1877, and held the office of high sheriff of Hertfordshire and other important public trusts at various times. He was treasurer of the Geological society for many years, and honorary or corresponding member of many foreign societies.

In scientific matters, Dr. Jeffreys had something of the conservatism natural to a person of his years; but his opinions, however firmly held, were never expressed with bitterness, and his geniality and hospitality bound to him in friendly ties not only scientific men, young and old, but the intelligent and cultured throughout his wide circle of acquaintance. He leaves a son, Mr. Howel Jeffreys, and five daughters, one the wife of Prof. H. N. Moseley of the Challenger expedition. His collection, which for British seas is absolutely unrivalled, possessing many of the actual types of Turton, Alder, and other early British naturalists, and an extremely rich and largely unique North Atlantic and North European series will form one of the treasures of the National museum at Washington, where a portion of it has already been received. W. H. DALL.

THE WASHINGTON NATIONAL MONUMENT.

THE history of the undertaking which has resulted in the completion of the Washington monument presents a number of interesting and curious facts; and the construction of the monument itself, by reason of the magnitude of the structure, has involved some problems of considerable engineering importance.

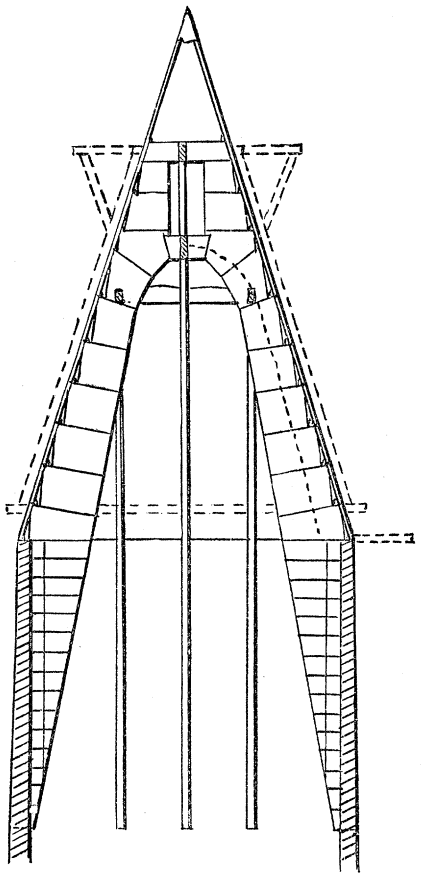
The early history of the monument may be said to date from 1783, when congress resolved to erect, wherever the residence of congress should be established, an equestrian statue of Washington; and in 1795, when it was proposed to build a monument commemorating the American revolution, Major L'Enfant, the designer of the plan by which the city of Washington is laid out, selected, and Gen. Washington himself approved, the site where the finished monument of which we write now stands.

After the failure of these and other similar plans, the next step was taken in 1833, when, under the auspices of the Washington national monument society, the aid of the people of the United States was invoked to raise the sum required to erect a great national monument, no one to contribute more than one dollar, — a restriction which was removed in 1845. Money came in slowly; but by 1847, $87,000 had been raised, and it was determined to make a beginning; and, by authority from congress, President Polk deeded the present site to the society. Building was at once commenced, but proceeded slowly; and in 1854 the society had spent $230,000, and raised the monument to a height of 152 feet above the base.

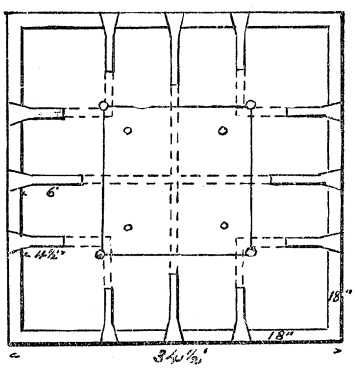
The original design by Robert Mills included an obelisk faced with white marble, 600 feet high, 55 feet square at the base, and 30 feet square at the top, surrounded at its base by a circular rotunda or colonnade 250 feet in diameter and 100 feet high, in which were to be placed statues of the nation's illustrious dead, with vaults beneath for the reception of their remains.

The base or foundation masonry was about 80 feet square at the bottom, laid at a depth of but eight feet below the surface of the ground, and carried up, in steps of about three feet rise, to a height of 25 feet, where it is 58 feet square. The slight depth to which the foundation was carried was due to the anxiety of the building committee to have something to show for the money expended. It was built of rubble masonry of blue gneiss, the blocks large and of somewhat irregular shapes (nearly as they came from the quarry), laid in a mortar of hydraulic cement and stone lime, the joints and crevices filled and grouted. The shaft of the obelisk was built hollow, with walls 15 feet thick at the base; the well, or hollow interior, being 25 feet square for the whole height then built. The exterior face, to an average depth of sixteen or seventeen inches, was of Maryland marble, usually called alum-stone. The remaining thickness of the walls was of blue-stone rubble backing, not the best construction for a building of such enormous weight.

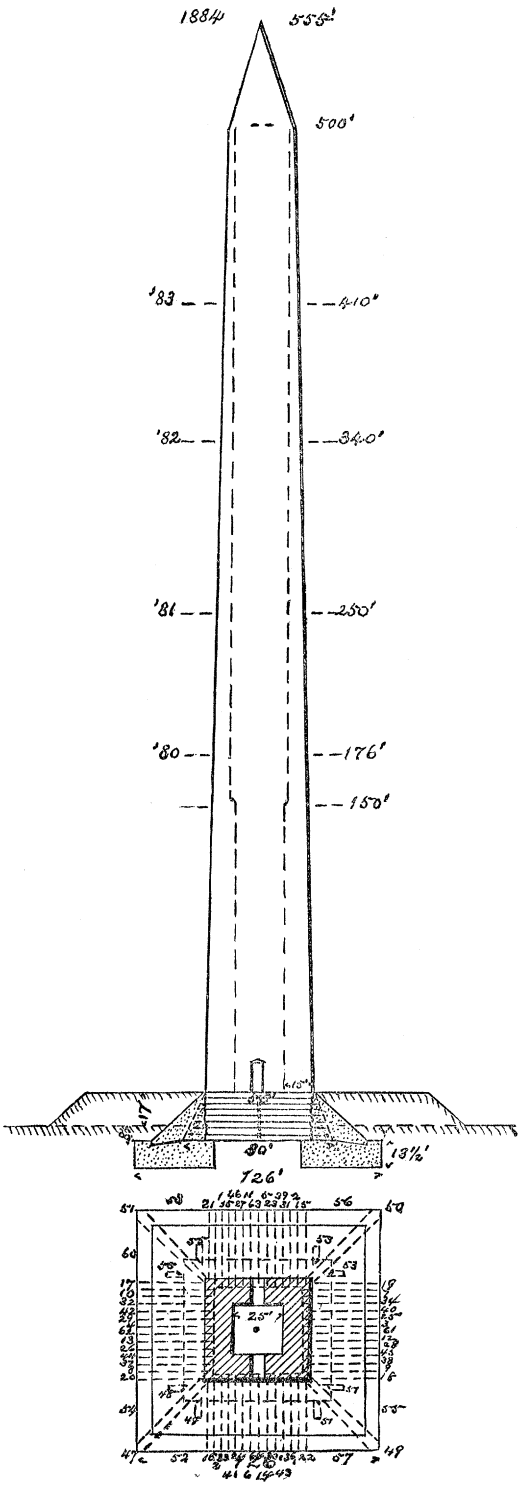
To ascertain the kind of earth that would be under the monument, a well was dug, some 25 feet deep, in the immediate vicinity of the site, and the earth particularly examined. The material was found very compact, requiring a pick to break it up, and was pronounced suitable for a structure of the kind. At a depth of twenty feet a solid bed of gravel was reached, and, six feet lower, water was struck. Before the first course of marble was laid, bench-marks were located from which to test the settlement of the monument. After building to 126 feet in height above the ground, the chairman of the building committee writes,



SECTION THROUGH APEX.



PLAN OF RIBS.



FOUNDATION.
126'

in 1853, 'There is no perceptible settlement' of the base, — a statement which seems hardly accurate, judging from what is usual, and from what appeared later. Here may be mentioned, as of interest later, that the architect, Mr. Mills, in 1848, levelled from the top of the third course or step of the foundation to a point on top of the meridian-stone monument near tide-water, planted by President Jefferson, and thus established a reference by which he might detect any settlement occurring in the progress of the work.

On Feb. 22, 1855, congress having been petitioned for aid, a committee of the house approved of the work done, and recommended an appropriation of $200,000. But this was the period of the Know-nothing excitement; and, on the very day that the appropriation was recommended, the books and papers of the monument society were forcibly seized by adherents of the American party, and a new board was illegally formed from their members. This action again delayed progress, and, during their rule of four years, only four feet were added, bringing the obelisk to the height of 156 feet above the base, at which elevation it long rested. On Feb. 22, 1859, this board was ousted by the incorporation by congress of a new Washington monument society for the purpose of finishing the work. These changes probably account for the more or less complete disappearance of the original plans, measurements, bench-marks, etc., which is afterwards noted. The civil war soon followed, and no actual work was done for many years. The society remained as custodian during this time, and made some attempts to re-awaken public interest. Numerous examinations were made by government officials of the condition of the stone work, which in some places was slightly chipped at the edges by flush jointing, and of the foundation. In April, 1874, Lieut. Marshall found that the axis of the shaft was inclined 1.4 inches to the north-west. At one time it was hoped that the bare shaft might be finished in some form by July 4, 1876; but the unsatisfactory condition of the foundation prevented.

All hope of completing the monument by the centennial anniversary having gone, the matter apparently rested until August, 1876, when an act of congress was approved, providing that there should be appropriated $200,000 in four annual instalments, to continue construction; the officers of the society being required to transfer the property to the United States, and the construction of the monument to be under the direction of the president of the United States, the supervising architects of the treasury and of the capitol, the chief of engineers, and the first vice-president of the monument society. In the examination called for in this act, it was very curiously discovered, by levels taken to what was then supposed to be the meridian-stone previously referred to, that the monument had, in twenty-eight years, settled nearly nine inches into the ground. A lively investigation by those most interested presently developed the fact that Gen. Babcock, when in charge of buildings and grounds in Washington, had, in the course of improvements, graded off and carted away the meridian-stone monument; so that, added to the loss of all plans and details, we must now relinquish all hope of knowing whether the monument had settled or not.

Congress then authorized the re-enforcing of the foundation; and the work was placed in charge of Lieut.-Col. Thomas Lincoln Casey, U.S. engineers, who had devised, and has successfully carried out, the plan shown in the sketch. The earth about the base, some 10,000 cubic yards, was first removed. Then a trench 4 feet wide, 13.5 feet deep, extending 23 feet outside of the old foundation, and tunnelling 18 feet under it, was excavated. The trench was then filled with concrete of four parts broken stone, three parts pebbles, two parts sand, and one part Portland cement, mixed by machinery in a cubical box rotating on a diagonal axis, and then thoroughly rammed in place. When the space under the old foundation was as nearly filled as convenient, more concrete was put into small gunny-sacks, and rammed home horizontally, while yet soft, with a heavy timber. The order in which these trenches were made and filled is numbered on the plan. At first it was intended to make and fill two opposite trenches at the same time; but it was found that removing 144 square feet of the foundation (only 2.5 %) caused a too rapid motion of the column, and, after the first four trenches, but one trench was made and filled at a time. This sensitiveness of the obelisk to disturbance appears to confirm the opinion that the old foundation was already carrying nearly the maximum allowable load.

The effect of cutting these trenches was studied by means of a plumb-line suspended from the top of the shaft, and hanging freely through a graduated metal circle near the floor. The greatest movement at the beginning of the work was $\frac{11}{24}$ of an inch. By careful watching and working, the original deflection of 1.75 inches was almost entirely

corrected. The area of the foundation was increased 150 %, or from 6,400 square feet to 16,000 square feet, and was carried down to 21.5 feet below the original surface of the ground. Careful levels showed, that, during the process of underpinning, the base of the monument settled two inches.

The foundation was further strengthened, and the pressure distributed over the whole of the new base, by placing a continuous buttress of concrete around the base, from the top of the old foundation halfway out on the concrete base; a portion of the foundation masonry being cut away, as shown in the sketch, to give a good bearing. A terrace of earth was afterwards added, to cover the rough masonry, and to still further increase the depth to which the foundation was carried, and thus to increase the resisting-power of the ground against lateral displacement.

The new foundation was completed in May, 1880; and on Aug. 7 President Hayes assisted in laying the first new stone on the shaft. On the new portion the space inside was enlarged from 25 feet square to 31.5 feet square, to diminish the weight by lessening the thickness of the walls; and solid granite backing, in two-feet courses to correspond with the outside marble courses, was substituted for the irregular rubble-work. When the wall grew considerably thinner, marble was used throughout. The thickness at 500 feet is 18 inches. The monument rose 26 feet in 1880, 74 feet in 1881, 90 feet in 1882, 70 feet in 1883, and 90 feet, to which was added the apex of 55 feet, in 1884.

Eight iron columns rise in the interior, shown by small circles on the plan of the top. Four of them are far enough from the wall to support the iron platforms and stairways by which the monument may be ascended: the other four act as guides for an elevator. These columns have been connected with the water-bearing stratum below the monument, and with the metallic point on the apex.

Several ways of capping the monument, or of constructing the apex to suit its exposed position, and secure permanence, were discussed. The adopted design was by Bernard R. Green, civil engineer. Three stone corbels, one foot thick at the edge, begin to grow out from each side of the well within the monument, at a point thirty feet below the top of the wall. They increase in width as they ascend, until at the top of the wall the middle one projects six feet, and the side ones four feet and one-half each. From them spring stone arched ribs, which in turn support the roof-covering of stone slabs seven inches thick. The middle ribs rise thirty feet, and intersect on a cross-shaped keystone; the side ribs abut against one another, and a square stone frame some seven feet lower down. The apex is terminated by an aluminium point.

After the main walls had reached their ultimate height, a frame carrying a derrick mast, which reached to a height of 75 feet, was erected on the tops of the iron columns. An opening was left in the lower roof-course at one side; the stone for the roof run out on a small balcony supported by projecting beams, and then raised to place. When all but three roof-courses were set (in all, some 14 feet in height), a platform was built around the top, supported on brackets resting on the slanting sides of the roof, and carried, in turn, on beams projecting through the apertures for observation left in the lower part of the roof, two on each side; and the nine remaining stones were distributed on this platform. The central derrick was then removed, and a small quadruped derrick erected on the platform and over the point of the roof. Thus these stones, including a cap-stone weighing 3,300 pounds, were readily set, and the apex completed Dec. 6, 1884. A small opening near the top, afterwards closed by a stone slab, permitted the retreat of the workmen who removed the scaffolding.

Since the completion of the foundation, and the resumption of building the shaft, some slight settlement has taken place, increasing regularly and uniformly with each addition of a few courses of stone. After a few weeks from any suspension of building, settlement has always ceased; and hardly a perceptible movement again occurred until after some 200 tons' weight had been added, when the same process of settling was repeated. Altogether, in the addition of 400 feet in height, and about 34,000 gross tons, 12,000 tons of which are in the earth terrace over the foundation, the settlement was two inches. The entire settlement, due to underpinning the foundation and completing the superstructure, is about four inches. The movements of the plumb-lines, of which there were two, — one from the height of 148 feet, and the other from 259 feet, — were but trifling. Changes in them were infrequent, and probably not always, if often, due to actual leaning of the shaft.

The workmen were protected against injury from falling by a strong net suspended around the outside of the shaft; and, since the resumption of construction by the United States, the only accident has been the breaking of the

arm of one of the men. The cost thus far is $1,188,000. The completed structure weighs 81,000 tons.

In this connection, some of the heights of notable structures may be of interest: Tower of Pisa, 179 feet; Bunker Hill monument, 221 feet; Great mosque, Cairo, 282 feet; Trinity spire, New York, 284 feet; Campanile, Florence, 290 feet; top of capitol, Washington, 307 feet; Milan cathedral, 355 feet; St. Paul's, London, 365 feet; Antwerp cathedral, 402 feet; Lutheran Mariankirche, Lubeck, 430 feet; St. Stephen's, Vienna, 441 feet; St. Rollox chimney, Glasgow, 450 feet; Great pyramid, 450 feet (originally 485 feet); St. Peter's, Rome, 455 feet; Strasbourg cathedral, 468 feet; Cologne cathedral, 511 feet; Philadelphia city hall, to be 535 feet; Washington monument, 555 feet.

Many memorial stones were contributed by the states, and by different organizations in this country, and by foreign countries. Some forty of these stones were set in the interior faces. One hundred still remain in the storehouse, and will probably be affixed as slabs to the interior walls in convenient places.

CHARLES E. GREENE.

THE ELECTRIC LIGHT FOR LIGHT-HOUSES AND SEARCH-LIGHTS.

THE recent experiments in England (*Nature*, vol. xxx. p. 362), upon the relative merits of electric, gas, and oil lights for lighthouse illumination, have called attention to the very marked failure of the arc-light to penetrate through a misty or foggy atmosphere; this failure being due to the vigorous absorption of the blue rays of the spectrum by such an atmosphere, — rays in which the arc-light is especially rich. A very striking case of similar failure was presented to the writer's notice a few evenings ago. One of the streets of Washington has recently been lighted by arc-lights on each side, upon posts several feet higher than the gas-lamps; so that, in looking along the street, the rows of electric lights above the gas offer a good opportunity for comparison. For several nights both were lighted; and one of these nights chanced to be extremely foggy for a few hours in the evening, the ground being covered with slush from melting snow. For this reason I went out of my way to see the effect upon these lights, and was rewarded by the sight of the arc-lights — overpoweringly bright close at hand — becoming almost as faint and yellow as the gas-lamps at a distance of less than half a mile. The extent of the arc-lights was only five blocks, and the treasury building at one end, and patent office at the other, prevented a view from a greater distance; but there can be no doubt, that, if the relative rates of absorption had continued in the same ratio for a greater distance, the arc-lights would have appeared fainter than the gas-lamps at a distance of not much over half a mile, and would have entirely disappeared long before the latter. The arc-lights are said by the company to be of about two thousand candle power, and the gas-lights probably equal between fifteen and twenty candles; so that the enormous difference of absorption under these circumstances is evident at a glance. To be sure, this was a very thick fog; but this is the very condition of things where penetrating power is most necessary for lighthouse lamps, and where the arc-light seems to fail utterly.

For search-lights, in naval warfare, as protection against torpedo attack in thick weather, and for other similar purposes, the case is just as bad, or even worse; for the light must traverse the necessary distance twice, — to the dangerous object, and then reflected back to the ship. For determining the best quality of light for submarine search, experiments upon the selective absorption of sea-water for various kinds of luminous radiant energy would seem to be desirable.

Professor Langley has shown, within the last year or two, that our atmosphere absorbs much more of solar radiant energy than has been heretofore supposed, and that this is very largely in the blue end of the spectrum; so that sunlight, if we were rid of our atmosphere, would be much bluer than we see it. He has shown, too, that this takes place by diffusion of the light by reflection in all directions from particles in the atmosphere, so that we get about half our daylight from the sky, even in a perfectly clear day; and that this is the cause of the blue sky.

The same explanation is sufficient to account for all the phenomena of the wonderful red afterglows following the sunsets of a year ago, if we can explain the presence of reflecting particles in a more or less stratified arrangement (Krakatoa dust, very likely) at an unusual height in the atmosphere. These would reflect sunlight to us in much greater amount and for much longer (semi-intermittent) intervals than the ordinary dust and clouds at a lower level of the atmosphere; and this selective absorption would account for the wonder-