Supplement to the Report of the Committee on Non-Theatrical Equipment

RESOLUTION TESTS ON 16-MM PROJECTION LENSES

R. KINGSLAKE

Since some means for the quantitative expression of the performance of a projection lens is very desirable, especially when attempting to set up standards of projector quality, it is suggested that the visual resolving power of the lens, expressed in lines per millimeter at the film plane, be used as a criterion. The lines should be equally spaced, with the spaces equal in width to the lines, so that a test-chart labeled "100 lines per mm," shall consist of straight black lines $^1/_{200}$ mm wide separated by $^1/_{200}$-mm spaces. At least three lines and two spaces should be included in the test-chart.

It is suggested further that the performance of a projection lens should be specified by stating the resolving power at (*a*) the center of the field, (*b*) the average of the mid-points of the top and bottom of the gate, (*c*) the average of the mid-points of the left and right sides of the gate, and (*d*) the average of the four corners of the gate. The gate dimensions should be in accordance with the SMPE standard, namely, 7.21 × 9.65 mm with a 0.5-mm corner radius.

To facilitate this test, a glass photographic test-plate has been constructed of the required size, and at each of the specified points is situated a panel carrying resolution test-charts spaced 20, 30, 40, up to 100 lines per mm, the lines lying both radial and tangential to the field (Fig. 10). A few additional panels may be added to complete the whole target (Fig. 11). The requirement for resolution is that both the radial and tangential lines at any spacing shall be clearly visible as lines and not as a diffuse patch.

A suitable target was made to a greatly enlarged scale by sticking paper prints from a negative transparency on a wooden board. This was then reduced photographically to the desired size on Eastman Spectroscopic High-Resolution plates (Type *548*), using a highly corrected Microfile lens. This emulsion has a very high resolving power, and it was found possible to make plates on which the 100-line charts are clearly recorded. A photomicrograph of a corner of one of the test-charts is shown in Fig. 12. The writer is indebted to

Mr. B. Elle of the Eastman Kodak Company for his kindness and skill in making these test-plates.

THE TEST PROJECTOR

A simple projector was then constructed to make the tests (Fig. 13). It consists of a standard Kodascope lamp house with 300-w lamp, ventilating fan, condenser, and heat-absorbing glass. The lamp was operated at perhaps 65 per cent of its rated voltage, and as a result

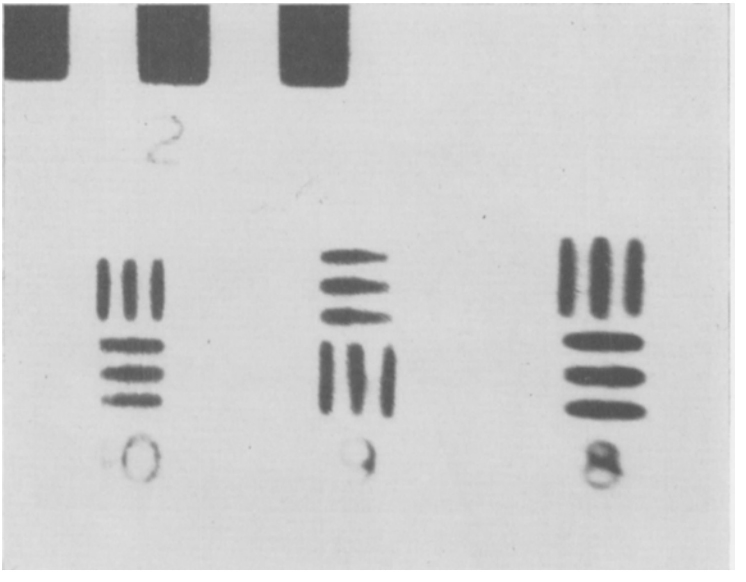

FIG. 12. A photomicrograph of the 100, 90, and 80-line sections of the test plate (×450).

of all these precautions, the test-plates remained cool enough not to fracture during the test. Adapters were constructed to hold various standard makes of projection lens, the rear of each adapter being machined square to the axis of the lens. The glass test-plate was then held against the rear face of the adapter, film side toward the lens, by means of spring clips. A circular hole just larger than the diagonal of the projector aperture was bored in the rear of each adapter to assist in the accurate centering of the test-plate relative to the projection lens axis.

Most projection lenses have a decidedly curved field. For this reason it is necessary to adopt a standard focusing procedure to be used in making a test. It was decided to focus the lens so that the resolution observable at the center of the field is as good as possible. This provides a definite and repeatable criterion of focus, based upon the assumption that most users of cine projectors are more interested in the center of the picture than in any other part.

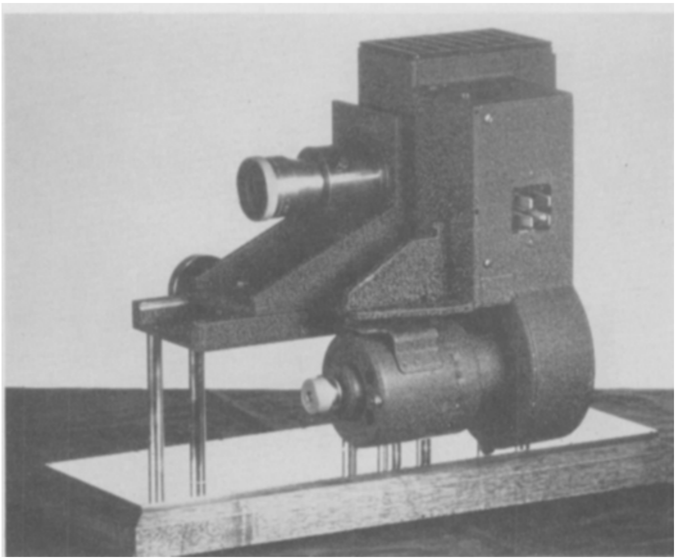

FIG. 13. The test projector.

The size of the projected image is not important, but it may conveniently be about 21 × 28 or 30 × 40 inches. The projected image should be studied close-up when determining the resolving power. A telescope to view the screen is practically a necessity when focusing the projector. Care must be taken to ensure that the light in the center of the field is falling perpendicularly on the screen.

THEORY

Assuming that the eye can resolve two lines subtending an angle of 1 in 2000 (1.7 minutes of arc), then an observer sitting at a distance of two picture-widths from the screen could just resolve details in the screen-image spaced at $^1/_{1000}$ of the picture width. Carried back into the film plane, the actual width of the gate being about 10 mm, this least resolvable distance becomes just $^1/_{100}$ mm. We may thus draw up a table of optimum eye resolutions for different viewing distances:

Viewing Distance (in Multiples of Picture Width)	Theoretical Number of Lines per Millimeter Resolvable by the Eye (Measured at the Film-Gate)
2	100
2.5	80
3	67
4	50
5	40
6	33

It is therefore useless to require better resolution in our projection lens than these figures. In practice, the finest resolution is needed only in the central parts of the screen, where the most significant parts of the picture will generally be found. Actual projected images can not usually be resolved to the extent indicated in this table, because the spherical aberration of the projection lens tends to blur the images slightly.

OTHER PROPERTIES OF THE IMAGE

Although good resolution is the principal requirement of an image-forming system, there are other properties that should be watched. However, if they are not easily noticeable when the image is viewed from a distance of two screen-widths, they are not likely to be serious.

(*a*) *Haze.*—Some lenses possess a large amount of spherical aberration, which has the effect of covering the image with a misty haze of light, without seriously upsetting the resolution. This causes unpleasant projected images, and lenses showing the defect should be avoided. A good projection lens gives a clean, crisp image.

(*b*) *Chromatic Aberration.*—This is not a common defect, and it may be detected by the presence of a colored haze visible in the finer details over the whole of the field.

(*c*) *Lateral Color.*—This defect is manifested by the presence of one-sided color fringes, appearing only in the outer parts of the field and vanishing completely in the center.

(*d*) *Distortion.*—In the presence of this aberration, straight lines in the outer part of the field appear as curved lines on the screen. The straight boundaries of the gate itself make good test objects for the presence of distortion. A lens should not be rejected on the ground of distortion unless it is bad enough to be distracting to an average observer.

OBSERVATIONS

A number of representative 16-mm projection lenses were tested by this method, and the results are recorded below. The positions (*a*), (*b*), (*c*), and (*d*) refer to the center, top, side, and corner of the frame as outlined above.

Manufacturer	E. F. (Inch)	*f*/No.	Resolution (*a*)	(*b*) (Lines per mm)	(*c*)	(*d*)	Remarks
(*a*)	1	2.5	80	50	20	<20	Normal lens type
	$1^1/_8$	2.5	70	70	60	50	Same lens with field flattener
	$1^1/_2$	2.5	80	70	60	50	
	2	2.5	70	70	60	50	
	2	1.6	100	60	20	<20	Normal lens type
	2	1.6	90	80	60	40	Same lens with field flattener
	3	2.0	100	70	50	20	
	3	1.4	90	80	70	40	
	4	2.5	80	60	50	40	
	4	1.6	60	50	40	30	
(*b*)	2	2	70	60	40	20	
	2	2	100	50	20	<20	
	$1^1/_2$	2	>100	30	<20	<20	
	1	2	100	30	<20	<20	
	3	2.5	80	70	50	30	
(*c*)	2	2	90	50	30	20	
	2	2	100	60	30	<20	
	2	1.6	60	40	30	<20	
(*d*)	1	2.46	100	40	<20	<20	
	$1^1/_2$	1.8	90	60	40	20	
	2	2.0	100	50	<20	<20	
	2	1.6	100	70	40	<20	
	3	2.3	90	60	50	40	
	$3^1/_2$	2.7	100	80	60	40	
	4	2.8	80	80	70	70	
(*e*)	2	1.65	90	40	30	20	
(*f*)	2	1.4	70	70	60	20	

CONCLUSIONS

The most common type of projection lens is the $f/1.6$ or $f/2.0$ lens, 2-inch focus, having excellent central definition, and a strongly curved field. These commonly show resolution figures of approximately:

(*a*)	(*b*)	(*c*)	(*d*)
100	60	30	<20

Upon refocusing, these figures can readily be changed to something like this:

50	70	30	20

If a 2-inch $f/1.6$ lens is equipped with a field flattener, the resolution in the center is slightly diminished, but that at the corners is much increased:

90	80	60	40

A similar case is found for a 1-inch $f/2.5$, which became transformed by the addition of a field flattener as follows:

(without)	80	50	20	<20
(with)	70	70	60	50

However, an $f/1.6$ lens in the 3-inch or 4-inch size is often quite satisfactory.

As a result of these studies, it is concluded that, assuming the lens is focused as accurately as possible for the center of the field, acceptable resolution figures would be as follows:

Center	80 lines per mm
Top and bottom	60
Left and right sides	40
Corners	30