SMPTE ST 2065-2:2020
Revision of ST 2065-2:2012

SMPTE STANDARD

Academy Printing Density (APD) — Spectral Responsivities, Reference Measurement Device and Spectral Calculation

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Approved May 27, 2020

Foreword

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SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual. This SMPTE Engineering Document was prepared by Technology Committee 10E Essence.

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "NOTE"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; then formal languages; then figures; and then any other language forms.

Introduction

Academy Printing Density (APD) is an optical printing density metric suitable for use with motion picture color negative and internegative films. APD is defined by the spectral responsivities Π_{APD}.

Π_{APD} are based on the spectral sensitivities of contemporary motion picture print films such as those of the Kodak Vision® family, of the Fujifilm Eterna® family, and of Fujifilm F-CP®. Its definition is also based on the spectral power distribution of a Bell & Howell Model C® printer lamp house with dichroic filters and the spectral transmittance of an Eastman Kodak Wratten® Filter No. 2B.

The spectral responsivities associated with any printing density metric are the product of the spectral power distribution of a printer light source, the spectral transmittance, reflection, and absorbance of the optical components of the photographic printer, and the spectral sensitivities of the print medium onto which the sample is to be printed.

The spectral responsivities used to determine the APD values of a sample are the spectral product (Π_{APD}) of the relative spectral power distribution of the influx (S_{APD}) and the relative spectral response of the receiver (s_{APD}), which includes the photodetector and all intervening components between it and the plane of the sample to be measured.

This standard is accompanied by the following elements:

Element (filename)	Description
st2065-2a-2020.csv	Tabulated Spectral Responsivities, see section 4.1.3
st2065-2b-2020.csv	Tabulated Influx Spectrum, see Annex A

At the time of publication, no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

1 Scope

This Standard defines Academy Printing Density (APD) by specifying the spectral responsivities Π_{APD} and the APD reference measurement device.

2 Normative References

The following standard contains provisions that, through reference in this text, constitute provisions of this standard. Dated references require that the specific edition cited shall be used as the reference. Undated citations refer to the edition of the referenced document (including any amendments) current at the date of publication of this document. All standards are subject to revision, and users of this engineering document are encouraged to investigate the possibility of applying the most recent edition of any undated reference.

ISO 5-1:2009, Photography and graphic technology -- Density measurements -- Part 1: Geometry and functional notation

ISO 5-2:2009, Photography and graphic technology -- Density measurements -- Part 2: Geometric conditions for transmittance density

ISO 5-3:2009, Photography and graphic technology – Density measurements – Part 3: Spectral conditions

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply:

3.1 Academy Printing Density

APD

printing densities defined by the spectral responsivities Π_{APD}

3.2 densitometer

device for directly measuring transmission or reflection optical densities

3.3 influx spectrum

spectrum of the radiant flux incident on the specimen surface or sampling aperture

Note to entry: The influx spectrum is a function of the energy source and the optical system on the source side of the specimen.

3.4 optical density

negative logarithm to the base 10 of the ratio of the integration of the spectral responsivities of a detection system and the spectral transmittance or reflectance of the sample under examination to the integration of the spectral responsivities of the detection system alone

3.5 printing density

optical density measured according to effective spectral responsivities defined by the spectral power distribution of a printer, including the light source, the spectral transmission, reflection and absorbance of its optical components, and the spectral sensitivity of a print medium

3.6 spectral power distribution

power, or relative power, of electromagnetic radiation as a function of wavelength

3.7 spectral product

wavelength-by-wavelength product of two or more spectral power distributions, spectral sensitivities, spectral responsivities, or spectral transmittances

3.8 spectral responsivities

spectral condition that represents the responses of a detection system, such as a scanner or a densitometer, as a function of wavelength

Note to entry: Spectral responsivities are determined by the spectral power distribution of the illumination, the spectral filtration effects of various optical components, and the spectral sensitivity of the detector.

3.9 spectral sensitivity

response of a detector to monochromatic stimuli of equal radiant power

3.10 spectral transmittance

fraction of the incident power transmitted as a function of wavelength

4 Academy Printing Density

4.1 Specification

4.1.1 Spectral Responsivities

The spectral responsivities used to calculate APD are denoted as Π_{APD}.

This document is accompanied by the following element, which tabulates spectral responsivity data of Π_{APD} for Red, Green and Blue at 2 nm intervals:

st2065-2a-2020.csv

NOTE 1 The file format of st2065-2a-2020.csv is Comma-separated Values (RFC 4180).

These data enable, and shall form the basis of, the calculation of Academy Printing Density from spectral transmittance data (Equation (1)).

NOTE 2 Π_{APD} is illustrated in Figure 1.

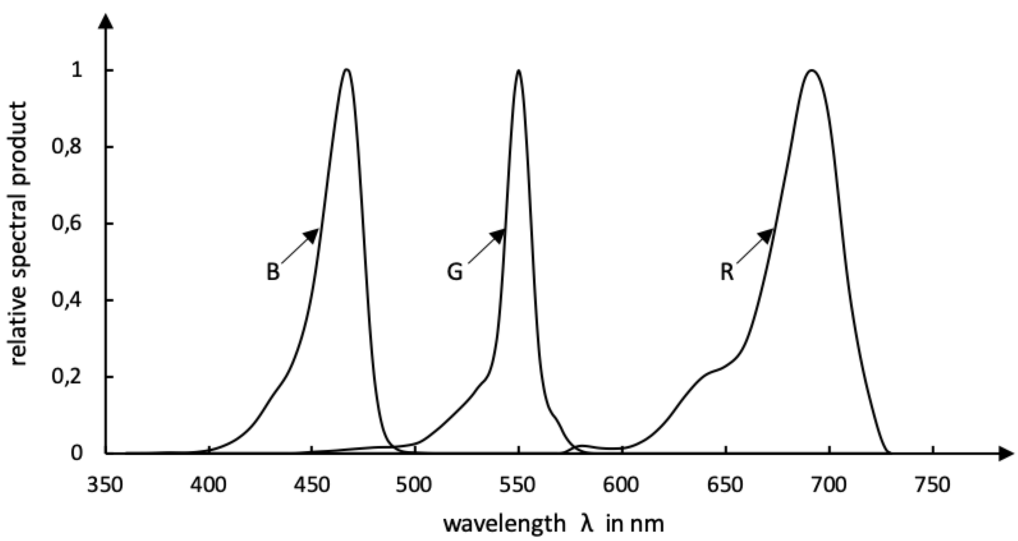

Figure 1 - Spectral responsivities, Π_{APD}, for Red (R), Green (G), and Blue (B)

The subscripted symbol S_{APD} denotes the relative spectral power distribution of the influx spectrum used in the calculation of the spectral product Π_{APD}.

NOTE 3 S_{APD} is described in Annex A.

4.1.2 Reference Measurement Device

4.1.2.1 General

This section specifies the conditions under which APD density measurements shall be made.

NOTE The specifications in this section are intended to eliminate ambiguity in the determination of the APD values of a sample.

4.1.2.2 Spectral Responsivities

The reference measurement device shall have spectral responsivities equal to the spectral responsivities Π_{APD}.

4.1.2.3 Measurement Geometry

The reference measurement device geometry shall conform to the ISO standard diffuse transmission density specification found in ISO 5-2.

4.1.2.4 Sample Conditions

The sample to be measured shall be at a temperature and relative humidity consistent with the sample conditions specification for density measurements found in ISO 5-3.

4.1.3 Spectral Calculation of APD Values

The spectral calculation of APD values requires the measurement of the spectral transmittance of the sample using a spectral measurement device. Spectral transmittance data shall be measured at intervals no larger than 5 nm. If sampling does not match the wavelengths used for equation (1), the spectral transmittance data shall be interpolated. Measured sample transmittance spectra shall be converted into APD values using equation (1).

$$APD_c = -\log_{10}\left[\frac{1}{\Pi_{\mathrm{sum},c}}\sum_{\lambda}\Pi_{\lambda,c} \times T_\lambda\right] \quad (1)$$

where:

- c is the channel equal to Red, Green, or Blue
- $\Pi_{\lambda,c}$, λ are the spectral responsivities, Π_{APD}, for each channel *c*, and wavelength λ, as tabulated in the element st2065-2a-2020.csv
- T_λ is the spectral transmittance of the sample at wavelength λ
- $\Pi_{\mathrm{sum},c}$ is the sum over the wavelengths of the spectral responsivities, Π_{APD}, for each channel *c*

NOTE 1 The spectral transmittance T_λ is equal to 10^{-D_λ}, where D_λ is the spectral density of the sample.

NOTE 2 A densitometer with spectral responsivities equal to the spectral responsivities of Π_{APD} could measure APD values directly.

NOTE 3 Conversions between other density metric values (i.e. ISO Status M density, scanner density, etc.) and APD values are possible and can be particularly useful in process control efforts. These transformations are product specific: a separate transformation needs to be determined for each sample (e.g. color negative and internegative film products). The transformations can take many forms including 3 x 3 matrix transformations followed by an offset, polynomial conversions, and 3-dimensional LUTs. Each type transformation will likely be imperfect and care needs to be taken when building such transformations to appropriately minimize the associated residual errors.

NOTE 4 Scanner density is the logarithm to the base 10 of the ratio of the integration of the spectral responsivities of a scanner and the spectral transmittance of the sample under examination to the integration of the spectral responsivities of the scanner alone.

Annex A Influx Spectrum S_{APD} (informative)

Π_{APD} incorporates the influx spectrum, S_{APD}, which models the lamp house of a Bell & Howell Model C® motion picture printer, filtered by an Eastman Kodak Wratten® Filter No. 2B.

This document is accompanied by the element st2065-2b-2020.csv, which tabulates the values of S_{APD} at 2 nm intervals.

NOTE The file format of st2065-2b-2020.csv is Comma-separated Values (RFC 4180).

The influx spectrum S_{APD} is illustrated in Figure A.1.

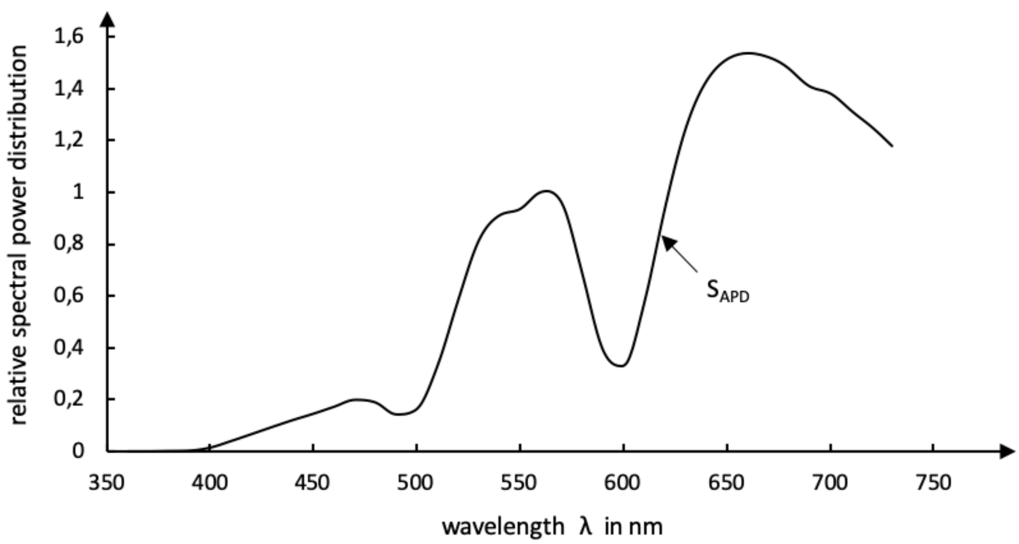

Figure A.1 — Influx Spectrum S_{APD} (Normalized to 1.0 at 560nm)

The basic light source for ISO densitometry, as specified in ISO 5-3, is CIE Standard Illuminant A. The lamp house of the Bell & Howell Model C® motion picture printer uses a tungsten light source that is separated into red, blue, and green components with a set of dichroic mirrors; those components are then modulated by a series of light valves in order to precisely control the ratios of red, green, and blue light, and after modulation are filtered with a Eastman Kodak Wratten® Filter No. 2B. Use of S_{APD} in the calculation of the spectral responsivities associated with APD therefore meets the light source requirement of ISO 5-3.

The specification of CIE Standard Illuminant A by ISO 5-3 is motivated, in part, by the need to manage fluorescence in the sample to be measured.

Filtration of the light source is permitted and in fact suggested by ISO 5-3 in order to protect the sample to be measured and optical elements from the heat of the light source.

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