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THE
EXECUTIVE DOCUMENTS

PRINTED BY ORDER OF THE

SENATE OF THE UNITED STATES

FOR THE

SECOND SESSION OF THE FORTY-SIXTH CONGRESS.

1879-'80.

IN SEVEN VOLUMES.

Volume 1--Nos. 1 to 50, except No. 17.
Volume 2--No. 17.
Volume 3--Nos. 51 to 99.
Volume 4--Nos. 100 to 180.
Volume 5--Nos. 181 to 216, except Nos. 208 and 209
Volume 6--No. 208.
Volume 7--No. 209.

TEXAS TECHNOLOGICAL

DEC 13 1952

WASHINGTON: COLLEGE
GOVERNMENT PRINTING OFFICE.
1880.

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the bed of the Delaware, between Bridesburg and Fort Mifflin light-house. The soundings made are represented by four sheets on a scale of four hundred feet to the inch, corresponding to the scale of the topographical sheets, the completion of which has been already mentioned. The hydrographic statistics are:

Miles run in sounding	323
Angles measured for position	10,350
Number of soundings	30,716

Permanent bench-marks were established at Five Mile Point, at Kensington water-works, at the old navy-yard, and at League Island. Each of these was referred to the others by simultaneous tidal observations. As usual, careful descriptions of the bench-marks were sent to the office.

While Assistant Marindin was at work in the Delaware, operations for improvement were in progress under the charge of Gen. J. N. Macomb, United States Engineers. At the request of that officer, Mr. Marindin was authorized to furnish the results of his survey of the bulkhead at Five Mile Point.

In prosecuting the general hydrography of the Delaware, abreast of the city of Philadelphia, a shoal was developed in the vicinity of the wharves of the American Transatlantic Steamship Company. Full particulars in regard to the obstruction were communicated in September, 1878, to the mayor of Philadelphia, in order that measures might be taken for its removal.

Assistant Marindin was aided at Philadelphia by Mr. J. B. Weir. When the operations of the party afloat were closed in November, the hydrographic sheets were completed and results of the current observations were put in form. Assistant Mitchell in due time presented an elaborate report, in which all the results of observations are embodied.

Geodetic operations in Pennsylvania.—When my last annual report was closed, the party of Prof. L. M. Haupt was engaged at Big Rock, a station near the Lehigh River, and at the eastern extremity of the scheme of triangulation in Pennsylvania. Angular measurements at that point were made by Prof. C. L. Doolittle, of Lehigh University. In July, 1878, the party was transferred to Maryland, and there two stations, Meeting House Hill and Principio, and, in Pennsylvania, Londonderry and Rawlinsville, were occupied in succession in the interval preceding the middle of October when the field-work was closed. At these stations the geodetic operations were conducted alternately by Professors Doolittle and Haupt. The statistics are:

Observing tripods and scaffolds erected	4
Stations occupied	5
Angular measurements	2,150

When the fiscal year closed, Professor Haupt was in readiness to resume field operations. Of these further mention will be made in my next annual report.

Pendulum observations.—Experimental and mathematical studies for the determination of gravity have been continued by Assistant C. S. Peirce. Flexure, as a source of error in the ordinary support used for pendulum experiments, and the possibility of allowing for the error, as suggested by him in 1875, are now admitted by European observers to be essentials for success in the investigation. Mr. Peirce says:

"There still remains a question in regard to the difference between the flexure under a force applied continuously and under one intermittent like that caused by a swinging pendulum. Experiments at Hoboken, N. J., show that this difference is large upon a wooden support, but insignificant upon a metallic support."

In a mathematical analysis published in the "Proceedings of the American Academy of Arts and Sciences," Assistant Peirce has shown that any difference between the statical and dynamical flexure which could possibly have an appreciable effect on the time of oscillation of the pendulum, would largely increase the rate of decrement of the amplitude of oscillation. He remarks further:

"No considerable effect of this sort exists, the rate of decrement being almost exactly the same upon the Repsold tripod that it is upon another support of much greater stiffness. But, although the difference between the statical and dynamical flexure will be very small when good

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judgment has been used in mounting the pendulum, the correction for flexure remains a source of anxiety and trouble in making the experiments. For this reason a careful mathematical study has been made of the method of avoiding the difficulty, as proposed by M. Faye, which consists in swinging two similar pendulums simultaneously on the same support, with equal amplitudes of oscillation, but opposite phases."

The views of Assistant Peirce in this connection are fully set forth in his paper on Faye's method, communicated to the American Journal of Science.

The concluding report of the season mentions, as a special difficulty in determining gravity, the uncertain effect of the wearing and blunting of the knife edge upon which the pendulum rests, and of its motion upon the plane which supports it. Experimental investigations of these subjects have already been undertaken, and will be further prosecuted in the course of the coming year.

The acceleration of gravity has been accurately measured by Assistant Peirce, at the Alleghany Observatory in Pennsylvania. Stations on the mountains in that State will be occupied in succession, as means for estimating the disturbing effect of the mass of the Appalachians on results for latitude, longitude, and azimuth.

In general reference to researches for completing the spectrum meter, Assistant Peirce thus remarks:

"One of the difficulties in the measurement of gravity is the circumstance that metallic bars, hitherto our ultimate standards of length, probably change in length in the course of years. The confusion into which such spontaneous changes in standards of length may throw all precise measurements referred to them, is too obvious to be insisted upon. Hence search has been made for a length in nature which should be more strictly invariable than that of a metallic bar."

The idea that a wave length of light would be more invariable than any substantial measure has been entertained by several distinguished physicists, such as Arago and Clarke Maxwell, but their suggestions are to be regarded as purely speculative. The means of comparing with great precision a wave length of light with a tangible object were not known when the suggestions were recorded. In reference to the basis for his subsequent development of the idea, Assistant Peirce thus observes:

"It was not until our ingenious countryman Lewis M. Rutherford, by various mechanical achievements, and especially by his manufacture of diffraction plates of extreme accuracy, had made the attempt practicable, that any one could seriously propose to measure a wave length to one-millionth part of its own length."

"The length of the wave depends, first, on the internal constitution of the chemical atoms of the substance which gives rise to the spectral line, and this we have reason to believe the most unalterable thing known in nature; secondly, on the density and elasticity of the luminiferous ether as it exists in vacuo; and though we have as yet no positive information in regard to the inalterability of these qualities, we have reason to suppose that they are free from influences which cause the spontaneous alterations of metallic bars."

The matter must necessarily remain tentative, but the end sought is well brought out in the results. After many essays Mr. Peirce succeeded in manufacturing in Mr. Rutherford's laboratory, with the aid of his trained assistant, Mr. D. C. Chapman, a comparator by which a diffraction plate of one centimeter width has been compared with each one of a decimeter scale of centimeters accurately to the one-millionth part of a centimeter. The further comparison of the decimeter with each one of a meter scale of decimeters has been commenced but not concluded.

The other part of the investigation, to compare the wave length of light with the breadth of the diffraction plate, has been successfully accomplished by means of a spectrometer of original construction, provided with a circle divided upon glass, after Mr. Rutherford's design.

In studying the various sources of error in measurements of the deviation of a line in the diffraction spectrum, Assistant Peirce observed the supplementary images, commonly called "ghosts," due to irregularities in ruling the lines. These he found to be an entirely new species of diffraction phenomena, and that instead of their position depending on the amount of irregularity in the ruling, as had been commonly supposed, only their brightness depends upon this, while their position depends solely on the period of the inequality. After confirming his mathematical analysis of the subject by careful angular and photometric measurements, Mr. Peirce presented the results in a memoir which was read at the last meeting of the National Academy of Sciences.

Among several forms of projection devised by Assistant Peirce, there is one by which the whole sphere is represented upon repeating squares. This projection, as showing the connection of all parts of the surface, is convenient for meteorological, magnetological, and other purposes. The angular relation of meridians and parallels is exactly preserved; and the distortion of areas is much short of the distortion incident to any other projection for the entire sphere.

SECTION III.

MARYLAND, VIRGINIA, AND WEST VIRGINIA. (SKETCHES NOS. 8, 10, AND 11.)

Longitude determinations.—For determining the longitude of a point in Statesville, N. C., of which further mention will be made under Section IV; and also of a point in Atlanta, Ga., to be referred to under the head of Section V, the usual arrangements were made at Washington, D. C., in November, 1878. The work was under the general charge of Assistant G. W. Dean, and Assistant Edwin Smith was directed to co-operate in the service. By permission of Rear-Admiral John Rodgers, U. S. N., Superintendent of the Naval Observatory, the station occupied by the observers in Washington for telegraphic longitude exchanges with the southern stations, was located in the Observatory grounds, and due arrangements were made for erecting a temporary structure. Meanwhile, Messrs. Dean and Smith were accommodated in the Transit of Venus building, and there, with Transit No. 8, each observer recorded one hundred and twenty-two observations on fifty-four stars for personal equation during five nights of November and December, 1878.

Assistant Smith proceeded to Statesville, N. C., on the 13th of December accompanied by Mr. C. H. Sinclair. Between the station there selected, and the station at Washington, telegraphic exchanges were recorded by Mr. Dean during four nights in December. As usual, the observers then changed places, Assistant Dean receiving at Statesville the signals sent by Mr. Smith during three nights from Washington.

Mr. Dean transferred the instruments from Statesville, to Atlanta, Ga., and from that station exchanged signals during five nights with Assistant Smith, who remained at the Naval Observatory in Washington. Changing places as before, Mr. Smith sent from Atlanta, during six nights, signals which were recorded by Assistant Dean, at Washington.

Exclusive of details immediately connected with longitude determinations, the two observers recorded at the Naval Observatory three hundred and ninety-two observations in January and February on ninety-three stars for chronometer corrections. In the next section reference will be made to the determination of longitude at Statesville, N. C. For the operations of the longitude party the usual facilities were afforded free of charge by the officers and operators of the Western Union Telegraph Company.

In March, when Assistants Dean and Smith again met in Washington, one hundred and fourteen observations were recorded by each on thirty-six stars during four nights with Transit No. 8. During January and February, Mr. F. H. Parsons aided in the work at the Naval Observatory in recording and also in computations.

Magnetic observations.—At the station established some years ago on Capitol Hill, in Washington, D. C., the magnetic declination, dip, and intensity have been observed annually by Assistant Charles A. Schott. In June, 1878, the series was continued by observing on the 9th, 10th, and 11th of that month.

Assistant Schott reports that his last observations show the law in regard to secular change of the magnetic declination at Washington to be as it was found by the observations of preceding years.

A third discussion of the secular change of declination (variation of the compass) in the United States and adjacent countries has been completed by Mr. Schott, and will be ready for issue at an early day.

Special hydrographic investigation.—Inquiry has frequently been made for such information as could be incidentally gathered by parties working afloat in regard to the growth of oysters, which, in the mass, are commonly termed *reefs*, and sometimes *rocks*. In order to meet the interest manifested, some general remarks by L. F. Pourtales, Esq., formerly Assistant in the Coast Survey, were given to the public in 1873, relating chiefly to oyster supply and to the manifest waste in the method employed in taking them in the waters near New York.