TELEPHOTOGRAPHY

CYRIL F. LAN-DAVIS,
F.R.P.S.

TELEPHOTOGRAPHY

SOME USEFUL BOOKS

LIGHT CAMPING KIT, AND HOW TO MAKE IT. By James H. Wood. With 50 Diagrams and Illustrations. Cloth, 1/- net (postage 1½d.).

"Should prove useful to beginners who contemplate making their camp kit at home. It is thoroughly practicable and ably and clearly illustrated."—*Camping*.

FIRST STEPS IN PHOTOGRAPHY. Full Instruction in the Simplest Terms for the Beginner. By J. C. H. Wallsgrove. *Fifth and Revised Edition.* Crown 8vo, paper, 6d. net (postage 1d.).

PHOTOGRAPHY: A Manual for Beginners in the Art and Practice of Photography. By Rev. A. H. Blake, M.A. With Illustrations. *Third Edition.* Crown 8vo, cloth, 1/- (postage 3d.).

HOW TO USE A CAMERA. A Practical and Up-to-date Manual for the Beginner. By Clive Holland. Fully Illustrated. Crown 8vo, cloth, 1/- (postage 3d.).

PHOTOGRAPHY IN COLOURS. A Text-book for Amateurs. By E. Lindsay Johnson. With 8 Coloured Plates and numerous text Illustrations. Crown 8vo, cloth, 3/6 net (postage 3d.).

London:

GEORGE ROUTLEDGE & SONS, LTD.

TELEPHOTOGRAPHY

BY

CYRIL F. LAN-DAVIS, F.R.P.S.

WITH SIXTEEN FULL-PAGE PLATES
AND SEVEN DIAGRAMS

LONDON
GEORGE ROUTLEDGE & SONS LIMITED
NEW YORK: E. P. DUTTON & CO.

CONTENTS

LIST OF PLATES

INTRODUCTION

The outstanding feature of the telephoto lens is its power of giving large direct pictures of distant objects. A mountain twenty miles away appears insignificant in an ordinary photograph. A telephotograph of the mountain may be made from the same standpoint, showing it thirty times as large as before.

The telephoto lens stands, in fact, in the same relation to an ordinary lens that a telescope does to the unaided eye. Details which are quite invisible to an observer can be plainly shown on a telephotograph. In the picture on page 109, there is a general view of the Mont Blanc range. In the next two pictures on pages 115 and 121, taken from the same standpoint with a telephoto lens, the very ridges and depressions in the snow can be seen.

One of the earliest examples of telephotography was the famous picture of Mont Blanc taken from Geneva, forty miles away. An even more wonderful telephotograph of Mount Kenya in British East Africa is reproduced on page 2. This was taken with a high-power telephoto lens from Nairobi, ninety miles away.

Apart from these striking uses, the telephoto lens is of great value for photographs of subjects near at hand, and particularly for artistic portraiture. Those unnaturally magnified hands and feet which too frequently disfigure photographic portraits are conspicuously absent from pictures taken with telephoto lenses. It may be added that there are important advantages to be gained by the use of these lenses for the reproduction of jewellery, natural history specimens and small objects of all kinds, and for astronomical and, particularly, solar photography.

In the following pages I have endeavoured to outline the theory of telephotography in the hope that this little book may be of service both to those who are at present using telephoto lenses and to those many others who think of so doing. In order that the essential simplicity of the subject may be shown, an attempt has been made to explain the theory in plain language without resort to complicated diagrams and mathematical abstractions. A number of numerical examples have been worked out, but for their comprehension a knowledge of simple arithmetic only is required.

The literature of telephotography comprises some half-dozen volumes, all of which, with the exception of Mr. T. R. Dallmeyer's *Telephotography*, published in 1899, deal more particularly with the practical side of the subject. Since the publication of Mr. Dallmeyer's book, there have been important advances in the construction and application of telephoto lenses, but there has been no general exposition of the theory of telephotography.

CYRIL F. LAN-DAVIS.

Plate 1.—Mount Kenya, British East Africa.—Telephotograph, taken from Nairobi, 90 miles away, with a Dallmeyer telephoto lens. (Photograph kindly lent by Mr. H. Binks, Nairobi.)

CHAPTER I

THE SCALE OF A PICTURE

THE SCALE OF A PICTURE

PHOTOGRAPHERS speak commonly of a quarter-plate or a half-plate lens, meaning lenses that will fit quarter-plate and half-plate cameras respectively. Such lenses are, however, quite arbitrarily named, as a half-plate lens can be quite well used on a quarter-plate, and frequently also the quarter-plate lens will work well on a half-plate.

The distinguishing feature between them is the difference in their "focal length," this being the name given to the most important measurement in a lens. It is usual for the manufacturer to engrave the focal length on each lens, and to state it in his catalogue. Methods of determining focal length will be given later.

If we compare the pictures of a house given, say, by a quarter-plate lens of 5″ focal length with that given by a half-plate of 7½″ focal length, both usual sizes, we see that the house is half as large again with the 7½″ lens as with the 5″, and a proportionately less area of ground is included. That is, if the image of the house be 2″ high with the 5″ lens, it will be 3″ high with the $7\frac{1}{2}$″; and we may say that for objects a considerable distance away, the scale of the picture depends entirely on the focal length.

For a picture four times as large as the 5″ lens we shall then require a lens of 20″ focal length; for eight times one of 40″, and in proportion. Now with ordinary lenses the distance from the lens to the ground-glass, generally called the extension or back focus, is nearly the same as the focal length.

A Rapid Rectilinear or an Anastigmat of 20″ focal length requires nearly 20″ extension, so that to enlarge our picture four times compared with the 5″ lens we require a camera four times as long; for eight magnifications we should require a camera eight times as long, and in proportion.

Clearly considerations of bulk and weight will prevent any considerable enlargement in this manner.

To obtain large pictures at short extensions we require, then, a lens of great focal length, needing only small extension; and these desiderata are united in the telephoto lens.

POSITIVE AND NEGATIVE LENSES

All lenses used for photography, such as Rapid Rectilinears, Anastigmats, and Portrait Lenses, give a real image on a piece of ground-glass placed at their focus. Such lenses are classified as "positive" lenses.

With the lenses used in opera-glasses and diminishing-glasses a real image on a piece of ground-glass cannot be obtained, and these lenses are classified as "negative" lenses, and are said to give "virtual" images, such as those in a mirror. Long-sighted people wear spectacles with positive lenses, and short-sighted ones those with negative lenses. The two types may be easily distinguished by holding them a little way from the eye and noticing that objects seen through positive lenses are blurred and indistinct, whilst objects seen through a negative lens are quite sharp, but less than natural size.

If, now, we combine a positive lens with a suitable negative, we obtain another positive lens, which may be used for photographic and other purposes.

This is the construction of the telephoto lens, as rediscovered almost simultaneously in 1891 by Thomas R. Dallmeyer in England, A. Duboscq in France, and Dr. A. Miethe in Germany. Major-General Waterhouse has shown that the idea in connection with telescopes is as old as the time of the great astronomer Kepler, who flourished in the early seventeenth century. The first practical telephoto lenses were, however, not constructed until 1890 and 1891, since which time several different systems have been invented.

PLATE 2.—HIMALAYA PEAK OF OVER 22,000 FEET ALTITUDE.—Telephotograph with the Adon. (Kindly lent by Dr. W. Hunter Workman.)

CHAPTER II

TELEPHOTO LENSES IN RELATION TO DISTANT OBJECTS

TELEPHOTO LENSES IN RELATION TO DISTANT OBJECTS

Positive lenses, as we have just seen, require extensions practically equal to their focal lengths, object and image being formed on opposite sides of the lens. Conversely, negative lenses require no extension at all, the object and the virtual image, which cannot be seen, being formed on the same side of the lens. When, now, positive and negative lenses are combined to form a telephoto lens, the result is that the focal length of the telephoto lens is much greater than the extension; and this is the chief advantage of the telephoto lens over ordinary lenses.

This disproportion between the focal length and the extension depends on the ratio between the focal lengths of the positive and negative lenses, or the "power" of the system. If, for instance, we take a positive of 5″ focal length and a negative of $2\frac{1}{2}$″ focal length, the ratio of the focal lengths of the positive and negative is 1 : 2. Then with $7\frac{1}{2}''$ camera extension we obtain $20''$ focal length.

If we change the negative to one of $1''$ focal length, making the ratio 1 : 5 instead of 1 : 2, the focal length at $7\frac{1}{2}''$ camera extension is $42\frac{1}{2}''$ instead of $20''$.

Now the scale of the picture depends on the focal length and not on the extension. If we focus a distant group of houses with an ordinary lens of $8''$ focal length, requiring $7\frac{1}{2}''$ extension, and select one house the image of which is $1''$ high, then on substituting the telephoto lens, composed of the $5''$ positive and $2\frac{1}{2}''$ negative, for the ordinary lens, we should find that the image would be $\frac{20}{8}$, or $2\frac{1}{2}''$ high; and with the telephoto lens, composed of the $5''$ positive and $1''$ negative, the image would be $\frac{42\frac{1}{2}}{8}$, or $5\frac{5}{16}''$ high. It is usual to speak of the difference in scale as a number of "magnifications" or "diameters." Comparing the $8''$ ordinary lens with the first telephoto lens, we may say that the number of magnifications or diameters is $2\frac{1}{2}$, and that the second telephoto lens gives $5\frac{5}{16}$ magnifications.

In every case the magnification is the linear ratio of the size of picture given by one lens to the size of picture given by another, this being the same as the ratio of their focal lengths. We can therefore say that the telephoto lens of 20″ focal length gives four magnifications compared with its positive only of 5″ focal length.

Here the word "magnification" applied to a telephoto lens means magnification compared with its own positive; but when another lens is also mentioned, it means the ratio of the sizes of image or focal lengths of this lens and the telephoto lens.

Clearly, then, by increasing the ratio of positive to negative we could get any magnification we pleased with a short-extension camera.

But the positive and negative lenses must be separated a certain distance to give the required focal length, and this separation depends also on their focal lengths.

The more we increase the ratio of positive to negative, keeping the extension fixed, the greater is the separation, and consequently the total length of the lens. For instance, at 7½″ extension with the 5″ positive and 2½″ negative, the separation for 20″ focal length is 2·125″, and at the same extension with the 5″ positive and 1″ negative the separation for 42½″ focal length is

4·1″. Moreover, as we decrease the focal length of the negative we necessarily also decrease its diameter; so that with a given positive, increased ratio between the focal length of the positive and negative means decreased covering power and illumination, and conversely a lower ratio means increased covering power and illumination.

Again, variation in the separation of the positive and negative lenses alters the focal length, extension, and covering power considerably.

Taking again our 5″ positive and $2\frac{1}{2}$″ negative, we can draw up a table to show the focal lengths and extensions at various separations.

Separation of Elements.	Extension.	Focal Length.	Magnification.
Inches.	Inches.	Inches.	
5	0	5	1
$3\frac{3}{4}$	$2\frac{1}{2}$	10	2
$3\frac{1}{2}$	$3\frac{3}{4}$	$12\frac{1}{2}$	$2\frac{1}{2}$
3·1	$7\frac{1}{2}$	20	4
3	10	25	5
2·8	$17\frac{1}{2}$	40	8
$2\frac{3}{4}$	$22\frac{1}{2}$	50	10
$2\frac{1}{2}$	Very large	Very large	Very large

It will be noticed that very small variations in the separation make large differences in the extensions and focal lengths. If a greater separation than 5″, which is equal to the focal length of the positive, were tried, the ordinary picture given by the positive would be formed in its normal position, and the rays of light would meet the negative lens beyond this position. We should then have a negative lens looking at a real object; and this, as explained on p. 7, does not give any real image.

As we decrease the separation the focal length and extension increase, until at $2\frac{1}{2}$″ separation they are both very large—that is, larger than any finite value we choose to put on them. If we wish to get a focus of 1000″ we require a separation of 2·512″, for 10,000″. 2·501″, and for infinite focal length and extension $2\frac{1}{2}$″ separation.

We see, then, that with a 5″ positive and $2\frac{1}{2}$″ negative we can obtain a sharp picture at all focal lengths above 5″, and at all extensions exceeding zero. It is simply a question of the extension which is available, and of suitable mechanical means for varying the separation.

Further examination of this table shows that the focal length is always equal to twice the extension in use added to the focal length of the positive. The reason for doubling the extension is that the ratio of positive and negative focal lengths, or the power, is 1 : 2. If this ratio were 1 : 5, we should have to multiply the extension by five and add the focal length of the positive. We should also in that case obtain the same range of focal lengths from 5″ to infinity, and extensions from zero to infinity; but the extensions and focal lengths would correspond differently.

If we make our 5″ positive of $1\frac{1}{4}''$ clear aperture, then the f/no. or intensity at each extension is found by dividing $1\frac{1}{4}''$ into the focal length.

At 5″ focal length the intensity is f $\frac{5}{1\frac{1}{4}}$, or f/4;

„ $12\frac{1}{2}''$ „ „ „ f $\frac{12\frac{1}{2}}{1\frac{1}{4}}$, or f/10;

„ 20″ „ „ „ f $\frac{20}{1\frac{1}{4}}$, or f/16;

so that as we increase the extension and focal length we necessarily get a less rapid lens, requiring increased exposure.

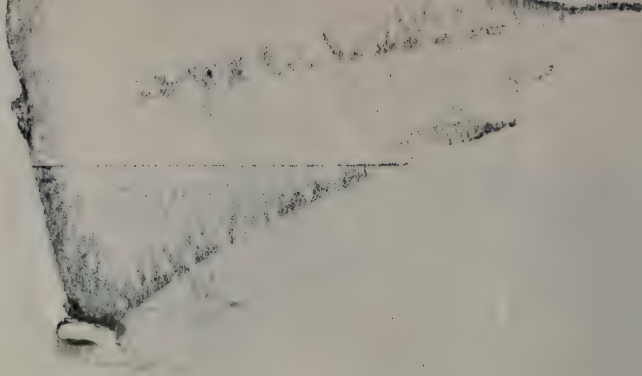
Another way of putting this, is to say that our positive of 5″ focal length and $1\frac{1}{4}''$ clear aperture works at f/4. At $2\frac{1}{2}$ magnifications the focal length has been increased $2\frac{1}{2}$ times, but the clear aperture is unaltered. The f/no. then, which, as before, is found by dividing the aperture into the focal length, has been increased $2\frac{1}{2}$ times, or the new f/no. is found by multiplying the stop of the positive by the magnification, *i.e.*, f/4 by $2\frac{1}{2}$, giving f/10 as the result. And f/10 requires not $2\frac{1}{2}$, but six times as much exposure as f/4.

Exposure, then, increases theoretically as the square of the magnification; but for distant subjects taken without a colour-screen, a rule of practice, founded solely on this observation, will generally lead to over-exposure. A safe working rule is that exposure should be increased as one-half the square of the magnification. The apparent disagreement between theory and practice is due to the greater actinic value of distant subjects. When a properly adjusted colour-screen is used, the full exposure may be given, as described more fully on pages 119 to 124.

Again, as we increase the extension and focal length of our telephoto lens we increase the covering power. At a small extension only a small plate is covered, and at long extension a large plate is covered, the covering power increasing in proportion to the extension. The field of view included scarcely varies, but the size of each individual object increases. If our film or plate increased equally, the field of view would be little altered; but as the telephoto lens is generally used on a camera with adjustable extension but fixed size of plate, the field of view steadily decreases as the magnification increases.

In connection with this subject of covering power, it must be remembered that increase in the separation of the elements decreases the covering power, so that the field of view at $2\frac{1}{2}''$ extension will be small. But using the lens on a quarter-plate, it may be said that with extensions of $5''$ and upwards, the field of view decreases in proportion as the magnification increases.

PLATE 3.—Telephoto snapshot with the No. 2 Series X Adon f/6.



CHAPTER III

SOME COMMERCIAL TELEPHOTO LENSES—VARIABLE TYPES—FIXED TYPES

SOME COMMERCIAL TELEPHOTO LENSES—VARIABLE TYPES—FIXED TYPES

The earliest telephoto lenses experimented with consisted of simple positive and negative lenses, the separations between which could be varied. They gave high magnification and produced some remarkable results, but they were difficult to use. The Simple Telephoto Lens patented by T. R. Dallmeyer in 1892 was of this type, but it was soon discarded for a more perfect system in which the positive was a well-corrected photographic lens, and the negative was composed of a pair of doublets.

This Telephoto Attachment can be fitted to any good photographic lens working at a reasonable aperture, the whole then forming a telephoto lens of variable focal length and covering power.

In the illustration, a quarter-plate Dallmeyer Stigmatic of 5·3″ focal length working at f/6 is shown combined with one of these attachments of $2\frac{1}{2}$″ focal length. This telephoto system covers a quarter-plate at extensions over $5\frac{1}{2}''$, and at this extension gives a picture on three times the scale given by the Dallmeyer Stigmatic alone, and at one-third of the intensity. At $10''$ extension the magnification is five diameters, the intensity correspondingly reduced to one-twenty-fifth, and the area illuminated sufficient for a half-plate. Any magnification

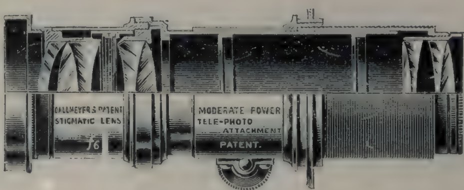


FIG. 1.

over three diameters may be obtained by choosing a suitable extension.

If a $3''$ negative be substituted for the $2\frac{1}{2}''$, the new telephoto system will cover a quarter-plate at extensions over $4\frac{3}{4}''$, and at this extension will increase the scale of the picture $2\frac{1}{2}$ times, thus showing that the lower-power system has greater covering power for less magnification. This combination is to be preferred for flower studies and portraiture when only a little greater focal length than usual is wanted. For a good-sized head-and-shoulders portrait, one can with this lens keep ten to twelve feet from the sitter, and thus avoid the unnatural disproportion in the size of the features so apparent in photographs made with lenses only a few feet from the subject.

If a $1\frac{1}{5}''$ negative be fitted in place of either the $2\frac{1}{2}''$ or $3''$, very much higher magnification is obtained, and the least extension at which the plate is covered is proportionately lengthened. A negative of this size may either be manufactured in the ordinary way, or it may be built up of other negatives placed in contact. Thus the $2''$ and $3''$ negatives used together give this focal length. If the camera be used at a fixed extension of say $10''$, then with the $3''$ lens we get four magnifications, with the $2\frac{1}{2}''$ five magnifications, and with the two together ten magnifications. Captain Owen Wheeler has gone even farther in this direction by combining three or four negatives, though the loss of light by absorption and reflection with such a combination may be considerable.

In order to simplify the calculations for exposure, many makers engrave a scale of magnifications on the telephoto tube. This method, if the figures are not too small to read, is sufficient where the lens is used for distant subjects; but the figures must not be relied on for near subjects, as the conditions are entirely altered by distance. An alternative method is the use of the Dallmeyer Calculator, a small spring tape-measure which is marked with the number of magnifications corresponding to each extension. A third method is sometimes adopted in which the "optical interval" is engraved on the lens mount. The magnification is then obtained by dividing the scale reading of the optical interval into the focal length of the negative.

Telephoto Attachments are made by the majority of opticians, including Messrs. Ross, Dallmeyer, Voigtländer, Zeiss, and Goerz, to suit their particular types of lenses. It is not, however, every positive lens that can be satisfactorily used in this way, as the negative lens magnifies the aberrations of the positive. Chromatic aberration, for instance, the presence of which means that the visual and photographic images do not coincide, increases as the magnification. Thus some lenses which are reasonably well corrected for ordinary work fail altogether in telephotography.

For this reason the best results are to be obtained with complete telephoto lenses, the aberrations of which have been balanced throughout the system. The best known of this type is the Adon Telephoto Lens, invented in 1899 and since greatly improved, optically and mechanically.

Fig. 2.—(Full size.)

This lens is of far simpler construction than the system just described. The front portion is a cemented doublet of $4\frac{1}{2}''$ positive focal length, and the back a cemented doublet of $2''$ negative focal length. An iris diaphragm is fitted to the aluminium mount, and the separation between the elements can be varied by rack and pinion movement. For greater portability the front is carried in a light sliding tube, which should be pulled out before the lens is used. The entire Adon weighs only 5 oz., and is thus suitable for light hand-cameras, as well as for instruments of long extension and substantial build.

The ratio of the focal lengths of the components is a little over 1 : 2, with the result that for medium extensions the Adon gives a picture on three times the scale of an ordinary lens used at equal extension. It covers plates of from $3\frac{1}{2} \times 2\frac{1}{2}$ in. to 15×12 in. in size, provided there be camera extension available. The focal lengths, extensions, intensities, and magnifications compared with 5″ and 8″ ordinary lenses are shown in the table on p. 31.

A model of the Dallmeyer Calculator marked with the f./no. and focal length at each extension is made, by the use of which all calculations and tables are dispensed with.

The Adon can also be obtained with a higher ratio of positive and negative, permitting of higher magnification in proportion to extension.

The Adon telephoto lens is really a reversion to the earlier forms, with the important difference that the ratio of the focal lengths of the components is low. It was the striving after abnormal magnifications and striking results which for so long prevented telephotography from being successful. Apart from the light weight and small size of the Adon, it has the important advantage of possessing no internal reflecting surfaces. If an anastigmat and telephoto attachment are used together, there are inevitably two or more such surfaces, and reflections from these surfaces have a considerable effect on the brilliancy of the pictures.

Camera Extension (measured from "Adon" Flange).	Focal Length.	F/No.	Linear Magnification compared with 5″ Lens.	Linear magnification compared with 8″ Lens.
Inches.	Inches.		Diameter.	Diameter.
4	12	10	2	...
5	16	13	3	2
6	18	15	...	...
7	20	17	4	...
8	22·5	19	...	...
9	24·5	21	5	3
10	27	22·5	...	...
11	29	24	6	...
12	31·5	26	...	4
13	34	28	7	...
14	36	30	...	...
15	38	32	...	...
16	40·5	34	8	5
17	43	36	...	...
18	45	38	9	...
19	47	39	...	6
20	49·5	41	10	...

On the other hand, there is more distortion with simple systems than with the more complicated types. But this distortion appears only at the edge of the field, and its undesirable effects can be entirely avoided by using the lens at a slightly longer extension. The Adon will, for instance, cover a quarter-plate at $5\frac{1}{2}''$ extension. If, however, it be used at extensions of $8''$ and over, there is no distortion on the quarter-plate.

The table on p. 31 shows that the intensities available range from about f/10 downwards. In favourable circumstances, snapshots may be made with the Adon, particularly on the sea-coast, where the light is strongly actinic; but for general purposes the aperture is rather small. The Grandac Rapid Telephoto lenses partly overcame this difficulty. They work at apertures of f/10, and have yielded remarkable results in the hands of capable photographers, one of whom, Mr. A. E. Dugmore, obtained strikingly beautiful results with the Grandac in photographing wild animals in Uganda.

Another form of rapid telephoto lens was introduced by Messrs. Busch in 1905, which differed from previous types in that it worked at a fixed extension and was of fixed focal length and rapidity. Busch Bis-Telars are made in a variety of sizes, and work at apertures of f/7 and f/9. Messrs. Zeiss make also the Magnar, working at f/10; and Messrs. Dallmeyer manufacture New Large Adons, working at f/10,

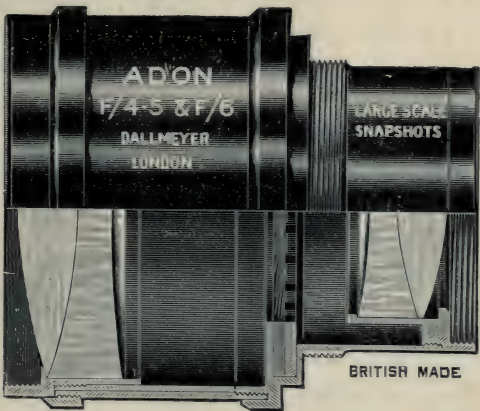


Fig. 3.

f/6 and f/4·5. Each of these lenses works well only at one particular extension, and for distant subjects gives one degree of magnification only. By placing the subject close to the lens, pictures on a larger scale can, of course, be obtained.

This fixed-focus type is just as simple to use as an ordinary lens of the same aperture. There are no calculations whatever to be made. The f/6 New Large Adon, for instance, is attached to the camera, focused on the ground-glass, and exposures are made just as for any other lens at f/6. The focal lengths in the several series are from 2 to 4 times as large as the extensions, and the pictures accordingly are on a scale of from 2 to 4 times the usual size. But to obtain the same rapidity as ordinary lenses at the same extension, the glass diameter must be increased in a like proportion. Rapid telephoto lenses are therefore of necessity larger and more expensive than ordinary lenses, and they have also less apparent depth of focus. They are therefore particularly suitable for reflex cameras, where the image may be focused up to the moment of exposure.

The ratio of the components varies in the lenses of different makers, but a high ratio always means a large picture in proportion to the extension, and, either medium rapidity and small size, or high rapidity and large size.

The No. 4 Series VII. $\frac{1}{2}$-plate New Large Adon, for example, of 20″ focal length, rapidity f/10 and extension 8″, is of the same size as the No. 2 Series X. $\frac{1}{4}$-plate New Large Adon of 12″ focal length, rapidity f/6, and $5\frac{1}{2}''$ extension. The front of each of these lenses is mounted in a light sliding tube which is pulled out in use and closed up for packing. The lenses closed, measure only $3\frac{1}{2}''$ and $3\frac{3}{4}''$ respectively over all, and they screw into a flange of 2″ inside diameter.

In many cameras, particularly those designed for films, the removal of the entire lens is difficult. The front combination, however, may be easily removed and replaced by the Junior Adon Telephoto lens. When the back lens and "Junior Adon" are used together, a magnification of nearly two diameters is obtained with short camera extension, whilst the intensity is almost as great as that of the original lens. There is a slight loss, but not such as causes any serious prolongation of exposure, although it is desirable to ensure even illumination by doubling the exposure. With greater extension, higher magnification is given.

The Junior Adon is of the fixed-focus type, and must be set for a definite camera extension. It is best used where the extension available is 6″ and over, as in the 3A and larger Folding Pocket Kodaks. At shorter extensions the entire film is not covered.

A simple telephoto lens which will show many of the properties of this construction may be made of a pair of spectacle glasses, one positive and the other negative. If these are mounted in cardboard tubes, and one tube arranged to slide over the other, the increase in focal length with decrease in separation and intensity may be immediately observed.

Let us sum up the advantages of the telephoto lens for distant subjects. Large-scale pictures are obtained direct on small cameras, thus saving the provision of heavy and bulky apparatus. The size of the picture and the angle included can be varied at will without change of standpoint. Details previously invisible are shown in the photographs, and the trouble, loss of quality and granular effect due to ordinary enlargement are eliminated, though telephotographs may be subsequently enlarged to get still higher magnification.

PLATE 4.—STEAMER *DUNMAIL* ON THE ROCKS AT ROBIN HOOD'S BAY, YORKS.—Taken with an Adon at $5\frac{1}{2}''$ camera extension from the cliffs above. Exposure, $\frac{1}{100}$ of a second. Time, 5 o'clock on an April afternoon. (Photograph kindly lent by Mr. H. B. Hopkins.)

CHAPTER IV

THE TELEPHOTO LENS IN RELATION TO NEAR SUBJECTS—EXPOSURE—DEPTH OF FOCUS—PERSPECTIVE—TELEPHOTO-MICROGRAPHY—THE SWING-BACK

THE TELEPHOTO LENS IN RELATION TO NEAR SUBJECTS — EXPOSURE — DEPTH OF FOCUS—PERSPECTIVE—TELEPHOTO-MICROGRAPHY—THE SWING-BACK

We have seen the advantages and disadvantages of telephoto lenses for distant subjects, and may now discuss the even more interesting case of its use for near subjects, for which purpose we must examine its optical properties more closely.

According to the theory of geometrical optics, light travels in straight lines, and every luminous point emits rays in all directions equally. Such rays are treated as parallel when the luminous point is at a great distance. When a number of rays impinge on the surface of a positive lens, they are reunited in the focus of the lens after undergoing various refractions at the various lens surfaces. By tracing the paths of the rays mathematically, one may determine the exact position of this focus, provided that certain data as to the lens are given.

Fortunately, however, it is not always necessary to calculate the refractions which the ray undergoes. The actual lens may be replaced by a series of points, known as the "cardinal points," by which its effect is fully determined. These "cardinal points" are the two focal points on opposite sides of the lens at which parallel rays are brought to a focus, and two points called either the "principal points" or the "nodal points," which are imaginary. They usually fall inside the lens, and are such that to an object placed at one principal point there corresponds at the other principal point an image of exactly the same size and the same way up. The distance between the principal point and the focal point on one side is exactly equal to the distance between the other principal point and the other focal point, both distances being defined as the focal length. In the following figures the lenses are, for the sake of greater clearness, shown as simple glasses, but the same reasoning applies to the more complex forms generally used.

In Fig. 4, L is a lens which is receiving on its front surface a pencil of rays coming from a distant object.

These parallel rays are brought by the lens to a focus at F^2, which is the point where the ground-glass is placed.

P^1, P^2 are the principal points, which usually fall inside the lens, and F^1, F^2 are the two focal

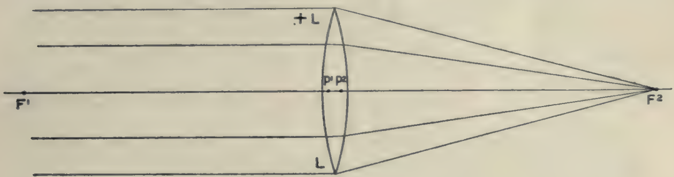


Fig. 4.—Ordinary lens.

points, which always fall outside the lens. The principal points are quite close together, and are sometimes treated as one point called the optical centre.

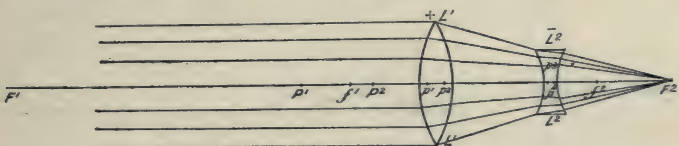


Fig. 5.—Telephoto lens.

Then $P^1 F^1 = P^2 F^2$, and this distance is the focal length, which is equal on both sides of the lens. In other words, the focal length is constant, whichever side of the lens faces the light.

The extension or back focus is $L F^2$, and this in the figure is nearly equal to $P^2 F^2$, the focal length, as is the case with all positive lenses. The exact position of the principal points differs in various constructions, but in each case these points fall within or near to the lens, so that the extension and the focal length are substantially equal.

When a negative lens is combined with a positive, the positions and separations of the principal points in the complete system are quite different from their positions in either element. The effect of the negative lens is to throw both principal points unequal distances in front of the positive component, and the focal points are as before on opposite sides of the lens.

The focal length of the system is, as before, equal whichever side of the lens faces the light, but the extensions are quite different.

In Figure 5, light from a distant subject shown as parallel rays is incident on the positive lens L^1, and after passing through the negative L^2 is brought to a focus at F^2. The corresponding focal point on the other side is F^1, and the principal points are shown at P^1 and P^2.

Then

$$\text{Focal Length} = P^1 F^1 = P^2 F^2 = F \text{ (say)}$$
$$\text{and Extension} = L^2 F^2 = v \text{ (say)}$$

This extension is a fraction of the focal length depending on the ratio of the focal lengths, or of the powers, which are the reciprocals of the focal lengths of the components.

Conversely, if we reverse the telephoto lens, then the extension $L^1 F^1$ is some multiple of the focal length, dependent also on the ratio of positive and negative. In this case the extension is much greater than the focal length.

For near subjects, with both ordinary and telephoto lenses, the position and scale of the image are determined by the distance of the object from the first focal point and by the focal length. This distance divided by the focal length is equal to the reciprocal of the magnification, which is the ratio of the size of the image to the size of the object. The term "magnification" is used whether object or image be larger. In the first case, it is less than unity, in the second case greater. This use of the word should not be confused with the sense in which we previously employed it. Now it refers to object and image. Previously it referred to two different images.

For instance, with a lens of 24″ focal length and an object 8 ft. from F^1

$$\text{Magnification} = \frac{1}{\frac{96}{24}} = \frac{1}{4}$$

In positive lenses the distance of F^1 from the lens is practically the same as its distance from the first principal point P^1 which lies in or near to the lens, and this distance is the focal length.

The total distance of an object from a positive lens for a magnification $\frac{1}{M}$ is therefore

$$MF + F \quad . \quad . \quad . \quad . \quad . \quad (1)$$

On the other hand, in telephoto lenses the distance of F^1 from the front lens is the distance of F^1 from P^1, plus the distance of P^1 from the lens, and this may be considerable. If m be the ratio of the focal lengths of the components of the system, i.e. $m = \frac{f_1}{f_2}$, then the total distance of an object from the front of the telephoto lens for a magnification $\frac{1}{M}$ is

$$MF + mF + f_1 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

or for equal magnification in the two cases the object must be placed a distance of

$$(m-1)\quad F + f_1$$

farther from the telephoto system than from an ordinary lens of equal focal length.

That is, the distance from the object with a telephoto lens is greater than with an ordinary lens by the distance by which the principal point has been thrown forward.

Correspondingly, the extension with the telephoto lens is less than the extension with an ordinary lens by the distance by which the second principal point has been thrown forward, and this distance in symbols is

$$F - \frac{F}{m} + f_2$$

The extension with an ordinary lens is

$$\frac{F}{M} + F \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and with the telephoto lens

$$\frac{F}{M} + \frac{F}{m} - f_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Clearly, as *m* increases both these differences increase, and the telephoto effect, as we may call it, becomes more marked.

To take an example, we wish to reproduce an object in one-third natural size, first with an ordinary lens of 20″ focal length; secondly, with a telephoto lens of 20″ focal length, positive of 5″ focal length, negative of $2\frac{1}{2}$″ focal length.

First,

Distance of object from lens $= 3.20 + 20 = 80''$

Distance of image from lens $= \dfrac{3.20+20}{3} = 26{\cdot}7''$

Secondly,

Distance of object from front lens

$$= 3.20 + 2.20 + 5 = 105''$$

Distance of image from back lens

$$= \frac{20}{3} + \frac{20}{2} - 2\tfrac{1}{2} = 14{\cdot}2''$$

In this case the telephoto lens has to be placed more than 2 feet farther from the object, whilst the camera extension is only just over half that required for the ordinary lens. The principal points are here separated by $15\frac{5}{8}$″; the first principal point is 25″ in front of the front lens, the second principal point $12\frac{1}{2}$″ in front of the back lens, and the separation of the lenses $3\frac{1}{8}$″. It will be observed that the over-all distance is $12\frac{1}{2}$″ greater with the telephoto lens.

If, now, we have an object 105″ away which we wish to reproduce on the scale of one-third, we require, as formula (1) shows, an ordinary lens of $26\frac{1}{4}''$ focal length, whereas by (2) the telephoto lens for the same reduction need be of only 20″ focal length. If, then, the two lenses be of equal clear aperture, say 2″, the telephoto lens works at f/10 and the ordinary lens at f/13, and the latter appears to require nearly twice as long an exposure as the former. As, however, the fronts of the telephoto lens and of the ordinary lens are at equal distances from the subject, and the images are of equal size, the exposures required are identical.

When, however, the focal lengths of the telephoto and ordinary lenses are equal, and the scales of image and clear apertures are the same, the distances from the lenses to the object are unequal. Exposures are then, as in the example on p. 48, in the ratio of the squares of the distances, according to the well-known law of inverse squares. With the ordinary lens the distance was 80″, and with the telephoto 105″. The exposures are therefore as $80^2 : 105^2$, and with the telephoto lens the plate requires nearly twice as long an exposure as with the ordinary construction.

This increased distance between object and lens applies only to near subjects. As the distance grows large, the difference between the distance from the principal point and the distance from the lens diminishes and finally vanishes. For practical purposes the difference vanishes at a distance of about one hundred times the focal length. The decrease in extension applies, however, both for near and distant subjects.

DEPTH OF FOCUS

THEORETICALLY, no lens, except a pinhole, has any depth of focus. Every object has an image corresponding to itself at a definite distance from the lens. When a 5″ lens has been focused for an object 500 feet away, we must alter the extension for one at 505 feet distance; just as when the lens has been focused for an object 5 feet away, we must alter the extension in order to focus one which is at 10 feet distance. The change of extension in the one case is ·00004 of an inch, and in the other ·24 of an inch.

Practically, therefore, with this 5″ lens, pinholes placed 500 and 505 feet away would both be in focus together, whilst those placed 5 and 10 feet away would not be. Each pinhole throws out a cone of rays which entirely fills the lens, and this cone is brought to a focus after passing through the lens, and diverges immediately after focus. The diameter of the cross-section of this cone of rays determines the sharpness on the plate. According to the usual convention, the image is sharp so long as the diameter of this cross-section does not exceed 1/100″. At 10″ the nearest distance of distinct vision, a circle of this size appears as a point. If, however, the picture is to be subsequently magnified, 1/250 of an inch is a better measure. On the other hand, large pictures are generally viewed considerably farther away than 10 inches, and therefore the permissible circle may then be larger than 1/100″.

We know that for equal magnification with lenses of equal focal length of ordinary and telephoto construction, the object must be farther from the telephoto lens. The cone of rays from the pinhole is thus of less angular diameter for the telephoto lens, and the cone of rays on the image side is also of less angular diameter. It takes longer, therefore, for the cross-section of this cone to attain the size of 1/100″, or in other words the telephoto lens has for near subjects greater depth of focus than an ordinary lens of the same focal length.

On the opposite page, Figure 6 represents the case of an ordinary lens, and Figure 7 that of a telephoto lens of equal clear aperture. The size of image in each case is identical, with the result that the telephoto lens has to be placed farther from the object than the ordinary lens. The lenses are shown as straight lines at L L, L^1 L^1, L^2 L^2 respectively.

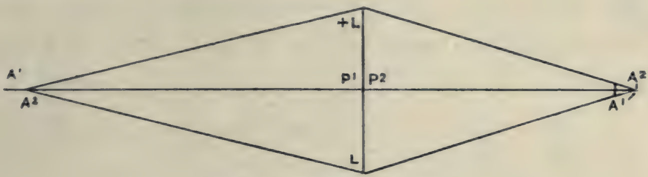


FIG. 6.—Ordinary lens.

If the point A^1 is sharply focused at $A^{1\prime}$, and the point A^2 a little nearer to the lens is taken, then in the upper figure the cone of rays sent out by A^2 entirely fills the lens L, and the image cone

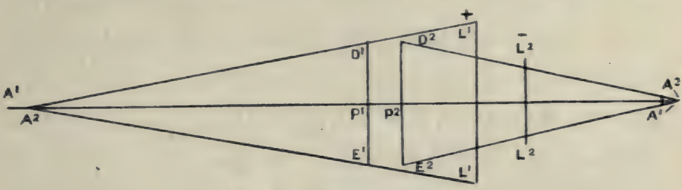


FIG. 7.—Telephoto lens.

is brought to a focus at $A^{2\prime}$ a little beyond $A^{1\prime}$. If a focusing screen be placed at $A^{1\prime}$ the cross-section of the cone focusing at $A^{2\prime}$ is of a certain size.

In the lower figure the cone of rays issuing from $A^{2\prime}$ entirely fills the lens L^1 L^1, but the diameter of its cross-section on the principal plane P^1 is D^1 E^1, which is less than the diameter of the lens L. The angle of the cone of rays forming the image at $A^{2\prime}$ is therefore smaller than the corresponding cone in the case of the lens L L, and the diameter of its cross-section at $A^{1\prime}$ in the lower figure is less than in the upper, giving the effect of increased depth of focus.

The additional exposure, in accordance with the law of inverse squares mentioned above, necessary to compensate for the increased distance from the object, must, however, be remembered, and the statement above is then only a variation of the well-known proposition that depth of focus is increased by reduction of aperture.

This law of inverse squares holds strictly for rays from a point-source of light, incident on surfaces in an otherwise dark room. It does not apply strictly to photographic work under normal conditions. The atmosphere itself is luminous, and tends to reduce the additional exposure required.

It is probably true, therefore, that for equal depth of focus with lenses of the same focal length and diameter the telephoto lens requires less exposure.

Of course, if a $5\frac{1}{2}''$ f/6 anastigmat and a 12″ f/6 telephoto lens are both fitted to a reflex, the depth with the anastigmat will be much greater than with the telephoto. But if lenses of equal focal length be compared, the telephoto should have the advantage.

The question of depth is, however, further complicated by the quality of the correction for spherical aberration of the lenses compared. It is by no means always true that commercial lenses of identical focal length and rapidity have equal depth of focus.

With a lens of either construction the nearest distance to the front principal point at and beyond which all objects are in focus for a circle of indistinctness of 1/100″ is one hundred times the clear aperture multiplied by the focal length with the addition of the focal length. More briefly:

$$\text{Nearest Infinity} = 100\, af + f$$

$$= 100\, f^2 \frac{a}{f} + f$$

where a is the clear aperture on the front principal plane, and f the focal length.

For a 20″ lens at f/10,

$$\text{Nearest Infinity} = 100.20^2 \frac{1}{10} + 20 \text{ in.} = 112 \text{ yds.}$$

For a near subject sharply focused at a distance u from the front principal point,

$$\text{Front depth} = \frac{u(u-f)}{100\, f^2 \frac{a}{f} + (u-f)}$$

$$\text{Back depth} = \frac{u(u-f)}{100\, f^2 \frac{a}{f} - (u-f)}$$

Taking as an example the cases of ordinary and telephoto lenses, each of 20″ focal length at f/10, giving a picture on one-third natural scale as on p. 48.

First, with the ordinary lens

$$\text{Front depth} = \frac{80\,(80-20)}{100.20^2 \frac{1}{10} + (80-20)} = 1{\cdot}18''$$

$$\text{Back depth} = \frac{80\,(80-20)}{100.20^2 \frac{1}{10} - (80-20)} = 1{\cdot}22''$$

Secondly, with the telephoto lens, and here

$$a = \frac{80}{105} \times 20 \times \frac{1}{10}$$

$$\text{Front depth} = \frac{80\ (80-20)}{100.20^2\ \frac{80}{105}\ \frac{1}{10} + (80-20)} = 1{\cdot}55''$$

$$\text{Back depth} = \frac{80\ (80-20)}{100.20^2\ \frac{80}{105}\ \frac{1}{10} - (80-20)} = 1{\cdot}60''$$

The telephoto lens has here more depth of focus for the same size of picture, but the increase of exposure required to compensate for the additional distance is as 1 : 1·7. If, then, the ordinary lens be set to f/13, the exposure necessary for f/10 and f/13, corresponding as 1 : 1·7, the depth of focus is equal in the two cases, and the only shortening of exposure with the telephoto arises from the luminosity of the atmosphere.

PERSPECTIVE

Perspective, or the representation of subjects in proportionate size, depends chiefly on the distance of the object from the lens. The false perspective which is so commonly seen in photographs, is due to the short distance from the object at which such photographs are taken, it being necessary with ordinary lenses closely to approach the subject in order to get a large picture. With the telephoto lens the picture may be taken from a suitable standpoint and correct perspective preserved.

The effect of distance is well seen in the pair of pictures reproduced as Plates 8 and 9. In the first, the hill appears insignificant, in the second the house has taken its proper position in respect to it.

In portraiture the effect is equally well marked. Hands and feet which appear disproportionately large when taken with an ordinary hand-camera lens, which is necessarily placed near the subject, assume their proper proportions in the telephotograph taken farther away, as shown in Plate 3.*

Ordinary long-focus lenses of high rapidity, such as must be used in order to get a large picture far enough away for natural perspective, are expensive, with the result that there is considerable advantage in choosing a New Large Adon or Bis-Telar for this work. Those photographers who pay due attention to perspective, generally prefer soft definition in the result, for which purpose special lenses have been constructed.

The first was the Dallmeyer-Bergheim, designed for Mr. J. S. Bergheim in 1893. In these lenses the spherical and chromatic aberration give a remarkable softness to the picture without destroying its structure. All the modelling is retained, but the negative itself is diffused, so that no faking during printing has to be done. At the same time the focusing must be learnt, as the image shown on the focusing screen is a little different from the result on the negative.

The Dallmeyer-Bergheim being adjustable, a considerable difference in the scale of the pictures may be obtained simply by altering the extension and without changing the distance of the camera from the sitter.

MM. Pulligny and Puyo introduced a similar type of lens in 1906 with the advantage of higher rapidity, and the latest Dallmeyer-Bergheim works at f/6 and upwards.

PLATE 5.—JOHN WYCLIFFE'S CHURCH AT LUTTERWORTH.—(Photograph kindly lent by Rev. R. Bryant.)

PLATE 6.—Taken with the Adon telephoto lens from the same standpoint as the picture in Plate 5, at 17″ extension. Exposure, 3 seconds. (Photograph kindly lent by Rev. R. Bryant.)

TELEPHOTO-MICROGRAPHY

SMALL objects, such as insects, articles of jewellery, screws, and the like, may be reproduced in natural size or on an enlarged scale with much less extension than is needed with a positive lens alone. The subject may also be placed farther away and natural perspective preserved.

Using the combination of 5″ positive and $2\frac{1}{2}$″ negative for an object 20″ away, an extension of 5″ only gives the image in natural size, and at an extension of $12\frac{1}{2}$″ the image is twice as large as the original. At 10″ extension, with the object 10″ away, the image would be on five times the scale; at 20″ it would be on nine times the scale, and any enlargement could be obtained, provided sufficient extension and separation between the lenses were available.

With a positive only, we should have to use a lens of $2\frac{1}{2}$″ focal length to give the image in natural size at 5″ extension, and the object would only be placed 5″ away. For an image on five times the scale, the extension must be 15″, and the object only 3″ in front of the lens.

The illumination with the lens so close to the subject would be a serious problem, whereas with the telephoto lens the increased working distance makes it easy to arrange satisfactory lighting.

The same advantages of decreased extension and improved perspective, as were found when photographing on a reduced scale, are thus obtained by the use of the telephoto lens for enlarging. The depth for equal glass diameters is much greater and the focusing is considerably easier, but for equal exposures there is no advantage in depth, as explained on p. 54.

With fixed camera extension one may obtain any degree of enlargement by bringing the object close enough and adjusting the separation of the elements. To get the greatest magnification on a particular camera, the bellows should be fully extended, the elements separated as widely as possible, and the object moved until the image is sharp. Any further magnification can then only be obtained by an increase either of the separation or of the extension.

Exposures are best found by trial and error, as conditions vary so much. A guess as to exposure should be made and the negative developed. If under-exposed, twice the previous exposure should be given, or if over-exposed, half should be tried. Successive exposures ought generally to be in the ratio of 2 : 1, as the effect of less proportionate increase or decrease can seldom be seen. Three or four trials will thus enable the photographer to get a good idea of the correct exposure. When the correct exposure has been found for one size of picture, it may be easily calculated for any other size according to the following rule:

> The exposure increases directly as the square of the magnification, and inversely as the square of the distance of the object from the lens.

For example, with our 5″ positive and $2\frac{1}{2}$″ negative used at 10″ extension, an object $17\frac{1}{2}$″ from the front lens is reproduced at twice its natural size. With the same extension the object must be placed 10″ away in order that its image may be five times as large, and the separation of the elements must be increased sufficiently to focus the picture.

If at 2 magnifications the object required 1 minute exposure, the new exposure

$$=\frac{5^2}{2^2}\ \frac{10^2}{17\frac{1}{2}^2}=2 \text{ minutes.}$$

Had we increased the size of the picture by altering the extension and distance of the object without altering the lens, we should have had to place the object 16″ from the front lens and increase the extension, the new exposure then

$$=\frac{5^2}{2^2}\ \frac{16^2}{17\frac{1}{2}^2}=5 \text{ minutes.}$$

There is thus a decided advantage in increasing the size of the image by adjustment of the lens rather than by alteration of the extension.

The illustration on p. 97 was taken with an Adon at 24″ distance. The extension was 11″, the separation of the lenses 4″, the magnification nearly two diameters, and the exposure in poor light 2 minutes. Focusing was done roughly by moving the object, and finally by the rack and pinion on the lens.

PLATE 7.—Taken with the Adon telephoto lens from the same standpoint as Plate 5 at 26″ extension. Exposure with 10-times screen, 16 seconds. (Photograph kindly lent by Rev. R. Bryant.)

THE SWING-BACK

One of the earliest applications of the telephoto lens was to architecture. Fine work on the ceiling, sculptural figures high up on the walls, gargoyles and other interesting details, must necessarily be photographed at a considerable distance. The telephoto lens gives the subject on a satisfactory scale, and enables the photographer to make a picture of an isolated piece.

Good general views of a cathedral are frequently difficult to obtain, owing to the proximity of other buildings. A more satisfactory picture can, however, often be obtained a mile or more away, when the smaller buildings and trees no longer obscure the view. The most suitable position can then be chosen, and the lens modified to include only that portion of the subject which is wanted.

For professional work, records of the state of the walls, of the appearance and spreading of cracks in buildings, of the permanence of the bricks, can be admirably made with the help of the telephoto lens. The resulting photographs are likely to be of great service in any disputes that may arise, and by the use of suitable colour-screens much additional knowledge as to the age of different parts may be obtained.

The camera must usually be tilted to include the upper portions of high buildings. Messrs. E. A. & G. R. Reeve[1] have pointed out that when this expedient is employed there must be a departure from the ordinary practice of keeping the back of the camera vertical. If the back be kept vertical, divergent distortion is introduced; that is to say, the image of a window is wider at the top than at the bottom. If the back is kept square to the baseboard, there is convergent distortion, but of small amount only. The correct position lies between these two, as shown by Plates 10 and 11.

In addition to this geometrical distortion, slight pin-cushion distortion is also generally present. The best position in which to set the swing-back should therefore be found by experiment, but an absolutely true reproduction cannot be obtained with the camera tilted. A

[1] *Brit. Journ. of Photography*, Dec. 1910.

square is transformed into a rectangle. This effect is not of great importance for ordinary work, but it should be remembered when exact measurements are in question. The best definition is obtained when the back is square to the baseboard and the geometrical distortion is then small.

To sum up, the advantages of the telephoto lens for near subjects are: the increased distance between object and lens giving improved perspective, the reduced exposure consistent with equal depth of focus for objects at moderate distances away, and the high magnification obtainable with short extension.

CHAPTER V

SIMPLE MEASUREMENTS AND CALCULATIONS —RULES AND TABLES

THE MEASUREMENT OF FOCAL LENGTH. POSITIVES

As the focal length of a positive lens is nearly the same as the extension, a good idea of its value can be obtained by measuring from the position of the diaphragm to the ground-glass, when distant objects are in sharp focus.

For an accurate determination there are a large number of methods, one of which is as follows:

Cut two pieces of paper exactly alike, say two rectangular pieces each measuring $3'' \times 1''$. Set one up in front of the lens at a distance of about double the extension for infinity, and focus on the ground-glass. The image will appear of nearly the same size as the other piece of paper, and it may be made to appear of exactly the same size by placing the first piece a little farther away or a little nearer and refocusing. When image and object are of exactly equal size, a mark should be made on the baseboard at the edge of the screen, and a distant object, a quarter of a mile or more away, should be focused by moving the screen, keeping the lens fixed. The distance between the two positions is the measurement of the focal length.

When a number of lenses have to be measured it is convenient to arrange the test described above for a collimator. A piece of fine wire should be stretched in the focal plane of the collimating lens, and another piece of fine wire of a known length should be placed two or three inches in front of the collimating lens, the whole being illuminated by an electric lamp at the back. The image of the front wire should then be focused and the positions of the lens and screen manipulated until the image and object appear to be of exactly equal size. The wire at the focus of the collimator is then focused by pushing in the ground-glass, and the distance between the two positions gives the focal length.

PLATE 8.—CAMSERICHT, PERTHSHIRE.—Taken with an 8″ positive, 100 feet away.
(Photograph kindly lent by Mr. R. L. Warham.)

Plate 9.—Taken with the Adon at 11″ extension, a quarter of a mile away. The house is the same size in this picture as in Plate 8. (Photograph kindly lent by Mr. R. L. Warham.)

NEGATIVES

As the image of an object formed by a negative lens cannot be received on the ground-glass, the focal length cannot be determined in the ways suggested above. An easy method which gives a near result is as follows :

Measure with a pair of compasses the clear aperture of the negative and describe on a card a circle with this measurement as radius. Place the negative in a beam of sunlight or in the path of the rays from a collimator, and move the card until the disc of light is of exactly this size. The focal length of the negative is then equal to the distance from the card to the middle of the glass.

To obtain an accurate measurement, the negative should be fitted for use with a positive in adjustable mount.

The size of image of a distant object thrown by the positive only is first measured. The negative is then attached and the system adjusted until the same object is four times as large. The position of the focusing screen should be noted and the separation between the lenses again adjusted until the new image is eight times as large as the original image, the negative not being moved. A quarter of the shift of the ground-glass divided by the size of image thrown by the positive is then an accurate measurement of the focal length.

If there is not sufficient extension available, the magnified images may be made two and four times as large as the original respectively, in which case one-half the shift divided by the size of image thrown by the positive is equal to the focal length of the negative.

SIMPLE CALCULATIONS

DISTANT SUBJECTS FARTHER AWAY THAN ONE HUNDRED TIMES THE FOCAL LENGTH.

I HAVE already mentioned the use of a Dallmeyer Calculator for the purpose of avoiding calculations when distant subjects are concerned. To those who desire to work out the results for themselves, two ways are open. All data must, of course, be taken in one standard of length, either the inch or the centimetre.

First, we may treat the telephoto as an ordinary positive lens of known focal length. This method is excellent with systems like the Adon.

(1) To find the focal length. Multiply the extension by the power of the system and add the focal length of the positive.

(2) To find the intensity. Divide the focal length by the clear aperture.

For instance, with a 5″ positive of $1\frac{1}{4}$″ clear aperture and a $2\frac{1}{2}$″ negative and 10″ extension,

$$\text{Power of system} = \frac{5}{2\frac{1}{2}} = 2$$

$$\text{Focal length} = 2.10 + 5 = 25$$

$$\text{Intensity} = \frac{25}{1\frac{1}{4}}$$

$$= f/20$$

and this f/no. is available for use with any exposure meter.

The covering power here is equal to the extension, so that a whole plate would just be covered.

Secondly, we may consider that the image is formed first by the positive and is subsequently magnified by the negative. This method is better for a positive with telephoto attachment.

(1) To find the magnification—

(*a*) Divide the extension by the focal length of the negative and add unity;

or (*b*) Divide the focal length of the negative by the optical interval.

(2) To find the intensity—

Multiply the f/no. on the positive by the magnification as found by either of the above methods.

(3) To find the focal length—

Multiply the focal length of the positive by the magnification.

Taking the same example as before—

5″ positive working at f/4, 2½″ negative, 10″ extension, and optical interval ½″

(*a*) Magnification $= \frac{10}{2\frac{1}{2}} + 1 = 5$

(*b*) ,, $= \frac{2\frac{1}{2}}{\frac{1}{2}} = 5$

Intensity $= f/4 \times 5$
$= f/20$

Focal length $= 5 \times 5 = 25$

To find the circle of illumination, the expression on p. 95 should be used. When the power of the system is two, the diagonal of the largest plate illuminated is about equal to the extension. When the power is higher, a smaller plate is covered; and, correspondingly, a lower-power system has more covering power.

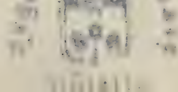


Plate 10.—Window.—Taken with the Adon with the baseboard tilted at 13° to the horizontal, focusing screen perpendicular to the baseboard. Here the inner frame appears wider at the bottom than at the top.

PLATE 11.—WINDOW.—Taken under the same conditions as Plate 10, but with the camera back vertical. Here the inner frame is wider at the top than at the bottom.

NEAR SUBJECTS

HOW TO FIND THE EXTENSION FOR A PARTICULAR SIZE OF IMAGE OF AN OBJECT AT A GIVEN DISTANCE

It is possible to determine the magnification by treating the telephoto system as a positive lens, the positions of the principal points of which are known, but it is generally easier to split the effect up into the work done by the positive and the negative separately.

We therefore determine the magnification by the positive alone, and find how much this image is magnified by the negative.

The positive magnification for a given lens depends only on the distance of the object from it. The negative magnification depends only on the extension used, and remains constant whatever the positive magnification and the distance of the object be.

The principal points of the positive and negative respectively may be taken to coincide with the lenses themselves, as only small errors are introduced by this assumption. Measurements from the object should be made to the centre of the positive, and measurements of extension to the centre of the negative.

The circle of illumination depends on the extension, and on the position and diameter of the stop. In built-up systems such as that composed of a positive with telephoto attachment, the stop is usually placed incorrectly, with the result that the field illuminated is diminished by stopping down. In the Adon and the fixed-focus type, reduction of aperture has scarcely any effect on the circle illuminated. It is usual for the intensities of the positive and negative lenses to be equal, so that the ratio of their diameters is equal to the ratio of their focal lengths or to the power of the system, and this permits of the formulæ generally given being considerably simplified.

Let M be the magnification produced by the whole system, m_1 and m_2 the positive and negative magnifications respectively, m the power of the system, f_1 and f_2 the focal lengths of the positive and negative, d_1 and d_2 their diameters, and v the extension. M and m_1

are greater than unity when the image is smaller than the object, and less than unity when the image is larger than the object.

Distance of object $= (m_1 + 1)\, f_1$

Negative magnification $= \dfrac{\text{Positive magnification}}{\text{Total magnification}}$

$= \dfrac{m_1}{M} = \dfrac{v}{f_2} + 1$

Positive magnification = Total magnification × negative magnification

Extension v $= (m_2 - 1)\, f_2$

Separation of elements $= \dfrac{(m \ -1)\, v + f_1 (1 + \frac{1}{M})}{m_2}$

Focal length $= \dfrac{mv + f_1}{\frac{m}{M} + 1}$

Diameter of circle covered at full aperture $= \dfrac{2mv}{m-1}\,\dfrac{d_2}{f_2}$

PLATE 12.—SCREW.—Taken with the Adon, 24″ distant from the object, at 11″ camera extension. Two magnifications. Exposure, 2 minutes.

EXAMPLES

TAKING our 5″ positive of $1\frac{1}{4}''$ aperture and $2\frac{1}{2}''$ negative of $\frac{5}{8}''$ aperture and an object 250″ away which is to be reproduced on $\frac{1}{7}$ scale, *i.e.* $M=7$, we wish to find the extension to use.

Here $250'' = \text{distance of object} = (m_1+1)\ 5$

$\therefore \quad m_1 = 49$

$$\text{Negative magnification} = \frac{49}{7} = 7$$

$$\text{Extension} = (7-1)\ 2\tfrac{1}{2} = 15$$

$$\text{Separation of elements} = \frac{(2-1)\times 15 + 5\ (1+\frac{1}{7})}{7} = 3''$$

$$\text{Diameter of circle illuminated at full aperture} = \frac{2\times 2\times 15}{2-1}\ \frac{\frac{5}{8}}{2\frac{1}{2}} = 15''$$

With the same lens, to determine the extension for a picture of an object 15″ away on three times the scale, *i.e.* $M=\frac{1}{3}$.

Here 15″ = distance of object

$= (m_1 + 1)\ 5$

$\therefore\ m_1 = 2$

Negative magnification $= 3.2 = 6$

Extension $= (6 - 1)\ 2\frac{1}{2}$

$= 12\frac{1}{2}''$

Separation of elements $= \dfrac{(2-1)\ 12\frac{1}{2} + 5\ (1+3)}{6}$

$= 5{\cdot}4''$

1. HOW TO FIND THE DISTANCE FROM THE SITTER AT WHICH THE LENS SHOULD BE PLACED TO TAKE A HEAD-AND-SHOULDERS PICTURE ON ½ SCALE.

Taking the head and shoulders as measuring 18″, we wish to get an image 9″ long, for which purpose a 10 × 8 camera would be wanted, having an available extension of probably 15″.

Negative magnification m_2

$$= \frac{\text{extension}}{\text{negative focal length}} + 1$$

$$= \frac{15}{2\frac{1}{2}} + 1 = 7$$

Positive magnification m_1

= Total magnification × negative magnification

$= 2.7 = 14$

Distance of object $= (m_1 + 1)\ f_1 = 15.5$

$= 75''$

Diameter of circle illuminated at full aperture $= \dfrac{2.2.15}{2-1}\ \dfrac{\frac{5}{8}}{2\frac{1}{2}} = 15$

Therefore, with this extension, the camera would be placed just over 6 feet from the sitter to get the size of picture required.

With an ordinary portrait lens of 11″ focal length, the camera would be only 33″ from the sitter, so that the rendering of perspective with the telephoto would be substantially better.

2. HOW TO FIND THE MAXIMUM MAGNIFICATION POSSIBLE WITH A GIVEN EXTENSION AND LENS SEPARATION.

With the same lens, let the extension be 15″ and the greatest separation be 5″.

$$5'' = \text{separation}$$

$$= \frac{(2-1)\ 15 + 5\ (1 + \frac{1}{M})}{7}$$

$$= \frac{20 + \frac{5}{M}}{7}$$

from which

$$\frac{1}{M} = 3$$

Thus three magnifications can be obtained in this case.

The following rules put the method more concisely:

1. TO FIND THE EXTENSION FOR A GIVEN MAGNIFICATION AND DISTANCE OF THE SUBJECT—

   Divide the distance of the subject by the focal length and subtract one. This is the first result.

   Multiply the first result by the scale of image desired and subtract one, thus obtaining the second result.

   Multiply the second result by the focal length of the negative, obtaining the camera extension required.

EXAMPLE.—Positive focal length = 5″.
Negative focal length = 2½″
Distance of subject = 30″. Image to be on ½ scale

$$\text{1st result} = \frac{30}{5} - 1 = 5$$

$$\text{2nd result} = \frac{5}{2} - 1 = \frac{3}{2}$$

$$\text{Extension} = \frac{3}{2}\ 2\tfrac{1}{2} = 3\tfrac{3}{4}$$

EXAMPLE.—Positive focal length = 5″.
Negative focal length = $2\frac{1}{2}$″
Distance of subject = 30″. Image to be on three times the scale

$$\text{1st result} = \frac{30}{5} - 1 = 5$$

$$\text{2nd result} = 3.5 - 1 = 14$$

$$\text{Extension} = 14.2\tfrac{1}{2} = 35''$$

It would be best in this case to bring the object nearer and so reduce the extension needed.

2. TO OBTAIN THE DISTANCE BETWEEN LENS AND SUBJECT FOR A DESIRED SCALE OF IMAGE—

Measure the extension available. Divide this by the focal length of the negative and add one. This is the first result.

Multiply the first result by the reciprocal of the scale of image required and add one, obtaining the second result.

Multiply the second result by the focal length of the positive, thus getting the distance of object desired.

EXAMPLE.—5″ positive and $2\frac{1}{2}$″ negative, 10″ extension.

Image to be on $\frac{1}{2}$ scale of object.

$$1\text{st result} = \frac{10}{2\frac{1}{2}} + 1 = 5$$

$$2\text{nd result} = 5\,\frac{1}{\frac{1}{2}} + 1 = 11$$

$$3\text{rd result} = 11.5 = 55''$$

It is essential to take care that all measurements be in inches or centimetres, not some in one and some in the other measure.

The accompanying table is intended for use with the Adon or other telephoto lens, in which the positive and negative are of $4\frac{1}{2}$″ and 2″ focal lengths respectively. The first column shows the scale of the image which it is desired to obtain. The second indicates the distance of the object, and the third and fourth the corresponding extension and separation of the elements. To make use of the table, the apparatus should be set up at the distances mentioned and focusing effected, first by moving the object, and, finally, by the rack and pinion on the lens. As the table shows, there are alternative ways of obtaining a particular scale of image. The most suitable, depending on the space, extension, and separation available, can easily be chosen.

The maximum lens separation in the standard model of the Adon is $2\frac{1}{2}''$, but additional tubes for increasing this separation may be obtained from the makers. For the higher magnifications the aperture must be reduced, and exposure in all cases determined by trial and error. The circle of illumination varies at each extension, the diagonal of the largest plate covered being in all cases about equal to the extension.

TABLE FOR THE ADON TELEPHOTO LENS FOR NEAR SUBJECTS

	Scale of Image.	Distance of Object.	Camera Extension.	Separation of Lenses.
		Inches.	Inches.	Inches.
Image smaller than object.	1/5	140	10	2·9
	1/5	95	6	3·2
	1/2	95	18	2·8
	1/2	50	8	3·2
	1/2	28	3	4
Equal size.	1	50	18	3·1
	1	28	8	3·7
Image larger than object.	3	28	28	3·4
	3	23	22	3·7
	3	19	16	4·2
	3	14	10	5
	6	14	22	4·8
	6	11½	16	5·6
	6	10	11	6·7
	6	7	4	12
	12	7	10	11·9
	20	7	18	11·7

Plate 13.—Emperor Moth.—Taken with the Adon telephoto lens. Exposure, 10 minutes.
(Photograph kindly lent by Mr. H. C. Davidson.)

Plate 14.—Taken from Argentière, 12 miles away, with $7\frac{1}{2}''$ Dallmeyer stigmatic.
(Photograph kindly lent by Dr. C. Atkin Swan.)

CHAPTER VI

WORKING DATA

WORKING DATA

Most cameras can be satisfactorily used for telephotography, provided that the lenses attached to them can be removed either entirely or in part. If the entire lens can be taken away, as is the more usual, any of the lenses described in Chapter III. may be fitted. Lenses of the fixed-focus type are very suitable for Reflex cameras; whilst lenses such as the Adon, or a telephoto attachment fitted to the existing lens on the camera, can best be used on cameras with a considerable range of extension. It is an advantage to have a rigid camera, as vibration destroys definition, particularly with high magnification. At the same time, it is not necessary to carry about the very heavy apparatus that was at one time thought necessary, provided that reasonable care is taken in manipulation, and ample time is given for the apparatus to come to rest after focusing and the like operations have been carried out. For this reason a simple shutter may advantageously be fitted.

Medium magnification fixed-focus telephotos are used exactly as ordinary lenses, and no special precautions apart from care in focusing and avoidance of vibration need be taken. Fine instantaneous work may be done with them, as with ordinary lenses working at f/6, f/4·5, and similar apertures.

The rest of this chapter refers, therefore, to lenses with which high magnification is undertaken. Vibration can in such cases be avoided by the use of a light strut, with one end on the front portion of the camera, the other end being attached to one of the legs of the tripod. This small additional support steadies the whole apparatus in a marked way.

Focusing.—A focusing glass of fairly high power should be used in order to reduce the "accommodation" of the eye. The depth of focus is generally considerable, and for this reason focusing is best done by the rack and pinion motion of the lens. A very slight turn of the pinion makes a considerable difference to the image, whilst the camera baseboard may

PLATE 15.—Taken from the same standpoint with a $7\frac{1}{2}''$ Dallmeyer stigmatic and 3″ Zeiss negative. Exposure, 10 seconds. (Photograph kindly lent by Dr. C. Atkin Swan.)

sometimes be moved backwards and forwards two or three inches without making any appreciable difference. I prefer, therefore, to set the camera to a definite extension, giving the magnification wanted, and to focus by means of the lens. Mechanical arrangements, such as the Hook's Joint Handle, may be employed, or an assistant can turn the pinion. It is, however, only in unusual circumstances that very long extensions are wanted, as it is often simpler to use a short-focus negative and thus reduce camera extension. If, for instance, one is limited to an extension of 12″ on which a telephoto lens consisting of a 6″ positive and a 3″ negative is used, the maximum obtainable is 5 magnifications. Then by simply replacing the negative by one of 2″ focal length, one increases the magnification to 7 diameters without altering the extension; and by using a negative of $\frac{3}{4}$ of an inch focal length, one can increase the magnification to 17 diameters, without the need for at all long extension. Magnification up to 40 and 50 diameters is sometimes obtained in this way, and the short camera extension required makes this method very convenient. At the same time, the limits imposed by the necessarily small diameter or high complexity of the high-power negatives should be remembered.

Very finely-ground glass should be chosen for the focusing screen. Entirely clear glass is troublesome, as on clear glass the image looks sharp in all positions.

Some years ago Mr. Douglas Carnegie[1] suggested a method of focusing which avoids straining the eyes. For this purpose, a clear disc should be left in the ground glass, over part of which a strip of thin brass or tinfoil should be stuck. The magnifier must then be set for the strip of brass and the picture focused approximately. A portion of the image which comes over the edge of the tinfoil should be selected, and the eye moved sideways across the field of the magnifier. When the object is in perfect focus, the part of the picture selected and the edge of the tinfoil will move together, whereas in all other positions one will move relatively to the other.

Stopping down must frequently be resorted to in order to get sharp definition, and apertures as small as f/220 and f/360 are quite common. It has been said that no smaller aperture than

[1] *Brit. Journ. of Photography*, Oct. 1907.

f/71 should be used; but Lord Rayleigh, who is usually quoted as authority for this statement, in a letter to the author disclaimed responsibility for the limit suggested.

Diffraction, with consequent impairment of definition, may occur with small stops, but the point at which this occurs depends on the brightness of the object. A much smaller stop could be used for such a subject as a distant mountain, than for a luminous body like the sun.

Exposure.—As with an ordinary lens, the important thing to ascertain is the f/no. at which the combination is working. In the fixed-focus type this f/no. is stated on the lens. In the case of the variable types this f/number must be ascertained in one of the ways already described. The f/no. so found may be used with any exposure meter, and the time of exposure for distant subjects obtained.

The f/ratio for a telephoto lens is exactly the same as for an ordinary lens, and is used to determine the exposure in the same way. It will be remembered that the f/nos. run f/2, f/2·8, f/4, f/5·6, f/8, f/11, f/16, f/22, f/32, f/45, f/64, f/90, f/128, f/180, f/256, f/360, etc., and that each f/no. requires double the exposure of the previous. If, for instance, 1 second be correct at f/4, 2 seconds are required at f/5·6, 4 seconds at f/8, 8 seconds at f/11, 16 seconds at f/16, 32 seconds at f/22, 64 seconds at f/32, 128 seconds at f/45, and in proportion.

For instance, the Adon at full aperture and at 6″ extension, works at f/15. If the Wynne speed number of the plate used be 90, and if the time taken for the sensitive paper to darken be 20 seconds, then the correct exposure, as shown by a Wynne actinometer, is half a second.

Having determined the exposure for the Adon at full aperture, the exposure at smaller stops is obtained by multiplying the exposure so found by the number on the iris handle.

If, for instance, one stops the Adon down to No. 4 stop, the exposure in the above case would be 2 seconds, at No. 16 stop it would be 8 seconds, and in proportion.

Again, if we are using an f/8 positive lens at 4 magnifications the f/no. of the system is f/32. If the positive only required $\frac{1}{4}$ of a second exposure, the telephoto at f/32 will require 4 seconds, just sixteen times as long.

PLATE 16.—Taken from the same standpoint with a $7\frac{1}{2}''$ Dallmeyer stigmatic and a $1\frac{1}{4}''$ Zeiss negative. Exposure, 30 seconds. (Photograph kindly lent by Dr. C. Atkin Swan.)

Although the exposure for the Adon determined by the Wynne meter is half a second, the character of the subject must be taken into consideration. An exposure which is correct for an open view of the sea with ships would not be right for one of the ships alone, which probably would be all that was included in the telephotograph. The instructions given with exposure meters state that additional exposure must be given for dark objects in the foreground and the like; and these differences should be borne in mind.

Besides, the atmosphere is itself luminous and affects the plate, giving the effect of flatness. When a screen is not used, only one-half to one-third the calculated exposure should therefore be given. If a suitable screen is used—and its use is to be recommended—the atmospheric haze is eliminated, and exposures according to calculation are correct. Dr. C. E. K. Mees, however, in a communication to the author, advises a slight diminution from the calculated times. He observes that there is a lower range of contrasts in distant subjects by reason of the removal below the limit of resolving power of most objects forming the extremes of contrast in the subject, and that as exposures must be in proportion to the scale of contrast, the calculated times may be decreased.

For subjects at moderate distances, the calculated exposures are correct; but for those quite close, trial and correction of error is the best way.

The optical correction of the colour screens should be good, as defects are magnified by the negative lens. The screens should therefore be made of optically-worked glass, or of gelatine cemented between flats. K_1, K_2, K_3, and G screens are all satisfactory.

Reasonable results can also be obtained by fitting less perfect screens to the back of the negative and stopping down. Focusing should always be done with the screen in position, as the interposition of the screen usually alters the focus.

A long hood is of great advantage, because it cuts off much of the stray light, which has a tendency to fog the plate. The hood thus increases the brilliancy of the pictures and improves the contrast. The simplest and most convenient form consists of a tube, or a set of tubes, sliding on the lens mount. These are entirely out of the way when not wanted, and they may be extended to a considerable distance in front of the lens. There are other forms also which consist of miniature cameras, and allow of very exact adjustment.

Plates should be fully developed to make sure that all detail has appeared.

Covering Power.—This term is sometimes used in two senses. It may refer either to the extent of field illuminated, or to the extent of field sharply defined. The maximum circle of illumination depends on the extension, and is sometimes diminished by stopping down. On the other hand, the field sharply defined is generally less than the circle of illumination, and may be increased up to this limit by reducing the aperture.

To ensure that a particular size of plate be illuminated, the diameter of the circle of illumination must be equal to or greater than the diagonal of the plate. As stopping down in variable-type lenses may decrease the area illuminated, a somewhat longer extension than the minimum should be chosen. With lenses in which the focal length of the positive is double that of the negative, the diameter of the circle of illumination at the largest stop is about equal to the extension, so that the area covered is very easily measured. This area depends on the extension, and is unchanged, whether the lens is focused for near or distant subjects.

To make sure that the entire plate is covered, a lighted candle or other bright object should be passed across the field, and the apparatus arranged in such a manner that the image, even if out of focus, can be seen to the extreme corners of the plate.

View-finders.—The angle included by a telephoto lens is small compared with that of an ordinary lens. The regular view-finder therefore includes far more subject than actually appears on the plate. With the fixed-focus type of telephoto lens, it is quite easy to mask down the ordinary finder; but for the variable-focus the task is rather difficult, as the field included varies with the magnification. A very simple finder can be made out of a piece of brass rod fitted at one end with a small brass plate, pierced with a sight hole. Along the rod a rectangular wire frame can be fitted, and this frame can be moved backwards and forwards along the rod to show the field included at various extensions. Another method is the use of one of the view-meters, which consist of the lenses of an opera-glass reversed in position. In the Dallmeyer form the distance apart of these lenses can be varied in accordance with the magnification of the telephoto lens. Such a finder may be made to serve for a fair range of extension, but it can scarcely be employed for all focal lengths from zero to infinity.

INDEX

Printed by Morrison & Gibb Limited, *Edinburgh*.