THE "DAVON" PATENT

SUPER-MICROSCOPE

FOR

METALLOGRAPHY

With (by permission) re-print of a Paper by

F. ROGERS, D.Eng., B.A., M.Sc., M. Inst. Mech. E.

Read before the Sheffield Metallurgical Society, Nov. 13, 1923.



CAST IRON. × 1,000. Taken with a 1/6" O.G.
(Slide No. 5.)

F. DAVIDSON & Co.,

MANUFACTURING OPTICIANS,

143
29, GREAT PORTLAND STREET, LONDON, W.1.

ESTABLISHED 1890 ENGLAND.

Telegrams: "Re-write, Wesdo, London." *'Phone:* Langham, 2429.

BROCHURE "A" deals with the MICRO-TELESCOPE and SUPER-MICROSCOPE for General Purposes

BROCHURE "B" deals with the SUPER-MICROSCOPE for Critical Microscopy and Photo-Micrography.

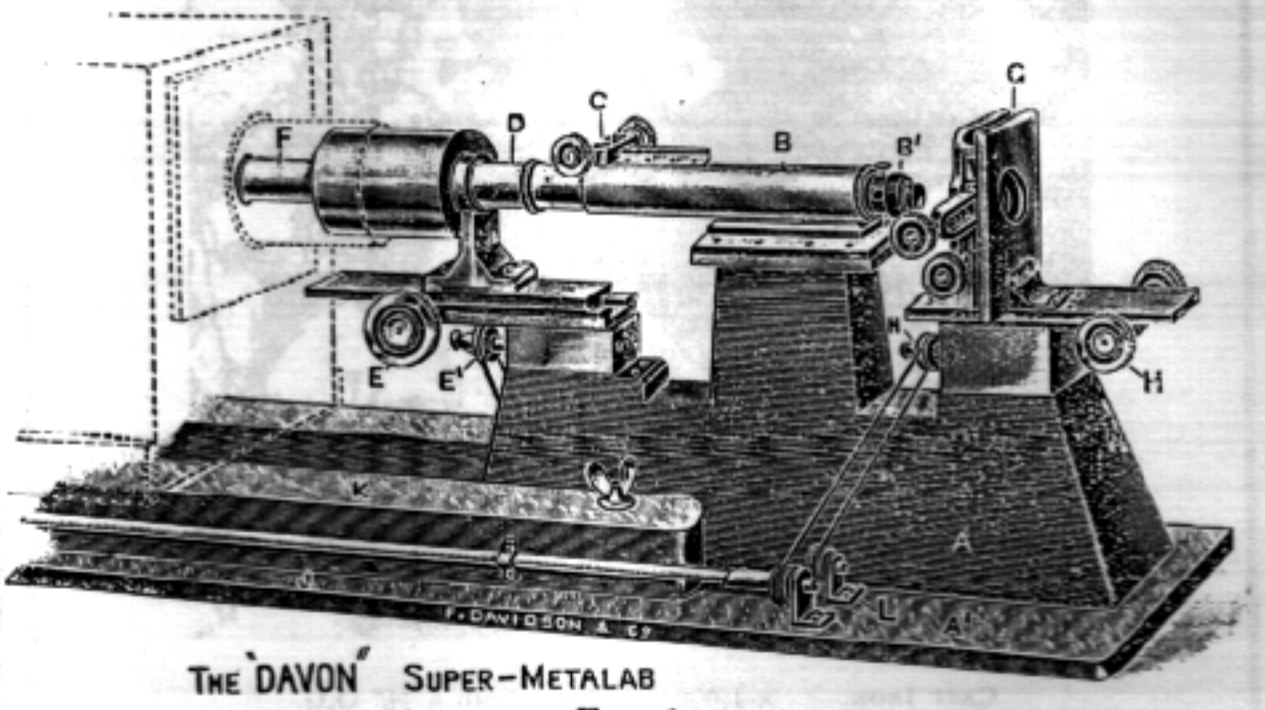
THE "DAVON" PATENT

Super-Microscope for Metallography.

THE *principle* has been explained at length in Brochure "B," and elaborated by DR. ROGERS in the paper read before the Sheffield Metallurgical Society, on November 13th, 1923. It is sufficient to summarise all that has been said into three words, viz., High Eyepiece Magnification. Others have been engaged upon the problem and many experiments have been made, but we claim to have achieved by means of the "Super-Microscope" system a measure of success far in advance of the results secured by other methods. A consideration of the fact that we utilise either a micro O.G. or the compound microscope for the eyepiece will enable one to realise that we employ the very highest type of eyepiece for our purpose.

For some time past, Dr. Rogers, convinced of its superiority, has collaborated with us in the development of the Super-Microscope principle in its particular application to metallography. The objects aimed at in the course of this collaboration have been as follows :—

(1.)—The production of a complete apparatus suitable for the most exacting requirements of research work, both in academical and modern factory laboratory conditions.



THE 'DAVON' SUPER-METALAB

FIG. 1.

"A"—Solid cast iron base, frosted finish ; "B"—the primary body tube with worked cover glass vertical illuminator "B¹"; "C"—rack and pinion of "collector" tube; "D"—the secondary microscope: "E"—the coarse focussing of the "secondary" and "E¹" the fine focussing ; "F"—eyepiece of secondary ; "G"—the mechanical stage ; "H" and "H"—coarse and fine focussing ; "K"—solid mahogany arm (on both sides) on which the camera rests when in position, and which may be swung to one side so that one can get close enough for visual observation if this method is preferred.

It will be seen that the fine focussing of both primary and secondary can be manipulated from the camera end by means of the rod and pulley arrangements, a tension wheel being provided so that any slackness of the cord can be taken up.

This instrument is tested for precision at a magnification of ×4,000.

It will be noted that the Super-Microscope is built on the solid base, thus assuring the maximum stability.

(2.)—The production of a simple type of super-microscope and camera for the purpose of very easy and rapid photography, giving results which are ample for the majority of the every day requirements of a busy works, but not involving expert operation nor the delays which are at present customary and perhaps unavoidable.

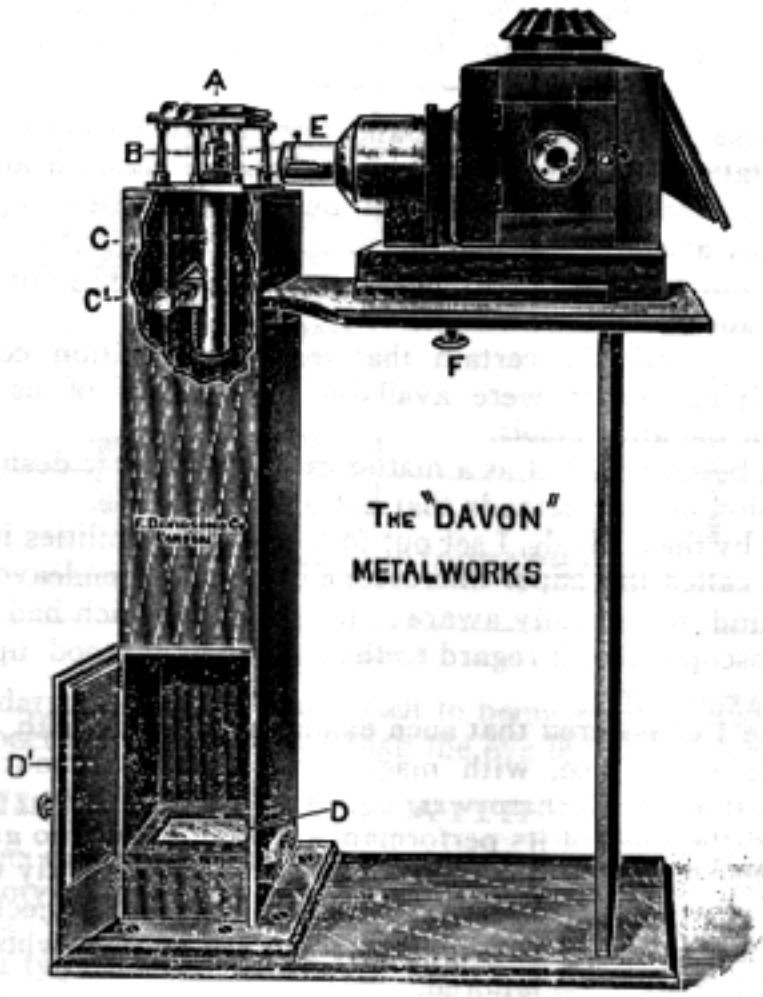


FIG. 2.

This section of the work has necessitated the extension of our own research work upon the super-microscope into the realms of very high magnification, as well as perfecting the mechanical means of utilising the Super-Microscope system. DR. ROGERS' technical and mechanical skill has been freely called upon during the experimental period referred to, and in the designing and construction of the types of apparatus which are illustrated and described.

The photographs reproduced are the work of our MR. J. D. JACOBS. If such can be done with the Super-Microscope system by one without experience, it is difficult to say what may be possible to an expert in metallography.

"A"—The mechanical stage; "B"—the primary objective and worked cover glass vertical illuminator; "C"—the secondary tube which screws on to the plate below the primary objective, the collector tube (not shewn) being first screwed into position; "C¹"—rack and pinion actuating the secondary objective; "D"—a silvered card focussing screen kept in exact register by means of invisible springs; "D¹"—the light-tight door; "E"—is a supplemental condenser with iris diaphragm and viewing slot fitted to all our metallurgical lantern bodies.

NOTE.—For safety in transit the collector and secondary tubes are removed. The former is first screwed into position underneath the platform, and then the latter. A flat specimen should then be put on top and focussed on the screen by means of the secondary pinion "C¹." When all this is done the "Metalworks" is available for rapid repetition work without any further alteration so long as the specimens are flat.

High-power and Rapid Photo-micrography of Metals.

Read before the Sheffield Association of Metallurgists, by F. Rogers, D.Eng., B.A., M.Sc., M. Inst. Mech. E. 13th November, 1923.

In the course of much research and investigation work upou metals, one realises the limitations that are set by the practicable magnifications combined with satisfactory resolution of detail at our disposal. Photographs of metal sections are rarely attempted at magnifications of above 1,500 diameters. In saying this I do not overlook the splendid results obtained by Sir R. A. Hadfield and Mr. Elliott and one or two others.

It is at times practically certain that more information could be read if enlarged magnifying power were available. As many of us know, this is particularly so in the alloy steels.

It need not be argued that as a matter of research it is desirable to utilise any such extension of our methods that becomes available.

Dominated by these ideals, I set out to test the possibilities in metallurgical work of what is called the super-microscope system. I endeavoured to do so with an open mind, whilst fully aware of the attitude which had been taken up by several microscopists with regard to the system as it stood up to that time, viz., about two years ago.

At that time I considered that such examples of work with the system as had come under my notice, with magnifications up to about 1,200 or 1,500 served only to show that there was something further to explore. If those results expressed the limit of its performance it would be of no great value from the point of view which I have indicated. Since evidently they did not—witness the fact that it had not then been applied with objectives of higher power than $\frac{1}{6}$"—a field therefore remained for investigation whose possibilities appeared too important to be ignored.

In the first instance the evidently minimum standard was adopted that:

With a primary objective of given N.A. the new system would be required to give results at least equal to those given by the existing eyepiece system.

If this were established, it would then be warranted to test the system at higher magnifications than were hitherto common.

Photographic results could alone be considered.

THE SUPER-MICROSCOPE SYSTEM.

The principle of the system consists, in essence, in replacing the usual eyepiece by a microscope (called the secondary).

This is made practicable by the interposition of a specially designed lens (called the collector).

The combination of collector and secondary microscope may be regarded as an attempt to constitute a superior principle in eye-piecing.

Photography is thus performed with the three lenses:—

Primary objective.

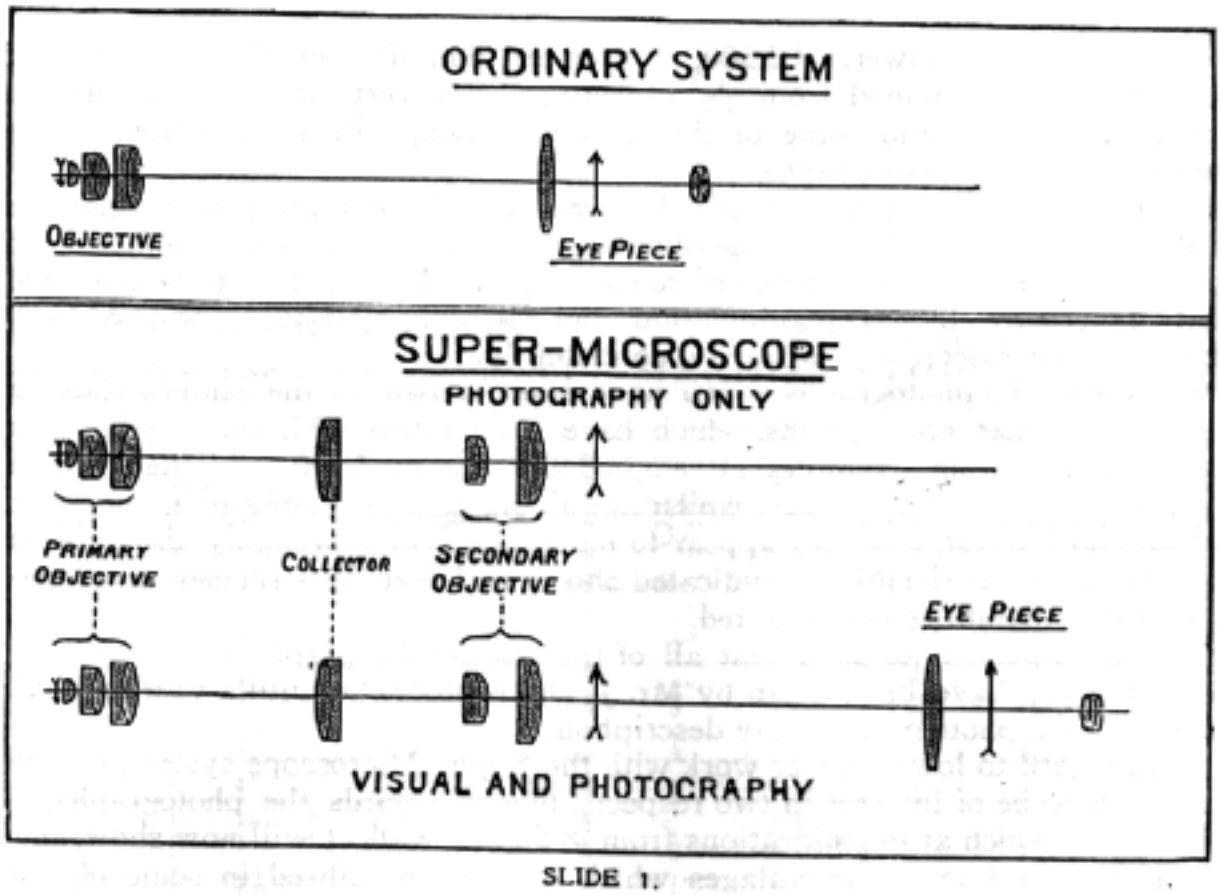
Collector.

Secondary Objective,
with, in some cases, the addition of an eyepiece.

In visual work the four lenses are used.

Typical sections comparing the ordinary and the super-microscope systems are shewn in slide 1.

The collector is in general used closer to the objective than the field lens of an eyepiece. Its design is such that the primary image formed above the collector is lower than in the ordinary microscope. Otherwise there is no fundamental difference between the collector and an eyepiece field lens.



SLIDE 1.

The secondary microscope lends itself to being made of high grade design, and in this respect is more advanced than the eye lens of an eyepiece.

RESULTS OBTAINED WITH THE SYSTEM.

Upon taking this matter up at the stage which I have mentioned existed about two years ago, my results with it are illustrated by the examples shewn in the next three slides.

Slide 2 is a typical result at X 500 with a $\frac{1}{6}$" objective and a projection eyepiece taken by the ordinary method. The same lenses give results whose critical quality can hardly be maintained above about X 750, and at X 1,000 they are heavily strained, (see slide 3).

No. 4 shows a result obtained with the same objective as in Nos. 2 and 3; and replacing the projection eyepiece by the super-microscope system—in this case the secondary objective was a 1".

Further examples at ×1,000 with a $\frac{1}{6}$" primary objective are shown in slides 5, 6, 7 and 8.

It was my opinion that results such as these showed sufficient promise to warrant further pursuit of the subject. Mechanically improved apparatus was produced, to which reference will presently be made, and the work with higher power primary objectives was then proceeded with.

With $\frac{1}{12}$" or 2 m/m objectives at ×1,500 results such as those shown in the succeeding slides were obtained. These are quite comparable with the results obtainable with the same objective used in the ordinary way.

This magnification is about the limit for critical definition with $\frac{1}{12}$" objectives used in the ordinary way. This is recognised in the ordinary approximate rule which regards about 1,000 times the numerical aperture as about the limit for critical definition.

It thus appears that just as with a $\frac{1}{6}$" so with a $\frac{1}{12}$" primary the super-microscope method gave results at least comparable with the ordinary method, and the trials with the super-microscope were, therefore pushed on with. A few examples at ×2,500 with $\frac{1}{12}$" primary objectives will next be shown.

It will be seen that several of these results are, for practical purposes, of critical definition; not quite so absolutely crisp as is possible at ×500 or ×1,000, but quite as good as is frequently accepted at those powers.

Beyond this power, ×2,500, it becomes doubtful whether such critical images can be obtained from $\frac{1}{12}$" objectives. Nevertheless, the results are consistently good and some of them, now shown, will be admitted to be thoroughly useful photographs.

In slide No. 21 at 3,500 it will be seen that the definition is comparable with any of those at 2,500. The obtaining of such excellence is sufficient to prove that the system is capable of remarkable work, and it is to be expected that experience in its manipulation and fairly favourable conditions will enable the microscopist to achieve it consistently.

Besides the photographs which have been shown by the lantern slides a number of other photographs, which have been taken with this system, are exhibited, including examples at ×5,000 and one at 7,500, all taken with a $\frac{1}{12}$" primary objective. These, whilst not of quite critical definition, are yet of substantial interest, and they appear to me to confirm thoroughly the opinion that the system is reliable as indicated above, and that even further investigation of its capabilities is warranted.

It is important to note that all of the photo-micrographs shown in the present paper have been taken by Mr. J. D. Jacobs, who until a year ago had never taken a photograph of any description.

In regard to lower power work with the Super Microscope system, I have found this to be of interest in two respects, first as regards the photographs, a selection of which at magnifications from ×500 to ×100 I will now show, and second in regard to the advantages which have been utilised in some of the apparatus to be described.

It has been mentioned that mechanically improved apparatus was made in order to effect the principle of this system.

The complete photographic microscope bench, suitable for research up to the highest powers, is shown in the next slide.

Whilst the investigation already described had reference to the development of the system for high power work, it appeared that it had certain potential advantages for medium and lower power work. These advantages have been incorporated in the works outfits, an example of which is shown here to-night.

The microscope is inverted, and the screen or plate is approximately on the bench level. The specimen is placed on top of the mechanical stage and requires no mounting or clamping. Thus far the microscope might have been either the ordinary or the super-microscope.

By the use of the super-microscope, however, the further advantage is gained that focussing by the secondary objective is sufficient, and for this purpose a coarse adjustment is all that is required.

Our investigations have shown that from x100 to x500 the advantages are in favour of the use of the super-microscope with this specialised outfit, and briefly summarised they are:—

(1) Obtaining comparatively high magnification from the given primary objective; this implies

(2) The advantages of longer working distance.

(3) Focussing without disturbance of either object or objective, and by a coarse movement instead of the usual delicate fine adjustment.

(4) Ease and rapidity of working as will be demonstrated.

With powers below x100, the ordinary arrangement of lenses gives suitable results, and under the circumstances the general mechanical arrangement of the apparatus is its chief recommendation.

It will be found as we have found in our investigations, that visual work is amply provided for by the substantial advance in convenience of the examination of the image upon the the screen.

I take this opportunity of expressing my thanks to Mr. F. Davidson and Mr. J. D. Jacobs, for their constant kindness and enthusiasm throughout the collaboration to which the present paper owes its origin.

VISUAL MAGNIFICATIONS

using an X 6 Eye Piece, measured by the Eikonometer.

Primary O.G.	Secondary O.G.	Magnification.
3"	1"	20 to 50
2"	1"	40 ,, 65
1½"	1"	70 ,, 100
⅜"	1"	200 ,, 220
¼"	1"	300 ,, 330
⅙"	1½"	400 ,, 500
⅙"	1"	700 ,, 800
⅙"	⅜"	1000 ,, 1250
1/12"	1½"	850 ,, 1000
1/12"	1"	1650 ,, 2000
1/12"	⅜"	2500 ,, 3250
Photographic 1/16"	1½"	With x 4 Projection Eye Piece. 2000 to 2500
Photographic 1/16"	1"	With x 7 Projection Eye Piece. 2500 to 3000
Photographic 1/16"	1"	3500 ,, 4500
Photographic 1/16"	1"	4500 ,, 5500

PHOTOGRAPHIC MAGNIFICATIONS

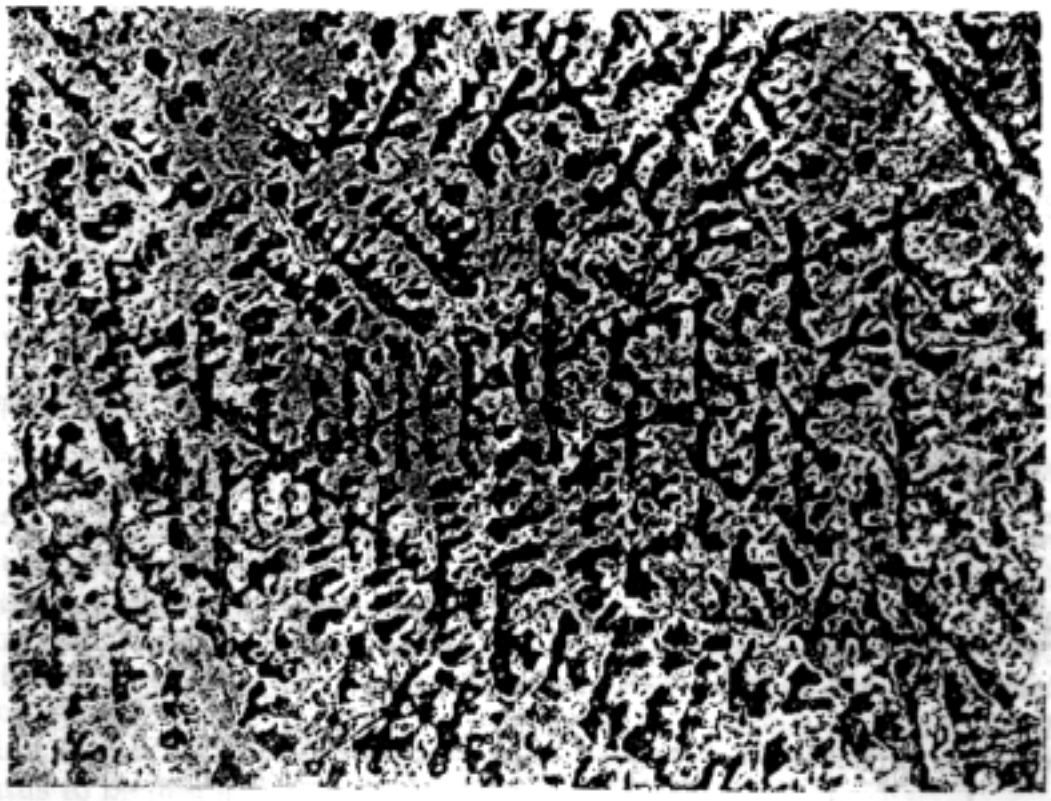
with full camera extension and *no* Eye Piece.

Primary. O.G.	Secondary O.G.	Magnification.
1"	1½"	65 ,, 75
⅔"	1½"	100 ,, 120
½"	1"	200
½"	⅔"	275
⅙"	1½"	350
⅙"	1"	500
⅙"	⅔"	750
⅙"	½"	1000
1/12"	1½"	1000
1/12"	1"	1500
1/12"	⅔"	2000
1/12"	½"	2500

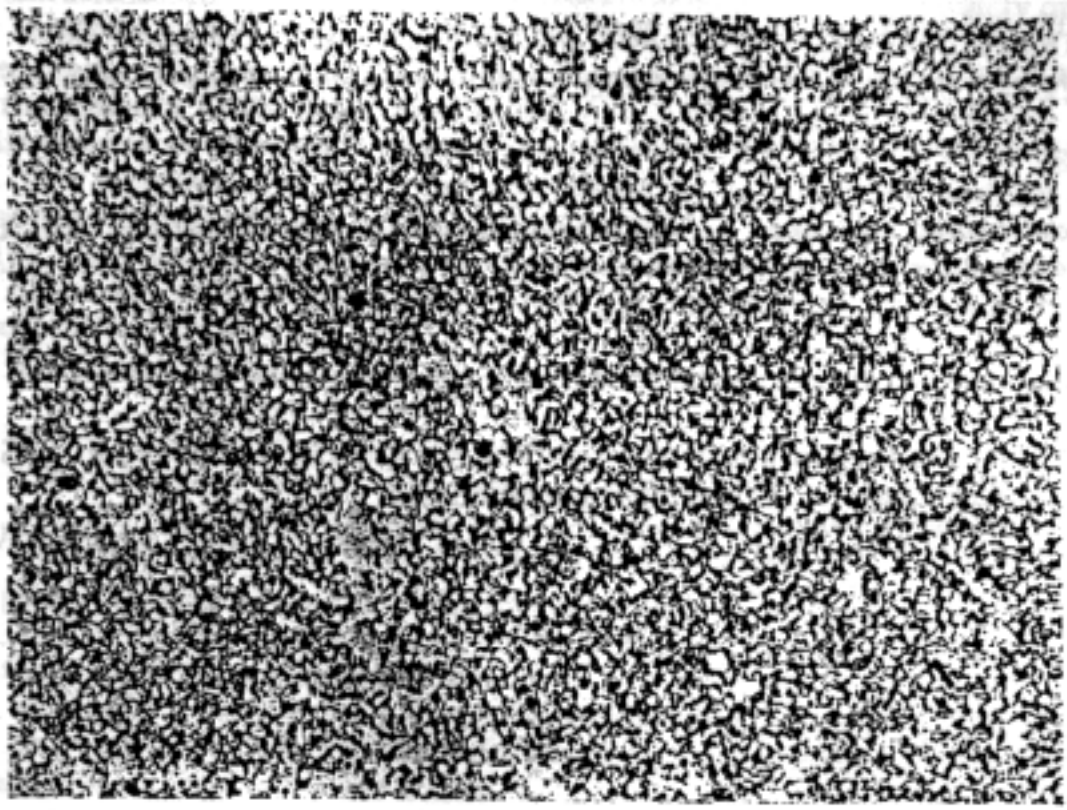
These tables can only be approximate as the magnifications will vary according to the make of the objectives one uses. Each user should therefore work out his own scale.

NOTE.—At the time of going to press we have under construction a Special Arc Lamp. If interested please advise.

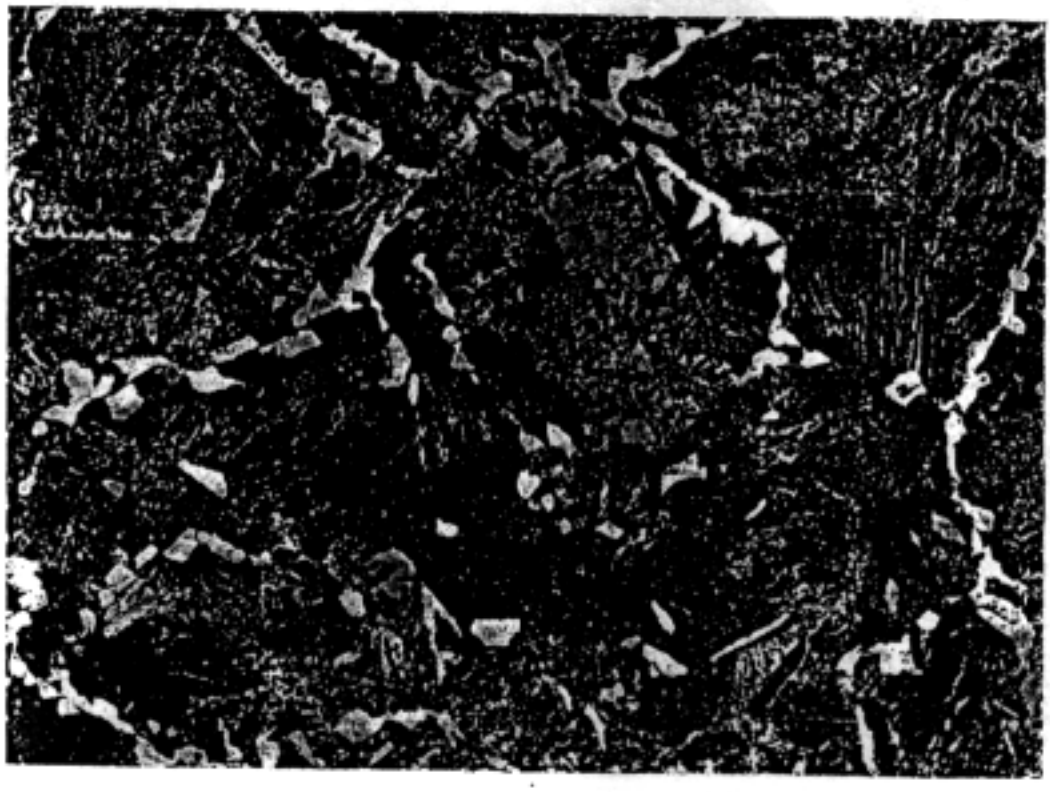
F. DAVIDSON & CO., 29, Great Portland Street, London, W.1.



BRONZE. X 100. Primary $\frac{2}{3}$". Secondary $1\frac{1}{2}$".



MILD STEEL. X 100. Primary $\frac{2}{3}$". Secondary $1\frac{1}{2}$".



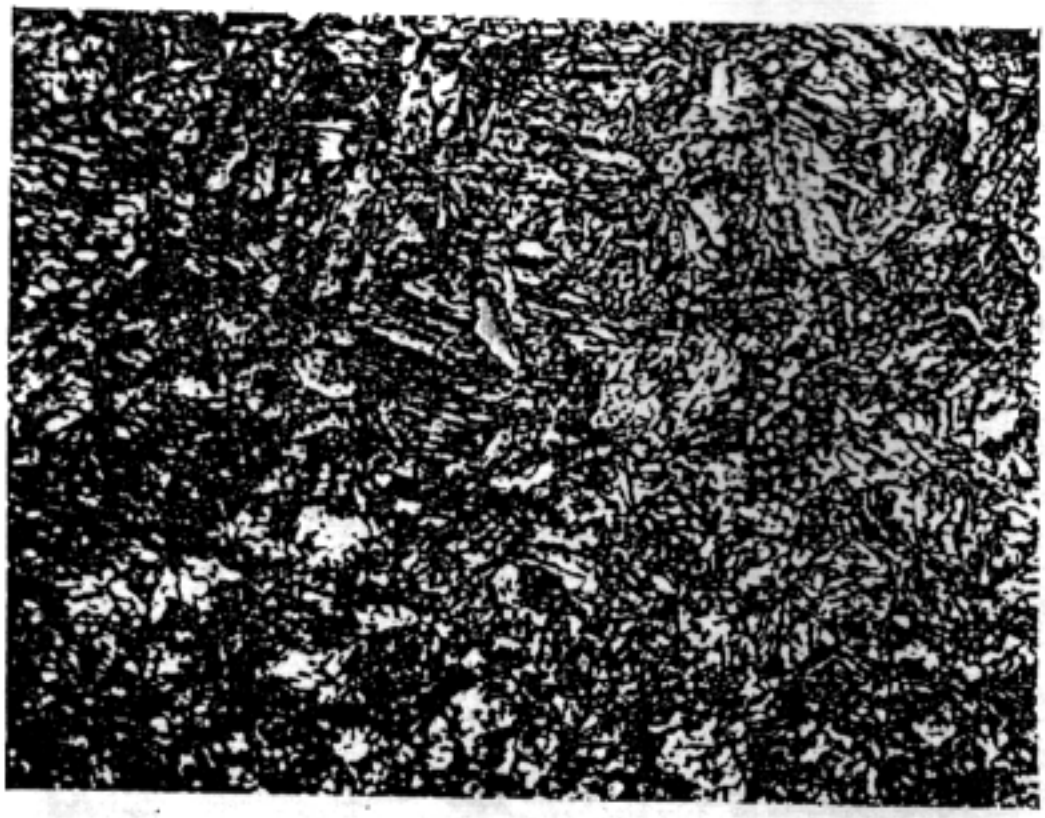
NICKEL STEEL FORGING. X 100. Primary $\frac{2}{5}$". Secondary $1\frac{1}{2}$".



NICKEL STEEL FORGING. X 250. Primary $\frac{1}{2}$". Secondary $\frac{2}{5}$".



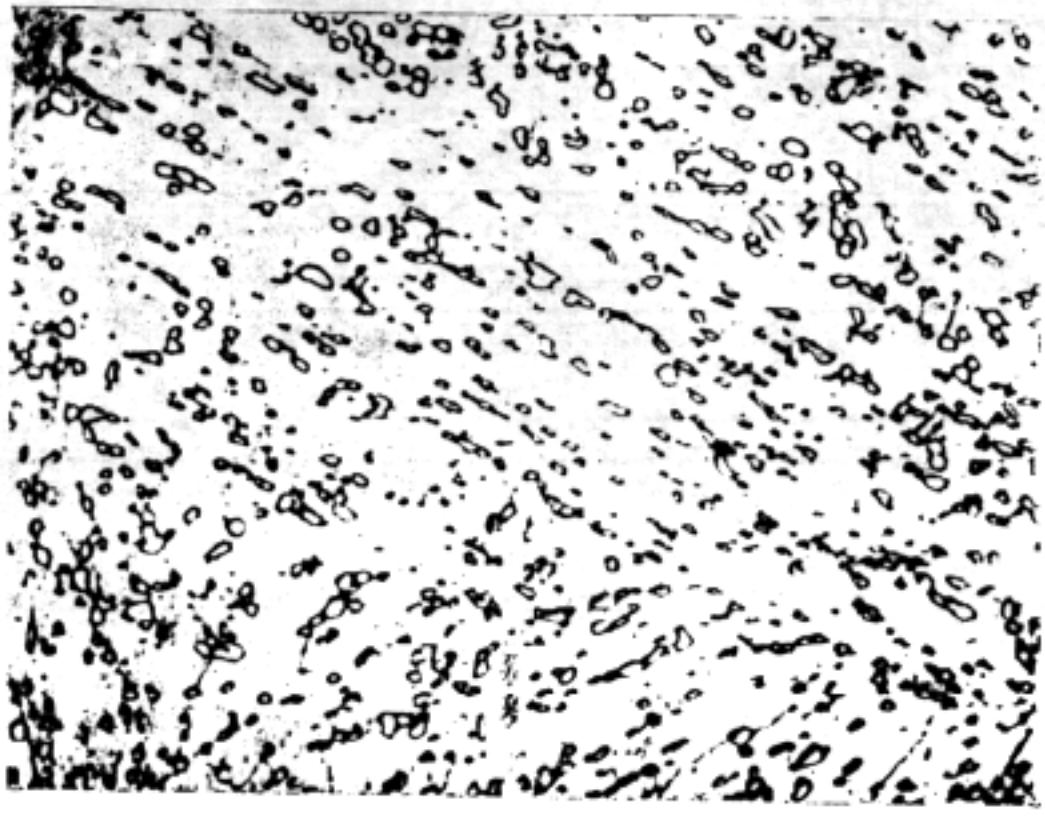
NICKEL STEEL FORGING. X 500. Primary $\frac{1}{6}$". Secondary 1".
(Slide No. 4.)



NICKEL CHROMIUM STEEL. X 1000. Primary $\frac{1}{6}$". Secondary $\frac{1}{2}$".
(Slide No. 7.)



CARBON STEEL. X 1,500. Primary $\frac{1}{12}$" (Fluorite). Secondary 1".



STAINLESS STEEL. X 2,500.

Primary $\frac{1}{12}$" (Fluorite). Secondary 1$\frac{1}{2}$" and X 4 Eyepiece.



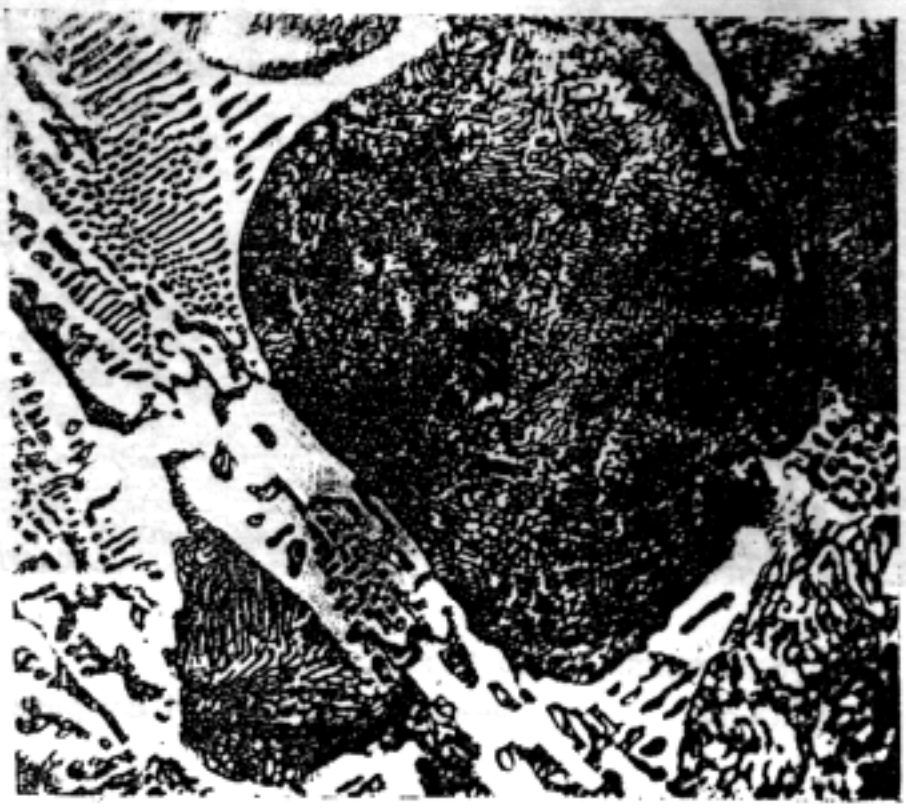
MAGNET STEEL. X 2,500. Primary $\frac{1}{12}$")Fluorite). Secondary $\frac{1}{2}$".



STAINLESS MILD STEEL. X 2,500.
Primary $\frac{1}{12}$" (Apo). Secondary 1$\frac{1}{2}$" and X 4 Eyepiece.



NICKEL STEEL FORGING. X 2,500. Primary $\frac{1}{1\frac{1}{2}}$" (Fluorite). Secondary $\frac{1}{2}$".



CAST IRON. X 1,500. Primary $\frac{\text{o}1\frac{1}{2}}{}$" (Fluorite). Secondary 1".

PRICE LIST.

	£	s.	d.
The "Davon" SUPER-METALAB, Fig 1	70	10	0
Complete with ½-plate camera in solid mahogany, and 2 double dark slides and 4 carriers for ¼-plate.			
For photographic magnifications ×50 to ×1,000, add—			
"Davon" 1½", 1", ⅔", O.G.s = 3 @ £1 18s. 0d.	5	14	0
"Davon" ½", £2 7s. 0d., ⅙" Fluorite O.G.,N.A. 0.82 £3 7s. 6d.	5	14	6
1 No. 2 Huyghenian Eyepiece, (for observation only)		9	0
	£82	7	6
For magnification up to ×2,500 add—			
1/12" Fluorite, O.G., N.A., 1.3	9	10	0
For magnifications beyond this add—			
Projection Eyepiece... ... ... each	3	7	6

A racking draw-tube is supplied so that observations can be made as with an ordinary microscope by replacing the "Collector" tube and "Secondary" with same.

The "DAVON" METAL WORKS CAMERA, Fig 2 (¼-plate), for rapid repetition work. Fixed focus for either ×100, 250, or 500	37	10	0
With 2 double dark slides and stand for illuminant, Made in solid mahogany. Please state what magnification is wanted.			

LANTERN BODIES FOR ILLUMINANTS.

	£	s.	d.
No. 271 Planished Steel, fixed front, height of optical centre 5¾", door opening on right side only. Fitted with 4" condenser and supplemental condenser with iris diaphragm (as in Fig 2)	8	5	0
No. 272 As above, but large enough to accommodate 500 c/p "Pointolite," etc. Centre 8½"	10	15	0
No. 273 Best quality mahogany, body lined planished steel, sliding brass front, door on both sides, 4" condenser and supplemental condenser with iris diaphragm. Centre 5¾"	11	10	0
No. 274 As No. 271, but in best quality planished steel ...	11	10	0

Self Illuminating Vertical Illuminator.

No. 730.



FIG. 3.

The ordinary method of illuminating etched metal surfaces is by means of a light focussed through a condensing system placed at right angles to the vertical illuminator on to the cover glass or prism which forms part of the latter. The difficulty of rapid and correct adjustment in order to get a uniformly illuminated field is well known.

With the illuminator illustrated it is always in its proper position with relation to the cover glass and is therefore under complete control. Every focussing movement of the microscope is accompanied automatically by the requisite movement of the illuminator.

IT CAN BE USED WITH ANY TYPE OF MICROSCOPE.

A special type of 4-volt lamp is supplied together with one of our "DAVON" batteries. This is the only type of dry battery which can be depended upon for a reasonably long life.

Complete **£3 10 6**, or without Battery, **£3 3 0.**

Spare Bulbs 1/9 each.



Short Focus MICRO-TELESCOPE,

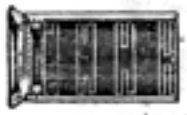
Complete **£9 18 0**

for the observation of fractures, etc.,

or with the "DAVON" Stand (see Brochure "A.")

£12 18 0.

Oak Case for either, £2 0 0



Attachment alone, 3½-in. Focus. No. 0494A. Price £3 12s. 6d.

It can be used at distances from 9" to 24" from the object. Magnification by visual comparison x90 and field $\frac{1}{10}$" full at the former, and x26 with a field of nearly $\frac{1}{2}$" at the latter distance. Intermediate magnifications and corresponding field at intermediate distances.

The attachment is made to fit the standard "Abbé" rim fitting in the understage of ordinary microscopes.

ADDITIONAL USE.

This is being used by the Metropolitan-Vickers Electrical Co.'s Research Department, as the telescope part of an apparatus to examine the bores of rotor and shaft forgings.