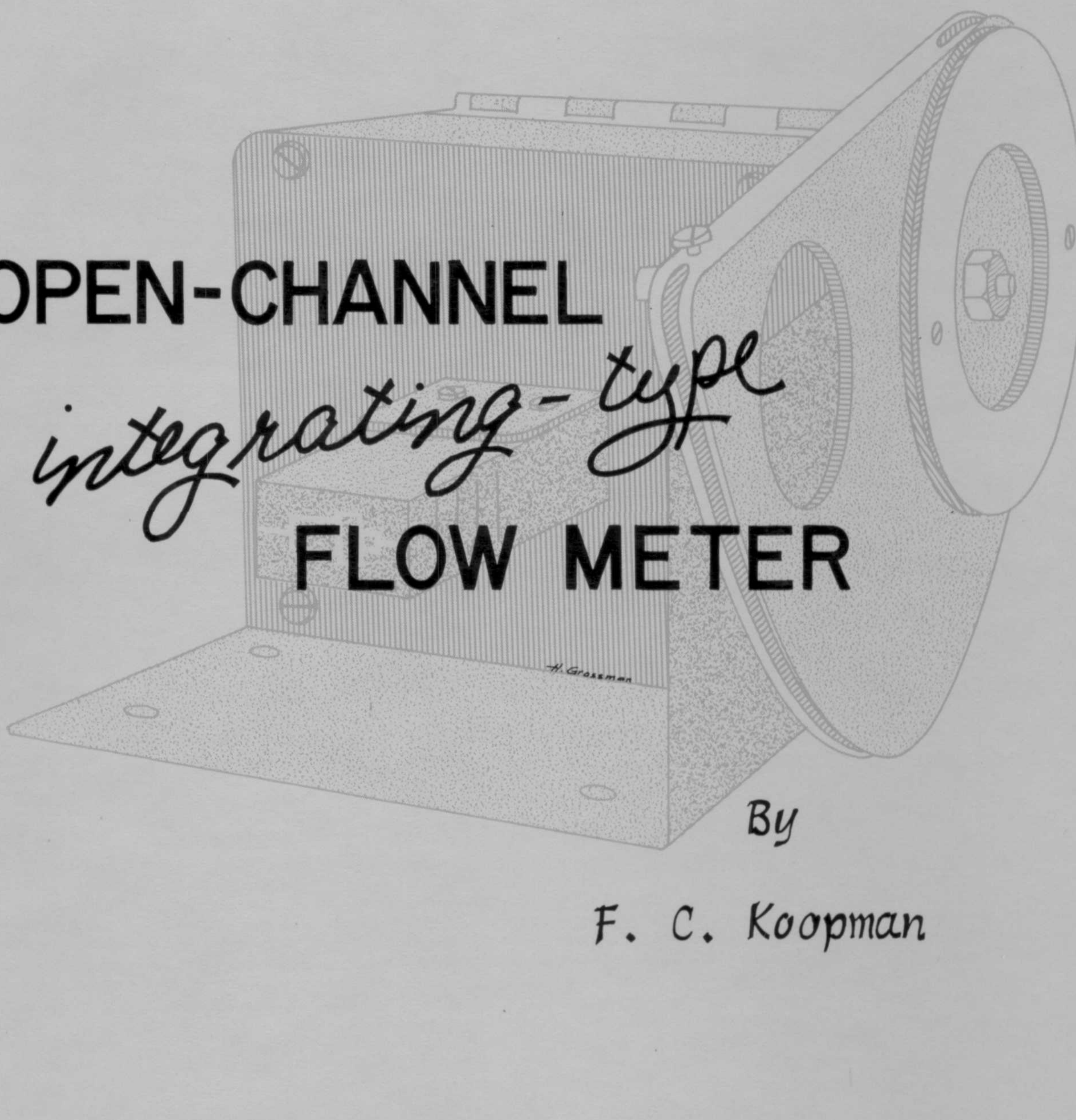
Open-file report

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

OPEN-CHANNEL integrating-type FLOW METER



By

F. C. Koopman

Prepared in cooperation with the New Mexico State Engineer

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Open-channel integrating-type flow meter

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F. C. Koopman

Abstract

A relatively inexpensive meter for measuring cumulative flow in open channels with a rated control, called a "totalizer", was developed. It translates the nonlinear function of gage height to flow by use of a cam and a float. A variable resistance element in an electronic circuit is controlled by the float so that the electron flow in the circuit corresponds to the flow of water. The flow of electricity causes electroplating of an electrode with silver. The amount of silver deposited is proportionate to the flow of water. The total flow of water is determined by removing the silver from the electrode at a fixed rate with an electronic device and recording the time for removal with a counter. The circuit is designed so that the resultant reading on the counter is in acre-feet of water.

Introduction

The New Mexico State Engineer is required to account for surface-water diversions on the Gila River and its tributaries in New Mexico to comply with the Supreme Court decree in the case of Arizona versus California. The measurement of these diversions is done by the U.S. Geological Survey in cooperation with the New Mexico State Engineer.

Many diversions in the Gila River stream system are so small that installation costs of conventional recorders, and the subsequent costs associated with determining total flow from recorder charts, would exceed the worth of the water being monitored. This made it necessary to use an inexpensive metering device that was simple to install and from which flow records could be easily obtained.

Ready-made instrumentation that would satisfy these criteria was not available. Thus, serious research and development was done to perfect an inexpensive meter. After about 1 year of intermittent experimentation on several types of devices, a meter, thought suitable, was developed and 20 such units were constructed and installed.

The instrument is called a "totalizer", and it is designed to measure cumulative flow in open channels which have a rated control. Two years of satisfactory field performance of the totalizer has proven its dependability. This report was prepared because its construction and operation is thought to be of interest to those measuring surface-water flow. Also, others may wish to consider its use as an alternate method of metering water in open channels.

The unit developed by the U.S. Geological Survey is for use in small flumes and is read out directly in total acre-feet by a digital counter.

Description of the meter

The entire totalizer system consists of a float, a cam, an electrical circuit, an integrating element, and a battery. With exception of the float, it is about the size of a cigar box (fig. 1) and is mounted in such a manner that the float movement (gage-height change) turns the cam. The cam is used to "linearize" the effect of the changing stage on the flow of water in the open channel. The integrating element is about the size of a small box of wooden matches and is easily removed from the totalizer for reading or replacement (fig. 2).

The meter is a direct-reading device that integrates flow relative to time. It converts the flow of water to a proportionate electrical flow which transports a metal ion (silver) from the electrolyte to an electrode in an electroplating process.

At the maximum recordable gage height for a particular meter there is a maximum electrical flow and a maximum current withdrawal from the battery (Mallory RM 42 or equivalent), however, experience has shown that battery replacement once a year is satisfactory.

The amount of metal deposited is proportionate to the electrical flow which, in turn, is proportional to the flow of water. To determine the flow of water it is necessary to reverse and maintain a fixed flow of electricity and record the time of transfer of the reverse flow with a counter.

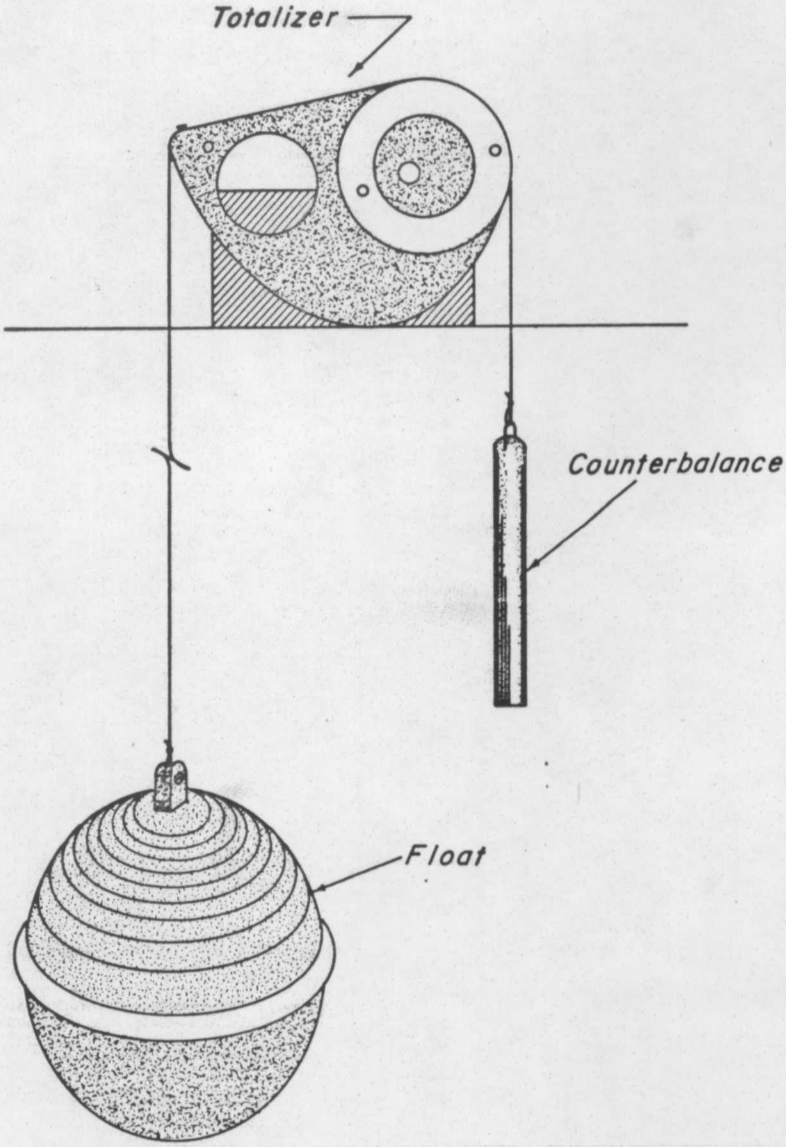

Figure 1.--Open-channel integrating-type flow meter (totalizer) with float and counterbalance.

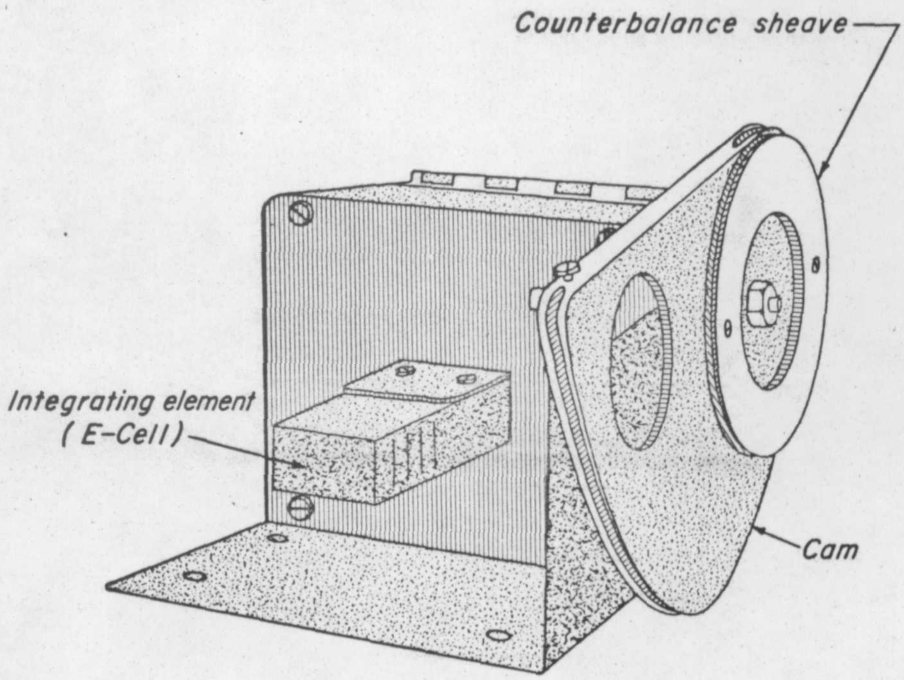

Figure 2.--Open-channel integrating-type flow meter (totalizer) with integrator (E-Cell) in position.

The element used for storing and transferring the silver is extremely rugged and stable, not vulnerable to shock and not affected by temperature changes. The element is called an E-Cell and is manufactured by, and available from, Bissett and Berman Co., 3860 Centinela Avenue, Los Angeles, Calif. 90066.

The circuit consists of two fixed resistors, one variable resistor (Potentiometer) that is controlled by the cam, a 1.35 volt mercury cell and the E-Cell (fig. 3).

The amount of total flow metered can be read any time after the E-Cell capsule is removed from the totalizer assembly. This can be done with a counter using an automobile battery as a power source or the unit can be returned to the office and read. The U.S. Geological Survey has preferred to replace each capsule with one that has been set at zero, and on which the time of installation and station name has been carefully marked. The date of removal is recorded on the capsule as it is retrieved from the station and these capsules are read and recordings made in the office. This necessitates a duplicate set of E-Cells on stand-by. This, however, is of minor consequence as the initial cost for one about equals the cost of one roll of A-35 chart paper. These E-Cells may be used over and over again with no change of accuracy.

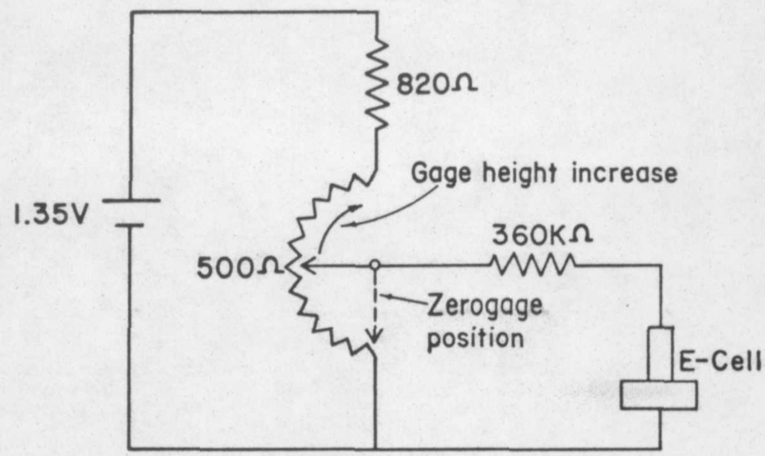

Figure 3.--Circuit for totalizer on a 1-foot Parshall flume.

Because of the peculiar construction of the E-Cell as an electrochemical device, it is read out only once and the flow recorded on the digital counter. The device is then ready to be used again as an integrator. The record is available only once on the counter. The EDR counter, supplied by Bissett and Berman, is used to read the flow. Other digital counters can be used. The EDR counter is based on a 3-milliampere current flow throughout the readout period that completely reverses the electrochemical process that stored the silver on the electrodes within the E-Cell.

If the data have to be documented, it is suggested that the E-Cell be noted with station number and corresponding dates of E-Cell operation. It can then be photographed with the digital readout for record documentation.

Construction

Equipment and parts needed to construct a totalizer meter include those components listed in table 1, plus a lathe, sabre saw, grinder, drill, and small hand tools. The totalizer is assembled in a 20-gage steel box with dimensions of 4x4x6 inches. A hinged lid facilitates battery change. All of the electrical circuit is mounted within the box, utilizing one isolated terminal strip and terminal mountings on the potentiometer and battery holder. The potentiometer is positioned so that the attached cam has clearance for rotation.

A sensitive ammeter is used in lieu of the E-Cell in the circuit to measure the microampere flow and is used to aid in determining the shape of the cam as described later. Correction must be made for resistance of the meter, or a resistor of the same value as the meter must be inserted in the circuit when the meter is removed and the E-Cell inserted for totalizer operation. The potentiometer must be a precision type (5 percent linearity or better) and it must have a small section of the resistance segment vacant on the 360-degree movement so that the wiper element is not in contact for a degree or two. This no-contact position of the wiper is the zero-gage-position of the shaft of the potentiometer and also zero gage setting for the cam setting. The cam should have a "stop" at this position to insure a nonreversal of the cam at this point of gage height. If the cam were permitted to turn below zero gage, an error would result so the totalizer would register a high flow when there was no flow.

Table 1.—List of materials and parts for one totalizer

	Cost (approximate)
1 each - Miniature utility cabinet 4"H x 5"W x 3"D, Bud Radio, Inc. part number C-1794 or equivalent ------------	$0.90
1 each - Battery holder "D" size ------------------------------	.60
1 each - Mercury Cell RM42R or equivalent --------------------	3.15
1 each - Potentiometer, 500 ohm, International Rectifier Corp. type 151 number 6638 or equivalent ----------------	5.00
1 each - Resistor, 820 ohm, ¼ watt, one percent, carbon[1/]------	.10
1 each - Resistor, 360,000 ohm, ¼ watt, one percent, carbon[1/]--	.10
1 each - Shaft lock, Raytheon SL105B or equivalent -----------	.15
1 each - Iron sheet, 20 gauge, 7x6 inches, to be bent and mounted to metal box to facilitate mounting of totalizer in gage shelter and act as stop for cam rotation (fig. 2) ---------------------------------	.50
1 each - Cloth-reinforced phenolic-sheet 3/16 x 6 x 8 inches for cam. Another size may be needed depending upon rating curve or readout characteristics demanded by operator-	1.10
1 each - Cloth-reinforced phenolic-sheet 3/16 x 4 x 4 inches for counterbalance sheave ------------------------------	.25
1 each - E-Cell mounted in holder with female connections - Bissett-Berman --	4.80
1 each - Bulkhead mount with male connections to mate with E-Cell holder --	.60
4 feet - Cable 0.021-inch diameter, nylon coated, 600 lb. test, or equivalent, Berkely and Co., Inc., Sprit Lake, Iowa - 51360 --	.10
Plus miscellaneous, metal screws, bolts, and hook-up wire -----	.25
Total ----------------	$17.60

1/ Resistance value for 1-foot Parshall flume, other values would be selected for other flumes or weirs dependent upon rating curve.

After the potentiometer, battery, E-Cell holder, and resistors are mounted on the metal box a template of thin soft wood is clamped on the potentiometer shaft in preparation for defining the shape of the cam. If the gage-height-flow relations are known, the cam can be designed mathematically, graphically with a function generator (Kingdon, 1970, p. 121-123) or by trial and error. The author chose to define the cam shape by trial and error because the operation is simple.

The microammeter is inserted where the E-Cell would normally be connected and the template rotated to the position of no electrical flow--this is zero gage. Changes in amperage are noted when the template is rotated. The relation of desired electrical flow and gage height can be tabulated for a gaging station with a good rating curve similar to that shown in table 2 for a 1-foot Parshall flume. With the potentiometer at zero, straight pins are inserted into the template on a horizontal line through the center of rotation and at the maximum distance from the center of rotation (fig. 4). A 2-foot cord is affixed to the pin and a weight attached so that the cord will hang plumb. Some provision should be made so that the vertical displacement of the weight can be ascertained in even tenths of feet. The cam is rotated to a microampere reading on the table and the cord positioned and held at the corresponding gage height by inserting pins in the template. This is done at all the gage heights until the cam configuration is defined by the pins on the template. These pins mark the bottom of the groove that holds the float line on the finished cam (fig. 5). The diameter of the cord used in calibrating the cam should be the same as that line used to hold the float on final location. A nylon-coated stainless-steel cable 0.021-inch diameter, 60 lb. test, has been used.

The counterbalance sheave is positioned on the cam so that the counterbalance weight operates eccentrically to compensate for the change in leverage of the float line on the cam as it moves. Note the eccentricity of the counterbalance sheave on figure 5.

Table 2.--Data used in construction of totalizer gages for 1-foot Parshall flume

Gage height	Second-feet fluid flow	Microampere
0.00	0.00	0.00
.10	-	-
.20	.35	2.167
.30	.64	3.962
.40	.99	6.128
.50	1.39	8.605
.565*	1.68	10.400
.60	1.84	11.390
.70	2.33	14.424
.80	2.85	17.643
.90	3.41	21.110
1.00	4.00	24.762
1.10	4.62	28.600
1.20	5.28	32.686
1.30	5.96	36.895
1.40	6.68	41.352
1.50	7.41	45.872
1.60	8.18	50.638
1.70	8.97	55.529
1.80	9.79	60.705

*Calibration point whereby: 0.565-foot gage height = 1.68 ft^3/sec or 100 acre-feet per 30 days and totalizer flow = 10.400 microampere

Note: Microampere divided by 6.19047 = fluid flow in second-feet.

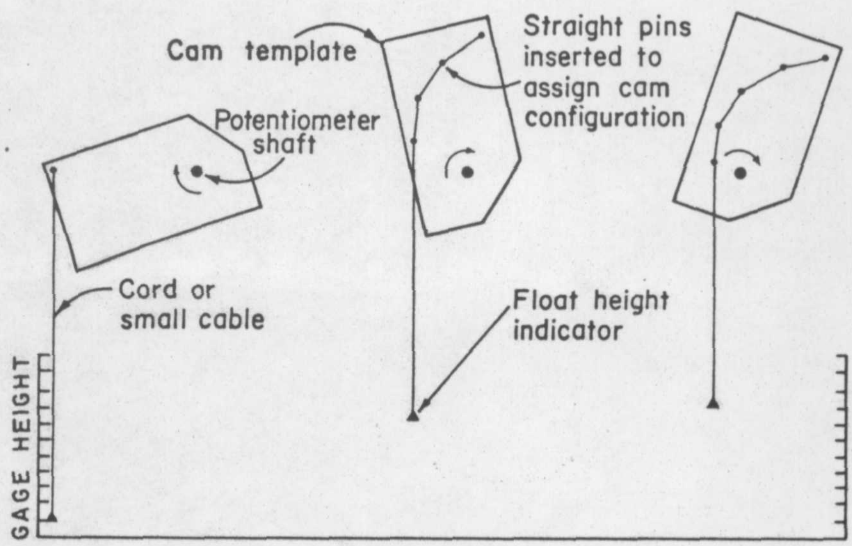

Figure 4.--Mechanical process of determining shape of totalizer cam.

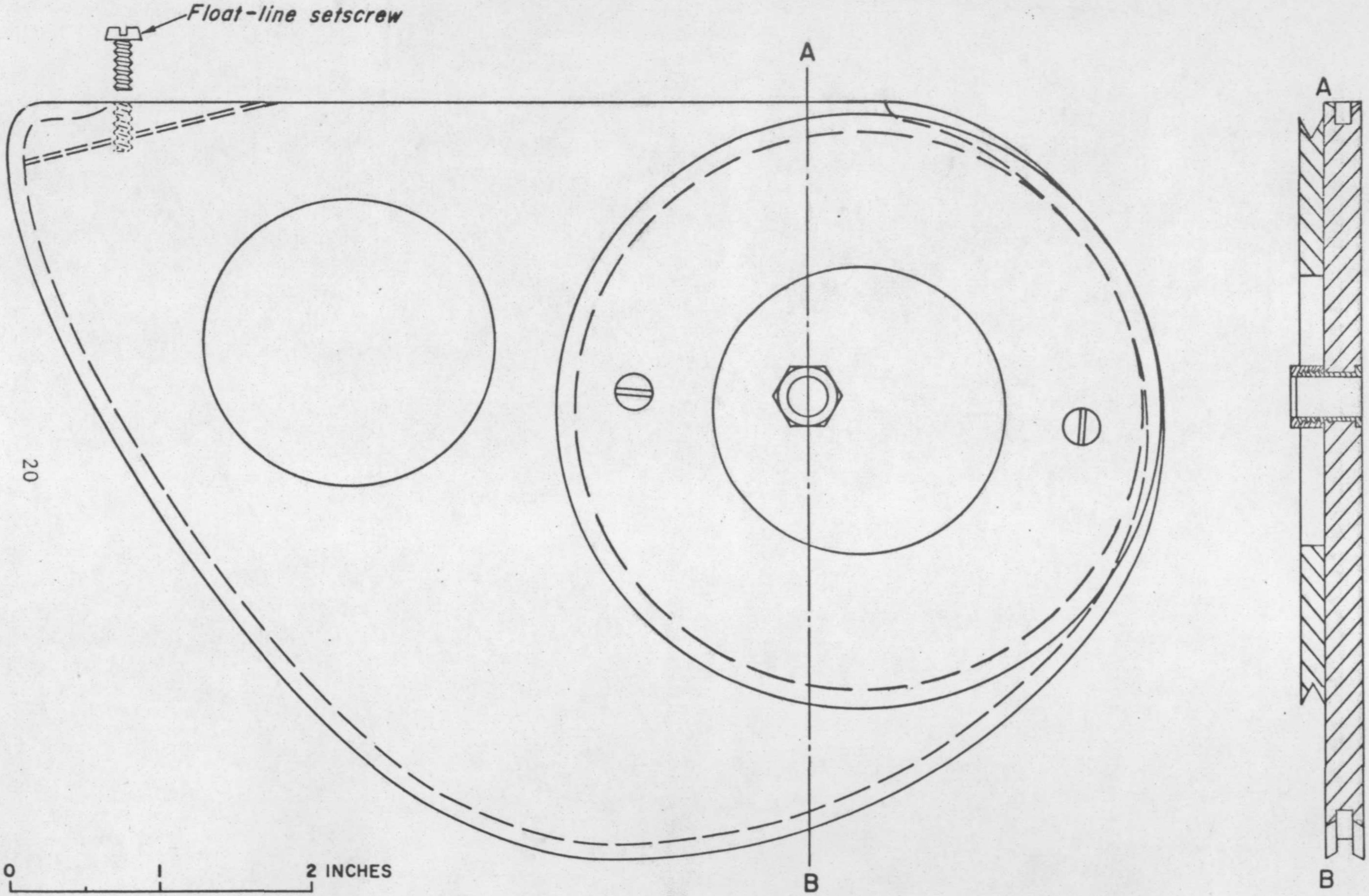

Figure 5.--Float controlled cam and counterbalance sheave for open-channel totalizer installation on a 1-foot width Parshall flume.

The cam may be eliminated if a nonlinear potentiometer is used in its place. A special potentiometer would have to be fabricated in accordance with the established rating curve of the control upon which the totalizer is to be installed. The use of precision resistance material in the correct geometric form for the potentiometer offers possibilities of substituting a sheave for the cam on the existing models.

Performance of the meter

Data collected during a 2-year period from about 20 stations equipped with the totalizer meter show that the device is electrically and mechanically sound.

Test data on a typical meter developed for a 1-foot Parshall flume in January, 1969, are shown in table 3 on the following page.

The percent error shown in table 3 at the lower gage heights can be improved by reshaping the cam.

The accuracy of the totalizer is affected by any shift of the control ratings caused by vegetation growth, sediment, or debris affecting the control. Consideration must be given to the stability of conditions at the control before installing the totalizer. Some records from one of the totalizers tested during 1968-69 were destroyed by vandalism; a corroded battery terminal on another led to loss of record.

Table 3.—Totalizer test data collected January 1969

Gage height (feet)	Flow in acre-feet/day	Integrator reading	Percent error
0.2	0.697	0.80	14.8 high
.25	1.13	1.23	9 high
.3	1.27	1.31	3 high
.4	1.96	1.97	-
.5	2.76	2.77	-
.6	3.46	3.45	-
.7	4.64	4.63	-
.75	5.13	5.12	-
.8	5.72	5.70	-
.9	6.77	6.77	-
1.0	7.97	7.95	-
1.1	9.20	9.08	1.4 low
1.2	10.5	10.29	2 low

The potential use of such a device is outstanding for recording the total of many things. The E-Cell can be used in a balanced circuit to show accumulated deviation from the average or other selected level and to record degree-days, average pressure, or other variables. With a modification of the circuit and a new cam it could be used as an integrating unit on any stable surface-water control that has an assigned rating curve.

Selected references

Bissett-Berman Corp., 1969, E-Cell device seminar: Bissett-Berman Corp., 36 p.

Kingdon, S. P., and Ohlson, G. F., 1970, Nonlinear function generator: Instruments and Control Systems, September 1970, p. 121-123.