DEPARTMENT OF COMMERCE

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U. S. COAST AND GEODETIC SURVEY

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INSTRUCTIONS
PRIMARY TIDE STATIONS

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CONTENTS

ILLUSTRATIONS

PREFACE

This publication supplements the Instructions for Tide Observations, issued as Special Publications No. 139 of the United States Coast and Geodetic Survey, by providing such additional detailed explanations as may be especially useful to tide observers at primary tide stations. A primary tide station is one which is maintained over a period of several years in order to obtain a continuous record of the tide in any locality. It is thus distinguished from the temporary tide stations established by hydrographic parties for the purpose of reducing soundings to a uniform datum.

The principal purposes served by the records from a primary tide station are as follows:

(*a*) To furnish data for the prediction of tides in any locality. Harmonic constants are derived from an analysis of the hourly heights of the tide covering a considerable period of time, and these constants are used in a tide-predicting machine to predict the times and heights of the tide in the same locality in the future. The predictions are published in the annual Tide Tables of the United States Coast and Geodetic Survey.

(*b*) To furnish data for the determination of datum planes for surveying and engineering projects. Mean sea level which is used as a datum for leveling operations over large areas and the low-water datums used for hydrographic work require long series of observations for precise determination.

(*c*) To furnish data pertaining to the mean and extreme rise and fall of the tide in any locality. This information is required by the engineer engaged in various projects such as the buildings of wharves and bridges, the improvement of harbors, the laying out of streets, and the planning of sewerage systems.

(*d*) To provide observational data for use in Admiralty Court cases in which the condition of the tide at a certain time is involved.

(*e*) To provide data for the study of crustal movements in the earth.

(*f*) To provide a standard series of observations in any region for use in reducing to mean values the results obtained from short series of observations taken in connection with special hydrographic work.

This publication was prepared by Paul Schureman, senior mathematician, under the direction of the chief, division of tides and currents.

INSTRUCTIONS
PRIMARY TIDE STATIONS

TIDE STAFF

1. At each primary tide station there must be a plain tide staff or equivalent device through which the heights of the tide may be

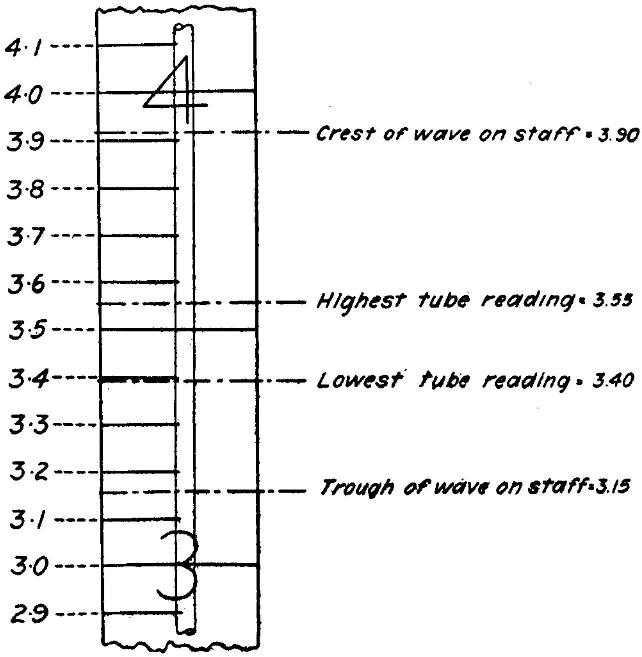

FIGURE 1.—Method of reading tide staff

ultimately referred to a system of bench marks on the land. Fixed and portable tide staffs and the glass tube used for obtaining accurate readings are described on pages 8 to 11 of Special Publication No. 139.

2. Vitrified scale.—To overcome difficulties resulting from the defacement of the graduations on a wooden tide staff, which may become illegible after the staff has been in use for some time, the office has recently adopted scales graduated in feet and tenths which are made by baking a vitrified coating on wrought-iron strips. These strips are in 3-foot sections about 2½ inches wide, the sections being so graduated that several of them may be placed end to end, forming a single continuous scale. These sections are secured to a wooden tide staff by brass screws with lead washers. It is believed that the scales can be kept clean with very little trouble and that the graduations will remain legible for a long period of time. Moreover, the weight of these scales on the staff will overcome the buoyancy of the water and render unnecessary the locking device heretofore used.

3. **Method of reading tide staff.**—The method of reading the tide staff is illustrated in Figure 1. It will be noted that the staff is graduated in tenths of a foot and not inches. The heights should be read to the nearest tenth or half tenth of a foot, the half tenth being represented by 5 in the second decimal place. Both the highest and lowest points reached by the waves should be read, the observer watching the staff for about a minute; and if a glass tube is used, the highest and lowest points reached by the water in the tube are also to be taken.

4. While the individual staff readings may at times seem rough and inaccurate, the final results, depending upon an average of a great number of such readings over a considerable period of time, reach a very satisfactory degree of precision provided they are taken in an unbiased manner. It is of great importance, therefore, that the tide observer when taking readings from the tide staff should be uninfluenced by any other consideration, and such readings are to be taken independently and without regard to the height of the tide as indicated by the automatic gauge.

TAPE GAUGE

5. In exposed localities where rough water renders the use of a tide staff impracticable a tape gauge may be substituted; or a tape gauge may be used in connection with a tide staff in localities where conditions may permit occasional readings on the latter. The tape gauge is illustrated in Figure 2 and is described in detail on pages 11 and 12 of Special Publication No. 139.

6. **Reference of tape gauge to bench marks.**—The method of determining the plane of flotation is described in Special Publication No. 139. This plane, under operating conditions, depends not only upon the float itself but also upon the weight of the counter-

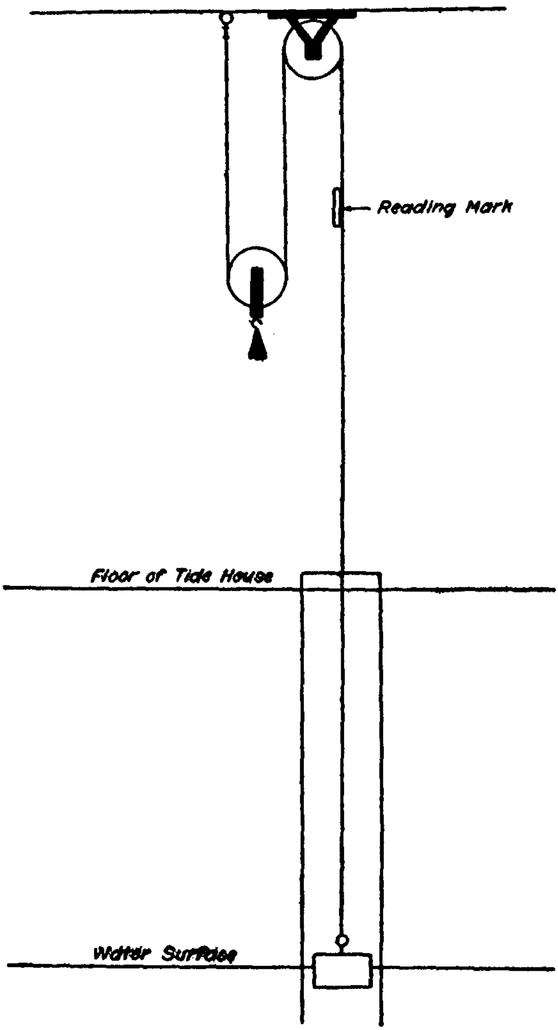

FIGURE 2.—Tape gauge

poise and connecting tape. The shifting of the tape from one side of the supporting pulley to the other side may cause a slight difference in the plane of flotation, which, although too small to be of material importance in the daily tape readings, must be taken into account in reducing the plane of flotation to a mean sea-level reading when referring the tape datum to bench marks.

7. In order to make this reduction, the tape reading taken at the reading mark at the time the measurements are made should be noted. In taking this reading it is assumed that the looped portion of the tape is below the reading mark.

Let R^1 = tape reading at time of measurement.
R = tape reading corresponding to mean sea level.
D = diameter of float in inches.
t = weight of tape per linear foot.
W = weight of a cubic foot of water at tide station.

The cross section of the float is $\frac{\pi D^2}{576}$ square feet and the bouyancy due to an immersion of 1 foot of a cylinder of the same diameter is $\frac{\pi WD^2}{576}$ pounds. Therefore, when the float is operating under normal conditions, an application of a force of 1 pound would change the plane of flotation by $\frac{576}{\pi WD^2}$ feet. When the apparatus is arranged as in Figure 2 with the counterpoise supported by a movable pulley, the shifting of 1 linear foot of tape from one side of the supporting pulley to the other side will cause a change of $1\frac{1}{2}t$ pounds in the pull on the float and the plane of flotation will be changed by $\frac{864\,t}{\pi WD^2}$ foot. The total correction to be applied to the plane of flotation as obtained by direct measurement, in order to reduce to the mean sea level value, is $\frac{864\,t}{\pi WD^2}(R-R^1)$ foot.

8. Taking the average weight of sea water along the coast as 64 pounds per cubic foot and the weight of the phosphor bronze tape as 0.011 pound per linear foot (the approximate weight of the tape now being used), the corrections for the portable gauge float and the standard gauge float are as follows:

.0045 $(R-R^1)$ foot for the 3¼-inch portable gauge float.

.00065 $(R-R^1)$ foot for the 8½-inch standard gauge float.

9. The elevation of any bench mark above the datum of the tape gauge is obtained by adding the tape reading of the plane of flotation as determined by the above measurements to the elevation of the bench mark above the reading mark of the gauge, the latter being determined by spirit leveling. If the bench mark is below the reading mark, the difference should be subtracted from the tape reading of the plane of flotation.

10. Care of tape gauge.—After the relation of tape gauge to bench marks has been determined by the measurement described above, any changes in the apparatus which might in any way affect the plane of flotation are to be carefully avoided; and in case of any accident to the gauge the matter should be immediately reported to the office.

AUTOMATIC TIDE GAUGE

11. There are two types of automatic tide gauge used by the United States Coast and Geodetic Survey, which are usually designated as the standard and the portable gauges. The standard gauge is designed chiefly for use at primary tide stations and the portable gauge for use at temporary tide stations established by hydrographic parties. Both gauges are described in considerable detail on pages 13 to 38 of Special Publication No. 139. The portable automatic tide gauge is also described in Special Publication No. 113. For the convenience of the tide observer at a primary tide station there are given below the page references in Special Publication No. 139 for the different parts of the standard automatic tide gauge, together with such additional comments as may be helpful to the observer.

12. Clocks.—See page 16 of Special Publication No. 139. In some of the gauges there have been recently installed a new clock unit consisting of two clocks mounted on a frame which is secured to the clock case by four winged nuts, the entire unit being easily removed from the case when necessary. The two clocks are fundamentally the same, and each is provided with two mainsprings. The one used for the motor clock is connected to a gear which operates the main cylinder. The one used for the time clock is provided with a cam which, acting upon a lever, stretches a spring attached to the back of the clock case. On the exact hour the spring is released and operates the hour-marking device. In this unit the time clock is on the right side of the case, the relative positions of the time and motor clock being reversed from the previous arrangement.

13. Removing or replacing clocks.—If the gauge is equipped with the clock unit described in the preceding paragraph, both clocks will be removed together as a unit. The toothed wheel that operates the main cylinder and the lever that operates the hour-marking device must first be disconnected from their respective shafts. The four winged nuts at the back of the clock case are then removed and the unit is lifted out. When installing a new unit special attention must be given to the attachment of the lever of the hour-marking device. Several trials may sometimes be necessary in order to obtain an adjustment which will give satisfactory hour marks. When attaching this lever it is suggested that the minute hand of time clock be set about five minutes past the figure "XII."

14. In the gauges in which the clocks are mounted independently in the clock case it will generally be found most convenient to take off the hands and face of the clock which is to be removed. The toothed wheel at the back of the motor clock or the lever of the hour-marking device at the back of the time clock must then be disconnected. Next remove the screws or winged nuts which secure the clock to the case, and the clock can be lifted out. When installing a new clock in an old gauge difficulty may be experienced in bringing the corresponding screw holes in line with each other. In such cases it will be sufficient to use only three of the screws. Care should be taken not to draw the screws too tight. In setting the screws in position, if a magnetized screw driver is not available it will be found convenient to rub soap in the slot of the screw head. This will cause the screw to cling to the screw driver while being placed in position.

15. When connecting the lever of the hour-marking device to the shaft from the time clock consideration must be given to the adjustment of the hour-marking device, and it will be found most convenient to complete this adjustment before replacing the face of the clock. In the older time clocks the tripping device may be released at will when testing the adjustment by raising a small wire lever near the upper part of the clockworks. In the time clock of the later clock unit there is no such lever, but the testing may be done by turning the minute hand around the dial past the figure "XII."

16. Care of clocks.—Each of the clocks will run for eight days with one winding, but it is desirable that they be wound twice a week. The clocks may be regulated and corrected as similar clocks in ordinary use. To avoid injury to the hour-marking device, the minute hand of the time clock must not be turned backward when between 10 minutes before and 10 minutes after the hour mark "XII." The hour hand, however, may be turned in either direction, so if it is necessary to set the clock back five minutes this may be accomplished by turning the hour hand backward a full hour and then turning the minute hand forward 55 minutes. If a clock consistently runs fast day after day, the regulating lever should be moved slightly toward the letter "S" on the left; but if the clock is running slow, the lever should be moved toward the letter "F" on the right, care being taken not to move the lever too much in order to avoid introducing an error in the opposite direction. If the loss or gain in any one day is less than three minutes, it is, in general, inadvisable to move the regulator unless there has been a corresponding loss or gain on a number of consecutive days.

17. If either clock is found to be stopped when the gauge is visited by the tide observer, he should note on the record the time of stopping as indicated by the hands of the clock, specifying which clock is affected. For example, "Time clock stopped 11:23." It may not always be known whether the clock stopped in the forenoon or afternoon, or even the exact day may be unknown, but the hour and minute should always be noted; and if the cause of the stopping is known, this should also be mentioned.

18. When a clock is found stopped attention should be given to the following possible causes:

(*a*) Note whether the clock needs winding.

(*b*) Note whether the hour and minute hands are together; if so, it is possible that the stopping has been caused by an interference between the hands. A greater clearance can sometimes be obtained by pressing the hour hand back toward the face of the clock. Note should also be made whether there is any interference between the minute and second hands.

(*c*) If the time clock has stopped, note whether the minute hand is near the figure "XII"; if so, it is possible that the stopping has been caused by the jamming of the hour-marking device, and this should be examined. The adjustment of the curve-tracing pencil should be such that the tripping hook does not press tightly against the tripping rod.

(*d*) The stopping of the motor clock may be caused by the jamming of the record paper in such a manner as to prevent the main cylinder from turning. When this occurs the cause of the jamming should be sought.

(*e*) Sometimes a clock may stop frequently because of a slight flexure in the frame caused by the screws securing it to the clock case being drawn too tight. If a clock which has just been installed gives trouble, it may be from this cause. A slight loosening of the screws may be helpful in such cases.

19. If either clock does not run satisfactorily and the tide observer finds that he is unable to remedy the trouble himself, the matter should be reported to the office in order that a new clock may be shipped to him. In an emergency in which a considerable loss of record might result while waiting for a new clock the observer may secure the services of a local jeweler at a reasonable rate to make such repairs as may be necessary. This office should be immediately notified in order that arrangements can be made for the jeweler to be paid directly by the office.

20. Rollers.—The three rollers of the gauge are described on page 16 of Special Publication No. 139. When connected with the clock the main cylinder rotates once in 12 hours and moves the record paper forward at the rate of 1 inch per hour. The receiving roller has at one end a small drum provided with a pawl and ratchet. When the gauge is in operation a cord wound around the drum and attached to a tension weight automatically winds the record paper on the receiving roller. The supply roller and receiving roller may each be released from the gauge by pressure on two pins projecting up from the bearings. When replacing these rollers on the gauge the ends with the removable flanges should usually be placed nearest the clock case, but if it is found that the record paper has a tendency to ride up on one of the flanges of the main cylinder, the supply roller may be turned end for end and used in the position in which the best results are obtained.

21. Tension spring.—This spring is described on page 17 of Special Publication No. 139.

22. Tension weight.—This weight is described on page 17 of Special Publication No. 139. When installing the tension weight it is generally best to lead the cord from the gauge to a pulley in the ceiling of the tide house and then suspend the weight from a movable pulley. This arrangement will permit the weight to act through a considerable period of time without attention and will lessen the danger of the weight reaching the limit of its fall during the absence of the tide observer. If it should be impracticable to suspend the tension weight from the ceiling of the tide house, an alternative arrangement is to have a separate compartment built under the floor, and adjacent to the float well, into which compartment both the tension weight and the counterpoise weight may be led. The tension-weight cord should be wound up each day the tide station is visited.

23. Pencil screw.—Described on page 18 of Special Publication No. 139. The threads at each end of the pencil screw are turned down to prevent the pencil arm from jamming on reaching the extreme limits of the rod.

24. Cleaning pencil screw.—Special attention must be given to keeping the pencil screw clean. Failure to attend to this is one of the most common, although least suspected, sources of trouble in the operation of the instrument. At frequent intervals the pencil screw should be wiped clean with a piece of cloth moistened with gasoline. From time to time, especially when changing the record paper at the end of each month, the pencil arm should be run back and forth by hand while giving the screw a more thorough cleaning. Care should be taken while doing this work not to slacken the float wire enough to let it spring off the drum.

25. Sometimes there may be a sticking when the pencil screw is apparently clean. This may be due to dirt which has collected inside the bearing of the pencil arm. In such cases it is necessary to run the arm to the extreme limit of the screw so that it becomes disengaged from the thread. The application of kerosene or gasoline with a squirt can while alternately engaging and disengaging the arm on the screw thread may remove the difficulty. Oil should not be put on the screw, since it tends to catch the dust and to gum the surface of the screw.

26. The principal indications of a dirty pencil screw are as follows: (1) A distorted tide curve, especially steps in the curve on a rising or falling tide and a flattening of the curve at high or low water; (2) a tendency of the recording pencil to raise off the paper on a falling tide and to dig into the paper on a rising tide, sometimes with sufficient force to tear the paper; and (3) the frequent breaking or tangling of the float wire.

27. Pencil arm.—This is described on page 18 of Special Publication No. 139. The pencil arm moves along the pencil screw toward the clock case on a rising tide and in the reverse direction on a falling tide. At an unusually high or low tide the pencil arm may move to the extreme end of the pencil screw and become disengaged from the screw thread. Springs are provided on each side of the arm to force it back upon the screw thread when the tide reverses. The pencil arm contains a holder in which either an ordinary or special automatic pencil can be used. It is important that the pencil should be sufficiently soft to trace a distinct line which will remain legible for a long time.

28. Pencil-arm adjustment.—The exact position of the pencil arm is unimportant. The position should be such that the record is near the middle of the paper at mean tide level, with no danger of its running off either edge during ordinary extreme high or low tides. The approximate adjustment of the pencil arm is usually taken care of when installing or replacing the float and counterpoise wire. A closer adjustment can afterwards be made by loosening the two nuts which secure the float-wire drum to the gauge. The pencil screw which moves the pencil arm can then be turned independently of the float-wire drum and brought to any desired position. Before loosening the clamping nuts, however, both the float-wire drum and the counterpoise drum should be held in such a manner as to prevent the wires from springing off and becoming tangled, and care should be taken not to release either until the clamping nuts have been again tightened after the adjustment has been made.

29. Hour-marking device.—This is described on page 19 of Special Publication No. 139. In the older gauges the hour-marking device is operated by a time clock with a regular striking mechanism. In the new clock unit described on page 5 of this publication the time clock has no such striking mechanism but has a cam attached to the main shaft, and this cam acts upon a lever that gradually stretches a spring at the back of the clock case. On the exact hour the lever drops, releasing the spring and causing the tripping rod to strike the hook on the pencil holder, thus producing an hour mark similar to that of the older gauges. The advantage of the newer type of gauge is that the work of stretching the spring is distributed over a large portion of the hour, while in the older gauge the entire work of making the hour mark is done at the time of the striking of the clock.

30. Adjustment of hour-marking device.—In order that the hour marks may be clear and distinct, special attention must be given to the adjustment of the hour-marking device. In general, this will depend upon the position of the recording pencil in the holder. This should generally be secured in such a position that the hook attached to the holder just clears the tripping rod or rests very lightly upon it. If the space between the hook and tripping rod is too great, the tripping of the latter will not move the pencil; if, on the other hand, the hook presses too tightly against the tripping rod, it may prevent the latter from moving at all and possibly cause the stopping of the time clock. In the new clock unit the space between the tripping rod and the hook on the pencil holder slowly increases during the last half of each hour, and the above instructions apply only to the earlier part of the hour.

31. If the gauge is provided with a fixed position for the recording pencil or if satisfactory hour marks can not be obtained through an adjustment of this pencil, it may be necessary to change the positions of the levers connecting with the clock. If a lever is secured to its shaft by a pin, a change by the tide observer will not usually be practicable; but if secured by a clamping screw, the position of the lever may be conveniently changed as desired. In the older type of gauge the only adjustment is for the lever attached to the spindle from the time clock (26, fig. 7, Special Publication 139). When changing this adjustment it is suggested that the face of the time clock be first removed in order that the observer may note the position of the releasing lever inside the clock. The lever at the back of the clock case may then be clamped in different positions until satisfactory results are obtained, the adjustment being tested by tripping the striking mechanism by hand. In the new clock unit there are two lever adjustments possible, one on the clock spindle and the other on the tripping rod. Successive trials will enable the tide observer to obtain the best results.

32. Datum pencil holder.—This is described on page 18 of Special Publication No. 139. The datum pencil holder should be so adjusted that the arm carrying the curve-drawing pencil may pass it without interference; and if an ordinary pencil is used in the holder, it should be cut short to insure ample clearance. The exact position for setting the datum-line pencil is not important, since its actual position relative to the tide curve is afterwards calculated by the tabulator from comparative notes made by the observer. It is desirable, however, that after having been once set in any position it should not be changed except for good cause, which should be stated in the record. For convenience in tabulating, a position near the middle of the record paper is recommended for the datum-line pencil, but if it should be found that there is danger of interference when the curve-drawing pencil passes over the datum-line pencil, the latter may be moved to a position nearer one edge of the paper.

33. Float-wire drum.—This drum is described on page 17 of Special Publication No. 139. In addition to those listed, drums 8 and 10 inches in circumference are now available.

34. Scale of gauge.—The following table indicating the proper float-wire drum and pencil screw to be used for different ranges of tide supersedes a similar table given on page 19 of Special Publication No. 139. For an extreme range exceeding 24 feet a requisition should be forwarded to the office for a special drum.

For an extreme range between the following limits	Scale	Circumference of drum	Pencil screw pitch
		Inches	*Inch*
Less than 5 feet	1:6	6	1
From 5 to 7 feet	1:8	8	1
From 7 to 8 feet	1:9	9	1
From 8 to 9 feet	1:10	10	1
From 9 to 11 feet	1:12	12	1
From 11 to 15 feet	1:16	16	1
From 15 to 18 feet	1:24	12	½
From 18 to 24 feet	1:32	16	½

35. Limits of operation.—While the record paper is approximately 13 inches wide, the full width is not available for the tracing of the tide curve. The maximum range of tide that can be represented by an unbroken curve will vary from approximately 5½ feet for a scale of 1:6 to about 29 feet for a scale of 1:32. In some of the gauges the maximum range will be slightly greater.

36. If the actual range is a little in excess of that which can be represented by an unbroken curve, the record can usually be interpreted from a consideration of the following facts: When the pencil arm reaches the extreme limit of motion at either end of the pencil screw it becomes disengaged from the screw thread and remains stationary, the pencil tracing a straight line on the record, but at the end of each complete revolution of the pencil screw the straight line is broken by an inward jog toward the middle of the paper, which indicates that the height of the tide has changed by an amount equal to the circumference of the float-wire drum. Some gauges are constructed so that outward jogs toward the edge of the paper are made at the half turn of the pencil screw. When the tide reverses and the pencil arm is again engaged with the pencil screw thread the adjustment of the curve relative to the datum line will have changed by an amout depending upon the number of full turns of the pencil screw which occurred during the disengagement. A half turn will have no effect on this adjustment. By taking into account the jogs made during the disengagement of the pencil screw, the tide curve can be extended beyond the limits of the record paper when tabulating the record.

37. The extreme limit within which the present standard gauge can operate is determined by the amount of wire which can be wound upon the float-wire drum. With the drum 16 inches in circumference threaded for 18 turns of wire, the extreme limit is a range of 24 feet. For greater ranges a larger drum must be used.

38. Counterpoise drum.—This is described on page 17 of special Publication No. 139. The counterpoise drum is threaded to accommodate 18 turns of wire and will hold a little more than 8 feet of wire when filled.

39. Counterpoise weight.—This is described on page 18 of Special Publication No. 139. It is usually best to suspend the counterpoise weight from a movable pulley with supporting wires leading to ceiling of tide house (see fig. 8, p. 21, Special Publication 139). If this arrangement should be impracticable, an alternative plan is to have a separate compartment built on the side of the float well into which the weight may be suspended. It is undesirable, however, to lead the counterpoise weight in the float well itself, as there is danger of interference with the float on an extreme high tide, and, moreover, damage may result if the weight should accidentally fall on the float.

40. Sliding pulley.—This pulley is described on page 18 of Special Publication No. 139.

41. Float.—The float is described on page 17 of Special Publication No. 139. Before installing the float it is a good plan to pass several loose loops of wire through the supporting ring to aid in its recovery if the wire connecting it with the gauge should be broken.

42. Wire.—The wire used to support the float and the counterpoise weight is phosphor bronze or nickel-chromium, No. 23 American wire gauge. The nickel-chromium wire is somewhat stronger than the phosphor bronze wire of the same size and is now being substituted for the latter, which has been in use for a number of years. It is important that the size of the wire for the float should be exactly as indicated, as the float-wire drum is designed for this size, and any change would introduce an error in the scale of the gauge. For the support of the counterpoise weight the exact size is umimportant, and a strong cord may be substituted without introducing any error in the record.

43. Wire installation.—The installation of new wiring for the float and counterpoise is a matter of considerable importance, and the tide observer should give special attention to the following instructions: The principal aims should be to avoid sharp bends or kinks which may weaken the wire, to have the wires of such length that the float-wire drum and the counterpoise drum will each be about one-half filled when the water outside is at its mean level, and to have the counterpoise weight so placed that it will be free to move within the limits required for the rise and fall of the tide. All pulleys through which the wires are led should be arranged to permit the free passage of the wire without any unnecessary friction. The method of procedure when installing new wiring on the gauge is described on pages 22 and 23 of Special Publication No. 139.

44. Breaking of wire.—If trouble is experienced in the frequent breaking of the float wire, special attention should be given to the following possible causes:

(*a*) Clean the pencil screw thoroughly. A dirty pencil screw, which jams the pencil arm and causes the float wire to slacken and become tangled, is one of the most frequent causes of the breaking of the float wire.

(*b*) Care must be taken to have the wires so adjusted on both the float-wire drum and the counterpoise drum that each will be about half filled at mean tide level. This adjustment will be accomplished if the installation of the wire is done in accordance with the instructions. If proper attention is not given to this matter the wire may come off the drum at the time of an extreme high or low tide.

(*c*) Avoid leaving any obstruction in the path of the counterpoise weight within the limits of its motion. If this weight should come in contact with some object on a rising tide, it would probably result in the slackening of the float wire sufficiently to cause it to spring off its drum.

(*d*) All wires should be examined at frequent intervals to see that they are free to move without interference from any source, especial attention being given to the several pulleys through which the wires pass. Sometimes a wire may be jarred out of the groove of the pulley and become jammed on the side of the sheave. When placing the cover over the gauge care should be taken not to let it strike or rest against any of the wires.

(*e*) When installing wires care must be taken to avoid any sharp bend or kink which might weaken the wire.

45. Record paper.—The paper for the standard automatic tide-gauge record is furnished in rolls about 13 inches wide and 66 feet in length, which is sufficient for one month of record. The paper is plain and without ruling of any kind. After the tide curve has been traced upon the tide roll the record is called a marigram. At primary tide stations the tide roll should be changed on the first day of each calendar month or as soon thereafter as practicable. Instructions for placing the paper on the gauge and also for removing it are given on page 24 of Special Publication No. 139. On some of the gauges the datum-pencil rod (14, fig. 5, Special Publication 139) is removable, thereby making the changing of the tide roll more easily accomplished. When installing a new tide roll it is generally best to lead the paper from the supply roller directly to the top of the main cylinder rather than under the bracing rod, in order to eliminate unnecessary friction. When replacing the flanges on the supply and receiving rollers care should be taken to tighten the binding nuts sufficiently to prevent them from backing off and jamming against the bearings.

46. Cautions in regard to paper.—In general, very little difficulty is experienced with the smooth running of the paper, but attention should be given to the following matters:

(*a*) Care must be taken when installing a new tide roll to lead the paper evenly over the main cylinder and to start the winding smoothly on the receiving roller. If the paper tends to ride up on one of the flanges of the main cylinder, a better alignment can sometimes be obtained by reversing the supply roller end for end.

(*b*) The pencils used for both the curve and datum line should be fairly soft, No. 1 or No. 2 being recommended, and these must be adjusted not to bear too heavily upon the paper. A hard pencil pressing heavily against the paper may cause it to tear, especially in damp weather.

(*c*) If the paper is found turned under the main cylinder, the tension weight should be examined to see that it has not caught on some object and to see that the suppporting cord is free to move through its pulleys. The receiving roller should then be examined to see that it is not jammed, as this may happen if the nut that secures the flange on the roller works loose and backs off against the bearing.

(*d*) If the paper is found torn at the edges by the small pins at the ends of the main cylinder, the supply roller should be examined to see that it is free to move. Sometimes the extra friction produced by leading the paper under the bracing rod will be sufficient to cause the tearing. In general, the paper should be led directly from the supply roller to the main cylinder. The tearing can also be caused by excessive pressure of one of the pencils against the paper.

47. Comparative notes.—In order to be available for use, the record curve as traced by the automatic tide gauge must be referred to correct standard time and also to some fixed datum as defined by a tide staff or bench mark. This is accomplished by entering on the record each day the tide station is visited and at the beginning and end of each marigram the correct time as obtained from some reliable source and also staff readings as taken directly from an outside staff. (Fig. 3.) At some stations a tape gauge (p. 2) is used either with or as a substitute for an outside staff. It is of the greatest importance that the correct time and staff readings

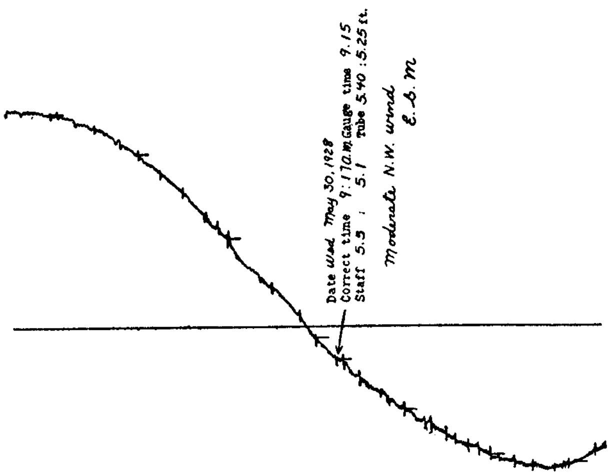

FIGURE 3.—Tide curve and comparative note

be obtained independently of the automatic gauge and then entered on the record with a tracer indicating the exact point of the tide curve to which they apply, this point being the position of the recording pencil at the time the reading is taken. The exact point of the curve may also be indicated by a short vertical line made by slightly rocking the float-wire drum while holding the wire to prevent it from springing off the drum, or by a short horizontal line made by tripping the hour-marking device by hand. The fact that the true time is written in the note will prevent this short horizontal line from being mistaken for a regular hour mark.

48. A rubber stamp with suitable inscription is furnished to each tide observer. In entering the date it is desirable to include the day of the week as a check on the day of the month. The correct time is to be taken from the observer's watch, which should be compared with standard time at frequent intervals. If, however, the observer's watch is set in accord with any other kind of time, such as "daylight-saving time," an allowance can be made and the entry given in standard time. The gauge time is to be taken from the time clock on the gauge, this clock being the one which actuates the hour-marking device.

49. The gauge time recorded in the note should be the time as indicated before any correction is made, so that the difference between the correct time and the gauge time will indicate the amount the clock has lost or gained since the previous visit to the gauge. After the note has been made on the marigram the gauge clock should be corrected and regulated if necessary. (See p. 7.) The gauge clock is to be set according to standard time throughout the year, regardless of the temporary use of daylight-saving time in some localities. The times as entered in the comparative note may be given either according to the 24-hour system, in which the afternoon hours are numbered consecutively above 12 hours for noon, or according to the usual 12-hour system. In the latter case care must be taken to indicate the forenoon and afternoon times by a. m. and p. m.

50. The method of reading the tide staff is explained on page 2. Sometimes there may be considerable wave motion in the vicinity of the tide staff, due to winds. The highest and lowest points reached by the waves are to be entered in the comparative note, the highest readings being placed first, with the lowest following in the spaces after the word "staff." If the tide staff is equipped with a glass tube, the highest and lowest readings of the water in the tube should also be recorded in the space following the word "tube." When the water is calm the same readings may be repeated for both highest and lowest.

51. At tide stations equipped with a tape gauge the highest and lowest tape readings are to be recorded at each visit to the tide station, and if there is also a tide staff at such station, the latter should be read and recorded when the weather is suitable for the purpose.

52. Portable automatic tide gauge.—Although the portable automatic tide gauge was designed chiefly for use at temporary tide stations, it may also be used at a primary tide station if a standard gauge is not available. The portable tide gauge is described on pages 29 to 38 of Special Publication No. 139.

FLOAT WELL

53. The float well is a vertical tube or square box partly open at the bottom designed to contain the float operating an automatic

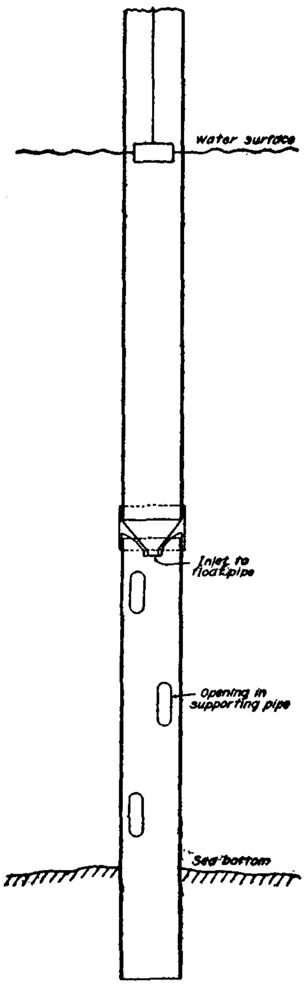

FIGURE 4.—Iron float well

or tape gauge and to dampen the effects of the wind waves. The float wells now generally used by this survey are constructed either of wood or iron. The wooden float well appears to be best adapted for protected localities, but for tide stations on the outer coasts exposed to the heavy seas an iron or steel pipe is used on account of its strength. The wooden float well is described on page 20 of Special Publication No. 139.

54. Iron float well.—An iron float well (fig. 4) is usually made up of sections of stock pipe connected by standard threaded couplings, galvanized pipe being preferred because of its greater durability. For the standard automatic tide gauge, pipe 12 inches in diameter is generally used, but for a tape gauge, pipe 4 inches in diameter is sometimes adopted. A special conical-shaped casting (fig. 5) with a hole at the apex for intake is provided by the

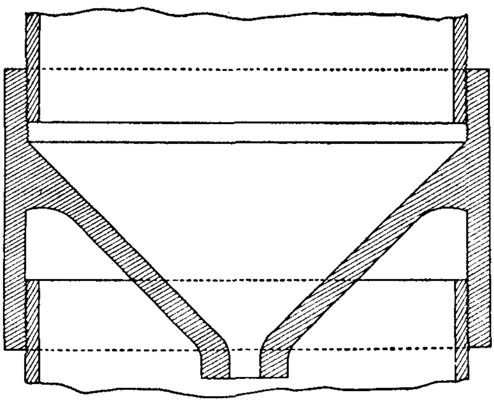

FIGURE 5.—Intake coupling for iron float well

office. This casting, which is installed with the apex downward, is threaded to serve also as a coupling and permits an additional supporting section of pipe to be placed below the intake. The supporting section must contain several large openings for the access of water to the intake. For a 12-inch float well, six such openings each approximately 3 inches wide by 9 inches long are usually provided, and these are arranged in pairs on opposite sides of the pipe and facing in different directions, the center of the upper pair being about a foot below the top end of the supporting section and the others arranged with centers approximately 3 and 5 feet below the top of the pipe. For a 4-inch pipe, the openings in the supporting section should be about 2 inches in diameter and arranged similarly to those in the larger pipe. When installed, the supporting section is sunk several feet into the ground.

55. Intake to float well.—The intake to a float well should be of such size that rough water on the outside will leave an unmistakable trace upon the record. In protected localities, an intake 1½ inches in diameter is recommended for a 12-inch float well, but for places exposed to heavy seas an intake from three-fourths to 1 inch in diameter is sufficient. The intake should be located several feet below the lowest probable tide and consist of a single large opening rather than several small ones. An intake in the bottom of a float well is more easily kept open than one in the side of the well. In a wooden float well the most convenient position for the intake is in a lower corner of a sloping bottom, the corresponding corner at the top being marked for identification, preferably by beveling off the corner sufficiently for the purpose. For an iron float well the office provides a special conical inlet coupling (fig. 5) with the intake in the center at the apex of the cone. The tide

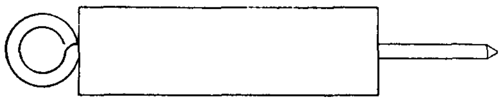

FIGURE 6.—Cleaning tool for float well

observer should be familiar with the position of the intake in the float well at his tide station.

56. Clearing float-well intake.—See page 27, Special Publication No. 139. A frequent cause of the clogging of the opening in an iron float well is the accumulation of iron-rust scales which have dropped from the sides of the pipe. If the intake of the float well is near the bottom of the harbor, a clogging may be caused by the accumulation of mud or sand around the outside of the well.

57. When cleaning the intake it is generally necessary to remove the float from the well; and to avoid any tangling of the float wire when raising the float, the wire should be secured by a clamp or looped around some convenient object to take up the slack. When cleaning an iron float well which is provided with a standard inlet coupling the special cleaning tool (fig. 6) is lowered into the well by a rope, and a clogged intake can usually be cleared without difficulty by successive tappings with this tool. If the intake is in the side of the well instead of the bottom, it may be necessary to work on the outside from a boat. When the position of the opening is known the work can usually be done without great difficulty by use of a boat hook at the time of the low tide.

58. To prevent freezing.—See pages 27 and 28 of Special Publication No. 139 for use of kerosene in float well. A 12-inch cylindrical pipe will require about 6 gallons of kerosene for each foot of height in the column of kerosene needed, and a wooden float well measuring 12 inches square on the inside will require about 7½ gallons for each foot in height. The column of kerosene will float on top of the water in the well with the surface of the kerosene a little higher than the surface of the water on the outside, the difference being equal to about one-eighth the whole column of kerosene. When an iron float well is used kerosene placed in the well at the time of installation may remain for a number of years with very little loss from leakage or evaporation. In a wooden float well, however, there is usually more or less leakage through the seams, and the supply of kerosene must be renewed each winter and possibly at intervals throughout the winter. When necessary to purchase kerosene for this purpose the tide observer should make a request to the office for proper authority in order that arrangements can be made for payment.

TIDAL BENCH MARKS

59. A bench mark is a definite point on a more or less permanent object used as a reference for elevations. Bench marks established in the vicinity of a tide station for the purpose of preserving the tidal planes determined from the observations at the station and making them available for future use are known as tidal bench marks. These bench marks serve as the basis for elevations which are carried by levels to numerous other bench marks established in various parts of the country. For a detailed discussion of bench marks, see pages 38 to 43 of Special Publication No. 139.

60. Primary bench mark.—While there are generally several bench marks in the vicinity of each primary tide station, one of these which may be conveniently located is selected as the "primary bench mark" for checking the elevation of the tide staff from time to time. It is desirable that the primary bench mark be as near the tide staff as practicable, but it should be located on the solid ground rather than on a wharf which may be more or less unstable. A temporary mark, however, may be established on a wharf close to the tide staff to permit the latter to be replaced at the same elevation if it should be removed for any cause. The tide observer should be familiar with the location of the primary bench mark and also with the other bench marks in the vicinity of the tide station and should report to the office any changes in any of them which may come to his attention.

TEMPERATURE AND DENSITY OBSERVATIONS

61. Tide observers who take temperature and density observations should be guided by Form 457 (fig. 7), which is used for

Form 457
Department of Commerce
U. S. Coast and Geodetic Survey

DENSITY AND TEMPERATURE

Station: Atlantic City (Steel Pier), N. J. Lat. 39° 21′ N. Long. 74° 25′ W.
Month: July Year: 1928 Observer: [illegible]
Warmest Sea Water: 24.2° Date: July 26th *Heaviest Sea Water: 1.02351 Date: July 2nd
Coldest Sea Water: 16.9° Date: July 7th *Lightest Sea Water: 1.02234 Date: July 27th & 28th

1928 Day of month (July)	Time of observation h. m.	Temperature: Outdoor air °	Temperature: Sea water °	Temperature: Water in jar °	Hydrometer No.	Density: Observed reading	Density: *Reduced value 15° C.	Remarks
1	10 18	26.0	15.4	17.6	227	10 238	10 243	
2	11 38	20.0	18.8	20.4		10 239	10 251	
3	11 33	24.2	20.0	21.0		10 232	10 246	
4	11 10	23.6	18.6	19.4		10 238	10 247	
5	11 11	22.2	17.9	19.4		10 236	10 244	
6	11 13	22.3	16.6	16.6		10 240	10 243	
7	11 23	22.7	16.9	16.8		10 244	10 248	
8	10 52	22.6	18.3	19.1		10 234	10 242	
9	11 09	24.8	17.6	19.6		10 233	10 242	
10	11 24	22.0	18.4	19.0		10 233	10 241	
11	11 22	20.2	17.6	18.3		10 234	10 241	
12	11 07	20.8	17.8	18.8		10 231	10 238	
13	11 17	21.1	17.4	18.1		10 232	10 238	
14	11 26	22.0	17.3	18.2		10 233	10 239	
15	11 03	24.0	17.8	19.6		10 230	10 239	
16	11 18	24.4	19.1	20.2		10 229	10 240	
17	11 08	27.8	19.5	21.6		10 221	10 236	
18	11 12	26.8	18.6	21.2		10 228	10 242	
19	11 16	27.0	20.1	21.4		10 229	10 243	
20	11 01	28.3	19.0	21.6		10 226	10 240	
21	11 24	21.2	17.7	18.8		10 234	10 241	
22	12 59	23.0	19.6	20.3		10 229	10 241	
23	11 13	28.8	19.8	21.6		10 226	10 238	
24	11 24	32.7	20.7	22.6		10 223	10 240	
25	10 50	27.2	21.8	23.4		10 216	10 235	
26	12 33	26.2	22.6	24.1		10 217	10 231	
27	13 32	26.3	24.1	26.0		10 211	10 234	
28	11 18	27.9	24.2	26.2		10 210	10 234	
29	13 06	28.8	21.2	22.6		10 220	10 237	
30	11 12	27.1	21.3	22.4		10 223	10 240	
31	11 36	24.8	21.7	22.6		10 222	10 239	
Sum			31 / 5959				31 / 31.7459	
Mean			19.22				[illegible]	

* Not to be filled out by observer.

[illegible] (over) Density reduced by [illegible] date August 16, 1928.

FIGURE 7.—Form 457, Density and Temperature

recording these observations. The observations should be taken each day at the time the tide station is visited.

62. Temperatures.—In general, the temperatures will be given in accordance with the centigrade scale, but if a Fahrenheit thermometer is being used for the air temperatures, the letter "F" should be placed at the top of the column containing these temperatures. The temperature of the sea water must be taken in the bucket immediately after the water has been drawn up before it has had time to be affected by the air temperature. The temperature of the water in the hydrometer jar is for use in reducing the hydrometer reading and should therefore be taken at the time the hydrometer is read. The scale of the centigrade thermometer is usually divided into degrees and half degrees, and the reading may be taken to the nearest half degree.

63. Sometimes the column of mercury in the thermometer may become separated in sections, causing erroneous readings. If the broken sections can not be easily jarred together by hand, it is suggested that a cord be attached as illustrated in Figure 8 and the

FIGURE 8.—Method of connecting broken mercury column in thermometer

thermometer whirled around rapidly. This will usually unite the broken sections of the column.

64. The table on page 24, which gives equivalent readings in centigrade and Faherenheit thermometer scales, affords a convenient means for converting the readings from one of these scales to those of the other scale between the limits 20° to 39.5° C. Beyond these limits the following formula may be used: Fahrenheit reading$=32° +$ (centigrade reading$\times 1.8$).

Conversion of centigrade to Fahrenheit scale

°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.	°C.	°F.
−20.0	−4	−10.0	14	0.0	32	10.0	50	20.0	68	30.0	86
−19.5	−3	−9.5	15	0.5	33	10.5	51	20.5	69	30.5	87
−19.0	−2	−9.0	16	1.0	34	11.0	52	21.0	70	31.0	88
−18.5	−1	−8.5	17	1.5	35	11.5	53	21.5	71	31.5	89
[1]−18.0*	0	[1]−8.0*	18	[1]2.0*	36	[1]12.0*	54	[1]22.0*	72	[1]32.0*	90
−17.5	0	−7.5	18	2.5	36	12.5	54	22.5	72	32.5	90
−17.0	1	−7.0	19	3.0	37	13.0	55	23.0	73	33.0	91
−16.5	2	−6.5	20	3.5	38	13.5	56	23.5	74	33.5	92
−16.0	3	−6.0	21	4.0	39	14.0	57	24.0	75	34.0	93
−15.5	4	−5.5	22	4.5	40	14.5	58	24.5	76	34.5	94
−15.0	5	−5.0	23	5.0	41	15.0	59	25.0	77	35.0	95
−14.5	6	−4.5	24	5.5	42	15.5	60	25.5	78	35.5	96
−14.0	7	−4.0	25	6.0	43	16.0	61	26.0	79	36.0	97
−13.5	8	−3.5	26	6.5	44	16.5	62	26.5	80	36.5	98
−13.0	9	−3.0	27	7.0	45	17.0	63	27.0	81	37.0	99
−12.5	10	−2.5	28	7.5	46	17.5	64	27.5	82	37.5	100
[1]−12.0*	10	[1]−2.0*	28	[1]8.0*	46	[1]18.0*	64	[1]28.0*	82	[1]38.0*	100
−11.5	11	−1.5	29	8.5	47	18.5	65	28.5	83	38.5	101
−11.0	12	−1.0	30	9.0	48	19.0	66	29.0	84	39.0	102
−10.5	13	−0.5	31	9.5	49	19.5	67	29.5	85	39.5	103

[1] * When two values in the column for the centigrade scale are given for the same whole degree in the Fahrenheit scale the one indicated by the asterisk should be taken when converting the Fahrenheit readings into the centigrade scale.

65. Density.—The unit of density is the density of fresh water at a temperature of 4° C. The actual density of the water at tide stations may vary from a little less than unity for fresh water at a temperature of more than 4° C. to approximately 1.031 for the heaviest sea water. To provide for this entire range of density three hydrometers are necessary—one with a scale ranging from 0.996 to 1.011, a second with scale from 1.010 to 1.021, and a third with scale from 1.020 to 1.031. The particular hydrometers to be used at any tide station will, of course, depend upon the density of the water, and the observer will select the hydrometers which will float with the stem partly immersed.

66. The hydrometers are numbered for identification and have been tested by the Bureau of Standards. Tables of correction have been furnished when necessary. The number of the hydrometer used for each observation should be entered in Form 457.

67. The method of reading the scale of the hydrometer, which is graduated downward, is illustrated in Figure 9. Except for densities less than unity, the first two figures will always be 1.0, as printed in the column of density in Form 457. The two figures immediately following will be determined by the first numbered scale graduation above the surface of the water, and if this is less than 10, it should be prefixed by a zero (0). The last figure, representing the fourth decimal place in the reading, is determined by the smallest subdivisions, each of which represents a change of

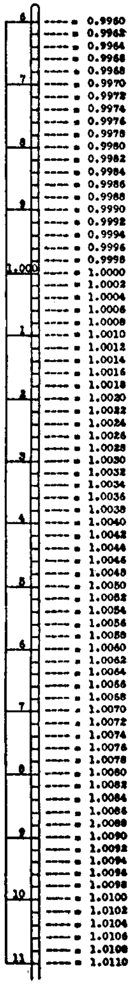

FIGURE 9.—Graduations of hydrometer scale

0.0002 in density. If the density of the water is less than unity, the printed figures 1.0 in the form should be stricken out and the reading as illustrated in Figure 9 substituted.

68. The water whose density is to be tested is poured in the jar provided for the purpose and the hydrometer floated in the same. A thermometer is then placed in the jar to obtain the temperature for correcting the density reading. A sufficient time should be allowed to elapse to permit the hydrometer, thermometer, and retaining jar to acquire the same temperature as the water. In reading the hydrometer the eye should be brought to the level of the surface of the water and the reading taken which appears to coincide with the level surface. After using, the jar and instruments are to be carefully cleaned to prevent the accumulation of salt.

69. Reduction of density.—The density of sea water as observed depends not only upon the amount of soluble matter contained in a unit volume but also upon the temperature of the water at the time of observations. It is therefore necessary to reduce the observed densities to some standard temperature in order that they may be comparable and indicate the amount of matter held in solution.

70. The table on pages 27–29 gives a series of differences to be applied to the observed densities in order to reduce them to a standard temperature of 15° C., this table being based upon an article on the reduction of hydrometer observations in Appendix 6 of the United States Coast and Geodetic Survey Report for 1891. If the temperature of the water in the jar at the time of the density observation is less than 15° C., the hydrometer reading will be too great, and the tabular difference must be substracted as indicated by the negative sign. If the temperature of the water in the jar is greater than 15° C., the tabular difference must be added to the observed hydrometer reading.

71. The differences in this table, which are expressed in ten-thousandths of a unit, are given for each whole degree of temperature from 0° to 35° C., and for each change of 0.0010 in the density from unity to 1.0310. For observed densities less than unity, the top line of the table may be used without material error. The differences are to be applied to the observed density readings to obtain the reduced values. For example, suppose a hydrometer reading of 1.0244 has been taken when the temperature of the water in the jar is 11.5° C. The nearest observed density reading given in the table is 1.0240. Following this line, we find differences of −7 and −5 for temperature 11° and 12°, respectively, giving an interpolated difference of −6 for a temperature of 11.5°. This difference of −6 applied to the original hydrometer reading of 1.0244 gives 1.0238 as the reduced value.

72. In the heading of Form 457, the heaviest and lightest sea water refer to the reduced values.

Differences for reducing densities of sea water to 15° C.

Observed density	Temperature of water in jar													Observed density
	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	
	Diff.	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	
1.0000	−3	−4	−5	−5	−6	−6	−6	−6	−6	−5	−5	−4	−3	1.0000
1.0010	−4	−5	−6	−6	−6	−6	−6	−6	−6	−5	−5	−4	−3	1.0010
1.0020	−4	−5	−6	−6	−7	−7	−6	−6	−6	−6	−5	−4	−3	1.0020
1.0030	−5	−6	−6	−7	−7	−7	−7	−6	−6	−6	−5	−4	−3	1.0030
1.0040	−5	−6	−7	−7	−7	−7	−7	−7	−6	−6	−5	−4	−3	1.0040
1.0050	−6	−7	−7	−7	−8	−7	−7	−7	−7	−6	−5	−5	−4	1.0050
1.0060	−6	−7	−8	−8	−8	−8	−8	−7	−7	−6	−6	−5	−4	1.0060
1.0070	−7	−7	−8	−8	−8	−8	−8	−7	−7	−6	−6	−5	−4	1.0070
1.0080	−7	−8	−8	−8	−9	−8	−8	−8	−7	−7	−6	−5	−4	1.0080
1.0090	−8	−8	−9	−9	−9	−9	−8	−8	−7	−7	−6	−5	−4	1.0090
1.0100	−8	−9	−9	−9	−9	−9	−9	−8	−8	−7	−6	−5	−4	1.0100
1.0110	−9	−9	−10	−10	−10	−9	−9	−8	−8	−7	−6	−5	−4	1.0110
1.0120	−9	−10	−10	−10	−10	−10	−9	−9	−8	−7	−6	−5	−4	1.0120
1.0130	−10	−10	−10	−10	−10	−10	−9	−9	−8	−7	−6	−5	−4	1.0130
1.0140	−10	−11	−11	−11	−11	−10	−10	−9	−8	−7	−7	−6	−4	1.0140
1.0150	−11	−11	−11	−11	−11	−10	−10	−9	−9	−8	−7	−6	−4	1.0150
1.0160	−11	−11	−12	−11	−11	−11	−10	−10	−9	−8	−7	−6	−4	1.0160
1.0170	−12	−12	−12	−12	−12	−11	−11	−10	−9	−8	−7	−6	−5	1.0170
1.0180	−12	−12	−12	−12	−12	−11	−11	−10	−9	−8	−7	−6	−5	1.0180
1.0190	−13	−13	−13	−13	−12	−12	−11	−10	−9	−8	−7	−6	−5	1.0190
1.0200	−13	−13	−13	−13	−13	−12	−11	−11	−10	−9	−7	−6	−5	1.0200
1.0210	−14	−14	−14	−13	−13	−12	−12	−11	−10	−9	−8	−6	−5	1.0210
1.0220	−14	−14	−14	−14	−13	−13	−12	−11	−10	−9	−8	−6	−5	1.0220
1.0230	−15	−15	−14	−14	−14	−13	−12	−11	−10	−9	−8	−6	−5	1.0230
1.0240	−15	−15	−15	−14	−14	−13	−12	−12	−10	−9	−8	−7	−5	1.0240
1.0250	−16	−15	−15	−15	−14	−13	−13	−12	−11	−9	−8	−7	−5	1.0250
1.0260	−16	−16	−16	−15	−15	−14	−13	−12	−11	−10	−8	−7	−5	1.0260
1.0270	−17	−16	−16	−15	−15	−14	−13	−12	−11	−10	−8	−7	−5	1.0270
1.0280	−17	−17	−16	−16	−15	−14	−13	−12	−11	−10	−9	−7	−5	1.0280
1.0290	−18	−17	−17	−16	−16	−15	−14	−13	−12	−10	−9	−7	−5	1.0290
1.0300	−18	−18	−17	−17	−16	−15	−14	−13	−12	−10	−9	−7	−6	1.0300
1.0310	−19	−18	−18	−17	−16	−15	−14	−13	−12	−10	−9	−7	−6	1.0310

Differences for reducing densities of sea water to 15° C.—Continued

Observed density	Temperature of water in jar 12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°	23°	24°	Observed density
	Diff.	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	
1.0000	−3	−2	−1	0	1	3	4	6	8	10	12	14	16	1.0000
1.0010	−3	−2	−1	0	1	3	4	6	8	10	12	14	16	1.0010
1.0020	−3	−2	−1	0	1	3	5	7	8	10	12	14	17	1.0020
1.0030	−3	−2	−1	0	1	3	5	7	8	10	13	15	17	1.0030
1.0040	−3	−2	−1	0	1	3	5	7	9	11	13	15	17	1.0040
1.0050	−4	−3	−1	0	1	3	5	7	9	11	13	15	17	1.0050
1.0060	−4	−3	−1	0	2	3	5	7	9	11	13	15	17	1.0060
1.0070	−4	−3	−1	0	2	3	5	7	9	11	13	15	18	1.0070
1.0080	−4	−3	−1	0	2	3	5	7	9	11	13	15	18	1.0080
1.0090	−4	−3	−1	0	2	3	5	7	9	11	13	16	18	1.0090
1.0100	−4	−3	−1	0	2	3	5	7	9	11	14	16	18	1.0100
1.0110	−4	−3	−1	0	2	3	5	7	9	12	14	16	18	1.0110
1.0120	−4	−3	−1	0	2	3	5	7	9	12	14	16	19	1.0120
1.0130	−4	−3	−2	0	2	3	5	8	10	12	14	16	19	1.0130
1.0140	−4	−3	−2	0	2	3	5	8	10	12	14	17	19	1.0140
1.0150	−4	−3	−2	0	2	3	5	8	10	12	14	17	19	1.0150
1.0160	−4	−3	−2	0	2	4	6	8	10	12	15	17	19	1.0160
1.0170	−5	−3	−2	0	2	4	6	8	10	12	15	17	20	1.0170
1.0180	−5	−3	−2	0	2	4	6	8	10	12	15	17	20	1.0180
1.0190	−5	−3	−2	0	2	4	6	8	10	13	15	17	20	1.0190
1.0200	−5	−3	−2	0	2	4	6	8	10	13	15	18	20	1.0200
1.0210	−5	−3	−2	0	2	4	6	8	10	13	15	18	20	1.0210
1.0220	−5	−3	−2	0	2	4	6	8	11	13	15	18	21	1.0220
1.0230	−5	−3	−2	0	2	4	6	8	11	13	16	18	21	1.0230
1.0240	−5	−3	−2	0	2	4	6	8	11	13	16	18	21	1.0240
1.0250	−5	−4	−2	0	2	4	6	9	11	13	16	19	21	1.0250
1.0260	−5	−4	−2	0	2	4	6	9	11	13	16	19	21	1.0260
1.0270	−5	−4	−2	0	2	4	6	9	11	14	16	19	22	1.0270
1.0280	−5	−4	−2	0	2	4	6	9	11	14	16	19	22	1.0280
1.0290	−5	−4	−2	0	2	4	6	9	11	14	16	19	22	1.0290
1.0300	−6	−4	−2	0	2	4	6	9	11	14	17	19	22	1.0300
1.0310	−6	−4	−2	0	2	4	7	9	12	14	17	20	22	1.0310

Observed density	Temperature of water in jar 24°	25°	26°	27°	28°	29°	30°	31°	32°	33°	34°	35°	Observed density
	Diff.	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	*Diff.*	
1.0000	16	19	21	23	26	29	31	34	37	40	43	46	1.0000
1.0010	16	19	21	23	26	29	32	34	37	40	43	47	1.0010
1.0020	17	19	21	24	26	29	32	35	38	41	44	47	1.0020
1.0030	17	19	22	24	27	30	32	35	38	41	44	47	1.0030
1.0040	17	19	22	24	27	30	33	35	38	41	44	48	1.0040
1.0050	17	20	22	24	27	30	33	36	39	42	45	48	1.0050
1.0060	17	20	22	25	28	30	33	36	39	42	45	49	1.0060
1.0070	18	20	22	25	28	31	33	36	39	43	45	49	1.0070
1.0080	18	20	23	25	28	31	34	37	40	43	46	49	1.0080
1.0090	18	20	23	26	28	31	34	37	40	43	46	50	1.0090
1.0100	18	21	23	26	29	32	34	37	40	44	47	50	1.0100
1.0110	18	21	23	26	29	32	35	38	41	44	47	51	1.0110
1.0120	19	21	24	26	29	32	35	38	41	44	48	51	1.0120
1.0130	19	21	24	27	29	32	35	38	42	45	48	51	1.0130
1.0140	19	22	24	27	30	33	36	39	42	45	48	52	1.0140
1.0150	19	22	24	27	30	33	36	39	42	45	49	52	1.0150
1.0160	19	22	25	27	30	33	36	39	43	46	49	53	1.0160
1.0170	20	22	25	28	31	34	37	40	43	46	49	53	1.0170
1.0180	20	22	25	28	31	34	37	40	43	47	50	53	1.0180
1.0190	20	23	25	28	31	34	37	40	44	47	50	54	1.0190
1.0200	20	23	26	28	31	34	38	41	44	47	51	54	1.0200
1.0210	20	23	26	29	32	35	38	41	44	48	51	55	1.0210
1.0220	21	23	26	29	32	35	38	41	45	48	51	55	1.0220
1.0230	21	24	26	29	32	35	38	42	45	48	52	55	1.0230
1.0240	21	24	27	29	32	36	39	42	45	49	52	56	1.0240
1.0250	21	24	27	30	33	36	39	42	46	49	53	56	1.0250
1.0260	21	24	27	30	33	36	39	43	46	50	53	57	1.0260
1.0270	22	24	27	30	33	37	40	43	46	50	53	57	1.0270
1.0280	22	25	28	30	34	37	40	43	47	50	54	57	1.0280
1.0290	22	25	28	31	34	37	40	44	47	51	54	58	1.0290
1.0300	22	25	28	31	34	37	41	44	47	51	55	58	1.0300
1.0310	22	25	28	31	34	38	41	44	48	51	55	59	1.0310

32351—29——3

TABULATIONS AND REDUCTIONS

73. The tabulations and reductions should be neatly made in ink and in accordance with the forms as outlined in the following paragraphs. For interpolated values to fill in gaps caused by lost record red ink may be used, and these values should be indicated by brackets. The headings on each sheet are to be filled out as completely as possible, except that at the primary tide stations the dates for the beginning and ending of the observations may be omitted and the latitude and longitude need be entered only on first page for each year. The words "party of" may be taken as equivalent to "observer" when the latter has charge of the station. In the tabulations the hours of the day are to be designated consecutively from 0^h (midnight) to 23^h (11 p. m.), thus avoiding the terms "a. m." and "p. m." Standard time should be consistently used throughout the tabulations, regardless of the fact that "daylight-saving time" may have been temporarily adopted for the locality.

74. Marking the hours.—On the record from the standard tide gauge the hours are indicated by short horizontal lines. The hour begins at the instant the mark leaves the curve, the length of the stroke having no significance. The time notes entered on the record by the observer should be examined, and if it is found that the difference between the correct time and the gauge time does not exceed three minutes at any time, the hour marks as automatically made by the gauge may be accepted as correct and marked accordingly. The marks are to be numbered consecutively from 0 (midnight) to 23 (11 p. m.), and the numbering checked at each time note on the marigram. In order to expedite the work, the numbering of the odd hours may be omitted if desired. The beginning of each day at the 0 hour should be marked with the appropriate date.

75. In cases where the hour-marking device has failed to work or when the hour marks are unreliable on account of the time clock being appreciably in error the following method may be used: First, from the comparative time notes ascertain the position on the curve of the nearest exact hour. This is done by laying off 1 inch on a piece of paper and dividing it into 12 equal parts, the inch measured parallel to the datum line representing one hour on the tide curve and each of the divisions five minutes. The correct time of the point on the curve being known, as indicated by a time note, the nearest exact hour is laid off by means of this "time scale." Second, through the points thus found, indicating the exact hours, draw lines perpendicular to the datum line and extending across the paper. Third, prepare a "dividing scale" from a strip of paper somewhat longer than the greatest distance between the time notes on the marigram. On the edge lay off equal divisions about 1⅓₂ inches long. These divisions should be numbered consecutively from 0^h to 23^h and repeated if necessary. This scale is then adjusted obliquely between two consecutive cross lines passing through the correct hour points so that the numbers on the scale will agree with the hours represented by the cross lines. With the scale in this position, each division is marked on the marigram by a dot. Fourth, these hour dots are referred to the tide curve by lines drawn through the dots and perpendicular to the datum line. These hour lines are numbered in the same manner as the hour marks automatically made by the time clock.

76. Comparative readings (Form 455).—This form (fig. 10) is used to obtain the relation between the datum line of a standard automatic tide-gauge record and the datum adopted for the tabulations. The latter datum is either the zero of the tide staff or tape gauge in actual use, or has a definite relation to the same. At primary tide stations it is the aim to maintain a fixed datum for the tabulations throughout the entire series of observations, and constants are introduced to take account of any changes in the tide staff. The corrected setting as calculated in Form 455 represents the scale reading of the datum line as referred to the datum adopted for the tabulations. A movable scale, usually of glass, is used in making these tabulations. In using this scale the side on which the graduations are cut should always be kept down next to the paper to avoid errors due to parallax in reading. The numbering of the divisions may be written on the upper surface.

77. In the first three columns of Form 455, the tabulator notes, respectively, the date, the time of staff reading, and the water level as read on the staff or tape, these items being taken directly from the observer's notes on the tide roll. The staff reading entered in the form is the mean between the highest and lowest readings recorded, but if a glass tube is used on the staff, the reading entered in the form should be the mean of the tube readings. If a tape gauge is used, the word "staff" at the head of the third column may be changed to "tape," and the reading entered should be the mean of the highest and lowest tape readings.

78. The preliminary scale setting of datum line, to be entered in the heading of the form, may be arbitrarily chosen at any convenient value. This preliminary setting should preferably be of such a value that the scale readings from the tide curve will be from one-half to 1½ feet less than the corresponding staff readings. The

Form 455
DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
Ed. July, 1928

TIDES: COMPARATIVE READINGS

Station: Seattle, Washington   Lat. 47° 37'
Party of W. C. Meyer   Time meridian 120° W.   Long. 122° 20'
Obs. begin   Obs. end   Tabulated by C. D. A.   Date Feb. 14, 1928.
Tide Gauge No. 96   Scale 1:24   Preliminary scale setting of datum line 16.00 feet

DATE Year 1928 mo.	d.	TIME OF STAFF READING h.	m.	STAFF A feet	SCALE B feet	DIFFERENCE A−B feet	PHASE OF TIDE*	REMARKS
Jan.	3	14	00	18.90	18.30	0.60	F	Scale setting for Jan. 3 to Jan. 5
	4	14	00	19.25	18.60	0.65	H	Sum of differences 1.95
	5	14	00	19.60	18.90	0.70	H	Mean difference 0.65
								Preliminary setting 16.00
	5	15	16	19.20	23.00	−3.80	F	Setting for reduction
	6	13	55	18.45	22.30	−3.85	R	to tide staff 16.65
	7	14	58	18.55	22.30	−3.75	R	Constant for fixed datum − 0.03
	8	16	29	18.65	22.60	−3.95	H	Setting for reduction
	9	13	58	15.60	19.20	−3.60	R	to fixed datum 16.62
	10	14	58	14.85	18.60	−3.75	R	
	11	16	00	14.20	17.90	−3.70	R	
	12	11	00	18.55	22.40	−3.85	F	New float was installed
	13	9	59	20.10	24.00	−3.90	H	on Jan. 5th
	14	10	58	19.15	23.00	−3.85	F	
	16	11	30	17.90	21.75	−3.85	H	
	17	13	00	17.10	21.00	−3.90	F	
	18	13	00	17.25	21.10	−3.85	H	
	19	13	58	17.25	21.10	−3.85	H	
	20	14	00	17.55	21.50	−3.95	H	
	21	15	00	18.25	22.20	−3.95	H	
	23	15	02	17.45	21.20	−3.75	R	
	24	15	59	17.35	21.25	−3.90	R	
	25	15	58	16.00	19.80	−3.80	R	
	26	10	58	16.05	20.00	−3.95	F	Scale setting for Jan. 5 to Feb. 1
	27	10	00	18.45	22.35	−3.90	F	Sum of differences −96.25
	28	11	00	18.25	22.30	−4.05	F	Mean difference −3.85
	30	11	41	18.90	22.85	−3.95	F	Preliminary setting 16.00
	31	11	00	19.00	22.80	−3.80	H	Setting for reduction to tide staff 12.15
Feb.	1	12	01	18.80	22.60	−3.80	H	Constant for fixed datum −0.03
								Setting for reduction to fixed datum 12.12

FIGURE 10.—Form 455, Comparative Readings

scale reading selected for the comparison should be ruled across the glass scale on the underside.

79. The values in the fourth column of the form are obtained by placing the scale on the record with the preliminary setting in coincidence with the datum line and reading the height of the curve at the point to which the corresponding staff reading refers. These readings are to be taken to the nearest 0.05 foot. The difference between staff and scale reading is to be entered in the fifth column, and the phase of tide at the time the staff reading was taken in the next column. Any change in the adjustment of the gauge should be explained in the column of "Remarks."

80. If there has been no change in the adjustment of the gauge, the differences (A — B) should be approximately equal. If an individual value differs materially from the apparent average of all, it must be rejected and excluded from the computation of the mean. The rejection is indicated by encircling the value in question. The differences are now summed and a mean obtained, the result being carried to two decimal places. To this mean difference there is added the preliminary scale setting and also any constant that may be necessary to refer to any datum other than staff zero. When a constant is necessary it is furnished by the office. The algebraic sum of these quantities will give the corrected scale setting to be used in the tabulations of the hourly heights and the high and low waters.

81. If there has been any change in the adjustment of the gauge, such as would be caused by replacing a broken float wire, the introduction of kerosene in the float well, a change in the position of the datum line, etc., the differences will form distinct groups. In such cases separate means and corrected scale settings must be computed for each adjustment of the gauge.

82. Sometimes an extreme high or low tide may move the pencil arm (p. 9) to the extreme limit of its motion so that it becomes disengaged from the threaded portion of the pencil screw. If the change in the height of the tide beyond this limit is small, the pencil arm will automatically reengage the screw thread after the tide reverses without any change in the adjustment of the gauge, but if the tide continues to rise or fall after the disengagement of the pencil arm by an amount equal to or greater than the circumference of the float-wire drum, the adjustment of the gauge will be automatically changed. Each complete turn of the drum at such times will be found registered by a jog in the record near the edge of the paper, and each such turn will signify a change in the adjustment equal to the circumference of the float-wire drum in use. If such change takes place at the time of high water, the curve will be lowered and the scale readings diminished, but if it takes place at the time of low water, the curve will be raised and the scale readings increased.

83. In using Form 455 the tide roll should be taken as the unit, regardless of the beginning or end of the calendar month, and each

Form 362
DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY

TIDES: HOURLY HEIGHTS

Station: Seattle, Washington Year: 1928
Observer: W. C. Meyer Lat. 47° 37′ Long. 122° 20′
Time Meridian: 120° W Tide Gauge No. 96 Scale 1: 24 Reduced to Staff. of 1904

Month and Day	mo. Jan d. 1	d. 2	d. 3	d. 4	d. 5	d. 6	d. 7	Horizontal Sum
Day of Series	1	2	3	4	5	6	7	
Hour	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
0	15.1	15.5	15.4	13.9	12.0	9.0	6.6	87.5
1	14.4	15.7	16.6	15.9	14.8	12.1	9.5	99.0
2	13.5	15.4	17.0	17.3	17.1	15.1	12.8	108.2
3	12.5	14.8	16.9	17.9	18.6	17.5	15.8	114.0
4	11.7	14.0	16.5	17.8	19.2	19.0	18.0	116.2
5	11.6	13.3	15.7	17.3	19.1	19.6	19.4	116.0
6	12.3	13.2	14.9	16.4	18.5	19.5	19.8	114.6
7	13.7	13.7	14.6	15.5	17.4	18.7	19.5	113.1
8	15.4	15.0	15.0	15.0	16.3	17.6	18.6	112.9
9	17.6	16.5	15.9	15.2	15.6	16.3	17.1	114.2
10	19.2	18.2	17.2	16.0	15.8	15.6	15.9	117.9
11	20.1	19.4	18.5	17.2	16.6	15.6	15.1	122.5
Noon	19.9	19.8	19.4	18.4	17.7	16.3	15.4	126.9
13	19.0	19.3	19.7	19.2	18.7	17.5	16.2	129.6
14	17.3	18.0	18.9	19.2	19.5	18.4	17.3	128.6
15	15.0	15.9	17.3	18.2	19.4	19.0	18.5	123.3
16	12.2	13.1	14.8	16.3	18.1	18.6	18.9	112.0
17	10.3	10.5	11.9	13.6	15.9	17.1	18.4	97.7
18	9.5	8.5	9.2	10.5	13.0	14.7	16.8	82.2
19	9.7	7.8	7.4	7.8	9.8	11.5	14.1	68.1
20	10.5	8.3	6.7	6.1	7.0	8.1	10.9	57.6
21	11.8	9.5	7.5	5.8	5.3	5.6	7.8	53.3
22	13.4	11.4	9.1	7.0	5.1	4.2	5.4	55.6
23	14.8	13.6	11.4	9.1	6.6	4.6	4.2	64.3
Sum	340.5	340.4	347.5	346.6	357.1	351.2	352.0	2435.3

Sum for — Divisor—(28d) 672; (29d) 696; (30d) 720; (31d) 744. Mean for month—

Tabulated by P. L. B. Date Feb. 15, 1928 Summed by W. H. M. Date Mar. 14, 1928

FIGURE 11.—Form 362, Hourly Heights

comparative note made by the observer on the tide roll should be included in the form.

84. Hourly heights (Form 362).—The hourly heights are tabulated in Form 362 (fig. 11). Unless otherwise directed by the office, these heights will be tabulated in yearly series, beginning with January 1 as the first day of each series. The days are to be entered consecutively, seven days to the page and using both sides of the form, without regard to change in calendar months or to the time of changing the tide roll. The side of the form having the wider margin on the left side should be used as the first page of each sheet. The "day of series" will be numbered consecutively through the year, beginning with "1" for the first day of January. If any part of the record is lost, blank spaces should be left for later interpolation of the missing tides. As stencils are to be used in connection with this form, it is important that the tabulated heights be written within the spaces provided, these spaces being indicated by the printed decimal points.

85. As a check on the arrangement of the days in the form, the following table gives the page, column of page, and day of series, for the first of each calendar month, when the series commences with January 1:

Common year				Leap year			
Month	Page	Column	Day of series	Month	Page	Column	Day of series
Jan. 1	1	1	1	Jan. 1	1	1	1
Feb. 1	5	4	32	Feb. 1	5	4	32
Mar. 1	9	4	60	Mar. 1	9	5	61
Apr. 1	13	7	91	Apr. 1	14	1	92
May 1	18	2	121	May 1	18	3	122
June 1	22	5	152	June 1	22	6	153
July 1	26	7	182	July 1	27	1	183
Aug. 1	31	3	213	Aug. 1	31	4	214
Sept. 1	35	6	244	Sept. 1	35	7	245
Oct. 1	40	1	274	Oct. 1	40	2	275
Nov. 1	44	4	305	Nov. 1	44	5	306
Dec. 1	48	6	335	Dec. 1	48	7	336
Dec. 31	53	1	365	Dec. 31	53	2	366

86. The tabulated heights are to be expressed in feet and tenths and are referred to the zero of the tide staff or to a datum having a fixed relation to the same. It is desirable that the datum should be *uniform throughout the series.* When the station is first established, it is the usaul practice to refer the tabulations directly to the tide staff, but if this staff should be subsequently changed in elevation through any cause, a constant is introduced in order that the tabulations may still be referred to the original staff. This constant is taken into account in the computation of the corrected scale setting in Form 455, which has already been explained.

87. A line corresponding to the corrected scale setting is ruled across the underside of the glass scale used for the tabulations. The scale is then moved along the record with this line in coincidence with the datum line on the record and the height of the tide read off at each hour mark. At each change in the adjustment of the gauge, the scale setting should be changed to accord with the new value as computed in Form 455.

88. After the tabulations of the hourly heights on any page have been completed, these are to be summed vertically and horizontally and the results written in the spaces provided. The total of the horizontal sums on any page must equal the total of the vertical sums, and this total page sum is to be written in the space provided near the lower right-hand corner of the form. If any of the pages are incomplete because of lost record, the sums of such lines or columns as may be affected should be entered with lead pencil instead of ink, in order that they may be modified after interpolations have been made.

89. Tide observers who tabulate their own records should retain at the end of each month the last incomplete sheet of the hourly heights in order that it may be completed when the record for the following month is available.

90. High and low waters (Form 138).—The times and heights of the high and low waters are to be tabulated by calendar months in Form 138 (figs. 12 and 13). When the record is removed from the tide gauge at the beginning of each calendar month it will include several tides of the current month as well as the record for the preceding month. A memorandum of these few tides belonging to the current month should be retained by the tide observer until the next record is available in order that they may be included in the tabulations for the month to which they belong.

91. In Form 138 the times are to be expressed in hours and tenths, the hours themselves being numbered consecutively from 0 (midnight) to 23 (11 p. m.). Standard time should be consistently used throughout the tabulations, regardless of any temporary use of daylight-saving time in the locality. The high and low water heights are to be expressed in feet and tenths and refer to the same datum as used for the hourly heights, the corrected scale setting being obtained from Form 455.

92. In Form 138 there are two lines for each calendar day, and in general the morning tides will be entered on the first line and the afternoon tides on the second line for the day. A tide occuring at midnight (0^h) is taken as belonging to the morning of the day just beginning. Blank spaces should be left for such tides as may be missing on account of lost record; but when only a single high or low

Form 138
DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
Ed. Feb., 1928

TIDES: HIGH AND LOW WATERS

Station: *Seattle, Washington* Lat. *47°37'*
Observations begin ______ end ______ Long. *122°20'*
Time meridian *120°W* Height datum *T.S. zero (1904)* which is *29.54* ft. below B. M. *7*

DATE Year 1928	MOON'S TRANSITS (Greenwich mean civil)	TIME OF— High Water	TIME OF— Low Water	LUNITIDAL INTERVAL High Water	LUNITIDAL INTERVAL Low Water	HEIGHT OF— High Water	HEIGHT OF— Low Water	REMARKS
mo. d.	hr. dec. 12.3	hr. dec.	hr. dec.	hr. dec.	hr. dec.	feet	feet	
Jan. 1	(6.7)	11.4	4.5	(4.7)	10.2	20.2	11.6	
	19.1	—	18.4	—	(11.7)	—	9.5	
2	(7.5)	0.9	5.8	5.8	10.7	15.7	13.1	
	20.0	12.0	19.1	(4.5)	(11.6)	19.8	7.7	
3	(8.4)	2.4	7.0	6.4	11.0	17.0	14.6	
	20.9	12.9	20.0	(4.5)	(11.6)	19.6	6.7	
4	(9.4)	3.5	8.2	6.6	11.3	17.9	15.0	
	21.8	13.8	20.9	(4.4)	(11.5)	19.2	5.8	
5	(10.3)	4.3	9.3	6.5	11.5	19.2	15.6	
	22.8	14.5	21.7	(4.2)	(11.4)	19.5	5.0	
6	(11.4)	5.2	10.4	6.4	11.6	19.7	15.6	
	23.9	15.3	22.4	(3.9)	(11.0)	19.0	4.1	
7	—	6.0	11.1	6.1	11.2	19.8	15.1	
	(12.4)	16.0	23.0	(3.6)	(10.6)	18.9	4.3	
8	0.9	6.7	12.0	5.8	11.1	19.9	15.0	
	(13.3)	17.0	23.9	(3.7)	(10.6)	18.8	4.9	
9	1.8	7.3	—	5.5	—	20.1	—	
	(14.2)	17.8	13.0	(3.6)	11.2	18.4	14.8	
10	2.7	8.0	0.5	5.3	(10.3)	20.0	5.5	
	(15.1)	18.5	14.0	(3.4)	11.3	17.3	14.2	
11	3.5	8.3	1.0	4.8	(9.9)	19.9	6.5	
	(15.8)	19.7	15.0	(3.9)	11.5	16.6	13.5	
12	4.2	9.1	1.9	4.9	(10.1)	19.8	8.1	
	(16.6)	20.5	15.7	(3.9)	11.5	16.0	13.1	
13	4.9	9.7	2.6	4.8	(10.0)	20.2	9.8	
	(17.3)	21.8	16.7	(4.5)	11.8	15.3	12.5	
14	5.6	10.3	3.3	4.7	(10.0)	19.4	11.2	
	(17.9)	23.2	17.3	(5.3)	11.7	14.8	10.8	
15	6.3	10.9	4.3	4.6	(10.4)	18.6	12.4	
	(18.6)	—	18.0	—	11.7	—	9.6	
16	7.0	1.0	5.3	(6.4)	(10.7)	15.1	13.6	
	(19.3)	11.5	18.9	4.5	11.9	17.9	8.6	
17	7.7	2.5	6.9	(7.2)	(11.6)	15.8	14.5	
	(20.0)	12.3	19.7	4.6	12.0	17.4	7.9	
Sums; carried forward				159.0	366.2	586.8	350.2	

FIGURE 12.—Form 138, High and Low Waters (front)

water actually occurs on a calendar day, the unused space may be filled with a dashed line.

93. The times and heights of the high and low waters are to be entered in the columns so designated. In selecting the time of high or low water from the tide curve attention should be given to the

Form 138
DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
Ed. Feb., 1928

TIDES: HIGH AND LOW WATERS

Station: Seattle, Washington

Highest tide: Date 1st & 13th Height 20.2 ft. Lowest tide: Date 6th Height 4.1 ft.

$(K_1+O_1) \div M_2$ or $2(DHQ+DLQ) \div Mn =$ 1.2 $F(Mn) =$ 1.004 $F_1 =$ 0.85

DATE Year 1928	MOON'S TRANSITS (Greenwich civil)	TIME OF— High Water	TIME OF— Low Water	LUNITIDAL INTERVAL High Water	LUNITIDAL INTERVAL Low Water	HEIGHT OF— High Water	HEIGHT OF— Low Water	REMARKS
mo. d.	hr. dec.	hr. dec.	hr. dec.	hr. dec.	hr. dec.	feet	feet	
Brought forward		.	.	159.0	366.2	586.8	350.2	
Jan 18	8.4	3.4	8.0	(7.4)	(12.0)	16.7	16.0	
	(20.8)	13.0	20.3	4.6	11.9	17.2	7.1	
19	9.2	4.2	9.0	(7.4)	(12.2)	17.5	15.4	
	(21.7)	13.8	20.9	4.6	11.7	17.3	6.5	
20	10.1	4.9	9.8	(7.2)	(12.1)	18.2	15.4	
	(22.6)	14.3	21.7	4.2	11.6	17.6	6.2	
21	11.0	5.5	10.5	(6.9)	(11.9)	19.0	15.9	
	(23.5)	15.0	22.2	4.0	11.2	18.3	6.2	
22	11.9	6.0	11.1	(6.5)	(11.6)	19.7	15.8	
	—	16.0	22.9	4.1	11.0	18.6	5.7	
23	(0.4)	6.4	11.9	(6.0)	(11.5)	19.6	15.0	
	12.9	16.7	23.4	3.8	10.5	18.1	5.3	
24	(1.3)	7.0	—	(5.7)	—	19.5	—	
	13.8	17.3	12.4	3.5	(11.1)	18.1	14.4	
25	(2.2)	7.5	0.1	(5.3)	10.3	19.6	5.6	
	14.6	18.1	13.1	3.5	(10.9)	17.7	13.6	
26	(3.0)	8.0	0.9	(5.0)	10.3	19.4	6.3	
	15.5	19.0	14.0	3.5	(11.0)	16.8	12.4	
27	(3.9)	8.5	1.6	(4.6)	10.1	19.5	7.1	
	16.3	20.2	15.0	3.9	(11.1)	16.4	11.6	
28	(4.7)	9.0	2.3	(4.3)	10.0	20.0	9.0	
	17.1	21.5	16.0	4.4	(11.3)	16.1	10.7	
29	(5.5)	9.9	3.3	(4.4)	10.2	20.1	11.2	
	17.9	23.2	16.9	5.3	(11.4)	16.0	9.5	
30	(6.3)	10.7	4.3	(4.4)	10.4	19.5	13.2	
	18.8	—	17.8	—	(11.5)	—	8.1	
31	(7.2)	0.9	6.0	6.1	11.2	16.6	14.7	
	19.7	11.4	18.4	(4.2)	(11.2)	19.9	7.3	HHW 31 / LLW 27
Sums	.	.	.	34 293.8	60 667.4	34 1079.8	60 634.4	599.7 / 204.7 Sums
	.	.	.	4.98	11.12	18.30	10.57	19.35 / 7.06 Means
Correction to intervals				−0.44	−0.44	10.57		Mn / DHQ / DLQ
Corrected intervals				4.54	10.68	7.73	Mn	Observed 7.73 / 1.05 / 3.51
						14.44	MTL	Factor 1.004 / 0.85 / 0.85
Tabulated by P. L. B.	Date Feb 15, 1928	Checked by E. C. M.						Corrected 7.76 / 0.89 / 2.98
Reduced by E. C. M.	Date Feb. 16, 1928	Checked by W. H. M.						

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FIGURE 13.—Form 138, High and Low Waters (back)

general trend of the curve rather than the individual peaks due to rough water. The aim should be to take the middle of a smooth arc covering an hour or more during the high or low water period.

It is not necessary to actually draw in such an arc, but the point at which a smoothed curve would have reached its maximum or minimum should be estimated as closely as possible.

94. In determining the times of the high and low waters to the nearest tenth of an hour it may be found convenient to construct a small scale 1 inch long and divided into 10 equal parts for use between the hour marks on the curve. An experienced tabulator, however, will usually be able to estimate the tenth accurately without the use of such a scale.

95. Lunitidal intervals (Form 138).—A lunitidal interval is the difference in time between the transit of the moon over the meridian of a place and the following high or low water. For convenience in computing the intervals, the times of the high and low waters are first referred to the transits of the moon over the meridian of Greenwich as expressed in Greenwich time and corrections afterwards applied to refer to the local meridian. The Greenwich transits in hours and tenths, which will be furnished by the office upon request, are entered in the column of "Moon's transits" in Form 138 (figs. 12 and 13). The lower transits are distinguished from the upper transits by being inclosed in parentheses, and they should be so indicated in Form 138.

96. From the time of each high and low water subtract the time of the first preceding moon's transit and enter the difference in the appropriate column of the form and on the same line as the tide from which it was obtained. In case the time of high or low water is nearly the same as that of the moon's transit, take the transit which precedes the tide by about 12 hours, but in no case must the same transit be used for two consecutive high waters or for two consecutive low waters. The lower transit of the moon applies to both high and low water, just the same as the upper transit does. When the time of the moon's transit is on one day and the following high or low water is on the next day the time of this tide must be increased by adding 24 hours before attempting to subtract the time of the transit. The high-water intervals will usually be approximately six hours greater or less than the low-water intervals, but the intervals for each phase of tide will usually agree among themselves within an hour or two. Intervals from the lower transits of the moon are to be indicated by parentheses. The high and low water intervals for the calendar month are summed separately and the means obtained to two decimal places.

97. Method of checking intervals.—The mean intervals as obtained above may be conveniently checked by the following method:

(*a*) Sum times of moon's transits occurring during month. The numbers of transits will usually be two less than twice the number of days in the month; that is, 54 for a 28-day month, 56 for a 29-day month, 58 for a 30-day month, and 60 for a 31-day month. For the sake of uniformity, if the number of transits should be one greater than this, the last transit must be omitted from the sum and the last day be considered as having only the single value. On the other hand, if the number of transits should be one less than the usual number, the deficiency must be supplied by including the last transit of the preceding month. From the sum of the transits subtract the product of 24 hours by the sum of the numerals indicating the days of the month on which only a single transit occurs. For example, if single transits occur on the 3d and 17th of a month, the sum 20 is multiplied by 24, and the product 480 hours is then subtracted from the sum of the transits. Designate the remainder by "T," which may be either positive or negative.

(*b*) Sum separately the times of high and low waters, limiting the number of items in each case to two less than twice the number of days in the month, following the method described for the summation of the moon's transits. From the sum of the time of the high waters subtract the product of 24 hours by the sum of the numerals indicating the days of the month on which only a single high water occurred, and from the sum of the times of the low waters subtract the product of 24 hours by the sum of the numerals indicating the days of the month on which only a single low water occurred. Designate these results by "H" and "L," respectively.

(*c*) Find the differences (H−T) and (L−T) and divide by the number of items included in each summation, which should be twice the number of days in the month less two. Such multiples of 12.42 hours may be applied or rejected from the means as may be necessary to reduce them to positive values of less than 12.42 hours. The results obtained should check very closely with the means as obtained directly from the individual intervals, although at times there may be a small difference in the second decimal place.

98. Example.—This method for checking the mean intervals is illustrated below for Seattle, Wash., for the month of January, 1928, these intervals having been computed in the regular manner in Figures 12 and 13. This being a 31-day month, the number of items included in each summation must be 60.

Sum of times of 60 transits, January, 1928	727.6
24×(7+22), single transits occurring Jan. 7 and 22	696
Difference (T)	31.6
Sum of times of 59 high waters, January, 1928	665.7
Time of high water Dec. 31, 1927, for deficiency	23.2
Sum of times of 60 high waters	688.9
24×(1+15+30), single high waters occurring Jan. 1, 15, and 30	1,104
Difference (H)	−415.1
Sum of times of 60 low waters, January, 1928	745.6
24×(9+24), single low waters occurring Jan. 9 and 24	792
Difference (L)	−46.4

(H−T)÷60=−446.7÷60=−7.44 hours for high-water interval.
(L−T)÷60=−78.0÷60=−1.30 hours for low-water interval.

Applying the tidal period 12.42 hours to each of the above negative intervals, we have 4.98 and 11.12 hours, respectively, for the high and low water intervals. It will be noted that these results agree exactly with those obtained in Figure 13 by the regular computations. An exact agreement, however, is not always to be expected, but the results will usually agree within one or two hundredths of an hour.

99. Correction to intervals.—Lunitidal intervals, as usually defined, refer to the transits of the moon over the local meridian. In order to reduce to the local meridian the intervals as directly obtained from the Greenwich transits, a correction must be applied which depends upon the meridian of the place and also upon the kind of time used for the tidal observations. This correction may be obtained from the following formula:

Correction $= 0.0667\,S - 0.0690\,L.$
in which L = west longitude of place in degrees
and S = west longitude of time meridian used for tide observations.

For east longitude, the signs of L and S should be reversed.

100. The table on pages 42–44, which is based upon the above formula, may be used when the times of the tide expressed in some standard time have been referred to the Greenwich transits. The table is directly applicable to west longitude but should have signs reversed for east longitude. The correction for the whole degrees of local longitude are to be taken from the column headed by the appropriate time meridian. To this should be applied the correction for the minutes of longitude, which is the same for all time meridians.

Correction for lunitidal intervals

[For west longitude use sign given; for east longitude reverse sign]

Time meridian, 0°		Time meridian, 15°		Time meridian, 30°		Time meridian, 45°	
Longitude	Correction	Longitude	Correction	Longitude	Correction	Longitude	Correction
°	*Hour*	°	*Hour*	°	*Hour*	°	*Hour*
		5	+0.655	20	+0.620	35	+0.585
		6	+ .586	21	+ .551	36	+ .516
		7	+ .517	22	+ .482	37	+ .447
		8	+ .448	23	+ .413	38	+ .378
		9	+ .379	24	+ .344	39	+ .309
		10	+ .310	25	+ .275	40	+ .240
		11	+ .241	26	+ .206	41	+ .171
		12	+ .172	27	+ .137	42	+ .102
		13	+ .103	28	+ .068	43	+ .033
		14	+ .034	29	− .001	44	− .036
0	0.000	15	− .035	30	− .070	45	− .105
1	− .069	16	− .104	31	− .139	46	− .174
2	− .138	17	− .173	32	− .208	47	− .243
3	− .207	18	− .242	33	− .277	48	− .312
4	− .276	19	− .311	34	− .346	49	− .381
5	− .345	20	− .380	35	− .415	50	− .450
6	− .414	21	− .449	36	− .484	51	− .519
7	− .483	22	− .518	37	− .553	52	− .588
8	− .552	23	− .587	38	− .622	53	− .657
9	− .621	24	− .656	39	− .691	54	− .726
10	− .690	25	− .725	40	− .760	55	− .795

Time meridian 60°		Time meridian, 75°		Time meridian, 90°		Time meridian, 105°	
Longitude	Correction	Longitude	Correction	Longitude	Correction	Longitude	Correction
°	*Hour*	°	*Hour*	°	*Hour*	°	*Hour*
50	+0.550	65	+0.515	80	+0.480	95	+0.445
51	+ .481	66	+ .446	81	+ .411	96	+ .376
52	+ .412	67	+ .377	82	− .342	97	+ .307
53	+ .343	68	+ .308	83	+ .273	98	+ .238
54	+ .274	69	+ .239	84	+ .204	99	+ .169
55	+ .205	70	+ .170	85	+ .135	100	+ .100
56	+ .136	71	+ .101	86	+ .066	101	+ .031
57	+ .067	72	+ .032	87	− .003	102	− .038
58	− .002	73	− .037	88	− .072	103	− .107
59	− .071	74	− .106	89	− .141	104	− .176
60	− .140	75	− .175	90	− .210	105	− .245
61	− .209	76	− .244	91	− .279	106	− .314
62	− .278	77	− .313	92	− .348	107	− .383
63	− .347	78	− .382	93	− .417	108	− .452
64	− .416	79	− .451	94	− .486	109	− .521
65	− .485	80	− .520	95	− .555	110	− .590
66	− .554	81	− .589	96	− .624	111	− .659
67	− .623	82	− .658	97	− .693	112	− .728
68	− .692	83	− .727	98	− .762	113	− .797
69	− .761	84	− .796	99	− .831	114	− .866
70	− .830	85	− .865	100	− .900	115	− .935

Correction for lunitidal intervals—Continued

Time meridian, 120°		Time meridian, 135°		Time meridian, 150°	
Longitude	Correction	Longitude	Correction	Longitude	Correction
°	*Hour*	°	*Hour*	°	*Hour*
110	+0.410	125	+0.375	140	+0.340
111	+ .341	126	+ .306	141	+ .271
112	+ .272	127	+ .237	142	+ .202
113	+ .203	128	+ .168	143	+ .133
114	+ .134	129	+ .099	144	+ .064
115	+ .065	130	+ .030	145	− .005
116	− .004	131	− .039	146	− .074
117	− .073	132	− .108	147	− .143
118	− .142	133	− .177	148	− .212
119	− .211	134	− .246	149	− .281
120	− .280	135	− .315	150	− .351
121	− .349	136	− .384	151	− .420
122	− .418	137	− .453	152	− .489
123	− .487	138	− .522	153	− .558
124	− .556	139	− .591	154	− .627
125	− .625	140	− .660	155	− .696
126	− .694	141	− .729	156	− .765
127	− .763	142	− .798	157	− .834
128	− .832	143	− .867	158	− .903
129	− .901	144	− .936	159	− .972
130	− .970	145	−1.005	160	−1.041

Time meridian, 157°30'		Time meridian, 165°		Time meridian, 180°	
Longitude	Correction	Longitude	Correction	Longitude	Correction
°	*Hour*	°	*Hour*	°	*Hour*
148	+0.288	155	+0.304	170	+0.269
149	+ .219	156	+ .235	171	+ .200
150	+ .149	157	+ .166	172	+ .131
151	+ .080	158	+ .097	173	+ .062
152	+ .011	159	+ .028	174	− .007
153	− .058	160	− .041	175	− .076
154	− .127	161	− .110	176	− .145
155	− .196	162	− .179	177	− .214
156	− .265	163	− .248	178	− .283
157	− .334	164	− .317	179	− .352
158	− .403	165	− .386	180	− .421
159	− .472	166	− .455	181	− .490
160	− .541	167	− .524	182	− .559
161	− .610	168	− .593	183	− .628
162	− .679	169	− .662	184	− .697
163	− .748	170	− .731	185	− .766
164	− .817	171	− .800	186	− .835
165	− .886	172	− .869	187	− .904
166	− .955	173	− .938	188	− .973
167	−1.024	174	−1.007	189	−1.042
168	−1.093	175	−1.076	190	−1.111

Correction for lunitidal intervals—Continued

[For minutes of longitude]

Longitude	Correction	Longitude	Correction	Longitude	Correction
′	*Hour*	′	*Hour*	′	*Hour*
1	−0.001	21	−0.024	41	−0.047
2	− .002	22	− .025	42	− .048
3	− .003	23	− .026	43	− .049
4	− .005	24	− .028	44	− .051
5	− .006	25	− .029	45	− .052
6	− .007	26	− .030	46	− .053
7	− .008	27	− .031	47	− .054
8	− .009	28	− .032	48	− .055
9	− .010	29	− .033	49	− .056
10	− .012	30	− .034	50	− .058
11	− .013	31	− .036	51	− .059
12	− .014	32	− .037	52	− .060
13	− .015	33	− .038	53	− .061
14	− .016	34	− .039	54	− .062
15	− .017	35	− .040	55	− .063
16	− .018	36	− .041	56	− .064
17	− .020	37	− .043	57	− .066
18	−. 021	38	− .044	58	− .067
19	− .022	39	− .045	59	− .068
20	− .023	40	− .046	60	− .069

101. Reduction of heights (Form 138).—Mean high water (*HW*) and mean low water (*LW*) for each calendar month are obtained by summing all the high waters and all the low waters and dividing by the number of observations, the latter being indicated by small figures just above the sum. The means, written below the sums, should be carried to two decimal places. The mean range (*Mn*) is obtained by subtracting the mean of the low waters from the mean of the high waters. The mean tide level (*MTL*), which is also known as half-tide level, is obtained by taking the half sum of the mean of the high waters and the mean of the low waters.

102. The above results are obtained for all primary tide stations. For stations on the Pacific coast, the means of the higher high waters and of the lower low waters and the diurnal inequalities should also be obtained. The higher of the two high waters and the lower of the two low waters of each day of the month are first indicated by a check mark. If the two high or two low waters on the same day are equal, either may be selected as the higher high or lower low water. When only one high or one low water occurs on a calendar day, by reason of one of the tides having occurred after midnight and therefore on the next calendar day, the single tide is to be checked if the tide just above it is unchecked; otherwise it should not be checked. If, however, the tide has become diurnal and only one high and one low water occur during the tidal day, these should both be checked. The checked heights are to be summed separately for the high and low waters, the sums being entered in the spaces provided, with the number of observations written above in small figures. The mean of the higher high waters (*HHW*) and the mean of the lower low waters (*LLW*) are then obtained, each result being carried to two decimal places.

103. The diurnal high water inequality (*DHQ*) is obtained by subtracting the mean of all high waters from the mean of the higher high waters, and the diurnal low water inequality (*DLQ*) is obtained by subtracting the mean of the lower low waters from the mean of all low waters.

104. Correction for longitude of moon's node.—There is a long-period variation in the range of tide due to changes in the inclination of the moon's orbit to the Equator. When the longitude of the moon's node is 0° the inclination of the orbit to the Equator is at a maximum and the range of tide is less than usual; and when the longitude of the moon's node is 180° the inclination is at a minimum and the range of tide is greater than usual. The time required for the longitude of the moon's node to pass through the cycle of 360° is approximately 19 years. In addition to the variations caused by changes in the longitude of the moon's node, the diurnal inequalities are subject to variations from month to month caused by changes in the declination of the sun. Because of these variations certain factors are necessary in order to reduce to mean values the ranges and inequalities obtained from short series of observations. If a series of observations extends over a period of 19 years, the factors are unnecessary.

105. Tables containing the factor $F(Mn)$ for reducing the observed range to a mean value and the factor F_1 for reducing the diurnal inequalities for the years 1925–1934 are given on pages 57 and 59 of Special Publication No. 139. These tables are based upon Tables 6, 14, and 32 of Harris's Manual of Tides. Similar tables covering the years 1891–1950 are given on pages 83 and 114 of Special Publication No. 135. Factor $F(Mn)$ depends not only upon the year of observations but also upon the relation of the diurnal to the semidiurnal wave in the locality. For stations along the Atlantic coast of the United States this relation may be assumed to be less than 0.2, and the first column of factors in the table may be used. For stations along the coast of the Gulf of Mexico the range of tide is very small, and the correction factor may be usually omitted. For stations on the Pacific coast the relation $2(DHQ+$

$DLQ) \div Mn$ should be determined from the inequalities and range as derived from the observations at the station, and its value will determine the column of the table to be used. The factor $F(Mn)$ is given for each calendar year and applies to the middle of that year. The factor F_1 is given for each month and may be applied directly to the high and low water inequalities as obtained from the observations for the corresponding months.

MISCELLANEOUS DUTIES OF TIDE OBSERVERS

106. Weekly report (Form 660).—Tide observers are required to forward to the office at the end of each week a report on Form 660. The daily notes should correspond to those entered on the marigram itself, but the tube readings may be omitted in this form. If staff readings are taken more than once during the same calendar day, a single set will be sufficient for the weekly report, but all such readings are to be noted on the marigram. In the column of "Remarks" there should be noted such items as "Float well cleaned," "Float wire broken," "Counterpoise wire off drum," "Time clock stopped 11:15," etc. The operating troubles are to be explained in detail on the back of the form, which must also include all other information requested.

107. Forwarding records to office.—On the first day of each calendar month, or the following day if the first occurs on Sunday, the record for the preceding month should be removed from the gauge, a comparative time and staff note being entered just before the removal. After the roll has been removed it should be rewound to bring the record on the inside with the 1st of the month at the beginning. A label, Form 489, which has been filled out as completely as possible, is to be pasted on the outside of the marigram in such a manner as not to seal the roll. As a protection against tearing, a few inches of the beginning of the roll should be folded inward, making a smooth edge of double thickness. The label is then pasted parallel to this edge and about 1 inch from it, with the bottom of the label toward the edge. Beginning with No. 1 for the first roll, the marigrams are numbered consecutively throughout the series, regardless of calendar years.

108. Unless the tide observer tabulates the records, the tide roll is to be forwarded to the office immediately after removal from the gauge. The roll should be well wrapped as a protection against damage and an addressed franking slip (Form 110) pasted on the outside. The roll should be sent by registered mail. Although the franking slip will serve in place of the ordinary postage, it will be necessary to prepay the registration fee. The tide observer will be reimbursed for this fee if he will obtain the usual registration receipt and include the item in his voucher for the month in which the marigram was mailed (see p. 49).

109. When tide records are to be tabulated at the tide station this work must be expedited and the records forwarded as soon as possible, as the office has frequent calls for information based upon the records. It is expected that the tabulations will be completed and forwarded to the office within one week after the record has been removed from the gauge.

110. When forwarding the tide records two copies of Form 413 must be filled out describing the record being transmitted, and these should be mailed in a separate envelope. Form 413 is used only for the formal transmission of records. Matters requiring special attention should be sent in separate communications.

111. Shipment of instruments to office.—Tide-gauge clocks and other instruments not exceeding 4 pounds in weight when packed may be shipped to the office by franked mail, but if the weight is in excess of 4 pounds, prepayment of postage is necessary. Government property should not be insured when making shipments.

112. In making shipments by express or freight Government bills of lading should be used, and copies may be obtained from the office when such shipments are to be made. Transportation charges for these shipments are settled by the office and must not be prepaid by the shipper. Arrangements for the payment of drayage charges should be taken up with the office when shipments of bulky articles by express or freight are contemplated.

113. Form 412, in duplicate, is to be used when instruments are shipped to the office.

114. Inventory (Form 14).—An inventory of instruments and general property on hand must be submitted to the office at the end of each calendar year. The inventory will include the tide gauge and such other Government property as may be in charge of the tide observer at that time.

115. Requisition for supplies.—Requisition for stationery may be made on Form 11, or, if only a few articles are needed, on a short form provided for this purpose. When the short form is used it should be made in duplicate. Form 12 (Requisition for Instruments and General Property) is to be used for requisitioning instruments such as tide staffs, clocks and wire for automatic tide gauges, hydrometers, thermometers, etc. This form should also be submitted in duplicate. Requisitions for stationery and instruments should always be made on separate forms, as they are handled by different sections in the office.

116. The following list includes articles of stationery which may be needed from time to time, together with the quantity which should usually be requested in a single order. If a tide station is somewhat isolated, the quantity may be increased.

Tide rolls for standard tide gauge	12
Form 489 (Label for tide-gauge records)	25
Form 660 (Weekly Report of Tide Station)	50
Form 138 (High and Low Waters)	25
Form 362 (Hourly Heights)	50
Form 455 (Comparative Readings)	25
Form 457 (Density and Temperature Observations)	25
Form 413 (Letter transmitting field records)	50
Form 11 (Requisition for Stationery)	10
Requisition for Stationery (short form)	20
Form 12 (Requisition for Instruments and General Property)	10
Form 14 (Inventory—Instruments and General Property)	5
Form 2a (Voucher for Personal Services)	15
Form 110 (Frank, mailing, addressed to the director)	25
Envelopes, white, addressed to director, 3⅞ x 8⅞ ... packages	2
Envelopes, manila, 8½ x 11½ ... do	1
Letter paper for field use, medium ... tablet	1
Cheesecloth for cleaning tide gauge ... yards	3

117. **Voucher for Personal Services** (Form 2a).—Tide observers who are paid by the United States Coast and Geodetic Survey must submit a voucher on Form 2a for each month of service. This form is to be made out in duplicate, the memorandum copy being attached to the original. The original only should be certified. Separate vouchers must be submitted for each calendar month, each being certified after the completion of the services for the month covered.

118. When a tide observer who is appointed at a monthly rate of pay does not serve the full calendar month his pay for the time served during that month will be computed in accordance with the following act of Congress:

Sec. 6. (a) Hereafter, when the compensation of any person in the service of the United States is annual or monthly, the following rules for division of time and compensation of pay for services rendered are hereby established:

"Annual compensation shall be divided into 12 equal installments, one of which shall be the pay for each calendar month; and in making payments for a fractional part of a month one-thirtieth of one such installments, or of a monthly compensation, shall be the daily rate of pay. For the purpose of computing such compensation and for computing time for services rendered during a fractional part of a month in connection with annual or monthly compensation, each and every month shall be held to consist of 30 days, without regard to the actual number of days in any calendar month, thus excluding the 31st of any calendar month from the computation and treating February as if it actually had 30 days. Any person entering the service of the United States during a 31-day month and serving until the end thereof shall be entitled to pay for that month from the date of entry to the 30th day of said month, both days inclusive; and any person entering said service during the month of February and serving until the end thereof shall be entitled to one month's pay, less as many thirtieths thereof as there were days elapsed prior to date of entry: *Provided,* That for one day's unathorized absence on the 31st day of any calendar month one day's pay shall be forfeited." (Act June 30, 1906.)

119. On the voucher for personal services there may be included a charge for money advanced by the tide observer in payment of the registration fee for forwarding the tide record to the office, but the registration receipt must be attached to the voucher when forwarded to the office. This item must be included in the voucher covering the same calendar month in which the fee was paid and not the month covered by the tide record. The receipt obtained when mailing the record during the first part of each calendar month should be retained until the end of the month to be included in the voucher for that month.

120. Because of the law affecting the employment of a person in more than one branch of the Government service when the combined salary exceeds $2,000 per annum, each tide observer is required to enter a statement on both the original and memorandum voucher as to whether or not he is so employed. A rubber stamp is provided for this purpose, which should be used in the upper right-hand corner of the voucher. If not employed in another branch of the service, the word "also" should be crossed out, but if so employed, the word "not" should be crossed out and the name of the other bureau and salary received noted. In either case the tide observer should place his initials below the note.

121. Emergency expenses.—Tide observers are not expected to incur any expenses in the operation of the tide station unless especially authorized by the Director of the United States Coast and Geodetic Survey. Unless an emergency exists, the tide observer should inform the office of any needed repairs and then wait for instructions. Time will be saved if the tide observer obtains an estimate of the cost of making the needed repairs and submits this when informing the office of the need for the repairs. If the cost is more than nominal, at least three estimates are to be obtained when possible.

122. In case of an emergency in which there would be a considerable loss of record if the observer waited until receiving instructions from the office, he may make immediate arrangements for having the work done, provided the cost is reasonable and does not exceed $5. In such cases arrangements will be made to have payment made directly by the office to the party doing the work, or the observer will be provided with suitable forms for obtaining necessary receipts.

123. When emergency work of considerable magnitude is necessary, the tide observer should inform the office by telegram which is to be sent collect and not prepaid by the observer.

124. Furnishing information to public.—All employees of the United States Coast and Geodetic Survey are expected to be courteous to the public when inquiries are made concerning their work, but the regulations prohibit the furnishing of copies of the records without authority of the director. When a tide station is so situated that there may be more or less frequent calls by local authorities for data from the tide-gauge record, and this is brought to the attention of the office, permission will usually be granted to the tide observer to supply such information upon request, but when this is done the party to whom the information is given should be informed that the results are preliminary and subject to revision by the office.

INDEX

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