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PORTABLE AUTOMATIC TIDE GAUGE

BY

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PREFACE

For use in the hydrographic work of the Survey the need has been felt for some time for a tide gauge more portable and more easily installed than the large type standard Coast and Geodetic Survey model, for which a somewhat elaborate platform and float well are necessary. A portable type gauge has been devised by the Coast and Geodetic Survey to fill this need, and developed for use of hydrographic and tidal parties in obtaining tidal observations covering short periods of time for the reduction of soundings taken during a survey, and for comparative purposes. The main objects sought in designing the instrument were portability and ease of installation without sacrificing the desired accuracy.

It is the purpose of this publication to give a description of this portable automatic tide gauge and to furnish the field engineers of the Survey detailed instructions for its installation and operation.

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PORTABLE AUTOMATIC TIDE GAUGE

By G. T. Rude, *Commander, United States Coast and Geodetic Survey, Chief, Division of Tides and Currents*

INTRODUCTION

The first instruments or means for the observation of tides naturally were simple, the more complicated and more efficient instruments evolving in the manner of all labor-saving and time-saving devices developed by man. The earliest means of observation were no doubt the marks left by the changing water level on rocky cliffs or ledges, then came the plain graduated staff, and finally the automatic or self-registering gauge, developing, as always developed by man, toward the end of saving to himself time and labor. There are also several forms of pressure gauges which have been designed primarily for obtaining observations offshore where it is impracticable to install the usual type of gauge. The Fave "Maregraphe Plongeur"[1] is an example of this type.

The earliest automatic tide gauge (fig. 1) of which we have record was devised by an English civil engineer, Henry R. Palmer. A paper descriptive of this gauge appears in the Philosophical Transactions of the Royal Society for the year 1831. This gauge was constructed for obtaining a continuous record of the rise and fall of the tide in the River Thames for getting the effect on the tidal régime of the river by the removal of London Bridge, "free (as expressed by Mr. Palmer) from the inaccuracies and doubts which the frequent and long-continued observations of individuals through nights and days must be liable."

There are many forms of automatic gauges, but the fundamental principle is a simple one. A float is connected by a wire or tape with a self-recording pencil or pen which moves at a reduced scale backward and forward across a paper record

[1] Annales Hydrographique, vols. 1908–1910, pp. 383–437, and 1921, pp. 193–237.

which is wound or wrapped on a cylinder, either vertical or horizontal. This paper is moved forward by means of a clock movement, thus causing the pencil to trace a curve on the paper. This curve or graph is an accurate representation of the tide of the locality. In another form of automatic tide gauge an arrangement for printing the height of the water at certain in-

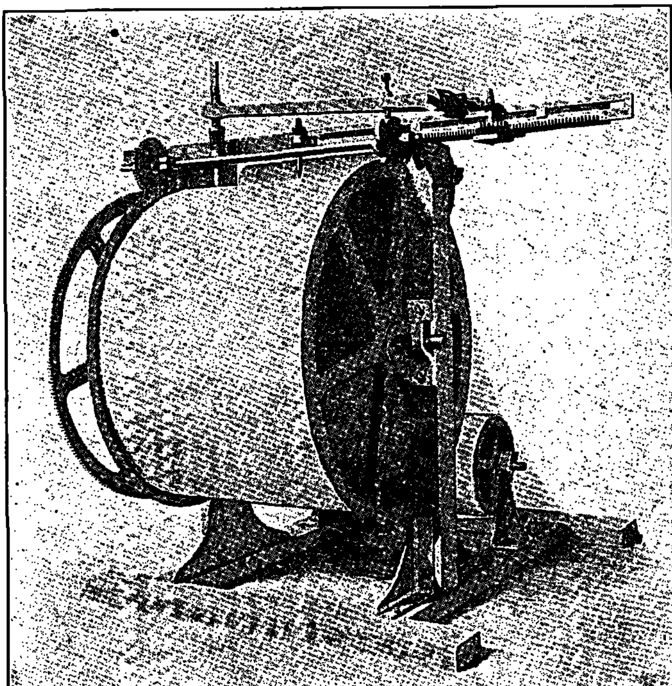

FIG. 1.—The first automatic tide gauge, designed by a British civil engineer, Henry R. Palmer. (From the Philosophical Transactions of the Royal Society, 1831)

tervals of time is substituted for the curve-tracing device. The printing gauge, however, has not proven to be as satisfactory as the curve-tracing gauge for the purposes of the Survey.

The portable automatic tide gauge, a curve-tracing gauge recently developed by the United States Coast and Geodetic Survey for use at places where only short series of observations are contemplated, has proven to be very satisfactory for this purpose. It is easy to transport, simple to install, and gives a continuous record of the tides without any attention from an observer, except for an occasional visit from day to day. In its first season in the field a continuous unbroken record for a period of eight days was obtained from this gauge in an isolated place in Alaska without any attention during that period.

GENERAL DESCRIPTION

The special features of the gauge are its small size, its single cylinder, on which the paper for the record is fastened by means of a spring clip, a single clock movement installed within the record cylinder, and a cast base with sleeve to fit on top of a float well of stock 3½-inch iron pipe. This pipe, in addition to serving as a float well, acts also as a support for the instrument, thus obviating the necessity of providing an elaborate platform and cumbersome float well. This feature renders the gauge especially adaptable for use by field parties, particularly in remote localities where wharves or piers are not available. Another departure from the usual design of automatic gauge is the use of a spring counterpoise instead of counterpoise weights for taking up the slack of the float wire on a rising tide. The record is traced by a stylus (or pencil) on sheets of cross-section paper with time and height coordinates.

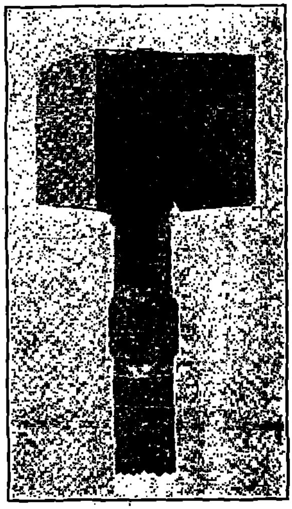

FIG. 2.—Coast and Geodetic Survey portable automatic tide gauge (with cover)

The gauge is 11 by 10½ inches on the base, and with its weatherproof metal cover in place is 10 inches high. The gauge is fastened by means of two hook screws to the short top section of the float well, this short section being furnished with the gauge; the weatherproof cover is secured in place by a padlock, so that the mechanism is completely covered and can not be tampered with, which is especially desirable when the gauge is installed in isolated places.

RECORD CYLINDER

The cylinder (*A*, fig. 3) on which the paper for the record is wound is 7 inches in length and about 6 inches in diameter. The cylinder is geared to a clock movement carried within the cylinder so as to rotate once in 48 hours, giving a fixed time scale of four-tenths of an inch to the hour.

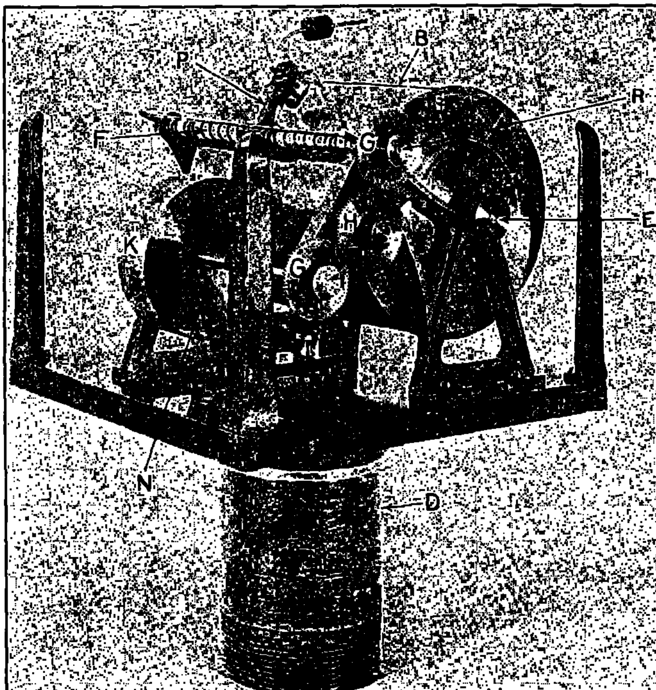

FIG. 3.—Coast and Geodetic Survey portable automatic tide gauge (without cover)

This cylinder rotates in such a direction that the top of the cylinder moves toward the stylus screw (*F*, fig. 3), and when installing the gauge the cylinder should be so placed in its supports that the milled-head nut (*E*, fig. 3) at the end of the axle of the cylinder comes on the same side of the instrument as the train of three gear wheels (*G*, *H*, *G*, fig. 3) connecting the float wire drum with the stylus screw.

Upon unclamping the milled-head nut (*E*, fig. 3) the cylinder may be turned freely and the stylus set on the cross-section marigraph paper to the nearest 10 minutes of the time scale, after which this screw is clamped. Then in order to set the stylus accurately to the nearest minute, the stylus tangent screw (*W*, fig. 9) is used, but whatever slack there may be in the record cylinder should first be taken out by lightly placing the hand on top of the cylinder and drawing it in a direction away from the stylus.

CLOCK MOVEMENT

The clock is an ordinary eight-day movement, mounted within the record cylinder. When properly adjusted the gauge will operate for eight days without attention in the meantime. The cylinder revolves once in two days and, since the lunar and solar days are of different lengths, the tide curve traced on the record advances sufficiently from one revolution of the cylinder to the next to obviate any interference of the curve for one day with that of any succeeding day. In general, it will probably be of advantage to have a single sheet of paper serve for about a week, with a comparative time note and staff reading once each day. The daily comparison may be dispensed with in cases where the gauge can be visited by the hydrographic party at the end of the week only.

TIME ADJUSTMENT

Before being issued to the field the clock movement is adjusted so that the record cylinder will make a full revolution as closely as possible once in 48 hours. Should the clock get out of adjustment it may be regulated by means of the adjusting attachment at one end of the record cylinder, as on an ordinary clock. In making this adjustment, however, the cylinder should be allowed a full 48-hour revolution and the clock movement adjusted according to the amount that the stylus fails or overruns a complete revolution of the cylinder, and not for any particular hour on the cross-section paper.

FLOAT

The float (fig. 4) is a hollow brass cylinder 3¼ inches in diameter and 15 inches long. Floating on the surface of the water in a pipe, it rises and falls with the tide, and communicates this motion to the mechanism of the gauge by means of a

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phosphor-bronze wire 0.012 inch in diameter. This float is weighted with shot to float with its upper end about 3½ inches above the surface of sea water and about one-half inch above the surface of kerosene oil, the oil being used in winter to prevent freezing of water in the float well. The weight of the float and shot is sufficient to wind the counterpoise spring on a falling tide and at the same time to actuate the recording stylus.

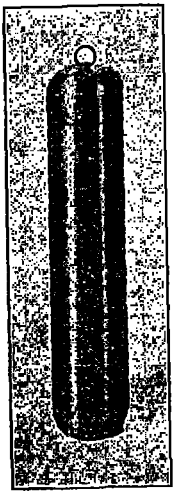

FIG. 4.—The float

FLOAT PIPE

The float pipe (fig. 5) consists of a section, or sections, of ordinary stock 3½-inch galvanized-iron pipe, of suitable lengths for the range of the tide and the depth of water. The sections are joined by ordinary stock couplings. When the float pipe is installed on a pier or wharf, a 3½-inch flange coupling, with a short section of 3½-inch pipe above the deck, affords a ready means of supporting the float pipe, and the conical inlet coupling described hereafter is screwed into the bottom of the longer section,

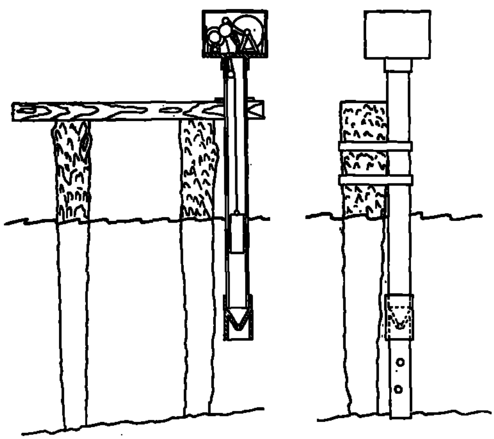

FIG. 5.—Methods of installation of the portable automatic tide gauge

reaching below extreme low water (left sketch, fig. 5). For greater security, or to provide a support for the instrument in a place at which no wharf or platform is available, an additional section of pipe may be screwed into this conical inlet coupling on its bottom end and perforated with several large holes to allow free access of the water to the inlet in the coupling

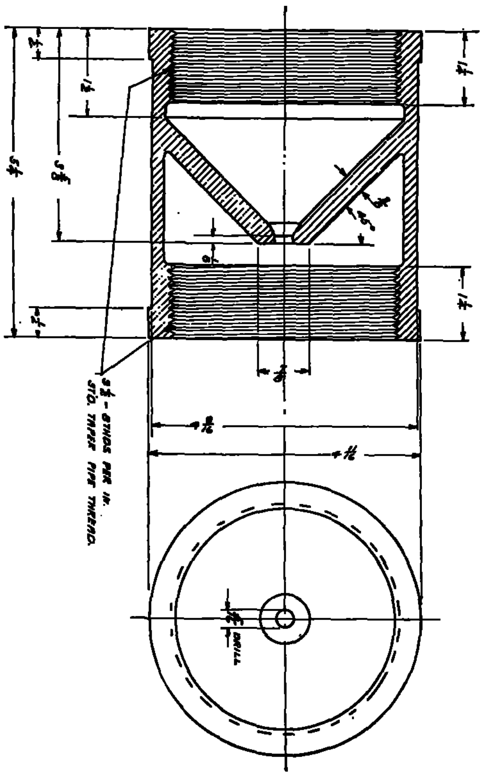

FIG. 6.—The conical inlet coupling (working drawing)

(right sketch, fig. 5). This lower section rests on the bottom or may be driven or jetted a few feet into the mud or sand.

When installing the gauge in isolated localities or on a bar where no pier is available, the float well supporting the gauge may be lashed to a single pile or net stake (right sketch, fig. 5) or to three poles driven about 6 feet apart with little penetration and the upper ends brought together and lashed in the form of a tripod, the float pipe being lashed in a vertical position at the apex of the tripod.

CONICAL INLET COUPLING

As an inlet for the tide to the float pipe a conical inlet coupling (fig. 6) is furnished with the gauge. This is installed with the apex d o w n w a r d. A quarter-inch or five-sixteenths-inch hole drilled at the bottom of this inverted cone allows ingress and egress of the tide to the float pipe while damping the water action. The inclined inner surface of this cone facilitates the cleaning of the float pipe of any obstructions which might affect the flow of water.

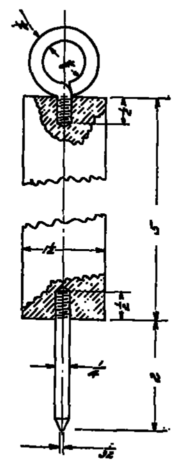

FIG. 7.—The cleaning rod (working drawing)

CLEANING ROD

For cleaning the float pipe a weighted brass cleaning rod (fig. 7) is furnished with the gauge. This device consists of a brass rod 5 inches long and 1½ inches in diameter, into one end of which is screwed a pointed brass shank 2 inches long and one-fourth inch in diameter and in the other end a small eye.

Should the opening in the conical inlet coupling become clogged, it can be easily cleaned by removing the float from the pipe, inserting the cleaning rod, to which a rope has been attached, and raising and lowering it several times in the pipe, allowing the pointed shank to pass through the inlet opening each time.

FLOAT WIRE DRUM

The phosphor-bronze wire, connecting the float with the mechanism, is wound on a threaded drum (*K*, fig. 3) 12 inches in circumference. This drum is rigidly fixed to that part of its axle which extends toward the gear wheel by means of a screw (*N*, fig. 3). The relationship of the circumference of this drum, the relative sizes of the uppermost and lowest gear wheels (*G*, *G*, fig. 3) of the train, and the pitch of the stylus screw (*F*, fig. 3) determine the scale of reproduction of the tidal curve.

COUNTERPOISE SPRING

Instead of employing the usual counterpoise weight for taking up the slack of the float wire on a rising tide, a spring 18 feet long, 0.25 inch wide, and 0.01 inch in thickness is used. This spring is coiled within the case of the float wire drum (*K*, fig. 3), one end fastened to the inside of the shell of this drum and the other end fastened to a separate extension of the axle. This

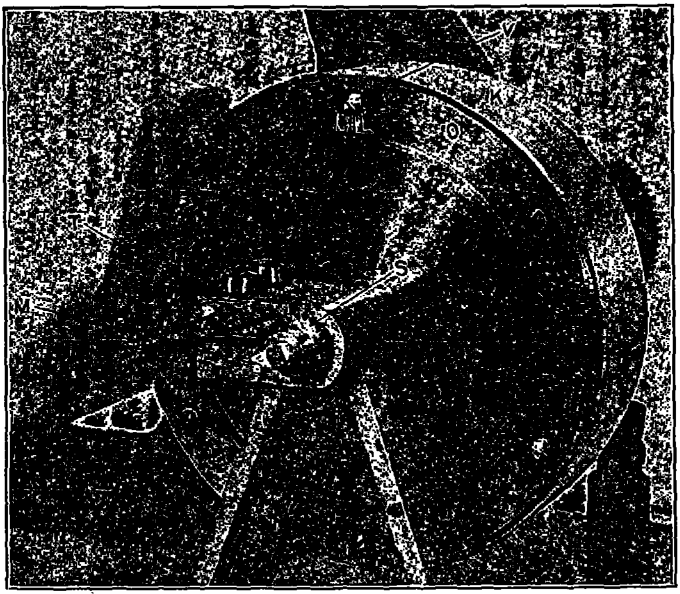

FIG. 8.—Detail of the float wire drum

subsidiary axle (*M*, fig. 8), extending from the float wire drum in a direction opposite to the gear wheels, is controlled by a ratchet and pawl (*S*, *T*. fig. 8), so that any desired tension may be put on the spring, using for this purpose the clock key on the squared end of the axle at *M*, Figure 8. In the latest model the case of the float wire drum contains an oil bath for the counterpoise spring so as to obviate deterioration from rust when in use in the field.

Should this spring be broken, a spare one may be installed as follows: Loosen screw (*N*, fig. 3) which holds the shaft connecting the float wire drum with its driving gear; then take out the six screws holding the cover plate (*O*, fig. 8) and remove it from the face of the drum. Slide the drum away from the standard toward the gear train and remove the screw which fastens the inner end of the spring to the fixed shaft. This screw is slotted in its shank, instead of in its head. Take out the screw holding the other end of the spring in the drum and remove broken spring. Now put in the screw, which is slotted in its shank through the round hole in the inner end of the new spring and fasten this end of the spring in place to the fixed shaft; wind the spring so that it will fit into its recess in the drum and attach its outer end in the drum case by means of the screw provided for that purpose, and reassemble. Put about a teaspoonful of fine watch oil inside the drum through the charging hole, which is closed by one of the six small screws (*V*, fig. 8) holding cover plate in place.

TENSION OF SPRING

It is very important to the proper functioning of the gauge that the tension of the spring be at its mean when the height of the tide is at approximate mean sea level. Otherwise the spring may be completely wound before the float reaches low water, thus causing a decided flattening of the marigraph curve at low water; or, on the other hand, the spring may be so completely unwound at high water that it will not have sufficient tension to take up the slack of the float wire, thus causing a defective high-water record. In actual practice the most accurate results will be obtained by using the middle of the spring. The proper adjustment is accomplished, when installing the gauge or when replacing a broken float wire, by fully winding the spring, which requires about 38 full turns (this may be tested in each gauge by fully unwinding the spring and then winding, keeping count of the turns), then unwinding 19 full turns, provided the water level at the time is at approximate mean sea level. If the height of the water as read on the tide staff at the time is not at mean sea level the spring is unwound or wound from the middle the same number of full turns that the water is above or below mean sea level in feet. (Care should be taken that full turns are made in each case and not half turns.) This adjustment of the tension of the spring is made by using the clock key on the subsidiary axle of the float wire drum at *M*, Figure 8.

GEARS

A train of three gears (*G*, *H*, *G*. fig. 3) connects the axle on which the float wire drum is mounted to the stylus screw. These gears determine the height scale for the operation of the gauge. The middle gear (*H*, fig. 3) is an idler which is used on the gauge for all scale ratios. The other two (*G*, *G*, fig. 3) are removable and, with several separate gears furnished with the gauge, provide for five different height scales, as follows:

Scale	Maximum range of tide	Number of teeth	
		Gear attached to float pulley axle	Gear attached to stylus screw
1:11¼	6	96	36
1:16⅞	9⅓	96	54
1:22½	12½	96	72
1:30	17	72	72
1:45	25	64	96

When installing the instrument care should be exercised in meshing the idler gear into the uppermost and lowest gear wheels. It should be meshed sufficiently to obviate unnecessary lost motion, but at the same time not so tightly as to lock the gear wheels or to put undue work on the float. In the latest model of this instrument the positions of the idler gear for each scale have been definitely fixed in the design of the instrument, so that adjustment is unnecessary, other than fitting the idler gear-bearing screw into the particular hole provided for the scale which is being used.

STYLUS SCREW

The rise and fall of the tide is communicated through the float wire drum and the gears described above to the stylus screw (*F*, fig. 3), which rotates backward and forward with the changes in the tide. This screw is made of phosphor bronze and the screw thread has a pitch of four-tenths of an inch. A carriage (*P*, fig. 3) for the recording stylus is moved back and forth along the screw by its rotation.

For adjusting the stylus to the height of the tide, as read on the tide staff, the milled-head nut (*R*, fig. 3) holding the upper gear wheel to the stylus screw is unclamped and the stylus screw then turned freely, without connection with the float wire drum, until the stylus point indicates on the cross-section paper the approximate height of the tide at that instant on the tide staff.

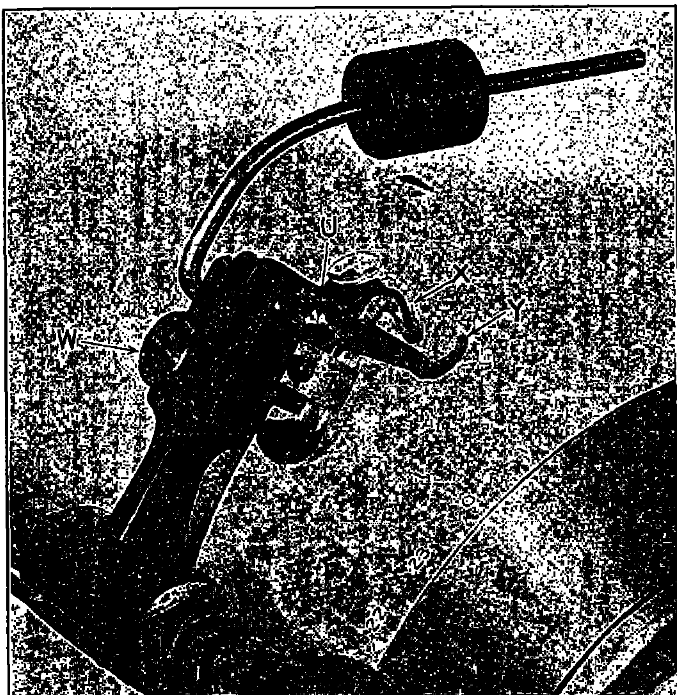

FIG. 9.—Detail of the stylus carriage

This milled nut is then clamped and a tangent screw (*U*, fig. 9) permits of setting the stylus to the exact reading of the height of the tide on the staff. The curve traced by the stylus will thereafter indicate on the record the reading at any instant of the water level on the tide staff as the tide rises and falls. The stylus should be reset each time the record paper is renewed.

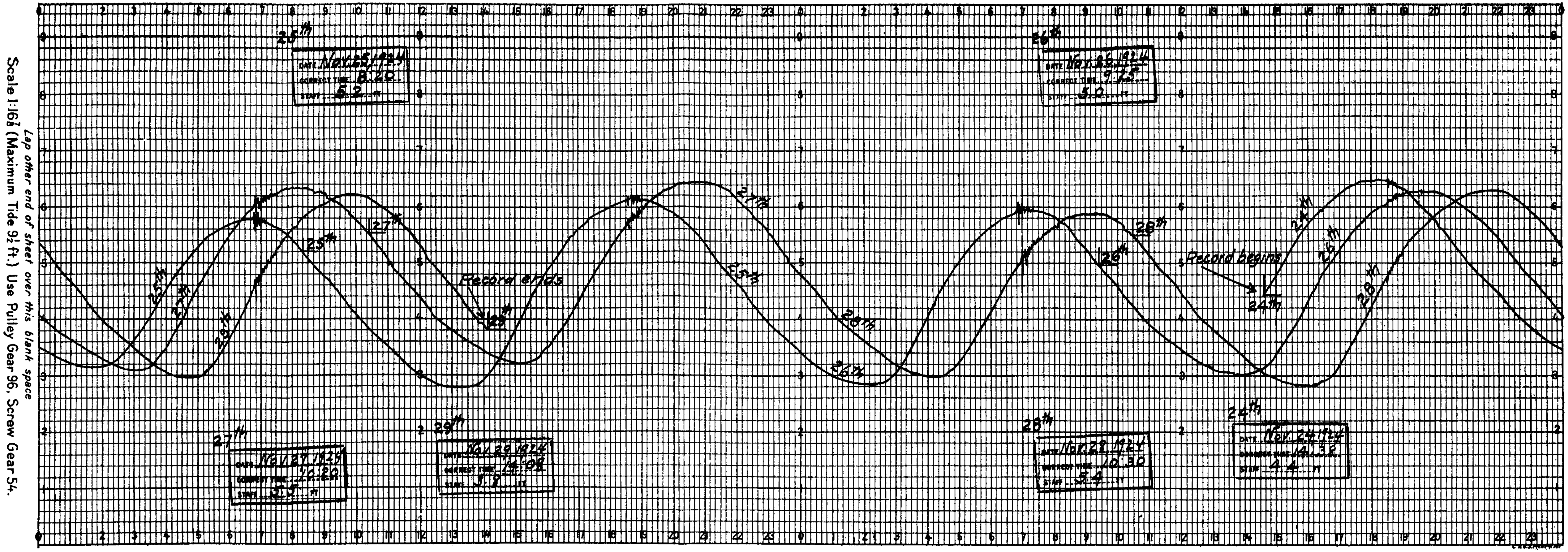

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FIG. 10.—Marigram or tide record at Washington, D. C., for the period November 24 to November 29, 1924

RECORDING STYLUS

In the first development of this gauge a pencil was employed for recording the tide graph. A special chronograph pen is now used on the latest model (*X*, fig. 9).

For the gauge on which the record is made by pencil, generally a No. 1 pencil will give best results. Under some conditions a No. 2 may prove more satisfactory. If the No. 1 pencil does not make a line sufficiently heavy to be easily read, one of the lead washers furnished with the gauge may be placed on top of the pencil.

When using the later model, on which the record is made by a stylus, care should be taken that the shoe (*Y*, fig. 9) be properly adjusted, so that the point of the stylus will ride over the spring clip (*B*, fig. 3) without catching. It is also important that the level of the ink in the reservoir be kept below the level of the stylus point, otherwise the ink will flow too freely, causing a blurred record. If the ink fails to flow freely, the stylus should be cleaned by inserting the fine wire furnished for this purpose. Care should also be taken in using the tangent screw (*W*, fig. 9) for setting the stylus to the exact time that the reservoir is not set so low that it drags on the clip, which holds the paper on the record cylinder, as it passes over.

A spare stylus is furnished with the gauge, and may be easily installed, should the other be broken, by loosening the band (*Z*, fig. 9) encircling the stylus, inserting the new one, and, while holding the band in place, tightening the small screw holding one end of this band. An extra stylus should always be kept on hand at the tide gauge. A supply is usually carried in stock in the office of the Coast and Geodetic Survey at Washington.

RECORD PAPER OR MARIGRAM

The tidal graph is made on sheets of special cross-section paper 7 by 19.7 inches (fig. 10), allowing in length for a half-inch overlap. This record paper is wrapped around the record cylinder and held in place by the metal clip (*B*, fig. 3) running lengthwise the cylinder. The paper is to be placed on the cylinder with the zero of the height scale at the end on which the milled-head nut (*E*, fig. 3) is located. The use of five different scales of cross-section paper permits the obtaining of the tidal graphs to five reduced scales, allowing therefore for the accommodation to suitable scales of ranges of tide from 0 to 25 feet. The scales as printed for this gauge are those indicated in the description of the gears.

The time coordinates of these sheets of paper are lines ruled parallel to the short edge of the paper, with moderately heavy lines four-tenths of an inch apart for the hours and with lighter lines subdividing the hour spaces into six equal parts for 10-minute intervals. The hour lines are numbered through two 24-hour periods, thus providing for the 48 hours of a complete rotation of the cylinder. For the height coordinates the sheets are ruled with lines parallel to the length of the paper, with moderately heavy lines for the footmarks and lighter lines for subdivisions of two-tenths of a foot. The smallest scale, however, for a tide of 25 feet, is subdivided into one-half foot only, instead of the two-tenths subdivisions on the larger scales.

TIDE STAFF

In order to have the tide curve near the middle of the marigram, it is necessary in setting the comparative tide staff to so fix it in place that the graduation on the tide staff corresponding to the middle scale reading of the marigraph paper will be at approximate mean sea level. If a portable staff is used, the support should be so fixed in place as to attain this object when the staff is in position in the guides.

An ordinary fixed tide staff may be used for connecting the marigraph curve with the actual height of tide when the gauge is maintained at a station for a short period of time. If the station is to be operated for a considerable period, a portable staff should be installed.

A substantial portable staff, which will maintain a fixed zero over long periods, has recently been developed by this bureau. The staff proper consists of a graduated board three-quarters of an inch thick, 4 inches wide, and from 12 to 16 feet long, hinged in the middle for ease in handling. The staff support, which is fixed permanently to a wharf or pile, carries the metal guides into which the staff is inserted for the readings. For accurate readings the wave action is damped out by a glass tube of one-half inch bore, partly closed at the lower end and attached to the staff by spring clips.

To counteract the effect of buoyancy and to hold the zero of the portable staff at the same fixed position when the staff is in place in the guides, a device has been developed consisting of a plate, bearing a pointed, grooved stud, securely fastened on the top surface of the support. A stop, carrying two spherical-end plungers which react against brass springs, is fastened to the staff at an exact footmark. As the staff is inserted in the guides and lowered to position the pointed stud pushes these plungers apart until the stop rests firmly on the seat formed by the plate on top of the support and bearing the stud. When it reaches this position the plungers snap into the groove and securely hold the staff downward against the effect of buoyancy of the water acting on the staff. A sharp jerk upward of the staff is sufficient to detach the plungers from the stud and allow the staff to be removed from the guides.

In waters infected with teredos the staff support should be entirely sheathed with sheet copper.

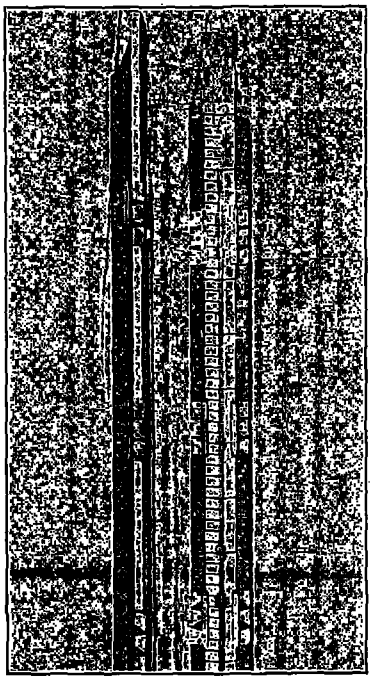

Fig. 11.—Side and front views of portable tide staff and support (upper half)

COMPARATIVE STAMP

A rubber stamp is furnished for the use of the observer in stamping a check-tide staff reading on the marigram at each visit to the gauge. It will be noticed, however, that comparative readings are not intended with this type of gauge to correct the recorded tides. Each time the stylus is set it should be made to read accurately with the staff reading, either when changing the paper record or when necessary for any other reason. When placing the impression of the stamp on the record paper it should be placed near the top or the bottom of the record and carry the date, correct time, and staff reading. To indicate on the tide curve the exact place to which the stamp refers, the hand should be placed lightly on top of the record cylinder and the cylinder moved slightly toward the stylus screw and back again to position; the hand should then be placed lightly on the float wire drum and the top of the drum moved slightly away from the stylus screw so as to raise the float a little out of the water and back again to position, thus causing the stylus to make a horizontal line on the marigram for the height and a vertical line for the time. Near the right angle thus made no writing should be done, except the date, in figures, agreeing with the date on the stamp to which it refers, thus, 24th, 25th, 26th, etc., without year or month (fig. 10). A light line connecting the comparative stamp note to the point of the tide curve to which it refers, as indicated by the right angle, may be helpful in interpreting the record, especially when the same sheet is left on the gauge for several days.

INSPECTION AND CARE OF GAUGE

If practicable, the gauge should be inspected every day, although when properly adjusted it functions without interruption of the record for a week. Reports from field parties indicate that in isolated localities where daily inspection has been impracticable the gauge has functioned satisfactorily for a week without attention in the meantime.

The paper record should be changed by the tide observer at the intervals specified by the officer in charge of the party. When changing the paper care should be taken to mark correct time and staff readings at the end before the finished record is taken off. After the new record sheet is placed on the cylinder an entry of the time and staff reading (made at the exact time) should be made at the beginning of the new record, using the comparative stamp furnished for the purpose. The entry "Record begins" should be made at the beginning of the curve when starting the new record: and when the marigram is taken off the entry "Record ends" should be made. These notes may be made near the corresponding time notes. (See fig. 10.) The clock should be wound every time the record is changed.

The float wire should be inspected and not allowed to foul on its drum. A kink in the wire will cause it to break easily, and it should be replaced as soon as a bad kink is noticed. A spool of this wire should always be kept at the tide station. If the supply runs low, a new spool should be requested from the office immediately.

The ball bearings in the journals of the stylus screw are of steel, and will corrode quickly, particularly in damp weather, *unless they are kept well oiled. It is very important to the* proper functioning of the gauge that these ball bearing journals work freely, so that a minimum amount of work may be put on the float, which is of small cross-section. Once each week a drop of fine watch oil should be put on these ball bearings. A supply of this oil is furnished with the gauge in the reservoir installed on the plate of the base of the instrument.

The stylus screw should be kept clean and free from grit or dust. A slight flattening of the tidal graph at high and low water is an indication that the stylus screw needs cleaning. This is accomplished by washing the screw with gasoline, placing the stylus carriage in various positions along the screw while doing so, and wiping dry afterwards with a piece of cheesecloth. The screw should then be wiped with a clean piece of cheesecloth, dampened with a few drops of fine watch oil. Oil should not be poured nor dropped on the stylus screw, since it tends to collect dust.

GENERAL SPECIFICATIONS

Base (*C*, fig. 3).—The base of the instrument is 11 by 10½ inches, cast brass, ribbed to central socket for setting and locking upon 3½-inch standard water pipe. The top, face, edges, and inside surface of the socket are machined.

Float pipe (*D*, fig. 3).—A short section of standard 3½-inch water pipe 7 inches long is furnished with the gauge. This short section of pipe is threaded at one end and the other end machined to fit freely and snugly into the socket in the base. Two small rectangular holes are machined in the unthreaded end of this piece of pipe to take the screw hooks for securing the instrument to the float pipe.

Record cylinder (*A*, fig. 3).—The record cylinder is a hollow brass cylinder 6.108 inches in diameter and 7.00 inches in length. This cylinder is carried in brass bearing standards mounted upon the base. The record cylinder is truly cylindrical and the outer surface concentric with the axis of rotation. The cylinder is balanced after the clock is assembled, so that there will be no tendency to variation in the time of rotation due to changing the loads on the driving clock by reason of lack of balance. In quantity production of these instruments all cylinders are interchangeable in the standards of the different gauges, so that spare cylinders with their clocks installed may be furnished to field parties.

Clock.—The clock is a high-grade eight-day movement, rotating the drum exactly once in 48 hours. If any movement is substituted in quantity production other than specified in detailed specifications, a sample is first submitted to the United States Coast and Geodetic Survey for examination and approval.

Stylus screw (*F*, fig. 3).—The stylus screw is mounted in the standards of the record cylinder on ball bearings, and is made of phosphor bronze 0.433 inch in diameter with square thread 0.4-inch pitch and 0.04-inch depth. The thread extends the entire length of the screw between bearings and terminates in two square circular grooves at each end to accommodate the pins in the stylus carriage when the end of travel is reached. The screw is truly concentric with the bearings.

Stylus carriage (*P*, fig. 3).—The stylus carriage is a brass sleeve sliding freely but not loosely on the stylus screw. This sleeve is fitted with two steel pins which engage in the thread of the stylus screw to provide lateral motion. A suitable arm and holder is provided to hold a stylus. A shoe (*Y*, fig. 9) is also provided to lift the point of the stylus over the paper-holding clip of the record cylinder.

Stylus (*X*, fig. 9).—The stylus is a glass siphon chronograph pen.

Gears (*G*, *H*, *G*, fig. 3).—The gears for changing the ratio between float wire drum and the stylus carriage are of brass, 40-diametrical pitch, of the following sizes: 96 teeth, 1 required; 72 teeth, 2 required; 64 teeth, 1 required; 54 teeth, 1 required; 36 teeth, 1 required; and 76 teeth, 1 required.

The gear spacing on the bearing standards are such that, while the gears run freely, there is no appreciable lost motion.

Float wire drum (*K*, fig. 3).—The float wire drum is of brass, 1.1 inches wide and grooved with a round bottom groove of 28 pitch in which is wound the bronze float wire which is 0.0125 inch in diameter. The effective diameter of the drum is 3.801 inches, so that each revolution will take up 12 inches of the float wire. A recess is provided in the drum to carry the spring for taking up the slack of the float wire. An oil-tight cover plate (*O*, fig. 8) is fastened over the spring recess. A small quantity of watch oil is inserted after the gauge is assembled so that the spring will operate in an oil bath. This cover plate fits flush with the inside of the rim of the drum so that there will be no edge to catch the float wire drum spring. The shafts on which the float wire drum is mounted are of steel, heavily nickel-plated all over to prevent corrosion, as are all other steel parts.

Float wire drum spring.—The spring which is inserted in the drum to take up the slack of the float wire on a rising tide is of thin spring steel 18 feet long, seven-sixteenths inch wide, and 0.010 inch thick. This spring is fastened to the shaft by a thin oval-headed screw slotted in the stem instead of the head.

Fair leader.—A brass fair leader to act as a guide to the float wire is mounted on a brass arm extending down inside the short section of float pipe.

Float wire.—The float wire is phosphor bronze, 0.0125 inch in diameter.

Float.—The float is a hollow brass cylinder, 3.25 inches in diameter and 15 inches long, tapered at ends and weighted so that the top will float 1 inch above the surface in kerosene oil.

Cover.—A strong galvanized-iron cover, No. 14, B. & S. gauge, is provided for weather protection. This cover is locked to the base by two small high-grade brass padlocks, the keys of which are interchangeable.

Conical inlet coupling.—A conical inlet coupling of brass is furnished with the gauge (fig. 6).

Cleaning weight.—A brass cleaning weight (fig. 7) for freeing the inlet coupling of foreign matter is furnished with the gauge.

Finish.—The instrument is finished with black baking enamel, carefully baked on and evenly and neatly applied. Varnished surfaces are lacquered with Bakelite lacquer, tinted slightly yellow with picric acid.

Packing case.—The whole of the instrument, with its cover, float, pipe, conical inlet coupling, cleaning weight, and other parts, is packed in a strong case so that it will travel safely in shipment. The case has three coats of shellac on the inside; on the outside, two coats of shellac, and two coats of high-grade blue-gray lead base waterproof paint. All outside edges and corners of this case are rounded with one-fourth inch radius.

Workmanship.—Workmanship and material are of the best quality and in keeping with good instrument-manufacturing practice. When making quantity production the instruments conform in all respects with the sample which is loaned the manufacturer for a suitable time to serve as a model. Patterns for cast parts of the instruments are loaned to the manufacturer and returned to the Coast and Geodetic Survey as soon as the necessary castings have been made.