Please read and send in as full a discussion as possible at earliest date

Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—*(Subject to revision.)*

N.B.—This Society, as a body, does not hold itself responsible for the statements and opinions advanced in any of its publications.

THE GRADIENT-TELEMETER LEVEL AND ITS ADVANTAGES ON PRELIMINARY WORK.

(By R. W. Macintyre, A.M. Can. Soc. C.E., March, 1903.)

Nowadays, when events are making such rapid history in the engineering world, the most deeply-felt want is for methods which will yield the necessary information at the minimum cost of time and expense. With this object in view, instruments of the Gradient-Telemeter type have been invented and placed before professional men for trial from time to time.

The present article merely deals with the particular class of instrument mentioned above, as in the writer's opinion it is in many respects unique and worthy of a separate niche in the temple of instrumental fame.

Now that transcontinental railways, colossal irrigation systems and other engineering enterprises are actually taking definite and practical shape, the question of improving upon the old-time methods of gathering preliminary details (especially in unexplored territory) becomes a momentous one, which is to some extent satisfactorily solved by the Telemeter. The instrument consists of an ordinary Y level (14 inch), with the addition of a compass and a gun-metal circle.

The whole principle upon which the instrument works is contained in this circle, which is a casting made in the shape of a cam; that is, in place of the circle being truly horizontal or at right angles to axis it is curved out of the horizontal, and consequently causes the telescope to tilt either upwards or downwards when revolved, through a vertical angle.

The circle (or gradient limb) is graduated around three-fourths of its circumference with numbers commencing at 1,200 and terminating with 10. Certain numbers are selected and classified as "pairs," each "pair" being engraved on the remaining one-fourth of the gradient limbs circumference for reference. The advantages of the Telemeter are as follows:—(1) The automatic measurement of distance, which dispenses with the services of two chainmen; (2) increased accuracy in measurements through rough and broken country; (3) the measurement of vertical distances either up or down hill from 1 to 140 feet (in ordinary practice) with one sight and from one station, in place of the limit being length of rod as with an ordinary level ; (4) compass being adjusted to read at right angles to line of sight, so that telescope can be clamped on rod and magnetic bearing taken, thus dispensing with picketman. Briefly, then, two men (an instrument man and rodman) can make a traverse, with accompanying levels at all necessary points, leaving the two chainmen and picketman available for duty elsewhere; and it may be remarked, *en passant*, that such traverses have, in the writer's experience, yielded most satisfactory results. For more accurate traverse work, the makers add a horizontal circle at small additional cost.

And, now, as to the method of using the instrument, it may be understood that no particular technical or mathematical difficulties bar the way; in fact, the strong point in this instrument is its perfect simplicity in design and theory.

By clamping the index at zero on the cam, the Telemeter becomes an ordinary Y level, and any readings taken at this stage are treated exactly as those of a level in the field-book. By moving the index from zero to 100 in the cam, we use the first "pair," i.e., 0 and 100, and the difference between the two readings (on rod) gives the horizontal distance without any calculation, each vertical foot on the rod representing 100 feet horizontal measurement. With all succeeding pairs, however, the telescope is necessarily tilted for each reading, being directly influenced by the position of index on cam, and although the method of obtaining horizontal distance remains unchanged throughout the pairs, the calculation for difference in elevation follows this formula:

For a "rise" reading (uphill), divide the distance measurement by either of the pair numbers used; add height of instrument to quotient; deduct the rod reading belonging to the pair number used as divisor, and the result will be difference in elevation between ground surface at instrument and ground surface at rod. For a fall (or downhill) reading, the same formula applies, except that the rod reading is added and the height of instrument deducted. The reasons on which this calculation is based are quite obvious, and can be readily grasped from the diagram A.

A most important automatic check on each pair of readings, together with the calculated result, can be obtained by unclamping the index and swinging the telescope until the horizontal cross-hair intersects the rod at the exact height of instrument, which is measured by a tape with a plumb-bob attachment hanging beneath centre of instrument. Assuming the H.I. to be 4.85′, the leveler moves telescope around gradient limb until he obtains this reading on rod; the vernier is then clamped and the reading on 8. limb taken; this reading is the distance in which a rise or fall of one foot occurs between ground at instrument and ground at rod, so that the difference in elevation (between these points), divided into the distance, should give gradient reading as quotient. This check is especially valuable in tracing clerical errors where the pair numbers are correctly entered, etc., and in obtaining the grades of country traversed with rapidity.

In telemeter work it is necessary to reduce the levels as they are taken in the field. This of course involves constant calculation all day long, but a little practice soon renders it a mechanical process performed mentally, and the prospect of reducing several miles of telemeter levels after reaching camp is a strong incentive to rapid field-work.

As regards the distance that can be covered in a day with the telemeter, the writer has completed nine miles through fairly rough country, but this included the picketing of a line by the writer and his rodman, and the sketching of all topography along the line in a specially designed field book. Generally speaking, the telemeter is at a slight disadvantage with the level in level country, as two readings must always be taken, but this is more than compensated for by distances being obtained without the aid of chainmen; also, all the information is entered in the leveler's field book, and thus condensed. In rough country, however, the telemeter (being able to negotiate vertical heights up to 140 feet in one sight) can leave any level a long way behind, to say nothing of the chainmen. Of course, to obtain a large vertical difference in one sight, a long base is necessary, owing to the fact that the vertical angle increases in direct proportion to distance between rod and instrument. It therefore follows that, to obtain the best results with a telemeter, a really first class telescope, with powerful lenses, is necessary, and any telemeter telescope not fulfilling this condition should be promptly rejected. The instrument used by the writer gives a very clear reading at 1,200 feet distance (horizontal). It may here be noted that the distances obtained by telemeter pairs are in all cases horizontal ones between rod and instrument.

For setting out railway curves, the maker combines a graduated horizontal circle with the gradient limb or cam at a small additional cost, thus adding to the instrument's efficiency. For setting out distances the subtense method is used, based on the following rule:—

If any two integers whatever be taken and used as divisors into the distance required, the result will be a gradient pair, which, being applied as any ordinary pair, will give on the rod a subtense in feet that is equal to the difference between the two selected integers.

Example (selected integers 2 and 9)

$$\left.\begin{array}{l}\text{Distance } 150 \text{ feet} \div 2 = 75 \\ \quad\text{"} \quad 150 \quad\text{"} \quad \div 9 = 16\tfrac{2}{3}\end{array}\right\}\text{Gradient pair.}$$

$$\text{Difference} \quad 7 \quad \text{giving subtense 7 feet.}$$

METHOD OF WORK.

The gradient pair is 75 and 16⅔; set up and send out rodman in direction of required line; move index to 75 on gradient limb and take reading, which assume to be 10.42 feet; unclamp and set index at 16⅔ and take second reading, which should be 3.42 feet, if the rod is exactly 150 feet from instrument; but as this is most important in ordinary work, it will be found necessary to move the rodman nearer or further until the subtense representing distance required is read on rod. Where distance to be set out is a constant one, a table of subtenses, with integers and resultant gradient pairs, can be easily prepared beforehand. The greater the subtense the more accurate the "setting out" will be.

Regarding the accuracy of telemeter levels, the writer's experience is that the checking in is not usually so close as with an ordinary level, but that there is a certain amount of "give and take," which limits the difference to within 1 foot in any distance of consequence, such as 75 to 100 miles. The rodman is a most important factor in obtaining satisfactory results, and should be selected with careful judgment. A rod-level should always be attached to the rod in the field, as a truly vertical position at right angles to the line of sight is absolutely necessary, or, in other words, a plumb-line suspended at the side of rod should strike the centre from top to bottom. This rule, however, does not apply to the face of rod, which must always be slanted over either to the right or left, so that the "vertical" hair in diaphram will intersect the centre of rod-face throughout its length. The reason for this is, that when the telescope is tilted up or down, by being moved around the gradient limb to the pair numbers selected, the diaphram (in common with the telescope) leans over to one side or the other, so that the cross-hairs are only truly vertical and horizontal respectively when the index is at zero on the gradient limb, and the instrument leveled up.

A valuable property of the telemeter not generally known is, that distance can always be measured by using any pair, whether the instrument has been levelled up at zero or not. For example, assume a 16-foot rod to be 1,000 feet from the instrument and a level reading of .8 feet is obtained as foresight. The instrument man cannot get the distance (by tilting either up or down) at the corresponding pair number of 100, for in the first case he strikes 2 feet above the top, and in the alternative case 2 feet below the foot of rod. However, after booking his level reading, he can depress or raise the line of sight by using the leveling screws, and then, having the whole rod to work upon, can obtain the distance by moving index to the pair number. Gradient pairs which do not include a level (or zero) reading can also be calculated from by this method, but the result will only be approximate, and such readings should only be used for "intermediate" sights.

The telemeter gives very satisfactory results in the strongest winds, and will stand a good deal of travelling in rigs extremes of temperature, etc., without geting out of adjustment. It is not designed for particularly accurate work in cities, etc., but for preliminary and even final location, contour work and exploration, it is a very decided success.

A specimen of telemeter field-notes, taken in the ordinary course of the surveys, is appended.

Station	Gradient Pairs	Read'gs on Rod	Resulting Distance	Height of Instrument	Difference of Level	Elevation above Datum	Check Gradient	REMARKS
						3086.56		B.M. No. 1
1) – Bs	100 & 50	15.55 8.28	727	4.92	+17.90	3104.46	40.6	On side of Ridge
+ Fs	$11\frac{1}{3}$ & 10	0.74 7.92						
			718 (1445)		+68.80	3173.26	10.44	On stone—Summit of ascent
2) + Bs	100 & 50	3.11 14.91	1180 (2625)	4.70	– 13.39	3159.87	88	N. edge of coulee
— Fs	$12\frac{1}{2}$ & $11\frac{1}{3}$	15.09 1.91						
			1318 (3943)		– 115.83	3044.04	11.4	Bed of coulee—(flowing springs)
3) — Bs	50 & $33\frac{1}{3}$	10.83 1.11	972 (4915)	4.80	+25.47	3069.51	38.2	S. edge of coulee
+ Fs	25 & 20	2.47 11.20						
			873 (5788)		+37.25	3106.76	23.4	On plug
4) + Bs	0 & 100	2.70 16.00	1330 (7118)	4.88	– 2.18	3104.58		N. outline of river valley
— Fs	$11\frac{1}{3}$ & 10	15.55 1.40						
			1415 (8533)		– 138.02	2966.43	10.2	W.L. of river – N. shore

The above are actual readings taken in the field during the ordinary season's work.

THE GRADIENT–TELEMETER LEVEL.

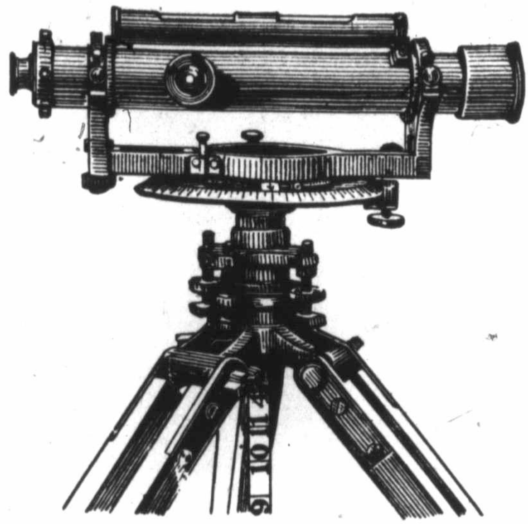

DIAGRAM A