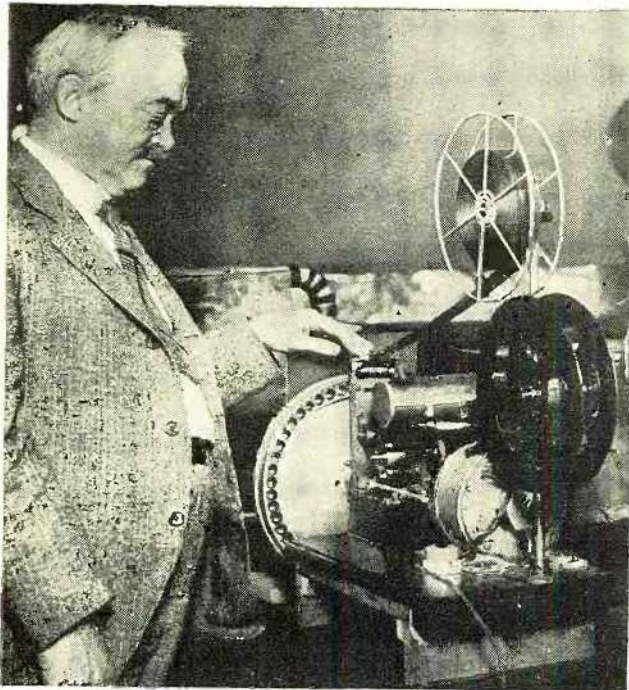
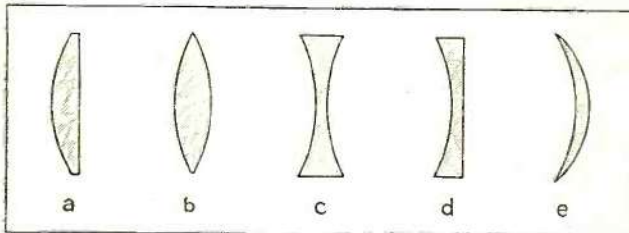


Lens Design for



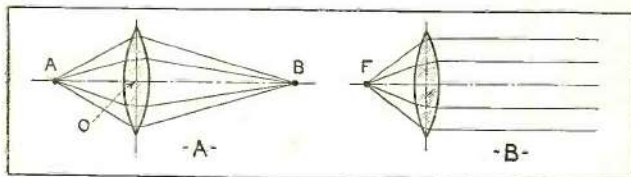
JENKINS LENS SCANNER

Here is one of the first lens-scanning discs as used by C. Francis Jenkins in a machine for broadcasting radio moving pictures



TYPES OF LENSES

Figure 1. A is a plano-convex lens, B a double-convex, C a double-concave, D a plano-concave and E a meniscus



FOCUSING LENSES

Figure 2. At A is a lens that focus points at A and B. At B is a lens with a focus point at F and another one at infinity

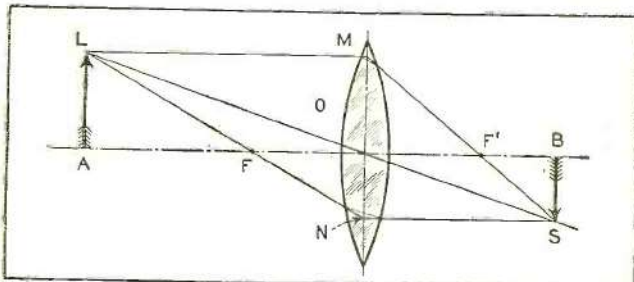


IMAGE PROJECTED BY A LENS

Figure 3. This diagram shows a graphical location of any image projected through a single lens system

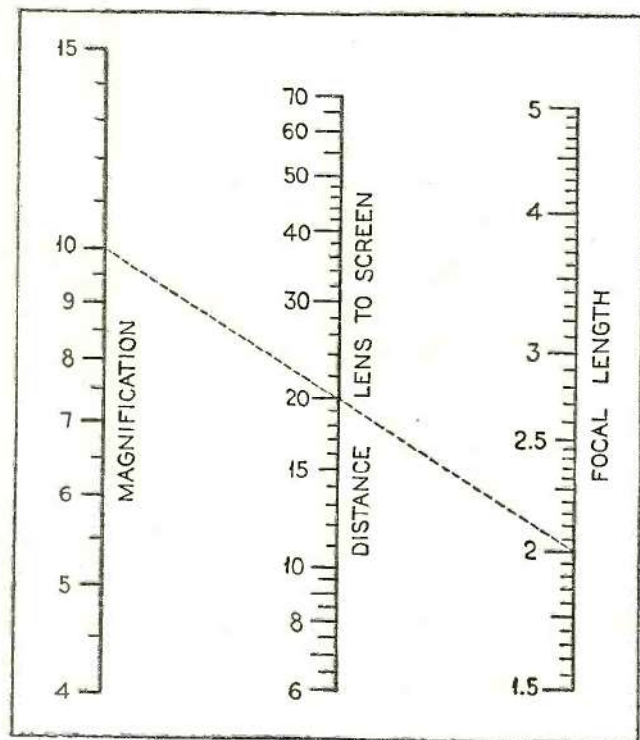
Television technique has progressed for the experimenter to know as applied to scanning and article, gives the simple formulas for and types of lenses

By Ralph

AS radio communication called for a great amount of investigation in the field of sound and acoustics, so television is calling attention to many optical problems. Fortunately, the optical laws are better known than most of the acoustical laws, and both physical and geometrical optical relations are well covered in literature. The particular problem that confronts the experimenter, in constructing the most modern projection systems of television reception, is the selection of suitable lenses for the scanning disc, or in adapting the equipment to use lenses that are available but whose properties may not be known.

Unless extensive polishing and checking processes have been used in the grinding process the lenses may all have certain variations which will have important bearings on the results when used in television. This article will review some of the optical laws and will give their applications to the particular problems involved in scanning.

A simple description of a general-purpose lens is furnished by three items: the diameter, the type of lens (plano-convex, etc., as illustrated in Figure 1), and the focal length. In the case of special lenses, where the grinding does not follow simple spherical surfaces, a more complete description is necessary, but, fortunately, television scanning does not require their use. The plano-convex and the double-convex shapes are best fitted for the particular requirements of scanning. Inasmuch as either type can be designed to have the same focal lengths,



MAGNIFICATION CHART

Figure 7. This chart shows the inter-relationship between magnifying power of a lens together with distance from lens to screen and focal length

Scanning Discs

now to the stage where it is important something about the optical methods reproduction. The author, in this lens working including both the length that are applicable

R. Batcher

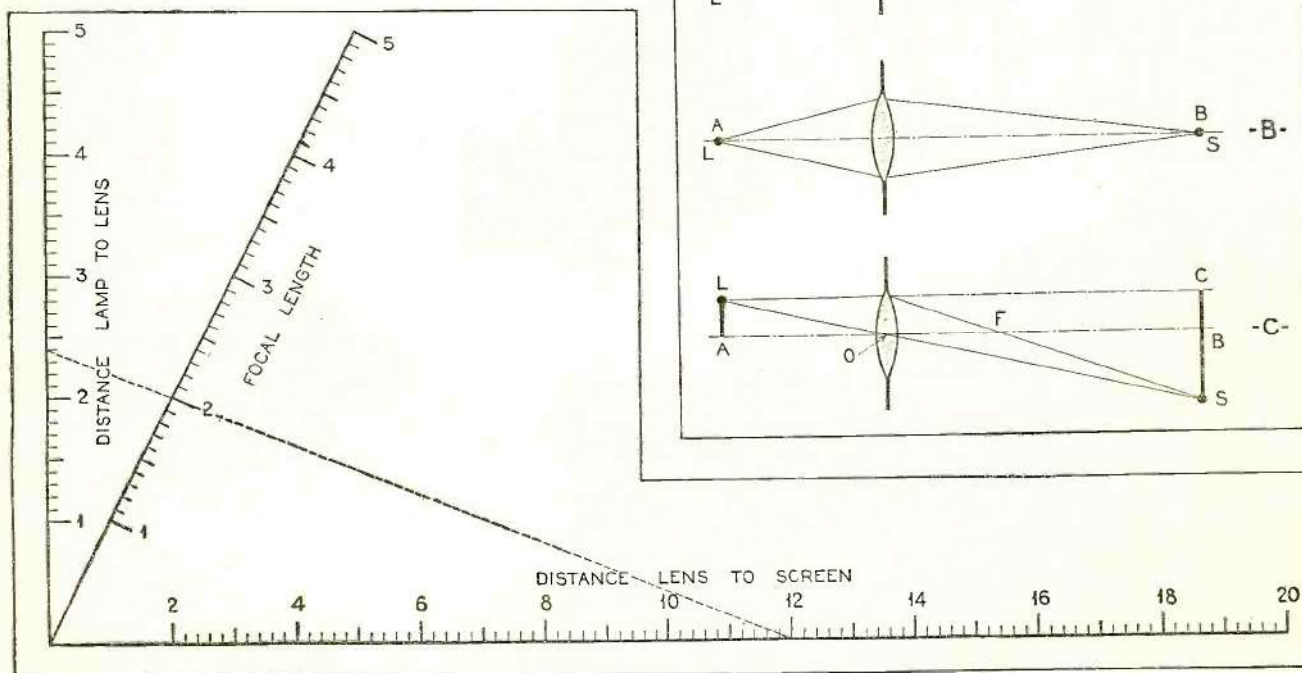
the following analysis can be used for either type.

A lens operates on the principle that a ray of light changes direction when changing from one medium, such as air, to a denser medium such as glass and vice-versa. In Figure 2, a bundle of light rays originating at some point A on the axis of the lens are refocused at a point B on the other side of the lens. It may be shown that the physical distances AO and BO are related by the following equation:

$$\frac{1}{AO} + \frac{1}{BO} = \left(\frac{D'}{D}\right) - 1 \left(\frac{1}{r_1}\right) + \left(\frac{1}{r_2}\right) = \frac{1}{F} \quad (1)$$

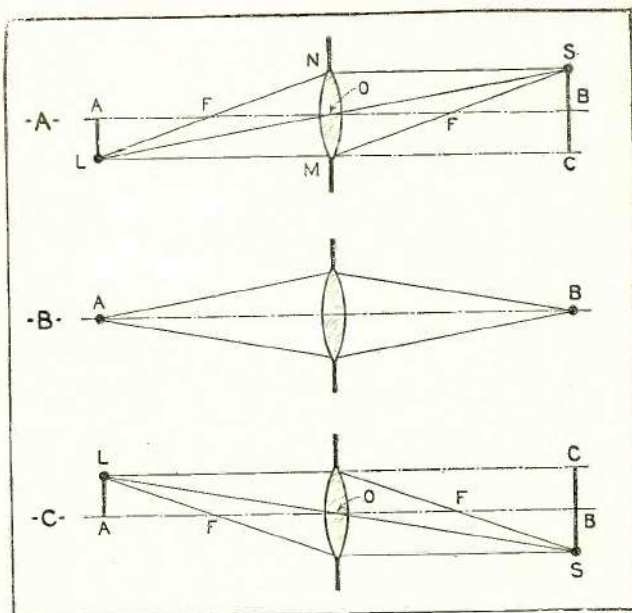
where $\left(\frac{D'}{D}\right)$ is the relative optical density of the glass with respect to that of air, and r_1 and r_2 are the radii of the curved surfaces. Since all these factors $\left(\frac{D'}{D}\right)$, r_1 and r_2 are constants for a given lens, they are usually combined into one constant $\left(\frac{1}{F}\right)$, where F is called the focal length. It is impossible to

determine the focal length of a lens from measurements alone, without knowing the optical density of the glass (which is known technically as the *index of refraction*). The value of this item averages between 1.5 and 1.6 but may run up to values a little under 2 for certain dense types of flint glass. It is, of course, possible to determine, (Continued on page 961)



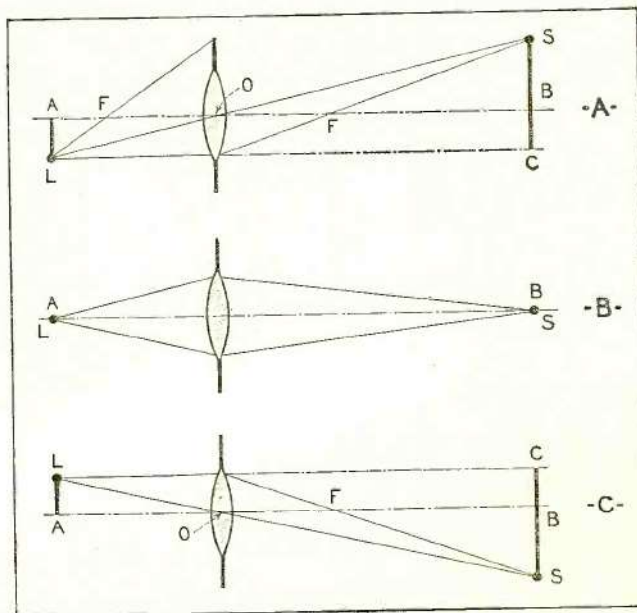
A CHART THAT SOLVES OPTICAL PROBLEMS

Figure 4. This is the focusing chart for finding the distance from lens to lens and the distance from lens to screen or lenses of varying focal lengths between one and five inches



PROBLEMS IN TELEVISION PROJECTION

Figure 5. Above shows three focus points in the diagrams A, B and C and how a lens system accomplishes this. Below, Figure 6, is shown three other diagrams at A, B and C in which the focal length has been considerably reduced



Scanning Discs Lens Design

(Continued from page 915)

experimentally, the focal length of a lens. The curvature of the surfaces is sometimes stated in units of *dioptries*, although, technically, this term also involves the index of refraction. One *dioptry* is the power of a lens whose focal length is one meter. Thus a lens having a focal length of 20 centimeters (approximately 8 inches) would have a refracting power of 5 *dioptries*. In the following analysis the focal length will be used instead of the dioptric equivalent.

The focal power relation (1) has several interesting properties. If either AO or BO is "infinity," as would be the case when the light rays are parallel, Figure 2b, such as in direct sunlight, F is found to be the distance from the center of the lens to the point where the rays come to a focus. This furnishes the simplest method for the experimental determination of the focal length of a lens. Figure 4 provides a simple method for obtaining a solution for Equation 1, where a straight line intersecting the center scale will indicate points on the other scales that satisfy this relation.

In order to illustrate these principles, a series of problems will be illustrated graphically in order to show how light rays are collected and refocused on the screen under various conditions. First the principles will be shown whereby images of objects located away from the axis of the lens are reproduced (see Figure 3). In this diagram the object AL is placed parallel to the plane of the lens. Imagine that one ray of light from the point L goes through the center of the lens O. Since it leaves the glass at the same angle that it enters, it is undeflected and continues on in the direction OS. Another beam of light from L will cross the axis through the focal point F and upon reaching the plane of the lens will be deflected in a direction parallel with the axis. It will eventually intersect the line OS at the point S. If the screen is located perpendicular to the axis so that it intersects this point, the image of AL will be sharply focused on it as BS. It can be shown from symmetry that a ray from L traveling parallel to the axis such as LM is deflected to pass through the focus point F' and if continued will also pass through S. Any two of the above three rays can be used to locate the position of the image.

In practice the present types of television discs are provided with lenses having focal lengths from 1.5 to about 3 inches. Generally speaking, lenses of the larger diameters are designed with longer focal lengths to decrease errors. On the other hand, the greater distance that the screen must be moved out to secure the required magnification precludes the idea of having the screen integral with the television cabinet.

In tracing out the actual ray path from a stationary light source through a moving-lens system the procedure is very similar. Three positions will be illustrated in Figures 5 and 6 which differ only in the lamp-to-lens spacing and therefore in the magnification. These diagrams are based on the assumption of a point source of light. With most types of crater lamps this condition is closely realized.

The light source L produces a conical beam of light directed toward the screen, the center of which is designated C. If the momentary position of the lens is such that its axis is displaced by an amount AL, according to the principles outlined in the description of Figure 3, the rays will be refocused at the point S. In Figure 5 the distance LM is equal to MC, and the displacement of the point S from the center of the screen SC = 2 AL. Figures 5b and

5c also represent other instantaneous conditions where the lens is first centered, and then displaced an amount AL in the opposite direction. Figure 6 represents the same problem, but the lamp is located closer to the scanning disc $AF = \frac{1}{2} FO$, to illustrate how greater magnification is obtained. In these figures it will be found that the distances AO and BO correspond to the Equation (1).

It will be seen that the light source cannot be moved nearer the lens than the focal length of the latter, or else the transmitted light cannot be focused on the screen. The closer the lamp is placed to the position F, the greater the magnification. Figure 7 is a chart that enables the required positions to be readily determined, where a straight line across the appropriate values of focal length and magnification intersects the third scale at a point that shows the required distance from lens to the screen.

In previous paragraphs the grinding variations were mentioned. In general, the important ones are: variations in the focal length and in the optical centering. The latter is due to the optical center of the lens (the line connecting the centers of curvature of the two surfaces) not coinciding with the physical center. This has the same effect as if the lens mounting hole was mislocated by an equal amount. This displaces the picture line either in a tangential direction (which will produce a blurred strip in the picture) or will displace the line radically (which permits a dark streak to show up on the screen.) Frequently this effect can be partially compensated for by rotating the lens around in the mounting hole by an amount determined by experiment, so that the distortion is less effective. Unless the lenses are held to closer limits by specifications, center variations might have a value of around .005 inch.

If all lenses come from the same source and are prepared in the same way, practically no variations in the focal lengths should be found. The extent of the effect can be shown by a numerical example: Assume the normal focal length is 2 inches and that a certain lens has a value of 1.95 inch. A magnification of 10 is used, and that the distance between centers of lenses is 1 inch. This particular lens will produce a line 10.25 inches long. Since the greatest displacement ($\frac{1}{8}$ inch) occurs at the edges of the picture, even this error might not be serious. If it happens that the particular lens is not located near the center of the series in the spiral, this additional magnification may cause two adjacent lines to be superimposed, however, causing the usual dark streak.

It is not difficult to pick out a lens, having excessive errors, by successively screening over various holes in the portion of the disc that produces the section of the picture in which the distortion occurs. If the line is displaced but is of the same length as the others, the trouble is due to either eccentricity of the optical axis or to an error in the location of the mounting hole. If the individual line is of a different length, the probable cause is that the focal length is different.

Another effect of less magnitude may be produced by differences in the thickness of the lens and in mounting systems, where small differences are found in the positions of the lenses wherein not all of their optical centers lie in the same plane. The actual change in magnification is directly proportional to the displacement relative to the distance between the lamp and lens. That

(Continued on page 962)



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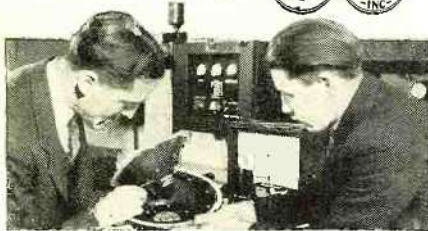
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Two-Volt Superheterodyne

(Continued from page 932)

volt tap is brought to the Class B output stage grids through a separate lead in the battery cable.

There are two possible methods of loading the C battery. The former method consisted of leaving the bleeder system, which was of relatively high resistance, permanently connected across the battery terminals thus producing a continuous low drain. This scheme, while infinitely more satisfactory than no loading at all, was based entirely on rough estimates of the probable number of hours that the set would be operated and on data collected from life tests of the batteries. If the set were operated either considerably more or less than the estimated time, the desired relationship between the B and C voltages would not obtain. Engineers of the National Carbon Company determined after a year's experimentation that intermittent draining at the proper rate while the set was actually in use would produce exactly the desired result, and this system was forthwith incorporated in the 727-DC. Notice in Figure 1, that an additional switch, ganged to the customary ON-OFF switch in the filament lines, is necessary to completely isolate the C battery when the set is not in use. Naturally a truly proportional draining will result only with the type of batteries for which the set was particularly designed. These are the Eveready Layerbuilt No. 486 B batteries and the No. 768 22½-volt C battery or their equivalents.

By this time the reader is no doubt wondering about the possibilities of image-frequency responses in a circuit which apparently has little discrimination against unwanted carriers. As a matter of fact, the

present circuit has a two-to-one signal to noise ratio advantages over the more selective siamese input system, including that of evident economy, and in actual tests it has displayed a remarkable freedom from image difficulties. Responsible in no small measure for this situation, is the use of 465 kc. intermediate-frequency amplification. This increases the separation of possible image frequencies from the desired carrier by a factor of 2.65 over the conventional 175 kc. system. Assuming that the desired station is at 550 kc., the corresponding image point would lie at 1480 kc. Evidently there are image points within the broadcast band for only three channels, namely 550, 560, and 570 kc. The wider separation of these points from the desired frequency means that for the same image response ratio as would be obtained under the 175 kc. system, we must provide the same amount of attenuation as before, but at points which are 2.65 times as far off the resonance curve of the carrier-tuning circuit.

Figure 2 is a front view of the chassis, at the right of which is mounted the high-Q input circuit assembly. The antenna coil is wound on a small bobbin suspended in the front end of the coil form. Immediately behind it is the secondary or first detector coil. The diameter, shape factor and wire size and spacing of this coil have been carefully chosen to give the highest possible ratio of inductive reaction to resistance (Q) the criterion of coil quality. At the rear end of the same form is wound the oscillator tank circuit. The oscillator is thus magnetically coupled directly to the first detector inductor instead of through an auxiliary pickup coil in series with the first detector cathode. The highly efficient transfer of energy from the antenna to the grid of the first tube results in a vastly improved signal to noise ratio over a siamese or other pre-selection system.

The use of 465 kc. intermediate-frequency amplification necessitates a great deal of care in amplifier design. Since coil losses increase rapidly with frequency, the i.f. transformer construction must be designed for high efficiency. The need for thorough shielding of components is also evident at this frequency. As can be seen in Figure 2, all tubes except the output pair are mounted with the special shield assembly extending along the rear of the chassis. This shield is divided into tube compartments by vertical fins attached to the front side. A one-piece cover, enclosing the top and back of the tube compartments, completes the shielding while allowing convenient removal or insertion of tubes from the rear of the cabinet. Figure 3, a bottom view of the chassis, shows the beautiful simplicity of assembly. Notice the extensive application of ground buses which prevent regeneration due to circulating currents in the chassis. Another interesting point is the diminutive size of the by-pass condensers—due, of course, to the use of the higher intermediate frequency.

Adequate swing for the grids of the Class B stage is secured by a preliminary stage resistance—coupled to the second detector in the conventional manner. The grid circuit of this tube contains also a treble-attenuating tone control for discrimination against static and for those who do not prefer the abundance of highs finally delivered from the compensated special permanent magnet dynamic. The overall fidelity from antenna to ear is more nearly horizontal than the characteristic displayed in Figure 6, which was obtained with a pure resistance load.

To sum up, the 726DC receiver is an inexpensive, highly sensitive superheterodyne

(Continued on page 963)

Lens Design

(Continued from page 961)

is, a displacement of 1/34 inch between the center of an individual lens and the normal plans of the other lenses would cause a 1% change in the magnification when the lens-lamp separation is 1.6 inch. An intentional displacement of this sort is sometimes used to compensate for variations in the focal length in some of the individual lenses.

The lens requirements for television scanning discs are really simple, inasmuch as the several distortional factors that complicate the design of many other optical instruments are unimportant here. An enumeration of some of these, however, might be of interest. We find:

1. Color of chromatic aberration; due to a variation in the index of refraction of glass with the wavelength of the color of light. Since one color (only) is to be transmitted, a sharp focus can always be made.
2. Spherical aberration; due to the fact that lens surfaces ground to a true spherical curve have a greater magnification at the edges than at the center. The effect, in television, might be to vary the light intensity at some portions of the projected spot, but this is not important with present-day standards.
3. Astigmatism; which is never present in lenses that are ground true, except to a slight extent for rays entering the lens at a sharp angle, a condition never found in scanning.

With the elimination of all complicating factors from lens design, and utilizing the nomographic charts included herewith, it is believed that this problem becomes a simple routine.