MODIFICATIONS TO THE WILD THEODOLITES

(Extract from an article published in *The Geographical Journal*, Vol. LXXXVIII, N° 5, London, November 1936, page 475).

There have been references during the past few years in many publications to some bold alterations to the axes of Wild theodolites made by J.L. RANNIE and W.M. DENNIS, two officials of the Geodetic Survey of Canada. They have recently published in the *Canadian Journal of Research* (Sec. A, vol. 14, May 1936), a paper entitled "Axis strain in theodolites, its effects and one method of removal". The fact of axis strain itself had been observed and a cure worked out before the methods of testing and separating errors described in the paper had been developed. The design and machining had become too refined for the material of which the axes were made, so that "minute deviations from cylindrical form existed in the steel cylindrical alidade and telescope bearing of a number of Wild Precision Theodolites, owing probably to slight dimensional changes in the metal during the years following manufacture. These imperfections of form produced changing strain in the steel axes as they revolved, and, through transfer of the strain through the instrument, caused changing deflection of the line of collimation which occasioned, in the measured values of angles, errors as large as two to four seconds of arc".

The alterations in design were in the direction of what is called a kinematic bearing, in which the restraining surfaces are never extensive, as they are in an ordinary journal bearing. The conventional V—bearing for the telescope trunnions, for example, has the necessary surfaces to restrict the motion of an axis; the surfaces of contact are small and do not require precise machining; they form a true kinematic bearing. The modifications made with the alidade axis of the Wild Universal Theodolite were to cut away metal until the bearing surfaces were reduced to 3 mm. in width. The tests show the results of the alterations to have been extremely successful.

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SURVEYOR'S LEVEL - Series S 300

Manufactured by COOKE, TROUGHTON & SIMMS Ltd.
Buckingham Works, York, England.

(Extracted from a descriptive pamphlet issued by the Makers).

GENERAL CONSIDERATIONS : The accuracy with which level sights can be taken depends primarily upon the magnification of the telescope and the smallness of the vertical angle which the spirit level will register.

There is no constructional difficulty in producing and mounting a spirit level to correspond with a telescope of the largest practicable size. The limiting factor, therefore, is the ability of the telescope to reveal detail.

In the present instrument the designers have aimed at producing an instrument of the smallest possible dimensions which will allow an ample margin over and above the accuracy required for all ordinary levelling operations. In this they have been greatly helped by the introduction of certain new types of optical glass which will allow the aperture of the object glass — which is the factor which controls the power of resolution — to remain the same as that formerly employed in a 14 in. level and yet the length of the telescope is reduced to little more than half.

The two essential requirements of a Surveyor's Level are :—

(1) That the line of sight shall remain constant throughout the focussing range, and

(2) That the relationship between the line of sight and the spirit level shall be permanent.

COLLIMATION : In this instrument the first condition may be regarded as reliably fulfilled, and nothing short of damage sufficient to put the instrument out of commission can destroy the permanence of this adjustment.

ADJUSTMENT OF SPIRIT LEVEL : As regards the second condition, it has not been considered advisable to dispense with the means whereby the Surveyor can remove any small discrepancy which may occur from time to time, and indeed it is doubtful whether this will ever be possible while the indication of "Level" depends upon the perfection of shape of a glass vial. Glass possesses a linear coefficient of expansion considerably different from that of the materials commonly used in the construction of Surveyor's levels, consequently, no matter what precautions are taken in mounting the level vial, minute changes may occur owing to variance of the external temperature. More important than this, however, is the fact that glass is a relatively unstable material and level vials are subject to minute changes within themselves for some months after manufacture, though after this initial period has elapsed it is seldom that any changes can be detected.

It is well known that a common cause of loss of parallelism between telescope and level arises from an imperfectly designed or constructed means of effecting this adjustment between these two elements — that is to say one which when used re-introduces a condition of strain into the metal or glass components from which the instrument ultimately recovers, and in doing so suffers a further loss of adjustment. Furthermore, it is not uncommon for trouble to arise due to unsatisfactory mounting of the glass spirit vial.

PERMANENCE OF ADJUSTMENT : All these points have been most carefully considered in designing the present instrument. The brackets carrying the spirit level unit are in one casting with the telescope tube, the glass vial is held in a geometric mount and cannot be strained, the ends of the metal level container are affixed to it in such a manner that no relative movement can take place between them, while the adjusting screws are arranged to be in a state of compression and consequently much less liable to variation than if they were subjected to a tension strain.

The coincidence reader and the illuminator are mounted independently of the level tube; thus, if the instrument is grasped, no strain is imparted to the level tube which is also protected by a metal guard.

INTERNAL FOCUSSING TELESCOPE : This instrument is fitted with an internal focussing telescope, the accommodation for focussing at various distances being made by the movement of a lens situated about midway between the eyepiece and the object glass, the two latter being at a fixed distance relatively to one another. On the external focussing telescope, which is still commonly in use, the focal accommodation for shorter distances is obtained by extending the telescope either at the objective end or the eye-end.

Since a certain amount of controversy appears to exist in some quarters as to the relative merits of each type of telescope for surveying instruments, we have thought it well to set down the following points :

(1) The internal focussing telescope is of constant length and therefore may be so constructed that moisture and dirt are effectively excluded from the interior.

(2) Since in an external focussing telescope one end must extend for the purpose of focussing short distances, the instrument is inevitably thrown out of balance thereby and it is not uncommon to find instruments giving an error on short distances up to 20 seconds of arc through this cause. The moving element in an internal focussing telescope is of small weight and is situated at the centre of the instrument where it cannot appreciably disturb the balance.

(3) It is also not uncommon for collimation errors to arise in external focussing telescopes having imperfectly fitted draw tubes due to the increased leverage on the draw tube fittings when the telescope is extended to focus a short distance, whereas in the internal focussing telescope the moving element can be geometrically mounted and straightline travel along the optical axis ensured.

(4) The internal focussing telescope may be constructed so that the "constant" in tacheometry is so small as to be negligible. This is not possible with the external focussing telescope except by the addition of a Porro Lens.

(5) The one advantage possessed by the external focussing telescope is that there are two less "glass-air" surfaces in the system, and consequently less loss of light (i.e. approximately 5% per surface). In internal focussing telescopes, however, this deficiency is usually more than compensated for by increasing the aperture ratio.

The makers consider that except on first order geodetic instruments, where long shots are the rule and little focussing adjustment is required, and also where the instrument may be used for astronomical observation, the advantages of the internal focussing telescope far outweigh the disadvantage and for this reason they have long employed the internal focussing system on all except such first order instruments.

LEVEL READER : The instrument S 300 is fitted with an optical system whereby the two ends of the "air space" are made to appear within an eyepiece, and on tilting the telescope the images move in opposite directions "Level" being registered when the two images coincide (see illustration). In this manner an extremely accurate setting is achieved, and in these instruments the degree of refinement with which the bubble may be set is well in excess of the corresponding ability of the telescope to perform its function.

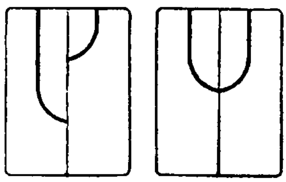
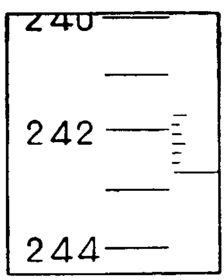


FIG. 1

CIRCLE : In view of the increasing demand for horizontal circles on levels, provision is made for fitting such if required. The graduations are on a disc of glass silvered on the underside, affixed to a metal mount and read with a microscope having a graticule micrometer. The illumination, on account of the high reflecting power of the circle, is exceptionally clear and bright.



Reading 242° 45′

FIG. 2

The circle is subdivided into degrees, numbered every two degrees, and the graticule is graduated to 10 mins. It is possible to read by interpolation to the nearest 2 mins.

LEVELLING BASE : The instrument is provided with a triangular levelling base with means of taking up wear in the levelling screw threads. A single screw for final levelling is provided, an extremely fine motion being obtained by the use of a different screw arrangement.

CLAMP AND SLOW MOTION : A clamp and slow motion for controlling movement of the instrument in azimuth are fitted.

ATTACHMENT TO TRIPOD : The system employed is considered to be the most appropriate to this type of instrument and combines the advantage that it automatically prevents any side movement of the feet of the levelling screws.

BOX : The instrument is fitted in a metal carrying case with leather handle; a sling shoulder strap can be provided if required. The clamping arrangements are cast integral with the case.

Fig. 3

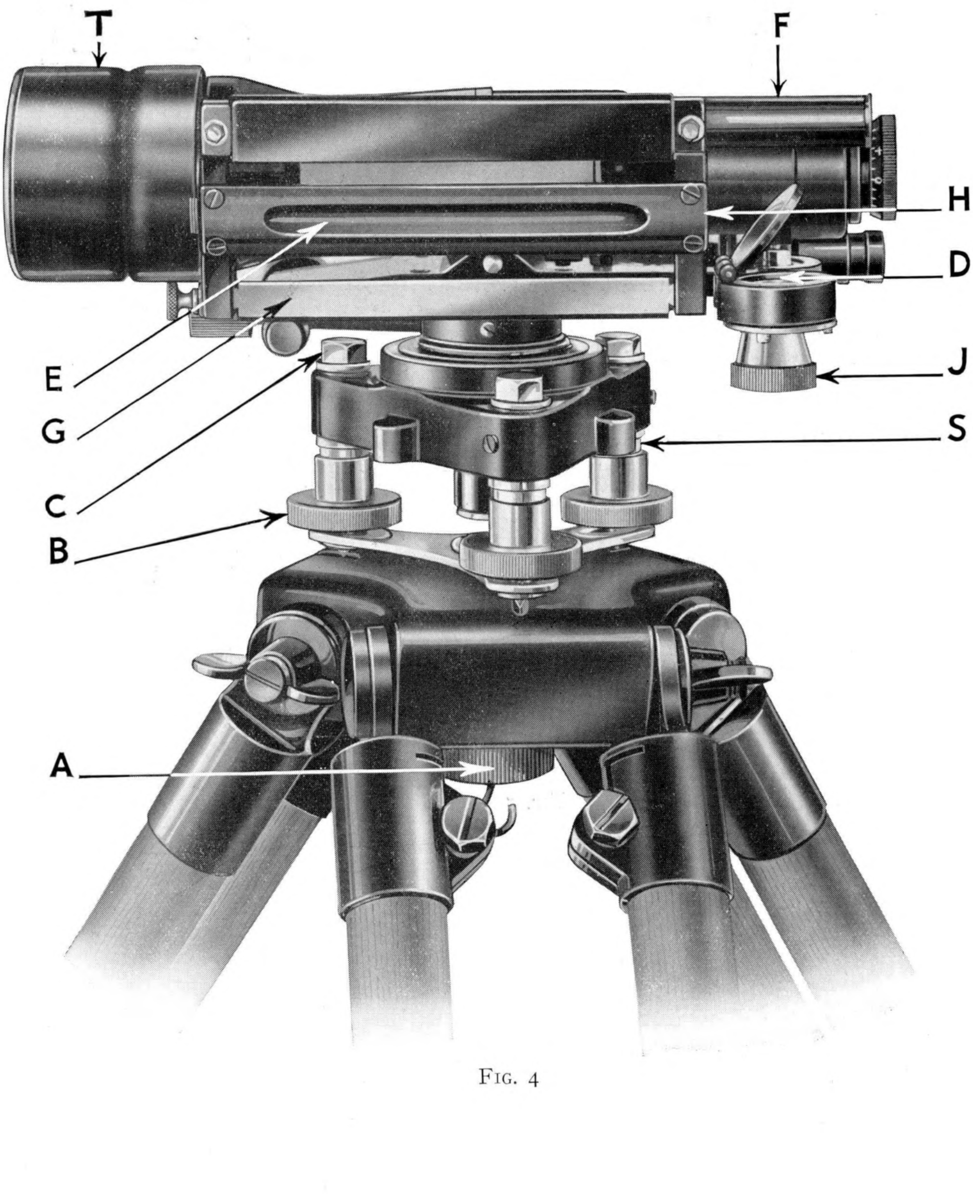


Fig. 4

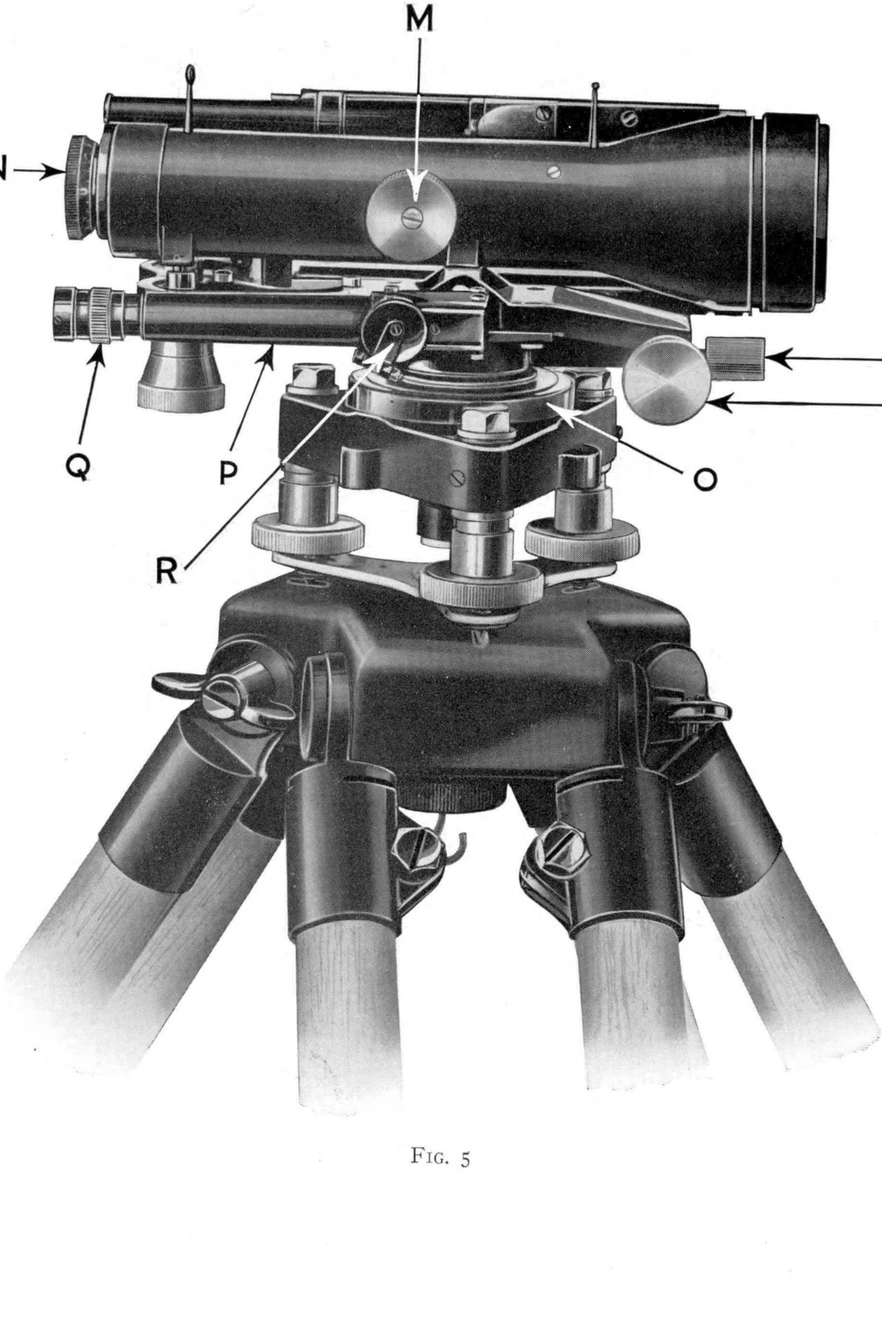


Fig. 5

ACCESSORIES: Rayshade, plummet and adjusting tools.

TRIPOD: The tripod, which has framed legs of round section, has been standardised after exhaustive tests under varying conditions of wind and weather. As an alternative a telescopic tripod can be supplied.

A. Attachment Screw.
B. Levelling screws.
C. Adjusting nuts for levelling screws.
D. Circular spirit level.
E. Main spirit level and guard.
F. Reading eyepiece for main spirit level.
G. Reflector for main spirit level.
H. Adjusting screws for main spirit level (not seen).
J. Fine-setting screw.
K. Clamp screw.

L. Azimuth slow-motion screw.
M. Focussing screw.
N. Screw-focussing eyepiece.
O. Horizontal circle.
P. Microscope for reading horizontal circle.
Q. Focussing eyepiece to microscope.
R. Illumination reflector to horizontal circle.
S. Lugs for securing instrument in box.
T. Rayshade.

(See fig. 4 & 5).

INSTRUCTIONS FOR USE.

1. *Setting Up.*

(a) Having screwed the level on to the tripod, bring bubble in circular spirit level central by manipulating the tripod legs and the three footscrews. Having once set up in this fashion, a fraction of a turn of the fine-setting screw will be sufficient to bring the bubble in the main spirit level to the centre of its run. If the index on the fine-levelling screw be set and circular level centred, the end of the main bubble will appear in the field of view of the coincidence device.

(b) Point the telescope at the staff and from the working position at the eye-end, bring the bubble of the long spirit level to the centre of its run by means of the fine-setting screw — observing the spirit level by the mirror or coincidence reader.

Thus, by cutting out the necessity for very accurate setting up of the vertical axis (i. e., by reversal of the long spirit level in two positions at right angles — the old method) a great economy in time is effected. Moreover, it will be noted that in this routine the observer does not move round the instrument, the staff and spirit level being read almost simultaneously.

2. *Elimination of Parallax.*

(a) Commence with the eyepiecc screwed right out and screw inwards until the cross lines on the graticule are sharply focussed. To facilitate this adjustment it may be found convenient first to put the telescope out of focus so that the cross lines only are seen in the field of view.

(b) Point the telescope at the staff and focus by turning the knurled head on the side of the telescope until the object is sharply defined.

The image of the object and the cross-lines should now be in the same plane, so that when the eye is moved up and down no movement of the image relative to the cross-lines (i. e. parallax) is apparent.

Presence of parallax indicates incorrect focus.

(c) Repeat (a) and (b) until correct.

ADJUSTMENT OF INSTRUMENT:

1. *Adjustment of Circular Level.*

(a) Set up instrument bringing "air space" to centre of circle etched on the level.

(b) Turn instrument through 180° about vertical axis.

(c) If the "air space" does not come to rest exactly in the centre of the circle remove half discrepancy by the levelling screws and half by the capstan screws under the circular level.

(d) Repeat the process until bubble maintains the central position with regard to the etched circle regardless of the direction in which the telescope is pointed.

The circular level now gives an indication of the verticality of the axis of the instrument.

2. *Adjustment of main level.*

(a) Select if possible a fairly level site and set up the instrument exactly midway between two staves erected about 100 feet apart and level up as nearly as possible with reference to the circular spirit level.

(b) Point the telescope at one of the staves, bring the bubble of the long spirit level to the centre of its run by means of the fine-setting screw and take the reading on the staff.

(c) Point the telescope at the other staff; again bring the bubble of the long spirit level to the centre of its run by means of the fine-setting screw and take the reading on the staff.

> The difference (Dl) between the readings obtained by (b) and (c) gives the difference in level of the staves, regardless of the relationship of the main level to the telescope axis.

(d) Move the level to a point as far beyond the higher of the staves as they are apart, but as nearly in line with them as will permit sights to be taken on both without appreciable movement in azimuth, and set up as before.

(e) Point the telescope at the further staff; bring the bubble of the long spirit level to the centre of its run by means of the fine-setting screw and take the reading on the staff.

(f) Point the telescope at the nearer staff; see that the bubble of the long spirit level is still in the centre of its run (if not, correct by means of the fine-setting screw) and take the reading.

> Subtract the reading obtained by (f) from that obtained from (e), taking care to note the sign of the result (D2), and if the level is in adjustment, this will be the same as Dl and "plus".
> If not, D2 — D1 is the amount by which the line of sight must be set up (if minus) or down (if plus) on the nearer staff.

(g) Having corrected the line of sight by tilting the telescope by means of the fine-setting screw, adjust the spirit level by means of the two capstan head screws.

(h) Check by repeating (e) and (f).

> N. B. When adjusting instrument, it is desirable always to observe the bubble through the mirror, since owing to refraction, the real position of the air bubble is not identical with its apparent position when viewed through the mirror.

ABRIDGED SPECIFICATION AND PRICES:

Telescope.
Magnification × 25.
Equivalent focal length 8.2 in. (20.9 cm.).
Aperture 1.5 in. (3.8 cm.).
Diaphragm simple cross with stadia lines 1 : 100.
Distance at which .01 ft. can be resolved.... 1,000 ft.

Spirit Level.
0.1 inch (2.5 mm.) = 30 seconds.

Circle.
Sub-divided to degrees, figured every 2 degrees, read by graticule graduated to 10 minutes. It is possible to read by interpolation to the nearest 2 minutes.

External Dimensions of Case.
Length 9.75 ins. (25.0 cm.).
Breadth 4.75 ins. (12.0 cm.).
Depth 6 ins. (15.25 cm.).

Weights.
Instruments 5 lbs. (2.3 kgs.).
One-piece tripod. 11.5 lbs. (5.2 kgs.).
Telescopic tripod 12.5 lbs. (5.6 kgs.).
Case and accessories 4 lbs. (1.8 kgs.).

S 300 SURVEYOR'S LEVEL, as described, with prismatic level reader, circle and one-piece tripod .... £ 25 : 10 : 0d.

S 301 SURVEYOR'S LEVEL, as described, with prismatic level reader, without circle, with one-piece tripod ...... £ 22 : 0 : 0d.

One of these Instruments is on view in the Library of the International Hydrographic Bureau.