

*An integrating micrometer for the geometrical analysis
of rocks.*

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[Read November 5, 1936.]

THIS instrument is a microscope stage-micrometer for the quantitative estimation of one to six different kinds of constituents in a substance, by the Delesse-Rosiwal [1] method. It is intended, primarily, for linear micrometric analysis in petrography, but has similar uses in mineralogy, chemistry, and metallography. Economic applications include the volumetric evaluation of components in building stones, road-metals, solid fuels, refractories, and slags.

The object of this new design is to combine speed and accuracy in operation with a particularly compact construction, mechanical simplicity, and strength. Special consideration has been given to the wear and cleansing of bearings, the definition of scale-divisions and zero-marks, and the rigidity of all supports for moving parts.

In use, the instrument measures to 0.01 mm., and automatically adds the successive intercepts of one to six distinct varieties of constituents on straight lines within an area of 25 × 22 mm. This is performed with equal ease upon polished fragments, thin-sections, preparations of crushed materials or detrital grains, whether mounted on English or Continental object-slides. It carries the substance backwards and forwards below the microscope objective in parallel straight lines which are 25 mm. long and spaced conveniently, within a distance of 22 mm., by means of a scale and vernier reading to 0.1 mm.

Though similar in certain respects, it differs from the petrographic micrometers of Prof. S. J. Shand [2], C. K. Wentworth [3], and Messrs. E. Leitz [4] in utilizing the 'travelling nut' method of measuring and summing lengths, in the fact that only *one* micrometer screw is employed throughout, and in the further fact that the whole instrument can be turned through 360° on the rotating stage of almost any modern petrographic microscope.

The first design of the present model was developed in August, 1936,¹ after six months of experiment with a type involving a fluid mechanism.

Existing Designs.

The basic principle underlying the utility of this, and previous petrographic micrometers of the Shand type, is that proportionality can be taken to exist between linear intercepts and volumes of constituents in a heterogeneous substance, provided all the constituents encountered are identified correctly and a sufficient number of their intercepts is measured in suitable directions. The validity of this principle was examined mathematically by A. Rosiwal [1 b], F. C. Lincoln and H. L. Rietz [5], A. Johannsen [6], and E. P. Polushkin [7]. It was tested experimentally by A. Johannsen and Stephenson [8], F. Fromm [9], W. F. Hunt [10], H. L. Alling and W. G. Valentine [11], A. Holmes [12], E. Thomson [13], and F. E. Thackwell [14], among others.

The chief difficulty in designing microscope stage-micrometers for measuring and adding linear intercepts is to find means whereby a specimen can be moved, at will, through a desired distance below an objective by any one at a time of several identical measuring and recording devices, such as micrometer screws.

First among designs of such micrometers was that produced by Prof. S. J. Shand, in 1916, to be followed by the more elaborate designs of C. K. Wentworth and Messrs. E. Leitz, in 1923 and 1928, respectively. The merits of all these instruments are numerous, as experience has shown, but they have certain disadvantages, including their considerable length, which prevents them from being rotated through 360° on a microscope, their undesirable leverage when attached to an unclamped microscope stage, and their relatively high cost. Further, their operation depends upon more than one micrometer screw-thread, with attendant possibilities of error; early types have inadequate means for compensating wear in the main screw-bearings, and two of them require special modes of attachment to a microscope stage.

The New Design.

Between 1935 and 1936 a new design was sought by the author to overcome some or all of these drawbacks, while combining adequate accuracy with simplicity and durability. Secondary aims were to enable the instrument to (a) be attached to a microscope in a few

¹ The instrument, and its modifications, were constructed by Unicam Instruments Ltd., Arbury Road, Cambridge.

seconds, without the necessity for special stage-fittings; (b) be capable of being operated by touch alone; (c) measure and record, simultaneously, up to six different kinds of constituents with an accuracy of 0.01 mm., during either right-to-left, or left-to-right, traverses of the specimen below the microscope objective; (d) record and be reset rapidly; (e) yield direct readings on all scales, without need for numerical conversions; and (f) accommodate either English or Continental object-slides. Further, it was desired that the instrument should be easy and inexpensive to manufacture, light in weight, and sufficiently robust to withstand handling by relatively inexperienced students as well as by advanced workers.

(a) *Principle.*—In this design, what has been called the ‘travelling-nut’ method of measuring and recording intercepts is fundamental: it may be explained as follows. If a drum-shaped nut is threaded on the part of a micrometer screw which is supported horizontally between two threaded bearings, and one edge of the nut coincides with a mark on a fixed scale set up parallel to the axis of the screw, then provided the nut is prevented from revolving by a suitable brake, it will not rotate or be translated when the screw is turned a small number of times in either one of two possible directions. If, however, the brake is lifted, and there is no slip between nut and screw, the nut will be carried by the screw away from the mark on the fixed scale by an amount equal to the translation of the screw through its bearings from the moment when the brake was lifted. Thus, relative to the mark on the fixed scale, the nut will continue to record the motion of the screw until either the screw ceases to move, or the brake is reapplied to the nut, or the nut meets one of the screw-bearings.

If, as in the instrument to be described, six identical nuts of this kind are threaded on the same part of the screw, at suitable intervals, each controlled by its own brake and placed opposite its own mark on the fixed scale, then small consecutive translations of the screw can be recorded by releasing and reclamping some, or all, of the six nuts, in any desired order, one at a time. This means that up to six sets of translations, corresponding to as many different sets of intercepts, can be measured and added together, any one set by any one particular nut.

In practice, the number of kinds of constituents in a specimen is determined by preliminary inspection, the requisite number of nuts allocated to the recording of six, or less than six, corresponding sets of intercepts and the specimen placed in a holder attached to the micrometer screw. As the specimen is carried by the revolving screw

below a microscope-objective, in the eyepiece of the microscope the images of constituents along the line of the image of the horizontal cross-wire move past the image of the vertical cross-wire one by one. Considering any given constituent, immediately the image of its nearer boundary, in the line of traverse, is tangential to the image of the vertical cross-wire the brake is lifted from the nut allocated for

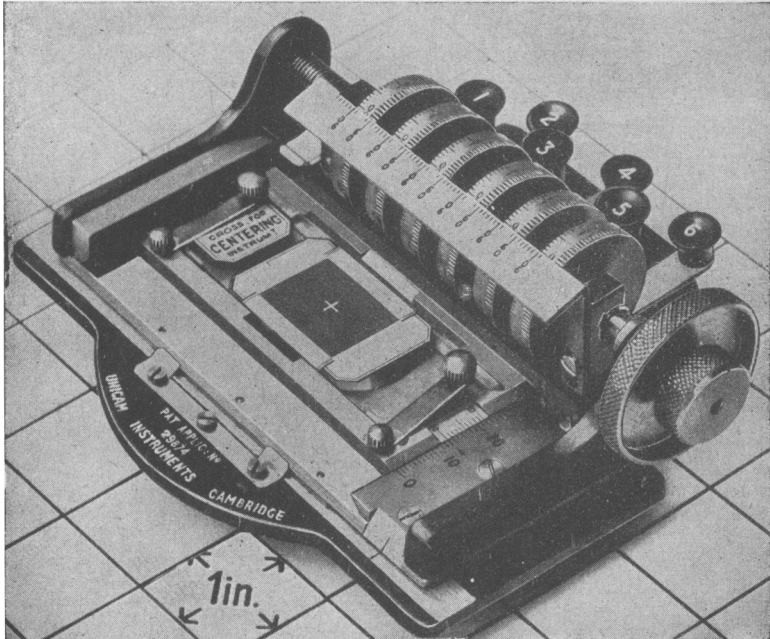


FIG. 1. Front view, showing details of large and small frames, scales, and turning-head.

recording intercepts of this kind of constituent and the nut begins to travel with the screw. The instant the image of the *farther* boundary of the constituent reaches, and becomes tangential to, the image of the cross-wire, the brake is allowed to return and clamp the nut. Meanwhile, the nut has been carried by the screw a distance equal to the intercept of the constituent on the line of traverse. This process is repeated for all other constituents on the line, the appropriate nuts being unclamped and clamped again as often as is necessary, until the end of the traverse is reached, when the total distances travelled by each nut are read on suitable scales and written down. Finally,

totals of measurements carried out along a sufficient number of suitably spaced and oriented straight parallel traverses in the requisite thin-sections, or other samples, will indicate the relative proportions,

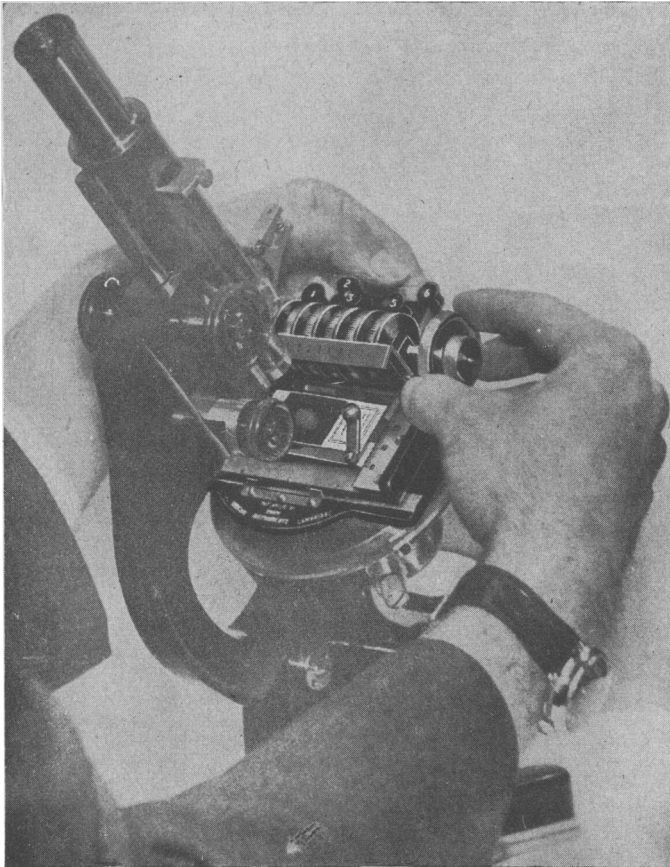


FIG. 2. The instrument in the operating position on a microscope stage.

by volume, of different constituents encountered, in terms of integrated intercepts of the latter. If due precautions have been observed, these volumes should be representative of the bulk of the specimen concerned.

In common with that employed by C. K. Wentworth and Messrs. E. Leitz, this method of measurement obviates errors arising from the

accidental remeasurement of a series of constituents, the diagnostic characters of which are doubtful or ambiguous, such as may occur when only one or two kinds of constituents are determined at a time along a given traverse line, or series of such lines, in the specimen.

(b) *Construction.*—From the accompanying figures it will be apparent that the instrument consists of a sub-rectangular base plate (1), with an annulus (2) and pair of ribs (3) on its lower surface, and two identical vertical columns (4) on its upper surface which support, in horizontal threaded bearings, a steel micrometer screw (5) carrying six divided drum-nuts (6) and a large brass frame (7) bearing upon it a smaller brass frame (8).

The base plate, annulus, and its extensions are integral parts of a single aluminium casting, to combine lightness and strength with ease and cheapness of manufacture. Near the centre of the plate is a circular hole (9) intended to coincide with the axial hole in a microscope stage, and surrounding this, on the lower surface, is the annulus (2), relieved of superfluous metal, with two parallel ribs (3) extending from it, at the ends of a diameter. The functions of this annulus are to contain the attachment mechanism of the instrument, to raise the base plate sufficiently above the surface of a revolving stage to avoid obscuring, or otherwise interfering with, its peripheral scale, vernier scale, or clamp, and to strengthen the plate about the central hole. The parallel ribs (3), being of the same depth as the annulus, prevent the base plate from tilting on a stage when the brake-keys (17), which control the drum-nuts, are depressed above the ribs.

The mechanism of attachment in the annulus consists of three short cylindrical rods (10) of brass, sliding in holes parallel to the plane of the base plate and disposed radially with an angular difference of 120° between any adjacent pair. Riveted at right angles to those ends of the rods nearest the centre of the annulus are small brass plates (11), each with a stiff rectangular 'jaw' (12) projecting from it a short distance below the lower surface of the annulus. Pins (13) attached to the jaw-plates (11), and sliding in holes in the annulus, prevent the rods (10) from revolving while allowing them to slide in the directions of their lengths. Suitable bevels on the faces of the jaws which meet the edge of the central hole in a microscope stage cause the instrument to be drawn into intimate contact with the stage as well as being held stationary in the plane of the same. Springs (14) of steel wire are fitted to the rods in order to return them towards the centre of the annulus whenever their

nuts (15) are revolved in the appropriate direction. The nuts themselves are tapered at the ends remote from the annulus, so that, automatically, these ends, and then the edges, are guided into the angles of a small cylindrical box-spanner, when necessary. The knurled handle of the latter has been made small in diameter to reduce leverage and consequent possibilities of bending the jaws.

The pair of vertical brass supports (4) screwed to the upper surface of the base plate retain an accurate steel micrometer screw (5) in horizontal threaded bearings (16). In profile the latter resemble the upper part of an 'S', having more than half of their bearing surfaces cut away to reduce frictional resistance and wear, as well as to facilitate cleaning and any necessary repairs. Normally, pressure exerted by six spring brakes against drum-nuts (6) threaded on the screw maintains the latter in position and eliminates 'play' due to wear in either the screw or its bearings. During recording, however, the screw is held in position, at any given instant, by pressure from a group of five spring-brakes (17). As a result, the screw, complete with its appended frames (7, 8), can be released from its bearings in a few moments by removing the plate (18) carrying all the spring-brakes, and also the small spring (19) on the base plate which presses against one edge of the large brass frame (7). These relieved bearings were developed and adapted after simple threaded bearings, split bearings, and partly relieved geometric bearings had been tested and rejected. A straight narrow channel (50) has been cut across the threads of these bearings (16), parallel to the length of the screw, where wear due to pressure from the spring-brakes (17) would be a maximum. In this way, localized wear, and any consequent tendency for 'rocking' of the screw in its bearings, is avoided. The screw is revolved through the bearings in either direction by means of a brass turning-head having two co-axial knurled surfaces of differing diameters. The surface of larger diameter (20) facilitates the making of small motions, such as are necessary in the recording of individual intercepts of constituents; the surface of smaller diameter (21) makes it possible to increase the rate at which the screw is returned to one extreme position after it has been moved to the other extreme position during recording.

The accurate micrometer screw (5) has a diameter of $\frac{5}{16}$ inch and a thread of 1 mm. pitch, cut and finished by a precision screw-cutting lathe. On the part of the screw between its bearings are threaded six identical brass drum-nuts (6) from each of which superfluous metal

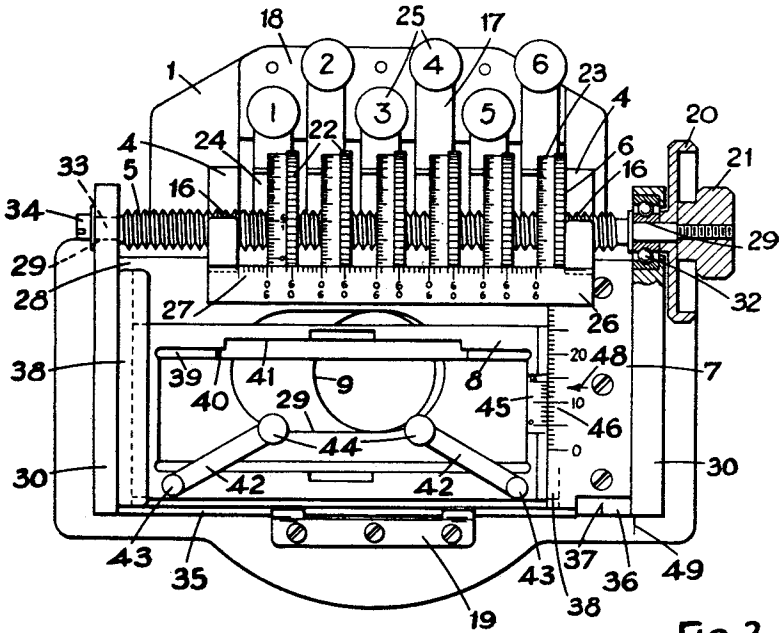


FIG. 3.

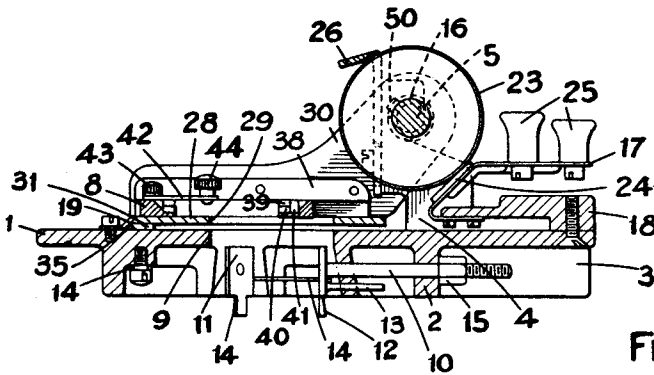


FIG. 4.

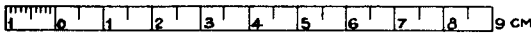


FIG. 3. Plan of upper surface.

FIG. 4. Vertical section through the middle of the instrument, viewed towards the left.

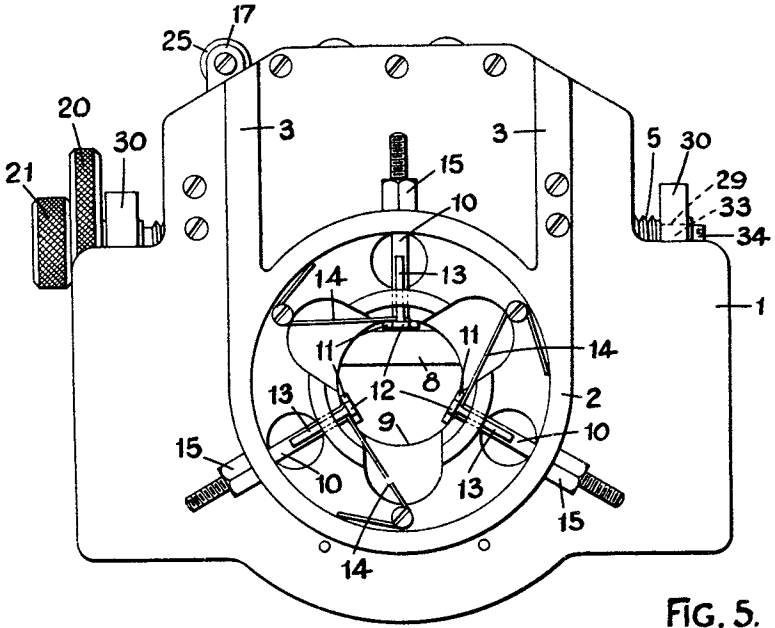


FIG. 5.

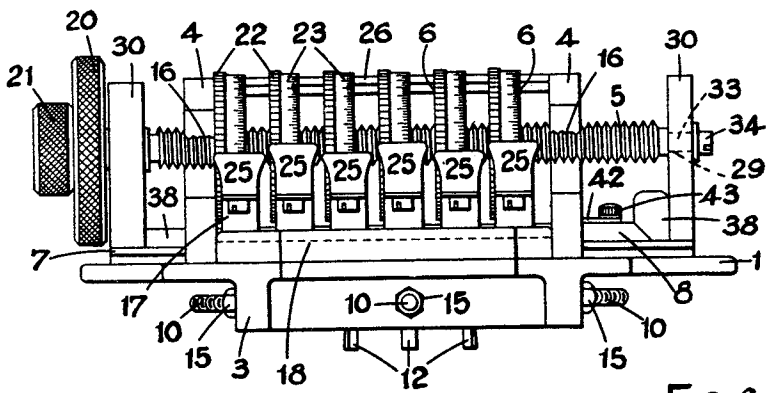


FIG. 6.

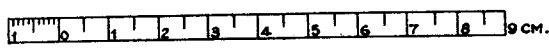


FIG. 5. Plan of lower surface.

FIG. 6. Back view.

has been removed, to leave a light, cylindrical shell, of adequate strength, with a sprung central bearing. The curved surface of each nut is divided circumferentially into two parts: a narrow milled flange (22), in contact with one edge of the nut and projecting 0.5 mm., above the other and wider part of this surface (23), which latter is divided into a hundred equal parts by graduations cut to meet the other edge in a direction parallel to the axis of rotation. Every tenth graduation, except the zero graduation and fiftieth graduation, has two numbers, one of which belongs to a clockwise series and the other to an anti-clockwise series, so that the drum-nuts can measure and record distances when the screw is rotated in either direction. The zero graduation is marked by a conspicuous red dot, to facilitate initial settings: the fiftieth graduation is marked with a single '5', as it indicates the centre of both series of numbers. By virtue of the pitch of the screw, one complete revolution of any drum-nut represents a motion of 1 mm. by the screw through its bearings, and each graduation on the periphery of any such nut therefore indicates a motion of 0.01 mm.

On the side of the micrometer screw remote from the central hole (9) in the base plate are six uniformly spaced spring-brakes (17) of phosphor-bronze strip, each of which is capable of meeting tangentially and holding the milled flange (22) of its appropriate drum-nut through the agency of a small strip of fibre sheet (24), riveted to the brake at a suitable point. The lower ends of all the brakes are bent away from the drum-nuts, round the edge of a horizontal plate (18) and attached to its lower side. This plate is screwed to the main base plate. The upper ends of these brakes are bent parallel with the base plate, away from the drum-nuts, to form keys (17), on the free ends of which are numbered thumb-buttons (25). Three long keys alternate with three short keys, and the free ends of the two groups are at different levels so that any of the six buttons (25) can be found by sense of touch alone after some little practice. The displacement of a brake-key necessary to release a drum-nut has been made about 3 mm., to save time in use, and lengthen the life of the key.

Nearly in contact with the graduated surfaces of the drum-nuts is an adjustable scale-support (26), parallel to the micrometer screw (5), and attached to the main columns (4) by lugs. On the edge closest to the drum-nuts are six consecutive scales (27), each of 8 mm., separated by 3 mm. from neighbouring scales. In any one scale,

the second and sixth divisions are doubly numbered, so that up to seven whole turns of a given drum-nut can be recorded when the latter is carried in the appropriate direction past the scale, by the micrometer screw, from either of these two divisions as initial zero. The support is so placed that the edge mentioned above is normal to the eyes of an operator: it is on the side of the micrometer screw remote from the brakes to avoid shadows cast by its edge upon the graduations of the drum-nuts.

The large brass frame (7) consists of a rectangular plate (28), with a wide central slot (29) in the direction of its length, which supports a small frame (8) in suitable guides (38). This large frame hangs from the micrometer screw by means of two brass plates (30) and bears on the base plate through a thin narrow strip of brass (31) attached below the long edge of the frame remote from the screw. The bearings in the connecting plates (30) are unthreaded, as are the parts of the micrometer screw which revolve in them. The bearing in the plate nearest the turning-head is attached to the screw through a small accurately made ball-race (32). The other plate receives a plane spindle (33), turned down on the end of the micrometer screw, and is retained between the head of a screw (34) in the end of this spindle and the full diameter of the micrometer screw. This combination of thrust-bearing and ball-bearing minimizes 'play' parallel to the screw which ball-races in *both* plate-bearings might make possible. The brass strip (31) beneath the frame constitutes a flat bearing on which the frame slides over the base-plate whenever the micrometer screw is revolved. In view of this attachment, the frame and micrometer screw are always translated together. The frame cannot *revolve* with the screw, however, on account of a relieved phosphor-bronze spring (19), fixed to the base-plate, which presses against a bevel (35) on the edge of the frame immediately above the sliding bearing. A wider bevel (36) on the same edge of the frame carries an engraved line (37), used during the process of centering the instrument on a microscope stage.

The small rectangular brass frame (8) on the large frame (7) is designed to carry the specimen for analysis. It slides parallel to the plane, but at right angles to the direction of motion of the large frame, between bevelled guides (38) of solid brass. The latter were adopted for the sake of accuracy, after a combination of solid guide and spring guide was found to prevent exact parallel motion of the frame. Different rectangular depressions (39, 40, 41) in the frame

accommodate English object-slides of dimensions 3 by 1 and 2 by 1 inches, and Continental slides of dimensions 28 by 48 mm. Any of these slides is retained in position by two small phosphor-bronze clips (42) attached to the frame beneath short milled columns (43) which are provided with milled brass buttons (44) on their free ends to facilitate adjustment of the clips. Traction or pressure with the thumbs on these milled columns serves to move the frame, and the amount of its motion can be measured, to 0.1 mm., by means of the vernier (45) on one of the short sides, in conjunction with a millimetre scale (46) on the contiguous guide. An engraved arrow (48) indicates the particular graduation of the latter opposite which the zero-graduation of the vernier must be set when centering the instrument on a microscope stage

(c) *Operation.*—A suitably prepared specimen is examined under the microscope at a low magnification; one to six different kinds of constituents are chosen for measurement, and an approximate estimate of their relative proportions is made by eye.

The instrument is set for centering on the microscope stage by (a) rotating the micrometer screw until the line '37' engraved across the bevel '35' on the large frame is collinear with the line '49' on the base plate; (b) sliding the small frame, in its guides, until the zero-graduation on its vernier coincides with the graduation on the main guide-scale marked by the engraved arrow '48'; and (c) inserting the 3 × 1 inches glass centering slide, bearing its engraved cross (fig. 1), in the frame under the spring clips with its correct face uppermost and its appropriate end adjacent to the vernier.

The instrument is placed on the stage with the micrometer screw left-and-right, and the turning-head (20, 21) on the right of the observer, after which the attachment-jaws (12) are drawn into contact with the edge of the axial hole (9) in the stage by means of the small box-spanner. The objective is focused on the engraved cross of the centering slide and the positions of the jaws (12) adjusted until, on rotating the stage through 360°, the image of the centre of the cross remains coincident with the image of the intersection of the cross-wires in the microscope eyepiece. When this is achieved, the geometric axis of the hole in the base plate of the instrument is collinear with the optic axis of the microscope. The micrometer screw is then traversed towards the right until it reaches an extreme position, when the centering slide is replaced by the specimen under consideration, care being taken to see that the object-slide of this

specimen falls into a depression in the frame matching its dimensions. Here it is convenient to lock the revolving stage if a clamp is provided.

To each constituent is allocated one or more drum-nuts for recording purposes. The exact form of the allocation depends upon the relative abundance of the several constituents, as estimated during the initial examination of the specimen. The drum-nuts are distinguished by the numbers on the buttons (25) of their respective brake-keys. Each of these drum-nuts is set with the graduation opposite its red zero-dot parallel to the nearest edge of the transverse scale-support (26), and its left-hand edge opposite the right-hand zero of its appropriate 8 mm. scale. This is done by holding down its brake-key with the left thumb, rotating the milled flange (22) of the nut with a convenient finger of the right hand, and reclamping the nut by releasing the key once more.

To choose an initial traverse line the small frame (8) is moved in its guides (38) until a suitable part of the specimen overlies that diameter of the centre hole in the base plate which is parallel to the micrometer screw. If the separation of traverse lines is determined by the scale (46) and vernier (45), it is convenient to make this initial line coincident with either a particular millimetre graduation, or the tenth of a millimetre nearest to it on the scale. The instrument is now prepared for measurement, and the process of recording is as follows.

The micrometer screw is revolved with the right hand by means of the outer knurled rim (20) of the turning-head, so that it travels from right to left through not only the threaded bearings of its main supports, but also those of the drum-nuts, carrying with it the appended frames (7, 8). During this revolution of the screw all the drum-nuts remain *stationary*, on account of their spring brakes.

Let $A, B, C, D, E,$ and F represent six different kinds of constituents, and $a_1, a_2, \dots a_n$ the individual particles of kind A and $f_1, f_2, \dots f_n$ individual particles of kind F . Then immediately the image of the nearer boundary of a_1 in the line of the horizontal cross-wire becomes tangential to the image of the vertical cross-wire at the intersection of the cross-wires, the key of the drum-nut recording intercepts of particles of A is depressed and held down by the left thumb. Soon the continued travel of the micrometer screw brings the image of the farther boundary of a_1 tangential with the same cross-wire at the same point, when the key is released and reclamps the drum-nut

instantly. It will be observed that, during the time for which the nut was unclamped, and therefore revolving with the screw,¹ it moved parallel to the line of traverse through a distance equal to the intercept of a_1 on the line of traverse, the latter being marked by the image of the horizontal cross-wire in any given field of view. This process is repeated for grains $a_1 \dots a_n$, as each passes the image of the vertical cross-wire, and the same simple operation is repeated for grains $b_1, b_2, \dots f_1, f_2, \dots$ as they appear, irrespective of their order of appearance, using the appropriate drum-keys in each case.

The normal maximum motion of any one of the drum-nuts from either of its zero positions is intended to be 6 mm. However, in case an operator causes a nut to overstep the zero of its transverse scale at the end of a traverse, an extra millimetre has been added at both ends of each transverse scale so that any nut can move a part, or all, of a seventh millimetre, provided that the next drum-nut in the direction of motion of the screw has travelled from its initial position by at least this distance. If, towards the end of a traverse, it is found that all the intercepts of a given kind of constituent cannot be recorded on a particular nut, and the other five nuts are in use, this particular nut can be returned to its initial zero with the fingertip, as described above, after completing either 6 mm. or 7 mm. of travel, and recording can be resumed immediately the operation has been noted by means of some convenient symbol, such as an asterisk.

When the micrometer screw reaches its extreme left-hand position, after travelling 25 mm., the integrated intercepts of constituents $A, B, C, \dots F$ are given immediately in millimetres, tenths and hundredths of a millimetre by the whole turns and fractions of a turn through which their appropriate drum-nuts have moved from initial positions. These readings are recorded on a sheet ruled as follows (p. 591), assuming that the second method of traversing described on the opposite page is adopted.

A new traverse line is chosen by moving the small frame (8) at right angles to the first line of traverse, either by an amount equal to one 'field width' or by a definite fraction of a millimetre determined with reference to the scale (46) and vernier (45). Before recording along this line the instrument must be set in one of two

¹ There is no significant slip between the nuts and the screw on account of the fact that the mass of each nut is disposed symmetrically about the screw, its bearing is sprung on the screw, and is full of viscous lubricant.

ways. Either the requisite number of drum-nuts must be released, spun, and clamped with their left-hand edges opposite the *left-hand* zeros of their respective transverse scales, or the micrometer screw must be returned to its extreme *right-hand* position and the drum-nuts set once more with their left-hand edges opposite the *right-hand*

Transverse Symbol.	Drum-nut Number						Effective Traverse mm.	Notes.
	1	2	3	4	5	6		
A								
B								
C								

Y								
Z								
Total								
Per cent.								

zeros on their transverse scales. If the first method is adopted, recording is carried out while the micrometer screw is moved from left to right by the turning-head, and the alternative graduation-numbers on the drum-nut and transverse scales are used. This method is more rapid than the second method, since the drum-nuts will tend to be close to, or opposite, the left-hand ends of their transverse scales, after the first traverse, but in making readings it must be remembered that the alternative numbering must be employed. The second method consists in revolving the micrometer screw back to the right-hand extreme of its motion by means of the smaller knurled surface (21) on the turning-head, after which each drum-nut is set with its left-hand edge opposite the right-hand zero of its appropriate transverse scale. Recording is then carried out while the micrometer screw is moved from right to left along the new line. This method has the merit that the same cycle of major operations is carried out in the same order for every traverse, and

only one set of numbers is concerned throughout. However, time is spent in returning the screw to the right-hand end of its traverse, and in many cases the drum-nuts concerned must be moved through a greater distance during resetting than is the case when the first method is adopted.

In the above manner the whole of a thin-section, or other specimen, of normal size can be explored and measured. If it is necessary to make determinations along traverse lines at 90° , or any other angle, to the first set, in the plane of the specimen, then either the specimen is remounted on its slide, or transferred to and reoriented on a new slide, or one end of the given slide is cut off to prevent its interference with the drum-nuts, and the part bearing the specimen is attached to the upper surface of the small frame (8) by means of dental wax or plasticine.

(d) *Utility*.—The chief value of the instrument lies in its ability to save time and energy otherwise spent in recording and adding many small measurements. Further, it diminishes the eye-strain involved in focusing the microscope-image and particular columns of a record-sheet alternately. For these reasons it tends to improve the speed and accuracy with which results are obtained, even in skilled hands. It is believed that the instrument will be of service for training students in the technique of micrometric analysis.

In petrography this micrometer has several well-known applications, chief among which are determinations of relative proportions of transparent or translucent minerals in many types of crystalline rocks or artificially prepared crystalline silicates, as well as of inclusions in natural and artificial minerals. From the volume-compositions which these data yield, weight-compositions and bulk chemical compositions can be derived, in certain cases, if representative figures for the specific gravities and chemical compositions of the constituents are known. It is valuable also in finding the ratio between glass and crystals in both natural glass-bearing rocks and those partly crystallized glasses of analogous composition which have been prepared in laboratory furnaces, commercial gas furnaces, or blast furnaces. The instrument can be used with equal success for quantitative studies of opaque petrographic specimens, including polished fragments of rocks, metallic ores [13], and meteorites. It should be of service also in the quantitative examination of oolitic and similar sediments.

In economic geology it promises to be of assistance for determining

the compositions of metalliferous minerals [13, 15, 16], natural solid fuels, refractories, building stones, and road-metals [17]. There would seem to be some applications for it in metric palaeontography, especially in such connexions as the quantitative study of microspores from coals, by the methods of A. Raistrick and J. Simpson [18], and similar palaeobotanical investigations.

For numerical analyses of mounts of detrital sediments, crushed rocks, diatomaceous or foraminiferal earths, globigerina or radiolarian oozes, spicule-rich beds, or separated microspores, the instrument can be employed as a simple mechanical stage, in conjunction with a counting device such as that introduced by C. J. C. Ewing in 1931 [19], or one developed recently by the author. In counting up to a hundred individuals of not more than six species of mounted particles along any one traverse, this micrometer can be employed without an extra tally by moving the appropriate drum-nuts one division per particle and reading the total number of particles of each kind at the end of each traverse. The arithmetic mean of diameters of one to six species of mineral-grain, or similar object, can be found conveniently from figures obtained by summing the diameters of a suitable number of each type on the micrometer, and enumerating individuals simultaneously with either of the above simple counting devices.

Since the validity of micrometric analysis by the Delesse-Rosiwal method has been tried and established, there seems to be some justification for the plea voiced by H. L. Alling [20] that more modal rock-data, obtained in this manner, would be of value, especially in relation to the body of normative data now available. It is hoped that this instrument will play its part in facilitating the collection of any such new modal information.

The author is deeply indebted to his father, Mr. J. A. W. Dollar, for financial assistance, and to Prof. C. E. Tilley for facilities in the workshop of the Department of Mineralogy and Petrology, University of Cambridge, during early stages in the development of the instrument. To Mr. A. N. Lanham, Chief Assistant in the above Department, the author would express his thanks for practical suggestions, and to Messrs. S. J. Stubbens, J. N. Stubbens, and E. S. Marsh, of Unicam Instruments, Ltd., Cambridge, he is equally grateful for unfailing patience and help in the construction and modification of experimental models.

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