

Head # GI 4805.18- Shaft # 8326036 - Meter No. 36
and
Head # GI 4805.19- Shaft # 8326037 - Meter No. 37

October and November, 1966

Figure 5



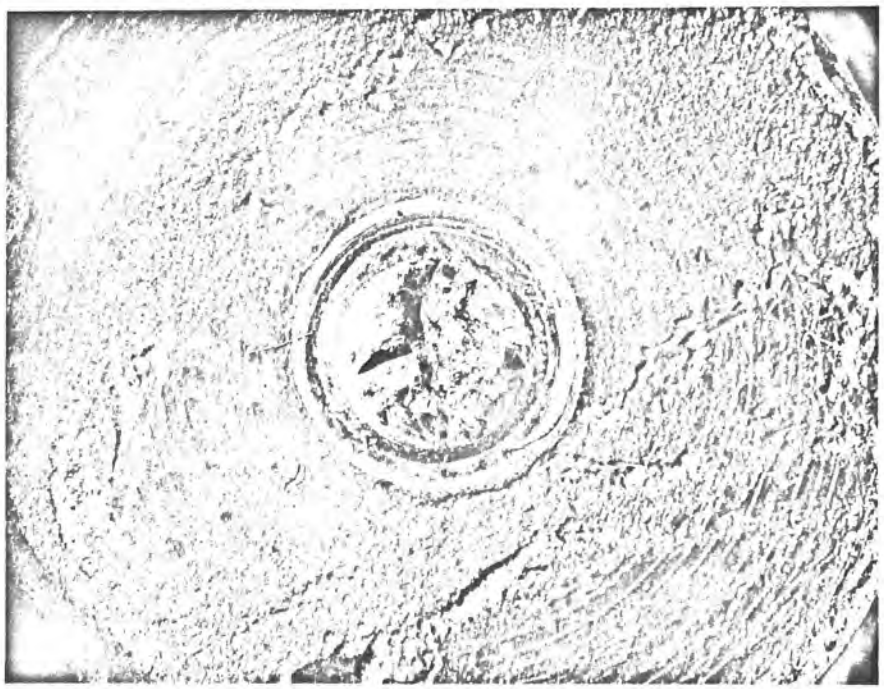
SECTIONAL VIEW OF PROPELLER SHAFT HOUSING OF MEASURE-RITE METER

FL 725

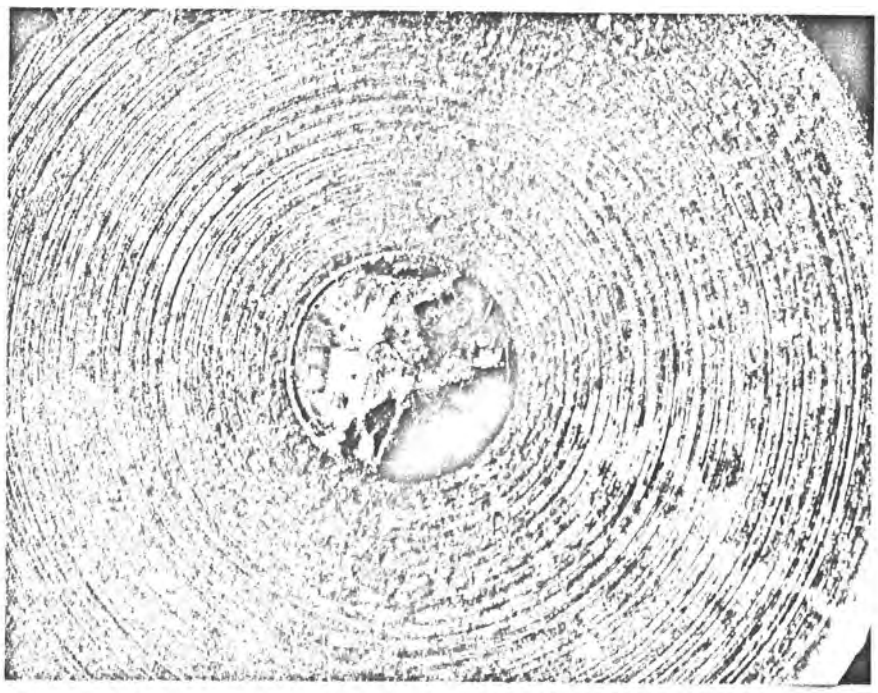
Figure 6

A. Silty clay sediment removed from inside the propeller shaft housing of Meter No. 37 after passing 6.7 acre-feet of water during laboratory calibration with clean water.

B. Sandy sediment removed from inside the propeller shaft housing of Meter No. 36 before laboratory calibration.

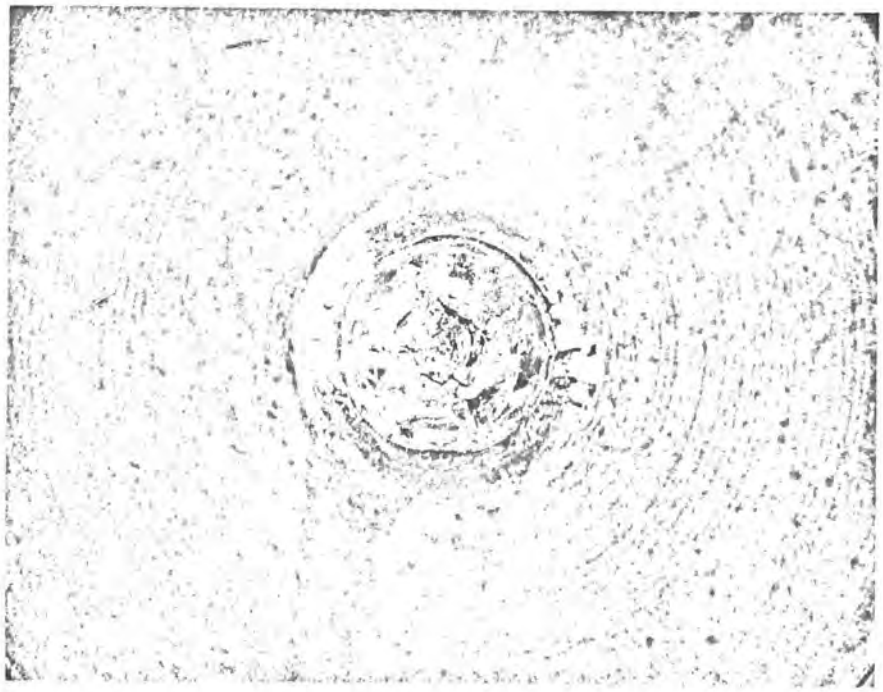


A. Propeller side (jewel in center of photograph).

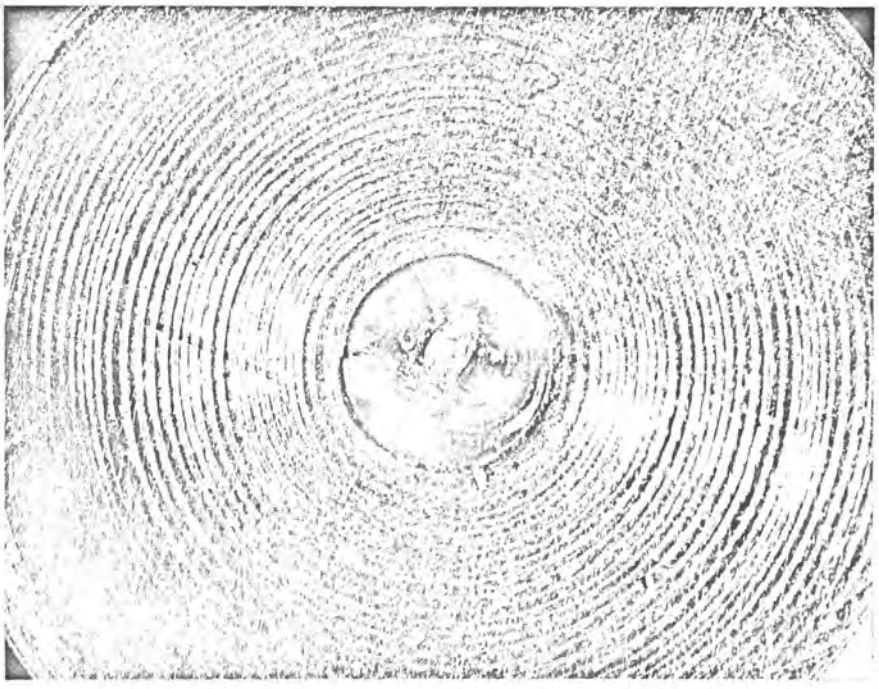


B. Register side.

Condition of jewel pivot bearings and brass bearing plate of Meter No. 37 after removing sediment but before obtaining final laboratory calibration (magnified 9X).



A. Propeller side (jewel in center of photograph).



B. Register side.

Condition of jewel pivot bearings and brass bearing plate of Meter No. 36 after removing sediment before obtaining laboratory calibration (magnified 9X).

APPENDIX

LABORATORY TESTS AND INSPECTION OF TWO MEASURE-RITE OPEN FLOW PROPELLER METERS

October and November 1966

BADGER METER MFG. COMPANY

MEASURE-RITE DIVISION

536 NO. VINCENT AVENUE • COVINA, CALIFORNIA

Ship To:

Bureau of Reclamation
Angostura Unit Office
% Lester C. Perrson
Oral, South Dakota

METER TEST RECORD

Serial Number 8326037

Date Tested 1-2-64

We certify that the test results shown in this report are correct to the best of our knowledge and belief.

MEASURE-RITE DIVISION

By CW

METER	TEST GEARS	TIME (Sec.)	TEST TANK Q = GALLONS	G. P. M.	%	INDEX
4700	18/42	67	4750	4250	99.0	2.24
2160		64	2220	2080	97.3	
1020		148	1060	430	96.3	
				av.	97.5	

Index is quantity in cubic feet passed through meter per spindle revolution.

Present Avg. 97.5 = 2.24 Tested Index

Desired 100% 2.3 Corrected Index

	SPECIFICATION	INDEX
Meter	18" OFI - ER	2.3
Registration	.01 Acre Ft.	5.228

Computation

A/B $\frac{18}{41}$ $\frac{.440}{.910}$

Auxiliary Equipment or Instrument Type ROFI - Dial 18 CFS, 0 - 25 Tach.

Meter Built According to Following Specification Sheets

Complete Meter Assembly SPEC. NO. _____ Meter Head Assembly SPEC. NO. _____

Exceptions Drop Pipe 5' Long Magnetic Gear Box

BADGER METER MFG. COMPANY

MEASURE-RITE DIVISION

536 NO. VINCENT AVENUE • COVINA, CALIFORNIA

Ship To:

Bureau of Reclamation
Angostura Unit Office
% Lester C. Perrson
Oral, South Dakota

METER TEST RECORD

Serial Number 8326036

Date Tested 1-2-64

We certify that the test results shown in this report are correct to the best of our knowledge and belief.

MEASURE-RITE DIVISION

By CW

METER	TEST GEARS	TIME (Sec.)	TEST TANK Q = GALLONS	G. P. M.	%	INDEX
4450	18/42	58	4350	4500	102.3	2.24
2150		62	2150	2080	100.0	
1080		154	1090	425	99.3	
				av.	100.5	

Index is quantity in cubic feet passed through meter per spindle revolution.

Present Avg. 100.5 / Desired 100% = 2.24 / 2.23

Tested Index / Corrected Index

	SPECIFICATION	INDEX
Meter	18'OFI - ER	2.23
Registration	.01 Acre Ft.	5.228

Computation

$$\frac{A}{B} = \frac{18}{42} \quad \frac{.440}{.910}$$

Auxiliary Equipment or Instrument Type ROFI - Dial 18 CFS, 0 - 25 Tach.

Meter Built According to Following Specification Sheets

Complete Meter Assembly SPEC. NO. _____ Meter Head Assembly SPEC. NO. _____

Exceptions Drop Pipe 5' Long Magnetic Gear Box