ENGINEER DEPARTMENT, UNITED STATES ARMY.

REPORT

ON

CURRENT-METER OBSERVATIONS

IN THE

MISSISSIPPI RIVER, NEAR BURLINGTON, IOWA,

DURING

THE MONTH OF OCTOBER, 1879,

ILLUSTRATED BY

ONE SKETCH AND FORTY-ONE PLATES,

BY

MAJOR ALEXANDER MACKENZIE,
CORPS OF ENGINEERS, U. S. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1884.

OFFICE OF THE CHIEF OF ENGINEERS,
UNITED STATES ARMY,
Washington, D. C., March 25, 1884.

SIR: I have the honor to submit herewith a report, with accompanying sub-report, tables, and plates, received from Maj. A. Mackenzie, Corps of Engineers, giving the final results of a series of observations taken with current-meters in the Mississippi River, near Burlington, Iowa, during the month of October, 1879, at the suggestion of a Board of Engineer officers constituted in 1878, to take into consideration the improvement of the low-water navigation of the Mississippi and Missouri rivers, together with a report thereon from Lieut. Col. H. L. Abbot, Corps of Engineers, to whom they were referred for remarks.

Lieutenant-Colonel Abbot confirms my appreciation of the merits of these observations and of the value of their results to officers of the Corps of Engineers and others engaged in the practice of gauging rivers. I would therefore beg leave to request that authority be granted to have the report with its illustrations printed at the Government Printing Office for the use of the Corps, and that five hundred copies be furnished this office for distribution upon the usual requisition.

Very respectfully, your obedient servant,

JOHN NEWTON,
Chief of Engineers, Brig. and Bvt. Maj. Gen.

Hon. ROBERT T. LINCOLN,
Secretary of War.

[First indorsement.]

Approved:
By order of the Secretary of War:

JOHN TWEEDALE,
Chief Clerk.

WAR DEPARTMENT,
March 27, 1884.

WILLET'S POINT, N. Y., *March* 8, 1884.

GENERAL: I have carefully read the final report of Major Mackenzie and accompanying documents forwarded to me for report by your letter of 25th ultimo.

This report covers the most exact set of measurements which has come to my knowledge, undertaken to investigate the changes of velocity in a vertical plane from surface to bottom in water flowing in a natural channel. The plan of *simultaneous* measurements at different depths by electrical meters is a decided advance over any of the older methods, and is novel and of much scientific interest.

The work was admirably planned and conducted, and, in my judgment, should be made public for the use of officers and others engaged in the practical gauging of rivers.

I regard the publication of the plates as important to a full appreciation of the results, and their value would fully warrant the expense of their reproduction by photolithography. The report in full cannot but be creditable to the Corps, and is sure to excite the interest of any student of the flow of water in natural channels. The only part which can be omitted without injury is the record (two sheets) illustrating the working of the chronograph. These are not essential.

Very respectfully, your obedient servant,

HENRY L. ABBOT,
Lieut. Col. of Engrs., Bvt. Brig. Gen'l.

The CHIEF OF ENGINEERS, U. S. A.

REPORT

ON

CURRENT-METER OBSERVATIONS NEAR BURLINGTON, IOWA.

REPORT.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., February 11, 1884.

GENERAL: I have the honor to transmit herewith tables and plates giving the results of a series of observations taken with current-meters in the Mississippi River, near Burlington, Iowa, during the month of October, 1879. These plates are accompanied by an explanatory report by Assistant Engineer G. A. Marr, under whose direction the observations were made.

Instructions from the Chief of Engineers, dated August 30, 1878, assigned to Maj. F. U. Farquhar, Corps of Engineers, the surveys and examinations of the Mississippi River at some point above the mouth of the Illinois River, desired by the Board of Officers, constituted by Special Orders No. 71, Series of 1878, Headquarters Corps of Engineers, to take into consideration the improvement of the low-water navigation of the Mississippi and Missouri rivers.

The work desired by this Board was a detailed transit survey of a considerable stretch of the river, with line of levels to determine the river slope at various points and various stages,—determinations of the cross-section at various stages, the object being to ascertain all facts connected with the motion and dimensions of sand waves,—discharge and sediment observations, and borings on the banks and in the bed of the river.

A portion of the Mississippi River between Burlington and Montrose, 42 miles in length, was selected for survey, and the immediate vicinity of Burlington was chosen for special study. The survey and examinations were commenced in September, 1878, and completed in October, 1879. A report on this survey, with plates and maps, was submitted in July, 1880, and the report and a portion of the plates are printed in the Report of the Chief of Engineers for the year 1880, part 2, page 1526.

While the above-mentioned survey was being made, with the sanction of the Chief of Engineers, a series of observations with current-meters and a specially-constructed chronograph was undertaken. This work was inaugurated by Maj. F. U. Farquhar, Corps of Engineers, and carried on under his general direction until June, 1879, at which date he was relieved from duty in connection with the improvement of the Mississippi River. Capt. B. D. Greene, Corps of Engineers, was in charge of the field observations during a portion of the time, and had general supervision of the work until June 1, 1880, at which date he was transferred to Detroit for duty. Assistant Engineer G. A. Marr, who submits the final report, was in immediate charge of the field-work, and has prepared the tables and plates showing the results.

The apparatus used in connection with these observations requiring particular mention was a chronograph and seven current-meters. The chronograph was specially constructed for the work by T. S. & J. D. Negus, of New York; it was provided with eight independent pens, permitting a continuous simultaneous record of six meters and the connecting of the two outside pens in one circuit for a time record. The six meters used in determining relative velocity were of the telegraphic pattern, and were made by Buff & Berger, of Boston. These meters are similar to the one used by General Ellis in his gauging of the Connecticut River, and are described by him on page 308, Report of the Chief of Engineers for 1878, part 1. A similar meter is also shown in Plate IV, page 136, Buff & Berger catalogue for 1883; those used bore the makers' numbers 21, 18, 19, 20, 11, 7, which numbers correspond respectively to the numbers 2, 3, 4, 5, 6, 7, used for the meters in this report and the accompanying tables and plates. The new numbers painted on meters and boxes were used to make the number of each meter agree with the corresponding pen of the chronograph. A propeller meter, procured from the engineer depot at Willet's Point, through the courtesy of General H. L. Abbot, was occasionally used. This meter was very simple and sensitive and gave excellent results.

The observations for determining the meter coefficients were made during the month of October, 1879, in Prairie Slough, an arm of the Mississippi River, near Burlington, Iowa. This slough has a uniform bed, and was virtually devoid of current during the time of observation.

The methods employed are fully described in the report of Mr. Marr, and the results are given in Table No. 1.

The observations for current velocity were made during the month of October, 1879, at the various points shown on the accompanying map of the Mississippi River in the vicinity of Burlington. The points were so selected as to give as great a variety of conditions as practicable. The six meters were used simultaneously at varying depths for determining the velocity of the current, and were frequently used on a horizontal frame for purposes of comparison. Observations furnishing a comparison of velocity as determined by meters and by floats were also made.

The meters, when in use for determining the velocity of the current, were held in position at their various depths by a wire rope suspended from a derrick, projecting about 20 feet in front of the bow of a quarter-boat, with a long rake, and drawing about 20 inches. The foot of the wire rope was held in position by a mushroom anchor weighing 150 pounds. The meters were allowed free motion in all directions, and were supposed to head directly in the current.

For the purpose of recording the revolutions of the meters, each was connected independently with one of the pens of the chronograph, the two outside pens being connected with a break-circuit chronometer, marking intervals of one second. The speed of the chronograph was such as to make the second intervals on the record about one-fourth of an inch. Portions of the records of the chronograph are shown on Sheets 1 and 2.

Great care was taken in the field observations, the reductions, and the preparation of the tables and plates. The results given are an accurate representation so far as the section of the river operated in is concerned. And as the methods and conditions under which the observations were taken and reduced are given, any one can determine for himself to what extent general conclusions can be drawn.

As all these special observations were made in connection with other work, no opportunity was afforded for working up the notes at the time they were taken, and during the reduction of the observations many new points have appeared which might have been investigated to advantage had they presented themselves while field-work was going on. Some of these points are referred to in the report of Mr. Marr.

The section of the Mississippi River in the vicinity of Burlington was a favorable one for some of the investigations ordered by the Board of Engineers, but from the excessive width and resulting shoalness of the section, and comparative irregularity of the bottom and channel, the point was not as favorable as some others discovered later, for the special observations with current-meters.

While the results presented contain much that is of interest in connection with the use of current-meters or other appliances for gauging purposes on the Mississippi River or similar streams, much more extended and valuable results could be obtained by the use of twelve meters, giving a greater number of points in the vertical curve and especially points nearer the surface and bottom,—by the addition of six pens to the chronograph, which the record will permit,—and by the selection of a point for observation where a more regular channel and greater depth could be secured.

The methods used, both for the field observations and subsequent reductions, are so fully given in Mr. Marr's report that but a brief summary of operations is here necessary.

In connection with the work for determining the meter co-efficients, a plotting of the velocity and revolutions of the meter indicated that within the limit of speeds used, (0.4 ft. to 6.3 ft. per second,) the relation is shown by a right line, and in determining the co-efficients the equation of a right line referred to rectangular co-ordinates was used. (See Table 1 and Plates I, II, III, and IV.)

For determining the velocity at various points in a vertical plane the meters were set and connected with the chronograph as previously described. The meters were allowed to run for from eleven to thirty-two minutes for each set of observations. This gave a continuous record of time and revolutions or parts of revolutions on the chronograph sheet. From this sheet records for each minute were taken for each meter, and the number of revolutions was converted into velocity in feet per second. The results for each set of observations were entered in tables and also plotted on cross-section paper, giving a vertical velocity curve for each minute of observation. From these minute curves a mean vertical velocity curve was constructed for each set of observations. The object of these observations being mainly to determine the relation of mean to mid-depth velocity, and it not being necessary in this connection to assign any special form or establish an equation for the mean vertical velocity curves, no attempt has been made to do so. To determine the relation above referred to, a graphic method was used. The velocities as given by the curves were taken off for each 0.4 of a foot in depth and formed into a table from which was obtained the mean velocity in the vertical plane. The mid-depth velocity was also taken graphically from the curve. These results are given in each case on the corresponding mean vertical velocity curve plate. In order to obtain a further comparison of the results, the formula of Humphreys & Abbot was applied to the mid-depth velocities. The comparisons of mean and mid-depth velocities are combined in Table 29. The co-efficient obtained from these observations for converting mid-depth into mean velocity is 0.958.

Very respectfully, your obedient servant,

A. MACKENZIE,
Major of Engineers.

The CHIEF OF ENGINEERS, UNITED STATES ARMY.

REPORT OF MR. G. A. MARR, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., July 2, 1883.

MAJOR: I have the honor to submit the following report on certain current-meter observations taken in the Mississippi River, near Burlington, Iowa.

These observations for current velocity were all taken in October, 1879, and a progress report giving a description of the field operations was submitted to you November 10, 1879, but as the observations could not be worked up in the field, and as many other duties have occupied my time since the field-work was completed, the reductions of the notes and preparation of tables and plates have been delayed till the present time. I have incorporated in this report the notes previously submitted.

The report is accompanied by a sketch showing the points at which observations were taken and giving the characteristics of the section of the river operated on, and by thirty-one tables and forty-one plates illustrating the plotted results of the observations taken, and by two sheets giving specimens of the record of the chronograph.

During the progress of the special surveys and examinations ordered by the Board of Engineers on the low-water navigation of the Mississippi and Missouri rivers, and executed principally under the direction of Bvt. Lieut. Col. F. U. Farquhar, Major of Engineers, it was decided to undertake, in addition to the work ordered by the Board, a more thorough system of observations with current-meters than had, up to that time, been realized. On account of the great fluctuations in velocity, not only from the surface downward, but also in the whole volume of water, it appeared that a system which would give simultaneous observations at several distinct points in a vertical plane would give much more reliable and valuable information than the use of a single meter at different depths. For the purpose of carrying out the above system, six of the best make of Buff & Berger telegraphic current-meters were obtained, and in order to secure a perfect record of the results a chronograph with eight pens was designed and made under the direction of Colonel Farquhar by T. S. & J. D. Negus, of New York. This instrument was very complete and admirably fulfilled the purposes for which it was constructed. With eight pens working independently, six could be used for the current-meters, giving for each meter an independent and complete record of the parts of revolutions, and the two outside pens could be used for time, being connected with a break-circuit chronometer, and marking intervals of one second on each edge of the sheet. From this record data could be obtained in any manner desirable, either the number of revolutions and parts of revolutions in a given time, or the time of a single revolution, or a part of a revolution. The speed of the chronograph was such as to make the second intervals on the record about one-fourth of an inch.

Many of the following methods, which were used for field work and for the reduction of the notes, were suggested by Capt. B. D. Greene, formerly of the Corps of Engineers, United States Army, who, for a time, was in charge of the field work.

ADJUSTMENT OF THE BUFF & BERGER METERS.

It was very necessary first of all to look carefully to the adjustment of the meters.

The wheel should play freely between the supporting arms, and yet should not be so loose as to endanger the fine platinum points that establish the electric current through the meter. If the wheel was quite loose it would invariably bend the platinum points, and a broken circuit would be the result, not always entirely lost, but too broken to be of value. This adjustment could not be made with the large screws containing the agates, as unless these screws were set up to the shoulder they would follow up the wheel in its revolution, and soon bind or perhaps lock the wheel entirely. To remedy this the large screws were set up to the shoulder after removing the fine screws containing the platinum points. If this made the wheel too tight or too loose, a small strip of very thin paper was inserted on either side (the side necessary to make the proper adjustment) of the set screws that hold the projecting arms to the meter frame. By this means a very fine and quite permanent set could be made for the arms, and it was then only necessary to make a careful adjustment of the screws with the platinum points. But before adjusting these small screws, it was carefully observed that the wheel had a play in the direction of its axis of about one-fifth of a millimeter. This in the agate bearings gave free and easy motion.

The adjustment of the wheel being made satisfactorily, the adjustment of the small screws containing the platinum points was made as follows. The screw holding the wheel and its frame to the main part of the meter, was loosened so that the wheel and frame could be revolved so as to be either side up. The meter was then connected with a battery, and a sounding key put in the circuit. The wheel was placed in a horizontal position so that its weight would bear on the lower agate. The wheel was then turned so that the platinum wire spring from the insulated wire would rest on the silver portion of the axis so as to close the circuit at that point. The small screw containing the platinum point was then turned up carefully until a circuit was established, which was indicated by the sounding key. At this point, if the screw was turned back a trifle, the circuit would be broken again, and generally a change of 10°, or even less, in turning the screw would make and break the circuit. The wheel was then inverted, and after turning the screw already adjusted back just 180°, or half a revolution, so as to be certain to have no current through that point, the other small screw was adjusted in the same manner as the previous one. Then the first screw adjusted was turned up the 180°, or half turn that it had been turned back, and the adjustment was complete. The great necessity for having a sounding key in the circuit when adjusting these small screws was, that otherwise the screw might be turned too far, thus causing the platinum point to be bent to one side, and making an imperfect contact which would result in a broken and irregular record.

There was also another adjustment to look after in the Buff & Berger instruments. The platinum wire spring that had one end attached to the end of the insulated wire, and the other end resting in a groove on the exterior of the axis, was liable to be disturbed, and if accidentally bent would either give too light a pressure to make a perfect record, or would press too heavily, and produce extra friction on the wheel, making it more difficult to revolve, and hence giving a different co-efficient.

To keep the adjustment of the spring as near uniform as possible, and as light as would give a perfect record, the following plan was adopted. A very delicate balance was procured, and, by means of a fine thread attached to the wire and the balance, the pressure of the spring was carefully weighed. In order to do this it was necessary to have the same connection with a battery and sounding key in circuit as for the other adjustment. The wheel was turned so that the platinum wire rested on the silver of the axis, which gave a closed circuit. The platinum spring was then lifted by means of the balance and thread, and the weight noted just at the point where the circuit would be broken. By this means as light a pressure as would give a good result could be established. It was generally found that a pressure of from 1 to 1½ grams was about as light as the spring could be used and be certain of giving a good result. When first tested some of the springs were found to exert a pressure of from 10 to 15 grams.

After these adjustments the Buff & Berger meters would give a good clear record with the wheel in any position, either horizontal, vertical, or at any point between.

The propeller meter, made by T. S. & J. D. Negus, and used occasionally in connection with the above meters, never needed any such adjustments, as the method of making and breaking the circuit is simple and the connections are entirely inclosed in a small compartment nearly water-tight. The instrument was never out of order in that respect during its entire use in the work.

METHOD OF DETERMINING METER CO-EFFICIENTS.

The place selected for rating the meters was in "Prairie Slough," just below Burlington, where at any stage of water less than 5 feet there was no inlet from above to cause a current, and where there was a depth of from 7 to 11 feet at a 2-foot stage. This gave practically a still sheet of water, except such fluctuations as might be caused by strong winds. A base of 800 feet was carefully measured with standard cherry rods prepared from the Coast Survey standard 5-foot rods in the office. The points on the base were designated as follows: At the east end "East Point"; 200 feet from this towards the west was called "$\frac{1}{4}$ Point"; at 400 feet, or the center, "Middle Point"; at 600 feet, "$\frac{3}{4}$ Point," and at the end of the 800 feet, "West Point."

A telegraph line and battery were established along the base, having ground connection at each end by large sheets of copper placed in the water. Three signal keys or sounders were used, being placed at "East Point," "Middle Point," and "West Point."

Observers were stationed at each of the stations along the line; those at the "East Point," "Middle Point," and "West Point" being furnished with theodolites and those at "$\frac{1}{4}$ Point" and "$\frac{3}{4}$ Point" with signal flags. A second observer at "East Point" was supplied with a chronometer.

Points $\frac{1}{4}$ and $\frac{3}{4}$ were provided with boards with slots cut in them and a string or wire stretched longitudinally along the center of the slot. The board and its wire were carefully set in front of and directly opposite each point, and stakes were set on the opposite side of the slough, these stakes being located by laying off 90° from the base with a theodolite.

A line for testing the meters was selected out in the slough opposite the base, and range stakes were set beyond each end of the line, care being taken to set these stakes so as to make the line or path of the steam-launch parallel to the base. Other range stakes were set on a prolongation of the line. This line was so selected as to be but little affected by influences from the bottom or sides of the slough, it being at this place quite uniform in depth.

A frame made of 2-inch gas-pipe was attached to the bow of the launch, and the meter to be tested was placed on a rod attached to the extreme forward end of this frame and at a point which would carry the meter about 2 feet below the surface and about 10 feet ahead of the launch. Insulated copper wires were attached to the meter before placing it in the water. These were brought up on the bow of the launch and connected with a battery of six Daniels cells. A register was placed in the circuit and also a sounding-key, which was placed in the engine-room to guide the engineer in keeping the speed of the launch uniform.

All being ready for work, the launch was got on line outside the limits of the base and prepared to run with as steady and uniform a speed as possible. As the launch approached the point opposite "East Point" the observer there stationed called "ready," held up one hand, and with the other made two breaks on the key-sounder. At these signals the observer on the launch commenced counting and watching the register, and the observer at the chronometer took up the "beat." As the jack-staff of the launch passed the cross-wire in his telescope the observer dropped his hand quickly, gave one tap on the key, and also called "tick" sharply, so that if the observer on the launch did not happen to be looking and see the hand drop he would get the signal "tick." The signals were all given as distinctly and sharply as possible. The reading on the register was noted and the time taken to the nearest tenth of a second so far as practicable.

At the next station, or "¼ Point," the observer at that point called "ready" and held up his flag, being in a position where he could be seen both by the observer on the launch and the observer at the chronometer. As the jack-staff passed his station or line of sight he dropped his flag as quickly as possible and called "tick." The same signals were given at the three remaining stations. At these signals the reading of the register on the launch was noted, and the difference of readings at "East Point" and at the other points gave the number of revolutions, or half revolutions, according to the meter used. A return trip was made over the same course, running from "West Point" to "East Point," using the same speed of boat as far as practicable. The results of these two trips were combined so as to eliminate effect of current, if any existed. The work was continued with a meter until various speeds of the launch had been tested, or, in other words, the meter tested for many different velocities, from quite slow to as fast as the register would record correctly.

METHOD OF USING CURRENT-METERS FOR DETERMINING CURRENT VELOCITY.

For using the meters for current observations a derrick was put up on the United States quarter-boat "Major E. F. Hoffmann." The main spar of the derrick was 35 feet long and was placed just forward of the cabin. To this spar was attached a boom 25 feet long, being set for this work about 12 feet from the lower end of the spar. A heavy set of double blocks and fall led from the upper end of the spar to the boom, by which the latter could be raised or lowered at will. From the upper end of the boom another double block and fall was used to handle the apparatus for current work. A cable wire rope, five-eighths of an inch in diameter and 32 feet long, was attached by an eye to the hook of the block at end of boom, and a mushroom anchor, weighing 150 pounds, was attached to the lower end of the cable by means of a clamp clevis which permitted the wire cable to pass freely through the current-meter frame. To the anchor was attached a bar of iron, 1 by 3 inches and about 3 feet long, which supported a gas-pipe 1 inch in diameter, made in lengths of 10 feet and provided with couplings, one side of the gas-pipe being perforated with half-inch holes for the introduction of the insulated wires that were to connect the meters with the battery and chronograph. This pipe was used to prevent the wires from becoming entangled in the meters, and the pipe and system of wires were always placed so as to be down-stream from the meters.

Six meters were used for these current observations, and were usually set on the wire cable equidistant from each other, and at the same distance from the bottom and surface of the river; for instance, in 21 feet depth of water the upper meter would be 3 feet below the surface, and with 3 feet between the meters, the lower one would be 3 feet above the bottom.

In order to give frequent direct comparisons between the six meters, a frame was prepared of oak pieces $2\frac{1}{2}$ by 6 inches, the frame being 12 feet long and $2\frac{1}{2}$ feet wide. Six iron bolts of three-quarter-inch round iron, and about $2\frac{3}{4}$ feet long, were set in the frame to support the meters, the bolts being placed 2 feet apart and 1 foot from either end. A piece of three-quarter-inch gas-pipe was set in the center of this frame and provided with a clamp screw. The wire cable was passed through the gas-pipe in the center of this frame, and clamped at a point where the center of the frame would be about 2 feet below the surface of the water when the mushroom anchor rested on the bottom. The frame was held in a horizontal position and stay-rods connecting the ends of the frame with the bow of the quarter-boat held the frame at a right angle to the direction of the current. The meters were placed on the frame and carefully set at the same height. This gave comparison of the meters at the same depth, and in order to eliminate any effect from lateral difference in the current, the meters were used in reverse positions on the frame.

COMPARISON OF METERS AND FLOATS.

There was also a comparison made between the velocity as determined by meters and as determined by the tin floats and the paint kegs used for the gauging operations in this vicinity.

For these comparisons a section of the river, giving as uniform a channel as possible, was selected on the east side of "Bar h," in the main channel.

Five meters, placed equidistant, were used in this work, one of the meters being at mid-depth. One pen on the chronograph was reserved for recording float observations.

A base of 200 feet, marked at each 50 feet, was carefully measured with the standard cherry rods, in a direction as nearly parallel to the direction of the current as practicable. Observers were stationed at the five points of the base, those at the ends and middle being provided with break circuit keys and theodolites; at the other two points flags were used, the signal for the passage of the float past these points being transmitted to the chronograph sheet by one of the observers at a key.

Telegraphic communication was established between the base stations and the chronograph on board the quarter-boat.

The quarter-boat was anchored so that the cable with the meters would be placed about 16 feet below the lower end of the base. The skiff containing the floats to be sent down was anchored about 100 feet above the upper end of the base, and trials made with the floats until the point was found from which the floats would pass from the skiff directly toward the cable containing the meters.

Work was then commenced, a continuous record of the five meters and a record of the passage of the floats past the points of the base being made on the chronograph. A warning of several breaks was given just before the single break of the passage of the float. (See Sheet 2.)

The observer at the lower point took a theodolite reading to the float as it passed the upper point, and the observer at the upper point did the same as the float passed the lower point, thus giving the path of the float.

The larger number of the observations were made with the floats tied at mid-depth, the remainder being taken with the floats tied at depths corresponding to the positions of the meters next above and below that at mid-depth.

Time was also taken with a chronometer on shore, in order to give a comparison between this method and the chronograph.

REDUCTION OF FIELD-WORK.

a. Meter co-efficients.—In the reduction of the observations taken to determine the co-efficients the following plan was adopted for eliminating the effect of any possible current. The observations were combined in pairs, consisting each of a down trip over the course laid out, and the following return trip. Noting the time of transit and the number of revolutions at the end of each 200 feet of the 800-foot base gave eight results for each round trip of the launch. In combining these separate results, the one giving the greatest time interval on the down trip was combined with the one giving the greatest time interval on the up trip. In this way the elements for forming four equations of condition were obtained for each round trip from "East Point."

To determine approximately the form of the line showing the relation between the number of revolutions of the meter (n) and the velocity (v') the observed values of n and v' were plotted in reference to a system of rectangular co-ordinates. The results are given on Plates I, II, III and IV, and show that within the limits of the observations taken, the line showing this relation is a right line, whose equation is $v' = a\,n + b$, in which v' = velocity in feet per second and n = number of revolutions of meter per second, quantities that become known from the observations. a is the tangent of the angle which the line makes with the axis of abscissas, and b the distance from the origin to the point of intersection with the axis of ordinates. In the use of this equation for the determination of meter co-efficients the observations have been such as to give from nineteen to thirty-nine equations of condition from which to derive final results for the two quantities a and b. These equations have been solved by method of least squares, and the results are given in Table 1.

In handling the meters great care was exercised that nothing should occur liable to affect their co-efficients, but in order to detect any accidental change, the horizontal frame previously described was generally used between each set of observations for the velocity in vertical plane. A number of these observations, sufficient to show such material change as did occur, have been reduced. Complete sets of observations on the horizontal frame have been worked up for October 29, and are given in Tables 2 and 3.

There was a very good agreement between the meters, excepting No. 2. On referring to Table 1 it will be noticed that there was a much poorer determination of that co-efficient, the probable error of the determination being 0.0086. The comparisons on the horizontal frame indicated an error of one-tenth of a foot per second for meter No. 2, and this was adopted as a correction for the meter.

b. Mean vertical velocity curves.—From the chronograph sheet which gives a constant record of the six meters used at different points in a vertical plane, mean velocities for each minute are derived and tabulated. (See for example Table 4.) The results have also been plotted on cross-section paper to more clearly show their relative values. (See for example Plate VI.) Mean values for each consecutive series of minute results have also been obtained, and these mean results have also been plotted on cross-section paper. As the values for mean velocities for each minute at the six different points from the surface to the bottom constantly gave evidence of a quite uniform curve, the method of drawing a curve for these mean values has been adopted and designated the mean vertical velocity curve. (See for example Plate VII.)

In the computations for the reduction of the work with meters used in a vertical plane, the average velocity for one minute of time was determined as giving the best results for showing the vertical velocity curves. Lines were ruled across the chronograph sheet for each minute, and the revolutions, or parts of revolutions, were counted for each of the six meters, and entered in a book of tabulation. The computations were carefully made in a regular form and are preserved. The velocities are given in feet per second. (See Sheet 1.)

The reduction of the observations of October 7, with the meters in a vertical plane, may be given as a sample of the methods used. These observations were taken in the channel between the Iowa shore and the first sand-bar above Burlington ("Bar *h*"). This is a straight and well-defined channel at the point where the observations were taken, but becomes more shoal a few hundred feet above. This was the main channel not many years ago.

On this date, October 7, two series of observations were obtained. The results for each minute are given in Tables 4 and 5. These results are also plotted on cross-section paper giving the vertical velocity curves for each minute graphically, which are shown on Plates VI and VIII. The mean results for tables are plotted on a larger scale, and the mean vertical velocity curves drawn; these are shown on Plates VII and IX.

The observations of other days have been reduced and plotted in the same manner as those of October 7, giving twenty-five different mean vertical velocity curves, each of which is derived from sets of observations extending through from eleven to thirty-two minutes. The observations and results of other dates than October 7 will be referred to in more detail in a subsequent portion of this report.

Referring to these mean velocity curves it appears that while there are not always a sufficient number of points in the observations of the different dates to show the slower velocity at the surface, yet in all cases where a sufficient number of observations have been taken the fact is so apparent that a retarded surface velocity has been assumed in all the mean velocity curves. This is especially apparent in the observations of October 7.

c. Comparisons of mean and mid-depth velocities.—Having obtained numerous results for mean velocities at various points from the surface to the bottom, we are now prepared to investigate the relation between mean and mid-depth velocities, to be used for gaugings on the Upper Mississippi River, and on all streams of similar characteristics.

From each mean vertical velocity curve results are taken from the plot for each 0.4 foot in depth. (See for example Plate VII.) Final mean velocities are derived from these results, and the mid-depth velocity is taken off graphically. This gives a comparison between the mean velocity (V_m) and mid-depth velocity ($V_{\frac{1}{2}D}$.)

The formula of Humphreys and Abbot,

$$V_m = V_{\frac{1}{2}D} - \frac{1}{12}(b\,v,)^{\frac{1}{2}}$$

in which

$$b = \frac{1.69}{(D+1.5)^{\frac{1}{2}}}$$

D being the depth of the river at any point, was also used to derive a mean velocity from the mid-depth velocity as taken from the mean vertical velocity curves, for the purpose of comparing the formula with the results of these observations. These quantities for each mean vertical velocity curve are shown on the respective curve plates.

The value v or the mean velocity of the whole cross-section of the river, as used in the above formula, was obtained by the following method from the mean velocities as determined on cross-section No. 1 of the gaugings made under the direction of the Board of Engineers on the low-water navigation of the Mississippi and Missouri Rivers, and reported on in Report of the Chief of Engineers for the year 1880, part 2, page 1526. The velocities for different stages were plotted on cross-section paper, and a line which proved to be a straight line, was drawn approximately through the different points. (See Plate V.) From this plot the value of v could be taken very closely for any stage. These gaugings referred to were taken about the same time as the current-meter observations.

d. Description and reduction of the observations taken subsequent to October 7.—In addition to the work of October 7, observations were taken on the following dates: October 11, 14, 21, 29, and 30, and reduced in a similar manner.

The position of the boat on October 11 was a few feet below cross-section No. 1 of gaugings, and the observations were taken in about 11 feet depth of water, on a flat middle ground where the current might have a slight tendency to divide. The water also became more shoal a few hundred feet down stream. The results here indicated a much greater velocity near the surface than the work of October 7. This might arise from the shoaling of the water below. There was no perceptible wind. The results for the work on October 11 are given in Tables 6, 7, and 8. These results are also plotted on cross-section paper giving the vertical velocity curves for each minute and are shown on Plates X, XII, and XIII, and the corresponding mean vertical velocity curves are shown on Plates XI and XIV. In the work given on Plate XIV, Table 7, a value for mean velocity was also derived by connecting the plotted points by straight lines, and taking off values from this broken line the same as from the curve, the result being a close agreement, showing that with quite irregular results, a mean curve can easily be drawn giving a more probable result for the mean and mid-depth velocities.

The work of October 14 was taken directly in the main steamboat channel of the river, in about 13 feet depth of water, and where the channel was quite uniform and direct for nearly a mile, with a width of from 300 to 500 feet. This channel must not, of course, be confounded with a section of the whole river. The results for this date are given in Tables 9 to 13, inclusive. The results for each minute are plotted to show vertical velocity curves, and are given on Plates XV, XVI, and XVIII, and mean vertical velocity curves are shown on Plates XVII, XIX, and XX.

The work of October 21 was also taken in main channel with about the same position of the boat as on October 14. The results for mean velocities for each minute are given in Tables 14 and 15, and plotted values of mean velocities for each table, and corresponding mean vertical velocity curves are given on Plate XXI.

On October 29 the observations were taken in the same channel as on October 7, but about 400 feet farther down stream. In this channel it will be noticed the results are much more regular than in the steamboat channel on the outside of "Bar *h*." The results for each minute on this date are given in tables 16 to 26, inclusive. The results for each minute are only plotted for two tables to show vertical velocity curves, and are given on Plates XXXI and XXXIII. The mean vertical velocity curves are given on Plates XXII to XXX, inclusive, and also on Plates XXXII and XXXIV.

The work of October 30 was in the main channel opposite Burlington, and below the point where the steamboat channel outside "Bar *h*," and the old channel between this bar and the Iowa shore unite. The current at this point was very much affected by whirls, and the results are quite irregular. The velocities for each minute are given in Tables 27 and 28, and the plotted results for the mean vertical velocity curves are given on Plates XXXV and XXXVI.

e. Compilation of results and determination of co-efficient.—The results as derived from the plates of mean vertical velocity curves are given in Table 29. In this table, columns 4, 5, 7, 8, and 9, are derived from original observations; column 6 is obtained by applying Humphreys & Abbot's formula to the data in column 4. For determining the ratio of mean to mid-depth velocity, twenty-five results are obtained from the observations, and given in column 8, having an extreme range of only 0.057. The mean of these twenty-five results gives a co-efficient (0.958) with probable error of less than 0.0025 for reducing mid-depth to mean velocity.

In Table 30 is given a comparison between the mean velocities as derived from the mid-depth velocities by using the co-efficient (0.958) and those derived from same mid-depth velocity by the Humphreys & Abbot formula. In this table column 2 gives the mid-depth velocity taken from mean vertical velocity curves; column 3 gives the mean velocity as deduced from mid-depth velocity of column 2 by applying co-efficient; column 4 gives mean velocity deduced from mean vertical velocity curves; and column 5 gives mean velocity obtained by applying Humphreys & Abbot's formula to data in column 2. It will be seen that for general results in various parts of the river the co-efficient 0.958 gives a less range of differences, but in the main steamboat channel the formula of Humphreys & Abbot gives results agreeing very closely with the actual mean velocities.

The ratio of depth of mean velocity fillet (m) to the whole depth (D) has a wider range of results, and hence its use to regulate the tying of floats at a certain depth to give mean velocity directly could not be considered as accurate as the co-efficient for reducing mid depth to mean velocity.

f. Comparison between current-meters and floats.—A full description of the method of making these comparisons has been previously given. The work was reduced by determining the velocity of the float over each 50-foot section of the 200-foot base and the velocity given by a meter at the same depths as the floats. The meter result was taken for the next consecutive time after the passage of the float, and for a time interval equal to that of the float over the last section of 50 feet. From an inspection of the results, it was found that the velocity was not uniform over the different sections of 50 feet, and hence a direct comparison of the velocity of the float with the velocity as shown by a meter located just below the section, could not be expected to give definite results. Yet these comparisons are valuable as they demonstrate that while the velocity of the current changed materially during the time the series of observations with floats was being made, the relation between the velocities over the different sections was preserved. To show these variations, the results for one series of floats are plotted on cross-section paper, and curves drawn. (See Table 31 and Plates XXXVII, XXXVIII, and XXXIX.) In calculating the velocity of the floats when their course diverged from a line parallel to the base sufficiently to make a perceptible increase in distance, the actual distance traversed, as taken from the plot, was used.

The velocities given by the five meters during the passage of the floats were all reduced for the time of each section, thus giving the five velocities in a vertical plane, as shown by the meters in their position below the base, while the floats were passing over each section of the base. These vertical velocity curves have also been plotted opposite each curve for the final sections.

The results for the floats over each section of the base and for the meter at same depth for next consecutive time; also for the velocities of the five meters, for this one series, are given in Table 31. The curves are given on Plates XXXVII, XXXVIII, and XXXIX.

g. Pulsations.—During the reduction of this current-meter work it was observed that there were very strong and well-defined pulsations. The results for each consecutive minute for a part of the work on October 14 have been plotted on cross-section paper with velocity in feet per second for vertical ordinate, and a horizontal scale of time. This is given on Plate XL, and it will be observed that there are quite extreme changes, or pulsations, in velocity; that they are much greater near the bottom than near the surface, and that the changes generally occur at about the same time from the surface to the bottom. As extreme changes or sudden pulsations are not shown on Plate XL, which only gives the average velocity per minute, Plate XLI is given where the number of quarter revolutions for each ten seconds is plotted with quarter revolutions in ten seconds for vertical or velocity scale, and a horizontal scale of time. This work of October 28, shown on Plate XLI, was a comparison of meters and floats, and only five meters could be used in a vertical plane, one pen being reserved for the record of floats. These curves, which give the continuous record of meters during the time of passage of one series of floats, show very plainly the extreme and sudden changes in velocity, amounting to nearly one-half the greatest velocity, in less than one minute of time. It will also be observed here that these extreme changes occur at about the same time from the surface to the bottom.

In connection with these pulsations it may be well to state here that the quarter-boat was always securely anchored in four directions. There were two heavy anchors with lines leading off quartering from the bow up stream from 150 to 200 feet, and also two anchors at the stern in the same manner. This would allow but very slight movement to the quarter-boat. Then, as the lower end of the cable was fastened to a 150-pound mushroom anchor there was no possibility of any perceptible swaying of the meters near the bottom. If these variations in velocity or pulsations were caused by the swaying of the meter-cable, it might be expected that the changes or pulsations would be much greater near the surface than near the bottom, but the reverse of this is true. Again, these pulsations cannot be referred to the effect of wind, as in that case they would be greater near the surface.

A full development of such curves as are shown on Plate XL for all of this current-meter work might give valuable data for study in regard to the effect of wind or the possible relation between these pulsations and sand waves; and in the case of a set of observations extended through varying stages some relation might be discovered between these pulsations and the rise or fall of a river.

A table of velocities corresponding to the revolutions could be prepared for each meter, and the velocity curves could be plotted readily from these tables by merely counting the number of quarter or half revolutions registered by the meter and referring to the table for the corresponding velocity.

h. General suggestions as to current-meter work.—It is to be regretted that these observations could not have been worked up in the field, which would have permitted carrying out many suggestions which have presented themselves during the reduction of the work. A few are mentioned for the benefit of any future similar observations with current-meters.

There always appear to be very decided whirls in the motion of the water. The question arises whether the planes of motion of these whirls are horizontal, vertical, or changeable. The Buff & Berger current-meters are made so as to have free motion in all directions. In their use for the work at Burlington, Iowa, the meters were always given free motion in all directions, and were supposed to head directly in the current. It would have been well, after having used the meters in this manner for half an hour, to have repeated the observations after putting in a pin, provided by the maker for the purpose, which only permits a motion in a horizontal plane; and to have again repeated the observations after the instrument was clamped so as to prevent horizontal swaying and allow vertical motion only; and finally, to secure a resultant velocity by clamping firmly in such a direction and manner as to make the meter head in a line parallel with the general direction of the current of the main channel. This would give data to show the effect of whirls, and determine whether this effect was greater in a horizontal or vertical plane.

If the chronograph specially constructed for this work is used in the future for current-meter observations, I would suggest that there be six additional pens with their magnets attached to the instrument, which addition would allow of the use of twelve current-meters in a vertical plane, and thus give the vertical curve much more accurately. There are six spaces on the present record sheets which would readily admit of the use of six more pens.

A self-registering water-gauge located as near as practicable to the point of observation with the meter, would give a very valuable record. Readings were taken every ten minutes on gauges in connection with the gaugings of the river at Burlington, and in calm weather a perpetual rising and falling could be detected, and perhaps it would be found from a self-registering gauge that fluctuations in height of water, or change of slope, would correspond very closely with the pulsations in velocity.

In this report the reductions have been made with reference to giving data to determine the relation of mean to mid-depth velocity, and any investigation of pulsations has only been incidental to such reduction.

Very respectfully, your obedient servant,

G. A. Marr,
Assistant Engineer.

Maj. A. Mackenzie,
Corps of Engineers, U. S. A.

TABLE 1.—*Table of meter coefficients.*

Meters.	Coefficients (*a*).	Constants (*b*).	Number of equations.	Probable error.
No. 2.	+3.71160	+0.24230	22	0.0086
3.	+3.81945	+0.09826	30	0.00006
4.	+3.76044	+0.11653	27	0.00023
5.	+3.81420	+0 10810	38	0.00008
6.	+3.73035	+0.15220	39	0.0004
7.	+3.74880	+0.12440	19	0.0001
Prop. meter.	+1.34132	+0.0740	36	0.00014

FORMULA.

$v' = an + b$
v' = velocity in feet per second.
n = number of revolutions per second.

Equations solved by method of least squares.

TABLE 2.—*Current-meter comparisons on horizontal frame. Burlington, Iowa, October* 14, 1879.

[Depth of water, 13.0 feet; meters below surface, 1.5 feet. For position of boat, see map.]

Meters.	Revolutions for 4 minutes before reversal.	Revolutions for 4 minutes. after reversal.	Mean for 4 minutes.	Velocities in feet per second.	Mean for 6 meters.	Mean omitting meter No. 2.	Correction for meter No. 2.
No. 2.	175.02	182.02	178.52	3.0032			
No. 3.	177.12	179.85	178.49	2.9388			
No. 4.	173.60	175.70	174.65	2.8530	2.9154	2.8978	—0.1054
No. 5.	171.80	182.07	176.94	2.9201			
No. 6.	171.22	182.10	176.66	2.8991			
No. 7.	174.80	177.80	176.30	2.8782			

REMARKS.—Frame set at a right angle to the direction of the current as near center of main channel as possible. The frame is such as to place the meters opposite each other and about 2 feet apart. To eliminate differences in velocities the meters were reversed in position on the frame, 4 minutes before reversal being combined with 4 minutes after reversal.

TABLE 3.—*Current-meter comparisons on horizontal frame. Burlington, Iowa, October* 29, 1879.

[Depth of water, 21.7 feet; meters below surface, 3.0 feet. For position of boat, see map. Frame set as for the work given in Table 2.]

Meters.	Mean results before reversal (11 minutes).	Mean results after reversal (19 minutes).	Combined results.	Mean for 6 meters.	Mean omitting No. 2.	Correction for No. 2.	Correction for No. 2, October 14, 1879.
Propeller.	2.3736	2.5085	2.4411				
No. 2.	2.5037	2.5597	2.5317				
No. 3.	2.4281	2.4407	2.4344	2.4458	2.4286	—0.1031	—0.1054
No. 4.	2.4106	2.3955	2.4031				
No. 5.	2.4827	2.4025	2.4426				
No. 6.	2.4811	2.3628	2.4219				

REMARKS.—On account of the poor determination of coefficient for meter No. 2, these comparisons are used to determine a correction for this meter, which is adopted as —0.1 foot for velocity in feet per second, and applied to all results.

TABLE 4.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 7, 1879.*

[Depth, 19.5 feet; stage, 0.85 foot. For position of boat, see map.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		16.0 feet.	12.75 feet.	9.5 feet.	7.0 feet.	4.5 feet	1.5 feet.
h. m. m.							
4 09 to 10	Calm.	1.652	1.919	2.025	2.012	2.076	2.027
10 to 11		1.352	1.623	1.787	1.945	2.064	2.024
11 to 12		1.243	1.588	1.878	2.079	2.142	2.074
12 to 13		1.420	1.661	1.824	1.933	2.129	2.136
13 to 14		1.194	1.435	1.705	1.948	2.132	2.121
14 to 15		1.410	1.531	1.796	1.999	2.132	2.067
15 to 16		1.512	1.874	2.028	2.001	2.142	2.046
16 to 17		1.546	1.737	1.840	2.009	2.129	2.080
17 to 18		1.537	1.734	2.050	2.136	2.201	2.124
18 to 19		1.478	1.884	2.053	2.120	2.213	2.111
19 to 20		1.559	1.900	2.072	2.123	2.167	2.080
20 to 21		1.605	2.021	2 044	2.152	2.232	2.086
21 to 22		1.383	1.804	1.956	2.117	2.207	2.086
22 to 23		1.525	1.865	2.053	2.196	2.254	2.124
23 to 24		1.426	1.836	1.997	2.091	2.148	2.027
24 to 25		1.420	1.807	2.009	2.101	2.154	2.071
25 to 26		1.556	1.709	1.853	2.085	2.142	2.049
26 to 27		1.488	1.795	1.925	2.101	2.185	2.105
27 to 28		1.407	1.948	2.066	2.126	2.179	2.055
Means for 19 results.		1.459	1.772	1.945	2.067	2.159	2.079

REMARK.—Average velocity for one minute of time.

TABLE 5.—*Subsurface velocities as given by current meters. Burlington, Iowa, October 7*—Continued.

[Depth, 21.25 feet; stage, 0.85 foot. For position of boat, see map. Average velocities for one minute.

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		18.5 feet.	15.75 feet.	13.25 feet.	10.75 feet.	6.75 feet.	2.75 feet.
h. m. m.							
5 19 to 20	Calm.	1.503	1.772	1.981	2.152	2.272	2.167
20 to 21		1.537	1.747	1.890	2.050	2.167	2.167
21 to 22		1.512	1.801	1.990	2.152	2.263	2.155
22 to 23		1.627	1.897	2.103	2.123	2.266	2.242
23 to 24		1.488	1.817	1.984	2.228	2.254	2.149
*27 to 28		1.760	1.912	2.025	2.120	2.275	2.227
28 to 29		1.565	1.760	1.990	2.145	2.266	2.196
29 to 30		1.649	1.963	2.053	2.076	2.316	2.239
30 to 31		1.488	1.830	1.962	2.082	2.213	2.217
31 to 32		1.679	1.827	1.987	2.063	2.282	2.280
32 to 33		1.546	1.852	2.084	2.158	2.247	2.167
33 to 34		1.645	1.871	2.056	2.174	2.269	2.155
34 to 35		1.664	1.919	2.072	2 133	2.288	2.149
35 to 36		1.509	1.823	1.931	2.006	2.241	2.199
36 to 37		1.472	1.820	2.009	2.098	2.241	2.199
37 to 38		1.686	1.871	2.047	2.120	2.232	2.186
38 to 39		1.410	1.839	2.163	2.190	2.257	2.149
†49 to 50		1.664	1.839	2.028	2.117	2.157	2.139
50 to 51		1.596	1.948	2.078	2.177	2.257	2.186
51 to 52		1.775	2.008	2.094	2.117	2 198	2.142
52 to 53		1.683	1.941	2.131	2.238	2 275	2 208
53 to 54		1.534	1.906	2.028	2.107	2.260	2.205
Means for 22 results.		1.591	1.862	2.031	2.128	2.250	2.187

* Stopped to adjust meter. † Stopped to adjust battery.

Table 6.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* **11, 1879.**

[Depth, 11.5 feet; stage, 0.75 foot. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		9.6 feet.	7.7 feet.	5.75 feet	4.3 feet.	2.9 feet.	1.5 feet.
h. m. m.							
3 12 to 13		1.645	1.811	1.909	2.012	2.070	2.152
13 to 14		1.621	1.871	1.964	2.050	2.107	2.161
14 to 15		1.744	1.833	1.909	2.022	2.070	2.121
15 to 16		1.624	1.774	1.870	1.999	2.048	2.105
16 to 17		1.656	1.903	1.978	2.095	2.123	2.149
17 to 18		1.633	1.865	2.008	2.088	2.123	2.142
18 to 19	alm.	1.611	1.[illegible]99	1.984	2.091	2.114	2.149
19 to 20		1.704	1.790	1.931	2.063	2.104	2.142
20 to 21		1.757	1.871	1.947	2.079	2.089	2.130
21 to 22		1.785	1.940	1.981	2.120	2.118	2.130
22 to 23		1.571	1.702	1.809	1.942	2.055	2.139
23 to 24		1.652	1.862	1.937	2.072	2.145	2.155
24 to 25		1.593	1.847	1.956	2.080	2.117	2.117
Means for 13 results.		1.661	1.836	1.937	2.055	2.099	2.138

Table 7.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* **11, 1879**—Continued.

[Depth, 11.0 feet; stage, 0.75 foot. For position of boat, see map. Average velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		9.1 feet.	7.2 feet.	5.25 feet	3.8 feet.	2.4 feet.	1.0 feet.
h. m. m.							
5 00 to 01		1.850	2.006	2.015	2.101	2.128	2.217
01 to 02		1.782	2.008	2.116	2.168	2.182	2.271
02 to 03		1.794	1.963	2.025	2.091	2.129	2.230
03 to 04		1.760	1.967	2.047	2.150	2.179	2.261
04 to 05		1.686	1.932	2.028	2.101	2.120	2.180
05 to 06		1.748	1.925	1.990	2.085	2.106	2.239
06 to 07		1.754	1.935	2.067	2.115	2.160	2.233
07 to 08		1.766	1.995	2.041	2.107	2.135	2.230
08 to 09		1.653	1.846	1.959	2.022	2.048	2.230
09 to 10		1.695	1.944	2.047	2.107	2.129	2.296
10 to 11		1.806	1.916	2.012	2.101	2.101	2.280
11 to 12		1.704	1.874	1.975	2.076	2.090	2.246
12 to 13		1.686	1.963	2.034	2.147	2.163	2.255
13 to 14		1.580	1.862	1.972	2.114	2.142	2.255
14 to 15	Calm	1.710	1.983	2.078	2.158	2.170	2.246
15 to 16		1.763	1.973	1.981	2.069	2.075	2.292
16 to 17		1.726	1.895	1.989	2.044	2.084	2.274
17 to 18		1.702	1.893	1.981	2.076	2.061	2.286
18 to 19		1.633	1.874	1.997	2.060	2.107	2.308
19 to 20		1.730	1.919	2.019	2.120	2.129	2.314
20 to 21		1.625	1.777	1.970	2.044	2.111	2.299
21 to 22		1.695	1.948	1.981	2.034	2.139	2.324
22 to 23		1.806	1.960	2.062	2.180	2.182	2.308
23 to 24		1.652	1.846	1.926	1.996	2.107	2.299
24 to 25		1.492	1.760	1.862	....	2.098	2.280
*26 to 27		1.803	2.053	2.091	2.123	2.156	2.249
27 to 28		1.656	1.852	1.954	2.056	2.142	2.361
28 to 29		1.757	1.963	1.986	2.044	2.075	2.296
29 to 30		1.570	1.774	1.987	2.076	2.148	2.358
30 to 31		1.853	1.992	2.081	....	2.191	2.352
Means for 30 results.		1.715	1.920	2.009	2.092	2.126	2.276

* Stopped chronograph to wind.

TABLE 8.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* 11, 1879—Continued.

[Depth, 11.0 feet; stage, 0.75 foot. For position of boat, see map. Average velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		9.1 feet.	7.2 feet.	5.25 feet.	3.8 feet.	2.4 feet.	1.0 feet.
h. m. m.							
5 44 to 45		1.724	1.935	2.033	2.118	2.129	2.242
45 to 46		1.675	1.838	1.954	2.066	2.148	2.267
46 to 47		1.761	2.008	2.088	2.147	2.182	2.252
47 to 48		1.744	1.984	2.091	2.136	2.120	2.236
48 to 49		1.797	2.008	2.053	2.111	2.132	2.267
49 to 50		1.766	1.979	2.091	2.176	2.173	2.299
50 to 51		1.772	1.928	2.044	2.141	2.177	2.289
51 to 52		1.819	2.056	2.066	2.163	2.177	2.274
52 to 53		1.712	1.941	2.033	2.055	2.072	2.211
53 to 54		1.644	1.842	1.937	2.031	2.092	2.224
54 to 55		1.698	1.858	2.025	2.091	2.107	2.280
55 to 56		1.915	2.048	2.044	2.123	2.114	2.239
56 to 57		1.670	1.852	1.987	2.076	2.129	2.280
57 to 58		1.775	1.893	1.967	2.088	2.104	2.289
58 to 59		1.582	1.860	2.003	2.120	2.191	2.321
59 to 60	Calm.	1.664	1.901	2.001	2.111	2.149	2.420
6 00 to 01		1.741	1.944	2.070	2.128	2.218	2.445
01 to 02		1.717	1.877	1.975	2.072	2.140	2.308
02 to 03		1.800	1.941	1.965	2.093	2.154	2.333
03 to 04		1.695	1.849	1.956	2.123	2.162	2.264
04 to 05		1.812	1.984	2.084	2.150	2.182	2.327
*07 to 08		1.689	1.919	1.994	2.087	2.170	2.311
08 to 09		1.792	1.941	2.039	2.104	2 151	2.305
09 to 10		1.627	1.844	1.950	2.101	2.157	2.311
10 to 11		1.554	1.792	1.957	2.066	2.126	2.277
11 to 12		1.678	1.951	2.003	2.044	2.111	2.274
12 to 13		1.731	1.909	1.972	2.066	2.135	2.292
13 to 14		1.704	1.919	1.997	2.079	2.129	2.271
14 to 15		1.698	1.909	2.015	2.115	2.151	2.321
15 to 16		1.723	1.890	2.033	2.101	2.129	2.261
16 to 17		1.757	1.995	2.067	2.101	2.125	2.217
17 to 18		1.743	1.876	1.931	2.047	2.092	2.280
Means for 32 results.		1.724	1.921	2.013	2.101	2.141	2.287

* Stopped chronograph to wind.

TABLE 9.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* 14, 1879

[Depth, 13.2 feet; stage, 0.89 foot. For position of boat, see map. Wind from south.]

Time.	Wind, up stream.	Velocities in feet per second at the given depths below water surface.					
		11.0 feet.	8.7 feet.	6.7 feet.	5.0 feet.	3.4 feet.	1.7 feet.
h. m. m.							
3 39 to 40	Force, 2..	2.385	2.520	2.623	2.724	2.813	2.889
40 to 41		2.142	2.465	2.592	2.673	2.692	2.745
41 to 42		2.119	2.406	2.564	2.716	2.777	2.861
42 to 43		2.198	2.493	2.576	2.641	2.639	2.717
43 to 44		2.293	2.616	2.717	2.778	2.776	2.877
44 to 45		2.065	2.476	2.601	2.695	2.748	2.817
45 to 46		2.143	2.481	2.601	2.657	2.707	2.749
46 to 47		2.108	2.482	2.627	2.756	2.829	2.898
47 to 48		2.287	2.562	2.714	2 794	2.850	2.905
48 to 49		2.224	2.541	2.678	2.807	2.850	2.873
49 to 50		2.137	2.517	2.609	2.644	2.683	2.699
50 to 51		2.136	2.527	2.648	2.695	2.745	2.789
51 to 52		1.788	2.333	2.558	2.708	2.776	2.830
52 to 53		1.809	2.438	2.603	2.710	2.767	2.842
53 to 54		1.840	2.398	2.506	2.643	2.760	2.811
54 to 55		1.816	2.449	2.495	2.587	2.669	2.798
55 to 56		1.986	2.427	2.580	2.673	2.770	2.848
56 to 57		2.048	2.562	2.686	2.767	2.841	2.911
57 to 58		2.270	2.508	2.551	2.624	2.731	2.780
58 to 59		2.314	2.544	2.605	2.691	2.721	2.745
59 to 60	Force, 2½.	2.218	2.500	2.636	2.753	2 849	2.880
4 00 to 01		2.179	2.473	2.611	2.727	2.751	2.802
01 to 02		2.270	2.546	2.706	2.815	2.850	2.867
02 to 03		2.346	2.595	2.667	2.768	2.813	2.895
03 to 04		2.232	2.353	2.462	2.567	2.693	2.789
Means for 25 results.....		2.134	2.488	2.609	2.705	2.764	2.825

TABLE 10.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* 14 1879—Continued.

[Depth, 13.2 feet; stage, 0.89 foot. For position of boat, see map. Wind from south.]

Time.	Wind, up stream.	Velocities in feet per second at the given depths below water surface.					
		11.0 feet.	8.7 feet.	6.7 feet.	5.0 feet.	3.4 feet.	1.7 feet.
h. m. m.							
4 15 to 16	Force, 2½.	2.290	2.527	2.630	2.724	2.798	2.848
16 to 17		2.097	2.339	2.525	2.676	2.754	2.864
17 to 18		2.332	2.603	2.637	2.670	2.729	2.817
18 to 19		1.979	2.333	2.551	2.695	2.790	2.811
19 to 20		2.270	2.527	2.623	2.740	2.799	2.852
20 to 21		2.382	2.629	2.650	2.748	2.804	2.855
21 to 22		2.181	2.559	2.714	2.751	2.771	2.808
22 to 23		2.236	2.428	2.562	2.675	2.779	2.811
23 to 24		2.354	2.554	2.648	2.711	2.771	2.817
24 to 25	Force, 3..	2.403	2.637	2.727	2.794	2.849	2.905
25 to 26		2.298	2.473	2.561	2.638	2.737	2.820
Means for 11 results.....		2.257	2.510	2.621	2.711	2.780	2.837

TABLE 11.—*Subsurface velocities as given by current meters. Burlington, Iowa, October* 14 1879—Continued.

[Depth, 12.9 feet; stage, 0.89 foot. For position of boat, see map. Strong south wind.]

Time.	Wind, up stream.	Velocities in feet per second at the given depths below water surface.					
		11.2 feet.	9.6 feet.	8.0 feet.	6.4 feet.	4.2 feet.	2.1 feet.
h. m. m.							
4 50 to 51	Force, 3..	2.263	2.452	2.501	2.552	2.561	2.667
51 to 52		2.126	2.266	2.329	2.393	2.507	2.602
52 to 53		1.942	2.263	2.407	2.576	2.686	2.736
53 to 54		2.290	2.474	2.540	2.683	2.782	2.808
54 to 55		2.385	2.543	2.570	2.600	2.499	2.464
55 to 56		2.227	2.482	2.551	2.619	2.678	2.724
56 to 57		2.247	2.477	2.451	2.573	2.637	2.755
57 to 58		2.276	2.514	2.594	2.697	2.709	2.720
58 to 59		2.205	2.395	2.484	2.633	2.767	2.780
59 to 60		2.332	2.592	2.589	2.700	2.801	2.852
5 00 to 01		2.207	2.411	2.529	2.699	2.749	2.836
01 to 02		2.211	2.495	2.511	2.708	2.771	2.864
02 to 03		2.292	2.610	2.617	2.724	2.760	2.827
03 to 04		1.987	2.320	2.399	2.501	2.637	2.792
*06 to 07		2.174	2.505	2.545	2.676	2.726	2.733
07 to 08		2.283	2.487	2.507	2.579	2.645	2.714
08 to 09		1.976	2.272	2.352	2.509	2.624	2.695
Means for 17 results.....		2.201	2.445	2.499	2.613	2.679	2.739

* Stopped chronograph to wind.

Table 12.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 14' 1879*—Continued.

[Depth, 13 feet; stage, 0.89 foot. For position of boat, see map. Strong south wind.]

Time.	Wind, up stream.	Velocities in feet per second at the given depths below water surface.					
		11.3 feet.	9.7 feet.	8.1 feet.	6.5 feet.	4.3 feet.	2.2 feet.
h. m. m.							
5 13 to 14		2.184	2.468	2.573	2.673	2.760	2.877
14 to 15		2.111	2.404	2.550	2.713	2.763	2 795
15 to 16		2.363	2.485	2.576	2.686	2.737	2.814
16 to 17		2.335	2.495	2.517	2.629	2.735	2.836
17 to 8		2.140	2.345	2.479	2.619	2.703	2.789
18 to 19		2.250	2.465	2.559	2.670	2.739	2.805
19 to 20		2.403	2.633	2.650	2.786	2.854	2.905
20 to 21		2.230	2.493	2.533	2.691	2.813	2.877
21 to 22		2.411	2.614	2.658	2.713	2.773	2.811
22 to 23		2.266	2.401	2.412	2 471	2.613	2.720
23 to 24	Force, 3.	2.276	2.457	2.540	2.586	2.720	2.774
24 to 25		2.204	2.455	2.481	2.617	2.746	2.845
25 to 26		1.927	2.239	2.370	2.522	2.633	2.711
26 to 27		2.125	2.363	2.448	2.597	2.714	2.774
27 to 28		2.017	2.261	2.371	2.548	2.673	2.742
28 to 29		2.261	2.525	2.623	2.699	2.767	2.839
29 to 30		2.405	2.660	2.667	2.718	2.776	2.842
30 to 31		2.103	2.385	2.492	2.583	2.712	2.774
31 to 32		2.080	2.336	2.445	2.500	2.664	2.770
32 to 33		2.071	2.385	2.498	2.583	2.717	2.792
33 to 34		2.082	2.350	2.464	2.603	2.763	2.817
Means for 21 results.....		2.202	2.439	2.519	2.629	2.732	2.805

Table 13.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 14' 1879*—Continued.

[Depth, 13 feet; stage, 0.89 foot. For position of boat, see map. Average velocities for one minute.]

Time.	Wind, up stream.	Velocities in feet per second at the given depths below water surface.					
		11.3 feet.	9.7 feet.	8.1 feet.	6 5 feet.	4.3 feet.	2.2 feet.
h m. m.							
5 40 to 41		2.119	2.382	2.443	2.594	2.720	2.767
41 to 42		2.408	2.540	2.583	2.656	2.732	2.808
42 to 43		2.191	2.546	2.558	2.710	2.804	2.880
43 to 44		2.083	2.434	2.558	2.697	2.801	2.848
44 to 45		2.111	2.380	2.495	2.635	2.740	2.774
45 to 46		2.307	2.517	2.514	2.672	2.773	2.870
46 to 47		2.295	2.547	2.606	2.730	2.836	2.902
47 to 48		2.327	2.653	2.684	2.813	2.857	2.905
48 to 49		1.993	2.315	2.396	2.486	2.574	2.655
49 to 50		2 066	2.380	2.446	2.557	2.676	2.758
50 to 51	Force, 3	2.338	2.543	2.545	2.617	2.731	2.833
51 to 52		2.171	2.514	2.580	2.681	2.765	2.820
52 to 53		2.185	2.501	2.558	2.705	2.779	2.867
53 to 54		2.157	2.497	2.543	2.665	2.776	2.836
54 to 55		2.065	2.353	2.409	2.595	2.749	2.764
55 to 56		2.170	2.385	2.415	2.548	2.707	2.811
56 to 57		2.007	2.344	2.362	2.486	2.642	2.711
57 to 58		2.167	2.395	2.388	2.555	2.728	2.783
58 to 59		2.122	2.407	2.489	2.598	2.711	2.770
59 to 60		2.154	2.493	2.534	2.692	2.760	2.823
6 00 to 01		1.952	2.263	2.313	2.449	2.571	2.655
01 to 02		2.116	2.425	2.449	2.583	2.676	2.752
02 to 03		2.190	2.613	2.655	2.743	2.824	2.848
03 to 04		2.037	2.339	2.357	2.501	2.686	2.805
Means for 24 results.....		2.155	2.449	2.495	2.624	2.734	2.802

TABLE 14.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 21, 1879.*

[Depth, 13.5 feet; stage, 1.27 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		11 3 feet.	9.0 feet.	6.8 feet.	5.2 feet.	3.5 feet.	1 8 feet,
h. m. m.							
6 20 to 21	Calm	2.422	2.575	2.540	2.675	2.717	2.758
21 to 22		2.385	2.425	2.526	2.684	2.731	2.733
22 to 23		2.380	2.590	2 648	2.805	2.850	2.877
23 to 24		2.054	2.393	2.525	2.633	2.740	2.764
24 to 25		2.221	2.379	2.384	2.548	2.639	2 733
25 to 26		2.126	2.465	2.547	2.667	2.731	2.724
26 to 27		2.335	2.493	2.545	2.649	2.683	2.727
27 to 28		2.334	2.501	2.553	2.619	2.706	2.736
28 to 29		2.414	2.547	2.623	2.733	2.791	2.842
29 to 30		2.348	2.578	2.587	2.724	2.767	2.786
30 to 31		2.142	2.522	2.594	2.692	2.785	2.833
31 to 32		2.464	2.562	2.642	2.765	2.808	2.820
32 to 33		2.247	2.495	2.589	2.683	2.714	2.745
33 to 34		2.235	2.465	2.529	2.651	2.749	2.764
34 to 35		2.289	2.562	2.636	2.730	2.779	2.798
35 to 36		2.522	2.648	2.645	2.729	2.757	2.749
36 to 37		2.385	2.582	2.562	2.684	2.779	2.836
37 to 38		2.230	2.508	2.623	2.702	2.784	2.795
38 to 39		2.525	2.605	2.628	2.743	2.788	2.823
39 to 40		2.525	2.611	2.611	2.673	2.739	2.755
40 to 41		2.303	2.508	2.575	2.694	2.798	2.833
41 to 42		2.443	2.595	2.623	2.689	2.746	2.786
42 to 43		2.233	2.549	2.586	2.683	2.723	2.761
43 to 44		2.317	2.541	2.655	2.740	2.788	2.805
Means for 24 results.		2.328	2.529	2.582	2.691	2.754	2.783

TABLE 15.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 21, 1879*—Continued.

[Depth, 13.7 feet; stage, 1.27 feet. For position of boat, see map. Mean velocity for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		12.0 feet.	10 3 feet.	8 6 feet.	7.0 feet	4.7 feet.	2.5 feet.
h. m. m.							
7 00 to 01	Calm.	2.119	2.329	2.428	2.524	2.732	2.777
01 to 02		2.100	2.323	2.501	2.598	2.687	2.770
02 to 03		2.117	2.355	2.486	2.576	2.759	2.789
03 to 04		2.117	2.412	2.490	2.549	2.675	2.724
04 to 05		2.242	2.444	2.586	2.586	2.687	2.714
05 to 06		2.029	2.304	2.390	2.516	2.644	2.692
06 to 07		2.111	2.326	2.402	2.497	2.589	2.652
07 to 08		1.952	2.188	2.365	2.457	2.679	2.758
08 to 09		2.201	2.414	2.486	2.587	2.732	2.745
09 to 10		2.063	2.331	2.465	2.540	2.690	2.730
10 to 11		2.241	2.390	2.482	2.595	2.740	2.830
11 to 12		2,219	2.489	2.576	2.689	2.830	2.895
12 to 13		2.270	2.447	2.465	2.540	2 651	2.742
13 to 14		2.122	2.299	2.456	2.555	2.686	2.677
14 to 15		2.066	2.285	2.335	2.417	2.602	2 686
15 to 16		2.080	2.272	2.415	2.498	2 676	2.761
16 to 17		2.126	2.344	2.456	2.605	2.711	2.755
17 to 18		2.184	2.466	2.581	2 638	2.728	2.755
18 to 19		1.944	2.228	2.370	2.471	2.678	2.758
19 to 20		2.075	2.454	2.567	2.632	2.732	2.739
20 to 21		2.185	2.444	2.468	2.559	2.636	2.702
21 to 22		1.998	2.314	2.476	2.567	2.656	2.686
22 to 23		2.106	2.368	2.401	2.463	2.636	2.652
23 to 24		2.162	2.441	2.486	2.544	2.675	2.730
24 to 25		1.868	2.228	2.413	2.598	2.765	2.823
Means for 25 results.		2.108	2.356	2.462	2.552	2.691	2.742

TABLE 16.—*Subsurface velocities as given by current meters. Burlington, Iowa, October 29, 1879.*

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
12 47 to 48	From N.N.W., blowing down-stream; force, 1 to 3.	2.067	2.119	2.312	2.374	2.362	2.355
48 to 49		1.694	1.984	2.208	2.351	2.366	2.392
49 to 50		1.965	2.032	2.137	2.349	2.393	2.418
50 to 51		1.723	2.001	2.162	2.304	2.346	2.414
51 to 52		1.723	1.989	2.298	2.363	2.379	2.367
52 to 53		1.999	2.143	2.312	2.407	2.365	2.369
53 to 54		1.780	1.983	2.202	2.304	2.368	2.403
54 to 55		1.831	2.184	2.396	2.456	2.401	2.393
55 to 56		2.074	2.151	2.350	2.299	2.341	2.387
56 to 57		2.012	2.219	2.326	2.366	2.389	2.401
57 to 58		1.887	2.000	2.196	2.294	2.370	2.375
58 to 59		1.829	2.103	2.275	2.318	2.341	2.370
59 to 60		2.002	2.196	2.320	2.329	2.336	2.308
1 00 to 01		1.999	2.194	2.388	2.370	2.347	2.359
(*)							
03 to 04		1.973	2.245	2.388	2.437	2.424	2.395
04 to 05		1.936	2.153	2.274	2.345	2.397	2.390
05 to 06		1.849	2.136	2.433	2.404	2.385	2.400
06 to 07		1.917	2.136	2.293	2.363	2.419	2.400
Means for 18 results.		1.903	2.109	2.293	2.357	2.374	2.383

* Chronograph stopped to adjust paper.

TABLE 17.—*Subsurface velocities as given by current meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
1 09 to 10	From N.N.W., blowing down-stream; force, 1 to 3.	1.946	2.184	2.328	2.443	2.444	2.401
10 to 11		1.851	2.091	2.271	2.341	2.376	2.418
11 to 12		1.784	1.938	2.166	2.261	2.325	2.372
12 to 13		1.755	1.986	2.213	2.349	2.422	2.434
13 to 14		1.822	2.035	2.263	2.359	2.395	2.370
14 to 15		1.959	2.104	2.369	2.376	2.357	2.359
15 to 16		1.813	2.064	2.191	2.310	2.357	2.336
16 to 17		2.046	2.226	2.326	2.377	2.389	2.415
17 to 18		1.811	1.942	2.150	2.241	2.344	2.406
18 to 19		1.726	1.923	2.123	2.269	2.352	2.378
19 to 20		1.770	2.018	2.170	2.326	2.384	2.432
20 to 21		1.967	2.120	2.299	2.399	2.363	2.375
21 to 22		1.880	2.075	2.247	2.338	2.343	2.359
22 to 23		2.093	2.253	2.361	2.376	2.387	2.378
23 to 24		1.908	2.142	2.363	2.345	2.333	2.372
24 to 25		1.934	2.153	2.293	2.347	2.381	2.379
25 to 26		1.749	1.949	2.075	2.232	2.352	2.412
(*)							
31 to 32		1.960	2.191	2.355	2.379	2.381	2.386
32 to 33		1.999	2.088	2.267	2.335	2.377	2.365
33 to 34		1.912	2.052	2.223	2.254	2.322	2.344
34 to 35		1.860	2.024	2.177	2.277	2.366	2.404
35 to 36		1.779	2.052	2.267	2.304	2.365	2.361
36 to 37		1.909	2.160	2.361	2.451	2.430	2.384
37 to 38		1.985	2.103	2.302	2.299	2.322	2.319
38 to 39		1.866	2.159	2.310	2.310	2.311	2.314
Means for 25 results.		1.883	2.081	2.259	2.332	2.367	2.379

* Chronograph stopped to adjust paper.

TABLE 18.—*Subsurface velocities as given by current meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
1 52 to 53	From N.N.W., blowing down-stream; force, 1 to 3.	2.022	2.332	2.419	2.396	2.389	2.484
53 to 54		1.967	2.225	2.427	2.404	2.323	2.334
54 to 55		1.933	2.194	2.352	2.330	2.357	2.431
55 to 56		1.863	2.075	2.269	2.382	2.405	2.397
56 to 57		1.710	2.080	2.242	2.338	2.360	2.306
57 to 58		1.936	2.242	2.339	2.398	2.384	2.365
58 to 59		1.962	2.184	2.302	2.381	2.352	2.418
59 to 60		2.095	2.304	2.427	2.424	2.371	2.451
2 00 to 01		2.012	2.315	2.409	2.448	2.400	2.417
01 to 02		1.901	2.179	2.333	2.396	2.385	2.407
02 to 03		1.862	2.046	2.236	2.341	2.390	2.468
03 to 04		2.023	2.213	2.399	2.388	2.390	2.406
04 to 05		1.914	2.199	2.439	2.467	2 470	2.465
(*)							
09 to 10		1.793	2 099	2.306	2.381	2.381	2.395
10 to 11		2.011	2.160	2.312	2.396	2.344	2.361
11 to 12		1.781	2.126	2.312	2.359	2.397	2.398
12 to 13		1.960	2.069	2.207	2.305	2.330	2.344
13 to 14		1.855	2.032	2.186	2.338	2.387	2.390
14 to 15		1.874	2.031	2.189	2.354	2.347	2.344
15 to 16		1.895	2.173	2.309	2.345	2.395	2.392
16 to 17		1.915	2.191	2.294	2.359	2.373	2.389
17 to 18		1.794	2.095	2.205	2.318	2.385	2.421
18 to 19		1.803	2.078	2.275	2.384	2.381	2.378
19 to 20		1.855	2.097	2.339	2.368	2.363	2.350
Means for 24 results.		1.906	2.156	2.314	2.375	2.377	2.396

* Stopped to fix pen No. 4.

TABLE 19.—*Subsurface velocities as given by current meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
2 22 to 23	From N.N.W., blowing down-stream; force, 1 to 3.	1.688	1.928	2.156	2.341	2.395	2.411
23 to 24		1.899	2.068	2.245	2.272	2.306	2.342
24 to 25		1.733	1.986	2.223	2.316	2.339	2.378
25 to 26		1.832	1.967	2.167	2.290	2.306	2.327
26 to 27		1.876	2.009	2.228	2.279	2.309	2.365
27 to 28		1.953	2.091	2.153	2.324	2.341	2.365
28 to 29		1.596	2.043	2.282	2.335	2.339	2.375
29 to 30		1.879	2.153	2.247	2.359	2.397	2.443
30 to 31		1.729	1.902	2.166	2.265	2.346	2.344
31 to 32		1.720	2.114	2.279	2.410	2.408	2.442
32 to 33		2.012	2.130	2.317	2.384	2.371	2.397
33 to 34		1.811	2.027	2.180	2.293	2.387	2.375
34 to 35		1.876	2.117	2.256	2.368	2.398	2.393
35 to 36		1.723	2.050	2.226	2 376	2.412	2.398
36 to 37		1.936	2.128	2.277	2.345	2.333	2.369
37 to 38		1.717	2.046	2.194	2.283	2.319	2.328
38 to 39		1.817	2.025	2.196	2.283	2.301	2.383
39 to 40		2.012	2.050	2.113	2.255	2.333	2.327
40 to 41		1.867	2.167	2.293	2.327	2.366	2.362
41 to 42		1.838	2.046	2.226	2.301	2.311	2.342
42 to 43		1.766	2.080	2.240	2.341	2.376	2.397
43 to 44		1.785	2.020	2.240	2.293	2.352	2.369
44 to 45		1.741	1.947	2.267	2.324	2.371	2.359
45 to 46		1.885	1.972	2.236	2.313	2.282	2.264
46 to 47		1.642	1.944	2.102	2.326	2.327	2.359
47 to 48		1.711	2.037	2.306	2.371	2.366	2.330
Means for 26 results.		1.809	2.040	2.224	2.322	2.350	2.367

TABLE 20.—*Subsurface velocities as given by current-meters, Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
3 01 to 02	From N. N. W., blowing down stream; force, 1 to 3.	1.904	2.131	2.347	2.415	2.406	2.412
02 to 03		1.855	2.032	2.228	2.316	2.339	2.393
03 to 04		1.718	2.097	2.266	2.382	2.398	2.384
04 to 05		1.985	2.133	2.258	2.335	2.343	2.365
05 to 06		1.662	2.007	2.140	2.224	2.363	2.386
06 to 07		1.865	2.126	2.263	2.399	2.397	2.423
07 to 08		1.874	2.116	2.212	2.276	2.339	2.407
08 to 09		1.917	2.176	2.301	2.365	2.349	2.350
09 to 10		1.932	2.170	2.267	2.357	2.338	2.344
10 to 1		1.733	1.966	2.097	2.332	2.405	2.434
11 to 12		2.000	2.222	2.294	2.357	2.365	2.400
12 to 13		1.827	2.147	2.306	2.341	2.371	2.404
13 to 14		2.030	2.255	2.353	2.395	2.389	2.378
14 to 15		1.568	1.811	2.146	2.346	2.409	2.421
15 to 16		1.787	1.938	2.180	2.310	2.365	2.383
16 to 17		1.875	2.095	2.175	2.283	2.330	2.376
7 to 18		1.652	1.941	2.073	2.138	2.233	2.356
18 to 19		1.726	2.012	2.204	2.376	2.379	2.341
19 to 20		1.847	2.017	2.186	2.348	2.389	2.390
20 to 21		1.694	2.018	2.288	2.343	2.349	2.375
21 to 22		1.821	2.219	2.288	2.382	2.368	2.344
22 to 23		1.783	2.099	2.191	2.312	2.357	2.379
23 to 24		1.900	2.080	2.164	2.304	2.362	2.392
24 to 25		1.890	2.123	2.255	2.366	2.408	2.392
25 to 26		1.865	2.165	2.291	2.421	2.422	2.390
26 to 27		1.958	2.128	2.286	2.360	2.371	2.395
Means for 26 results.		1.833	2.086	2.233	2.338	2.367	2.385

TABLE 21.—*Subsurface velocities as given by current-meters, Burlington, Iowa, October 29 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
3 29 to 30	From N. N. W., blowing down stream; force, 1 to 3.	1.810	1.933	2.097	2.293	2.370	2.411
30 to 31		1.895	2.122	2.321	2.310	2.355	2.338
31 to 32		1.866	2.122	2.326	2.370	2.412	2.407
32 to 33		1.923	2.232	2.360	2.357	2.312	2.297
33 to 34		1.836	2.095	2.344	2.426	2.406	2.397
34 to 35		1.744	2.020	2.196	2.307	2.366	2.403
35 to 36		1.948	2.154	2.310	2.351	2.352	2.328
36 to 37		2.061	2.111	2.331	2.368	2.347	2.345
37 to 38		1.907	2.139	2.283	2.407	2.357	2.338
38 to 39		2.037	2.269	2.363	2.352	2.338	2.359
39 to 40		1.827	2.136	2.307	2.384	2.381	2.367
40 to 41		1.839	2.032	2.183	2.335	2.414	2.470
41 to 42		1.884	2.126	2.253	2.368	2.412	2.356
42 to 43		1.969	2.043	2.236	2.376	2.362	2.330
43 to 44		1.865	2.199	2.366	2.396	2.377	2.390
44 to 45		1.866	2.077	2.319	2.334	2.327	2.333
45 to 46		1.865	2.159	2.339	2.401	2.379	2.404
46 to 47		1.899	2.181	2.285	2.363	2.379	2.389
47 to 48		1.941	2.185	2.309	2.401	2.460	2.462
48 to 49		1.814	2.061	2.245	2.345	2.369	2.414
49 to 50		1.886	2.108	2.245	2.255	2.323	2.338
50 to 51		1.736	2.116	2.342	2.387	2.377	2.412
51 to 52		1.853	2.106	2.234	2.280	2.323	2.404
52 to 53		1.772	2.021	2.131	2.276	2.355	2.412
53 to 54		1.734	1.911	2.035	2.196	2.285	2.367
54 to 55		1.767	2.058	2.242	2.381	2.397	2.366
Means for 26 results.		1.867	2.104	2.270	2.347	2.367	2.378

TABLE 22.—*Subsurface velocities as given by current meters, Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
3 56 to 57	From NW., down stream; force, 1 to 3.	1.585	2.032	2.191	2.349	2.422	2.393
57 to 58		1.726	2.148	2.358	2.434	2.403	2.404
58 to 59		1.756	2.177	2.274	2.396	2.439	2.429
59 to 60		1.885	2.182	2.283	2.385	2.374	2.333
4 00 to 01		1.815	2.051	2.162	2.312	2.341	2.370
01 to 02		1.590	1.927	2.154	2.261	2.322	2.375
02 to 03		1.527	1.871	2.048	2.287	2.365	2.378
03 to 04		1.722	1.973	2.126	2.229	2.338	2.373
04 to 05		1.825	2.032	2.224	2.338	2.311	2.334
05 to 06		1.711	2.040	2.229	2.343	2.354	2.378
06 to 07		1.837	2.119	2.312	2.363	2.349	2.338
07 to 08		1.763	2.000	2.148	2.287	2.365	2.353
08 to 09		1.735	2.069	2.304	2.409	2.398	2.432
09 to 10		2.022	2.267	2.325	2.401	2.400	2.415
10 to 11		2.043	2.227	2.264	2.376	2.377	2.410
11 to 12		1.684	2.089	2.298	2.479	2.514	2.572
12 to 13		1.981	2.218	2.317	2.343	2.422	2.467
13 to 14		1.821	2.143	2.301	2.393	2.393	2.400
14 to 15		1.795	2.170	2.310	2.376	2.400	2.434
15 to 16		1.994	2.283	2.353	2.404	2.412	2.420
16 to 17		2.041	2.211	2.342	2.343	2.389	2.381
17 to 18		1.874	2.177	2.344	2.437	2.385	2.421
18 to 19		1.914	2.086	2.191	2.243	2.358	2.393
19 to 20		1.832	2.007	2.215	2.388	2.368	2.372
20 to 21		1.880	2.009	2.299	2.365	2.358	2.372
21 to 22		1.822	2.108	2.228	2.340	2.360	2.397
22 to 23		1.889	2.133	2.280	2.324	2.360	2.387
Means for 27 results.		1.817	2.102	2.255	2.356	2.382	2.397

TABLE 23.—*Subsurface velocities as given by current-meters, Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet	9.6 feet.	6.6 feet.	3.6 feet.
h. m. m.							
4 24 to 25	From N.W., down stream; force, 1 to 3.	1.743	1.983	2.127	2.238	2.339	2.421
25 to 26		1.725	2.055	2.212	2.280	2.328	2.395
26 to 27		1.919	2.128	2.237	2.340	2.393	2.428
27 to 28		1.767	2.014	2.202	2.319	2.339	2.398
28 to 29		1.611	1.973	2.158	2.269	2.355	2.381
29 to 30		1.727	2.116	2.224	2.313	2.376	2.362
30 to 31		1.860	2.060	2.161	2.2[illegible]8	2.257	2.348
31 to 32		1.755	2.021	2.084	2.279	2.355	2.409
32 to 33		1.708	1.993	2.166	2.294	2.379	2.361
33 to 34		1.824	2.105	2.350	2.398	2.373	2.389
34 to 35		1.921	2.116	2.213	2.252	2.306	2.355
35 to 36		1.561	1.809	2.029	2.177	2.312	2.355
36 to 37		1.833	2.029	2.167	2.244	2.292	2.341
37 to 38		1.580	1.939	2.119	2.299	2.358	2.378
38 to 39		1.669	2.017	2.134	2.268	2.373	2.406
39 to 40		1.468	1.902	2.054	2.171	2.304	2.406
40 to 41		1.666	2.014	2.172	2.293	2.329	2.359
(*)							
48 to 49		1.591	1.919	2.127	2.196	2.316	2.342
49 to 50		1.725	2.026	2.277	2.401	2.374	2.359
50 to 51		1.817	2.139	2.388	2.424	2.397	2.412
51 to 52		1.918	2.077	2.293	2.338	2.371	2.387
52 to 53		1.897	2.105	2.239	2.261	2.343	2.372
53 to 54		1.891	2.082	2.236	2.373	2.409	2.404
54 to 55		1.874	1.990	2.173	2.254	2.311	2.355
55 to 56		1.942	2.167	2.315	2.334	2.327	2.344
56 to 57		1.841	2.116	2.326	2.407	2.400	2.403
57 to 58		1.842	2.060	2.150	2.241	2.320	2.428
Means for 27 results.		1.766	2.035	2.198	2.293	2.346	2.381

* End roll No 2; paper changed.

TABLE 24.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.88 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. *m.*							
4 59 to 60	From N.W., down-stream; force, 1 to 3.	1.798	2.095	2.224	2.354	2.424	2.442
5 00 to 01		1.724	2.000	2.196	2.404	2.368	2.404
01 to 02		1.989	2.071	2.186	2.296	2.323	2.341
02 to 03		1.857	2.140	2.282	2.370	2.370	2.386
03 to 04		1.975	2.168	2.264	2.377	2.392	2.429
04 to 05		1.867	2.167	2.318	2.401	2.377	2.361
05 to 06		1.882	2.126	2.325	2.402	2.393	2.428
06 to 07		1.814	2.021	2.272	2.392	2.393	2.429
07 to 08		1.897	2.179	2.286	2.346	2.371	2.398
08 to 09		1.749	2.026	2.245	2.368	2.339	2.404
09 to 10		1.746	2.041	2.269	2.349	2.358	2.379
10 to 11		1.733	2.100	2.237	2.377	2.393	2.431
11 to 12		1.848	2.080	2.307	2.319	2.349	2.369
12 to 13		1.783	2.102	2.315	2.421	2.381	2.398
13 to 14		1.928	2.201	2.406	2.412	2.358	2.414
14 to 15		1.813	2.100	2.318	2.435	2.427	2.420
15 to 16		1.925	2.100	2.320	2.385	2.358	2.373
16 to 17		1.782	2.027	2.282	2.365	2.355	2.362
17 to 18		1.866	2.182	2.372	2.420	2.435	2.454
18 to 19		1.881	2.075	2.244	2.345	2.349	2.378
19 to 20		1.851	2.255	2.428	2.442	2.425	2.439
20 to 21		(*)	2.137	2.250	2.352	2.374	2.423
21 to 22		(*)	2.091	2.170	2.351	2.395	2.404
22 to 23		1.836	2.117	2.266	2.345	2.387	2.407
23 to 24		1.620	1.871	2.053	2.290	2.350	2.383
24 to 25		1.959	2 031	2.153	2.294	2.330	2.379
25 to 26		2.035	2.287	2.334	2.382	2.358	2.404
Means for 27 results.		1.846	2.103	2.271	2.370	2.375	2.401

* Pen not recording for lower meter.

TABLE 25.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.6 feet; stage, 1.9 feet. For position of boat, see map. Mean velocity for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.6 feet.	15.6 feet.	12.6 feet.	9.6 feet.	6.6 feet.	3.6 feet.
h. m. *m.*							
5 43 to 44	Light from N.W., down-stream; force, ¼ to ½.	1.870	2.094	2.185	2.266	2.331	2.359
44 to 45		1.796	1.987	2.169	2.277	2.333	2.383
45 to 46		1.749	1.972	2.064	2.266	2.298	2.333
46 to 47		1.964	2.085	2.216	2.355	2.320	2.266
47 to 48		1.948	2.167	2.267	2.341	2.325	2.330
48 to 49		1.933	2.072	2.269	2.319	2.360	2.344
49 to 50		1.752	2.009	2.280	2.418	2.366	2.338
50 to 51		2.007	2.133	2.290	2.385	2.389	2.384
51 to 52		1.963	2.133	2.275	2.435	2.381	2.362
52 to 53		1.922	2.095	2.314	2.373	2.405	2.358
53 to 54		2.058	2.193	2.304	2.323	2.347	2.378
54 to 55		1.931	2.083	2.240	2.348	2.338	2.299
55 to 56		1.907	2.078	2.191	2.205	2.276	2.331
56 to 57		1.874	2.054	2.207	2.345	2.349	2.414
57 to 58		1.984	2 125	2.215	2.318	2.338	2.352
58 to 59		1.831	1.893	2.084	2.293	2.330	2.361
59 to 60		1.780	2 035	2.202	2.324	2.338	2.317
6 00 to 01		1.783	1.933	2.127	2.288	2.400	2.386
Means for 18 results.		1.890	2.063	2 217	2.327	2.346	2.350

TABLE 26.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 29, 1879*—Continued.

[Depth, 21.7 feet; stage, 1.9 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		18.7 feet.	15.7 feet.	12.7 feet.	9.7 feet.	6.7 feet.	3.7 feet.
h. m. m.							
6 03 to 04	Light, from N.W., down-stream; force, ¼ to ½.	1.928	2.100	2.207	2.302	2.304	2.289
04 to 05		1.718	1.856	2.035	2.171	2.301	2.313
05 to 06		1.804	2.092	2.189	2.272	2.328	2.269
06 to 07		1.749	1.998	2.129	2.241	2.309	2.355
07 to 08		1.837	2.026	2.237	2.359	2.387	2.341
08 to 09		1.904	2.120	2.210	2.299	2.336	2.386
09 to 10		1.885	2.037	2.272	2.319	2.389	2.311
10 to 11		1.757	1.919	2.091	2.240	2.343	2.369
11 to 12		1.875	2.077	2.263	2.319	2.371	2.384
12 to 13		1.795	2.080	2.290	2.395	2.454	2.393
13 to 14		1.914	2.117	2.282	2.321	2.371	2.333
14 to 15		1.955	2.035	2.185	2.304	2.349	2.342
15 to 16		1.964	2.208	2.360	2.381	2.377	2.352
16 to 17		1.783	1.966	2.266	2.402	2.400	2.384
17 to 18		1.837	1.978	2.226	2.293	2.316	2.345
18 to 19		1.815	2.049	2.269	2.363	2.363	2.375
19 to 20		1.954	2.061	2.096	2.131	2.193	2.297
20 to 21		1.866	2.009	2.105	2.225	2.352	2.342
21 to 22		1.787	2.014	2.189	2.357	2.376	2.347
22 to 23		1.792	2.021	2.223	2.310	2.311	2.310
Means for 20 results.		1.846	2.038	2.206	2.300	2.346	2.342

TABLE 27.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 30, 1879.*

[Depth, 27.6 feet; stage, 1.91 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		23.6 feet.	19.6 feet.	15.6 feet.	11.6 feet.	7.6 feet.	3.6 feet.
h. m. m.							
5 05 to 06	From N.W., down-stream; force, 1 to 3.	2.183	2.221	2.331	2.354	2.282	2.355
06 to 07		2.190	2.321	2.420	2.357	2.347	2.361
07 to 08		2.112	2.176	2.307	2.310	2.273	2.336
08 to 09		2.052	2.126	2.306	2.329	2.322	2.362
09 to 10		2.143	2.157	2.247	2.280	2.276	2.305
10 to 11		2.113	2.185	2.255	2.307	2.293	2.338
11 to 12		2.189	2.284	2.307	2.302	2.303	2.361
12 to 13		2.105	2.157	2.207	2.243	2.155	2.232
13 to 14		1.960	2.179	2.293	2.258	2.242	2.293
14 to 15		2.027	2.171	2.277	2.291	2.317	2.390
15 to 16		2.178	2.253	2.345	2.352	2.392	2.390
16 to 17		1.811	2.128	2.259	2.280	2.300	2.393
17 to 18		2.097	2.216	2.224	2.235	2.155	2.190
18 to 19		2.061	2.085	2.107	2.185	2.185	2.236
19 to 20		2.005	2.164	2.318	2.406	2.333	2.294
20 to 21		2.075	2.181	2.245	2.305	2.287	2.378
21 to 22		1.843	2.094	2.236	2.341	2.349	2.474
22 to 23		2.097	2.269	2.341	2.382	2.373	2.398
23 to 24		2.136	2.176	2.202	2.233	2.231	2.305
24 to 25		1.959	2.102	2.275	2.355	2.370	2.387
25 to 26		2.094	2.136	2.194	2.229	2.233	2.286
26 to 27		2.217	2.211	2.224	2.298	2.257	2.243
27 to 28		2.175	2.119	2.231	2.230	2.222	2.236
28 to 29		2.142	2.196	2.255	2.274	2.308	2.338
29 to 30		1.957	2.165	2.248	2.244	2.252	2.316
30 to 31		2.137	2.235	2.285	2.291	2.322	2.316
Means for 26 results.		2.079	2.181	2.267	2.295	2.284	2.327

TABLE 28.—*Subsurface velocities as given by current-meters. Burlington, Iowa, October 30, 1879*—Continued.

[Depth, 27.6 feet; stage, 1.91 feet. For position of boat, see map. Mean velocities for one minute.]

Time.	Wind.	Velocities in feet per second at the given depths below water-surface.					
		23.6 feet.	19.6 feet.	15.6 feet.	11.6 feet.	7.6 feet.	3.6 feet.
h. m. m.							
5 32 to 33	From N. W., down stream; force, 1 to 3.	1.966	2.080	2.218	2.252	2.241	2.286
33 to 34		1.817	2.095	2.261	2.285	2.300	2.353
34 to 35		1.985	2.193	2.328	2.355	2.374	2.437
35 to 36		2.008	2.109	2.229	2.277	2.254	2.300
36 to 37		2.065	2.215	2.326	2.351	2.325	2.404
37 to 38		2.119	2.276	2.302	2.321	2.325	2.378
38 to 39		1.926	2.196	2.279	2.376	2.350	2.414
39 to 40		2.008	2.210	2.384	2.395	2.379	2.392
40 to 41		1.983	2.092	2.218	2.250	2.263	2.313
41 to 42		2.081	2.170	2.263	2.236	2.311	2.296
42 to 43		2.104	2.165	2.306	2.301	2.336	2.383
43 to 44		2.276	2.310	2.360	2.371	2.343	2.397
44 to 45		2.092	2.215	2.283	2.321	2.354	2.420
45 to 46		2.008	2.177	2.229	2.238	2.273	2.361
46 to 47		2.047	2.134	2.271	2.266	2.260	2.278
47 to 48		1.848	2.027	2.263	2.324	2.355	2.445
48 to 49		2.024	2.205	2.374	2.396	2.422	2.459
49 to 50		2.070	2.140	2.317	2.388	2.377	2.428
50 to 51		1.796	2.117	2.223	2.285	2.279	2.456
51 to 52		2.055	2.215	2.264	2.302	2.401	2.460
Means for 20 results.		2.014	2.167	2.285	2.314	2.326	2.383

TABLE 29.—*Compilation of results from plates of final plotted curves.*

Date.	Stage.	Depth. (D)	$V_{½D}$.	V_m	V_m derived from $V_{½D}$, H & A formula.	m	$\frac{V_m}{V_{½D}}$	$\frac{m}{D}$
1879.						*Feet.*		
Oct. 7	0.85	19.5	1.941	1.814	1.876	11.88	0.935	0.609
		21.25	2.139	1.990	2.075	13.80	0.930	0.649
11	0.75	11.5	1.962	1.902	1.889	6.68	0.969	0.581
		11.0	2.012	1.970	1.938	6.12	0.979	0.556
		11.0	2.022	1.987	1.948	6.06	0.983	0.551
14	0.89	13.2	2.625	2.521	2.553	8.02	0.960	0.608
		13.2	2.633	2.559	2.561	7.80	0.987	0.599
		12.9	2.604	2.533	2.532	7.80	0.973	0.605
		13.0	2.629	2.568	2.557	7.50	0.977	0.577
		13.0	2.624	2.559	2.552	7.56	0.975	0.582
21	1.27	13.5	2.620	2.561	2.547	7.90	0.977	0.585
		13.7	2.587	2.499	2.514	8.25	0.966	0.600
29	1.88	21.6	2.328	2.206	2.260	14.25	0.948	0.660
		21.6	2.303	2.189	2.235	13.90	0.950	0.644
		21.6	2.348	2.217	2.280	14.73	0.944	0.682
		21.6	2.279	2.151	2.211	13.90	0.944	0.644
		21.6	2.296	2.167	2.228	14.10	0.944	0.653
		21.6	2.316	2.185	2.248	14.36	0.943	0.665
		21.6	2.326	2.174	2.258	14.35	0.935	0.664
		21.6	2.258	2.132	2.190	13.90	0.944	0.644
		21.6	2.328	2.186	2.260	14.32	0.939	0.663
	1.90	21.6	2.278	2.164	2.210	14.10	0.950	0.653
	1.90	21.7	2.272	2.150	2.204	13.95	0.946	0.643
30	1.91	27.6	2.270	2.225	2.205	17.20	0.980	0.623
		27.6	2.287	2.231	2.222	16.60	0.976	0.601
						Means.	0.958	0.622

TABLE 30.—*Comparisons of derived results.*

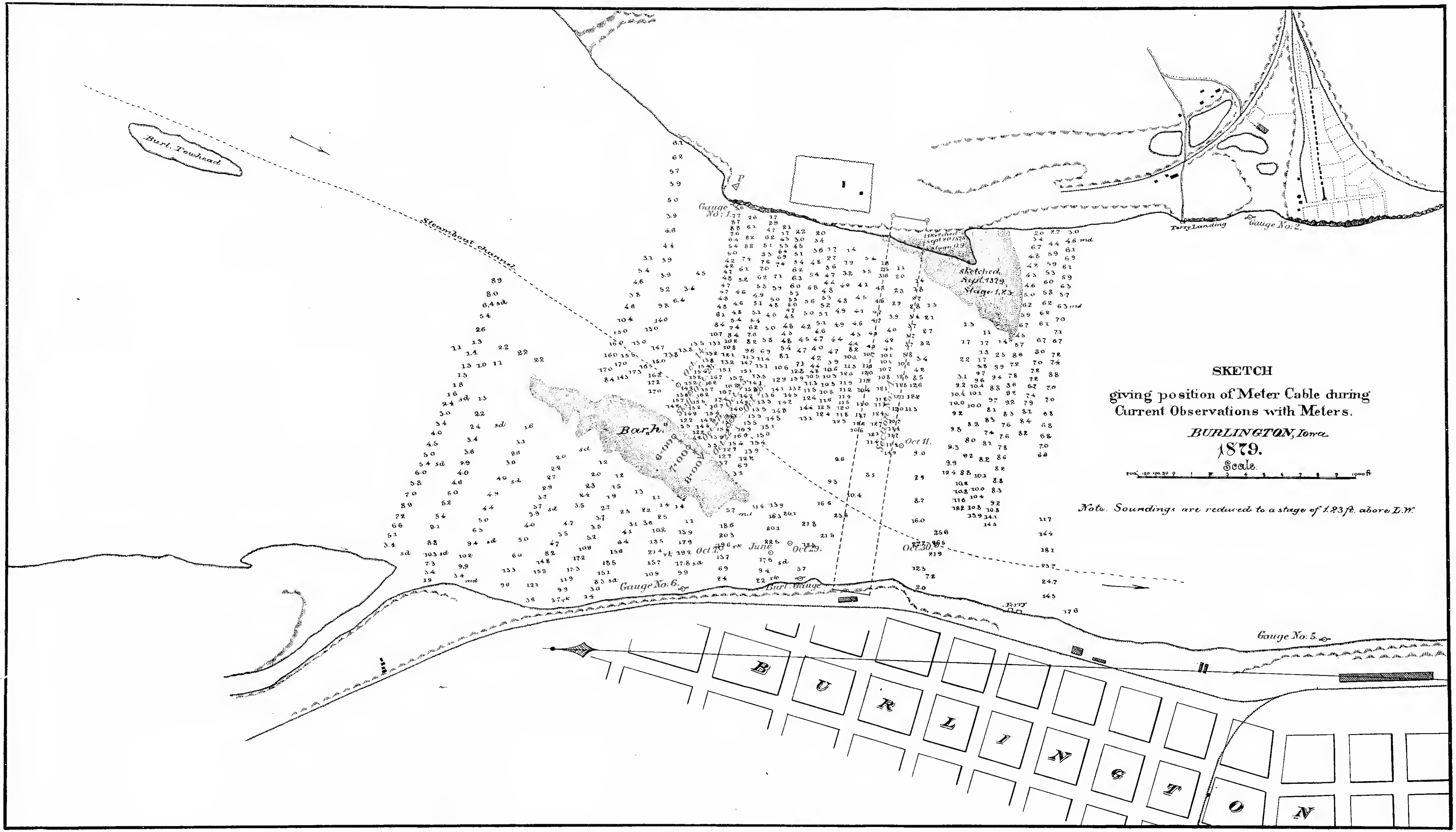
Date.	$V_{\frac{1}{2}D}$	$0.958\ V_{\frac{1}{2}D}$	V_m	$\left[V_{\frac{1}{2}D}-\frac{1}{12}(bv)^{\frac{1}{2}}\right]$	$V_m-0.958\ V_{\frac{1}{2}D}$	$V_m-\left[V_{\frac{1}{2}D}-\frac{1}{12}(bv)^{\frac{1}{2}}\right]$
Oct. 7	1.941	1.859	1.814	1.876	−0.045	−0.062
	2.139	2.049	1.990	2.075	−0.059	−0.085
11	1.962	1.880	1.902	1.889	+0.022	+0.013
	2.012	1.927	1.970	1.938	+0.043	+0.032
	2.022	1.937	1.987	1.948	+0.050	+0.039
14	2.625	2.515	2.521	2.553	+0.006	−0.032
	2.633	2.522	2.559	2.561	+0.037	−0.002
	2.604	2.495	2.533	2.532	+0.038	+0.001
	2.629	2.519	2.568	2.557	+0.049	+0.011
	2.624	2.514	2.559	2.552	+0 045	+0.007
21	2.620	2.510	2.561	2.547	+0.051	+0.014
	2.587	2.478	2.499	2.514	+0.021	−0.015
29	2.328	2.230	2.206	2.260	−0.024	−0.054
	2.303	2.206	2.189	2.235	−0.017	−0.046
	2.348	2.249	2.217	2.280	−0.032	−0.063
	2.279	2.183	2.151	2.211	−0.032	−0.060
	2.296	2.200	2.167	2.228	−0.033	−0.061
	2.316	2.219	2.185	2.248	−0.034	−0.063
	2.326	2.228	2.174	2.258	−0.054	−0.084
	2.258	2.163	2.132	2.190	−0.031	−0.058
	2.328	2.230	2.186	2.260	−0.044	−0.074
	2.278	2.182	2.164	2.210	−0.018	−0.046
	2.272	2.177	2.150	2.204	−0.027	−0.054
30	2.270	2.175	2.225	2.205	+0.050	+0.020
	2.287	2.191	2.231	2.222	+0.040	+0.009

TABLE 31.—*Subsurface velocities as given by current meters and floats, Burlington, Iowa, October 28, 1879.*

[Depth, 16.4 feet; stage, 1.88 feet. For position of boat, see map (series 4).]

Time.	Interval of time.	Wind.	Velocities in feet per second at the given depths below water-surface. 13.7 feet.	10.9 feet.	8.2 feet.	5.5 feet.	2.7 feet.	Velocity of floats and meter at mid-depth.	Number of section.	Number of float.
h. m. s.	s.									
4 17 25.6	18.1	Southwest, up-stream; force, 1 to 1½.	2.372	2.609	2.719	2.821	2.909	2.762	1	1
	21.0		1.998	2.440	2.623	2.574	2.812	2.381	2	
	21.1		2.367	2.470	2.634	2.756	2.857	2.370	3	
	18.8		2.432	2.399	2.442	2.695	2.990	2.660	4	
19 03.4	18.8		2.181	2.272	2.597	2.776	2.915	2.597	5	
19 38.5	18.4		2.275	2.517	2.589	2.668	2.732	2.717	1	2
	19.7		1.781	2.216	2.388	2.567	2.742	2.538	2	
	18.3		1.831	2.097	2.526	2.818	2.868	2.732	3	
	16.8		2.208	2.565	2.679	2.804	2.878	2.976	4	
21 08.5	16.8		2.418	2.571	2.657	2.753	2.961	2.657	5	
21 45.0	17.4		1.769	2.019	2.283	2.591	2.794	2.874	1	3
	21.2		2.081	2.287	2.476	2.582	2.743	2.358	2	
	19.0		1.876	2.239	2.541	2.924	2.999	2.632	3	
	18.7		2.271	2.580	2.781	2.902	2.995	2.674	4	
23 20.0	18.7		2.529	2.559	2.630	2.673	2.825	2.630	5	
23 58.9	19.6		2.481	2.529	2.567	2.604	2.769	2.556	1	4
	22.1		2.179	2.332	2.418	2.567	2.790	2.267	2	
	20.0		1.743	2.123	2.406	2.535	2.721	2.505	3	
	20.4		1.884	2.237	2.351	2.548	2.744	2.456	4	
25 41.4	20.4		1.825	2.097	2.481	2.595	2.767	2.481	5	
26 11.3	15.9		2.068	2.320	2.623	2.813	2.979	3.151	1	5
	18.7		1.988	2.141	2.313	2.821	2.885	2.679	2	
	18.4		1.872	2.397	2.543	2.637	2.757	2.723	3	
	17.6		1.982	2.073	2.392	2.557	2.738	2.847	4	
27 39.5	17.6		2.172	2.469	2.590	2.757	2.833	2.590	5	
28 17.3	17.0		2.386	2.665	2.704	2.722	2.758	2.941	1	6
	21.9		2.532	2.605	2.649	2.808	2.988	2.283	2	
	18.6		2.427	2.675	2.780	2.887	3.005	2.688	3	
	18.0		2.333	2.395	2.665	2.815	2.908	2.778	4	
29 50.8	18.0		2.380	2.454	2.649	2.704	2.826	2.649	5	
30 30.6	18.0		1.704	2.061	2.545	2.720	2.960	2.778	1	7
	23.1		2.335	2.326	2.656	2.791	2.922	2.164	2	
	20.5		1.921	2.124	2.547	2.536	2.641	2.439	3	
	18.7		2.167	2.416	2.434	2.678	2.835	2.674	4	
32 09.6	18.7		1.740	2.028	2.484	2.668	2.835	2.484	5	
32 34.5	15.6		1.962	2.020	2.431	2.736	2.920	3.205	1	8
	19.4		1.845	2.072	2.535	2.831	2.950	2.577	2	
	18.6		1.933	1.962	2.366	2.641	2.850	2.688	3	
	17.5		1.865	2.030	2.496	2.702	2.838	2.857	4	
34 03.1	17.5		2.062	2.461	2.749	2.832	2.929	2.749	5	
38 27.7	18.5		2.214	2.679	2.805	2.912	3.005	2.708	1	9
	21.9		2.172	2.418	2.546	2.703	2.912	2.288	2	
	21.4		1.777	2.182	2.396	2.635	2.924	2.341	3	
	19.5		1.955	2.400	2.754	2.905	3.026	2.569	4	
40 08.5	19.5		2.336	2.703	2.821	3.022	3.113	2.821	5	
40 44.4	16.3		1.970	2.500	2.614	2.746	2.841	3.067	1	10
	19.4		1.893	2.293	2.631	2.851	3.012	2.577	2	
	18.8		2.230	2.755	2.882	2.938	3.034	2.660	3	
	16.6		2.373	2.808	2.903	2.940	2.967	3.012	4	
4 42 12.1	16.6		2.322	2.658	2.823	2.923	3.040	2.823	5	

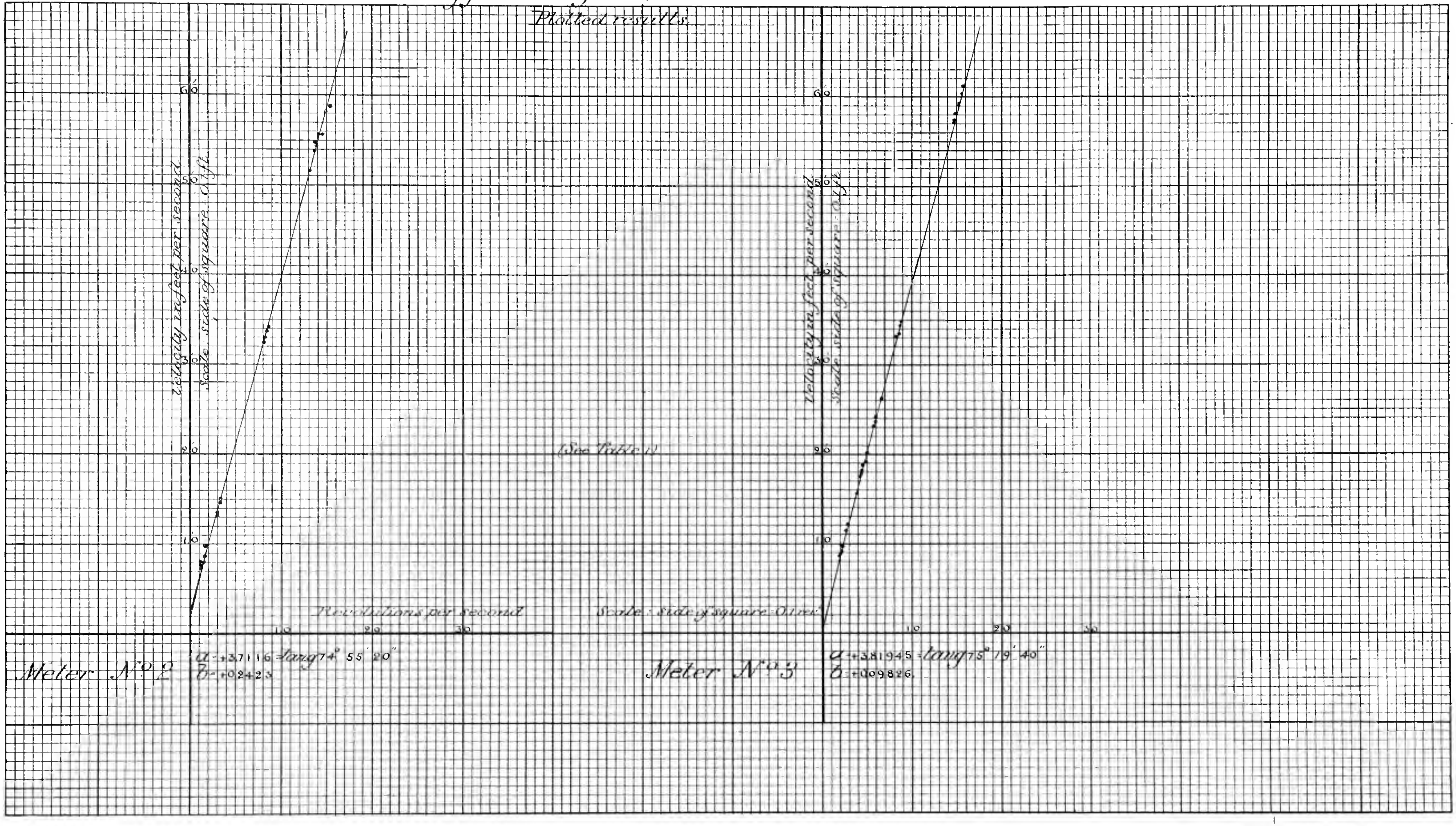
REMARKS.—Floats tied at 8.2 feet being at mid-depth. In column of mid-depth velocities by floats and meter, sections 1, 2, 3, and 4 are given by floats, and section 5 by meter. A base of 200 feet, opposite which the floats passed, was divided into four sections of 50 feet each, and numbered from the up-stream end downward, giving sections 1, 2, 3, and 4 of table. The meters were located about 16 feet below the base, and constitute section 5 of table.

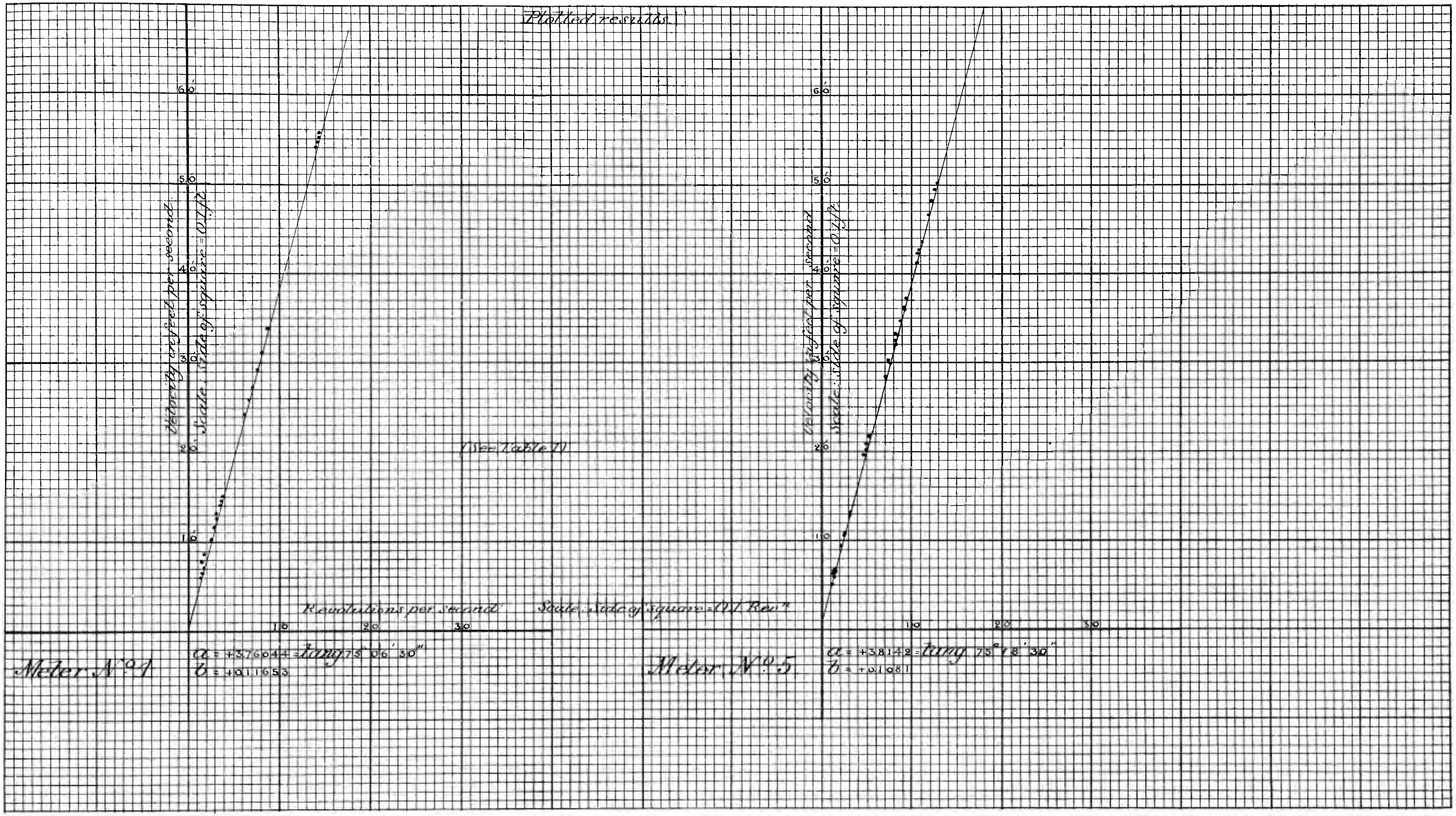

SKETCH
giving position of Meter Cable during
Current Observations with Meters.
BURLINGTON, Iowa.
1879.
Scale.
Note. Soundings are reduced to a stage of 1.23 ft. above L.W.
Burl. Towhead
Steamboat channel
Bar
Gauge No. 1.
Gauge No. 2.
Gauge No. 5.
Gauge No. 6.
Burl. Gauge
Ferry Landing
Ferry
Sketched Sept. 1879. Stage 1.23.
Oct. 11.
Oct. 29.
Oct. 30.
June
B U R L I N G T O N

Coefficients of current-meters.

Plate I.

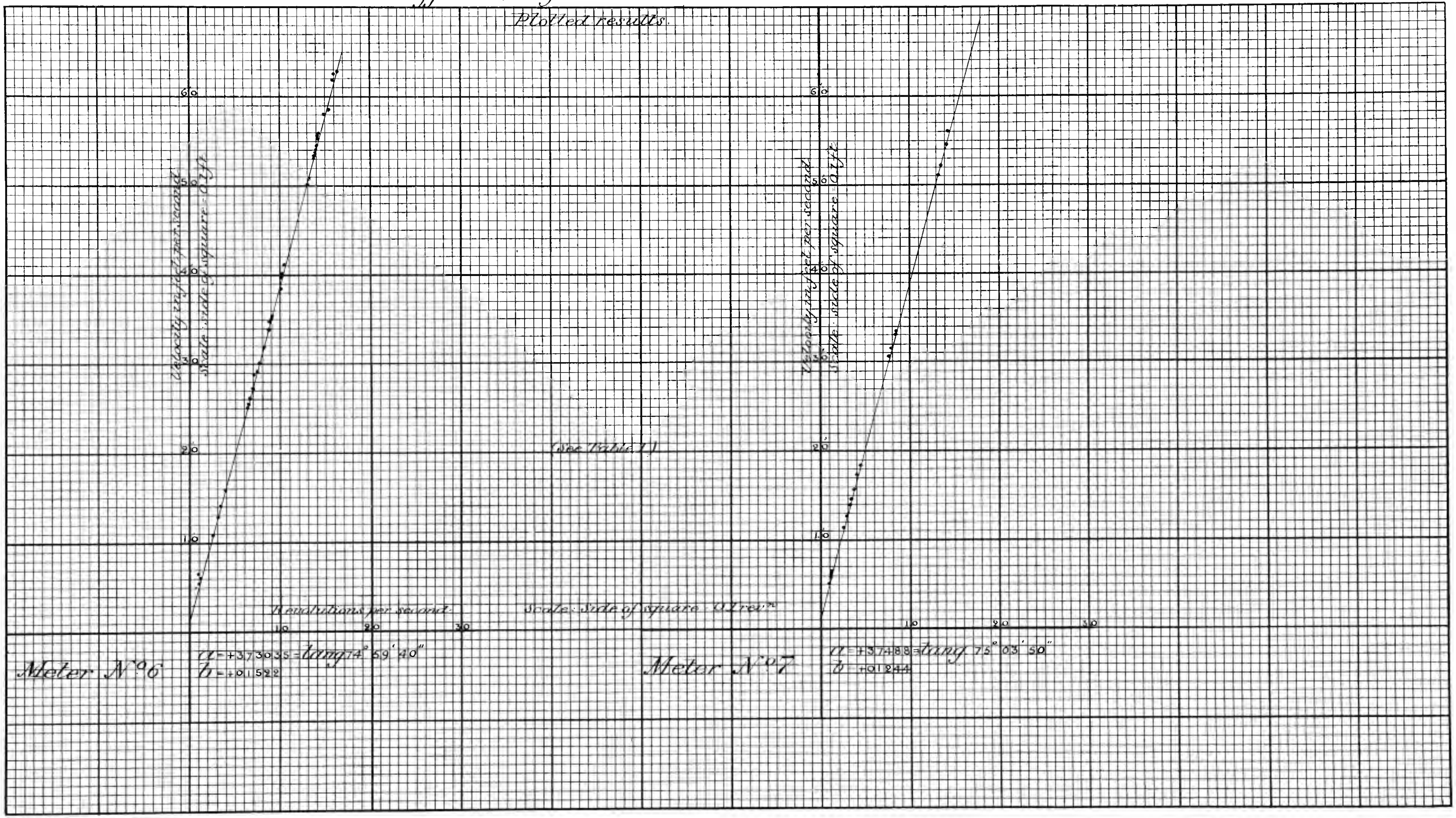
Plotted results.





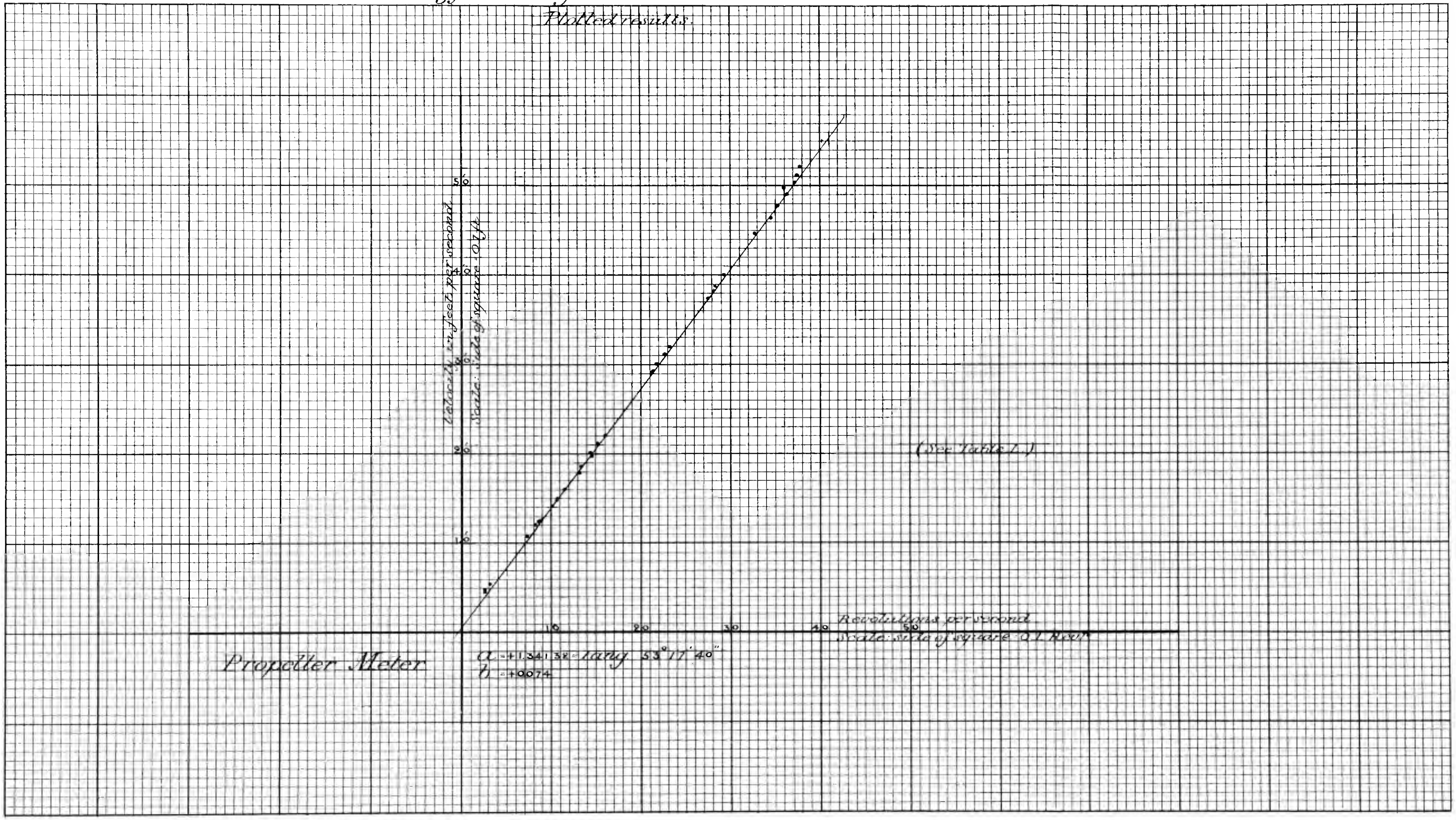
Plotted results.
(See Table I)
Velocity in feet per second
Scale: Side of square = 0.1 ft.
Revolutions per second
Scale: Side of square = 0.1 Rev.
Meter No. 1
a = +3.76044 = tang 75° 06′ 30″
b = +0.11653
Meter No. 5
a = +3.8142 = tang 75° 18′ 30″
b = +0.1081

Coefficients of Current-meters.



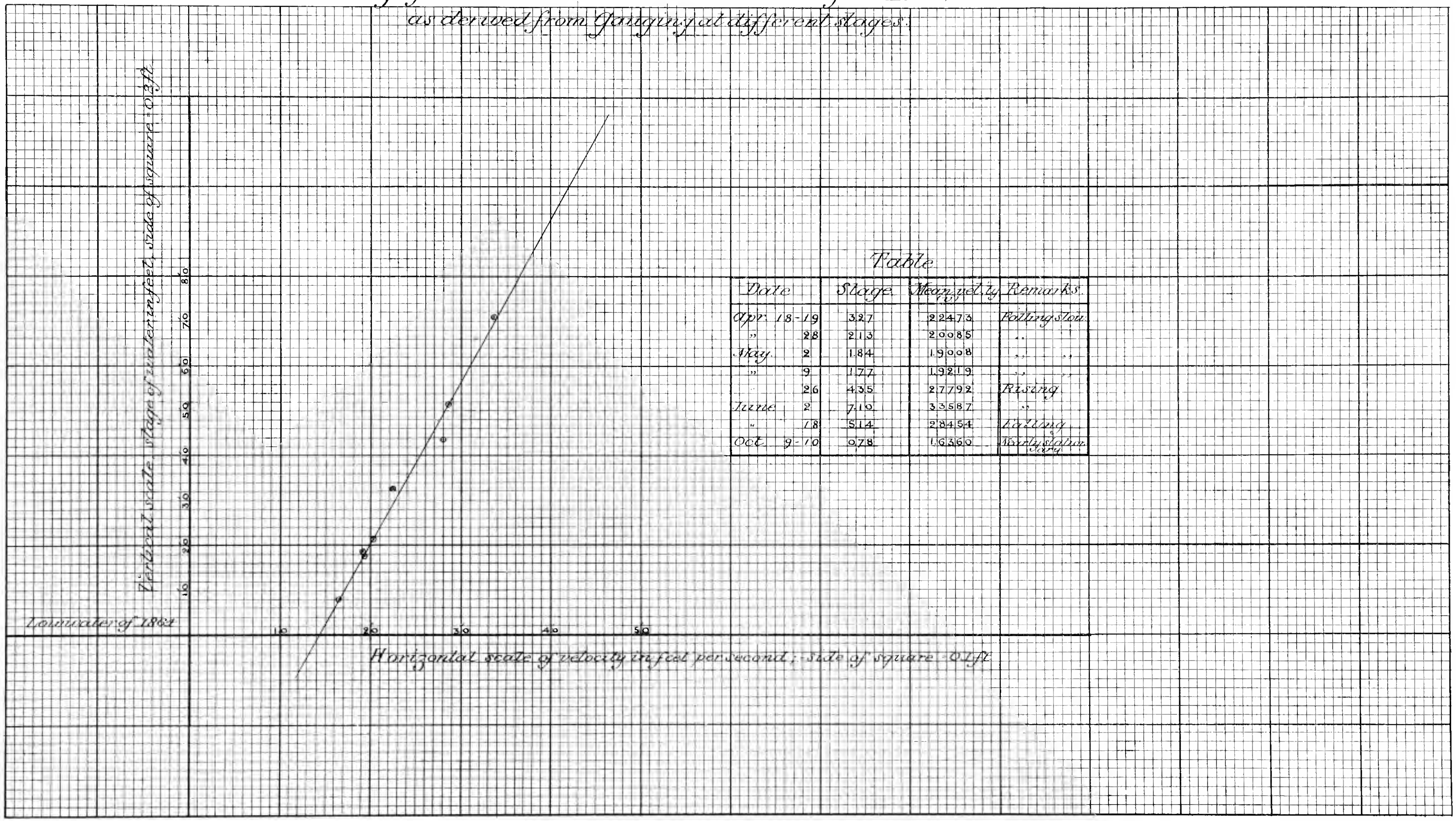
Coefficients of current-meters

Plotted results.



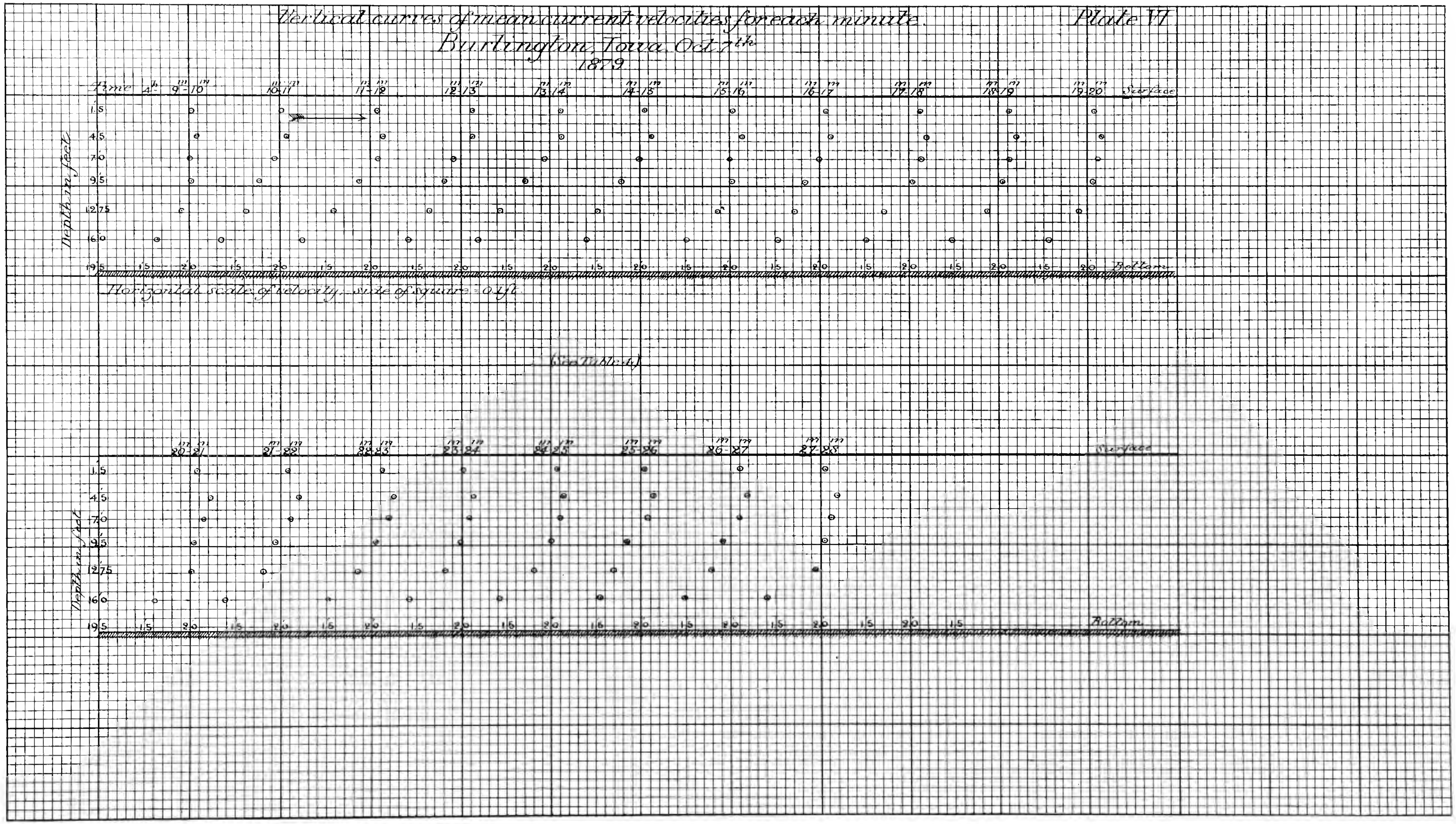
Mean velocity of River at Cross-section N°1 Burlington Iowa 1879. *Plate. V.*

as derived from Gauging at different stages.

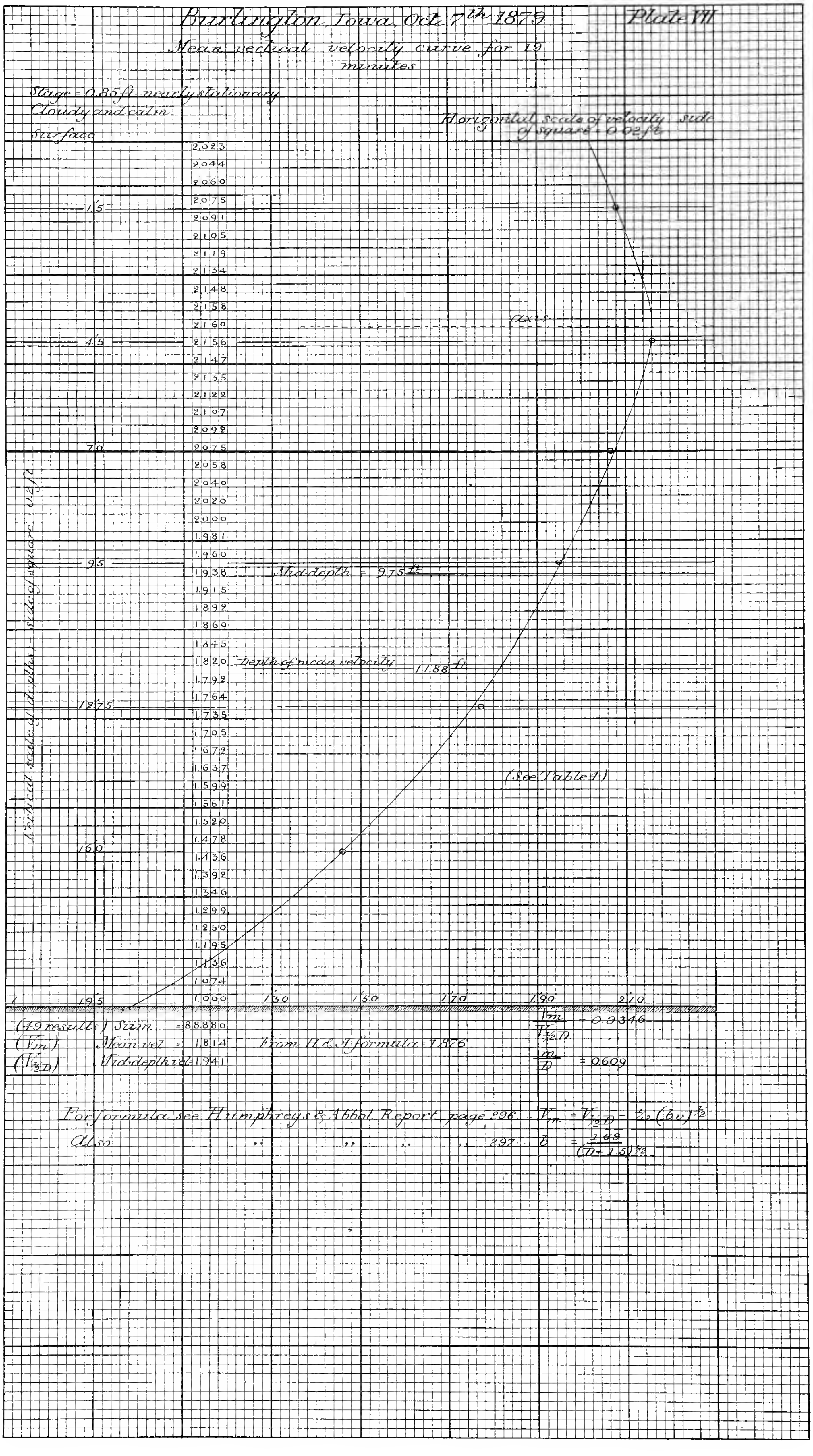


Table

Date		Stage	Mean vel.ty (V)	Remarks.
Apr.	18-19	327	22473	Falling slow.
"	28	213	20085	"
May.	2	1.84	1.9008	" "
"	9	1.77	1.9219	" "
"	26	435	27792	Rising
June	2	7.10	33587	"
"	18	514	28454	Falling
Oct	9-10	078	1.6360	Nearly stationary

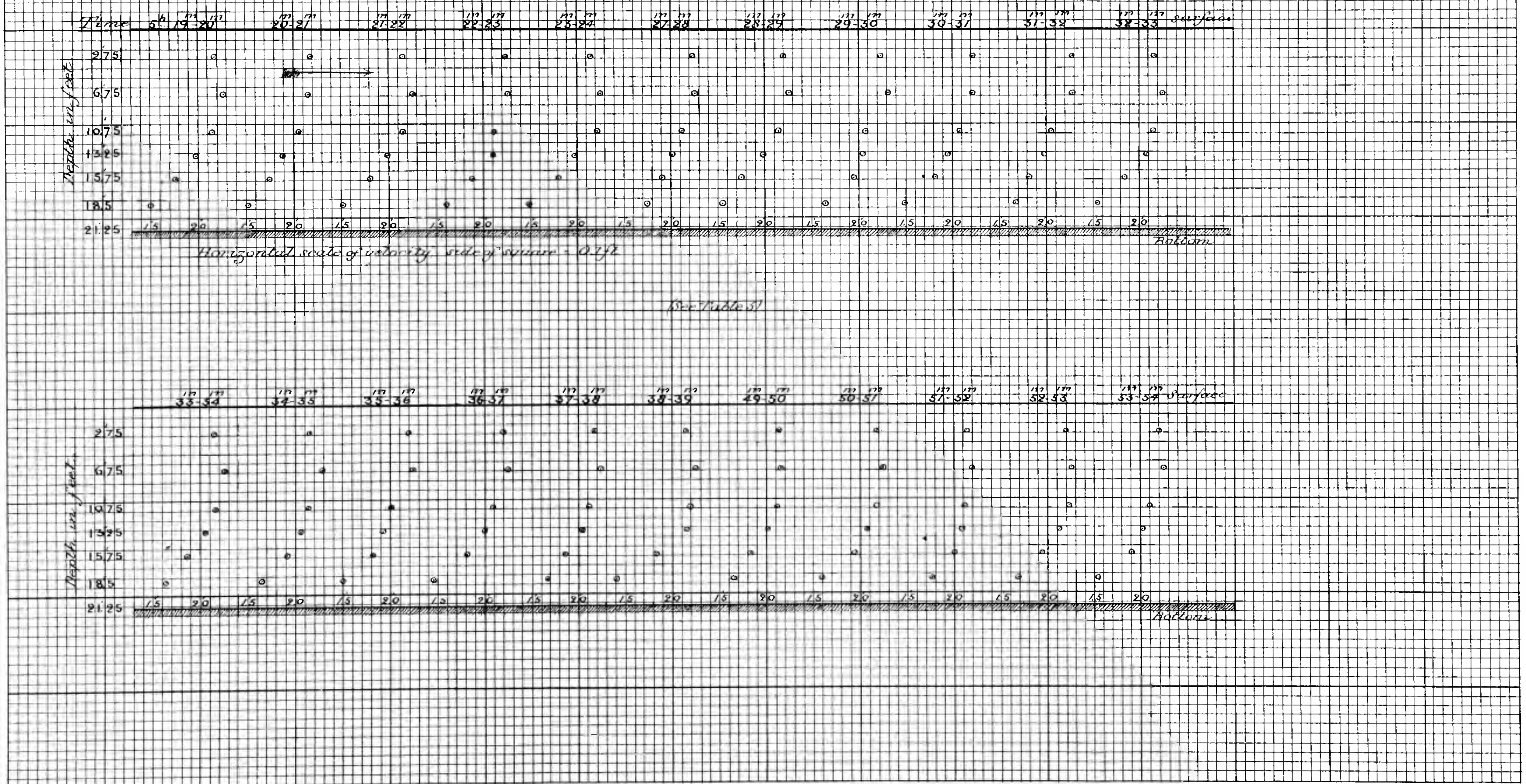


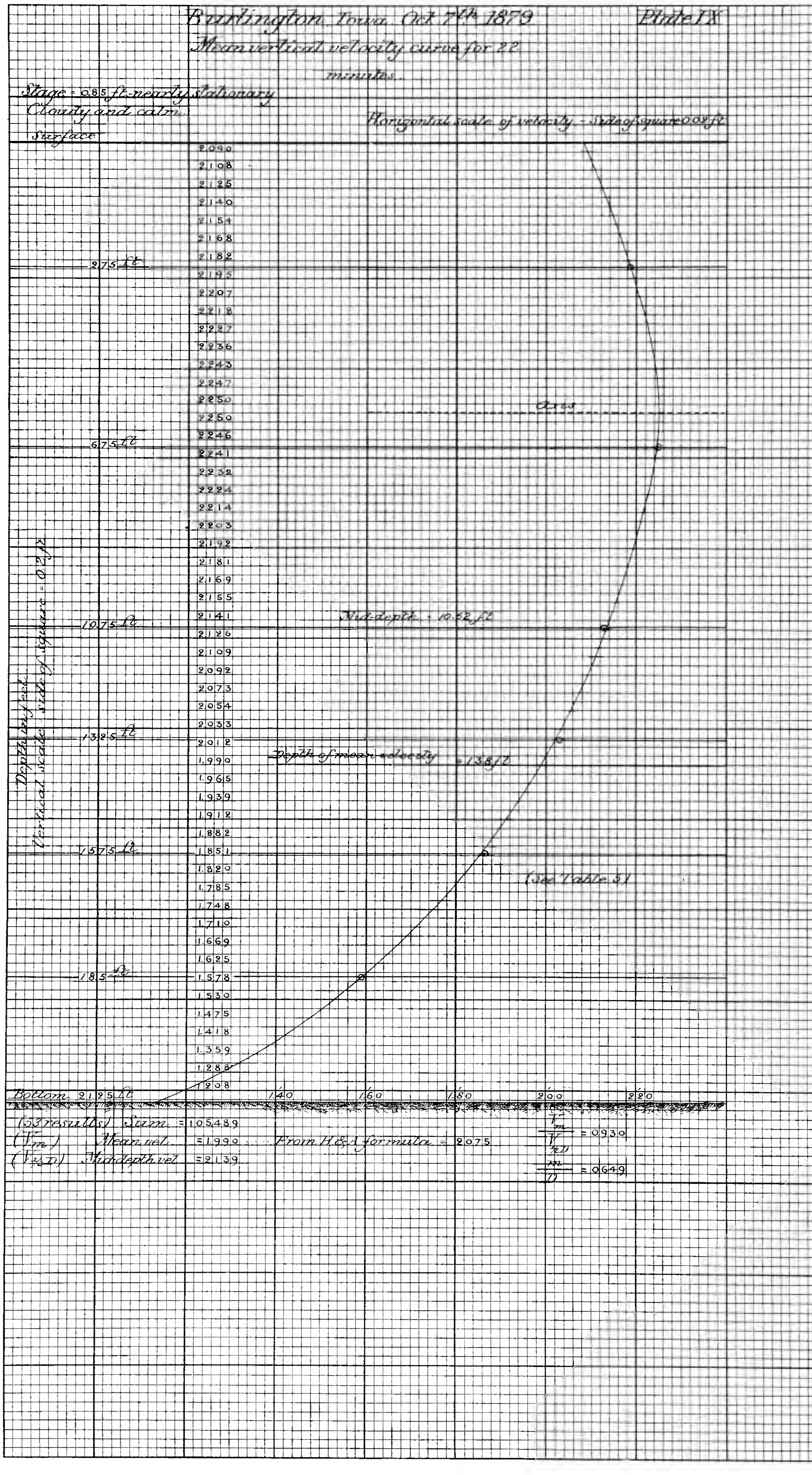
Vertical curves of mean current velocities for each minute.
Plate VI
Burlington, Iowa Oct 7th 1879
Time 4h 9m-10m 10m-11m 11m-12m 12m-13m 13m-14m 14m-15m 15m-16m 16m-17m 17m-18m 18m-19m 19m-20m
Surface
Depth in feet
1.5
4.5
7.0
9.5
12.75
16.0
19.5
Bottom
Horizontal scale of velocity – side of square = 0.1 ft.
(See Table 4)
20m-21m 21m-22m 22m-23m 23m-24m 24m-25m 25m-26m 26m-27m 27m-28m


Burlington, Iowa, Oct. 7th 1879
Plate VII
Mean vertical velocity curve for 19 minutes
Stage = 0.85 ft. nearly stationary
Cloudy and calm
Surface
Horizontal scale of velocity side of square = 0.02 ft.
Vertical scale of depths, side of square 0.2 ft.
axis
2.023
2.044
2.060
2.075
2.091
2.105
2.119
2.134
2.148
2.158
2.160
2.156
2.147
2.135
2.122
2.107
2.092
2.075
2.058
2.040
2.020
2.000
1.981
1.960
1.938
1.915
1.892
1.869
1.845
1.820
1.792
1.764
1.735
1.705
1.672
1.637
1.599
1.561
1.520
1.478
1.436
1.392
1.346
1.299
1.250
1.195
1.136
1.074
1.000
1.5
4.5
7.0
9.5
12.75
16.0
19.5
1.30
1.50
1.70
1.90
2.10
Mid-depth = 9.75 ft.
Depth of mean velocity 11.88 ft.
(See Table 4)
(49 results) Sum = 88.880
(V_m) Mean vel. = 1.814 From H. & A. formula = 1.876
($V_{\frac{1}{2}D}$) Mid-depth vel. 1.941
$\frac{V_m}{V_{\frac{1}{2}D}} = 0.9346$
$\frac{m}{D} = 0.609$
For formula see Humphreys & Abbot Report page 296. $V_m = V_{\frac{1}{2}D} - \frac{1}{72}(bv)^{\frac{1}{2}}$
Also " " " " 297. $b = \frac{1.69}{(D+1.5)^{\frac{1}{2}}}$

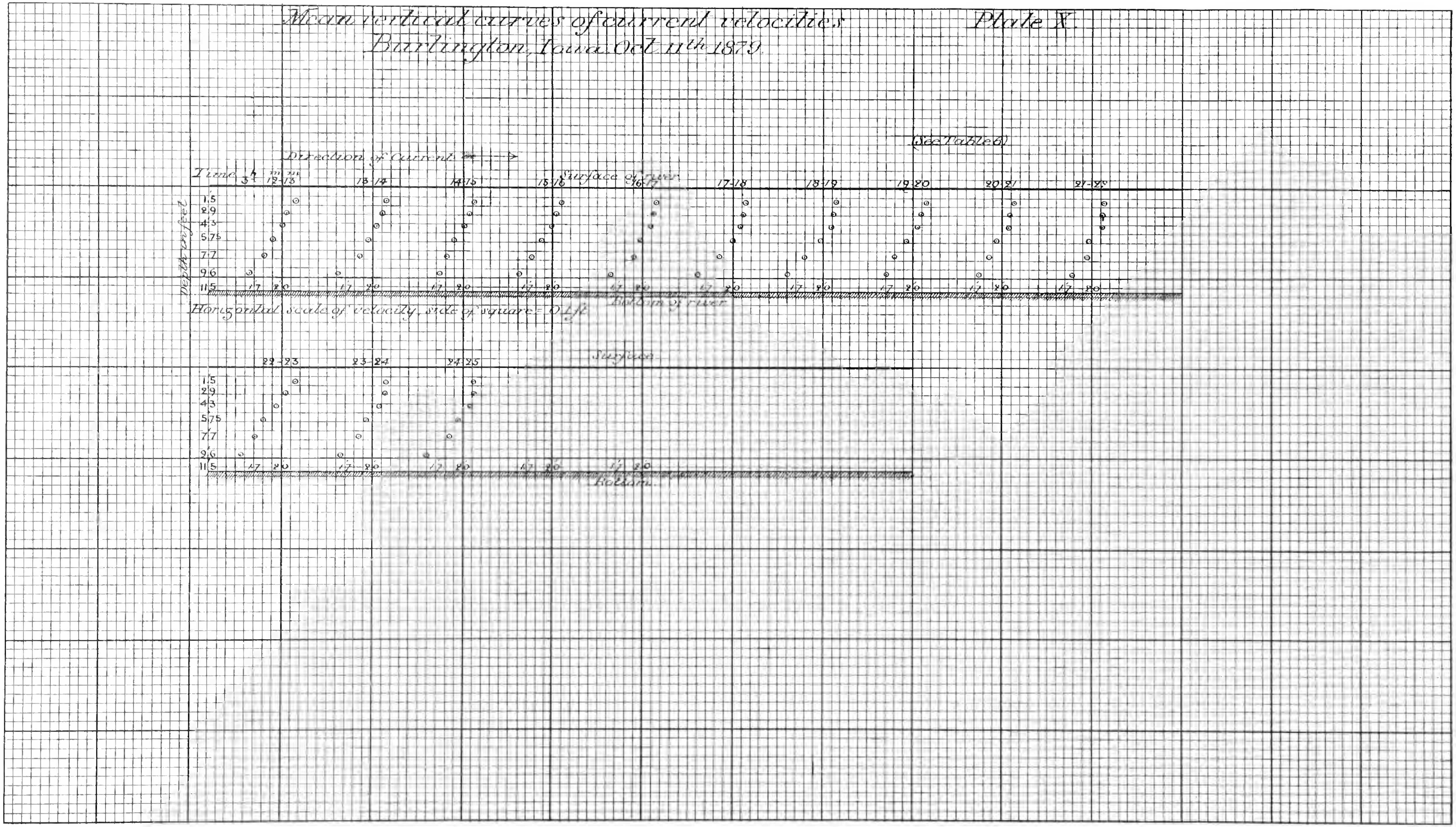
Vertical curves of mean current velocities for each minute. Plate VIII.

Burlington, Iowa, Oct. 7th 1879.





Burlington, Iowa. Oct 7th 1879
Plate IX
Mean vertical velocity curve for 22 minutes.
Stage = 0.85 ft nearly stationary
Cloudy and calm.
Surface
Horizontal scale of velocity - Side of square 0.02 ft
Depth in feet
Vertical scale side of square = 0.2 ft
2.75 ft
6.75 ft
10.75 ft
13.25 ft
15.75 ft
18.5 ft
2.090
2.108
2.125
2.140
2.154
2.168
2.182
2.195
2.207
2.218
2.227
2.236
2.243
2.247
2.250
2.250
2.246
2.241
2.232
2.224
2.214
2.203
2.192
2.181
2.169
2.155
2.141
2.126
2.109
2.092
2.073
2.054
2.033
2.012
1.990
1.965
1.939
1.912
1.882
1.851
1.820
1.785
1.748
1.710
1.669
1.625
1.578
1.530
1.475
1.418
1.359
1.288
1.208
Axis
Mid-depth = 10.52 ft
Depth of mean velocity = 13.8 ft
(See Table 5)
Bottom 21.25 ft
1.40
1.60
1.80
2.00
2.20
(53 results) Sum = 105.489
(Vm) Mean vel. = 1.990 From H & A formula = 2.075
(V½D) Middepth vel. = 2.139
Vm / V½D = 0.930
m / D = 0.649


Mean vertical curves of current velocities
Burlington, Iowa Oct 11th 1879.
Plate X.
(See Table 6)
Direction of Current
Time h m
12-13
13-14
14-15
15-16
16-17
17-18
18-19
19-20
20-21
21-22
22-23
23-24
24-25
Surface of river
Depth in feet
1.5
2.9
4.3
5.75
7.7
9.6
11.5
Bottom of river
Horizontal scale of velocity, side of square = 0.1 ft
Surface
Bottom

Current-meters, Oct. 11th 1879.

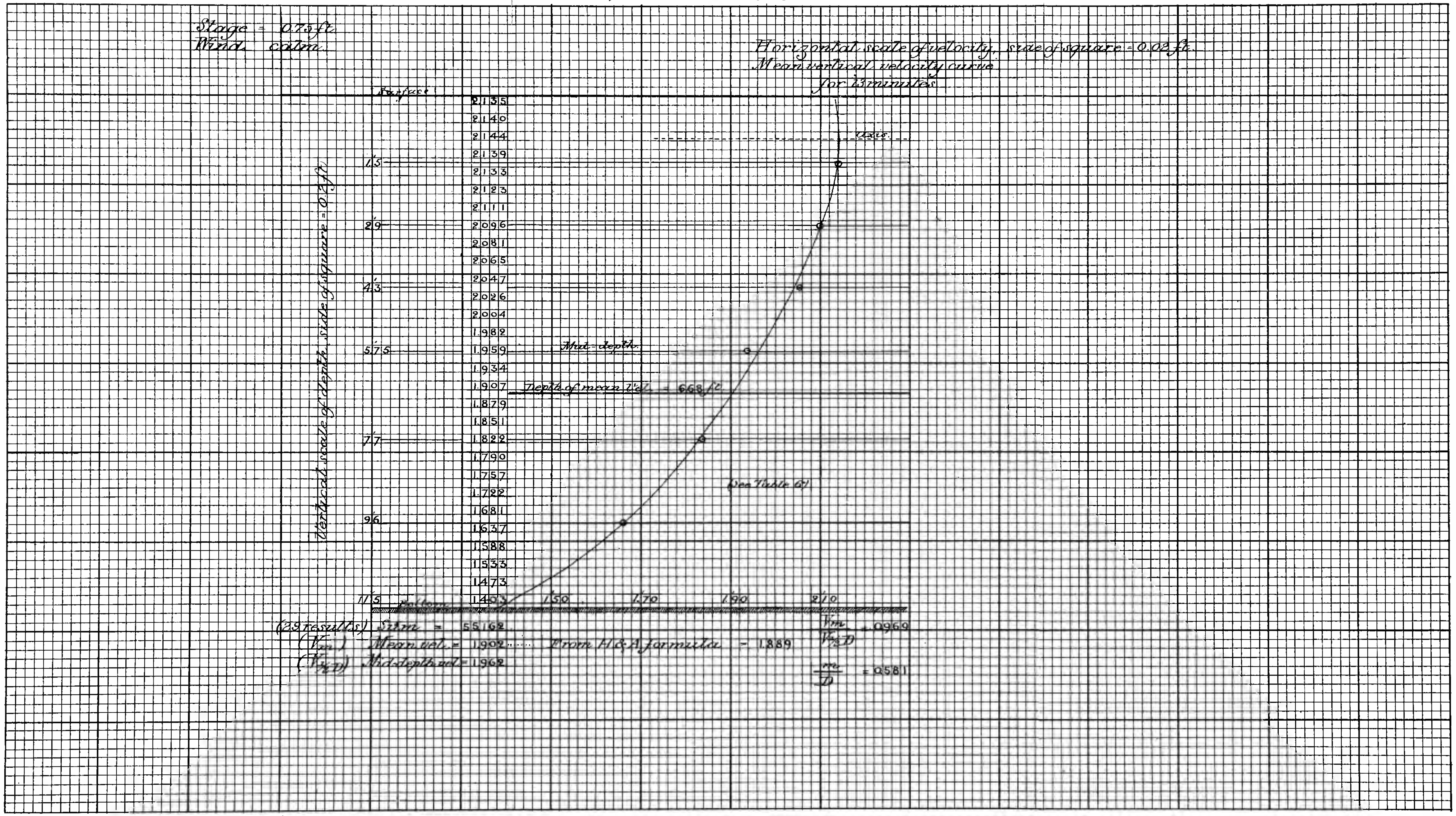
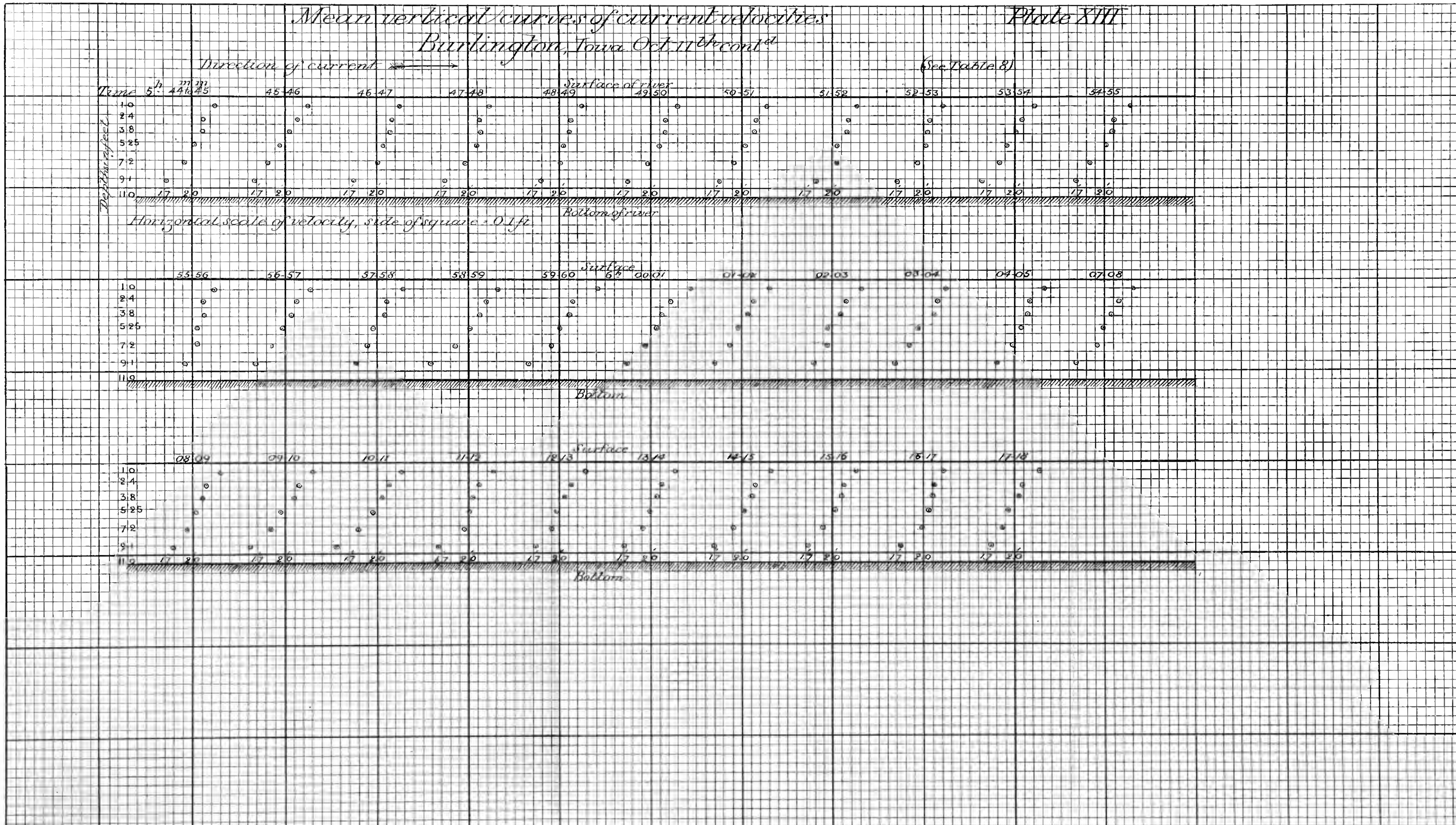


Plate XII

Mean vertical curves of current velocities
Burlington Iowa Oct 11th cont'd

(See Table 7)


Mean vertical curves of current velocities
Plate XIII
Burlington, Iowa Oct. 11th cont'd
Direction of current
(See Table 8)
Surface of river
Time 5h 44m 45m
45-46
46-47
47-48
48-49
49-50
50-51
51-52
52-53
53-54
54-55
Depth in feet
1.0
2.4
3.8
5.25
7.2
9.1
11.0
17
20
Bottom of river
Horizontal scale of velocity, side of square = 0.1 ft.
Surface
55-56
56-57
57-58
58-59
59-60
6h 00-01
01-02
02-03
03-04
04-05
07-08
Bottom
Surface
08-09
09-10
10-11
11-12
12-13
13-14
14-15
15-16
16-17
17-18
Bottom

Current-meters,-Oct 11th contd.

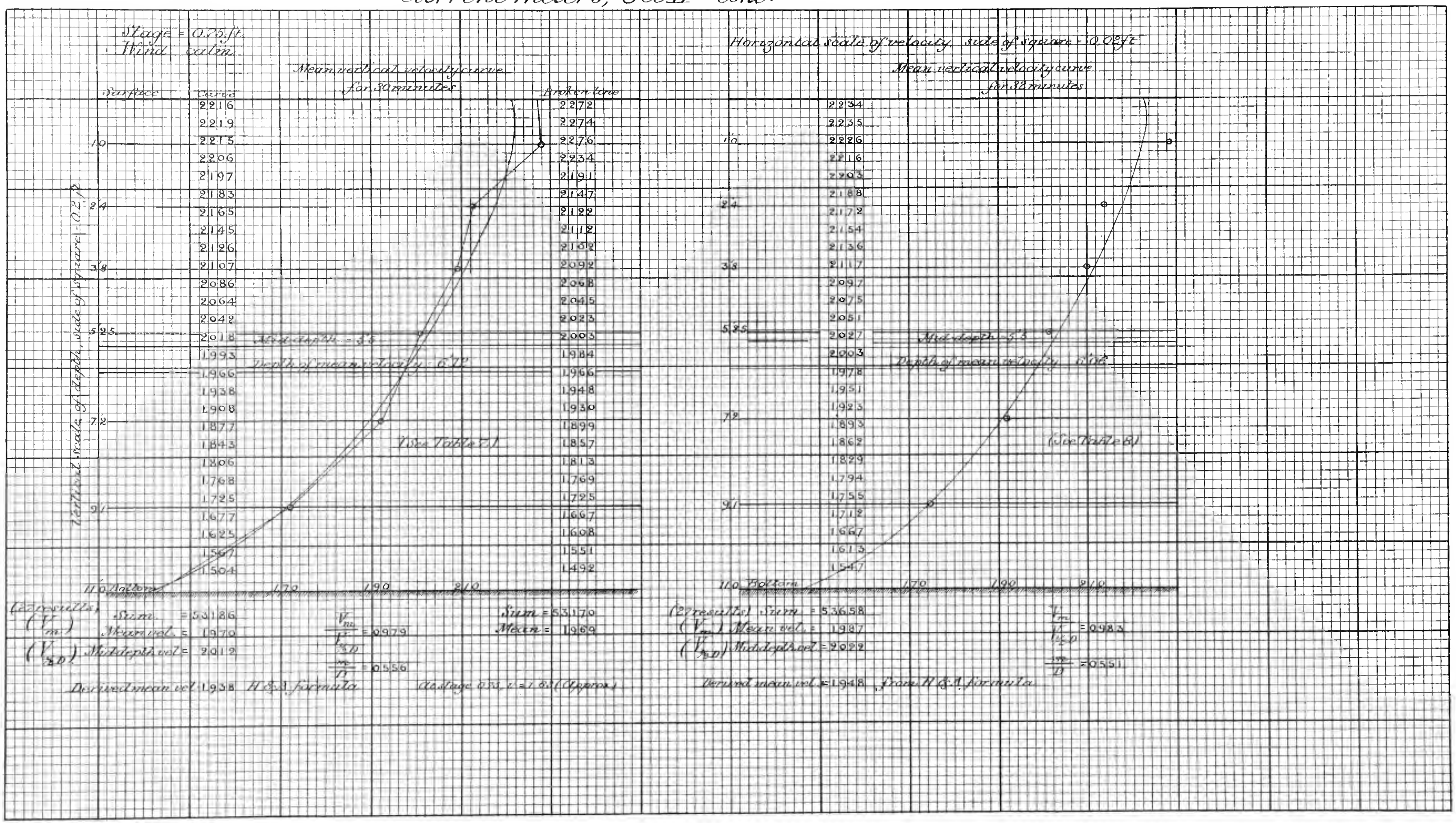
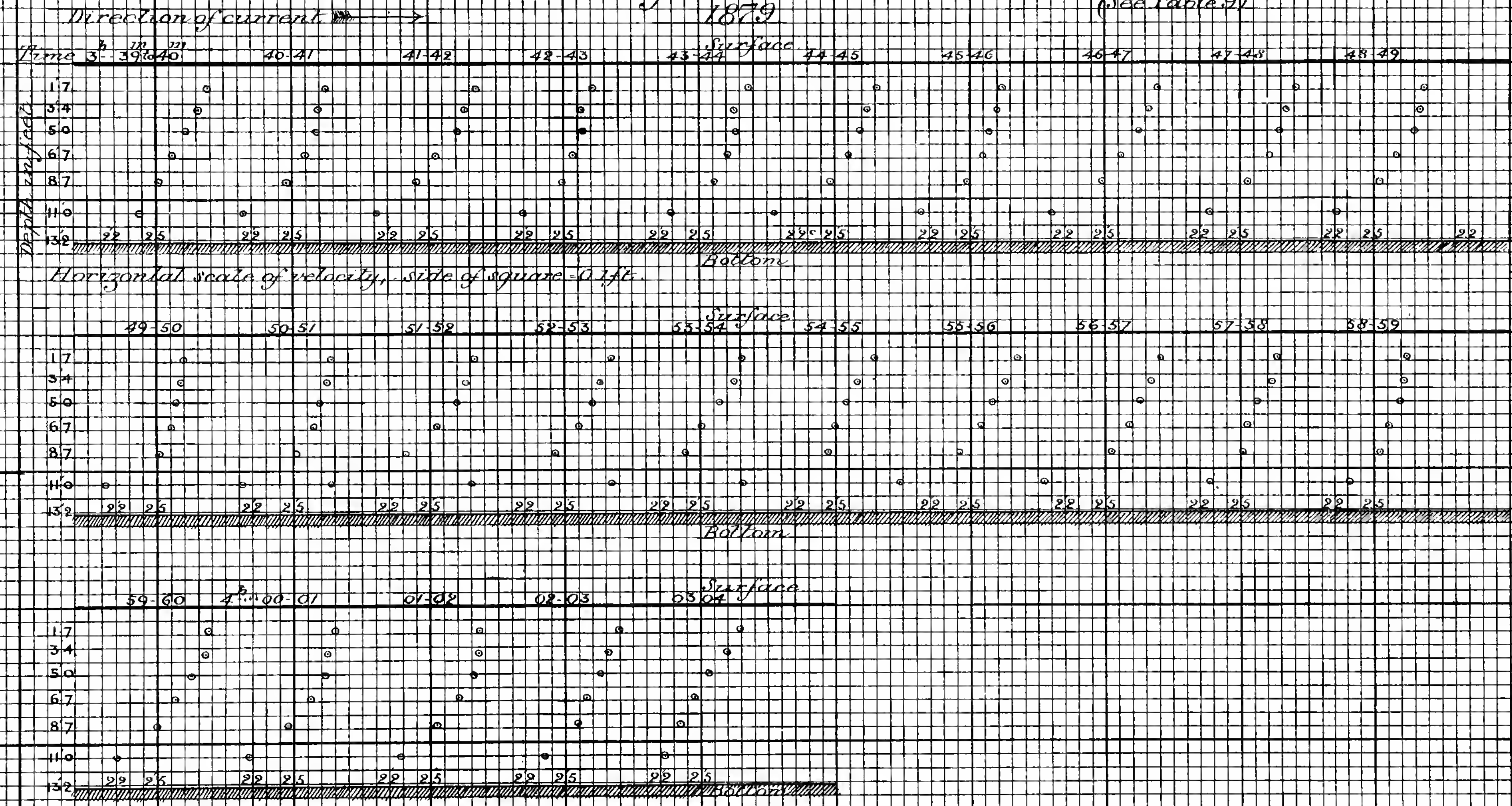


Plate XV

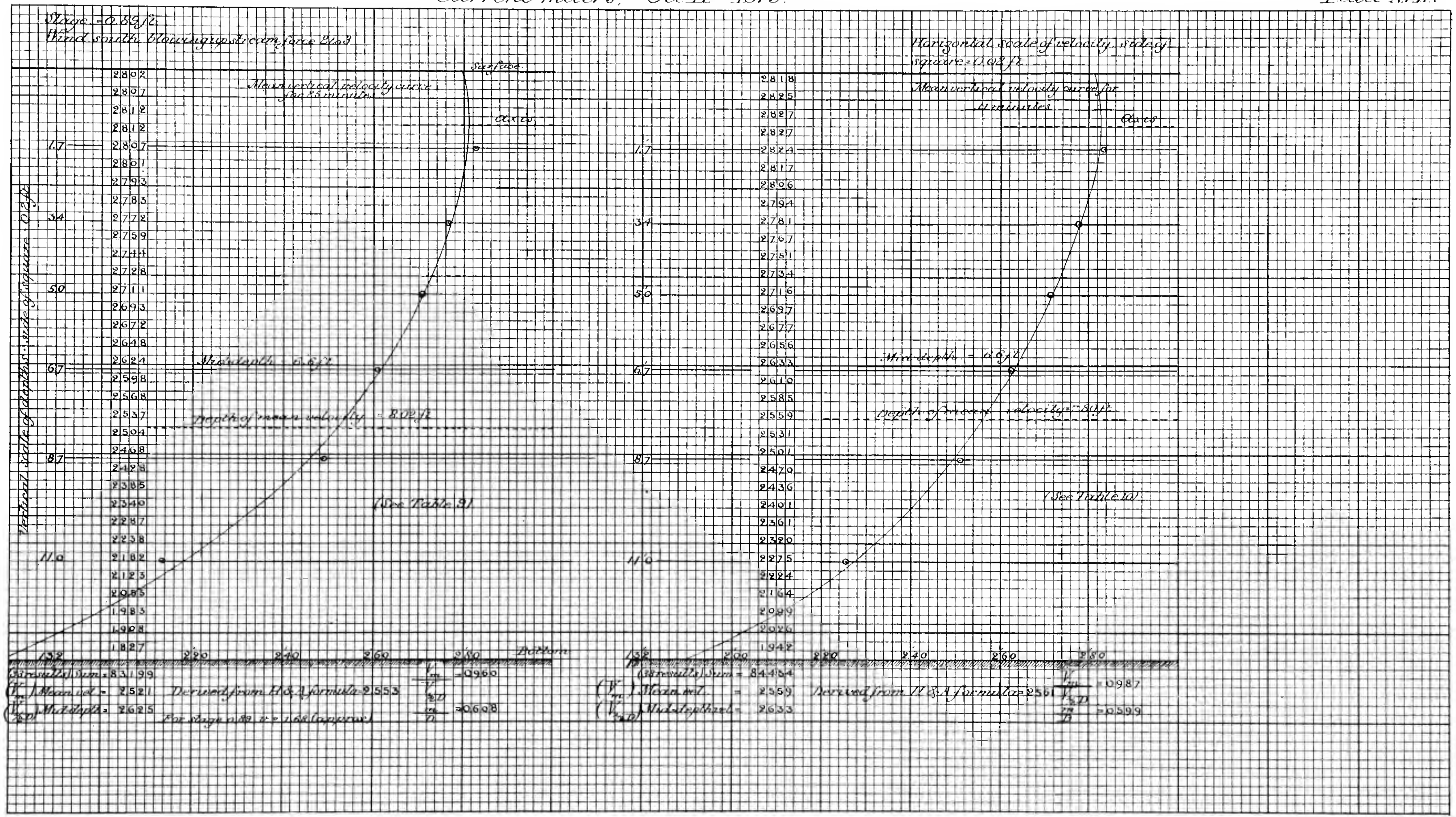
Mean vertical curves of current velocities
Burlington, Iowa. Oct 11th 1879

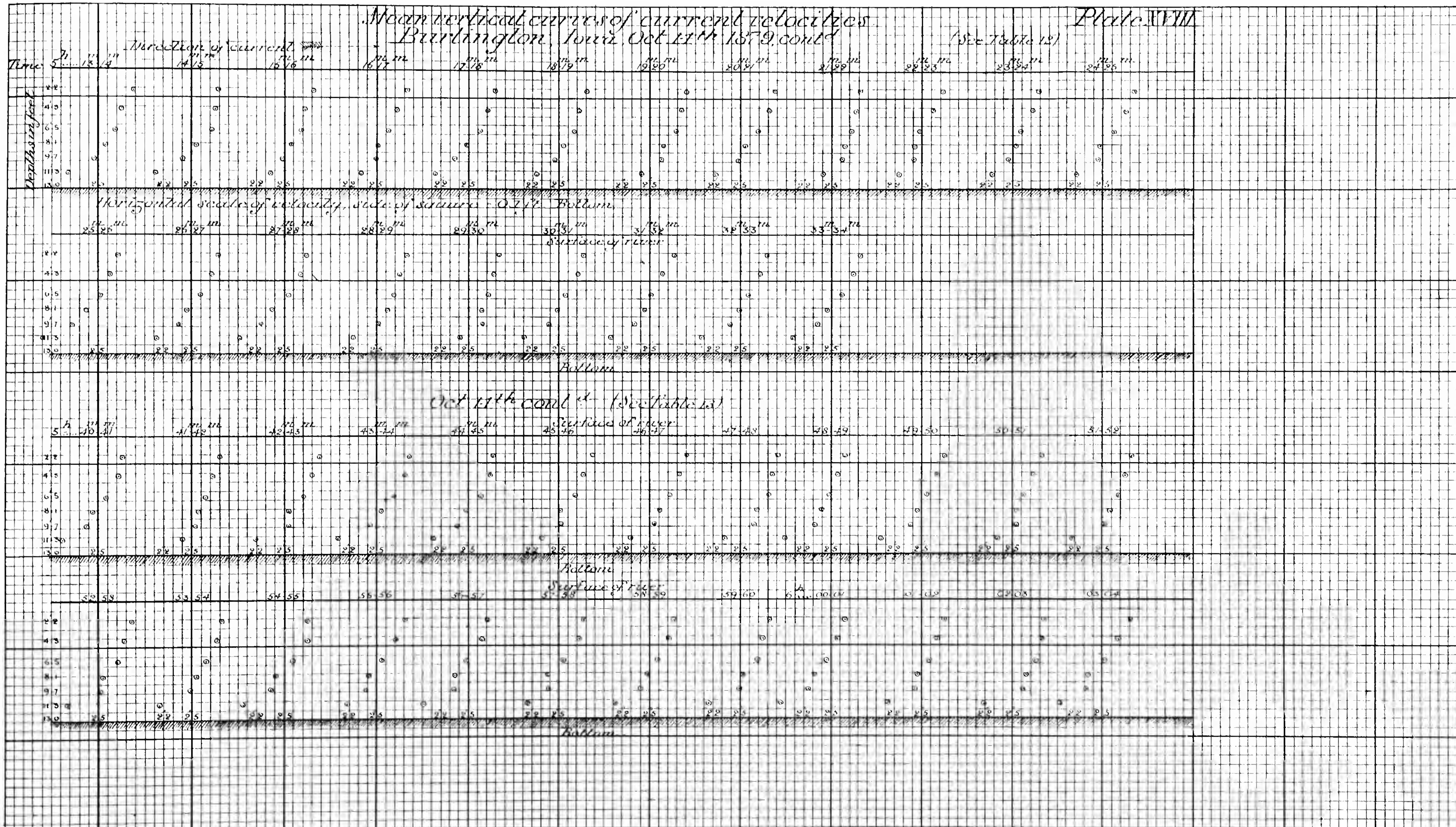
(See Table 9)



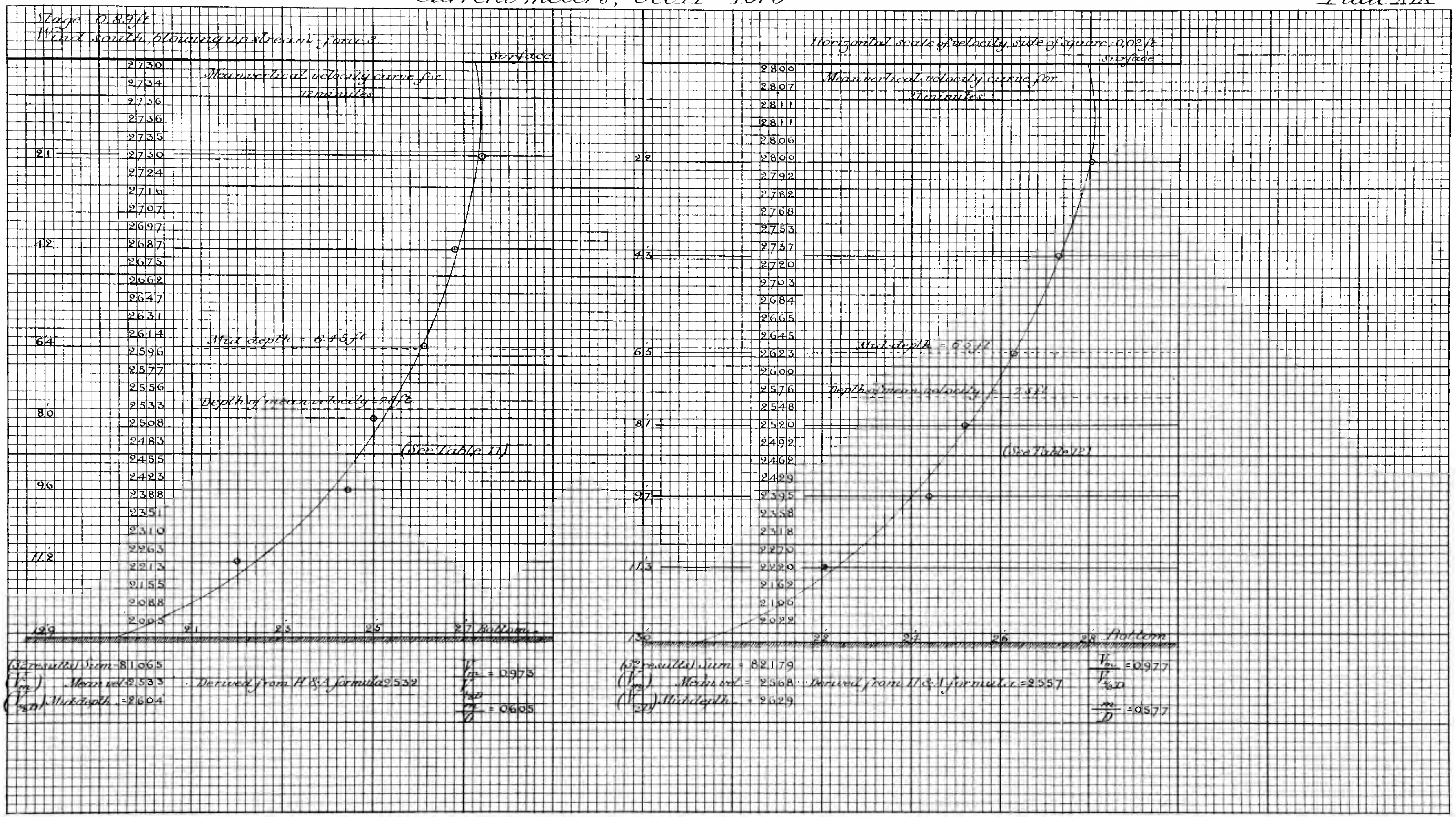
Mean vertical curves of current velocities at
Burlington, Iowa, Oct 14th contd
1879
Plate XVI.
(See Table 10)
Direction of current
Depths in feet
Horizontal scale of velocity — side of square = 0.1 ft.
Bottom of river
Oct. 14th contd. (See Table 11)
Surface
Bottom
Stopped.

Current meters, Oct 14th 1879.

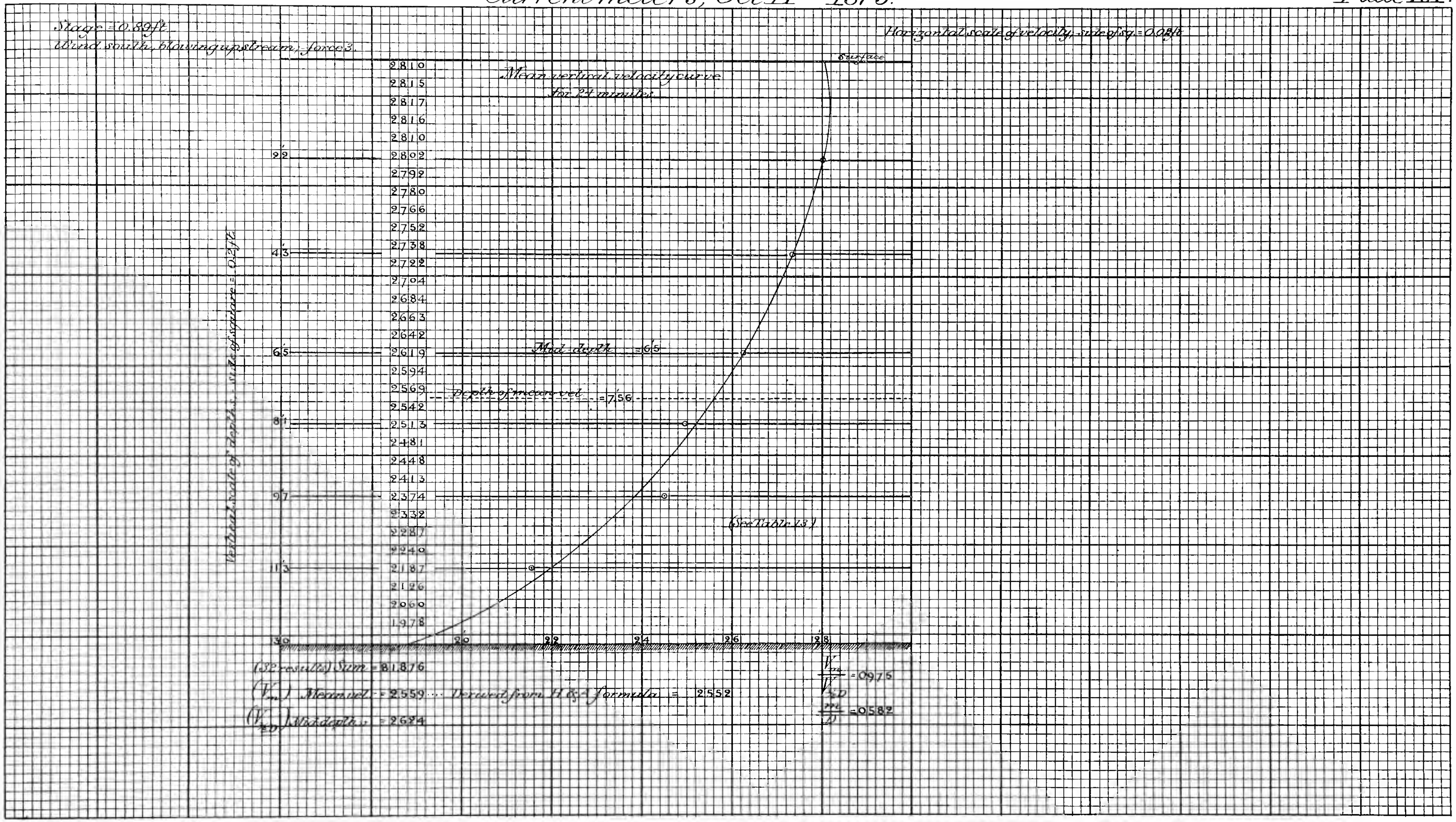



Mean vertical curves of current velocities
Burlington, Iowa. Oct 11th 1879. cont'd
Plate XVIII
(See Table 12)
Direction of current
Time
Depths in feet
Horizontal scale of velocity, side of square 0.1 ft.
Bottom
Surface of river
Oct 11th cont'd (See Table 13)

Current meters, Oct 14th 1879



Current-meters, Oct 14th 1879.



Current-meters - Oct. 21st. 1879.

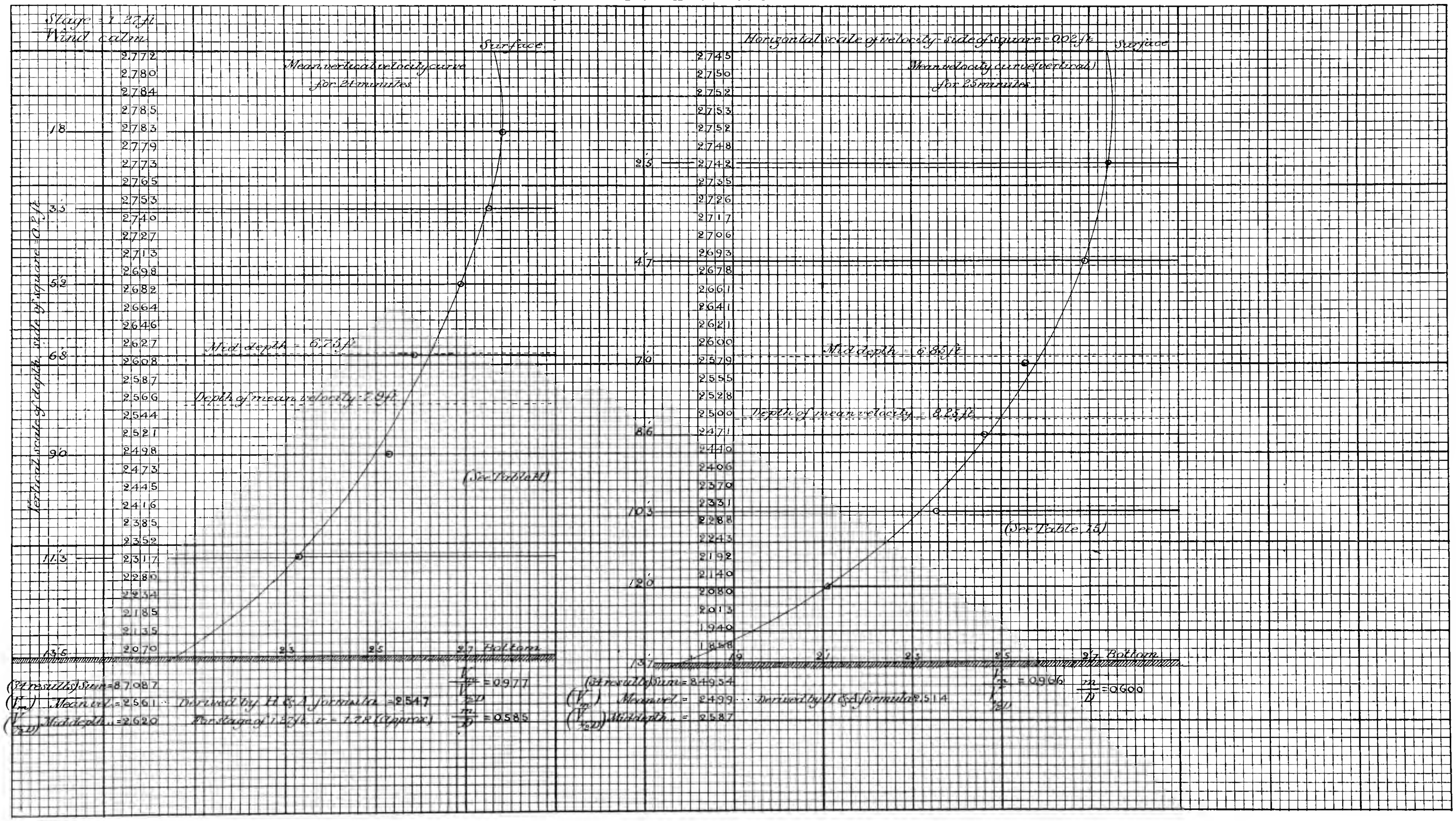


Plate XXII.

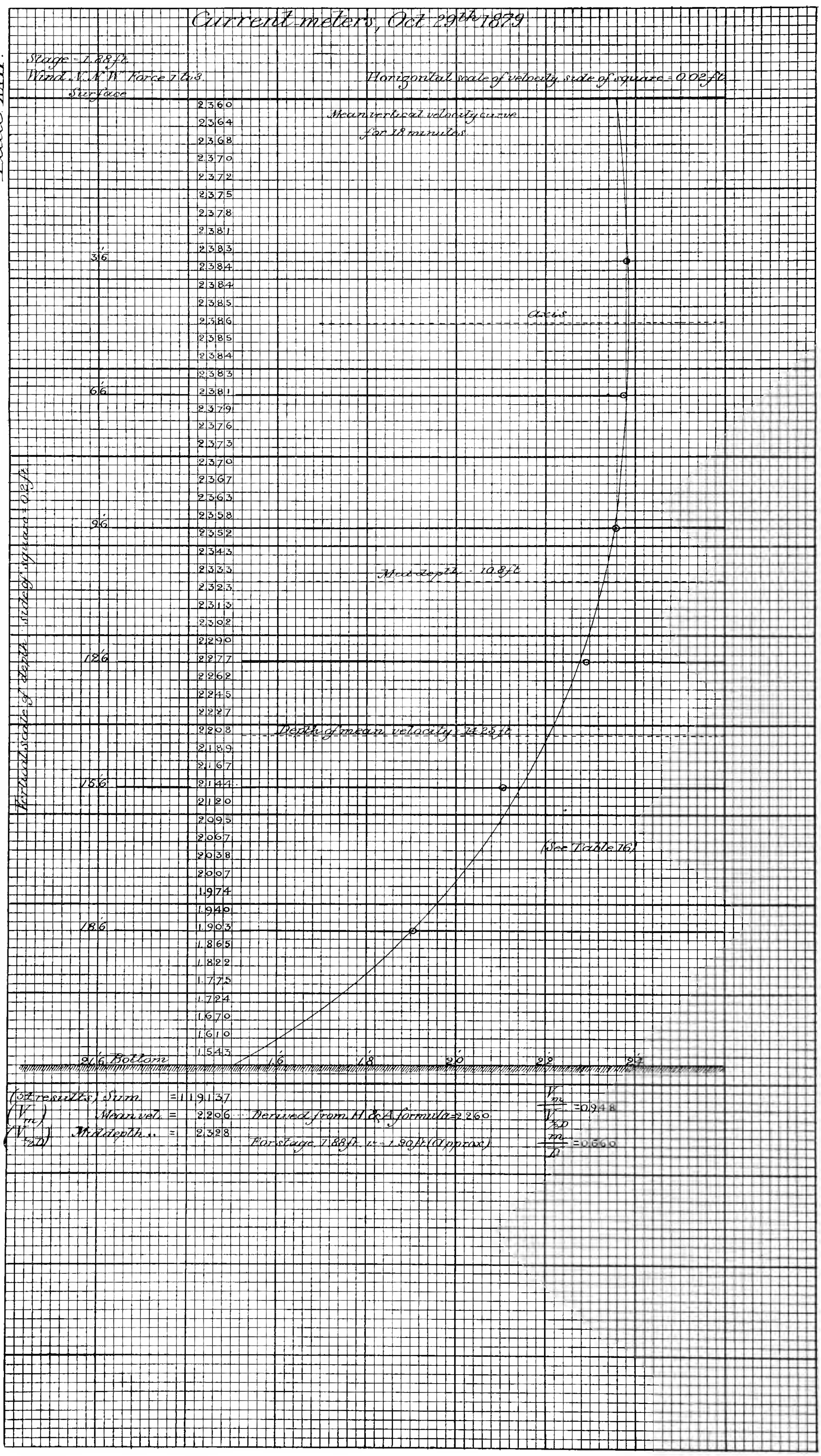

Current-meters, Oct 29th 1879
Stage = 1.88 ft.
Wind. N.N.W. Force 1 to 3.
Surface
Horizontal scale of velocity, side of square = 0.02 ft.
Vertical scale of depth, side of square = 0.2 ft.
Mean vertical velocity curve for 18 minutes.
Axis
Mid-depth - 10.8 ft.
Depth of mean velocity = 14.25 ft.
(See Table 16)
3.6'
6.6'
9.6'
12.6'
15.6'
18.6'
21.6' Bottom
1.6
1.8
2.0
2.2
2.4
2.360
2.364
2.368
2.370
2.372
2.375
2.378
2.381
2.383
2.384
2.384
2.385
2.386
2.385
2.384
2.383
2.381
2.379
2.376
2.373
2.370
2.367
2.363
2.358
2.352
2.343
2.333
2.323
2.313
2.302
2.290
2.277
2.262
2.245
2.227
2.208
2.189
2.167
2.144
2.120
2.095
2.067
2.038
2.007
1.974
1.940
1.903
1.865
1.822
1.775
1.724
1.670
1.610
1.543
(54 results) Sum = 119.137
(V_m) Mean vel. = 2.206 Derived from H. & A. formula = 2.260
($V_{\frac{1}{2}D}$) Mid-depth .. = 2.328 For stage 1.88 ft. v = 1.90 ft. (Approx.)
$\frac{V_m}{V_{\frac{1}{2}D}}$ = 0.948
$\frac{m}{D}$ = 0.660

Plate XXIII.

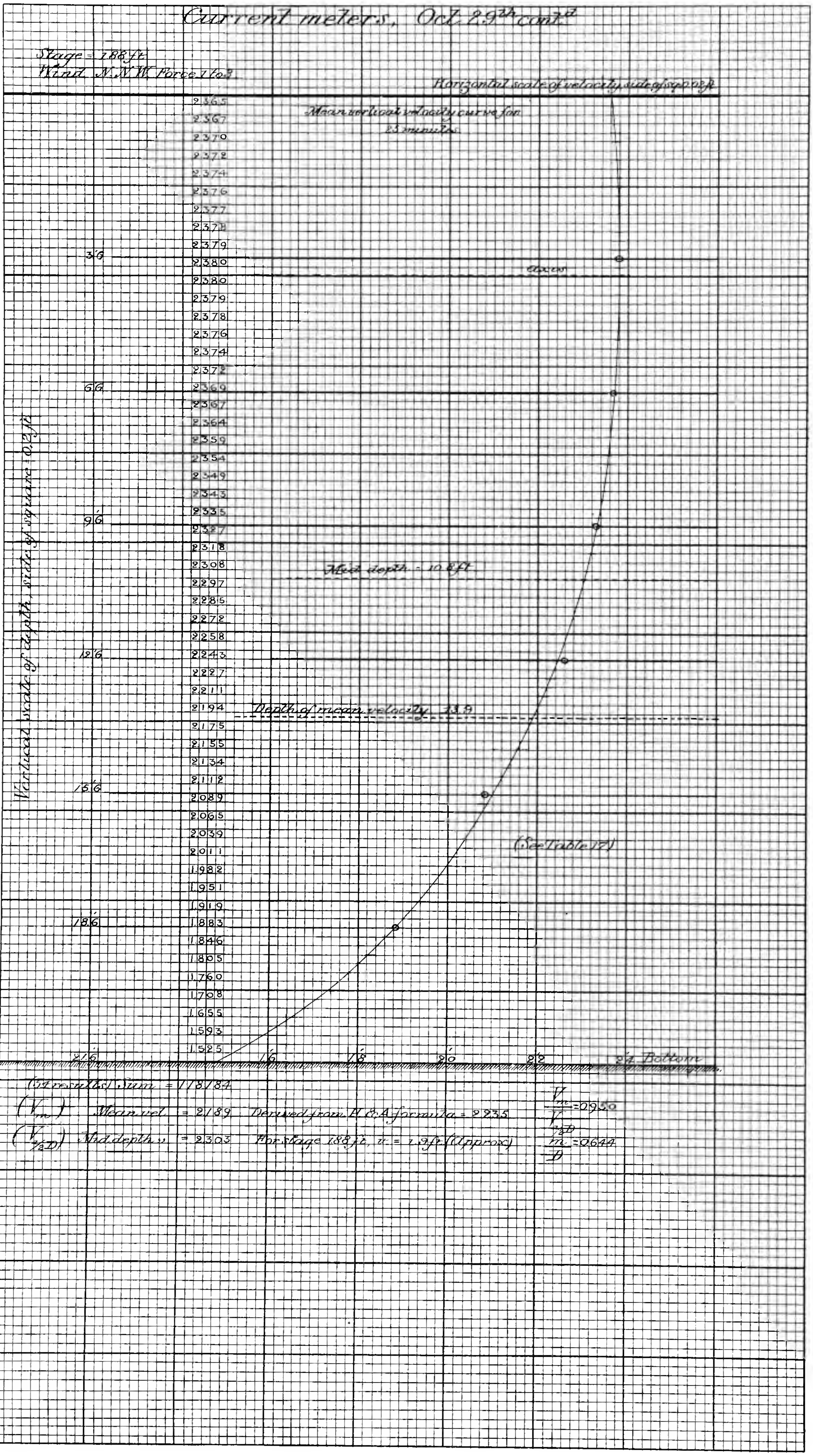

Current meters, Oct. 29th cont.
Stage = 18.8 ft
Wind N.N.W. Force 1 to 3
Horizontal scale of velocity, side of sq. 0.02 ft
Vertical scale of depth, side of square 0.2 ft
Mean vertical velocity curve for 25 minutes
2365
2367
2370
2372
2374
2376
2377
2378
2379
3.6
2380
2380
axis
2379
2378
2376
2374
2372
6.6
2369
2367
2364
2359
2354
2349
2343
2335
9.6
2327
2318
2308
Mid depth - 10.8 ft
2297
2285
2272
2258
12.6
2243
2227
2211
2194
Depth of mean velocity 13.9
2175
2155
2134
2112
15.6
2089
2065
2039
2011
(See Table 17)
1982
1951
1919
18.6
1883
1846
1805
1760
1708
1655
1593
21.6
1525
1.6
1.8
2.0
2.2
21.4 Bottom
(54 results) Sum = 118.184
(V_m) Mean vel. = 2189 Derived from H. & A. formula = 2235
(V_{1/2D}) Mid depth " = 2303 For stage 18.8 ft, v = 1.9 ft (Approx)
V_m / V_{1/2D} = 0.950
m / √D = 0.644

Plate XXIV

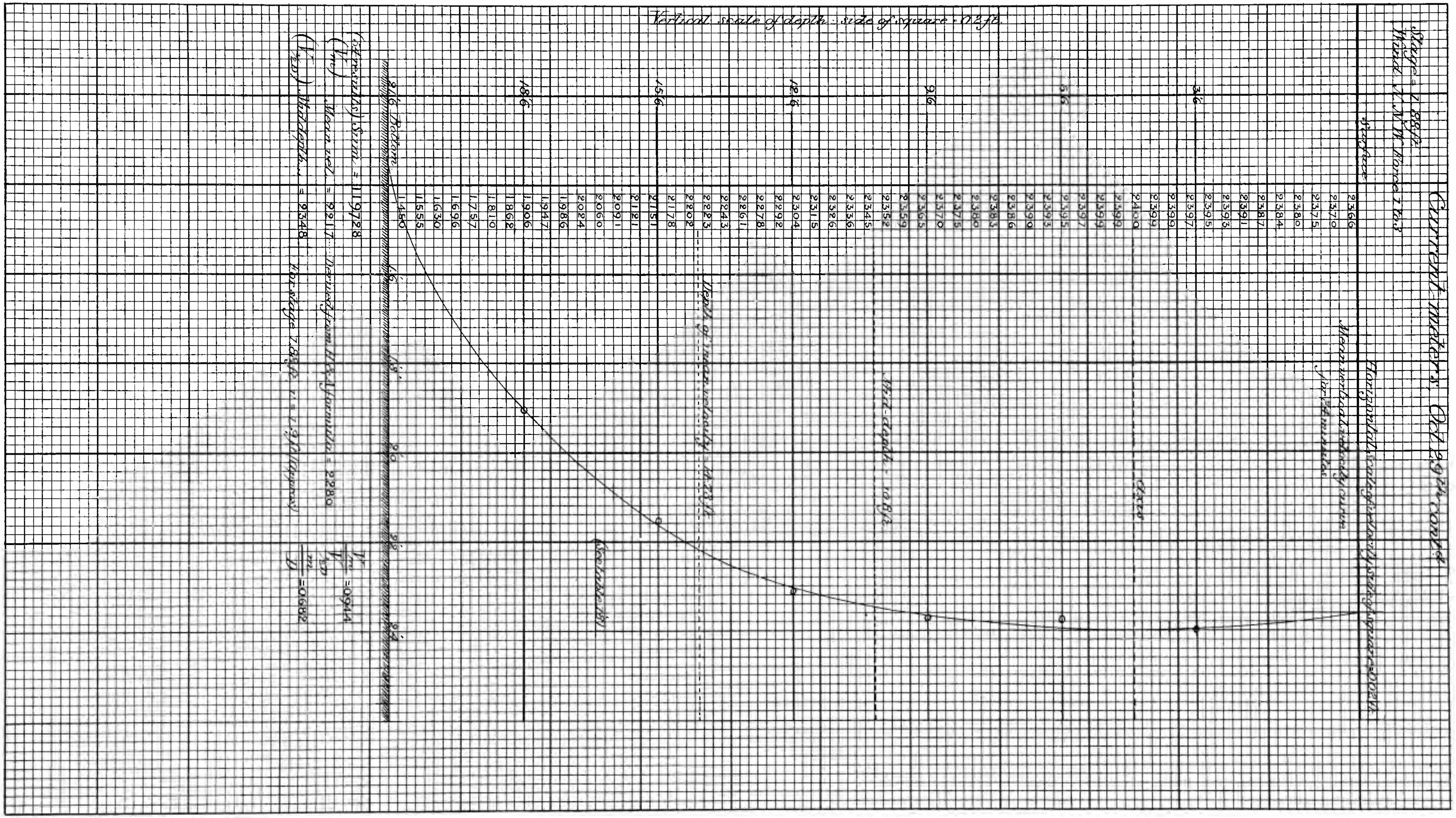
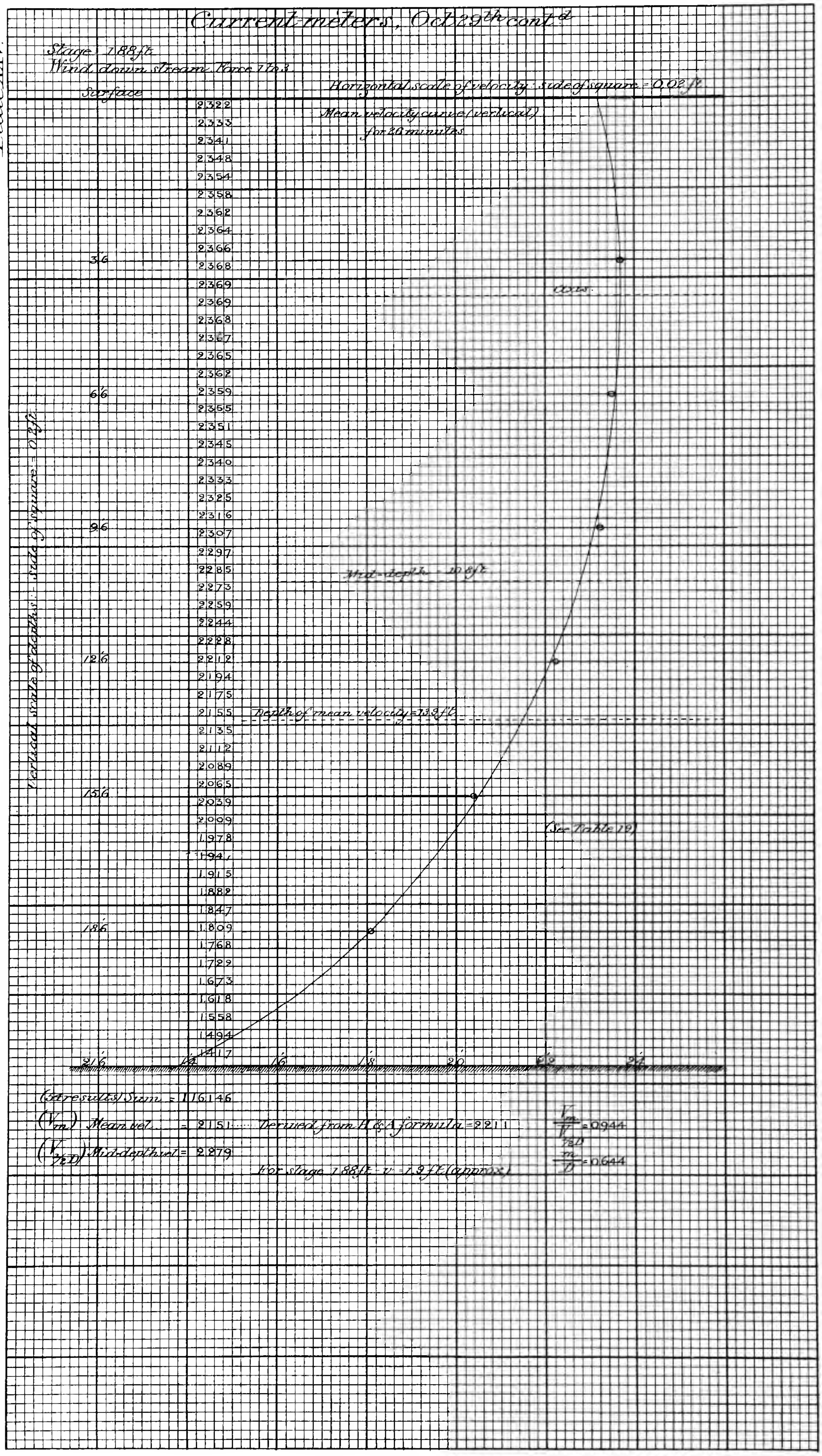

Current Meters, Oct 29th cont'd
Stage = 7.88 ft
Wind N.N.W. Force 1 to 3
Surface
Vertical scale of depth : side of square = 0.2 ft.
Horizontal scale of velocity : side of square = .002 ft.
Mean vertical velocity curve
Axis
Mid depth = 10.8 ft
Depth of mean velocity
Bottom
See table
Sum = 11.9728
Mean vel = .2217 ... Derived from formula = .2280
= .9348
1450
1555
1630
1696
1757
1810
1868
1906
1947
1986
2024
2060
2091
2121
2151
2178
2202
2223
2243
2261
2278
2292
2304
2315
2326
2336
2345
2352
2359
2365
2370
2375
2380
2383
2386
2390
2393
2395
2397
2399
2399
2400
2399
2399
2397
2395
2393
2391
2387
2384
2380
2375
2370
2366

Plate XXV.



Current-meters, Oct 29th contd
Stage 7.88 ft
Wind down stream Force 1 to 3
Surface
Horizontal scale of velocity : side of square = 0.02 ft
Mean velocity curve (vertical) for 20 minutes
Vertical scale of depths : - side of square = 0.2 ft
3.6
6.6
9.6
12.6
15.6
18.6
21.6
2.322
2.333
2.341
2.348
2.354
2.358
2.362
2.364
2.366
2.368
2.369
2.369
2.368
2.367
2.365
2.362
2.359
2.355
2.351
2.345
2.340
2.333
2.325
2.316
2.307
2.297
2.285
2.273
2.259
2.244
2.228
2.212
2.194
2.175
2.155
2.135
2.112
2.089
2.065
2.039
2.009
1.978
1.941
1.915
1.882
1.847
1.809
1.768
1.729
1.673
1.618
1.558
1.494
1.417
axis
Mid-depth = 10.8 ft
Depth of mean velocity = 13.3 ft
(See Table 19)
1.4
1.6
1.8
2.0
2.2
2.4
(73 results) Sum = 116.146
(V_m) Mean vel. = 2.151 .... Derived from H & A formula = 2.211
($V_{½D}$) Mid-depth vel = 2.879
For stage 7.88 ft v = 1.9 ft (approx)
$\frac{V_m}{V_{½D}}$ = 0.944
$\frac{m}{D}$ = 0.644

Plate XXVI

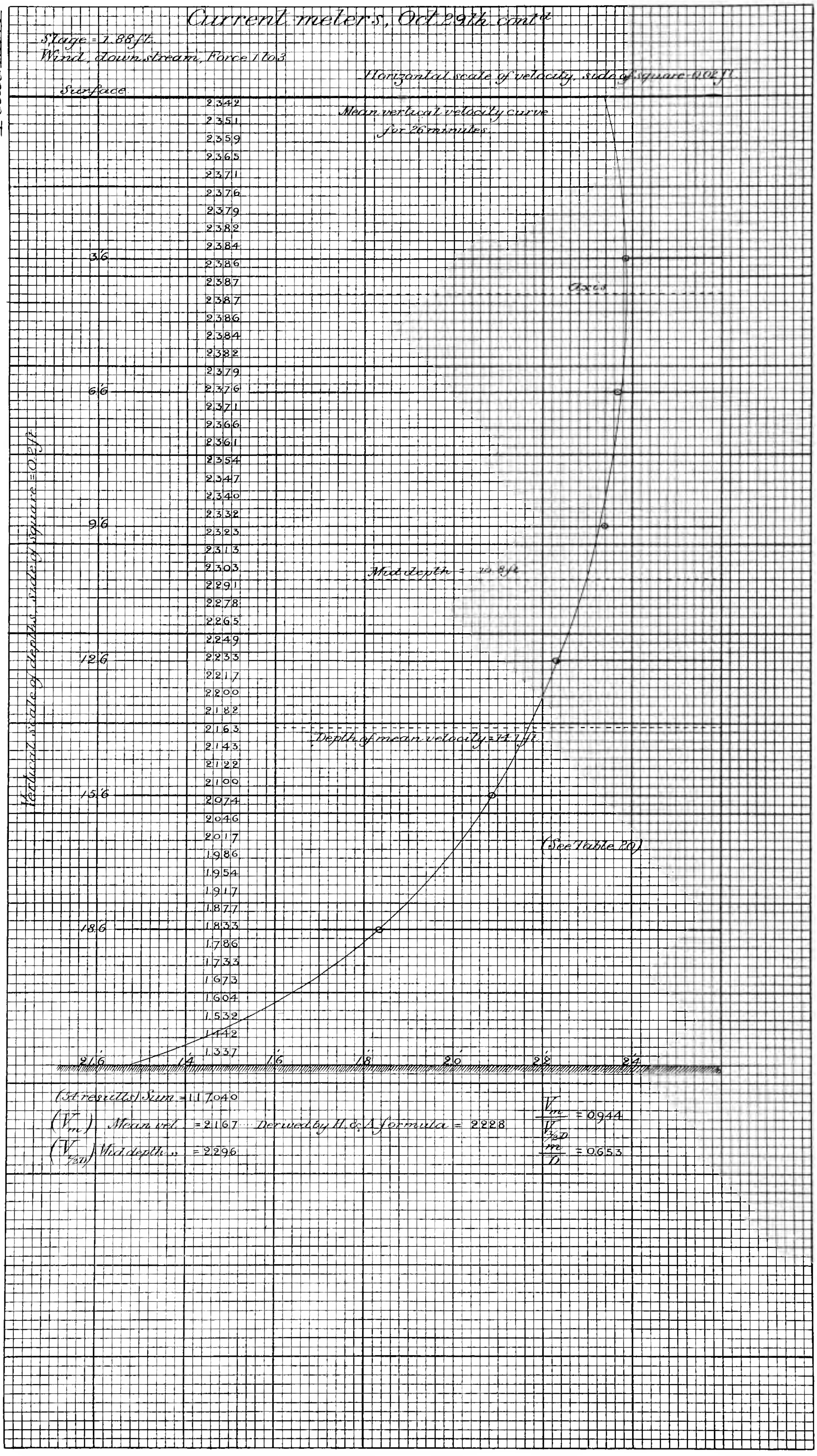
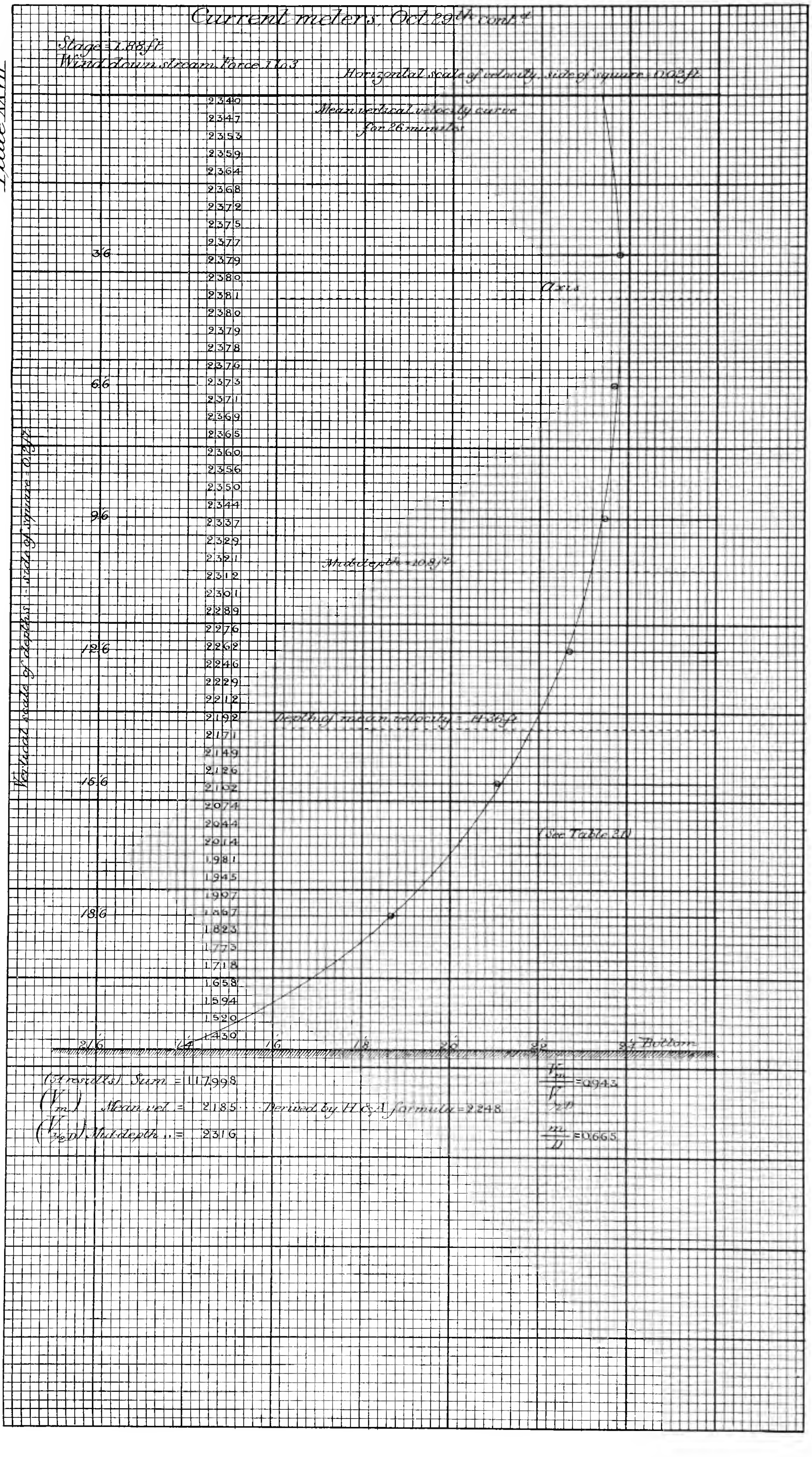
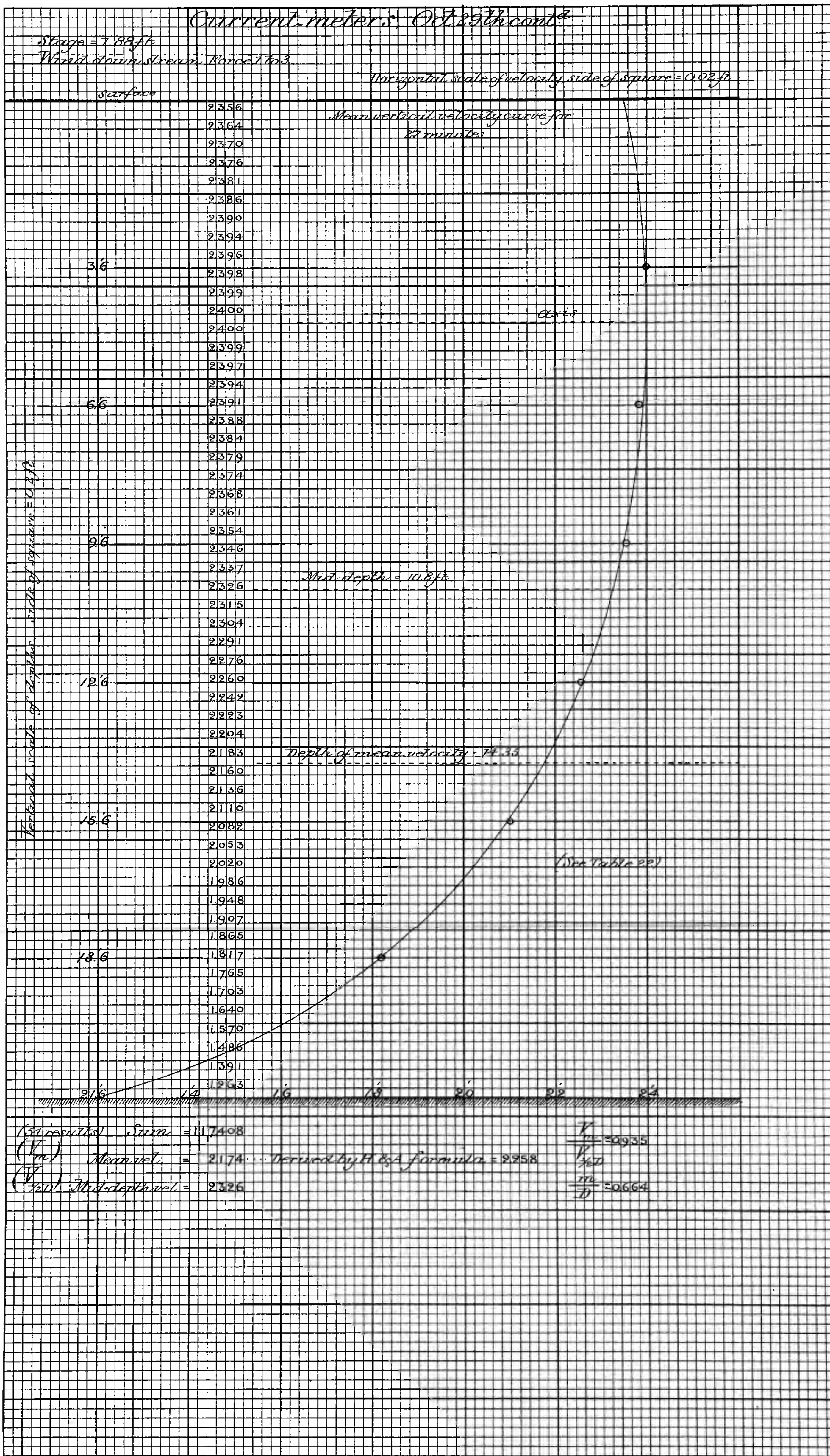

Current meters, Oct 29th contd
Stage = 1.88 ft.
Wind, down stream, Force 1 to 3
Horizontal scale of velocity, side of square = 0.02 ft.
Surface
Mean vertical velocity curve
for 26 minutes.
2349
2351
2359
2365
2371
2376
2379
2382
2384
2386
2387
2387
2386
2384
2382
2379
2376
2371
2366
2361
2354
2347
2340
2332
2323
2313
2303
2291
2278
2265
2249
2233
2217
2200
2182
2163
2143
2122
2100
2074
2046
2017
1986
1954
1917
1877
1833
1786
1733
1673
1604
1532
1442
1337
3.6
6.6
9.6
12.6
15.6
18.6
21.6
Axis
Mid depth =
Depth of mean velocity =
(See Table 20)
1.4
1.6
1.8
2.0
2.2
2.4
Vertical scale of depths, side of square = 0.2 ft.
(54 results) Sum = 117.040
(V_m) Mean vel. = 2.167 Derived by H. & A. formula = 2.228
(V_{1/2D}) Mid depth " = 2.296
V_m / V_{1/2D} = 0.944
m / D = 0.653

Plate XXVII



Current meters, Oct 29th cont.d
Stage = 1.88 ft.
Wind down stream Force 1 to 3
Horizontal scale of velocity, side of square = 0.02 ft.
Vertical scale of depths :- side of square = 0.2 ft.
Mean vertical velocity curve for 26 minutes
Axis
Mid-depth = 10.8 ft.
Depth of mean velocity = 14.36 ft.
(See Table 21)
Bottom
3.6
6.6
9.6
12.6
15.6
18.6
21.6
1.4
1.6
1.8
2.0
2.2
2.4
2.340
2.347
2.353
2.359
2.364
2.368
2.372
2.375
2.377
2.379
2.380
2.381
2.380
2.379
2.378
2.376
2.373
2.371
2.369
2.365
2.360
2.356
2.350
2.344
2.337
2.329
2.321
2.312
2.301
2.289
2.276
2.262
2.246
2.229
2.212
2.192
2.171
2.149
2.126
2.102
2.074
2.044
2.014
1.981
1.945
1.907
1.867
1.823
1.773
1.718
1.658
1.594
1.520
1.430
(51 results) Sum = 117.998
(V_m) Mean vel. = 2.185 · · · Derived by H.&A. formula = 2.248
($V_{1/2D}$) Mid-depth " = 2.316
$\frac{V_m}{V_{1/2D}}$ = 0.943
$\frac{m}{D}$ = 0.665


Current-meters. Oct. 29th cont.d
Stage = 7.88 ft.
Wind down stream. Force 1 to 3.
Horizontal scale of velocity side of square = 0.02 ft.
surface
Mean vertical velocity curve for 22 minutes
axis
Mid-depth = 10.8 ft.
Depth of mean velocity = 14.33
(See Table 22)
Vertical scale of depths, side of square = 0.4 ft.
3.6
6.6
9.6
12.6
15.6
18.6
21.6
1.4
1.6
1.8
2.0
2.2
2.4
2356
2364
2370
2376
2381
2386
2390
2394
2396
2398
2399
2400
2400
2399
2397
2394
2391
2388
2384
2379
2374
2368
2361
2354
2346
2337
2326
2315
2304
2291
2276
2260
2242
2223
2204
2183
2160
2136
2110
2082
2053
2020
1.986
1.948
1.907
1.865
1.817
1.765
1.703
1.640
1.570
1.486
1.391
1.263
(54 results) Sum = 117.408
(V_m) Mean vel. = 2.174 Derived by H. & A. formula = 2.258
($V_{½D}$) Mid-depth vel. = 2.326
$\frac{V_m}{V_{½D}}$ = 0.935
$\frac{m}{D}$ = 0.664

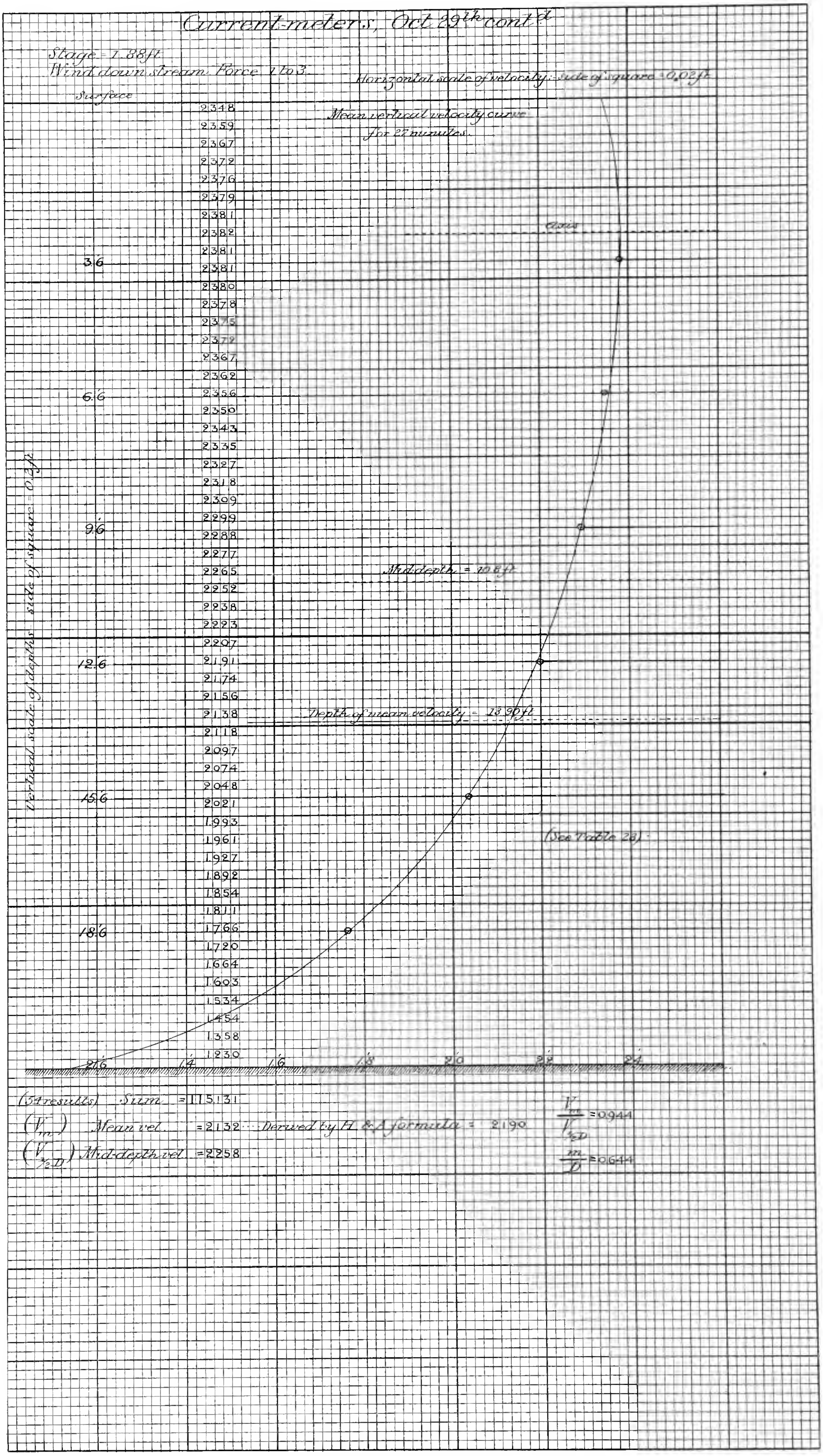
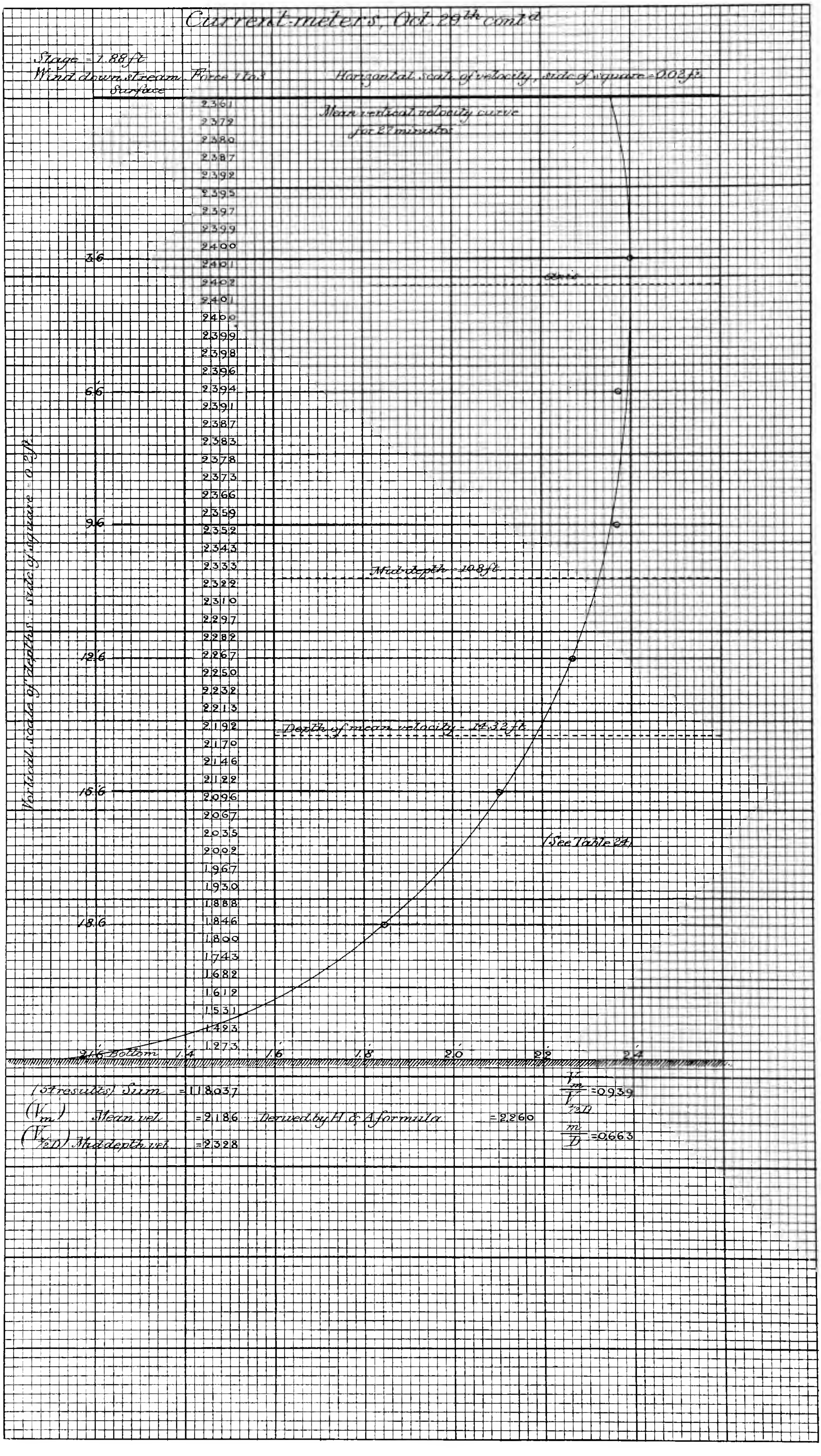

Current-meters, Oct 29th contd
Stage = 1.88 ft
Wind down stream. Force 1 to 3.
Horizontal scale of velocity: side of square = 0.02 ft
Surface
Mean vertical velocity curve for 27 minutes.
axis
Vertical scale of depths: side of square = 0.2 ft
3.6
6.6
9.6
12.6
15.6
18.6
2348
2359
2367
2372
2376
2379
2381
2382
2381
2381
2380
2378
2375
2372
2367
2362
2356
2350
2343
2335
2327
2318
2309
2299
2288
2277
2265
2252
2238
2223
2207
2191
2174
2156
2138
2118
2097
2074
2048
2021
1993
1961
1927
1892
1854
1811
1766
1720
1664
1603
1534
1454
1358
1230
Mid-depth = 10.8 ft
Depth of mean velocity = 13.90 ft
(See Table 28)
21.6
1.4
1.6
1.8
2.0
2.2
2.4
(54 results) Sum = 115131
(V_m) Mean vel. = 2132 ... Derived by H. & A. formula = 2190
($V_{1/2 D}$) Mid-depth vel. = 2258
$\frac{V_m}{V_{1/2 D}}$ = 0.944
$\frac{m}{D}$ = 0.644

Plate XXX



Current-meters, Oct. 29th contd
Stage = 1.88 ft
Wind down stream Force 1 to 3
Surface
Horizontal scale of velocity, side of square = 0.02 ft.
Mean vertical velocity curve for 2nd minutes
Vertical scale of depths:- side of square = 0.2 ft.
2361
2379
2380
2387
2392
2395
2397
2399
2400
3.6
2401
2402
2401
2400
2399
2398
2396
6.6
2394
2391
2387
2383
2378
2373
2366
2359
9.6
2352
2343
2333
Mid-depth - 10.8 ft
2322
2310
2297
2289
12.6
2267
2250
2232
2213
2192
Depth of mean velocity - 14.32 ft
2170
2146
2122
15.6
2096
2067
2035
2002
(See Table 24)
1967
1930
1888
18.6
1846
1800
1743
1682
1619
1531
1493
1273
21.6 Bottom
1.4
1.6
1.8
2.0
2.2
2.4
(54 results) Sum = 118037
(V_m) Mean vel. = 2186
Derived by H & A formula = 2260
$(V_{1/2 D})$ Mid depth vel. = 2328
$\frac{V_m}{V_{1/2 D}}$ = 0.939
$\frac{m}{D}$ = 0.663

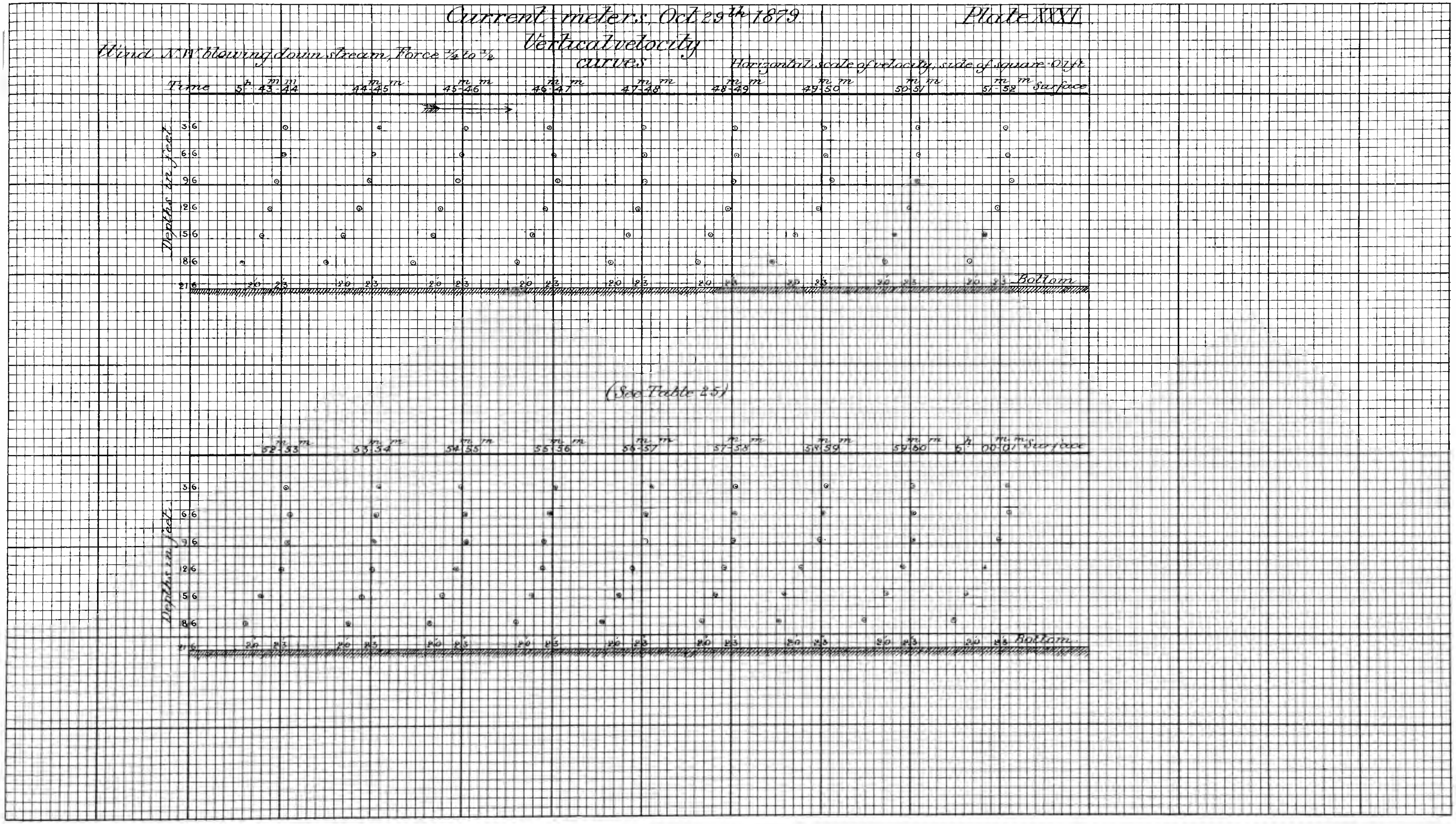
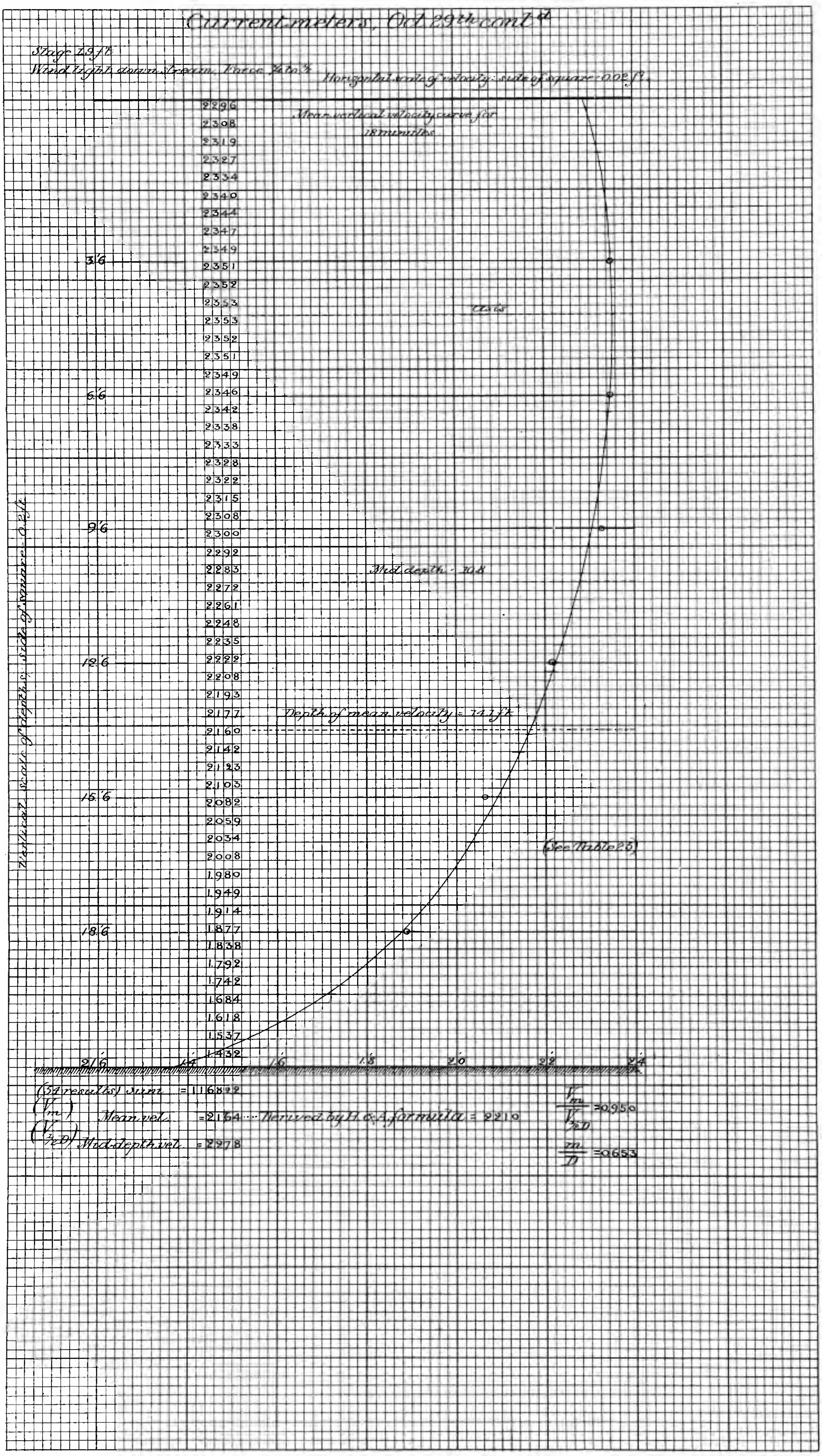
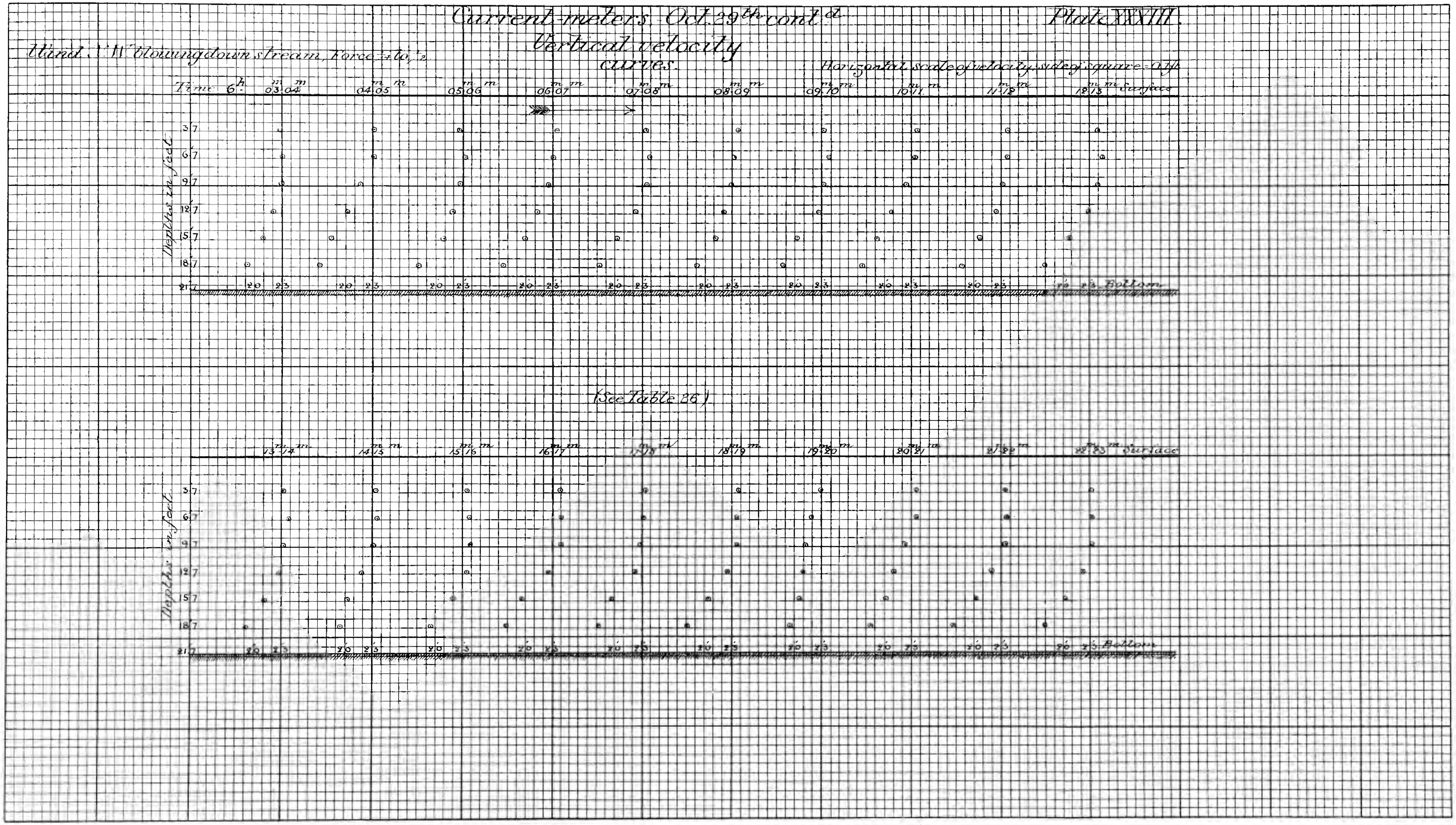

Current-meters: Oct 29th 1879.
Plate XXXI
Vertical velocity curves
Wind N.W. blowing down stream, Force ¼ to ½
Horizontal scale of velocity, side of square ·01 ft
Time
5h 43m-44m
44-45
45-46
46-47
47-48
48-49
49-50
50-51
51-52
Surface
Depths in feet
3·6
6·6
9·6
12·6
15·6
18·6
21·6
·20 ·23
Bottom
(See Table 25)
52-53
53-54
54-55
55-56
56-57
57-58
58-59
59-60
6h 00-01
Surface
Depths in feet
Bottom

Plate XXXII


Current meters, Oct. 29th cont.d
Stage 1.9 ft.
Wind light down stream. Force ½ to ¾
Horizontal scale of velocity: side of square = 0.02 ft.
Mean vertical velocity curve for 18 minutes
axis
Vertical scale of depths: side of square = 0.2 ft.
3.6
6.6
9.6
12.6
15.6
18.6
21.6
2296
2308
2319
2327
2334
2340
2344
2347
2349
2351
2352
2353
2353
2352
2351
2349
2346
2342
2338
2333
2328
2322
2315
2308
2300
2292
2283
2272
2261
2248
2235
2222
2208
2193
2177
2160
2142
2123
2103
2082
2059
2034
2008
1.980
1.949
1.914
1.877
1.838
1.792
1.742
1.684
1.618
1.537
1.432
Mid depth - 10.8
Depth of mean velocity = 14.1 ft.
(See Table 25)
1.4
1.6
1.8
2.0
2.2
2.4
(54 results) sum = 116892
(V_m) Mean vel. = 2164 ... Derived by H. & A. formula = 2210
($V_{\frac{1}{2}D}$) Mid-depth vel. = 2278
$\frac{V_m}{V_{\frac{1}{2}D}}$ = 0.950
$\frac{m}{D}$ = 0.653



Current-meters Oct. 29th contd.
Plate XXXIII.
Vertical velocity curves.
Wind S.W. blowing down stream, Force 1 to 1½
Horizontal scale of velocity: side of square = 0.1 ft.
Time 6h 03m 04m
04m 05m
05m 06m
06m 07m
07m 08m
08m 09m
09m 10m
10m 11m
11m 12m
12m 13m Surface
Depths in feet
Bottom
(See Table 86)
13m 14m
14m 15m
15m 16m
16m 17m
17m 18m
18m 19m
19m 20m
20m 21m
21m 22m
22m 23m Surface
Depths in feet
Bottom

Plate XXXIV.

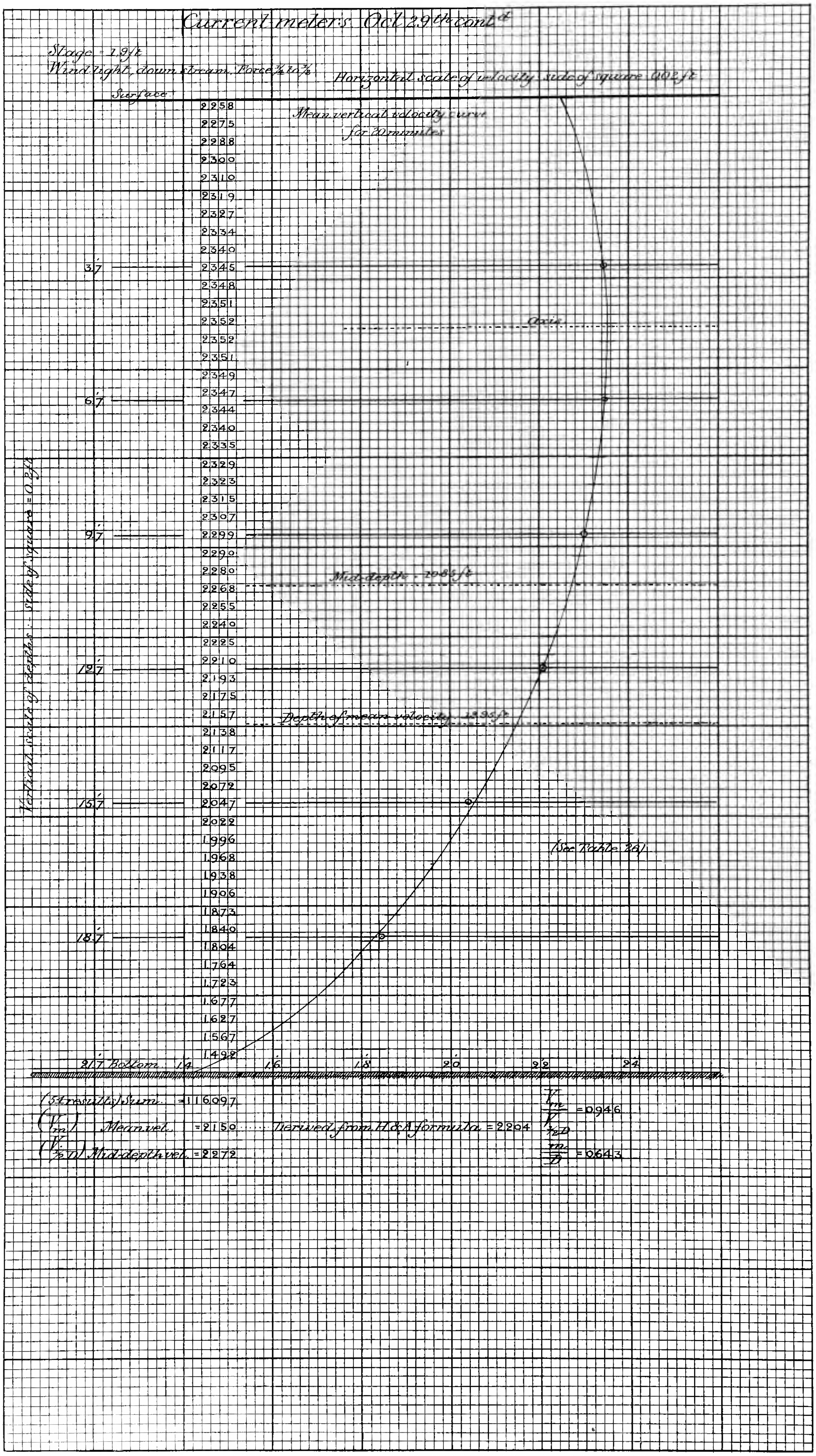

Current meters. Oct 29th cont^d
Stage = 1.9 ft
Wind right, down stream. Force ⅛ to ⅜
Horizontal scale of velocity : side of square 0.02 ft.
Vertical scale of depths : - side of square = 0.2 ft
Surface
Mean vertical velocity curve for 20 minutes
2258
2275
2288
2300
2310
2319
2327
2334
2340
3.7'
2345
2348
2351
2352
Axis
2352
2351
2349
6.7'
2347
2344
2340
2335
2329
2323
2315
2307
9.7'
2299
2290
2280
Mid-depth = 10.85 ft
2268
2255
2240
2225
12.7'
2210
2193
2175
2157
Depth of mean velocity = 13.95 ft
2138
2117
2095
2072
15.7'
2047
2022
1996
1968
1938
1906
(See Table 26)
1873
1840
18.7'
1804
1764
1723
1677
1627
1567
1492
21.7' Bottom
1.4
1.6
1.8
2.0
2.2
2.4
(54 results) Sum = 116097
(V_m) Mean vel. = 2150 ... Derived from H. & A. formula = 2204
(V_½D) Mid-depth vel. = 2272
V_m / V_½D = 0.946
d_m / D = 0.643

Plate XXXV

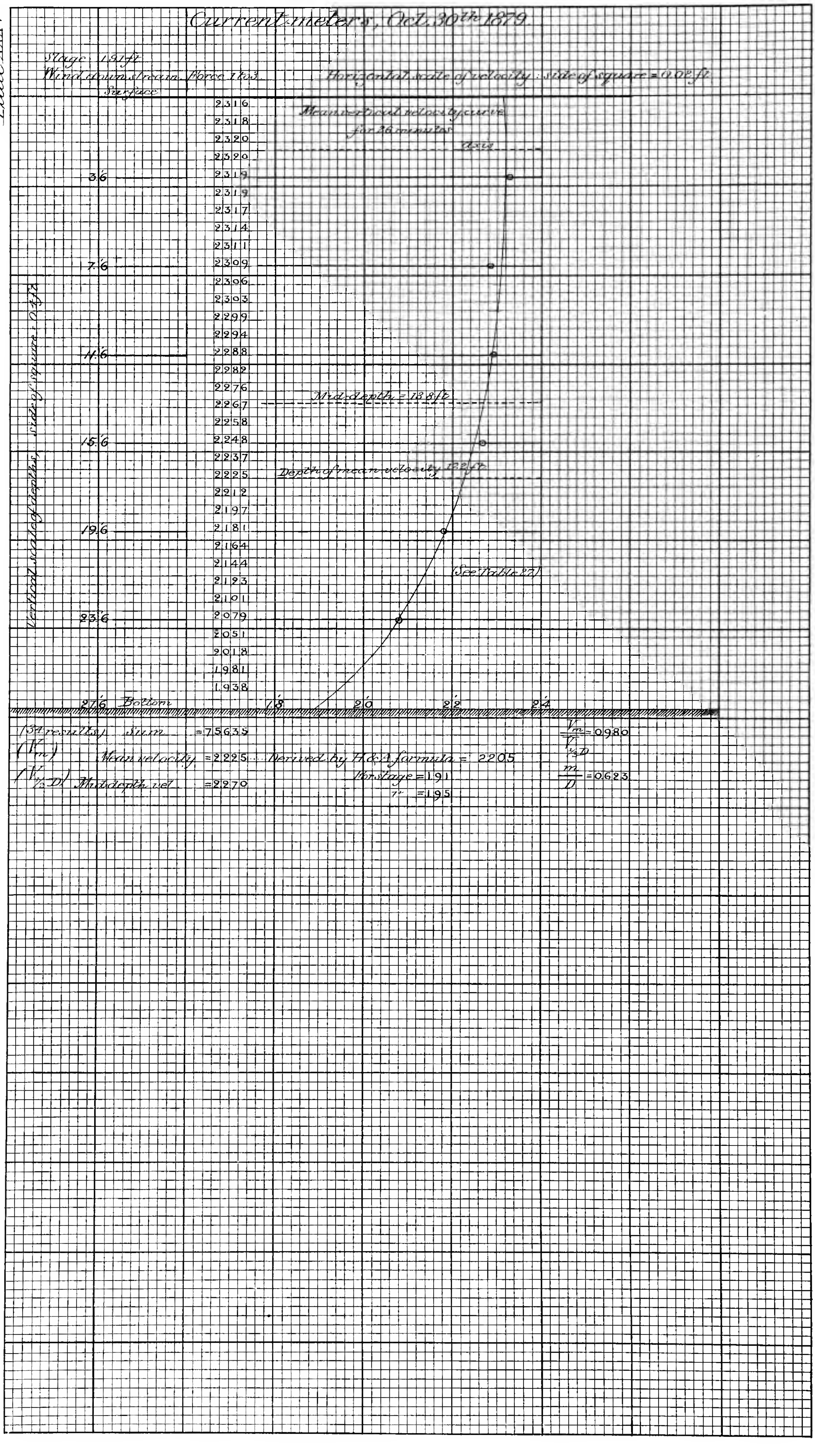
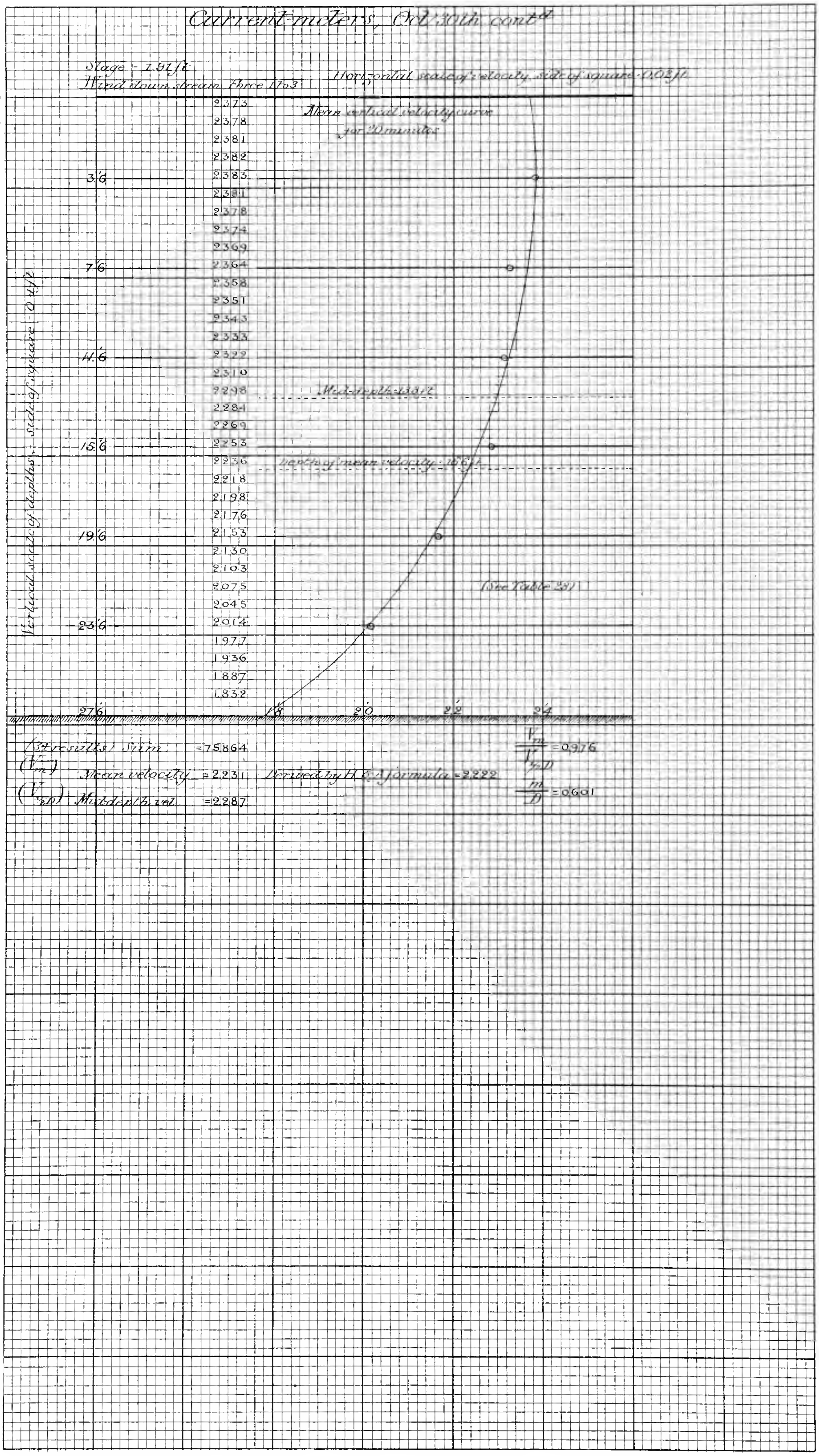
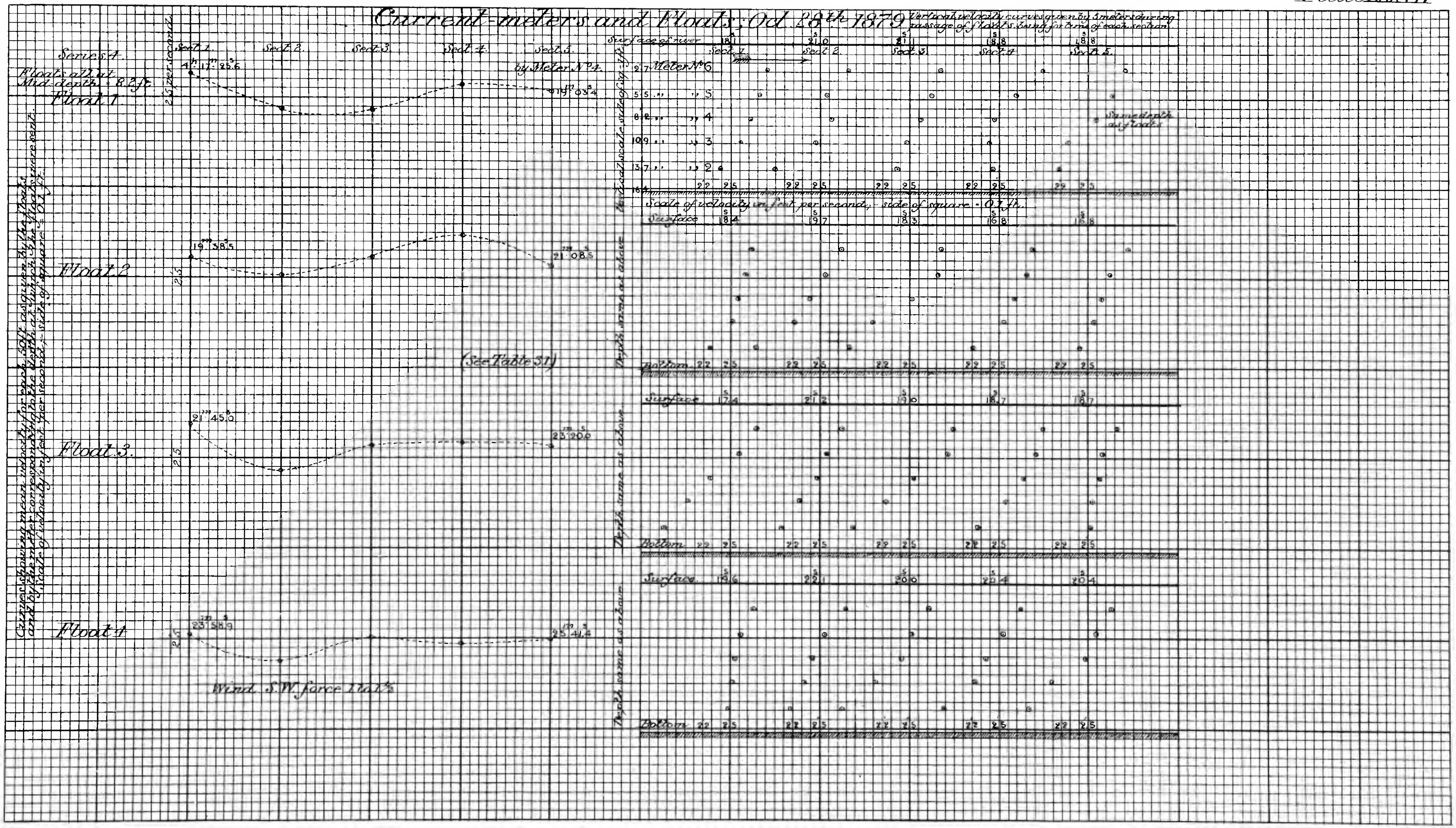

Current-meters, Oct. 30th 1879.
Stage: 19.1 ft.
Wind down stream. Force 1 to 3.
Surface
Horizontal scale of velocity: side of square = 0.02 ft.
Vertical scale of depths, side of square: 0.4 ft.
Mean vertical velocity curve for 36 minutes
Axis
Mid-depth = 13.8 ft.
Depth of mean velocity 17.2 ft.
(See Table 27)
3.6
7.6
11.6
15.6
19.6
23.6
27.6 Bottom
1.8
2.0
2.2
2.4
2.316
2.318
2.320
2.320
2.319
2.319
2.317
2.314
2.311
2.309
2.306
2.303
2.299
2.294
2.288
2.282
2.276
2.267
2.258
2.248
2.237
2.225
2.212
2.197
2.181
2.164
2.144
2.123
2.101
2.079
2.051
2.018
1.981
1.938
(34 results) Sum = 75.635
(V_m) Mean velocity = 2.225 … Derived by H. & A. formula = 2.205
($V_{½D}$) Mid-depth vel. = 2.270
For stage = 19.1
r = 19.5
$\frac{V_m}{V_{½D}}$ = 0.980
$\frac{m}{D}$ = 0.623

Plate XXXVI



Current-meters, Oct. 30th contd
Stage = 1.91 ft
Wind down stream. Force 1 to 3
Horizontal scale of velocity, side of square = 0.02 ft
Vertical scale of depths, side of square = 0.4 ft
Mean vertical velocity curve for 20 minutes
3.6
7.6
11.6
15.6
19.6
23.6
27.6
2.373
2.378
2.381
2.382
2.383
2.381
2.378
2.374
2.369
2.364
2.358
2.351
2.343
2.333
2.322
2.310
2.298
2.284
2.269
2.253
2.236
2.218
2.198
2.176
2.153
2.130
2.103
2.075
2.045
2.014
1.977
1.936
1.887
1.832
1.8
2.0
2.2
2.4
(See Table 23)
(34 results) Sum = 75.864
(Vm) Mean velocity = 2.231
(V½D) Mid-depth vel. = 2.287
Vm / V½D = 0.976
m / D = 0.601


Current-meters and Floats: Oct. 28th 1879
Vertical velocity curves given by 5 meters during passage of floats. Same for time of each section.
Series A.
Floats all at Mid-depth = 8.2 ft.
Float 1
Float 2
Float 3.
Float 4
Sect. 1.
Sect. 2.
Sect. 3.
Sect. 4.
Sect. 5.
by Meter No. 4.
Meter No. 6
Surface of river
Scale of velocity in feet per second; scale of square = 0.1 ft.
Surface
Bottom
Same depth as floats
(See Table 31)
Wind. S.W. force 1 to 1½
Depth same as above
Vertical scale, side of sq. = 1 ft.
Curves showing mean velocity for each 500 ft. as given by the floats and by the meter corresponding to the depth at which the floats were set.
Scale of velocity in feet per second; side of square = 0.1 ft.

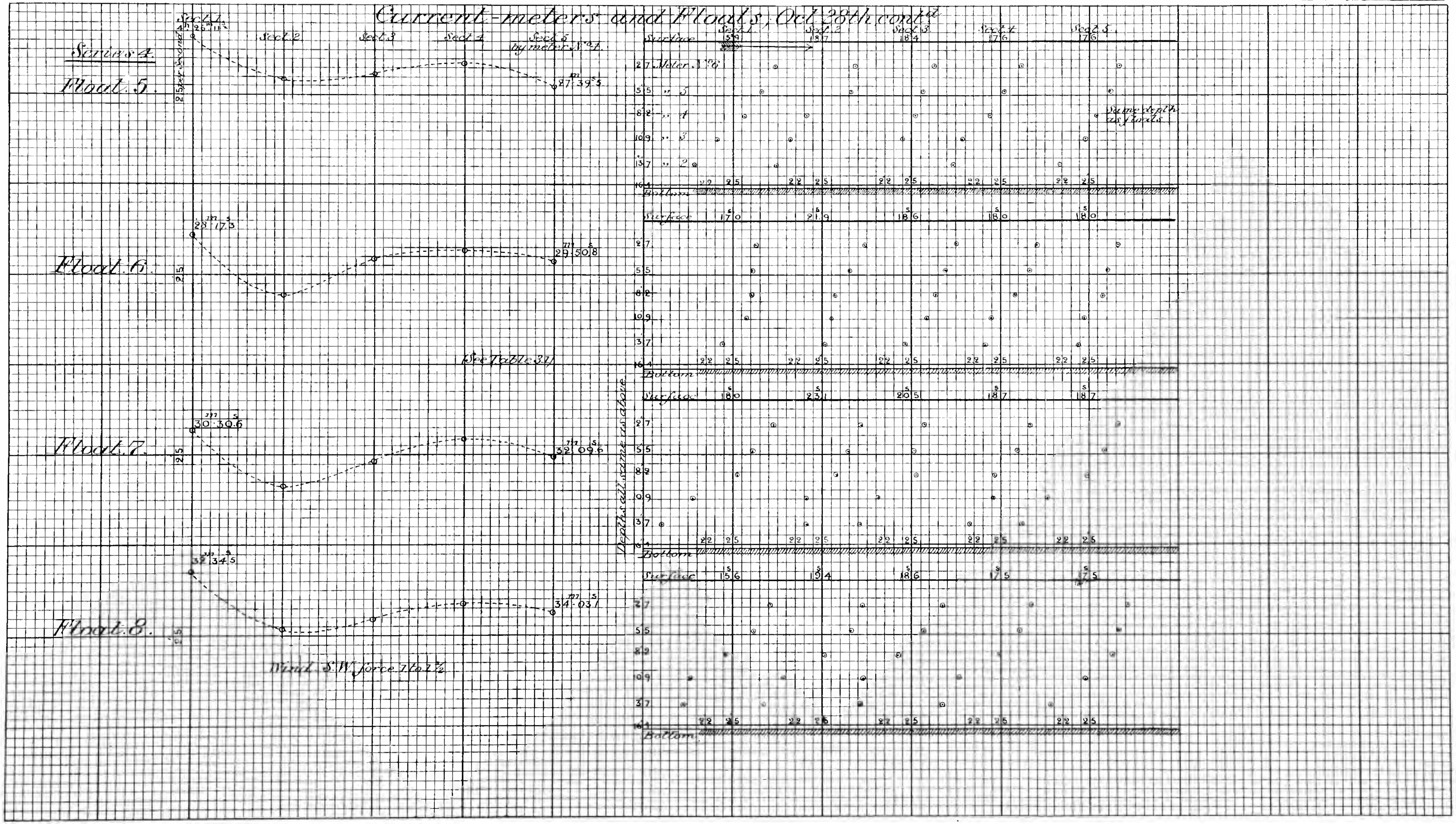
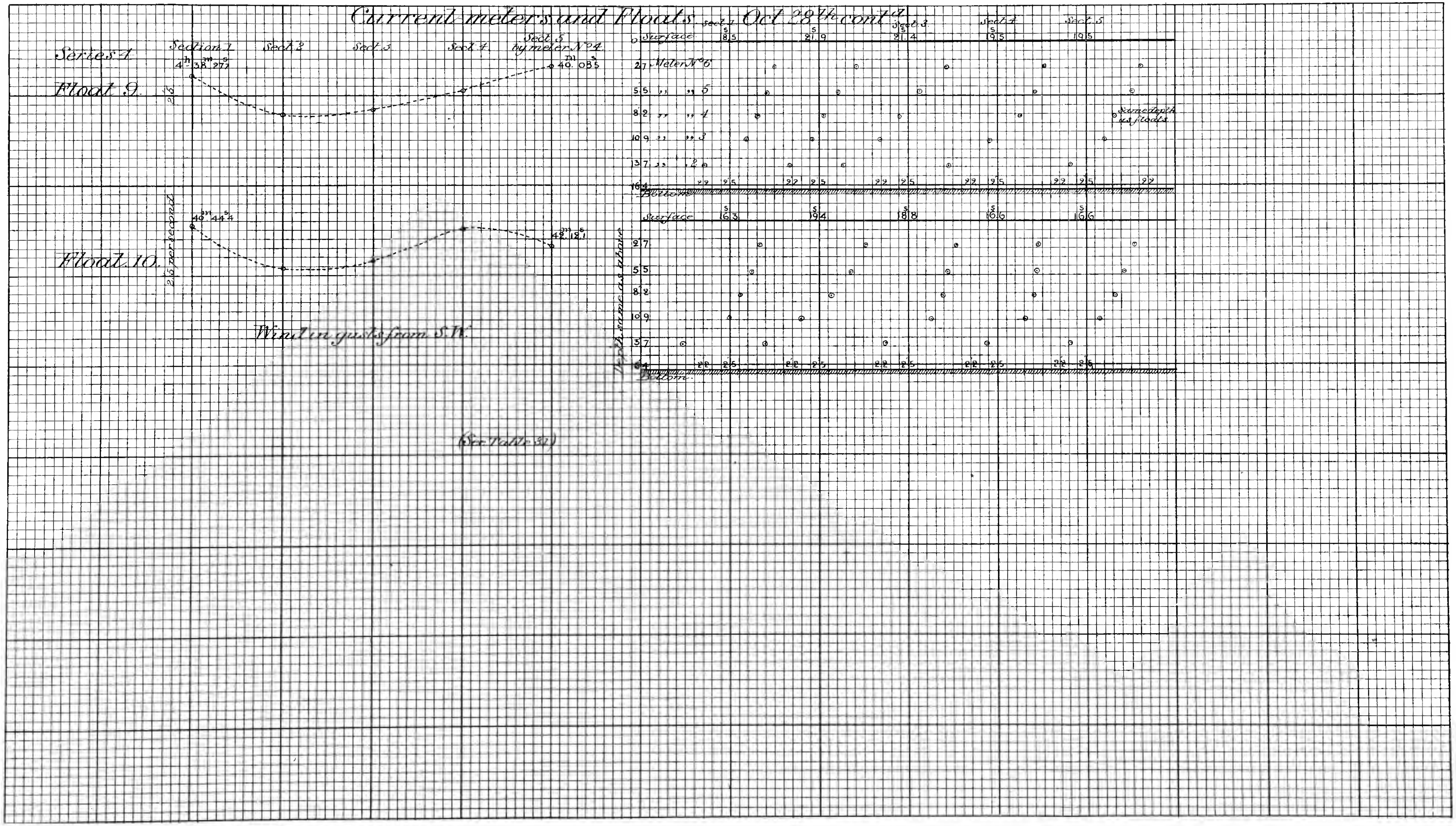

Current-meters and Floats, Oct 28th contd
Series 4
Float 5.
Float 6.
Float 7.
Float 8.
Sect 1
Sect 2
Sect 3
Sect 4
Sect 5
by meter No. 4.
Surface
Bottom
Same depth as floats
(See Table 31)
Depths all same as above
Wind S.W. force 1 to 1½

Plate XXXIX



Current meters and Floats. Oct 28th cont'd
Series 1
Float 9.
Section 1
Sect 2
Sect 3
Sect 4
Sect 5 by meter No 4
4h 38m 27.7s
40m 08.5s
Float 10.
40m 44.4s
42m 12.1s
2.5 per second
Wind in gusts from S.W.
(See Table 31)
Surface
Bottom
Meter No 6
Same depth as floats
Depth same as above

Plates XL and XLI
removed to my Turbulence
file (Macroturbulence)