PHOTOMICROGRAPHY WITH SIMPLE APPARATUS.

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(Read at the Meeting, March 3, 1920.)

RECORDS obtained by photomicrography are frequently of great service in many industries and scientific investigations at the present day, but it is a common misconception that in order to obtain satisfactory results it is necessary to employ expensive apparatus such as those figured in the catalogues of microscopical dealers. My purpose is to demonstrate that by means of simple and inexpensive apparatus it is possible to obtain satisfactory results with magnifications not exceeding about forty diameters.

The essential apparatus consists of a camera, a lens, a support for the object, and some source of illumination. The camera may be of any form, however simple, provided that it allows of extension from about 10 cm. to not less than 50 cm., and is so arranged that focussing may be achieved by altering the position of the back. Its size should allow the use of half plates if necessary. The lens may consist of any form of short focal length camera lens or a microscope objective, according to the magnification required. The micro-lenses I chiefly employ are achromatic objectives ranging in focal length from 76 to 8 mm., and costing ten shillings each in pre-war days. The object holder may be of any simple form and should be fitted with rubber bands or metal clips. Daylight in this country, at least, is too variable and uncertain to be of much use for this work, and some form of artificial illumination should be employed. I have at various times used the following: Oil lamp, batwing gas burner, incandescent gas (upright), acetylene (cycle lamp, flat flame), electric $\frac{1}{2}$ watt 50 c.p., and magnesium ribbon. Of these, the two latter are the most satisfactory for constancy, high actinic power and convenience.

The relative actinic power of the above illuminants when using ordinary (not ortho- or pan-chromatic) plates is approximately as follows:

	Equivalent Exposures.			
Batwing burner	...	...	...	40 seconds.
Incandescent gas	...	...	...	10 "
Acetylene (flat flame)	...	...	...	6 "
Electric $\frac{1}{2}$ watt 50 c.p.	...	...	...	3 "
Magnesium ribbon	...	...	...	1 " (1.5 cm.)

PLATES.—In regard to the numerous makes upon the market there is but little to choose between them for this work. On the whole, an "Ordinary" plate is slightly superior owing to its fineness of grain and ease of manipulation, but where economy of time is a consideration one requiring shorter exposures, such as a "Special Rapid," will be found satisfactory. On occasions when only a few copies are required and a negative image will serve the purpose equally as well as a positive, bromide paper may be used in the dark slide instead of the plate, this being much more economical. Although a half-plate camera is very suitable for

this work, any smaller sized plate may be employed by using adapters in the dark slide.

ARRANGEMENT OF APPARATUS: *First Method.*—The camera is fitted with a short focus (10 to 12 cm.) single meniscus photographic lens, and is then firmly fixed to the working bench. The object is placed in position and focussed roughly by altering its distance from the lens, the final focussing being done by adjusting the front or back of camera. By this method magnifications up to about $\times 4$ may be attained.

Second Method.—The arrangements adopted in the first method are used with the addition of a large diameter lens on a separate support between the camera lens and the object. This will enable a magnification of about $\times 8$ to be obtained before the optical qualities of the camera lens are upset sufficiently to produce poor images on the plate.

Third Method.—The general arrangements given above are adopted, but the camera lens is removed and replaced by a microscope objective fitted into a cork. According to the focal length of objective used (7.6 to 8 mm.) and the extension of camera, magnifications varying from $\times 5$ to $\times 40$ may be obtained without any difficulty in manipulation. It is possible with transparent objects to use an objective of only 4 mm. focal length and attain a magnification of about $\times 75$, but the difficulty of focussing by means of the camera rackwork is great.

Fourth Method.—This method, which allows of magnification up to $\times 400$, requires the use of a microscope and is therefore somewhat outside the scope of this paper. It will be sufficient to mention that the microscope is placed horizontally, and the camera without any lens is placed with its lens mount against the eyepiece. In order to keep the camera fairly rigid and at the same time allow of its ready removal for observation through the microscope, it is placed upon a pile of paper-covered magazines and has a wooden bar with weights suspended from each end laid across the base-board.

ILLUMINATION OF OBJECTS.—The method to be adopted for illumination depends chiefly upon whether the object is opaque or transparent, and secondly upon the detail required to be shown in the finished print. Transparent objects are usually photographed by transmitted light, and may be illuminated by (a) light passing through direct from the illuminant to the objective; (b) polarised light, by using a polariser and analyser before and behind the objective; and (c) black background obtained by the use of a 4-inch condenser having a central stop to prevent direct light from the illuminant reaching the objective, while the object is illuminated by an annular cone of rays from the periphery of the condenser.

When photographing opaque objects the light must be reflected by the object, which may be illuminated (a) by direct light from illuminant on the same side of the object as the objective; (b) by direct light with the use of a condenser between illuminant and object; (c) a Lieberkuhn reflector fitted to objective.

With objects which are not flat and require to be photographed with sharp detail in various planes, it will be necessary to reduce the aperture of the objective by placing black paper stops at the back which may be held in position by a small screw cap or a circular steel spring.

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Since lenses of long focal length require a comparatively large even illumination when dealing with transparent objects, it is advisable to insert one or two pieces of ground glass between the illuminant and object. The increase in exposure necessitated by this addition is shown below:

One piece of ground glass	...	...	...	...	× 1.3
Two pieces of ground glass	...	...	...	...	× 1.5

EXPOSURE.—The determination of the correct exposure required is a difficult problem in photomicrography, and up to the present no exposure meter has been produced which is of any use for the purpose. The exposure depends upon a number of factors, among them being—the colour of the object, the method of mounting illumination (transmitted or reflected), actinic power of illuminant, aperture of lens used, magnification, speed of plate, etc.

By keeping a full record of the details of each exposure one soon acquires a series which is of great value in the determination of any exposure required for a new object. My own record contains spaces for twenty-one particulars in addition to a column for "remarks," but it is rarely necessary to fill up more than half of these.

The following table is an abbreviated form of my exposure record, and the figures given may be a guide to anyone commencing this work for the first time:

Object.	Mounting.	Magn.	Method.	Illumination.	Illuminant.	Objective.	Stop.	Plate.	Exposure.
Coralline pebble	Dry	2	1	Direct, reflected	Incandescent gas	111 mm.	F. 8	Imp. Ord	2 min.
Brome grass ...	"	3	1	Dark back-ground	Incandescent gas	"	F. 22	Imp. N.F.	5 min.
Woven linen ..	"	9	2	Direct, reflected	Magnesium	111+240 mm	F. 16	" "	12 in Mg.
Ink and pencil marks	Xylol	11	3	Direct, transmitted.	$\frac{1}{2}$ watt, 50 c.p.	64 mm.	4 mm.	Imp. S.R.	6 in Mg.
Woven horsehair	Balsam	37	3	Polarised	Magnesium	8 mm.	"	Thames	30 in Mg.
Globigerinia	Dry	19	3	Lieberkuhn	$\frac{1}{2}$ watt, 50 c.p.	22 mm.	1.5 mm.	Imp. Ord.	10 min.
Lions on half-a-crown	"	10	3	Direct, reflected	" "	76 mm.	4 mm.	Imp. S.R.	"
Mercury globules from Reinsch test 0.0001 mg.	"	320	4	Direct, transmitted	" "	4 mm. + eye-piece × 5	5 mm. in Abbé condenser	" "	30 min.

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DISCUSSION.

Mr. W. F. REID remarked that if all schools taught their students to make the best of such simple means as illustrated by Mr. Ward, it would be of great help. He had fitted up several kinds of apparatus, using a vertical camera, the great advantage being that it was less subject to vibration.

With regard to illumination, the use of acetylene was to be recommended if a proper generator were available, as it worked very well. This method was adopted by the Italians in warfare. A great deal also depended upon the kind of light that was used, as it could be split up, and thus different results obtained. One of the

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difficulties in photographing with invisible rays was the correct focusing of the apparatus.

In the case of photographing insects, different results were obtained with ultra-violet rays with the visible lights cut off, and an excellent photograph of a portion of the insect could be obtained straight away, without mounting, with the reflected light cut off.

Mr. GILBARD thought much better results in colour work could be obtained in different colour screens—that is, yellow, green and blue—were used. The latter especially was to be recommended, as this would sometimes bring out detail where yellow failed to do so.