COLOUR MOTION-PICTURE FILM MATERIALS ESPECIALLY SUITED TO PRESENTATION BY COLOUR TELEVISION

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Introduction

This document indicates the requirements of television broadcasting authorities for complete systems of motion-picture photography, in colour, especially suited to give optimum results when the material is presented by colour television, rather than by optical projection. It does not preclude the use of existing film materials, should they prove to be satisfactory, but it is primarily intended as a guide to the desirable characteristics to be aimed at when designing new products specially for colour television.

To facilitate communication between manufacturers of motion-picture materials for television purposes and consumers in general - as well as for the exchange of internal technical information between television stations - common technical terms are required so as to avoid misunderstandings and misinterpretations. Additionally, this document contains recommendations regarding the parameters that must be measured in order to describe the performance of motion-picture materials suited to presentation by television and suggests how these measurements should be carried out and presented.

Chapter 1

Basic requirements of television organizations

1. System requirements

1.1. Reproduction systems

The systems of colour motion-picture photography offered for use in colour-television broadcasting may employ either the colour negative directly or the colour negative/colour positive process, or they may use a process in which colour-reversal film is exposed in the camera from which reversal prints could be made subsequently. It is anticipated that there will be applications for both these systems.

1.2. Format

For television production, the normal format is 16 mm, but there is a limited application of the 35-mm format.

Regarding Super-8 film, the EBU has recommended that the use of this format in television should be restricted to those occasions where, for one reason or another, l6-mm film cannot be used. Generally, only original film material will give adequate picture quality, and even then the justification of some especially interesting event which might not otherwise have been obtained, seems to be necessary.

1.3. Lighting conditions

Television broadcasting authorities have a wide variety of requirements for colour motion-picture materials, including the following:

a) materials to be used for high-quality productions under controlled conditions with adequate lighting;

b) materials to be used for high-quality productions of the drama and documentary type on location using portable, though not necessarily small, lighting equipment;

c) materials for news gathering, documentary and similar types of productions on location - often shot under adverse, available-light conditions (daylight or tungsten light) or where only small, portable lighting units can be used.

The systems offered must give satisfactory results with naturally-lit outdoor subjects in which the lighting contrasts may be high, and they must give excellent results under controlled studio lighting with a maximum key-to-filler light ratio of 4 : 1.

Two types of film are required: one balanced for 3200 K (artificial light), and the other balanced for 5500 K (daylight). However it is not unusual to filter for daylight using a film balanced for artificial light.

1.4. Copying

The systems of colour photography employed must permit the economic production of multiple copies.

1.5. Final image

The system must be such that the final product (transmission print or original) provides a positive image, either directly or, in the case of negative film, by reversing the image electronically by conventional means.

1.6. Assessment of image

The prints must be physically capable of optical projection in conventional apparatus and must be capable of being edited by conventional means. The picture obtained by optical projection must be a conventional presentation and it must be possible to make satisfactory visual appraisals of picture content, although it is recognised that picture quality may be less than the optimum for optical projection because, for instance, of low contrast. If an optical projection system is used for the judgement or evaluation of films for television transmission, it must conform with the requirements for such projection as laid down in CCIR Recommendation 501-1 (" Appraisal of film intended for colour television ").

1.7. Information published

The sensitivity of the systems of colour motion-picture photography offered must be stated in terms of currently recognised international standards (e.g. ISO 100/21°).

The spectral sensitivity of film stocks must be published and, similarly, the absorption characteristics of the dyes. These, together with any inter-image effects taking place in the system, will be included in the computation of electronic masking to be applied to the electrical signals during scanning.

2. Laboratory techniques - requirements

All measurements on the performance of the systems offered must be made in accordance with the methods described in *Chapter 3*.

This performance must be achieved either by means of commercial processing and print services, comparable in cost with normal colour film processing, or by some reasonably simple process which may be carried out by the user. The time required to obtain the processing services and secure the return of finished prints must also be comparable with that in present professional colour-film printing practices.

Television rum processing operations take place in small regional film-processing facilities as well as in large central laboratories. There are therefore a number of important basic requirements:

1) The processes must be designed to ensure the maximum possible protection against environmental pollution.

2) The film manufacturers must provide complete processing instructions and formulae for their products,

3) Chemicals required for processing shall be readily available,

4) For any given process, it should be possible to purchase the required chemicals in the form of " pre-packed processing kits ".

5) These pre-packed kits must be labelled in accordance with European Economic Community recommendations and national regulations, stating their content and the safety precautions required when handling them.

6) It is desirable that, wherever possible, the processing solutions be of types that can be regenerated and recycled.

7) The chemical and sensitometric processing controls should be as simple as possible.

8) To simplify operations, the processes should not require unduly high temperatures. The energy and water consumption for any given process should be as low as possible.

3. Constraints of use

It is very important, in order to meet the requirements for making serial programmes, that a guarantee be given that the characteristics of the emulsions - under proper storage conditions - are stable over a set period, e.g. one year, from the date of delivery.

Furthermore, the manufacturer shall not pre-record any information on the edge of 16-mm film which may be occupied by the sound track and is now reserved for the recording of a time-code (such as the EBU code described in [1]).

Chapter 2

Physical characteristics of film stock

1. Packaging

Film stock should be presented in accordance with the relevant ISO standards, in particular as regards reel dimensions, direction of winding, etc. Manufacturers are asked to give all appropriate information for each of their products.

2. Dimensional characteristics of raw stock

2.1. Dimensions of 35-mm raw stock

The dimensions of 35-mm raw stock and the corresponding tolerances, such as are recommended in ISO Standard 491-1983, are deemed to be suitable for obtaining satisfactory results when the developed film is scanned in a telecine. 35-mm colour film stocks intended for television must therefore comply with this standard.

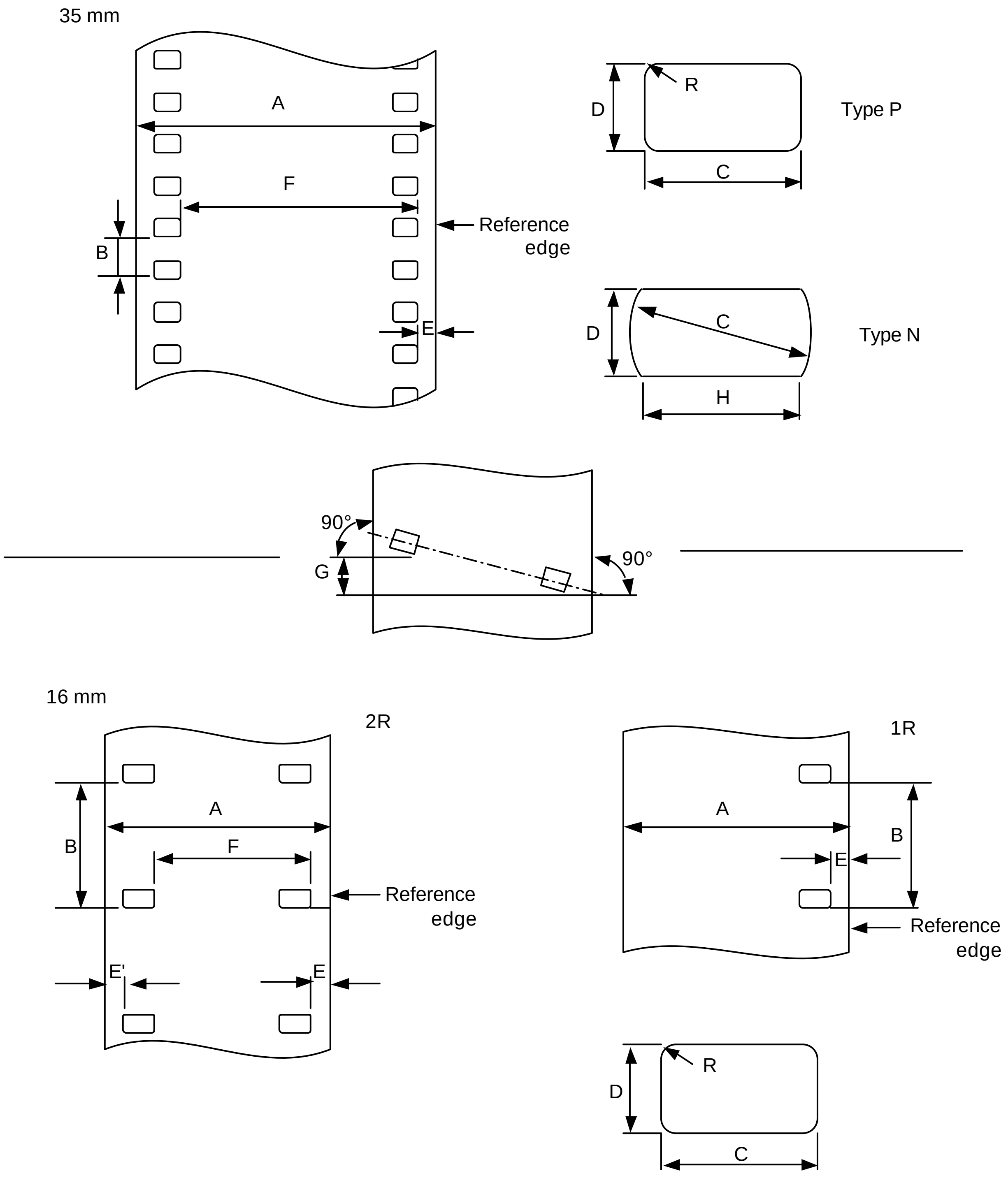


Fig. 1. -Designation of dimensions for 35 and 16-mm films

- Negative raw stock: Type N perforations, short pitch.

ISO Standard* 491-1983 *(Cinematography* - 35 *mm motion-picture film* - *Cutting and perforating dimensions)

Dimension	Millimetres	
A	34.975	± 0.025
B	4.74	± 0.01
C	2 800	+ 0.005 - 0.015
D	1.850	+ 0.005 + 0 015
E	2.01	± 005
F	28.17	± 0.05
G	0.025	max.
H	2.08	nominal
L*	474.0	± 0.4

- Positive raw stock: Type P perforations, long pitch.

ISO Standard 491-1983 (Cinematography - 35 mm motion-picture film - Cutting and perforating dimensions}

Dimension	Millimetres	
A	34.975	± 0.025
B	4.75	± 0.01
C	2 800	+ 0.005 - 0.015
D	1.98	± 0.01
E	2.01	± 0.05
F	28.17	± 0.05
G	0.025	max.
R	0.50	± 0.025
L*	475.0	± 0.4

* Dimension L represents the length of any 100 consecutive perforation intervals.

2.2. Dimensions of 16-mm raw stock

- Professional camera films: Types lR and 2R, short pitch

ISO Draft Proposal
***ISO/DP* 69-1985**
***(Rev.* of *ISO* 69-1972)**

Dimension	Millimetres	
A	15.95	± 0.025
B	7.605	± 0.010
C	1.83	± 0.010
D	1.27	± 0.010
E	0.900	± 0.025
E'	0.900	± 0.050
F	12.32	reference
G	0.01	maximum
L*	760.5	± 0.8
R	0.25	± 0.03

The tolerances on dimensions B, C, D and E are important in achieving satisfactory steadiness. Therefore the ISO is proposing to tighten the constraints on 16-mm raw stock dimensions by adding tolerances on the variation of these dimensions over a certain length of film. It is proposed in a revision of ISO 69 that the following tolerances should be observed for films designated by the manufacturers for professional camera use.

In any 50 consecutive perforation intervals,

B_{max} - B_{min} should not exceed 0.010 mm

C_{max} - C_{min} should not exceed 0.010 mm

D_{max} - D_{min} should not exceed 0.010 mm

E_{max} - E_{min} should not exceed 0.020 mm

In addition, in any two consecutive perforation intervals, the variation in B should not exceed 0.005 mm. Also, between consecutive perforations, the variation in E should not exceed 0.010 mm.

It is not considered necessary to give a limit on the variation of C between consecutive perforations, since this parameter has a comparatively small effect on steadiness of the projected image.

These values for the maximum variations of B, C, D and E may be difficult to achieve with current manufacturing equipment, but it is recommended that future equipment should be designed to produce film which satisfies these requirements.

* Dimension L represents the length of any 100 consecutive perforation intervals.

- Print raw stock: Types 1R and 2R, long pitch.

ISO Draft Proposal
***ISO/DP* 69-1985**
(*Rev.* of *ISO* 69-1972)

Dimension	Millimetres	
A	15.95	± 0.025
B	7.620	± 0.010
C	1.83	± 0.010
D	1.27	± 0.010
E	0.900	± 0.050
E'	0.900	± 0.050
F	12.32	reference
G	0.025	maximum
L*	762.0	± 0.8
R	0.25	± 0.03

The dimensions of 16-mm print raw stock and the corresponding tolerances, such as recommended in the ISO Standard 69-1972 (Cinematography - 16 mm motion picture raw stock film - Cutting and perforation dimensions) and which have been taken over unchanged into ISO DP 69, are not adequate to obtain satisfactory steadiness when the print is scanned in a te1ecine. Dimensions B, C, D and E should therefore preferably be held to closer tolerances (as proposed for professional camera films). In particular, it is the maximum variation in B and E from one perforation to the next within any small group of consecutive perforations that is the most important.

3. Dimensional characteristics of processed film

To permit the optimum design of equipment in which processed film is used (film-scanners, splicers, etc.), the manufacturer should indicate, for each type of film, the percentage of shrinkage after standard development.

The maximum shrinkage should be 0.2 % for negative films and 0.4 % for reversal and print films, stored under the conditions as specified in [2].

* Dimension L represents the length of any 100 consecutive perforation intervals.

4. Friction coefficient

The raw stock should have characteristics such that the friction coefficient allows correct film motion (without additional noise and deposit) in the various cameras used *.

5. Resistance to abrasion

The film materials must have a high resistance to mechanical abrasion to ensure that they perform satisfactorily with conventional cameras, editing tables and telecine projectors.

* An apparatus which enables measurement of the frictional properties of 16-mm raw film stock under conditions as close as possible to those occurring in its practical use in the camera is described in Appendix 1.

The "paper clip" method [3] is a simple practical method which could give a comparative indication of frictional properties of processed film (e.g. degree of lubrification).

Chapter 3

Technical characteristics of film stock

The technical characteristics of film stock are assessed mainly from results of densitometry measurements. These measurements should be made in conformity with the pertinent ISO standards and, in particular, ISO Standard 5 [4], except when stated otherwise in the following specifications.

1. Colorimetric characteristics

1.1. Spectral sensitivity curves of the layers

For each type of film stock, the manufacturers should furnish the spectral sensitivity curves of the three sensitive layers.

These curves express, on a logarithmic scale, the relative sensitivity of each layer to the various monochromatic radiations of the visible spectrum.

The spectral sensitivity is defined as the inverse of the energy for each radiation necessary to obtain, after processing, an equivalent neutral density of 1.0 for colour reversal films and, for colour negative films, a density of 1.0 above minimum density, produced by neutral exposure.

An example of the layout of these curves is given in *Appendix 2.*

1.2. Spectral density curves of the dyes

For each type of film stock, the manufacturers should furnish the spectral density curves of the dyes. These must be made available when the film stock appears on the market, in order to make it possible to determine any colorimetric corrections in film-scanners that may be necessary.

For colour print and colour reversal films, these curves should indicate the densities of the yellow, magenta and cyan dyes, over the range of the useful spectrum, which make it possible to obtain, by superposition, a visual neutral density of 1.0 for a visually neutral sample when illuminated by a xenon arc light. They will be determined without taking the base into consideration.

For colour negative films, the curves should indicate the densities of the yellow, magenta and cyan dyes over the range of the useful spectrum, making it possible to obtain, by superposition, the overall spectral density that corresponds to a neutral exposure producing a density of 0.65 above D_{min} (which corresponds to the exposure of an 18 % grey).

Also, the overall spectral minimum density response should be given.

An example of the layout of these curves is given in *Appendix 2.*

2. Uniformity of density values

For any uniform exposure with a given batch, the densities produced with the same processing should not show any fluctuations perceptible to the eye under normal television viewing conditions.

3. Sensitometric characteristics

Whenever exchanges of data take place, television organizations will employ conventional sensitometry as used by the film industry [5]. To avoid confusion regarding the interpretation of data, it is necessary to state the conditions applied. The exposure of sensitometric wedges must be similar to the one used in practice and, for camera film, the conditions mentioned below should be applied.

3.1. Exposure conditions

3.1.1. Exposure time

The exposure time should be, if possible, 1/50th of a second, which corresponds to the average exposure conditions in cameras; if this figure cannot be implemented, the time used should not, in any case, entail any departure from the reciprocity law.

3.1.2. Illuminant

The sensitometer should have a luminous source with a continuous spectrum. The exposure colour-temperature of 3200 K $^{+0}_{-100}$ (artificial light) or 5400 K $^{+200}_{-100}$ (daylight) will be obtained by means of suitable filters *.

3.1.3. Exposure range

The grey-scale used in the sensitometer should comprise twenty or twenty-one steps. Each step will be neutral for the entire usable spectrum (the tolerance being ± 1 %), the increments of density being 0.15 in the case of twenty steps or 0.20 in the case of twenty-one steps.

* In practice, the transmission characteristics of lenses produce a slight modification of the colour temperature of the radiation and this effect may be simulated in the sensitometer by means of a filter, for which a standardized characteristic exists (ISO Standards 2241 and 2239). Where such filters are used, this must be stated. ISO standard 7589-1984 [6] which overrides standards 2241 and 2239 gives the spectral power distribution of studio tungsten light and daylight, taking into account their transmission through a standard lens.

3.2. Measurement status

Densities shall be measured using a diffuse transmission densitometer [4b]. (For colour films the difference between diffuse and semi-specula measurements can be neglected.)

In measuring densities of colour films, it is at present routine practice to measure the integral densities of the film through blue, green and red filters.

The densitometer and the set of filters used should be such that their combined characteristics meet the definition of a response of "visual", "Status A" or "Status B" density type as appropriate [4c]. For colour reversal films and print films either the visual density or Status A density values shall be determined and for colour negative films the Status M density values.

3.3. Characteristic curves

For each type of film stock, the manufacturers should publish the characteristic curves corresponding to the three sensitive layers. The integral visual density curve should also be published for each type of reversal or print film stock.

The characteristic curves are defined as the curves obtained when plotting the density (D) against the logarithm to the base 10 of the exposure values (lg H).

The measurement conditions should be those defined in Section 3.2. If it is not possible to respect them, the exposure and measurement conditions applying should be indicated with the published curves.

An example of the layout of these curves is given in *Appendix 2.*

3.4. Neutral balance data

For each type of reversal or print film stock, the manufacturers should publish the neutral balance data under the measurement conditions defined in Section 3.2.

The neutral balance data should be given in the form of two ratios:

- the ratio of the densities obtained with the blue and green filters for a visually neutral sample when illuminated by a xenon source;
- the ratio of the densities obtained in the same conditions with the red and green filters.

3.5. Parameters derived from the characteristic curves of reversal films

3.5.1. Minimum density

The minimum density (D_{min}) of a reversal film corresponds to the density of the base and the residual density of the processed film.

This density (which should be given for each layer) must be readable on one of the exposed steps.

3.5.2. Maximum density

The maximum density (D_{max}) is the density obtained after processing of the film stock without any exposure (maximum formation of dyes).

This density (which should be given for each layer) must be readable on the exposed strip.

3.5.3. Speed

The speed of a reversal emulsion shall be expressed as indicated in ISO Standard 2240-1982 [7], i.e. by means of any of the following equations:

$$S_{ISO} = \frac{10}{\sqrt{H_S \times H_T}}$$ in arithmetic representation

$$S^0_{ISO} = 1 + 10_{\lg} \frac{10}{\sqrt{H_S \times H_T}}$$ in logarithmic representation

where H_S and H_T are exposure values derived from consideration of the extreme regions in the characteristic curve.

The curve of the integral visual density shall be used.

This method gives only an average figure and is mainly useful when choosing film stocks for various purposes. In the case of sensitometry or of the exchange of data, it is useful to be able to express the speed of an emulsion more precisely. For internal purposes, it is useful to find from the characteristic curve the value of lg H corresponding to a density D = 1.00. It might be useful to indicate, in addition to this value, for certain transfer characteristics, the value of lg H determined for a density D = 0.50.

3.5.4. Contrast

For this parameter too, the integral visual density curve will be considered.

Two quantities must be evaluated in order to characterise the contrast response of a reversal film stock:

- the contrast γ_1 of the central part (mostly straight) of the characteristic curve
- the toe contrast γ_2.

These quantities are average slopes that shall be determined from the point on the curve corresponding to a density of 0.80 (Fig. 2).

A decrease in lg H of 0.60 shall be used to determine the "average gradient" contrast γ_1

An increase in lg H of 0.40 shall be used to determine the toe contrast γ_2

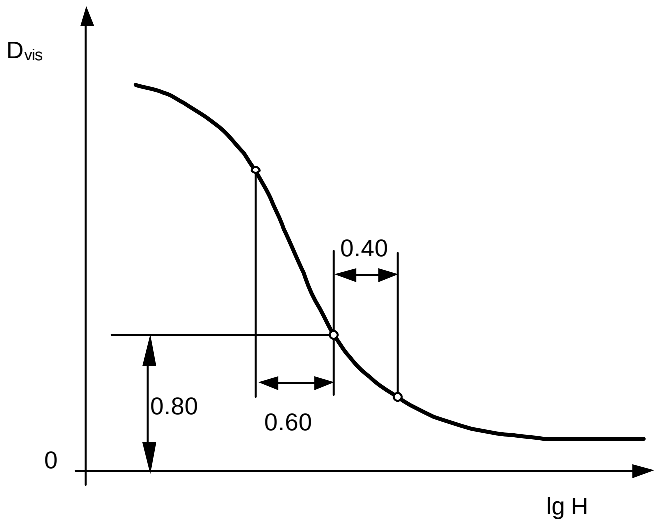


Fig. 2. - Use of the characteristic curve for determining contrast

3.5.5. Usable exposure range

The determination of the usable exposure range (Δlg H) will be effected on the basis of the characteristic curve of the green-sensitive layer.

This exposure range is defined as the difference between the logarithms of the exposures for two slopes of this curve. For reversal films normally used in television the slopes shall be:

- 0.2 for high lights, and
- 0.9 for low lights.

Nevertheless, if the density corresponding to the slope of 0.9 is higher than 2.75, the exposure range will be determined with the logarithm of the exposure corresponding to the reference density of 2.75.

3.5.6. Colour balance

The colour balance of a reversal film stock shall be characterised by the density differences between the layers sensitive to blue and green, on the one hand, and between those sensitive to red and green, on the other hand, for exposures producing, respectively, densities of 0.5, 1.0 and 1.7 in the green-sensitive layer.

3.6. Parameters derived from the characteristic curves of negative films

3.6.1. Minimum density

The minimum density (D_{min}) of a negative film corresponds to the base + emulsion density of an unexposed area of film, that has been processed normally.

This density (which should be given for each layer) must be readable on one of the steps.

3.6.2. Speed

The speed of a negative emulsion shall be determined using the characteristic curves of the three sensitive layers. It is expressed by the following equations:

$$S = \frac{\sqrt{2}}{\sqrt{H_G \times H_S}} \quad \text{in arithmetic representation}$$

$$S = 1 + 10\lg\left(\frac{\sqrt{2}}{\sqrt{H_G \times H_S}}\right) \quad \text{in logarithmic representation}$$

where HG is the exposure in lux-seconds needed to produce in the green-sensitive layer a density of 0.20 above D_{min}.

HS is the exposure in lux-seconds needed to produce a density of 0.20 above D_{min} of either the red or blue-sensitive layers, the less sensitive layer being used (s = slowest).

The arithmetic speed number is normally in agreement with the exposure index (EI) given by the raw film manufacturers.

3.6.3. Contrast

The contrast is determined for the three sensitive layers. It is measured using an average gradient of the range of densities produced in normal exposure of the negative, which will be printed on the linear portion of the print film's characteristic.

This density range is defined as being between D_{min} + 0.20 and a density corresponding to a 19 H value which is greater by 1.2 than that which produced D_{min} + 0.20.

The contrast is the slope of the " best fit " line through the densities measured between these points.

In Fig. 3 an example is given for the determination of the contrast for one sensitive layer.

3.6.4. Usable exposure range

The usable exposure range (Δlg H) shall be measured using density differences from the linear characteristic determined for the contrast measurement.

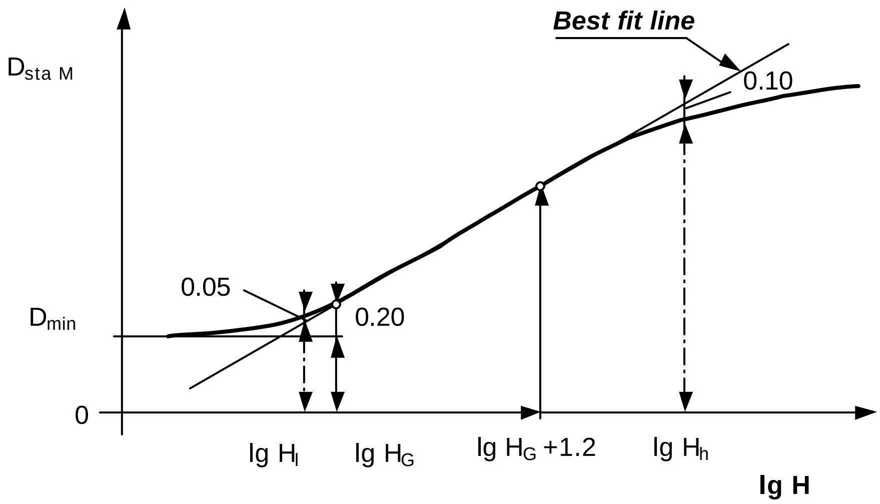


Fig. 3. - Use of the characteristic curve for determining contrast and usable exposure range

Using the characteristic curve of the green-sensitive layer, this exposure range is defined as the difference in lg exposure values between two exposures H_l and H_h :

Δlg H = lg H_h - lg H_l

where:

- H_l is the exposure value that produces a density 0.05 above that of the idealised linear characteristic,
- H_h is the exposure value that produces a density 010 lower than that of the idealised linear characteristic.

4. Image structure characteristics

4.1. Resolution

The resolution performance of film materials intended for television is usually expressed in terms of depth of modulation in fine picture detail compared with that in a coarse pattern. As the degree of resolution of a 625-line, 50-field/s television system is conveniently characterised at picture detail corresponding to a video frequency of 5 MHz, film resolution is accordingly stated at this frequency cut-off point of the transmitted signal. (A video frequency of 5 MHz is equivalent to 13 cycles per mm on 35-mm film and to 28 cycles per mm on 16-mm film.) The response to a coarse pattern producing 0.5 MHz in the video output is taken to be the reference (≈ 100 %).

For comparison purposes, it might in some cases be of interest to quote also resolution values at 3 MHz.

4.1.1. Resolution measurement

For testing in operational practice, the relative depth of modulation of a film emulsion is determined by measuring the resultant transparency-differences of photographed frequency gratings of varying spatial distribution. The black and white bars of these gratings should have a rectangular luminance distribution and be of equal widths. The original test pattern should have a luminance range of not greater than 20:1.

Two different procedures can be used for the qualitative assessment of film resolution:

a) The exposure of the gratings on the film can be carried out with a film camera by imaging a reflective or a transparent test chart * via a lens onto the film. To avoid losses of modulation depth caused by the lens itself it must have a high optical transfer function (the response of the lens at the highest frequency of interest should be at least three times the film response). Furthermore, the dimensions of the image of the gratings on the film must be accurate.

b) The frequency gratings can also be directly exposed on the film without using a lens. This is achieved by contact printing from a high-definition master onto the film under test, either in a sensitometer or in a printer. In this way, the resultant depth of modulation is independent of the characteristic of an imaging lens. For consistent results, however, it is necessary to maintain close contact during the exposure.

In general, the resultant values of the depth of modulation are not only a property of the film emulsion under test but can also be affected by the actual effective exposure and processing conditions. To check these effects it is recommended that either a neutral grey scale be placed beside the frequency gratings, when filming, or the gratings be superimposed in groups on a step wedge.

The exposure should be such as to produce, by averaging the density of the black and white bars of the 0.5 MHz bars, a density of $1.1^{+0.1}_{-0.15}$ for colour reversal films and a density of $0.65^{+0.05}_{-0.1}$ above minimum density for colour negative films.

The measurements from the grey scale and frequency gratings are carried out using a microdensitometer with either Status A, Status M, or visual filtration. Colour negatives are measured directly using Status M filtration for R, G, B values. Colour reversal originals and prints from negatives or reversal originals can be measured either with Status A filtration or visual filtration. In any case the filtration actually used should be indicated with the measurement results. Any prints should be made on commercially-available machines with a known resolution performance.

4.1.2. Performance requirements

Desirable minima for the relative depth of modulation at 3 and 5 MHz are given in *Appendix* 3 for different groups and types of film materials commonly used in television. The figures given can actually be obtained in practice.

* A reflective test chart, which contains appropriate frequency gratings, is described in *Appendix* 4.

4.2. Granularity

Granularity is the objective evaluation of random microdensity fluctuations in photographic images. As the physical properties of film materials mentioned in this document are directly related to television requirements, photographic granularity is accordingly expressed in the form of signal-to-noise ratio.

The signal-to-noise ratio for continuous random noise is defined for television purposes as the logarithmic ratio, in decibels, of the peak-to-peak amplitude of the picture signal to the r.m.s. amplitude of the noise. With regard to images recorded on film, the value of the peak-to-peak signal is derived from the recommended density range for film which can be reproduced in television, and the r.m.s. noise is derived from the r.m.s. value of the fluctuations at a specified film density.

4.2.1. Granularity measurement

The signal-to-noise ratio of televised film pictures can generally be measured at the output of the telecine. However, such a measurement will include the noise generated by the telecine itself. To avoid the need to separate the telecine noise from the film noise, and to provide a simpler standard method of measurement, it is recommended to use a device which analyses the granular structure of the film in a similar way to a television film-scanner, which takes account of the film gauge, and which gives results that compare well with measurements made at the linear output of an average telecine, provided that the telecine is aperture-corrected for its own high-frequency losses.

The Steffelbauer Type FEM 3 film measuring equipment * fulfils these requirements and is already used by a large number of organizations. Its analysing aperture size on the film (30 µm for the 35-mm format and 12 µm for the 16-mm format) was chosen to be equivalent to the scanning spot size in an average flying-spot telecine for the CCIR 625/50 television standard.

The granularity of films for television should be measured on a uniform neutral area. For reversal films, the performance should be stated at an density of 1 ± 0.05. When measuring a print from a colour negative, the negative should be exposed and processed to produce a negative density of 0.65 above D_{min} and should be printed to achieve a neutral print density of 1 ± 0.05 as in the case of reversal film. As film grain may not be uniformly distributed, measurements should be made in at least ten different places and the average taken.

4.2.2. Performance requirements

The granularity that can be tolerated in a film intended for television reproduction is dependent on the resolution of the film because aperture correction increases the visibility of the grain. The values of signal-to-noise ratios in *Appendix* 3 represent the minimum desirable standards of granularity; they can be attained now with the best current products. These values are measured in the luminance channel (VA.-channel) at a film density of 1.0, using the Steffelbauer Type FEM 3 equipment, in the " unweighted" mode. They represent values that can be achieved in a print made from current fine-grain film materials which also meet the resolution requirements in Section 4.1.

Films suitable for use in adverse circumstances might not be able to meet these requirements. In cases where forced processing is necessary, the signal-to-noise ratio should not be degraded by more than 1.5 dB per stop.

In the negative/positive process it is important that the recommendation for the exposure speed of an emulsion should be strictly followed as the granularity of the negative, which is density-dependent, will also appear on the print.

* .Manufactured by Steffelbauer, Hofangerstrasse 100, D-8000 München 83.

5. Luminance characteristic of a film system with a positive image

The response which relates the lg luminance of the original scene with the resultant visual density of the film is regarded as the luminance characteristic of the film. In professional motion-picture practice this response is conventionally specified by the slope ("gamma-value") of the straight portion of the characteristic.

The reproduction of film in colour television has shown, however, that the effective luminance characteristic of film materials intended for television is not sufficiently described by such a single gamma-value, but that the actual shape of the curve, especially in the toe and shoulder regions, has also an important effect on the picture quality. This is of particular importance when reversal films have been force-processed, with inevitable degradation of the luminance response. By determining in addition a value for the usable exposure range (Δlg H), a more-detailed description of the effective luminance characteristic of a reversal film material with regard to its reproduction performance in television is given.

On account of the limited contrast-handling ability of the television system, the film density range, within which all-important picture details shall lie, must be also specified.

5.1. Luminance characteristic measurement

Tests of the luminance characteristic of colour motion-picture film materials offered will be made by photographing a step wedge of neutral grey extending over a luminance contrast of at least 40:1 (preferably 1000:1) and illuminated by a light source of the appropriate colour temperature. For routine testing in operational practice the step wedge is suitably exposed on the film in a sensitometer. If however a film camera is used and a transparency or a reflective test-chart is imaged on the film by a lens, the effects of optical flare must be taken into consideration.

In examining the luminance response of the film the resultant visual density value of each step of the exposed wedge is measured with a densitometer, the geometric characteristics and spectral sensitivity of which conform with ISO Standard 5 [4]. Density versus lg H is then plotted.

5.2. Performance requirements

The luminance characteristic of those colour rum materials offered as being especially suited to colour television presentation should be designed to give the best possible reproduction of the original scene when the rum is displayed by means of colour television. On account of different viewing conditions and the limited contrast-handling ability of the television system compared with a conventional optical projection system, rum material intended for television should have a luminance characteristic with a lower slope than that adopted for optical projection. A desirable gamma-value in the middle straight part of the characteristic is given in *Appendix* 3.

Starting from the fact that the television system is capable of handling only a limited contrast range, higher-contrast scenes should be reproduced without significantly degrading highlight and shadow details.

For international exchange the recommended overall density range of films with a positive image should not exceed 2.4. The minimum density should be 0.25 ± 0.1 and hence the maximum density should not be greater than 2.75. However, it must be recognised that in shadow areas approaching this maximum density, colour and luminance reproduction will be distorted.

These densities can be measured directly from the characteristic curve for a reversal original, but if the measurements are made from a reversal print, then the printing machine should be adjusted so that a neutral density of 1.0 ± 0.05 on the original is printed through to a neutral density of 1.0 ~ 0.1 on the reversal print.

If the measurements are made from a print derived from a negative, the printing machine should be adjusted so that a density of 0.65 ± 0.05 above D_{min} on the negative (corresponding to a correct exposure with an 18 % reflectance grey) prints through on to the print, giving a neutral density of 1.0 ± 0.1.

Any printing machine must have a known good resolution performance.

6. Neutral colour balance, hue reproduction and colour saturation

The colorimetry of all film systems with positive images must give optimum neutral colour balance, hue reproduction and colour saturation when examined visually by light having a correlated colour temperature near to 6500 K*. For practical evaluation purposes the range of 5400 ± 400 K attained by xenon projection systems is acceptable.

6.1. Colour-shift method

For comparison and appraisal of films, with regard to neutral colour balance and colorimetric performance, the colour shift method can be used. This procedure is based upon a test sample method in which the chromaticity of the reproduced neutrals and colours is compared with the chromaticity of the original neutrals and colours, using the same illuminant. To provide results which relate to the perceptibility of the colorimetric shifts, those effects which are caused by different conditions when viewing the original scene and its reproduction must be taken into account [8, 9].

The magnitude and the direction of the colour shift between the object and reproduced test samples can then be plotted in an approximately uniform chromaticity diagram (e.g. u'v' diagram of the 1976 CIELUV colour space).

In addition to a neutral grey scale, a set of critical test-colours is recommended for use in practical tests (e.g. simulation of the spectral reflectances of human skin-tones, blue sky, foliage, etc.) **.

6.2. Measurement

In normal laboratory practice the neutral balance is successfully controlled by means of colour densitometry. The integral densities -measured with densitometers having Status A response for example - depend considerably on the shape of the spectral characteristic of the film dyes as well as on the spectral response functions of the densitometer. This procedure is therefore unsuitable for objective evaluation of the reproduction performance of different film materials. Thus the neutral balance and the colour performance of the film material under test should be specified by colorimetric values. These can be obtained by measuring the spectral transmission of the film and determining mathematically the coordinates in the CIE chromaticity diagram. Alternatively, a colorimeter having a spectral response close to that of the CIE standard observer may be used.

* In accordance with CCIR Recommendation 501-1 (" Appraisal of film intended for colour television ").

** A reflective test chart which contains these important test colours is described in *Appendix* 4.

Appendix 1

IRT friction measuring apparatus

1. Introduction

The physical properties of a film support are important factors affecting the use of film in cameras. In particular, film surfaces with inappropriate sliding characteristics may cause abnormally high or irregular friction of the film in the camera gate. Besides increased noise and power consumption of the camera motor drive, this can also cause excessive picture jitter. Furthermore, it may happen that abrasion debris, due to wearing of the film surface, is deposited on the film guides or on the aperture plate in the camera: the rubbing to which the film is subjected may then increase suddenly. If the resisting force opposing the normal film movement exceeds a certain value the advance of the film is hindered and, in extreme cases, blocked completely. The perforation holes risk being damaged and breakage of the film may follow.

2. Conventional test methods

In order that the user may know if the perturbations to the film movement are due to the film rather than the camera, a test instrument is required to determine the frictional characteristics of the film. For this purpose, several procedures are in use which all apply a continuous motion of two adjoining surfaces:

- inclined plane testing device (so called "paper-clip" method) [3],
- friction balance method,
- standard test method for plastic film.

The second method was described in an article by K.O. Frielinghaus ("Die Reibung des Films im Filmkanal von Kinogeräten") in the *Bild und Ton* review (Heft 1, 1953) while the third is the subject of an American standard ("Standard test method for static and kinetic coefficients of friction of plastic film and sheeting ", ANSI/ASTM D 1894-78). However, none of these methods give reliable information on the frictional characteristics of the raw film stock in the camera, as the variables that apply there are rather different.

3. Frictional conditions in the film camera

In contrast to the above-mentioned conventional test methods with continuous motion, the film in a camera moves in a series of jumps, that is, with non-uniform motion (so-called intermittent film transport). It is precisely this discontinuous film movement with high acceleration to maximum speed and then sudden braking to a complete standstill which has a great influence on the frictional conditions. The sticking and sliding forces follow each other at very short intervals.

As far as the forces on the film are concerned, i.e. the elastic compression or extension or the plastic deformation in the event of excessive forces being applied, it is the maximum resistance during the advancement of the film which is important. This force, directed in the opposite direction to that of the film motion, comprises the inertial force acting on the film during its acceleration and the frictional force in the film gate. For l6-mm film the inertia of the section of film in motion is very small in comparison to the frictional force.

Furthermore, in order to obtain reliable results, the measurements should be carried out under all of the geometric and mechanical circumstances that apply in the camera. As far as is known, the methods of measurement used by film manufacturers, although all derivatives of the friction balance, particularly the ballast weight method, differ in various ways in the constructional details and in the realization of the sliding surfaces and they all differ from practical operating conditions. In conventional cameras the guiding of the film in the region of the aperture plate is effected by a fixed rail fitted with narrow guides which only touch the edges of the emulsion. The back of the film slides over a spring-loaded back-plate which ensures that the film is held flat during the exposure. Also, a fixed guide is fitted at one side, with a spring-loaded guide on the opposite side. To avoid scratching the film, all the surfaces in contact with it are perfectly polished and are often chromium plated.

4. IRT friction measuring apparatus for 16-mm raw film stock

4.1. Mechanical construction

At the Institut für Rundfunktechnik (IRT) a conventional camera has been modified in order to enable measurements to be made of the forces which are actually applied to the film as it moves. The aperture plate and the film guide can move in the vertical direction. As the film moves downwards, the aperture plate held against the film tends to be dragged with it, although it is held back by a quartz crystal against which it pushes. The piezoelectric system, which is highly pressure-sensitive, serves to measure the fast variations in the dynamic forces.

The effective gate pressure of the apparatus can be individually adjusted by a spring balance and controlled during the film transport by a force measuring device.

4.2. Signal processing

In the apparatus built by the IRT (see *Fig. A1.1.*), the charges induced in the crystal by the pressure changes are first transformed into proportional voltages by an amplifier. After the elimination, by low-pass filtering, of the resonant oscillations inherent in the system, the peak values of the forces on the film during the sliding period are determined. The output voltage obtained after rectification indicates the maximum resistive force developed during the advancement of the film; this may be read and recorded. Large amplitude variations indicate that there are variations in the frictional characteristics between adjoining surfaces.

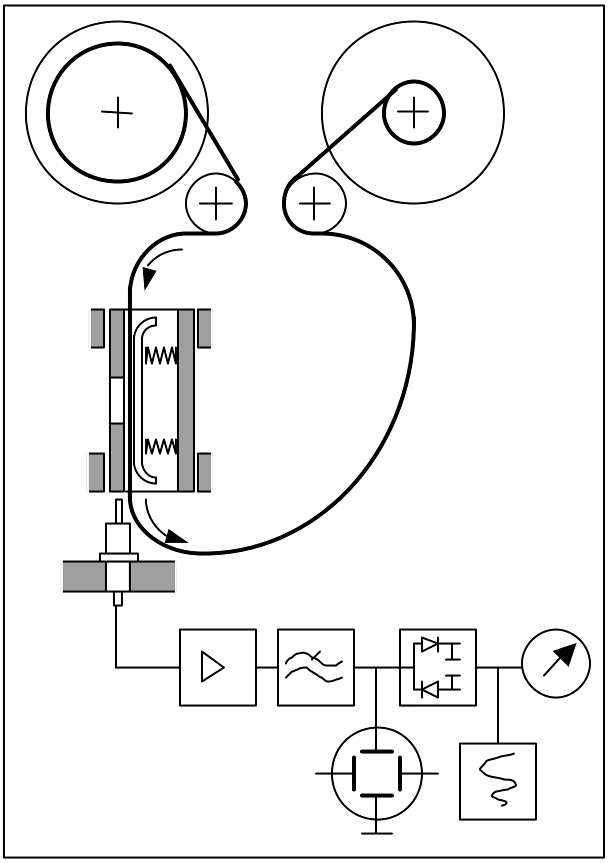


Fig. A1.1. - IRT friction measuring apparatus

4.3. Future system development

As yet there is only one set of this IRT friction measuring apparatus. Standardization of the measurement conditions would certainly allow an exchange of data between users and raw film manufacturers, but from experience gained with this apparatus it appears that this method is too complex for routine use by broadcasting organizations. The IRT is therefore examining the correlation between the results given by this method and those obtained by methods which, although less appropriate, are easier to implement. In the meantime the IRT is prepared to carry out measurements of the frictional characteristics of 16-mm raw stock, on request.

* * *

The present description is an edited extract from a more-detailed article published in the BKSTS Journal Vol. 64; No.2, February 1982 under the title "A proposal for the measurement of the frictional properties of raw film stock", by W. Eilhammer and M. Rotthaler (IRT).

Appendix 2

Layout of curves characterising a film stock

To facilitate the consultation of documents issued by manufacturers, the broadcasting organizations would like to see some standardization in the ways of plotting the various curves that are used to describe a film stock. As a first step, the EBU recommends that the published curves be drawn up conforming to the marking indicated hereafter and that they be accompanied by the information as set out in *Figs A2.1.* to *A2.3.*

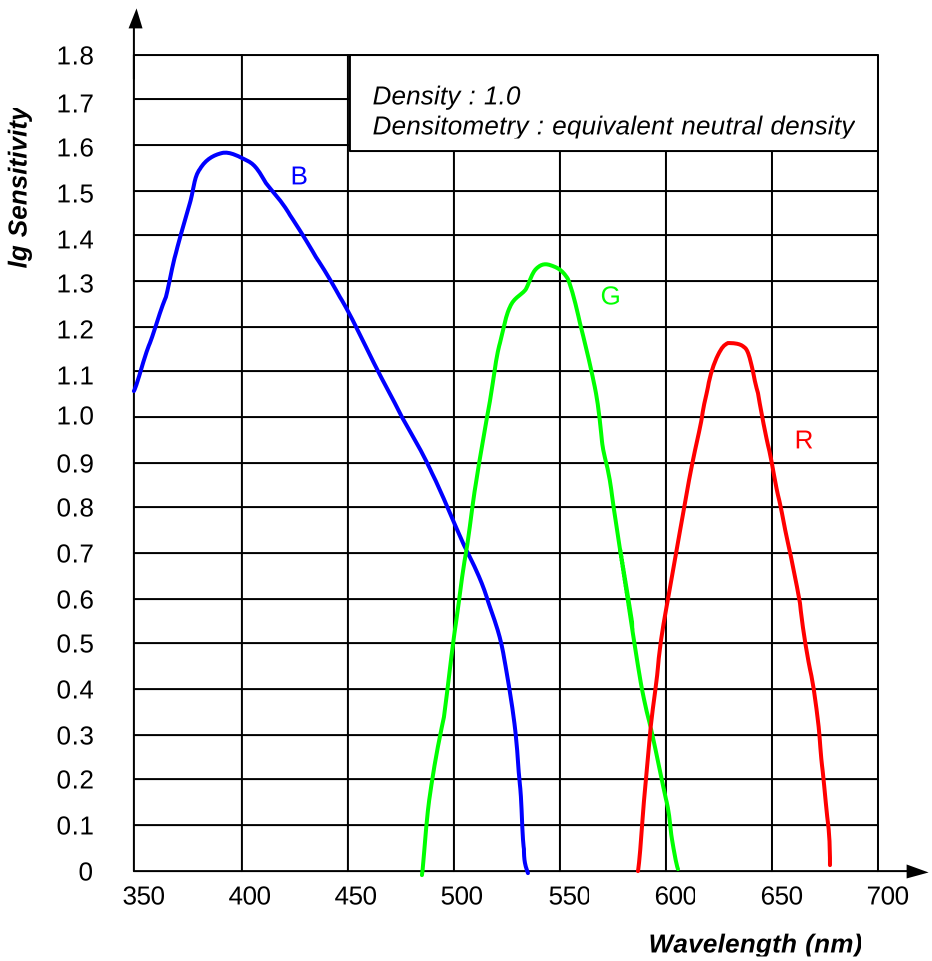


Fig. A2.1. -Spectral sensitivity curves of a three-layer set

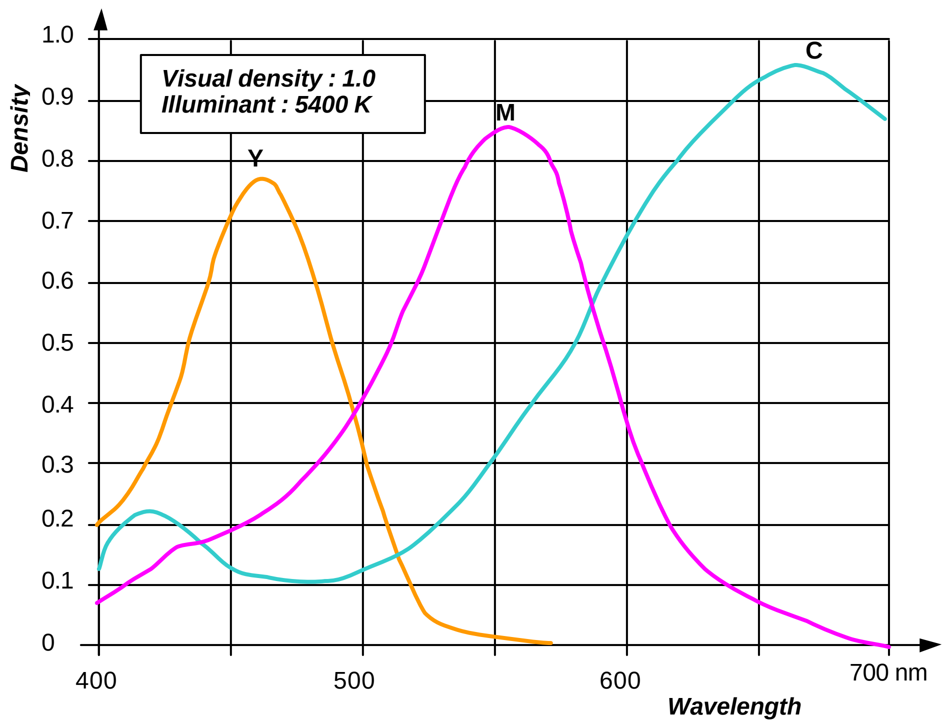


Fig. A2.2. -Spectral density curves of a dye-set

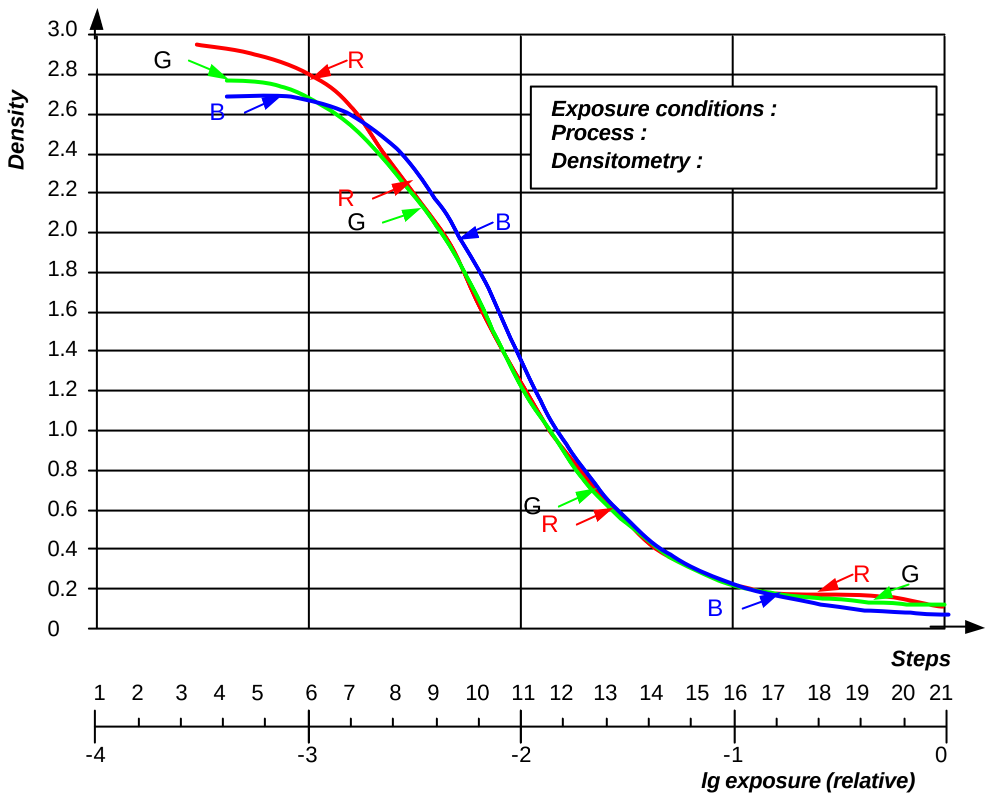


Fig. A2.3. - Characteristic curves

Appendix 3

Typical values for some characteristics

1. Image structure characteristic

1.1. Resolution

Typical values for the relative depth of modulation at 3 and 5 MHz are given below for different gauges and types of film materials commonly used in television. The figures given can actually be obtained with the best current products of exposure index approximately 125/22°. Higher speed negatives and reversal camera films are available but some loss of resolution and increase in granularity may occur when using these films.

		3 *MHz*	**5 *MHz***
35 mm	negative/positive *	100 %	85 %
16 mm	negative original	90 %	60 %
16 mm	negative/positive*	85 %	50 %
16 mm	reversal original	80 %	45 %
16 mm	reversal original/print*	70 %	35 %

To obtain these values, correct exposure and processing must be observed and the luminance characteristic should also meet the requirements as specified in *Chapter* 3, § 5.

1.2. Granularity

35 mm	negative/ positive	**41**	dB
16 mm	negative/positive	37	dB
16 mm	reversal original	37	dB
16 mm	reversal original/print	36.5	dB

These values are determined using the methods described in Chapter 3, Section 4.2.

* This assumes a dry contact printer.

2. Gamma value

The overall luminance characteristic of a film system providing a positive image should have a gamma value as follows :

$$g = 1.4^{+0.3}_{-0.1}$$

The range of tolerances corresponds to different applications.

Appendix 4

EBU film test-chart

For the comparison and appraisal of films under operational conditions, a reflective test-chart is a convenient tool. To enable measurements of the most important characteristics of film materials especially intended for colour television (such as density, granularity, resolution and colour rendering), three groups of elements should be placed on the film test-chart :

- A neutral nine-step grey scale, which varies from D = 0.2 (60 % reflectance, white) to D = 1.8 (1.5% reflectance, black) by equal density increases of 0.2. *(Tab/e A4.1* shows the nearest Munsell samples). The resultant contrast range is thus 40 : 1, which is representative of the average reproduceable contrast range in television.
- Single groups of vertical black and white bars with varying spatial distribution. The bars should have a rectangular distribution of brightness and be arranged symmetrically about the centre where the bars corresponding to 0.5 MHz are placed. The frequencies will be, from left to right: 1; 3; 0.5; 5 and 7 MHz.

Table A4.1. -Relationship between the StElpS of the grey scale and the samples In the Munsell Atlas

Density specified	Nearest Munsell sample (matt finish)
0.2	N 8.25/
0.4	N 6.75/
0.6	N 5.5 /
0.8	N 4.5 /
1.0	N 3.75/
1.2	N 3 /
1.4	N 2.25/
1.6	N 1.75/
1.8	N 1.25/
0.7 (background)	N 5 /

- A group of at least nine test colours, which are an appropriate selection of those contained in the Macbeth Color Rendition Chart " ColorChecker " (Table A4.2 shows the Munsell notation of the selected test colours). They consist of five familiar colours of special importance (with spectral reflectances which represent dark and light skin-tone, foliage, blue sky, moderate red) and four saturated colours (blue, green, red and yellow).

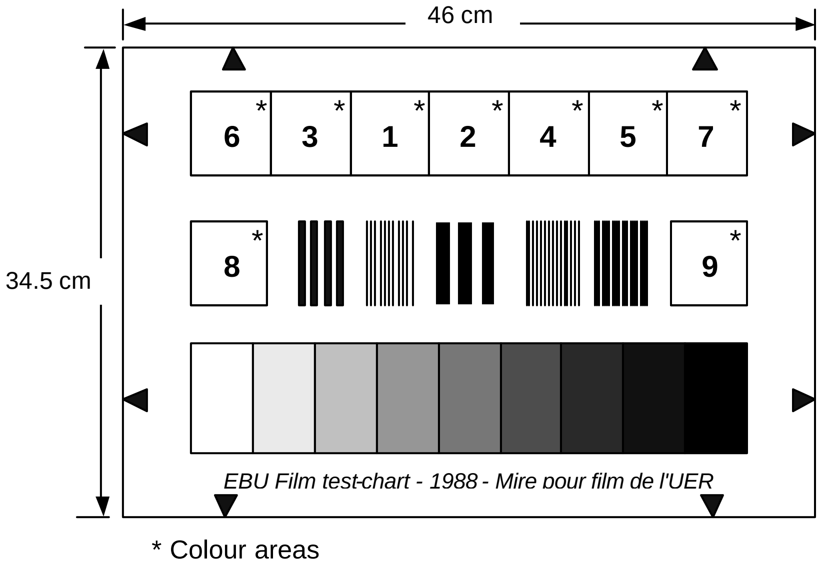
In order to take account of the deterioration in quality at increasing distance from the centre of the lens, all the components of the test-chart should be contained within an area identical to Zone A as specified in EBU doc. Tech. 3218, *Appendix* 1.

The background of the film test-chart should be as neutral as possible and have a density of 0.7, corresponding to a medium picture reflectance of 20 %. It is suggested that the overall structure and the dimensions of the EBU film test-chart be as shown in *Fig.* A4.1.*.

Name of test colour	Munsell notation (hue, value, chroma)		
1. dark skin	3.05	YR	3.69/3.2
2. light skin	2.2	YR	6.47/4.1
3. foliage	6.65	GY	4.19/4.15
4. blue sky	4.3	PB	4.95/5.55
5. moderate red	2.5	R	5/10
6. blue	7.5	PB	2.9/12.75
7. green	0.1	G	5.38/9.65
8. red	5	R	4/12
9. yellow	5	Y	8/11.1

Table A4.2. - Relationship between the coloured areas and the samples in the Munsell Atlas

Fig. A4.1. - Structure and dimensions of the EBU film test-chart



* Such a test chart can be obtained from Doss Klischee & Litho GmbH, Grolandstrasse 76, D-8500 Nürnberg 1

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