Kodak
LENSES & SHUTTERS

THE Eastman Kodak Company has manufactured its own lenses for many years, and there has grown in its organization a large group of experts of long experience and great skill. It is this fact which accounts for the outstanding position of the Company among the world's manufacturers of lenses. The real value of a lens can be judged only by its performance, and on this basis Kodak lenses hold an unexcelled position in the particular fields for which they are designed.

Modern photographic lenses and shutters of high quality represent the most perfectly developed stage of optical and mechanical skill. The production of a good lens requires the co-operation of many experts, each of whom is selected after many years of training and painstaking experience: lens designers who apply their knowledge of mathematics and geometrical optics to the calculation of the shapes and arrangements of different kinds of glass which go to form a lens; technicians and craftsmen who grind and polish the glass and assemble it to a finished lens; physicists and optical experts who work in conjunction with the designers of the lens and camera, and who control the optical quality of the finished product.

The shutter is important both because it times the exposure and because its case must maintain the spacing and alignment of the lens elements. Successful shutter design depends on the application of the knowledge of physicists and engineers, and on the skill of experienced craftsmen. Here again, as in the case of lenses, the Eastman Kodak Company has attained an outstanding position.

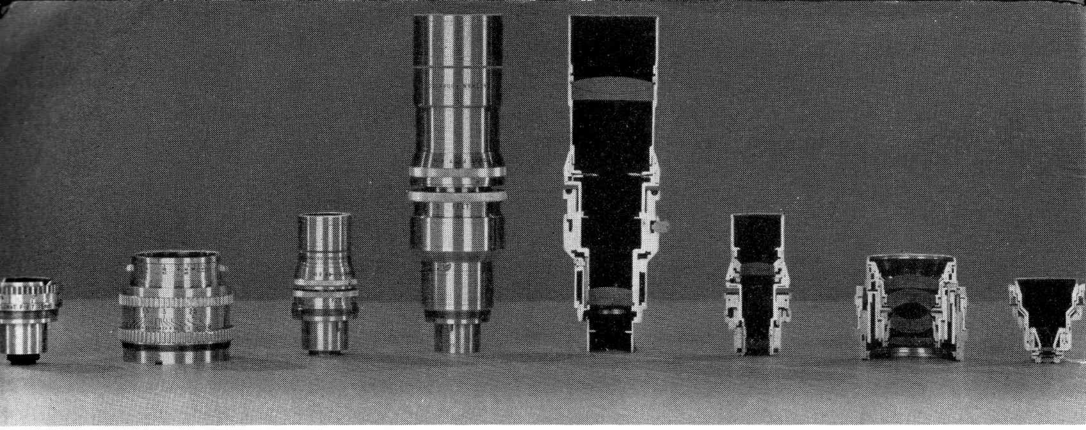
In order to meet the high standards required of photographic lenses and because of the specialized nature of the

● *"Winter Pattern" taken with a Kodak Recomar 33, Kodak Anastigmat f/4.5.*

LENS SPECIFICATIONS

Kodak Ektars

Kodak Anastigmats



● *Special Kodak lens types—Long focus, wide aperture, wide angle.*

work involved, the Eastman Kodak Company maintains a separate factory devoted to the production of optical work of the highest precision. Lenses and lens mounts for every purpose are designed here, and models of them are made and tested; from these models, lenses are made for use on cameras of Kodak manufacture.

A SHORT HISTORY OF PHOTOGRAPHIC LENSES

DURING the 100 years in which photography has been practiced, lens design has reached a remarkable degree of advancement. The earliest photographs were taken with a single meniscus "landscape" lens, with a small stop or diaphragm situated a short distance in front of the concave side of the lens. The speed of this lens was only about *f*/12, but it had surprisingly satisfactory covering power over the 50° field normally demanded of it. This lens, first designed by Wollaston, is still manufactured in large quantities for simple cameras, for which it is entirely satisfactory. Such lenses are not used at greater apertures, because the quality of the image would be spoiled by several aberrations. These are (1) Spherical aberration, which gives a very slight blurring or haziness of the definition over the entire picture. This defect becomes rapidly greater with increased aperture, and is the factor which prevents the use of this type of lens above about *f*/12. (2) Astigmatism, which makes the image decidedly unsatisfactory beyond the 50° field. Astigmatism could be removed by changing the shape of the lens, but only with the result that the field becomes curved. Since photographs are practically always made on a flat film, it is clear that a flat field is essential, even though it involves the introduction of some astigmatism into the outer parts of the image.

When portrait photography was attempted around 1840, the low speed of the landscape type of lens was a great limitation, so, in that year, the famous Petzval Portrait Lens was designed. This had the remarkable speed of *f*/3.5, but the construction was such that complete flattening of the field was impossible, even if considerable astigmatism were permitted. This type of lens therefore will not cover a field of more than about 20°, and for critical definition, 10° represents about its limit. Nevertheless, for projection and some other purposes where a 10° field is adequate, the Petzval type of lens is still extensively used, at apertures up to *f*/1.6.

Further attempts to discover a type of construction intermediate between the landscape lens and the portrait lens revealed the fact that types with good covering power could be made to operate only at small apertures. A compromise was the Rapid Rectilinear Lens, designed in 1866, which at *f*/8 covered a 45° field reasonably well before the inevitable astigmatism began to spoil the image.

Optical theory was advancing rapidly during the latter part of the last century, and in 1880, it was realized that the elimination of astigmatism with simultaneous flattening of the field would be much simplified if optical glass of high index and low dispersion could be obtained. By 1888, this problem had been solved by the introduction of barium crown glass having just the desired properties. This led to a great burst of activity in the design of lenses, and within 15 years, a considerable number of entirely new lens types had appeared, in all of which the possibility existed of flattening the field with simultaneous removal of astigmatism. Such lenses received the name "anastigmat," although some of the types were so unpromising and were so poorly designed that pictures made by them were no better than those made by a good rapid rectilinear lens.

The early anastigmats worked at low apertures, and for many years *f*/8 was considered a fair speed for general use. But, gradually, the unsuitable types were eliminated, and good types were worked out more fully, so that by 1914, *f*/4.5 had become the normal speed of a good lens. Since 1920, *f*/3.5 has become common, and recently, by following up some of the early types in greater detail, *f*/2 and even faster lenses have been made for miniature cameras, all of which cover satisfactorily the "normal" field of 50°. The Kodak Ektar *f*/2, 50 mm., is an excellent example of a modern miniature camera lens. In ciné lenses, because the field is ordinarily only 25° in size, the larger apertures are achieved more easily.

LENS PROPERTIES

THEORETICAL LIMITS OF DEFINITION

THE structure of light itself imposes a limit to the definition of a theoretically perfect lens. The simple geometric theory of light would indicate that the smaller the aperture, the better the definition. Actually, this is not the case, and the wave theory of light indicates that the larger the aperture, the better the definition. Due to the structure of light waves, a beam of light in passing through a small aperture does not continue unchanged but spreads slightly at the aperture edges. This behavior is analogous to the spreading of water waves after passing through a small opening in a breakwater. As a result of this spreading of light, or diffraction, the image of a point of light is a small blur, for a theoretically perfect lens. The size of the blur is decreased as the aperture is increased, as light waves coming from various parts of the aperture reinforce each other at the center of the image, but cancel out in its outer portions. This interference effect depends on wave length as well as the size of the aperture. Two such images which are very close together may merge and be indistinguishable. As the size of blur is decreased by increasing the aperture, the two images become smaller and appear separate, or are resolved. The term "resolving power" refers to the ability to create separate images of points in the subject which are close together. A textbook on physical optics should be consulted for a full explanation of this matter.

The relation between resolving power for points, effective lens diameter, and wave length is stated thus: $\alpha = 1.22\,\lambda/L$

where α is the angular separation of two points just resolved
where λ is the wave length of light
and L is the effective diameter of the lens.

Therefore, the angular resolving power for two distant points is the same for all theoretically perfect lenses of the same effective diameter, regardless of relative aperture. It also follows that the linear separation of images just resolved in the focal plane is proportional to the *f*-number of the aperture regardless of effective diameter.

Thus, for theoretically perfect lenses, the wider the relative aperture, the higher is the resolution and the finer is the detail resolved in the aerial image. In the case of telescope lenses, this is achieved in practice; consequently, large telescope lenses have a resolving power, can tolerate magnification, and show detail in proportion to their apertures. It is for this reason that astronomers make larger and larger telescopes. But, in the case of a telescope lens, only a very small *field* is used, the stars observed being usually at the very center of the field. When a lens is made for a camera, however, it must have a wide field in order to give a picture of appreciable size, since otherwise the focal length would be too great and the camera very clumsy. A lens cannot be made to give a theoretically perfect image for a wide field and, in practice, the resolving power of a photographic lens is determined by a balance between the residual lens aberrations and the aperture.

Resolving power measurements are not as significant as the appearance of an artificial star image examined with a microscope on a lens bench. This image gives more detailed information as to the nature and extent of the residual aberrations and thus of the quality and performance of the lens.

THE ABERRATIONS OF A LENS

It might be of interest to know something of the various shortcomings which render an ordinary biconvex lens useless for photographic purposes, and all of which must be corrected in a photographic objective.

A single biconvex lens can be used to form an image, but it will be found to suffer from the following seven major defects called "aberrations." If the paths were calculated for a number of oblique rays of light through this lens from a distant point situated off to one side of the lens axis, the possible kinds of departure of these rays from the ideal image position can be summarized as follows:

(1) Spherical Aberration: If this defect is present, the various rays from a single zone of the lens intersect at a point on the middle ray of the beam, but the rays from different zones cross at different distances from the lens. The effect of a small amount of this aberration on the image of an extended subject is to cover it with a haze of light. If present in large amounts, spherical aberration may spoil the sharpness and crispness of definition, approximately uniformly over the whole field. As the magnitude of this aberration usually rises rapidly with increased lens aperture, it becomes progressively troublesome and harder to their apertures. It is for this reason that astronomers make larger and larger telescopes. But, in the case of a telescope lens, only a very small *field* is used, the stars observed being usually at the very center of the field. When a lens is made for a camera, however, it must have a wide field in order to give a picture of appreciable size, since otherwise the focal length would be too great and the camera very clumsy. A lens cannot be made to give a theoretically perfect image for a wide field and, in practice, the resolving power of a photographic lens is determined by a balance between the residual lens aberrations and the aperture.

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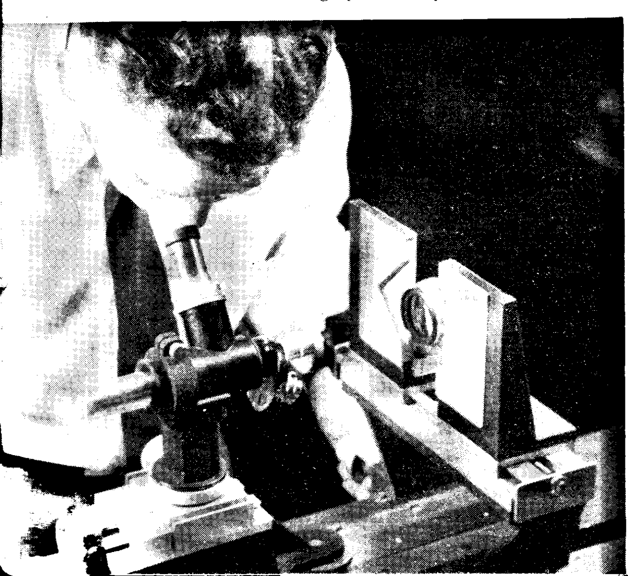
(2) Coma: Coma is a kind of lateral spherical aberration. In spherical aberration itself, the various zones of a lens suffer from a longitudinal difference of focus; in coma, the rays from the various zones strike the image plane at different distances from the center. Thus in the presence of coma, a single point in the subject is imaged as an arrowhead pointing radially toward the center of the field or outward from it.

(3) **Astigmatism:** In this aberration, a single point in the subject is imaged not as a point but as two mutually perpendicular short focal lines, one line being closer to the lens than the other. One of these lines is in a direction tangential to the field, and the other is radial and points toward the middle of the picture. The longitudinal distance from one of the lines to the other is a measure of the astigmatism present in the lens. Neither coma nor astigmatism exists at the center of the picture.

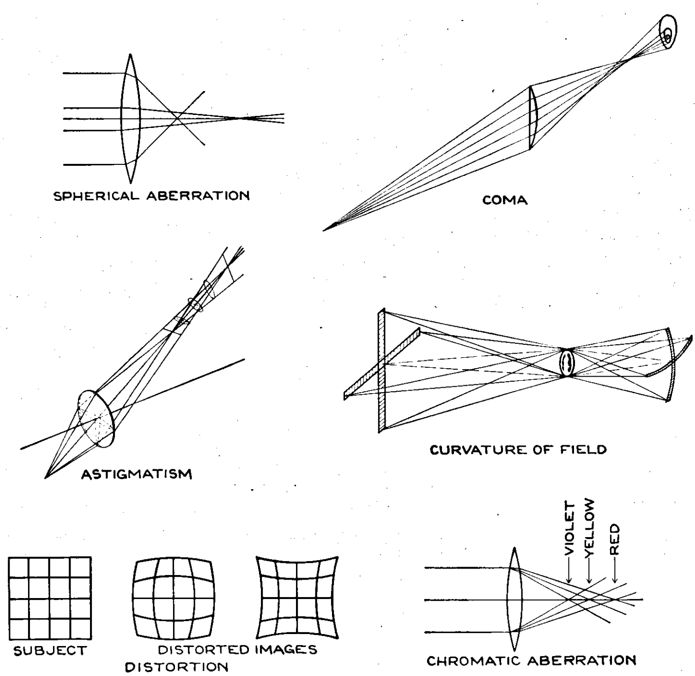
(4) **Curvature of Field:** If the positions of the two astigmatic line images formed by a lens having astigmatism were to be computed for a number of subject-points lying in the same plane, it would be found that all the tangential lines lie on one image surface and the radial lines on another. Since astigmatism does not exist on the lens axis, these two image surfaces coincide in the center of the picture, but are separate in the outer parts if astigmatism is present. When these image surfaces are flat or almost flat, the lens is said to have a flat field, which of course is necessary if the image is to be rendered as sharply as possible on a flat film.

(5) **Distortion:** When a lens has distortion, the magnification is different in different parts of the field. This results in a distortion of the image, for instance, causing a square object to be imaged as a barrel-shaped or cushion-shaped figure. When distortion is present, a straight line running across the center of the picture remains straight, but straight lines lying in the outer parts of the image field are curved as shown on page 9.

• *To determine the quality of the image produced by a lens, the image of an artificial star is examined at a magnification of 200 times.*



(6) Chromatic Aberration: Because the degree of refraction or bending of a ray of light by a polished glass surface varies with the color of the light, it is clear that every property of a lens varies with color. Thus the position of the image itself changes slightly with the color or wave length of light, this effect being known as chromatic aberration. Fortunately, it is possible to eliminate this defect by using two or more different kinds of glass in a lens, and within recent years, a sufficiently wide variety of optical glasses has become available to enable any type of lens to be properly achromatized.



LENS ABERRATIONS
THE SUBJECT IS TO THE LEFT OF THE LENS, IMAGE TO THE RIGHT.
ALL ABERRATIONS ARE SHOWN GREATLY EXAGGERATED.

(7) Lateral Color, or chromatic difference of magnification. In this aberration, the focal length of the lens varies from one color to another, hence, the size of the image in one color differs from its size in another color. If present, this aberration results in colored fringes surrounding the images in the outer parts of the field. In black-and-white photography, these colored fringes appear as a slight blur or fuzziness, but in color work, especially if the lens is used in an enlarger, colored fringes may show up very badly. For this reason, Kodak lenses, according to their intended purposes, are adequately corrected for this aberration.

● *"Looking Down on Rio" taken with a No. 34 Kodak Anastigmat f/4.5.*

LENS PERFORMANCE

A LENS of even the highest quality is incapable of imaging a point source of light as a geometrical point. Instead, such a point is imaged as a small blur with a very bright center and with the brightness falling off away from the center. The size of such an image naturally cannot be measured precisely.

DEFINITION AT VARIOUS APERTURES

The character of such a point image changes slightly for different apertures, but is such for good lenses that they perform satisfactorily at all the apertures provided. There is, however, a slight difference in performance on changing the aperture, apart from depth of field and lens speed changes. Decreasing the aperture from wide open generally improves definition slightly, and removes the slight haze caused by residual spherical aberration. This haze disappears for an aperture decrease of one full stop* or less, and a slight increase in image contrast results. Definition generally improves in the center of the picture for the first full stop decrease, but remains unchanged by further decrease until *f*/16 is reached. Definition away from the center is slightly improved by decreasing the aperture further to about two stops from the maximum. Usually there is little change on further aperture decrease, except for a continued gain in depth of field. However, when f/16 is reached, a slight decrease in definition sets in, due to the wave nature of light.

The question arises, especially in miniature camera work, how small an aperture can be used without loss of definition. For all apertures normally available, that is, *f*/22 or larger, the limiting definition in the case of good lenses is imposed by the type of film and not by the lens. This is true even for negative films of highest quality. An aperture of *f*/22 or *f*/16 may limit definition in the case of a slow-copying film of high resolution, such as Kodak Micro-File. Hence, *f*/11 or *f*/8 may be preferable.

The use of enlarger lenses at their smaller apertures may limit print definition in extreme enlargements, but not in ordinary work.

It must be repeated that these small changes in performance with aperture are of little consequence. These effects on definition are much smaller than those due to slight errors in focusing judgment and to slight camera motion.

* E.g. from *f*/2.0 to *f*/2.8, or *f*/4.5 to *f*/6.3.

CIRCLE OF CONFUSION AND DEPTH OF FIELD

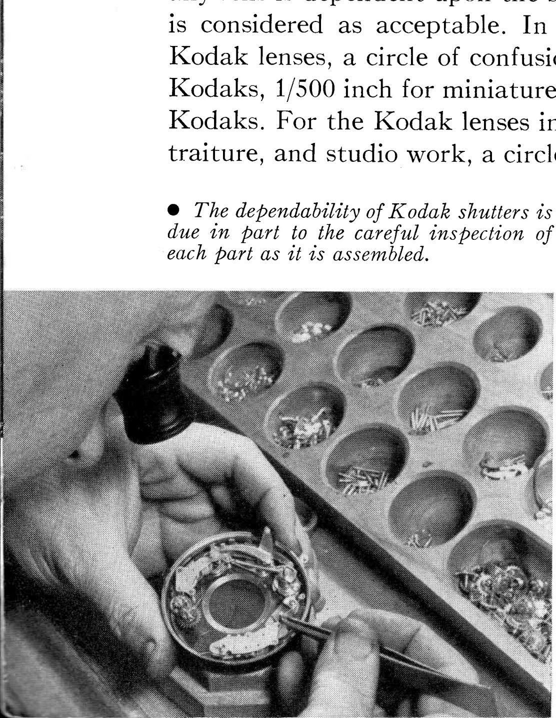
WHEN a lens is focused for a certain distance, objects at that distance only are sharpest. Objects at all other distances are more or less out of focus, and points outside of the plane focused upon are imaged as blurred circles which are referred to here as "circles of confusion." The farther the points are from the plane focused upon, the larger the circles of confusion and the greater the out-of-focus effect.

For critical definition or sharpness, the circle of confusion *in the print* should not be larger than 1/100 inch if the print is to be viewed at the normal viewing distance of 10 inches, or, on an angular basis, the circle of confusion should not subtend more than two minutes of arc at the eye when the print is viewed for correct perspective (i.e., when the viewing distance is equal to the focal length of the camera lens times the amount of enlargement, if any). When the circles of confusion exceed these limits, they appear to the eye as small blurs rather than points, and details within the image no longer appear sharp.

The depth of field of a lens refers here to the range of distances on the near and far sides of the plane focused upon, within which details are imaged with acceptable sharpness in the final print. Depth of field increases with increasing subject distance, decreases with increasing relative aperture, and increases with decreasing focal length, other things being equal. Depth formulas are on pages 40 and 41.

In addition to the factors mentioned above, the depth of field for any lens is dependent upon the size of the circle of confusion which is considered as acceptable. In computing the depth of field for Kodak lenses, a circle of confusion of 1/200 inch is used for folding Kodaks, 1/500 inch for miniature Kodaks, and 1/1000 inch for Ciné-Kodaks. For the Kodak lenses intended for commercial, press, portraiture, and studio work, a circle of confusion approximately equal to 1/2000 of the focal length is used in computing the depth of field. This is a smaller circle than is usually used in computing depth of field tables for such lenses and is for critical definition when the print is viewed for normal perspective. At the limits of the range of sharpness, the circles of confusion are of the

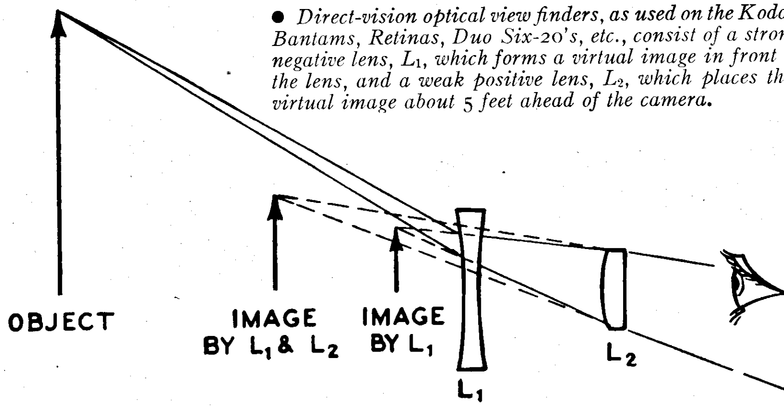
● *The dependability of Kodak shutters is due in part to the careful inspection of each part as it is assembled.*



above dimensions, and between the limits, the circles of confusion are smaller. In the plane focused upon, these circles are a minimum.

Depth of field tables so computed for each lens are in the specification, pages 34 to 49.

● *Direct-vision optical view finders, as used on the Kodak Bantams, Retinas, Duo Six-20's, etc., consist of a strong negative lens, L_1, which forms a virtual image in front of the lens, and a weak positive lens, L_2, which places this virtual image about 5 feet ahead of the camera.*

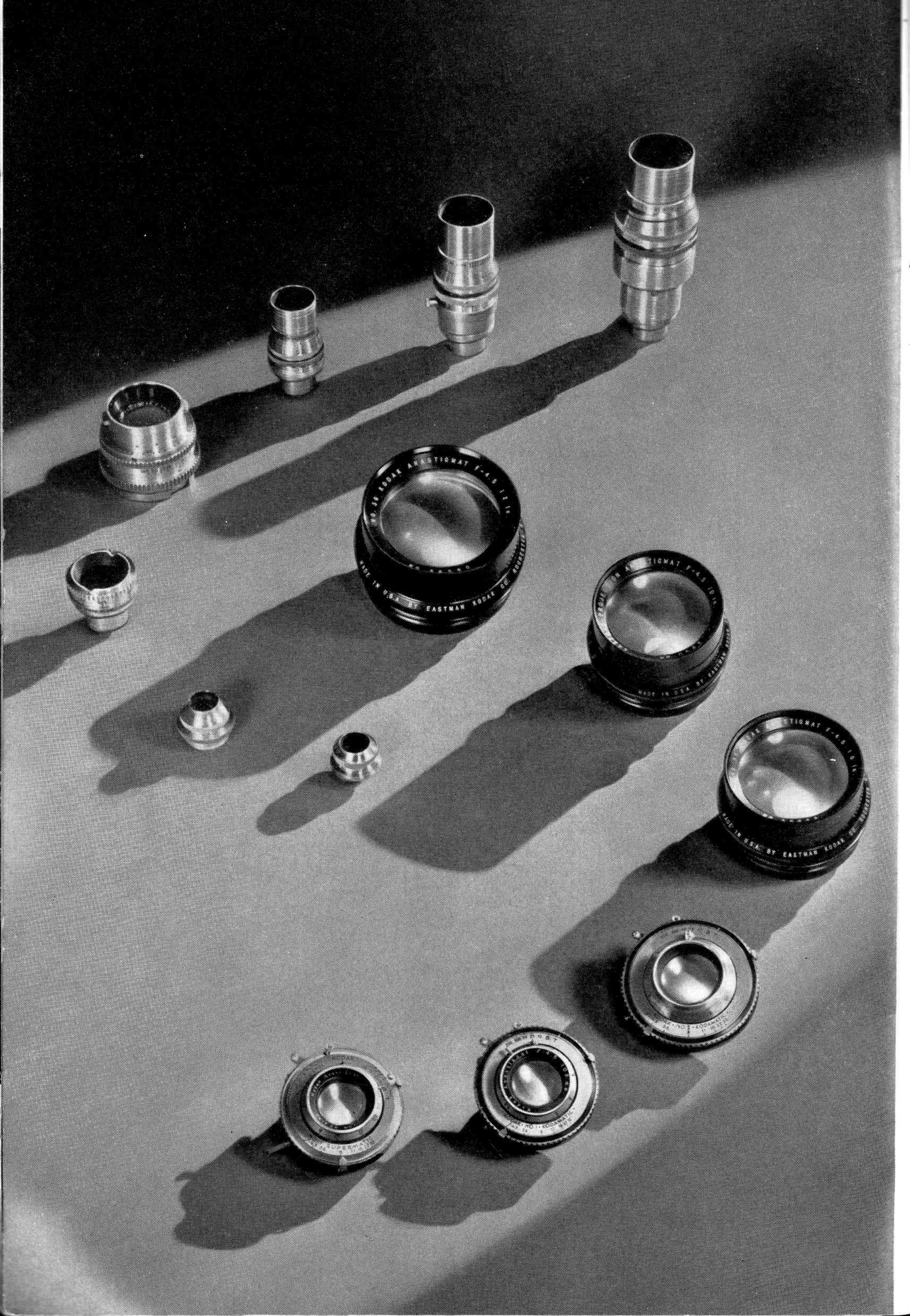


DEFINITION AND CAMERA TECHNIQUE

Poor definition in negatives is most often due to faults in camera handling, in particular, camera motion and focusing error. Small cameras are not held sufficiently steady by the average person for longer than 1/50 to 1/100 second, nor large hand cameras for longer than 1/25 second. While the use of a good tripod eliminates camera motion, in many cases such use is inconvenient.

When a tripod is not available or its use not convenient, it is recommended that shutter speeds of 1/25 second or less be used for large cameras, and 1/50 or preferably 1/100 second for small cameras, if light conditions permit. Camera motion can be reduced by the use of a cable release, since the camera may be gripped firmly with both hands. To release a shutter properly involves a "trigger squeeze" and care should be taken to avoid hand motion. Holding the breath at the instant of exposure often helps.

Focusing error may be minimized by the proper use of coupled range finders, or separate range finders. The acquiring of ability for precise estimation of distance is also desirable. For all close-ups, the distance cannot be estimated with sufficient accuracy, but must be measured either with a range finder or a suitable rule or tape. A general knowledge of depth of field should also be applied in securing good definition throughout the subject.


MADE IN U.S.A. BY EASTMAN KODAK CO.

MANUFACTURE OF KODAK LENSES

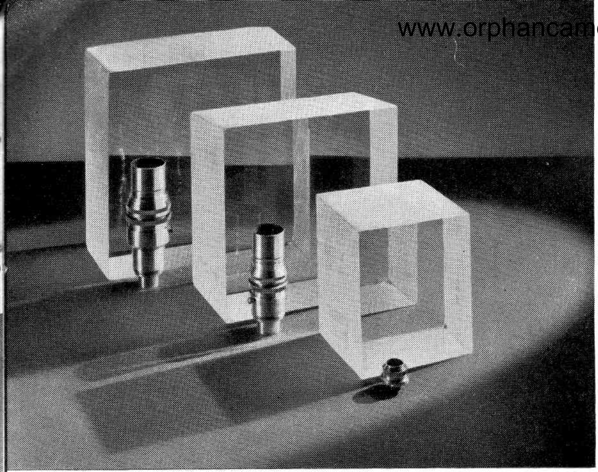
LENS DESIGN

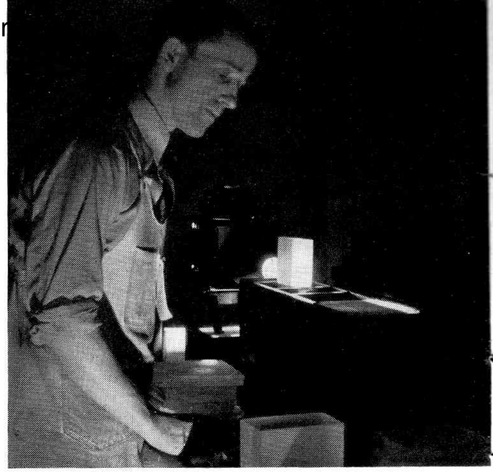
It is not commonly realized that lens design is a very long, tedious, and complicated process requiring months or even years. Briefly, it comprises the following operations: First, the designer must decide the type that is to be used, based usually on previous experience. A likely form must then be worked out, which is tested trigonometrically by much numerical computation to determine its defects. The design is then altered, and the corresponding changes in the various lens defects (aberrations) are ascertained. On the basis of these changes, further alterations in the lens construction are then attempted, until eventually a formula is reached which is satisfactory in all respects. In the course of a design, a number of different combinations of optical glass types may be studied before an acceptable design is reached. In the design of each camera of Kodak manufacture, a lens and shutter are often developed at the same time.

TESTING NEW LENS DESIGNS

When a new design has been completed, a sample is made with the utmost care and tested in every possible way. First the lens is used to form an image of a distant point source, and the image is examined on an optical bench at a magnification of about 200 times. The lens is tilted about its nodal point during the test so that the quality of definition over the entire flat field can be examined. The lens is next used to take photographs of various outdoor and indoor test objects. A photographic test provides a permanent record of the performance of the particular lens, and it is also valuable as it reveals any ghosts and flare spots due to internal reflections from the polished glass surfaces. If the lens has a focusing mount, the accuracy of the focusing scale is also checked by actual photographic tests. Faster lenses intended for use on enlargers must also be tested and if necessary adjusted to remove lateral color. This is because enlargers are becoming more and more commonly used for making three-color separation negatives, and noticeable chromatic difference of image size will ruin the color prints so produced.

Other properties of the lens are also examined, such as its light transmission, the uniformity of illumination over the field, and the accuracy of the diaphragm numbers.





● *Optical glass in slab form before being cut into small slabs for molding. The slabs may range in weight from a few ounces to several pounds.*

● *Each piece of glass is carefully checked on this instrument and classified as to index of refraction before being cut for molding.*

MANUFACTURING METHODS

POPULAR conception has sometimes associated precision-made products with "handmade" methods. However, it has been proved that modern production methods in many fields provide a quality of product never before attained, and many examples are seen in our everyday life. It is now established that lenses and shutters are products of this type, and the very nature of the processes and the intricate steps involved in their manufacture can be best carried out by craftsmen who are specialists in a particular line. This specialization of skill is clearly evident in Kodak lens manufacture. The technicians and craftsmen who produce Kodak lenses are carefully chosen and are assigned to work for which they are particularly suited, either by natural aptitude or by special training.

As pointed out before, the first stage in the creation of a new photographic lens is its design, which calls for extensive experience and involves thousands of exact computations. Some points of interest in lens design have been described briefly on pages 7-9.

Regular production of a lens for camera use can be started only after a model of the lens and its mount, as conceived by the lens designer, has been thoroughly tested in the laboratory and under actual working conditions. For the sake of simplicity and continuity, a typical lens and its mount will now be traced through the various stages of production and inspection.

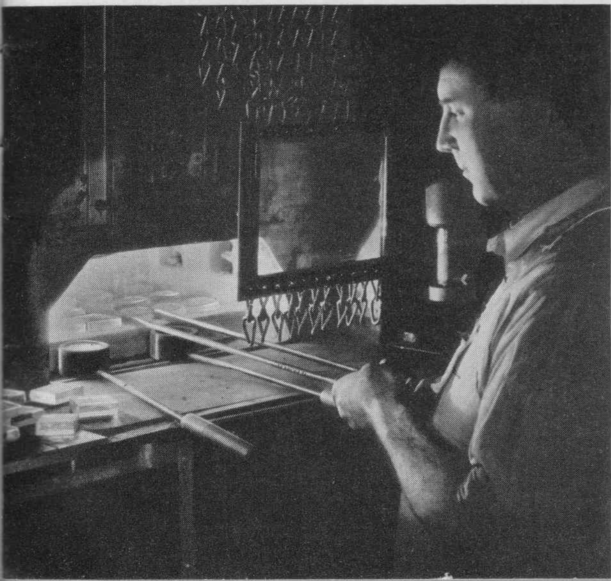
LENS BLANKS

OPTICAL glass is examined for possible flaws and the refractive and dispersive properties are carefully checked. It is then cut or sawed into squares or slabs of the proper dimensions. These slabs are then heated or "puddled" in a furnace until the glass is soft. The soft slabs are then put into a hot mold and pressed into discs of approximately the same diameter as the finished lens and with the surfaces curved, to reduce the time required for grinding. The hot molded discs or "blanks" are then placed in annealing ovens and allowed to cool very slowly to remove any internal strains set up in the molding operation. After being annealed, the blanks are examined and any which show fire cracks, deep pits, imbedded dirt, large bubbles, or striations are discarded. The blanks which pass inspection must be free from these and other defects.

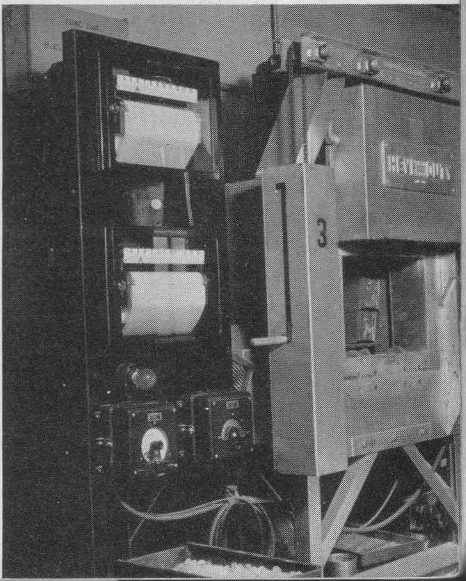
LENS GRINDING

AFTER being molded and annealed, the blanks are sent to the grinding rooms. There the blanks are ground by hand with coarse emery until each surface has approximately the correct curvature and the proper thickness, with due allowance for the amount of glass that will be removed by the final grinding and polishing operations.

For the final grinding and polishing, the rough ground blanks are cemented with pitch to a cast-iron tool in such a way that all their



● *Small slabs, cut from the large slabs pictured on the opposite page, are softened at 1600° F. and then pressed to form the molded blanks from which the lenses are ground.*



● *Electric annealing oven which removes any strain present in the molded blanks. A week is required for the molded blanks to cool to room temperature.*

• *Inspecting molded and annealed lens blanks for fire cracks, striations, and large bubbles.*

upper surfaces lie in a single spherical surface. This is done by affixing small buttons of pitch to the backs of the blanks, and then sticking them face down upon a smooth spherical grinding lap having the exact radius of curvature which is to be formed on the lenses. A suitable "blocking body" is then heated and lowered onto the pitch buttons. The pitch softens and sticks to the hot body, so that when cool, the whole block of lenses can be lifted from the lap and the lenses are ready to grind. The block of lenses is placed on a revolving spindle, the lens surfaces are painted with emery and water, and the lap is moved back and forth over the lenses. The grinding is done with successively finer grades of emery as the surface becomes smooth and takes on the required curvature. The lenses are checked carefully with contour gauges and inspected for scratches as the grinding is continued.

LENS POLISHING

WHEN every lens on the block has been smoothly ground, the emery is washed away, and the lenses are polished with rouge and water on a pitch-lined polishing shell. Polishing takes from one to ten hours depending on the size of the lenses and other factors. The accuracy of the radius of curvature and the sphericity of the surfaces are tested by means of a glass test plate of opposite curve. When such a test plate is laid upon a lens surface, the presence of "Newton's Rings" or interference colors in the thin layer of air between the surfaces allows measurement of the closeness of "fit" between them to within a few millionths of an inch.

After being polished, the finished surfaces are sprayed with shellac and removed from the "blocking body." They are then remounted, polished side down, on another body, and the second lens surface ground and polished.

When both sides have been polished, the lens is cleaned by successive bathings in alcohol, xylol, ammonium hydroxide, and soap suds to remove every trace of grease, shellac, pitch, etc. The lenses are then inspected again for surface scratches, thickness, and sphericity.

CENTERING AND EDGING

AFTER grinding and polishing, the lenses may be decentered, that is, the optical and geometrical centers may not coincide and the lenses must be larger than the mount. To correct these, each lens is cemented to a hollow lathe chuck in such a way that it is centered to make the optical axis of the lens coincide accurately with the axis of rotation of the lathe spindle. This is accomplished by the lathe operator, who adjusts the lens on the rotating chuck until the image of a test object, reflected by the lens surface, no longer appears to rotate. The optical and rotational axes then coincide.

A grinding wheel charged with diamond dust is then brought up against the edge of the lens, and the excess glass is ground off to make the lens perfectly symmetrical and of the proper diameter. If the edge is to be beveled this is also done at this time.

CEMENTING

IN certain types of lenses, two or more of the elements are cemented together to form a single unit. Cementing is done in a special room which is kept scrupulously clean and free from dust. The cement, Canada balsam, is specially refined to remove dirt and excess turpentine. The elements to be cemented are heated to a predetermined temperature on automatically controlled hot plates, the Canada balsam applied, and the two surfaces placed in contact at once to exclude air bubbles and dust. Great care must be taken to keep the cemented elements centered, and after being cemented they are inspected to make sure that they did not slip in the operation. The temperature at which the cementing is done must be carefully controlled so that all solvents will be driven off to insure a permanent bond without discoloring the balsam which would turn brown if overheated.

● Checking the lens blanks for thickness. The blanks are rough-ground by hand with coarse emery and water to obtain the proper thickness and surface curvature.

• *Rough-ground blanks cemented to blocks for grinding and polishing. The number of blanks blocked on a single tool is determined by the shape of the lens surface.*

MANUFACTURE OF LENS MOUNTS

MOUNTING the lens is an important step in the manufacture of a photographic objective. The quality of a lens depends as much on the mounting as on the optical parts that comprise it. The mount for each lens type is designed with the lens. It is of course obvious that the extreme care which is exercised in the manufacture of Kodak lens elements would be wasted if the lens were not properly mounted. A lens mount must not only center the lens with respect to the camera axis and keep the principal planes of the lens parallel with the camera front, but it must also maintain the separation between the elements which the designer specified in the formula. The mounts for front-element focusing lenses must be accurately made with the appropriate threads. Such mounts must be free from play so that the lens will be accurately focused for the distance indicated on the scale, regardless of whether the focusing mount is turned clockwise or counter-clockwise.

To assure the maintenance of accuracy of mounts, extensive use is made of special gauges and inspection methods, and particular care is taken in the selection of the proper material. A complete laboratory for testing material is maintained at Rochester. Here, extensive mechanical and chemical tests are made on the materials used in the manufacture of mounts and shutters. Samples are tested for strength, durability, and resistance to corrosion. Special attention is paid also to the threads in Kodak mounts. As soon as a thread chaser starts to cut threads whose surfaces are not smooth and true to shape (even though the pitch and count are correct), it is discarded. This is only one reason why Kodak mounts have a reputation for smooth operation, for lack of play, and for remaining in accurate working order. Kodak lens mounts are made by craftsmen and instrument makers equipped with finest tools available for the work.

MOUNTING THE LENS ELEMENTS

When the lens elements have been completed and the mounts made, the lenses are assembled in the mounts and given a final inspection. These lenses (with the exception of the simple types of single element lenses) are mounted in one of two different ways. One method is to spin the lens in the mount and the second method makes use of a retaining ring. Either method makes a positive, permanent job and keeps the lens in perfect alignment in the mount. Kodak lenses are never cemented or waxed into place. The mounts for Kodak lenses are turned so that the lenses are an accurate fit, that is, the lens and

● *Lens grinding and polishing—Shells charged with emery move over the rotating blocks to grind the blanks. For polishing, pitch-lined shells are used with rouge.*

• *Centering and edging—Each lens element must be centered accurately and its edge ground to fit the mount.*

mount diameters are made so that the lens slips into the mount snugly and without play. In the spinning method, the mount is made with a suitably thin sleeve on it. After the lens is slipped into the mount, this sleeve is turned over with a rounded tool so that the lens is held firmly in the mount. The final step in assembly is the mounting of the lens in the shutter.

FINAL INSPECTION

AFTER the lens has been mounted, it is sent to the inspection department. All the previous inspections, described before, have been departmental inspections with the primary purpose of checking on the accuracy and the quality of the work being done by that particular department. In addition, final inspection is carried out in a department entirely independent of the rest of the plant. The sole purpose of this inspection department is to examine each lens manufactured to see that it meets the rigid requirements and specifications to which all Kodak lenses and shutters are made. Adequate tests are carried out here on each individual lens, not merely on lenses representing a group.

The great care that is exercised in the inspection of lenses is exemplified by the reproduction on page 26 of a test exposure made with an Eastman Ektar *f*/6.3, 14-inch lens. This is but one of the many tests to which Kodak lenses are put before they are released for camera use.

Quality in a lens or shutter may not be in evidence upon first examination. The purchaser must rely to a certain extent upon the integrity and reputation of the manufacturer to guarantee this quality. The Eastman Kodak Company confidently accepts that responsibility.

KODAK LENSES

ALL Kodak lenses, other than those of small aperture, are anastigmats, and the Kodak Ektars in particular represent an optical improvement over the usual anastigmat. Kodak lenses are made not only for still cameras but also for enlargers, slide projectors, and for Ciné-Kodaks and Kodascopes. Lenses for these various purposes are described here from the standpoint of general groups, and complete data are given for each lens in the specification section of this booklet, pages 34 to 51.

KODAK EKTARS

THERE has been a growing demand, especially from those doing precision photographic work of a specialized nature, for lenses which meet the most exacting requirements. In line with its policy of catering to discriminating photographers, the Eastman Kodak Company recently announced the first of a new series of high-quality lenses. These lenses are designated as Kodak Ektars. They are anastigmats, but are made to higher standards than the term anastigmat ordinarily implies.

The Kodak Ektars are not, in general, intended to replace, but rather to supplement the established Kodak Anastigmat Lenses, which are manufactured to precise standards and which are designed to give excellent results adequate for most photographic work, both black-and-white and color.

In producing Kodak Ektar Lenses, the lens designers have brought to their task the experience of years in designing lenses of quality for all photographic purposes, and they have taken advantage of new and improved

● *The sphericity of the lens surface is checked with a test plate. Errors of* 1/100000 *of an inch are easily detected.*

types of optical glass. Many different models have been made and tested. As a result, the Kodak Ektars represent all that skill, care, and optical research can produce.

In manufacture, every step is carefully controlled, and in many cases, special tools and testing methods have been devised. The lens mountings have likewise received the attention they deserve. Such meticulous care in workmanship is a guarantee that full value has been built into these lenses.

In particular, the performance characteristics of all Kodak Ektar Lenses are:

● *Cementing—To correct for certain aberrations, a lens design may call for two or more glasses in a single unit.*

1. A Kodak Ektar Lens is of outstanding excellence and of preeminent quality.

2. The degree of all residual aberrations in Kodak Ektars is negligible. For example, astigmatism, which is normally present in small amounts in all lenses, has been reduced to a new low.

3. Kodak Ektar Lenses are carefully corrected for lateral chromatic aberration, which is particularly important when Kodachrome transparencies made with these lenses are to be reproduced photomechanically or by other color printing processes.

4. An Ektar Lens is focused as a complete unit.

5. In black-and-white photography, the quality of Kodak Ektar Lenses is most evident when fine-grain negative materials are used or when a small portion of a negative is to be considerably enlarged. The Kodak Ektars are also suited to making negatives from which photomural enlargements are to be made.

6. Relative aperture (diaphragm) markings are accurate within extremely close limits.

Kodak Ektar *f*/2.0, 45 mm., supplied with the Kodak Bantam Special, is extremely well corrected and is suitable for Kodachrome as well as black-and-white photography. Its high speed and wide angle of view make it an excellent all-purpose lens for night photography indoors as well as daylight outdoor photography. Full details are on page 36.

Kodak Ektar *f*/3.5, 50 mm., supplied on the Kodak Retina I, is another highly corrected lens which gives superb results in Kodachrome or black-and-white. The specifications for this lens are on page 37.

Kodak Ektar *f*/3.7, 107 mm., supplied for 2¼ x 3¼-inch cameras such as the Speed Graphic of this size. It is of particular interest to photographers using 2¼ x 3¼-inch Kodachrome Professional Film. It is equally suitable for black-and-white photography especially under adverse light conditions or where short exposures are necessary. Complete specifications including size of filter required, etc., are on page 35.

Eastman Ektar *f*/6.3, 14-inch, is designed especially for commercial color photography with 8 x 10 and 5 x 7 studio and view cameras. This lens is corrected to a very high degree and is especially well corrected for transverse chromatic aberration or lateral color; it is therefore ideally suited to Kodachrome and black-and-white photography. Each lens is tested for exact register of the images of the three primary

● *Kodak lens mounts are made by skilled instrument makers equipped with the finest and most modern tools and the most accurate types of gauges.*

colors. The lens is set up so that the light from the test object passes through the lens obliquely. The rectangles are made of colored gelatin, each passing a narrow band of the spectrum. If the lens has been properly made and assembled, the narrow black lines through the rectangles on the test object will be continuous in the test exposure. A test negative is made for each of these lenses, and kept on file. Specifications for this lens are on page 34.

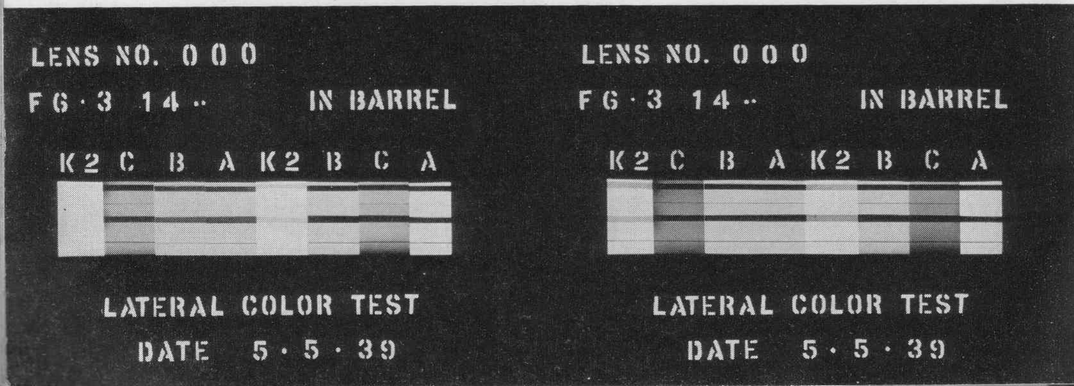
Kodak Anastigmat *f*/4.5 Lenses for commercial, portrait, and press work are available in a variety of focal lengths from 5½ to 12 inches. They are supplied in barrels or shutters for mounting on interchangeable lens boards for use on appropriate cameras including view, studio, and press cameras of the Speed Graphic and Graflex types. They are highly corrected anastigmats and their excellence is attested by the popularity they have long enjoyed among leading photographers. Specifications and dimensions for these lenses are on pages 47, 48, and top of page 49.

FASTER LENSES FOR FOLDING KODAKS

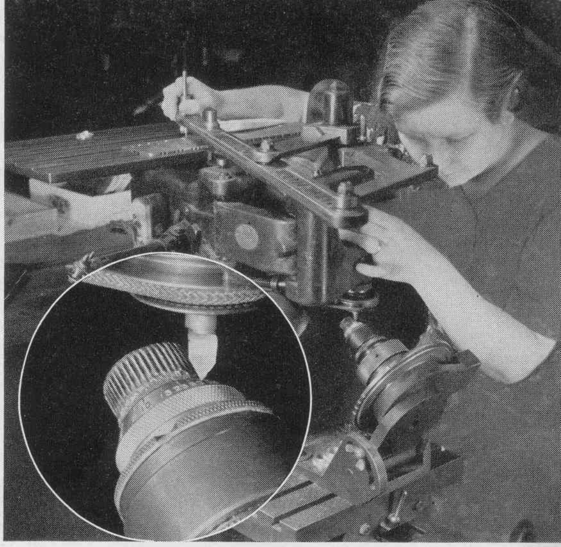
Kodak Anastigmat Specials are made in a variety of focal lengths and in relative apertures of *f*/3.5 and *f*/4.5. They are made according to the most reliable optical formulas and the newest types of optical glass, and are mounted in front-element-focusing lens mounts. Complete data are given for a number of these lenses in the specification section of this booklet.

Kodak Anastigmats are also manufactured in a variety of focal lengths, and in relative apertures from *f*/3.5 to *f*/8.8. These lenses and the Kodak Anastigmat Specials permit the taking of pictures under unfavorable light conditions or at the faster shutter speeds required by moving subjects. These Kodak Anastigmats, like others having high relative apertures, require focusing. They are

● *Test exposures made with Eastman Ektar f/6.3, 14-inch lenses. The test to the left was made with a lens deliberately thrown out of adjustment to illustrate the effect.*



mounted in front-element-focusing mounts except the Kodak Anastigmat as used on the 3A Kodak, the Kodak Recomars, and the Kodak Duo Six-20 which are focused by moving the entire lens and shutter assembly along the camera axis.



• *Engraving focusing scales—Focusing scales on Kodak and Ciné-Kodak lens mounts are engraved accurately.*

Lenses for Simple Cameras are designed for beginners in photography or for those who want cameras that do not require focusing or shutter or lens adjustments. Such cameras must necessarily be equipped with lenses of comparatively small relative aperture, and hence a single shutter speed. Lenses in this group are the Kodak Single Meniscus and Doublet Lenses. Another group of simple lenses, which includes the Kodak Diway, Twindar, and Bimat Lenses, has a simple but efficient method of focusing for subjects as close as five feet from the lens.

These lenses and shutters, within their limitations, will produce excellent pictures. Cameras so equipped have the advantages of lightness of weight, simplicity of operation, and are inexpensive.

CINÉ-KODAK LENSES

THE superb quality and precision of Kodak lenses is particularly evident when Ciné-Kodak and Kodascope Lenses are considered. The Ciné-Kodak produces a series of very small images on a strip of film only 8 mm. or 16 mm. wide. These tiny images are subsequently magnified many times when projected on the screen for viewing. The Kodak lenses for Ciné-Kodaks are made in focal lengths ranging from 12.5 mm. to 6 inches with relative apertures from *f*/1.9 to *f*/4.5. Kodascope lenses are made in focal lengths of from 1 inch to 4 inches with relative apertures from *f*/1.6 to *f*/2.5. These ranges of focal lengths and apertures are equal to practically any situation the movie maker may meet either in taking the picture or in projecting the final image. Cross-sectional diagrams of several typical Ciné-Kodak lenses are shown on page 28.