III. NIKKOR LENSES

General Introduction

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Aperture control ring
Presets the automatic aperture diaphragm. Also moves the meter coupling prong on the camera.

Infrared marking
Corrects image plane displacement when using infrared film.

Depth-of-field scale
Depth of field is indicated by lines which are color-coded to match the color-coding of f-numbers on the aperture scale.

Focusing ring
Scalloped for quick and accurate focusing.

Screw-in thread
Accepts filter, lens hood, adapter ring, slide copying adapter or close-up lens. Comes in 52mm-diameter size on most Nikkor lenses.

Meter coupling prong
Engages the coupling pin on the Photomic finder, coupling the lens diaphragm to the exposure meter system. Found on most Nikkor Auto lenses.

Aperture scale
Has click-stops at each f-number. Permits intermediate settings.

Aperture index

Distance index

Milled grip ring
For gripping the lens firmly when it is being mounted or detached.

Distance scale
Calibrated both in meters and feet (except for a few Nikkor lenses which are marked in either meters or feet).

A. Introduction

Today, Nippon Kogaku is one of the world's undisputed leaders in the field of high quality 35mm camera lenses. Nikkor lenses, the quintessence of Nippon Kogaku's own design, manufacture and rigid quality control, are recognized as equal to or better than any lens available in the world market.

Thoroughgoing research, strict quality control and meticulous assembly of Nikkor lenses result in uniform masterpiece lenses. They feature high definition, fast speed and better color rendition. These are the fundamental guidelines of Nippon Kogaku which launched lens production in 1929 and commercialized 35mm lenses in 1937.

Nikkor lens mounts are ruggedly constructed to provide heavy-duty, lifetime use. The large diameter mount guarantees less vignetting, a more secure fit, greater strength and versatility than any other lens system available. There are over 40 lenses to choose from for use with the Nikon F2, the Nikon F and the Nikkormat cameras.
The Nikon range of lenses in many focal lengths between 6mm and 2000mm, plus special purpose lenses, are all integral parts of the most comprehensive camera and lens system available.

B. Production Process in Brief

Nippon Kogaku prepares glass material for its own lenses. This is a great advantage because the quality of lenses is heavily dependent upon the quality of the original glass material.

The widest range of optical glass—more than 200 types—are now available to meet demanding design specifications.
New types of optical glass have been playing a significant role in lens making. Introduced in 1953 was optical glass utilizing rare earths such as lanthanum and thorium. These new types of material brought about substantial improvements in the quality and performance of Nikkor lenses and a reduction in production cost.

Here is a brief description of how Nikkor lenses are manufactured—from melting of the raw materials to final testing of finished lens before shipment:
First, raw materials are cooked in a crucible. They are heated to around 1,500°C.
The mixture is then either cooled in the crucible until it hardens or cast according to its usage. The solid mixture hardened in the crucible is broken into lumps.
Each lump of glass is rigidly inspected against undesirable bubbles, stria and nontransparent elements.

Now, the glass is heated again until it becomes soft to allow for molding into rough shapes of blocks. It is then either cut and/or pressed, and annealed by cooling slowly for a period of days or weeks. From this process, discs of the right size for a particular lens element emerge. Before the next process, each glass is rigidly inspected to make sure it is completely suitable for use as a lens. In the grinding-polishing stage, the lens surface is ground by fine meshed sand (such as carborundum or corundum) to obtain roughly the specified curvature.

Next, the surface is polished with cerium oxide to obtain finer curvature, texture and transparency. To make sure that the polished lens will have its optical axis in the center, extraneous marginal edges are ground off.
Now, a thin low-refractive layer coating is applied to the glass surface by the vacuum depositing method to minimize surface reflections.
For lens assembly, the lens elements are placed in a barrel and aligned at specific distances between each other, with their optical axes centered. This is a most important process which calls for incomparable skill and meticulous precision.

In addition to performance and precision tests, the completed lenses are given another series of tests for vibration, heat resistance, sub-zero temperature, and various torture tests.
Only those lenses which have fulfilled Nippon Kogaku's rigid lens standards can bear the company's guarantee of quality and leave the plant.

C. Lens Designation

Each Nikkor lens has certain markings indicating the optical design, leading features and general purpose among other information.

(1) Code Letters
The code letter after the "NIKKOR" engraving is indicative of the number of elements in each lens. The letters are from Latin or Greek:

U for 1 element (Uns)
B for 2 elements (Bini)
T for 3 elements (Tres)
Q for 4 elements (Quatuor)
P for 5 elements (Pente)
H for 6 elements (Hex)
S for 7 elements (Septem)
O for 8 elements (Octo)
N for 9 elements (Novem)
D for 10 elements (Decem)

Thus, the Nikkor-P Auto 105mm lens is constructed with five lens elements, and the Nikkor-UD Auto consists of eleven elements.

(2) Lenses having "Auto" are equipped with automatic diaphragms which are coupled directly to the shutter release and mirror action mechanisms.

(3) Lenses designed for special purposes are distinguished by the names preceding Nikkor:

Fisheye-Nikkor	(A circular fisheye image covering 180° or 220° angle of view, equidistant projection)
OP-Fisheye-Nikkor	(Orthographic projection)
PC-Nikkor	(Perspective Control)
GN Nikkor	(Guide Number for use with flash)
Micro-Nikkor	(Microphotography)
Medical-Nikkor	(Medical and dental photography)
Zoom-Nikkor	(Zoom optics)
Reflex-Nikkor	(Mirror and lens optics)
EL-Nikkor	(For enlargers)

(4) Maximum aperture of each lens is designated, for example, as 1:1.4, which means the aperture is f/1.4, f1.4 or F1.4.

(5) Focal length of each lens is designated as f=50mm or f=1000mm.

(6) Each lens has its own serial number.

D. Recent Technical Accomplishments

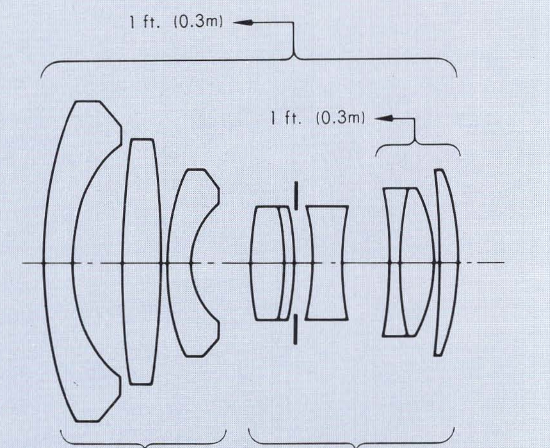
Nippon Kogaku's extensive line of interchangeable lenses, each one excelling in resolution, speed and color fidelity, is the result of the company's intensive research and development program.

Following are recent major technical accomplishments achieved by Nippon Kogaku in lens design:

Multi-Layer Coating
Today, more 35mm camera lenses contain a greater number of elements than ever, because of demands for faster lenses and better lens performance required for them.
With more elements, a lens inevitably produces more internal surface reflections, making multilayer coating a necessity.
In multi-layer coating, extremely thin layers of chemicals of different properties are placed on the surface of the elements one after another singly or combined to reduce reflections on the lens surface, minimize ghost image and flare, increase light transmission and improve color performance.
All surfaces of the 28mm f/2 and 35mm f/1.4 and a portion of the 55mm f/1.2 lens and others now have multi-layer coating.
For a photographic lens with a comparatively small number of elements, however, single-layer coating on each air/glass surface suffices.

Automatic Image Quality Correction at Close Distances

This is a unique automatic correcting system for image quality at close range. It is also called the "floating elements" correction system.
Three high speed Nikkor wideangle lenses of retrofocus type have this system at present. They are the 24mm f/2.8, 28mm f/2 and 35mm f/1.4 Nikkor Auto lenses.



Schematic diagram of Nikon's invention applied to the 24mm f/2.8 Nikkor Auto.

This system enables these Nikkor wideangle lenses to reduce image deterioration at close range and achieve picture quality throughout their whole focusing range.
This is because lenses are generally not designed specifically for close distance shooting but primarily for medium to long distance shots. To ensure image quality at close range, most lenses are designed in such a way that their closest focusing distance is limited to a point where image deterioration does not become noticeable. Under Nikon's automatic focusing formula, introduced in 1967 as the first of its kind in the world, the rear elements are so arranged that this group shifts for image correction during focusing, according to the distance focused on.

E. Mechanical Features

Automatic Diaphragm

The two most important features of F-mount Nikkor lenses are the superb optical performance and the automatic diaphragm. The diaphragm remains fully open except at exposure time.
By depressing the shutter release button, the diaphragm automatically closes down to the pre-selected f/stop. It returns to the full lens aperture opening instantly after the shutter action is completed. Nikkor lenses equipped with such an automatic diaphragm are designated as "Auto" lenses.
When the lens is removed from the camera, the diaphragm remains at the f/stop indicated on the scale, providing convenience in using extension rings, bellows focusing attachments, etc.

Functional Styling

The black styling accentuated by bands of mat chrome is not only aesthetically pleasing but serves a functional purpose as well. On every wideangle or normal focal length lens, there is a mat chrome band with a milled surface forward of the diaphragm ring. The lens can be gripped with this band when being changed. This eliminates the problem of where to hold the lens when changing it.

Meter Coupling Prong

Most automatic Nikkor lenses have a coupling prong on the diaphragm ring. The Photomic series exposure meters are coupled to the lens by slipping the meter coupling pin into the slot of the coupling prong. Automatic lenses without the coupling facility on the diaphragm ring are the 200 – 600mm zoom, the 400mm f/4.5, the 600mm f/5.6 and the 800mm f/8.

Scales and Indicators

The f/stop markings of the diaphragm ring are equidistantly spaced. The use of intermediate settings is possible. Most normal lenses are equipped with a front thread with a diameter of 52mm to accept most lens-front accessories, such as filters, close-up attachment lenses, lens caps, in common.
Most distance marks on the focusing ring are graduated in both feet and meters, but some rings

have either feet or meters. Instead of the usual depth-of-field lines, those on the Nikkor lenses are color-coded to correspond with the colors of f-numbers on the diaphragm scale. This outstanding feature enables easy and rapid reading of the depth of field for each lens opening.

Lens Mount

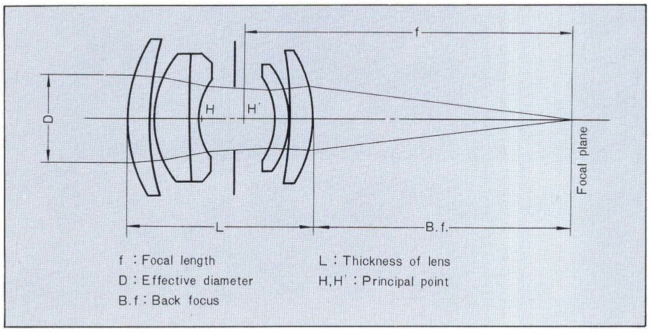
The rear section of the lens barrel which is mounted on the camera is usually referred to as the "lens mount." Nikkor lenses feature a three-tab bayonet lens mount.

This design enables any interchangeable F-mount Nikkor lens to be mounted to the camera rapidly and securely by a 1/6 counter-clockwise turn after the f-number index dot on the lens barrel is aligned with the index on the front scutcheon of the camera body. With the f-number index dot at the top center position, the slot on the lens mount is joined to the spring-loaded coupling pin on the lens mount flange of the camera body. This also connects the automatic diaphragm with the shutter release and mirror mechanisms.

To remove the lens, depress the lens release button on the left side of the camera body, turn the lens clockwise and pull it out. The chrome button retracts the coupling pin and allows the lens to be withdrawn from the bayonet fitting. Most Nikkor lenses can be mounted directly on the camera body. Some super telephoto Nikkor lenses require the use of the Focusing Unit between the lens and camera body. This unit is commonly used for the 400mm, 600mm, 800mm and 1,200mm lenses.

F. Technical Terms

Following is a glossary of technical terms describing the unique features, construction, applications and other aspects of camera lenses:



1. Focal Length

The focal length is the factor that determines the size of the image reproduced on the film, picture angle which covers the area of the subject to be photographed, brightness of the image on the film plane, depth of field, etc. The light rays which come from a point at infinity run parallel along the optical axis of the lens to converge on a point called "focal point" after passing through the lens. The distance from the rear surface of the last element to the focal point in the lens system is referred to as the "back focus" and is not the focal length in the strict sense of the word. Focal length is the distance from the principal point to the focal point. There are principal (H and H') and focal points (F and F') both on the object and image sides of each lens.

In most camera lenses, the principal point does not coincide with the center of the lens system, especially in a telephoto or retrofocus lens where it is distant from the center.

Some special lenses are designed so that their principal points cross. This means that the first point is located on the image side and the second point on the object side.

2. Flange Focal Distance

The flange focal distance (FFD), sometimes called the "flange back," is the distance from the mechanical rear end surface of the lens mount to the focal plane of the lens.

Thus, it determines the position of the lens which is properly seated in the camera mount, depending on the mechanical design of the camera (46.5mm in the Nikon and the Nikkormat cameras). The FFD is one of the important elements for consideration in assembling, fitting and testing of a lens.

3. Speed and F-number of Lens

The "speed" of a lens is indicated by its f-number, that is, the ratio of the diameter of the opening to the focal length of the lens.

f-number = f/D

D: diameter of opening (aperture)

f: focal length

With the focal length constant, the larger the aperture, the more light passes, and the smaller the aperture, the less light is transmitted. The

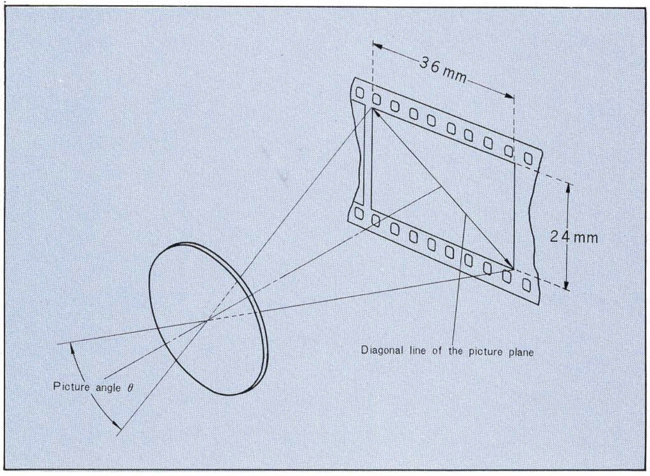
lens is usually equipped with a diaphragm which controls the brilliance of the image and the depth of field. In a Reflex-Nikkor, however, the lens speed cannot be expressed simply by the ratio of the lens diameter to the focal length but by an equivalent f-number value, because the cross-section of light bundles entering it is doughnut-shaped (except at the focal point). This value is calculated by comparing the effective ring area of the mirror which corresponds to the disc-shaped opening area of an ordinary lens.
The f-numbers are marked (see table below) so that each consecutive marking or "stop" denotes a halving of the next larger and doubling of the next smaller aperture (i.e., of the amount of light passing through the lens). For example, f/4 will be half as bright as f/2.8.

f-numbers	1	1.4	2	2.8	4	5.6	8	11	16	22	32	45	64

In certain lenses, however, maximum f-number is different from figures in this system.
As a result, for any given scene, there are various combinations of f-numbers and shutter speeds which yield the same amount of light that reaches the film. Each combination, called "light value" or "exposure value," provides flexibility in adjusting exposure, according to the desired f-number or shutter speed.
Light passing through the lens is reduced slightly by absorption and reflection occurring within the lens elements and on their surfaces. The f-numbers indicate the amount of light striking the outer lens surface. T-stops (transmission-stops) indicate the amount of light actually passing through the lens. Therefore, T-stops are a more accurate indication of light to which the film is exposed.
T-stops are always larger than the corresponding f-numbers of the same lens. Differences in exposure and depth-of-field values derived from T-stops and from f-numbers are virtually negligible in practice.

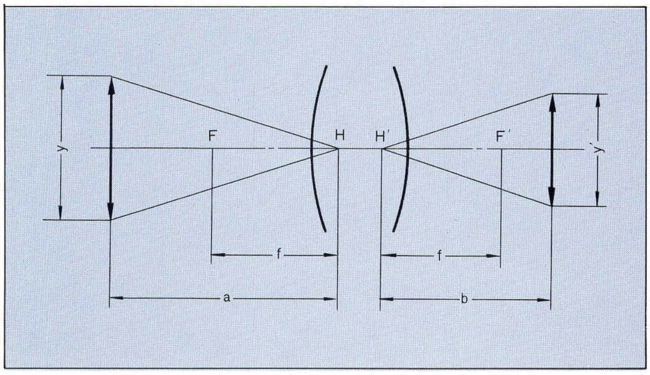
4. Picture Angle (Angle of View)

The picture angle or angle of view of a lens is the angle at the image side principal point subtended by the diagonal (43.2mm)—or sometimes, by the horizontal or vertical measurement of the picture frame (24 x 36mm)—when the lens is focused on infinity (see diagram). When the lens is moved forward to focus on closer objects the picture angle decreases. In most cases, lenses designed for 35mm cameras do not cover a format larger than 24mm x 36mm.



5. Object Distance, Image Distance and Reproduction Ratio

The object distance is defined as the distance from the first principal plane of the lens to the focused object plane, and the image distance, from the second principal plane to the image plane on the film. The distance engraved on the lens barrel, however, does not represent the object distance, but the distance from the object to the image plane: The sum of the object and image distances, plus the distance between the first and second principal planes.



The following relationship is established between the focal length of the lens (f), object distance (a) and image distance (b):

$$1/a + 1/b = 1/f$$

The reproduction ratio or magnification (β) — the proportion of the image (Y') to that of the object size (Y) — is equal to the ratio of the image to object distance, as shown by:

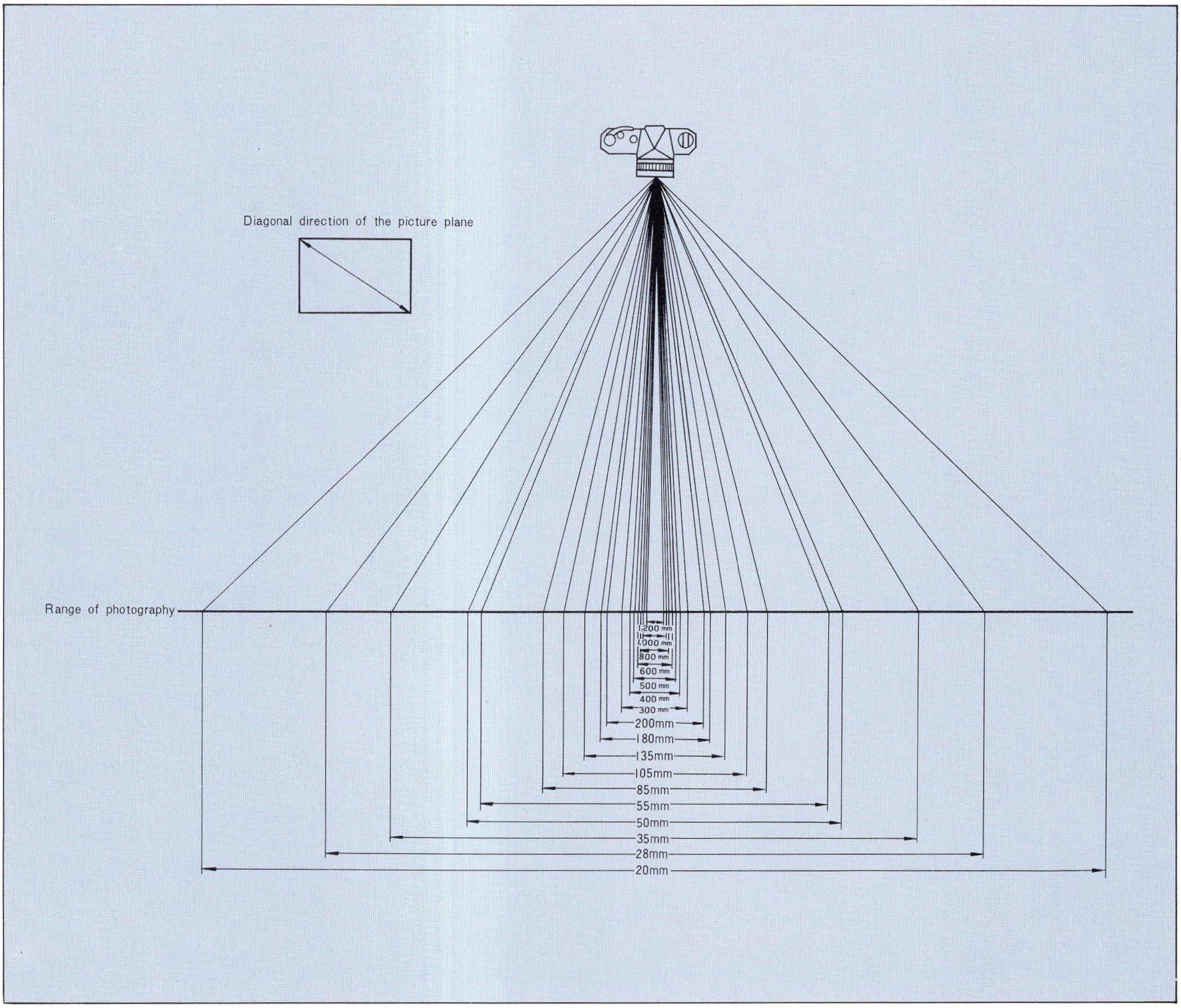
$$\beta = \frac{Y'}{Y} = \frac{b}{a}$$

Thus, the following relations are obtained:

$$a = f\left(1 + \frac{1}{\beta}\right)$$

$$b = f(1 + \beta)$$

Focal length(mm)	20	28	35	50	55	85	105	135	180	200	300	400	500	600	800	1,000	1,200	2,000
Diagonal direction	94°	74°	62°	46°	43°	28°30′	23°20′	18°	13°30′	12°20′	8°10′	6°10′	5°	4°10′	3°	2°30′	2°	1°10′
Horizontal direction	83°	64°	53°	39°	36°10′	23°50′	19°30′	15°	11°30′	10°20′	6°50′	5°10′	4°10′	3°30′	2°30′	2°	1°40′	1°
Vertical direction	61°	45°	37°	26°	24°40′	16°	13°	10°	7°30′	6°50′	4°30′	3°30′	2°50′	2°20′	1°40′	1°20′	1°10′	0°40′



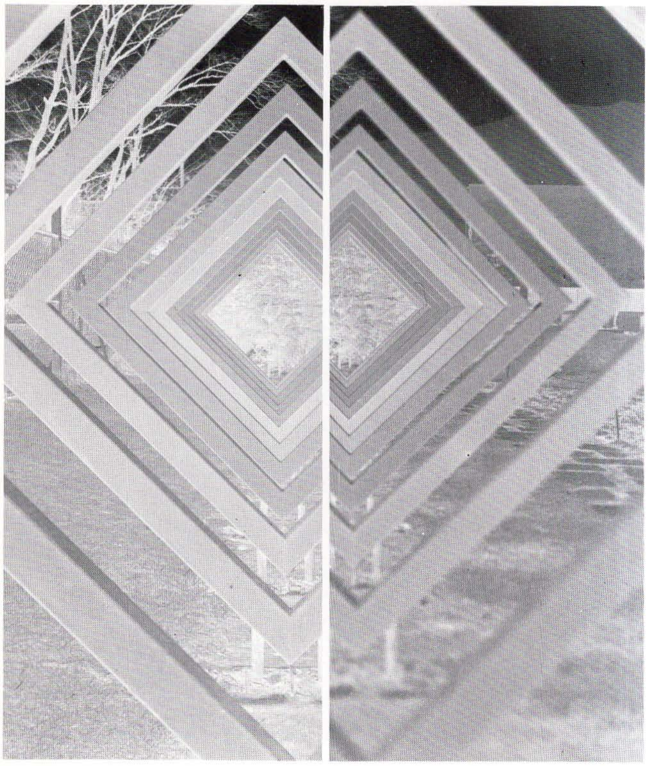
6. Infra-Red Markings

All Nikkor lenses except for Reflex-Nikkor lenses have a red dot or line near the black or white index provided for reading the distance scale on the focusing ring. When taking pictures with infra-red film, a sharp image will be obtained at a position slightly farther away as compared with the image produced with visible light.

Therefore, this image plane displacement can be corrected by shifting the distance indicated on the black or white index to the red dot or the red line when the image is brought into sharp focus. The longer the focal length, the greater is the displacement or shift. In the normal or wideangle lens, however, when the aperture is stopped down to f/8 or more, correction will not be necessary, as it is covered by the depth of field at such a small aperture.

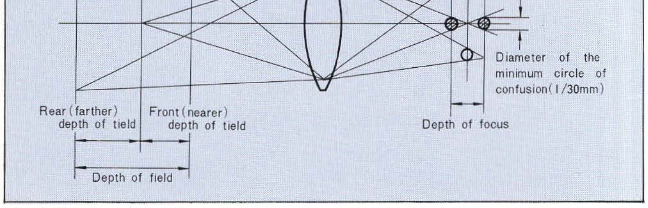
7. Depth of Field

Almost all objects or scenes to be photographed are three-dimensional. Subjects closer or farther away from the object on which the lens is focused produce progressively blurred images. This blur is usually expressed in terms of the diameter of the circle of confusion.



If this blur remains within given limits, the image will appear acceptably sharp. The zone extending in front of and behind the focused distance within which the image is permissibly sharp is called "depth of field."

Considering that in 35mm photography, the picture is to be enlarged and viewed at some distance, the permissible diameter of the circle of confusion is usually taken as small as 1/30mm for all Nikkor lenses. The depth of field, divided into the front (nearer to the lens) and rear (farther from the lens) depths, is calculated by the following equations:



$$\text{Front (nearer) depth} = \frac{d.F.a^2}{f^2 + d.F.a}$$

$$\text{Rear (farther) depth} = \frac{d.F.a^2}{f^2 - d.F.a}$$

When F = f-number
f = focal length of lens
a = distance of the object focused
d = permissible diameter of circle of confusion.

Hence: The smaller the aperture and the shorter the focal length, the greater the depth of field. The depth is greater in the rear side than in the front. The greater the distance of object, the greater the depth.

With the lens set on infinity, the distance of the nearest object acceptably sharp is called "hyper-focal distance" which varies with the lens' focal length and the f-stop chosen. When the lens is focused on such a distance for the same f-stop, every object within the range from infinity to one half of the hyperfocal distance will be in focus or included in the depth of field.

In taking snap-shots, especially with a lens of short focal length, it may be convenient to make use of this hyperfocal distance.

The depth of field is often miscalled the depth of focus. But the latter is a certain range of focusing movement within which the image still appears permissibly sharp, that is, the diameter of the circle of confusion is within 1/30mm.

Hyperfocal Distances of Wideangle and Normal Lenses

(Unit: meter)

f-number / Focal Length	1.4	2	2.8	4	5.6	8	11	16
20mm	—	—	—	3.2	2.3	1.7	1.2	0.9
24mm	—	—	6.3	4.4	3.1	2.2	1.6	1.2
28mm	—	12.4	8.8	6.2	4.4	3.2	2.3	1.6
35mm	27.9	19.6	14.0	9.8	7.0	5.0	3.6	2.5
45mm	—	—	23.3	16.3	11.6	8.2	5.8	4.2
50mm	57.2	40.1	28.4	20.1	14.2	10.1	7.2	5.1

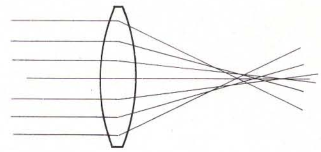
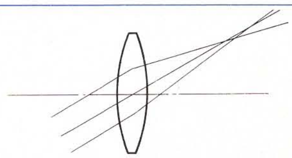
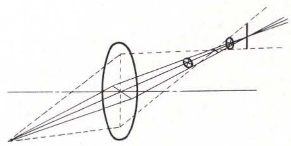
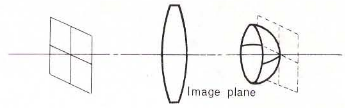
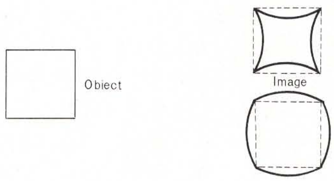
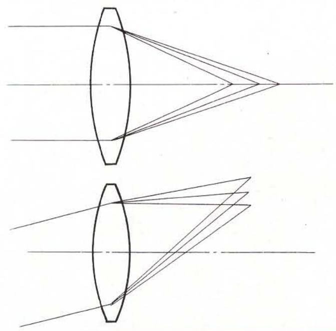
8. Aberrations of Lenses

It is essential that the photographic lens provide sharp, correctly-formed images on the film plane. For this purpose, the lens must be capable of gathering light rays originating at every point on the object plane and forming an exactly similar image on the film plane.

A perfect lens would produce the exact shape of image to that of the object over the whole picture field.

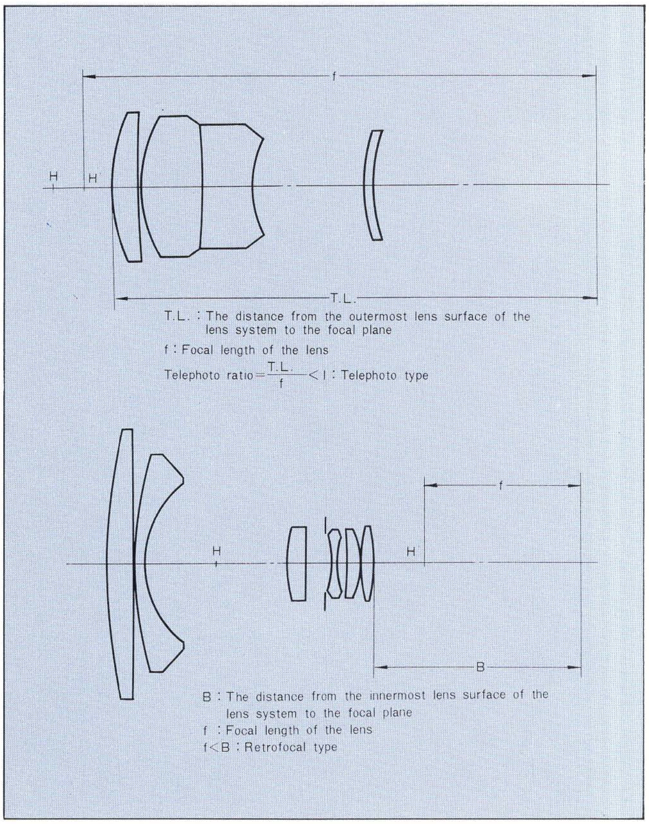
In practice, however, it is not possible to attain such an ideal result: The light rays in each bundle are scattered near the ideal point generally referred to as "aberrations of the lens."

For the convenience of designing the lens, aberrations are classified into chromatic aberrations, spherical aberrations, coma, astigmatism, curvature of image field and distortion (see table below). The lens cannot completely be free from all these aberrations. The performance of a lens is primarily determined by the residual amounts of various aberrations. The lens is designated as being "correct" when its aberrations are properly corrected to fulfill the purpose of the lens.

Aberrations	Effect by Stopping Down Diaphragm	
(Spherical Aberration) When the spherical aberration is not corrected, the light rays coming from an object on the axis and passing through the off-center zones of the lens focus on various points on the axis different from that of the rays passing through the central zone of the lens. This phenomenon is called the "spherical aberration" which blurs the image at the picture center.	By stopping down the diaphragm, this aberration will be greatly improved but this may cause displacement of focus when the aberration is not sufficiently corrected.	
(Coma) Off-axis rays fall at different points of focus after passing through or being reflected on the different zones of a lens or mirror, resulting in unsymmetrical image blur. This aberration is referred to as "coma."	Image quality is improved by stopping down the diaphragm.	
(Astigmatism) Mostly in simple lenses, there sometimes occurs "astigmatism" in which lines of an object point off the axis fail to come to the same focus plane. Horizontal lines of the object will focus at one point while vertical lines will focus at another point. Thus the image on the focus plane is more or less an elongated elliptical shape. About midway between the focus points of the perpendicular lines, there will be a circular image instead of an ellipse. However, in today's lenses with many elements, such an aberration is usually very well corrected and seldom poses a problem for the photographer.	Image quality cannot be improved by stopping down the diaphragm. The effect becomes inconspicuous thanks to the increased depth of focus.	
(Curvature of Image Field) The sharpest image must be formed on a flat plane as films are always flat. But when this aberration exists, the sharpest image is formed on a curved surface instead. Therefore, it is impossible to obtain a sharp image of the entire object plane.	Same as above.	
(Distortion) If image magnification is not the same over the entire image field but varies radially outward from the center, the resultant shape of the image will be distorted. If magnification increases outward, a square object is imaged in the shape of a pincushion. If it decreases, the image of the square has laterally bulging sides and the distortion is said to be "barrel-shaped."	Cannot be improved by stopping down the diaphragm.	
(Chromatic Aberrations) Longitudinal chromatic aberration is a variation in location of the image plane with changes in wave lengths. It produces the image point surrounded by different colors which result in a blurred image in black-and-white pictures. Lateral chromatic aberration is a variation in image size or magnification with wave length. This aberration does not appear at axial image points but toward the surrounding area, proportional to the distance from the center of the image field.	Cannot be improved by stopping down the diaphragm. For correction, a lens system with at least a pair of compensating lens elements is needed. These are made of different types of glass to suit designated refractive index and color dispersion.	

9. Types of Lens

To correct aberrations within proper limits, the photographic lens should consist of at least three components. Among an unlimited number of combinations of different glass types and curvatures, only a few are considered suited to correct aberrations. According to a wide range of focal length and aperture, lenses are grouped into several types. Some are named after their inventor (e.g., Petzval type), others after the number of elements comprising the lens (e.g., Triplet) or after an established brand name of a particular type of lens.



On the other hand, some types of lenses have to be designed within certain restrictions. In a telephoto lens, for example, the distance from the outermost lens surface to the focal plane is designed shorter than the focal length (the distance between the second principal point H' and the focal plane F'). Many long-focus lenses now on the market feature this formula.

To further reduce the length of a lens barrel, it is common practice to combine a reflecting mirror surface and the lens elements (called "catadioptric"), as in the Reflex-Nikkor.

On the other hand, lenses for the SLR camera must have a certain clearance between the lens and the focal plane. The back clearance of wideangle lenses of conventional design is too small to allow the movement of the reflex-mirror. In such a case, a "retrofocus" type lens is the answer. Its back focal distance is greater than the focal length. This type lens is advantageously applied to wideangle lenses for use with the single-lens reflex camera. It is also called the "inverted telephoto" type.

10. Resolution of Photographic Lenses

Sometimes, the calculation results of the aberrations are utilized as a criterion to determine the picture quality of photographic lenses. However, it is known among lens designers that there are many other factors that have to be taken into consideration in examining the optical performance of lenses. Judgment based solely on the calculation results is often erroneous, especially in designing photographic lenses of large apertures.

The quality of a lens may be accurately described quantitatively—in terms of resolution or its ability to separate the lines of different thicknesses precisely marked on a test chart. Hence, the more lines a lens can separate, the higher its resolution or resolving power.

This resolution involves the diffraction of light that affects the sharpness of the image, as the lens is stopped down to a smaller aperture. It is regarded as a reliable criterion for judging the quality of a lens.

In comparing lenses, however, resolution tests present a number of problems. It is difficult to test various lenses exactly under the same conditions.

The results of a test may differ if it is conducted by different people at different times. Measurement and determination of the resolving power are governed by numerous factors like these:

* Form or shape of testing marks.
* Contrast of marks shown on the test chart.
* Illumination of the test chart.
* Whether the test mark images are observed in the air or projected on a screen or photographed.
* Criterion distinguishing resolved test mark from the unresolved test mark.
* Sight of inspector who judges the focused plane.
* F-stop of lens chosen for the test.
* Reproduction ratio of image chosen for the test.
* Tolerance limit for determining resolution.
* Sharpest image plane chosen.
* Fineness of emulsion grain of film used for photographing.
* Thickness of emulsion layer.
* Length of exposure time in photographing the test chart.
* Method of development of film negative.
* Actual position of film plane on the camera used.

angle or camera position, such distortion would become obvious to the eye, even though the moving eye makes allowances for such distortions. In the use of long focus or telephoto lenses, camera position can create foreshortening or flatness to the main subject relative to other objects in the scene, which are not obvious when viewed by the constantly moving human eye.

Depth of field, too, can change the perspective of the final picture and thereby distort the subject matter, something the human eye does not do. The shades of white, grey and black in a black-and-white photograph can easily lead to a distorted sense when looking at a picture. A brilliant color in a color picture against dull colors, too, can present a different sense to the viewer of the picture than what the real subject matter might be.

The apparent convergence of vertical lines, say in a picture of a tall building, is the result of the correct geometrical perspective of the subject as seen by even the best quality lenses. This is because these lines are not on the optical axis of the lens.

Thus, important to the beginning photographer, is that he should never point the camera upward or downward in making pictures, especially those which have a considerable number of vertical lines. If such pictures are made, a general rule to follow is to place the camera in a position about half way between the top and bottom of the subject with the camera pointed horizontally.

Use of a wideangle lens, although intended for such photography, could present a distorted picture, too, if the camera-lens position is off the axis.

If it is impossible to correct the situation by moving the camera-lens position, then such lenses as the PC-Nikkor 35mm f/2.8 lens, with rising and falling front objective, is an ideal solution to the problem of convergence of parallel vertical lines. This movement of the lens is similar to the swinging back of many larger view cameras.

Where a long focus or telephoto lens is utilized, expanding the depth of field is one way to eliminate foreshortening or flatness in the negative. But, with greater depth of field by stopping down the diaphragm, the use of a tripod becomes more important because of the slower shutter speed and the weight of the lens itself.

Essentially, distortion or unnatural perspective is the result of the camera-lens combination being either too close to the subject or too far away. Since the human eye is constantly moving, it literally ignores distortion in a subject because of "visual perception."

What is desired in the final print, whether it be with or without distortion, should determine the selection of lens and camera position. Because we are making a "still" picture, the perspective which we receive from the final print must be considered before making the exposure on the negative.