LOCATING THE WASHINGTON MONUMENT

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On November 19, 1934, work was begun to permanently and accurately locate the Washington Monument, latitudinally and longitudinally speaking. A triangulation party in charge of Lieut. John BOWIE, Jr., taking advantage of the scaffolding erected around the Monument for the purpose of repairing and cleaning it, ascended to the 500-foot level in the scaffolding-elevator and then climbed by ladder the additional 55 feet to the wind swept top of the monument. Here they set up their theodolite and proceeded to observe and record the various angles to other triangulation stations by means of which the position of the monument might be computed. Directions were also taken to various prominent structures such as the Capitol, church spires, etc., in order that they, too, might be located.

These records were then submitted to the triangulation section of the Division of Geodesy where the final computations were made. As a result the position of the Monument is now determined to be exactly 38º 53' 21".681 in latitude and 77º 02'07".955 in longitude and no longer need be referred to merely as being near 15th Street and Constitution Avenue, N. Y.

The historic structure now takes its place in the national network of triangulation stations which covers the United States.

GEODETIC BASE IN THE ISLAND OF GRAND CANARY MEASURED BY THE HYDROGRAPHIC EXPEDITION OF THE ARCHIPELAGO

by

LIEUTENANT (H) JULIO CUVILLO (*).

With the object of giving seamen who use our charts an idea of their accuracy, I give here a summary of the work to be done to obtain a *Geodetic Base* and thus show the degree of accuracy and the attention devoted to the surveys of our coasts.

To obtain the outline of the coasts it is necessary to calculate the geographical positions of a certain (usually very large) number of points in the area but, as the taking of observations at each of these for its latitude and longitude would be a terrific job (apart from other reasons of a technical character which militate against this), in practice it is preferred to determine the position of one or several (but few) points and to deduce the others from these, connecting them by a series or chain of triangles in which the angles formed at each station by the lines joining two others are observed.

In order that the lengths of the sides of the triangles thus formed may be found it is necessary to know the length of one of them, and this as accurately as possible, seeing that on the precision with which this length is known depends the accuracy of all the triangles of the chain.

This side, the length of which must be known with great accuracy, is called the *Base* and is measured directly on the ground by means of an appliance which is essentially nothing more than a wire of special steel alloy the variations in length of which, due to temperature, in addition to being very small, are perfectly regular and known.

The measurement of a distance with a wire of this sort is based on the following considerations:–

If we stretch a wire at a determined tension it will form a catenary and, conse-

(*) *Information compiled from* Revista General de Marina, *Madrid, March,* 1936.

quently, the rectilinear distance between its extremities (the chord of the catenary) is not equal to the length of the wire. However, if we always apply the same tension to it there is no doubt but that the "separation", or rectilinear distance between its ends, will always be the same.

It is this rectilinear distance or chord of the catenary which is taken as the unit of length for measuring distances. The wire is stretched, successively, between two tripods separated by a distance equal to this chord and aligned along the base to be measured, the back end of the wire always being placed on the tripod where the fore end was previously. The wire should be of such length that the chord between its extremities is 24 m. (78.74 ft.) when the tension applied to the wire is 10 Kg. (22 lbs.), produced by weights suspended to its ends.

The ground over which such operations can be carried out must be, if not horizontal, at most at a slight angle though bases may be measured with these wires the extremes of which are at a difference in altitude of 10 % of the length (tables of reduction to the horizontal up to this percentage of difference in altitude are provided with the wire). The accuracy of the measurement is the greater the smaller the slope of the ground.

This being accepted, I will set out the results obtained in the measurement of the *Geodetic Base* in the Island of Grand Canary carried out by the Hydrographic Expedition in 1933.

To make the base the main-road from Carrizal to Juan Grande was selected as it runs in a straight line for a distance of 8 kms (5 stat. miles) with no pronounced gradients; but only that part was found suitable for the Base which extends from about km. 12 to km. 14 at its western end, for this is the only part which has continuous and easy gradients, and, beyond this, not only is the ground somewhat soft, but also it is a place much beaten by the Nly and NEly winds which prevail in these islands at that season.

As soon as the site was selected, on 16th May and following days work was begun on the alignment of the base, the construction of the pillars and the placing of the permanent marks to mark the ends.

The pillars were three in number; on account of the shortness of the base, this was divided into two sections (of 1 km. each) with the object of making sure that one section should be measured in a working day seeing that, on account of the distance of the site of the Base from the port where the Expedition had its quarters, it was possible to work only some four hours daily; besides the pillars at the ends were not in sight of each other.

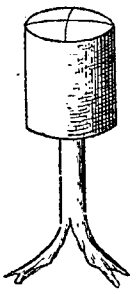

FIG. 1.

The marks at the two ends, which consist of large metal bolts with cylindrical heads the tops of which are silver-plated and engraved with two very fine lines forming a cross (as shown in fig. 1), were cemented into the bottom of cavities fashioned of cement and enclosed in the cement of the pillars constructed over them. These last are of horizontal section in the form of a U with the open side parallel to the Base and on the western side thereof (fig. 2). In the upper face a square block of wood is inserted through which the reference mark can be registered.

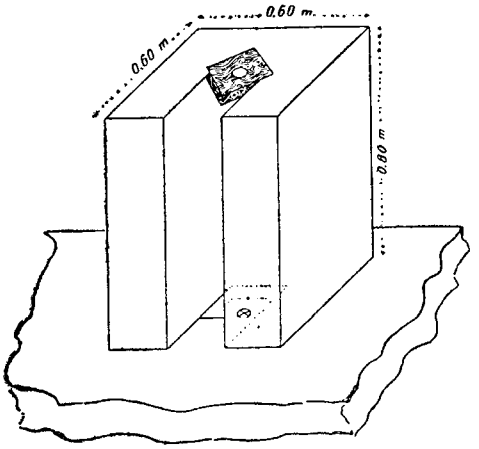

FIG. 2.

The pillars were suitably closed up as soon as the Base had been measured in order to protect the permanent marks from the effects of the weather.

When the pillars were completed the staff was trained during the 26th and 27th May.

The staff was divided into two groups for the measuring operations — the *aligning group*, consisting of one officer, one assistant and one seaman for the transport of the tripods; the *measuring group*, composed of three officers and four seamen for the transport of the pickets to support the weights (tension pickets).

The levelling was always done by an officer.

The southern section of the Base was measured four times, on 29th and 31st May and on 2nd and 6th June.

The northern section was measured five times on 8th, 10th, 13th, 16th and 19th June.

The results and the wires used were as follows:–

SOUTHERN SECTION.

Measurement number.	*Wire N°*	*Length in mm.*	*e*	*(ee)*
1 (forward).....	918,890 & tape	1143773,447	1,770	3,132900
2 (backward).....	912,890 & tape	1143772,587	0,91	0,828100
3 (forward).....	912,890	1143772,136	0,4590	0,210681
4 (backward).....	911,890 & tape	1143768,538	3,1390	9,853321
	Mean	1143771,677		

Mean error of single measurement	2,1623
Mean error of the mean.....	1,0811
Probable error of single measurement.....	1,4584
Probable error of the mean	0,7292

NORTHERN SECTION.

Measurement number.	*Wire N°*	*Length in mm.*	*e*	*(ee)*
1 (backward).....	910,890 & tape	1013350,431	discarded	discarded
2 (forward).....	918.890 & tape	1013336,768	1,44525	2,088747
3 (backward).....	912,890 & tape	1013334,626	0,69675	0,485461
4 (forward).....	911,890 & tape	1013332,455	2,86775	8,223990
5 (backward).....	918,890 & tape	1013337,442	2,11925	4,491221
	Mean	1013335,32275		

Mean error of single measurement	2,2775
Mean error of the mean	1,1286
Probable error of single measurement	1,5227
Probable error of the mean	0,7614

Consequently, the resulting length of the base (not reduced to M.S.L.) is 2157106,99975 mm. ± 1.0548, with a relative error of 1/2046090.

To reduce this to M.S.L. a correction of 29.46 mm. must be applied.

A glance at the above results will show :–

(1) That the measurements of the same section with the same wire gave almost identical results or results that differed by but very small quantities.

(2) That the measurements obtained with Wire N° 918 were always greater than the mean, though by a little only; the check measurements with N° 912 were very close to the mean and those made with N° 911 were always below the mean and by an amount exceeding the difference from the mean given by N° 918.

These two considerations lead to the following conclusions:–

(*a*) That the accidental errors in the measurement of the Base were small seeing that the results obtained with the same wire are almost equal and, thus, that the differences in the various measurements may be due to the fact that :–

(*b*) The wires used, Nos 911, 912, & 918 had underegone changes in length in relation to each other.

These conclusions naturally lead to a comparison of the wires, the only method of judging whether there had been any change in their lengths. This comparison was made on 28th June in the garage of the building allocated to the Expedition; here many of the causes of error, e. g. wind, passage of vehicles, etc., were eliminated. Two tripods were fixed to the floor with cement and the movable reference marks were arranged very firmly above them.

Two "reading-parties" were formed, each of whom took twenty readings of each wire, the positions of the "readers" being changed after every tenth reading.

The results obtained were:–

Wire N° 910	Mean of 40 readings	7,25
	Length of wire, by comparison	23999,72
	Length of stretch	23992,4700
Wire N° 911	Mean of 40 readings	9,5125
	Length, by comparison	24001,92
	Length of stretch	23992,4075
Wire N° 912	Mean of 40 readings	6,8216
	Length, by last comparison	23999,27
	Length of stretch	23992,4484
Wire N° 918	Mean of 40 readings	8,4875
	Length, by comparison	24000,95
	Length of stretch	23992,4625

From these comparisons it was decided, in effect, that Wire N° 911 differs sensibly from the other three, the lengths of which may be taken as being equal.

Hence, taking the three wires which gave very closely the same measurement as being satisfactory, we can assume the mean length given by these three wires to be the true length of the stretch measured, i. e. 23992.46 mm. and, therefore, apply the following corrections:–

to N° 918	0,00
» N° 912	0,01
» N° 911	0,05
» N° 910	0,01

On this assumption the results of the measurements of the sections of the Base and the length of the Base itself appear as follows:–

SOUTHERN SECTION.

Measurement number.	*Wire N°*	*Length in mm.*	*e*	*(ee)*
1 (forward).....	918,890 & tape	1143773,447	0,9475	0,896809
2 (backward).....	912,890 & tape	1143773,057	0,5575	0,310249
3 (forward).....	912,890	1143772,606	0,1065	0,011342
4 (backward).....	911,890 & tape	1143770,888	1,6115	2,595321
	Mean	1143772,4995		

Mean error of single measurement.....	1,1275
Mean error of the mean.....	0,5637
Probable error of single measurement.....	0,7605
Probable error of the mean	0,3802

NORTHERN SECTION.

Measurement number.	*Wire N°*	*Length in mm.*	*e*	*(ee)*
1 (backward).....	910,890 & tape	1013350,431	discarded	discarded
2 (forward).....	918,890 & tape	1013336,768	0,81775	0,668715
3 (backward).....	912,890 & tape	1013335,036	0,91425	0,835853
4 (forward).....	911,890 & tape	1013334,555	1,39525	1,946723
5 (backward).....	918,890 & tape	101337,442	1,49175	2,215318
	Mean	101335,95025		

Mean error of single measurement.....	1,3756
Mean error of the mean.....	0,6878
Probable error of single measurement.....	0,9278
Probable error of the mean	0,4639

This gives the length of the Base, without reduction to M.S.L., as 2157108.44975 mm. ± 0.5998, with a relative error of 1/3599380.

This base, which is very short compared to the sides of the first order triangles of the Hydrographic Expedition, was extended to about four times its value by means of the quadrilateral shown in fig. 3, the calculated base being the distance between points R & A (Roque Acuario and Arinaga).

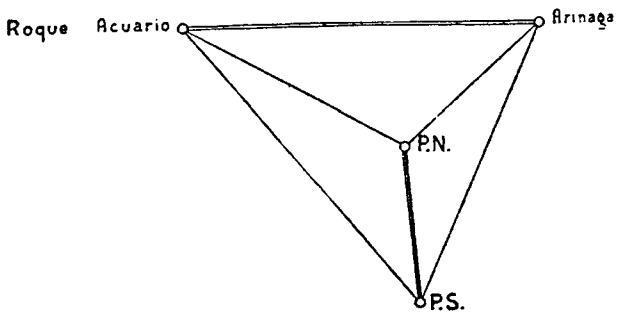

FIG. 3.