
# 20F Technology Committee On-Screen Light Measurement Study Group Report

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# 1 Introduction

There are seven identified SMPTE standard or recommended practice documents that identify or refer to methods of measuring screen luminance. Each document identifies a different specific methodology for measurement. While each of these approaches has some validity, each will result in different measured screen characteristics from the point of view of peak brightness and light distribution.

This study group was charged with recommending a unified approach to screen luminance measurement. Our work statement is copied in Appendix 1. Early in the process it was decided that there were three different applications of the screen luminance measurement procedure – review rooms and premium cinemas, general cinemas, and 3D. It was also assumed that the measurement procedure will apply to digital projection primarily – and recommendations for test patterns, etc. were focused on digital platforms. This report details the approach we took to the study group task, and provides recommendations for the measurement approaches.

It should be noted that this group was tasked to study issues around measurement of screen brightness, and not the absolute brightness values to be put into a future SMPTE specification. The group did not consider issues of colour measurement.

# 2 Committee Administrative details

## 2.1 Meeting Schedule

The study group held its first meeting April 8th 2013 and met (mostly) biweekly until completion of the study group. Our final meeting was March 10.

## 2.2 Membership and participation

Total membership is 29, with an average meeting attendance of 8. There were representatives from exhibition, studios, manufacturing, and the cinema consulting world. (In addition a detailed set of survey questions were sent out broadly to the community with 200 responses.) It should also be noted that participation in this committee resulted in 2 new SMPTE memberships. Chair was Matt Cowan, Entertainment Technology Canada Ltd, and Secretary was John Nieminen, Christie Digital Systems.

# 3 Why does Screen Brightness matter?

When colour timing is performed on a movie, it is done at the SMPTE specified peak luminance of 48 cd/m^2. Additionally, the luminance distribution across the screen is also specified to be 85% of center luminance (nominal) but no less than 75% of peak brightness at the sides and corners of the screen (reference SMPTE ST 431-1-2006). Critical color relationships are developed by the cinematographer to achieve the right emotional impact of the movie. If the brightness on the screen is more or less than the level used to create the colour in the movie, it will have a different emotional effect on the audience – with a difference in perceived colour (Abney effect), different contrast perception (contrast sensitivity function) and a different perception of flicker and judder (critical flicker frequency). Consistent screen luminance between the director's viewing of the content and the public's viewing of the content is necessary for the public to view the content as the director intended.

# 4 Study Group Process

The group initially reviewed existing references to screen brightness measurement, especially in the context of cinema screens. Two key areas were reviewed:

1. SMPTE Documents – Standards, Engineering Guidelines and Recommended Practices. This identified 7 specific documents where screen brightness was identified. These documents were reviewed – see appendix 2 for a summary. The review found that while there are similar approaches to brightness measurement in these documents, they did not provide a consistent procedure, especially in terms of number and location of points to measure on the screen, and location within the theatre. It was also believed that the specification of the measurement apparatus and conditions were not adequate. A summary of the documents can be found in Appendix 2.

2. SMPTE Journal articles – There have been a number of references to screen brightness measurement and approaches in the SMPTE journal and other journals. These were reviewed and summarized. They provided some general information on measurement, and observations about such things as screen gain implications. Two summaries were compiled. The first was restricted to the SMPTE Journal, while the second reviewed various journals. The list of SMPTE Journal papers can be found in Appendix 4.

Practically, in the process of producing a movie, screen brightness is being measured by many organizations, including creatives (directors, cinematographers), post production houses, cinema system installers, manufacturers and exhibitors. It was decided to circulate a survey to the wider community to solicit information about how screen brightness is being measured in the field.

The survey is summarized in Appendix 3.

# 5 Findings

We reviewed the SMPTE documents that specifically reference measurement of screen brightness. As identified in the work statement, there is indeed a diversity of approaches to measurement. SMPTE ST 196-2003 is the closest to being comprehensive, and SMPTE RP 431-2:2011 DCQ - Reference Projector and Environment is the most current specification requiring screen brightness measurement.

SMPTE ST 196 represented a good starting point and framework for defining a measurement procedure. Sections 3, 4, 5, and 6 touch on the key measurement considerations, and this report focuses on clarification of these considerations.

The work of this committee has boiled down to a relatively small number of factors that need to be considered in defining a brightness measurement methodology.

## 5.1 Conditions in theatre for measuring brightness:

5.1.1 For measuring brightness, the theatre should be set up in its “operational” mode, with show lighting in its normal setting. In installations, where the projector is adjusted between flat and scope presentations, the brightness should be measured in each of these settings to ensure consistent performance. It should be noted that any brightness measurements must be made with the projector in a fully calibrated mode (i.e. white point and primaries calibrated to DCI requirements). Typically the calibration process will diminish the color corrected light output slightly. To ensure the projector is in calibrated mode, it is recommended that the test patterns for measuring brightness be provided to the projector through the server, as a digital cinema package (DCP) file.

## 5.2 Apparatus required for accurate measurements:

5.2.1 Luminance measurement instruments shall have a photopic spectral response as defined by CIE 1931 2 degree observer. The tolerance of the meter's photopic function is a question to be resolved. Case in point is an instrument that uses a photopic filter instead of a spectrometer for measurement. In particular, with the evolving narrow bandwidth light sources (LED, LASER), a small error in the photopic filter at one or more of the illumination wavelengths can result in a large error in measurement.

There is also a question about whether the 2 degree observer is the right observer model for cinema application. Note that this difference can have a large effect on color measurement, but significance for luminance is small.

The study group believes that for broad spectrum measurements, for example Xenon, a high quality photopic filter based luminance Meter will provide adequate accuracy, but for evolving systems using LED sources or lasers, the narrow band of the illumination could result in significant errors in luminance measurement and are not recommended. The recommended tolerances are identified in 5.2.4 below.

5.2.2 Luminance measurement instruments should have an acceptance aperture of 1 degree or less. This will allow for precision when measuring near the edge of the screen.

5.2.3 Contribution of Lens Flare was raised as an issue with measurement of peak white fields. Several ad hoc measurements were made using LS-100 and PR 650 meters. The tests compared the readings for measuring a full white screen, to a measurement target of 1.5 degrees - (slightly larger than the 1 degree spot size of the meter). The results showed that the meters read between 6.6% and 10% higher on a full screen white than on a spot. (The spot was created by masking down the full screen to ensure the same intensity at the measurement point). As a result of this it is recommended that the test patterns used for measuring screen brightness consist of a black background with only the measurement target points illuminated.

5.2.4 Total measurement error of the instrument shall be considered in determining luminance tolerance limits. For example, if the rated total measurement error of the instrument is +/-5%, and the tolerance on the luminance specification is 20%, the actual luminance value may be out of tolerance if the measured value is 15% from the ideal luminance value (20% - 5% = 15%). The rated total instrument error includes effects due to initial calibration error, drift in calibration with time, temperature, and other effects, error due to less than perfect photopic response, error due to "lens flare" (a variation in measured value due to light outside the target area), and other errors.

5.2.5 For measuring narrow band illumination (e.g. lasers) projectors, conventional simple luminance meters may introduce significant measurement errors due to slight mismatch of their filters from the photopic curve. It is recommended that a spectrometer be used for all measurements involving narrow band illumination sources.

5.2.6 Luminance meters shall measure the average (mean) value of luminance over a period sufficient to reduce variation in measured value due to projector flicker to 1% of the reading or less with flicker frequencies of 48Hz or higher and duty cycles of 50% or higher.

5.2.7 The luminance of black – The residual luminance of a black screen is a significant aspect for good theatre performance. It is implied in the digital cinema SMPTE ST 431 family of specifications where off-to-on contrast ratio is specified. In addition, SMPTE ST 196 identifies a value for the limit of screen luminance caused by stray lighting in the theatre. These are both important aspects of image performance. The measurement of black performance parallels the measurement of brightness, in that it is also a luminance measurement. This will require a luminance meter that is capable of measuring .02 cd/m^2 with reasonable accuracy.

## 5.3 Locations on screen where measurement should be made:

5.3.1 The existing standards reference a number of different strategies for where on screen the luminance is to be measured. RP 98 specifies 9 equal sized zones (3x3 grid), and requires measurement in the center of each zone. SMPTE ST 196 specifies 9 locations, - center screen and 5% in from corners and edges. SMPTE ST 431-1 identifies 5 locations – center screen and the corners, measured 5% in from edge. CST is close to standardizing a specification in France (AFNOR) which defines 9 points. (see figure 1 below)

In practice, (see results of survey in appendix 3) it appears that the dominant procedure is to measure a single point near the center of the screen, where the specific point is chosen to be the brightest point on the screen. This, of course, results in the highest possible luminance reading, but doesn't address the quality of the light distribution across the screen. We believe that standardized measurement points will assure the best image quality for the audience.

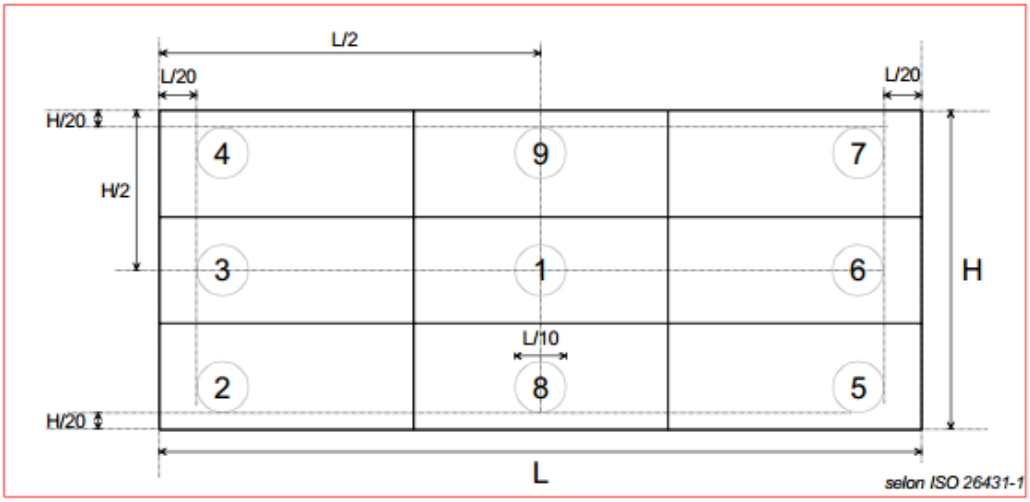



**Figure 1 — Points de mesure (from NF S 27-100 draft supplied by CST, France)**

We recommend that a superset grid be defined which consists of 9 locations on the screen, as in figure 2. This is compatible with the measurement locations proposed in the French NF S 27-100 draft. From a practical point of view, we believe that the number of locations to be measured will depend on the criticality of the application. For example, a standard cinema will continue to use a single point for routine luminance checking. We believe that this point needs to be defined as the center of the screen, as opposed to the brightest point. For more critical applications, including initial cinema set-up, we

believe that the light distribution across the screen is important and will need a more comprehensive measurement.

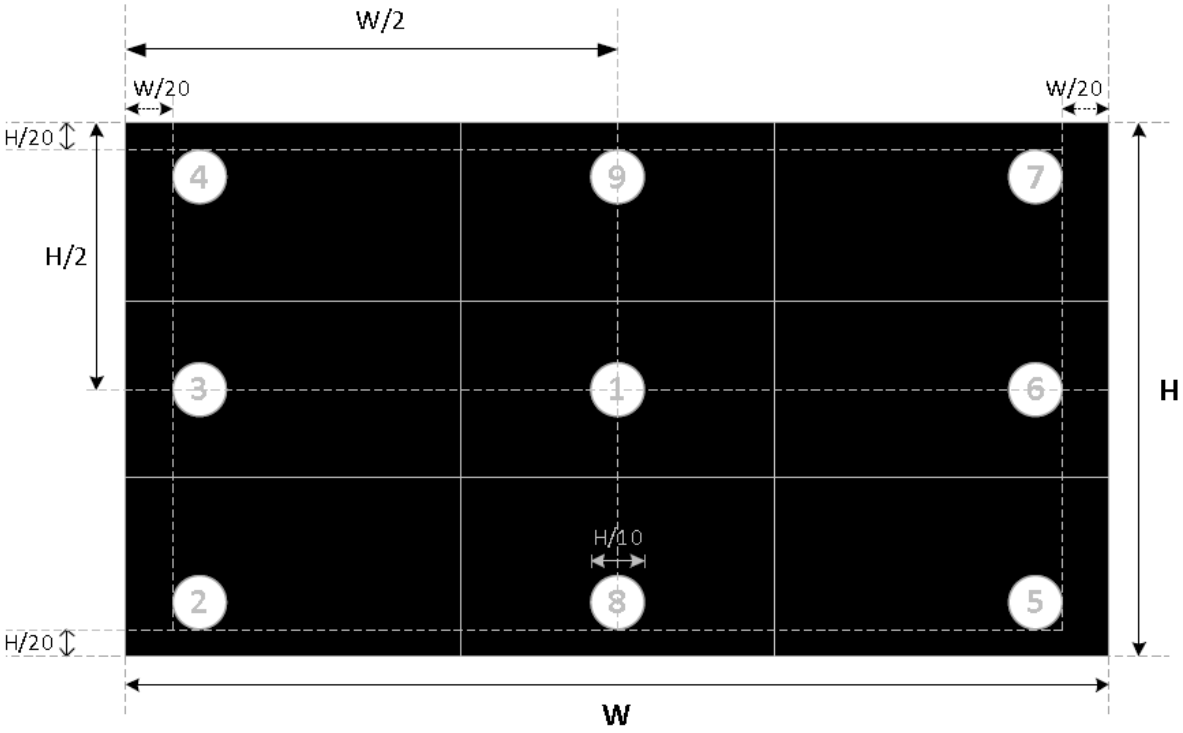



**Figure 2 — Measurement Target for 3 Screen Heights for 1.85:1 Aspect Ratio**

To simplify the measurement process, it is recommended that several measurement targets be created in DCP format to support this recommendation. This will standardize the location on screen where the measurement is taken. Suggested test patterns are illustrated in the "test pattern" section, below.

It has been found that measuring on a full white field will introduce lens flare errors, in some ad hoc test cases giving a reading that could be 10% high. To minimize this error, it is recommended that the measurement target have white measurement areas, with a black background elsewhere.

In creating test targets, it is recommended that the target area be sufficiently larger than the measuring spot of the instrument such that aiming errors aren't introduced. Because essentially all photometers and spectrometers will support a 1 degree spot, it is recommended that the measurement target be 2 degrees in size from the furthest measuring location.

The proposed pattern from NS F 27-100 has chosen to locate the corner and edge targets with their edge defined as 5% from the edge of the frame. This study group agrees with that approach and recommends that we adopt the same. The proposed NS F 27-100 pattern further identifies the test targets as 10% of the width (but are interestingly drawn as 5% of the width). Based on calculations of 1 degree and 2 degree spot sizes vs screen height (see Figure 3 below), we recommend that two test patterns be created – one to cover a 2 degree spot from 3 screen heights and one for a 2 degree spot at 5 screen heights. Respectively, these would have approximately 5% and 10% of screen width, or approximately 9% and 18% of screen height. These are illustrated to scale in the section on test patterns.

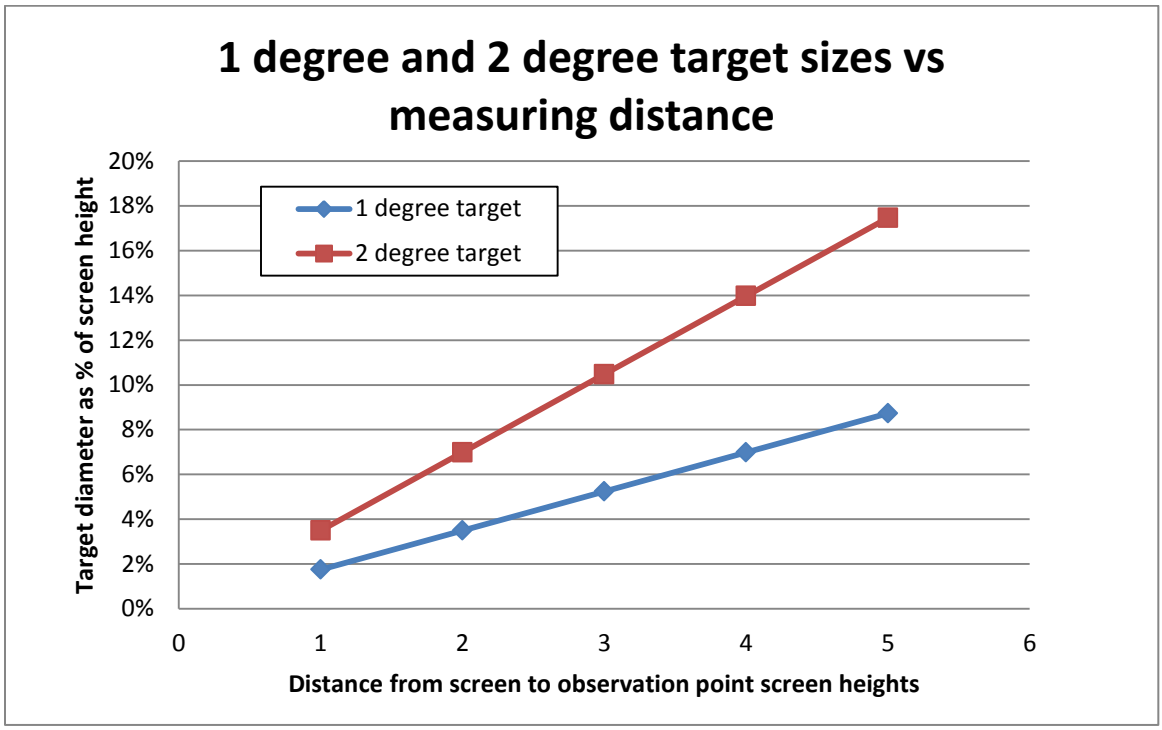



**Figure 3 — Target Size vs Measuring Distance**

Our recommendation is that we identify three classes of measurement criticality

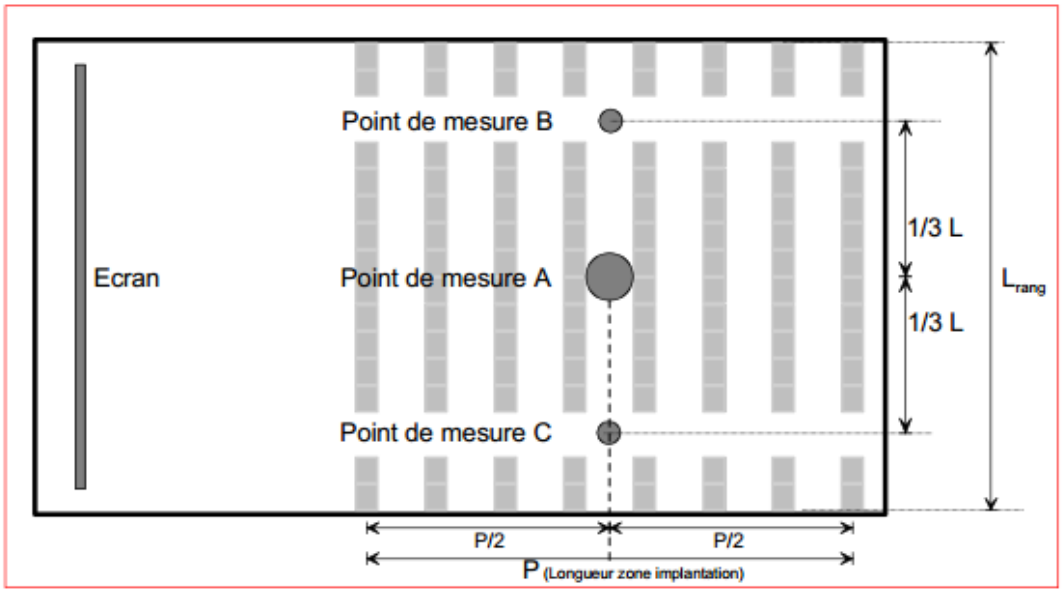
i. Critical review rooms and premium auditoriums – measure all 9 points. This will ensure that the luminance uniformity is maintained across the screen, for the best possible audience experience.
ii. General cinemas – first installation or significant configuration change (e.g. new screen, new projector, new cinema.) – do a comprehensive measurement of light distribution across the screen to ensure quality. This is recommended to be a 5 point measurement as in SMPTE ST 431-1. For clarification, it is recommended that the 5 points be taken from the standard 9 point pattern – the 5 points being the center point plus the four corner points.
iii. General cinemas – maintenance – measure a single point at the center of the screen

Standardization will need to put acceptance limits on the light distribution for each of these situations.

For measuring black levels, there are two separate scenarios. For contrast ratio applications, a single point will be acceptable. For stray light measurement, a more comprehensive measurement grid will be required, since stray light may be specific to certain areas of the screen. It is recommended that for measurement of the black luminance level, that the projector be projecting a black pattern, with faint dashed lines indicating a center target area.

## 5.4 Locations in the auditorium where measurements should be made

5.4.1 SMPTE ST 196 specifies a 3 location measurement approach – the center and two ends of the center row in the auditorium. This is close to being consistent to the CST proposal in the NF S 27-100 draft (see Figure 4 below). Current convention (see survey summary in Appendix 3) typically takes measurements from a single point in the auditorium. It is important to have reasonable luminance distribution across the auditorium so that every seat is seeing a good image on the screen. To that end, we believe that the 3 point approach in SMPTE ST 196 should be augmented to include two front row locations, corresponding to the seats near either end of the row (see figure 5).




**Positionnement de l'observateur – Relevé de luminance**

**Figure 4 — Proposal for cinema measurement locations (from AFNOR NF S 27-100 draft supplied by CST, France)**

5.4.2 The committee discussed the specific locations from which the measurements should be taken.

i. There is an argument to be made for locating the distance from the screen as a ratio of screen height. This would choose a point where the angle subtended by the image is constant. This is appealing because test patterns could be precisely created which present targets suitable for a 1 degree spot meter. From a viewer experience point of view, it makes more sense to assume that the "sweet spot" is the seat at the geometric center of the seating area, so it was decided to pick specific locations as opposed to screen height ratios. Note also, that this allows closer harmony with the NF S 27-100 draft.
ii. The primary location should be a point in the center row of the theatre.

There was substantial debate about whether the prime point should be chosen as the center of the center row, or a point perpendicular to the screen, or the specular ray of the projected image from the center of the screen. Best practice in theatre design puts

the projector and screen both on center with the seating area, leaving the point moot. There are a small number of theatres that for practical reasons have the screen or projector or both offset from the seating area.

Additional locations were defined towards the end of the row. The proposal by the CST identifies locations that are 1/6 of the theatre width in from the ends. This seems reasonable – it is in harmony with the CST proposal (which is ultimately expected to be submitted to ISO), In the front row, we believe that taking 2 measurements will complete the light distribution data. It was decided that the ends of the front row were too extreme, and in most cases represent seats that the theatre wouldn't necessarily promote. The locations were chosen to be 1/6 of the theatre width in from the ends of the row.

5.4.3 These 5 locations should be used in both high gain and low gain screens as the quality of the viewing experience should be measured for these representative locations, regardless of the screen technology. (Paying customers will be seated there.)

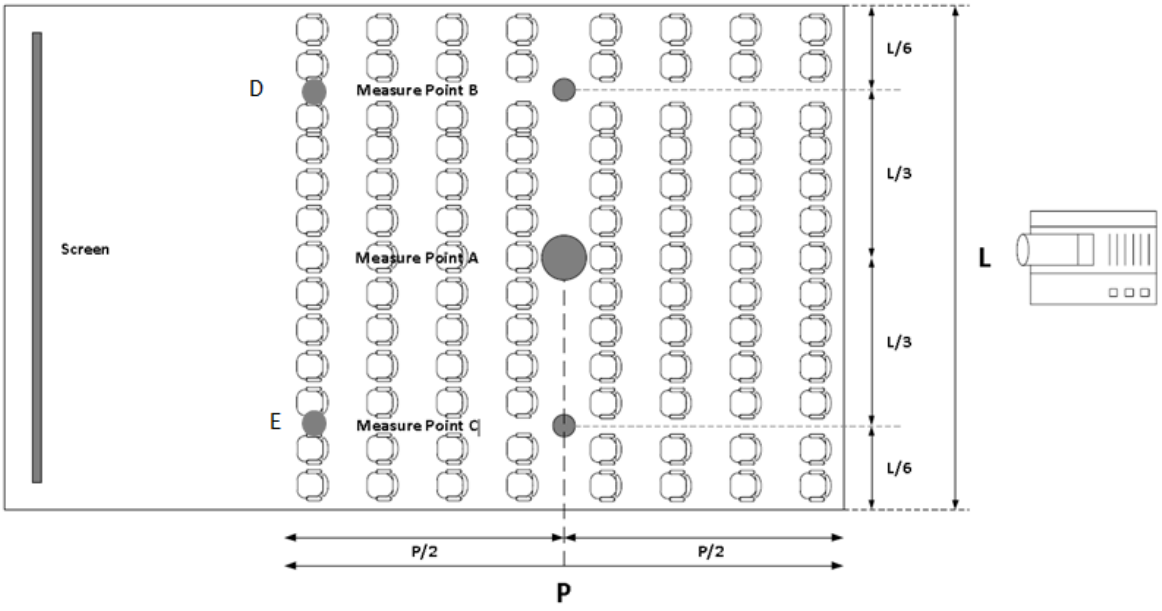



**Figure 5 — Recommended measurement locations in theatre.**

5.4.4 Considerations for theatres with balconies: There are a limited number of theatres with balconies for a second layer of the audience. It is important that the light distribution be reasonable for audience in the balcony. The committee recommends that 3 measurement points be located in the balcony. The primary point should be the vertical projection of the center measurement point in the theatre. This should line up with the perpendicular line to the screen centerline as it would in the main level. The additional points should be in the same row, and similarly, be 1/6 of the row width in from the walls.

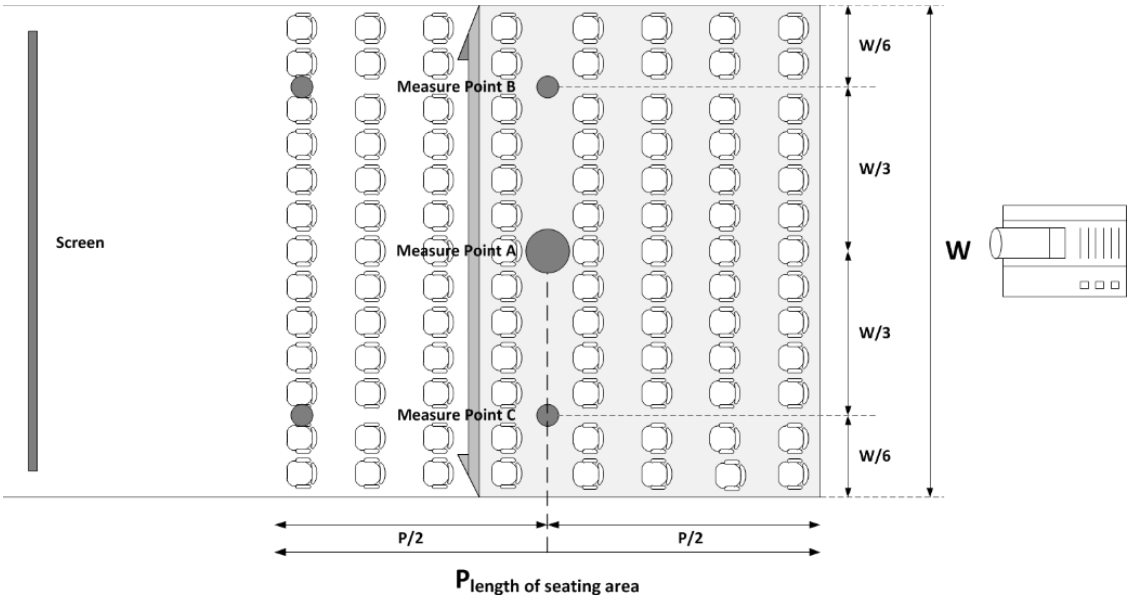



**Figure 5 — Recommendation for 3 additional measurement locations on the balcony corresponding to locations directly above the center theatre locations.**

## 5.5 Frequency of measurement due to aging or other changes

Measurements shall be made as often as necessary to ensure luminance values stay within the tolerances specified by standards and recommended practices. This will be determined by the experience of the user, the projector manufacturer, and the lamp manufacturer. It is expected that the cinema will have an internal procedure for periodic measurement of screen luminance.

## 5.6 3D considerations – representing luminance to the eyeball

5.6.1 Many, but not all, 3D systems use time division multiplexing to deliver separate images to each of the viewers' two eyes. These systems will present left eye and right eye images sequentially, often with multiple “flashes” of each eye within a frame time. One popular method is called “Triple Flash” where in a single frame time, each eye is flashed alternately three times. This means that each eye is only active for approximately half of the frame time. (Some systems do project both eye images simultaneously.) There are also losses in the "demultiplexing" glasses worn by the viewer such that the luminance detected by the eye is reduced compared to what would be seen with no glasses. Because in all cases, the viewer wearing 3D glasses will see lower luminance, it is necessary for the luminance measuring instrument to emulate what the eye will see. This is achieved with the addition of a demultiplexing filter in front of the luminance meter. This filter is the same type used in glasses by the viewers, and may simply be a set of glasses held over the lens of the luminance meter.

Normally, measurements should be taken using the glasses filter over the lens of the meter. It is possible to set up a measurement system where a reference measurement is taken through the glasses filter, and compared to a measurement with no glasses in the measurement process. This would yield a factor that could be used to compare the “no glasses” measurement with a “with glasses” measurement, allowing for

simpler routine measurements in the future. This process would be valid assuming that no changes were made to the system (e.g. projector dark time).

5.6.2 3D may be a special case due to the illumination fall-off on silver screens or other high gain screens. Therefore, it is recommended that the screen luminance be measured from not only the central locations of the auditorium, but also the end points of the front row.

5.6.3 With high gain screens, the luminance distribution across the screen may suffer. It is recommended that measurements be taken of all 9 points identified above.

5.6.4 3D Test Patterns

i. For measuring luminance in 3D, the eye being measured should exhibit the pattern, and the other eye should be black. To put the same pattern on both eyes will introduce an error due to ghosting or crosstalk. This could range from 3% to almost nothing depending on the specific system being used. By having only one eye active, it is also clear that the projector is in the 3D mode and the eye of interest is being measured.
ii. It is possible to have different luminance levels in each eye. Measuring left and right eyes separately will ensure that the 3D system is operating properly, and indicate if there is a difference.

5.6.5 Recommended procedure for 3D measurement

i. Set projector in 3D mode
ii. Play test patterns from server
iii. Set up measuring instrument in each of the 5 locations indicated for 2D measurement.
iv. From each measurement location, measure all 9 points on the screen. Measure left and right eyes separately. Set up measuring meter to measure the appropriate screen locations same as 2D
v. Cover the meter's lens with a 3D filter. This may be one lens from the 3D eyeglasses, or it may be a special filter designed to attach to the meter.
    1. For polarized systems, ensure that the orientation of the glasses or filter is correct.
    2. For spectral division systems, ensure that the filter is perpendicular to the optical axis of the measuring instrument.
vi. Of particular note:
    1. Polarizer system must be clean.
    2. Filter on glasses should be comparable to conventional eyewear filter
    3. Recommend using eyewear at site since this represents "real" eyewear. Hold eyewear normal to the axis of measuring device and keep the horizontal axis accurately aligned.

5.6.6 Alternative approaches

i. The question was raised whether, after an initial characterization, it is reasonable to take a center measurement, and assume that the light distribution characteristics would track the initial characterizations. This would allow a single point measurement to be taken and compared to the same point in the initial characterization. It is believed that this approach would be valid for periodic verification, but not if significant changes have been made to the system (e.g. new screen, new lamp, new projector, etc.)
ii. Similarly, the question was raised whether it would be reasonable to devise a comparative measurement approach, where after initial characterization using the 3D filter on the instrument, making a comparison measurement with no filter in place for future reference. Periodic measurements could be made more simply using no filter and comparing them to the reference

measurement. While simpler, this approach does not check the complete system, and account for possible changes in the 3D system. It is therefore not recommended that this approach be used.

## 5.7 Considerations for Black level

The luminance of screen "black" is important for the theatrical experience. The black level is addressed in SMPTE documents through (a) specification of the off to on contrast ratio of the digital projector (SMPTE ST 431 family) and through the specification of maximum level of ambient light illumination on the screen (SMPTE ST 196)

In practice, this is a more difficult measurement than measuring white, because the luminance levels are 3 orders of magnitude less, and because it isn't possible to project a series of test targets without adding to the light on the screen. To that end, the following approaches are recommended.

a. For measuring black level as it relates to off to on contrast, it is recommended that the meter be positioned on a tripod to measure white in the center of the screen. Without changing the direction of the meter, switch the projector to projected black (do not use the dowser) and make a measurement. For the purposes of SMPTE ST 431 family specifications, all ambient lighting in the theatre should be turned off.

b. For measuring the level of ambient spill on the screen, it is recommended that the projector be either dowsed or the lamp turned off, and the theatre lighting be at its normal working level for shows. The observer should then look for the brightest portion of the screen, and measure the luminance of that area. This could be an area where an exit light or aisle light is casting some light on the screen.

c. It is recommended that both of these measurements be taken from the center seat of the auditorium.

# 6 Test Patterns

It is strongly recommended to provide standardized test targets for measuring screen brightness. These patterns should identify target areas for screen measurements. These targets would be designed to reflect measurement from a location related to screen height, so a standard set of targets would work for all theatres. It is also recommended that the targets be designed with full white in the target areas, and black elsewhere, to minimize the effect of lens flare in the measurement. These targets should be supplied in DCP format to ensure that the measurement is color corrected white.

In a black background test pattern, the size of the test targets is dependent on the distance from the screen where the measurement is taken. Two sets of test patterns are recommended – one for 3 screen heights and less, and one for 5 screen heights. Clearly for different geometry, new test patterns could be constructed with the test target corresponding to a 2 degree circle from the measurement location.

Following are examples of test patterns recommended for use for measuring screen luminance. Included below are patterns for 1.85:1 screen – an additional set of patterns should be created for 2.35:1 aspect ratio screens.

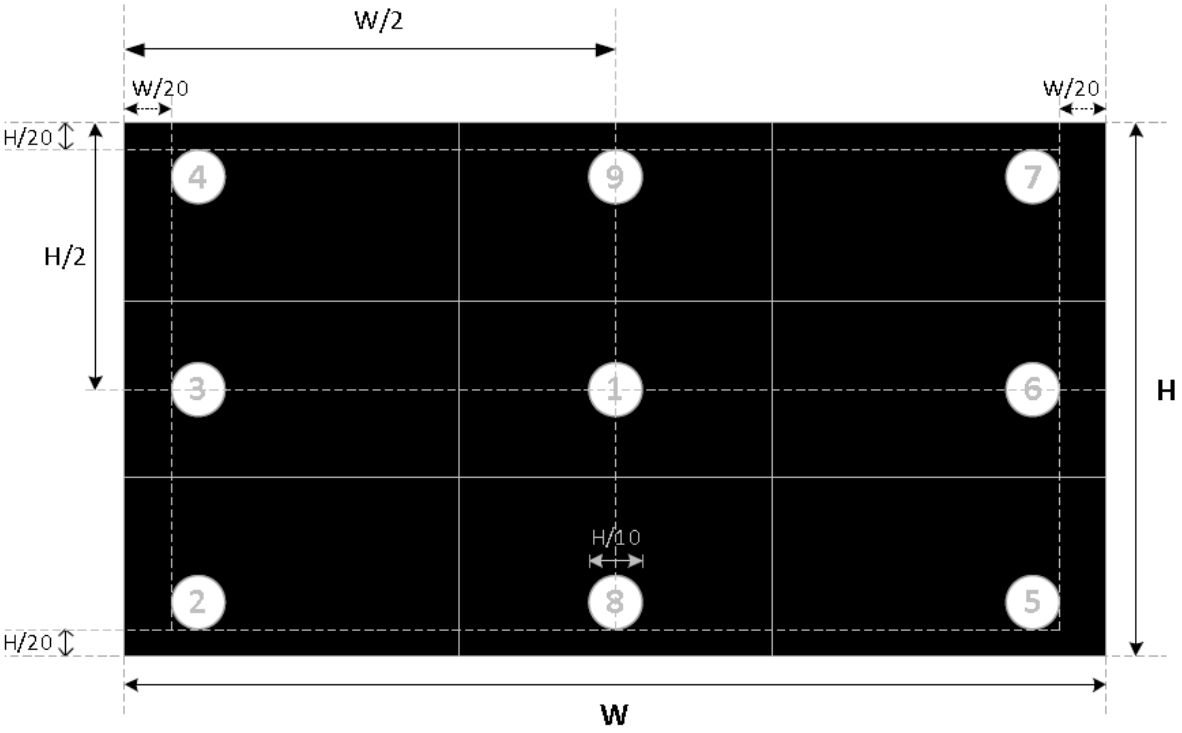



**Figure 6 — Measurement Target for 3 Screen Heights for 1.85:1 Aspect Ratio**

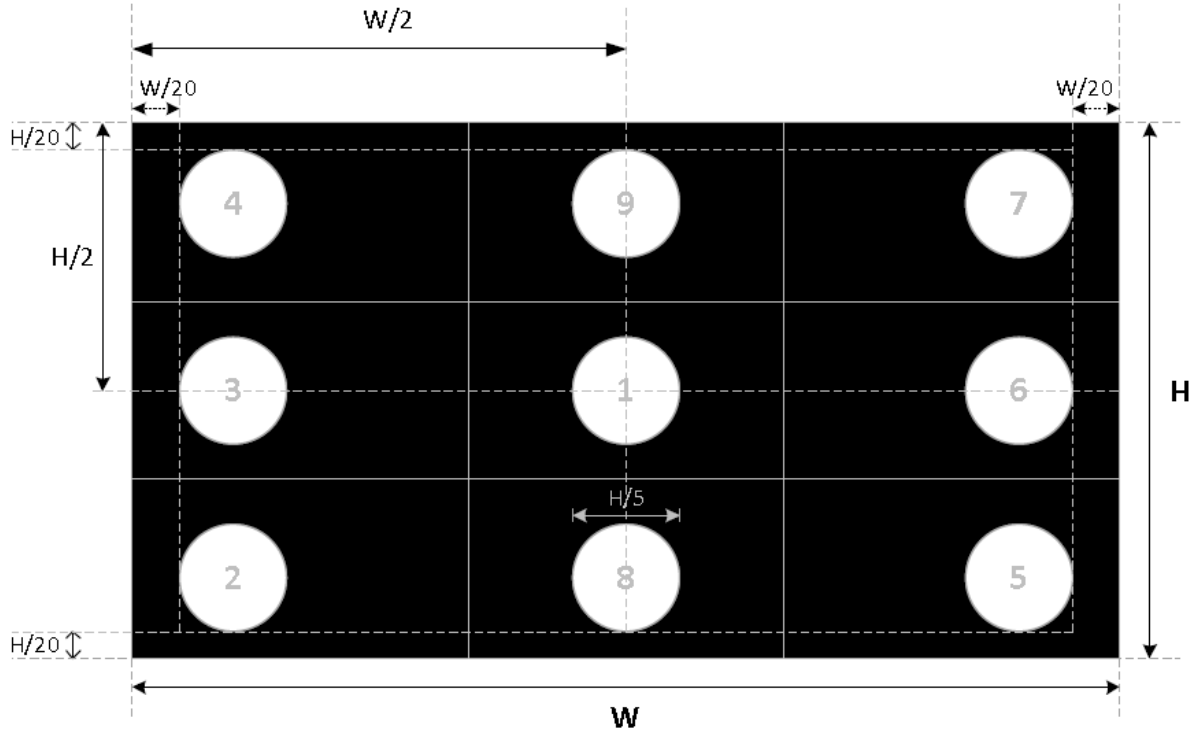



**Figure 7 — Measurement Target for 5 Screen Heights for 1.85:1 Aspect Ratio**

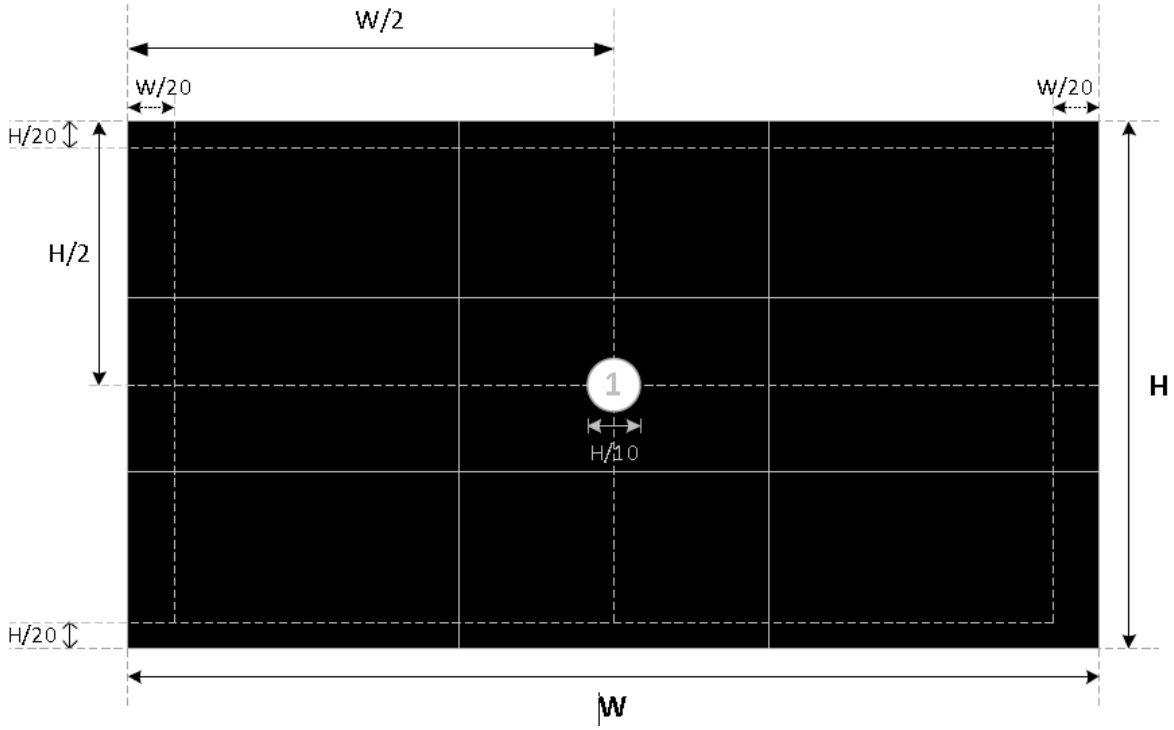



**Figure 8 — Measurement Target for 3 Screen Heights for 1.85:1 Aspect Ratio**

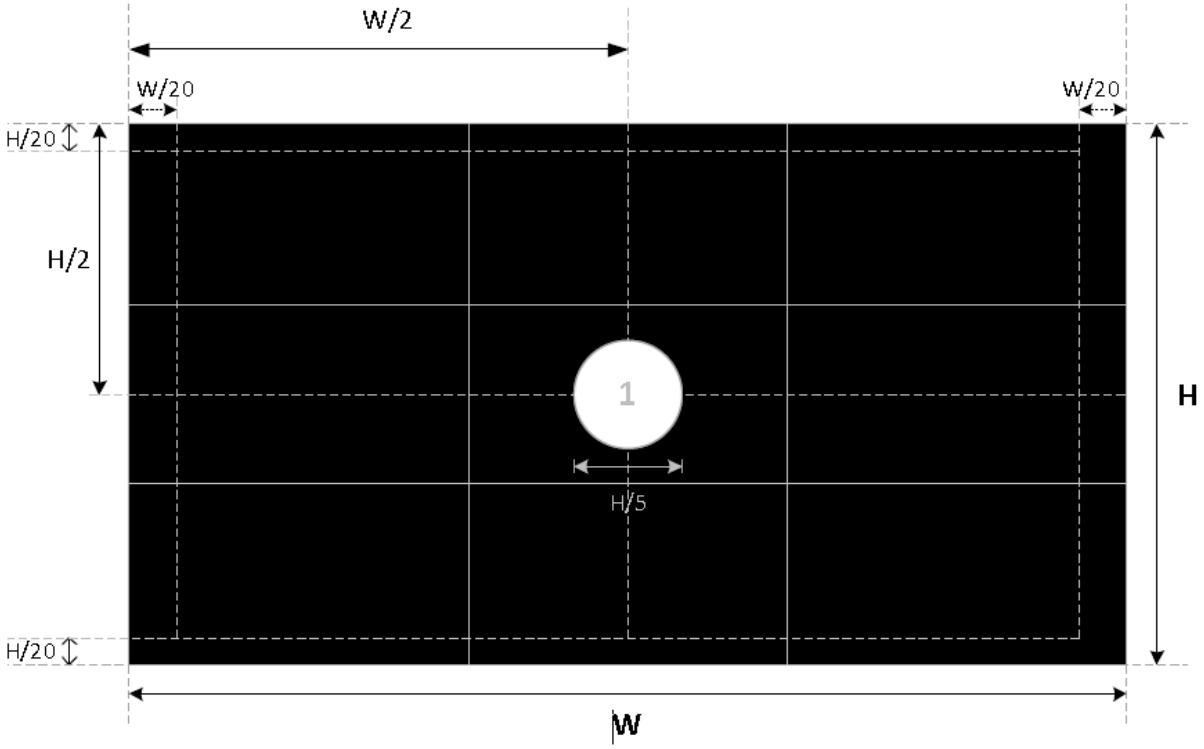



**Figure 9 — Measurement Target for 5 Screen Heights for 1.85:1 Aspect Ratio**

# 7 Procedures — Review Rooms, Premium Theatres, Normal Cinemas

The study group has identified that the objectives of measuring screen performance will differ between review rooms, premium theatres and normal cinemas. To this end, it is recommended (and as noted above), that the same basic procedure be used for measuring screen performance in all cases, with a different number of measurements being used for each situation, and different acceptance criteria, consistent with the approaches in SMPTE documents in the past.

It is also expected that upon installation of a new theatre or theatre configuration, a more rigorous approach be taken to gathering data.

Recommendations are as follows:

- Review rooms and Premium theatres
  - Measure light distribution at all 9 screen points
  - Measure from 3 locations in the middle row and 2 locations in the front row.
  - Measure black level at the center of the screen from the center seat of the auditorium
  - Measure ambient lighting contribution at brightest point of black screen
  - Measure from 3 points of the balcony – directly above the 3 locations in the middle row of the lower level, if appropriate.
- Normal cinemas
  - New configuration (first installation of new equipment, screens, or theatre geometry)
    - Measure 9 screen points upon installation
    - Measure from 3 locations in middle row and 2 locations at front row
  - Maintenance - Measure single point at center of screen from center seat location.
- 3D Installations (see also discussion in 3D in 6 c. above.)
  - Use same measurement screen points and theatre locations as for 2D for the cinema type.
  - Use a glasses filter over the measuring lens so the meter sees only left or right eye image.
- Record keeping
  - Records should be kept of all screen measurements, to track projector and lamp performance
  - For example, Harkness Screens offers “Digital Screen Archiver” facility for maintaining records of screen brightness. (By example, not by endorsement.)

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# Appendix 1: Study Group Work Statement (As passed down from 20F parent committee)

## Project Description:

Six SMPTE standards documents specify different ways to measure the light on the screen or do not specify any method. A Study Group will be formed to examine current measurement technologies and requirements, and to recommend a single consistent method for light measurement. The study will include measurements for stereoscopic presentations.

**Reports to:** TC-20F

**Project Type:** Study Group

**Chair:** Matt Cowan [mcowan@reald.com]

**Proponents:** Dolby Laboratories, Cinecert, the Walt Disney Studios

**Document Editor:** Matt Cowan [mcowan@reald.com]

## Problem to be solved:

SMPTE has inconsistent on-screen light measurement methods in its standards. The following documents all specify different ways to measure the light on the screen or do not specify any method.
ST 196-2010 Indoor Luminance and Viewing Conditions
RP 94-2007 Screen Gain Determination
RP 95-2003 Installation of Gain Screens
RP 98-1998 Measurement of Screen Luminance
ST 431-1-2006 Screen Luminance Level and Uniformity
RP 431-2-2011 Reference Projector and Environment

## Project scope:

Examine current measurement technologies and requirements, and recommend a single consistent method for light measurement. The study will include measurements for stereoscopic presentations.

## Specific tasks:

1. Literature review of light measurement methodology.
2. Define requirements for light measurement methods (not light levels) for cinema screens.
3. Recommend a single method for on-screen light measurement for 2D exhibition.
4. Recommend a method for on-screen 3D light measurements.

**Form of output:** Engineering Report

**SMPTE TC liaisons:** 21DC

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## Appendix 2: Comparison of significant points in existing SMPTE standards

| Standard/RP | Procedure | Measurement locations | Screen Sampling | Specifications (for reference – luminance not in the mandate of this SG) |
|---|---|---|---|---|
| **RP 12-1997** Screen Luminance for Drive-In Theaters – Film | Measure from several locations using open gate (film) projector and luminance spot photometer | Primary from center of viewing area. Also measurements from any car in the audience | Primary – screen center.<br>Additional along horizontal center line, within 10% of screen width of edges | 16 fL open gate center +/- 2 at center<br>Edges between 55% and 100% of screen center and symmetrical<br>Recommended level 7 fL<br>Compromise spec down to 4.5 fL at center<br>From any viewing position, luminance shall be no less than 33% of max luminance along center line. |
| **RP 94-2000** Gain Determination of Front Projection Screens | Measure angular performance at 5° increments. Use test sample in lab | Center of center row, edge of center row<br>Or goniometer setup (presumably in lab) | If on installed screen, measure "head on" and from 30 degrees | Compare to gain 1 test sample or "standardized matte white cardboard" |
| **RP 95-2003** Installation of Gain Screens | Does not actually address measurement of screen luminance | | | Defines radius of curvature and tilt angle. Recommends to locate audience within ½ maximum gain angle cone |
| **RP 98-1995** Measurement of Screen Luminance in Theaters | Open gate film projector | 6 locations – left edge, right edge, center seats in center and back rows | 9 locations – divide screen into 9 equal rectangles (3x3) measure center of each rectangle | For each of the 6 locations:<br>Screen center 12 – 22 fL<br>Sides 75-90% of screen center<br>Review room 16 fL<br>Sides and corners >80% of center<br>No readings greater than center<br>Corner readings not less than 8 fL.<br>Top, bottom Left Right readings not less than 10 fL<br>Non center measurements shall not differ by more than 4 fL |

| | | | | |
|---|---|---|---|---|
| **ST 196-2003** for Motion-Picture Film – Indoor Theater and Review Room Projection – Screen Luminance and Viewing Conditions | Spot photometer<br><br>Note that these are "system" measurements – projector + screen properties. | Center of seating area – center and each end of middle row<br><br>Luminance distribution measured from "any seat in middle row"<br><br>Recommends measuring projector light incident on screen to separate the variables | 9 locations. Screen center and 5% in from edges and corners | Center 12 – 22 fL<br><br>Sides 75% - 90% of center, but not less than 10 fL<br><br>Review room 16 fL +/-2 at center<br><br>Sides and corners at least 80% of center<br><br>Luminance symmetrically distributed<br><br>Luminance at any point not brighter than center<br><br>Stray light – 1/600 review rooms and 1/400 theatres<br><br>Viewing locations within 15 degrees of perpendicular to center of screen<br><br>Viewers at 3 PH +/- 1 PH |
| **ST 431-1-2006** for DCQ – Screen Luminance Level, Chromaticity and Uniformity | 5 point measurement, spot photometer for light, spectroradiometer for color | Single point at geometric center of seating area of auditorium | 5 point – center screen and locations 5% in from top/bottom/edges of screen in each corner. | Non-specular, equally reflective<br><br>Cinema - 14 fL +/- 3<br><br>Review rooms 14 fL +/- 0.1 fL<br><br>Sides and corners 80% - 90% review<br><br>Cinema not specified for uniformity<br><br>White Uniformity +/- .008 x,y review<br><br>White uniformity +/- .015 x,y theatrical |
| **RP 431-2:2011** for DCQ - Reference Projector and Environment | Descriptive of performance specified in ST 431-1 | Color grading 1.5 to 3.5 screen heights | References 9 point measurement from ST 431-1 (not consistent) | Screen characteristics shall reflect uniformly across all angles |

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# Appendix 3: Summary Results: Luminance Survey 1 for TC 20F On-screen light measurement SG

**Online SMPTE Survey Form – June 13-20, 2013.**

Background – The purpose of the study group includes research into the various past and existing documents, technology and practices dealing with the correct and appropriate measurement of luminance from the cinema screen. To investigate current practices, an anonymous survey was created with the assistance of SMPTE staff, and disseminated to interested groups.

There were over 200 responses of which 86 gave substantial, significant data; 12 post houses, 2 animation companies, 2 film festival groups, 26 exhibitors, 21 service companies, 16 vendors, and 7 others involved with QC and standards. 21 of the 31 persons who self-identified were from non-US groups.

This document is an attempt to summarize that data. It is impossible to make final conclusions since some service companies or exhibitors may represent hundreds or thousands of users. 35% of the respondents also signified that they use outside parties for their screens, which could also skew the absolute numbers in the responses. In some regards, the comments and remarks to the questions were more enlightening than the responses.

1. Approximately 27% of the respondents use Photo Research, 21% Minolta, and 12% each Specbos and USL test equipment. Many used multiple pieces of gear depending on need.

2. Only 50% of respondents have a written procedure for luminance measurement and calibration. 71% use different procedures for 2D and 3D screens.

3. Calibration is done daily or more often by post houses and film festivals while the time between calibration in exhibition ranged from every bulb change or every month to once a year. One exhibitor reported that they have regular “health checks” and bi-weekly “by eye” checks and re-focusing of the lamp every 300 hours.

4. There was no majority or uniformity in regards to answers of where to measure in the room or on the screen:
    a. “for 3D we measure from the "sweet" spot in the room where the hot spot is as centered as possible…”.
    b. There is a slight difference in the light level goal of 3.5-4.5 ftL for 3D in large rooms (20%) v small rooms (20%) with higher goals (up to 10ftL) in large rooms (16%) and small rooms (12%).
    c. The majority of respondents (55%) use ‘white’ from the projector, 18% from the server manufacturer, and 14% from the 3D manufacturer. “Other” (18%?) was not specified.
    d. 75% of respondents set their 3D measurement from the center of the screen, while 38% measure from the brightest point on the screen. 20% also measure sides and/or corners.

5. Less than 10% of respondents change lamp or level between 2D and 3D movies. An unknown percentage of technicians, depending on the projector, change the lamphouse or switch in more bulbs for 3D showings. Some increase amperage for 3D, though some mention that striking the lamp becomes more difficult after running more power, then reducing it for 2D. Many mention that the projectors have been under-spec’d for the room size.

## Appendix 4: SMPTE Journal Articles on Luminance

This is a list of SMPTE Journal articles discussing light levels as applied to cinema applications. A search for "luminance" returns 1,694 articles; the word "screen" returns 7,183 results. Here's an attempt at finding ones related to cinema screens and light measurement. Articles that appear under a search for "luminance" that do not appear to have cinema application (for example, apply to television) are not listed.

Luminance — A Tutorial Paper, Robert E. Levin, *J SMPTE; October 1968; 77:(10) 1005-1011; doi:10.5594/J13629*

Automatic Luminance Tuning for High Intensity Xenon Lamp Consoles in Motion Picture Film Projection, Mark C. Regel, doi: 10.5594/J04265 *SMPTE Mot. Imag J. February 1, 2000 vol. 109 no. 2 118-121*

The Luminance Discrimination of the Human Eye, E. M. Lowry, doi: 10.5594/J11331 *SMPTE Mot. Imag J. September 1, 1951 vol. 57 no. 3 187-196*

Measured and Observed Discrepancies of Screen Luminances, Yorick G. Hurd, *SMPTE Mot. Imag J. February 1, 1973 vol. 82 no. 2 87-91*

A New Photometer for Measuring Screen Brightness, Richard A Walker and James K. Branch, *SMPTE Mot. Imag J. September 1, 1974 vol. 83 no. 9 737-741*

Portable Screen-Brightness Meter for Theater Use, doi: 10.5594/J10794 *SMPTE Mot. Imag J. October 1, 1969 vol. 78 no. 10 873-874*

International Lighting Vocabulary, L. E. Barbrwo, doi: 10.5594/J07262 *SMPTE Mot. Imag J. April 1, 1964 vol. 73 no. 4 331-332*

SMPTE Recommended Practice 12 – Minimum Screen Luminance for Drive-In Theaters, doi: 10.5594/J09361 *SMPTE Mot. Imag J. July 1, 1962 vol. 71 no. 7 512-519*

Screen Luminance for Indoor Theaters, doi: 10.5594/J09386 *SMPTE Mot. Imag J. September 1, 1961 vol. 70 no. 9 730-731*

British Standard 1404:1953 Screen Luminance (Brightness) for the Projection of 35mm Film , doi: 10.5594/J17061 *SMPTE Mot. Imag J. January 1, 1954 vol. 62 no. 1 79-81*

The Effective Gain of a Projection Screen in an Auditorium, doi: 10.5594/J17316 *SMPTE Mot. Imag J. October 1, 2010 vol. 119 no. 7 62-67*

High-Brightness Projection Screens with High Ambient Light Rejection, doi: 10.5594/J13630 *SMPTE Mot. Imag J. October 1, 1968 vol. 77 no. 10 1012-1024*

Objective Evaluation of Projection Screens, doi: 10.5594/J04881 *SMPTE Mot. Imag J. December 1, 1953 vol. 61 no. 6 702-720*

Screen Illumination of 35-mm Film Projection, doi: 10.5594/J04220 *SMPTE Mot. Imag J. December 1, 1983 vol. 92 no. 12 1310-1313*

Practical Solution to the Screen Light Distribution Problem, doi: 10.5594/J01834 *SMPTE Mot. Imag J. June 1, 1951 vol. 56 no. 6 680-683*

Some Comments on the Design of Large-Screen Motion-Picture Theaters, doi: 10.5594/J06855 *SMPTE Mot. Imag J. March 1, 1976 vol. 85 no. 3 159-163*

Averaging Screen-Illumination Readings, doi: 10.5594/J11171 *SMPTE Mot. Imag J. March 1, 1958 vol. 67 no. 3 144-148*