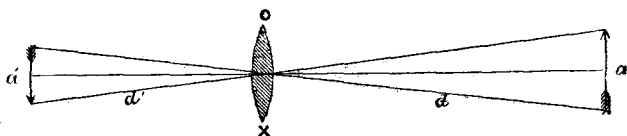


Mr. GRAVATT said, that as long ago as the year 1828, he had used the dumpy level for measuring distances, and by doing so, had been able on many occasions to dispense with chainmen. He was aware that several other Engineers had also adopted the same system, but possibly its application might hitherto have been limited, from the want of a correction for the errors introduced in focussing the instrument. He thought that point had been rightly treated in the Paper, but it would be well that the theory of the matter should also be correctly understood.

Fig. 1.



In Fig. 1, if O X represented the object glass, a the direct image, and a' the inverted image formed within the telescope, then $\frac{d}{d'} = \frac{a}{a'}$, and by the common focal theorem, when f represented the principal focal length of the telescope, $\frac{1}{d'} + \frac{1}{d} = \frac{1}{f}$, by means of which two equations, and eliminating d' , the equation $d = \frac{f}{a'} a + f$ was obtained, as given in most of the books which treated of optics. It was therefore evident, that if a cross hair was fixed on the diaphragm of a telescope, at a distance from the centre level hair of $\frac{1}{66}$ of the principal focal length of the telescope, then at a distance of one chain, plus the principal focal length, a space of one foot would be subtended on the level staff, and in a similar manner at a distance of n chains, plus the principal focal length, a space n feet would be subtended on the staff. The preceding distances being from the object glass, it was necessary to add the distance from the object glass to the centre, or vertical axis of the instrument, before the distance to the centre of the instrument could be obtained. In the dumpy level, the distance from the anterior focus, added to the distance from the object glass to the centre of the instrument, amounted to about 2 links. So that assuming a space of 3.45 feet was subtended on the staff between the cross hairs, the true distance from the staff, to the centre of the instrument, would be 3.47 chains; or, if 5.67 feet on the staff, were subtended between the cross hairs, the true distance would be 5.69 chains; or, generally, if n feet were subtended on the staff, the distance from the staff to

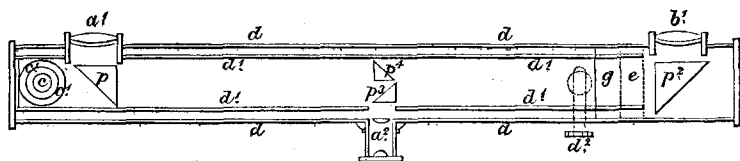
the centre of the instrument would be n chains plus 2 links. He believed, that the instrument makers generally ascertained the distance apart, at which the cross hairs should be placed, by means of Troughton's micrometer, and then, with great care cut lines on the diaphragm to indicate the correct position at which the ends of the hairs were to be fixed. In his original level, he made both the upper and the lower cross hairs adjustable, with regard to the centre hair, and used, in addition, a Cavalho's mother-of-pearl micrometer. With an instrument of that construction he had frequently measured a distance of 17 chains. With a longer staff than was ordinarily used, no doubt a greater distance could be measured, but to measure distances accurately by this method, practice in reading the staff at known distances was essential.

Captain W. S. MOORSOM, said, that the Paper, and the illustrations given by Mr. Gravatt, had considerably modified his opinion as regarded the utility of the micrometer. He had previously considered the micrometer to be an instrument more adapted for the general purposes of military reconnaissance, than for ascertaining the minute details which were required in engineering surveying. From what had transpired, there could however be no doubt but that it might, with great advantage, be more generally applied to many of the practical operations connected with levelling. His previous experience had satisfied him, that a quick and accurate observer could rapidly ascertain, with sufficient correctness for military purposes, the movement of a column of troops, the situation of forts, or of batteries of position, or the speed and course of vessels at sea. One telescope which he had used, was made by Mr. West, of Charing Cross. It had six cobweb wires across the diaphragm, and was fitted with a bronzed prismatic compass in the cover of the field-glass. With similar additions any ordinary telescope might be converted into a portable surveying instrument. He must however incidentally notice, that no bright brass fittings should be used in instruments intended for military purposes, on account of their affording an immediate mark for the enemy's sharpshooters. Happening to be on a part of the coast of Dorsetshire when the 'Great Eastern' made her first voyage out of the Thames, he was enabled to ascertain her rate of progress by means of a watch with a second-hand, and the micrometer and compass which he had just described. He laid the telescope and compass on a stone seat, which was conveniently situated for the purpose, and when the extent of the vessel, from stem to stern, covered a certain number of wires, he noted the time and the bearing. After an interval had elapsed, he found that the extent of the vessel from stem to stern covered a greater number of the wires, and he again noted the time and the bearing. Having ascertained the proportional angle subtended by the micrometer

wires, he was enabled, by taking the length of the 'Great Eastern' as a base, to compute the distance at each observation. For although her course was not directly at right angles to the line of sight, the amount of obliquity was so small as not to vitiate the results. By plotting her position at each time of observation from the bearing and distances thus obtained, he was enabled to ascertain that her speed was from 13 miles per hour, to 14 miles per hour, and that she was steering in a direct line for Portland Breakwater.

Mr. P. ADIE remarked, that the arrangement described by the Author was of a much earlier date than had been mentioned in the Paper. He had been acquainted with the system for the last twenty years. It had also been very generally employed in deer-stalking. In the telescopes used for that purpose, there were different spaces in the diaphragm which subtended the height of a deer at certain given distances. He however doubted that the system could be used with accuracy for military purposes, as owing to the varying stature of different individuals, the distance deduced from the height of a man would probably be subject to a variation of as much as 20 per cent. In measuring distances by the telescope, it was of the greatest importance to substitute, if it possibly could be done, a certain for an uncertain base. With this view he had designed a small instrument which he exhibited. It consisted of two telescopes, the tube of one, working inside of the tube of the other, the object glasses of the two telescopes being placed at right angles to their respective tubes, at a distance apart of 18 inches from centre to centre, the rays of light being reflected by means of prisms to an eye-glass in the middle of the instrument. The interior details would be best understood by reference to Fig. 2:—

Fig. 2.



In the above figure d , d , d , d , represented the outer tube, which as it bore a fixed divided segment at e , might be called the limb of the instrument. At one extremity of the outer tube there was an object glass b^1 . A totally reflecting prism at p^2 , received the rays formed by this object glass, and reflected them along the inner tube d^1 , d^1 , d^1 , d^1 to a prism reflector at p^1 , which again reflected them into the upper half of the eye-piece a^2 . The inner tube or vernier arm d^1 , d^1 , d^1 , d^1 , carried its vernier at g , and had

a female centre c^1 , c^1 , fixed to it at its other extremity ; this worked upon a male centre at c , which was fixed to the limb, or outer tube. The object glass a^1 , belonging to the inner tube was fixed to it on the same plane, and at a given distance from the object glass belonging to the outer tube b^1 . There was also a totally reflecting prism fixed to the inner tube at p , which received the rays from the object glass a^1 , and reflected them along the inner tube to a second reflecting prism p^1 , also fixed to the inner tube, by which the rays were again reflected to the lower half of the eye-piece a^2 . The object glass a^1 , the prisms p^2 and p^1 , and the vernier g , being all fixed to the inner tube moved along with it : the pointing of the two telescopes being adjusted to suit the distance by means of the tangent screw d^2 . In using the instrument, the two images of the object were not allowed to overlap each other, but were made continuous. By this arrangement simultaneous observations were obtained by two powerful telescopes, and the distance between the object glasses a^1 and b^1 being known, the angle between their directions, or in other words, the angle formed by the inner and outer tube, was read on the limb at e , in parts of degrees, by means of the vernier, and by reference to a tabular scale exposed on the instrument, the distance might at once be determined. As the time occupied in observing and reading the angle, only amounted to a few seconds, as many observations could be made as might be required for the attainment of an accurate result. It was always best to direct the two telescopes to some well-defined line or mark in the object, the distance of which was to be determined. With an instrument like that exhibited, which had the two object-glasses eighteen inches apart, distances exceeding two miles could not be accurately measured, and a larger instrument would be required. As the distance increased, the accuracy of its measurement, by the instrument, decreased. At one mile, the greatest error would be about 20 feet, while at two miles, the greatest error would be about 40 feet. In distances of less than one mile, a greater degree of accuracy was of course attainable. The great advantage which this instrument possessed, over others used for measuring distances, arose from the fact, that the accuracy of the operation was in no way dependent upon the knowledge of the dimensions of the object from which the distance was measured. The instrument was the only one that he was acquainted with, by which an angle of two seconds could be ascertained, and in all the ordinary modes of measuring distances by the telescope, it was essential that angles should be determined to that degree of minuteness. It was true, that in engineering operations, distances were sometimes obtained by measuring bases of from 50 yards, to 100 yards long, and that in that case, the angles did not require to be so minutely read ; but, on the

other hand, it must be remembered that in such cases the base had each time to be accurately measured, an operation which could not be performed without a considerable loss of time, and that there were two angles to be observed, which if they were small, was a difficult task to execute with a pocket sextant, so that in most cases, the loss of time involved by adopting that method would render it practically unavailable when immediate results were required.

Mr. G. W. HEMANS remarked, that although the system of measuring distances by the telescope had undoubtedly been known for the last twenty years, or more, yet it was possible that its application might hitherto have been limited, from the want of a correction for the errors introduced in setting the instrument to the focus corresponding to the distance, which having now been supplied, the method would probably come into more general use.

Mr. METFORD stated, through the Secretary, that he had for many years been acquainted with the method of measuring distances by the telescope, which had been described in the Paper, and from the results of his personal experience could testify to its practical utility. The instrument which he used was a Gravatt's 10-inch dumpy level, in which the distance hairs were so placed on the diaphragm as to subtend half a foot on the staff for each chain of distance. By means of these distance hairs, he had been enabled to find out old hidden stumps, for the purposes of levelling over them, and when tested by accurate measurement, the total error per mile in the distance measured by the telescope, did not exceed four links. He was thus enabled, by the use of the staff and distance hairs, to dispense with the assistance of chainmen. When in levelling operations the distance was measured by the distance hairs, it was desirable, that the levelling instrument should have the power of measuring horizontal angles, as it frequently occurred that it was necessary to place it out of the line along which the distance was measured. He had also lately applied the system of dividing the field of view of the telescope, to certain purposes connected with rifle practice. After numerous experiments, he had succeeded in cutting several concentric circles and radial lines on glass, with a diamond fragment, so that they would be visible in the field of view of the telescope. When the glasses were placed in the field of view, the grooves, or lines appeared black, and it was found unnecessary further to blacken them. By the use of these grooved glasses, he had been enabled to do away with the necessity for a marker at the target, as he found that if a white spot to aim at was marked on an upright butt, an observer, by means of the concentric rings, and radial lines, could localize and read the exact position at which the shots struck. This method of noting and recording the shots, possessed decided advantages over the ordinary method of mark-

ing a target in squares, and employing a marker at the target, and a recorder at a telescope stationed near the experimentalist. According to the system usually adopted in private shooting ranges, the marker was obliged to come out from his shelter and point out the place where the shot had struck the target, the recorder on his part identifying this position by means of the telescope, and noting it upon a paper previously prepared with squares similar to those shown upon the target. In the first instance, Mr. Metford divided the surface of the glass, which he introduced into the telescope, into squares, in accordance with the usual system of recording the shots; but upon trial he found that the system of concentric rings, and radial lines, enabled him at once to determine the value of the different shots in relation to the centre. In one telescope, with a magnifying power of fifteen, the spaces between the circles subtended four inches at one hundred yards. In another, of a magnifying power of twenty-three, the spaces between the circles subtended two inches at a distance of one hundred yards. There was, however, one advantage which the system of recording by squares possessed over that of recording by concentric rings and radial lines, namely, that the mean centre of the shooting could be more easily ascertained. It was also more difficult to cut the concentric and radial lines than the vertical and horizontal lines; but with either system, when the height or the length of the target was known, its distance could be easily ascertained.

Captain MOORSOM considered, that for measuring distances, the pocket sextant was a preferable instrument to that which had been exhibited by Mr. Adie. In using that instrument the base would only be 18 inches, whereas with the pocket sextant, a line could be laid off at a right angle to the direction of the object, along which, a longer and more convenient base could be measured. The acute angle at the other end of the base being then ascertained, the distance of the object could at once be accurately determined.

Mr. J. SCOTT RUSSELL observed, that there were many methods of measuring distances, which, although they appeared very rough, were yet extremely useful as approximations in trial surveys. Referring to the example which had been given of determining the speed of the 'Great Eastern,' he would notice another method by which her speed might have been determined, or that of any other vessel, when the length was known. If the exact time at which the stem of a vessel passed a given line was noted by a watch indicating seconds, and the exact time at which the stern passed the same line was also noted, the interval between the two observed times would give the time in which the vessel had passed over her own length, no matter in what direction she was

going. To determine the speed was only then a matter of simple proportion. Taking the example of the 'Great Eastern,' if it was observed that she had passed through her own length in 35 seconds, then her speed would be 20 feet per second, or 13·64 miles per hour. It had been asserted that the actual speed attained by the 'Great Eastern' fell considerably short of that which had been originally expected by those who designed her, but that was a mistake. Those who were in a position to know what speed was expected from her, always estimated it about 14 knots per hour as the average, and almost 15 knots per hour as the maximum. It was true that a greater speed had been anticipated by those unacquainted with the matter. The only way he could account for the error was, that a famous builder of American sailing-ships, but not of steam-ships, and who was accustomed to guess the speed of vessels by their shape, without reference to their power, came over to this country, and when he saw the 'Great Eastern' he was so pleased with her lines, that he said, "I will undertake to say, from the shape of this vessel alone, she will go 20 knots an hour."

While upon the subject of approximations he would also notice another rough-and-ready mode of surveying, which as a young man, he had adopted with success. On one occasion he had to ascertain the area of a large lake. It so happened, that he had two instruments by which angles could be measured with great minuteness. A base line was carefully set out, and one of the instruments was set up at each of its extremities, in charge of an assistant. A man with a staff was then sent round the margin of the lake, with instructions to stop at a given number of stations and to hold the staff upright. The two assistants, at the two extremities of the base-line, took simultaneous angles to the staff each time it was held up, from which, the positions of the several stations were determined, and in this way, although the lake was a very large one, and would have taken a long while to survey by the ordinary methods, its contour was mapped in a few hours, and he was enabled at once to calculate, how much its contents would be augmented, or diminished by raising, or lowering the level of its surface.

Mr. ALEXANDER GORDON said, that about twenty-four years ago, he witnessed the manner in which Mr. Scott Russell measured the speed of a new steamer called the 'Fire King' on the Clyde. The apparatus used was made by Dent; it was not strictly a watch, although somewhat similar. The second hand of the apparatus was split, so that measurements could be taken in parts of seconds. A line was set out in a direction at right angles to the course, and the speed of the vessel was measured very accurately by using her length as a base, and by taking the interval of time

which was occupied between the successive passages of the fore-part of the ship, and of the after-part of the ship. Such a method of measuring the speed of a vessel would, however, be obviously inapplicable when she was approaching the observer, either directly, or at a very oblique angle.

Mr. MALLET observed, that the great improver of instruments of this kind was M. Porro, an officer of Engineers in the service of Piedmont, a detailed account of whose 'Instruments pour le levés des plans,' was given by M. H. de Senármont in the 'Annales des Mines,' 4th series, vol. xvi. (1849). An instrument for measuring distances was known at least 200 years ago, under the name of 'stadium,' and all subsequent improvements had been based on the same principle upon which that instrument had been constructed; namely, the similarity of the triangles formed inside the telescope by the image, and outside the telescope by the object itself. The results derivable from this class of instruments, in their simple form, could only be considered as approximations, and were chiefly available for such purposes as estimating the distance for rifle-shooting, &c. One peculiarity of the instruments constructed on the system of M. Porro, consisted in the micrometer net or scale, being so arranged, that the distance was at once read from the staff, and hence the necessity for tabular deduction was dispensed with. He had personally tested the degree of accuracy with which distances could be measured by M. Porro's instruments, and he had found, by comparison with trigonometrical measurements, that distances of 500 yards in length could be read off in favourable weather to within 3 inches or 4 inches. This result agreed closely with the results obtained by M. Porro, and M. de Senármont, who stated that in a distance of 800 metres the error did not exceed 2 centimètres. The correction necessary for the varying position of the focus was completely effected by M. Porro's method, and in careful hands his instrument was of great use in affording rapid approximations.

As regarded the instrument which had been exhibited by Mr. Adie, its power would necessarily be limited to distances not exceeding 400 yards or 500 yards, owing to the extreme difficulty of measuring the very small angles which were subtended at more remote distances. In Dr. Brinkley's investigations as to the measurement of the parallax of the fixed stars, that astronomer had found that when working with an eight-feet circle, and aided by all the appliances of a fixed observatory, no measurement of an angle of less than three seconds could be relied upon. Another element which would tend to vitiate the result at great distances, would be the personal equation of the observer. This relation expressed the difference which existed between the observing powers of different individuals.

Mr. GRAVATT said, that in the investigations made by Dr. Brinkley, the difference really turned on the coefficient of the refraction, and not on the measurement of the angle. As regarded the personal equation, the precise instant at which a given contact took place, would be differently estimated by a bold, and a timid man.

Mr. J. SCOTT RUSSELL remarked, that by disciplining the senses, the personal equation could to a great extent be eliminated. It might safely be asserted, that few men could determine with perfect precision an interval of time to the tenth part of a second. If any one would obtain a stop-watch, which would indicate that division of time, they would at first find that they failed to stop the hand at the intended instant, but by continual practice, they would on the one hand, get rid of the agitation which occasioned them to stop too late, and on the other hand, of the eagerness which made them stop too soon. In short, if they took the trouble thoroughly to educate themselves, they would observe with an amount of precision, which people who had not taken the same pains, would consider to be unattainable.

Mr. MALLET, in explanation of his previous remarks, would define the personal equation to be the average difference of accuracy derived from a great number of instances, between two, or more observers, in the record of a fact, or class of facts. No human observations could be absolutely accurate, and all records of observations must therefore be considered only as approximations. Observations might approximate nearer and nearer to the truth, but the relation between the residues left between the best approximations of separate observers, constituted the personal equation, a quantity which could not be wholly eliminated, or got rid of. In illustration, when assisted by his son, Dr. John Wm. Mallet, in making some experiments, as to the transit of a wave of impulse, analagous to an earthquake wave, through solids, such as rock formations, they found that the limit of instrumental error in the instruments employed, for the measurement of time (which could always be measured with much greater accuracy than space) was about the $\frac{1}{3000}$ th part of a single second—a quantity easily ascertained from the reduction of a number of observations, but inappreciable by direct observation. The limit of direct observational power for time was about $\frac{1}{200}$ th part of a second, and the comparison of his own personal equation with that of his son, showed that the latter was a sharper observer than he was, by about the $\frac{1}{2000}$ th part of a second. These figures were given from memory, but they were sufficiently accurate to convey a general idea of his meaning.

Mr. C. B. LANE said, that thirteen years, or fourteen years ago, he fitted a Gravatt's level with an additional diaphragm plate and adjusting screws, for the purpose of measuring horizontal distances.

The additional plate was constructed, so as to slide vertically between a pair of grooves in the ordinary diaphragm plate, and by this means, a horizontal wire was adjusted in the same plane with, and parallel to, the ordinary central horizontal wire. The result of his experience of this mode of measuring distances, did not induce him to recommend, that it should be employed where great accuracy was required; but for trial sections, or analogous operations, and particularly for measuring distances over broken ground, he thought it gave more trustworthy results than the means usually employed in such cases.
