Appendix No. 8.

REPORT OF THE MEASUREMENT OF THE YOLO BASE, YOLO COUNTY, CALIFORNIA.

By GEORGE DAVIDSON, Assistant.

The development of the "Davidson quadrilaterals" looked to obtaining a base-line in that part of the Sacramento Valley lying immediately east of the Vaca or Berryessa Mountains; and after the selection of the stations "Vaca Mountain" and "Monticello" an examination was made for the location.

Vaca Mountain station commands the whole flat country to the east of it, but Monticello does not overlook the whole of these plains on account of a peak of nearly the same elevation standing a short distance to the southeast of the station.

The streams and sloughs running eastward from the Berryessa Mountains, which form the western boundary of the Sacramento Valley, are usually short and not very large. But in the rainy season they carry large volumes of water, with swift currents, and are subject to overflows. These overflows have gradually raised their banks from some distance on either side, so that the stream may be said to run on a ridge. Cache Creek (Rio Jesus Maria), having the great equalizing reservoir of Clear Lake as its source, does not present this last feature in a marked degree, but Putah Creek (Rio de las Putas), Anderson, Dry, and Willow Sloughs do. The sloughs which are dry and grassy in summer and fall are bank-full in winter, and even overflow. The banks of Dry Slough are very markedly higher than the adjacent land. These stream ridges lie nearly east and west, and therefore cross the line of any base chosen parallel to the Berryessa Mountains.

Under instructions of the Superintendent, I commenced the examination of the plains of Yolo County between Cache and Putah Creeks for a suitable base-line, in April, 1876, having with me Assistants Rockwell and Eimbeck. After familiarizing myself with the country for a few days, and locating special objects, I easily located a 6-mile base-line lying east and west midway between Cache and Putah Creeks, and then obtained a proper quadrilateral, with its longest diagonal parallel to the line Vaca Mountain–Monticello.

Further examination proved that not only this longer diagonal of the quadrilateral was available for a base-line, but also that another of the sides of the quadrilateral could be had. Upon representing the facts to the Superintendent, and showing that the long line would obviate the occupation of two extra stations on the plains, which would be required if either short base was adopted, he accepted the long base by telegraph.

Fortunately, there is a ridge of 35 feet elevation lying on the south side of Cache Creek bottom. This gave favorable elevation to the north end. At the southern end of the base on Putah Creek the land is low, and, fortunately, *Monticello* comes out from behind an outlying peak. Half a mile northward of the Putah the station Monticello is invisible.

Within eight days the whole question had been settled. Assistant Eimbeck was then detailed to erect signals at Vaca Mountain and Monticello stations, both somewhat difficult of access. Assistant Rockwell was detailed to make a plane table survey with telemeter from Northwest to Southeast base station, so as to determine the relative positions of houses, fences, improvements, sloughs, etc. In this work he made the length of the base 17 573½ metres by telemeter rod. The wheat was then 4 feet high and the measurements not easily made.

When this was about finished I received instructions to occupy stations Mount Diablo and Mount Helena on the scheme of work to extend eastward, and north and south, and to connect with the primary work along the coast.

In 1878 I was ordered to Europe to examine the instruments of precision at the Paris Exhibition.

In 1879 I occupied the stations Mount Lola and Round Top, in the Sierra Nevada.

In 1880 I occupied the stations Southeast Yolo base, Northwest Yolo base, Monticello, and Vaca Mountain.

In June of that year I instructed Sub-Assistant Dickins to make a new topographical survey of the line of the base to ascertain what improvements had been made upon it. His length differed 10 metres from Mr. Rockwell's. Both lengths were obtained by telemeter.

I studied the wearing of the banks of the Putah Creek, which had been cutting the left bank badly to the east of the Southeast base, and the right bank badly above the Southeast base.

For various reasons I moved the Southeast base station about 300 yards westward of the provisional station of 1876. The location of the Northwest base was not changed.

The line appears to avoid all the probable improvements for some years at least, but as it passes through a very rich tract of wheat country, it must eventually be occupied.

As the high ridge of Willow Slough lies directly across the line, I decided to build a brick shaft 30 to 35 feet above the ground at Southeast base, and one of 15 feet elevation at Northwest base. These piers are elsewhere described. The Southeast base station is about 25 metres from the left bank of the Putah Creek, and the ground is 23 feet above low water therein. There is a slight levee between the bank and the station, with a post and board fence thereon.

GENERAL LOCATION OF THE YOLO BASE-LINE.

The line is in Yolo County, in the Sacramento Valley, and nearly midway between the Sacramento River and the Vaca or Berryessa Mountains. (See sketch No. 28.) It lies nearly parallel with the California Pacific Railroad, joining the towns of Davisville and Woodland (county seat), and between 3 and 4 miles west therefrom. Its general direction is N. 16° 53′ W., and S. 16° 53′ E. The south end lies in the northwest quarter of section 19, township 8 north, range 2 east, Diablo meridian, being 3⅛ miles west and 1⅛ miles south of Davisville. It is reached by taking the county road west from Davisville and turning southward on the unopened road which is a south continuation of the Plainfield road. The land is owned by W. H. Soule, post-office Davisville, Yolo County, California.

The north end lies in the extreme southeast corner of the southeast quarter of section 28, township 10 north, range 1 east, Diablo meridian, being 4⅓ miles west of the railroad passing through Woodland, and immediately on the north side of the county road running west towards Madison and Copay Valley. The land is owned by Mr. Jefferson Wilcockson, of Sacramento, but now rented by Mr. William Gibson, living one mile south of Woodland; there is no fence around the land. On the opposite side of the road is Mr. James Oliver's ranch. He is familiar with all the operations here and was heliotroper in 1880. His post-office is Woodland.

The land immediately west of the base-line is a little higher, but between that higher ground and the foot-hills there is a general depression parallel with the line of the mountains and the base. Just west of the northern part of the line the land is rolling, whilst on the east it is quite thickly filled up with farm-houses and the large groves around them. From Willow Slough southward the soil is very good, and this part is largely occupied by farm-houses and large surrounding groves. In a very few years improvements will doubtless cover the line.

MARKING THE BASE STATIONS.

In June, 1880, upon the final location of the two ends of the base, they were marked before the occupation of the stations with the 20-inch theodolite, as shown in sketch No. 29.

The soil at Southeast base is a very fine sand, with an admixture of clay, but not sufficient to cause it to be designated other than a fine sandy soil, formed from the material deposited by overflows of the Putah Creek. It is easily worked with the spade and does not require the pick.

The elevation of the pier was such that it required a large foundation, and this was projected at 70 inches square and 50 inches below the surface, to be built of well-burned brick, with cement. The sketch shows the general proportions of this pier and base. Below this base, however, there was placed a granite block 12 inches, squared on top, and 2 feet 11 inches deep, with a somewhat irregular base of 20 inches. This was a truncated pyramid, irregularly square. The top of this stone reached within 4 inches of the base of the main work, and was wholly separated from it. The base of it was in cement, placed in the lower excavation. On the the top was deeply cut the legend as shown in sketch. The marking for station point was on a flat-headed round copper bolt, 5 inches long and five-eighths inch diameter. The head was turned with a flat spherical surface, $1\frac{5}{8}$ inches diameter, and into the top was inserted a German-silver wire. In the polished end of this wire was punctured, with a needle, a fine hole about one-twenty-fourth inch in depth (by estimation). This mark was transferred to the surface by means of a finely turned $4\frac{1}{2}$-pound plummet, hung carefully over it, and examined by a magnifier. Then meridian instrument No. 1 was placed on its brick stand at the transit and latitude observatory, at right angles to the base line, and a 6-inch Gambey theodolite on the line to the northward, nearly on line of base. The foot-screws of the meridian instrument were removed and the base cemented to the pier and adjusted, and the fine plummet thread brought between the middle thread and the micrometer thread, which had been moved close thereto. Mr. Gilbert adjusted the theodolite and brought the X-threads on the plummet thread. Then Mr. Colonna placed four stubs around the station, two east and west, two north and south. In each pair of copper nails fine points were pricked, in line with the plummet thread and the meridian instrument and the theodolite. These marks were for tests and checks, lest the instruments should be disturbed.

Over the copper bolt in the subsurface block, a nearly hemispherical glass about 3 inches in diameter was placed, and the earth then tamped around it to the level of the ground upon which the base of the brickwork was to rest.

The work for the brick foundation then commenced by wetting the soil at the bottom of the excavation, spreading a good layer of cement thereon, and working it well to establish its connection with the soil. Brick courses were carried up 14 inches solid and 70 inches square; then the pier was battered and brought to receive the surface block of granite 26 inches square by 25 inches deep; upon this being properly placed, the brickwork carried to the surface with sides of 54 inches. This work was then allowed to stand for twenty-four hours, when the surface-mark for the station was made. This marking is on the upper surface of a copper bolt, which was set in lead and then driven until the head was battered out nearly even with the surface of the stone, polished and burnished. Then a minute hole was made in the copper at the intersection of the lines from the instruments; after which cross-lines were made with a penknife merely as guides to find the hole. Into this mark was stuck a fine needle, placed vertical, and all was then covered with a glass tumbler, and the work on the *hollow* pier was commenced.

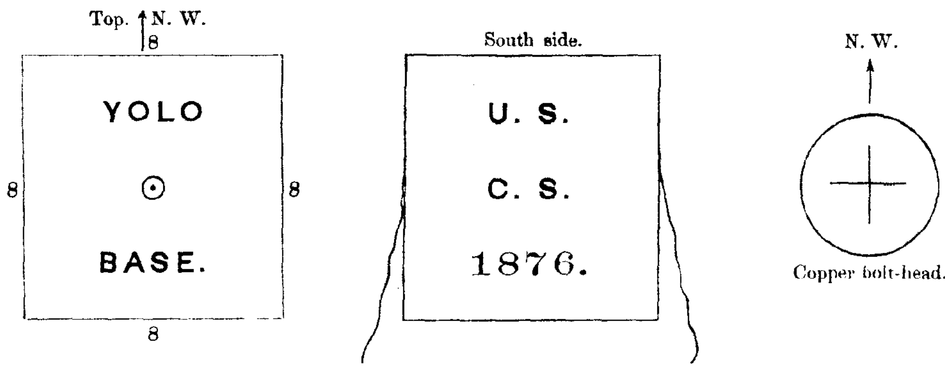
The pier is here 54 inches square, with a hollow shaft $16\frac{1}{2}$ inches square (to the top). To see the mark, two sight channels were left in the pier, one from the hollow center towards the meridian instrument, and one from the hollow center towards the theodolite. A wooden box with trap-door on top protected the glass and mark from falling mortar, etc.

In filling in earth around the subsurface part of the structure four barrels of *charcoal and charcoal dust*, which had been burnt for the purpose, were mixed with the earth in tamping.

The pier was carried $33\frac{1}{4}$ feet above the surface, and upon its top was laid a granite slab 40 by 40 by 8 inches, with a hole $1\frac{1}{4}$ inches diameter in the center. Upon this granite slab, after the pier had set, the position circle and theodolite were centered by means of the instruments already referred to. Subsequently, to provide against the possibility of the pier getting a cant during wet weather, etc., four reference marks were established to recover the station. These are especially referred to on page 142. This precaution was proven to have been necessary after the rainy season of 1880-'81.

The making of the Northwest base station was almost identical with that of the Southeast base. The same character of granite blocks, masonry, etc., was used; and the same methods of marking and reference. The soil at this station is a moderately stiff clay below the surface, and had to be picked out. When it was replaced around the brickwork two barrels of charcoal were mixed with the earth in tamping.

It should be mentioned that when the base-line was measured the extremity of a bar projected 1.96 metres beyond the base station. To mark the end of this bar, one of the "fence stones" was placed in the ground, with its surface even with the top of the soil. Into the top of this stone block was leaded a copper bolt, with a small mark in it, to denote the point from which the fraction of a bar was measured. The top of this stone is marked:



REFERENCE MARKS FOR SOUTHEAST BASE STATION.

(Sketch No. 6.)

To provide means for restoring the station in case of the tower taking a lean during the time it was allowed to stand after the horizontal directions and azimuths had been measured, Assistant Colonna was detailed in December, 1880, after leaving Vaca Mountain station, to place sub-surface marks, below the reach of the plow, on the line of the base northward, and at right angles thereto eastwardly, which he did, as per sketch.

To place the subsurface structure of brick in cement, a hole for each was dug 3 by 3 by 3 feet; then two courses of bricks were laid in cement; then a cube of granite, one foot each side, was set on this. In the upper surface a copper bolt was set, leaded, and driven in solid. The brickwork was then carried up and around the stone three bricks square on the outside. Each block is 1¼ feet high and the tops are 18 inches below the surface.

To mark the bolt in the granite cube, meridian instrument No. 1 was placed over No. 2 block, and its center marked by a drill-hole in the top of the copper bolt. Then the instrument was directed to the station, and a drill-hole made in bolt No. 1 on the line. The meridian instrument was then placed over No. 3 block. The copper bolt was marked in the same manner as No. 2 bolt had been, and then the instrument was directed to the station, and the No. 4 bolt was marked by drill-hole in the line. All were tested repeatedly. The bolts Nos. 1 and 3 were protected by drinking-glasses turned over them; around each glass, cement was placed to form a hard setting for them, but was prevented from adhering to the stone by placing a sheet of paper under the cement. Nos. 2 and 4 had not this protection. The granite block of No. 2 cracked when the bolt was driven home solidly.

The zenith telescope and transit piers, being on the line No. 1–No. 2, were removed to the lowest two courses, which are 18 inches below the surface, as rough references only.

THE BASE LINE LEVELED AND MEASURED WITH FIFTY-METRE WIRE.

When I was occupying the stations Southeast base and Northwest base with the large theodolite, Assistant Colonna was detailed to run a line of levels and repeat between the two stations, and then to connect the Northwest base with the California Pacific Railroad bench-mark at Woodland. Fifty-metre telegraph wire was compared with a Chesterman steel tape on top of a straight level fence.

In measuring, the ground passed over was either high stubble or summer fallow. The wire was strained 48 pounds by a spring balance at the forward end. A stub was driven in the ground at every 50 metres, and a tack driven in top of the stub.

The following measures were made:

	Metres.
349 measures, 50 metres each	17450
1 measure, 25 metres	25
1 measure, 50 feet	15.24
Base	=17490

The count was checked by levelings as follows: The level instrument was each time set over a pin, and the rods held on a stub; this gives 100 metres to each station, unless otherwise noted. Thus, check

	Metres.
159 stations by 100 metres	15900
1 station by 150 metres	150
13 stations by 100 metres	1300
1 station by 50 metres	50
3 stations by 25 metres	75
1 station by 15.24 metres	15.24
Base	=17490

The levels were run over the base-line twice. The two rods, Boston pattern, were kept plumb by means of a plumb-bob attached to each. One rod was held over the back stub, and the other over the forward stub, and the readings were made as nearly simultaneously as practicable.

The rods had been compared with a standard yard and found practically correct.

	Feet.
The first measurement, from southeast base to northwest base, gave for the difference of level	81.931
The second, from northwest base to southeast base	82.122
Mean difference of level	82.026

The levelings between northwest base and Woodland, California Pacific Railroad bench-mark were

	Feet.
I. From northwest base to Woodland	92.698
II. From Woodland to northwest base	92.669
	92.683

The railroad bench-mark, as given by the railroad engineers, is 60.6 feet above mean low water of San Francisco Bay. Therefore we have, provisionally

Southeast Yolo base station = 71.257 feet above low water, San Francisco.

Northwest Yolo base station = 153.282 feet above low water, San Francisco.

The plan I had in view to determine this satisfactorily was to connect the Southeast base station (via Dixon and railroad) with the Coast and Geodetic Survey bench-mark at Benicia by a line of levelings to be carried out this winter.

TEMPORARY MARKS ON BASE-LINE.

After studying the different methods of marking the points on the base when the work closed at night, at lunch, and at the approach to a bridge, I adopted a granite block 12 by 12 by 4 inches, with a copper bolt five-eighths inch diameter projecting two inches above surface, with its end double beveled and silvered. On one face of this dull knife-edge a small fine line was drawn from the edge downwards. This line was the point of reference. When the "mark" was to be fixed in position a hole was scraped in the soil to a depth of 3 or 4 inches, and the block placed in it. The knife-edge was placed in the line of the bar, and the fine line approximately located under the end of the bar.

An ivory scale divided to 0.50mm was then placed in line with the bar, and a given division of the scale—for instance, 20.00mm—was made coincident with the fine line by means of a magnifier. The scale was made level. Then, with the sector, the end of the bar was transferred to the scale. After some progress, the method adopted with the sector was to level the transit axis, point on bar, and read the scale once; then reverse the transit axis level, adjust and point on end of bar, and read the sector again; then reverse the telescope in the Y's, level transit axis, point on end of bar, and read scale; reverse transit axis level, adjust and point on end of bar, and read scale. At each reading the ivory scale was reset.

The sector was placed a distance of nearly 20 feet from the end of the bar and at right angles thereto. The magnifying power of the telescope was measured 20 diameters. The legs of the tripod of the sector were cut short, so that the height of the telescope was about 3 feet above the ground. This enabled the end of the bar and the metre scale to be seen with the same focus of the telescope. Three of these granite marking-blocks were in use, so that no block was removed until another, or a kilometre block ahead, had been established. After some progress of the work, I adopted the rule of using the sector always on one side of the bars.

THE MOVABLE COVER FOR THE BASE APPARATUS.

Having determined to measure the base-line with the beams and trestles carrying the base-bars protected from the direct action of the sun, I gave to Assistant Gilbert a general idea of what I wished, and the cover was constructed under his direction at Sacramento.

To protect the bars from the direct action of the sun, to secure them from injury at night, or during any temporary suspension of the measurement, and to allow ample room for movement during work on both sides of the trestles and bars, it was necessary to have a cover 50 feet long, 12 feet wide, and 9 feet high, one that should possess great strength and yet be light enough to be easily moved by two or three men.

The foundation was a parallelogram of the length and width just named; the material was Puget Sound fir, and the size of the timbers 2½ by 6 inches; the angles were strengthened by heavy three-eighths-inch angle-irons and stout bolts. The canvas cover was stretched over wagon bows of ash, spliced so as to obtain the necessary width and height.

Four wheels were used, each having a diameter of 3½ feet, and each pair secured 10½ feet from the end, in such a way that they could be readily detached and the frame-work allowed to rest on the ground. This was always done during any temporary suspension of the measurement, and at night the cover was completely closed by canvas curtains and secured so as to afford entire protection to the apparatus against wind and rain. The whole cover complete weighed about 1,200 pounds, and on hard, level ground could be moved by one man.

When at work, the standard bar No. 2 was carried secured to the rail on the shady side of the cover. Suitable shelves and bags served to hold such tools, instruments, etc., as were needed from time to time during the progress of the work; thus loaded the wheels doubtless sustained a weight of 1 500 pounds. The entire frame-work is fastened together with ordinary carriage bolts, and can be readily taken apart for shipment. The movable cover became known throughout the region as the "Yolo buggy."

THE ORGANIZATION OF THE PARTY.

The readiest way of understanding the movement of the party at work is by an examination of the annexed plan (Sketch No. 30), exhibiting the bars and tripods or trestles in position, and the traces of the men's forward movements.

As we actually reached an average of fifty-seven bars per hour, and frequently several consecutive bars in forty-five seconds each, it will be readily understood that the whole of the movements must have been almost as regular as machinery. Every officer and man had a specific duty assigned to him, and no deviation was allowed therefrom. The general forward movement may be said to commence at the command "Break," when the contact slide of the forward bar was drawn back, and the after bar was drawn back, lifted out, and moved forward. The tripod men relieved the tightening of the legs, picked up the tripods, and moved forward, where the tripods were put in line and in position by an officer; the plates followed and were placed outside the position of the legs; then the tripods were placed on the plates, accurately distanced, leveled, and clamped. The "buggy" moved forward as soon as the plates were raised. One officer, near the sector, guarded the bar which remained in position. An officer then received in his own hands the after end of the forward bar, and was then responsible for it until the next "break" of contact.

The details of aligning the bar, raising or depressing the after end, making approximate contact, reading the Borda and mercurial thermometers, reading the sector, and making final contact under a magnifier, fell into their regular and necessary sequence.

It was the duty of each officer to guard against errors of reading scales and thermometer; of the recorder, to announce any seeming deviation from regularity of change; and of the chief, to call for any re-examination if he suspected mistakes.

The sector readings for inclination were checked by a re-reading; and in the second measurement one officer read the sector and left it without announcing his reading until the second officer had given the degrees and minutes.

It will be noticed that the bars were carried forward on one side of the line of tripods, officers and plate and tripod men remaining on the other, and no one was permitted to pass under the bars. When no actual measurement was being made, and when the night or bench-mark or any other mark was being referred to, all hands left the inside of the "buggy" until recalled.

At the close of the day the bars and standard were put in position on the comparing beam, resting on two trestles for the morning comparison, and lightly covered with canvas against rain beating through the light cover. At night the watchman had a hammock swung under the "horse" or trestle over the wheels.

Before the measurement commenced the bars were compared with the standard bar, in the condition in which they had remained over night; then the sectors were examined by the leveling instrument for the determination of the zero of the inclination arc. The after bar was then plumbed over the night mark, and at its satisfactory measurement the command "Break" announced the forward movement of the bars. The night mark was covered by a box and left intact until another mark had been secured.

It will be seen by the plan that the following personnel of the party was requisite on the ground:

Chief of Party Davidson, Assistant Gilbert, Sub-assistants Dickins, Pratt, Blair, Recorder Hill, Mechanician Suess	7
Men, 11; watchman, 1; driver (and extra, who also attended to bridges, etc.), 2	14
In camp: cook, officers' steward, men's steward	3
Total, officers and men	24

FOOT PLATES OF THE TRESTLES.

These plates were devised as a substitute for those with circular groovings, the latter being too limited in their range. The plate herewith exhibited in section and plan was found to answer all the purposes demanded. (See Sketch No. 29.)

The plates were laid independently of each other, and with very little practice the men became familiar with the best mode of stamping them down. They were used on every character of ground, and had their severest test on that part of the line torn open by innumerable "drying cracks," as mentioned in this report. Each plate weighed 9¼ pounds, and the points were turned steel riveted on top. There were none of them broken or injured in the work.

COMPARISONS OF THE BASE BARS WITH THE FIELD STANDARD BAR.

I had brick piers built at Southeast base, Middle base, Northwest base, and Camp Schott, upon which to place the frame made by Mr. Suess, in camp, for carrying the two base bars and standard bar during comparison. Independent piers carried the comparators. All the earlier comparisons were made on this frame and piers at camp and at Southeast base.

Having determined to make comparisons of the base bars and standard every morning before commencing measures, I directed Mr. Pratt to make a portable wooden beam, which should rest on two ordinary trestles. Upon each end of this beam a comparator was to be secured, and the comparisons were to be made upon the assumption that the beam did not change in length during the period of each comparison, or if change took place it might be measured by knowing the temperature of the beam and its coefficient of expansion.

As soon as the beam was constructed these daily comparisons were made. At northwest base this beam rested on the brick piers, but their comparators were in their places on the beam. At Camp Schott, at the close of the measurements, the beam also rested on brick piers; comparators on the beam.

The beam is described as follows, in Mr. Pratt's own words. Of course it would have been better made and with special adjustments if time and means had been available. It was made by Mr. Pratt in camp, and its working was satisfactory:

"The idea of using in the field a single beam so arranged that one base bar could be laid on it at a time and its measure or comparison taken, then removed entirely and replaced by another bar, and so on, was suggested to you, I believe, by Assistant Schott.

"The beam was proportioned and made to carry out Assistant Schott's suggestions, which accounts for its being so narrow. After it reached the field it was decided that it would be best to put all the bars on at one time, and I devised and executed all the present attachments. The crudeness of construction and arrangement was due to the limited means at hand. The planks that compose the beam are of thoroughly seasoned two-inch white cedar, and are securely bolted together in such a manner that they can be retightened at any time in case of shrinkage. In order to make it as portable as possible, the usual carriage for carrying the bars was discarded, the bars themselves acting for that purpose by simply resting on the two hard wood pieces, which are at right angles, and have round metallic rails fixed to their under sides. Each one of these rails rests on two grooved metallic rollers, one on either side of the beam; the two rollers on the back of the apparatus, as seen in the drawing (sketch No. 30), are connected with each other by a shaft, and also with the wheels at either end, which are used by the observers to move the bars backward and forward. There is a little lost motion in that portion of the shaft which is between the two metallic rollers, which enables the observers to give either end of the bars a slight independent movement.

"Under the points of support to each bar are placed diagonal metallic plates, with an adjusting screw in each end, by which means the bars are raised or depressed to the exact height of the abutting pieces on the comparators. By referring to the sketch the handles of these adjusting screws will be seen to project above the tops of the base bars."

MOVING THE BASE BARS INTO LINE.

Various plans were suggested to move the bar sideways by mechanical means, but that proposed by Mr. Gilbert was accepted as the simplest, and was capable of being made by a blacksmith. (See sketch No. 29.)

An iron rod one-half inch diameter and about 14 inches long had a coarse thread cut upon it for about four inches under the beam. One end of this rod was loosely fixed to the tripod just below the level of the under side of the bar beam and behind the uprights on the tripod. The free end of the screw bar, with a cross for turning by was lifted by the operator up and against the under side of the beam upon which was fastened an iron plate with a 3-inch longitudinal knife-edge placed at an angle with the bar equal to the thread of the screw. This knife edge therefore entered one of the threads, and as the screw was turned that end of the bar was necessarily moved sideways.

Had there been time and proper means for executing a fair piece of workmanship, it would have worked with sufficient smoothness; even as it was, we owe the quickness of our measures, in great part at least to this simple and coarsely made contrivance.

MEASURE FOR FRACTIONAL BARS.

It was almost certain that a fractional bar would need to be measured at the northwest end of the base-line, and also at each "fence stone."

To make such measures with accuracy I made known to Mr. Pratt what I wished done, and left the details to him. So I transcribe his description of the measure for the fractional bars as shown in sketch No. 30.

"The wooden portion of the bar is of thoroughly seasoned white cedar 0.05m thick, 0.113m deep, and 3.225m long; in order to prevent warpage it was split in two equal pieces and one of them turned 180°, and then they were securely fastened together. One of the lower edges was rabbeted out sufficiently to let in a steel bar 0.012m square; this steel bar was graduated to three metres, and each one of these individual metres was compared with a standard metre by means of a micrometer beam compass, which I devised especially for this purpose. Sliding on this steel rod is a vernier, with clamps and slow motion. On the side of the bar is an ordinary base-bar sector for measuring the inclination.

"In measuring a fraction of five metres, which occurred at all of the fence stones and at Northwest base, the zero of the bar was placed over, and usually in contact with, the fine point in the copper bolt, then the vernier was moved until it came vertically under, as determined by a transit sector, the end of one of the base bars; the whole metres were then read off subject to the corrections obtained by comparison, and the fractional portion of a metre was transferred, with a knife-edged beam compass, to a metre scale to be read."

ALIGNING TELESCOPES.

The aligning telescopes, one at the forward end of each bar, were upon my recommendation somewhat improved in their practical working, at the close of the first measurement, and subsequently Mr. Pratt fitted set screws to abut against a stud in the metallic end of the wooden beam, by which means they could be corrected in azimuth. Several improvements are yet desirable, and will be introduced.

In the second measurement the bars were aligned between adjacent kilometre stones.

COMPARATORS.

The observations for comparison of the base bars with the standard were made with the two micrometer Fauth lever of contact comparators which accompanied the apparatus. These comparators are described and illustrated in Assistant Schott's paper on the construction of the apparatus (Appendix No. 7).

[NOTE.—Assistant Davidson has studied carefully the working of the apparatus in the field, and has made plans for certain improvements suggested by the severe tests applied during the progress of the several measurements.]

RATE OF MEASUREMENT.

The following tabulation gives in detail the time occupied with each operation in the measurement in the field. It indicates how well the party increased in efficiency in the successive measurements. The summary very clearly exhibits the results attained.

	First measurement.	Second measurement.	Third partial measurement.
Total number of bars laid	3498	3498	1498
Total number of working days	20	18	8
Total number of working hours	183½	171¼	53½
Average daily number of bars	175	194	187
Average daily number of bars per hour*	28	37	43
Highest hourly average for day	39	45	54
Highest number bars in one day	271	276	324
Highest number bars in one hour	42	49	57

*Actual time of laying the bars.

The actual time of working during the measurements, which amounted to 8 494 bars, was 408 hours. This included comparisons with the standard, adjustments, and all delays whatever from the time of reaching the field to leaving it. The average number of bars laid per hour under these conditions was 20¾. But the actual time of laying the 8 494 bars, not including any delays, was 247 hours; this gives an average of 34⅓ bars per hour.

Tabulation of daily work.

FIRST MEASUREMENT. YOLO BASE LINE.

Date.	Time for comparisons.	Time for testing instruments.	Time for plumbing down.	Setting stones, accidents, etc.	Time for lunch, noon.	Sum of delays, etc.	Time of beginning work, a. m.	Time of ending work, p. m.	Time occupied during work.	Actual time of laying bars.	Number of bars laid during day.	Average number of minutes to each bar.	Average number of bars to each hour.
1881.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.			
September 19	0 15	0 35	0 56	0 15	0 50	2 41	8 20	5 40	9 20	6 39	126	3.17	19
20	....	0 22	1 14	1 38	1 23	4 37	7 45	5 45	10 00	5 23	97	3.33	18
21	....	0 16	0 30	....	0 45	1 31	7 55	5 25	9 30	7 59	163	2.94	21
22	0 33	0 00	0 43	0 34	0 00	1 50	8 20	12 10	3 50	1 50	47	2.34	26
24	0 17	0 00	0 83	1 29	1 00	4 09	7 50	5 52	10 02	5 53	115	3.07	20
27	0 18	0 31	0 54	0 43	0 33	2 59	7 54	5 33	9 39	6 40	182	1.87	27
28	0 40	0 20	0 44	1 08	1 00	3 52	8 32	5 38	9 06	5 14	134	2.34	26
29	0 17	0 20	0 41	0 25	0 37	2 20	7 18	5 35	10 17	7 57	237	2.01	30
30	0 19	0 15	0 32	1 54	0 41	3 41	7 12	5 20	10 08	6 27	185	2.07	29
October 3	0 20	0 27	0 35	2 36	0 58	4 56	8 58	5 37	8 39	3 43	114	1.96	31
4	0 22	0 16	0 40	0 57	1 09	3 24	7 12	5 20	10 08	6 44	225	1.79	34
5	0 23	0 20	0 46	1 47	0 50	4 06	6 55	5 26	10 31	6 25	226	1.70	35
6	1 11	0 19	0 52	0 54	0 57	4 13	7 23	5 20	9 57	5 44	192	1.78	34
7	0 15	0 25	0 28	1 14	0 46	3 08	7 55	5 24	9 29	6 21	204	1.86	32
8	0 38	0 16	0 31	0 46	0 59	3 10	7 28	5 23	9 55	6 45	229	1.77	34
10	0 35	0 38	0 29	0 28	0 28	2 38	7 20	5 25	9 65	7 27	271	1.65	36
11	0 36	0 23	0 28	0 54	0 43	3 04	7 36	4 49	9 13	6 09	201	1.84	33
12	0 31	0 23	0 20	1 01	0 51	3 05	7 54	4 45	8 51	5 46	200	1.73	35
13	0 35	0 10	0 38	0 23	0 50	2 36	8 20	4 50	8 30	5 54	231	1.53	39
14	0 35	0 13	0 06	1 33	....	2 27	7 55	2 18	6 23	3 56	119	1.99	30
Average=	....	....	....	....	....	....	....	....	....	....	175	2.14	28

Number of days, 20; total number of bars, 3 498; actual time of laying bars, 118 hours 56 minutes.

SECOND MEASUREMENT. YOLO BASE LINE.

October 17	0 31	1 22	0 44	0 43	0 48	4 08	8 15	5 07	8 52	4 44	106	2.68	22
18	0 35	1 09	0 40	....	0 34	2 58	8 45	4 39	7 54	4 56	168	1.76	34
19	0 44	1 12	0 39	0 41	0 48	4 04	7 50	4 43	8 53	4 49	160	1.81	33
20	0 45	0 41	0 36	0 15	0 45	3 02	7 50	4 50	9 00	5 58	220	1.63	37
21	0 31	0 13	0 47	0 31	0 45	3 47	8 00	4 53	8 53	5 06	192	1.59	38
22	0 30	0 38	0 26	0 38	0 45	2 57	7 45	4 24	8 39	5 42	252	1.32	45
24	0 37	0 53	0 41	0 15	0 36	3 02	7 08	4 37	9 29	6 27	256	1.51	40
25	0 37	0 28	0 41	0 53	1 11	3 50	7 17	4 25	9 08	5 18	192	1.66	36
26	0 36	0 40	0 36	0 14	0 20	2 26	7 00	1 35	6 35	4 09	166	1.50	40
27	0 49	0 39	0 22	....	....	1 50	12 40	4 43	4 03	2 13	94	1.42	42
28	0 30	0 41	0 22	0 09	0 42	2 24	7 50	4 45	8 55	6 31	200	1.85	33
29	0 37	1 02	0 18	1 58	1 10	5 05	7 00	4 48	9 48	4 43	174	1.63	37
31	0 31	0 51	0 26	0 56	0 39	3 23	7 00	4 55	9 55	6 32	242	1.62	37
November 2	0 35	0 50	0 51	0 15	0 44	3 15	7 10	4 50	9 40	6 25	250	1.54	39
3	0 38	0 47	0 41	0 43	0 55	3 44	7 20	4 55	9 35	5 51	252	1.39	43
4	0 49	0 31	0 36	0 45	0 47	3 28	7 30	4 45	9 15	5 47	230	1.51	40
5	0 35	0 33	0 24	0 33	0 45	2 50	7 40	4 50	9 10	6 20	276	1.38	43
7	0 30	0 30	0 23	....	....	1 23	7 50	11 11	3 21	1 58	68	1.74	34
Average =	....	....	....	....	....	....	....	....	....	....	194	1.64	37

Number of days, 18; number of bars, 3 498; working hours, 171½; total actual time of laying bars, 93 hours 29 minutes.

THIRD PARTIAL MEASUREMENT. YOLO BASE LINE.

Date.	Time for comparisons.	Time for testing instruments.	Time for plumbing down.	Setting stones, accidents, etc.	Time for lunch, noon.	Sum of delays, etc.	Time of beginning work, a. m.	Time of ending work, p. m.	Time occupied during work.	Actual time of laying bars.	Number of bars laid during day.	Average number of minutes to each bar.	Average number of bars to each hour.
November 11	0 35	0 57	0 27	0 44	0 32	3 15	7 30	4 30	9 00	5 45	242	1.43	42
12	0 31	0 22	0 19	0 24	....	1 36	7 27	12 50	5 23	3 47	158	1.44	42
14	0 39	0 27	0 38	0 10	0 22	2 16	7 52	4 20	8 28	6 12	252	1.48	41
16	0 37	0 26	0 20	0 13	....	1 36	9 10	2 10	3 00	1 24	46	1.83	33
18	0 25	1 26	0 49	0 15	0 22	3 17	8 45	4 35	7 50	4 33	178	1.53	39
19	0 55	0 30	0 31	0 22	0 31	2 49	8 08	4 13	8 05	5 16	222	1.43	42
21	0 34	0 46	0 46	0 10	0 25	2 41	7 45	4 28	8 43	6 02	324	1.12	54
22	0 32	0 18	0 13	0 11	....	1 14	8 00	10 46	2 46	1 32	76	1.21	50
Average ...	....	....	....	....	....	....	....	....	....	....	187	1.40	43

Number of days, 8; number of bars, 1 498; working hours, 53¼; total actual time of laying bars, 34 hours 31 minutes.