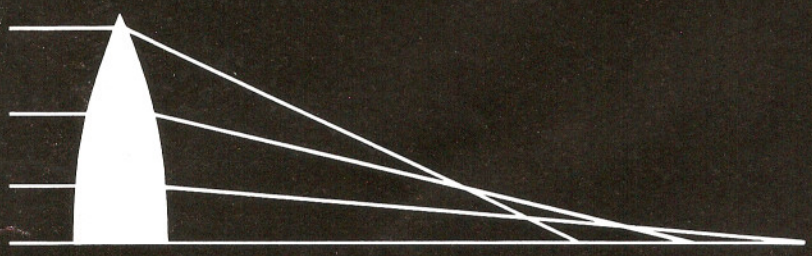
OPTICS FOR THE MICROSCOPE

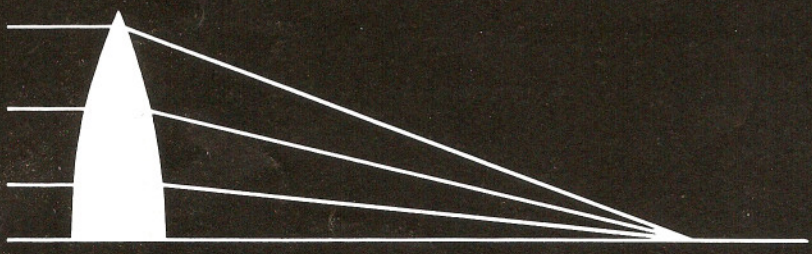
VICKERS INSTRUMENTS

Optics for the MICROSCOPE

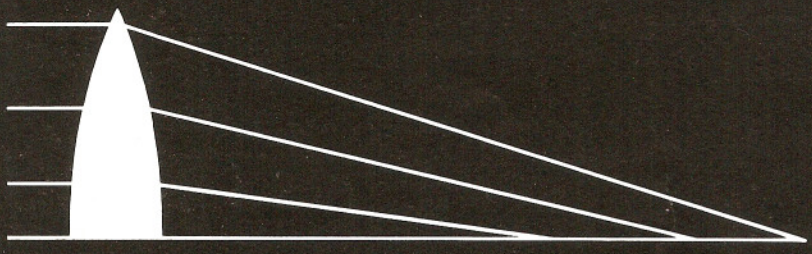
Microscope optical systems, like all lens systems, suffer from aberrations which make the images they form more or less imperfect, and we give here a short description of the chief aberrations affecting microscopes. The information is far from complete, and for further detail a text book should be consulted. The aim is to give an understanding of the different types of microscope objectives, eyepieces and condensers, and an indication of the type of performance to be expected from each.



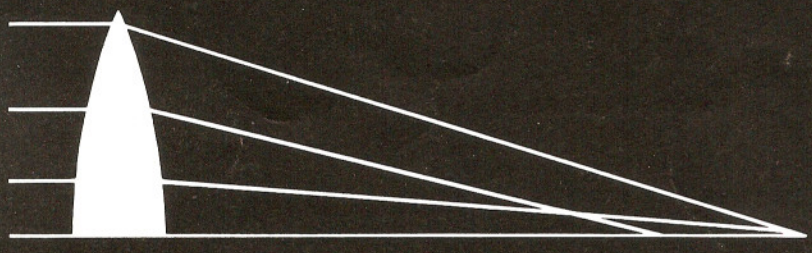
Uncorrected spherical Aberration.
Light from the outer zones of the lens is brought to a shorter focus than light from the zones near the axis.



Corrected spherical Aberration.
Light from all zones is brought to the same focus.



Overcorrected spherical Aberration.
Light from the outer zones is brought to a longer focus than light from the zones near the axis.



Zonal Aberration.
Light from the outer zone and from the zone near the axis is brought to the same focus, but light from the middle zone is brought to a shorter focus.

OBJECTIVES

Microscope objectives, which form the primary image of the object in a microscope, suffer from a number of aberrations. Ideally, a point of light in the object plane should be perfectly imaged as a point of light in the image plane, and if the object is regarded as consisting of an infinite number of points, then, if each is perfectly imaged, a perfect image of the object will be formed. In practice a point on the object is never quite perfectly imaged because of the various lens aberrations.

The aberrations can be divided into those which affect mono chromatic light and those which are caused by the dispersal of white light into the colours of the spectrum. And again, into those which affect objects in the middle of the microscope field and those which affect objects at the edge of the field.

AXIAL ABERRATIONS

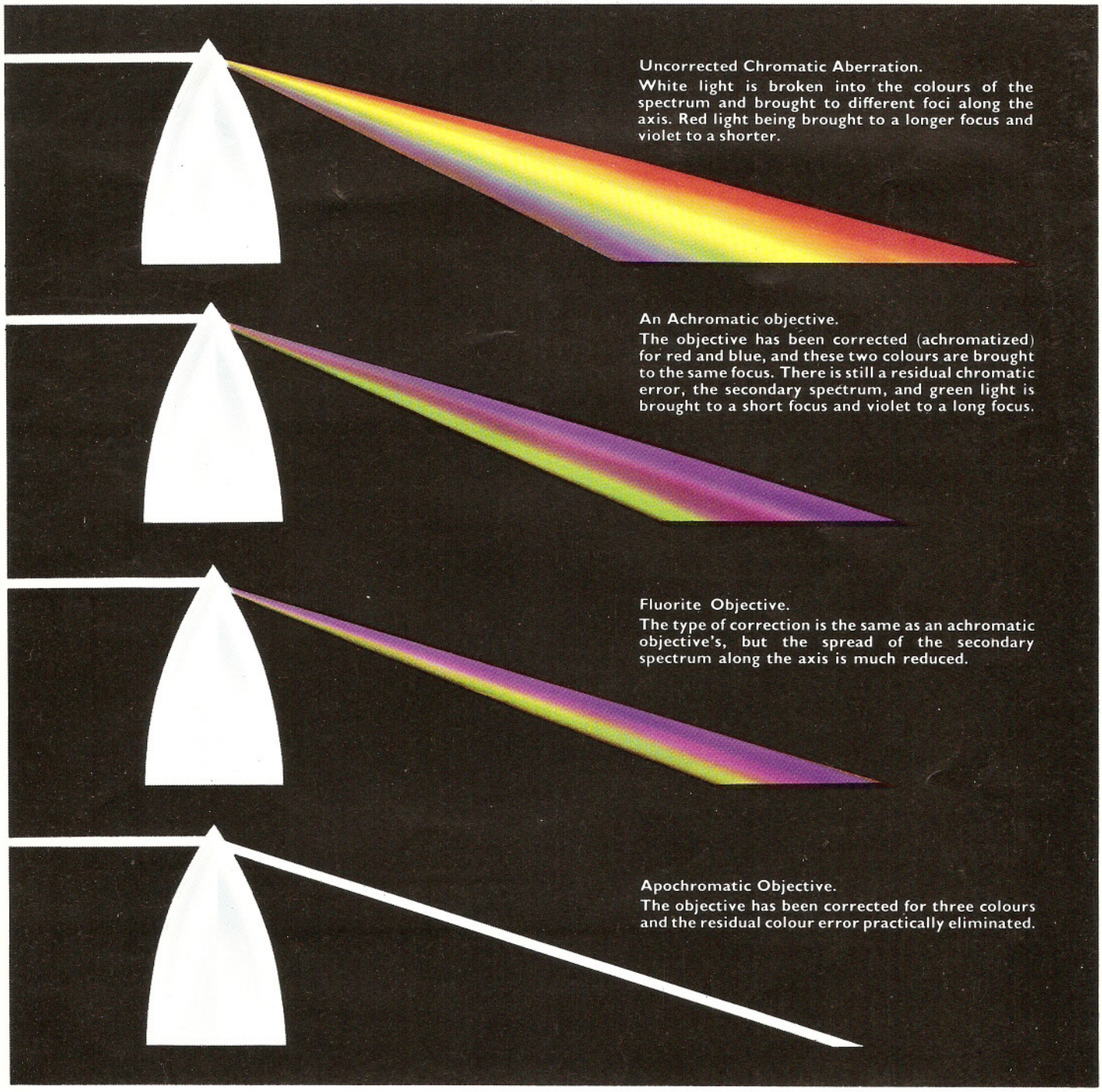
SPHERICAL ABERRATION

The principal mono chromatic aberration is spherical aberration. Different parts of the aperture of an uncorrected lens will focus light from a single object point into different image planes, light from the outer zones being brought to a shorter focus than light from the zones near the axis.

Spherical Aberration can be substantially corrected by the suitable construction and choice of glasses of a lens system, and it may sometimes be over corrected, in which case the rays from the outer zones are brought to a longer focus than those of the inner zone.

ZONAL ABERRATION

In practice spherical aberration cannot be corrected entirely and there are usually some zones with a very slightly different focus from the rest. This residual aberration is called zonal aberration.



The colour spreads are for illustration only and are much exaggerated

CHROMATIC ABERRATION

The next aberration to consider is chromatic aberration. When white light is refracted by glass or other substances the blue end of the spectrum is refracted more than the red. This effect can be corrected by suitable design, but there is always a small chromatic error left which is called secondary spectrum. In an achromatic objective the red and the blue light can be brought to the same focus, but green light will then be brought to a slightly shorter focus and violet light to a longer focus.

This residual, or secondary, spectrum can be considerably reduced by using fluorite in the design, though this adds to the cost of the objective.

The effect can be reduced still further by more complex constructions, also using fluorite, in the apochromatic objectives. These objectives bring not only the red and blue light (2 colours) to one focus, but correct for three colours. The residual colour aberration, now known as tertiary spectrum, is very small. In addition, apochromatic objectives correct the spherical aberrations for two colours instead of for one, as is the case with achromatic objectives.

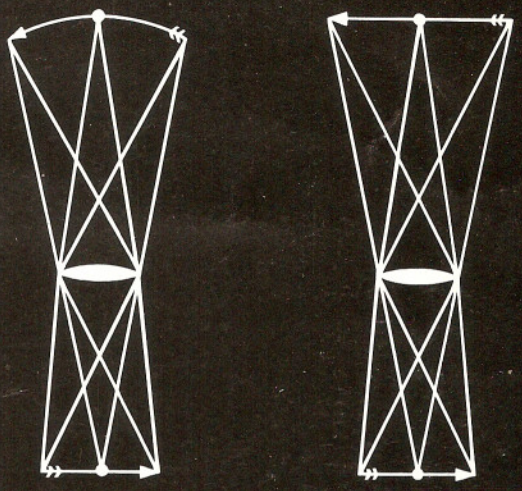
OFF AXIS ABERRATIONS

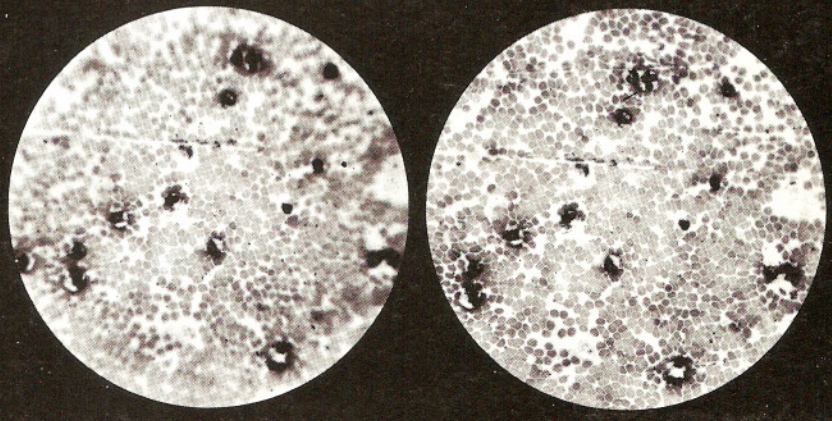
FIELD CURVATURE

Field curvature is the inability of a lens system to form a flat image of a flat object. Most microscope objects are substantially flat, but the image of them in the eyepiece or on a photographic plate is curved so that only part of the specimen is sharp at any one time. The image may appear to be part of a sphere* in shape and this aberration is sometimes referred to, quite incorrectly, by microscope users as "spherical aberration." The amount of field curvature varies according to the power and Numerical Aperture of the objective. High power objectives with high N.A. will have more field curvature, and low power objectives with low N.A. will have less. In general, when the power is above x10 field curvature will become obtrusive. The Vickers Microplan objectives are designed to minimise this error and these objectives have almost flat fields so that practically the whole of the image of a flat object appears in focus at once. The Microplan objectives are also free from Coma and Astigmatism. (See next paragraph.)

*In fact it is not spherical but a more complex shape.

Field Curvature.
Most objectives produce a curved image of a flat object. Microplan objectives produce an almost flat image of a flat object so that the whole field appears in focus at once.





Malarial human blood with normal x40 objective left and x40 Microplan objective right.

COMA

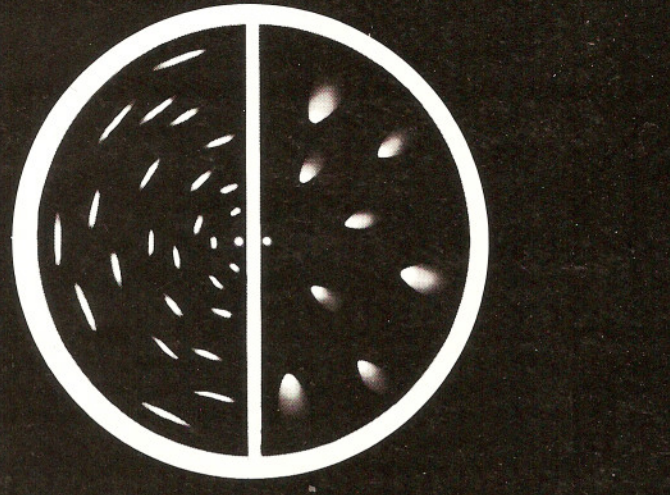
Coma is the aberration which causes a point object, such as a pinhole in a sliver film, to be imaged with a flare like the tail of a comet to one side of it radial to the centre of the field. The flare may be outward (outward coma) or inward (inward coma).

Occasionally coma is seen in the centre of the field, but in this position it always indicates either faulty manufacture or that the objective has been damaged.

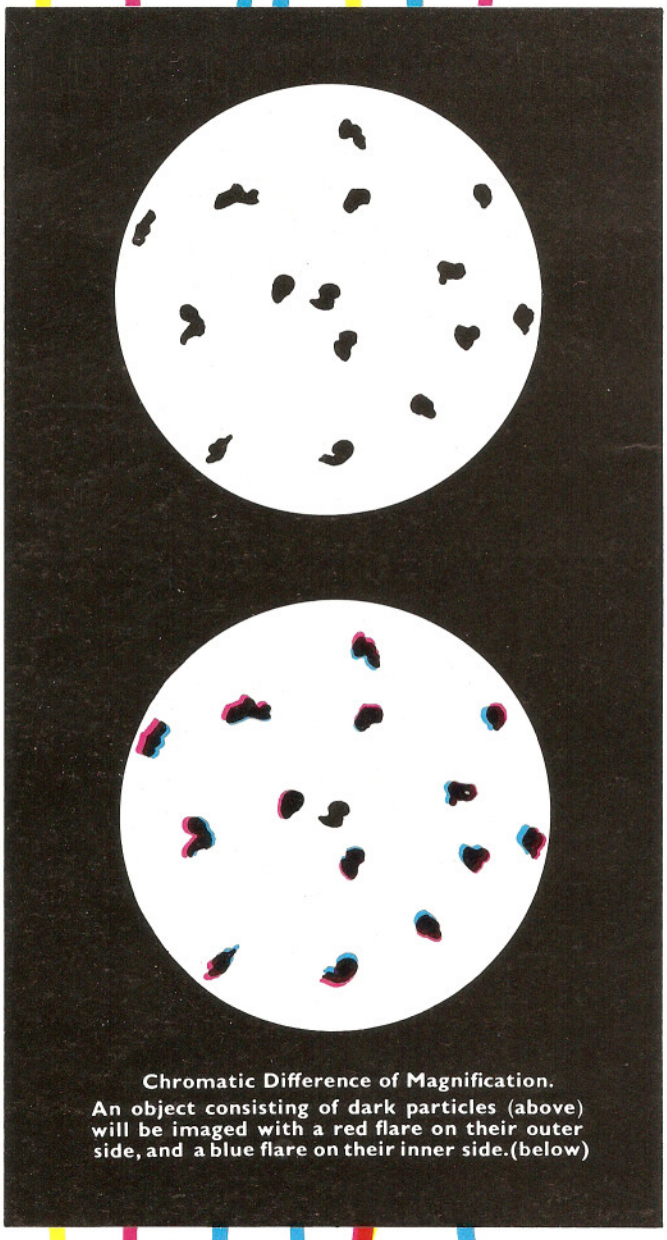
ASTIGMATISM

When astigmatism is present a point on the object will have two foci, one above the other, but each, instead of being a perfect point, will be a line. The two focal lines will be at right angles to each other.

Astigmatism may also be seen in the centre of the field but then, like coma, it always indicates faulty manufacture or damage to the objective.



Right Coma. A point is imaged with a flare on one side.
Left Astigmatism. A point is imaged as a line. There will be another image at a slightly different focus which will be another line at right angles.



Chromatic Difference of Magnification.
An object consisting of dark particles (above) will be imaged with a red flare on their outer side, and a blue flare on their inner side.(below)

CHROMATIC DIFFERENCE OF MAGNIFICATION

Nearly all objectives which have the constructions universally used in higher N.A. objectives suffer from this aberration, which simply means that the objective has slightly different magnifications for different colours of the spectrum. The magnification is greatest for violet and blue and least for red. This means that a dark object near the edge of the field will have a red fringe on its outer side and a blue fringe on its inner side, and a bright object on a dark field will show the reverse effect.

Chromatic Difference of Magnification is not corrected in the objective but is corrected by using an eyepiece which has an equal and opposite error, a Compensating Eyepiece. It is a common misconception that Compensating Eyepieces (see later in this leaflet) are only to be used with Apochromatic or Fluorite objectives. This is quite untrue and most objectives of x40 and over are improved by the use of compensating eyepieces. As most low power objectives have no chromatic difference of magnification the use of compensating eyepieces would introduce this aberration in a negative form. However, to avoid the necessity of changing eyepieces when low power objectives are used some low power objectives (e.g. the x10 and x20 Microplan objectives) have chromatic difference of magnification introduced into them.

MAGNIFICATION AND NUMERICAL APERTURE

The magnification of an objective is the ratio of the size of an object to the size of the image of that object formed by the objective in the microscope tube, e.g. 1:40 or x40. The total magnification of the microscope will be the objective magnification multiplied by the eyepiece magnification times any other magnifying system in the microscope, such as a magnification changer or a binocular head with a magnification factor.

It should be noted that the resolution of the microscope, that is, its ability to resolve fine details, is quite independent of the magnification. This is dependent on the Numerical Aperture, or N.A., of the objective being used, and the magnification need only be sufficient to disclose the detail which is being resolved. It is usually considered that magnifications greater than 1000X N.A. of the objective being used are unnecessary (empty magnification).

IMPORTANCE OF USING MICROSCOPE OBJECTIVES CORRECTLY

It is only possible to correct miscroscope objectives for certain fixed conditions of use, and any variation from those conditions will impair the performance.

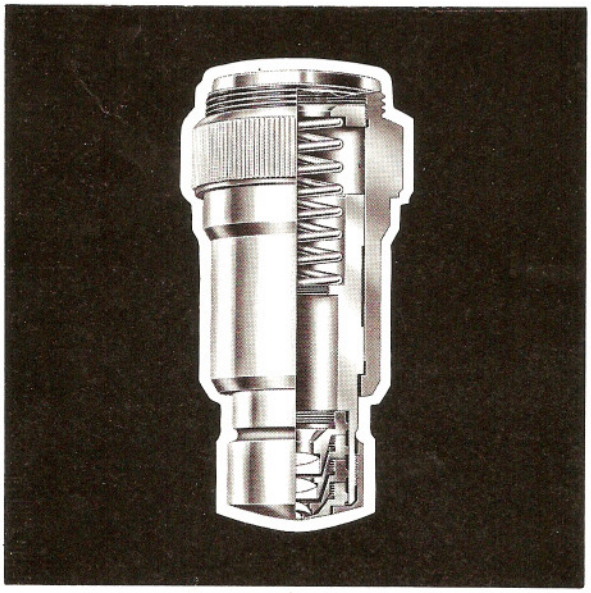
Vickers objectives are corrected for use with a coverglass on the specimen 0.18 mm. thick, and this will include any mounting medium between the specimen and the underside of the coverglass. They are corrected for cover glasses with refractive index Nd=1.524 and dispersion V= 57 as supplied by Chance-Pilkington and others. The objectives are corrected for a mechanical tube length, i.e. objective shoulder to eyepiece shoulder, of 160 mm. Variations from any of these conditions will impair the performance of the objectives. All the objectives listed have a 44 mm. body length.

IMMERSION OIL

Vickers oil immersion objectives are corrected for a coverglass 0.18 mm. thick on the specimen, made of glass with refractive index nd=1.524 and dispersion V= 57, and for use with immersion oil of nd=1.524 and V=44. It will be noticed that it is not possible to obtain an oil whose characteristics exactly match that of the coverglass so that if no coverglass is used, as is common when looking at smears, the optical properties of the space between the objective and the object will have changed and the performance will be affected. So critical can these conditions be that when objectives for metallurgical microscopes (where no coverglass is used) are being adjusted in the factory the immersion oil must be temperature controlled as its optical properties vary enough with room temperature to affect the performance.

There may sometimes be good reasons why it is not always possible or convenient to use the objectives under the precise conditions for which they were designed, but every effort should be made to adhere to these conditions where possible, and it should be realised that departure from the ideal conditions will always more or less impair the optical performance.

When required it is sometimes possible to adjust objectives specially for non-standard conditions of use, e.g. a special coverglass thickness, but this will usually involve an increased cost.



TYPES OF OBJECTIVES

ALL VICKERS OBJECTIVES

of 100x, 40x and 20x have sprung receding mounts so that there is no possibility of the specimen or the objective being damaged during focusing, and are bloomed with anti-reflection films. Objectives corrected for infinity tube length for the M55 Microscope and strain-free objectives for polarizing microscopes are not dealt with in this leaflet.

ACHROMATIC OBJECTIVES

These are the objectives most in use, and their performance is quite adequate for the majority of purposes. They are made in three types.

For objects covered with a 0.18 mm. thick cover glass.
For phase contrast microscopy on covered objects.
For opaque objects, corrected for no cover glass.

The latter are for use chiefly on metallurgical microscopes.

	N.A.	For use with cover glass	Phase Contrast	For use without cover glass	for Trilux Condenser
3 x	0.1	M022011	—	M022011	—
5 x	0.15	M022111	—	M022111	—
10 x	0.25	M022311	M022315	M022311	M022319
20 x	0.5	M022411	M022415	M022412	M022419
40 x	0.65	M022511	M022515	M022512	M022519
40 x	0.85	M022911	—	M022912	—
100 x oil immersion	1.30	M022611	M022615	M022612	M022619

MICROPLAN OBJECTIVES

These objectives have flat fields free from coma and astigmatism. They have achromatic type of colour correction, and have smaller working distances than achromatic objectives. It is recommended to use compensating eyepieces with Microplan objectives. They are made in three types as are the achromatic objectives.

	N.A.	For use with cover glass	Phase Contrast	For use without cover glass	For Trilux Condenser
10 x	0.25	M025111	M025115	M025111	M025119
20 x	0.5	M025411	M025415	M025412	M025419
40 x	0.7	M025211	M025215	M025212	M025219

FLUORITE OBJECTIVES

These objectives have improved colour correction and a very high standard of performance on the axis.

	N.A.	For use with or without cover glass	Phase Contrast	For Trilux Condenser
50 x oil immersion	0.95	M023611	M023615	M023619
100 x oil immersion	1.30	M023511	M023515	M023519

APOCHROMATIC OBJECTIVES

These objectives have the highest standard of axial performance.

	N.A.	For use with cover glass	Phase Contrast	For use without cover glass
10 x	0.30	M024011	M024015	M024011
20 x	0.65	M023911	M023915	—
40 x	0.95	M023811	—	—
80 x	1.32	M023711	—	M023712

LONG WORKING DISTANCE OBJECTIVES

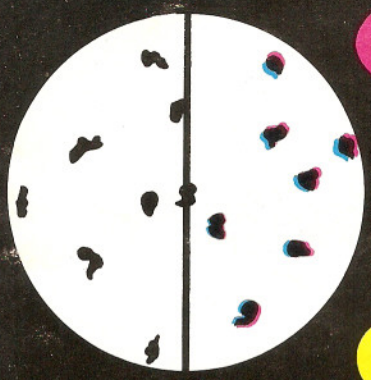
These objectives increase the working distance to 12.8 mm.

	N.A.	For use with cover glass
40 x	0.57	M022547

	N.A.	Phase Contrast
40 x	0.57	M022545

Lens cells for objectives are centred and turned on special purpose high precision machines designed by ourselves.

EYEPIECES



Chromatic difference of magnification (right) is corrected by compensating eyepieces producing a colour free image (left).

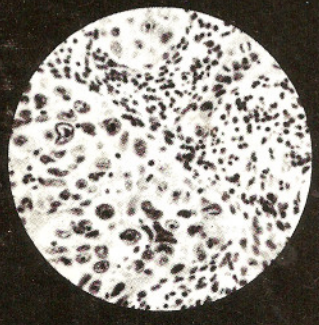
Eyepieces are supplied singly for monocular instruments or in pairs for binocular instruments. It is very important that eyepieces for binocular microscopes should be accurately paired so that they are precisely centred, of equal magnification, and equal apparent field, if eyestrain is to be avoided. When they have been so selected Vickers paired eyepieces are engraved with similar numbers so that the pairs will not get accidentally separated.

HUYGENIAN EYEPIECES

Huygenian Eyepieces are used in most simple and student microscopes as they are very economical and give a perfectly adequate performance for many purposes.

	Single	Pairs
6 x	M040100	M040120
8 x	M040700	M040720
10 x	M040300	M040320

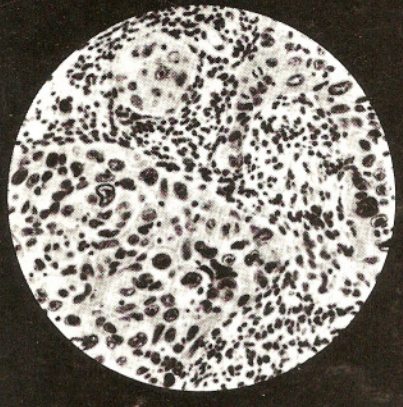
COMPENSATING EYEPIECES



As explained earlier, most higher powered objectives suffer from chromatic difference of magnification, which is corrected by the use of compensating eyepieces which have equal and opposite chromatic difference. This does mean, however, that when an objective with no chromatic difference of magnification, such as low power objectives, is being used, or when there is a graticule such as a scale in the eyepiece, the image seen will be strongly coloured. An exception is our x20 Compensating Eyepiece where a scale can be used as much of the compensation is achieved by a lens system below the scale.

	Single	Pairs
6 x	M041100	M041120
8 x	M041700	M041720
10 x	M041300	M041320
20 x with focusing micrometer	M041602	M041622

COMPLAN EYEPIECE



Above. Field of view with x5 Huygenian Eyepiece.

Centre. Field of view with x10 Huygenian Eyepiece.

Lower. Field of view with x10 Complan Eyepiece. Though the magnification is x10 the field covered is the same as the x5 Huygenian.

The x10 Complan eyepiece is a new introduction of some importance. It is a compensating eyepiece with an exceptionally wide field, and exceptionally long eyepoint, a so-called Comfort Eyepiece. Although the magnification is x10 the field of view is equal to that of a x5 Huygenian eyepiece. As the principal purpose of using low power eyepieces is to obtain a wider field of view, and as the x10 Complan Eyepiece has practically as large a field as it is possible to achieve in the standard microscope eyepiece tube diameter, a lower power eyepiece is unnecessary when an instrument is equipped with x10 Complan eyepieces.

The eye distances of the x10 Complan eyepiece is long enough to allow most spectacle wearers to continue to wear their glasses when using the microscope. Screw on eye cups are supplied with the Complan x10 eyepieces to help locate the users eyes correctly when spectacles are not being worn.

This eyepiece is a great advance and provides a new standard of microscope performance and comfort, especially when used with Microplan objectives.

Some users find a little practice is needed with eyepieces of such wide field, as the eye must be accurately located. A screw-in stop is provided to reduce the field if any difficulty is experienced. Even with this stop in the field is still wide in comparison with most eyepieces. The stop can also be used to clamp a graticule or scale into position.

	Single	Pair
Complan Eyepiece 10x	M041301	M041321

MICROMETER EYEPIECE

This is a Kellner positive type eyepiece which will accommodate a graticule in the focal plane so that it appears super-imposed on the image in the microscope and features of the object can be measured. The Micrometer Eyepiece can be adjusted to focus the scale precisely. The graticules can be easily interchanged.

10x Kellner micrometer eyepiece (single) M042302

10x Kellner micrometer eyepieces (pair) M042322

SCREW MICROMETER EYEPIECE

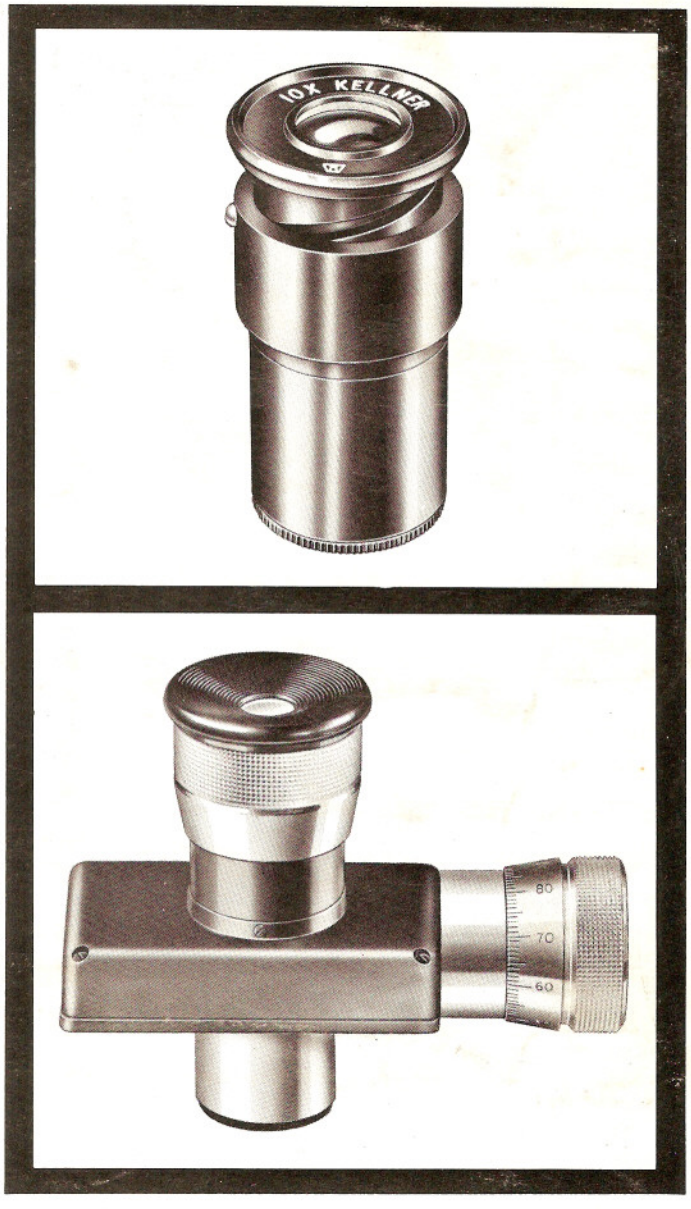
In this eyepiece a fine line is made to traverse the field of view by means of an accurate screw. The drum controlling the movement is divided into 100 parts, each representing 0.01 mm. displacement of the line. The fixed divisions provided on a graticule in the field of view indicate whole revolutions of the drum and are not intended for the purpose of direct measurement. Evaluation is made by comparison with a stage micrometer, as with fixed graticule eyepieces. The tube to fit into the microscope is tapered to prevent rotation in the drawtube.

Screw Micrometer Eyepiece M011525

POINTER EYEPIECE

The Pointer Eyepiece is a 8x Huygenian eyepiece with a pointer at its focal plane. This can be used to point to any feature in the field of the microscope to which one wants to draw attention.

Pointer Eyepiece 10x M040306



GRATICULES

EYEPIECE GRATICULES

These are accurately divided scales on glass discs to fit Vickers eyepieces with a graticule location diameter of .75 in.

1 mm. squares, thick lines at 5 mm. squares	M047554
Porton globe and circle	M047575
1 cm. square, divided into 0.1 mm. squares, thick lines at 0.5 mm.	M047580
1 cm. divided into 100 parts	M047020
1 cm. divided into 100 parts with crosslines	M047588
Particle size analysis. B.S. 3625	M047001
Crosslines	M047010
Graticules for 20x compensating eyepiece only:	
0.5 cm. divided into 50 parts	M047025
Particle size analysis. B.S. 3625	M047005

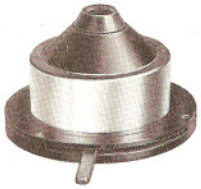
Special types of graticules for dust counting, etc., can be supplied to order.

STAGE MICROMETERS

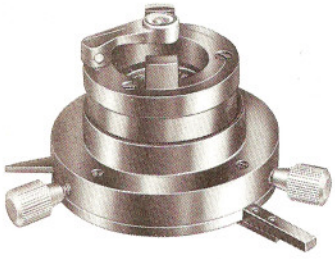
These are comprised of very accurate scales and are used chiefly for calibrating the graticule in the eyepiece prior to using the latter for making measurements on the actual specimen. The 1 mm. scale is a very useful adjunct in photo-micrography for measuring the image of a stage micrometer projected on to the focussing screen for the determination of magnification.

Stage micrometer 1 mm. divided into 100 parts on glass	M001586
Stage micrometer 1 mm. divided into 100 parts on metal	M151290

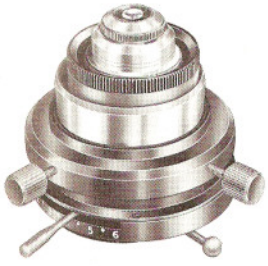
CONDENSERS



Abbe Condenser

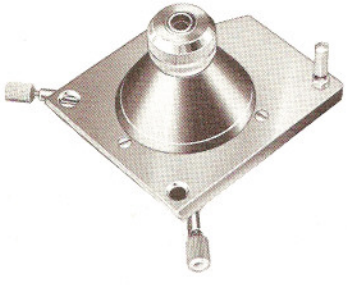


Swing out top lens Condenser

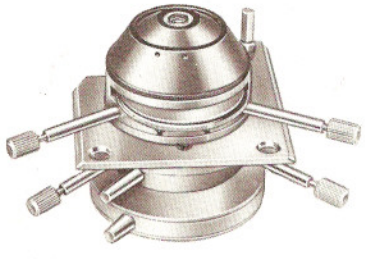


Achromatic Condenser

Aplanatic Condenser



Dark ground Trilux Condenser for the Patholux



Trilux Condenser for the Patholux

Vickers condensers are supplied in two forms; on sliding changers to fit the substage of Patholux microscopes, or to fit the standard R.M.S. substage sleeve fitting as used in the other microscopes. Each condenser except the Dark Ground condenser, has an iris diaphragm. All condensers for the Patholux are in centring mounts.

ABBE CONDENSER

The simplest and least expensive substage condenser is the two lens Abbe. It is entirely suitable for student microscopes and other microscopes where the most critical work is not to be done.

Abbe condenser	M150715
Abbe condenser for PATHOLETTE	M160650
Abbe condenser for PATHOLUX	M320930

SWING OUT TOP LENS CONDENSER

This condenser is of the Abbe type, but the top lens can be swung to one side so changing the condenser from a short focal length high aperture one into a longer focal length low numerical aperture condenser, and so allowing the field of view to be filled with low power objectives without having to change the light source or de-focus the condenser. This facility is a great convenience on any type of microscope.

Swing-out condenser without centring mount	M150430
Swing-out condenser with centring mount	M220450
Swing-out condenser for PATHOLUX	M320870

ACHROMATIC CONDENSER

The Achromatic Condenser is corrected for chromatic and spherical aberration, so that a sharp image of the field iris is possible and stray light, due to condenser aberrations, which might impair the contrast of the microscope image, is avoided.

The condenser for the Patholux has a swing in supplementary lens which allows the field to be filled when low power objectives are used. The condenser is not perfectly corrected when this lens is swung in.

Achromatic condenser in centring mount	M150805
Achromatic condenser for use with built-in illuminator	M150807
Achromatic condenser for PATHOLUX	M320800

APLANATIC CONDENSER

This system uses a four-lens construction which results in a greatly improved correction for spherical aberration and a reduction in chromatic aberration. It is very suitable for most routine microscopy.

Aplanatic condenser in centring mount	M220263
Immersion aplanatic condenser for PATHOLUX	M320840

DARKGROUND CONDENSER

The Darkground Illuminator provides a hollow cone of light between the apertures 1.25 and 1.33, suitable for darkground illumination with high power objectives not exceeding N.A. 11. Objectives with apertures in excess of this figure must be stopped-down by means of a funnel stop. The illuminator must be used in immersion contact with the slide, the thickness of which should not vary beyond the limits 1.2 to 1.4 mm. The image of the light source which is formed is exceedingly small and the illuminator must be exactly centred.

Dark ground condenser in centring mount	M150810
Dark ground condenser for PATHOLUX	M320910

TRILUX CONDENSER

The Trilux condenser, which is available for the Patholux microscopes, allows light field, dark field and phase contrast microscopy to be done with the same condenser, changing from one type of microscopy to another simply by turning a knurled ring on the condenser.

It is necessary to use phase contrast objectives with this condenser to obtain phase contrast effects, but the condenser can also be used with normal objectives for light field and dark field microscopy.

The Trilux condenser gives light field, dark field and phase contrast microscopy with full efficiency and is in no sense a compromise.

The light field illumination is full cone and not annular, and the substage iris diaphragm can be used in the normal way. The phase contrast is the annular type and gives a very high standard of performance. Phase contrast objectives must of course be used and these are normally fitted with phase plates with 70% absorption which is the most suitable for most objects, but objectives can be fitted with phase plates with higher absorption for objects with low phase retardations if required. The dark field part of the condenser is a system employing reflecting and refracting surfaces and is very highly corrected, and gives a performance comparable in every way with the usual bicentric or cardioid dark field condensers. It will give dark field with objectives up to N.A. 0.70 when dry and up to N.A. 1.10 when oil immersed. For light field or phase contrast the condenser can be used with or without oil immersion.

EASE OF OPERATION

The changeover of illumination with the Trilux is done by rotating a wheel of stops below the condenser which introduces the appropriate form of illumination. For light field, light is allowed to enter the central part of the condenser. For phase contrast a ring of light appropriate to the aperture of the phase ring for each objective enters the central part of the condenser. For dark field a ring of light enters the outer reflecting part of the condenser. Each diaphragm registers in position with a click.

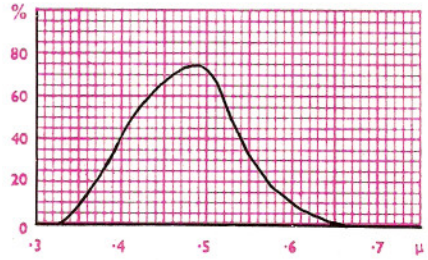
Trilux condenser for PATHOLUX **M320720**

FILTERS (2 mm. thick)

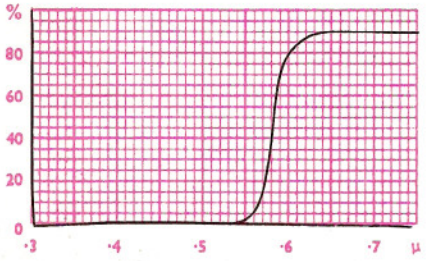
Note: M151538 is 3mm. thick

		2″ x 2″ Filters	32 mm. dia. Filters	Approx. Integrated Visible transmission
Light red	(OR2 or RG1)	M001759	M151536	21 %
Orange	(OY1 or OG2)	M001760	M151538	42 %
Yellow	(OY4 or OG4)	M001761	M151539	84 %
Dark green	(OGR1 or VG9)	M001763	M151535	22 %
Daylight blue	(OB8 or BG34)	M001757	M151540	24 %
Deep blue	(OB10 or BG12)	M151532	M151527	0.9 %
Turquoise	(OB2 or BG23)	M001762	M151545	22 %
Neutral	(ON10 or NG9)	M001764	M151534	7 %
Neutral	(ON11 or NG4)	M001758	M151537	19.7 %
Heat absorbing	(HA3 or KG1)	M505608	M151533*	—
Ground glass		M001765	M151547	—
Heat absorbing	(HA3 or KG1)	—	1.225″ dia. M720265†	—

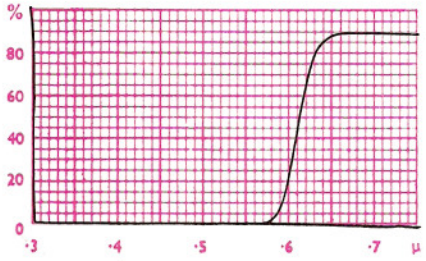
* M151533 is an untoughened heat filter for use with low power illuminators.
† M720265 is a toughened heat filter for use with high intensity illuminators.



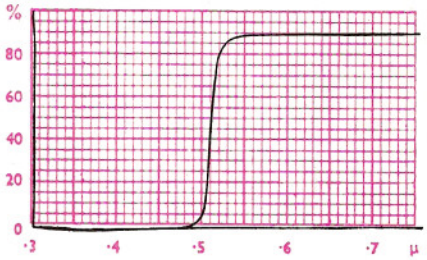
Turquoise



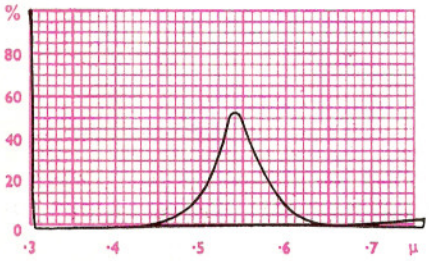
Light Red



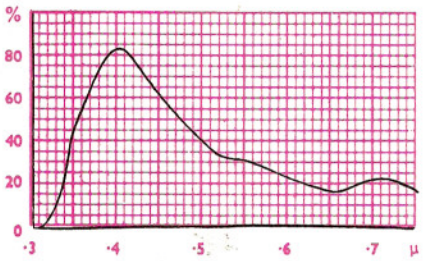
Orange



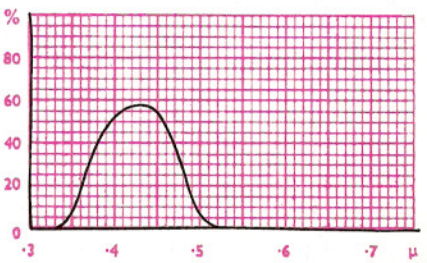
Yellow



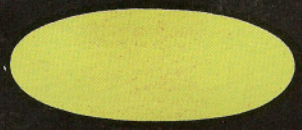
Dark Green



Daylight Blue



Deep Blue





VICKERS LTD.

VICKERS INSTRUMENTS

HAXBY ROAD · YORK
York 24112

PURLEY WAY · CROYDON
Croydon 3845

VO/1 Printed in England by Dunkeld Press Ltd., Oxted. Surrey 4/65