

(*Paper No. 1659.*)

### "On Cushing's Reversible Level."

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EVERY practical engineer is aware of the inconvenience attending Gravatt's adjustment for collimation in all levelling instruments, where the telescope is a fixture in its supports. It has occurred to Mr. Cushing, Inspector of Scientific Instruments, India Office, to get rid of this inconvenience, by making the eye-end and the object-end of the telescope interchangeable. For this purpose he fixes to the internal tube of the telescope a gun-metal socket, which is turned and ground with a short conical fitting and wide flange, to receive the eye-end with its eye piece and diaphragm. On the opposite end of the outer tube a precisely similar fitting receives the cell containing the object-glass, both of the ends being identical as regards the fitting, though the object-end is necessarily rather longer than the other, on account of its having to carry, on the outside, the cover or dew cap. The eye-end is attached to the telescope by two screws placed  $180^\circ$  apart in the flange of its socket, which screws are not intended to be taken out. Corresponding holes in the flange of the eye-end allow it to be inserted in its socket, when a short rotary motion from left to right will bring it into its proper position against a stop. The object-glass cell has precisely the same kind of attachment, and will, like the eye-end, fit the socket at either end of the telescope.

Another valuable improvement in this level is the abolition of the spider lines, which have till now been the weakest part of the instrument, and a never-failing source of anxiety to engineers, especially when serving in out-of-the-way places where there are no means of getting them replaced. In lieu of these, Mr. Cushing substitutes fine and well-defined lines, ruled with much skill and care by a diamond on a disc of plane and parallel glass.<sup>1</sup> This

<sup>1</sup> The idea of having "lines on glass" is by no means a new one, as General Sabine, R.A.,—formerly President of the Royal Society—in his pendulum observations about the year 1822, had a transit instrument fitted in this way. In addition to this, several of the instruments used twenty years ago on the Ordnance Survey were similarly fitted, but as these glass lines were liable to a little roughness on their edge, they were given up by the Survey Officers, as not being such even lines as the spider threads; besides, they were not capable of being cleaned when dust lodged on the glass.

disc fits into a sliding diaphragm, inserted in the interior of the eye-end of the telescope, and provided with two screws for vertical collimation. A valuable part of the invention is, that even after the instrument has been adjusted the eye-end can be removed from its socket, and the cross lines cleaned (if necessary), and replaced again in position, without in any way disturbing the adjustment. The lines will bear a high magnifying power, and are, of course, as applicable to theodolites as to levels.

Great care has been bestowed on the construction of all other parts of this level. The instrument has been made by Messrs. T. Cooke and Son, of York, and is on the tribrach principle. The

FIG. 1.

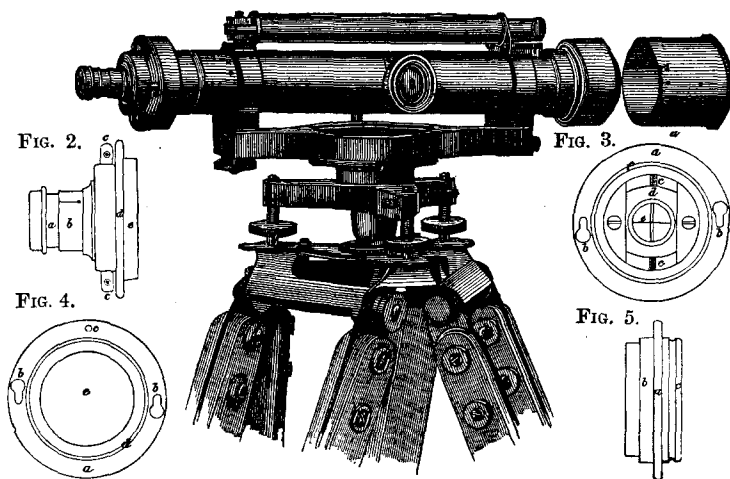


Fig. 2. Eye-end (removed from telescope): (a) eye-piece, (b) eye-piece socket, (c) collimation screws, (d) flange, (e) fitting for socket of telescope.

Fig. 3. Eye-end (plan of interior): (a) flange, (b) holes for attachment screws, (c) collimation screws, (d) sliding diaphragm, (e) disc with cross lines, (f) fitting for socket of telescope.

Fig. 4. Object-glass cell: (a) flange, (b) holes for attachment to telescope, (c) hole for small fixing screw, (d) milled edge for turning and removing cell, (e) object-glass.

Fig. 5. Object-glass cell: (a) flange, (b) fitting for telescope socket, (c) milled edge with hollow behind for firmer grip.

horizontal limb and the tribrach are both cast hollow underneath, so as to give a maximum amount of strength and rigidity with a minimum amount of metal. The ends of the horizontal limb carry the supports of the telescope; but a new feature is introduced in their attachment, for though the support nearest the object-end is in contact with the limb, it is capable of a slight rocking motion in the direction of the axis of the telescope, so as to admit of the second adjustment (hereafter described), whilst the other support

is provided with two large nuts for clamping and permanently securing the telescope to the opposite end of the limb when this adjustment has been performed. The object glass of the telescope has a focal length of 14 inches, and a clear aperture of 1.6 inch; while the bubble tube, which is about 7 inches long, and has an angular value of about 5" of arc for each of its graduations, is carried immediately above the telescope, one end being attached to one of the telescope supports, and the other end secured by two opposing nuts, for purposes of adjustment, to the top of the other support. The usual small cross-level is also provided.

There are three adjustments for this instrument: 1st. The vertical collimation; 2nd. To make the line of collimation perpendicular to the vertical axis; 3rd. To set the bubble tube parallel to the line of collimation.

1st. *The vertical collimation.*—Set up the instrument on its stand, either in or out of doors, with one foot-screw under the telescope, and without reference to the level of the instrument. Take out the small fixing screw at the top of the object-glass cell, and, having focussed the cross lines, direct the telescope on any convenient object,<sup>1</sup> and bisect it with the horizontal line, ascertaining at the same time that there is no parallax in the telescope. Now carefully turn the eye-end in its socket from right to left, until the holes in the flange of the eye-end are opposite the heads of the screws in the socket, and remove it; then replace it again, but in an inverted position, taking care to turn the eye-end from left to right until it comes to a stop, when the lines will be in their proper position. If the point be still bisected, the collimation is perfect; but if not, correct half the distance of its deviation from the horizontal line by the foot-screw under the telescope, and the other half by the two screws that give vertical motion to the diaphragm carrying the disc with the cross lines. Repeat till perfect.

2nd. *To make the line of collimation perpendicular to the vertical axis.*—The object being now bisected, and all parallax eliminated, remove the eye-end and the object-glass cell from their respective sockets, and place them in the opposite ends of the telescope. If the object is still bisected on turning the telescope half round, the line of collimation is perpendicular to the vertical axis; but if not, correct half the error by the two large clamping nuts at one end of the horizontal limb, and the other half by the foot-screw under

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<sup>1</sup> If this be done in-doors, a small circular dot on a sheet of note paper, placed about 20 feet from the instrument, will answer the purpose.

the telescope. As soon as it is found that the eye- and object-ends can be reversed without any apparent change of position in the object intersected, the small fixing screw should be returned, and the object cell made secure. It is important, in changing the object-glass from end to end, to keep that part of the cell which has the small screw-hole in it always uppermost.

3rd. *To set the bubble tube parallel to the line of collimation.*—Level the instrument stand approximately by the legs, and turn the telescope so that it is parallel to two foot-screws, bringing the bubble by their motion to the centre of its run. If it remain so on turning the telescope half round, the level is correct; but if not, bring the bubble halfway back by the foot-screws over which it stands, and the other half by the two opposing nuts at the eye-end of the bubble-tube. Having perfected this, the levelling must be completed by turning the telescope a quarter round, so that one end of the level is over the third foot-screw, by which the bubble must be brought to the centre of its run. The bubble should now remain in the centre during a complete revolution, and the small cross-level can then be adjusted.

It will be seen from the above that the facility of adjustment of the Y level is preserved, while at the same time the superior compactness, increased optical power, and greater stability of adjustment of the Dumpy level are retained. The substitution of fine lines ruled on glass for the spider lines hitherto in use is also a decided improvement. This instrument will therefore undoubtedly prove of the greatest practical utility to all surveyors. The Author is indebted to Mr. Cushing, not only for allowing him to inspect the instruments, but also for furnishing him with the necessary descriptions and drawings. Twenty of these levels have been ordered for the Indian Government.

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