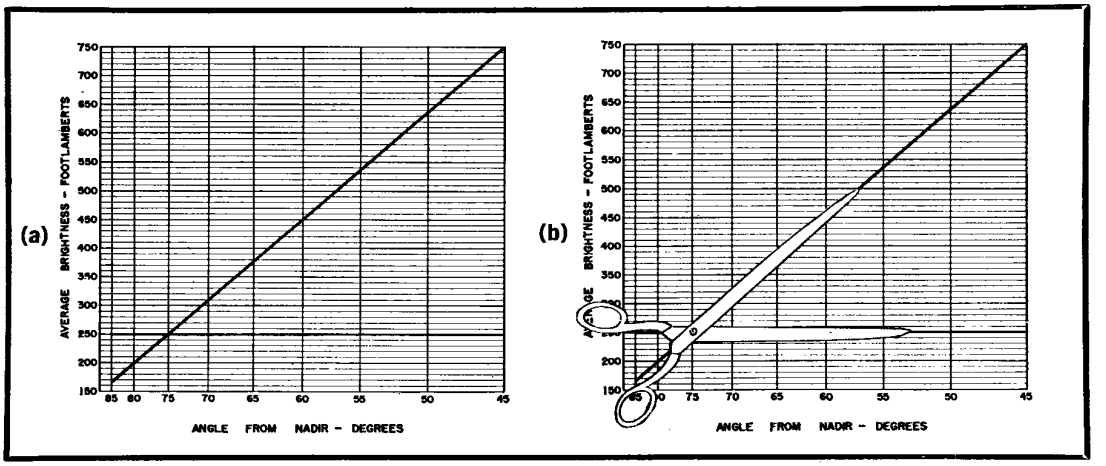


# Derivation, Background and Use of the 'Scissors Curve'

By C. L. Crouch (Fellow)

**THE** expression "scissors curve" was facetiously applied to the graph where two straight lines crossed each other at an apparent "fulcrum" point; drawing loops at the left-hand ends of these lines emphasized the resemblance to a pair of scissors (see Fig. 1). This expression caught on and has been used widely to describe the graph of limiting brightnesses of luminaires for office and school lighting. The two lines represent the limiting conditions between luminaires of uniform brightness (horizontal line) and luminaires having a nonuniform brightness distribution (slant line). For instance, luminaires that have a luminous cylinder enclosing the lamps (which would appear uniformly bright at all angles) would be allowed as high as 250 footlamberts brightness for the usual range of sizes of offices and schoolrooms. The slant line represents the maximum nonuniformity in brightness that would be allowed at the various angles for lighting systems in the same range of room sizes. In other words, each line represents the limiting brightness line for the same degree of protection from discomfort glare. Between these two straight lines there can be any number of straight lines drawn through the "fulcrum" point to represent various conditions of nonuniformity as one departs from the uniform condition. Since both lines represent equal effect and there can be any number of other straight lines that rotate about the "fulcrum" point, one can see that the little triangle at the left-hand side equals the large triangle on the right-hand side in relative comfort effect. If one adds a component to the little triangle, then he must take it away from the large triangle. See Fig. 2. If one adds a component to the large triangle, he must take it away from the little triangle. The relative sizes of the triangles, where the little triangle equals the large

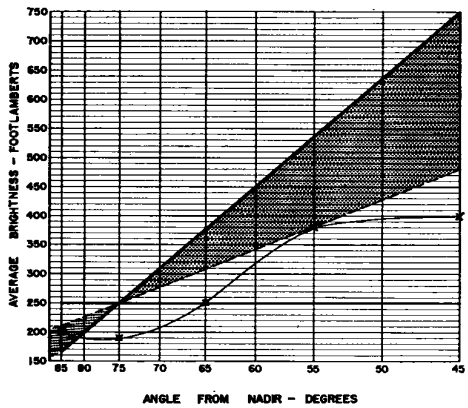


*Figure 2. When one increases the brightness of a nonuniform luminaire above 75 degrees (adds a component to the little triangle) he must reduce the brightness below 75 degrees (take away from the large triangle).*

*Figure 1. (top of page) (a) Direct-glare-zone limiting-brightness curves for the "American Standard Guide for School Lighting and the "Recommended Practice for Office Lighting." (b) When loops are drawn at the ends of the curves or the diagram is overlaid with a pair of scissors, the "scissors curve" connotation becomes apparent.*

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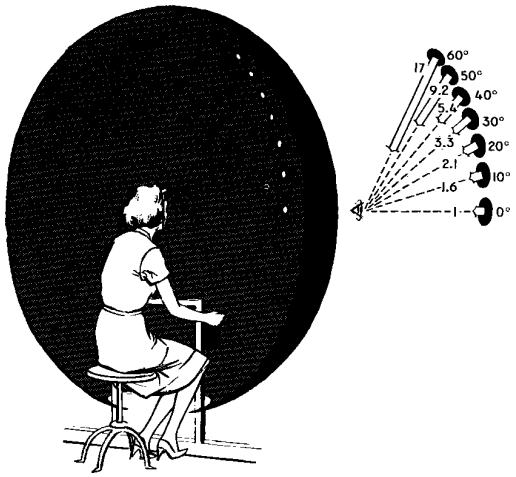
triangle in relative glare effect, were determined by the relative number of luminaires or, rather, segments of solid angle in the two triangles. If one thinks of the luminaires at 45 degrees as being above the horizontal line of sight, he will readily see that very few luminaires are within his field of view. On the other hand, if one is looking at luminaires above 75 degrees, this means that he is seeing the luminaires down at the end of a large room, which means that there are a large number of luminaires contributing brightness toward his eyes at that angle. Thus a little brightness added at the high angles from 75 degrees and up means a great contribution toward the eyes from a large number of luminaires. This is equivalent to a far larger component of brightness from relatively few luminaires at steeper angles with the line of sight.

## Development of "Scissors Curve"

In August 1953, R. L. Oetting and Phelps Meaker[1] presented a short form of glare evaluation to the Office Lighting Committee. This system divided up a large office of 100 by 100 feet with 10-foot source height into four areas of equal glare effect. These areas became zones with midpoint appraisal angles.

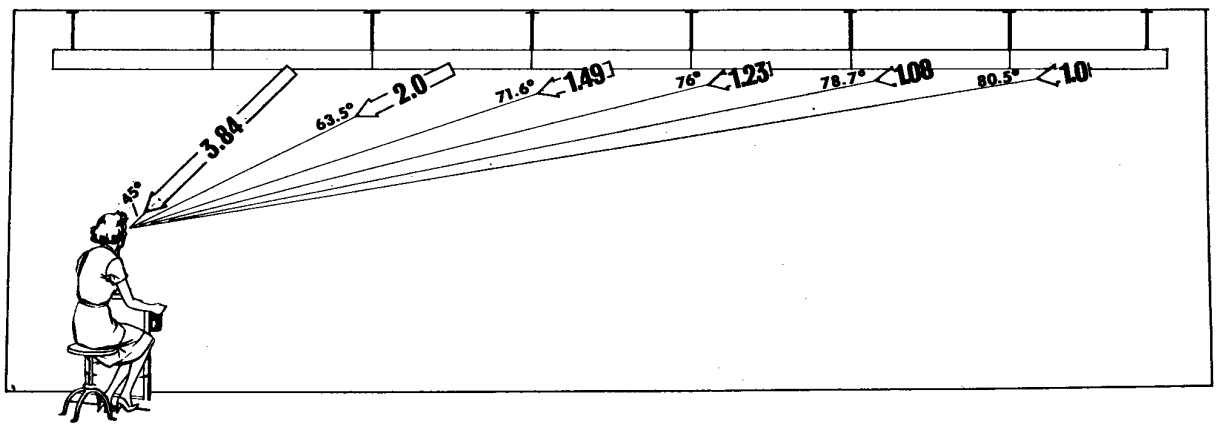



The limiting brightness of uniform luminaires for each one of the zones was calculated. Then any other brightness that might be found at the appraisal angles in the midzones could be related to the calculated limiting brightness through a relative index system. This allowed appraisal of any nonuniform brightness systems.

In 1955, the delegation of educators and the delegation of architects on the Joint Task Committee on School Lighting insisted that a greatly simplified straightforward procedure be developed for showing limits of average brightness for luminaires. As a result, the IES delegates to the Joint Task Committee —J. M. Chorlton, E. M. Strong and C. L. Crouch— met with Carl Allen, Secretary of the IES School Committee, and J. J. Neidhart, Chairman of the IES Office Lighting Committee. Using S. K. Guth's[2] laboratory data from the "porthole" experiment (see Fig. 3), the shape of the maximum nonuniform brightness curve was established. This was the curved line shown in Fig. 4. Since the portholes were very small, in solid angle, the values of Guth's limiting brightnesses were very high. It was necessary, therefore, to relate the shape of his curve to actual limiting brightness values that would be found in regular lighting systems. In order to determine the values as they would apply to these rooms, the Oetting and Meaker index system was used as described above. This established the limiting brightness values for the various angles of view. The concept of applying the Guth "porthole" experiment data to the problem and the use of the index system to determine the limiting brightnesses was carried out by C. L. Crouch.

After these values had been obtained and the uniform luminaire brightness had been determined as 250 footlamberts, the conferees were faced with a straight horizontal line on the graph at 250 foot-

*Figure 3. (left and below) Representation of the Guth "porthole" experiment and relative degrees of brightness derived.*



lamberts and a hyperbolic shaped curve for the luminaires of nonuniform brightness. At this point, Professor Strong developed a nonuniform scale of angles for the abscissa that straightened out the hyperbolic line into a straight line. When the values were established for both the horizontal line and the hyperbolic line, it was found that they crossed at 75 degrees. After the lines were drawn and a study made of the diagram, it was realized that there could be any number of nonuniform curves between the uniform horizontal line and the maximum nonuniform slant line. This allowed great flexibility for the luminaire designer to have any number of average brightness distributions between the uniform condition and the maximum nonuniform condition.

After the development of the graph, J. J. Neidhart tried out a large number of various types of luminaires for which average brightness curves were available. He found that after most diligent study and comparison with the values of visual-comfort-rating systems, the results confirmed the validity of the graph. In other words, those that had a good rating by other means showed good conformity to the "scissors curve." As a result of thorough study, the Office Lighting Committee adopted the scissors curve as the criterion for the 1956 Edition of the "Recommended Practice for Office Lighting."[3] The Joint Task Committee on School Lighting became bogged down with the problem of veiling reflection and footcandle levels so that, while they adopted the "scissors curve" as their limiting brightness criterion, they were unable to get out their Practice[4] until 1962.

In the meantime, the Office Lighting Committee revised their Practice and brought out the 1960 Edition[5] with the "scissors curve" again incorporated.

In connection with the 1960 Office Practice and the 1962 School Practice, it was found that the levels of illumination had increased from the originally calculated basis of 50 footcandles and, therefore, it was necessary to study the effect of the increased field brightness with the higher levels. This was done by O. Phelps Meaker, who found that while the increasing field brightness would have permitted a higher limiting brightness, yet the increase of solid angle of the luminaires to give the higher footcandles compensated in the other direction. Therefore, the limiting values were found to be applicable over a 30- to 100-footcandle range. Further, it was realized that it was not necessary to consider angles above 85 degrees because one could not see these angles in any ordinary room.

While it is true that in glare evaluation one can have higher brightness levels for smaller rooms, the School Committee took the lead in indicating that all structures are comparatively flexible these days and will become increasingly so in the future. They pointed out that there is a rapidly increasing tendency to have movable partitions that can follow the increasing variations in teaching methods. This is becoming increasingly true of offices also, where low partitions are used in areas subject to change within relatively short intervals and where full partitions are movable according to the module system. A small office today may be part of a very large general office tomorrow. Using the "scissors curve" provides adequate protection for these variations. The criterion of the Society is to design for the "commonly found more difficult conditions." Thus the "scissors curve" protects the public for all sizes of rooms up to 100 by 100 feet. For all practical purposes, this means any size room no matter how large it may be.

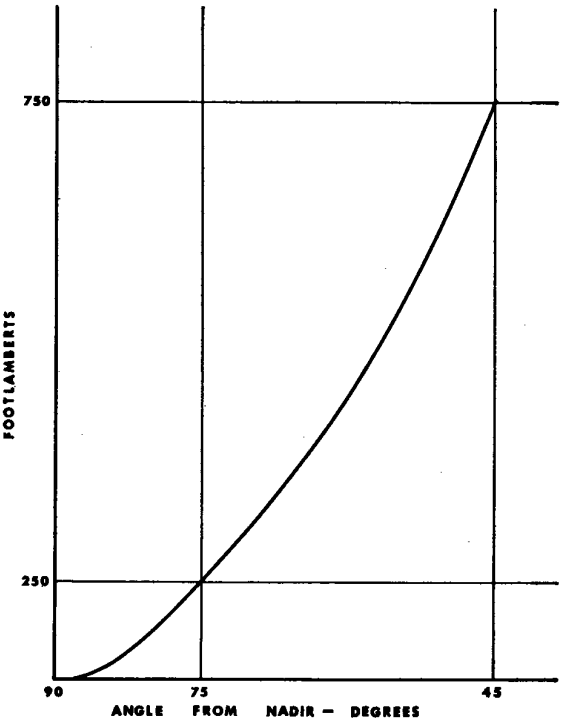



*Figure 4. Shape of maximum nonuniform brightness curve using Guth data.*

## Future Status

In connection with the approval of the 1962 "American Standard Guide for School Lighting," the President of the Society asked the Committee on Recommendations for Quantity and Quality of Illumination to give its appraisal of the "scissors curve" before it was adopted in this particular Practice. The RQQ Committee gave very thorough consideration to all the known data at that time, and concluded that the "scissors curve" represented the best possible criterion to use from a viewpoint of current knowledge. However, they stated that the Society should expedite the development of an IES

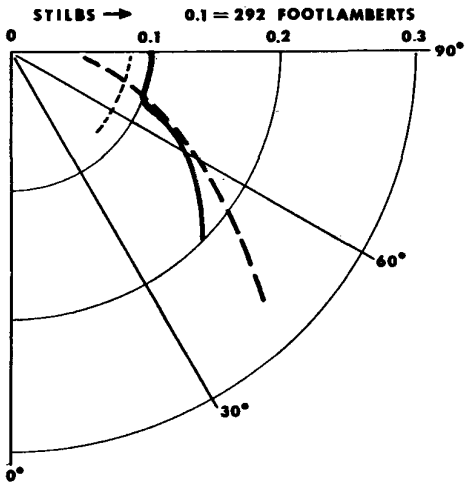



*Figure 5. Polar plot showing relationship between a recent German glare-evaluation study (solid line) and the "scissors curve" (broken lines).*

comprehensive discomfort-glare-evaluation system. They strongly urged that IES encourage the Illuminating Engineering Research Institute to obtain the information to bridge the gaps of knowledge that existed at that time. Report No. 6[6] of the IES Committee on Standards of Quality and Quantity outlined the various gaps of knowledge that hindered the development of a comprehensive glare-evaluation system. IERI has been diligently pursuing the evaluation of discomfort glare from large-area sources at Cornell University and research has been going on in England and on the Continent. Furthermore, S. K. Guth has been developing his data and information more comprehensively.[7]

Messrs. Bradley and Logan[8] have brought out a proposed glare-evaluation system based on the Guth formulae. It has had considerable confirmation by the work of Allphin[9] on the evaluation of discomfort glare in a simulated office. While a number of questions raised in SQQ Report No. 6 have not been answered by research, it was proposed by Messrs. Bradley and Logan to use their method as the best current substitute for the original objective of the RQQ Committee to develop a system where all of the unknowns had been tied down firmly by research.

Since the Bradley-Logan method has been broached to the Society, the RQQ Committee have had a hearing by these authors and appointed a direct-glare-evaluation subcommittee in the person of G. A. Fry. It had been through the work of Dr. Fry that the SQQ Report No. 6 had been developed. Further, he had studied the continuing work, both here and abroad, from the research viewpoint and he was asked to evaluate the Bradley-Logan method in terms of its appropriateness in evaluating discomfort glare. Dr. Fry has made considerable strides in studying the subject and consulting with the people involved. It is anticipated that in the near future there will be some results of very tangible benefit to the Society.

Once a comprehensive glare-evaluation system has been developed, it is anticipated by some that the Society may still wish to have some simplified criterion for the limitation of brightness of luminaires for its Practices in the field. In the writer's trip to England and the Continent last October, he received considerable comment from practicing IES engineers in London that would indicate the desire to have a simplified criterion similar to the "scissors curve." The consulting engineers seem to feel the need for such a simplified criterion.

In Holland and in Germany, an appeal was made to several of the speakers at a conference that a simplified criterion be developed for limiting the brightness of luminaires. Out of this discussion has come a paper that is being presented before the IES Conference this fall by H. W. Bodmann, G. Söllner and E. Senger. The paper is entitled "A Simple Glare-Evaluation System."[10]

It was never intended that the "scissors curve" continue indefinitely. It was the best that we had with the knowledge that was available. It is anticipated that in the not-too-distant future, it will be superseded by a much better criterion. In the meantime, I thought you should not be disheartened in the use of this tool, especially in view of the results obtained in the recent comprehensive glare-evaluation study by the German authors[10] as shown in Fig. 5. The general investigation was with scale-model rooms using actual scale-model figures and the great variation of types of distribution and mounting-spacing relationships of luminaires.

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