UL 2802

STANDARD FOR SAFETY

Performance Testing of Camera Image Quality

UL Standard for Performance Testing of Camera Image Quality, UL 2802

First Edition, Dated September 20, 2013

Summary of Topics

This revision of UL 2802 dated April 7, 2020 includes requirements to adjust tolerance specifications and clarifications; Figure 1 – Figure 10

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated November 26, 2019.

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Standard for Performance Testing of Camera Image Quality

First Edition

September 20, 2013

This UL Standard for Safety consists of the First Edition including revisions through April 7, 2020.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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CONTENTS

INTRODUCTION

PERFORMANCE

APPENDIX A EXAMPLE IMAGES

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INTRODUCTION

1 Scope

1.1 This standard defines a method to determine video camera digital image quality ratings through a series of performance based tests that are conducted on production camera units.

1.2 The camera images analyzed for this test program are digital images that are generated by individual video frames or still image captures.

1.3 Each camera tested will achieve a Performance Score for each of the individual tests (except Signal to Noise Ratio and Field of View), based on the test data generated.

1.4 Typical applications of this document applies to security video cameras, digital video cameras and or analog cameras with associated digital encoders and related image viewing / configuration software, as applicable.

1.5 The safety requirements that apply to cameras covered by this standard are defined in Section 4.

1.6 Section 6 of this standard defines the test criteria and Section 7 defines the test methods used.

1.7 The suitability of the camera for a specific use case is not determined by this standard. The resulting test scores are intended to provide objective information that will be useful when determining camera use applications (i.e. a camera that performs well in sensitivity and grey level tests may be a good choice for low light use cases).

1.8 This standard performs an evaluation on a specific camera configuration that utilize image sensors, processors and software, operating system, lens, camera housing / body and the like. Changes to any of the cameras critical components may require reconducting the performance tests for each camera configuration.

2 Undated References

2.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

2.2 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

3 Terminology

3.1 For the purpose of this standard, the following definitions apply.

3.2 ALIASING – The effect of different video signals that are being sampled becoming indistiguishable from each other.

3.3 APERTURE STOP – An aperture in an optical system is an opening in the optical path. The aperture in a digital camera controls the amount of light reaching the image sensor. In the case when an optical system has a variable aperture, the aperture will have a number of aperture stops, which refer to the opening size of the aperture. In photography, one aperture stop refers to an aperture area ratio of two, which is equivalent to light intensity ratio of two. The aperture stop is also referred as “Optical Stop” or “Stop”.

3.4 CENTERED PROCESS (Cp) – Assuming that the process output has a normal distribution, Cp estimates what the process is capable of producing if the process mean were to be centered between the specification limits.

3.5 CRITICAL COMPONENTS – Components of the camera that when changed or replace will have an effect on the safety or performance of the camera. Examples include but are not limited to: image sensors, processors and viewing software, operating system, lens, camera housing / body and the like.

3.6 DARK ROOM ENVIRONMENT – An environment that can be made completely dark with controllable lighting conditions for light intensity and other optical measurements. A darkroom environment is 0.001 lux or 1/10 of the lowest light sensitivity test level detectable by the camera.

3.7 FULL SCALE SIGNAL – Maximum pixel value for each type of image format. For example an 8 bit image format has a pixel value range of 0-255. The full scale value for this format is 255.

3.8 LINE PAIRS PER PICTURE HEIGHT (LP/PH) – A unit of measure of video camera resolution.

3.9 MODULATION TRANSFER FUNCTION (MTF) – The magnitude component of OTF.

3.10 OPTICAL TRANSFER FUNCTION (OTF) – The most detailed measure of the resolution of an optical imaging system.

3.11 PROCESS CAPABILITY INDEX (Cpk) – An index that measures an adjustment of Cp for a non-centered distribution.

3.12 SATURATION – Overly bright colors or grey levels which result in loss of details of a target image. A saturated digital image would be at maximum full scale (see 3.7).

3.13 SPATIAL FREQUENCY RESPONSE (SFR) – A measure of MTF.

3.14 WHITE BALANCE (WB) – White balance refers to the process of adjusting colors in an image to be as accurate as possible relative to what appears to the human eye.

PERFORMANCE

4 General

4.1 In addition to the performance requirements contained within this standard, the product shall comply with the applicable safety requirements contained within one or more of the following standards as applicable:

a) Standard for Information Technology Equipment, Safety – Part 1: General Requirements, UL 60950-1, or

b) Standard for Audio, Video, and Similar Electronic Apparatus – Safety Requirements, UL 60065, or

c) Standard for Audio / Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1, or

d) Standard for Commercial Closed Circuit Television Equipment, UL 2044.

4.2 Outdoor use requirements are detailed in the Standard for Information Technology Equipment – Safety – Part 22: Equipment to be Installed Outdoors, UL 60950-22.

4.3 Operating parameters such as supply voltage, input/output circuit parameters, normal operating temperature, and storage temperature are specified by the manufacturer.

4.4 Products intended for use in air-handling spaces in accordance with Section 300.22 (C) of the National Electrical Code, NFPA 70, must meet the requirements of the Standard for Fire Test for Heat and Visible Smoke Release for Discrete Products and Their Accessories Installed in Air-Handling Spaces, UL 2043.

4.5 The camera must be configured for optimum results for each test. For example, this includes setting the camera to full resolution, optimizing exposure and gain during each test program. The test lab shall record the camera settings for each test.

4.6 The manufacturers' image viewing / configuration software must be utilized for capturing images for the test program. The software is considered a critical aspect of image quality measured during the tests.

4.7 Camera configurations that utilize different image sensors, processors and software, operating system, lens, camera housing / body and the like may require conducting the performance tests for each camera configuration.

5 Individual Performance Score Per Tests

5.1 Results of video camera image quality tests are designated by scores which range from 0 – 100 for each test. 0 being the lowest level of performance and 100 being the highest level of performance. Because of dynamic variables such as lighting conditions and viewing angles associated with Field of View Confirmation (see Section 6.2) and Signal to Noise Ratio (see Section 6.3) Tests, individual performance scores are not associated with these two tests.

6 Video Camera Test

6.1 Image resolution

6.1.1 This specification measures the image resolution at the lens hyper focal distance (also see Image Resolution Test, Section 7.1 and Appendix example, A3). The overall resolution score is calculated by averaging the resolution score at the center and the four corners of the image resolution target.

6.1.2 The equation to calculate the resolution score is:

$$Resolution\ \ score\ = \tau / 20 - 5$$

6.1.3 τ is the measured resolution in LP/PH. The following table illustrates the relation between the measured resolution and the performance rating values at MTF 50.

Table 1
Examples of calculated image resolution score

Performance score	Measured resolution	Note
100	2100 LP/PH	MTF50
75	1600 LP/PH	MTF50
50	1100 LP/PH	MTF50
25	600 LP/PH	MTF50
0	100 LP/PH	MTF50

6.2 Field of view confirmation

6.2.1 Because the lens parameters vary significantly at different viewing angles for variable optical zoom lens, it is necessary to specify the lens parameters for a given viewing angle for this test. Therefore, it is important to measure the field of view before measuring other camera performance parameters.

6.2.2 For cameras with variable zoom lenses, images shall be captured at a single specified zoom value per the manufacturer, and analyzed for the field of view. The camera performance shall be measured and rated for the specific viewing angle utilized for the test. Cameras may be tested and analyzed at multiple zoom values and the Field of View rating is designated at each zoom value as identified by the manufacturer.

6.2.3 The field of view is calculated with the following equation:

$$\theta = 2\tan^{-1}\left(\frac{2d}{w}\right)$$

6.2.4 Where θ is the video camera field of view, *d* is the distance between the video camera and the test target, *w* is the width of the test target.

6.2.5 Since field of view is based on use cases, the field of view confirmation does not obtain an independent performance score considered by this standard. The field of view parameter is recorded for distortion, sensitivity, and resolution tests.

6.3 Signal to noise ratio

6.3.1 The purpose of this test is to quantitatively measure the grey level related performance. The signal to noise ratio shall be measured, per Signal to Noise Ratio Test, Section 7.3, for each grey level in the grey level measurement. Because the noise level is fixed under a given lighting condition, signal to noise ratio is different for each grey level due to the difference of the signal strength. Therefore, this document only specifies the signal to noise ratio measurement method for grey level and other measurements used within this document. Signal to Noise Ratio does not result in an independent performance score since this is an abstract parameter. The signal to noise ratio is used as an element for grey level and sensitivity tests.

6.4 TV distortion

6.4.1 The purpose of the TV distortion measurement is to quantify how much the image geometrically deviates from the two dimensional projection of the actual subject captured by the image. TV distortion shall be measured per the TV Distortion Test, Section 7.4 (also see Appendix example A4).

6.4.2 The total TV distortion score is determined by the largest measured TV distortion between 80% and 90% of the image field. The linear equation to convert the measured distortion to the TV distortion score is as follows:

$$TV\ \ distortion\ \ score = -1000\tau + 102$$

Where τ is the distortion in percentage

Table 2
Examples of calculated TV distortion score

TV distortion performance score	TV distortion
100	0.2%
80	2.2%
50	5.2%
30	7.2%
0	10.2%

6.5 Relative illumination

6.5.1 The purpose of measuring the relative illumination is to quantify the illumination degradation in the image corners with respect to the image center. The relative illumination shall be measured per the Relative Illumination Test, Section 7.5, with the camera manufacturer's default lens correction setting.

6.5.2 The equation to calculate the relative illumination score is as follows:

$$Relative\ \ illumination\ \ score = -400(\tau - 0.9)^2 + 100$$

Where τ is the relative illumination

Table 3
Examples of calculated relative illumination

Performance score	Relative illumination
100	90%
96	80%
84	70%
64	60%
0	40%

6.6 Dynamic range

6.6.1 The purpose of the dynamic range measurement is to quantify how well a camera can function under the condition with very strong light sources (examples include sunlight reflection, or strong artificial light for image recognition applications). This specification characterizes the video camera dynamic range by measuring the video camera grey level under different lighting conditions. For example, if a video camera can work properly under a maximum illumination of 200 kLux and under a minimum illumination of 1 Lux, the dynamic range of the video camera is 200 thousand times.

6.6.2 The dynamic range shall be measured, per the Dynamic Range Test, Section 7.6 with the dynamic range test target (also see Appendix example A5). This test is conducted in a dark room.

6.6.3 The linear equation to calculate the dynamic range score is as follows:

$$Dynamic\ \ range\ \ score = 100\log_{10}(\tau) - 447.71$$

Where τ is the luminous emittance in Lux

Table 4
Examples of calculated dynamic range

Performance score	Dynamic range
100	300,000 Lux
82	200,000 Lux
67	140,000 Lux
37	70,000 Lux
0	30,000 Lux

6.7 Maximum frame rate

6.7.1 The purpose of the maximum frame rate testing is to measure how well a camera can capture images of a subject in motion. Because different video cameras may have different resolutions, and the image size is larger for higher resolution, for the purpose to compare the video camera performance, the maximum frame rate shall be measured at a fixed resolution, per the Frame Rate Test, Section 7.7.

6.7.2 The linear equation to calculate the frame rate score is as follows:

$$Frame\ \ rate = 10(\tau - 10)/11$$

Where τ is the frame rate

Table 5
Maximum frame rate

Performance score	Frame rate
100	120 fps
64	80 fps
45	60 fps
18	30 fps
0	10 fps

6.8 Grey level

6.8.1 Grey level is an important camera parameter to quantify image quality. Images with more grey levels can reveal more details of the subjects in the image. This specification quantifies the video camera's grey level by measurements of the grey level patches with a luminous emittence ratio of the square root of two between adjacent grey level patches. Because there is no statistical difference in the case when the noise level is higher than the difference of the two adjacent grey levels, the noise level shall be measured for each grey level per the Signal to Noise Ratio test, Section 6.3. This specification also uses a 95% confidence interval to determine the noise level and differentiate the adjacent grey levels.

6.8.2 Grey level shall be tested per the Grey Level Test, Section 7.8. This test shall be conducted in a dark room.

6.8.3 The equation to calculate the grey level score is as follows:

$$Grey\ \ level\ \ score = 10b\tau - 20$$

6.8.4 Where τ is the grey level count, *b* is a scale factor and it is equal to average red, green and blue signal summation of the brightest patch to 95% of the full scale average of the red, green and blue signal summation.

Table 6
Examples of calculated grey level score

Performance score	Grey level	Maximum signal ÷ 95% of full scale
100	12 half stops	1
80	10 half stops	1
60	8 half stops	1
30	5 half stops	1
0	2 half stops	1

6.9 Sensitivity

6.9.1 The video camera sensitivity shall be measured with the grey level test target shown in Figure 10 at a distance, where the test target can occupy more than 70% of the image captured by the video camera under test. The test shall be performed in a dark room, per the Sensitivity Test, Section 7.9 (also see Appendix example A6) under a calibrated lighting condition and the measured result should be normalized equivalent to a frame rate of 30 frames per second (fps). The sensitivity is calculated based on the uniform illumination level that is at least two grey level patches in the captured test image having a signal to noise ratio greater than 10.

6.9.2 The equation to calculate the sensitivity score is as follows:

$$Sensitivity\ \ score = -20\tau + 101$$

Where τ is the sensitivity in lux

Table 7
Examples of calculated sensitivity with minimum 3 measurable grey levels at 30 frames per second (fps)

Sensitivity score	Sensitivity, normalized at 30 fps
100	0.05 lux
97	0.2 lux
81	1 lux
41	3 lux
0	5.05 lux

6.10 Bad pixel

6.10.1 Bad pixels in video cameras are defected pixels generally due to material defects caused by the manufacturing process. The most obvious bad pixels are hot and dark pixels. The hot pixels are pixels that always output high signals, while the dark pixels are pixels that always have zero outputs, regardless of the light condition. The most common bad pixels are the defected pixels that differ from the majority of the pixels by more than 20%.

6.10.2 The bad pixel rating shall be based on the total number of bad pixels.

6.10.3 The bad pixel shall be tested per the Test Procedure, Section 7.10.2, with a uniformly illuminated Lambertian lamp shown in Figure 1. This test shall be conducted in a dark room.

6.10.4 The linear equation to calculate the bad pixel score is as follows:

$$Defect\ \ score = \text{-}0.5\tau + 100.5$$

Where τ is the defect count in ppm (parts per million)

Table 8
Examples of calculated bad pixel score

Bad pixel score	Defect pixel count ppm (parts per million)
100	1
76	50
51	100
26	150
0	201

6.11 Veiling glare

6.11.1 Veiling glare is caused by stray light in the video camera's optical system, or by leakage current to the adjacent pixels due to pixel saturation. This standard specifies a method to quantify the veiling glare by calculating the grey level degradation and color shift due to stray light generated in the camera optics.

6.11.2 The veiling glare test shall be performed in accordance with the Veiling Glare Test, Section 7.11 (also see Appendix example A7). This test shall be conducted in a dark room.

6.11.3 The linear equation to calculate the veiling glare score is as follows:

$$Veiling\ \ glare\ \ score = 100(1-\tau)(1-\epsilon)$$

6.11.4 Where τ is the grey level degradation, which is equal to one minus the ratio of grey level count under the lighting condition that generates measurable stray light in the camera optical system, ϵ is the color shift, which is equal to the average difference of the color shift. The color shift is the absolute difference of the red to green signal ratio and blue to green signal ratio with and without the unbalanced ambient light.

Table 9
Example of calculated veiling glare score

Performance score	Grey level degradation τ	Color shift ϵ
100	0	0
80	20%	0
50	50%	0
20	80%	0
0	100%	0

6.12 Markings

6.12.1 The marking requirements of the end product safety standards (reference 4.1 and 4.2) shall apply.

7 Video Camera Test Method

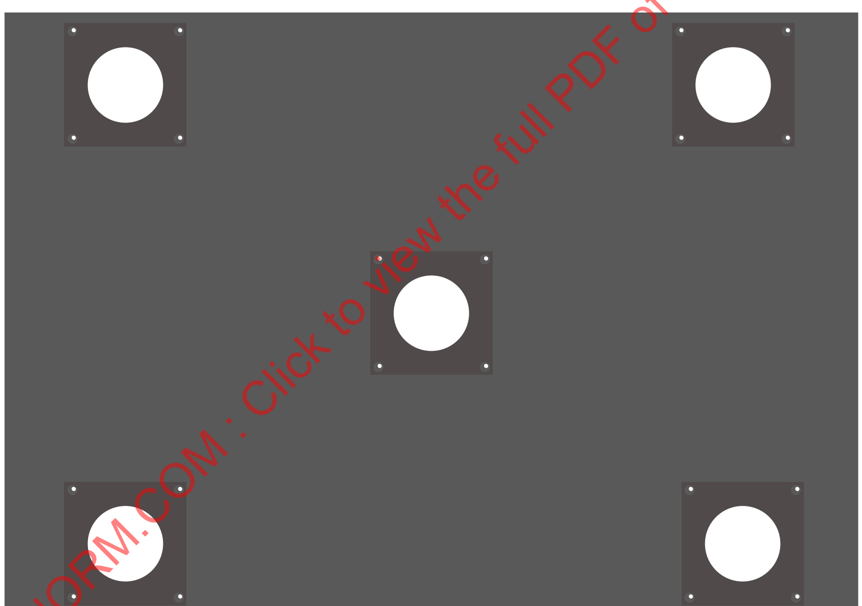
7.1 Image resolution test

7.1.1 Test equipment

7.1.1.1 The video camera image resolution shall be tested with the image resolution target. The image resolution target has a center measurement disk and four corner measurement disks on upper left corner, lower left corner, upper right corner and lower right corner. Adjust the location of the center of the corner disks (all four corners) so that they are located at 80% (±5%) of the image field of view.

Figure 1

Image resolution test target



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The large light sources (5 patches shown as circles) are 56 mm ±1 mm (2.20 in ±0.04 in) in diameter and spaced depending on the aspect ratio of the camera (reference 7.1.1.1).

7.1.2 Test setup

7.1.2.1 For this test the image resolution target shall be placed at a maximum of three standard distances to measure the image resolution for the near field (0.0 m – 0.5 m (0.0 ft – 1.6 ft)), mid field (> 0.5 m – 2 m (> 1.6 ft – 6.6 ft)), and far field (> 2 m (> 6.6 ft)). At each distance tested, an image shall be captured and analyzed. The final image resolution score shall be (at a minimum) that of the mid field score.

Exception: Depending on the field of view of the lens, the final image resolution score is an average of the resolution scores of the near field and mid field scores, or mid field and far field scores, or all three *distance (near, mid, and far field) scores. The final score shall identify the field(s) used to determine the overall performance score.*

7.1.3 Test procedure

7.1.3.1

1) Adjust the lighting condition of the image resolution test equipment, so that the video camera can capture the test image with good signal to noise ratio (the signal is more than 10 times of the noise). The luminous emmitance of the light sources are all calibrated to the same value (±1%).

2) Turn on the video camera.

3) Adjust the camera settings so that the images of the lamps are not saturated. The signal value of the center lamp image shall be < 90% of the full scale signal value.

4) Capture a still image.

5) Adjust the test target distance from the camera and adjust the light sources accordingly.

6) Where applicable (see 7.1.2.1), repeat the previous steps until all fields – near field, mid field, and far field are tested.

7.1.4 Calculation

7.1.4.1 The resolution shall be calculated in terms of LP/PH (also see Reference Number 1, of Section 8 for methods and Appendix example A3).

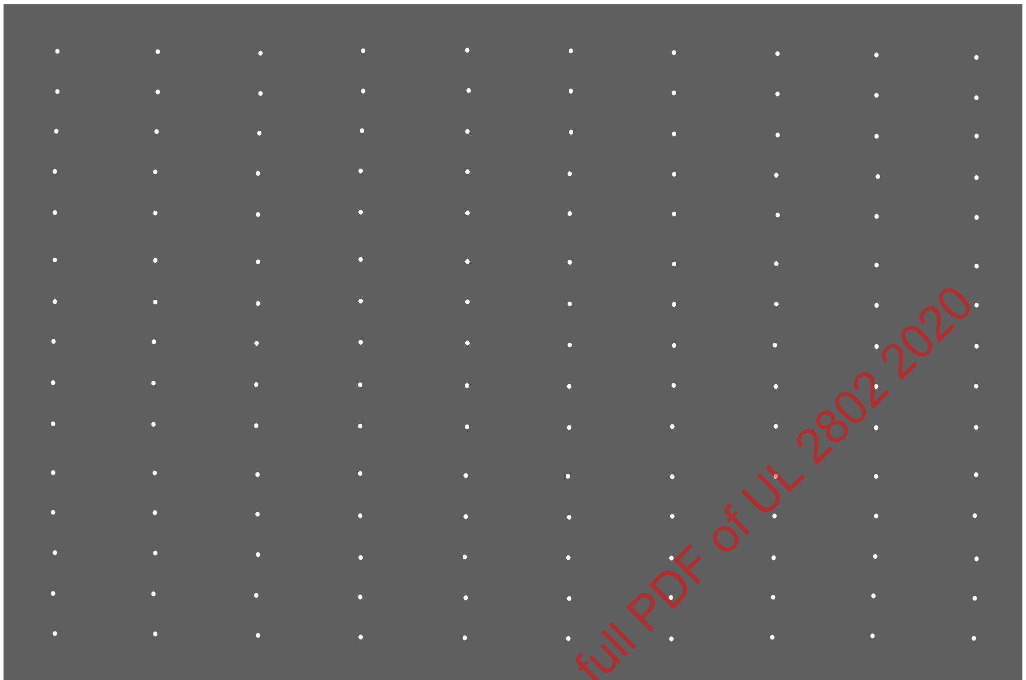
7.2 Field of view test

7.2.1 Test equipment

7.2.1.1 The video camera field of view shall be tested with a field of view and TV distortion test target.

Figure 2

Field of view test target



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The test fixture contains 300 LEDs in a matrix of 15 columns and 20 rows. Each column has 20 individual LEDs (shown as small dots) that are spaced 60 mm ±1 mm (2.36 in ±0.04 in) apart on center. Each column shall be 1140 mm ±5 mm (44.88 in ±0.20 in) from the center of the top LED to the center of the bottom LED. Each row has 15 LEDs that are spaced 130 mm ±1 mm (5.12 in ±0.04 in) apart on center. Each row shall be 1820 mm ±5 mm (71.65 in ±0.20 in) from the center of the right LED to the center of the left LED.

7.2.2 Test setup

7.2.2.1 The field of view test target shall be in front of the video camera under test, so that the video camera view finder is filled with the test target.

7.2.3 Test procedure

7.2.3.1

1) Turn on the field of view test target.

2) Turn on the video camera.

3) Adjust the camera setting to optimize the exposure.

4) Adjust the video camera distance to the test target, so that the corner of the test target can be seen in the video image.

5) Capture a still image. A minimum of 10 columns with 15 LEDs each is to be captured in the image.

7.2.4 Calculation

7.2.4.1 The field of view can be calculated with the following equation:

$$\theta = 2\tan^{-1}\left(\frac{2d}{w}\right)$$

7.2.4.2 Where θ is the video camera field of view, *d* is the distance between the video camera and the test target, *w* is the width of the test target.

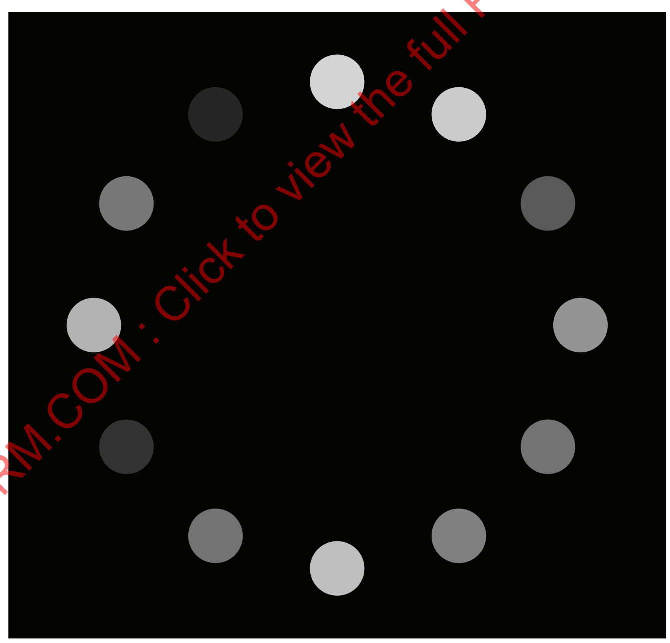
7.3 Signal to noise ratio test

7.3.1 Test equipment

7.3.1.1 The video camera signal to noise ratio shall be tested with a grey level target based on temporal signal to noise ratio method.

Figure 3

Signal to noise ratio measurement test target



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The test fixture consists of the twelve light sources (shown as circles), which are 50 mm ±1 mm (1.97 in ±0.04 in) in diameter and spaced 458 mm ±2 mm (18.03 in ±0.08 in) from each other measured center to center [example: the 3 o'clock and 9 o'clock positions are 458 mm (18.03 in) apart center to center].

7.3.2 Test setup

7.3.2.1 The grey level test target shall be placed in front of the video camera under test, and the video camera view finder shall capture the image of the whole panel of the grey level test target.

7.3.2.2 The noise level shall be measured and recorded for each grey level (1/2 stop per step) normalized to 30 fps.

7.3.3 Test procedure (Conducted in a dark room environment)

7.3.3.1

1) Turn on the grey level test equipment.

2) Turn on the video camera.

3) Measure the frame rate.

4) Capture 18 still images (for temporal noise analysis).

7.3.4 Calculation

7.3.4.1 The calculation shall be performed by using the method described in Reference Number 2 of Section 8.

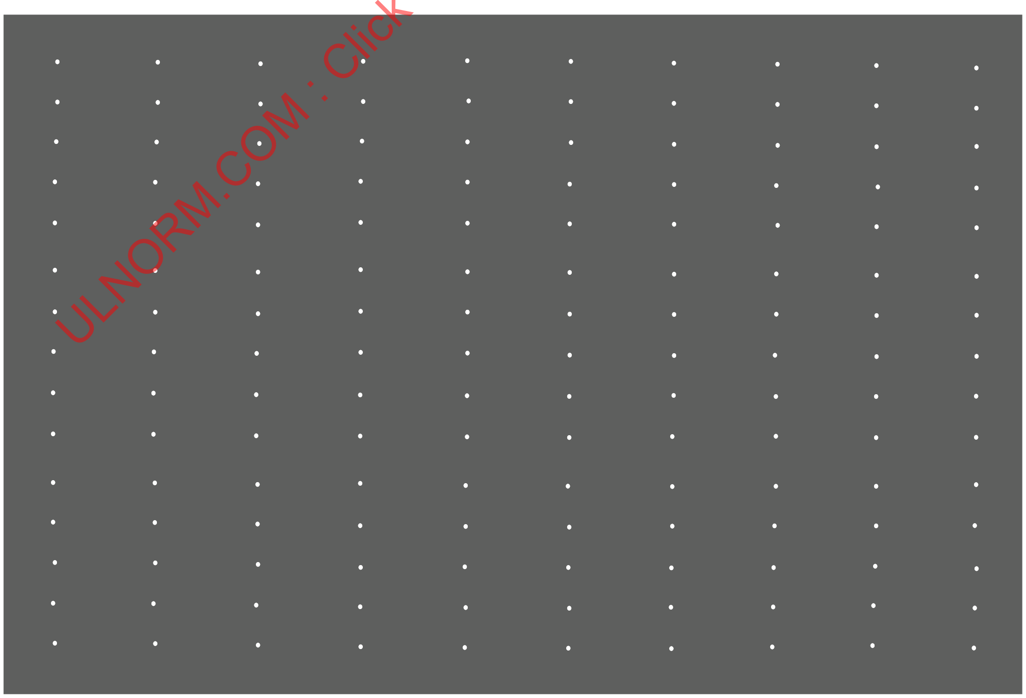
7.4 TV distortion test

7.4.1 Test equipment

7.4.1.1 The video camera shall be tested with the TV distortion test target, shown below in Figure 4.

Figure 4

TV distortion test target



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Identical to Field of View Test Fixture (Figure 2)

7.4.2 Test setup

7.4.2.1 The TV distortion test target shall be placed in front of the video camera under test, so that the video camera view finder is filled with the test target.

7.4.3 Test procedure

7.4.3.1

1) Turn on the video camera.

2) Adjust the video camera settings to optimize the exposure and focus.

3) Optimize the alignment between the camera and the test target so that the camera focus is perpendicular to the center of the test target.

4) Capture a still image. A minimum of 10 columns with 15 LEDs each are to be captured in the image.

7.4.4 Calculation

7.4.4.1 The TV distortion shall be calculated by using the method described in Reference Number 3 of Section 8 (also see Appendix example A4).

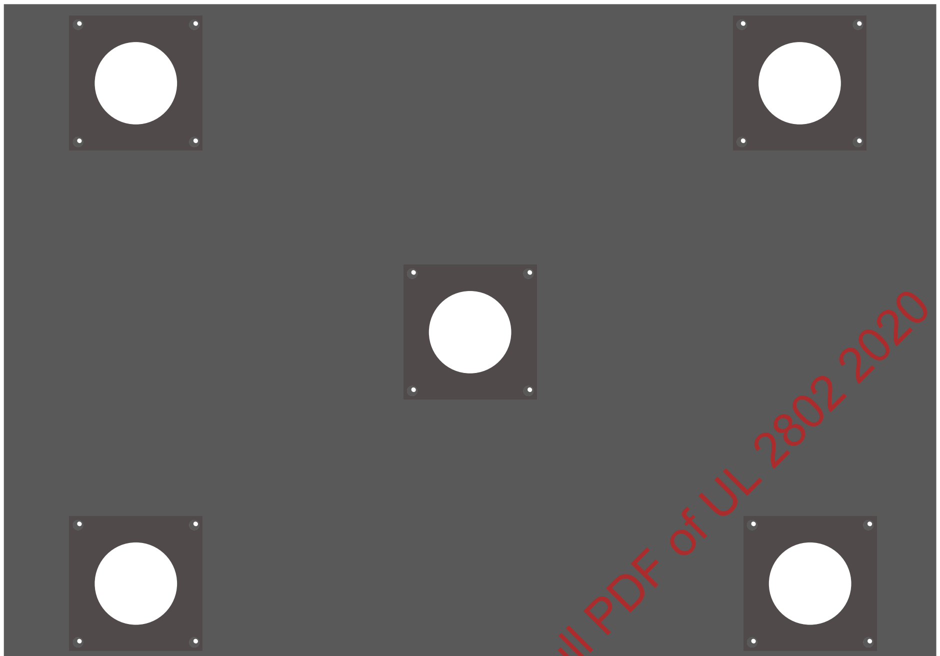
7.5 Relative illumination test

7.5.1 Test equipment

7.5.1.1 The video camera relative illumination shall be tested with a test target incorporating one lamp with diffused and uniformly illuminated light emitting surface in the center and one lamp with diffused, uniformly illuminated light emitting surface in each of the four corners of the test target, also see Figure 5.

Figure 5

Relative illumination test



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Identical to Resolution Test Fixture (Figure 1)

7.5.2 Test setup

7.5.2.1 The relative illumination test target shall be placed in front of the video camera under test, so that the video camera can capture the image of the whole panel of the relative illumination test target. For accurate measurement of the relative illumination, it is important to make sure that the image of the panel of the relative illumination test target fills up the entire field of view of the video camera and the centers of the corner lamps are located at 80% (±5%) of the image field.

7.5.2.2 The center and corner lamps shall be calibrated to the same luminous emittance value (±1%) Lux.

7.5.3 Test procedure (Conducted in a dark room environment)

7.5.3.1

1) Turn on the video camera.

2) Turn on the relative illumination test target.

3) Adjust the camera settings so that the images of the lamps are not saturated. The signal value of the center lamp image shall be < 90 % of the full scale signal value.

4) Capture a still image.

7.5.4 Calculation

7.5.4.1 The calculation shall be performed by analyzing the captured still image. The relative illumination is the ratio of the average signal of the corner lamps to the average signal of the center lamp.

$$Relative\ illumination\ score = L(corner\ average) / L(center\ average)$$

"L" is the signal level of the lamp images

7.6 Dynamic range test

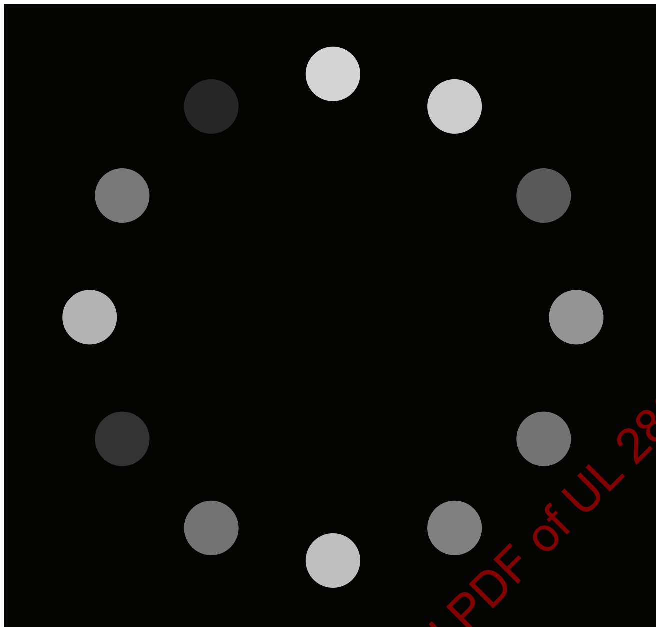
7.6.1 Test equipment

7.6.1.1 The video camera dynamic range shall be tested with the dynamic range test target (see Figure 6). The dynamic range test target has 12 uniform Lambertian lamps, which can generate a maximum luminous emittance up to 300 kLux at the defused emitting surface of the lamp. For the dynamic range test the relative luminous levels of the 12 lamps are listed in the following table. The color temperature of the lamps should be in the range for the video cameras to achieve white balance.

Lamp	Relative luminous level
1	1.0000
2	0.7071
3	0.5000
4	0.3536
5	0.2500
6	0.1768
7	0.1250
8	0.0884
9	0.0625
10	0.0442
11	0.0313
12	0.0221

Figure 6

Dynamic range test target



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The test fixture consists of the twelve light sources (shown as circles), which are 50 mm ±2 mm (1.97 in ±0.08 in) in diameter and spaced 458 mm ±2 mm (18.03 in ±0.08 in) from each other measured center to center [example: the 3 o'clock and 9 o'clock positions are 458 mm (18.03 in) apart center to center].

7.6.2 Test setup

7.6.2.1 The grey level test target shall be placed at a distance in front of the video camera under test, so that the video camera is focused and can capture the image of whole grey level test target.

7.6.3 Test procedure (Conducted in a dark room environment)

7.6.3.1

1) Turn on the dynamic range test target.

2) Start the dynamic range test target from the luminous level of 50 k lux.

3) Turn on the video camera.

4) Adjust the settings to optimize the exposure for the best grey level.

5) Capture a still image.

6) Set the grey level test target to the next luminous level, and repeat the previous step until the number of grey levels reduces to less than 12, but greater than or equal to 8. Record the luminous level of the brightest lamp.

7.6.4 Example calculation

7.6.4.1 The dynamic range rating is determined by the luminous level of the brightest lamp without saturation. The following table provides an example of the luminous levels of the 12 lamps and the measured signals for each lamp. Because the measured signals of the top three lamps are within the measurement tolerance, the maximum luminous level of this test result is 100000 Lux (also see Appendix example A5).

Lamp	Luminous emittance	Signal
1	200000 Lux	253
2	141421 Lux	253
3	100000 Lux	252
4	70711 Lux	225
5	50000 Lux	199
6	35355 Lux	178
7	25000 Lux	150
8	17678 Lux	128
9	12500 Lux	109
10	8839 Lux	95
11	6250 Lux	75
12	4419 Lux	58

7.7 Frame rate test

7.7.1 Test equipment

7.7.1.1 The video camera frame rate shall be tested with a frame rate tester (see Figure 7).

7.7.1.2 The frame rate tester is an LED array driven by square wave current. The frequency accuracy of the square wave current shall be equal to or better than 0.1Hz.

7.7.1.3 In the maximum frame rate measurement, the distance between the frame rate tester and the video camera under test shall be adjusted, so that the image of the frame rate tester shall cover 90% or more of the video camera's field of view.

7.7.2 Test setup

7.7.2.1 The frame rate tester shall be placed in front of the video camera under the test, so that the video camera's view finder is filled with the test target.

7.7.3 Test procedure

7.7.3.1

1) Turn on the video camera.

2) Adjust the video camera settings to optimize the exposure and focus.

3) Select the video camera frame rate for test.

4) Turn on the frame rate tester.

5) Set the test fixture frame rate to the value per the video camera frame rate specification.

6) If the image on the video camera viewfinder is not still, adjust the frame rate of the frame rate tester until the image on the video camera viewfinder is still. In the case when the frame rate is higher than 60 frames per second (fps), compare the difference between two adjacent frames to verify if the frequency of the test camera and the frequency of test are synchronized.

7) Record the frame rate shown on the frame rate tester display.

7.7.4 Calculation

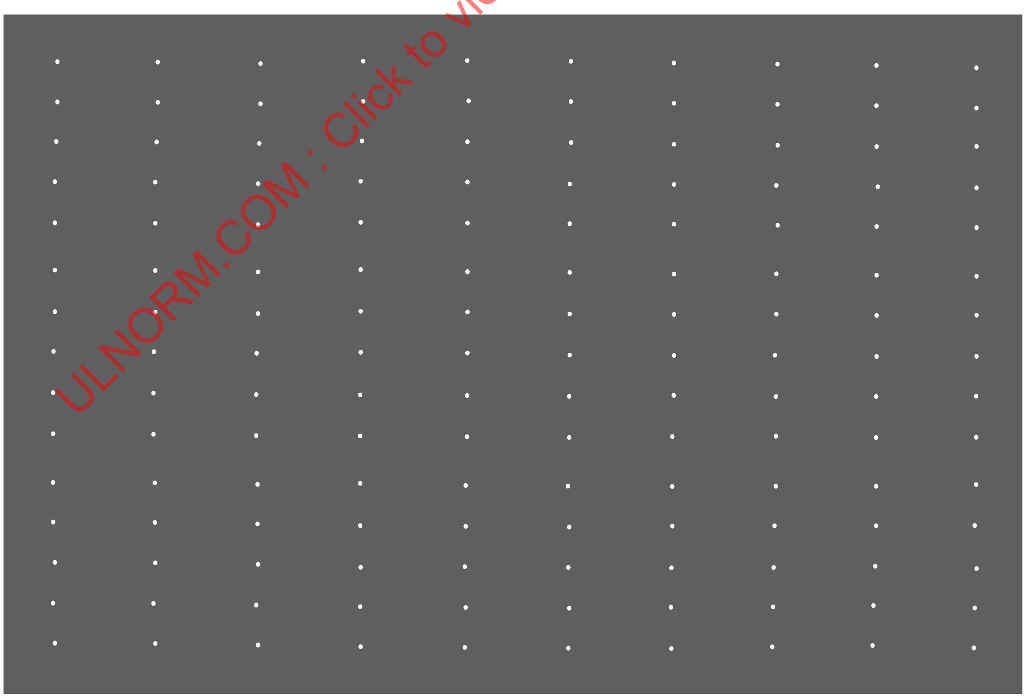
7.7.4.1 No further calculations are required for frame rate test in the case when the frame rate is less than or equal to 60 fps.

7.7.4.2 For frame rate higher than 60 fps, comparing the frame to frame variation is required. In the case when the LED frame rate tester is used and the frame rate of the video camera is different from that of the frame rate tester, the images of two adjacent frames will be different. In the analysis of frame difference, only the pixels with signal level greater than 60% of the full scale signal in at least one of the frames shall be used for the calculation. The video camera frame rate is the frame rate when the difference of the adjacent frames is minimized.

7.7.4.3 For an accurate measurement it is necessary to start the frame rate test from a frame rate lower than the specified frame rate.

Figure 7

Frame rate test target



su1659a

Identical to Field of View Test Fixture (Figure 2)

7.8 Grey level test

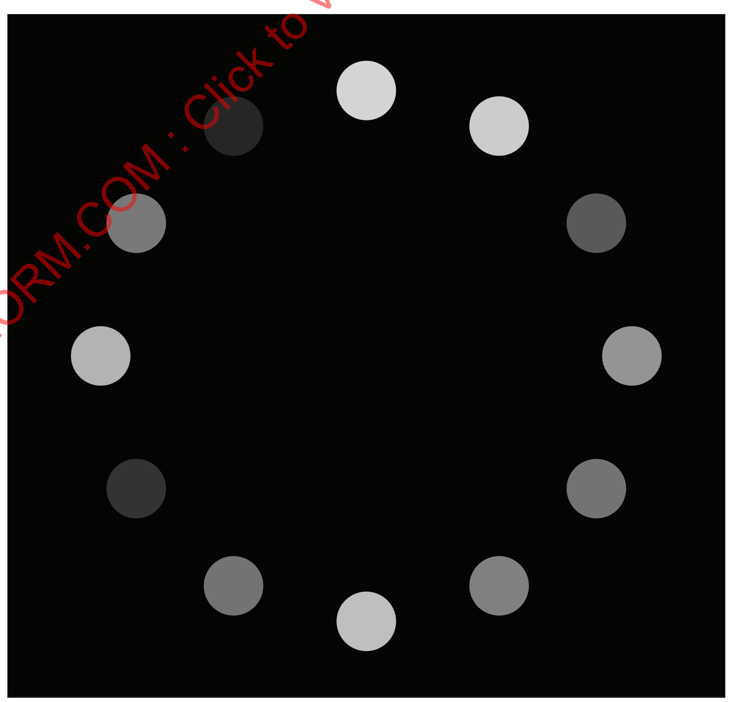
7.8.1 Test equipment

7.8.1.1 The video camera grey level shall be tested with a grey level target with 12 lamps. The luminous emittances measured at the surface of the 12 lamps are listed in the following table. The color temperature of the lamps should be in the range for the video cameras to achieve white balance.

Grey level	Luminous emittance (±1%)
1	7000 Lux
2	4950 Lux
3	3500 Lux
4	2475 Lux
5	1750 Lux
6	1237 Lux
7	875 Lux
8	619 Lux
9	438 Lux
10	309 Lux
11	219 Lux
12	155 Lux

Figure 8

Grey level test target



su1586

Identical to Signal to Noise Test Fixture (Figure 3)

7.8.2 Test setup

7.8.2.1 The grey level test target shall be placed in front of the video camera under the test, so that the video camera view finder can capture the image of whole panel of the grey level test target.

7.8.3 Test procedure (Conducted in a dark room environment)

7.8.3.1

1) Turn on the grey level test target.

2) Turn on the video camera.

3) Set the video camera frame rate to 30 fps or the maximum frame rate the camera can achieve if less than 30 frames per second.

4) Adjust the video camera settings to optimize the exposure and focus.

5) Capture 18 still images (for temporal noise analysis).

7.8.4 Calculation

7.8.4.1

1) Measure each of the twelve grey level pads and record the digital count for each pad.

2) Calculate the noise level.

3) In the case where the noise level is less than 1.2 % of the full scale signal for adjacent grey level pads, use 1.2 % of the full scale signal as the criteria to differentiate valid grey levels.

4) Remove the overlapped grey levels from the total of 12 measurable grey levels.

5) Calculate the ratio of the maximum measured signal to the full scale pixel signal.

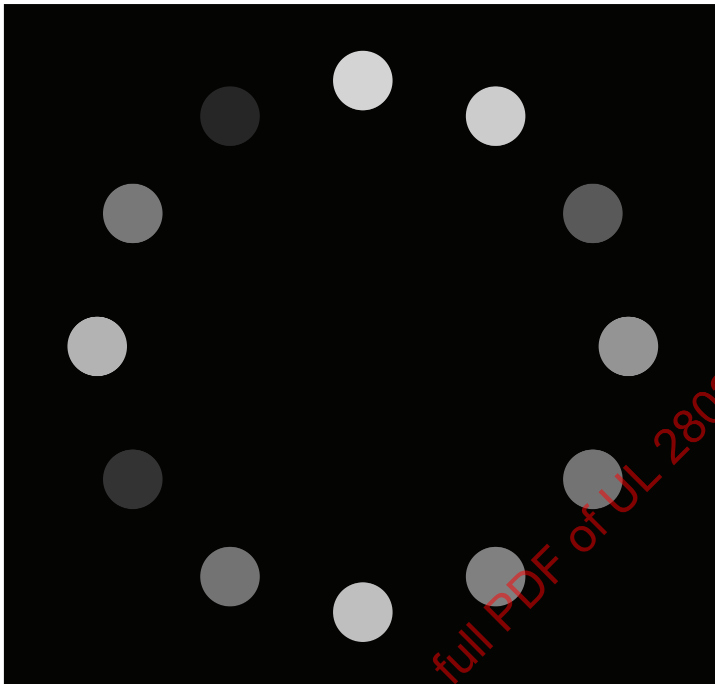
7.9 Sensitivity test

7.9.1 Test equipment

7.9.1.1 The video camera sensitivity shall be tested with a grey level test target. The difference between the two tests is the luminous level of the target.

Figure 9

Sensitivity test target / Grey level test target



su1586

Identical to Signal to Noise Test Fixture (Figure 3)

7.9.2 Test setup

7.9.2.1 The grey level test target shall be placed in front of the video camera under test, so that the video camera view finder can capture the entire image of whole panel of the grey level test target.

7.9.3 Test procedure (Conducted in a dark room environment)

7.9.3.1

1) Turn on the video camera.

2) Turn on the sensitivity test equipment.

3) As a starting point for this test, set the sensitivity test equipment to lighting conditions based on the manufacturers specifications.

4) Capture a still image.

5) Measure the frame rate and exposure time under the same exposure setting.

6) Calculate the number of grey levels according to the method used for the grey level calculation.

7) The sensitivity is defined as the luminous emittance level of the grey level lamp that is two levels higher than the grey level lamp with a signal to noise ratio less than 10. The following calculation (ref. 7.9.4.1) provides example data to explain the calculation method.

7.9.4 Calculation

7.9.4.1 See grey level calculation (also see Appendix example A6). The following table provides example data to illustrate the calculation method. In this case, lamp 9 has a signal to noise ratio lower than 10, and there is no signal overlap for lamps 7, 8 and 9, therefore the sensitivity of this test result is 0.25 Lux.

Lamp	Lamp luminous emittance	Average RGB signal	Signal to noise ratio
1	2 Lux	253	25
2	1.41 Lux	253	25
3	1.00 Lux	252	25
4	0.707 Lux	225	20
5	0.500 Lux	199	18
6	0.353 Lux	178	17
7	0.250 Lux	150	15
8	0.177 Lux	128	11
9	0.125 Lux	109	9
10	0.088 Lux	95	8
11	0.063 Lux	75	7
12	0.044 Lux	58	1

7.10 Bad pixel test

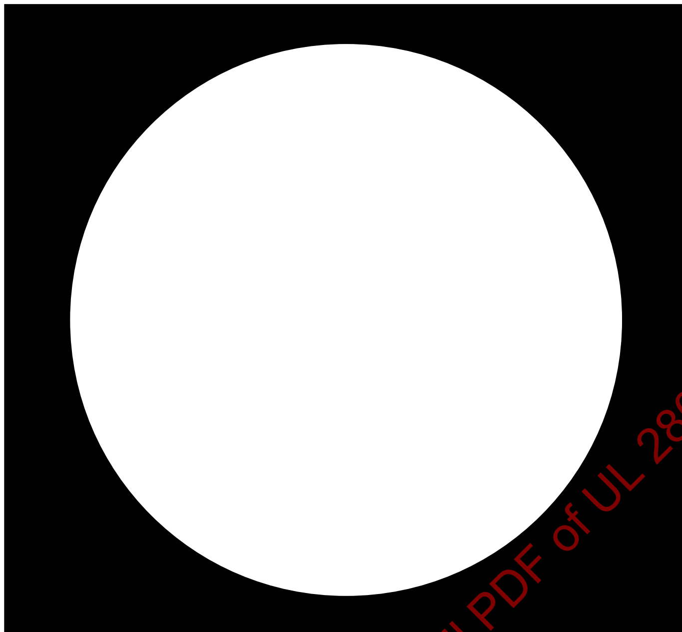
7.10.1 Test equipment

7.10.1.1 The equipment for the bad pixel test is a diffused uniform lamp. The luminous uniformity on the light emitting surface of the lamp should be within ±2% of the average luminous emittance of the lamp. The luminous emittance of the lamp is 2500 Lux ±10% measured at the emitting surface of the lamp.

7.10.1.2 The bad pixel test shall be performed with the Lambertian lamp at a distance of 1 cm. or less from the video camera under the test, so that the lens shading effect can be minimized.

Figure 10

Bad pixel test target



su1587

The test target consists of one uniform lamp 56 mm ±1 mm (2.20 in ±0.04 in) in diameter

7.10.2 Test procedure (Conducted in a dark room environment)

7.10.2.1

1) Turn on the video camera.

2) Turn on the diffused lamp.

3) Adjust the camera settings so that the image of the lamp is not saturated. The average signal value of the image shall be < 90 % of the full scale signal value.

4) Capture a still image.

7.10.3 Calculation

7.10.3.1 The bad pixel calculation shall be performed by averaging the signal intensity in each of the image blocks of 32x32 pixels. The bad pixels are the pixels with signal intensity more than 20% different from the average value within a 32 x 32 pixel block.

7.11 Veiling glare test

7.11.1 Test equipment

7.11.1.1 The veiling glare shall be tested with the veiling glare test apparatus and grey level test target. The purpose is to quantify the grey level degradation and color shift when the video camera operates under lighting conditions with light sources outside of the video camera field of view that generates stray