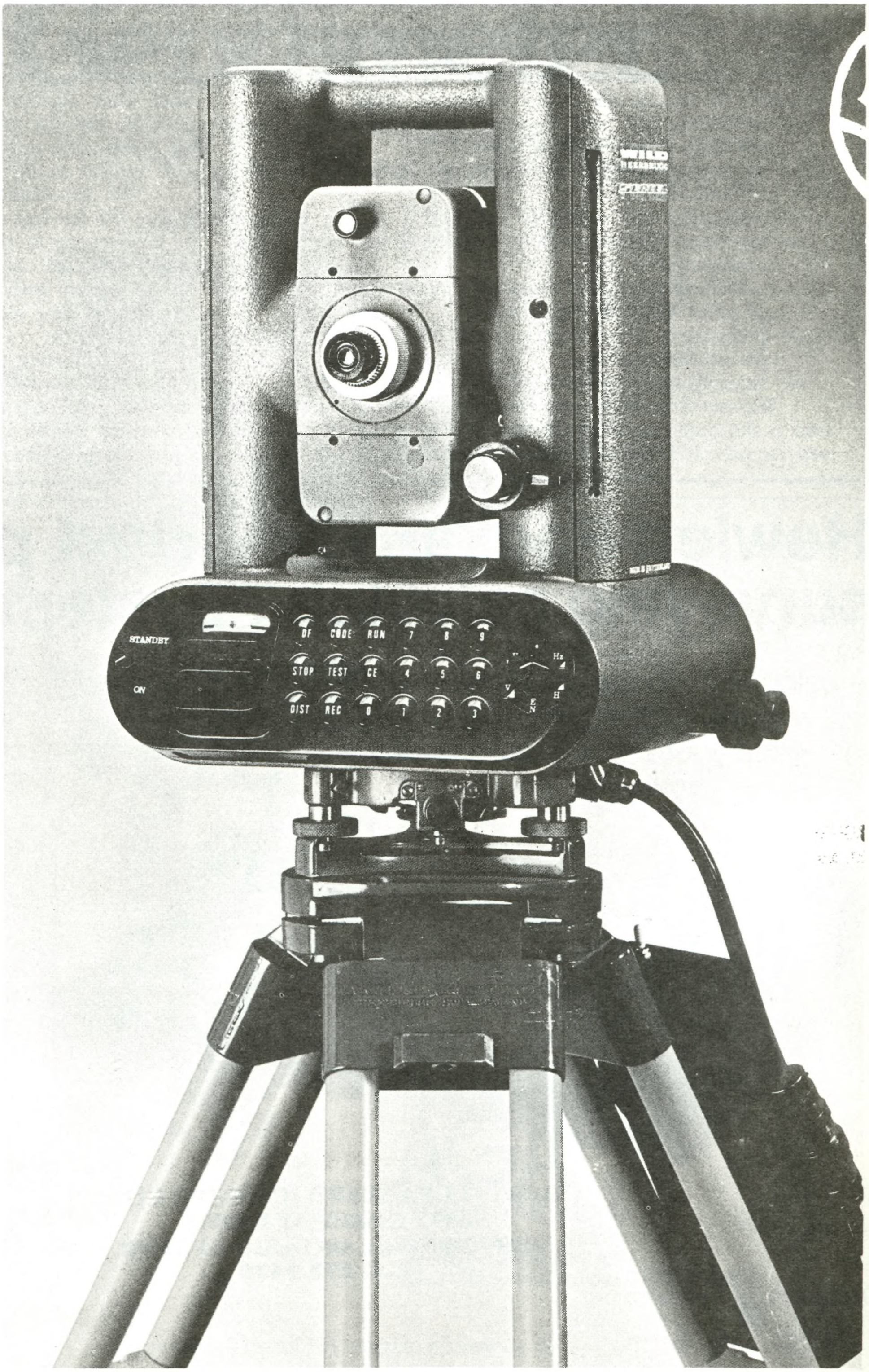
In June 1977, at the FIG Congress in Stockholm, Wild Heerbrugg Ltd. introduced the Tachymat TCI, a surveying instrument system developed in conjunction with SERCEL. It was introduced into this country at the C.I.S. Annual Meeting in Calgary, Alberta, in May of this year.

Following are extracts from a paper entitled "The Measuring and Recording Systems of the Wild Tachymat TCI" by H. R. Schwendener, Esq. of Wild Heerbrugg, presented at the ACSM-ASP Convention in Washington, D.C., U.S.A. in March 1978, and reprinted here with the permission of Wild-Leitz Canada Ltd.

THE WILD TACHYMAT TAC 1



TELESCOPE AND DISTANCER

The telescope and distancer form a compact unit which transits about the tilting axis for measurements in both faces. Measurements can be taken throughout the range -40° (depression) to +40° (elevation). Transmitting and receiving optics as well as the sighting telescope are coaxial. Only one pointing is needed for angle and distance measurement. The image is erect. When focussed to infinity, the telescope has a magnification of 26 x and a field of view of 1.8° (32 m at 1000 m). At close range the field of view widens while the magnification decreases. Two optical sights and the telescope's zoom effect guarantee quick and comfortable pointing at all ranges. The shortest focussing distance, and therefore pointing for distance measurement, is 2.0 m. Fig. 1 shows the optical system of the TC1 telescope and distancer.

Infra-red light from the transmitting (GaAs) diode (1) is focused to a point (4) by the lens systems (2) and (3). Point (4) lies in the focal plane of the telescope objective (7). The light is then reflected off a mirror (5) onto a glass plate (6) which is perpendicular to the optical axis of the telescope. Plate (6) is coated to reflect infra-red light whilst transmitting visible light. Thus the infra-red light from the GaAs diode passes through the objective (7) to form the outgoing beam (8). Part of the returning beam (9), reflected back from the prism, is collected by the ring objective (10). It is then directed onto a metal-surfaced ring mirror (11). The light is reflected off the mirror (11) to focus at the receiving diode (12), which is an avalanche photo diode.

A beam splitter (13) is positioned at 45° in front of the lens system (2). 96% of the infra-red light is transmitted and 4% reflected through 90°. An automatic shutter (14) allows either the 96% of the light to pass along the external measurement path to prism (5), plate (6) and objective (7), or the 4% to the prism (15). When the shutter blocks the external path, the infra-red light from the GaAs diode (1) is diverted via the prism (15) and lens system (16) to the photo diode (12). This is the internal calibration path which is measured repeatedly during a distance measurement. The transmitting and receiving electronics are housed in compartments above and below the telescope.

This telescope design, which is patented, ensures complete separation of the transmitting and receiving light paths and of the transmitting and receiving electronic systems. During the distance measurement, automatic filters (17 and 18) ensure an optimum received signal. Breaks in the beam or fluctuations in the signal due to moving branches or leaves do not affect the measurement.

The standard deviation of the measured distance is —+ (5 mm + 5 mm/km). Using a circular prism with a diameter of 70 mm, distances up to 1000 m can be measured. With 11 prisms, the maximum range is 2 km. The display of distance is unambiguous up to 1999.999 m.

ANGLE MEASUREMENT

The opto-electronic principle of the angle measurement and the arrangement of the optical-mechanical components are identical for both the horizontal and vertical circles. An incremental system is used. A circle carries a reflecting grating of 12 500 intervals on a diameter of 80 mm, each interval corresponding to 0.0329. Interpolating by a factor 32 results in an increment of 0.0019 (3.24").

A circle is scanned by two sensors (Fig. 2). These are fixed to the alidade and are positioned diametrically opposite each other in relation to the circle. This arrangement eliminates any residual circle eccentricity and provides an interpolation factor 2.

Each sensor comprises an infra-red light source (1), a detector (5), a lens and an analyzer grating. The infra-red light is made telecentric by the lens (2) and passes through the analyzer grating (3) to the circle (4). It is reflected off the circle, passes back through the analyzer grating, and is focused by the lens onto the detector. The analyzer and circle gratings are phase gratings. Compared to amplitude gratings, phase gratings give a higher intensity of light and an interpolation factor 2.

To explain the principle of a sensor, it is convenient to imagine the system unfolded and to consider that two analyzer gratings (3) and two lenses (2) (instead of one) and a transparent circle grating (4) (instead of a reflective grating) are being used (fig. 3).

A beam of incident light is diffracted by the analyzer grating (3) and split into two first-order beams + and —. Each of these beams strikes the circle grating (4) and is diffracted again. Thus four first-order beams are produced, + + +—, —+, and ——. As the spacing of the analyzer grating is twice that of the circle grating, the diffraction angle at the circle is twice that at the analyzer. Thus beams +— and —+ converge to meet at the analyzer grating (3'). These beams are diffracted again, each being split into two. The beams +—+ and —+— leaving the analyzer (3') will coincide and can interfere.

As the exit angles of the beams leaving the circle are different, a shift of the circle relative to the analyzer influences the phase of the two beams in different ways. The result is an intensity modulation of the image of the light source (1) formed at the detector (5) due to interference. The modulation period is half of the period of the grating of the circle.

The gratings of the circle and analyzer are radial. The spacing or grating constants increase with radius. Thus the beam from the light source to the circle passes through a fractionally smaller spacing of the analyzer grating than the beam reflected off the circle to the detector (fig.). Thus the beams +—+ and —+— (fig.) do not coincide exactly, as was stated above, but they

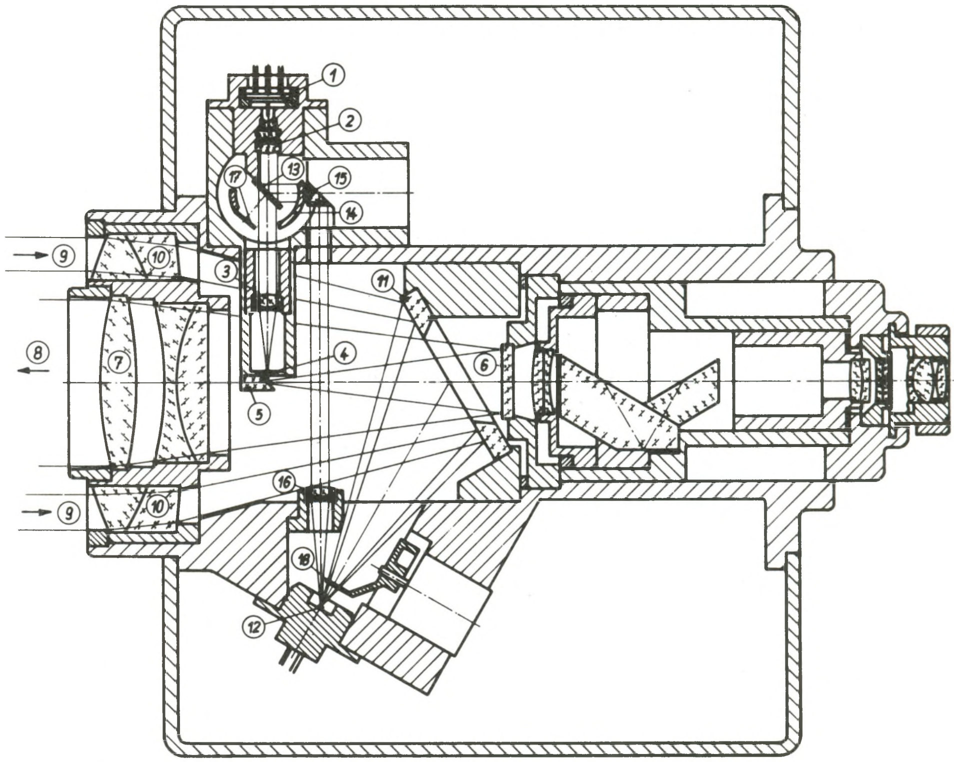


Fig. 1

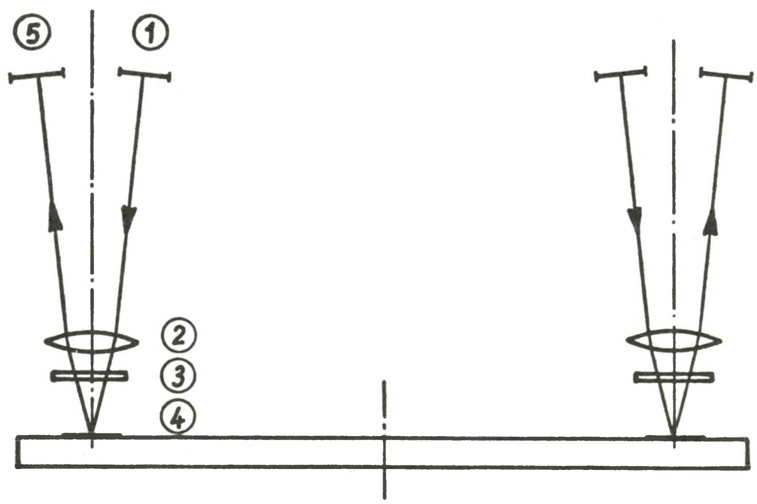


Fig. 2

are displaced parallel to each other. Therefore the image of the light source at the detector will not simply be bright or dark. But, instead, interference-fringes, are formed in the image plane of the light source.

This effect is utilised by arranging four photo detectors in the image plane in such a way that four sine signals in phase quadrature are produced. By adding and subtracting these signals, four additional signals, displayed by 45°, are obtained. Finally, eight signals, equally distributed over the Moiré-period, are available. Interpolation by a factor 8 is thus achieved.

The total interpolation factor 32 is built up as follows:

—Phase gratings on the circle and analyzer 2 x
—Electronic processing of the detector signals 8 x
—Diametrically opposed sensors 2 x

Thus a resolution of 0.0019 (3.24”) is obtained from a circle grating with 0.0329 spacings.

In a perfect incremental system the maximum possible error is half the increment, in this case —+ 5cc or —+ 1.62”. This would correspond to a standard deviation of about —+ 3cc or —+ 1”. Due to unavoidable imperfections in manufacture and pointing errors of the observer, the ideal situation can never be achieved. With the Tachymat, the standard deviation of a direction, measured in face left and face right, is —+ 6cc or —+ 2”.

The accuracy of a direction is therefore equivalent to the accuracy of a distance measurement at about 1000 m.

As the angle measuring system is incremental, the circles have neither codes nor numbers. Before starting to measure the horizontal circle reading is set to zero or to any desired value by means of the keyboard. Clockwise angles are then continuously counted and displayed. If a minus sign is entered, counter-clockwise angles are shown, the minus sign remaining in the display to prevent confusion. A sequence of commands — not the pressing of a single key — is required to set zero or the required value. This ensures that the horizontal circle setting cannot be changed inadvertently.

PLUMB LINE SENSOR

The vertical circle is housed in one standard. In the other standard is a pendulum suspended on crossed tapes. It swings in a vertical plane parallel to the telescope and defines the plumb line in the direction of the target. The position of the pendulum relative to the instrument is measured. The system of measurement is similar to that of the circles. The pendulum compensates for residual errors in levelling up the instrument and can be considered to act as an automatic index for the vertical circle. The microprocessor combines the vertical circle measurement with the pendulum measurement.

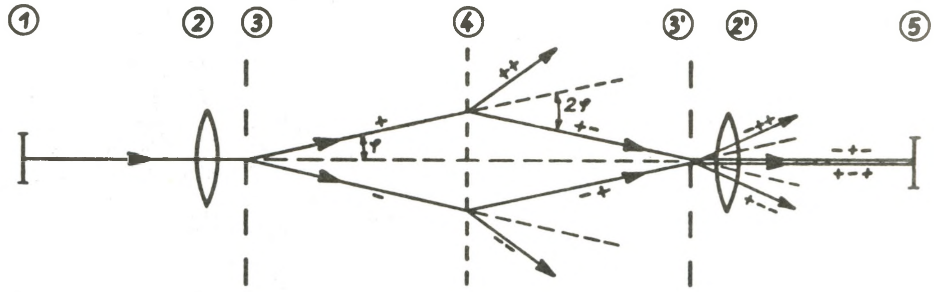


Fig. 3

Under certain circumstances, for instance in a gale-force wind or if there are severe ground vibrations, it may be advantageous to by-pass the pendulum. A tubular level allows the operator to set the standing axis vertical. Measurements are then taken without referring to the pendulum. Being able to ignore the plumb line sensor is essential on drilling platforms, or if the instrument has to be set up with the standing axis far out of the vertical.

Before starting to measure at a station, the vertical circle reading is referenced to the plumb line by pointing to a well defined point in both face left and face right. A program, stored in the microprocessor, ensures that the vertical circle reading is 90° (1009) in face left and 270° (3009) in face right with the telescope horizontal; i.e. exactly as with a standard theodolite. The standard deviation of a vertical angle measured in face left and face right is about —+ 10cc or —+ 3”; in a single face, about —+ 20cc or — + 6”. The accuracy of trigonometrical levelling with the Tachymat can be compared, therefore, to that of routine levelling with a levelling instrument.

KEYBOARD, MICROPROCESSOR AND DISPLAY

There is an identical keyboard on both sides of the instrument. By means of the keyboard, commands for measurement and for recording field data are passed to the microprocessor. Additional information concerning the subsequent processing of the measurements can also be input via the keyboard. If a key is pressed which does not form part of a command recognised by the microprocessor, the command is not accepted. Each key that is accepted is acknowledged by an audible tone.

RECORDING

An optional recording attachment is available for the Tachymat. It is placed on top of the instrument and is held firmly by spring catches. When in position, the recording attachment forms an integral part of the instrument.

Recordings are made on magnetic tape cassettes. A sealed cover protects the tape deck and cassette against damp, rain and dust. The recording attachment and the cassettes specified for the Tachymat function from —20°C to +50°C. The cassettes have a pre-recorded clock-track to control the tape transport speed. The recording attachment and the whole recording system are controlled.

Data is recorded on magnetic tape using the bi-phase-level technique. The bit density is 400 bits per inch. As recorded blocks alternate with gaps, the tape can be driven backwards and forwards counting blocks as it goes. By this means, it is possible to return to any recorded block and to recall the recorded data into the displays of the Tachymat.

When designing the recording system, special attention was given to ensuring the highest possible degree of data safety. It is impossible to overwrite data or to erase recorded data accidently. Correction messages have to be entered via the keyboard as code blocks. The computer will then correct the data at the processing stage. There is, however, a command sequence which allows the operator to erase the entire tape should he wish to do so.

The large capacity of the cassette — about 1800 blocks can be recorded — matches the performance of the Tachymat. Measuring and recording is extremely quick. When surveying for digital terrain models in open areas, it is easily possible to measure and record 150 to 200 points per hour. In a very hard day’s work, a cassette could be nearly full.