CHAPTER III.

APPARATUS EMPLOYED FOR PHOTO-MICROGRAPHY.

The Microscope and Accessories.

FIG. 88 shows the appliances originally used in these researches. They were made by Nachet & Fils, of Paris, and gave complete satisfaction.

A total reflection prism was fixed above the objective to illuminate opaque bodies. That arrangement, however, had the inconvenience of reducing the utility of the microscope, and microscopes such as are made by Nachet and others at the present time are certainly to be preferred.

The microscope stands on a table of suitable height, under a movable vertical camera which slides between two uprights. The vertical is very much superior to the horizontal camera for studying metals. The chief reason for this is, that pieces of varying shape, seldom terminated by two parallel planes, have to be examined. In that case the mounting of the specimen is done very quickly and correctly by putting a little soft wax (sculptors' modelling cement) upon a glass plate and embedding the specimen in the wax. The levelling is effected by means of two pieces of glass tube of equal height placed one on each side of the specimen.

A sample so mounted would often move if it were

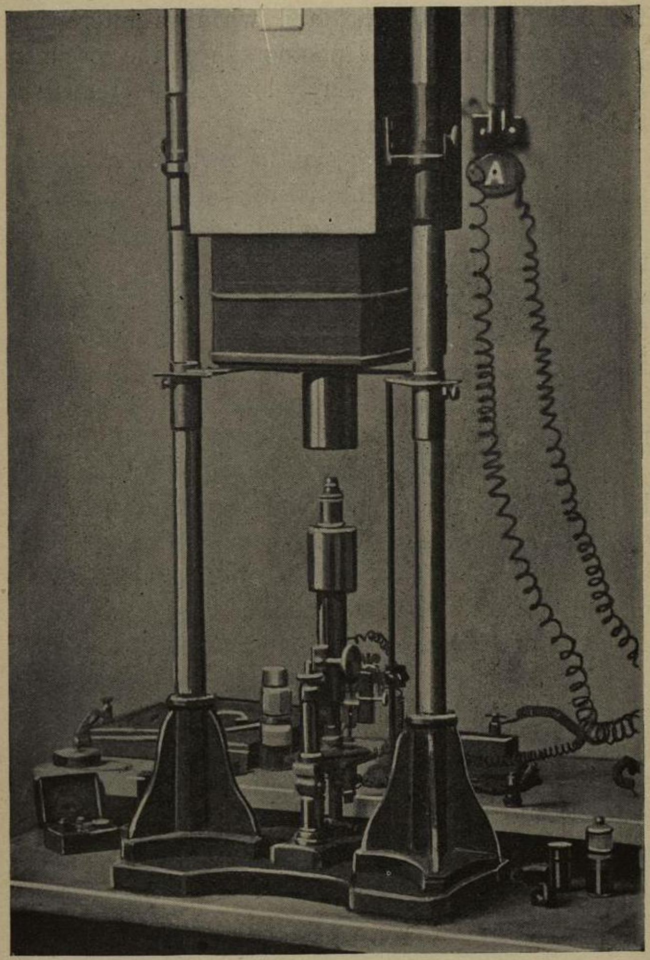

Fig. 88.—Nachet photo-micrographic appliances.

placed vertically, and it would be necessary then to replace the wax by a cement which would harden, or by cutting the metal so that it had two parallel planes. Besides, with the vertical camera the microscope is in the best position for use, and when an interesting point is noticed and the photograph of the specimen required, the camera is simply lowered and joined to the fixed socket of the microscope.

The micrometer focussing screw has a forked aluminium lever, and this is worked with a rod.

The space between the uprights gives freedom for the movement of the camera. The only inconvenience, which is, however, not serious, is that it is necessary to stand upon a stool to bring the camera into focus for photographing.

Nachet's No. 2 eye-piece is generally used, and, when measurements are required, a micrometer eye-piece.

For photographing, the ordinary eye-piece is replaced by one for projection. According as the draw-tube is extended or shortened, and as the projection eye-piece itself is more or less extended, the magnification is modified, the extension of the camera being constant.

To obtain the least magnification with each objective, the projection eye-piece is removed and a velvet tube introduced into the draw-tube to avoid reflection upon the photographic plate.

The set of objectives comprises Nachet's Nos. 0, 2, 3, 5, 7, and 9. These objectives are generally used to give the following respective magnifications, with suitable adjustment of the camera:—

0	. . .	6 to	20	diameters.
2	. . .	20 „	50	„
3	. . .	50 „	150	„
5	. . .	150 „	400	„
7	. . .	400 „	600	„
9	. . .	600 „	2000	„

No. 7 is not so suitable as the others for the examination of opaque bodies, and can be dispensed with. All the others are necessary. Nos. 0 and 2 are not used with the prism. It is therefore removed, if vertical light is used, and replaced by a cover glass placed at 45° between the specimen and the objective. The objective No. 0 is mounted on the socket of the camera as in ordinary cameras, and not upon the microscope.

For illumination I have, for several years, used exclusively a good 6-volt electric lamp, with facilities for increasing to 8 volts. The lamp is fed by accumulators, and a varying resistance is interposed in the circuit. For examining specimens a mild light is preferable, and is not so wearying to the eyesight. A resistance is therefore interposed in the circuit, and about 4 volts used. For photographing the voltage is increased to 8. This consumes 3 ampères.

The prism can be lighted directly by the lamp without the introduction of a condenser, and all colour is thus avoided; but owing to refraction there are a few shadows cast upon the surface, and these shadows are rather troublesome where the specimens are very brilliant and uniform. Under such conditions a magnifying glass is placed between the lamp and the opening of the microscope, avoiding focussing on the prism.

A vertical partition with two movable shutters must be arranged in front of the prism, to do away with, or at least, diminish any colour.

The length of time for exposures is but little longer with No. 9 objective than with No. 3, for the same extension of the camera. The exposures may vary from ½ to 20 minutes, according to the magnification required for a given objective, the distance of the lamp, and the opening of the partition. The colour and the brilliancy of the specimen have naturally a great influence.

No definite rule can be laid down for the time any object must be exposed, and it needs long experience to expose correctly, and even then it is easy to be mistaken.

The photographic plates I usually employ are Lumière's orthochromatic plates for yellow and green screens. A green screen should give good results, especially for photographing, but it has the inconvenience of lengthening the time of exposure.[1]

During the last few years there have been many improved forms of microscope stands designed for the examination of metals and alloys, and there are few standard makers of this class of apparatus who have not turned their attention in that direction. The developments have, however, tended towards the requirement of the laboratory rather than of the workshop, and it can be stated, probably without contradiction, that there is not to be found in the market a simple form of stand with illuminating arrangement suitable for the use of foundry foremen and assistants in steel and engineering establishments.

That there is need of such an instrument is undoubted. For most purposes a high-power magnification is not required. For instance, the examination of steel castings and forgings, in order to determine whether or not the treatment to which they have been subjected has been suitable for the purpose required, does not need a greater magnification than 20 to 50 diameters. Such magnification would enable

[1] The succeeding paragraphs (to p. 128) are by Dr Stead.

the foundryman to determine approximately what is the proportion of phosphorus in his castings and pig-iron, and whether or not the percentage of combined carbon is great or small. In designing a workshop microscope, three conditions are imperative:—

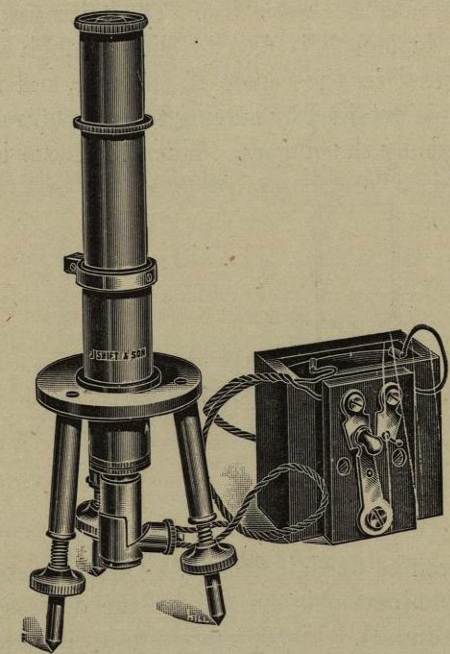

Fig. 89.

1. It must be simple, contain as few parts as possible, and be capable of bearing rather rough handling.
2. The illuminating reflectors and source of light must be attached to the object-glasses.
3. The cost must be low.

The design of microscope eventually approved was submitted to Messrs J. Swift & Son, who made the model illustrated in fig. 89.

The following is a detailed description: –

The stand consists of a disc supported by three legs, the length of which can be adjusted by turning the milled screws. The lower terminals of the legs consist of hard steel points, and the upper ends are secured by screws into the brass disc. The microscope tube, 8 inches in length, is free to slide through a second tube secured in the centre of the disc, and when in use, focus is obtained by moving the tube upwards and downwards by the fingers. When the focus is found

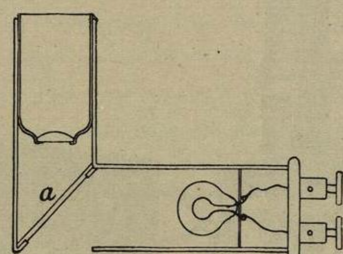

Fig. 90.

the tube can be fixed, if desired, by a small set-screw.

The illumination is effected by the devices shown in figs. 90 and 91. Fig. 90 represents a vertical section through the 1-inch object-glass and illuminator.

The latter consists of two tubes united as shown, at the junction of which a $\frac{1}{2}$-inch cover-glass (*a*) is placed at an angle of 45°. One limb slides on to the lowest part of the object-glass, and into the other is placed a 4-volt incandescent electric lamp. A small 4-volt dry battery supplies the electric current for the lamp. When the circuit is made, by switch or button, the rays from the lamp are partially reflected on to the object, which is thereby sufficiently lighted to

enable its structure to be seen clearly. The illumination can be changed from vertical or direct to oblique by a very simple device. The lamp is masked on the lower side by coating it with a metallic paint just sufficient to admit rays passing horizontally to the cover-glass reflector, but not downwards. By removing the cover-glass and rotating the lamp through 90° the rays then fall obliquely on the object.

The illuminator (fig. 91) is similar in general design to the last, but it is so constructed that a $\frac{1}{3}$-inch objective can be employed. In this, the reflector is

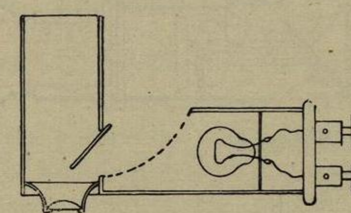

Fig. 91.

placed above the nose of the objective. It consists of a piece of silvered glass placed at an angle of about 45°. As the position of the lamp is constant with relation to the reflector, the latter is fixed once for all at the exact angle to give the maximum illumination of the object. The silvered reflector slides into the slit cut in the objective and projects about $\frac{1}{8}$ inch outside, so that when it requires cleaning it can be readily removed and replaced.

It is advisable to force the light to a maximum, for although the lamps do not last as long under such conditions they can be readily replaced with new ones, which cost only one shilling each, and the illumination obtained is so much better.

When working with this microscope the object can, after preparation and levelling, be placed on an ordinary table or flat surface, and the nose of the objective placed over it.

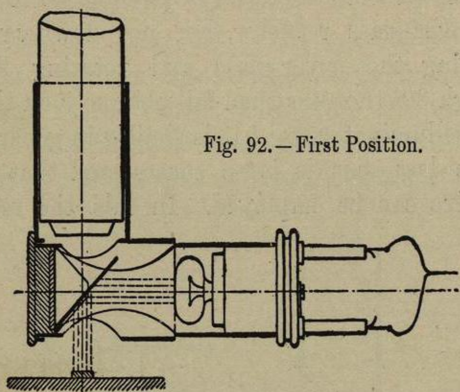

Fig. 92.—First Position.

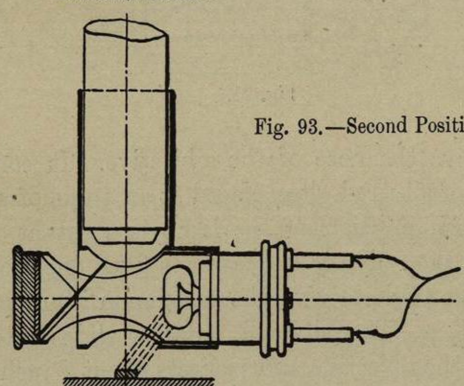

Fig. 93.—Second Position.

The battery, if convenient, can be carried in a coat pocket, or be placed on a table near the microscope, and the light switched on by pressing the button. Very little electricity is required, for it is only when looking at the object that the current is used. When it is desired to examine the finished surface of parts

of machinery, the microscope is placed over the part the examination of which is required, and the light is switched on. The sharp-pointed legs of the stand, when pressed on to the metal, prevent the microscope from slipping. In this way either flat or curved surfaces can, after suitable preparation, be readily examined.

An improved illuminating device is shown in figs. 92 and 93. This, as in the previous arrangement described, is attached to the object-glass. The lower part, carrying the electric lamp at one end and a plug into which is fixed a very thin glass disc at an angle of 45°, is arranged so as to slide to the right and left. When in the first position vertical rays of light are thrown by reflection from the cover-glass on to the object. When in the second position—produced by sliding the lower tube about half an inch to the left—rays of light falling at an angle from the electric lamp impinge on the object, illuminating it in this way by oblique rays of light.

It is advisable to use a small accumulator in preference to the dry battery, as the charge of electricity is more lasting. This instrument should be found most useful in workshop practice.

Polishing Machines.

From time to time elaborate machines for polishing metal sections have been designed and put on the market, but experience has proved that the simplest devices are the most efficient.

All polishing machines consist essentially of discs which are caused to rotate by hand or other power, either horizontally or vertically.

In the type made by Messrs Baird & Tatlock, a series of discs of metal have cemented upon them emery paper of varying degrees of fineness, and for fine polishing a covering of thick cloth of fine texture. On the under side of each disc a stem is fixed vertically to the centre of the disc. The rotating arrangement consists of a vertical shaft on which is secured a pulley wheel, the upper part of this shaft is drilled down the central axis, and into this the stems of the polishing blocks are placed. The shaft and polishing discs, when in position, are rotated by any suitable force or power. The machine designed by Stead, and made by Messrs Carling & Sons of Middlesbrough, can be readily understood by fig. 94. The polishing blocks are conical, the smaller end being upwards. The papers and the polishing cloths are secured in position by forcing rings over them, down the conical sides of the blocks. The prepared blocks are simply placed on the rotating table, and are carried round by friction only. The block for fine polishing is covered with a double layer of cloth, between which is placed specially prepared calcined alumina in fine powder. Jewellers' diamantine powder answers admirably. Fine polishing is always done on cloth-covered blocks, kept continually moist with clean water. Only the finest parts of the powder find their way through the porous cloth. Osmond's polish-attack is done on blocks covered with parchment, which are kept moist with a solution of 1 per cent. of nitrate of ammonia in water.

It is quite easy, with a little practice and beginning with a filed or sawn surface of metal, to obtain a perfect polish in ten minutes. The chief point to remember is gradually to diminish the pressure of the specimen against the polishing surfaces. The amateur

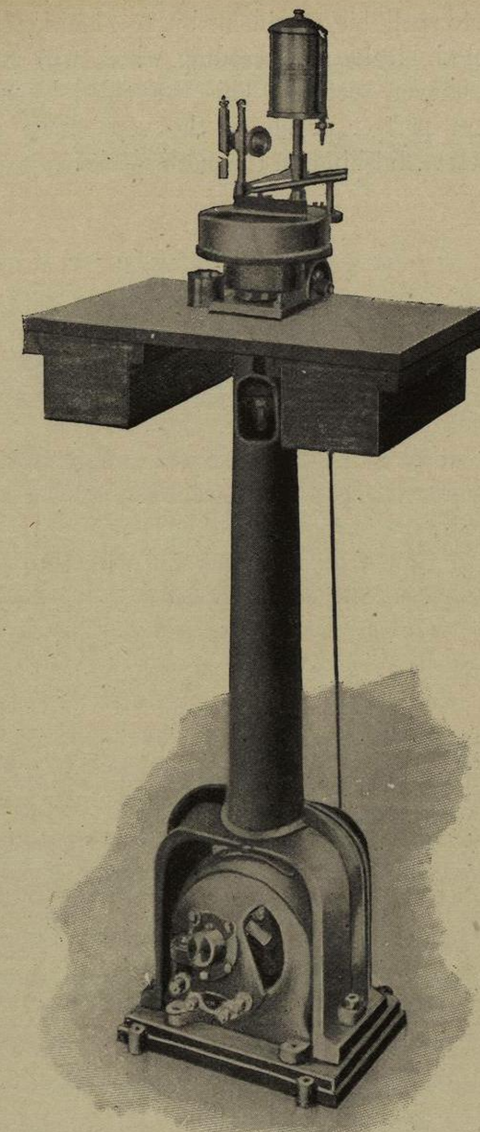

Fig. 94.—Stead's polishing machine.

is liable to spoil his specimens by too long polishing on the cloth blocks, a proceeding which will produce a very uneven surface. This is avoided by making an almost perfect polish on the very finest emery paper before finishing on the cloth blocks.

CHAPTER IV.

PRACTICAL APPLICATIONS OF METALLOGRAPHY.[1]

Introduction.—The study of the structure of metals is practically useful in two different directions:—

1. It develops the scientific instinct, when there is a trace of that instinct to be developed, by arousing inquiries as to what underlies the varied structures seen under the microscope. It stimulates research in order that an answer may be given as to why the varied structures are arranged in the order in which they are found, and to determine what conditions of heating and treatment are necessary to modify and alter them. The spirit of inquiry thus developed, and the efforts to explain the phenomena observed, are essentially highly educational, and must tend to train scientifically the mind of the student.

2. On the other hand, it has direct practical value, for, by its application, one can often judge by the structure of metals the thermal and mechanical treatment to which they have been subjected, for there is a constant relation between microstructure and the

[1] Abridged from a lecture delivered by Dr J. E. Stead, F.R.S., before the West of Scotland Iron and Steel Institute, 12th January 1912, and reproduced here by permission of the Council.