BRITISH STANDARD 1404 : 1947

SCREEN BRIGHTNESS

FOR THE PROJECTION OF 35-MM FILM

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BRITISH STANDARDS INSTITUTION

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British Film Institute
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The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard :

National Physical Laboratory
Manufacturers of Cinema Screen and Projector Equipment

BRITISH STANDARD RECOMMENDED PRACTICE FOR

SCREEN BRIGHTNESS

FOR THE PROJECTION OF 35-MM FILM

FOREWORD

The Cinematograph Industry Standards Committee authorised the appointment of a committee in 1939 to consider the question of screen brightness for the projection of 35-mm colour and black-and-white film. A comprehensive series of investigations has been carried out, the results of which form the basis for the recommendation given in this publication. A report of the investigations is included in the Appendix.

The possibility of laying down a more precise standard will be considered at a later date in the light of experience gained with this recommended practice.

SCREEN BRIGHTNESS FOR 35-MM FILMS

The screen brightness should lie between 8 and 16 foot-lamberts (approximately 2·5 and 5·0 candles per square foot). The measurement of screen brightness should be made normal to the centre of the screen with the projector running and with no film in the gate.

NOTE. The method of measurement for screen brightness and permissible limits for the variation of brightness across the screen are being investigated and will be the subject of a further recommendation.

APPENDIX

REPORT ON TESTS

used as the basis for this British Standard

Introduction

The subject of screen brightness was brought to the attention of the British Standards Institution in 1938, and a committee was formed to consider the possibilities of standardization. The preliminary work of this committee consisted largely in the measurement of screen brightness at a number of motion picture theatres. The theatres were chosen to cover the range of conditions in and around London, and it was found that the range of brightnesses achieved was greater than 10 to 1. The lowest brightness gave obviously poor results and the highest brightness gave good results, but it was impossible to determine the optimum brightness from this data. This was, however, not unexpected, and the purpose of the data was to determine the possible attainable brightness with equipment available at the time, under projection conditions obtaining in existing theatres, since it would be useless to publish a standard requiring an ideal brightness greater than the maximum value attainable under practical conditions.

The next stage was the viewing of film selected as typical and projected over a range of brightnesses but no quantitative results came from this examination. At this stage the war intervened and the work was abandoned for six years. The committee was, however, re-constituted in 1945 and the work re-commenced at the stage at which it was left at the outbreak of war.

General

It was generally believed at the time when the committee re-commenced this work that, for a given black-and-white print, there would be a fairly sharply defined minimum brightness below which the projection would be judged unsatisfactory. Above this brightness there would be a region where the projection would be satisfactory and, at extremely high brightness levels, the quality might slowly deteriorate due to grain visibility, flicker, or other like causes. It was not possible to make more than a guess as to the extent of the region of satisfactory projection, and it was early agreed that experimental data would be essential before it would be possible to publish a recommended practice. Experimental conditions which would enable the required data to be obtained were devised, and it was immediately apparent that the simple assumption stated above represented the problem divorced from a number of significant and highly complex variables. The various factors which must be taken into account are dealt with below, and an account of the experimental work carried out is given.

Black-and-white and colour film

It is generally believed that colour film (even excluding additive processes) requires more light than black-and-white film for satisfactory projection. It was accordingly agreed that both types of film should be subjected to the same experiments. As will be shown later, it may be said that no very significant difference was in fact found between the two types of film.

Density of print

Density of print is an extremely important factor. Assuming that the subject range is accommodated on the straight line portion of the negative material, the toe of the positive material will introduce a compression of the highlight tones of the print, unless the print is made so dark (minimum denstiy about 0·6) that only the straight line portion of its characteristic is utilised. A light print (utilising the toe of the curve) will have a lower discrimination of tones in the highlights and must therefore be inferior in its photographic content to a darker print, in which the highlight tone discrimination is not reduced. On the other hand, the dark print will result in a lower effective screen brightness, when projected under the same conditions as the light print, and it is known that (over a certain range) a reduction in brightness results in a reduction of tone discrimination due to the behaviour of the human eye itself. It may be rightly argued from this that each potential screen brightness has its own optimum print density, and indeed it is common practice to make special prints, for important showings, of density level adjusted for the particular theatre in which the film is to be projected.

A print can be made of such a density that the tone reproduction inherent in the print cannot be improved by any further adjustment of the density. A print so made and projected with sufficient light behind it would give the best possible projection conditions, but this ideal projection could only be achieved in the laboratory, since it would require a screen brightness some five times that attained by the brightest theatre screen in London. At the other end of the print density scale is the print having its extreme highlight represented by clear base, beyond which the density cannot be further reduced without intolerable loss of tone discrimination and with little if any advantage in effective brightness (only the shadows and middle tones being increased in brightness).

Prints made for general release are adjusted for density within very narrow limits, and this fact alone indicates that, for the average theatre, a decrease of density gives an inferior result owing to loss of tone discrimination in the highlights. Since it was obviously valueless to arrive at a standard involving the use of a screen brightness, say, five times that attainable with existing theatres with equipment available, it was decided to carry out the initial experiments with normal release prints and to consider denser prints later, if such an extension were indicated by the first results.

Contrast of print

Contrast of print is related to, but probably of less significance than print density. It will be appreciated from what has been said above that a loss of tone discrimination (due to low brightness, etc.) might be at least partially offset by an increase of contrast. The overall contrast (contrast between highlights and shadows) is largely controlled by factors other than the film itself (auditorium lighting, scatter in the atmosphere, etc.); film contrast would therefore only offer the possibility of a minor correction. It was decided, for this reason and for reasons similar to those relating to print density, to carry out the initial tests using film having normal contrast and return to this factor if it seemed indicated by the results.

Types of film

It was not thought that the type of film used would have a pronounced effect on the results, but in view of the rapid change-over taking place in this country at the time of the experiments, it was decided to use only release prints made on the newly developed fine-grain release positive. The colour film employed was 'Technicolor,' since this film was the only type readily available.

Projector, arc and screen

Other factors were the projector, arc and screen but the only one of these three factors likely to have a significant effect on the results was the nature of the arc. The following are the details of the equipment used :—

Projector	Kalee 12
Projector lens	Taylor Hobson Ultimum F.1.9
Lamp	Kalee N.L.
Carbons	8 mm H.I. positive, copper coated, good standard quality
	7 mm H.I. negative „ „ „ „ „
Electrical conditions	62 amps, 38 arc volts
Screen	Non-perforated, matt, white

Since the screen brightness was measured during the tests, the fact that the screen was unperforated made no difference to the results. The perforations are too small to see at a normal viewing distance and their only effect is to reduce slightly the reflection factor of the screen. This was automatically taken into account when the screen brightness was measured.

Auditorium Lighting

The significance of auditorium lighting is difficult to assess. It is also a factor which it is difficult to reproduce, depending, as it does, not only on the power and number of the lights, but also upon their distribution, polar distribution of light from each lamp and the nature of the walls and ceiling, etc,. of the auditorium.

The committee agreed that auditorium lighting is a subject upon

which an authoritative recommendation is urgently needed, and proposed that the subject be considered at the earliest opportunity. It was, however, decided that if it could be shelved for the time being to allow the work on screen brightness to proceed, it would be more satisfactory than allowing the two factors to get mixed, probably to the detriment of both. To take auditorium lighting into account in quantitative detail would have had practical difficulties which would have delayed the work very considerably. It was also felt that the range of possible levels of auditorium lighting was not very large, and that the variation would not have a serious effect on any results obtained on the most desirable screen brightness. The actual experimental tests on screen brightness were carried out in a room in which light reflected from the screen during projection produced an illumination level in the auditorium not far removed from an average effective auditorium lighting.

Auditorium lighting affects the projection in two ways—it affects the degree of dark adaptation of the audience, and it affects the tone discrimination on the screen.* Light from the projector reflected from the screen and back again from the auditorium contributes largely to the latter effect even in a big theatre. The tests had to be carried out in a small theatre with a small screen because it was necessary to cover a range of brightnesses 5–10 times those normally attainable with the same equipment. Although the small theatre was provided with 'black' walls, the amount of twice-reflected light was much greater than normal and varied considerably with the particular scene being projected. These conditions made the use of a set level of auditorium lighting almost impossible but it may be noted that, although in this case auditorium lighting was almost entirely controlled by the nature of the scene projected, no significant variations of most satisfactory brightness levels were found to correspond with changes of type of scene and therefore of level of effective auditorium lighting. Neglect of this factor at this stage therefore seems partially justified by the results.

Choice of subject

Optimum screen brightness may depend on the subject matter of the film being projected. In order to take care of this, use was made of a wide variety of different types of subject. The subjects were selected from current material being produced at the time and included such variants as high and low key shots, interiors and exteriors, night scenes, cartoons, etc. The results indicated only insignificant variations in optimum brightness levels according to the type of scene.

* Even though no light falls directly on the screen, reflected light from the walls does, as evidenced by the fact that the white screen is clearly visible although the projector may be shut down.

Method of experiments

The general scheme of the tests was to project the test film (black-and-white and colour, each about 400 ft) under the conditions agreed at a range of brightness levels on the screen varying by factors of 2 times, from a value lower than the lowest brightness found in a London theatre to a value several times the highest found. The members of the committee, most of whom were experts in viewing and judging film, viewed each projection without knowing the brightness and noted general comments on the quality of the projection as a whole and specific comments if desired on any selected scenes. Specific comments were also noted on factors such as visibility of grain, flicker, etc. The brightness levels were arranged in a 'selected random' order so that no member of the audience could guess the brightness of any particular showing by reference to the previous showing. The brightnesses were not disclosed to the audience until the whole of the test was complete. The black-and-white and colour film were dealt with on separate occasions.

The screen brightness was controlled throughout by the insertion of a blackened copper gauze or gauzes between the arc and the film and the actual brightness obtained for each projection was measured after the projection by allowing the film to run out and measuring the brightness of the screen with the projector running, by means of a Macbeth illuminometer. A subsidiary calibrated photo-electric instrument was also employed as a check.

The observers remained in the 'theatre' for 20 minutes before the tests began, to reach a suitable state of adaptation, and the period between projections was several minutes, sufficient to allow a recovery and loss of accurate memory of the previous projection.

The observers' note books, which were previously made out in a standard tabular form, were collected and the comments adjusted to a standard pattern with the agreement of the observers. An attempt was then made to obtain some semi-quantitative as well as qualitative conclusions in the manner to be described later.

Comments were elicited under the following table headings :

1. Visibility of grain.
2. Appearance of flicker.
3. Incidence of glare.
4. Specific comments on individual subjects.
5. General quality of projection.

Examination of the results showed that no useful data could be obtained from the comments in sections 3 and 4. Glare was noted at the higher brightnesses and on some scenes at intermediate levels, but there were insufficient data to draw any useful conclusions. Specific comments on individual subjects were infrequently made, and the results may be summed up by saying that dark interiors and night scenes were spoilt in

effect by too high a brightness level, and the cartoon film needed less light than the normal type of picture for satisfactory projection.

The remaining three sections, referring to grain, flicker and general quality were examined in detail with a view to arriving at some quantitative information.

Estimation of quality of projection

The comments of all observers were first reduced to a common form by agreement with the observers individually. The common simplified form was as follows :—

Brightness	much too low.
	too low.
	slightly low.
	satisfactory.
	slightly high.
	too high.
	much too high.

As an illustration, the comment 'Brightness too low for all scenes, but not much below limit acceptable' was translated into 'slightly too low.' When the reduced comments on each individual projection were tabulated a very marked measure of agreement between observers was found. (It may be mentioned that each observer wrote his comments during or after each projection before silence was broken.) In some cases agreement was unanimous, and only rarely were more than two contiguous comments applied to any one projection. The observers' comments on each projection were then 'averaged' by ascribing to each projection an average category plus or minus so many points according to the number of observers who had disagreed with the majority. For example, if 7 observers returned 'slightly high' and 3 observers 'too high' the projection was rated 'slightly high — 3.' The values so obtained were then plotted on a uniform ordinate scale against the logarithm of the measured screen brightness as abscissa, and a smooth curve drawn round the points. The results are shown in fig. 1 in which curve A refers to the black-and-white and curve B to the colour film.

Grain and flicker

Grain and flicker may be considered together since they were dealt with in the same way. The same kind of procedure was adopted as for the general quality of projection, but the categories into which the individual observers' comments were divided were as follows :

Grain Flicker	not visible (visible only in parts if looked for)
	just visible (could be seen if looked for)
	visible (sufficiently visible to attract attention)
	distinctly visible (becoming annoying)
	prominent (intolerable)

It is relevant that the observers sat in the auditorium on either side of the horizontal projection axis at distances ranging from 15 to 20 ft from the 6-ft wide screen. This was designed to give the same angular dimension of picture as would be obtained from about the centre of an average theatre. In no case did the angle between the normal to the screen centre and the line of sight of the observer exceed 30°.

In the same way as described in the last section, the observations of the individual observers were 'averaged' giving weight to minority opinions, and curves were drawn showing judgment category against the logarithm of the measured screen brightness. The results are shown in fig. 2 for black-and-white and fig. 3 for colour film.

Discussion of results of tests

In general it will be seen that the points lie very close to the curves drawn considering the variations which might have been expected from experiments of this nature. It will also be noticed that the general quality of the curves for black-and-white and colour are not very different. In fact they are of precisely the same form but are displaced on the logarithmic (log) brightness axis in relation to one another. It was rather surprising that according to these results the optimum brightness for colour film (represented by the highest point of the curve) is less than for black-and-white. It will, however, be noticed that the curve for colour does not drop as rapidly in the region of high brightness. This could be interpreted to mean that colour will stand more light than black-and-white. No specific comment is offered on this point, but it is the view of the committee that, consistent as the results seem to be, these experiments cannot be relied upon to have established this point. The committee have accepted the two curves as being the same within experimental error, and since there is no question of making different recommendations for black-and-white and colour film the results of the two tests have been in effect averaged. The curves for flicker are also regarded as the same for both types of film, but it is considered that the grain curves indicate a real difference due to the difference of 'graininess' of the two types of film. The incidence of visible grain occurs at a lower brightness for black-and-white films.

The next problem was to arrive at a recommended practice for screen brightness which would apply to black-and-white and colour film alike. It is clear that such a recommendation should include a tolerance and that, because of unavoidable variations in screen reflectivity, arc adjustment, etc., it would be useless to allow a tolerance covering a range of less than 2 to 1.

Black-and-white film. The optimum log. brightness will be seen from the curve to be 1·25, which suggests a range from 1·10 to 1·40, and over this range the projection was generally agreed to be satisfactory. It will be noted, however, that both grain and flicker increase rapidly over this region, which suggests that the range may be on the high side since

members of the audience sitting near the screen may be seriously troubled by these factors.

Colour film. The optimum log. brightness from the curve is about 1·10 which suggests a range from 0·85 to 1·15, and over this region grain and flicker are only just starting to become visible.

Recommended standard

The figures chosen above and translated into foot-lamberts are as follows :—

	Minimum	Maximum
Black-and-white	12	24
Technicolor	7	14

The choice of a figure between these values weighted on the low side to avoid running into difficulties with grain in black-and-white finally led to the recommendation given herein.

With further reference to the curves, it is the committee's opinion that for both black-and-white and colour film a screen brightness less than 4·5 foot-lamberts is unsatisfactory, and that while a normal type release print is used a screen brightness greater than 30 foot-lamberts is unsatisfactory.

It cannot be too strongly emphasised that if the possibility of using a denser print is considered, the upper limit may well be extended with advantageous results but, while a brightness in excess of 30 foot-lamberts can only be achieved in certain special theatres with equipment available at present, it does not seem necessary at this stage to investigate this aspect of the problem.

Acknowledgements

The committee wishes to express its thanks to Mr. C. H. Champion of Messrs. Charles H. Champion & Co. Ltd., Mr. L. Koppel and members of the research staff of the Ship Carbon Company of Great Britain Ltd., who provided the accommodation for the tests and carried out the initial work necessary before the experiments could be attempted. Also to Messrs. Kalee for the loan of the projector which was used in the tests.

Without this assistance, which was freely given in a spirit of co-operation and valuable criticism, this work could not have been completed.

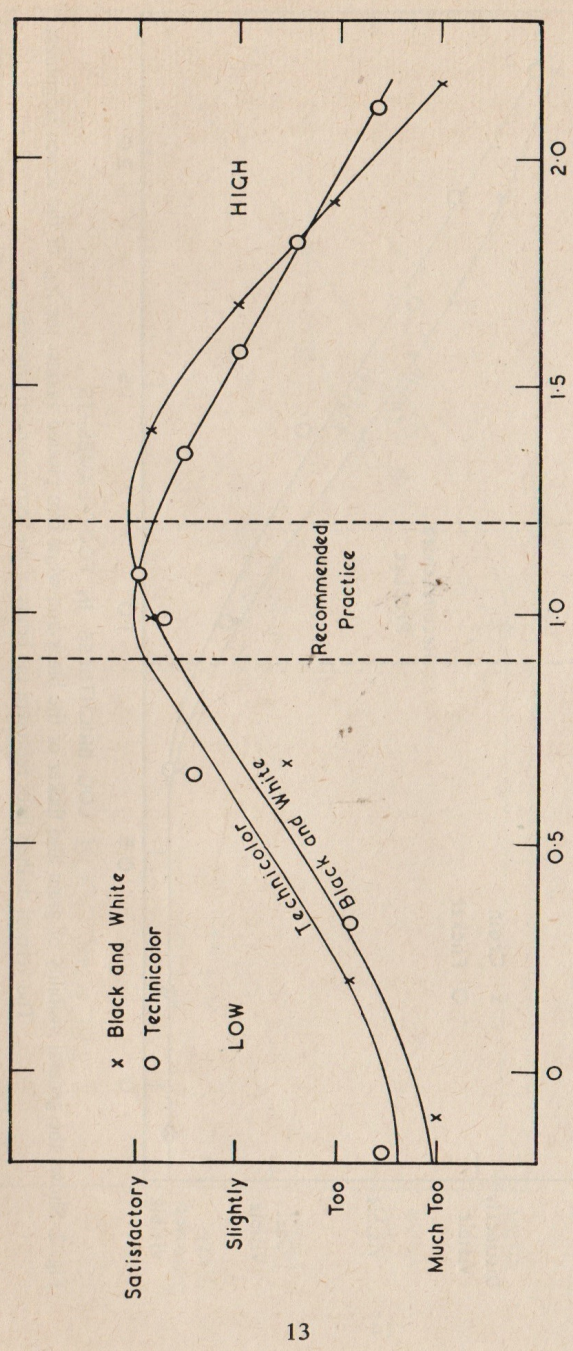

Fig. 1. Shows the general quality of both black-and-white and Technicolor films plotted against the log. of the screen brightness. The vertical dashed lines represent the limits of the recommended practice.

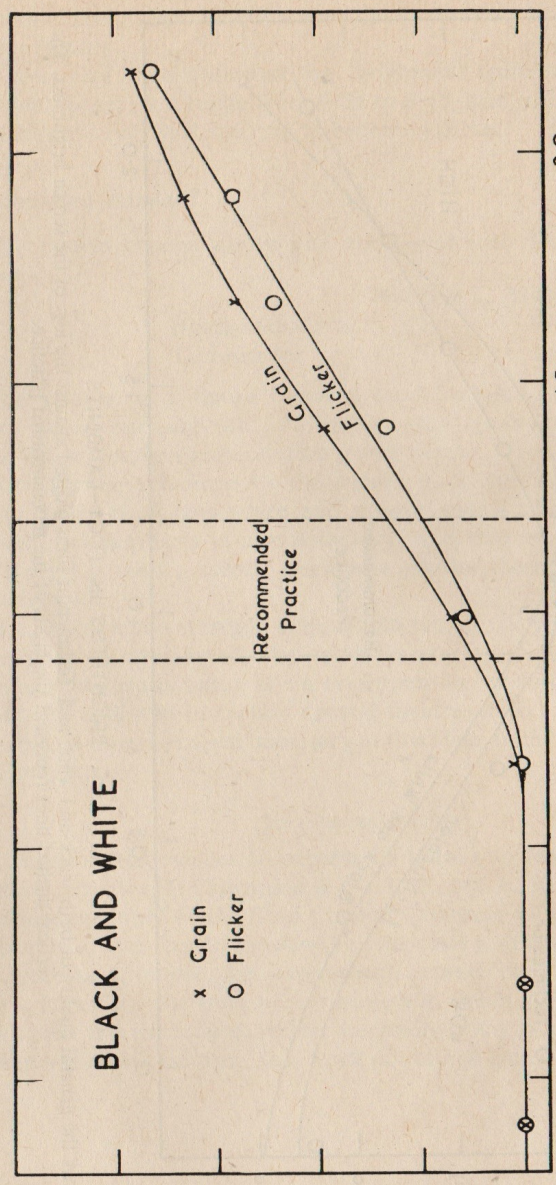

Fig. 2. Shows the general visibility of grain and flicker of the black-and-white film plotted against the log. of the screen brightness. The vertical dashed lines represent the limits of the recommended practice.

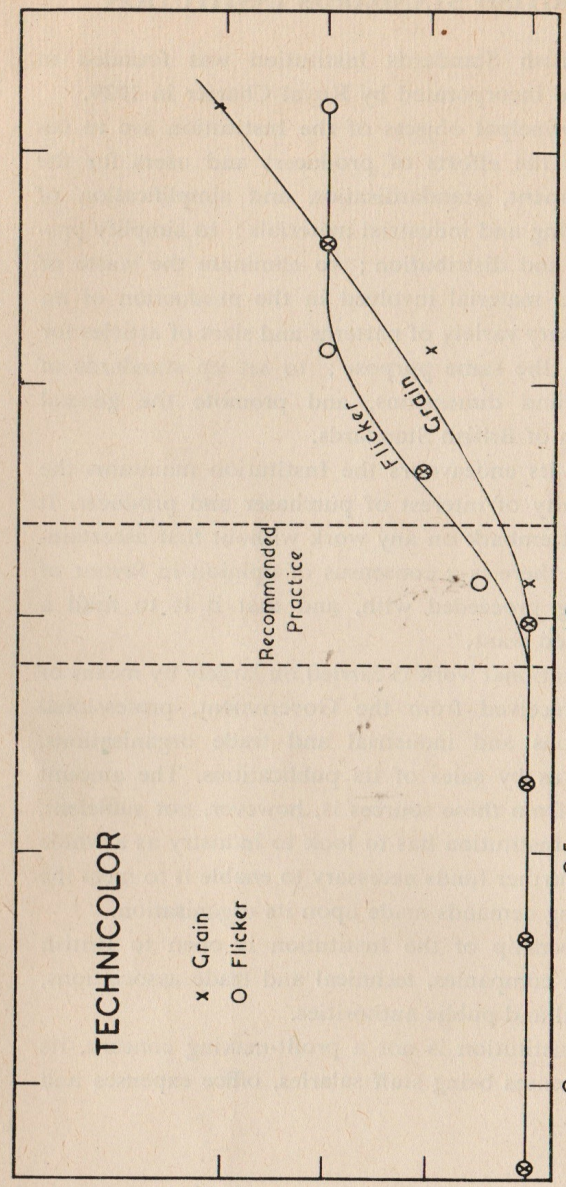

Fig. 3. Shows the general visibility of grain and flicker of the Technicolor film plotted against the log. of the screen brightness. The vertical dashed lines represent the limits of the recommended practice.

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