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USE AND CARE OF CURRENT METERS

Excerpt from proposed manual
"Gaging the Flow of Streams"
Issued in preliminary form
by
The Geological Survey, 1935.

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The small Price meter. - When stream gaging was first undertaken by the U. S. Geological Survey in 1888, engineers of the Survey began experimenting with the various types of current meters available at that time in order to find one which could be used under the wide variety of conditions that were certain to be encountered. As a result of these investigations Survey engineers, about 1896, developed a meter containing certain essential features of the Price acoustic and the large Price electric meter. This meter is known as the small Price and has since been used by the Survey almost exclusively owing to its adaptability to general stream gaging work. Modifications in its design have been made as years of additional experience have brought forth the need of certain improvements and as a result six types, in addition to the original small Price, have been developed, all of which have been manufactured and sold by W. & L. E. Gurley of Troy, New York. The original small Price was designated by the manufacturer as the 617-type meter and provided a contact for each revolution of the rotor. Later the 621 type was developed about 1907, introducing the penta contact feature. When a meter has interchangeable single-contact and penta-contact heads it is designated as 624-type or combination meter. Later the Covert yoke was introduced, which permitted a half-inch round rod to be screwed into the upper limb of the yoke so that the meter could be used without a tail in measuring from ice cover. This meter with interchangeable heads was called 623-type or combination meter, probably a development of the 618-type meter which had a circular base plate, no tail, and was never used to any great extent by the Survey. Following the combination-type meters came the 622 type known as the Improved Price which incorporated into one unit the features of the single and penta head. It also included a change in the pitch of the pivot and bearing and omitted the bucket raising feature of the combination-type meter. After this change came the preparation of the first rigid set of specifications covering the manufacture of meter parts. These specifications made many of the parts in the assembly interchangeable without materially affecting the rating of the meter, and in addition governed the manufacture of the most recent development known as the type A meter. The major changes in the type A meter from the 622 type are as follows: enlarging the diameter of both the pivot and bearing, reestablishing the bucket raising feature of the combination-type meter, raising the position of the bearing seat nearer the center of gravity of the bucket wheel, lengthening the pivot, thus creating a longer air chamber below the bearing, and improving the construction of the pivot and bearing by using better metals which have been subjected to special heat treatment.

The small Price meter has perhaps been used more extensively and has been subjected to more investigation than any other current meter. As a result, both by reason of this situation and by reason of the natural advantages afforded by this type, the small Price is now better adapted to general use than any other meter that has been developed. It is light and yet strong, sensitive yet durable. It will measure without great error, velocities ranging from less than ¼ of a foot per second to velocities sixty times as great. It can be used readily whether suspended by a cable or supported on a rod. It will hold its rating under hard usage. It is easily repaired; is quickly taken apart for cleaning and oiling; and is reassembled just as quickly without a change in rating. It is sensitive but has no ball bearings. It can be used by a person working alone from a cableway, bridge, boat, or while wading. No other current meter known to the engineers of the Geological Survey satisfies so completely all of these conditions.

Types in use. - The types of small Price current meter now in use by the Survey are designated as follows: Single Point, Penta, Combination, 622-type, and type A. The combination meter, with plain or Covert yoke, has interchangeable single-contact and penta-contact heads and is therefore a combination of the Single Point and Penta meters. Of all the above types the type A is the one now coming into the most general use, in general supplanting the others as replacements become necessary. Although results of equal accuracy are obtainable with each type of meter when used under ordinary conditions, it is generally conceded by the engineering personnel of the Survey that the type A meter is superior to the other types in simplicity, construction, durability and in accuracy when used in measuring low velocities.

In order that a current meter may be intelligently used and properly cared for, it is essential that the engineer becomes familiar with each of its integral parts, as well as with the meter in its assembled form. Complete failure of any part to function is usually obvious but small irregularities which may introduce a large percentage error in results, are not always readily detectable. For this reason each part of the type A meter will be individually described in the discussion to follow and at the same time its functional characteristics will be set forth. The essential differences in the earlier types, as compared with the type A meter, will also be brought out in a separate discussion of each.

Yoke. - The yoke is a one-piece, vertical horseshoe-shaped casting made of bronze and nickel-plated. A short horizontal rear extension, lying in the plane of the meter cups has a hole horizontally drilled in the end for the insertion of the tail piece and is also vertically slotted near the tail piece end for the insertion of the weight hanger. The yoke is laterally drilled in the slotted section to accomodate a screw for attaching the yoke to the hanger. This slot is made shorter on the top of the boss than on the bottom in order to limit the downward tilting of the meter and thus protect it from being damaged against the nose of the old style sounding weight. The end of the upper arm of the yoke is vertically drilled to enclose and carry the lower end of the chamber. The end of the lower arm is also vertically drilled to carry the pivot, and both holes are coaxial so as to support the rotor assembly in a true vertical position. The contact chamber and the pivot are each held in place by means of keeper screws, one located in the face of the upper arm of the yoke and the other in the face of the lower arm of the yoke. A keeper screw is also provided on the rear extension of the yoke to hold the tail piece in place.

Tail piece. - The function of the tail piece is to hold the meter parallel to the direction of flow. It is made of hard rolled brass and 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 assembly to be taken apart readily and is a feature which adds to the convenience of packing. The nose piece of the tail, which fits into the rear extension of the yoke, is attached to the vane carrying the front guide rack and the locking lever. Extending from the end of the guide rack is a slot, open at the rear end of the vane, in which the other vane is inserted. Near the outer edge of this vane is a long slot closed at both ends which carries a large round-headed screw washer and nut used in balancing the meter assembly. The other vane carries the rear guide rack which is notched to permit the locking of the vanes by the lever. Extending from the foremost end of this guide rack is a slot open at the front end of the vane to permit its insertion into the other vane. All parts of the tail piece are nickel-plated.

Bucket wheel. - The bucket wheel consists of six conical-shaped cups soldered to a frame to form a well balanced assembly. The metal at the open end of each cup is bent over to lie flat against the inside of the cups. This feature gives each cup a rounding edge and adds to its strength and durability. Both cups and frame are made of rolled brass, chromium-plated with the outer surfaces highly polished. The frame is centrally drilled for the bucket-shaft bushing and the hole notched for a dowel pin. The letter "T" is stamped on the frame to identify the top-side of the bucket wheel.

Bucket wheel hub. - The bucket wheel hub encases the pivot bearing and the lower end of the shaft and also supports the bucket wheel by means of a shoulder. The outer circumference of the hub, just above the shoulder, is threaded for a hexagonal nut which is used to clamp firmly the bucket wheel to the hub. The outer circumference below the shoulder is threaded to carry the bucket-raising nut. A small dowel pin on the upper surface of the shoulder holds the bucket wheel securely in place by engaging the notch of the bucket wheel frame. The hub and the hexagonal nut are made of 18-8 stainless steel.

Shaft. - The shaft is made of 18-8 stainless steel and of sufficient length to extend from the bucket wheel hub to a point just below the cap of the contact chamber. The lower end of the shaft is turned down to a smaller diameter and is threaded to fit a socket in the upper end of the bucket wheel hub. The upper end of the shaft is turned to a 0.125 inch diameter and is rounded on the top to provide a smooth bearing surface. This is necessary as it bears against the bottom surface of the contact-chamber cap when the velocities are sufficiently high to raise the bucket wheel off the pivot point. A knife edge is cut in the upper end of the shaft in order to provide a means of electrically registering each revolution of the bucket wheel. Beginning with the enlarged diameter at the knife-edge end and extending for a short distance, the shaft is acme threaded, the pitch of the threads being such as to mesh with the penta gear in the contact chamber. A small hole is drilled through the shaft to permit the passage of a pin used in fitting the shaft into the bucket wheel hub.

Pivot. - The pivot is made of a steel alloy designated as A-Metal and contains the following elements: 0.95 percent carbon, 0.275 silicon, 1.07 manganese, 0.54 chromium, 0.16 vanadium and 0.64 tungsten. The point of the pivot is ground and polished on an angle of 90 degrees to an initial radius of 0.01 inches. It is heat treated to a Rockwell hardness of C-58 within 0.125 inches of the point. Next the pivot is reground to eliminate any warping that may have taken place during the heat operation. Great care is also exercised in regrinding and polishing the point, to reduce the heat friction to a minimum, otherwise the final bearing surface, which is approximately 0.010 inches, might become annealed. The lower end of the pivot is threaded to carry a hexagonal 18-8 stainless steel nut which is used to adjust the clearance between the point and the pivot bearing. A slightly tapered flat surface is provided on the side of the pivot to contact the keeper screw set in the yoke.

Pivot bearing. - The pivot bearing consists of a bushing made of the same alloy as the pivot. Its outside diameter is 0.30 inches; its height is 0.31 inches, and it is drilled to a diameter of 0.201 inches and a depth of 0.1875 inches. The bottom of the pivot seat, after hardening, is ground to a diameter of 0.205 inches, and on an angle of 105 degrees at the bottom and a radius of 0.025 inches at the apex. Any pivot bearing having a Rockwell hardness under C-60 is rejected. The bearing, like the pivot, is given a glass-smooth finish and the heat from the friction produced by this operation is kept down to a minimum. The pivot bearing is pressed into the cylindrical recess made in the lower end of the bucket wheel hub.

Penta gear. - The penta gear is made of 18-8 stainless steel and is hobbed so that it will mesh smoothly with the worm on the shaft. It contains ten teeth which contact the shaft and are so arranged that each complete revolution of the axle represents ten complete revolutions of the bucket wheel. Two additional teeth, placed 180 degrees apart and in direct alignment with two of the gear teeth, are also carried by the axle for the purpose of electrically indicating every fifth revolution made by the bucket wheel. This axle is mounted on a bronze frame in a horizontal position and the assembly is housed in the contact chamber, being held in place by means of a set screw. The base of the frame through which this set screw passes is slotted to permit the adjustment of the gear teeth with the worm on the shaft.

Contact chamber. - The contact chamber is a P-shaped unit of solid rolled brass, nickel-plated and drilled to carry the penta gear, the upper portion of the shaft, and to enclose the contact points of the single and penta binding posts. The top of the chamber has a slightly greater diameter than the main body and is drilled and internally threaded to carry a knurled cap which, when firmly fastened, leaves a small clearance between its bottom face and the top of the main chamber. A small phosphor bronze lug is brazed in the chamber to hold the shaft in perfect alignment with the pivot. The contracted portion of the chamber is of sufficient length to extend through the upper arm of the yoke and is drilled so that the shaft can pass through with ample clearance. The set screw through the upper arm of the yoke engages in a shallow groove around the circumference of the contracted end of the chamber, holding the entire chamber securely in position. The back of the main chamber is drilled and tapped to carry two binding posts, one for contacting the penta gear and the other for contacting the knife edge on the shaft.

Binding posts. - Two 18-8 stainless steel binding posts with 18-8 stainless steel knurled nuts are used, one binding post designed to contact the knife edge of the shaft and the other to contact the index teeth of the penta gear. They are identical in construction except for the lengths of cable wire necessary in making the contacts. The exposed post end is threaded and burred to prohibit the complete removal of the knurled nut. The contact chamber end is turned down and tapped for the insertion of a No. 26 bronze cable wire. This cable wire is of sufficient length to reach the knife edge on the shaft or the index teeth on the penta gear. To the end of the cable wire is fastened a ball of silver solder which makes the contact. Each binding post is insulated from the contact chamber by a threaded dilecto bushing.

Required changes for low velocity work. - For low velocity work two alterations are made in the Geological Survey type A meter before it is rated. First, the penta gear is removed from the contact chamber, thus leaving only the single point contact; and second, the radius of the pivot point is reduced from 0.010 to .005 of an inch.

622 type meter. - The 622 type meter varies from the Geological Survey type A only in the shaft assembly and pivot. In the type A meter, this assembly consists of a shaft, bucket wheel hub, pivot bearing and pivot. In the 622 type meter, an additional part is included known as the pivot-bearing housing. This housing is made of brass and carries the pivot bearing, the bearing end being enlarged and knurled on the side. On the upper surface of the knurled enlargement is a small dowel pin which fits into a notch made in the lower

end of the bucket wheel hub. The upper portion of the housing is drilled and threaded to fit the lower end of the shaft. The bucket wheel hub encases the pivot-bearing housing and is drilled so that the lower end of the shaft may pass through the hub and screw into the socket in the housing. The outer circumference of the hub, below the shoulder, is left smooth thus eliminating the bucket-raising feature. The pivot bearing is smaller than for the type A meter both in its inside and outside diameters. It is ground on an angle of 105 degrees and to a radius of 0.025 of an inch at the apex. The pivot is turned down at the bearing end, thus providing a shoulder at 0.250 inches from the point. The point is ground on an angle of 90 degress and to a radius of 0.010 of an inch at the point. Both shaft assemblies have the same over-all length, thus making the 622 shaft assembly adaptable to the type A meter.

Assembly and adjustment of the 622 type and Geological Survey type A meters. - The procedure in assembling these meters may best be followed by referring to figure (8) which shows a type A meter completely assembled and also the shaft assembly for the 622 type meter. Either is assembled as follows: first, assemble the tail piece (10) and fasten it to the yoke by means of set screw (7). Next, place the bucket wheel (24) on the bucket wheel hub (13) with the side marked "T" up and with the dowel pin on the hub fitting in the notch in the bucket wheel frame. These parts are clamped together by means of the bucket wheel hub nut (14). This assembly is next placed in the yoke (8), and in the case of the type A meter, the shaft (12) is passed through the hole in the upper arm of the yoke and screwed directly into the top of the bucket wheel hub (13). In the 622 type meter, before this assembly is placed in the yoke, the pivot-bearing housing (22) is inserted into the bucket wheel hub (20) with the dowel pin on the housing fitting in the notch in the bottom of the hub. The shaft (12) is then inserted in the same manner as for the type A meter except that it is screwed down into the top of the pivot-bearing housing. The penta gear (6) is next loosely fastened in the contact chamber (2) by means of a small set screw passing through the adjusting slot of the penta gear pad. The contact chamber with the chamber head cap (1) removed, is slipped over the upper end of the shaft and the lower end of the chamber inserted into the hole in the upper arm of the yoke. This step necessitates extreme caution in order that the worm shaft or the penta gear will not become marred. The contact chamber is then adjusted so that the vertical mark on the chamber coincides with the horizontal mark on the arm of the yoke and is held in place by tightening set screw (7). The cap is then screwed into the contact chamber. The next step is to insert the pivot (17) or (23) through the hole in the lower arm of the yoke and after adjusting so as to give the proper vertical play to the shaft assembly, set screw (7) is tightened against the flattened side of the pivot. The proper amount of play is obtained in the following manner: first, loosen the keeper screw (19) in pivot-adjusting nut (18) and with the contact chamber cap screwed tightly, turn the meter over so that the top of the shaft rests on the bottom of the cap. The pivot is then lowered onto the pivot bearing thus absorbing all vertical play in the meter. Set screw (7) in the yoke is then tightened sufficiently to hold the pivot in place and the pivot-adjusting nut (18) on the pivot is then tightened against the yoke. Set screw (7) in the yoke is then loosened slightly and the pivot-adjusting nut (18) turned to the right one-quarter of a turn. With the pivot-adjusting nut in this position the keeper screw is firmly tightened thus locking the nut, and the set screw in the yoke again tightened. This adjustment provides .008 of an inch end play which has been found to be the proper amount for the shaft assembly. Since the meter is always rated with this amount of play, it is essential that this procedure in adjustment be strictly observed when installing a new pivot or when the point wears down.

With the meter adjusted for the proper play, the cap is again removed from the contact chamber, the penta gear properly meshed with the worm shaft after which the pad screw is firmly tightened. Contact points are next placed in proper adjustment. The meter assembly is then placed with the shaft in a vertical upright position and subjected to a spin test. If, with a new pivot and bearing a run of 3 minutes or more, without binding or stopping, is observed, the contact chamber cap may then be replaced and the meter considered in proper adjustment.

The meter thus assembled is then suspended on a hanger with the tail piece adjusted with the vane carrying the balance weight (11) parallel with the yoke. The assembly is then balanced by moving the balance weight along the slot to the desired position.

Operation and care of the 622 type and Geological Survey type A meters. - The operation of a current meter, like any other instrument of precision, will largely be affected by the way in which it is used. While the design, material and construction of the meter are also factors contributing to its successful operation, they will not prevent errors due to improper care of the instrument. Each field man is therefore urged to exert every effort in keeping his meter in the proper condition but in so doing he should not make such repairs as are likely to affect the rating of the instrument. In order that he may satisfy himself as to the condition of the meter, he should examine it both before and after each measurement with regard to the following details:

(1) Proper balance, if used from a cable suspension.

All meters leaving the Washington office are balanced by adjusting the balance weight on the tail piece without a lead wire being connected to the binding post on the contact chamber. This lead wire should be flexible enough so that it will not interfere with the free swinging of the meter on the hanger, nor prevent the meter from assuming a horizontal position when it comes to rest. It should not be so long as to touch the cups when the meter is horizontal and the top of the hanger pushed ahead as far as possible. Both the weight hanger screw and the meter hanger screw should be replaced if badly worn as the wear in either may cause enough friction to prevent the meter from swinging freely upon the hanger.

(2) Proper mounting, when used from a rod suspension.

When the Price current meter is used from a wading rod with a double-end hanger, it should be arranged so that the meter shaft is always parallel to the wading rod and the wading rod in turn held in a vertical position. The need of such precautionary steps is obvious as it can readily be seen that the pivot bearing will not bear evenly on the pivot point in any other position. Furthermore, experiments and tests have shown that the meter decidedly underregisters when held in position other than vertical. Care should also be taken to eliminate all possibility of interference in the rotation of the cups by the wire leading to the contact chamber.

(3) True shaft alignment.

The shaft of any meter may become bent if the meter is subjected to a sharp blow or if the bucket wheel, for those meters equipped with the bucket-raising feature, is lifted improperly. When lifting the cups from the pivot point by means of the bucket-raising nut, they should always be held stationary and the bucket-raising nut turned as spinning the rotor while the bucket-raising nut is held stationary may create sufficient momentum which, when suddenly checked, may spring either the yoke or the shaft. The shaft assembly does not need to be dismantled to ascertain whether or not the shaft is in alignment. With the contact chamber in place, the cap removed and the meter held in a vertical position, the bucket wheel may be turned slowly, and by watching the metal frame to which is fastened the inner edges of the cups, it can be observed whether or not the shaft is bent. In addition to this test, the movement of the shaft inside the contact chamber may also be observed and if any wabble is noticed which is not caused by a worn bearing lug in the chamber, it is further evidence that the shaft is bent. As a final test, the shaft may be dismantled and rolled on a flat surface. Any meter found with a bent shaft should be returned to Washington for inspection and repairs.

(4) Proper condition of pivot point and pivot bearing.

After every discharge measurement both the pivot and pivot bearing should be thoroughly cleaned, thus removing all water, old oil, dirt, or abrasive substance that may be present. The pivot should then be examined with a magnifying glass to see whether the point is fractured, worn flat, or rough at the apex. Any pivot, fractured or having a rough point, should be discarded and returned to Washington for regrinding. In order to examine conveniently and clean the pivot bearing, the contact chamber should be carefully removed so as not to mar the penta gear, if such is present, and the shaft assembly should be tilted to one side. Occasionally the pivot bearing becomes coated with an oily substance which can not be removed with a cloth. In this case a blunt, soft wooden pin, turned several times within the bearing, will usually assist in cleaning and if the bearing shows signs of rust, a few drops of oil may be used. The pivot bearing, like the pivot point, should be examined for possible fracture, pits and roughness, but in no case should the bearing be removed from the housing by the engineer in the field. No meter should ever be packed or transported with the pivot bearing resting on the pivot point. Those meters possessing the bucket-raising features should always have the cups raised by means of the bucket-raising nut and those not possessing this feature should have the pivot removed and the cups held in place by a dummy plug.

(5) Cleaning, oiling, and inserting new parts.

Every 622 Price or Geological Survey type A current meter, in addition to the pivot bearing just discussed, has bearing surfaces above the bucket wheel in the nature of cylindrical bearings, mesh bearings and thrust bearings. These bearings should also be examined, oiled and cleaned after each discharge measurement. If at any time it is necessary to insert a new part while in the field, the meter should always be tested afterwards for the proper adjustment. Additional precaution should be taken if it is found necessary to replace the contact chamber cap, as all caps do not screw into the chamber to the same fixed depth. The reason for this is that during high velocities the caps become worn by the head of the shaft riding on the cap and it occasionally becomes necessary to reface the cap when the meter is being repaired. Before a new cap is tightened into the contact chamber, the pivot should always be lowered, or the cups released by lowering the bucket-raising nut, as the head of the shaft may be brought to bear against the cap with sufficient pressure to either bend or throw the shaft out of alignment. For lubricating purposes the highest grade of oil should be used as tests have shown that inferior oils do not eliminate the corrosion of several of the parts.

When using either the 622 type or the Geological Survey type A meter it is rather difficult to retain oil in the contact chamber unless a definite procedure is followed in adding the oil. This is accomplished by removing the contact chamber and filling it with oil through the hole at the bottom, care being taken that the cap is tight in the chamber. The meter is then inverted and the chamber replaced. After the meter has been used the cap should be loosened slightly to allow a small amount of air to enter. By screwing down the cap, oil is then forced around the shaft thus forcing out any water that has collected in the lower part of the chamber or about the shaft. The use of this method eliminates the frequent oiling of the parts contained in the contact chamber and the continual presence of the oil provides additional electrical insulation which is particularly desirable when making observations in deep water.

(6) Standard requirements for operation.

The common method for determining the condition of the meter is the so-called spin test and only by the correct interpretation of the results thus obtained, is the condition of the meter definitely determined. In subjecting a meter to a spin test, it should be so placed that the shaft is in a vertical position and the cups protected against all air movements. As the rotating cups near the stopping point, they should be carefully observed to note whether they stop abruptly or gradually. Velocities over .6 of a foot per second give sufficient excess motive power to overcome any appreciable effect of mechanical resistance in the meter. Therefore, the principal value of the spin test for velocities above .6 of a foot per second, is to indicate whether or not the meter is operating freely. Any meter that will spin 1½ minutes is in satisfactory condition for measuring all except very low velocities and as a matter of fact, a meter that will spin one minute will measure velocities above one foot per second without appreciable error.

As the velocity decreases the motive power also decreases and for velocities below .6 of a foot per second, the difference between the motive power and the mechanical resistance of the meter becomes very small. For this reason a meter should be in excellent adjustment and spin at least two minutes when velocities below .6 of a foot per second are measured.

623 (combination) type meter. - The 623 (combination) type meter varies from the 622 or type A meter only in the construction of some of its integral parts. Although the parts of the 623 type meter have never been standardized, several of them have been greatly improved from time to time and as a result, the meter has become more durable and sensitive. The tail piece and the bucket wheel are essentially the same as in improved types. The yoke is slightly different in shape and contains a shorter tail piece extension. It is made either with or without a round threaded socket situated on top of the upper arm. This socket provides a means for suspending the meter from the end of the wading rod and when not in use is protected by means of a knurled cap. A yoke containing this socket is known as the "Covert yoke" (named after C. C. Covert former district engineer of the U. S. Geological Survey) and was developed primarily to assist in measuring the flow of water beneath ice cover. Two interchangeable contact chambers are used, one arranged to complete an electrical circuit every revolution of the rotor and the other containing a penta gear arrangment to accomplish this result every fifth revolution of the rotor. The newest development in the shaft is a stainless steel one-piece construction, threaded at the upper end to carry either the knife blade used in contacting each revolution or the worm which operates the penta gear. The lower end of the shaft, instead of screwing into the bucket-wheel hub, as is the case in the type A meter, is drilled and threaded to screw directly onto the upper end of the hub, thus holding the bucket wheel in place. The bucket-wheel hub is similar in construction to that of the type A meter in that it encloses the pivot bearing and carries the bucket-raising nut. The pivot is carried by a pivot housing which is drilled and threaded. The pivot is turned down at the point-end thus producing a shoulder a short distance from the point. The enlarged diameter of the pivot is threaded throughout to fit the pivot housing and carries a small lock nut which keeps the pivot from turning in the housing. The pivot is ground to a sharp point on an angle of 60 degrees and the pivot bearing on an angle of 75 degrees, the bearing being slightly rounded at the apex.

The procedure of assembling the 623 type meter and adjusting it for vertical play is essentially the same as for the 622 and 622 A types. In the assembling the main difference is that the bucket wheel is held in place by the shaft instead of by a separate nut and when the shaft assembly is placed in the yoke the shaft must be passed through the hole in the upper arm from underneath. In adjusting for the vertical play, the lock nut which holds the pivot fast in the pivot housing is loosened and turned back several threads. The meter is then turned over on the cap with the shaft resting in a vertical position. Following this the pivot is screwed down until all vertical play is taken up and the shoulder on the pivot housing is resting snugly against the yoke. The pivot is then backed off one-third of a turn which provides the proper vertical play, and the lock nut securely fastened.

The same precautionary steps as discussed under "Operation and care of the 622 and type A meters" should be observed for the 623 type meter.

Rating of Current Meters. - In order to derive the velocity of the water from the rate of rotation of the rotor of a current meter, a relation must be established between the speed of the rotor and the velocity of the water causing it to turn. The procedure of establishing this relation is known as "rating the current meter". Theoretically, one standard rating should be applicable for all meters of a certain make but owing to slight variations in their construction, such a rating can not be used for accurate work. Ratings also differ even for the same meter if it is suspended differently, or if sounding weights of different sizes and shapes are used, or if the meter is suspended in different positions with respect to the bottom of the sounding weights. For the reasons thus given, each meter used by the Survey is individually rated with a standard suspension and coefficients are developed by which ratings for other suspensions may be computed.

The National Bureau of Standards' current meter rating station. - The meter rating station operated by the National Bureau of Standards in Washington consists of a reinforced concrete basin 400 ft. long, 6 ft. wide and 6 ft. deep. Located on each side and extending over the entire length of this channel are rails which carry an electrically driven rating car. This car is equipped to move the meter at various rates of speed through the still water in the flume. Although this rate of speed is adjusted approximately by means of a regulating gear, the actual velocity of the moving car is obtained by measuring the distance it travels in a given time. This is accomplished by means of a graduated scale located along the side of the flume. In rating a current meter, from 8 to 10 double runs are made, with these runs so distributed as to define the relations of the speed of the rotor in revolutions per second and the velocity of movement through the water for the range of velocities to be encountered. Practical considerations usually limit the ratings to velocities ranging from one-tenth of a foot per second to about 15 feet per second although the rating car can be operated at both higher and lower speeds.

Current Meter Ratings. - After current meters are rated by the National Bureau of Standards they are returned to the Geological Survey, the meters going directly to the Division of Field Equipment. The blueprints of the ratings are transmitted by the Director of the National Bureau of Standards to the Director of the Geological Survey and then referred to the Water Resources Branch. These ratings show the plotting of each individual run made in the rating flume and are plotted at two scales with the revolutions per second of the rotor as the ordinate and the velocity of motion in feet per second as the abscissa. The observations for velocities corresponding to one revolution per second or less are plotted at a larger scale than the velocities greater than those corresponding to one revolution per second. The values used in plotting are the results of the run in each direction, consequently these values are plotted in pairs, two points for each double run. Theoretically, the rotor of the meter passing over a given distance should revolve the same number of times regardless of any variation in the velocity of motion causing it to turn. This is usually found to be approximately true for the higher velocity ratings, but for lower velocity ratings the friction of the instrument ceases to decrease proportionately in percentage with the decrease in rotation of the rotor, thus making it necessary to use two or more straight lines with different slopes to express graphically the complete rating of a current meter. If the rating is expressed by one scale a break in the slope of the line will usually occur between 0.5 and 1.0 revolutions per second and the line will not pass exactly through the origin of the coordinates because a small amount of velocity is required to overcome the inertia of the rotor. It is the usual practice, however, to express the rating for velocities corresponding to one revolution per second and less by one straight line drawn on an enlarged scale and the ratings above one revolution per second by another straight line which may have a different slope. Occasionally examination of the runs made in rating the current meter reveals that more than two straight lines are necessary to accurately express the rating.

The rating tables are prepared in the Water Resources Branch where the procedure is as follows: The rating curves or diagrams as prepared at the National Bureau of Standards are first examined to ascertain if there are any changes in slope. With the points of change in slope as the control points, the equations of the lines between those points are computed and corresponding values of revolutions per second and velocities are tabulated on Form 9-206c. A study of these tabulated values is then made to ascertain if any of the rating tables on file are sufficiently close to these values so that an existing table can be used without appreciable error. There are now on file several hundred current meter rating tables and a system has been devised whereby it is easy to select a table corresponding to any individual rating if such a table is available. A new table is computed if no table is found that is sufficiently close to the tabulated values. In general, it should be noted that errors in reading the stop watch in making current meter measurements are considerably greater than the error incurred in using rating tables taken from the existing file.

Instructions for shipment of current meter. - When a current meter is transmitted by the district office to Washington for repairs and rating, a special mimeograph form letter in triplicate is filled out setting forth the following information: how shipped, number of Government bill of lading, shipping box number, type of meter, Water Resources number of meter, serial number of the contact chambers, and the district office ownership. A brief statement is also given regarding the necessary repairs which are considered needed and the suspensions for which ratings are desired. Shipping and billing instructions must also be shown which include the address to which the meter is to be returned and the appropriation and allotment to which any charges are to be made. The meter, when returned to the district office, is accompanied by two copies of Form 9-445a which shows the itemized charges for the costs of new parts, if any, and the labor charges for work done by the Division of Field Equipment in repairing and testing the meter. On this form is also shown the spin test of the meters when ready for shipment to the field. Upon receipt of the meter by the district office, the original copy of Form 9-445a is signed and returned to Washington.

Inspection and repairs of current meters by the Division of Field Equipment. - A current meter, when received from the field, is first examined by an engineer in the Water Resources Branch and its condition noted and needed repairs compared with those requested in the letter of transmittal (in triplicate and to which may have been added comments respecting the meter and the rating desired at the National Bureau of Standards) which the district engineer used in transmitting the meter. The meter, with one copy of the letter of transmittal, is then sent to the Division of Field Equipment. The meter is given an initial spin test (by mechanical means) and carefully examined in the Division of Field Equipment, where all necessary repairs to put the meter in first-class condition are made. The meter is then sent to the National Bureau of Standards for rating, after which it is returned to the Division of Field Equipment for another spin test before being returned to the district engineer.

In addition to the mechanical spin tests, some of the more important tests made to the meter during and after repairing and before the meter is rated, are as follows:

The cups are tested to assure that they are properly balanced and that the centers of the cups rotate in one plane.

The shaft is tested to see that it is perfectly straight and in proper alignment.

The axis of the meter yoke and tail piece is tested to assure that it is perpendicular to the shaft about which the cups rotate.

The cylindrical part of the lower bearing is tested to see that it has not worn sufficiently to allow excessive side play.

The bearing lug in the contact chamber is also tested for effects of wear.

After the meter is rated and returned by the National Bureau of Standards it is given a spin test and its general condition is observed for effects of possible injuries or damages which may have occurred subsequent to preparing the meter for rating. If the meter appears to be in good condition when received from the Bureau of Standards after rating, the pivot and bearing are carefully wiped, polished and oiled, and the meter given a final spin test, after which it is returned to the district engineer.