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Chapter B2

CALIBRATION AND MAINTENANCE OF VERTICAL-AXIS TYPE CURRENT METERS

By George F. Smoot and Charles E. Novak

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PREFACE

The series of manuals on techniques describes procedures for planning and executing specialized work in water-resources investigations. The material is grouped under major subject headings called books and further subdivided into sections and chapters; Section B of Book 8 is on instruments for measurement of discharge.

The unit of publication, the chapter, is limited to a narrow field of subject matter. This format permits flexiblity in revision and publication as the need arises.

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SYMBOLS AND UNITS

Symbol	*Definition*	*Unit*
C	Constant.	
K	Proportionality constant.	
N	Angular velocity of meter rotor.	revolutions/sec
V	Velocity.	ft/sec

CALIBRATION AND MAINTENANCE OF VERTICAL-AXIS TYPE CURRENT METERS

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Abstract

The purpose of this chapter is to describe the procedures used in the manufacture and calibration of current meters and to present in detail information pertinent to their proper maintenance and repair. Recent intensive studies on the calibration of current meters and the effects of wear of the component parts on the performance of the meters have led to the adoption of new procedures for the manufacture, calibration, maintenance, and repair of meters. This chapter, therefore, updates the provisional manual "Care and Rating of Current Meters" (1957) by including these new procedures.

Introduction

Precision instruments and their proper use and maintenance are prerequisites for the collection of accurate data. Current meters are precision instruments and their proper use and maintenance are doubly important because of the hard usage often received by them in measuring stream velocities. The following quotation from an earlier provisional manual emphasizes the importance the Water Resources Division attaches to this aspect of streamflow measurements:

> The operation of a current meter, as of any scientific instrument, will be largely affected by the way in which it is used. While the design, material, and construction of the meter may be large factors in its successful operation, these factors may not prevent errors due to improper care and use of the instrument. In this connection each fieldman is urged to use the greatest possible care to see that his meter is kept in proper condition.

The condition of the fieldman's current meter is one of the most important building stones in the foundation of good streamflow records. Routine servicing, inspection for minor damage, and proper lubrication should be standard operating procedure. The amount of pride taken in maintaining his meter in optimum condition is also a measure of the pride a man can be expected to take in other areas of his work.

This chapter updates the provisional manual "Care and Rating of Current Meters" (1957, out of print).

Description of the Small Price Current Meter

Rotating-element current meters can be broadly classified into two general categories according to the orientation of the revolving axle; the axis may be vertical, or it may be horizontal and parallel to the direction of flow. Current meters having horizontal axes with propeller—shaped rotors and those having vertical axes with cup or vane-type rotors have been experimented with extensively to determine their respective advantages and disadvantages.

Although many characteristics of different current meters are still unknown, the experiments and investigations thus far conducted are conclusive in one respect, namely, that current meters of either the horizontal- or vertical- axis type when carefully designed and constructed, and when used under favorable conditions, will measure accurately the velocity of flowing water.

When streamflow investigations were undertaken by the Geological Survey in 1888, engineers of the Survey began experimenting with the various types of current meters available at that time to find one that could be used under a wide variety of field conditions. About 1896, as a result of these investigations, they developed a meter containing certain features of the Price acoustic and the large Price electric meters. This meter, which was called the small Price (fig. 1), has since been used by the Survey almost exclusively because of its adaptability to general stream gaging.

The small Price current meter probably has been used more extensively and has been subjected to more investigation than any other type of current meter. As a result of this extensive investigation and because of the natural advantages afforded by the type, the small Price has been perfected in its details; the type-AA Price meter is now better suited to general use than any other meter. It is light and yet strong, sensitive yet durable. It will measure with a high degree of accuracy velocities ranging from 0.1 foot per second to more than 20 feet per second. It is easily repaired, it can be quickly taken apart for cleaning and oiling, and it can be quickly reassembled without change in rating.

To properly use and care for a current meter, the user must be familiar with all of its parts, as well as with the assembled meter. If any part fails completely because of excessive wear or damage, the condition is usually obvious, but small irregularities that may introduce large percentage errors in velocity determinations are not always readily detected. For this reason the parts of the type-AA meter and their functional characteristics are described; the numbers assigned to the various parts in this description correspond to the numbers used in the assembly diagram of the type-AA current meter shown in figure 2.

Yoke

The yoke (8) is a 1-piece horseshoe-shaped casting made of chromium-plated bronze. A short horizontal rear extension contains a hole for connection of the tailpiece. This extension contains two bosses—one which is slotted vertically and and drilled horizontally for the hanger and hanger screw, and one which is drilled vertically for the keeper screw of the tailpiece. The slot for the hanger is of such dimensions as to limit the tilting of the meter so that neither the yoke nor the tailpiece will strike the weight. The upper arm of the yoke is drilled to receive the stem of the P-shaped contact chamber; the lower arm is drilled to receive the pivot. These holes are coaxial so as to properly aline the rotor assembly and the pivot. The contact chamber and pivot are held in position by a keeper screw having a knurled fillister head.

Tailpiece

The tailpiece is made of a hard-rolled nickel-plated brass, and it consists of two separate vanes which, when assembled, are locked together at right angles to each other by means of a lever arrangement. This two-piece construction permits the tailpiece to be taken apart readily for convenience in packing. The nosepiece of the tail fits into the rear extension of the yoke. A means to balance the meter assembly is provided in the lower part of the tailpiece by a long horizontal slot containing a short heavy screw that may be adjusted to the proper position to obtain the desired balance.

Bucket wheel

The bucket wheel (21) consists of six cone-shaped cups soldered to a frame to form a symmetrical and balanced assembly 5 inches in diameter and 2 inches high. The cups and frame are made of nickel-plated hard rolled brass. The frame is centrally drilled for the shaft and notched for a dowel pin. The letter "S" is stamped on the frame to identify the top side of the bucket wheel. The year of manufacture is also identified—S–67, S–68, for example.

Bucket-wheel hub

The bucket-wheel hub (13) encases the pivot bearing and the lower end of the shaft and supports the bucket wheel. The hub is threaded in three places: (1) for the bucket-wheel hub nut, (2) for the bucket-raising nut, and (3) for the shaft. A small dowel pin maintains the bucket wheel in a fixed position with reference to the bucket-wheel hub. The bucket-raising nut is provided so that the pivot bearing can be raised from the pivot when the meter is not is use.

Shaft

The shaft (12) is made of stainless steel and is of sufficient length to extend from the bucket-wheel hub to a point 0.008 inch below the cap of the

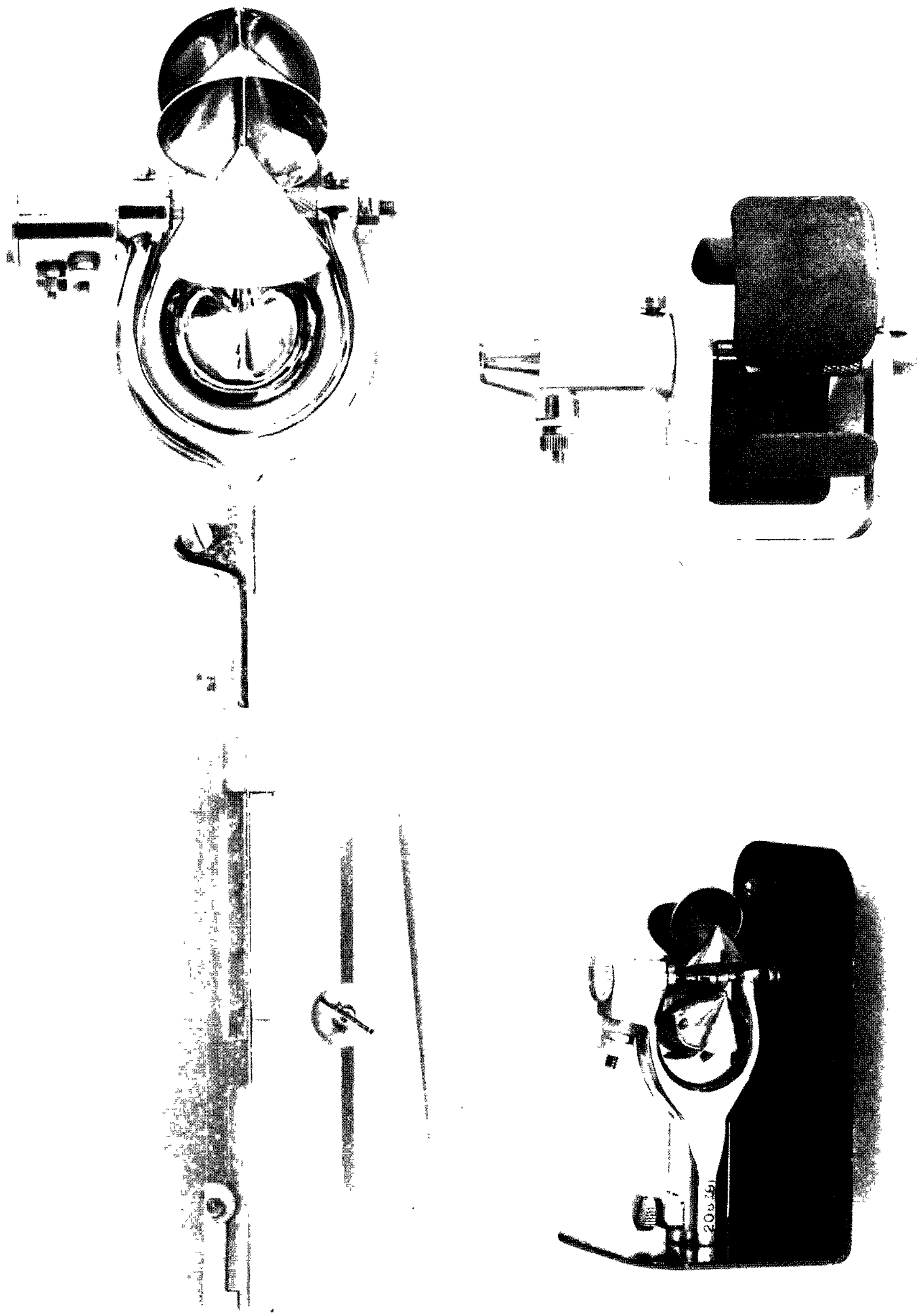
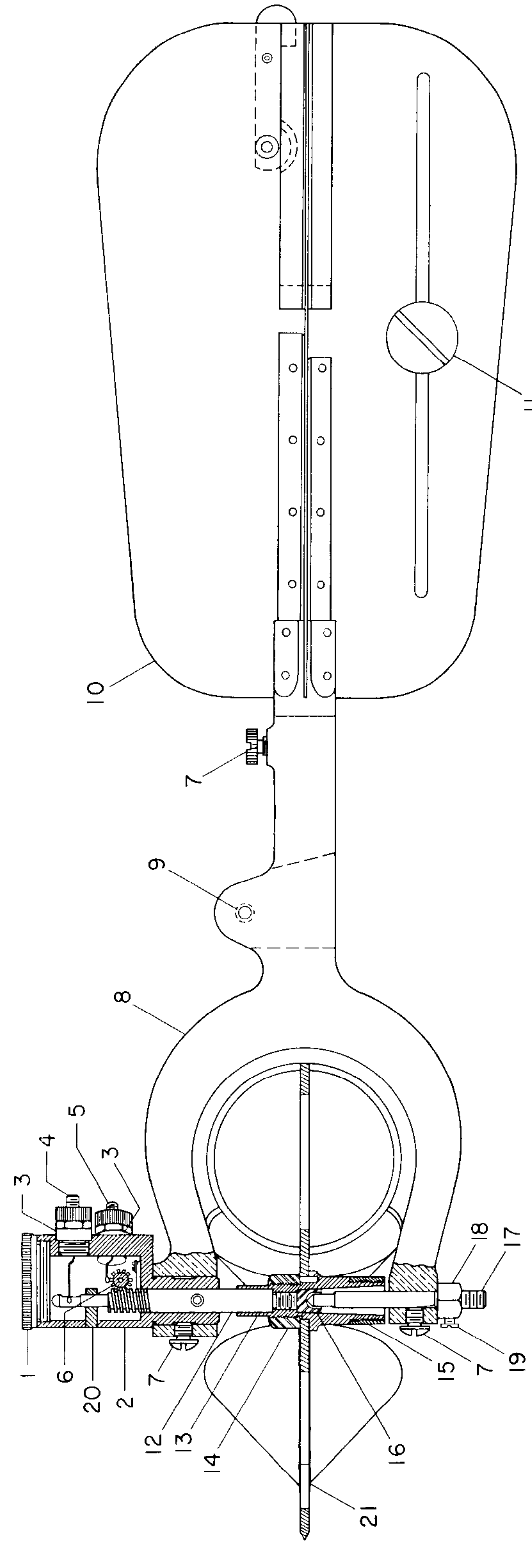


Figure 1.—Small Price (above), pygmy (lower left), and ice (lower right) meters.



EXPLANATION

1. Cap for contact chamber
2 Contact chamber
3 Insulating bushing for contact binding post
4. Single-contact binding post
5 Penta-contact binding post
6. Penta gear
7. Set screw
8. Yoke
9. Hole for hanger screw
10 Tailpiece
11. Balance weight
12 Shaft
13. Bucket-wheel hub
14 Bucket-wheel hub nut
15. Raising nut
16 Pivot bearing
17. Pivot
18. Pivot-adjusting nut
19. Keeper screw for pivot-adjusting nut
20. Bearing lug
21. Bucket wheel

Figure 2.—Assembly diagram of type-AA Price current meter.

contact chamber. The upper one-half inch of the shaft is turned to 0.125-inch diameter and is rounded at the top to provide a smooth bearing surface for the thrust of the shaft against the bottom of the contact-chamber cap. An eccentric is cut in the 0.125-inch diameter part of the shaft to provide a means for making an electrical contact for each revolution of the bucket-wheel hub. The shaft also contains an acme thread that meshes with the penta gear within the contact chamber. A small hole is drilled at about the midpoint of the shaft to facilitate the use of a pin for tightening the shaft into the bucket-wheel hub.

Pivot

The pivot (17) is made of tempered, precipitation-hardening stainless steel. The upper end of the pivot is ground and polished to form an angle of 90° and the point rounded to a radius of 0.005 inch. The lower end of the pivot is threaded to provide for the hexagonal stainless-steel nut that is used to adjust the clearance between the pivot point and the pivot bearing. A slightly tapered flat surface on the pivot above the threads serves as a contact surface for the pivot-keeper screw.

Pivot bearing

The pivot bearing (16) is made of tungsten carbide and has highly polished bearing surfaces. It is pressed into the cylindrical recess in the lower end of the bucket-wheel hub. The bearing being of greater hardness than the pivot causes the major part of the wear to take place on the pivot which is easily replaceable.

Penta gear

The penta gear (6) is made of stainless steel and is fitted to mesh smoothly with the acme threads on the shaft. The gear makes one complete revolution for each 10 revolutions of the bucket wheel. Two gear teeth, 180° apart, are extended beyond the others to provide a means for making two electrical contacts for each revolution of the gear, with the result that contacts are made at each fifth revolution of the bucket wheel. The gear is mounted in a bronze frame in a horizontal position, and the assembly is housed in the contact chamber where it is held in place by means of a brass screw. The base of the frame through which this screw passes is slotted to permit the adjustment of the gear teeth with the worm on the shaft.

Contact chamber

The contact chamber (2) is a P-shaped chromium-plated brass unit which houses the penta gear, the upper part of the shaft, the shaft bearing, and the single- and penta-contact binding posts. The upper end of the chamber is drilled and threaded internally to carry a knurled cap. A small phosphor-bronze lug, brazed to the chamber wall, serves as the upper bearing for the shaft. The stem of the contact chamber extends through the upper arm of the yoke and is drilled axially so that the shaft can pass into the chamber with ample clearance. The cap is tightly fitted so that the chamber serves as an air trap to prevent silty water from entering the bearing.

Binding posts

Two stainless-steel binding posts (4) and (5) are placed at the rear of the contact chamber. One post is designed to contact the eccentric of the shaft and the other to contact the two extended teeth of the penta gear. They are identical in construction except for the lengths of the slender stainless steel cables that terminate in beads of silver solder through which the contacts are made. Each binding post is insulated from the contact chamber by a bushing (3) made of nylon.

Calibration of Current Meters

The principal of operation of a rotating-element type velocity meter is based on the proportionality between the local flow velocity and the resulting angular velocity of the meter rotor. The velocity of the water is determined by counting the number of revolutions of the rotor during a measured interval of time and consulting the meter calibration table.

If an ideal current meter, that is, one equipped with a correctly shaped rotor and a frictionless bearing mechanism, were to measure the flow velocity of a perfect liquid, the relation between the flow velocity and the rotor speed would be very simple:

$$V = KN \tag{1}$$

where V denotes the local flow velocity, K is the proportionality constant, and N is the rotor speed expressed in revolutions per unit of time. In actual practice there are resistances opposing rotation caused by friction between the liquid and the rotor and by the mechanical friction of the bearings. Consequently, this simple relationship does not exist, and one must be determined empirically. The establishment of this relation, known as "rating the current meter," is done for the Survey by the National Bureau of Standards.

The current-meter rating station operated by the National Bureau of Standards in Washington, D.C., consists of a sheltered reinforced concrete basin 400 feet long, 6 feet wide, and 6 feet deep. Atop the vertical walls of the basin and extending its entire length are steel rails that carry an electrically driven rating car. This car is operated to move the current meter at a constant rate through the still water in the basin. Although the rate of travel can be accurately adjusted, the average velocity of the moving car is determined for each run by making an independent measurement of the distance it travels during the time that the revolutions of the bucket wheel are electrically counted. A scale graduated in feet and tenths is used for this purpose.

A small Price meter is rated by towing it at eight different velocities (0.25, 0.50, 0.75, 1.10, 1.50, 2.20, 5.00, and 8.00 feetp er second). A pair of runs are made at each velocity. A pair consists of two traverses of the basin, one in each direction. The data obtained consists of 16 observations of the velocity of the car (V) and revolutions per second of the rotor (N). The meter rating is determined from these data and is expressed as two linear equations:

For N less than 1.00,

$$V = K_1N + C_1, \tag{2}$$

For N greater than 1.00,

$$V = K_2N + C_2, \tag{3}$$

where

$$K_2 = K_1 + C_1 - C_2. \tag{4}$$

Because there is rigid control in the manufacture of the small Price meter, virtually identical meters are produced and, for all practical purposes, their rating equations are identical. Therefore, there is no need to calibrate each meter individually. Instead, a standard rating is established by calibrating a large number of meters that have been constructed according to Survey specifications, and this rating is then supplied with each meter.

To insure that all small Price meters are virtually identical, dies and fixtures for their manufacture were purchased by the Water Resources Division and supplied to the manufacturer in 1967 for use in constructing meters. These same dies and fixtures will be supplied to the successful bidder in subsequent years. All rotors manufactured by use of the standard dies and fixtures are stamped "S" on the top side of the bucket wheel. The year of manufacture is also identified—S–67, S–68, for example. To further insure that all meters are identical, quality control procedures are followed, including the rating of a sample of meters from each new group procured.

For convenience in field use, the data from the current-meter ratings are reproduced in tables, a sample of which is shown in figure 3. The velocities corresponding to a range of 3–350 revolutions of the bucket wheel within a period of 40–70 seconds are listed in the tables. This range in revolution and time has been found to cover general field requirements. To provide the necessary information for the few instances where extensions are required, the equations of the rating table are shown in the spaces provided in the heading. Because of limited space, the equations are presented in an abbreviated form.

The expression V = 2.140N + 0.015 (2.155) V = 2.150N + 0.005 shown in the heading of the table in figure 3 is to be interpreted as follows:

V represents velocity in feet per second.

N represents the number of revolutions of the bucket wheel per second.

That part, V = 2.140N + 0.015, to the left of the parentheses is the equation used for computing velocities shown in the table less than 2.155 feet per second.

That part, V = 2.150N + 0.005, to the right of

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RATING TABLE FOR TYPE AA CURRENT METER

EQUATIONS: $V = 2.140N + 0.015$ (2.155) $V = 2.150N + 0.005$ . . . . STANDARD RATING NO. . . . X . . . .

Time in Seconds	VELOCITY IN FEET PER SECOND									Time in Seconds
	Revolutions									
	3	5	7	10	15	20	25	30	40	
40	.176	.282	.390	.550	.818	1.09	1.35	1.62	2.15	40
41	.172	.276	.380	.537	.798	1.06	1.32	1.58	2.10	41
42	.168	.270	.372	.525	.779	1.03	1.29	1.54	2.06	42
43	.164	.264	.363	.513	.762	1.01	1.26	1.51	2.01	43
44	.161	.258	.355	.501	.745	.988	1.23	1.47	1.96	44
45	.158	.253	.348	.491	.728	.966	1.20	1.44	1.92	45
46	.155	.248	.341	.480	.713	.945	1.18	1.41	1.88	46
47	.152	.243	.334	.470	.698	.926	1.15	1.38	1.84	47
48	.149	.238	.327	.461	.684	.907	1.13	1.35	1.80	48
49	.146	.233	.321	.452	.670	.888	1.11	1.33	1.76	49
50	.143	.229	.315	.443	.657	.871	1.09	1.30	1.73	50
51	.141	.225	.309	.435	.644	.854	1.06	1.27	1.69	51
52	.138	.221	.303	.427	.632	.838	1.04	1.25	1.66	52
53	.136	.217	.298	.419	.621	.823	1.02	1.23	1.63	53
54	.134	.213	.292	.411	.609	.808	1.01	1.20	1.60	54
55	.132	.210	.287	.404	.599	.793	.988	1.18	1.57	55
56	.130	.206	.282	.397	.588	.779	.970	1.16	1.54	56
57	.128	.203	.278	.390	.578	.766	.954	1.14	1.52	57
58	.126	.199	.273	.384	.568	.753	.937	1.12	1.49	58
59	.124	.196	.269	.378	.559	.740	.922	1.10	1.47	59
60	.122	.193	.266	.372	.550	.728	.907	1.09	1.44	60
61	.120	.190	.261	.366	.541	.717	.892	1.07	1.42	61
62	.119	.188	.257	.360	.533	.706	.878	1.05	1.40	62
63	.117	.185	.253	.355	.526	.694	.864	1.03	1.37	63
64	.115	.182	.249	.349	.517	.684	.851	1.02	1.35	64
65	.114	.180	.245	.344	.509	.673	.838	1.00	1.33	65
66	.112	.177	.242	.339	.501	.663	.826	.988	1.31	66
67	.111	.175	.239	.334	.494	.654	.814	.973	1.29	67
68	.109	.172	.235	.330	.487	.644	.802	.959	1.27	68
69	.108	.170	.232	.325	.480	.635	.790	.945	1.26	69
70	.107	.168	.229	.321	.474	.626	.779	.932	1.24	70
	3	5	7	10	15	20	25	30	40	

Time in Seconds	VELOCITY IN FEET PER SECOND									Time in Seconds
	Revolutions									
	50	60	80	100	150	200	250	300	350	
40	2.69	3.23	4.30	5.38	8.07	10.76	13.44	16.13	18.82	40
41	2.63	3.15	4.20	5.25	7.87	10.49	13.11	15.74	18.36	41
42	2.56	3.08	4.10	5.12	7.68	10.24	12.80	15.36	17.92	42
43	2.50	3.00	4.00	5.00	7.50	10.00	12.50	15.00	17.50	43
44	2.45	2.94	3.91	4.89	7.33	9.78	12.22	14.66	17.11	44
45	2.39	2.87	3.83	4.78	7.17	9.56	11.95	14.34	16.73	45
46	2.34	2.81	3.74	4.68	7.02	9.35	11.69	14.03	16.36	46
47	2.29	2.75	3.66	4.58	6.87	9.15	11.44	13.73	16.02	47
48	2.24	2.69	3.59	4.48	6.72	8.96	11.20	13.44	15.68	48
49	2.20	2.64	3.51	4.39	6.59	8.78	10.97	13.17	15.36	49
50	2.15	2.58	3.44	4.30	6.46	8.60	10.76	12.90	15.06	50
51	2.11	2.53	3.38	4.22	6.33	8.44	10.54	12.65	14.76	51
52	2.07	2.49	3.31	4.14	6.21	8.27	10.34	12.41	14.48	52
53	2.03	2.44	3.25	4.06	6.09	8.12	10.15	12.17	14.20	53
54	2.00	2.39	3.19	3.99	5.98	7.97	9.96	11.95	13.94	54
55	1.96	2.35	3.13	3.91	5.87	7.82	9.78	11.73	13.69	55
56	1.93	2.31	3.08	3.84	5.76	7.68	9.60	11.52	13.44	56
57	1.89	2.27	3.02	3.78	5.66	7.55	9.43	11.32	13.21	57
58	1.86	2.23	2.97	3.71	5.56	7.42	9.27	11.13	12.98	58
59	1.83	2.19	2.92	3.65	5.47	7.29	9.12	10.94	12.76	59
60	1.80	2.15	2.87	3.59	5.38	7.17	8.96	10.76	12.55	60
61	1.77	2.12	2.82	3.53	5.29	7.05	8.82	10.58	12.34	61
62	1.74	2.09	2.78	3.47	5.21	6.94	8.67	10.41	12.14	62
63	1.71	2.06	2.74	3.42	5.12	6.83	8.54	10.24	11.95	63
64	1.69	2.02	2.69	3.36	5.04	6.72	8.40	10.08	11.76	64
65	1.66	1.99	2.65	3.31	4.97	6.62	8.27	9.93	11.58	65
66	1.64	1.96	2.61	3.26	4.89	6.52	8.15	9.78	11.41	66
67	1.61	1.93	2.57	3.21	4.82	6.42	8.03	9.63	11.24	67
68	1.59	1.90	2.53	3.17	4.75	6.33	7.91	9.49	11.07	68
69	1.57	1.88	2.50	3.12	4.68	6.24	7.79	9.35	10.91	69
70	1.54	1.85	2.46	3.08	4.61	6.15	7.68	9.22	10.76	70
	50	60	80	100	150	200	250	300	350	

Figure 3.—Sample current-meter rating table.

the parentheses is the equation used for computing the values for V more than 2.155 feet per second.

The term within parentheses (2.155) is the velocity common to both equations.

Data do not indicate that there is any significant difference between a rod rating and a cable suspension rating when Columbus-type weights and hangers are properly used with the meter. Therefore, no suspension coefficient is indicated, and none should be used.

Assembly and Disassembly of the Small Price Current Meter

To provide the proper care to a current meter, which is of extreme importance as pointed out earlier, each fieldman should become thoroughly acquainted with all the component parts as well as with the assembled meter. He should also be familiar with the steps outlined below, which are necessary to assemble or disassemble a meter.

Assembly

The procedure in assembling the small Price current meters may best be followed by referring to figure 2 which shows a sectional view of a type-AA meter and the names of the parts.

1. Assemble the two vanes of the tailpiece (10).
2. Insert the tailpiece assembly, with balance weight underneath, into the yoke (8) and tighten the tailpiece set screw (7).
3. Place the bucket wheel (21) onto the bucket-wheel hub (13) with the side marked "S" upward, and with the dowel pin on the hub fitting the notch in the bucket-wheel frame. These parts are held together by means of the bucket-wheel hub nut.
4. Place the bucket-wheel assembly within the arms of the yoke (8) and pass the shaft (12) through the hole in the upper arm of the yoke. Screw the shaft directly into the bucket-wheel hub (13), then insert a pin into the hole in the shaft and use the pin to tighten the shaft in the hub.
5. Loosen the penta gear (6) in the contact chamber (2) by a **single** turn of the small screw that passes through the adjusting slot of the gear pad. **Do not remove this screw completely as it is difficult to replace.**
6. Slip the contact chamber, with the cap (1) removed, over the upper end of the shaft and into the hole in the upper limb of the yoke. This should be done with great care in order not to damage either the threaded shaft or the penta gear.
7. Aline the contact chamber with the yoke by making the centerline of the yoke bisect the angle formed by the two contact binding posts. Some meters have been provided with grooved marks on the front of the contact chamber and on top of the upper arm of the yoke; making these marks coincide insures the proper alinement.
8. Tighten the yoke set screw (7) to hold the contact chamber in place.
9. Screw the cap (1) onto the contact chamber.
10. Insert the pivot (17) through the hole in the lower arm of the yoke after placing a drop of oil in the lower bearing and on the pivot.
11. Adjust the pivot as described in table 1. This adjustment allows a vertical play of 0.008 inch, the amount of play used when the meter is rated.
12. Return the meter to an upright position, and remove the cap from the contact chamber. Adjust the penta gear to mesh properly with the threads on the shaft and tighten the small (unnumbered) screw which holds the penta gear assembly.
13. Spin the bucket wheel rapidly while

Table 1. Adjustment of pivot

Sequence	*Operation*
1	Make sure that the meter has been properly oiled; then hold meter in inverted position with pivot uppermost.
2	Release keeper screw (19) for pivot adjusting nut (18) and unscrew the nut a few turns.
3	Release set screw (7) and advance pivot until all vertical play of the hub assembly is eliminated.
4	Tighten set screw (7) temporarily and advance pivot adjusting nut (18) until it touches the yoke.
5	Release set screw (7) (not too far because the pivot should not revolve) and advance the pivot adjusting nut one-fourth turn. Then tighten keeper screw (19).
6	Push the pivot inward as far as it will go and tighten set screw (7).

watching the action of the penta gear to make sure that there is complete freedom of action between the gear and the threads on the shaft. Then apply oil to the penta gear and to the three bearing surfaces (one drop on the vertical shaft and two on the horizontal shaft that supports the gear).

14. Adjust the contact wires so that these wires touch the edge of the single and penta eccentrics very lightly. Then replace the cap on the contact chamber and listen with a headset for a sharp click.

15. Place the assembled meter on a solid surface with the shaft vertical, and make a spin test (see page 10).

Disassembly

In general, the disassembly of small Price current meters offers no difficulties and hence it will not be described in detail. The following precautions, however, should be observed.

1. Removal of the contact chamber from the yoke should be done carefully and without exerting appreciable force, so that the penta gear and shaft will not be damaged.

2. The contact-chamber cap should never be unscrewed when the upper end of the shaft bears forcibly against its underside, a condition which exists if the bucket-wheel raising nut has been previously tightened, and if the pivot adjustment has been made so tight that there is no play between the end of the shaft and the underside of the cap.

When the bucket-raising nut has been tightened, the upper end of the shaft bears against the underside of the cap at a point that is about three–sixteenths of an inch "off center" with respect to the center of the cap. If those two parts are in contact with each other when the cap is being either tightened or loosened, a severe bending force occurs at the point where the upper end of the shaft emerges from the upper bearing. Lack of attention to this subject is a common cause for "bent shafts" on Price-type current meters.

When the bucket-wheel-and-hub assembly is raised from the pivot by means of the raising nut, the bucket wheel should always be held stationary and the raising nut should be turned by hand. The bucket wheel should never be spun with the raising nut held stationary, as this method may cause several excess turns which may result in the shaft becoming bent or the yoke becoming sprung.

Inspection and Repair of Current Meters

To make sure that the current meter is in good condition and is properly lubricated, the operator should examine it, both before and after each discharge measurement, with regard to the details under the heading immediately following. Because all meter parts are manufactured to be interchangeable without affecting the calibration of the meter, replacement of any of the component parts can be made in the field.

Rotor and shaft alinement

By spinning the bucket wheel slowly and then watching the metal frame to which the cups are fastened, eccentricity in the bucket–wheel-and–hub assembly may be readily detected. If eccentricity is observed while making this test, either the wheel or shaft is bent, and further tests should be made to find the source of the eccentricity. The cap should be removed and the movement of the shaft inside the contact chamber should be observed. If, while the bucket wheel is rotating, any eccentricity in the movement of the top of the shaft is observed, the shaft should be removed from the assembly and should be further tested by observing its performance while rolling it on a clean flat surface. Any meter found to have a bent shaft should be repaired by replacing that shaft with a new one. If eccentricity is not found in the shaft, it may be present in the bucket wheel. Should the fault lie there, the rotor should be replaced with a new one.

Sprung yoke

The yoke may become sprung so that the distance between the upper and lower arms is too small or too great to permit proper adjustment of the rotor assembly within this space. It may also be distorted so that the coaxial holes will no longer properly aline the rotor assembly and the pivot. If either of these conditions is suspected, the alinement and spacing should be checked with a special yoke alinement gage that is available from the Property Maintenance Section, Silver Spring, Md.

In addition to the above, the stem of the yoke (that part from the slot for the hanger to the end onto which the tailpiece fits) occasionally becomes bent. A bent stem causes the bucket wheel to assume a position that is out of proper alinement with the flow lines of the water. If the amount of distortion in the yoke is minor and can be properly straightened, this should be done; if not, the yoke should be replaced with a new one.

Damaged cups

The bucket wheel and cups on it have more influence on the meter rating than has any other component. Cups should therefore be examined closely as any small distortion will cause a change in rating. Only for the most minor dents where the cups can be straightened to "like new" condition should repairs be attempted; otherwise the bucket wheel should be replaced with a new one.

Damaged tailpiece

The tailpiece should be examined for damage. It may be straightened if the damage is not too serious; otherwise it should be replaced with a new one.

Contact chamber

The contact chamber should be examined for proper meshing of the penta gear with the acme thread on the shaft and for proper adjustment of the contact wires. Proper adjustment of these parts should be maintained at all times. It should also be inspected for excessive wear of the upper bearing. Any missing or damaged parts such as screws, chamber caps, or binding posts should be replaced. Should the need arise, the entire contact chamber may be replaced with a new one.

Pivot and bearings

The pivot should be examined with a magnifying glass to see whether the point is fractured, rough, or warn flat at the apex. The point of a new pivot is rounded to a radius of approximately 0.005 inch; wear resulting in a radius greater than 0.010 inch is excessive. If any of these conditions exist, the pivot should be replaced with a new one.

To examine the pivot bearing conveniently, the contact chamber should be removed carefully and the bucket–wheel–and–hub assembly should be tilted to one side so that the lower arm of the yoke will not obstruct examination. The pivot bearing should then be examined for possible fracture, pits, or roughness. If any of the above are found, the entire hub assembly should be replaced with one containing a new pivot bearing.

No current meter should be packed or transported with the pivot bearing resting on the pivot. The pivot and pivot bearing should always be separated by the raising nut.

Lubrication

All bearing surfaces should be inspected to see that they have a thin coating of instrument oil. The small Price current meter has bearing surfaces above the bucket wheel in addition to the pivot bearing. These consist of (1) the bearing surfaces between the penta gear and the acme threads on the shaft, (2) the cylindrical bearing of the small shaft of the penta gear, (3) the cylindrial bearing of the shaft within the bearing lug, and (4) the thrust bearing between the shaft and the cap.

Spin tests

The spin test is an easy method of determining the condition of the bearings of a current meter. In making this test, the meter should be placed so that the shaft is in a vertical position and the bucket wheel is protected from air currents. The bucket wheel is then given a quick turn by hand to start it spinning, the duration of which is timed with a stopwatch. As the rotating bucket nears the stopping point, its motion should be carefully observed to see whether the stop is abrupt or gradual. Regardless of the duration of the spin, if the bucket wheel comes to an abrupt stop, the cause of such behavior should be found and corrected before the meter is used. In such instances, a lack of oil, the maladjustment of the penta gear, and a misalinement of the yoke are possible sources of trouble that should receive early attention.

The normal spin for a small type–AA Price should be approximately 4 minutes and should under no circumstances be less than 1½ minutes. Large variations in the duration of the spin test will be introduced by slight varations from the vertical position of the shaft. Some operators accordingly provide themselves with a small circular level vial that can be placed on the cap of the meter to help them make such a test with the shaft alined in a truly vertical position.

Another common test to determine the condition of the bearing of a current meter is to hold the meter so that the shaft is in a vertical position and while keeping the shaft in as nearly a fixed position as possible, to revolve the yoke and tailpiece in a horizontal plane around it. If the bucket wheel remains in a fixed position, it is an indication that the bearings are satisfactory, whereas if the bucket wheel tends to revolve with the yoke and tailpiece, it is an indication that the meter requires attention.

Routine Cleaning and Oiling of Current Meters

At the end of each day's use, the current meter should be thoroughly cleaned and oiled. The pivot and pivot bearing need special attention; unlike all other parts of the meter they are subject to rusting and, therefore, it is desirable that they be dried before they are oiled.

The outline below gives a step-by-step procedure for the cleaning and oiling of current meters.

Equipment:

1. Screwdrivers of proper size for use on set screws in the yoke and on the pivot-adjusting nut.
2. Large soft cloth that will readily absorb water for wiping the outer surfaces of the meter.
3. Cotton-tipped swabs for cleaning the bearing surfaces.
4. Supply of oil (instrument oil that is available from the Property Maintenance Section is recommended) in a container with facilities that permit a drop of oil to be applied in places that otherwise are difficult to reach.

Dismantle the current meter as follows:

1. Release the raising nut.
2. Release the two set screws in the yoke, holding the contact chamber and the pivot in place with forefinger and thumb.
3. Remove the contact chamber from the yoke slowly and carefully. Do not remove the cap at this time.
4. Remove the pivot from the yoke.

Clean the parts as follows:

1. Pivot bearing.
   a. Clean and dry the air pocket and the pivot bearing, using a cotton-tipped swab.
   b. Inspect the pivot bearing.
2. Pivot hole in the yoke.
   Swab the pivot hole in the yoke with a cotton-tipped swab.
3. Shaft.
   Clean and dry the shaft—particularly the acme threads.
4. Pivot.
   Wipe the pivot until it is thoroughly dry.
5. Contact chamber.
   a. Remove the cap and shake out any water that may be trapped within the contact chamber. Occasionally, clean the chamber thoroughly by allowing hot water to flow into it under pressure. A jet of water such as that issuing from a hot-water tap is recommended. Hoppe's powder solvent has been used successfully to remove gummed oil if cleaning with hot water is not successful.
   b. Wipe the interior of the stem of the contact chamber.
   c. Swab the hole in the bearing lug by means of a cotton-tipped swab inserted through the stem of the contact chamber. Cleaning the hole in the bearing lug **from the top** frequently causes the contact wires to bend and eventually break, whereas cleaning it **from the bottom** neither bends the wires nor affects their adjustment.

Oil as follows:

1. Shaft.
   Apply a film of oil to (a) the acme threads (liberally, so that the excess oil will later spread over the penta gear and the penta shaft), (b) the area that enters the bearing lug, and (c) the uppermost end of the shaft.
2. Pivot bearing.
   Apply a thin film of oil over all exposed parts of the pivot bearing.
3. Pivot hole in yoke.
   Apply a drop of oil to the sides of the hole through which the pivot passes.
4. Pivot.
   Apply a thin film of oil to the pivot.

Reassemble as follows:

1. Replace the pivot and tighten the set screw that holds it in place. Make sure that the pivot lock nut bears against the yoke, and that the set screw bears against the flattened part of the pivot.

2. Fit the contact chamber over the end of the shaft and into its hole in the upper arm of the yoke. Do this slowly and carefully without applying much force, otherwise the penta gear or shaft may become damaged.

3. Match the marks on the contact chamber and yoke, and tighten the set screw holding the contact chamber in place.

4. Check the contact wires. The adjustment of both the single- and penta-contact wires should be examined to be sure that the adjustments are as light as possible without impairing the electrical contact.

5. Replace the cap on contact chamber.

6. Move the bucket-wheel-and-hub assembly up and down to determine whether the pivot adjustment is correct.

7. Check the operation of the current meter with a spin test.

8. Unless the current meter is to be used immediately, raise the pivot bearing off the pivot by means of the bucket-raising nut.

Low-Velocity Price Meter

The low-velocity meter differs from the general purpose Price meter in that the penta gear is removed and the single eccentric is replaced by a double eccentric which makes two electrical contacts for each revolution of the bucket wheel. These meters are produced by the same dies and fixtures used in the manufacture of the general purpose meter. Consequently, they also have a single standard rating, and any parts may be replaced without the necessity of calibration. The duration of the normal spin should be 4½–5 minutes, and it should never be less than 2½ minutes. In all respects other than those pointed out above the two types of meters are identical and all of the preceding paragraphs apply to the low-velocity meter.

Pygmy Current Meters

The Geological Survey designed the first of its pygmy current meters (see fig. 1) in 1936. The pygmy current meter is of the Price type in that it contains a cup-type bucket wheel mounted on a vertical shaft having bearings that operate in air pockets. The bucket wheel is 2 inches in diameter (two-fifths the size of that in the small Price current meter). The pygmy meter is designed particularly for the measurement of discharges of those streams that are so shallow that the small Price current meter fails to perform accurately, but which have too great a flow to be measured conveniently by either volumetric means or with small weirs.

The pygmy meter differs from the type-AA small Price current meter in respects other than size (see fig. 4). The contact chamber is an integral part of the yoke and contains a single-revolution contact only. The meter has no tailpiece nor has it any provision for suspension from a cable. There is no bucket-wheel raising nut on the pygmy meter, but a small brass plug is provided to replace the pivot when the meter is stored or transported.

The bucket wheel revolves about 2¼ times as fast as that of the small Price current meter. This relatively high speed, combined with the fact that no multiple-contact arrangement is provided, limits its use to conditions where the revolutions are counted aurally to velocities not exceeding 3 feet per second.

The Survey's pygmy current meters are constructed so that the bucket-wheel-and-hub assembly may be removed from the yoke as a unit for convenience in cleaning and oiling. Instructions for removing and replacing such assemblies follow:

To remove the bucket-wheel-and-hub assembly from the yoke:

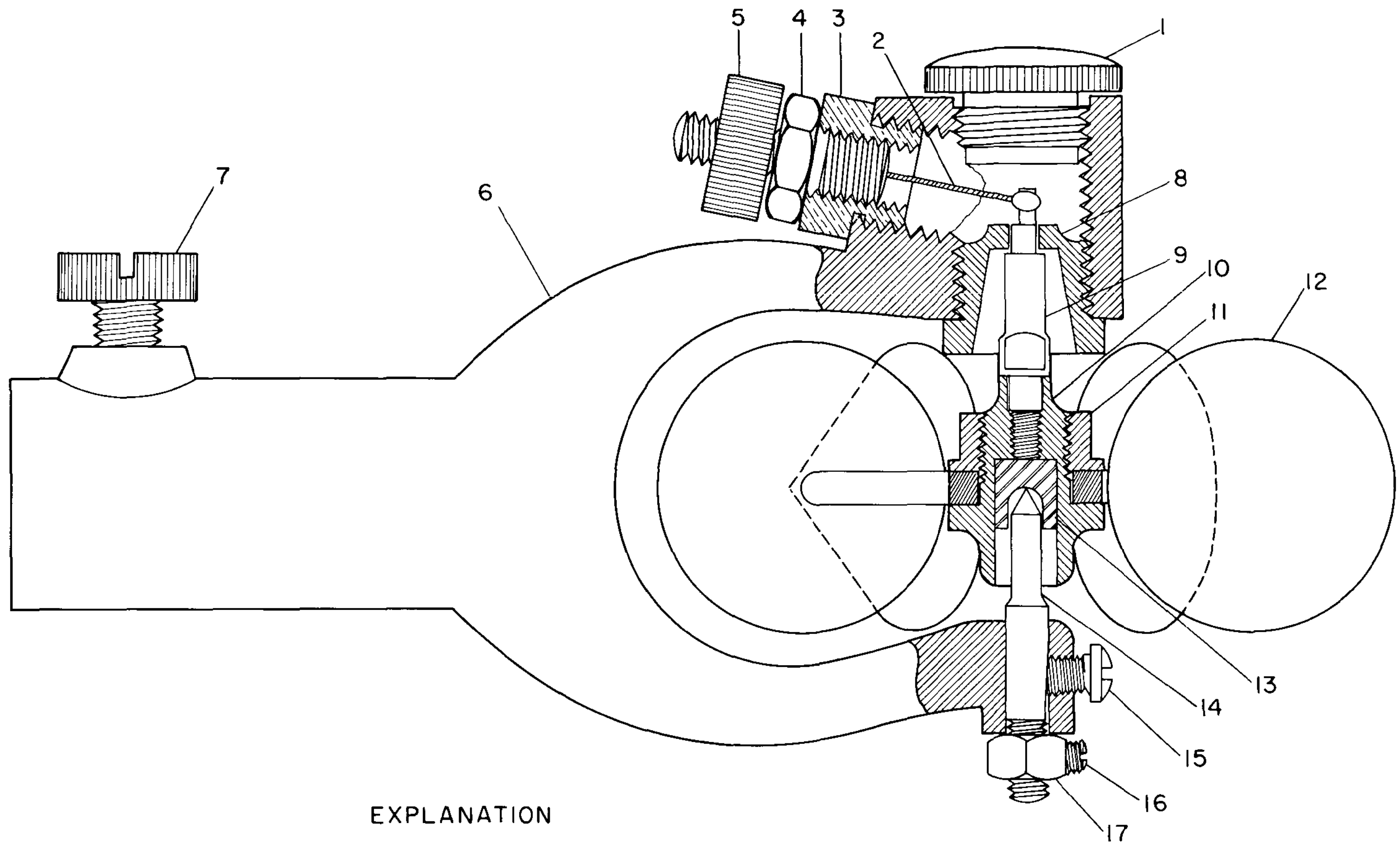
1. Remove the cap.

2. Release the set screw holding the pivot in the yoke.

3. Remove the pivot.

4. Tighten the set screw into the yoke (otherwise, it may offer difficulties in removing the bucket wheel).

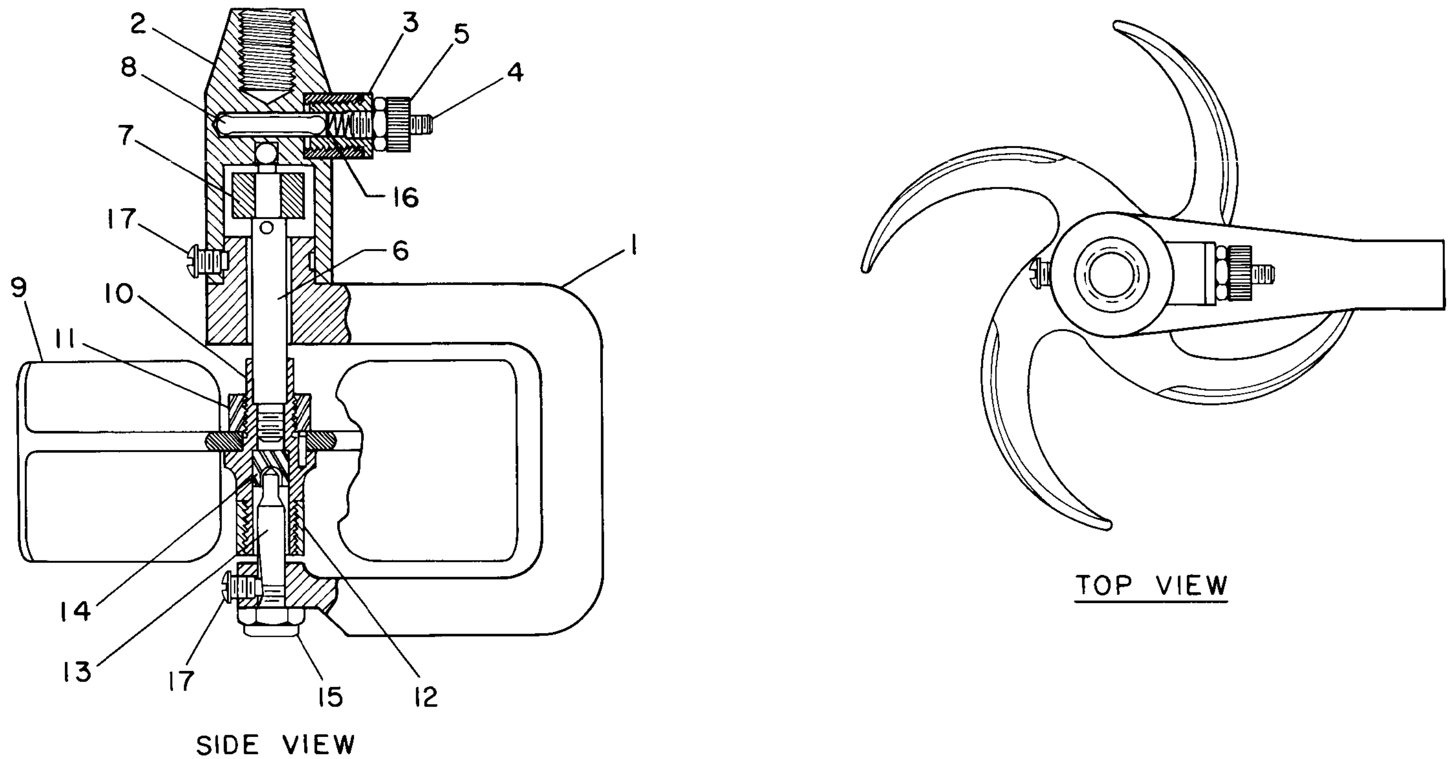
5. Lower the bucket wheel to the lowest position in the yoke and carefully slide it forward and outward. If it is found that the bucket-wheel-and-hub assembly does not come out freely, return it to its original position and rotate it one-sixth of a turn. Repeat this operation until successful. **Never apply force in removing the bucket-wheel-and hub assembly** because the shaft and eccentric may become bent.



EXPLANATION

1. Cap for contact chamber	10. Bucket-wheel hub
2. Binding-post beaded wire	11. Bucket-wheel hub nut
3. Binding-post insulating bushing	12. Bucket wheel
4. Binding-post body	13. Pivot bearing
5. Binding-post nut	14. Pivot
6. Yoke	15. Pivot set screw
7. Yoke set screw	16. Pivot-adjusting nut keeper screw
8. Upper bearing	17. Pivot-adjusting nut
9. Shaft	

Figure 4.—Assembly diagram of pygmy current meter.



EXPLANATION

1. Yoke
2. Contact chamber
3. Binding-post insulating bushing
4. Binding post
5. Binding-post nut
6. Shaft
7. Magnet
8. Glass switch
9. Vane
10. Vane hub
11. Vane hub nut
12. Raising nut
13. Pivot
14. Pivot bearing
15. Pivot-adjusting nut
16. Compression-spring assembly
17. Set screw

Figure 5.—Assembly diagram of ice meter.

To insert the bucket-wheel-and-hub assembly into the yoke:

1. With the pivot removed, set screw tightened, cap removed, and yoke and shaft held upside down, direct the upper end of the shaft into the hole of the upper bearing, and carefully adjust the bucket wheel into position within the arms of the yoke. **Do not apply force.** If the bucket wheel cannot be placed within the yoke without forcing, remove it, turn it one-sixth of a revolution, and repeat until successful.
2. Unscrew the set screw to a position that will permit the pivot to be inserted.
3. Insert the pivot.
4. Tighten the set screw and turn the yoke right side up.
5. Replace the cap.

Investigations have shown that there are very slight differences in the rotors of pygmy meters that prevent a standardized rating. Because the rotors are not identical, they cannot be replaced in the field. Meters are calibrated individually and each is supplied with its own rating table. A pygmy current meter which has been damaged should be returned to the Property Maintenance Section for repair and recalibration. The duration of the normal spin should be approximately 1½ minutes and should never be less than half a minute.

Ice Meters

Ice meters (see fig. 1) are also the vertical-axis type but differ from the Price in that the rotor used consists of four curved vanes. Other differences may also be seen in figure 5, which illustrates the assembly diagram of the ice meter. They are:

1. There is no rear extension of the yoke. The meter is supported by a section of special wading rod that screws into the top of the contact chamber. The object of this arrangement is to reduce the size of the ice hole required for inserting the meter.
2. The upper bearing is a small sphere instead of a sleeve.
3. The electrical contact is a magnetically actuated glass-sealed switch. There are two contact closures for each revolution of the rotor, one each time the poles of the magnet are alined with the leaves of the switch.

Assembly or disassembly of the ice meter offers no special problems except that the magnet is very brittle and must be handled with care, as all parts should be. Care and lubrication should be of the same type described for the Price meter.

Investigations have shown that there are very slight differences in the rotors of ice meters that prevent a standardized rating. Because the rotors are not identical, they cannot be replaced in the field. Meters are calibrated individually and each is supplied with its own rating table. An ice meter which has been damaged should be returned to the Property Maintenance Section for repair and recalibration. The duration of the normal spin should be approximately 5 minutes and should never be less than 2 minutes.

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