science for a changing world

Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter A8

# DISCHARGE MEASUREMENTS AT GAGING STATIONS

By Thomas J. Buchanan and William P. Somers

Book 3

APPLICATIONS OF HYDRAULICS

The care and rating of vertical-axis meters is described below and by Smoot and Novak (1968).

#### Horizontal-axis current meters

The types of horizontal-axis meters in use are the Ott, Neyrpic, Haskell, and Hoff. The Ott meter is made in Germany, the Neyrpic meter in France, and both are used extensively in Europe. The Haskell and Hoff meters were developed in the United States where they are used to a limited extent.

The Ott meter is a precision instrument but is not used extensively in this country because it is not as durable as the Price meter under extreme conditions. (See fig. 7.) The makers of the Ott meter have developed a component propeller which in oblique currents automatically registers the velocity projection at right angles to the measuring section for angles as much as 45° and velocities as much as 8 fps. For example, if this component propeller were held in the position *AB* in figure 8 it would register $V \cos \alpha$ rather than $V$, which the Price meter would register.

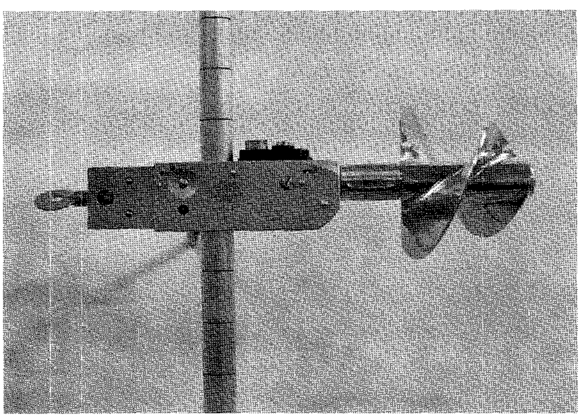

Figure 7.—Ott current meter.

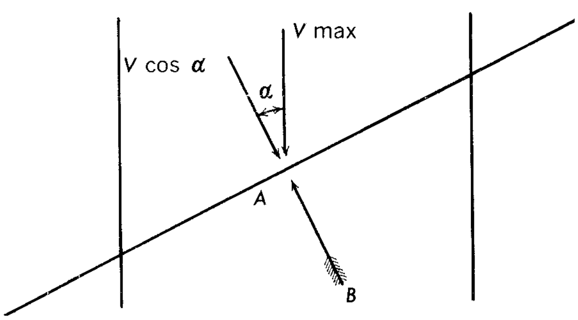


Figure 8.—Velocity components measured by Ott and Price current meters.

The Neyrpic meter is used rarely in this country because it has the same disadvantages as the Ott meter.

The Haskell meter has been used by the U.S. Lake Survey, Corps of Engineers, in streams that are deep, swift, and clear. By using propellers with a variety of screw pitches, a considerable range of velocity can be measured. The meter is durable, but has most of the other disadvantages of horizontal-axis meters.

The Hoff meter is used by the Geological Survey, the Department of Agriculture, and others, especially for measuring pipe flow. (See fig. 9.) The lightweight propeller has three or four vanes of hard rubber. The meter is suited to measurement of low velocities, but not for rugged use.

#### Optical current meter

The Geological Survey, in cooperation with the California Department of Water Resources, has developed an optical current meter. (See fig. 10.) This meter is a stroboscopic device designed to measure surface velocities in open channels without immersing equipment in the stream. The optical current meter will find its principal use in measurements of surface velocity during floods when it is impossible to use conventional stream-gaging equipment because of extremely high velocities and a high debris content in the stream.

#### Care of the vertical-axis current meter

The calibration and maintenance of vertical-axis type current meters is presented in detail

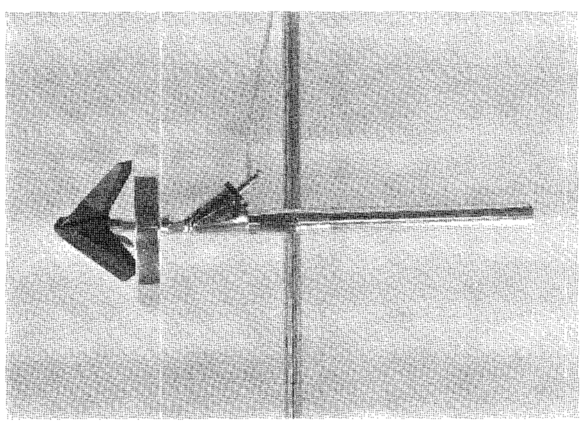

Figure 9.—Hoff current meter.

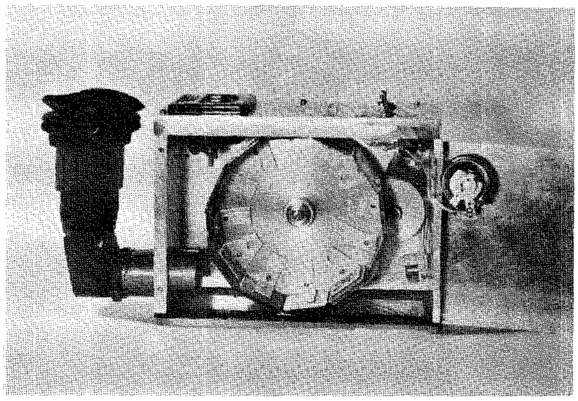

Figure 10.—Optical current meter.

by Smoot and Novak (1968). A brief description of the checks of the condition of a meter and the care and cleaning of it during daily field use is presented in the next few paragraphs.

Before and after each discharge measurement, examine the meter cups or vanes, pivot and bearing, and shaft for damage, wear, or faulty alinement. Before using the meter, check its balance if on a hanger, check the alinement of the rotor axis with a hanger or wading rod, and adjust the conductor wire to prevent interference with meter balance and rotor spin.

Clean and oil meters daily when in use. If measurements are made in water carrying noticeable suspended sediment, clean the meter immediately after each measurement. Surfaces to be cleaned and oiled are the pivot bearing, pentagear teeth and shaft, cylindrical shaft bearing, and thrust bearing at the cap.

After oiling, spin the rotor to make certain it operates freely. If the rotor stops abruptly, find the cause and correct the trouble before using the meter. On notes for each measurement, record the duration of spin. Obvious decrease in spin duration indicates need for attention to the bearings.

The pivot needs replacement more often than other meter parts. Examine the pivot after each measurement. Replace a fractured, rough, or worn pivot.

Keep the pivot and pivot bearing separated except during measurements. Use the raising nut if provided, or, for pygmy meters, replace the pivot by the brass plug.

Most minor repairs can be made in the field. Repair attempts, however, should be limited only to minor damages. This is particularly true of the rotor because minor dents in the bucket wheel or cups can have a large influence on the meter rating. Unless minor dents in the cups can be straightened out to "like new" condition, the entire rotor should be replaced with a new one. Badly sprung yokes, bent yoke stems, misalined bearings and tailpieces, should be reconditioned in shops equipped with the specialized facilities needed.

#### Rating of current meters

In order to determine the velocity of the water from the revolutions of the rotor of a current meter, a relation must be established between the angular velocity of the rotor and the velocity of the water turning it. The establishment of this relation, known as "rating the current meter," is done for the Geological Survey by the National Bureau of Standards.

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 the meters 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. Identicalness of meters is insured by supplying the dies and fixtures for the construction of small Price meters to the manufacturer who makes the successful bid.

Meters which have been rated by means of rod suspension, and then by means of cable suspension using Columbus-type weights and hangers, have not shown significant differences in rating. Therefore, no suspension coefficients are needed, and none should be used, if weights and hangers are properly used.

The current-meter rating station operated by the National Bureau of Standards in Washington, D.C., has a sheltered reinforced concrete basin 400 feet long, 6 feet wide, and 6 feet deep. An electrically driven car rides on rails extending the length of the basin. The car carries the current meter at a constant rate through the still water in the basin. Although the rate of travel can be accurately adjusted by means of a hydraulic regulating gear, 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 rotor are electrically counted. A scale graduated in feet and tenths of a foot is used for this purpose. Eight pairs of runs are usually made for each current meter. A pair of runs consists of two traverses of the basin, one in each direction, at approximately the same speed. Practical considerations usually limit the ratings to velocities ranging from 0.1 fps to about 15 fps, although the rating car can be operated at lower speeds. Unless a special request is made for a more extensive rating, the lowest velocity used in the rating is about 0.2 fps, and the highest is about 8.0 fps.

For convenience in field use, the data from the current-meter ratings are reproduced in tables, a sample of which is shown in figure 11. The velocities corresponding to a range of 3 to 350 revolutions of the rotor within a period of 40 to 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 extending a table for the few instances where extensions are required, the equations of the rating table are shown in the spaces provided in the heading. The equation to the left of the figure in parentheses (2.28 in fig. 11) is the equation for velocities less than 2.28 fps and the equation to the right is for velocities greater than 2.28 fps. The 2.28 fps is the velocity common to both equations.

It should be noted that the equations given are those of the rating table, and not necessarily those of the actual rating. If a rating table already on file matches a rating within tolerances, that table is selected in preference to preparing a new one. Those tolerances are listed below.

| *Revolutions of rotor per second* | *Tolerance, in percent* |
|---|---|
| 0.0 | 1.0 |
| 1.0 and above | .5 |

## Sounding equipment

Sounding (determination of depth) is commonly done mechanically, the equipment used depending on the type of measurement being made. Depth and position in the vertical are measured by a rigid rod or by a sounding weight suspended from a cable. The cable is controlled either by a reel or by a handline. A sonic sounder is also available, but it is usually used in conjunction with a reel and a sounding weight.

Sounding equipment used by the Geological Survey is described in the following categories: wading rods, sounding weights, sounding reels, handlines, and sonic sounder.

### Wading rods

The two types of wading rods commonly used are the top-setting rod and the round rod. The top-setting rod is preferred because of the convenience in setting the meter at the proper depth and because the hydrographer can keep his hands dry. The round rod can be used in making ice measurements as well as wading measurements, and has the advantage that it can be taken down to 1-foot lengths for storing and transporting.

The top-setting wading rod has a ½-inch hexagonal main rod for measuring depth and a ⅜-inch diameter round rod for setting the position of the current meter. (See fig. 12.)

The rod is placed in the stream so the base plate rests on the streambed, and the depth of water is read on the graduated main rod. When the setting rod is adjusted to read the depth of water, the meter is positioned automatically for the 0.6-depth method. (See fig. 13 and p. 32.) The 0.6-depth setting might also be described as the 0.4-depth position up from the streambed. When the depth of water is divided by 2 and this new value is set, the meter would be at the 0.2-depth position up from the streambed. When the depth of water is multiplied by 2 and this value is set, the meter would be at the 0.8-depth position up from the streambed. These two positions represent the conventional 0.2- and 0.8-depth positions in reverse. (See p. 32.)

The round wading rod consists of a base plate, lower section, three or four intermediate sections, sliding support, and a rod end (not essential). (See fig. 14.) The parts are assembled as shown in figure 15. The meter is mounted on the sliding support and is set at the desired position on the rod by sliding the support.

The round rod is also used in making ice measurements. Intermediate sections of the round rod are screwed together to make an ice rod of desired length. (See fig. 16.) The most convenient length for an ice rod is about 3 feet

326-253 O—69——3

DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
Water Resources Division
RATING TABLE FOR TYPE. AA ...CURRENT METER NO.. 3684 ..........
SUSPENSION Rod RATED February 16, 1962

INDEX........ 377-376
EQUATIONS. V = 2.250R + 0.030(2.280)2.240R + 0.040
Limits of Actual Rating. 0.25 .. to . 8.0 .... feet per sec
at Bureau of Standards, Wash., D.C. Condition of Meter New

NO. 3684

| Time in Seconds | 3 | 5 | 7 | 10 | 15 | 20 | 25 | 30 | 40 | Time in Seconds |
|---|---|---|---|---|---|---|---|---|---|---|
| | VELOCITY IN FEET PER SECOND — Revolutions | | | | | | | | | |
| 40 | .199 | .311 | .424 | .592 | .874 | 1.15 | 1.44 | 1.72 | 2.28 | 40 |
| 41 | .195 | .304 | .414 | .579 | .853 | 1.13 | 1.40 | 1.68 | 2.23 | 41 |
| 42 | .191 | .298 | .405 | .566 | .834 | 1.10 | 1.37 | 1.64 | 2.17 | 42 |
| 43 | .187 | .292 | .396 | .553 | .815 | 1.08 | 1.34 | 1.60 | 2.12 | 43 |
| 44 | .183 | .286 | .388 | .541 | .797 | 1.05 | 1.31 | 1.56 | 2.08 | 44 |
| 45 | .180 | .280 | .380 | .530 | .780 | 1.03 | 1.28 | 1.53 | 2.03 | 45 |
| 46 | .177 | .275 | .372 | .519 | .764 | 1.01 | 1.25 | 1.50 | 1.99 | 46 |
| 47 | .174 | .269 | .365 | .509 | .748 | .987 | 1.23 | 1.47 | 1.94 | 47 |
| 48 | .171 | .264 | .358 | .499 | .733 | .968 | 1.20 | 1.44 | 1.91 | 48 |
| 49 | .168 | .260 | .351 | .489 | .719 | .948 | 1.18 | 1.41 | 1.87 | 49 |
| 50 | .165 | .255 | .345 | .480 | .705 | .930 | 1.15 | 1.38 | 1.83 | 50 |
| 51 | .162 | .251 | .339 | .471 | .692 | .912 | 1.13 | 1.35 | 1.79 | 51 |
| 52 | .160 | .246 | .333 | .463 | .679 | .895 | 1.11 | 1.33 | 1.76 | 52 |
| 53 | .157 | .242 | .327 | .455 | .667 | .879 | 1.09 | 1.30 | 1.73 | 53 |
| 54 | .155 | .238 | .322 | .447 | .655 | .863 | 1.07 | 1.28 | 1.70 | 54 |
| 55 | .153 | .235 | .316 | .439 | .644 | .848 | 1.05 | 1.26 | 1.67 | 55 |
| 56 | .151 | .231 | .311 | .432 | .633 | .834 | 1.03 | 1.24 | 1.64 | 56 |
| 57 | .148 | .227 | .306 | .425 | .622 | .819 | 1.02 | 1.21 | 1.61 | 57 |
| 58 | .146 | .224 | .302 | .418 | .612 | .806 | 1.00 | 1.19 | 1.58 | 58 |
| 59 | .144 | .221 | .297 | .411 | .602 | .793 | .983 | 1.17 | 1.56 | 59 |
| 60 | .142 | .218 | .292 | .405 | .592 | .780 | .968 | 1.15 | 1.53 | 60 |
| 61 | .141 | .214 | .288 | .399 | .583 | .768 | .952 | 1.14 | 1.51 | 61 |
| 62 | .139 | .211 | .284 | .393 | .574 | .756 | .937 | 1.12 | 1.48 | 62 |
| 63 | .137 | .209 | .280 | .387 | .566 | .744 | .923 | 1.10 | 1.46 | 63 |
| 64 | .135 | .206 | .276 | .382 | .557 | .733 | .909 | 1.08 | 1.44 | 64 |
| 65 | .134 | .203 | .272 | .376 | .549 | .722 | .895 | 1.07 | 1.41 | 65 |
| 66 | .132 | .200 | .269 | .371 | .541 | .712 | .882 | 1.05 | 1.39 | 66 |
| 67 | .131 | .198 | .265 | .366 | .534 | .702 | .870 | 1.04 | 1.37 | 67 |
| 68 | .129 | .195 | .262 | .361 | .526 | .692 | .857 | 1.02 | 1.35 | 68 |
| 69 | .128 | .193 | .258 | .356 | .519 | .682 | .845 | 1.01 | 1.33 | 69 |
| 70 | .126 | .191 | .255 | .351 | .512 | .673 | .834 | .994 | 1.32 | 70 |
| | 3 | 5 | 7 | 10 | 15 | 20 | 25 | 30 | 40 | |

| Time in Seconds | 50 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | 350 | Time in Seconds |
|---|---|---|---|---|---|---|---|---|---|---|
| | VELOCITY IN FEET PER SECOND — Revolutions | | | | | | | | | |
| 40 | 2.84 | 3.40 | 4.52 | 5.64 | 8.44 | 11.24 | 14.04 | 16.84 | 19.64 | 40 |
| 41 | 2.77 | 3.32 | 4.41 | 5.50 | 8.24 | 10.97 | 13.70 | 16.43 | 19.16 | 41 |
| 42 | 2.71 | 3.24 | 4.31 | 5.37 | 8.04 | 10.71 | 13.37 | 16.04 | 18.71 | 42 |
| 43 | 2.64 | 3.17 | 4.21 | 5.25 | 7.85 | 10.46 | 13.06 | 15.67 | 18.27 | 43 |
| 44 | 2.59 | 3.09 | 4.11 | 5.13 | 7.68 | 10.22 | 12.77 | 15.31 | 17.86 | 44 |
| 45 | 2.53 | 3.03 | 4.02 | 5.02 | 7.51 | 10.00 | 12.48 | 14.97 | 17.46 | 45 |
| 46 | 2.47 | 2.96 | 3.94 | 4.91 | 7.34 | 9.78 | 12.21 | 14.65 | 17.08 | 46 |
| 47 | 2.42 | 2.90 | 3.85 | 4.81 | 7.19 | 9.57 | 11.95 | 14.34 | 16.72 | 47 |
| 48 | 2.37 | 2.84 | 3.77 | 4.71 | 7.04 | 9.37 | 11.71 | 14.04 | 16.37 | 48 |
| 49 | 2.33 | 2.78 | 3.70 | 4.61 | 6.90 | 9.18 | 11.47 | 13.75 | 16.04 | 49 |
| 50 | 2.28 | 2.73 | 3.62 | 4.52 | 6.76 | 9.00 | 11.24 | 13.48 | 15.72 | 50 |
| 51 | 2.24 | 2.68 | 3.55 | 4.43 | 6.63 | 8.82 | 11.02 | 13.22 | 15.41 | 51 |
| 52 | 2.19 | 2.62 | 3.49 | 4.35 | 6.50 | 8.66 | 10.81 | 12.96 | 15.12 | 52 |
| 53 | 2.15 | 2.58 | 3.42 | 4.27 | 6.38 | 8.49 | 10.61 | 12.72 | 14.83 | 53 |
| 54 | 2.11 | 2.53 | 3.36 | 4.19 | 6.26 | 8.34 | 10.41 | 12.48 | 14.56 | 54 |
| 55 | 2.07 | 2.48 | 3.30 | 4.11 | 6.15 | 8.19 | 10.22 | 12.26 | 14.29 | 55 |
| 56 | 2.04 | 2.44 | 3.24 | 4.04 | 6.04 | 8.04 | 10.04 | 12.04 | 14.04 | 56 |
| 57 | 2.00 | 2.40 | 3.18 | 3.97 | 5.93 | 7.90 | 9.86 | 11.83 | 13.79 | 57 |
| 58 | 1.97 | 2.36 | 3.13 | 3.90 | 5.83 | 7.76 | 9.70 | 11.63 | 13.56 | 58 |
| 59 | 1.94 | 2.32 | 3.08 | 3.84 | 5.73 | 7.63 | 9.53 | 11.43 | 13.33 | 59 |
| 60 | 1.91 | 2.28 | 3.03 | 3.77 | 5.64 | 7.51 | 9.37 | 11.24 | 13.11 | 60 |
| 61 | 1.87 | 2.24 | 2.98 | 3.71 | 5.55 | 7.38 | 9.22 | 11.06 | 12.89 | 61 |
| 62 | 1.84 | 2.21 | 2.93 | 3.65 | 5.46 | 7.27 | 9.07 | 10.88 | 12.69 | 62 |
| 63 | 1.82 | 2.17 | 2.88 | 3.60 | 5.37 | 7.15 | 8.93 | 10.71 | 12.48 | 63 |
| 64 | 1.79 | 2.14 | 2.84 | 3.54 | 5.29 | 7.04 | 8.79 | 10.54 | 12.29 | 64 |
| 65 | 1.76 | 2.11 | 2.80 | 3.49 | 5.21 | 6.93 | 8.66 | 10.38 | 12.10 | 65 |
| 66 | 1.73 | 2.08 | 2.76 | 3.43 | 5.13 | 6.83 | 8.52 | 10.22 | 11.92 | 66 |
| 67 | 1.71 | 2.04 | 2.71 | 3.38 | 5.05 | 6.73 | 8.40 | 10.07 | 11.74 | 67 |
| 68 | 1.68 | 2.02 | 2.68 | 3.33 | 4.98 | 6.63 | 8.28 | 9.92 | 11.57 | 68 |
| 69 | 1.66 | 1.99 | 2.64 | 3.29 | 4.91 | 6.53 | 8.16 | 9.78 | 11.40 | 69 |
| 70 | 1.64 | 1.96 | 2.60 | 3.24 | 4.84 | 6.44 | 8.04 | 9.64 | 11.24 | 70 |
| | 50 | 60 | 80 | 100 | 150 | 200 | 250 | 300 | 350 | |

Figure 11.—Current-meter rating table.

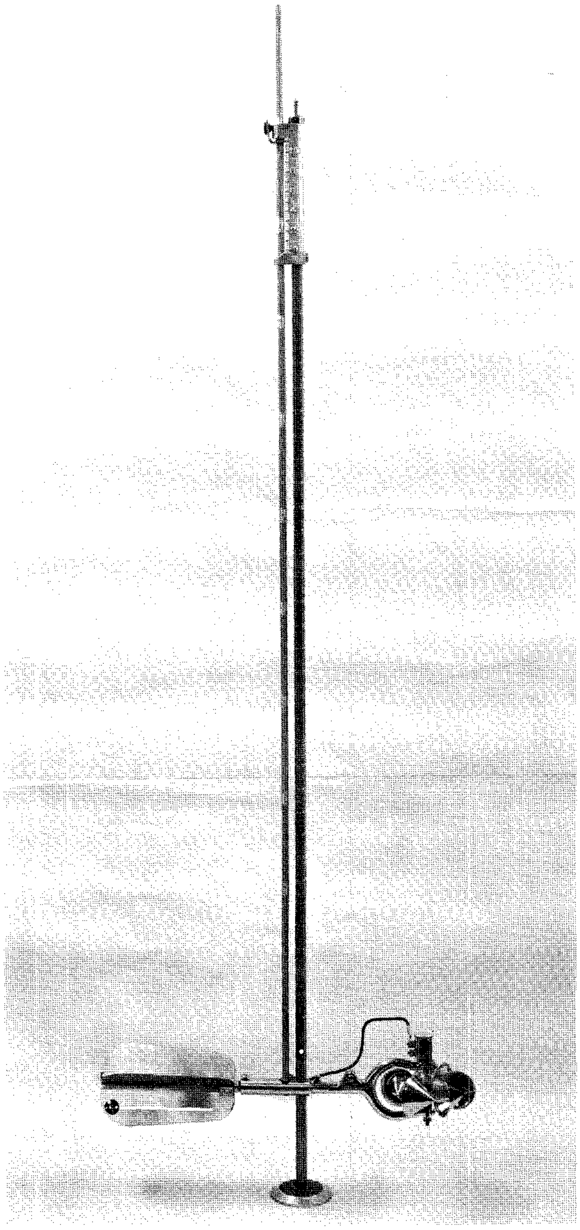

Figure 12.—Top-setting wading rod with meter attached.

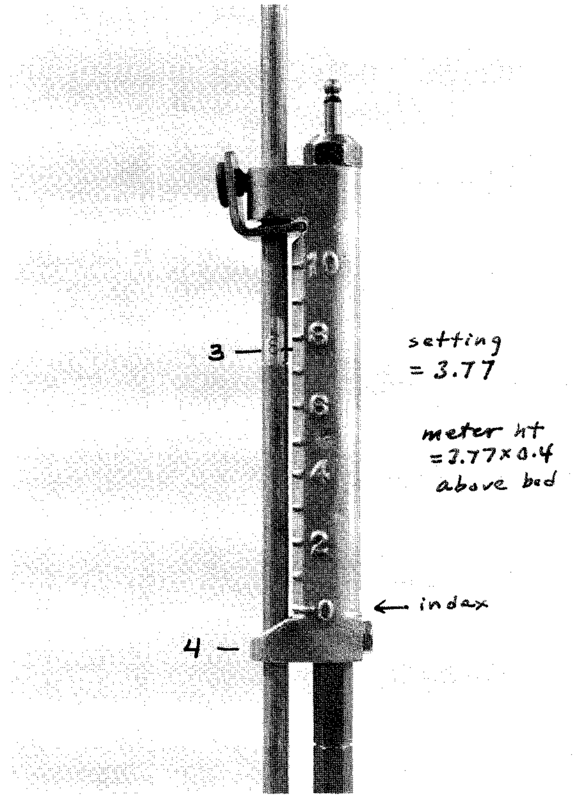


Figure 13.—Closeup view of setting scale on handle of top-setting rod.

longer than the maximum depth of water to be found in a cross section. About 12 feet is the maximum practical length for an ice rod; depths greater than 10 feet are usually measured with a sounding weight and reel. The base plate, sliding support, and lower section are not used on an ice rod. Instead a special lower section is screwed directly into the top of the contact chamber of the vane ice meter. (See fig. 16.) If a Price meter is used under ice cover, another special lower section is used to hold the meter by means of the hanger screw. (See fig. 17.) All lower sections for ice rods now are made so that the center of the vanes or cups is at the 0-foot point on the rod.

#### Sounding weights and accessories

If a stream is too deep or too swift to wade, the current meter is suspended in the water from a boat, bridge, or cableway. A sounding weight is suspended below the current meter to keep it stationary in the water. The weight also prevents damage to the meter when the assembly is lowered to the streambed.

The sounding weights now used are the Columbus weights, commonly called the C type. (See fig. 18.) The weights are streamlined to offer minimum resistance to flowing water. Each weight has a vertical slot and a drilled horizontal hole to accommodate a weight hanger and securing pin.

The weight hanger is attached to the end of the sounding line by a connector. The current

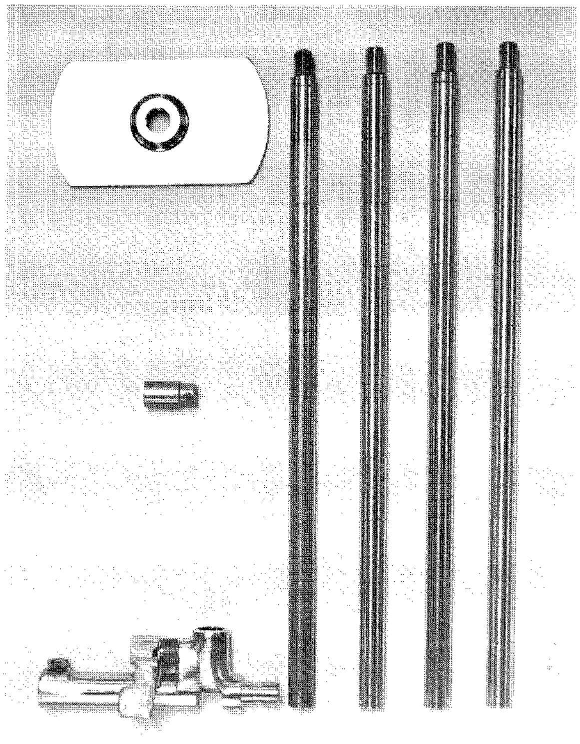

Figure 14.—Parts for round wading rod.

meter is attached beneath the connector, and the sounding weight is attached to the lower end of the hanger.

There are three types of weight hangers (fig. 19):

1. The Columbus or C type, ⅛ by ¾ by 12 inches (for weights up to 150 pounds).
2. Heavy weight, ⅛ by ¾ by 18 inches (for 200- and 300-pound weights).
3. Heavy weight, ⅛ by 1½ by 18 inches (for 200- and 300-pound sounding weights which have the slots properly extended to accommodate a 1½-in. hanger).

The Columbus hanger has three holes in it in order to properly position the meter. The hanger screw of the current-meter yoke is placed through the bottom hole to support the meter when a 30-pound sounding weight is used. The center of the meter cups is then 0.5 foot above the bottom of the weight. This arrangement is designated as 30 C .5, which means that a 30-pound Columbus weight is being used and the center of the meter cups is

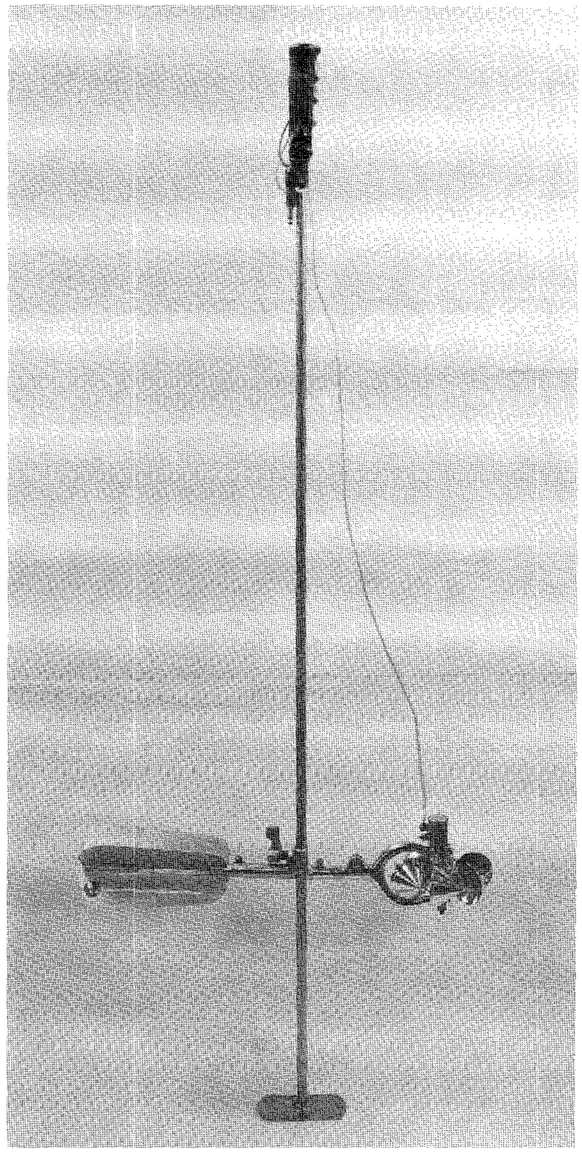

Figure 15.—Round wading rod with meter attached.

0.5 foot above the bottom of the weight. The hanger screw goes through the middle hole when 15- or 50-pound weights are used. The designations for these arrangements are 15 C .5 and 50 C .55. The hanger screw goes through the upper hole when 50-, 75-, 100-, and 150-pound weights are used. The designations for these arrangements are 50 C .9, 75 C 1.0, 100 C 1.0, and 150 C 1.0. Each of the two heavy-weight hangers has only one hole for the hanger screw of the meter. The designations for these arrangements are 200 C 1.5 and 300 C 1.5.

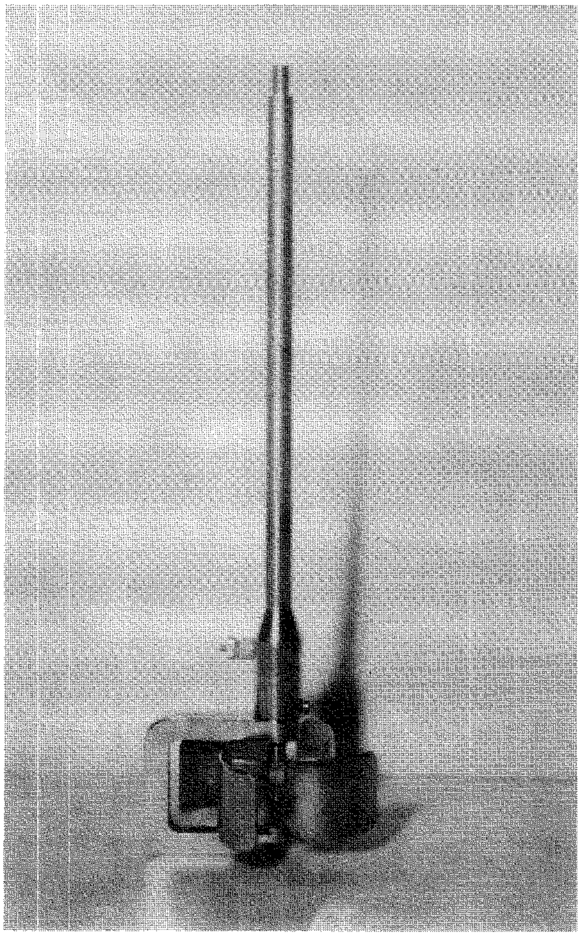

Figure 16.—Lower section of ice rod for use with vane ice meter.

Weight-hanger pins of various lengths are available for attaching the sounding weight to the weight hanger. (See fig. 19.) The stainless steel pins are threaded on one end to screw into the weight hanger and slotted on the other.

### Sounding reels

A sounding reel has a drum for winding the sounding cable, a crank and ratchet assembly for raising and lowering the weight or holding it in any desired position, and a depth indicator. Table 1 contains detailed information on each of the five reels most commonly used.

The A-pack reel is light, compact, and ideal for use at cableway sites a considerable distance from the highway. (See fig. 20.) It can also be used on cranes, bridge boards, and boat booms.

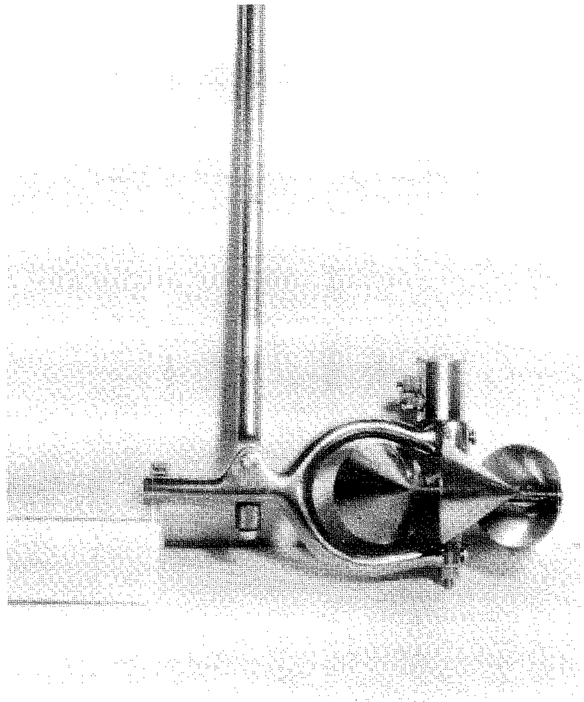

Figure 17.—Lower section of ice rod for use with Price meter.

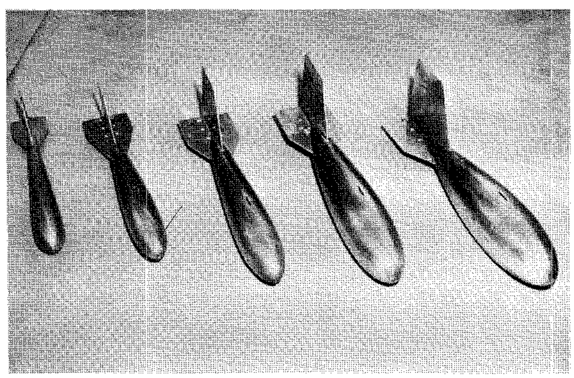

Figure 18.—15-, 30-, 50-, 75-, and 100-pound Columbus sounding weights.

The Canfield reel is also compact with uses similar to that of the A-pack reel. (See fig. 21.)

The A–55 reel is for general purpose use with the lighter sounding weights.

The B–56 reel (a major modification of the B–50 reel) can handle all but the heaviest sounding weights and has the advantage that it can be used with a handcrank or power equipment. (See fig. 22.)