1¼ inch broad, and trussed both laterally and vertically, so as to be rendered perfectly inflexible. They were con­structed in such a manner that they might be used either by butting the end of one rod against the end of another, or by bringing fine transverse lines drawn upon them at the dis­tance of an inch and half from each extremity into exact coincidence; but although the last method was considered by General Roy to deserve the preference, it was found on trial to be attended with so much inconvenience and loss of time that it was abandoned, and the measurement by contacts alone adhered to. The weather proved wet and unfavourable, and before the measurement was half com­pleted, the deal rods were found, notwithstanding all the care which had been taken to prepare them of the best materials, so liable to sudden and irregular variations of length, from changes in the hygrometrical state of the at­mosphere, as to leave no hopes of determining by their means the length of the base with the precision which was aimed at. As, however, so much of the work had been done, it was thought desirable to continue it until the whole base was measured, in order that the result might be compared with that which should afterwards be found by a different method

General Roy cites some experiments to show how unfit deal rods are for such a purpose as the measurement of the base of a great trigonometrical operation. On one occa­sion the measuring rods, when compared with the standard, were found to exceed it, at a medium, one fifteenth part of an inch ; so that if the whole base had been measured with the rods in that state, the difference would have amounted to more than 7½ feet, exclusive of any expansion or con­traction of the standard, which was of the same material. Another experiment, made after the operation had been completed, was still more decisive. A line of 300 feet was accurately measured off in the garden of Sir Joseph Banks when the rods were in a dry state, the sun shining bright, and the temperature 68°. The rods were exposed to the dew during the night, and when lifted from the grass on the following morning were found to be quite wet except­ing on the sides in contact with the ground. The line was then remeasured, and its length as given by the rods found to be less by 0·498 of an inch (or nearly half an inch) than on the preceding evening. Hence it appeared that the dew imbibed in one night, or a period not exceeding four­teen hours, caused such an expansion of the rods as in the whole base would have amounted to 45·484 inches. (Trig. Survey, vol. i. p. 50.) There experiments were important, as deal rods had been employed in all the prin­cipal operations of the kind which had previously been undertaken for determining the magnitude and compression of the earth.

The measurement with the deal rods being completed, and the proper allowance (so far as it could be determined from the comparisons with the standard) made for the ex­pansion, the distance between the centres of the pipes ter­minating the base, reduced to the level of the lower ex­tremity at Hampton Court, and at the temperature of 63°, was found to be 27,406∙26 feet of the standard scale from which the lengths of the measuring rods were laid off.

When it was discovered that the measurement by means of the deal rods would prove unsatisfactory, and General Roy was considering the different alternatives that might be adopted, it was suggested by Lieutenant-colonel Cal- del-wood that glass rods should he substituted for those of deal. As it was found upon trial that there would be no difficulty in obtaining glass tubes of the desired length, and that they could be provided much sooner than rods of metal; and as it was obvious that the rate of expansion could be determined with equal certainty, it was resolved to adopt the suggestion. Accordingly, three hollow tubes, perfectly straight, upwards of twenty feet in length and about an inch in diameter, were selected, and converted by Ramsden into measuring rods. The tubes were placed in cases, to which they were made fast at the middle, and braced at several other points, so as to prevent them from bending or shaking, but not so closely as to prevent their free expansion or con­traction. Both ends were ground perfectly smooth and at right angles to the axis of the bore ; one end having a fixed apparatus or metal button attached to it for making the contacts, and the other end a moveable apparatus, or slider, which was pressed outwards by a slender spring, and against which the fixed extremity of the succeeding rod was pushed, until a fine line on the slider was brought into exact coincidence with another fine line on the glass rod, in which state the distance between the extremities was exactly twenty feet.

The ground on which the base was measured not being quite level, the whole distance was divided into hypothenuses or inclined lines in the same vertical plane, each con­taining thirty lengths of the measuring rods, or 600 feet; and the method pursued was to place the rods exactly in straight lines stretching from one extremity of a hypothenuse to another, and then to determine the relative heights of the two extremities of the hypothenuse by the spirit-level, for the purpose of reducing to the horizon. The cases con­taining the measuring rods were supported on trestles about two and a half feet above the surface of the ground.

The new measurement with the glass rods was begun on the 18th of August, and concluded on the 30th. On ar­riving at the south-east extremity the end of the 1370th rod was found to overshoot the centre of the pipe terminat­ing the base, by 17∙875 inches ; and after the rate of expan­sion of the rods had been determined, and the proper equa­tions applied, the difference between the present and the former measure with the deal rods was found to be 20·964 inches, of which the greater part is probably owing to the over-rated expansion of the deal rods, which, when brought into use, appear to have contracted sooner than was ima­gined, and thereby given a shorter distance than was as­signable from the mean of any two comparisons with the standard. No use was made of the measurement with the deal rods in any of the subsequent operations.

After the measurement on the ground had been com­pleted, it was necessary to determine by actual experiments the expansion of the glass rods, in order to obtain the exact length of the base. For this purpose an ingenious micro­scopic pyrometer, invented by Ramsden, was employed, by means of which the expansion of the brass scale, and of glass rods and various other substances, was ascertained for every degree of Fahrenheit from 32° to 212°. The glass measuring rods could not themselves be submitted to ex­periment on account of their great length ; the rod on which the experiments were made was 5 feet in length, 0·93 inch in diameter, weighing 1 lb. 13½ oz. and drawn from the same pot of metal as the measuring rods. These experiments were made in the winter of 1784 and spring of 1785.

In order to give a clearer idea of the number of minute circumstances to be attended to in an operation of this kind, we shall here state the final result in the words of General Roy. (Trig. Survey, vol. i. p. 84.)

Feet.

Hypothenusal length of the base as measured by 1369∙925521 glass rods *of* 20 feet each + 4∙31 feet, being the distance between the last rod and the centre of the north-west pipe, 27,402∙8204 Reduction of the hypothenuses to be subtracted, 0∙0714

Apparent length of base reduced to level of

south-east extremity.. 27,402∙7490

Add the difference between the expansion of

the glass above, and contraction of it below,

62°," 4∙1867 inches. = 0∙3489