APPENDIX No. 22.

REPORT OF A CONFERENCE ON GRAVITY DETERMINATIONS, HELD AT WASHINGTON, D. C., IN MAY, 1882.

In pursuance of a correspondence between Major (now Lieut. Col.) J. Herschel, R. E., and the Superintendent of the United States Coast and Geodetic Survey, relative to the most advantageous mode of prosecuting pendulum observations and the scientific value of the same, the following-named gentlemen met at the Coast Survey Office, May 13, 1882, for an informal conference: The Superintendent of the Coast and Geodetic Survey; Major Herschel, R. E.; Prof. C. S. Peirce, Prof. S. Newcomb (on the part of astronomy), and Messrs. George Davidson and C. A. Schott (on the part of geodesy). Maj. J. W. Powell, Director of the United States Geological Survey (on the part of geology), was unable to attend.

The proceedings of the conference were as follows:

TWO LETTERS.

[Read to the conference to explain the immediate cause of the meeting.]

No. 1.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
Washington, May 4, 1882.

Maj. J. HERSCHEL, R. E., *Brevoort House, New York:*

MY DEAR SIR: In pursuance of my letter of yesterday's date, I will now submit to you the proposition that, as Superintendent, &c., I invite at once, or at your earliest convenience, a conference on gravity observations, the participants in which would be, beside yourself and Peirce, Newcomb, on the part of astronomy; King and Powell, on the part of geology; and Davidson and Schott, on the part of geodesy. During such conference the greatest range of discussion would of course be in place, but its outcome, I conceive, must necessarily be formulated in a few propositions, some of which would be mainly intended to recite the scientific objects and usefulness of such work, and commend it to public patronage, others, to define the degree of accuracy to be attained in the observations, in order to entitle them to be ranked as contributions to science. As neither you nor ourselves are charged with any special powers in the premises, it appears to me that no other useful results can be reached by a conference than some such public declarations, the value of which rests upon the standing of the party making them. If this proposition meets your views, I shall be happy to make such arrangements for the earliest day you may find convenient. I regret that it will be necessary to tax you with coming to Washington, as all other parties are here, and being officially engaged it would be out of our power to meet you elsewhere.

It will be well if you will formulate in advance such expressions of opinion as appear to you desirable in the premises, in order that after comparing notes we may be able to submit propositions that will readily meet the assent of the conference.

Yours, very truly,

J. E. HILGARD,
Superintendent.

No. 2.

NEW YORK, *May* 5, 1882.

Prof. J. E. HILGARD:

MY DEAR SIR: I am very glad to learn that you are well inclined towards the idea of a conference, and that now, in fact, it rests with me to indicate when I can be in Washington for the purpose.

As it is not a matter which presses until you have issued invitations, when of course it should not be delayed, and as it will be well to give a few days' notice in any case, I will not consider myself in any way required to hasten my departure from New York, but only to give you as early an indication as I can when I can undertake to be in Washington. At this moment I am not in a position to say precisely, but it will almost certainly be within a week from this date. I shall most likely be able to leave this city about Wednesday next.

With regard to the lines of discussion, it must depend to some extent on the degree of publicity which the proceedings would have. It is not to be denied or concealed that there is coming into existence a certain rivalry between what may be called the German and the English schools. I am anxious that the former shall not wrongly claim American adhesion on the one hand, and on the other that American opinion shall not be wrongfully interpreted as favoring the German system. With reference to this last, for instance, I have just received the following from M. C. Wolf, in the course of a reply to my Washington letter: "Je vous félicite vivement de vos travaux sur le pendule, et surtout d'avoir pris une autre voie que celle dans laquelle les Americains se sont lancés, á la suite des Allemands et des Suisses, J'ai eu ici de vives discussions avec M. Ch. Peirce au sujet de ses expériences avec le pendule reversible de Repsold, instrument qui me parait construit dans de déplorables conditions de stabilité."

Now there is just enough truth in this to make one regret the misapprehension as to the American position. But so long as your survey uses a reversible pendulum, without some very distinct statements as to the principles, such misapprehensions will continue, and the Germans will deny that the Americans stand by the differential method.

I hold it to be a very lamentable thing that men of zeal, eager to advance science, should continue to be misled by the old school of physics into launching upon the difficult and precarious enterprise of absolute determinations of gravity, generally in ignorance of the real difficulties of the research, and *always* indifferent to the utility of such determination. The German school is responsible for this.

This brings before us prominently the question of utility, a question which has always been shirked or disposed of by common-places, devoid of any real force. I know this through having urged (for nearly twenty years), very much in vain, the views which I hold at this day, and which I now see gaining ground so slowly. I sum it up in the broad statement that *we do actually* know the mean figure of the earth *as well as we can know it* so long as the irregularities which deform it remain unknown. It is not the force of gravity which we seek, but the irregularities of the surface.

Now this is one of the points on which, at a conference, I should wish to find unanimity, if it is true, or if not, then a better and more indisputable dogma to take its place.

With this as a foundation, the question becomes one of ways and means to study the irregularities with advantage. Here there is great room for difference of opinion. What can be done depends on the cost, in its most general sense, of doing it. Absolute measurements are indefinitely costly, and may be put aside. Differential measurements, also, are frightfully costly, if conducted as I have been conducting these; but I have had in view to prove incontestably that results of practical value can be obtained with a tenth, perhaps a twentieth, the labor that I devoted to them. All depends on the method.

Another point involved in the question of utility is, as you say, as to the degree of precision demanded. All stations of observation should be recognized from the first as belonging to one of two categories—either they are *points d'appui* or they are not. In the latter case the precision demanded is governed by the degree of irregularity which experience teaches as governing the quantity measured, the distances which separate the points being taken into account. A high degree of precision is plainly needless (for points of the second order) if they are widely scattered, whereas if a number of such points are crowded in a small area, their precision ought to be higher because of the information to be gained by intercomparison. Points of the second order widely scattered have no present value other than as indicating tentatively the degree of disturbance. From this point of view there would seem to be an advantage in placing the stations always *in pairs* so as to indicate the variability as well as the variation.

I must now go further. Scientific observation has two distinct aspects. Viewed in one way, it is seen as a means of livelihood, as an intellectual enjoyment, as an employment, as a pursuit worthy of recognition and encouragement, for every reason except that of its ultimate utility. Viewed in the other way, it is a source of expenditure and a drain upon the available power of the time and country, which can only be justified if it attains useful ends in a reasonably expeditious way. For myself, I doubt if I could conscientiously recommend the expenditure of public money on pendulum observations on the ground of their utility; although I could and would recommend it for pendulum *experiments*, having for their object to increase the facility of observation; for I imagine, as things now stand, the prospect of obtaining results in sufficient number and frequency to enable us to study the irregularities successfully is very remote. You will doubtless recognize in this the ground of my inability to offer my services, backed by hopes of support from the British Government, for the prosecution of differential work on this continent. But I have no business to press such considerations on other people, nor to bring them forward at a conference, except incidentally in discussing the proper distribution of stations and the degree of precision demanded. The same arguments and motives had a successful campaign in dictating my latitude work in India; and there is room for their application in the present case. They point out the urgent need for economy in every detail of installation and observation—in the choice of stations and the buildings to be occupied, in the distribution of time to be taken up by the observations, and by the calculations respectively, so as to get, in short, as many results of a sufficient degree of accuracy, and no more, as possible within the year. All this, and much more, seems to me to be involved in the broad question whether or not pendulum research can be satisfactorily carried on with a view to studying the earth's irregularities.

Another phase of this question should deal with the distinction between a study of the large and of the small irregularities. There is a vast difference between such work as that of Malaspina, of Freycinet, of Sabine, of Foster, of Lütke, and of all the other explorers; and that of Kater in England, and of Basevi in India. The work before you here has or may have the characters of both; for the vastness of your disposable area demands a large plan, while the numerous opportunities for prosecuting minuter internal exploration require more special consideration. The degree of precision to be aimed at must be governed partly by what we know of possible variation and partly by what the instruments are capable of. Here, as in other branches of research, we should bear in mind that there is almost always a point in the scale of precision where it becomes questionable whether it would not be wiser to change the whole system if higher precision is wanted. Below that point there is no difficulty. Above it the price to be paid becomes onerous.

You will readily perceive that I fully recognize, as one of the chief subjects upon which discussion should turn, this of requisite precision. At the same time I doubt if it can be discussed to much advantage by those who are not intimate with the figures actually to hand. I would therefore avoid the *vexata quæstio* of probable errors and keep to principles. It is by the latter alone that plans of operation can be governed reasonably. "Frequency to be preferred to accuracy," for example, is a principle easy to limit or extend as may be desired, and far more widely intelligible to the uninitiated than any specification in figures suited to certain categories of cases. Above all we should aim at being intelligible. Without that there will be no outside interest and no support.

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Yours truly,

J. HERSCHEL.

SIX REASONS FOR THE PROSECUTION OF PENDULUM EXPERIMENTS.

By C. S. PEIRCE.

1. The first scientific object of a geodetical survey is unquestionably the determination of the earth's figure. Now, it appears probable that pendulum experiments afford the best method of determining the amount of oblateness of the spheroid of the earth; for the calculated probable error in the determination of the quantity in question from the pendulum work already executed does not exceed that of the best determination from triangulation and latitude observations, and the former determination will shortly be considerably improved. Besides, the measurements of astronomical arcs upon the surface of the earth cover only limited districts, and the oblateness deduced from them is necessarily largely affected, so that we cannot really hold it probable that the error of this method is so small as it is calculated by least squares to be. On the other hand, the pendulum determinations are subject to no great errors of a kind which least squares cannot ascertain; they are widely scattered over the surface of the earth; they are very numerous; they are combined to obtain the ellipticity by a simple arithmetical process; and, all things considered, the calculated probable error of the oblateness deduced from them is worthy of unusual confidence. In this connection it is very significant, as pointed out by Colonel Clarke (*Geodesy*, p. vi), that while the value derived from pendulum work has for a long time remained nearly constant, that derived from measurements of arcs has altered as more data have been accumulated, and the change has continually been in the direction of accord with the other method. It is needless to say that the comparison of the expense of the two methods of obtaining this important quantity is immensely in favor of pendulum work.

2. Recent investigations also lead us to attach increased importance to experiments with the pendulum in their connection with metrology. The plan of preserving and transmitting to posterity an exact knowledge of the length of the yard after the metallic bar itself should have undergone such changes as the vicissitudes of time bring to all material objects, was at one time adopted by the British Government. It was afterwards abandoned because pendulum operations had fallen into desuetude, and because doubts had been thrown upon the accuracy of Kater's original measure of the length of the second's pendulum. Yet I do not hesitate to say that this plan should now be revived, for the following reasons:

First, because measurements of the length of the second's pendulum, although formerly subject to grave uncertainties, are now secure against all but very small errors. Indeed, we now know that the determinations by Kater and his contemporaries, after receiving certain necessary corrections, are by no means so inaccurate as they were formerly suspected to be. Secondly, metallic bars have now been proved, by the investigations of Professor Hilgard and others, to undergo unexpected spontaneous alterations of their length, so that some check upon these must be resorted to. To this end the late Henri Ste. Claire Deville and Mascart constructed for the International Geodetical Association a metre ruled upon a sort of bottle of platin-iridium, with the idea that the cubic contents of this bottle should be determined from time to time, so as to ascertain whether its dimensions had undergone any change. I am myself charged with, and have nearly completed, a very exact comparison of the length of a metre bar with that of a wave of light, for the same purpose. Neither of these two methods is infallible, however, for the platin-iridium bottle may change its three dimensions unequally, and the solar system may move into a region of space in which the luminiferous ether may have a slightly different density (or elasticity), so that the wave length of the ray of light used would be different. These two methods should therefore be supplemented by the comparatively simple and easy one of accurately comparing the length of the second's pendulum with the metre or yard bar. Thirdly, I do not think it can be gainsaid by any one who examines the facts that the measurements of the length of the second's pendulum by Borda and by Biot in Paris and by Bessel in Berlin do, as a matter of fact, afford us a better and more secure knowledge of the length of their standard bars than we can attain in any other way. So also I have more confidence in the value of the ratio of the yard to the metre obtained by the comparison of the measurements of the length of the second's pendulum at the Kew observatory by Heaviside in terms of the yard and by myself in terms of the metre than I have in all the elaborate and laborious comparisons of bars which have been directed to the same end. I will even go so far as to say that a physicist in any remote station could ascertain the length of the metre accurately to a one hundred thousandth part more safely and easily by experiments with an invariable reversible pendulum than by the transportation of an ordinary metallic bar.

A new application of the pendulum to metrology is now being put into practice by me. Namely, I am to oscillate simultaneously a yard reversible pendulum and a metre reversible pendulum. I shall thus ascertain with great precision the ratio of their lengths without any of those multiform comparisons which would be necessary if this were done by the usual method. These two pendulums will be swung, the yard one in the office of the Survey, at a temperature above 60° F., which is the standard temperature of the yard, the other nearly at 0° C., which is the standard temperature of the metre; and thus we shall have two bars compared at widely different temperatures, which, according to ordinary processes, is a matter of great difficulty. The knife-edges of the pendulums will be interchanged and the experiments repeated. Finally, the yard pendulum will be compared with a yard bar and the metre pendulum with a metre bar, and last of all the yard pendulum with its yard bar will be sent to England, the metre pendulum with its metre bar to France, for comparison with the primary standards; and thus it is believed the ratio of yard to metre will be ascertained with the highest present attainable exactitude.

3. Geologists affirm that from the values of gravity at different points useful inferences can be drawn in regard to the geological constitution of the underlying strata. For instance, it has been found that when the gravity upon high lands and mountains is corrected for difference of centrifugal force and distance from the earth's centre, it is very little greater than at the sea-level. Consequently it cannot be that there is an amount of extra matter under these elevated stations equal to the amount of rock which projects above the sea-level; and the inference is that the elevations have been mainly produced by vertical and not by horizontal displacements of material. On the other hand, Mendenhall has found that gravity on Fujisan, the well-known volcanic cone of Japan, which is about 12,000 feet high, and which is said to have been upheaved in a single night, about 300 B. C., is as much greater than that in Tokio as if it had been wholly produced by horizontal transfer. This conclusion, if correct, must plainly have a decisive bearing upon certain theories of volcanic action. Again, it has long been known that gravity is in excess upon islands, and I have shown that this excess is fully equal to the attraction of the sea-water. This shows that the interior of the earth is not so liquid and incompressible that the weight of the sea has pressed away to the sides the underlying matter. But in certain seas gravity is even more in excess than can be due to the attraction of the ocean, as if they had been the receptacle of additional matter washed down from the land. It is evident that only the paucity of existing data prevents inferences like these being carried much further. On the two sides of the great fault in the Rocky Mountains gravity must be very different, and if we knew how great this difference was we should learn something more about the geology of this region; and many such examples might be cited.

4. Gravity is extensively employed as a unit in the measurement of forces. Thus, the pressure of the atmosphere is, in the barometer, balanced against the weight of a measured column of mercury; the mechanical equivalent of heat is measured in foot pounds, etc. All such measurements refer to a standard which is different in different localities, and it becomes more and more important to determine the amounts of these differences as the exactitude of measurement is improved.

5. It may be hoped that as our knowledge of the constitution of the earth's crust becomes, by the aid of the pendulum investigations, more perfected, we shall be able to establish methods by which we can securely infer from the vertical attractions of mountains, etc., what their horizontal attractions and the resulting deflections of the plumb-line must be.

6. Although in laying out the plan of a geodetical survey the relative utility of the knowledge of different quantities ought to be taken into account, and such account must be favorable to pendulum work, yet it is also true that nothing appertaining to such a survey ought to be neglected, and that too great stress ought not to be put upon the demands of the practically useful. The knowledge of the force of gravity is not a mere matter of utility alone, it is also one of the fundamental kinds of quantity which it is the business of a geodetical survey to measure. Astronomical latitudes and longitudes are determinations of the direction of gravity; pendulum experi-

ments determine its amount. The force of gravity is related in the same way to the latitude and longitude as the intensity of magnetic force is related to magnetical declination and inclination; and as a magnetical survey would be held to be imperfect in which measurements of intensity were omitted, to the same extent must a geodetical survey be held to be imperfect in which the determinations of gravity had been omitted; and such would be the universal judgment of the scientific world.

NOTES ON DETERMINATIONS OF GRAVITY.

By Assistant C. A. SCHOTT.

The conference was invited by the Superintendent of the Coast and Geodetic Survey for the purpose of eliciting an interchange of views respecting the utility and best means of prosecuting pendulum research in the interest of science in general, and with especial regard to the future work of the Coast and Geodetic Survey.

Major Herschel, R. E., having expressed his willingness to favor the meeting with his presence and give it the benefit of his great experience in pendulum work, the time of meeting must be considered extremely favorable.

The following rough notes are offered with a view of inviting discussion on some points considered of importance and interest.

Respecting the question of the utility to geodesy and geology of pendulum work as bearing on the figure and density of the earth, it is sufficiently answered by the resumption of this work in recent years in the leading government surveys conducted in Europe, Asia, and America; but in carrying on these operations different opinions continue to be held as to the best and most economical means both with regard to form of instrument and method of observation.

It may be added that the results already reached are in themselves sufficient to stimulate the further prosecution of the work, since they render it almost certain that still more valuable deductions may be reached.

The pendulum work executed for some years past under the direction of the late Superintendent of the Coast and Geodetic Survey had for its immediate object the study, theoretical and practical, of the best methods available, and to gather the results at various important pendulum stations in Europe, to bring them into strict comparability, and to form a connected system which may be used for combination with similar operations commenced in the United States.

Mr. C. S. Peirce, Assistant, Coast and Geodetic Survey, having brought this work to a close in Europe,* its future prosecution at home now claims renewed attention, both with respect to the economy and efficiency of the plans which it may be desirable to adopt.

The value of the pendulum results depending largely upon their direct comparability and the geographical extent, it would in the first place appear most desirable, in order to form a second and independent connection of the pendulum work executed on the other side of the Atlantic, to swing the American pendulums at the two stations, Washington and Hoboken, just occupied by Major Herschel with the old pendulums belonging to the Royal Society, and to add thereto at least one more American station in order to secure three stations of satisfactory accord between these instruments.

It is, perhaps, the general opinion that differential measures are at present more desirable than absolute measures, since undoubtedly greater accuracy can be reached in the former and a greater number may be secured with the same expenditure; indeed, the determination of the length of a second's pendulum is, in geodesy, of less importance than a knowledge of ratios of times of oscillation of an invariable pendulum swung at stations on a line selected for investigation.

The determination of the length of a second's pendulum is quite a special operation, to be undertaken only at a base station.

While the mean figure of the earth may be considered as tolerably well known from the fact of the close approach of the value of the compression as deducted from purely geodetic operations and

* Mr. Peirce remarked that that work was not yet quite completed.

from pendulum work, yet this may be taken only as an encouragement for the joint prosecution of both operations.*

On the other hand, our knowledge of the magnitude of the mean figure of the earth is, in the opinion of some, not quite as satisfactory, and in support of this it may be stated that the recent abandonment, in the Coast and Geodetic Survey, of the Besselian spheroid of revolution for that of Clarke, involving in our latitude an increase of the radii vectores between one-third and one-half of a statute mile, was no inconsiderable change; and though we cannot look forward to any future change of such a magnitude, the difference was sufficiently large to make itself felt in our oblique arc lying along the Atlantic coast between Maine and Georgia.

The combination of the Peruvian arc, the only one in America as yet worked in with the meridional arcs measured in the eastern hemisphere, with the two arcs measured by the Coast and Geodetic Survey, viz, the Nantucket arc and the Pamplico-Chesapeake arc, showed a satisfactory accord (that is, within limits that may be explained by local deflections). This seems to prove that the curvature of North America does not sensibly differ from the curvature in the same latitudes of the eastern hemisphere; yet the conclusion is weakened by the fact that the Peruvian arc is extremely short, and, what is worse, is supported by but two astronomical latitudes, and that in a region where local deflection probably exists of an excessive magnitude. It is true the computed corrections to the two latitudes are small, and this might lead to too great a confidence in the assigned value of the magnitude of the earth's axis. A remeasure and extension of this arc to be supplied with a considerable number of astronomical latitudes would seem to be a great desideratum, especially when we consider the important position of the arc, giving it, so to say, undue leverage in comparison with the position of other arcs. It is not at all unlikely that the results of its remeasure and extension may have an important effect on our knowledge of the probable uncertainty in the assigned value for the resulting mean figure of the earth.†

This mean figure might be defined as that of a geometrical solid whose surface most nearly approaches the equipotential surface of the mean sea level, intersecting it so that the aggregate of the volumes above and below it may be equal and a minimum. It would be the object of geodesy to trace out on this geometrical surface the boundaries of these areas, and to determine their elevations above or depression below it; in fact, work out the actual irregularities with reference to this ideal mean figure.

For pendulum research the region of the Mississippi Valley would seem to be very favorable, both in regard to its geological structure, as presenting broad features, and with respect to gradual changes in elevation of surface between New Orleans and our northern boundary, near the forty-ninth parallel, the land rising but little above 1,000 feet. Here a study of the law of change of gravity with the latitude seems inviting.

Supplementary to the above line, the thirty-ninth parallel might be chosen for the study of the law of change of gravity with altitude, starting from the sea level and passing over the inconsiderable elevations of about 2,500 feet on the Appalachian range and the descent to the Mississippi Valley, we have the gradual rise of the great plains up to 8,000 feet, and next the lower Rocky Mountain plateau, with a final return to the sea level. While on the first named line about 6 or 8 stations might suffice, on the second from 12 to 15 ought to be contemplated.

Respecting the kind of pendulum most suitable for differential measures of gravity, there may be little difference in practice between the use of two invariable pendulums, the one to check the

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*Major HERSCHEL. I do not regard the agreement of geodetic and gravity figures an argument for the latter. I can never regard the geodetic figure, derived from the comparisons of the curvatures of certain *land* portions only, as a true indication of a figure which is two-thirds sea. There is every reason to regard the land curvatures as too great.

†Major HERSCHEL. I should hardly advocate a remeasurement of the Peruvian arc as a step towards a better determination of the earth's figure. It has the fatal disadvantage of position in a valley between vast mountainous tracts.

Mr. PEIRCE. Major Herschel's objection to the important scheme of remeasuring the Peruvian arc would apply, *à fortiori*, against allowing that arc to enter into the determination of the figure. In my humble judgment an American figure of the earth, wholly from geodetic measurements on these continents, is so greatly wanted that it is the duty of this Survey to undertake it. Although the Peruvian arc is at present bad, I should think that if sufficiently extended and provided with an adequate number of latitude determinations, the objections to it would nearly disappear.

other, and an unchangeable pendulum of a plain rod (of lenticular cross-section) having two fixed knife-edges symmetrically disposed; the means for correcting for difference of temperature and for difference of pressure from respective mean quantities to be determined at a base station. Observations to be made in 4 positions (upper knife-edge, lower knife-edge, face front, and face back). The accord of the 4 results will furnish a criterion for the unaltered condition of the pendulum.

A reversible pendulum of outer symmetrical form may also be made to answer the purpose, provided it be swung only with heavy end down (face front and back) and no change whatever is made in the supporting knife-edge or in any other part of the instrument. Two such pendulums would seem desirable in order to detect any change due to accident. With such a pendulum the correction for difference of pressure can be applied with greater certainty than in one of the other forms.

Respecting the stand of the Repsold apparatus, experience has shown it to be unfit for the work, and stiffer support should be provided.

If pendulums could be swung through 24 hours the result could be made independent of variations in the clock rate due to the daily variation of temperature and pressure. The same standard time stars should be observed each night. For shorter durations of swing, say for 6 hours only, this advantage might in a measure be secured either by making four fresh starts and thus continue the work during twenty-four hours, or if that be too laborious, to observe on the first day, say from 6 to 12 a. m. and p. m., and on the following day from 0 to 6 p. m. and a. m., and unite the results into one, or in general, for any station by a *symmetrical distribution* of the swings over the twenty-four hours.

Time furnished telegraphically by an observatory whose clock is protected from changes of temperature and pressure will be preferable to any local determination at a field station.

Should the duration of swing be too limited for this scheme, night work may be recommended, with a set of transit observations just before and another immediately after the close of a swing, the same two sets of stars to be used each night and for several stations as long as practicable.

Three days successful work at any one station may suffice, and about two weeks might be estimated for the time required for occupation during the best season. The observatory to be prepared by an advance party.

The method of coincidences furnishes all needful accuracy, but if, in the absence of a clock or otherwise, a chronometer be used (as more portable and less liable to injury), coincidences of the chronometer beat with the transit of the pendulum over a vertical line might be tried.

The question whether or not it is advisable to swing in a vacuum chamber (say at a density just below any that might naturally be expected at a place which it is proposed to visit) would seem to depend largely upon the time a pendulum can be made to swing advantageously. If its sectional dimensions are such as to displace much air and require it to do much work against friction, the duration of swing may be so short as to demand the use of an exhausted receiver. What the experience is with the new reversible pendulums of the pattern of the one sent last summer to one of the polar research stations of the Signal Corps the writer is not informed.

The above notes are respectfully submitted.

CHAS. A. SCHOTT.

MAY 13, 1882.

COMMUNICATIONS.

GENERAL REMARKS UPON GRAVITY DETERMINATIONS.

By Major (now Lieut. Col.) JOHN HERSCHEL, R. E.

The following propositions are *from my point of view*, but seem likely to be assented to in the main by other members of the conference.

1. *Figure of the earth.*—By this we imply the actual (or conceivable) continuous water surface as exemplified by the mean sea level; which surface may be everywhere nearly, though nowhere fully, represented by some assumed simple geometrical figure, such as an elliptic spheroid, to be known *ad hoc* as the *mean* figure.

2. *Object of pendulum research.*—If we regard the mean figure as known, then the object of pen-

dulum research is, in the first place, to trace out the degree of separation everywhere subsisting between the actual and the mean figures; or, if it should appear that by a change of the mean figure there would result a less degree of separation, then to ascertain, first, what should be the amount of this alteration, and then to trace out the residual separation. Bearing in mind the large body of past work, which has undoubtedly sufficed to indicate very closely what the mean figure is, it should now be recognized as more particularly the object of pendulum research to enlarge our knowledge of the *irregularities of figure* rather than to aim at improving the *mean* figure; which after all can never be anything more than one *of reference*, by which to describe the actual figure.

3. *Extension of research among the irregularities.*—This is *prima facie* desirable, especially when geodetic surveys are in progress, or are certain to be instituted as civilization advances. But gravimetrical exploration in regions which can never be reached by surveying operations is of scarcely less importance.

4. As regards *distribution of stations* of observation, there seems to be nearly equal advantage in laying them out in a *linear series* at sufficiently close intervals, or superficially scattered over a limited selected area, with a view to tracing out the *sectional* or *solid* forms of the existing *irregularities*.

5. *The absolute force of gravity.*—If this also be admitted as an ultimate object of pendulum research, it must be remembered that it can only be determined for the whole earth when the exact relation of the place of observation to the whole surface is correctly known. It follows that a precise knowledge of the absolute force of gravity for the earth as a whole is not at present attainable. There are, nevertheless, reasons for now determining, with all the precision at present possible, *the length of the second's pendulum* at different places on the earth's surface.

6. *Reasons for prosecuting absolute determinations.*—Regarding the local force of gravity as a constant, the length of a pendulum is a function of its rate of oscillation; or, in other words, its rate is a measure of its length. From this it follows that lengths, otherwise incommensurable, can be compared through their corresponding times of oscillation, because we have means (in the pendulum itself, for instance) of comparing together, with any desired degree of precision, these times. Thus, for example, the metre and the yard can be compared by this means (as I understand) with greater precision than by the complicated system of linear comparisons requisite to measure their difference in terms of each.

7. *Constancy of gravity tested against constancy of length.*—This is another reason for determining with the utmost precision the length of the second's pendulum in terms of this or that standard. For if, in the far distant future, there should appear a concurrence of testimony indicating change, it might be brought home to either of the bars, or even to gravity itself, according to the evidence. The absence of the requisite evidence in the past would be a grave reproach hereafter.

8. *The invariable pendulum.*—The impossibility of ascertaining the exact relation of any station to the whole surface, short of a general knowledge of the latter, calls necessarily for such explorations as are set forth in Article 2. It is generally acknowledged that the differential pendulum—of which the "invariable" may be regarded as the type—is best adapted for such work. The pattern known as Kater's has hitherto been without a rival; but any pattern will answer the purpose in which the principle of invariability—*i. e.*, fixity of knife-edge and absence of all movable parts—is embodied.

9. *The reversible pendulum* is recognized as having many excellent qualities; and is capable of being used *temporarily* as an invariable pendulum. But its proper field is the absolute measurement for which it was designed; for if its knife-edges are interchangeable it is liable at any time to have its invariable character destroyed, either intentionally or accidentally.

10. With regard to the degree of precision to be aimed at, nothing very definite can be laid down, since it depends largely on the circumstances. A gross error in a solitary arctic station, for instance, might be of little consequence, while an error of even a small fraction of a second in the difference between two central points would entail far-reaching consequences. When the object is tentative exploration only, accuracy may well be sacrificed to expedition and frequency. And in general it should be remembered that the local disturbance varies with the change of site. What the rate of this change may be can only be guessed until data are obtained. A group of contiguous determinations of a low order of accuracy would always be more valuable than a single one of the

very highest order. A solitary station can contribute only to the general problem of mean figure and will of necessity be vitiated by the amount of the local disturbance, as to which there is no evidence. If the range of such disturbance *on the whole of that parallel* were known, it would not be unreasonable to take one-fourth part of that as the range of probable error permissible in the determination itself. Every consideration which takes into account the existence of local disturbance points to the preference to be given to frequency of distribution rather than accuracy of result. Moreover, it is difficult, if not impossible, to estimate the probable error in any case whatever. The history of pendulum observation abounds with inexplicable contradictions and anomalies indicative of unknown causes of error; and hardly a single observer has ventured to estimate the probable error of his result. Practically, the question of precision is cut by a variety of circumstantial exigencies; and it would seem best to leave it at the discretion of the observer, or director of the work.

11. *Other modes of research.*—The foregoing indicates so plainly the need of tentative exploration of a low order of accuracy that it is very much to be desired that some simpler means should be found of obtaining at least a rude measure of the local deflection. Various statical modes have been proposed, but none has yet shown a satisfactory test. That a "stathmometer"—a term designed to leave untouched the present use of "gravimeter"—will some day be invented is highly probable. It might be, perhaps, the sooner if the very great need for it were more widely known, and if, at the same time, it were understood that its object would be served even though it should fail to rival the pendulum in accuracy.

J. HERSCHEL.

Mr. PEIRCE. The conception which Major Herschel has presented for the purpose of gravity determinations requires thorough study. Considered from a purely mathematical point of view, it is certain that if we know the distribution of gravity over the whole earth, or even over a large region, we can deduce corrections of the earth's radius vector. Within 20° of the station whose radius vector was to be corrected an accurate knowledge of the residuals of gravity would be necessary, while beyond that point a rougher determination would suffice. But whether this conception of the nature of pendulum work could be usefully adopted at the present time, or until two or three times the existing number of stations have been occupied, is a practical question in regard to which there is something to be said on both sides. The views of Major Herschel, though founded on known propositions of mathematics, are so novel and so far-reaching in their consequences that we cannot commit ourselves to an immediate decision in regard to them. But they offer much food for reflection and study, and I am quite sure that apart from the important service that Major Herschel has done us in connecting the American (and through that the continental European) system of stations directly with the great *réseau* of the English work by means of the Kater invariable pendulums, American geodetical science is under great obligation to him for the suggestions contained in the paper he has presented to the conference.

OPINIONS CONCERNING THE CONDUCT OF GRAVITATION WORK.

By C. S. PEIRCE.

I. There are six reasons for determining gravity, which I have already set forth.

II. In determining the compression of the earth's spheroid from the variation of gravity, it is best, for the present, to reject all experiments not made with Kater's invariable pendulums. But the completion of Major Herschel's history of pendulum determinations is greatly to be desired.

Major Herschel thought the limitation to Kater's invariable pendulum too narrow; and pointed out that it would exclude the work of Freycinet and of Duperrey as well as a great part of that of Foster.

III. The ordinary correction for continental attraction is vastly too great. It should be omitted.

Major Herschel remarked: "Admitting this as a conclusion drawn from the facts, it must not be forgotten that this is nothing but an *à posteriori* dogma. I do not see how it can be lawfully acted upon, unless the assumption that it has a true *à priori* cause is kept continually in view *as* *such.*" Mr. Peirce replies as follows: "In my opinion, the correction for continental attraction is not only refuted by observation but it has no *à priori* support from premises which we have any reason to suppose true. If we could make our pendulum experiments underground at the level surface of which the sea-level is a part, there would be no correction to be made for continental attraction. Since they cannot be made there, the observed gravity had to be reduced to what it would be at that level. The coefficient of this reduction depends entirely on the distances of the successive level surfaces without reference to the situation of the material masses, except so far as this situation affects those distances. To calculate the reduction exactly upon this principle would be impossible; but we approximate to it within the limits of other neglected terms if we use Young's rule * without the term depending on continental attraction. Stokes reaches this same result; but having reached it, he remarks that if this theoretically correct procedure were used the figure of the earth would be less regular than in using the old rule. He offers no proof of this, however; and the facts which have been ascertained since his memoir was written prove that the contrary is true. Young's rule supposes that if all the rock rising above the sea-level were annihilated, the present level surface would remain a level surface, which is certainly not true. When Major Herschel admits, as he seems to do, that a certain conclusion is proved by the facts but at the same time maintains it cannot be 'lawfully' acted upon, he seems to be using the language of a game with conventional rules. I would propose to act upon any proposition that seems to be true." Mr. Schott agreed with Mr. Peirce.

NOTE BY MAJOR (NOW LIEUTENANT-COLONEL) HERSCHEL.—I should like the issue between Mr. Peirce and myself, on the general question of the reduction on account of continental or mountain attraction, to be somewhat differently stated than it appears here. In the first place, what I have said about an "*à posteriori* dogma" had reference, if I remember rightly, not so much to the rejection of the continental reduction *in toto* as to its modification by an arbitrary constant, about which Mr. Peirce is now silent. However, my words are general enough, no doubt, to cover this rejection in any form, but all I maintain is that the assumption on which it rests shall be plainly presented and never disregarded. Mr. Peirce contends that the reduction for continental attraction has no claim to any such apologetic treatment, urging that, as it has no rational foundation, it should go; the displacement of matter, which appears as land elevation, being in all probability a merely vertical displacement, while for the continental attraction to have any jurisdiction, it would be necessary to show the existence of at least a very considerable *lateral* displacement as the cause, or part cause, of elevation. Now it is just here that I would step in and urge the claim of the latter, of which there is ample proof in the enormous thickness and extent of stratified deposits, all of which must be due to erosion and removal horizontally. Something also might be said for glacial transfer, and for lava streams.—J. H.

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IV. The residuals of the different stations are materially diminished by subtracting the entire downward attraction of the ocean, liberally estimated.

Mr. Peirce admitted that this would involve a falsification of the earth's figure, so as to give a sort of mean figure.

Major HERSCHEL. "The addition of the sea attraction has a legitimate *raison d'être*, as it is reasonable to affirm that the *sea* matter is *added* matter."

Mr. PEIRCE. It seems to me if the attraction of the sea is to be allowed for because it is added or horizontally displaced matter, then the attraction of the continents should not be allowed for, because it is not added, that is, is only vertically displaced matter."

V. The occupation of additional arctic stations, if done well, would probably improve the value of the compression. New equatorial stations are also desirable, but new stations in middle latitudes can hardly affect the value of the compression.

Major HERSCHEL. "The actual distribution is shown in a diagram given in my Appendix to Vol. V of the India Survey. This diagram shows how very restricted is the area actually occupied by differential stations. The southern hemisphere is very poorly represented."

* This so-called rule is identical with *Bouguer's* formula for the same.

VI. In middle latitudes, the main thing at present is to study the relation of gravity to geographical and geological conditions.

Major Herschel concurred.

VII. Gravity determinations should be made at intervals on lines of geodetic levels, and the levels be corrected accordingly.

Mr. Schott concurred.

VIII. Economical questions should, as far as possible, be solved by the application of mathematics.

IX. The invariable reversible pendulum reunites the advantages of the two instruments possessing the one and the other of these characters, and is to be recommended under the limitation implied in No. II above.

Major HERSCHEL. I am obstinately opposed to any attempted combination of the invariable and reversible principles in one instrument. They are incompatible; and the combination is impossible without so modifying the invariable principle that it is practically abandoned altogether. It is very undesirable that any new element of doubt should be imported into the already much abused term "invariable." It was first used by Godin, as well as by Bouguer, and by la Condamine. They all meant a rigid pendulum with fixed knife-edge. Kater borrowed the word from the French, but as he at the same time introduced a "convertible" pendulum, with two fixed knife-edges, which made a great noise abroad, the two got mixed up, and the German text-books (copying from Muncke*) flagrantly confused the two. Still, the German use is strict in denoting a rigid pendulum with fixed knife-edges. But Mr. Peirce now intends to upset this last stronghold of the "invariable" pendulum by making it variable at the will of the observer. The invariable pendulum proper *can* undergo no change without violating its name. Closely connected with the term "invariable," as designating a particular form of construction, is the term "invariability" as denoting a principle involved in its design. I cannot possibly demur to the construction of any form of pendulum which may be thought desirable; but I do urgently protest against the designation of it in a way to create needless confusion. The principle of the invariable pendulum supposes it to continue unchanged as long as human carelessness will permit, or longer if possible. But by making its knife-edges interchangeable, with a view to giving it a greater range of utiltity, this first characteristic is voluntarily destroyed; and in becoming reversible *in the full sense of the word* it ceases to be invariable. Why, then, adopt a self-contradictory compound name which serves no purpose but to ruin the word as well?

At the same time I must say that Mr. Peirce seems to *read the word* differently.

Mr. PEIRCE. By an invariable reversible pendulum, I mean one in which the knives remain in place from one station to another. Major Herschel's objections seem to be directed against the use of the word invariable as applied to such an instrument; but it is not so much the word as the thing that I advocate. The Geodetical Association has unanimously recommended the reversible pendulum, and I should certainly think that their opinion ought to be respected, even if I did not share it. On the other hand, there is much to be said in favor of differential instruments. I am not aware that Major Herschel has brought forward any objection to reuniting the differential or invariable and the reversible principles in one instrument except this, that if the knives can be changed they might be changed by carelessness. But it appears to me that the whole weight of this argument, such as it is, is against the invariable pendulum. For there is no fabrication of human hands that cannot be changed by carelessness. Can a Kater invariable pendulum be safely exposed to careless treatment? The difference between the ordinary invariable pendulum and the invariable reversible pendulum in this respect is that if the former suffers injury the work is hopelessly vitiated, while if the latter is injured, it is only necessary to fall back on the reversible principle. The following are the advantages which I think I see in the use of the invariable reversible pendulum:

1st. It satisfies the requirements of those who advocate the reversible pendulum, who constitute the greater weight of living authority.

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* *Gehler's Physikal. Wörterbuch.* Art. *Pendel.* VII, pp. 304-407. Leipzig, 1833. By far the ablest treatise, historical and otherwise, of its day, and perhaps so still.

2d. It ought to satisfy those persons who advocate the invariable pendulum.

3d. It determines gravity in two nearly independent ways, without more experiments than are necessary for a single determination. When these results agree they may be assumed to be correct.

4th. If the instrument be considered as a differential one, the difference in the reduced time of oscillation with heavy end down and with heavy end up must remain unchanged so long as the instrument is invariable and can hardly escape change otherwise. And from this change the necessary correction can be calculated and applied. If on the other hand the instrument be considered as an absolute one, the same difference is the best test of the accuracy of the work.

Mr. SCHOTT. For the strict intercomparability of results at two or more stations, I think it to be almost essential to satisfactory work that an absolutely invariable pendulum be employed. This condition would, however, not exclude the use of a pendulum having interchangeable knife-edges, provided that between any two stations no such interchange took place, while the interchange might be effected after the particular comparative measures were secured.

NOTE BY MAJOR (NOW LIEUTENANT-COLONEL) HERSCHEL.—The view of this subject here presented by Mr. Schott, in this last paragraph, is so sensibly correct that only a strong conviction that it does not meet the whole case, and is directly opposed to the principle of inviolability which I wish to see recognized, would tempt me to add to this discussion. We are agreed, and universal practice shows it to have been widely recognized, that invariability must be maintained during at least the whole course of a series of differential determinations. [In the East Indian series, for instance, it was maintained during eight or nine years, and at more than thirty installations.] No one pretends to set any limit, either to the time or to the number of stations, which is to restrict a series of differential measures. But it is said, "when the series is completed there is no longer any need to guard or preserve the pendulum from change; its work is done." But it is just at this point, I contend, that we ought, on the contrary, to be growing more and more solicitous for the protection of the pendulum. The more stations it has visited, the more intimate is our knowledge of its time of vibration, or vibration-number, or whatever be the function we may adopt by which the results of observation are to be expressed. Even if, at the time, only one of the stations visited was a "known" station, we ought yet to contemplate and anticipate the time when, by the superposition of later series, the fundamental vibration-number (*i. e.*, its equatorial vibration No.) shall rest on more than one, perhaps on many known stations. Even if such considerations as these fail to convince, some weight will surely be conceded to the argument that, as one continuous series is better than two or more, covering the same stations, and as by merely guarding the pendulum stringently during the temporary pause between two sets of operations, otherwise called series, these will in fact constitute one only, it is right to take the proper precautions to bring this about. I confess I am surprised, not that this principle has not been acted upon, in times past, but that it should at this day need more than the most cursory enunciation, and that we are even now debating whether we shall not continue to throw away one-half of the net results of each set of observations with invariable pendulums. We do no less, when we break off a series and, by interchange of knife-edges, interrupt the continuity of a series.

J. H.

JULY 4, 1883.

X. Four classes of errors affect the observed period of oscillation, as follows:

1st. Those which are nearly constant throughout the work at any one station. Such arise, for example, from the flexure of the support, from an error in the adopted coefficient of expansion at a tropical or arctic station, and from other causes.

2d. Those which remain nearly constant for a considerable time, say an hour or a day, but which vary from day to day. Such arise, for example, from the knife resting differently on the supports on different days, from erroneous determinations of temperature, or from similar causes.

3d. Those which are continually varying throughout the observations.

4th. Those which arise from errors in the comparison of the pendulum with the time-piece.

The first class of errors demand the most solicitous scrutiny. The other three classes may be distinguished by the study of the residuals of the observations. The third class is the most important of the last three.

XI. Further insight into the nature of the errors is obtained by comparing the residuals with large and with small arcs, and by comparing the residuals of the reversible pendulum in its two positions.

Small arcs and heavy pendulums are to be recommended.

Major HERSCHEL. In recommending "small arcs," Mr. Peirce leaves us to guess what magnitude he contemplates. In setting out upon my recent experience, I intended to swing in arcs as small as I could anyway *see* them, certainly below 30′′. But I found that both Sir G. Airy and Professor Stokes were strongly opposed to such a course, and I abandoned the intention in favor of arcs falling from say 70′ to 7′. The objections urged were all theoretical. I should still advocate the practical testing of the doubt in any series of observations of an experimental character.

Mr. PEIRCE. I find the errors of observation are not increased by continuing the oscillation down to arcs of 1′.

XII. The method of coincidences as perfected by Major Herschel is to be recommended, especially in connection with a clock whose pendulum swings from knives.

XIII. The experiments should be continued for 24 hours, beginning and ending with star observations, when this is convenient. But this should not be absolutely required.

XIV. The swinging in *vacuo* is to be recommended.

Major Herschel dissented.

XV. The flexure of the support may be advantageously avoided by swinging two pendulums simultaneously on the same support with opposite phases. When this is not done the flexures should be measured, and in doing this the measures must be made at the middle of the knife-support or else the position of the instantaneous axis of motion must be determined.

XVI. The separation of the atmospheric effect into two parts is requisite for an exact temperature correction.

XVII. The influence of atmospheric moisture ought to be studied.

XVIII. The use of rollers in place of knives is to be condemned.

XIX. The probable accidental error of a determination of gravity must not exceed 5 millionths ($\frac{1}{200000}$), and the total which may reasonably be feared must not exceed 10 millionths ($\frac{1}{100000}$).

Professor Newcomb and others agreed to this, but Major Herschel and Mr. Schott objected to any numerical criterion of this sort.

XX. A good gravimeter is an important desideratum.

CONCLUSIONS PROPOSED BY PROFESSOR NEWCOMB, AMENDED AND ADOPTED BY THE CONFERENCE.

1. The main object of pendulum research is the determination of the figure of the earth. From a sufficient number of observations suitably distributed over the surface of the earth the actual figure may be determined.

2. A complete geodetic survey should include determinations of the intensity of gravity. These determinations should be made at as many critical points of local deflection and physical structure within the area of the survey as possible; and these should be combined with others distributed over the whole globe.

3. A minute gravimetric survey of some limited region is at present of such interest as to justify its execution.

4. Extended linear gravimetric exploration is desirable, to be ultimately followed by similar work distributed over large areas.

5. Each series of such determinations should be made with the same apparatus, so that the differential results should not be affected by constant errors peculiar to the apparatus.

6. While it is inadvisable at present to strictly fix a numerical limit of the permissible probable error of pendulum work, yet such determinations ought commonly to be accurate to the $\frac{1}{200000}$ part.

7. Since different pendulums may be used in different regions, all should be compared at some central station.

8. Determinations of absolute gravity will probably prove useful in comparing the yard and the metre, and they should at any rate be made in order to test the constancy of gravity against the constancy of length of a metallic bar.

9. In the present state of our experience, unchanged pendulums are decidedly to be preferred for ordinary explorations.

APPENDIX No. 11.

RESULTS OF THE TRANSCONTINENTAL LINE OF GEODETIC SPIRIT-LEVELING NEAR THE PARALLEL OF 39°. FIRST PART FROM SANDY HOOK, N. J., TO SAINT LOUIS, MO., EXECUTED BY ASSISTANT ANDREW BRAID.

(WITH A MAP).

By CHARLES A. SCHOTT, Assistant.

When the Survey undertook the geodetic connection of the Atlantic and Pacific coasts by a chain of triangles it became evident that a line of spirit-leveling would be needed in order that the various base lines might be accurately referred to the sea level, their common plane of reference. If these elevations were merely known through barometric observations, or ordinary spirit-leveling, the referred length would not possess that degree of accuracy which must be secured in a geodetic operation of refinement and of great extent; it was consequently decided to carry a line of spirit-leveling of precision from ocean to ocean, following, as near as practicable, the triangulation along the thirty-ninth parallel, and resting for its datum level on each side on tidal observations continued for a series of years.

Such a line of levels passing centrally over the country, and thus readily accessible from places lying to the north and south of it, while available for the use of the geographer, the meteorologist, the engineer, the geologist, and others, will have other important scientific bearings upon our knowledge of the physics of the globe; it bears upon the questions of the hydrodynamic equilibrium of the ocean level at different points under the action of disturbing forces, such, for instance, as the following: Is there any difference in height, and, if so, of what amount (from *a priori* considerations it must be small*) between the mean level of the Gulf of Mexico and that of the Atlantic? Or, what difference in the results of precise spirit-leveling have we to expect from levels between two given points by two different routes not on the same level surface? To answer the first question, a branch line from Saint Louis to the Gulf has been already partly executed in connection with the survey of the Mississippi River, and with reference to the second, the investigation will be of great importance, involving, as it does, two effects, viz, that of the inclination of two adjacent equipotential surfaces as related to the general figure of the earth, and the other involving the local deflections of the vertical and irregularities in the intensity of gravity, thus deforming the surfaces of level and altering their distances. Along our east and west line the first or more general effect will be trifling (as it reaches its maximum value in a meridional direction), but the second will enter to its full extent. When crossing the Alleghanies, we can assume that the effect of local deflections will be small, since complete compensation takes place when passing over slopes equal, but oppositely inclined, and, in general, the differential effect may not be cumulative when crossing a number of parallel ridges unless they should all be of similar cross-section. When ascending the great western plains by a long and gentle slope up to the Rocky Mountain Plateau, and then rapidly descending to the sea-level, we have conditions favorable to the development of effect on the results of spirit-leveling due to local deflections in the direction of the vertical and variations in the intensity of gravity. Thus we perceive the intimate connection between geodetic, astronomical, hypsometric, and pendulum work, all of which will be

* It may be mentioned in this connection that spirit-leveling in Europe apparently brought out the result that the mean level of the Atlantic at Brest, France, is higher by one metre than the mean level of the Mediterranean at Marseilles.

prosecuted in the direction indicated. The effects of local deflections mentioned cannot be precisely evaluated under any circumstances so that the question of the relative level of the Gulf and Atlantic might first be ascertained by a line of spirit-levels across the peninsula of Florida (Fernandina to Cedar Keys) and the result compared with that of the line Sandy Hook, Saint Louis, New Orleans (or Mobile). Precisely in the same relation as this short cut stands to the eastern part of our line of levels, the cut across the Isthmus of Panama stands to the whole line, and in both cases these considerations will enter into the discussion of the probable error in the leveling operation when comparing its magnitude with the apparent actual resulting difference at the terminal sea-level.

DETERMINATION OF THE MEAN TIDAL LEVEL* AT SANDY HOOK, N. J.

The tidal observations made at Sandy Hook, by means of a self-registering tide-gauge, commenced October 21, 1875, and have been continued without interruption to the present time. The following table of annual mean readings (in feet) of low and of high waters was communicated to me by Mr. Avery, in charge of the Tidal Division of the office:

	1876.	1877.	1878.	1879.	1880.	1881.		
								Feet.
Mean reading of low water	6.07	6.27	6.36	6.19	6.15	6.13	Mean	6.195
Mean reading of high water	10.69	10.88	11.09	10.90	10.87	10.97	Mean	10.900
Mean range	4.62	4.61	4.73	4.71	4.72	4.84	Range	4.705
Mean reading of half-tide level	8.380	8.575	8.725	8.545	8.510	8.550	Half-tide	8.548
Differences from the mean	− .168	+ .027	+ .177	− .003	− .038	+ .002		± 0.031

A probable error of ± 0.031 feet or ± 9.3^{mm} in the starting-level is rather greater than is desirable, and it refers to a mean reading of the sea-level itself roughly determined, since the annual tabular means contain *fractional parts* of a lunation; hence some effect of the semi-monthly inequality in height must be expected to enter into the result. In the mean time Mr. Ferrel submitted these tides to a discussion by the harmonic analysis (compare his Tidal Researches, Washington, 1874; also his discussion of Tides in Penobscot Bay, Appendix No. 11, Coast and Geodetic Survey Report for 1878). He communicated the following table of "Tide-gauge reading of mean sea-level from *hourly* co-ordinates" (uncorrected for shifting of index of gauge between one year and another, the index of 1881 alone being identical with that of the table of low and high waters):

	From lunar tide.	From solar tide.	Difference.
	Feet.	*Feet.*	*Feet.*
1876	5.3423	5.3427	− .0004
1877	5.4292	5.4288	+ .0004
1878	5.0978	5.0977	+ .0001
1879	5.0461	5.0467	− .0006
1880	5.3334	5.3338	− .0004
1881	8.5703	8.5694	+ .0009

Here the results from lunar tide are the mean of five components and the results from solar tide the mean of four components, hence the small difference in the half-tide level indicated. Calling

*A slight acquaintance with the laws of the tides indicates that the level of reference for spirit-leveling of precision can be no other than the average or so-called half-tide level of the ocean. This matter was also practically tested in 1842, when twenty-two tidal stations were established round the coast of Ireland and their zeros of staffs connected by spirit-levels; the tidal observations have been discussed by the Astronomer Royal (Phil. Trans. Roy. Soc., 1845), and the results will be found on page 551 of the British Ordnance Survey, London, 1858. The spirit-leveling operations of the great trigonometrical survey of India, commenced in 1858, were started from the mean (average) sea-level of Karachi Harbor (Tables of Height in Sind, the Punjab, etc., Calcutta, 1863). In the leveling connecting the Baltic with the Swiss levels the plane of reference is the mean water at Swinemunde depending on fifty-four years of observations. (Leveling in connection with the measurement of arcs, by Dr. Seibt, Berlin, 1882.)

attention to the fact that these values for the several years needed reduction to the same zero level before they could be used, these index corrections were furnished to Mr. Ferrel by the Tidal Division, who applied them, however, to other components (than the above), viz., to O (lunar declinational) and to L (lunar elliptic) and to N (of the same type as L). His corrected hourly readings gave the following values for the mean sea-level:

	Component O.	Component L.	Component N.	Difference O − L.
	Feet.	*Feet.*	*Feet.*	*Feet.*
1876	8.4133	8.4215	8.4212	− .0082
1877	8.5886	8.5651	8.5665	+ .0235
1878	8.7262	8.7516	8.7516	− .0254
1879	8.5435	8.5515	8.5516	− .0080
1880	8.5178	8.5124	8.5122	+ .0054
1881	8.5692	8.5714	8.5715	− .0022

These differences are larger than those exhibited above, which is accounted for by the fact that the results under O and L are not mean values of several terms.

Uniting the results, first combining L and N, their mean with O, and taking the mean of the four values of 1881, we find the following results for the mean reading of the sea-level:

	Feet.	Δ
1876	8.4173	+ .1437
1877	8.5772	− .0162
1878	8.7389	− .1779
1879	8.5475	+ .0135
1880	8.5150	+ .0460
1881	8.5701	− .0091

Mean, 8.5610 ± 0.0289 feet, adopted for the starting-level. From the low and high waters for these years we had the value 8′.548 ± 0′.031 in good accord with the preceding value derived from the harmonic analysis.

The annual values for the mean level as derived from the low and high water $\frac{1}{2}$ (L + H) and as deduced from the harmonic analysis (H. A.) compare as follows:

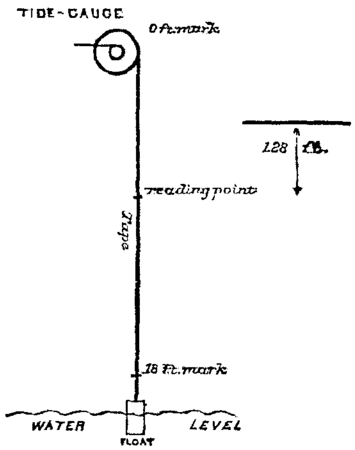
	$\frac{1}{2}$ (L + H).	H. A.	Difference.
1876	8.380	8.417	− .037
1877	8.575	8.577	− .002
1878	8.725	8.739	− .014
1879	8.545	8.548	− .003
1880	8.510	8.515	− .005
1881	8.550	8.570	− .020

The level as given by H. A. is found to be higher for every year,* and there is apparently a rise in the mean level during the years 1876–'77–'78, afterwards a fall; but this as well as the apparent increase in the annual range of the tide may be due to accidental circumstances, as disturbing causes of the annual mean height of the sea-level, variations in the mean annual direction and force of the wind, and in the atmospheric pressure, as well as variations in the direction and velocity of ocean currents are prominent factors. There may also be periodic fluctuations in the sea-level

* It is to be remarked that in consequence of the quarter-diurnal tide the high and low waters should both be slightly higher, and consequently also the mean level deduced from them, than the value given by the harmonic analysis; but in fact we find the latter the higher by 0.013 foot or 4.0mm; hence it would seem that the effect is marked by some other irregularity.

(possibly a nineteen-year period) and the relative position of the levels of land and sea* may be subject to a slow secular change.

Changes in the tide-gauge itself, such as changes in the float-line, stretching or contracting of the tape transmitting the motion, and settling of the wharf upon which the tide-house is placed, are of course carefully watched and allowed for when required. For a description of the automatic tide-gauge see Coast Survey Report for 1876, Appendix No. 8. The tide-house is on the freight-wharf of the New Jersey Southern Railroad at Sandy Hook, on its western or inner shore, and about 3km from the point. The tide-house bench mark (designated by T. H. in the table) is a horizontal pencil line with five tacks driven into it on the northwest corner post, and about six feet above the floor of the house; this bench-mark formed the starting-point and level of reference of the line of levels run by Assistant Andrew Braid in 1881. There were other bench-marks established in its neighborhood, and in particular one on the stone tower of the main light-house on the Hook, and another across the narrow channel on the sloping ledge of the southern of the Navesink lights. These marks were connected by Mr. Braid with that in the tide-house, the elevation of which above the mean tidal level, as given by the gauge, is as follows:



	Feet.		Feet.	
Float-line below the 18-foot mark on tape, 8¾ inches, or..........	0.729	±	.005	(estimated)
Hence, reading of float-line	18.729			
Reading of mean sea-level or half-tide level (see above)	8.561	±	.029	
Hence, index or reading mark above mean sea-level	10.168			
Tide-house bench-mark above index $15\frac{5}{16}$ inch, or	1.276	±	.005	(estimated)
Hence, bench-mark T. H. above sea-level	11.444	±	.030	
	$=3^{m}.4881 \pm 0^{m}.0091$			

Which value has been adopted for the present. The observations of the tides are continued; hence the probable error of the mean sea-level ($\pm 0^{m}.0088$) may be further reduced hereafter.

The line of spirit-levels between Sandy Hook, N. J., and Saint Louis, Mo., was run by Assistant Andrew Braid with level Coast and Geodetic Survey No. 1, and the metric rods either A and B or E and F. The method of observing was the same throughout. In Coast and Geodetic Survey Report for 1880, Appendix No. 11, Mr. Braid explains his method of observing (pp. 137, 138), describes and figures his instrument (Plate No. 46), and gives a specimen of his record (p. 139), to which the reader may be referred for detail information.

INSTRUMENTAL CONSTANTS.—Magnifying power of telescope 26; focal distance 41cm; aperture 35mm; diaphragm with 3 horizontal and nearly equidistant spider-lines; angular distance middle line to (true) upper line, 1012″.7, and of middle line to (true) lower line 995″.3. One division of micrometer, 442″.8. Value of one division of the level, 5″.32; but this does not enter into the work. The ring inequality was determined on several occasions. The brass scales of the rod were

* Thus at Brest, France, it is stated that the mean level of the ocean from 1834 to 1878 had sunk or the ground had risen about 1mm a year. (Nature, No. 658, June, 1882.) In his annual report of the geological survey of New Jersey for the year 1881, Mr. George H. Cook, State geologist, devotes Chapter III, pp. 20-32, to facts and discussion of the encroachment of the sea upon the low-lying lands. It would appear that the relative change of land and sea along the coast of New Jersey points either to a gradual rise of the sea-level or to a gradual subsidence of the land. The subject of the currents off the coast, and in particular for that part of it lying north of Barnegat, is referred to on page 30. For the mere change of outline of Sandy Hook between the years 1779 and 1853 due to varying currents and supposed unaccompanied by vertical changes, the reader may be referred to Chart No. 8 of Coast Survey Report for 1853. The permanency of our level of reference is of the utmost importance, and if it should be found subject to secular change it may be detected by means of a branch line of levels to some other part of the coast where apparently no indications of change exist. It is the intention of the Superintendent of the Survey to connect the Hagerstown bench-mark with the tide-gauge at Old Point Comfort, Va., and thus secure a check upon its height as well as a second reference to the sea-level.

compared with a standard metre at the office and found of the following length: Rod A = $3^m.000105$ at 68°.0 F., and rod B = $3^m.000076$ at 68°.3 F., giving the middle metre double weight; the length of the average metre of the rods was $1^m.000075$ for A at 68°.4 F. and 0.999996 for B at 68°.3 F. The comparisons of the lengths of the metre marks of rods E and F at 68°.4 F. give the result:

		E	F
Staff metre....	First	$1^m.000052$	$1^m.000052$
	Second	$1^m.000039$	$0^m.999959$
	Third	$1^m.000121$	$1^m.000120$

The coefficient of expansion is assumed equal .00001 For construction of the staves see Assistant Tittmann's paper, Coast and Geodetic Survey Report for 1879, Appendix No. 15. In Appendix No. 11, Report for 1880, Mr. Braid explains the method of leveling followed on the Lower Mississippi River, which is the same as that adopted for the transcontinental line (now extending to Etlah, Mo.), viz: Two parallel lines are run simultaneously and in the same direction, one by staff A, the other by staff B, the rods being placed at different distances from the instrument; alternate parts of the line are run in opposite directions. On level ground, or where the slope is not interfering, the distance from staff to staff (with the instrument as near as may be midway between) is, on the average, 220m, half that distance being stepped off by the rodman when passing from the instrument to the position of the staff. The corresponding staffs of the simultaneous A and B lines are about 20 metres apart.

The following table gives the time of beginning and ending of field work for the several sections of the line and their length:

	Ending.	Beginning.	Distance leveled.
			Kilometres.
Sandy Hook, N. J., to Hagerstown, Md.......	188[illegible], July 7	1881, Dec. 12	441
Hagerstown, Md., to Grafton, W. Va.........	1878, May 15	1878, Sept. 7	309
Grafton, W. Va., to Athens, Ohio............	1878, Sept. 7	1878, Dec. 14	228
Athens, Ohio, to Mitchell, Ind	1879, July 5	1879, Nov. 8	459
Mitchell, Ind., to Saint Louis, Mo............	1882, July 6	1882, Oct. 21	347
Total development..........................			1 784

The line of levels generally follows a railroad track, with the exception of the space between Hagerstown and Cumberland, Md., where Mr. Braid followed the turnpike for a short distance and afterwards the canal banks. Primary bench-marks are indicated in the record by letters of the alphabet, secondary bench-marks by Roman numerals; the former consist in most cases of a square cavity, three fourths to one inch square and about one-fourth to three-eighths of an inch deep, with legend "U. S. C. & G. S.," and the letter assigned to it; the secondary bench-marks are indicated in the same way, but with a number instead of a letter. The leveling refers to the bottom ledge of the mark. There are also a number of temporary marks, not further described, since most of these will soon become obliterated. A copy of the description of the bench-marks follows the results of each section.* The following names of the more prominent places along the route will, in general, indicate sufficiently the location of the line:

SECTION 1.—Sandy Hook, Perth Amboy, Somerville, Annandale, in New Jersey; Easton, Allentown, Reading, Harrisburg, Chambersburg, in Pennsylvania.

SECTION 2.—Hagerstown, Williamsport, Cumberland, in Maryland.

SECTION 3.—Grafton, Parkersburg, in West Virginia.

SECTION 4.—Athens, Chillicothe, Cincinnati, in Ohio; Lawrenceburg, North Vernon, Mitchell, in Indiana.

SECTION 5.—Vincennes, in Indiana; Olney, Flora, Sandoval, in Illinois; Saint Louis, in Missouri.

The route followed by the leveling party is shown on accompanying map No. 32½.

The office computation was made by Messrs. Christie and Farquhar, of the Computing Division, with temporary aid given by Subassistants Weir and Pratt. The correction for curvature and refraction, for ring inequality, for index error of rods, and variation in length of rods

*In many cases the record contains diagrams to facilitate the finding and identification of the mark, and there are also route diagrams showing the exact location of the line. Application can be made to the office for detail information.

with temperature were duly made when needed; effects arising from change in length of bubble and from collimation error are eliminated in the process of observing. The observer's computation was collated with the office computation, and the final table of results was drawn up by Mr. Christie.

PROBABLE ERROR OF RESULTS FROM GEODETIC SPIRIT-LEVELING.

The probable error of the operation of spirit-leveling of precision developed in a distance of one kilometre has generally been adopted as a convenient measure of stating the precision reached* as well as for comparison of the values of similar work. If, in accordance with the method of least squares we take the probable error of leveling proportional to $\sqrt{s}$, or what comes to the same, the weight of a result to be inversely proportional to the length s, and if—

d = difference in results from two measures of a line of length s, the two measures supposed made preferably in opposite directions and independent of each other,

n = the number of such lines of double leveling,

m' = the mean error of a *single* leveling per kilometre, *i. e.*, per unit of length,

m'' = the same for *double* leveling; then with $p = \frac{1}{s}$

$$m' = \sqrt{\frac{1}{2n}\left[\frac{dd}{s}\right]} \qquad \text{and } m'' = \frac{m'}{\sqrt{2}}$$

r'' = probable error of a double leveling of a line of length $L = [s]$; then †

$$r'' = 0.675\, m'' \sqrt{L}$$

In our case, where the marks are distributed over the whole line with tolerable regularity, the average distance between them being about one km.,‡ and where the weights become equal, the computation of the probable error is much simplified by the use of the formula

$$0.675 \sqrt{\frac{\Sigma d^2}{4\Sigma s}}$$

for the probable error in 1km., for a double line; hence, for the resulting difference of height from a double leveling over the whole distance L,

$$r'' = 0.675 \sqrt{\frac{\Sigma d^2}{4}}$$

in our case, the two expressions lead to the same numerical value. This probable error must be combined with that of the sea-level or with ± 9.1mm for the tide-house bench mark at Sandy Hook in order to obtain the probable error of the height above the sea. Collecting our results for probable error per kilometre from the double line of levels and for the whole sections, we have:

Section.	Beginning and end of line.	Probable error per kilometre.	Probable error developed from Sandy Hook.	Terminal point.	Bench-mark height above sea.	Probable error.
		mm.	*mm.*		*m.*	*mm.*
I	Sandy Hook, N. J., to Hagerstown, Md	± 1.03	±21.6	Hagerstown, Md............	168.340	±23.4
II	Hagerstown, Md., to Grafton, W. Va.........	1.18	29.9	Grafton, W. Va.............	303.864	31.3
III	Grafton, W. Va., to Athens, Ohio	1.54	37.9	Athens, Ohio	200.155	39.0
IV	Athens, Ohio, to Mitchell, Ind	0.94	43.0	Mitchell, Ind........	209.681	43.9
V	Mitchell, Ind., to Saint Louis, Mo.	1.05	47.2	Saint Louis, Mo.............	126.908	48.1

* With respect to levelings of precision executed of late years in Europe, in the opinion of the Geodetic Association, a probable error in the resulting difference of height as large as ± 3mm per km. may still be tolerated, but one of ± 5mm would be considered as surpassing an allowable limit. A value of ± 2mm may be considered to represent a fair measure and one of ± 1mm a measure of high precision.

† The formulæ given by Assistant Braid in Coast and Geodetic Survey Report for 1880, page 140, viz:

$$\text{Mean error of one kilometre for } \textit{single} \text{ leveling} = \sqrt{\frac{1}{n}\left[\frac{2v^2}{s}\right]} \text{ and for } \textit{double} \text{ leveling } \sqrt{\frac{1}{2n}\left[\frac{2v^2}{s}\right]}$$

are identical with the corresponding expressions m' and m'' above, since $v = \frac{d}{2}$.

‡ Varying on the average between half a kilometre in the eastern sections to 2 kilometres in the western, according to the natural facilities offered.

The numbers in the last column were found by the combination of the preceding probable errors with that of the sea-level mark ($\pm 9.1^{mm}$).* In consequence of the method adopted of running two parallel lines simultaneously, the condition of the entire independence of the two sets of results, as supposed in the above formulæ, is not satisfied, and the computed probable errors are necessarily too small, since the instrumental and atmospheric conditions are nearly the same for the two lines.

Further results will be given as the work progresses.

* About as much would be developed in leveling a line of 60 kilometres.

Transcontinental line of Spirit-levels.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Simultaneous lines. Rod A, first line.	Rod B, second line.	Rods A and B alternately, third line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ^2
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	$(mm)^2$
T. H. mark	....	0.000	....	....	....	....	+ 3.4881	0.0	....	....	...
T. H. to A	0.415	0.415	− 0.0104	− 0.0156	....	− 0.0130	+ 3.4751	....	+5.2	+ 5.2	27.0
A to B	0.202	0.617	− 0.6155	− 0.6114	− 0.6103	− 0.6124	+ 2.8627	....	−4.1	+ 1.1	16.8
B to 6	0.235	0.852	− 1.3464	− 1.3473	− 1.3445	− 1.3461	+ 1.5166	....	+0.9	+ 2.0	0.8
6 to 9	2.434	3.286	+ 0.0264	+ 0.0279	....	+ 0.0271	+ 1.5437	....	−1.5	+ 0.5	2.2
9 to C	0.707	3.993	+ 4.4090	+ 4.4097	....	+ 4.4094	+ 5.9531	2.3	−0.7	− 0.2	0.5
9 to I	0.575	3.861	+ 3.1769	+ 3.1754	....	+ 3.1761	+ 4.7198	2.4	+1.5	+ 2.0	2.2
6 to 5	3.078	3.930	+ 0.4400	+ 0.4395	+ 0.4430	+ 0.4408	+ 1.9574	....	+0.5	+ 2.5	0.2
5 to II	2.170	6.100	+ 0.3589	+ 0.3622	+ 0.3657	+ 0.3623	+ 2.3197	2.5	−3.3	− 0.8	10.9
II to 4	1.009	7.109	+ 0.9686	+ 0.9656	+ 0.9694	+ 0.9679	+ 3.2876	....	+3.0	+ 2.2	9.0
4 to 3	0.610	7.719	− 0.0462	− 0.0455	....	− 0.0458	+ 3.2418	....	−0.7	+ 1.5	0.5
3 to 1	0.138	7.857	+11.2677	+11.2670	....	+11.2673	+14.5091	....	+0.7	+ 2.2	0.5
1 to 2	0.281	8.138	+22.9924	+22.9891	....	+22.9908	+37.4999	....	+3.3	+ 5.5	10.9
2 to III	0.288	8.426	+24.2156	+24.2136	....	+24.2146	+61.7145	3.0	+2.0	+ 7.5	4.0
III to D	0.038	8.464	+ 1.5598	+ 1.5594	....	+ 1.5596	+63.2741	3.0	+0.4	+ 7.9	0.2
4 to 7	1.960	9.069	− 0.6453	− 0.6432	− 0.6481	− 0.6455	+ 2.6421	....	−2.1	+ 0.1	4.4
7 to 8	1.900	10.969	− 0.4875	− 0.4883	− 0.4906	− 0.4888	+ 2.1533	....	+0.8	+ 0.9	0.6
8 to IV	0.244	11.213	+ 0.6694	+ 0.6689	+ 0.6689	+ 0.6691	+ 2.8224	2.8	+0.5	+ 1.4	0.2
8 to 10	2.553	13.522	− 0.4475	− 0.4448	− 0.4384	− 0.4436	+ 1.7097	....	−2.7	− 1.8	7.3
10 to 11	1.450	14.972	+ 2.6555	+ 2.6596	+ 2.6433	+ 2.6528	+ 4.3625	....	−4.1	− 5.9	16.8
11 to 12	2.268	17.240	+ 0.1413	+ 0.1456	+ 0.1399	+ 0.1423	+ 4.5048	....	−4.3	−10.2	18.5
12 to 13	2.054	19.294	− 1.3603	− 1.3539	− 1.3567	− 1.3570	+ 3.1478	....	−6.4	−16.6	41.0
13 to V	2.420	21.714	− 2.0870	− 2.0897	{ − 2.0907 − 2.0854 }	− 2.0882	+ 1.0596	4.3	+2.7	−13.9	7.3
V to 14	1.659	23.373	+ 5.7285	+ 5.7267	+ 5.7308	+ 5.7287	+ 6.7883	....	+1.8	−12.1	3.2
14 to 15	2.282	25.655	+ 2.5068	+ 2.5021	+ 2.4976	+ 2.5022	+ 9.2905	....	+4.7	− 7.4	22.1
15 to 16	1.498	27.153	+ 1.1852	+ 1.1854	+ 1.1776	+ 1.1827	+10.4732	....	−0.2	− 7.6	0.0
16 to E	0.361	27.514	+ 1.2553	+ 1.2570	....	+ 1.2561	+11.7293	4.6	−1.7	− 9.3	2.9
16 to 17	1.996	29.149	+ 7.8762	+ 7.8817	+ 7.8851	+ 7.8810	+18.3542	....	−5.5	−13.1	30.2
17 to 18	2.908	32.057	+ 2.9162	+ 2.9255	+ 2.9251	+ 2.9223	+21.2765	....	−9.3	−22.4	86.5
18 to 19	0.900	32.957	− 8.7006	− 8.6968	− 8.6884	− 8.6953	+12.5812	....	−3.8	−26.2	14.4
19 to 20	1.768	34.725	+20.3191	+20.3169	+20.3240	+20.3200	+32.9012	....	+2.2	−24.0	4.8
20 to 21	1.401	36.126	− 8.8790	− 8.8843	− 8.8828	− 8.8820	+24.0192	....	+5.3	−18.7	28.1
21 to 22	2.924	39.050	+ 0.2465	+ 0.2475	+ 0.2408	+ 0.2449	+24.2641	....	−1.0	−19.7	1.0
22 to 23	1.078	40.128	− 5.1639	− 5.1616	− 5.1676	− 5.1644	+19.0997	....	−2.3	−22.0	5.3
23 to 27	1.369	41.497	+ 2.3214	+ 2.3172	+ 2.3214	+ 2.3200	+21.4197	....	+4.2	−17.8	17.6
27 to 26	2.338	43.835	−11.3133	−11.3042	−11.3203	−11.3126	+10.1071	....	−9.1	−26.9	82.8
26 to 25	0.562	44.397	+ 1.4061	+ 1.4018	+ 1.4018	+ 1.4032	+11.5103	....	+4.3	−22.6	18.5
25 to VI	0.721	45.118	+ 5.2773	+ 5.2771	....	+ 5.2772	+16.7885	7.4	+0.2	−22.4	0.0
25 to 24	0.321	44.718	− 1.2507	− 1.2520	− 1.2563	− 1.2530	+10.2573	....	+1.3	−21.3	1.7
24 to 28	0.419	45.137	+ 1.0689	+ 1.0648	+ 1.0684	+ 1.0674	+11.3247	....	+4.1	−17.2	16.8
28 to 29	1.208	46.345	+ 6.6717	+ 6.6666	+ 6.6674	+ 6.6686	+17.9933	....	+5.1	−12.1	26.0

Transcontinental line of Spirit-levels—Continued.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Simultaneous lines. Rod E, first line.	Simultaneous lines. Rod F, second line.	Rods E and F alternately, third line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Discrepancy. Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm*)²
29 to VII	3.556	49.901	−16.2916	−16.2890	−16.2843	−16.2883	+ 1.7050	7.7	−2.6	−14.7	6.8
VII to 30	2.172	52.073	+ 1.7696	+ 1.7713	+ 1.7686	+ 1.7698	+ 3.4748	....	−1.7	−16.4	2.9
30 to VIII	1.458	53.531	+ 0.9598	+ 0.9688	....	+ 0.9643	+ 4.4391	8.3	−9.0	−25.4	81.0
VIII to 34	0.226	53.757	− 1.8068	− 1.8058	....	− 1.8063	+ 2.6328	....	−1.0	−26.4	1.0
34 to F	0.748	54.505	− 0.2687	− 0.2690	....	− 0.2688	+ 2.3640	8.3	+0.3	−26.1	0.1
F to 33	0.642	55.147	+ 2.4160	+ 2.4151	....	+ 2.4155	+ 4.7795	....	+0.9	−25.2	0.8
33 to 32	0.821	55.968	+ 6.3092	+ 6.3076	....	+ 6.3084	+11.0879	....	+1.6	−23.6	2.6
32 to 35	0.754	56.722	+ 5.2727	+ 5.2726	....	+ 5.2727	+16.3606	....	+0.1	−23.5	0.0
35 to 36	1.694	58 416	+ 8.8845	+ 8.8918	....	+ 8.8881	+25.2487	....	−7.3	−30.8	53.3
36 to 37	1.751	60.167	+ 5.0606	+ 5.0682	....	+ 5.0644	+30.3131	....	−7.6	−38.4	57.8
37 to 40	1.486	61.653	− 2.3714	− 2.3762	....	− 2.3738	+27.9393	....	+4.8	−33.6	23.0
40 to 39	1.958	63.611	− 1.3910	− 1.3994	....	− 1.3952	+26.5441	....	+8.4	−25.2	70.6
39 to IX	1.815	65.426	− 1.0509	− 1.0539	....	− 1.0524	+25.4917	9.7	+3.0	−22.2	9.0
IX to 38	0.585	66.011	− 1.1582	− 1.1560	....	− 1.1571	+24.3346	....	−2.2	−24.4	4.8
38 to 44	2.115	68.126	− 2.2584	− 2.2615	....	− 2.2599	+22.0747	....	+3.1	−21.3	9.6
44 to X	2.954	71.080	− 2.6162	− 2.6103	....	− 2.6133	+19.4614	10.0	−5.9	−27.2	34.8
X to 45	0.606	71.686	+ 0.4459	+ 0.4450	....	− 0.4455	+19.9069	....	+0.9	−26.3	0.8
45 to 47	2.907	74.593	− 3.3133	− 3.3177	....	− 3.3155	+16.5914	....	+4.4	−21.9	19.4
47 to XII	1.836	76.429	− 1.6052	− 1.6039	....	− 1.6046	+14.9868	10.0	−1.3	−23.2	1.7
XII to 48	1.834	78.263	+ 2.2515	+ 2.2442	....	+ 2.2479	+17.2347	....	+7.3	−15.9	53.3
48 to 46	1.543	79.806	− 4.9379	− 4.9411	....	− 4.9395	+12.2952	....	+3.2	−12.7	10.2
46 to XI	1.868	81.674	− 2.3987	− 2.3939	....	− 2.3963	+ 9.8989	10.1	−4.8	−17.5	23.0
XI to XIII	0.362	82.036	+ 0.9928	+ 0.9949	....	+ 0.9938	+10.8927	10.1	−2.1	−19.6	4.4
XI to 41	0.554	82.228	+ 0.0006	− 0.0004	....	+ 0.0001	+ 9.8990	....	+1.0	−16.5	1.0
41 to 42	1.469	83.697	+ 0.4699	+ 0.4731	+ 0.4843	+ 0.4758	+10.3748	....	−3.2	−19.7	10.2
42 to 43	1.271	84.968	+ 4.1196	+ 4.1204	+ 4.1230	+ 4.1210	+14.4958	....	−0.8	−20.5	0.6
43 to 49	1.627	86.595	+ 9.0111	+ 9.0135	+ 9.0064	+ 9.0103	+23.5061	....	−2.4	−22.9	5.8
49 to 50	2.450	89.045	− 5.1240	− 5.1195	....	− 5.1218	+18.3843	....	−4.5	−27.4	20.2
50 to XIV	0.368	89.413	+ 6.5511	+ 6.5506	....	+ 6.5509	+24.9352	10.8	+0.5	−26.9	0.2
XIV to G	0.036	89.449	+ 2.8902	+ 2.8899	....	+ 2.8900	+27.8252	10.8	+0.3	−26 6	0.1
50 to 51	2.498	91.543	+ 2.8214	+ 2.8211	....	+ 2.8213	+21.2056	....	+0.3	−27.1	0.1

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Discrepancy. Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm*)²
51 to 52	3.529	95.072	+ 8.5201	+ 8.5198	+ 8.5200	+ 29.7256	....	+ 0.3	−26.8	0.1
52 to XV	1.785	96.857	− 3.8483	− 3.8546	− 3.8515	+ 25.8741	11.0	+ 6.3	−20.5	39.7
XV to 53	2.681	99.538	+13.0679	+13.0706	+13.0692	+ 38.9433	....	− 2.7	−23.2	7.3
53 to 54	1.370	100.908	+ 4.6154	+ 4.6114	+ 4.6134	+ 43.5567	....	+ 4.0	−19.2	16.0
54 to 55	1.985	102.893	+ 4.6674	+ 4.6631	+ 4.6653	+ 48.2220	....	+ 4.3	−14.9	18.5
55 to 56	2.010	104.903	+ 4.9493	+ 4.9528	+ 4.9511	+ 53.1731	....	− 3.5	−18.4	12.2
56 to 57	1.472	106.375	− 0.5307	− 0.5257	− 0.5282	+ 52.6449	....	− 5.0	−23.4	25.0
57 to 58	1.610	107.985	+13.8987	+13.8971	+13.8979	+ 66.5428	....	+ 1.6	−21.8	2.6
58 to 59	1.613	109.598	+14.6625	+14.6653	+14.6639	+ 81.2067	....	− 2.8	−24.6	7.8
59 to 63	1.594	111.192	+ 7.0621	+ 7.0705	+ 7.0663	+ 88.2730	....	− 8.4	−33.0	70.6
63 to 62	0.518	111.710	+ 4.6206	+ 4.6230	+ 4.6218	+ 92.8948	....	− 2.4	−35.4	5.8
62 to 61	0.731	112.441	+ 7.2700	+ 7.2689	+ 7.2694	+100.1642	....	+ 1.1	−34.3	1.2
61 to XVI	1.326	113.767	+ 8.0814	+ 8.0827	+ 8.0820	+108.2462	11.8	− 1.3	−35.6	1.7

Transcontinental line of Spirit-levels—Continued.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ^2
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	$(mm)^2$
XVI to 60	1.362	115.129	− 3.3481	− 3.3541	− 3.3511	+104.8951	......	+ 6.0	−29.6	36.0
60 to 70	2.521	117.650	− 4.4895	− 4.4874	− 4.4884	+100.4067	......	− 2.1	−31.7	4.4
70 to 71	1.611	119.261	+10.3865	+10.3890	+10.3878	+110.7945	......	− 2.5	−34.2	6.2
71 to 68	1.608	120.869	+ 9.3449	+ 9.3500	+ 9.3474	+120.1419	......	− 5.1	−39.3	26.0
68 to 67	1.777	122.646	+15.8966	+15.9041	+15.9003	+136.0422	......	− 7.5	−46.8	56.2
67 to 72	2.542	125.188	+18.3370	+18.3326	+18.3348	+154.3770	......	+ 4.4	−42.4	19.4
72 to 73	3.756	128.944	−14.6553	−14.6470	−14.6511	+139.7259	......	− 8.3	−50.7	68.9
73 to 74	1.606	130.550	− 6.9057	− 6.9067	− 6.9062	+132.8197	......	+ 1.0	−49.7	1.0
74 to 75	0.847	131.397	− 2.3667	− 2.3695	− 2.3681	+130.4516	......	+ 2.8	−46.9	7.8
75 to 76	2.378	133.775	−10.4149	−10.4106	−10.4127	+120.0389	......	− 4.3	−51.2	18.5
76 to 77	2.032	135.807	− 7.4857	− 7.4779	− 7.4818	+112.5571	......	− 7.8	−59.0	60.8
77 to 78	2.482	138.289	−10.5440	−10.5416	−10.5428	+102.0143	......	− 2.4	−61.4	5.8
78 to XVII	0.633	138.922	− 2.5670	− 2.5663	− 2.5667	+ 99.4476	13.3	− 0.7	−62.1	0.5
XVII to 82	0.723	139.645	+ 0.7122	+ 0.7073	+ 0.7097	+100.1573	......	+ 4.9	−57.2	24.0
82 to 81	3.019	142.664	− 8.6542	− 8.6549	− 8.6545	+ 91.5028	......	+ 0.7	−56.5	0.5
81 to 80	1.576	144.240	− 0.7811	− 0.7863	− 0.7837	+ 90.7191	......	+ 5.2	−51.3	27.0
80 to XVIII	3.113	147.353	−10.5459	−10.5404	−10.5431	+ 80.1760	13.6	− 5.5	−56.8	30.2
XVIII to 79	1.220	148.573	− 5.9724	− 5.9746	− 5.9735	+ 74.2025	......	+ 2.2	−54.6	4.8
79 to 66	1.206	149.779	− 4.8083	− 4.8071	− 4.8077	+ 69.3948	......	− 1.2	−55.8	1.4
66 to XIX	1.331	151.110	− 4.0314	− 4.0298	− 4.0306	+ 65.3642	13.6	− 1.6	−57.4	2.6
XIX to 65	0.512	151.622	− 2.2295	− 2.2295	− 2.2295	+ 63.1347	......	0.0	−57.4	0.0
65 to 64	0.404	152.026	+29.3191	+29.3195	+29.3193	+ 92.4540	......	− 0.4	−57.8	0.2
64 to XX	0.393	152.419	+16.4387	+16.4387	+16.4387	+108.8927	13.6	0.0	−57.8	0.0
XX to H	0.068	152.487	+ 1.9212	+ 1.9218	+ 1.9215	+110.8142	13.6	− 0.6	−58.4	0.4
XIX to 83	1.764	152.874	+ 1.9025	+ 1.8970	+ 1.8997	+ 67.2639	......	+ 5.5	−51.9	30.2
83 to 84	1.147	154.021	− 1.0912	− 1.0958	− 1.0935	+ 66.1704	......	+ 4.6	−47.3	21.2
84 to 85	2.497	156.518	+ 0.4223	+ 0.4238	+ 0.4230	+ 66.5934	......	− 1.5	−48.8	2.2
85 to 86	1.267	157.785	+ 0.3850	+ 0.3823	+ 0.3837	+ 66.9771	......	+ 2.7	−46.1	7.3
86 to 87	1.468	159.253	+ 0.8361	+ 0.8276	+ 0.8319	+ 67.8090	......	+ 8.5	−37.6	72.2
87 to 88	1.458	160.711	− 0.0900	− 0.0924	− 0.0912	+ 67.7178	......	+ 2.4	−35.2	5.8
88 to 89	2.039	162.750	− 0.0940	− 0.1007	− 0.0974	+ 67.6204	......	+ 6.7	−28.5	44.9
89 to 90	1.786	164.536	− 0.5251	− 0.5309	− 0.5280	+ 67.0924	......	+ 5.8	−22.7	33.6
90 to 91	1.420	165.956	+ 2.7145	+ 2.7192	+ 2.7168	+ 69.8092	......	− 4.7	−27.4	22.1
91 to 94	0.994	166.950	− 0.5240	− 0.5249	− 0.5245	+ 69.2847	......	+ 0.9	−26.5	0.8
94 to 93	1.131	168.081	+ 0.3048	+ 0.2989	+ 0.3019	+ 69.5866	......	+ 5.9	−20.6	34.8
93 to 92	2.482	170.563	+ 2.9417	+ 2.9388	+ 2.9402	+ 72.5268	......	+ 2.9	−17.7	8.4
92 to 95	2.513	173.076	+ 2.1905	+ 2.1868	+ 2.1886	+ 74.7154	......	+ 3.7	−14.0	13.7
95 to 96	1.877	174.953	+ 0.9534	+ 0.9516	+ 0.9525	+ 75.6679	......	+ 1.8	−12.2	3.2
96 to 97	2.252	177.205	+ 1.5440	+ 1.5508	+ 1.5474	+ 77.2153	......	− 6.8	−19.0	46.2
97 to I	1.808	179.013	+20.6964	+20.6961	+20.6963	+ 97.9116	15.0	+ 0.3	−18.7	0.1
97 to XXI	2.142	179.347	+12.9821	+12.9805	+12.9813	+ 90.1966	15.0	+ 1.6	−17.4	2.6
XXI to 102	0.342	179.689	+ 2.5619	+ 2.5631	+ 2.5625	+ 92.7591	......	− 1.2	−18.6	1.4
102 to 101	0.607	180.296	+ 5.2495	+ 5.2505	+ 5.2500	+ 98.0091	......	− 1.0	−19.6	1.0
101 to 100	2.088	182.384	+15.9779	+15.9821	+15.9800	+113.9891	......	− 4.2	−23.8	17.6
100 to 99	2.171	184.555	+ 5.6936	+ 5.6993	+ 5.6965	+119.6856	......	− 5.7	−29.5	32.5
99 to 98	1.314	185.869	+10.4085	+10.4028	+10.4057	+130.0913	......	+ 5.7	−23.8	32.5
98 to 103	3.562	189.431	− 4.5249	− 4.5257	− 4.5253	+125.5660	......	+ 0.8	−23.0	0.6
103 to 104	2.119	191.550	−10.8775	−10.8770	−10.8773	+114.6887	......	− 0.5	−23.5	0.2
104 to XXII	1.092	192.642	+ 2.2782	+ 2.2807	+ 2.2794	+116.9681	15.4	− 2.5	−26.0	6.2
XXII to 105	1.787	194.429	+ 8.0814	+ 8.0732	+ 8.0773	+125.0454	......	+ 8.2	−17.8	67.2
105 to 106	1.642	196.071	+ 9.0241	+ 9.0265	+ 9.0253	+134.0707	......	− 2.4	−20.2	5.8
106 to 107	1.266	197.337	− 4.0234	− 4.0215	− 4.0224	+130.0483	......	− 1.9	−22.1	3.6
107 to XXIII	2.042	199.379	− 0.7061	− 0.7073	− 0.7067	+129.3416	15.7	+ 1.2	−20.9	1.4
XXIII to 112	1.909	201.288	+ 6.8478	+ 6.8469	+ 6.8474	+136.1890	......	+ 0.9	−20.0	0.8
112 to 113	2.738	204.026	+ 5.4299	+ 5.4343	+ 5.4321	+141.6211	......	− 4.4	−24.4	19.4

Transcontinental line of Spirit-levels—Continued.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm*)²
113 to 114	0.934	204.960	+ 4.6841	+ 4.6841	+ 4.6841	+146.3052	....	0.0	−24.4	0.0
114 to 124	3.851	208.811	− 9.7298	− 9.7229	− 9.7264	+136.5788	....	− 6.9	−31.3	47.6
124 to 123	1.591	210.402	+ 5.2042	+ 5.2053	+ 5.2047	+141.7835	....	− 1.1	−32.4	1.2
123 to 122	1.269	211.671	− 0.7888	− 0.7918	− 0.7903	+140.9932	....	+ 3.0	−29.4	9.0
122 to 121	2.635	214.306	− 4.2477	− 4.2485	− 4.2481	+136.7451	....	+ 0.8	−28.6	0.6
121 to 120	0.599	214.905	+ 4.4438	+ 4.4472	+ 4.4455	+141.1906	....	− 3.4	−32.0	11.6
120 to 119	1.623	216.528	− 6.3476	− 6.3489	− 6.3482	+134.8424	....	+ 1.3	−30.7	1.7
119 to 118	1.327	217.855	− 1.2923	− 1.2921	− 1.2922	+133.5502	....	− 0.2	−30.9	0.0
118 to 117	2.512	220.367	− 5.2592	− 5.2546	− 5.2569	+128.2933	....	− 4.6	−35.5	21.2
117 to 116	1.862	222.229	− 1.7003	− 1.6974	− 1.6988	+126.5945	....	− 2.9	−38.4	8.4
116 to 115	2.792	225.021	− 1.9911	− 1.9973	− 1.9942	+124.6003	....	+ 6.2	−32.2	38.4
115 to 108	1.842	226.863	− 5.8094	− 5.8086	− 5.8090	+118.7913	....	− 0.8	−33.0	0.6
108 to 109	2.704	229.567	− 4.9810	− 4.9811	− 4.9811	+113.8102	....	+ 0.1	−32.9	0.0
109 to 110	1.106	230.673	−10.3835	−10.3881	−10.3858	+103.4244	....	+ 4.6	−28.3	21.2
110 to 111	2.655	233.328	−21.1712	−21.1664	−21.1688	+ 82.2556	....	− 4.8	−33.1	23.0
111 to J	1.550	234.878	− 1.7769	− 1.7782	− 1.7776	+ 80.4780	16.4	+ 1.3	−31.8	1.7
J to 128	1.243	236.121	+ 2.1501	+ 2.1528	+ 2.1515	+ 82.6295	....	− 2.7	−34.5	7.3
128 to 127	1.388	237.509	+ 3.2521	+ 3.2534	+ 3.2528	+ 85.8823	....	− 1.3	−35.8	1.7
127 to 126	3.152	240.661	+15.7920	+15.7930	+15.7925	+101.6748	....	− 1.0	−36.8	1.0
126 to 125	3.292	243.953	+ 3.5989	+ 3.5954	+ 3.5971	+105.2719	....	+ 3.5	−33.3	12.2
125 to 129	2.083	246.036	+ 3.6567	+ 3.6555	+ 3.6561	+108.9280	....	+ 1.2	−32.1	1.4
129 to 130	2.377	248.413	+ 7.0364	+ 7.0362	+ 7.0363	+115.9643	....	+ 0.2	−31.9	0.0
130 to 134	2.327	250.740	+ 4.2824	+ 4.2766	+ 4.2795	+120.2438	....	+ 5.8	−26.1	33.6
134 to XXIV	3.384	254.124	+11.6491	+11.6506	+11.6498	+131.8936	16.6	− 1.5	−27.6	2.2
XXIV to 135	0.514	254.638	+ 2.9866	+ 2.9898	+ 2.9882	+134.8818	....	− 3.2	−30.8	10.2
135 to 141	2.115	256.753	+ 9.6631	+ 9.6631	+ 9.6631	+144.5449	....	0.0	−30.8	0.0
141 to 142	2.175	258.928	− 3.7156	− 3.7128	− 3.7142	+140.8307	....	− 2.8	−33.6	7.8
142 to XXV	1.265	260.193	+ 6.5025	+ 6.5053	+ 6.5039	+147.3346	16.7	− 2.8	−36.4	7.8
XXV to 145	1.977	262.170	− 8.6919	− 8.6902	− 8.6910	+138.6436	....	− 1.7	−38.1	2.9
145 to 144	1.076	263.246	+ 2.3105	+ 2.3091	+ 2.3098	+140.9534	....	+ 1.4	−36.7	2.0
144 to 143	2.479	265.725	+ 5.5321	+ 5.5407	+ 5.5364	+146.4898	....	− 8.6	−45.3	74.0
143 to 140	2.458	268.183	+ 0.7733	+ 0.7706	+ 0.7720	+147.2618	....	+ 2.7	−42.6	7.3
140 to 139	0.974	269.157	− 3.4426	− 3.4468	− 3.4447	+143.8171	....	+ 4.2	−38.4	17.6
139 to 138	2.174	271.331	+ 5.8382	+ 5.8297	+ 5.8339	+149.6510	....	+ 8.5	−29.9	72.2
138 to 131	2.373	273.704	+ 2.5448	+ 2.5427	+ 2.5437	+152.1947	....	+ 2.1	−27.8	4.4
131 to 132	2.926	276.630	− 4.3516	− 4.3578	− 4.3547	+147.8400	....	+ 6.2	−21.6	38.4
132 to 133	1.385	278.015	− 1.9742	− 1.9713	− 1.9727	+145.8673	....	− 2.9	−24.5	8.4
133 to 136	1.821	279.836	− 4.1364	− 4.1390	− 4.1377	+141.7296	....	+ 2.6	−21.9	6.8
136 to 137	0.072	279.908	− 0.3026	− 0.3021	− 0.3023	+141.4273	....	− 0.5	−22.4	0.2
137 to K	0.190	280.098	+ 0.5485	+ 0.5468	+ 0.5476	+141.9749	17.5	+ 1.7	−20.7	2.9
137 to XXVI	0.416	280.324	+ 3.2367	+ 3.2364	+ 3.2365	+144.6638	17.5	+ 0.3	−22.1	0.1
137 to 148	1.953	281.861	+ 0.1393	+ 0.1374	+ 0.1383	+141.5656	....	+ 1.9	−20.5	3.6
148 to 147	2.965	284.826	− 4.9048	− 4.9057	− 4.9053	+136.6603	....	+ 0.9	−19.6	0.8
147 to 146	2.775	287.601	− 2.9135	− 2.9173	− 2.9154	+133.7449	....	+ 3.8	−15.8	14.4
146 to XXVII	2.009	289.610	−10.2271	−10.2192	−10.2231	+123.5218	17.7	− 7.9	−23.7	62.4
XXVII to 149	2.622	292.232	+ 7.4301	+ 7.4277	+ 7.4289	+130.9507	....	+ 2.4	−21.3	5.8
149 to 150	1.722	293.954	+ 6.0924	+ 6.0944	+ 6.0934	+137.0441	....	− 2.0	−23.3	4.0
150 to 151	1.336	295.290	+ 0.4227	+ 0.4233	+ 0.4230	+137.4671	....	− 0.6	−23.9	0.4
151 to 154	1.693	296.983	− 7.7427	− 7.7475	− 7.7451	+129.7220	....	+ 4.8	−19.1	23.0
154 to 153	3.082	300.065	− 9.3709	− 9.3719	− 9.3714	+120.3506	....	+ 1.0	−18.1	1.0
153 to 152	2.286	302.351	− 0.5319	− 0.5361	− 0.5340	+119.8166	....	+ 4.2	−13.9	17.6
152 to 155	2.697	305.048	− 6.7718	− 6.7812	− 6.7765	+113.0401	....	+ 9.4	− 4.5	88.4
155 to XXVIII	2.947	307.995	− 0.9659	− 0.9607	− 0.9633	+112.0768	18.2	− 5.2	− 9.7	27.0
XXVIII to 159	1.343	309.338	+ 5.1935	+ 5.1901	+ 5.1918	+117.2686	....	+ 3.4	− 6.3	11.6
159 to 158	1.642	310.980	+ 8.0906	+ 8.0949	+ 8.0928	+125.3614	....	− 4.3	−10.6	18.5
158 to 157	2.770	313.750	+ 5.1039	+ 5.1103	+ 5.1071	+130.4685	....	− 6.4	−17.0	41.0

Transcontinental line of Spirit-levels—Continued.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm*)²
157 to 162	3.372	317.122	−16.4445	−16.4426	−16.4436	+114.0249	....	− 1.9	−18.9	3.6
162 to 156	4.297	321.419	−17.3639	−17.3619	−17.3629	+ 96.6620	....	− 2.0	−20.9	4.0
156 to XXIX	0.600	322.019	+12.0927	+12.0936	+12.0931	+108.7551	18.5	− 0.9	−21.8	0.8
XXIX to L	0.340	322.359	+ 3.2951	+ 3.2929	+ 3.2940	+112.0491	18.5	+ 2.2	−19.6	4.8
156 to 160	0.677	322.096	− 0.4216	− 0.4205	− 0.4211	+ 96.2409	....	− 1.1	−22.0	1.2
160 to 163	0.614	322.710	−0.5056 −0.5159 −0.5152 −0.5040	−0.5077 −0.5160 −0.5153 −0.5071*	− 0.5091	+ 95.7318	....	+ 1.3	−20.7	1.7
163 to 164	0.675	323.385	−0.3462 −0.3441 −0.3329	−0.3512 −0.3437 −0.3306†	− 0.3390	+ 95.3928	....	+ 0.7	−20.0	0.5
164 to 165	0.724	324.109	+13.9378	+13.9382	+13.9380	+109.3308	....	− 0.4	−20.4	0.2
165 to 169	2.551	326.660	+10.2388	+10.2332	+10.2360	+119.5668	....	+ 5.6	−14.8	31.4
169 to 166	3.603	330.263	+ 5.3357	+ 5.3386	+ 5.3372	+124.9040	....	− 2.9	−17.7	8.4
166 to 167	2.952	333.215	+ 8.1294	+ 8.1222	+ 8.1258	+133.0298	....	+ 7.2	−10.5	51.8
167 to 168	2.886	336.101	− 3.4626	− 3.4695	− 3.4660	+129.5638	....	+ 6.9	− 3.6	47.6
168 to 170	2.825	338.926	+ 1.0131	+ 1.0145	+ 1.0138	+130.5776	....	− 1.4	− 5.0	2.0
170 to 171	2.177	341.103	+ 3.4853	+ 3.4763	+ 3.4808	+134.0584	....	+ 9.0	+ 4.0	81.0
171 to 172	1.753	342.856	+ 4.7450	+ 4.7508	+ 4.7479	+138.8063	....	− 5.8	− 1.8	33.6
172 to 173	2.221	345.077	+ 0.1045	+ 0.1047	+ 0.1046	+138.9109	....	− 0.2	− 2.0	0.0
173 to 174	2.486	347.563	+ 3.7642	+ 3.7679	+ 3.7660	+142.6769	....	− 3.7	− 5.7	13.7
174 to 175	1.820	349.383	− 3.3149	− 2.3200	− 3.3175	+139.3594	....	+ 5.1	− 0.6	26.0
175 to M	1.847	351.230	+ 4.8750	+ 4.8740	+ 4.8745	+144.2339	19.4	+ 1.0	+ 0.4	1.0
M to 176	3.185	354.415	+ 0.4707	+ 0.4709	+ 0.4708	+144.7047	....	− 0.2	+ 0.2	0.0
176 to 177	2.809	357.224	− 5.7601	− 5.7716	− 5.7658	+138.9389	....	+11.5	+11.7	132.2
177 to 178	2.482	359.706	+15.7487	+15.7440	+15.7464	+154.6853	....	+ 4.7	+16.4	22.1
178 to 179	2.641	362.347	− 3.5971	− 3.5994	− 3.5983	+151.0870	....	+ 2.3	+18.7	5.3
179 to 182	3.108	365.455	+11.0716	+11.0648	+11.0682	+162.1552	....	+ 6.8	+25.5	46.2
182 to 181	2.149	367.604	− 0.6150	− 0.6153	− 0.6152	+161.5400	....	+ 0.3	+25.8	0.1
181 to 180	2.867	370.471	− 0.6354	− 0.6347	− 0.6351	+160.9049	....	− 0.7	+25.1	0.5
180 to 193	2.735	373.206	+15.6064	+15.6063	+15.6064	+176.5113	....	+ 0.1	+25.2	0.0
193 to 194	2.904	376.110	− 5.4378	− 5.4398	− 5.4388	+171.0725	....	+ 2.0	+27.2	4.0
194 to 188	2.633	378.743	+ 7.8495	+ 7.8514	+ 7.8504	+178.9229	....	− 1.9	+25.3	3.6
188 to 187	1.975	380.718	+ 1.9435	+ 1.9497	+ 1.9466	+180.8695	....	− 6.2	+19.1	38.4
187 to 186	2.053	382.771	+ 9.6586	+ 9.6565	+ 9.6575	+190.5270	....	+ 2.1	+21.2	4.4
186 to 185	2.322	385.093	+ 8.4885	+ 8.4958	+ 8.4922	+199.0192	....	− 7.3	+13.9	53.3
185 to 184	1.397	386.490	+ 1.3915	+ 1.3898	+ 1.3907	+200.4099	....	+ 1.7	+15.6	2.9
184 to 183	1.340	387.830	− 1.6236	− 1.6282	− 1.6259	+198.7840	....	+ 4.6	+20.2	21.2
183 to XXX	0.181	388.011	+ 0.5368	+ 0.5365	+ 0.5366	+199.3206	20.4	+ 0.3	+20.5	0.1
183 to 192	2.339	390.169	+13.7796	+13.7826	+13.7811	+212.5651	....	− 3.0	+17.2	9.0
192 to 191	2.769	392.938	+17.2464	+17.2461	+17.2462	+229.8113	....	+ 0.3	+17.5	0.1
191 to 190	3.372	396.310	− 6.8102	− 6.8180	− 6.8141	+222.9972	....	+ 7.8	+25.3	60.8
190 to 189	2.085	398.395	−12.6775	−12.6759	−12.6767	+210.3205	....	− 1.6	+23.7	2.6
189 to 195	3.721	402.116	− 3.1371	− 3.1303	− 3.1337	+207.1868	....	− 6.8	+16.9	46.2
195 to 196	2.517	404.633	−15.8293	−15.8334	−15.8314	+191.3554	....	+ 4.1	+21.0	16.8
196 to 197	1.465	406.098	+ 0.8022	+ 0.8063	+ 0.8043	+192.1597	....	− 4.1	+16.9	16.8
197 to N	0.578	406.676	− 2.9933	− 2.9927	− 2.9930	+189.1667	20.8	− 0.6	+16.3	0.4
197 to 198	2.687	408.785	− 5.0741	− 5.0813	− 5.0777	+187.0820	....	+ 7.2	+24.1	51.8
198 to 199	2.993	411.778	+ 6.7928	+ 6.7956	+ 6.7942	+193.8762	....	− 2.8	+21.3	7.8
199 to 200	3.351	415.129	+ 0.5389	+ 0.5378	+ 0.5384	+194.4146	....	+ 1.1	+22.4	1.2
200 to 201	1.151	416.280	− 1.1972	− 1.2023	− 1.1998	+193.2148	....	+ 5.1	+27.5	26.0
201 to 209	3.606	419.886	−16.0136	−16.0178	−16.0157	+177.1991	....	+ 4.2	+31.7	17.6
209 to 205	3.175	423.061	+ 3.0184	+ 3.0158	+ 3.0171	+180.2162	....	+ 2.6	+34.3	6.8

* Weight 3. † Weight 2.

Transcontinental line of Spirit-levels—Continued.

SECTION I.—FROM SANDY HOOK, N. J., TO HAGERSTOWN, MD.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks.			Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy.		Δ²
			Rod E, first line.	Rod F, second line.	Mean.			Partial Δ	Total.	
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm*)²
205 to XXXI	0.272	423.333	− 0.7987	− 0.8010	− 0.7999	+179.4163	21.1	+ 2.3	+36.6	5.3
205 to 206	2.500	425.561	− 9.0881	− 9.0956	− 9.0919	+171.1243	....	+ 7.5	+41.8	56.2
206 to 207	2.469	428.030	− 1.4737	− 1.4709	− 1.4723	+169.6520	....	− 2.8	+39.0	7.8
207 to 208	2.667	430.697	+ 2.3448	+ 2.3439	+ 2.3444	+171.9964	....	+ 0.9	+39.9	0.8
208 to 204	3.177	433.874	+ 5.8335	+ 5.8341	+ 5.8338	+177.8302	....	− 0.6	+39.3	0.4
204 to 203	1.048	434.922	+ 7.4887	+ 7.4917	+ 7.4902	+185.3204	....	− 3.0	+36.3	9.0
203 to 202	3.321	438.243	+ 9.5128	+ 9.5209	+ 9.5169	+194.8373	....	− 8.1	+28.2	65.6
202 to A	3.129	441.372	−26.4940	−26.5002	−26.4971	+168.3402	21.6	+ 6.2	+34.4	38.4

SECTION I.—*Descriptions of primary and secondary bench-marks between Sandy Hook, N. J., and Hagerstown, Md.*

T. H.—A heavy line on the northwest corner post, inside the tide-house at Sandy Hook. It is the starting-point of the line of levels.

No. I—The centre of the inner edge of the second embrasure, southwest corner of the fort at Sandy Hook.

A & B—Sandy Hook, are cedar posts 4 feet long and 8 inches in diameter, sunk in the ground with ends projecting about 4 inches. In the centre of each post is a copper nail surrounded by five others in form of a pentagon. These posts are 12 metres apart and bear east-northeast from the steamer-landing and nearly northeast from the tide-house, and are distant from the latter about 500 metres. They are also 95 metres northwest of the railroad red engine-house, and are in the edge of the cedars, where the ground is elevated a few feet above the marsh.

C.—A cross on the head of a copper bolt inserted in the wall of the main light-house tower at Sandy Hook. It is a few inches west of the northwest angle of the tower and 9¼ inches above the sloping ledge near its base.

No. II—A heavy granite post which projects about 2 feet above the surface of the ground, on the east side of the track of the New Jersey Southern Railroad about three-fourths mile north of Highland Station.

No. III—Navesink Highlands. A mark on top of a heavy granite post, 13 metres south of the southernmost light-house tower.

D—Navesink Highlands light-house. The bottom surface of a square cavity cut on the sloping ledge at the southeast corner of the base of the southernmost tower.

No. IV—Seabright, N. J. The bottom surface of a square cavity cut on the north wing-wall of the west abutment of the bridge over South Shrewsbury River.

No. V—A square cavity cut on the south pier of the "Oceanport Drawbridge," about 1½ miles north of Branchport Station, New Jersey Central Railroad.

E—Red Bank, N. J. A marble post near the southeast corner of the house of Rev. B. F. Leipser. The house stands on southwest corner of Monmouth and Pearl streets.

No. VI—Matawan, N. J. The centre of a triangle cut on a flagstone in front of Benjamin Tuttle's house, on Main street.

No. VII—Morgan Station, New Jersey Central Railroad, N. J. The centre of a triangle cut on the southeast pier of the drawbridge over Cheesequake Creek.

No. VIII—The centre of a triangle cut on stone wall at crossing of Camden and Amboy branch of Pennsylvania Railroad and New Jersey Central Railroad, near South Amboy.

F—The bottom surface of a square cavity cut on the pier at the north end of drawbridge, Raritan Bay. It is marked thus:

F
B □ M
U. S. C. & G. S.
1881

No. IX—A slight circular concavity, bounded by a triangle, cut on the west end of the south wall of stone bridge near Metuchen's Tank Station of Lehigh Valley Railroad. By means of this bridge the Pennsylvania Railroad crosses the Lehigh Valley Railroad.

No. X—A square cavity marked thus: B □ M, cut on stone abutment at the northwest corner of a small iron railroad bridge, about 150 metres east of South Plainfield Station, Lehigh Valley Railroad.

No. XI—Cut on northeast corner of stone abutment of railroad bridge (New Jersey Central Railroad) about one-fourth mile east of Bound Brook, N. J. It is marked thus: B □ M.

No. XII—Cut on the south end of a small railroad bridge, about three-fourths mile west of New Market Station, Lehigh Valley Railroad. It is marked thus:

B □ M
XII

No. XIII—A square cavity cut on top of the west end of the north abutment of road bridge over Raritan River and Canal at Bound Brook, N. J. It is marked thus: B □ M.

No. XIV—The bottom surface of a circular cavity in top of a granite monument (True Meridian Monument of the State Survey) in the grounds of the court-house at Somerville, N. J.

G—A square cavity cut in the stone at the base of the easternmost pillar of the court-house front, at Somerville, N. J. It is marked thus:

G
B □ M
U. S. C. & G. S.
1881.

No. XV—Cut on the southwest corner of the railroad bridge over the north branch of the Raritan River, near North Branch Station, New Jersey Central Railroad. It is marked:

B □ M
XV

No. XVI—Cut on projecting stone near the centre of the north abutment wall of overhead bridge, about one mile east of Annandale, N. J.

No. XVII—One-fourth mile west of Bloomsbury, N. J., on the northwest corner of a stone bridge (New Jersey Central Railroad) over wagon road. It is marked thus:

B □ M
1881

No. XVIII—Cut on coping stone at east end of the north parapet of New Jersey Central Railroad bridge over the Delaware and Lackawanna Canal, 1½ miles east of Phillipsburg, N. J. It is marked the same as No. XVII.

No. XIX—Easton, Pa. Cut on one of the central piers of the railroad bridge across the Lehigh River. It is marked thus:

U. S.
B □ M
XIX.

No. XX—Cut on foundation stone at the west corner of the jail at Easton, Pa. It is marked thus:

U. S.
B □ M
XX

H—Easton, Pa. The sill of a blind window on east side of the court-house. It is marked thus:

H
U. S. C. & G. S.
B □ M
1881.

I—Allentown, Pa. Cut on the sill of a basement window, on the south side of the front entrance of the jail. It is marked thus:

I
U. S. C. & G. S.
B □ M
1881.

No. XXI—About 1½ miles west of Allentown, Pa. It is cut on the northeast corner of a bridge (Philadelphia and Reading Railroad) over a wagon road. It is marked B □ M.

No. XXII—Cut on the top stone of the middle of the north side of a bridge (Philadelphia and Reading Railroad) over a small run, about one-half mile west of Macungie Station. It is marked thus:

XXII
B □ M
1881.

J—Reading, Pa. Cut on the coping stone of the eastern abutment of the northeasternmost railroad bridge at the railroad depot. It is marked thus:

J
U. S. C. & G. S.
B □ M
1881.

No. XXIII—About one-fourth mile east of Shamrock Station, Philadelphia and Reading Railroad. Cut on the southeast corner of a railroad bridge. It is marked thus: B □ M.

No. XXIV—About one-eighth mile east of Robesonia Station, Philadelphia and Reading Railroad. Cut on a pier of a small bridge. It is marked thus:

XXIV
B □ M
1881.

No. XXV—Cut at the east end of the base of the north wall of an overhead bridge, about 1½ miles west of Womelsdorf Station, Philadelphia and Reading Railroad. It is marked thus:

XXV
B □ M
1881.

No. XXVI—The centre of the cross, on a white marble block, built into the front wall of Saint Mary's Catholic Church, at Lebanon, Pa., at the south side of the southernmost front entrance.

K—The bottom of a square cavity, in the top of a marble post, in the grounds of Mr. P. L. Weiner, southeast corner of Eighth and Church streets, Lebanon, Pa. The top of the post is marked:

U. S.
□
B. M.

and its south face bears the letter K.

No. XXVII—At the southwest corner of the bridge (Philadelphia and Reading Railroad) over "Joe Crider's Dam," about 1¼ miles west of Annville, Lebanon County, Pennsylvania. It is marked thus:

XXVII
B □ M
1881

No. XXVIII—Cut on stone parapet of the bridge over Swatara River and Canal, between Beaver and Hummelstown Stations (Philadelphia and Reading Railroad.) It is marked thus:

XXVIII
B □ M
1881

No. XXIX—Harrisburg, Pa. The centre of the top surface of the monument (in the capitol grounds) marking the astronomical station of the Coast and Geodetic Survey.

L—Cut at the base of the pillar at the southeast corner of the capitol building, Harrisburg, Pa., and is marked thus:

L
U. S. C. & G. S.
B □ M
1881.

M—Carlisle, Pa. Cut on the base of the column, at the west side of the jail entrance. It is marked thus:

M
U. S. C. & G. S.
B □ M
1881

No. XXX—Shippensburg, Pa. Cut on the water-table of the house and store of Mr. C. J. Reddig, northwest corner of Main and Railroad streets. It is marked thus: B □ M.

N—Cut on the pedestal, at base of the northernmost pillar of the front of the court-house at Chambersburg, Pa. It is marked thus:

N
U. S. C. & G. S.
B □ M
1881.

No. XXXI—Greencastle, Pa. The centre of a cross, cut in a stone in the front wall of the Philadelphia and Reading Railroad depot. It is south of the entrance and seven inches above the level of the sidewalk.

A—Hagerstown, Md. Cut on the water-table of the court-house, which stands at the corner of Washington and Jonathan streets. The bench-mark is on the Jonathan street side. It is marked thus:

A
B □ M
U. S. C. S.
Oct. 1877.

Transcontinental line of Spirit-levels—Continued.

SECTION II.—FROM HAGERSTOWN, MD., TO GRAFTON, W. VA.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ.	Total.	
	km.	km.	m.	m.	m.	m.	± mm.	mm.	mm.	(mm.)²
A	....	441.372	....	....	....	+168.3402	21.6	....	+34.4	....
A to 1	0.566	441.938	− 0.4735	− 0.4726	− 0.4730	+167.8672	....	− 0.9	+33.5	0.8
1 to I	1.198	443.136	+ 3.9905	+ 3.9914	+ 3.9909	+171.8581	21.6	− 0.9	+32.6	0.8
I to 3	1.043	444.179	+ 7.7253	+ 7.7268	+ 7.7260	+179.5841	....	− 1.5	+31.1	2.2
3 to II	0.716	444.895	− 2.5639	− 2.5639	− 2.5639	+177.0202	21.6	0.0	+31.1	0.0
II to 4	1.623	446.518	+ 1.1564	+ 1.1633	+ 1.1599	+178.1801	....	− 6.9	+24.2	47.6
4 to 5	0.627	447.145	−15.6442	−15.6483	−15.6463	+162.5338	....	+ 4.1	+28.3	16.8
5 to IV	0.987	448.132	−11.7305	−11.7296	−11.7300	+150.8038	21.7	− 0.9	+27.4	0.8
IV to 6	0.271	448.403	+ 4.0371	+ 4.0364	+ 4.0367	+154.8405	....	+ 0.7	+28.1	0.5
6 to 7	0.567	448.970	− 5.1413	− 5.1403	− 5.1408	+149.6997	....	− 1.0	+27.1	1.0
7 to 8	0.585	449.555	− 5.1227	− 5.1230	− 5.1228	+144.5769	....	+ 0.3	+27.4	0.1
8 to V	0.194	449.749	− 8.1843	− 8.1822	− 8.1833	+136.3936	21.7	− 2.1	+25.3	4.4
V to 9	1.426	451.175	− 4.8648	− 4.8661	− 4.8654	+131.5282	....	+ 1.3	+26.6	1.7
9 to 11	0.456	451.631	− 7.0137	− 7.0122	− 7.0130	+124.5152	....	− 1.5	+25.1	2.3
11 to 12	0.392	452.023	− 9.5686	− 9.5689	− 9.5687	+114.9465	....	+ 0.3	+25.4	0.1
12 to 13	0.137	452.160	− 5.7244	− 5.7248	− 5.7246	+109.2219	....	+ 0.4	+25.8	0.2
13 to B	0.248	452.408	− 0.1036	− 0.1035	− 0.1036	+109.1183	21.8	− 0.1	+25.7	0.0
B to 14	1.253	453.661	+ 0.1406	+ 0.1353	+ 0.1380	+109.2563	....	+ 5.3	+31.0	28.1
14 to 15	1.381	455.042	− 0.1286	− 0.1283	− 0.1285	+109.1278	....	− 0.3	+30.7	0.1
15 to 16	0.741	455.783	− 0.0574	− 0.0551	− 0.0562	+109.0716	....	− 2.3	+28.4	5.3
16 to 17	1.018	456.801	− 0.0035	− 0.0034	− 0.0035	+109.0681	....	− 0.1	+28.3	0.0
17 to 18	1.021	457.822	− 0.2061	− 0.2110	− 0.2085	+108.8596	....	+ 4.9	+33.2	24.0
18 to 19	0.929	458.751	+ 0.0090	+ 0.0129	+ 0.0109	+108.8705	....	− 3.9	+29.3	15.2
19 to 20	1.138	459.889	+ 0.2207	+ 0.2187	+ 0.2197	+109.0902	....	+ 2.0	+31.3	4.0
20 to 21	0.900	460.789	− 0.0592	− 0.0569	− 0.0581	+109.0321	....	− 2.3	+29.0	5.3
21 to 22	1.825	462.614	+ 0.1171	+ 0.1172	+ 0.1172	+100.1493	....	− 0.1	+28.9	0.0
22 to 23	0.268	462.882	+ 0.4856	+ 0.4868	+ 0.4862	+109.6355	....	− 1.2	+27.7	1.4
23 to C	0.764	463.646	+ 3.7106	+ 3.7075	+ 3.7090	+113.3445	22.0	+ 3.1	+30.8	9.6
C to 24	0.479	464.125	− 1.0881	− 1.0867	− 1.0874	+112.2571	....	− 1.4	+29.4	2.0
24 to VI	0.592	464.717	+ 1.0021	+ 1.0063	+ 1.0042	+113.2613	22.0	− 4.2	+25.2	17.6
VI to 25	0.359	465.076	+ 0.3310	+ 0.3307	+ 0.3309	+113.5922	....	+ 0.3	+25.5	0.1
25 to 26	1.480	466.556	− 0.4139	− 0.4121	− 0.4130	+113.1792	....	− 1.8	+23.7	3.2
26 to D	0.617	467.173	+10.1046	+10.1033	+10.1040	+123.2832	22.1	+ 1.3	+25.0	1.7
D to 27	1.060	468.233	− 0.0404	− 0.0375	− 0.0390	+123.2422	....	− 2.9	+22.1	8.4
27 to 28	0.898	469.131	+ 0.1460	+ 0.1436	+ 0.1448	+123.3870	....	+ 2.4	+24.5	5.8
28 to 29	1.382	470.513	+ 0.0525	+ 0.0502	+ 0.0514	+123.4384	....	+ 2.3	+26.8	5.3
29 to 30	1.663	472.176	− 0.2555	− 0.2589	− 0.2572	+123.1812	....	+ 3.4	+30.2	11.6
30 to 31	1.333	473.509	+ 0.2285	+ 0.2326	+ 0.2305	+123.4117	....	− 4.1	+26.1	16.8
31 to VII	0.588	474.097	+ 0.2449	+ 0.2443	+ 0.2446	+123.6563	22.2	+ 0.6	+26.7	0.4
VII to 32	1.579	475.676	− 0.0172	− 0.0169	− 0.0170	+123.6393	....	− 0.3	+26.4	0.1
32 to 33	1.360	477.036	− 0.0695	− 0.0714	− 0.0705	+123.5688	....	+ 1.9	+28.3	3.6
33 to 34	1.354	478.390	− 0.1080	− 0.1073	− 0.1076	+123.4612	....	− 0.7	+27.6	0.5
34 to E	0.811	479.201	− 0.0682	− 0.0642	− 0.0662	+123.3950	22.2	− 4.0	+23.6	16.0
E to 35	1.698	480.899	+ 0.2246	+ 0.2192	+ 0.2219	+123.6169	....	+ 5.4	+29.0	29.2
35 to 36	1.105	482.004	+ 0.0128	+ 0.0135	+ 0.0131	+123.6300	....	− 0.7	+28.3	0.5
36 to 38	1.572	483.576	− 0.2338	− 0.2315	− 0.2326	+123.3974	....	− 2.3	+26.0	5.3
38 to 39	0.819	484.395	+ 0.2057	+ 0.2095	+ 0.2076	+123.6050	....	− 3.8	+22.2	14.4
39 to 40	1.947	486.342	− 0.5674	− 0.5704	− 0.5689	+123.0361	....	+ 3.0	+25.2	9.0
40 to 41	1.233	487.575	+ 0.5719	+ 0.5744	+ 0.5731	+123.6092	....	− 2.5	+22.7	6.2
41 to 42	1.392	488.967	− 0.0784	− 0.0842	− 0.0813	+123.5279	....	+ 5.8	+28.5	33.6
42 to VIII	0.888	489.855	+ 4.0097	+ 4.0078	+ 4.0088	+127.5367	22.5	+ 1.9	+30.4	3.6
VIII to F	1.689	491.544	+ 0.7553	+ 0.7615	+ 0.7584	+128.2951	22.6	− 6.2	+24.2	38.4
F to 43	0.709	492.253	+ 0.0319	+ 0.0356	+ 0.0337	+128.3288	....	− 3.7	+20.5	13.7
43 to 44	1.384	493.637	+ 0.1647	+ 0.1654	+ 0.1651	+128.4939	....	− 0.7	+19.8	0.5
44 to 45	1.366	495.003	− 1.2581	− 1.2609	− 1.2595	+127.2344	....	+ 2.8	+22.6	7.8
45 to 46	0.917	495.920	+ 1.2802	+ 1.2794	+ 1.2798	+128.5142	....	+ 0.8	+23.4	0.6
46 to 47	1.134	497.054	+ 0.1621	+ 0.1586	+ 0.1603	+128.6745	....	+ 3.5	+26.9	12.3

Transcontinental line of Spirit-levels—Continued.

SECTION II.—FROM HAGERSTOWN, MD., TO GRAFTON, W. VA.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
47 to 48	1.215	498.269	− 0.0732	− 0.0705	− 0.0718	+128.6027	....	− 2.7	+24.2	7.3
48 to 49	1.548	499.817	+ 0.3720	+ 0.3653	+ 0.3686	+128.9713	....	+ 6.7	+30.9	44.9
49 to IX	1.461	501.278	+ 1.2537	+ 1.2534	+ 1.2536	+130.2249	22.8	+ 0.3	+31.2	0.1
IX to 50	0.900	502.178	+ 0.5224	+ 0.5230	+ 0.5227	+130.7476	....	− 0.6	+30.6	0.4
50 to 51	1.562	503.740	− 0.2117	− 0.2109	− 0.2113	+130.5363	....	− 0.8	+29.8	0.6
51 to 52	1.301	505.041	+ 0.3728	+ 0.3691	+ 0.3709	+130.9072	....	+ 3.7	+33.5	13.7
52 to 53	1.498	506.539	+ 0.3134	+ 0.3135	+ 0.3135	+131.2207	....	− 0.1	+33.4	0.0
53 to G	1.308	507.847	+ 4.1005	+ 4.0999	+ 4.1002	+135.3209	22.8	+ 0.6	+34.0	0.4
G to 54	1.589	509.436	+ 0.4053	+ 0.4090	+ 0.4071	+135.7280	....	− 3.7	+30.3	13.7
54 to 55	0.895	510.331	− 0.2223	− 0.2214	− 0.2218	+135.5062	....	− 0.9	+29.4	0.8
55 to X	1.022	511.353	+ 2.1921	+ 2.1904	+ 2.1912	+137.6974	22.9	+ 1.7	+31.1	2.9
X to 56	1.965	513.318	+ 0.1240	+ 0.1217	+ 0.1229	+137.8203	....	+ 2.3	+33.4	5.3
56 to 57	0.960	514.278	+ 0.2818	+ 0.2842	+ 0.2830	+138.1033	....	− 2.4	+31.0	5.8
57 to 58	1.600	515.878	+ 0.2801	+ 0.2779	+ 0.2790	+138.3823	....	+ 2.2	+33.2	4.8
58 to XI	0.246	516.124	+ 1.2980	+ 1.2972	+ 1.2976	+139.6799	22.9	+ 0.8	+34.0	0.6
XI to 59	0.903	517.027	+ 0.7870	+ 0.7870	+ 0.7870	+140.4669	....	0.0	+34.0	0.0
59 to XII	1.803	518.830	− 0.3178	− 0.3157	− 0.3168	+140.1501	22.9	− 2.1	+31.9	4.4
XII to 60	1.203	520.033	+ 0.0029	+ 0.0024	+ 0.0027	+140.1528	....	+ 0.5	+32.4	0.2
60 to 61	1.634	521.667	+ 0.7359	+ 0.7370	+ 0.7364	+140.8892	....	− 1.1	+31.3	1.2
61 to XIII	2.045	523.712	+ 1.6695	+ 1.6699	+ 1.6697	+142.5589	23.0	− 0.4	+30.9	0.2
XIII to 62	1.308	525.020	− 0.0249	− 0.0254	− 0.0251	+142.5338	....	+ 0.5	+31.4	0.2
62 to 63	1.718	526.738	+ 0.4618	+ 0.4592	+ 0.4605	+142.9943	....	+ 2.6	+34.0	6.8
63 to 64	1.570	528.308	+ 2.0753	+ 2.0755	+ 2.0754	+145.0697	....	− 0.2	+33.8	0.0
64 to 65	2.055	530.363	+ 0.3511	+ 0.3524	+ 0.3517	+145.4214	....	− 1.3	+32.5	1.7
65 to 66	1.622	531.985	− 0.7265	− 0.7283	− 0.7274	+144.6940	....	+ 1.8	+34.3	3.2
66 to 67	1.529	533.514	+ 2.9832	+ 2.9835	+ 2.9834	+147.6774	....	− 0.3	+34.0	0.1
67 to 68	1.911	535.425	+ 0.2570	+ 0.2524	+ 0.2547	+147.9321	....	+ 4.6	+38.6	21.2
68 to 69	1.517	536.942	− 0.2210	− 0.2229	− 0.2220	+147.7101	....	+ 1.9	+40.5	3.6
69 to H	1.334	538.276	+ 2.3656	+ 2.3686	+ 2.3671	+150.0772	23.1	− 3.0	+37.5	9.0
H to 70	1.944	540.220	+ 3.3000	+ 3.2970	+ 3.2985	+153.3757	....	+ 3.0	+40.5	9.0
70 to 71	0.414	540.634	+ 4.7588	+ 4.7567	+ 4.7577	+158.1334	....	+ 2.1	+42.6	4.4
71 to 72	0.896	541.530	+ 4.7058	+ 4.7025	+ 4.7042	+162.8376	....	+ 3.3	+45.9	10.9
72 to XIV	0.099	541.629	− 0.5564	− 0.5568	− 0.5566	+162.2810	23.1	+ 0.4	+46.3	0.2
XIV to 73	0.957	542.586	+ 0.5349	+ 0.5349	+ 0.5349	+162.8159	....	0.0	+46.3	0.0
73 to 74	1.452	544.038	− 0.3372	− 0.3357	− 0.3365	+162.4794	....	− 1.5	+44.8	2.2
74 to 75	1.671	545.709	− 0.1526	− 0.1503	− 0.1514	+162.3280	....	− 2.3	+42.5	5.3
75 to 76	1.587	547.296	+ 0.3824	+ 0.3809	+ 0.3816	+162.7096	....	+ 1.5	+44.0	2.3
76 to 77	1.315	548.611	− 0.1780	− 0.1764	− 0.1772	+162.5324	....	− 1.6	+42.4	2.6
77 to 78	1.895	550.506	− 0.2396	− 0.2376	− 0.2386	+162.2938	....	− 2.0	+40.4	4.0
78 to 79	0.307	550.813	+ 0.4421	+ 0.4425	+ 0.4423	+162.7361	....	− 0.4	+40.0	0.2
79 to XV	1.336	552.149	+ 1.9889	+ 1.9819	+ 1.9854	+164.7215	23.3	+ 7.0	+47.0	49.0
XV to 80	1.689	553.838	+ 0.2443	+ 0.2499	+ 0.2471	+164.9686	....	− 5.6	+41.4	31.4
80 to 81	1.865	555.703	+ 1.0625	+ 1.0590	+ 1.0608	+166.0294	....	+ 3.5	+44.9	12.2
81 to 82	1.513	557.216	+ 1.2019	+ 1.1996	+ 1.2007	+167.2301	....	+ 2.3	+47.2	5.3
82 to 83	2.044	559.260	+ 0.0104	+ 0.0139	+ 0.0122	+167.2423	....	− 3.5	+43.7	12.3
83 to 84	1.331	560.591	+ 5.1768	+ 5.1729	+ 5.1748	+172.4171	....	+ 3.9	+47.6	15.2
84 to 85	2.749	563.340	+ 2.3589	+ 2.3615	+ 2.3602	+174.7773	....	− 2.6	+45.0	6.8
85 to 86	0.564	563.904	− 0.0092	− 0.0080	− 0.0086	+174.7687	....	− 1.2	+43.8	1.4
86 to 87	1.945	565.849	− 0.1307	− 0.1268	− 0.1287	+174.6400	....	− 3.9	+39.9	15.2
87 to 88	1.069	566.918	+ 0.1057	+ 0.1074	+ 0.1065	+174.7465	....	− 2.7	+37.2	7.3
88 to 89	1.657	568.575	+ 0.0200	+ 0.0203	+ 0.0202	+174.7667	....	− 0.3	+36.9	0.1
89 to 90	1.487	570.062	− 0.1989	− 0.2052	− 0.2021	+174.5646	....	+ 6.3	+43.2	39.7
90 to 91	1.764	571.826	+ 0.1927	+ 0.1905	+ 0.1916	+174.7562	....	+ 2.2	+45.4	4.8
91 to 92	1.504	573.330	+ 2.7870	+ 2.7887	+ 2.7879	+177.5441	....	− 1.7	+43.7	2.9
92 to 93	0.256	573.586	− 0.1348	− 0.1351	− 0.1350	+177.4091	....	+ 0.3	+44.0	0.1
93 to XVI	0.676	574.262	+ 1.7064	+ 1.7042	+ 1.7053	+179.1144	23.7	+ 2.2	+46.2	4.8
XVI to 94	0.185	574.447	+ 2.8076	+ 2.8057	+ 2.8067	+181.9211	....	+ 1.9	+48.1	3.6

Transcontinental line of Spirit-levels—Continued.

SECTION II.—FROM HAGERSTOWN, MD., TO GRAFTON, W. VA.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
94 to 95	0.107	574.554	+ 2.9419	+ 2.9409	+ 2.9414	+184.8625	....	+ 1.0	+49.1	1.0
95 to 96	2.331	576.885	+ 1.6793	+ 1.6788	+ 1.6790	+186.5415	....	+ 0.5	+49.6	0.2
96 to 97	0.848	577.733	− 0.1740	− 0.1727	− 0.1733	+186.3682	....	− 1.3	+48.3	1.7
97 to 98	2.424	580.157	+ 0.0072	+ 0.0074	+ 0.0073	+186.3755	....	− 0.2	+48.1	0.0
98 to 99	0.570	580.727	− 0.0724	− 0.0780	− 0.0752	+186.3003	....	+ 5.6	+53.7	31.4
99 to 100	1.875	582.602	+ 0.0743	+ 0.0744	+ 0.0743	+186.3746	....	− 0.1	+53.6	0.0
100 to 101	0.317	582.919	+ 0.0513	+ 0.0515	+ 0.0514	+186.4260	....	− 0.2	+53.4	0.0
101 to 102	1.482	584.401	+ 1.5330	+ 1.5329	+ 1.5330	+187.9590	....	+ 0.1	+53.5	0.0
102 to I	1.133	585.534	+ 2.1457	+ 2.1469	+ 2.1463	+190.1053	23.8	− 1.2	+52.3	1.4
I to 103	1.247	586.781	+ 2.8642	+ 2.8602	+ 2.8622	+192.9675	....	+ 4.0	+56.3	16.0
103 to 104	0.267	587.048	− 1.6519	− 1.6484	− 1.6502	+191.3173	....	− 3.5	+52.8	12.2
104 to 105	2.637	589.685	+ 1.5553	+ 1.5572	+ 1.5563	+192.8736	....	− 1.9	+50.9	3.6
105 to 106	1.682	591.367	+ 1.9943	+ 1.9951	+ 1.9947	+194.8683	....	− 0.8	+50.1	0.6
106 to 107	1.734	593.101	+ 2.8240	+ 2.8214	+ 2.8227	+197.6910	....	+ 2.6	+52.7	6.8
107 to XVII	1.422	594.523	− 0.3732	− 0.3735	− 0.3734	+197.3176	23.9	+ 0.3	+53.0	0.1
XVII to 108	1.156	595.679	+ 3.9592	+ 3.9567	+ 3.9580	+201.2756	....	+ 2.5	+55.5	6.3
108 to 109	1.538	597.217	+ 0.6937	+ 0.6951	+ 0.6944	+201.9700	....	− 1.4	+54.1	2.0
109 to 110	1.358	598.575	+ 5.0048	+ 5.0077	+ 5.0062	+206.9762	....	− 2.9	+51.2	8.4
110 to 111	1.426	600.001	− 0.7084	− 0.7126	− 0.7105	+206.2657	....	+ 4.2	+55.4	17.6
111 to 112	1.624	601.625	+ 0.0020	+ 0.0019	+ 0.0020	+206.2677	....	+ 0.1	+55.5	0.0
112 to 113	1.452	603.077	+ 2.7360	+ 2.7347	+ 2.7353	+209.0030	....	+ 1.3	+56.8	1.7
113 to XVIII	0.725	603.802	+ 2.5289	+ 2.5291	+ 2.5290	+211.5320	23.9	− 0.2	+56.6	0.0
XVIII to 115	2.288	606.090	+ 3.4140	+ 3.4117	+ 3.4129	+214.9449	....	+ 2.3	+58.9	5.3
115 to 116	0.963	607.053	+ 2.3147	+ 2.3147	+ 2.3147	+217.2596	....	0.0	+58.9	0.0
116 to 117	0.390	607.443	+ 0.3438	+ 0.3432	+ 0.3435	+217.6031	....	+ 0.6	+59.5	0.4
117 to 118	1.565	609.008	+ 2.0632	+ 2.0652	+ 2.0642	+219.6673	....	− 2.0	+57.5	4.0
118 to 119	1.910	610.918	+ 5.7194	+ 5.7180	+ 5.7187	+225.3860	....	+ 1.4	+58.9	2.0
119 to 120	1.688	612.606	+ 3.1739	+ 3.1699	+ 3.1719	+228.5579	....	+ 4.0	+62.9	16.0
120 to 121	1.153	613.759	+ 1.0672	+ 1.0616	+ 1.0644	+229.6223	....	+ 5.6	+68.5	31.4
121 to XIX	1.862	615.621	+ 4.2780	+ 4.2736	+ 4.2758	+233.8981	24.1	+ 4.4	+72.9	19.4
XIX to 122	1.408	617.029	+ 2.9328	+ 2.9267	+ 2.9297	+236.8278	....	+ 6.1	+79.0	37.2
122 to 123	2.317	619.346	+ 4.9722	+ 4.9725	+ 4.9724	+241.8002	....	− 0.3	+78.7	0.1
123 to 124	1.542	620.888	+ 2.2438	+ 2.2436	+ 2.2437	+244.0439	....	+ 0.2	+78.9	0.0
124 to 125	0.327	621.215	+ 0.6686	+ 0.6689	+ 0.6687	+244.7126	....	− 0.3	+78.6	0.0
125 to J	0.215	621.430	+ 0.0113	+ 0.0138	+ 0.0126	+244.7252	24.2	− 2.5	+76.1	6.2
J to 126	1.793	623.223	+ 7.9878	+ 7.9937	+ 7.9907	+252.7159	....	− 5.9	+70.2	34.8
126 to 127	1.607	624.830	+ 3.4980	+ 3.5094	+ 3.5037	+256.2196	....	−11.4	+58.8	130.0
127 to 128	1.647	626.477	+ 6.3315	− 6.3356	+ 6.3336	+262.5532	....	− 4.1	+54.7	16.8
128 to 129	1.753	628.230	+ 7.6956	+ 7.6894	+ 7.6925	+270.2457	....	+ 6.2	+60.9	38.4
129 to 130	1.670	629.900	+ 8.6968	+ 8.6906	+ 8.6937	+278.9394	....	+ 6.2	+67.1	38.4
130 to 133	1.531	631.431	+ 8.7896	+ 8.7914	+ 8.7905	+287.7299	....	− 1.8	+65.3	3.2
133 to 134	0.676	632.107	+ 5.5492	+ 5.5466	+ 5.5479	+293.2778	....	+ 2.6	+67.9	6.8
134 to 135	0.706	632.813	+11.2106	+11.2098	+11.2102	+304.4880	....	+ 0.8	+68.7	0.6
135 to XX	0.139	632.952	+ 2.9403	+ 2.9416	+ 2.9409	+307.4289	24.9	− 1.3	+67.4	1.7
XX to 136	1.026	633.978	+22.2756	+22.2779	+22.2768	+329.7057	....	− 2.3	+65.1	5.3
136 to 137	0.243	634.221	+ 5.5416	+ 5.5443	+ 5.5429	+335.2486	....	− 2.7	+62.4	7.3
137 to 138	0.133	634.354	+ 2.8546	+ 2.8547	+ 2.8547	+338.1033	....	− 0.1	+62.3	0.0
138 to 139	0.891	635.245	+19.9130	+19.9181	+19.9155	+358.0188	....	− 5.1	+57.2	26.0
139 to 140	0.765	636.010	+17.2142	+17.2153	+17.2148	+375.2336	25.0	− 1.1	+56.1	1.2
140 to 141	0.879	636.889	+18.8744	+18.8775	+18.8759	+394.1095	....	− 3.1	+53.0	9.6
141 to 142	0.504	637.393	+10.9713	+10.9630	+10.9672	+405.0767	....	+ 8.3	+61.3	68.9
142 to 143	0.228	637.621	+ 5.4681	+ 5.4720	+ 5.4700	+410.5467	....	− 3.9	+57.4	15.2
143 to 144	0.774	638.395	+16.7073	+16.7043	+16.7058	+427.2525	....	+ 3.0	+60.4	9.0
144 to 145	0.792	639.187	+17.5417	+17.5463	+17.5440	+444.7965	....	− 4.6	+55.8	21.2
145 to 146	0.772	639.959	+17.2213	+17.2176	+17.2195	+462.0160	....	+ 3.7	+59.5	13.7
146 to 147	0.910	640.869	+20.1918	+20.1976	+20.1947	+482.2107	....	− 5.8	+53.7	33.6
147 to 148	0.634	641.503	+13.7728	+13.7715	+13.7721	+495.9828	....	+ 1.3	+55.0	1.7

Transcontinental line of Spirit-levels—Continued.

SECTION II.—FROM HAGERSTOWN, MD., TO GRAFTON, W. VA.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ.	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
148 to 149	0.118	641.621	+ 2.8569	+ 2.8570	+ 2.8570	+498.8398	....	− 0.1	+54.9	0.0
149 to 150	0.103	641.724	+ 2.3830	+ 2.3828	+ 2.3829	+501.2227	....	+ 0.2	+55.1	0.0
150 to 151	0.812	642.536	+17.4878	+17.4924	+17.4901	+518.7128	....	− 4.6	+50.5	21.2
151 to 152	0.787	643.323	+17.1792	+17.1813	+17.1802	+535.8930	....	− 2.1	+48.4	4.4
152 to 153	0.898	644.221	+19.4817	+19.4816	+19.4816	+555.3746	....	+ 0.1	+48.5	0.0
153 to 154	0.884	645.105	+19.0520	+19.0573	+19.0547	+574.4293	....	− 5.3	+43.2	28.1
154 to 155	0.124	645.229	+ 2.3381	+ 2.3374	+ 2.3377	+576.7670	....	+ 0.7	+43.9	0.5
155 to 156	0.110	645.339	+ 2.8626	+ 2.8666	+ 2.8646	+579.6316	....	− 4.0	+39.9	16.0
156 to 158	1.136	646.475	+24.7405	+24.7387	+24.7396	+604.3712	....	+ 1.8	+41.7	3.2
158 to 159	1.234	647.709	+25.8738	+25.8784	+25.8761	+630.2473	....	− 4.6	+37.1	21.2
159 to 160	1.048	648.757	+23.1769	+23.1828	+23.1799	+653.4272	....	− 5.9	+31.2	34.8
160 to 161	0.138	648.895	+ 3.0246	+ 3.0234	+ 3.0240	+656.4512	....	+ 1.2	+32.4	1.4
161 to 176	0.932	649.827	+20.5837	+20.5867	+20.5852	+677.0364	....	− 3.0	+29.4	9.0
176 to XXV	0.773	650.600	+16.3311	+16.3247	+16.3279	+693.3643	25.7	+ 6.4	+35.8	41.0
XXV to 177	0.434	651.034	+ 4.5086	+ 4.5052	+ 4.5069	+697.8712	....	+ 3.4	+39.2	11.6
177 to 178	1.074	652.108	+16.4486	+16.4541	+16.4513	+714.3225	....	− 5.5	+33.7	30.2
178 to 179	0.996	653.104	+17.1726	+17.1690	+17.1708	+731.4933	....	+ 3.6	+37.3	13.0
179 to 180	0.702	653.806	+14.1850	+14.1880	+14.1865	+745.6798	....	− 3.0	+34.3	9.0
180 to 181	0.842	654.648	+16.6639	+16.6678	+16.6659	+762.3457	....	− 3.9	+30.4	15.2
181 to 182	0.998	655.646	+17.4292	+17.4252	+17.4272	+779.7729	....	+ 4.0	+34.4	16.0
182 to 183	1.353	656.999	+20.7280	+20.7305	+20.7292	+800.5021	....	− 2.5	+31.9	6.3
183 to 184	1.254	658.253	−12.7362	−12.7351	−12.7357	+787.7664	....	− 1.1	+30.8	1.2
184 to 185	1.468	659.721	−14.6186	−14.6117	−14.6152	+773.1512	....	− 6.9	+23.9	47.6
185 to 186	0.235	659.956	− 2.5130	− 2.5145	− 2.5137	+770.6375	....	+ 1.5	+25.4	2.2
186 to 171	1.735	661.691	−17.0557	−17.0563	−17.0560	+753.5815	....	+ 0.6	+26.0	0.4
171 to XXIII	0.528	662.219	− 4.9314	− 4.9300	− 4.9307	+748.6508	26.1	− 1.4	+24.6	2.0
XXIII to 170	1.302	663.521	− 7.1585	− 7.1658	− 7.1622	+741.4886	....	+ 7.3	+31.9	53.3
170 to 169	1.781	665.302	− 5.1545	− 5.1546	− 5.1545	+736.3341	....	+ 0.1	+32.0	0.0
169 to XXII	1.566	666.868	− 3.4189	− 3.4127	− 3.4158	+732.9183	26.3	− 6.2	+25.8	38.4
XXII to 168	1.618	668.486	− 4.4137	− 4.4204	− 4.4170	+728.5013	....	+ 6.7	+32.5	44.9
168 to 167	1.662	670.148	− 2.8081	− 2.8234	− 2.8158	+725.6855	....	+15.3	+47.8	234.1
167 to 162	1.563	671.711	− 1.2918	− 1.2934	− 1.2926	+724.3929	....	+ 1.6	+49.4	2.6
162 to XXI	1.724	673.435	+ 0.6201	+ 0.6215	+ 0.6208	+725.0137	....	− 1.4	+48.0	2.0
XXI to K	0.475	673.910	− 0.8695	− 0.8649	− 0.8672	+724.1465	26.9	− 4.6	+43.4	21.2
K to 163	1.406	675.316	+10.6557	+10.6503	+10.6530	+734.7995	....	+ 5.4	+48.8	29.2
163 to 164	1.596	676.912	+10.4175	+10.4090	+10.4132	+745.2127	....	+ 8.5	+57.3	72.2
164 to 165	0.248	677.160	+ 0.2986	+ 0.2980	+ 0.2983	+745.5110	....	+ 0.6	+57.9	0.4
165 to 166	0.306	677.466	− 0.2969	− 0.2978	− 0.2973	+745.2137	....	+ 0.9	+58.8	0.8
166 to 172	1.176	678.642	+ 7.0076	+ 7.0115	+ 7.0095	+752.2232	....	− 3.9	+54.9	15.2
172 to 173	1.418	680.060	+ 2.9448	+ 2.9467	+ 2.9458	+755.1690	....	− 1.9	+53.0	3.6
173 to 174	1.744	681.804	−12.7354	−12.7339	−12.7347	+742.4343	....	− 1.5	+51.5	2.2
174 to 175	0.260	682.064	− 0.2658	− 0.2656	− 0.2657	+742.1686	....	− 0.2	+51.3	0.0
175 to XXIV	0.270	682.334	− 0.0822	− 0.0816	− 0.0819	+742.0867	27.2	− 0.6	+50.7	0.4
XXIV to 187	1.454	683.788	+11.1691	+11.1639	+11.1665	+753.2532	....	+ 5.2	+55.9	27.0
187 to XXVI	0.906	684.694	+ 3.0095	+ 3.0029	+ 3.0062	+756.2594	27.3	+ 6.6	+62.5	43.6
XXVI to 188	0.796	685.490	+ 7.6488	+ 7.6509	+ 7.6499	+763.9093	....	− 2.1	+60.4	4.4
188 to 189	1.167	686.657	+ 6.3244	+ 6.3257	+ 6.3251	+770.2344	....	− 1.3	+59.1	1.7
189 to 190	0.297	686.954	+ 1.3364	+ 1.3336	+ 1.3350	+771.5694	....	+ 2.8	+61.9	7.8
190 to 191	2.082	689.036	− 0.8092	− 0.8068	− 0.8080	+770.7614	....	− 2.4	+59.5	5.8
191 to XXVII	1.000	690.036	−23.1014	−23.0998	−23.1006	+747.6608	27.4	− 1.6	+57.9	2.6
XXVII to 192	1.034	691.070	−22.0227	−22.0170	−22.0199	+725.6409	....	− 5.7	+52.2	32.5
192 to 193	0.849	691.919	−18.9775	−18.9674	−18.9724	+706.6685	....	−10.1	+42.1	102.0
193 to 194	0.370	692.289	− 7.8838	− 7.8839	− 7.8839	+698.7846	....	+ 0.1	+42.2	0.0
194 to 195	0.897	693.186	−19.7166	−19.7217	−19.7191	+679.0655	....	+ 5.1	+47.3	26.0
195 to 196	0.888	694.074	−19.4975	−19.4960	−19.4968	+659.5687	....	− 1.5	+45.8	2.2
196 to 197	0.481	694.555	−10.9016	−10.9052	−10.9034	+648.6653	....	+ 3.6	+49.4	13.0
197 to 198	0.560	695.115	−10.3929	−10.3944	−10.3936	+638.2717	....	+ 1.5	+50.9	2.

Transcontinental line of Spirit-levels—Continued.

SECTION II.—FROM HAGERSTOWN, MD., TO GRAFTON, W. VA.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ^2
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	$(mm)^2$
198 to 199	0.920	696.035	−17.2855	−17.2810	−17.2833	+620.9884	....	− 4.5	+46.4	20.2
199 to 200	0.880	696.915	−19.0624	−19.0571	−19.0597	+601.9287	....	− 5.3	+41.1	28.1
200 to 201	0.785	697.700	−16.6539	−16.6531	−16.6535	+585.2752	....	− 0.8	+40.3	0.6
201 to 202	0.484	698.184	−11.1995	−11.1997	−11.1996	+574.0756	....	+ 0.2	+40.5	0.0
202 to 203	0.121	698.305	− 2.3662	− 2.3677	− 2.3670	+571.7086	....	+ 1.5	+42.0	2.2
203 to 204	0.116	698.421	− 2.6793	− 2.6791	− 2.6792	+569.0294	....	− 0.2	+41.8	0.0
204 to 205	0.765	699.186	−16.2671	−16.2654	−16.2662	+552.7632	....	− 1.7	+40.1	2.9
205 to 206	0.872	700.058	−18.7509	−18.7440	−18.7475	+534.0157	....	− 6.9	+33.2	47.6
206 to 207	0.896	700.954	−19.1809	−19.1774	−19.1791	+514.8366	....	− 3.5	+29.7	12.2
207 to L	0.880	701.834	−19.8225	−19.8213	−19.8219	+495.0147	28.0	− 1.2	+28.5	1.4
L to 208	0.625	702.459	−13.6424	−13.6417	−13.6421	+481.3726	....	− 0.7	+27.8	0.5
208 to 209	0.924	703.383	−16.3822	−16.3794	−16.3808	+464.9918	....	− 2.8	+25.0	7.8
209 to 210	1.412	704.795	−14.2263	−14.2155	−14.2209	+450.7709	....	−10.8	+14.2	116.6
210 to 211	1.669	706.464	−17.5770	−17.5764	−17.5767	+433.1942	....	− 0.6	+13.6	0.4
211 to XXVIII	1.268	707.732	− 6.2425	− 6.2424	− 6.2424	+426.9518	28.2	− 0.1	+13.5	0.0
XXVIII to 212	0.887	708.619	+10.9820	+10.9815	+10.9817	+437.9335	....	+ 0.5	+14.0	0.2
212 to 213	0.856	709.475	+16.6329	+16.6306	+16.6318	+454.5653	....	+ 2.3	+16.3	5.3
213 to 214	1.124	710.599	+23.4658	+23.4704	+23.4681	+478.0334	....	− 4.6	+11.7	21.2
214 to 215	0.702	711.301	+13.7024	+13.7056	+13.7040	+491.7374	....	− 3.2	+ 8.5	10.2
215 to 216	1.118	712.419	+23.1035	+23.1060	+23.1047	+514.8421	....	− 2.5	+ 6.0	6.3
216 to XXIX	0.464	712.883	+ 8.6224	+ 8.6254	+ 8.6239	+523.4660	28.4	− 3.0	+ 3.0	9.0
XXIX to 217	0.813	713.696	+16.8893	+16.8865	+16.8879	+540.3539	....	+ 2.8	+ 5.8	7.8
217 to 218	0.872	714.568	+17.3817	+17.3807	+17.3812	+557.7351	....	+ 1.0	+ 6.8	1.0
218 to 219	1.262	715.830	+ 3.8555	+ 3.8533	+ 3.8544	+561.5895	....	+ 2.0	+ 8.8	4.0
219 to 220	2.362	718.192	− 4.8390	− 4.8467	− 4.8429	+556.7466	....	+ 7.7	+16.5	59.3
220 to 221	1.700	719.892	−13.2774	−13.2683	−13.2728	+543.4738	....	− 9.1	+ 7.4	82.8
221 to 222	1.242	721.134	−25.1201	−25.1256	−25.1229	+518.3509	....	+ 5.5	+12.9	30.2
222 to 223	1.218	722.352	−25.3955	−25.3917	−25.3936	+492.9573	....	− 3.8	+ 9.1	14.4
223 to 224	1.014	723.366	−19.6401	−19.6434	−19.6418	+473.3155	....	+ 3.3	+12.4	10.9
224 to 225	1.125	724.491	−22.8407	−22.8468	−22.8437	+450.4718	....	+ 6.1	+18.5	37.2
225 to 226	1.279	725.770	−25.9283	−25.9302	−25.9293	+424.5425	....	+ 1.9	+20.4	3.6
226 to 227	0.878	726.648	−16.7356	−16.7363	−16.7359	+407.8066	....	+ 0.7	+21.1	0.5
227 to 228	1.419	728.067	−28.3652	−28.3767	−28.3710	+379.4356	....	+11.5	+32.6	132.2
228 to 229	1.586	729.653	−12.8009	−12.8059	−12.8034	+366.6322	....	+ 5.0	+37.6	25.0
229 to 230	1.451	731.104	−13.5412	−13.5537	−13.5475	+353.0847	....	+12.5	+50.1	156.2
230 to 231	1.625	732.729	−10.9522	−10.9568	−10.9545	+342.1302	....	+ 4.6	+54.7	21.2
231 to 232	1.644	734.373	− 6.7658	− 6.7656	− 6.7657	+335.3645	....	− 0.2	+54.5	0.0
232 to 233	0.595	734.968	− 1.9741	− 1.9741	− 1.9741	+333.3904	....	0.0	+54.5	0.0
233 to 234	0.305	735.273	− 1.8678	− 1.8606	− 1.8642	+331.5262	....	− 7.2	+47.3	51.8
234 to 235	0.296	735.569	− 0.8823	− 0.8814	− 0.8818	+330.6444	....	− 0.9	+46.4	0.8
235 to 236	1.947	737.516	− 6.6076	− 6.6133	− 6.6105	+324.0339	....	+ 5.7	+52.1	32.5
236 to 237	1.844	739.360	− 3.4272	− 3.4254	− 3.4263	+320.6076	....	− 1.8	+50.3	3.2
237 to 238	0.617	739.977	− 1.8823	− 1.8821	− 1.8822	+318.7254	....	− 0.2	+50.1	0.0
238 to 239	1.185	741.162	− 2.0114	− 2.0099	− 2.0106	+316.7148	....	− 1.5	+48.6	2.2
239 to 240	0.842	742.004	+ 0.2588	+ 0.2571	+ 0.2579	+316.9727	....	+ 1.7	+50.3	2.9
240 to 241	0.869	742.873	− 1.0637	− 1.0672	− 1.0654	+315.9073	....	+ 3.5	+53.8	12.2
241 to 242	2.122	744.995	− 2.8666	− 2.8748	− 2.8707	+313.0366	....	+ 8.2	+62.0	67.2
242 to XXX	1.392	746.387	− 0.8952	− 0.8958	− 0.8955	+312.1411	29.8	+ 0.6	+62.6	0.4
XXX to 243	1.879	748.266	− 8.4117	− 8.4180	− 8.4149	+303.7262	....	+ 6.3	+68.9	39.7
243 to M	1.610	749.876	+ 0.1371	+ 0.1389	+ 0.1380	+303.8642	29.9	− 1.8	+67.1	3.2

SECTION II.—*Description of primary and secondary bench-marks between Hagerstown, Md., and Grafton, W. Va.*

A—Hagerstown, Md. Already described.

Nos. I, II, IV, and V—Cut on top of mile-posts 1, 2, 4, and 5 on the turnpike between Hagerstown and Williamsport. These probably cannot be depended upon as permanent.

B—The bottom surface of a square cavity, cut on the top surface of the stone on the west side of the aqueduct of Chesapeake and Ohio Canal over the Conococheague River at Williamsport, Md. It is marked thus:

B
B □ M
U. S. C. S.
Nov. 1877

C—About 7 miles west of Williamsport, Md. Cut on the coping-stone of Dam No. 5, Potomac River. It is marked thus:

C
B □ M
U. S. C. S.
1877

No. VI—About 7¾ miles west of Williamsport, Md. Cut on top layer of stone of the second canal-lock (Chesapeake and Ohio Canal), above Dam No. 5.

D—Nine and one-fourth miles west of Williamsport, Md. Cut on the top layer of stone at west end of the sixth lock above Dam No. 5.

No. VII—Cut on the coping-stone ot the upper end of "overflow" at "Big Pool," Chesapeake and Ohio Canal. It is about 13½ miles west of Williamsport, Md., and nearly opposite Cherry Run Station of Baltimore and Ohio Railroad.

E—Cut on the coping-stone of the aqueduct (Chesapeake and Ohio Canal) over Licking Creek, about 8 miles east of Hancock, Md. It is marked thus:

E
B □ M
U. S. C. S.
1877.

No. VIII—Cut on the coping-stone at the southeast end of Lock No. 52, Chesapeake and Ohio Canal, and is about 1 mile east of Hancock, Md.

F—Cut on the coping-stone on the middle of the north side of the Chesapeake and Ohio Canal aqueduct at Hancock, Md. It is marked thus:

F
B □ M
U. S. C. S.
1878.

No. IX—Cut on the coping-stone of Lock No. 53, Chesapeake and Ohio Canal, and is about 6 miles west of Hancock, Md.

G—Cut on the coping-stone of Lock No. 55, Chesapeake and Ohio Canal, at Dam No. 6, and about 10 miles west of Hancock, Md. It is marked thus:

G
B □ M
U. S. C. S.
1878.

No. X—Cut on the coping-stone at the north end of Lock No. 56, Chesapeake and Ohio Canal, about 12¼ miles west of Hancock, Md.

No. XI—Cut on the top of the wing-wall at the south side and east end of Lock No. 57, Chesapeake and Ohio Canal. It is about 15¼ miles west of Hancock and 4¾ miles east of Little Orleans, Md.

No. XII—Little Orleuas, Md. Cut on the coping-stone of the aqueduct (Chesapeake and Ohio Canal) over Fifteen-mile Creek.

No. XIII—About 3 miles west of Little Orleans, Md. Cut on the coping of Lock No. 58, Chesapeake and Ohio Canal.

H—About 12 miles west of Little Orleans, Md., and 2 miles east of the canal tunnel. It is cut on the coping of Lock No. 61, and is marked thus:

H
B □ M
U. S. C. S.
1878

No. XIV—At the north end of the canal tunnel. It is cut on the stone foundation, a short distance below the level of the tow-path.

No. XV—Cut on the coping-stone of Lock No. 67, Chesapeake and Ohio Canal, and is about 5 miles east of Oldtown, Md.

No. XVI—Cut on the coping-stone of Lock No. 72, Chesapeake and Ohio Canal, and is about 9¼ miles east of Cumberland, Md.

I—Cumberland, Md. Cut on the coping stone of the feed-lock, at the western terminus of the Chesapeake and Ohio Canal. It is marked thus:

I
B □ M
U. S. C. S.
1878

No. XVII—Cut on the abutment of a small drain on the Baltimore and Ohio Railroad, about 5½ miles west of Cumberland, Md. It is marked thus: B □ M.

No. XVIII—Cut on the foundation-stone, at the southwest angle of a drain on the Baltimore and Ohio Railroad, about 12 miles west of Cumberland, Md. It is marked thus: B □ M.

J—Cut on the top of the middle pier of Baltimore and Ohio Railroad bridge, over a small drain about one-fourth of a mile east of Keyser, W. Va. It is marked thus:

J
B □ M
U. S. C. S.
1878.

No. XX—Cut on the top step at the northwest corner of the Baltimore and Ohio Railroad bridge over the Potomac River at Bloomington, Garrett County, Maryland. It is also about 2 miles west of Piedmont, W. Va., and is marked thus: B □ M.

No. XXI—About 1 mile west of Oakland, Md. Cut on a large rock beside the track of the Baltimore and Ohio Railroad.

No. XXII—About 3 miles east of Oakland, Md. Cut on the west abutment of a small bridge, Baltimore and Ohio Railroad, and is marked thus: B □ M.

No. XXIII—Cut on top stone of a "cattle guard," a short distance north of Deer Park, Garrett County, Maryland. It is marked thus: B □ M.

No. XXIV—Near Hutton's Switch Station, Md. (Baltimore and Ohio Railroad). Cut on the abutment of a bridge over a small run.

No. XXV—Cut on the abutment of a small bridge (Baltimore and Ohio Railroad) about 10¾ miles west of Bloomington, Md. It is marked B □ M.

K—Cut on the abutment, southwest corner of Baltimore and Ohio Railroad bridge over the Youghiogheny River. It is about 1¼ miles west of Oakland, Md., and is marked thus:

K
B □ M
U. S. C. S.
1878

No. XXVI—Two miles east of Cranberry Summit Station of Baltimore and Ohio Railroad, Preston County, West Virginia. Cut on southeast corner of railroad bridge over a small stream.

No. XXVII—Cut on the coping-stone, near the middle of the "slide-wall" (Baltimore and Ohio Railroad), about 1½ miles west of Cranberry Summit, and is marked thus: B ◻ M.

L—Cut on the coping-stone of abutment at northwest corner of the Baltimore and Ohio Railroad bridge over Salt Lick Creek, 4 miles east of Rowlesburg, W. Va. It is marked thus:

L
B ◻ M
U. S. C. S.
1878

No. XXVIII—Rowlesburg, W. Va. Cut at the base of the centre pillar at the west end of Baltimore and Ohio Railroad bridge over Cheat River. It is marked thus: B ◻ M.

No. XXIX—Cut on top of the "Buckhorn Wall," about 40 metres from its eastern end. It is about 3¼ miles west of Rowlesburg, W. Va., and is marked thus: B ◻ M.

No. XXX—Cut on corner-stone of abutment of a small bridge, Baltimore and Ohio Railroad, about 2 miles east of Grafton, W. Va.

Transcontinental line of Spirit-levels—Continued.

SECTION III.—FROM GRAFTON, W. VA., TO ATHENS, OHIO.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm*)²
M	....	749.876	....	....	....	+303.8642	29.9	....	+ 67.1	....
M to 244	1.582	751.458	+ 0.6017	+ 0.6021	+ 0.6019	+304.4661	....	− 0.4	+ 66.7	0.2
244 to 245	1.592	753.050	+ 0.5691	+ 0.5660	+ 0.5676	+305.0337	....	+ 3.1	+ 69.8	9.6
245 to 246	1.004	754.054	+ 2.5745	+ 2.5815	+ 2.5780	+307.6117	....	− 7.0	+ 62.8	49.0
246 to 247	0.566	754.620	+ 0.3852	+ 0.3836	+ 0.3844	+307.9961	....	+ 1.6	+ 64.4	2.6
247 to 248	0.237	754.857	+ 0.1918	+ 0.1930	+ 0.1924	+308.1885	....	− 1.2	+ 63.2	1.4
248 to 249	1.901	756.758	+ 5.1765	+ 5.1757	+ 5.1761	+313.3646	....	+ 0.8	+ 64.0	0.6
249 to XXXI	1.699	758.457	+16.6513	+16.6410	+16.6461	+330.0107	30.2	+10.3	+ 74.3	106.1
XXXI to 250	1.722	760.179	+17.6430	+17.6348	+17.6389	+347.6496	....	+ 8.2	+ 82.5	67.2
250 to 251	0.696	760.875	− 2.4806	− 2.4899	− 2.4852	+345.1644	....	+ 9.3	+ 91.8	86.5
251 to 252	0.202	761.077	− 2.3132	− 2.3025	− 2.3079	+342.8565	....	−10.7	+ 81.1	114.5
252 to 253	1.574	762.651	−15.5557	−15.5574	−15.5565	+327.3000	....	+ 1.7	+ 82.8	2.9
253 to 254	1.068	763.719	−10.4566	−10.4612	−10.4589	+316.8411	....	+ 4.6	+ 87.4	21.2
254 to 255	1.392	765.111	− 2.8579	− 2.8662	− 2.8621	+313.9790	....	+ 8.3	+ 95.7	68.9
255 to 256	0.520	765.631	− 1.2810	− 1.2852	− 1.2831	+312.6959	....	+ 4.2	+ 99.9	17.6
256 to 257	0.521	766.152	+ 2.1326	+ 2.1284	+ 2.1305	+314.8264	....	+ 4.2	+104.1	17.6
257 to 258	1.668	767.820	− 7.4740	− 7.4682	− 7.4711	+307.3553	....	− 5.8	+ 98.3	33.6
258 to 259	1.693	769.513	− 1.9129	− 1.9045	− 1.9087	+305.4466	....	− 8.4	+ 89.9	70.6
259 to 260	1.858	771.371	+ 0.4836	+ 0.4807	+ 0.4822	+305.9288	....	+ 2.9	+ 92.8	8.4
260 to 261	1.886	773.257	− 0.1704	− 0.1749	− 0.1727	+305.7561	....	+ 4.5	+ 97.3	20.2
261 to 262	0.995	774.252	+ 3.1431	+ 3.1437	+ 3.1434	+308.8995	....	− 0.6	+ 96.7	0.4
262 to 263	1.600	775.852	−10.1136	−10.1137	−10.1136	+298.7859	....	+ 0.1	+ 96.8	0.0
263 to XXXII	1.567	777.419	− 0.1590	− 0.1564	− 0.1577	+298.6282	31.2	− 2.6	+ 94.2	6.8
XXXII to 264	1.587	779.006	+10.0635	+10.0514	+10.0575	+308.6857	....	+12.1	+106.3	146.4
264 to 265	0.932	779.938	+ 8.9285	+ 8.9306	+ 8.9295	+317.6152	....	− 2.1	+104.2	4.4
265 to 266	0.982	780.920	+10.1117	+10.1186	+10.1151	+327.7303	....	− 6.9	+ 97.3	47.6
266 to 267	1.112	782.032	+ 5.6101	+ 5.6212	+ 5.6157	+333.3460	....	−11.1	+ 86.2	123.2
267 to 268	1.785	783.817	−16.4038 A and B	−16.4180 −16.3987	−16.4068	+316.9392	....	+14.2	+100.4	201.6
268 to 269	0.823	784.640	− 2.0214	− 2.0180	− 2.0197	+314.9195	....	− 3.4	+ 97.0	11.6
269 to 270	1.982	786.622	−11.9896	−11.9995	−11.9945	+302.9250	....	+ 9.9	+106.9	98.0
270 to 271	2.161	788.783	−11.4046	−11.3985	−11.4016	+291.5234	....	− 6.1	+100.8	37.2
271 to 274	1.180	789.963	+ 4.7982	+ 4.7868	+ 4.7925	+296.3159	....	+11.4	+112.2	130.0
274 to 273	2.204	792.167	+ 4.7504	+ 4.7484	+ 4.7494	+301.0653	....	+ 2.0	+114.2	4.0
273 to 272	1.496	793.663	+ 7.4260	+ 7.4173	+ 7.4216	+308.4869	....	+ 8.7	+122.9	75.7
272 to 275	1.501	795.164	+15.0037	+15.0012	+15.0025	+323.4894	....	+ 2.5	+125.4	6.2
275 to 276	2.618	797.782	+22.0995	+22.0911	+22.0953	+345.5847	....	+ 8.4	+133.8	70.6
276 to 277	0.993	798.775	− 9.8501	− 9.8508	− 9.8505	+335.7342	....	+ 0.7	+134.5	0.5
277 to 278	1.562	800.337	−15.6472	−15.6410	−15.6441	+320.0901	....	− 6.2	+128.3	38.4
278 to 279	1.004	801.341	− 0.7555	− 0.7617	− 0.7586	+319.3315	....	+ 6.2	+134.5	38.4

Transcontinental line of Spirit-levels—Continued.

SECTION III.—FROM GRAFTON, W. VA., TO ATHENS, OHIO—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ^2
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	$(mm)^2$
279 to 280	0.732	802.073	+ 6.3633	+ 6.3567	+ 6.3600	+325.6915	....	+ 6.6	+141.1	42.6
280 to 281	1.873	803.946	−13.1677	−13.1589	−13.1633	+312.5282	....	− 8.8	+132.3	77.4
281 to 282	1.754	805.700	+ 2.6249	+ 2.6252	+ 2.6251	+315.1533	....	− 0.3	+132.0	0.0
282 to 283	1.006	806.706	+ 1.8837	+ 1.8787	+ 1.8812	+317.0345	....	+ 5.0	+137.0	25.0
283 to 284	2.010	808.716	+ 6.4061	+ 6.4161	+ 6.4111	+323.4456	....	−10.0	+127.0	100.0
284 to 285	1.916	810.632	− 7.1256	− 7.1202	− 7.1229	+316.3227	....	− 5.4	+121.6	29.2
285 to 286	1.513	812.145	−15.2583	−15.2626	−15.2605	+301.0622	....	+ 4.3	+125.9	18.5
286 to 287	1.482	813.627	−14.7049	−14.7004	−14.7026	+286.3596	....	− 4.5	+121.4	20.2
287 to 288	1.728	815.355	−16.7947	−16.7967	−16.7957	+269.5639	....	+ 2.0	+123.4	4.0
288 to 289	2.306	817.661	−10.4547	−10.4515	−10.4531	+259.1108	....	− 3.2	+120.2	10.2
289 to 290	0.334	817.995	− 0.6052	− 0.6080	− 0.6066	+258.5042	....	+ 2.8	+123.0	7.8
290 to 291	1.856	819.851	−10.1455	−10.1406	−10.1431	+248.3611	....	− 4.9	+118.1	24.0
291 to 292	1.819	821.670	+ 0.2335	+ 0.2359	+ 0.2347	+248.5958	....	− 2.4	+115.7	5.8
292 to 293	2.426	824.096	− 3.8822	− 3.8955	− 3.8888	+244.7070	....	+13.3	+129.0	176.9
293 to XXXIII	2.096	826.192	− 0.7488	− 0.7443	− 0.7466	+243.9604	34.0	− 4.5	+124.5	20.2
XXXIII to 294	1.502	827.694	− 4.3221	− 4.3198	− 4.3209	+239.6395	....	− 2.3	+122.2	5.3
294 to N	1.948	829.642	+ 5.7485	+ 5.7469	+ 5.7477	+245.3872	34.0	+ 1.6	+123.8	2.6
N to 295	1.666	831.308	+14.9851	+14.9801	+14.9826	+260.3698	....	+ 5.0	+128.8	25.0
295 to 296	2.105	833.413	− 1.2417	− 1.2410	− 1.2414	+259.1284	....	− 0.7	+128.1	0.5
296 to 297	1.238	834.651	−10.6765	−10.6727	−10.6746	+248.4538	....	− 3.8	+124.3	14.4
297 to 298	2.333	836.984	+15.8253	+15.8310	+15.8282	+264.2820	....	− 5.7	+118.6	32.5
298 to 299	1.332	838.316	+13.5795	+13.5767	+13.5781	+277.8601	....	+ 2.8	+121.4	7.8
299 to 300	2.134	840.450	+ 2.1549	+ 2.1594	+ 2.1571	+280.0172	....	− 4.5	+116.9	20.2
300 to 301	1.606	842.056	−15.9740	−15.9759	−15.9749	+264.0423	....	+ 1.9	+118.8	3.6
301 to 302	1.373	843.429	−13.7521	−13.7452	−13.7487	+250.2936	....	− 6.9	+111.9	47.6
302 to XXXIV	1.838	845.267	− 5.5182	− 5.5239	− 5.5210	+244.7726	34.3	+ 5.7	+117.6	32.5
XXXIV to 303	0.541	845.808	+ 5.3126	+ 5.3100	+ 5.3113	+250.0839	....	+ 2.6	+120.2	6.8
303 to 304	1.920	847.728	+18.9970	+19.0022	+18.9996	+269.0835	....	− 5.2	+115.0	27.0
304 to 305	1.626	849.354	− 1.1946	− 1.1908	− 1.1927	+267.8908	....	− 3.8	+111.2	14.4
305 to 306	2.272	851.626	{ − 4.4404 A and B	− 4.4220 } − 4.4379 }	− 4.4334	+263.4574	....	−12.2	+ 99.0	148.8
306 to 307	1.667	853.293	+ 8.6697	+ 8.6719	+ 8.6708	+272.1282	....	− 2.2	+ 96.8	4.8
307 to 308	1.867	855.160	−18.3885	−18.3940	−18.3913	+253.7369	....	+ 5.5	+102.3	30.2
308 to 309	2.414	857.574	−12.6726	−12.6695	−12.6711	+241.0658	....	− 3.1	+ 99.2	9.6
309 to 310	1.338	858.912	− 2.5662	− 2.5605	− 2.5633	+238.5025	....	− 5.7	+ 93.5	32.5
310 to 311	2.115	861.027	− 7.0902	− 7.0892	− 7.0897	+231.4128	....	− 1.0	+ 92.5	1.0
311 to 312	1.308	862.335	− 6.1530	− 6.1541	− 6.1536	+225.2592	....	+ 1.1	+ 93.6	1.2
312 to 313	1.997	864.332	−11.4254	−11.4221	−11.4237	+213.8355	....	− 3.3	+ 90.3	10.9
313 to 314	0.496	864.828	+ 2.1633	+ 2.1579	+ 2.1606	+215.9961	....	+ 5.4	+ 95.7	29.2
314 to 315	0.866	865.694	− 4.2949	− 4.2945	− 4.2947	+211.7014	....	− 0.4	+ 95.3	0.2
315 to XXXV	0.160	865.854	− 0.1252	− 0.1266	− 0.1259	+211.5755	34.9	+ 1.4	+ 96.7	2.0
XXXV to 316	1.886	867.740	− 2.5895	− 2.5872	− 2.5883	+208.9872	....	− 2.3	+ 94.4	5.3
316 to XXXVI	1.605	869.345	+ 0.1770	+ 0.1797	+ 0.1783	+209.1655	34.9	− 2.7	+ 91.7	7.3
XXXVI to 317	1.412	870.757	− 3.0278	− 3.0272	− 3.0275	+206.1380	....	− 0.6	+ 91.1	0.4
317 to 325	0.602	871.359	+ 5.4569	+ 5.4558	+ 5.4564	+211.5944	....	+ 1.1	+ 92.2	1.2
325 to 324	1.622	872.981	+15.8654	+15.8709	+15.8681	+227.4625	....	− 5.5	+ 86.7	30.2
324 to 323	1.846	874.827	+18.6473	+18.6424	+18.6449	+246.1074	....	+ 4.9	+ 91.6	24.0
323 to 322	1.133	875.960	+10.5281	+10.5251	+10.5266	+256.6340	....	+ 3.0	+ 94.6	9.0
322 to 320	1.464	877.424	−14.1583	−14.1585	−14.1584	+242.4756	....	+ 0.2	+ 94.8	0.0
320 to 319	0.457	877.881	− 4.1323	− 4.1318	− 4.1321	+238.3435	....	− 0.5	+ 94.3	0.2
319 to 318	2.370	880.251	−22.9786	−22.9823	−22.9804	+215.3631	....	+ 3.7	+ 98.0	13.7
318 to XXXVII	1.688	881.939	− 2.8448	− 2.8434	− 2.8441	+212.5190	35.0	− 1.4	+ 96.6	2.0
XXXVII to XXXVIII	1.736	883.675	− 1.1464	− 1.1452	− 1.1458	+211.3732	35.0	− 1.2	+ 95.4	1.4
XXXVIII to 321	2.176	885.851	+13.3652	+13.3728	+13.3690	+224.7422	....	− 7.6	+ 87.8	57.8
321 to 326	1.695	887.546	{ +14.3394 A and B	+14.3597 +14.3445	} +14.3479	+239.0901	....	−13.5	+ 74.3	182.2
326 to 327	0.655	888.201	− 5.4051	− 5.4010	− 5.4031	+233.6870	....	− 4.1	+ 70.2	16.8
327 to 328	1.299	889.500	{ −13.1363 −13.1452	−13.1499 −13.1425	} −13.1435	+220.5435	....	+ 5.4	+ 75.6	29.2

Transcontinental line of Spirit-levels—Continued.

SECTION III.—FROM GRAFTON, W. VA., TO ATHENS, OHIO—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm.*)²
328 to 329	1.013	890.513	− 9.5916	− 9.5949	− 9.5932	+210.9503	......	+ 3.3	+ 78.9	10.9
329 to 330	1.447	891.960	−13.5856	−13.5916	−13.5886	+197.3617	....	− 3.0	+ 75.9	9.0
330 to 331	2.447	894.407	− 4.9181	− 4.9131	− 4.9156	+192.4461	....	− 5.0	+ 70.9	25.0
331 to 332	1.302	895.709	− 1.2374	− 1.2275	− 1.2325	+191.2136	....	− 9.9	+ 61.0	98.0
332 to 333	1.923	897.632	− 5.5999	− 5.6036	− 5.6017	+185.6119	....	+ 3.7	+ 64.7	13.7
333 to 334	1.848	899.480	+ 0.0093	+ 0.0129	+ 0.0111	+185.6230	... .	− 3.6	+ 61.1	13.0
334 to 335	1.778	901.258	− 0.5651	− 0.5659	− 0.5655	+185.0575	....	+ 0.8	+ 61.9	0.6
335 to 336	1.222	902.480	+ 0.8127	+ 0.8093	+ 0.8110	+185.8685	....	+ 3.4	+ 65.3	11.6
336 to 337	2.052	904.532	− 0.0890	− 0.0798	− 0.0844	+185.7841	....	− 9.2	+ 56.1	84.6
337 to 338	2.415	906.947	− 0.3896	− 0.3939	− 0.3917	+185.3924	....	+ 4.3	+ 60.4	18.5
338 to 339	2.210	909.157	+ 2.4611	+ 2.4662	+ 2.4636	+187.8560	....	− 5.1	+ 55.3	26.0
339 to 340	1.121	910.278	+ 6.1105	+ 6.1138	+ 6.1122	+193.9682	....	− 3.3	+ 52.0	10.9
340 to 341	2.231	912.509	− 8.3213	− 8.3265	− 8.3239	+185.6443	....	+ 5.2	+ 57.2	27.0
341 to 342	1.953	914.462	+ 0.0448	+ 0.0380	+ 0.0414	+185.6857	....	+ 6.8	+ 64.0	46.2
342 to XXXIX	0.789	915.251	− 0.4247	− 0.4193	− 0.4220	+185.2637	36.1	− 5.4	+ 58.6	29.2
XXXIX to 343	2.194	917.445	+ 9.5731	+ 9.5744	+ 9.5737	+194.8374	....	− 1.3	+ 57.3	1.7
343 to 344	0.362	917.807	− 7.0733	− 7.0705	− 7.0719	+187.7655	....	− 2.8	+ 54.5	7.8
344 to O	0.166	917.973	+ 0.0451	+ 0.0452	+ 0.0452	+187.8107	36.2	− 0.1	+ 54.4	0.0
O to 345	0.725	918.698	− 6.9335	− 6.9356	− 6.9346	+180.8761	....	+ 2.1	+ 56.5	4.4
345 to 346	0.254	918.952	− 0.5732	− 0.5790	− 0.5761	+180.3000	....	+ 5.8	+ 62.3	33.6
346 to XL	0.439	919.391	+ 9.1618	+ 9.1619	+ 9.1619	+189.4619	36.2	− 0.1	+ 62.2	0.0
XL to 347	0.821	920.212	+ 3.5356	+ 3.5290	+ 3.5323	+192.9942	....	+ 6.6	+ 68.8	43.6
347 to 348	2.518	922.730	+ 5.3259	+ 5.3177	+ 5.3218	+198.3160	....	+ 8.2	+ 77.0	67.2
348 to 349	2.412	925.142	− 3.6913 A and B	− 3.7097 − 3.7098	− 3.7036	+194.6124	....	+12.3	+ 89.3	151.3
349 to 350	0.292	925.434	− 1.4239 A and B	− 1.4277 − 1.4225	− 1.4247	+193.1877	....	+ 2.5	+ 91.8	6.2
350 to 351	2.093	927.527	− 3.9931	− 3.9846	− 3.9889	+189.1988	....	− 8.5	+ 83.3	72.2
351 to 352	2.064	929.591	− 2.9637	− 2.9695	− 2.9666	+186.2322	....	+ 5.8	+ 89.1	33.6
352 to 353	0.676	930.267	+ 1.3612	+ 1.3625	+ 1.3619	+187.5941	....	− 1.3	+ 87.8	1.7
353 to XLI	0.909	931.176	+ 2.5886	+ 2.5915	+ 2.5900	+190.1841	36.8	− 3.1	+ 84.7	9.6
XLI to 354	2.633	933.809	+ 9.4362	+ 9.4327	+ 9.4344	+199.6185	....	+ 3.5	+ 88.2	12.2
354 to 355	1.792	935.601	+10.5093	+10.4992	+10.5043	+210.1228	....	+10.1	+ 98.3	102.0
355 to 356	2.452	938.053	− 0.1382	− 0.1324	− 0.1353	+209.9875	....	− 5.8	+ 92.5	33.6
356 to 357	0.693	938.746	− 7.3025	− 7.3040	− 7.3033	+202.6842	....	+ 1.5	+ 94.0	2.2
357 to XLII	0.994	939.740	− 9.4945	− 9.4863	− 9.4904	+193.1938	37.2	− 8.2	+ 85.8	67.2
XLII to 358	0.958	940.698	− 8.0547	− 8.0621	− 8.0584	+185.1354	....	+ 7.4	+ 93.2	54.8
358 to 359	2.180	942.878	+ 0.2132	+ 0.2111	+ 0.2122	+185.3476	....	+ 2.1	+ 95.3	4.4
359 to 360	1.230	944.108	+ 0.7471	+ 0.7501	+ 0.7486	+186.0962	....	− 3.0	+ 92.3	9.0
360 to XLIII	1.667	945.775	− 1.1685	− 1.1675	− 1.1680	+184.9282	37.3	− 1.0	+ 91.3	1.0
XLIII to 361	2.092	947.867	+ 1.0665	+ 1.0660	+ 1.0662	+185.9944	....	+ 0.5	+ 91.8	0.2
361 to 362	1.669	949.536	− 0.2438	− 0.2520	− 0.2479	+185.7465	....	+ 8.2	+100.0	67.2
362 to 367	1.700	951.236	+ 0.3803	+ 0.3892	+ 0.3848	+186.1313	....	− 8.9	+ 91.1	79.2
367 to XLVIII	2.862	954.098	+ 1.6002	+ 1.5988	+ 1.5995	+187.7308	37.5	+ 1.4	+ 92.5	2.0
XLVIII to 366	1.508	955.606	− 0.0775	− 0.0739	− 0.0757	+187.6551	....	− 3.6	+ 88.9	13.0
366 to XLVII	1.441	957.047	+ 0.4000	+ 0.4053	+ 0.4027	+188.0578	37.5	− 5.3	+ 83.6	28.1
XLVII to 363	2.187	959.234	+ 0.5199	+ 0.5185	+ 0.5192	+188.5770	....	+ 1.4	+ 85.0	2.0
363 to XLIV	1.846	961.080	− 0.2408	− 0.2336	− 0.2372	+188.3398	37.6	− 7.2	+ 77.8	51.8
XLIV to XLV	2.031	963.111	+ 1.3835	+ 1.3871	+ 1.3853	+189.7251	37.6	− 3.6	+ 74.2	13.0
XLV to 364	0.862	963.973	+ 0.1374	+ 0.1323	+ 0.1348	+189.8599	....	+ 5.1	+ 79.3	26.0
364 to XLVI	1.916	965.889	+ 0.4416	+ 0.4341	+ 0.4379	+190.2978	37.8	+ 7.5	+ 86.8	56.2
XLVI to 365	1.876	967.765	+ 1.0180	+ 1.0150	+ 1.0165	+191.3143	....	+ 3.0	+ 89.8	9.0
365 to XLIX	1.578	969.343	+ 0.9850	+ 0.9796	+ 0.9823	+192.2966	37.8	+ 5.4	+ 95.2	29.2
XLIX to 368	1.896	971.239	+ 0.5598	+ 0.5592	+ 0.5595	+192.8561	... .	+ 0.6	+ 95.8	0.4
368 to 369	2.044	973.283	+ 0.8281	+ 0.8280	+ 0.8280	+193.6841	....	+ 0.1	+ 95.9	0.0
369 to 370	2.434	975.717	− 0.8604	− 0.8671	− 0.8637	+192.8204	....	+ 6.7	+102.6	44.9
370 to L (50)	1.718	977.435	+ 5.2218	+ 5.2182	+ 5.2200	+198.0404	37.9	+ 3.6	+106.2	13.0
L (50) to P	0.147	977.582	+ 2.1142	+ 2.1142	+ 2.1142	+200.1546	37.9	0.0	+106.2	0.0

SECTION III.—*Description of primary and secondary bench-marks between Grafton, W. Va., and Athens, Ohio.*

M—Grafton, W. Va. Cut on top of the north side of the central pier of the Baltimore and Ohio Railroad bridge over Taggart's Valley Creek, a branch of the Monongahela River. It is marked thus:

M
B □ M
U. S. C. S.
1878

No. XXXI—About 5½ miles west of Grafton, W. Va. Cut on corner-stone of the east end of a trestle which is numbered 2½ (Baltimore and Ohio Railroad, Parkersburg branch). It is marked thus: B □ M.

No. XXXII—Cut on corner-stone of the west abutment of the Baltimore and Ohio Railroad bridge east of Bridgeport, Harrison County, West Virginia. It is marked thus: B □ M.

No. XXXIII—About 2 miles east of West Union, Doddridge County, West Virginia. Cut on top of the pier at the west end of Baltimore and Ohio Railroad bridge No. 21, over Middle Island Creek. It is marked thus: B □ M.

N—About one-fourth mile east of West Union, W. Va., and is cut on the top of the southwest corner of the pier of Baltimore and Ohio Railroad bridge No. 23, over Middle Island Creek. It is marked thus:

N
B □ M
U. S. C. & G. S.
1878

No. XXXIV—Cut on the southeast corner-stone of the pier of bridge No. 26 (Baltimore and Ohio Railroad), about 10 miles west of West Union, W. Va., and is marked thus: B □ M.

No. XXXV—Cut on the coping-stone of the eastern abutment of Baltimore and Ohio Railroad bridge No. 31, over Bond's Creek, about one-fourth mile east of Cornwall Station. It is marked thus: B □ M.

No. XXXVI—Cut on the eastern abutment of Baltimore and Ohio Railroad bridge No. 35, over Bond's Creek, 1 mile east of Cairo, Ritchie County, West Virginia. It is marked thus: B □ M.

No. XXXVII—Cut on the west abutment of Baltimore and Ohio Railroad bridge over Goose Creek, about 200 metres east of Petroleum, W. Va. It is marked thus: B □ M.

No. XXXVIII—Cut on the northeast corner-stone of abutment of Baltimore and Ohio Railroad bridge No. 44, about 1 mile west of Petroleum, W. Va. It is marked thus: B □ M.

No. XXXIX—Cut on the foundation at northwest corner of Baltimore and Ohio Railroad bridge No. 52, 2 miles east of Parkersburg, W. Va.

O—At Parkersburg, W. Va. Cut on the water-table, south front, near western corner, of the post-office and court-house. It is marked thus:

O
B □ M
U. S. C. & G. S.
1878

No. XL—Belpre, Ohio. Cut on the wing-wall of the second pier from west end of Baltimore and Ohio Railroad bridge, which crosses the Ohio River at this point. It is marked thus: B □ M.

No. XLI—Cut on southwest corner of abutment of Marietta and Cincinnati Railroad bridge over Little Hocking Creek, near its junction with the Ohio River, and at Little Hocking Station. It is marked thus: B □ M.

No. XLII—About one-half mile east of Coolville Station, Marietta and Cincinnati Railroad. Cut on coping of abutment of a railroad bridge, and is marked thus: B □ M.

No. XLIII—About 3¾ miles west of Coolville, Athens County, Ohio. Cut on east abutment of a small railroad bridge, and is marked thus: B □ M.

No. XLIV—About 1 mile west of Guysville, Ohio, and is cut on the eastern abutment of Marietta and Cincinnati Railroad bridge, and marked thus: B □ M.

No. XLV—Cut on the west abutment of Marietta and Cincinnati Railroad bridge over Little Hocking River, about 2½ miles west of Guysville, Ohio, and is marked thus: B □ M.

No. XLVI—Cut on the west abutment of a small bridge (Marietta and Cincinnati Railroad), about 150 metres east of "Canaan Chapel," Canaanville, Athens County, Ohio. It is marked thus: B □ M.

No. XLVII—About three-fourths of a mile west of Stewart, Athens County, Ohio. Cut on the west abutment of Marietta and Cincinnati Railroad bridge over Little Hocking River. It is marked thus: B □ M.

No. XLVIII—One and one-fourth miles east of Stewart, Athens County, Ohio. Cut on top of the wall of the west abutment of Marietta and Cincinnati Railroad bridge, and is marked thus: B □ M.

No. XLIX—Cut on the coping of a railroad culvert, about 1½ miles west of Canaanville, Athens County, Ohio, and is marked thus: B □ M.

No. L—Cut on the south abutment (east side and fourth step from top) of road bridge over Marietta and Cincinnati Railroad and the Hockhocking River at Athens, Ohio. It is marked thus: B □ M.

P—Athens, Ohio. Cut on top of the pier of the bridge over the Marietta and Cincinnati Railroad and the Hockhocking River, and is marked thus:

P
B □ M
U. S. C. S.
1878

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM ATHENS, OHIO, TO MITCHELL, IND.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks.			Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy.		Δ²
			Rod A, first line.	Rod B, second line.	Mean.			Partial Δ	Total.	
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm*)²
P	....	977.582	....	....	....	+200.1546	37.9	....	+106.2	... ...
P to 1	1.447	979.029	− 0.8493	− 0.8453	− 0.8473	+199.3073	....	− 4.0	+102.2	16.0
1 to 2	1.813	980.842	+ 0.0606	+ 0.0676	+ 0.0641	+199.3714	....	− 7.0	+ 95.2	49.0
2 to 3	1.282	982.124	+ 1.4109	+ 1.4075	+ 1.4092	+200.7806	....	+ 3.4	+ 98.6	11.6
3 to 4	1.699	983.823	+ 8.4320	+ 8.4396	+ 8.4358	+209.2164	....	− 7.6	+ 91.0	57.8
4 to 5	1.293	985.116	− 1.5909	− 1.5922	− 1.5916	+207.6248	....	+ 1.3	+ 92.3	1.7
5 to 6	1.523	986.639	+14.3414	+14.3494	+14.3454	+221.9702	....	− 8.0	+ 84.3	64.0
6 to 7	2.527	989.166	+25.4324	+25.4386	+25.4355	+247.4057	....	− 6.2	+ 78.1	38.4
7 to 8	0.595	989.761	+ 1.8004	+ 1.8035	+ 1.8020	+249.2077	... .	− 3.1	+ 75.0	9.6
8 to 10	3.366	993.127	−27.3858	−27.3919	−27.3889	+221.8188	... .	+ 6.1	+ 81.1	37.2
10 to 9	1.185	994.312	− 3.3943	− 3.3957	− 3.3950	+218.4238	....	+ 1.4	+ 82.5	2.0
9 to 12	1.470	995.782	+ 0.9569	+ 0.9564	+ 0.9567	+219.3805	....	+ 0.5	+ 83.0	0.2
12 to 11	2.332	998.114	− 5.1541	− 5.1547	− 5.1544	+214.2261	....	+ 0.6	+ 83.6	0.4
11 to LI	2.405	1000.519	+ 3.0152	+ 3.0146	+ 3.0149	+217.2410	38.4	+ 0.6	+ 84.2	0.4
LI to 13	2.194	1002.713	− 3.2828	− 3.2782	− 3.2805	+213.9605	....	− 4.6	+ 79.6	21.2
13 to 14	2.202	1004.915	+ 0.4068	+ 0.3994	+ 0.4031	+214.3636	....	+ 7.4	+ 87.0	54.8
14 to 15	3.136	1008.051	+ 1.9142	+ 1.9123	+ 1.9132	+216.2768	....	+ 1.9	+ 88.9	3.6
15 to LII	2.959	1011.010	+ 1.6157	+ 1.6202	+ 1.6180	+217.8948	38.5	− 4.5	+ 84.4	20.3
LII to 17	1.884	1012.894	+ 7.7143	+ 7.7185	+ 7.7164	+225.6112	....	− 4.2	+ 80.2	17.6
17 to 16	2.808	1015.702	−10.8643	−10.8697	−10.8670	+214.7442	....	+ 5.4	+ 85.6	29.2
16 to 18	3.123	1018.825	+14.5309	+14.3558	+14.5334	+229.2776	.. ..	− 4.9	+ 80.7	24.0
18 to 19	2.320	1021.145	− 2.7059	− 2.7102	− 2.7081	+226.5695	....	− 4.3	+ 76.4	18.5
19 to 20	2.852	1023.997	− 2.7417	− 2.7361	− 2.7389	+223.8306	... .	− 5.6	+ 70.8	31.4
20 to LIII	3.202	1027.199	− 8.4063	− 8.4066	− 8.4064	+215.4242	38.7	+ 0.3	+ 71.1	0.1
LIII to 21	1.157	1028.356	+ 1.9727	+ 1.9742	+ 1.9734	+217.3976	....	− 1.5	+ 69.6	2.2

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM ATHENS, OHIO, TO MITCHELL, IND.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks.			Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy.		Δ^2
			Rod A, first line.	Rod B, second line.	Mean.			Partial Δ	Total.	
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm.*)[2]
21 to 22	2.801	1031.157	+ 9.3109	+ 9.3082	+ 9.3096	+226.7072	......	+ 2.7	+ 72.3	7.3
22 to 23	2.023	1033.180	+10.4067	+10.4158	+10.4112	+237.1184	......	− 9.1	+ 63.2	82.8
23 to 24	1.868	1035.048	− 8.6092	− 8.6161	− 8.6126	+228.5058	......	+ 6.9	+ 70.1	47.6
24 to 25	2.061	1037.109	−14.7564	−14.7486	−14.7525	+213.7533	......	− 7.8	+ 62.3	60.8
25 to 26	0.869	1037.978	− 3.7108	− 3.7136	− 3.7122	+210.0411	......	+ 2.8	+ 65.1	7.8
26 to 27	1.368	1039.346	− 5.7052	− 5.7049	− 5.7051	+204.3360	......	− 0.3	+ 64.8	0.1
27 to 28	3.862	1043.208	−14.4579	−14.4621	−14.4600	+189.8760	......	+ 4.2	+ 69.0	17.6
28 to 29	2.950	1046.158	− 2.2281	− 2.2323	− 2.2302	+187.6458	......	+ 4.2	+ 73.2	17.6
29 to 30	0.631	1046.789	− 1.8801	− 1.8770	− 1.8784	+185.7674	......	− 3.1	+ 70.1	9.6
30 to 31	3.135	1049.924	− 2.0535	− 2.0462	− 2.0499	+183.7175	......	− 7.3	+ 62.8	53.3
31 to 32	2.584	1052.508	+ 0.6817	+ 0.6780	+ 0.6799	+184.3974	......	+ 3.7	+ 66.5	13.7
32 to LIV	2.027	1054.535	− 1.1455	− 1.1484	− 1.1470	+183.2504	39.2	+ 2.9	+ 69.4	8.4
LIV to 33	2.418	1056.953	+ 3.5396	+ 3.5403	+ 3.5400	+186.7904	......	− 0.7	+ 68.7	0.5
33 to 36	0.821	1057.774	+ 6.4447	+ 6.4433	+ 6.4440	+193.2344	......	+ 1.4	+ 70.1	2.0
36 to 35	2.241	1060.015	+20.1473	+20.1504	+20.1489	+213.3833	......	− 3.1	+ 67.0	9.6
35 to LV	1.570	1061.585	−12.7770	−12.7803	−12.7787	+200.6046	39.2	+ 3.3	+ 70.3	10.9
LV to 34	2.580	1064.165	+ 1.9054	+ 1.9007	+ 1.9031	+202.5077	......	+ 4.7	+ 75.0	22.1
34 to 37	2.777	1066.942	− 3.9738	− 3.9741	− 3.9740	+198.5337	......	+ 0.3	+ 75.3	0.1
37 to 38	2.463	1069.405	− 5.3983	− 5.3976	− 5.3979	+193.1358	......	− 0.7	+ 74.6	0.5
38 to 41	1.343	1070.748	− 7.5024	− 7.5067	− 7.5046	+185.6312	......	+ 4.3	+ 78.9	18.5
41 to 40	2.760	1073.508	+ 0.2594	+ 0.2587	+ 0.2591	+185.8903	......	+ 0.7	+ 79.6	0.5
40 to 39	2.757	1076.265	+ 5.2173	+ 5.2192	+ 5.2183	+191.1086	......	− 1.7	+ 77.9	2.9
39 to 42	1.040	1077.305	+ 2.9375	+ 2.9418	+ 2.9396	+194.0482	......	− 4.3	+ 73.6	18.5
42 to Q	0.113	1077.418	+ 0.5909	+ 0.5925	+ 0.5917	+194.6399	39.3	− 1.6	+ 72.0	2.6
42 to 43	0.574	1077.879	− 0.5028	− 0.5034	− 0.5031	+193.5513	......	+ 0.6	+ 72.6	0.4
43 to 44	1.898	1079.777	+ 3.0179	+ 3.0146	+ 3.0163	+196.5676	......	+ 3.3	+ 75.9	10.9
44 to 45	2.370	1082.147	+14.5119	+14.5108	+14.5113	+211.0789	......	+ 1.1	+ 77.0	1.2
45 to 46	1.318	1083.465	+13.3850	+13.3831	+13.3841	+224.4630	......	+ 1.9	+ 78.9	3.6
46 to 47	3.048	1086.513	−11.4466	−11.4530	−11.4498	+213.0132	......	+ 6.4	+ 85.3	41.0
47 to 48	1.273	1087.786	− 1.2272	− 1.2315	− 1.2294	+211.7838	......	+ 4.3	+ 89.6	18.5
48 to LVI	3.447	1091.233	+ 1.6395	+ 1.6427	+ 1.6411	+213.4249	39.4	− 3.2	+ 86.4	10.2
LVI to LVII	2.658	1093.891	+ 3.8251	+ 3.8176	+ 3.8214	+217.2463	39.4	+ 7.5	+ 93.9	56.5
LVII to 49	1.642	1095.533	+ 3.3990	+ 3.3967	+ 3.3978	+220.6441	......	+ 2.3	+ 96.2	5.3
49 to 50	2.215	1097.748	+ 7.9542	+ 7.9574	+ 7.9558	+228.5999	......	− 3.2	+ 93.0	10.2
50 to 51	2.037	1099.785	+15.9381	+15.9358	+15.9370	+244.5369	......	+ 2.3	+ 95.3	5.3
51 to 52	2.235	1102.020	+21.3782	+21.3784	+21.3783	+265.9152	......	− 0.2	+ 95.1	0.0
52 to 53	2.315	1104.335	+17.7174	+17.7119	+17.7146	+283.6298	......	+ 5.5	+100.6	30.2
53 to 54	0.593	1104.928	+ 2.6032	+ 2.6020	+ 2.6026	+286.2324	......	+ 1.2	+101.8	1.4
54 to 55	1.821	1106.749	− 3.9766	− 3.9774	− 3.9770	+282.2554	......	+ 0.8	+102.6	0.6
55 to LVIII	1.317	1108.066	− 4.2102	− 4.2107	− 4.2104	+278.0450	39.6	+ 0.5	+103.1	0.3
LVIII to 56	1.914	1109.980	− 2.0490	− 2.0444	− 2.0467	+275.9983	....	− 4.6	+ 98.5	21.2
56 to 57	1.904	1111.884	+ 8.3201	+ 8.3102	+ 8.3151	+284.3134	......	+ 9.9	+108.4	98.0
57 to 58	2.227	1114.111	−10.7835	−10.7824	−10.7829	+273.5305	......	− 1.1	+107.3	1.2
58 to 59	0.532	1114.643	− 5.3906	− 5.3922	− 5.3914	+268.1391	......	+ 1.6	+108.9	2.6
59 to 65	1.929	1116.572	+11.2037	+11.2017	+11.2027	+279.3418	......	+ 2.0	+110.9	4.0
65 to 64	2.676	1119.248	+13.3042	+13.2940	+13.2991	+292.6409	......	+10.2	+121.1	104.0
64 to 63	1.784	1121.032	+ 4.5179	+ 4.5104	+ 4.5141	+297.1550	......	+ 7.5	+128.6	56.5
63 to 62	1.987	1123.019	−17.4198	−17.4149	−17.4173	+279.7377	......	− 4.9	+123.7	24.0
62 to 61	0.767	1123.786	+ 7.3481	+ 7.3480	+ 7.3480	+287.0857	......	+ 0.1	+123.8	0.0
61 to 60	2.183	1125.969	+ 6.3334	+ 6.3264	+ 6.3299	+293.4156	......	+ 7.0	+130.8	49.0
60 to 66	1.758	1127.727	− 1.9496	− 1.9495	− 1.9496	+291.4660	......	− 0.1	+130.7	0.0
66 to 67	1.725	1129.452	+ 7.3610	+ 7.3642	+ 7.3626	+298.8286	......	− 3.2	+127.5	10.2
67 to 68	1.112	1130.564	+10.9462	+10.9428	+10.9445	+309.7731	......	+ 3.4	+130.9	11.6
68 to 71	2.017	1132.581	+ 6.9469	+ 6.9494	+ 6.9482	+316.7213	......	− 2.5	+128.4	6.2
71 to 72	0.612	1133.193	+ 3.3874	+ 3.3874	+ 3.3874	+320.1087	......	0.0	+128.4	0.0
72 to 73	1.656	1134.849	+ 8.0193	+ 8.0203	+ 8.0198	+328.1285	......	− 1.0	+127.4	1.0

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM ATHENS, OHIO, TO MITCHELL, IND.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	±*mm.*	*mm.*	*mm.*	(*mm.*)²
73 to 75	1.749	1136.598	+ 8.9500	+ 8.9521	+ 8.9510	+337.0795	....	− 2.1	+125.3	4.4
75 to 76	1.760	1138.358	+ 0.7337	+ 0.7371	+ 0.7354	+337.8149	....	− 3.4	+121.9	11.6
76 to 77	1.619	1139.977	+10.8087	+10.8073	+10.8080	+348.6229	....	+ 1.4	+123.3	2.0
77 to 69	1.627	1141.604	+ 2.8393	+ 2.8386	+ 2.8390	+351.4619	....	+ 0.7	+124.0	0.5
69 to 70	2.488	1144.092	−10.8359	−10.8339	+10.8349	+340.6270	....	− 2.0	+122.0	4.0
70 to 74	2.063	1146.155	− 5.3463	− 5.3438	− 5.3451	+335.2819	....	− 2.5	+119.5	6.2
74 to 80	1.731	1147.886	−14.6184	−14.6204	−14.6194	+320.6625	....	+ 2.0	+121.5	4.0
80 to 79	2.758	1150.644	+ 2.9832	+ 2.9824	+ 2.9828	+323.6453	....	+ 0.8	+122.3	0.6
79 to 78	1.893	1152.537	+ 9.6357	+ 9.6328	+ 9.6343	+333.2796	....	+ 2.9	+125.2	8.4
78 to LIX	1.773	1154.310	−11.0715	−11.0705	−11.0710	+322.2086	40.2	− 1.0	+124.2	1.0
LIX to 81	1.814	1156.124	−10.3902	−10.3892	−10.3897	+311.8189	....	− 1.0	+123.2	1.0
81 to 82	2.132	1158.256	− 3.6095	− 3.6048	− 3.6072	+308.2117	....	− 4.7	+118.5	22.1
82 to 83	2.115	1160.371	− 2.0586	− 2.0617	− 2.0601	+306.1516	....	+ 3.1	+121.6	9.6
83 to LX	2.089	1162.460	− 4.2311	− 4.2363	− 4.2337	+301.9179	40.3	+ 5.2	+126.8	27.0
LX to 84	1.514	1163.974	+ 1.4515	+ 1.4534	+ 1.4524	+303.3703	....	− 1.9	+124.9	3.6
84 to 85	1.797	1165.771	+ 2.0840	+ 2.0850	+ 2.0845	+305.4548	....	− 1.0	+123.9	1.0
85 to 86	1.831	1167.602	− 2.4145	− 2.4122	− 2.4133	+303.0415	....	− 2.3	+121.6	5.3
86 to 87	1.775	1169.377	− 9.1419	− 9.1369	− 9.1394	+293.9021	....	− 5.0	+116.6	25.0
87 to 88	1.840	1171.217	− 6.8339	− 6.8315	− 6.8327	+287.0694	....	− 2.4	+114.2	5.8
88 to 89	2.031	1173.248	+ 1.1142	+ 1.1113	+ 1.1127	+288.1821	....	+ 2.9	+117.1	8.4
89 to 93	1.876	1175.124	− 8.5435	− 8.5413	− 8.5424	+279.6397	....	− 2.2	+114.9	4.8
93 to 94	2.223	1177.347	− 5.7499	− 5.7478	− 5.7488	+273.8909	....	− 2.1	+112.8	4.4
94 to 95	1.717	1179.064	− 6.0326	− 6.0312	− 6.0319	+267.8590	....	− 1.4	+111.4	2.0
95 to 96	1.776	1180.840	+ 2.7743	+ 2.7748	+ 2.7745	+270.6335	....	− 0.5	+110.9	0.3
96 to 97	2.254	1183.094	− 7.0677	− 7.0631	− 7.0654	+263.5681	....	− 4.6	+106.3	21.2
97 to 98	1.749	1184.843	−14.9108	−14.9032	−14.9070	+248.6611	....	− 7.6	+ 98.7	57.8
98 to 99	2.570	1187.413	−20.3289	−20.3290	−20.3289	+228.3322	....	+ 0.1	+ 98.8	0.0
99 to 100	0.565	1187.978	− 4.8023	− 4.8022	− 4.8023	+223.5299	....	− 0.1	+ 98.7	0.0
100 to LXI	2.119	1190.097	−12.1865	−12.1808	−12.1836	+211.3463	40.5	− 5.7	+ 93.0	32.5
LXI to 102	1.090	1191.187	−10.0242	−10.0311	−10.0277	+201.3186	....	+ 6.9	+ 99.9	47.6
102 to 103	2.377	1193.564	−16.1987	−16.1969	−16.1978	+185.1208	....	− 1.8	+ 98.1	3.2
103 to 92	1.349	1194.913	− 6.6781	− 6.6735	− 6.6758	+178.4450	....	− 4.6	+ 93.5	21.2
92 to R	0.429	1195.342	− 0.9451	− 0.9471	− 0.9461	+177.4989	40.6	+ 2.0	+ 95.5	4.0
R to 91	2.032	1197.374	− 0.3825	− 0.3889	− 0.3857	+177.1132	....	+ 6.4	+101.9	41.0
91 to 90	1.727	1199.101	− 2.4133	− 2.4073	− 2.4103	+174.7029	....	− 6.0	+ 95.9	36.0
90 to 104	2.094	1201.195	+ 3.8305	+ 3.8232	+ 3.8269	+178.5298	....	+ 7.3	+103.2	53.3
104 to LXII	2.198	1203.393	+ 1.7034	+ 1.7035	+ 1.7034	+180.2332	40.8	+ 0.1	+103.1	0.0
LXII to 106	1.973	1205.366	+19.9105	+19.9117	+19.9111	+200.1443	....	− 1.2	+111.9	1.4
106 to 107	1.589	1206.955	+16.1168	+16.1199	+16.1184	+216.2627	....	− 3.1	+108.8	9.6
107 to 108	2.641	1209.596	+ 3.9260	+ 3.9296	+ 3.9278	+220.1905	....	− 3.6	+105.2	13.0
108 to 109	0.800	1210.396	− 7.5684	− 7.5679	− 7.5682	+212.6223	....	− 0.5	+104.7	0.2
109 to 110	3.259	1213.655	−32.6422	−32.6371	−32.6396	+179.9827	....	− 5.1	+ 99.6	26.0
110 to 111	2.566	1216.221	+ 7.1306	+ 7.1343	+ 7.1324	+187.1151	....	− 3.7	+ 95.9	13.7
111 to 112	2.517	1218.738	− 1.7178	− 1.7168	− 1.7173	+185.3978	....	− 1.0	+ 94.9	1.0
112 to 113	3.176	1221.914	−16.3209	−16.3233	−16.3221	+169.0757	....	+ 2.4	+ 97.3	5.8
113 to 114	0.885	1222.799	− 5.1658	− 5.1688	− 5.1673	+163.9084	....	+ 3.0	+100.3	9.0
114 to 115	1.958	1224.757	−12.1350	−12.1292	−12.1321	+151.7763	....	− 5.8	+ 94.5	33.6
115 to LXIII	2.419	1227.176	+ 2.7153	+ 2.7125	+ 2.7139	+154.4902	41.0	+ 2.8	+ 97.3	7.8
LXIII to 116	1.490	1228.666	− 3.6049	− 3.6049	− 3.6049	+150.8853	....	0.0	+ 97.3	0.0
116 to LXIV	3.622	1232.288	+ 0.0633	+ 0.0671	+ 0.0652	+150.9505	41.0	− 3.8	+ 93.5	14.4
LXIV to S	0.302	1232.590	− 0.1039	− 0.1015	− 0.1027	+150.8478	41.0	− 2.4	+ 91.1	5.8
S to 122	2.505	1235.095	+17.1825	+17.1870	+17.1848	+168.0326	....	− 4.5	+ 86.6	20.3
122 to T	0.681	1235.776	− 1.3158	− 1.3159	− 1.3159	+166.7167	41.0	+ 0.1	+ 86.7	0.0
S to 121	2.083	1234.673	− 2.5429	− 2.5441	− 2.5435	+148.3043	....	+ 1.2	+ 92.3	1.4
121 to 120	2.686	1237.359	+ 0.2496	+ 0.2476	+ 0.2486	+148.5529	....	+ 2.0	+ 94.3	4.0
120 to 119	1.861	1239.220	− 0.2426	− 0.2502	− 0.2464	+148.3065	....	+ 7.6	+101.9	57.8

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM ATHENS, OHIO, TO MITCHELL, IND.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod A, first line.	Rod B, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
119 to 118	3.013	1242.233	− 0.1115	− 0.1062	− 0.1088	+148.1977	....	− 5.3	+ 96.6	28.1
118 to 117	3.117	1245.350	− 0.1987	− 0.2048	− 0.2018	+147.9959	....	+ 6.1	+102.7	37.2
117 to LXV	2.226	1247.576	+ 0.8732	+ 0.8773	+ 0.8753	+148.8712	41.2	− 4.1	+ 98.6	16.8
LXV to 123	2.546	1250.122	+ 0.2071	+ 0.2056	+ 0.2063	+149.0775	....	+ 1.5	+100.1	2.2
123 to 124	2.493	1252.615	− 0.7199	− 0.7131	− 0.7165	+148.3610	....	− 6.8	+ 93.3	46.2
124 to 125	3.713	1256.328	− 0.3951	− 0.3921	− 0.3936	+147.9674	....	− 3.0	+ 90.3	9.0
125 to 126	2.297	1258.625	+ 1.6776	+ 1.6751	+ 1.6764	+149.6438	....	+ 2.5	+ 92.8	6.2
126 to 127	3.403	1262.028	− 1.6373	− 1.6339	− 1.6356	+148.0082	....	− 3.4	+ 89.4	11.6
127 to LXVI	0.706	1262.734	− 0.8103	− 0.8085	− 0.8094	+147.1988	41.3	− 1.8	+ 87.6	3.2
LXVI to 128	3.120	1265.854	− 1.6681	− 1.6689	− 1.6685	+145.5303	....	+ 0.8	+ 88.4	0.6
128 to 135	0.478	1266.332	+ 0.6589	+ 0.6560	+ 0.6574	+146.1877	....	+ 2.9	+ 91.3	8.4
135 to U	0.117	1266.449	+ 2.0857	+ 2.0852	+ 2.0855	+148.2732	41.3	+ 0.5	+ 91.8	0.2
135 to 134	2.330	1268.662	− 0.7465	− 0.7447	− 0.7456	+145.4421	....	− 1.8	+ 89.5	3.2
134 to 133	2.075	1270.737	+ 0.2904	+ 0.2953	+ 0.2928	+145.7349	....	− 4.9	+ 84.6	24.0
133 to 132	1.924	1272.661	+ 5.9936	+ 5.9946	+ 5.9941	+151.7290	....	− 1.0	+ 83.6	1.0
132 to 131	2.310	1274.971	− 3.5296	− 3.5334	− 3.5315	+148.1975	....	+ 3.8	+ 87.4	14.4
131 to 130	1.218	1276.189	+ 0.6357	+ 0.6386	+ 0.6372	+148.8347	....	− 2.9	+ 84.5	8.4
130 to 129	1.913	1278.102	− 0.6046	− 0.6013	− 0.6030	+148.2317	....	− 3.3	+ 81.2	10.9
129 to LXVII	2.133	1280.235	+ 2.3783	+ 2.3730	+ 2.3757	+150.6074	41.4	+ 5.3	+ 86.5	28.1
LXVII to 136	3.654	1283.889	+21.0770	+21.0774	+21.0772	+171.6846	....	− 0.4	+ 86.1	0.2
136 to 137	1.483	1285.372	+12.5046	+12.4974	+12.5010	+184.1856	....	+ 7.2	+ 93.3	51.8
137 to 141	2.087	1287.459	+18.5276	+18.5314	+18.5295	+202.7151	....	− 3.8	+ 89.5	14.4
141 to 142	3.266	1290.725	+31.9681	+31.9720	+31.9700	+234.6851	....	− 3.9	+ 85.6	15.2
142 to 143	1.957	1292.682	+18.6616	+18.6608	+18.6612	+253.3463	....	+ 0.8	+ 86.4	0.6
143 to 144	3.082	1295.764	+26.3473	+26.3462	+26.3468	+279.6931	....	+ 1.1	+ 87.5	1.2
144 to 145	3.827	1299.591	+21.4459	+21.4482	+21.4470	+301.1401	....	− 2.3	+ 85.2	5.3
145 to 146	0.957	1300.548	+ 3.4677	+ 3.4636	+ 3.4657	+304.6058	....	+ 4.1	+ 89.3	16.8
146 to 147	2.169	1302.717	+ 0.4087	+ 0.4112	+ 0.4099	+305.0157	....	− 2.5	+ 86.8	6.2
147 to LXVIII	3.990	1306.707	−21.9792	−21.9785	−21.9788	+283.0369	41.6	− 0.7	+ 86.1	0.5
LXVIII to 138	2.942	1309.649	−16.0553	−16.0566	−16.0560	+266.9809	....	+ 1.3	+ 87.4	1.7
138 to 139	3.139	1312.788	+10.1448	+10.1497	+10.1473	+277.1282	....	− 4.9	+ 82.5	24.0
139 to 140	0.572	1313.360	+ 5.2413	+ 5.2416	+ 5.2414	+282.3696	....	− 0.3	+ 82.2	0.1
140 to 148	2.521	1315.881	+20.0879	+20.0867	+20.0873	+302.4569	....	+ 1.2	+ 83.4	1.4
148 to 150	2.862	1318.743	− 4.9439	− 4.9462	− 4.9450	+297.5119	....	+ 2.3	+ 85.7	5.3
150 to 149	2.937	1321.680	− 4.6357	− 4.6357	− 4.6357	+292.8762	....	0.0	+ 85.7	0.0
149 to 151	2.466	1324.146	−14.9216	−14.9136	−14.9176	+277.9586	....	− 8.0	+ 77.7	64.0
151 to 152	2.794	1326.940	− 1.3745	− 1.3781	− 1.3763	+276.5823	....	+ 3.6	+ 81.3	13.0
152 to 153	2.077	1329.017	−16.1173	−16.1229	−16.1201	+260.4622	....	+ 5.6	+ 86.9	31.4
153 to 154	1.879	1330.896	− 7.3402	− 7.3321	− 7.3361	+253.1261	....	− 8.1	+ 78.8	65.6
154 to 155	3.293	1334.189	+ 0.8370	+ 0.8386	+ 0.8378	+253.9639	....	− 1.6	+ 77.2	2.6
155 to 156	1.959	1336.148	− 6.0772	− 6.0813	− 6.0793	+247.8846	....	+ 4.1	+ 81.3	16.8
156 to 157	2.539	1338.687	− 0.7785	− 0.7764	− 0.7774	+247.1072	....	− 2.1	+ 79.2	4.4
157 to 158	0.685	1339.372	− 2.0041	− 2.0072	− 2.0057	+245.1015	....	+ 3.1	+ 82.3	9.6
158 to 159	2.157	1341.529	−11.8845	−11.8824	−11.8835	+233.2180	....	− 2.1	+ 80.2	4.4
159 to 160	2.790	1344.319	− 6.6481	− 6.6523	− 6.6502	+226.5678	....	+ 4.2	+ 84.4	17.6
160 to LXIX	2.993	1347.312	−17.5961	−17.5888	−17.5924	+208.9754	42.0	− 7.3	+ 77.1	53.3
LXIX to 161	1.462	1348.774	+11.6155	+11.6132	+11.6143	+220.5897	....	+ 2.3	+ 79.4	5.3
161 to 162	2.630	1351.404	+ 1.3430	+ 1.3448	+ 1.3439	+221.9336	....	− 1.8	+ 77.6	3.2
162 to 163	3.087	1354.491	−14.6662	−14.6597	−14.6629	+207.2707	....	− 6.5	+ 71.1	42.2
163 to 164	3.404	1357.895	−21.7044	−21.7099	−21.7072	+185.5635	....	+ 5.5	+ 76.6	30.2
164 to 174	3.123	1361.018	+ 1.8883	+ 1.8850	+ 1.8867	+187.4502	....	+ 3.3	+ 79.9	10.9
174 to 168	3.887	1364.905	− 8.8481	− 8.8490	− 8.8486	+178.6016	....	+ 0.9	+ 80.8	0.8
168 to 167	2.212	1367.117	− 3.4400	− 3.4499	− 3.4449	+175.1567	....	+ 9.9	+ 90.7	98.0
167 to 166	2.539	1369.656	+ 7.2820	+ 7.2851	+ 7.2835	+182.4402	....	− 3.1	+ 87.6	9.6
166 to 165	3.002	1372.658	+ 2.9072	+ 2.9131	+ 2.9102	+185.3504	....	− 5.9	+ 81.7	34.8
165 to 173	1.847	1374.505	−11.6258	−11.6271	−11.6265	+173.7239	....	+ 1.3	+ 83.0	1.7
173 to 172	2.617	1377.122	− 2.2776	− 2.2773	− 2.2774	+171.4465	....	− 0.3	+ 82.7	0.1

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM ATHENS, OHIO, TO MITCHELL, IND.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks.			Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy.		Δ²
			Rod A, first line.	Rod B, second line.	Mean.			Partial Δ.	Total.	
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
172 to 171	2.261	1379.383	+ 0.6674	+ 0.6664	+ 0.6669	+172.1134	....	+ 1.0	+83.7	1.0
171 to 170	2.145	1381.528	− 1.5725	− 1.5666	− 1.5696	+170.5438	....	− 5.9	+77.8	34.8
170 to 169	2.039	1383.567	− 1.4206	− 1.4175	− 1.4190	+169.1248	....	− 3.1	+74.7	9.6
169 to 175	2.076	1385.643	+ 0.3842	+ 0.3857	+ 0.3849	+169.5097	....	− 1.5	+73.2	2.2
175 to 176	4.129	1389.772	− 1.1202	− 1.1200	− 1.1201	+168.3896	....	− 0.2	+73.0	0.0
176 to 177	2.415	1392.187	+ 0.3636	+ 0.3678	+ 0.3657	+168.7553	....	− 4.2	+68.8	17.6
177 to 178	1.708	1393.895	− 4.4726	− 4.4721	− 4.4723	+164.2830	....	− 0.5	+68.3	0.2
178 to 179	1.703	1395.598	− 0.7329	− 0.7390	− 0.7359	+163.5471	....	+ 6.1	+74.4	37.2
179 to 180	2.117	1397.715	− 1.2777	− 1.2797	− 1.2787	+162.2684	....	+ 2.0	+76.4	4.0
180 to V	1.333	1399.048	+ 0.7653	+ 0.7673	+ 0.7663	+163.0347	42.5	− 2.0	+74.4	4.0
V to 181	3.217	1402.265	− 2.2499	− 2.2518	− 2.2509	+160.7838	....	+ 1.9	+76.3	3.6
181 to 182	0.961	1403.226	+ 0.5668	+ 0.5685	+ 0.5677	+161.3515	....	− 1.7	+74.6	2.9
182 to 185	2.871	1406.097	− 1.1087	− 1.1143	− 1.1115	+160.2400	....	+ 5.6	+80.2	31.4
185 to 184	2.276	1408.373	+ 0.4700	+ 0.4662	+ 0.4681	+160.7081	....	+ 3.8	+84.0	14.4
184 to 183	2.090	1410.463	− 1.3920	− 1.3854	− 1.3887	+159.3194	....	− 6.6	+77.4	43.6
183 to 186	3.024	1413.487	+ 0.2435	+ 0.2462	+ 0.2448	+159.5642	....	− 2.7	+74.7	7.3
186 to LXX	2.142	1415.629	− 0.2619	− 0.2643	− 0.2631	+159.3011	42.6	+ 2.4	+77.1	5.8
LXX to 187	0.594	1416.223	− 0.4813	− 0.4820	− 0.4816	+158.8195	....	+ 0.7	+77.8	0.5
187 to 188	2.418	1418.641	+ 5.4594	+ 5.4563	+ 5.4578	+164.2773	....	+ 3.1	+80.9	9.6
188 to 189	2.741	1421.382	− 6.7784	− 6.7826	− 6.7805	+157.4968	....	+ 4.2	+85.1	17.6
189 to 190	1.921	1423.303	+ 0.4605	+ 0.4525	+ 0.4565	+157.9533	....	+ 8.0	+93.1	64.0
190 to 191	1.882	1425.185	− 0.8013	− 0.7944	− 0.7978	+157.1555	....	− 6.9	+86.2	47.6
191 to W	1.600	1426.785	+ 0.2032	+ 0.2074	+ 0.2053	+157.3608	42.8	− 4.2	+82.0	17.6
W to 192	0.365	1427.150	− 0.1600	− 0.1571	− 0.1586	+157.2022	....	− 2.9	+79.1	8.4
192 to 196	2.845	1429.995	+14.1549	+14.1562	+14.1556	+171.3578	....	− 1.3	+77.8	1.7
196 to 197	1.610	1431.605	+17.4048	+17.4085	+17.4066	+188.7644	....	− 3.7	+74.1	13.7
197 to 195	1.122	1432.727	+12.1813	+12.1871	+12.1842	+200.9486	....	− 5.8	+68.3	33.6
195 to 194	1.115	1433.842	+ 2.7457	+ 2.7490	+ 2.7474	+203.6960	....	− 6.3	+62.0	39.7
194 to 193	2.308	1436.150	+ 3.4879	+ 3.4869	+ 3.4874	+207.1834	....	+ 1.0	+63.0	1.0
193 to X	0.500	1436.650	+ 2.4980	+ 2.4971	+ 2.4975	+209.6809	43.0	+ 0.9	+63.9	0.8
193 to 200	1.756	1437.906	+ 9.8940	+ 9.8989	+ 9.8964	+217.0798	....	− 4.9	+58.1	24.0
200 to 199	4.288	1442.194	− 7.9892	− 7.9875	− 7.9883	+209.0915	....	− 1.7	+56.4	2.9
199 to 198	2.518	1444.712	− 5.1143	− 5.1141	− 5.1142	+203.9773	43.0	− 0.2	+56.2	0.0

SECTION IV.—Description of primary and secondary bench-marks between *Athens, Ohio, and. Mitchell, Ind.*

P—Athens, Ohio. Already described.

No. LI—At Moonville, Ohio. Cut on the eastern abutment of Marietta and Cincinnati Railroad bridge over Raccoon Creek, and is marked thus: B □ M.

No. LII—One mile south of Zaleski, Ohio. Cut on the south abutment of Marietta and Cincinnati Railroad bridge over Raccoon Creek, and is marked thus: B □ M.

No. LIII—Cut on the coping of a small drain or culvert, about one-half mile east of Hamden Station, Marietta and Cincinnati Railroad. It is marked thus: B □ M.

No. LIV—Cut on the east abutment of Marietta and Cincinnati Railroad bridge over Big Salt Creek, about 1½ miles east of Londonderry Station, and is marked: B □ M.

No. LV—One and one-half miles east of Schooley's Station, Marietta and Cincinnati Railroad Cut on the eastern abutment of railroad bridge over Walnut Creek, and is marked thus: B □ M.

Q—Cut on the pedestal of the lamp-post which stands on the north side of the steps of the front entrance of the court-house at Chillicothe, Ohio. It is marked thus:

Q
B □ M
U. S. C. & G. S.
Aug. 5, 1879.

No. LVI—Cut on the west abutment of Marietta and Cincinnati Railroad bridge over branch of Paint Creek, about 1¼ miles east of Musselman's Junction, Ross County, Ohio. It is marked thus: B □ M.

No. LVII—Cut on the east abutment of Marietta and Cincinnati Railroad bridge over branch of Paint Creek, about one-fourth mile west of Musselman's Junction, Ross County, Ohio. It is marked thus: B □ M.

No. LVIII—Cut on the eastern abutment of Marietta and Cincinnati Railroad bridge, about 1 mile east of Lyndon Station, and is marked thus: B □ M.

No. LIX—Cut on the eastern abutment of Marietta and Cincinnati Railroad bridge, at Martinsville, Clinton County, Ohio. It is marked thus: B □ M.

No. LX—Cut on the east abutment of Marietta and Cincinnati Railroad bridge, about three-tenths mile east of Clinton Valley Station, and is marked thus: B □ M.

No. LXI—Cut on the west abutment of Marietta and Cincinnati Railroad bridge, about 3¼ miles east of Loveland, Ohio, and is marked thus: B □ M.

R—Loveland, Ohio. Cut on the east abutment of Marietta and Cincinnati Railroad bridge over the Little Miami River. It is marked thus:

R
B □ M
U. S. C. & G. S.
1879.

No. LXII—Cut on the pier of the Marietta and Cincinnati Railroad bridge over Sycamore Creek, a short distance west of Remington Station, and is marked thus: B □ M.

No. LXIII—Cut on the west abutment of Marietta and Cincinnati Railroad bridge, a short distance west of Cummingsville, Hamilton County, Ohio. It is marked thus: B □ M.

No. LXIV—Cut on the south abutment of Marietta and Cincinnati Railroad bridge over Gest street, suburb of Cincinnati, Ohio. It is marked thus: B □ M.

S—Cut on the west abutment of Marietta and Cincinnati Railroad bridge over Mill Creek, at Eighth Street Station, Cincinnati, Ohio. It is marked thus:

S
B □ M
U. S. C. & G. S.
1879.

T—Is bench-mark No. 1 of the Cincinnati city engineer, and is on the front water-table of the court-house. It is the centre of the top of a hexagonal copper bolt inserted in the stone.

No. LXV—A square cavity cut in top of a stone monument, about 46 metres west of Delhi Station of Ohio and Mississippi Railroad (Hamilton County, Ohio).

No. LXVI—Hamilton County, Ohio. Cut on a pier (first pier from Ohio side of river) of Ohio and Mississippi Railroad bridge over Miami River, near its junction with the Ohio River. It is about 2 miles east of Lawrenceburg, Ind., and is marked thus: B □ M.

U—Lawrenceburg, Ind. Cut on the water-table of the court-house front. It is marked thus:

1879
U. S. C. & G. S.
B □ M
U

No. LXVII—Cut on the east abutment of Ohio and Mississippi Railroad bridge No. 11, over South Hogan Creek, about 3½ miles west of Cochran Station, Dearborn County, Indiana. It is marked thus: B □ M.

No. LXVIII—Cut on the east abutment of Ohio and Mississippi Railroad bridge over Greasy Run, a short distance east of Delaware, Ripley County, Indiana. It is marked thus: B □ M.

No. LXIX—Cut on the east abutment of Ohio and Mississippi Railroad bridge, over north fork of Vernon River, about three-fourths mile east of North Vernon, Jennings County, Indiana. It is marked thus: B □ M.

V—Cut on the west abutment of Ohio and Mississippi Railroad bridge over east fork of White River, about 2 miles east of Medora, Jackson County, Indiana. It is marked thus:

V
B □ M
U. S. C. & G. S.
1879.

No. LXX—Cut on the coping stone of arch (Ohio and Mississippi Railroad) over wagon-road, about 200 metres east of Fort Ritner Station, Lawrence County, Indiana. It is marked thus: B □ M.

W—Cut on the eastern abutment of Ohio and Mississippi Railroad bridge over east fork of White River, about one-third mile east of Scottville, Lawrence County, Indiana. It is marked thus:

W
B □ M
U. S. C. & G. S.
1879.

X—Cut on the sill of window near the west corner of the south face of M. N. Moore's store, at Mitchell, Ind. It is marked thus:

X
B □ M
U. S. C. & G. S.
Nov. 19, 1879.

Transcontinental line of Spirit-levels—Continued.

SECTION V.—FROM MITCHELL, IND., TO SAINT LOUIS, MO.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ^2
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	$(mm.)^2$
X	....	1436.650	....	....	....	+209.6809	43.0	....	+63.9	....
X to 52	1.238	1437.888	+ 6.7184	+ 6.7165	+ 6.7175	+216.3984	....	+ 1.9	+65.8	3.6
52 to 51	1.796	1439.684	− 3.1796	− 3.1754	− 3.1775	+213.2209	....	− 4.2	+61.6	17.6
51 to 50	1.612	1441.296	+ 6.3682	+ 6.3648	+ 6.3665	+219.5874	....	+ 3.4	+65.0	11.6
50 to 49	2.141	1443.437	−11.2144	−11.2220	−11.2182	+208.3692	....	+ 7.6	+72.6	57.8
49 to 48	1.715	1445.152	− 4.2731	− 4.2734	− 4.2733	+204.0959	....	+ 0.3	+72.9	0.1
48 to 58	1.924	1447.076	− 7.8070	− 7.8029	− 7.8049	+196.2910	....	− 4.1	+68.8	16.8
58 to 59	0.888	1447.964	− 2.2270	− 2.2308	− 2.2289	+194.0621	....	+ 3.8	+72.6	14.4
59 to 60	2.702	1450.666	−17.7108	−17.7106	−17.7107	+176.3514	....	− 0.2	+72.4	0.0
60 to 57	3.449	1454.115	− 9.1924	− 9.1887	− 9.1906	+167.1608	....	− 3.7	+68.7	13.7
57 to 56	0.805	1454.920	+ 0.2505	+ 0.2502	+ 0.2504	+167.4112	....	+ 0.3	+69.0	0.1
56 to 55	1.512	1456.432	+ 1.5765	+ 1.5711	+ 1.5738	+168.9850	....	+ 5.4	+74.4	29.2
55 to 54	2.032	1458.464	− 9.8100	− 9.8124	− 9.8112	+159.1738	....	+ 2.4	+76.8	5.8
54 to 53	2.306	1460.770	− 5.8564	− 5.8521	− 5.8543	+153.3195	....	− 4.3	+72.5	18.5
53 to 43	1.623	1462.393	− 0.5716	− 0.5669	− 0.5692	+152.7503	....	− 4.7	+67.8	22.1
43 to 44	1.936	1464.329	− 1.8103	− 1.8068	− 1.8086	+150.9417	....	− 3.5	+64.3	12.2
44 to 45	1.652	1465.981	− 2.5557	− 2.5547	− 2.5552	+148.3865	....	− 1.0	+63.3	1.0
45 to 39	1.252	1467.233	− 1.0028	− 1.0061	− 1.0044	+147.3821	....	+ 3.3	+66.6	10.9
39 to 40	1.512	1468.745	− 0.6134	− 0.6226	− 0.6180	+146.7641	....	+ 9.2	+75.8	84.6
40 to 41	1.584	1470.329	− 0.9310	− 0.9383	− 0.9347	+145.8294	....	+ 7.3	+83.1	53.3
41 to 42	1.050	1471.379	+ 0.3445	+ 0.3518	+ 0.3482	+146.1776	....	− 7.3	+75.8	53.3
42 to 34	2.681	1474.060	+ 2.1296	+ 2.1321	+ 2.1308	+148.3084	....	− 2.5	+73.3	6.2
34 to Y	0.438	1474.498	+11.1637	+11.1625	+11.1631	+159.4715	43.5	+ 1.2	+74.5	1.4
34 to 35	2.462	1476.960	− 2.9209	− 2.9241	− 2.9225	+145.3859	....	+ 3.2	+76.5	10.4
35 to 36	1.634	1478.594	− 0.2067	− 0.2022	− 0.2044	+145.1815	....	− 4.5	+72.0	20.2
36 to 37	2.336	1480.930	− 0.4961	− 0.4914	− 0.4938	+144.6877	....	− 4.7	+67.3	22.1
37 to 38	1.391	1482.321	− 0.2105	− 0.2142	− 0.2124	+144.4753	....	+ 3.7	+71.0	13.7

Transcontinental line of Spirit-levels—Continued.

SECTION V.—FROM MITCHELL, IND., TO SAINT LOUIS, MO.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
38 to 46	2.088	1484.409	− 0.0640	− 0.0603	− 0.0621	+144.4132	....	− 3.7	+67.3	13.7
46 to 47	1.353	1485.762	+ 2.9001	+ 2.8981	+ 2.8991	+147.3123	....	+ 2.0	+69.3	4.0
47 to 33	1.794	1487.556	+ 8.6598	+ 8.6459	+ 8.6528	+155.9651	....	+13.9	+83.2	193.2
33 to 32	0.848	1488.404	+ 8.2677	+ 8.2733	+ 8.2705	+164.2356	....	− 5.6	+77.6	31.4
32 to 31	1.948	1490.352	− 3.7156	− 3.7201	− 3.7178	+160.5178	....	+ 4.5	+82.1	20.2
31 to 30	2.856	1493.208	− 4.9627	− 4.9584	− 4.9606	+155.5572	....	− 4.3	+77.8	18.5
30 to 22	2.710	1495.918	+ 4.5787	+ 4.5746	+ 4.5767	+160.1339	....	+ 4.1	+81.9	16.8
22 to 23	1.056	1496.974	− 8.0543	− 8.0538	+ 8.0541	+152.0798	....	− 0.5	+81.4	0.2
23 to 24	2.970	1499.944	+12.2140	+12.2137	+12.2139	+164.2937	....	+ 0.3	+81.7	0.1
24 to 25	2.674	1502.618	− 8.0267	− 8.0187	− 8.0227	+156.2710	....	− 8.0	+73.7	64.0
25 to 26	0.910	1503.528	+ 0.8670	+ 0.8714	+ 0.8692	+157.1402	....	− 4.4	+69.3	19.4
26 to 29	2.352	1505.880	− 2.1918	− 2.1986	− 2.1952	+154.9450	....	+ 6.8	+76.1	46.2
29 to 28	2.484	1508.364	+ 1.8463	+ 1.8381	+ 1.8422	+156.7872	....	+ 8.2	+84.3	67.2
28 to 27	2.036	1510.400	+ 0.1554	+ 0.1474	+ 0.1514	+156.9386	....	+ 8.0	+92.3	64.0
27 to 21	1.074	1511.474	− 7.3365	− 7.3341	− 7.3353	+149.6033	....	− 2.4	+89.9	5.8
21 to Z	0.706	1512.180	+ 5.9810	+ 5.9783	+ 5.9796	+155.5829	44.4	+ 2.7	+92.6	7.3
21 to 20	1.510	1512.984	− 4.3996	− 4.3942	− 4.3969	+145.2064	....	− 5.4	+84.5	29.2
20 to 19	2.444	1515.428	− 6.3593	− 6.3592	− 6.3592	+138.8472	....	− 0.1	+84.4	0.0
19 to 16	2.612	1518.040	− 3.0963	− 3.0962	− 3.0963	+135.7509	....	− 0.1	+84.3	0.0
16 to 17	0.788	1518.828	+ 1.4418	+ 1.4445	+ 1.4432	+137.1941	....	− 2.7	+81.6	7.3
17 to 18	2.160	1520.988	+11.1511	+11.1487	+11.1499	+148.3440	....	+ 2.4	+84.0	5.8
18 to 8	2.048	1523.036	+ 1.1512	+ 1.1505	+ 1.1508	+149.4948	....	+ 0.7	+84.7	0.5
8 to 9	1.224	1524.260	− 4.0379	− 4.0364	− 4.0371	+145.4577	....	− 1.5	+83.2	2.2
9 to 10	2.766	1527.026	− 6.9323	− 6.9276	− 6.9300	+138.5277	....	− 4.7	+78.5	22.1
10 to 11	1.338	1528.364	+ 3.1842	+ 3.1856	+ 3.1849	+141.7126	....	− 1.4	+77.1	2.0
11 to 12	1.884	1530.248	− 1.8216	− 1.8158	− 1.8187	+139.8939	....	− 5.8	+71.3	33.6
12 to 13	1.106	1531.354	+ 4.3563	+ 4.3523	+ 4.3543	+144.2482	....	+ 4.0	+75.3	16.0
13 to 14	0.970	1532.324	+ 9.8019	+ 9.8009	+ 9.8014	+154.0496	....	+ 1.0	+76.3	1.0
14 to 15	1.198	1533.522	+ 9.7299	+ 9.7334	+ 9.7317	+163.7813	....	− 3.5	+72.8	12.5
15 to 7	2.417	1535.939	− 3.6203	− 3.6148	− 3.6176	+160.1637	....	− 5.5	+67.3	30.2
7 to 6	1.537	1537.476	− 0.9891	− 0.9851	− 0.9871	+159.1766	....	− 4.0	+63.3	16.0
6 to 5	2.074	1539.550	−17.4715	−17.4725	−17.4720	+141.7046	....	+ 1.0	+64.3	1.0
5 to 1	2.564	1542.114	−12.4928	−12.4946	−12.4937	+129.2109	....	+ 1.8	+66.1	3.2
1 to I	1.232	1543.346	+ 2.2159	+ 2.2141	+ 2.2150	+131.4259	44.6	+ 1.8	+67.9	3.2
I to A_2	0.090	1543.436	+ 1.1951	+ 1.1951	+ 1.1951	+132.6210	44.6	0.0	+67.9	0.0
A_2 to 2	0.953	1544.389	− 2.2227	− 2.2245	− 2.2236	+130.3974	....	+ 1.8	+69.7	3.2
2 to 3	0.192	1544.581	− 0.4059	− 0.4051	− 0.4055	+129.9919	....	− 0.8	+68.9	0.6
3 to 62	2.826	1547.407	− 4.4135	− 4.4080	− 4.4107	+125.5812	....	+ 4.5	+73.4	20.2
62 to 61	4.440	1551.847	+ 1.1834	+ 1.1837	+ 1.1835	+126.7647	....	− 0.3	+73.1	0.1
61 to 64	5.740	1557.587	+ 3.6275	+ 3.6248	+ 3.6262	+130.3909	....	+ 2.7	+75.8	7.3
64 to 67	2.326	1559.913	+ 3.8706	+ 3.8724	+ 3.8715	+134.2624	....	− 1.8	+74.0	3.2
67 to 66	3.034	1562.947	− 0.5495	− 0.5421	− 0.5458	+133.7166	....	− 7.4	+66.6	54.8
66 to 65	2.533	1565.480	+ 1.9632	+ 1.9676	+ 1.9654	+135.6820	....	− 4.4	+62.2	19.4
65 to 82	1.984	1567.464	+ 7.9713	+ 7.9780	+ 7.9746	+143.6566	....	− 6.7	+55.5	44.9
82 to 83	1.781	1569.245	+ 9.5233	+ 9.5233	+ 9.5233	+153.1799	....	0.0	+55.5	0.0
83 to 84	1.984	1571.229	+ 4.7647	+ 4.7717	+ 4.7682	+157.9481	....	− 7.0	+48.5	49.0
84 to 89	1.636	1572.865	− 8.6453	− 8.6425	− 8.6439	+149.3042	....	− 2.8	+45.7	7.8
89 to 90	1.726	1574.591	− 9.4631	− 9.4598	− 9.4614	+139.8428	....	− 3.3	+42.4	10.9
90 to 91	2.580	1577.171	+11.1975	+11.2026	+11.2000	+151.0428	....	− 5.1	+37.3	26.0
91 to 92	2.169	1579.340	+ 5.9209	+ 5.9165	+ 5.9187	+156.9615	....	+ 4.4	+41.7	19.4
92 to 93	2.616	1581.956	+ 7.7484	+ 7.7441	+ 7.7463	+164.7078	....	+ 4.3	+46.0	18.5
93 to 68	2.461	1584.417	− 9.2658	− 9.2718	− 9.2688	+155.4390	....	+ 6.0	+52.0	36.0
68 to 69	2.658	1587.075	+ 4.0827	+ 4.0850	+ 4.0838	+159.5228	....	− 2.3	+49.7	5.3
69 to 70	2.045	1589.120	− 5.5777	− 5.5758	− 5.5767	+153.9461	....	− 1.9	+47.8	3.6
70 to 71	1.984	1591.104	+ 0.7068	+ 0.7039	+ 0.7053	+154.6514	....	+ 2.9	+50.7	8.4
71 to 72	2.346	1593.450	− 2.7253	− 2.7214	− 2.7233	+151.9281	....	− 3.9	+46.8	15.2
72 to 73	0.925	1594.375	− 6.2494	− 6.2539	− 6.2517	+145.6764	....	+ 4.5	+51.3	20.2

Transcontinental line of Spirit-levels—Continued.

SECTION V.—FROM MITCHELL, IND., TO SAINT LOUIS, MO.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm*)².
73 to II	0.346	1594.721	+ 1.0858	+ 1.0839	+ 1.0849	+146.7613	45.1	+ 1.9	+53.2	3.6
II to B_3	0.376	1595.097	+ 1.7392	+ 1.7412	+ 1.7402	+148.5015	45.1	− 2.0	+51.2	4.0
73 to 74	2.166	1596.541	−14.1528	−14.1514	−14.1521	+131.5243	....	− 1.4	+49.9	2.0
74 to 75	0.965	1597.506	+ 3.1006	+ 3.0997	+ 3.1002	+134.6245	....	+ 0.9	+50.8	0.8
75 to 81	3.000	1600.506	− 1.2031	− 1.2043	− 1.2037	+133.4208	....	+ 1.2	+52.0	1.4
81 to 79	1.306	1601.812	+ 6.0955	+ 6.0999	+ 6.0977	+139.5185	....	− 4.4	+47.6	19.4
79 to 78	1.690	1603.502	+ 0.9105	+ 0.9063	+ 0.9084	+140.4269	....	+ 4.2	+51.8	17.6
78 to 77	1.729	1605.231	+ 4.9426	+ 4.9365	+ 4.9395	+145.3664	....	+ 6.1	+57.9	37.2
77 to 76	1.779	1607.010	+ 0.2799	+ 0.2841	+ 0.2820	+145.6484	....	− 4.2	+53.7	17.6
76 to 80	1.627	1608.637	− 3.4410	− 3.4375	− 3.4392	+142.2092	....	− 3.5	+50.2	12.2
80 to 85	2.206	1610.843	−10.2226	−10.2154	−10.2190	+131.9902	....	− 7.2	+43.0	51.8
85 to 86	2.806	1613.651	− 2.0615	− 2.0665	− 2.0640	+129.9262	....	+ 5.0	+48.0	25.0
86 to 87	1.166	1614.817	+ 1.0662	+ 1.0647	+ 1.0655	+130.9917	....	+ 1.5	+49.5	2.2
87 to III	0.858	1615.675	+ 0.0422	+ 0.0422	+ 0.0422	+131.0339	45.3	0.0	+49.5	0.0
III to 94	1.932	1617.607	− 0.6800	− 0.6782	− 0.6791	+130.3548	....	− 1.8	+47.7	3.2
94 to 96	2.877	1620.484	+ 8.8059	+ 8.8074	+ 8.8066	+139.1614	....	− 1.5	+46.2	2.2
96 to 97	1.560	1622.044	+ 4.2585	+ 4.2631	+ 4.2608	+143.4222	....	− 4.6	+41.6	21.2
97 to 98	1.441	1623.485	− 2.7038	− 2.7094	− 2.7066	+140.7156	....	+ 5.6	+47.2	31.4
98 to 99	1.596	1625.081	− 0.2468	− 0.2447	− 0.2457	+140.4699	....	− 2.1	+45.1	4.4
99 to 100	1.228	1626.309	− 3.0926	− 3.0914	− 3.0920	+137.3779	....	− 1.2	+43.9	1.4
100 to 101	1.652	1627.961	+ 5.3683	+ 5.3742	+ 5.3712	+142.7491	....	− 5.9	+38.0	34.8
101 to 102	1.262	1629.223	+ 3.4517	+ 3.4474	+ 3.4495	+146.1986	....	+ 4.3	+42.3	18.5
102 to C_3	0.346	1629.569	+ 3.5094	+ 3.5083	+ 3.5089	+149.7075	45.5	+ 1.1	+43.4	1.2
C_3 to 103	1.804	1631.373	− 0.7167	− 0.7165	− 0.7166	+148.9909	....	− 0.2	+43.2	0.0
103 to 104	1.019	1632.392	+ 3.0946	+ 3.0947	+ 8.0946	+152.0855	....	− 0.1	+43.1	0.0
104 to 111	1.477	1633.869	+ 0.8545	+ 0.8552	+ 0.8549	+152.9404	....	− 0.7	+42.4	0.5
111 to 110	2.041	1635.910	− 5.4351	− 5.4388	− 5.4365	+147.5039	....	+ 3.7	+46.1	13.7
110 to 109	1.536	1637.446	+ 5.7440	+ 5.7409	+ 5.7425	+153.2464	....	+ 3.1	+49.2	9.6
109 to 108	0.676	1638.122	+ 0.5277	+ 0.5274	+ 0.5276	+153.7740	....	+ 0.3	+49.5	0.1
108 to 107	1.732	1639.854	+ 3.3891	+ 3.3885	+ 3.3888	+157.1628	....	+ 0.6	+50.1	0.4
107 to 106	1.974	1641.828	− 3.7905	− 3.7927	− 3.7916	+153.3712	....	+ 2.2	+52.3	4.8
106 to 105	2.392	1644.220	+13.6425	+13.6493	+13.6459	+167.0171	....	− 6.8	+45.5	46.2
105 to 121	1.460	1645.680	− 6.4476	− 6.4480	− 6.4478	+160.5693	....	+ 0.4	+45.9	0.2
121 to 120	2.366	1648.046	+ 5.2644	+ 5.2712	+ 5.2678	+165.8371	....	− 6.8	+39.1	46.2
120 to 119	1.996	1650.042	− 7.1607	− 7.1647	− 7.1627	+158.6744	....	+ 4.0	+43.1	16.0
119 to 118	1.640	1651.682	− 3.7410	− 3.7387	− 3.7399	+154.9345	....	− 2.3	+40.8	5.3
118 to IV	1.800	1653.482	−10.8356	−10.8323	−10.8339	+144.1006	45.7	− 3.3	+37.5	10.9
IV to 117	1.188	1654.670	+ 8.7609	+ 8.7596	+ 8.7602	+152.8608	....	+ 1.3	+38.8	1.7
117 to 116	2.010	1656.680	+ 2.8500	+ 2.8559	+ 2.8529	+155.7137	....	− 5.9	+32.9	34.8
116 to 115	0.938	1657.618	+ 2.5645	+ 2.5727	+ 2.5686	+158.2823	....	− 8.2	+24.7	67.2
115 to 114	1.334	1658.952	+ 1.3386	+ 1.3404	+ 1.3395	+159.6218	....	− 1.8	+22.9	3.2
114 to 113	2.022	1660.974	+ 6.2187	+ 6.2085	+ 6.2136	+165.8354	....	+10.2	+33.1	104.0
113 to 112	3.009	1663.983	− 5.4294	− 5.4288	− 5.4291	+160.4063	....	− 0.6	+32.5	0.4
112 to 122	1.990	1665.973	− 3.1088	− 3.1047	− 3.1067	+157.2996	....	− 4.1	+28.4	16.8
122 to 122½	1.901	1667.874	+ 1.0567	+ 1.0577	+ 1.0572	+158.3568	....	− 1.0	+27.4	1.0
122½ to 123	1.908	1669.782	+ 2.4204	+ 2.4222	+ 2.4213	+160.7781	....	− 1.8	+25.6	3.2
123 to 124	1.916	1671.698	+ 3.0214	+ 3.0171	+ 3.0192	+163.7973	....	+ 4.3	+29.9	18.5
124 to D_2	0.726	1672.424	+ 2.6139	+ 2.6126	+ 2.6133	+166.4106	46.0	+ 1.3	+31.2	1.7
124 to 128	1.326	1673.024	+ 1.7116	+ 1.7109	+ 1.7113	+165.5086	....	+ 0.7	+30.6	0.5
128 to 127	2.217	1675.241	− 0.0387	− 0.0382	− 0.0385	+165.4701	....	− 0.5	+30.1	0.2
127 to 126	1.785	1677.026	+ 1.0158	+ 1.0190	+ 1.0174	+166.4875	....	− 3.2	+26.9	10.2
126 to 125	2.026	1679.052	− 4.4221	− 4.4153	− 4.4187	+162.0688	....	− 6.8	+20.1	46.2
125 to V	1.778	1680.830	− 0.7193	− 0.7232	− 0.7212	+161.3476	46.0	+ 3.9	+24.0	15.2
V to 129	2.172	1683.002	− 1.4676	− 1.4739	− 1.4708	+159.8768	....	+ 6.3	+30.3	39.7
129 to 130	2.388	1685.390	− 2.7825	− 2.7850	− 2.7837	+157.0931	....	+ 2.5	+32.8	6.2
130 to 131	1.776	1687.166	− 1.3279	− 1.3338	− 1.3308	+155.7623	....	+ 5.9	+38.7	34.8

Transcontinental line of Spirit-levels—Continued.

SECTION V.—FROM MITCHELL, IND., TO SAINT LOUIS, MO.—Continued.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
131 to 134	2.192	1689.358	− 1.6774	− 1.6774	− 1.6774	+154.0849	....	0.0	+38.7	0.0
134 to VI	1.740	1691.098	− 4.6074	− 4.6038	− 4.6056	+149.4793	46.2	− 3.6	+35.1	13.0
VI to 133	0.528	1691.626	− 1.1486	− 1.1485	− 1.1486	+148.3307	....	− 0.1	+35.0	0.0
133 to 132	2.235	1693.861	− 5.6072	− 5.6115	− 5.6093	+142.7214	....	− 4.3	+39.3	18.5
132 to 135	3.176	1697.037	+ 0.0099	+ 0.0116	+ 0.0107	+142.7321	....	− 1.7	+37.6	2.9
135 to 136	2.266	1699.303	− 4.7711	− 4.7757	− 4.7734	+137.9587	....	+ 4.6	+42.2	21.2
136 to VII	2.285	1701.588	− 1.2113	− 1.2152	− 1.2132	+136.7455	46.2	+ 3.9	+46.1	15.2
VII to 138	2.347	1703.935	+ 5.6171	+ 5.6199	+ 5.6185	+142.3640	....	− 2.8	+43.3	7.8
138 to 139	2.472	1706.407	+ 1.9595	+ 1.9626	+ 1.9610	+144.3250	....	− 3.1	+40.2	9.6
139 to E_3	1.540	1707.947	− 9.9514	− 9.9558	− 9.9536	+134.3714	46.3	+ 4.4	+44.6	19.4
E_3 to 137	0.936	1708.883	+ 4.0306	+ 4.0326	+ 4.0316	+138.4030	....	− 2.0	+42.6	4.0
137 to F_3	0.217	1709.100	+ 4.9910	+ 4.9902	+ 4.9906	+143.3936	46.3	+ 0.8	+43.4	0.6
137 to 147	2.412	1711.295	+ 3.9929	+ 3.9978	+ 3.9953	+142.3983	....	− 4.9	+38.5	24.0
147 to 146	2.278	1713.573	− 2.3521	− 2.3571	− 2.3546	+140.0437	....	+ 5.0	+43.5	25.0
146 to 145	1.946	1715.519	− 1.8960	− 1.8918	− 1.8939	+138.1498	....	− 4.2	+39.3	17.6
145 to 144	2.442	1717.961	− 3.0026	− 2.9973	− 2.9999	+135.1499	....	− 5.3	+34.0	28.1
144 to 143	1.931	1719.892	− 1.9395	− 1.9432	− 1.9414	+133.2085	....	+ 3.7	+37.7	13.7
143 to 142	0.606	1720.498	+ 0.7691	+ 0.7699	+ 0.7695	+133.9780	....	− 0.8	+36.9	0.6
142 to 141	1.892	1722.390	+ 4.0525	+ 4.0525	+ 4.0543	+138.0323	....	− 3.6	+33.3	13.0
141 to 140	0.554	1722.944	+ 0.6659	+ 0.6680	+ 0.6670	+138.6993	....	− 2.1	+31.2	4.4
140 to 148	2.324	1725.268	+ 4.2323	+ 4.2287	+ 4.2305	+142.9298	....	+ 3.6	+34.8	13.0
148 to 149	1.756	1727.024	− 2.3477	− 2.3465	− 2.3471	+140.5827	....	− 1.2	+33.6	1.4
149 to 150	2.037	1729.061	− 0.5254	− 0.5248	− 0.5251	+140.0576	....	− 0.6	+33.0	0.4
150 to 151	0.652	1729.713	+ 2.3568	− 2.3547	+ 2.3557	+142.4133	....	+ 2.1	+35.1	4.4
151 to VIII	2.406	1732.119	− 3.8148	− 3.8230	− 3.8189	+138.5944	46.6	+ 8.2	+43.3	67.2
VIII to 153	2.522	1734.641	+ 5.7657	+ 5.7723	+ 5.7690	+144.3634	....	− 6.6	+36.7	43.6
153 to 152	1.818	1736.459	+ 7.4267	+ 7.4269	+ 7.4268	+151.7902	....	− 0.2	+36.5	0.0
152 to 154	2.134	1738.593	+ 6.5333	+ 6.5368	+ 6.5351	+158.3253	....	− 3.5	+33.0	12.2
154 to 155	2.173	1740.766	+ 7.6667	− 7.6614	− 7.6641	+150.6612	....	− 5.3	+27.7	28.1
155 to 156	2.038	1742.804	− 4.1831	− 4.1793	− 4.1812	+146.4800	....	− 3.8	+23.9	14.4
156 to G.A.F	0.194	1742.998	+ 1.9902	+ 1.9894	+ 1.9898	+148.4698	46.7	+ 0.8	+24.7	0.6
156 to 157	1.641	1744.445	+ 0.1797	+ 0.1751	+ 0.1774	+146.6574	....	+ 4.6	+28.5	21.2
157 to 158	2.136	1746.581	−12.1447	−12.1421	−12.1434	+134.5140	....	− 2.6	+25.9	6.8
158 to 159	0.906	1747.487	+ 0.9496	+ 0.9525	+ 0.9511	+135.4651	....	− 2.9	+23.0	8.4
159 to G_3	0.818	1748.305	+ 4.6316	+ 4.6344	+ 4.6330	+140.0981	46.7	− 2.8	+20.2	7.8
159 to 166	2.597	1750.084	− 2.3251	− 2.3306	− 2.3279	+133.1372	....	+ 5.5	+28.5	30.2
166 to 165	2.060	1752.144	+10.9278	+10.9236	+10.9257	+144.0629	....	+ 4.2	+32.7	17.6
165 to 164	2.022	1754.166	+15.4386	+15.4455	+15.4421	+159.5050	....	− 6.9	+25.8	47.6
164 to 163	2.712	1756.878	+ 8.8780	+ 8.8775	+ 8.8777	+168.3827	....	+ 0.5	+26.3	0.2
163 to 162	1.077	1757.955	− 1.5163	− 1.5160	− 1.5161	+166.8666	....	− 0.3	+26.0	0.1
162 to 161	1.777	1759.732	+ 2.0339	+ 2.0298	+ 2.0318	+168.8984	....	+ 4.1	+30.1	16.8
161 to 160	2.288	1762.020	+ 3.4454	+ 3.4400	+ 3.4427	+172.3411	....	+ 5.4	+35.5	29.2
160 to 167	2.153	1764.173	− 5.3718	− 5.3712	− 5.3715	+166.9696	....	− 0.6	+34.9	0.4
167 to 168	1.577	1765.750	−12.1110	−12.1113	−12.1111	+154.8585	....	+ 0.3	+35.2	0.1
168 to 169	1.922	1767.672	−11.5356	−11.5273	−11.5315	+143.3270	....	− 8.3	+26.9	68.9
169 to IX	1.430	1769.102	− 5.5280	− 5.5336	− 5.5308	+137.7962	47.0	+ 5.6	+32.5	31.4
IX to 170	0.497	1769.599	− 2.8123	− 2.8126	− 2.8124	+134.9838	....	+ 0.3	+32.8	0.1
170 to 172	0.606	1770.205	− 3.0494	− 3.0471	− 3.0483	+131.9355	....	− 2.3	+30.5	5.3
172 to 171	1.944	1772.149	− 2.0654	− 2.0632	− 2.0643	+129.8712	....	− 2.2	+28.3	4.8
171 to H_3	1.005	1773.154	+29.8292	+29.8278	+29.8285	+159.6997	47.1	+ 1.4	+29.7	2.0
170 to 178	1.116	1770.715	− 5.1441	− 5.1408	− 5.1425	+129.8413	....	− 3.3	+29.5	10.9
178 to 177	2.514	1773.229	− 0.7519	− 0.7585	− 0.7552	+129.0861	....	+ 6.6	+36.1	43.6
177 to 176	2.106	1775.335	− 0.0106	− 0.0073	− 0.0089	+129.0772	....	− 3.3	+32.8	10.9
176 to 175	1.854	1777.189	− 0.3143	− 0.3094	− 0.3119	+128.7653	....	− 4.9	+27.9	24.0
175 to 174	2.846	1780.035	+ 0.9271	+ 0.9238	+ 0.9255	+129.6908	....	+ 3.3	+31.2	10.9
174 to 173	2.118	1782.153	− 2.3301	− 2.3265	− 2.3233	+127.3675	....	+ 6.4	+37.6	41.0

Transcontinental line of Spirit-levels—Continued.

SECTION IV.—FROM MITCHELL, IND., TO SAINT LOUIS, MO.—Concluded.

Bench-marks.	Distance between bench-marks.	Total distance Sandy Hook to bench-mark.	Difference of height of successive bench-marks. Rod E, first line.	Rod F, second line.	Mean.	Total height above mean sea-level at Sandy Hook.	Probable error of total height.	Discrepancy. Partial Δ	Total.	Δ²
	km.	*km.*	*m.*	*m.*	*m.*	*m.*	± *mm.*	*mm.*	*mm.*	(*mm.*)²
173 to 179	1.202	1783.355	− 1.2296	− 1.2340	− 1.2318	+126.1357	....	+ 4.4	+42.0	19.4
179 to I₃	0.059	1783.414	+ 0.7713	+ 0.7706	+ 0.7709	+126.9066	47.2	+ 0.7	+42.7	0.5
179 to 183	0.025	1783.380	+22.4494	+22.4489	+22.4491	+148.5848	....	+ 0.5	+42.5	0.2
183 to 182	0.624	1784.004	− 0.7478	− 0.7442	− 0.7460	+147.8388	....	− 3.6	+38.9	13.0
182 to 184	0.000	1784.004	−19.8287	−19.8287	−19.8287	+128.0101	....	0.0	+38.9	0.0
184 to 180	0.020	1784.024	− 1.2238	− 1.2233	− 1.2235	+126.7866	....	− 0.5	+38.4	0.2
179 to 185	0.052	1783.407	− 0.7328	− 0.7329	− 0.7329	+125.4028	....	+ 0.1	+42.1	0.0
185 to E.T.G	0.374	1783.781	− 5.7827	− 5.7801	− 5.7814	+119.6214	....	− 2.6	+39.5	6.8
185 to 186	0.590	1783.997	....	....	− 0.1599	+125.2429	....	....	+42.1	....
186 to W.T.G	0.116	1784.113	− 5.6164	− 5.6160	− 5.6162	+119.6267	....	− 0.4	+41.7	0.2
186 to 180	0.058	1784.055	+ 1.5394	+ 1.5388	+ 1.5391	+126.7820	....	+ 0.6	+42.7	0.4
180	....	1784.040	....	....	....	+126.7843	....	....	40.6	....
180 to J₃	0.067	1784.107	+ 0.1234	+ 0.1234	+ 0.1234	+126.9077	47.2	0.0	+40.6	0.0
180 to K₃	0.636	1784.676	+ 0.1230	+ 0.1239	+ 0.1235	+126.9078	47.2	− 0.9	39.7	0.8

SECTION V.—*Description of primary and secondary bench-marks between Mitchell, Ind., and Saint Louis, Mo.*

X—Mitchell, Ind.; already described.

Y—The centre of a cross, cut on the face of the stone cap of a basement window, on the northwest side of the court-house at West Shoals, Martin County, Indiana. It is marked thus:

Y
B + M

Z—Cut on the sill of a basement window, at southeast corner of court-house at Washington, Daviess County, Indiana. It is marked thus:

Z
B □ M
U. S. C. & G. S.
1882.

A_3—Cut on the stone ledge on the northwest front of the court-house at Vincennes, Ind. It is marked thus:

A_3
B □ M
U. S. C. & G. S.
1882.

No. I—The centre of the top surface of the easternmost stone pier of the Coast and Geodetic Survey astronomical observatory, in the grounds of the Vincennes court-house.

B_3—Cut at the base of one of the columns of the north face of the court-house at Olney, Richland County, Illinois. It is marked thus:

B_3
B □ M
U. S. C. & G. S.
1882.

No. II—Near the southeast corner of the grounds of the public school at Olney, Ill., on the monument marking the end of the U. S. E. base-line.

The top of the monument bears the inscription "U. S.," and the bench-mark is the centre of the space inclosed by the lower curve of the S.

No. III—Cut on the eastern abutment of Ohio and Mississippi Railroad bridge over Little Wabash River, about 1½ miles east of Clay City, Ill., and is marked thus: B □ M.

C_3—Cut on a front basement window, near southeast corner of the public school building at Flora, Clay County, Illinois, and is marked thus:

C_3
B □ M
U. S. C. & G. S.
1882.

No. IV—Cut on the west abutment of Ohio and Mississippi Railroad trestle over Skillet Fork of Little Wabash River, about 2½ miles east of Iuka, Ill. It is marked thus:

B □ M
IV

D_3—The centre of a cross, cut on the southwest corner of the court-house at Salem, Ill. It is marked thus:

D_3
B □ M
U. S. C. & G. S.
1882.

No. V—Cut on the coping stone, at the east end of a long arched culvert, at Odin Station of Ohio and Mississippi Railroad. It is marked thus:

B. M. V.
□

No. VI—Cut on the west abutment of Ohio and Mississippi Railroad trestle about 2½ miles west of Sandoval, Ill. It is marked thus:

U. S.
B □ M
VI.

No. VII—Cut on the west abutment of Ohio and Mississippi Railroad culvert about one-fourth mile east of Collins Station, and is marked thus:

B □ M.
VII

E_3—About one-fourth mile east of Carlyle, Ill. Cut on a pier of the Ohio and Mississippi Railroad bridge over the Kaskaskia River. It is marked thus:

E_3
B □ M
U. S. C. & G. S.
1882.

F_3—Cut on the station ledge, under the windows of the east face of the court-house at Carlyle, Ill. It is marked thus:

B □ M
F_3
U. S. C. & G. S.
1882.

No. VIII—Cut on west abutment of Ohio and Mississippi Railroad bridge over Sugar Creek, about 1 mile west of Ariston, Ill. It is marked thus:

U. S.
B □ M
VIII.

G_3—Cut on the sill of a basement window on the east face of the public school building at Lebanon, Saint Clair County, Illinois. It is marked thus:

1882
U. S. C. & G. S.
G_3
B □ M.

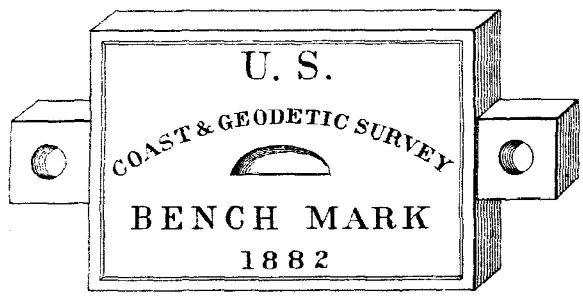
No. IX—Cut on the east abutment of Ohio and Mississippi Railroad bridge, about one-fourth mile east of Caseyville, Saint Clair County, Illinois. It is marked thus:

B □ M
IX.

H_3—The centre of the head of the copper bolt inserted in the stone monument marking the north end of the "American Bottom Base."

I_3—A mark on a large bronze plate inserted in the south face of the eastern land pier of the "Great Bridge" at East Saint Louis, Ill.

The plate bears the inscription—



J_3—A similar plate inserted in the western land pier of the "Great Bridge" at Saint Louis. Bench-marks I_3 and J_3 were placed as near as possible on the same level as the Saint Louis (so-called) "City Directrix" described below.

K_3—Known at Saint Louis as the "City Directrix." It has been in use for many years, and was originally the top surface of the pedestal of a monument which stood on Front street near Market. The monument shaft was destroyed at the time of the great fire in that locality, but the pedestal remained. It is now level with the curbstone and forms a part thereof. A ┳ mark has since been cut to indicate the point used for a bench-mark.

U.S. COAST AND GEODETIC SURVEY

J.E. Hilgard, Supt.

TRANSCONTINENTAL LINE OF SPIRIT-LEVELS

SKETCH SHOWING THE POSITION OF THE PRINCIPAL BENCH-MARKS

SANDY HOOK, N.J. TO ST. LOUIS, MO.

1878 – 82

Scale $\frac{1}{3000000}$