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Working Party on Lighting and Light-Signalling (GRE)
(Forty-fifth session, 2-6 October 2000,
agenda item 2.4.)

PROPOSAL FOR DRAFT AMENDMENTS (SUPPLEMENT 21 TO THE 03 SERIES) TO REGULATION No. 37

(Filament lamps)

Revision 1

Transmitted by the Expert from the Working Party “Brussels 1952" (GTB)

Note: The text reproduced below was prepared by the expert from GTB in order to introduce in the Regulation a definition of “white light” and to insert a method of measurement of the colour of lamps. The revised text takes into account the consideration of this subject by GRE during its forty-fourth session, including the alignment of trichromatic coordinates for amber light with those proposed in document TRANS/WP.29/GRE/2000/13 (TRANS/WP.29/GRE/44, para. 32).

Note: This document is distributed to the Experts on Lighting and Light-Signalling only.

Informal document No. 1
(44th GRE, 3-6 April 2000,
agenda item 2.5.)

Review of color coated bulb test methods and data

(Transmitted by the expert from the
International Electrotechnical Commission)

Review of color coated bulb test methods and data

To support GTB R37 Bulb Color Proposal

Abstract

This report consists of a compilation of test results on the color measurement of “colored” (color-coated) bulbs and is intended to support the GTB Regulation No.37 (R37) bulb color proposal. Results from independent measurements carried out by General Electric Lighting, Osram Sylvania, and Philips Lighting confirm that the proposed method is effective in evaluating the new requirements (conformance to ECE white light specifications) for the allowable color tolerances.

Introduction

During the November 1999 GTB meeting a proposal (document CRP #3) was tabled by W. van Dam to change the colorless bulb requirement in R37. In December 1999 this proposal was also considered at the SAE replaceable bulb task force meeting. Representatives of the lighting industry (Federal Mogul, General Electric Lighting, Osram Sylvania, and Philips Lighting) have since investigated whether the regulatory goal can be achieved with the proposed measurement method. A summary of the investigations is presented in this report.

Test Apparatus and Procedure

General Electric Lighting (GEL), Osram Sylvania (Osram), and Philips Lighting (Philips) have carried out tests based on the same principle of determining the spatial chromaticity distribution within a well-defined angular region around the bulb. This distribution is determined by measuring color coordinates of individual rays emerging from a position on the bulb surface within the defined angular region. Detailed descriptions of the test set-ups and measurement procedures are presented in Appendices A, B, and C for GEL, Philips, and Osram respectively.

Measurements can be carried out with the bulb in fixed position, while the detector rotates around it (Philips), as well as by rotating and tilting the bulb in front of a fixed detector (GEL, Osram). The key input variables of the test method are angular acceptance of the detector and the measurement grid. Values of the key input variables that define the three applications of the originally proposed measurement method are summarized in Table 1.

Table 1. Values of the key input variables for the GEL, Osram and Philips test set-up.

Test set-up	Angular acceptance of detector (degrees)	Measurement points per test
GEL	1.3	13
Osram	5	1140
Philips	15	252

The experimental test results indicate insensitivity to the key input variables provided that:

1. Measurement points cover the full extent of the base area of the conical measurement volume;
2. The angular aperture of the colorimeter is between 1.3° and 15°.

Measurement results

The three tests provide a data set comprising a representative sample of bulbs. An overview of the bulbs, which were used in the tests, is given in Table 2.

Table 2. Bulbs tested in GEL, Osram and Philips tests.

Test	Bulbs tested	
GEL	9004 clear 9004 absorption coated 9004 interference coated	9011 (HIR) 9012 (HIR)
Osram	9004 interference coated 9005 blue 9006 blue	H1 blue H7 blue
Philips	H4 standard H4 Blue Vision	“brand X”

The test results indicate that a clear distinction exists between bulbs that exhibit very little color separation, and bulbs that have widely spread color coordinates for different spatial measurements across the bulb surface. The former bulbs have color coordinates that fall within the ECE white light area, and the latter color coordinates, which fall outside of the white light boundaries over a broad area.

Measuring the color of emitted light in an integrating sphere has the disadvantage that the result is averaged and does not reflect the color of individual rays. Using the proposed method will clearly identify any rays outside the acceptable white light area.

Conclusions and Recommendations

Although only a small number of bulbs out of the large variety presently found on the market could be examined, it is obvious that the introduction of this test will allow to clearly identify a large fraction of these as non-compliant. The verification of non-compliance is very easy, because one measurement result outside the white light area is sufficient.

The test criterion is very suitable because it directly relates to the color of light emitted by the headlamp. Usually, the optics of a headlamp does not change the color of a light source significantly.

It is therefore recommended to amend ECE Regulation No.37 in the way proposed by GTB. Furthermore, global adoption as a standard to foster harmonization is supported.

APPENDIX A

General Electric Lighting Test Method and Results

A.1 Test Method

A.1.1 Apparatus and Procedure

A schematic view of the General Electric test set-up is shown in Figure A.1. The bulbs are mounted on the table of a type-A goniometer. A colorimeter is placed at 10 ft distance from the center of the table. At this distance the angular acceptance of the colorimeter is 1.3°.

Both double filament 9004 (HB1) bulbs and single filament coated HIR bulbs were tested. For the double filament bulbs the major filament is energized during the tests. All bulbs are positioned in normal (horizontal) operating position, with reference axis perpendicular to the detector axis, when the goniometer is at (x=0,y=0). For double filament bulbs, each bulb is positioned so that the major filament axis is perpendicular to the detector axis as well.

During the measurements the bulb is rotated and tilted in front of the fixed detector. Color coordinates are measured over a grid that falls within a cone, which has its symmetry axis coinciding with the detector axis, and top-angle located in the center of the filament. The grid points are listed in Table A.1 and graphically depicted in Figure A.1.

Table A.1. General Electric measurement grid.

Horizontal angle (x) (degrees)	Vertical angle (y) (degrees)
-30	0
-15	-15, 0, 15
0	-30,-15,0,15,30
15	-15,0,15
30	0

A.1.2 Test Bulbs

Preliminary tests were limited to 9004 and HIR bulbs. Both clear and coated 9004 bulbs were tested. The coated bulbs can be further divided into bulbs with absorption coatings and bulbs with visually perceived light and dark interference coatings. A summary of all tested bulbs is given in Table A.2.

Table A.2. General Electric test bulbs.

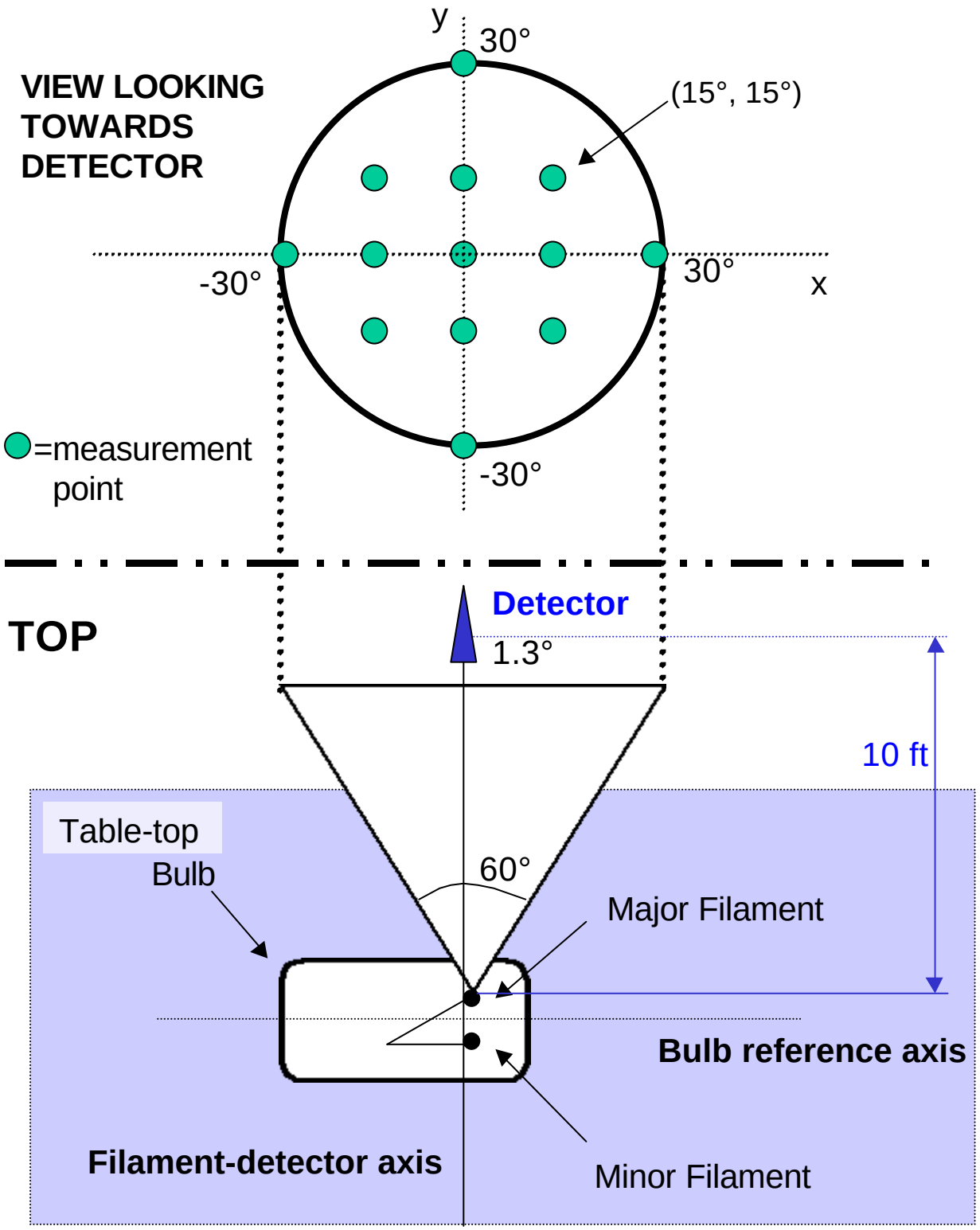
Bulb type	Bulb coating	Manufacturer
9004 (HB1)	Clear	A,B
9004 (HB1)	Blue (absorption)	B,C
9004 (HB1)	Blue (light interference)	D
9004 (HB1)	Blue (dark interference)	D,E.F
9011 (HIR1)	HIR coating	U
9012 (HIR2)	HIR coating	U,V

A.2 Results

The measured color coordinates for the 9004 and HIR bulbs are plotted in Figures A.2 and A.3, respectively. These figures are sub-sections of the CIE chromaticity diagram, with the boundaries of the ECE white light area marked as solid lines.

Figure A.2 shows that the color coordinates for clear and absorption 9004 bulbs have very little spread over the conical measurement grid, and fall well within the white light area. For the light interference coated bulb (manufacturer D) a larger spread in *x* and *y* is observed, but the conglomerate of measurements is still located within the boundaries of the white light area. The dark interference coated bulbs, however, show a large spread over the conical measurement grid, and have color coordinates that predominantly fall outside of the white light area.

The measurements on HIR bulbs in Figure A.3 show that the color coordinates of the tested coated HIR lamps are very stable, and well within the specified limits.


VIEW LOOKING TOWARDS DETECTOR
y
30°
(15°, 15°)
-30°
30°
x
-30°
=measurement point
TOP
Detector
1.3°
10 ft
Table-top
Bulb
60°
Major Filament
Bulb reference axis
Filament-detector axis
Minor Filament

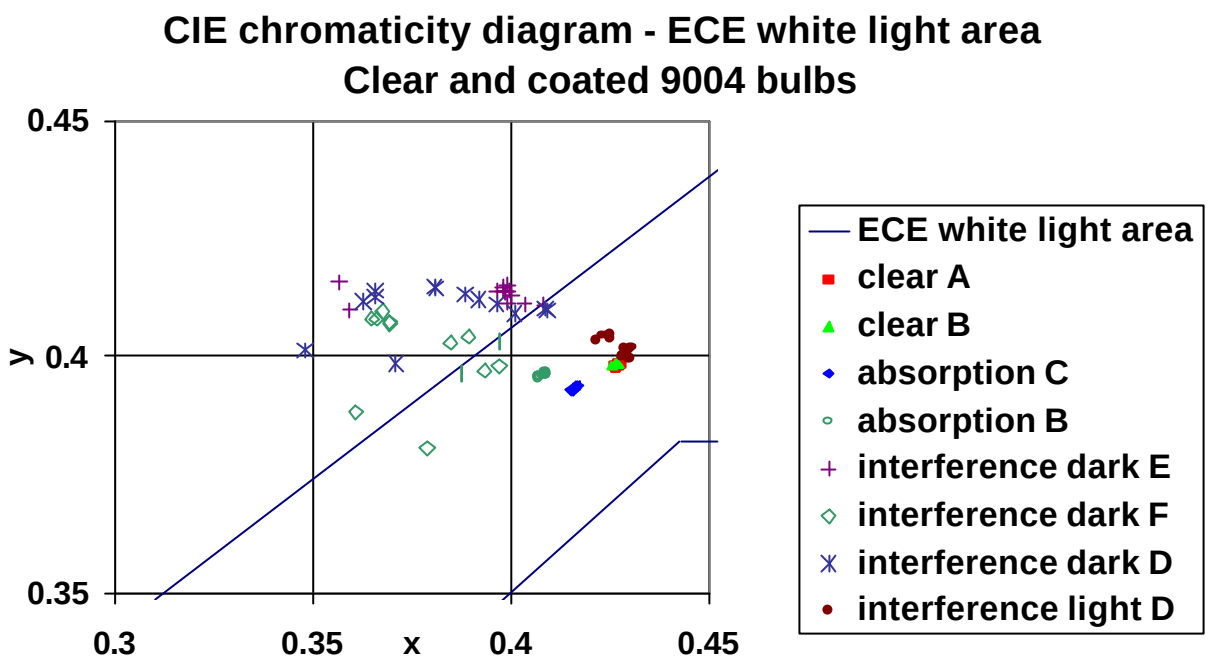


Figure A.2. Detail of the ECE white light area in the CIE chromaticity diagram. Color coordinates *x* and *y* are shown for clear and coated 9004 bulbs. Measurements are made with the method described in Section A.1.

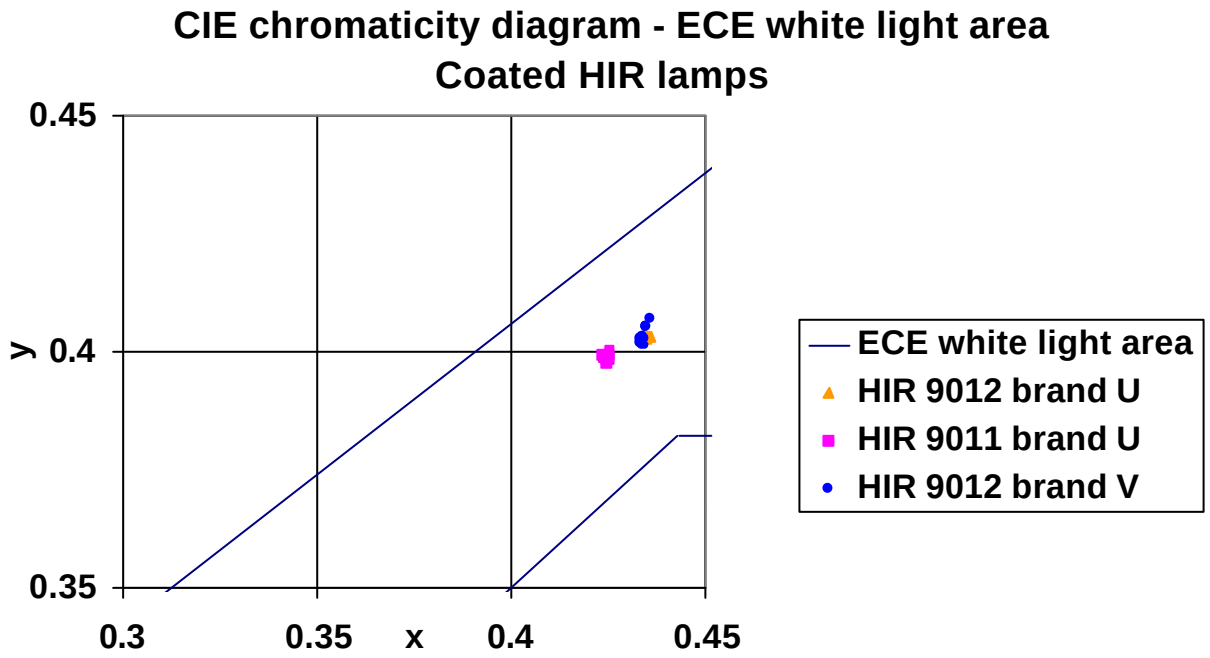


Figure A.1. Schematic view of the experimental arrangement used for 9004 and HIR bulbs at General Electric. The figure shows the set-up for a 9004 bulb.

Figure A.3. Detail of the ECE white light area in the CIE chromaticity diagram. Color coordinates *x* and *y* are shown for HIR coated lamps. Measurements are made with the method described in Section A.1.

APPENDIX B

Philips Lighting Test Method and Results

B.1 Test Method

B.1.1 Apparatus and Procedure

The Philips Lighting measurements were carried out with a colourmetric 3D-goniometer, which has a detector aperture of 15°. All bulbs were oriented horizontally, in normal operating position. The measurements are carried out with stationary bulb, and detector rotating around the bulb. Color coordinates were measured over a grid, defined by:

- polar angle : 60° ... 120° in 10° steps;
- azimuthal angle : -180° ... 180° in 10° steps.

The complete grid corresponds to rays in 252 different directions to each bulb.

B.1.2 Test Bulbs

Test bulbs were Philips H4 Standard and Blue Vision, as well as a “Brand X” bulb.

B.2 Results

The measured color coordinates are plotted in Figure B.1 for the two H4 bulbs and the “brand X” bulb. The figure is a section of the CIE chromaticity diagram, with the boundaries of the ECE white light area marked as solid lines.

The figure shows that the Standard and “Blue Vision” bulbs have very little spread in color coordinates over the measurement grid, and fall well within the white light area. For the “brand X” bulb a long stretched band of x-y coordinates is observed, which falls largely outside the white light area.

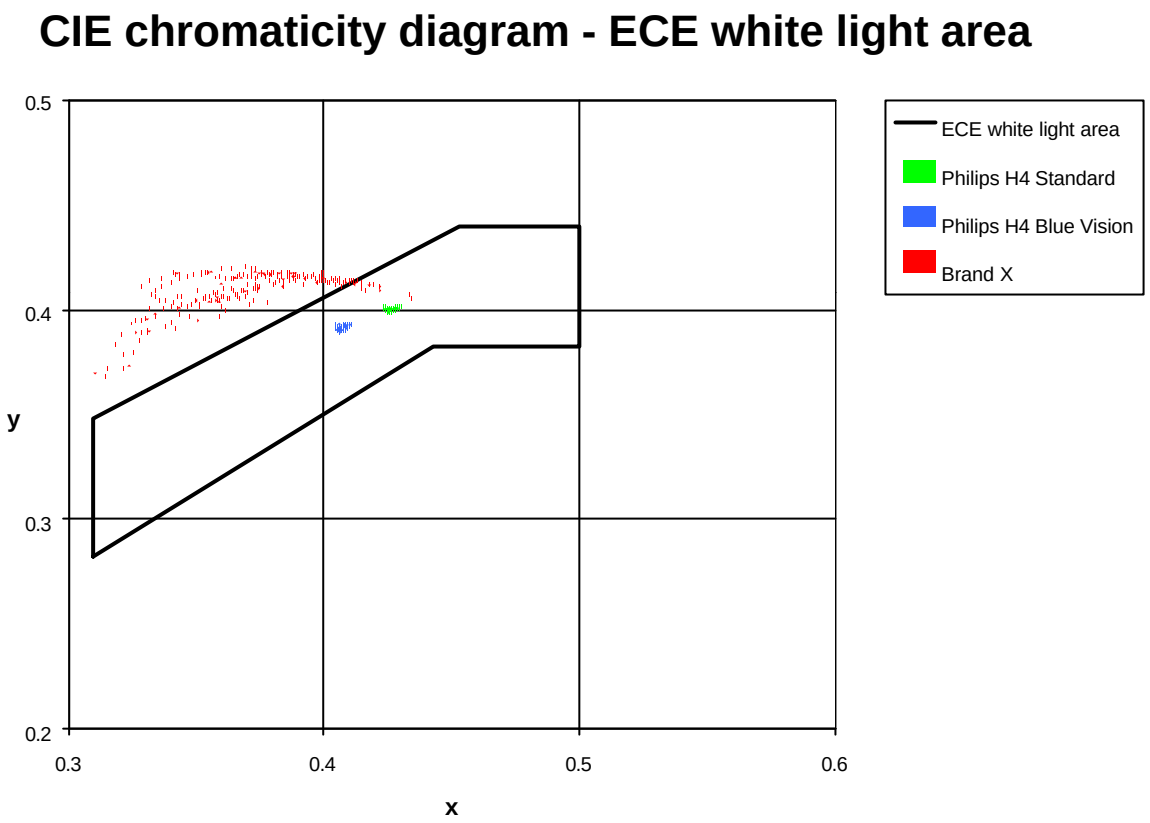


Figure B.1. ECE white light area in the CIE chromaticity diagram. Color coordinates *x* and *y* are shown for the 3 bulbs tested. The data set for each bulb consists of 252 data points.

APPENDIX C

Osram Sylvania Test Method and Results

C.1 Test Method

C.1.1 Apparatus and Procedure

Measurements were made in the TML at Cherry Hill using a modified Type B goniometer with a colorimeter positioned to receive light in a 5° cone as measured from the center of the coil. The Type B goniometer was limited to 90° azimuthal rotation (rotation about its vertical or polar axis) due to the limited distance between the goniometer framework and the detector required to realize a 5° measurement angle. A small horizontal rotational stage was mounted on the goniometer such that its axis of rotation coincided with the polar axis of the goniometer. Each bulb was mounted on this stage so that the coil being measured was centered on the added rotational stage's axis and on the axes of rotation of the goniometer. The chromaticity distribution around each bulb was measured in four segments of 90° azimuthal angle. This was accomplished by rotating the added rotational stage by 90° between readings to cover a band (±35° polar angle) around the full circumference of the bulb. Scans were made beyond 30° polar angle so adjacent readings could be combined to simulate a sensor with a larger receptor angle.

C.1.2 Test Bulbs

The bulbs, which were tested, are listed in Table C.1.

Table C.1. Osram Sylvania test bulbs.

Lamp type/coating	Manufacturer
H1 blue	A
9005 (HB3) blue	A
9006 (HB4) blue	A
H7 blue	A
9005 (HB3) blue	B
9006 (HB4) blue	B
9004 (HB1) interference coated	1
9004 (HB1) interference coated	2
9004 (HB1) interference coated	3

C.2 Results

The measured color coordinates for the bulbs of manufacturers A and B are plotted in Figure C.1. The figure is a section of the CIE chromaticity diagram, with the boundaries of the ECE white light

area marked as solid lines. The figure shows that these bulbs show very little spread in color coordinates over the measurement grid, and fall well within the white light area.

Figures C.2-C.13 present data taken on minor and major filament for three different 9004 bulbs with interference coatings. For each of the pairs of figures on a page, the top figure shows the data points as measured with a 5° aperture detector. When, at a given angular setting, adjacent readings with the 5° aperture detector are combined, a detector with 15° aperture can be simulated. The simulated 15° aperture response based on the 5° data set is shown in bottom figures of C.2-C.13.

Of the bulbs with interference coatings, #1 and #2 fail the specification, but it is observed that bulb #3, which has a similar shape color separation as bulb 1 and 2, but rotated, conforms to the specification.

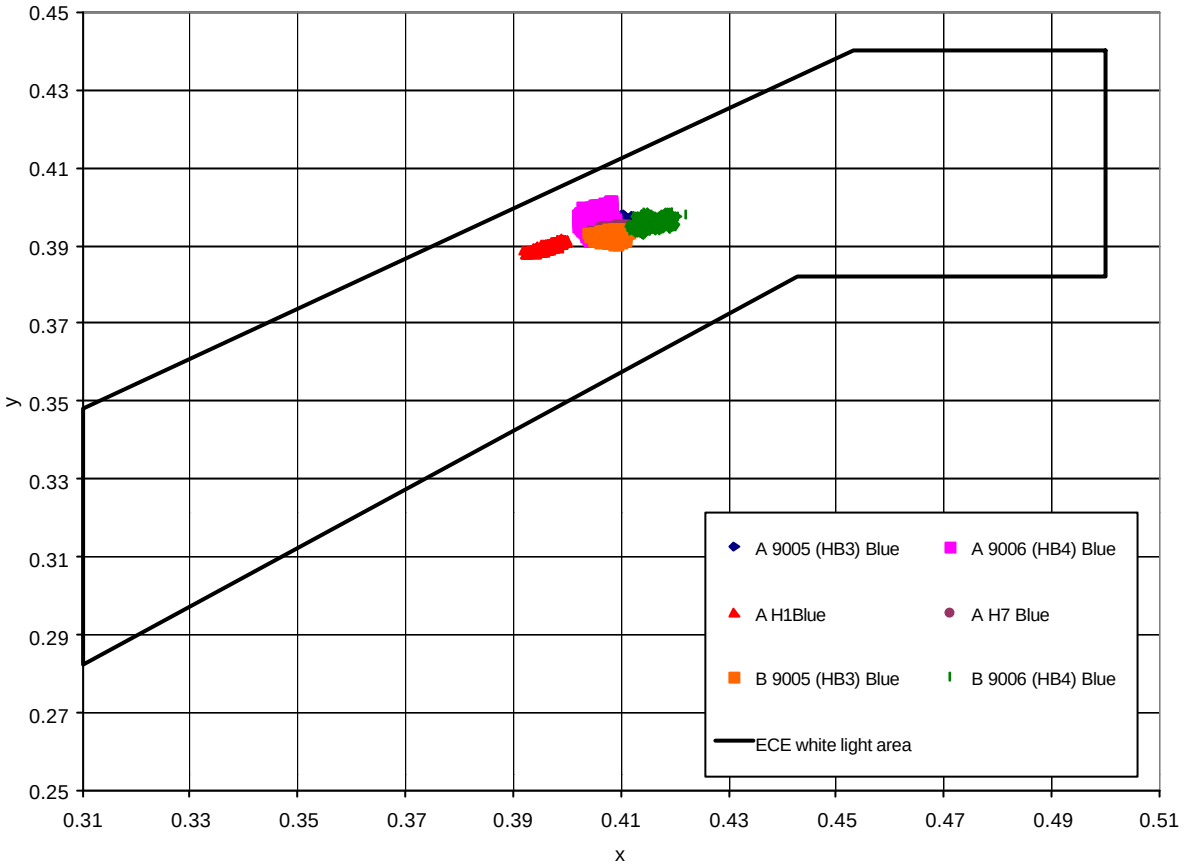


Figure C.1. ECE white light area in the CIE chromaticity diagram. Color coordinates *x* and *y* are shown for the tested bulbs of brand A and B.

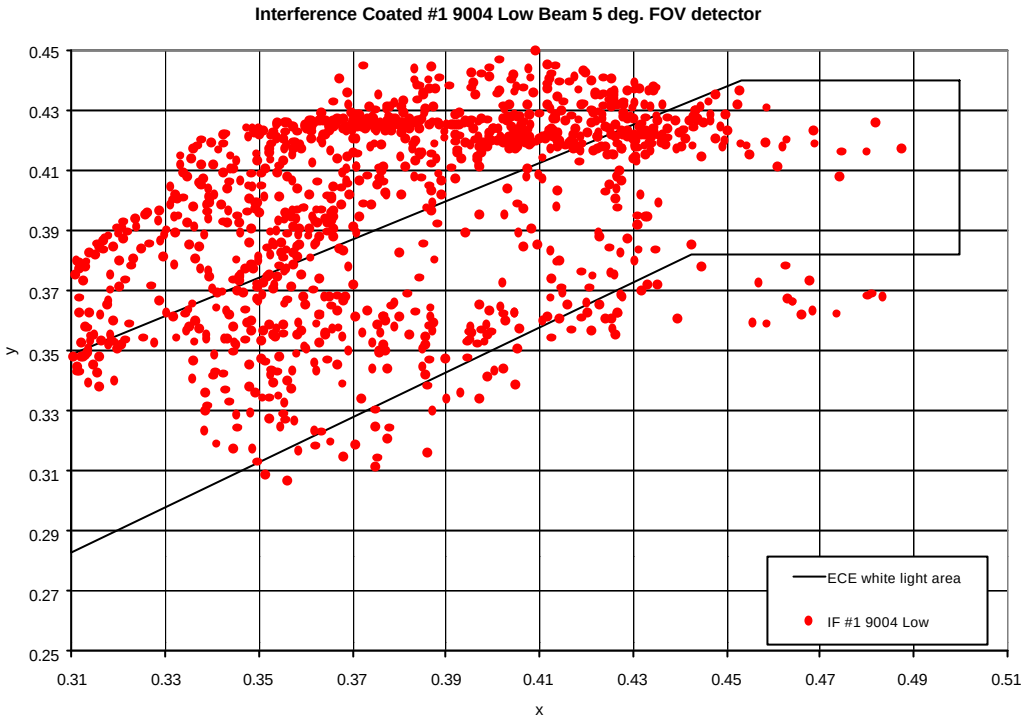


Figure C.2. Color coordinates *x* and *y* of interference coated 9004 bulb #1 with minor filament energized, measured with 5° FOV detector.

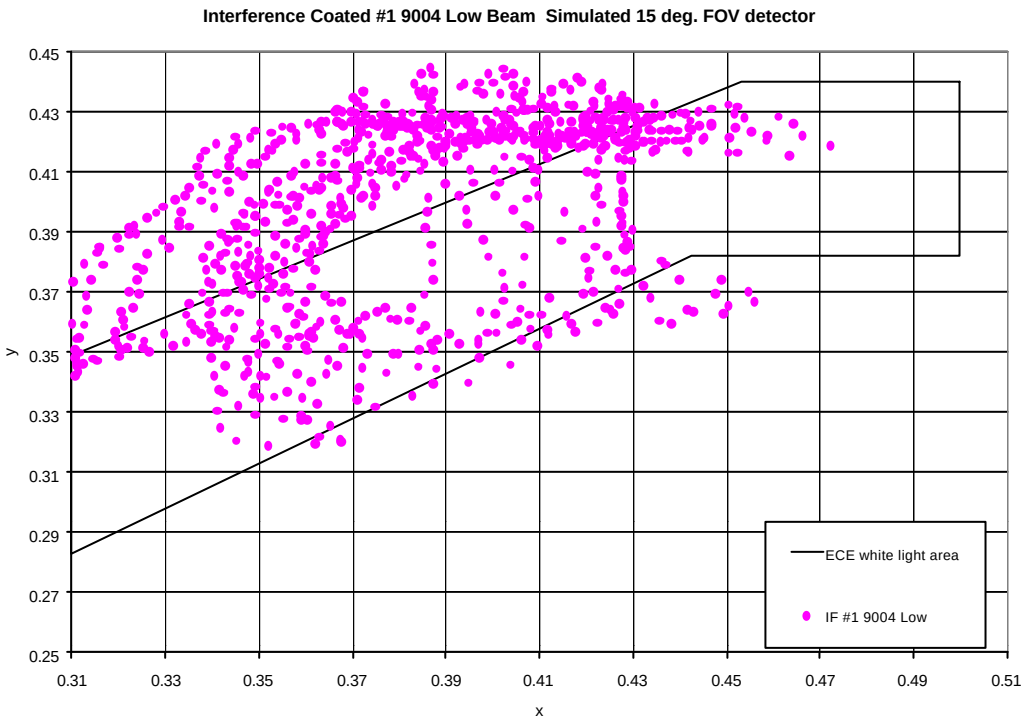


Figure C.3. Simulation of a 15° FOV detector response calculated with data from Figure C.2 (minor filament).

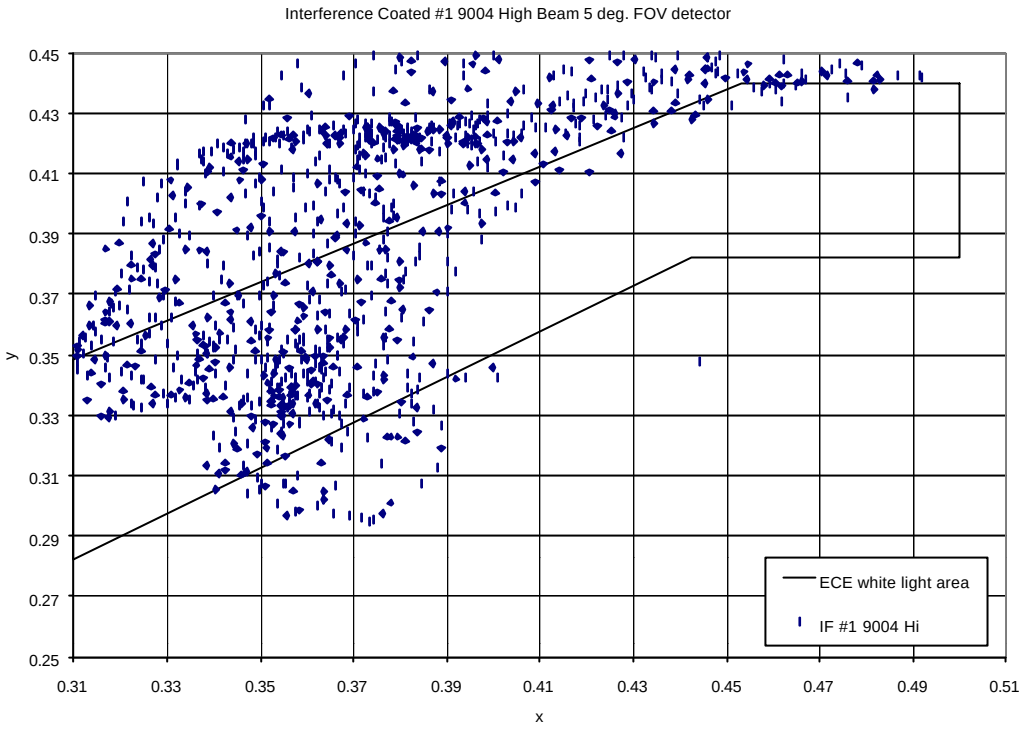


Figure C.4. Color coordinates *x* and *y* of interference coated 9004 bulb #1 with major filament energized, measured with 5° FOV detector.

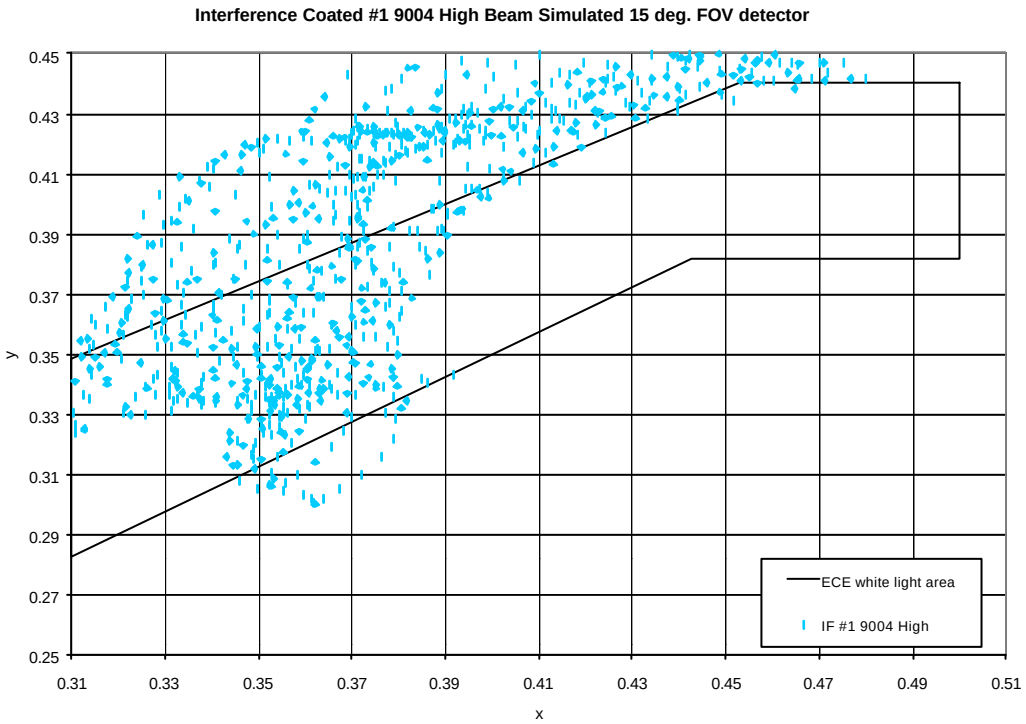


Figure C.5. Simulation of a 15° FOV detector response calculated with data from Figure C.4 (major filament).

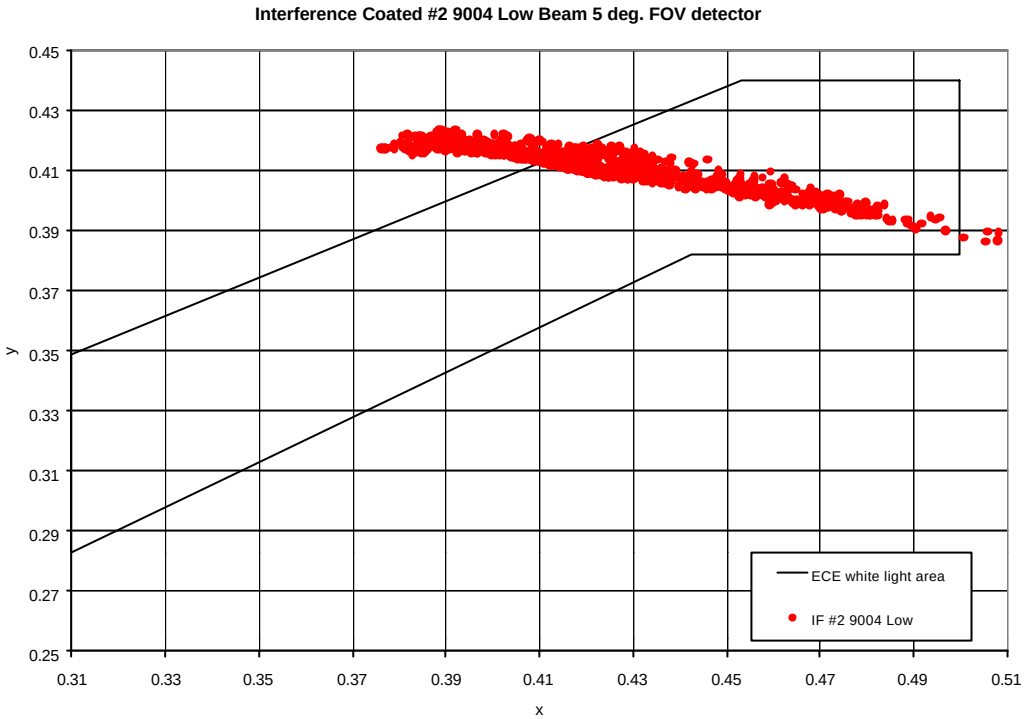


Figure C.6. Color coordinates *x* and *y* of interference coated 9004 bulb #2 with minor filament energized, measured with 5° FOV detector.

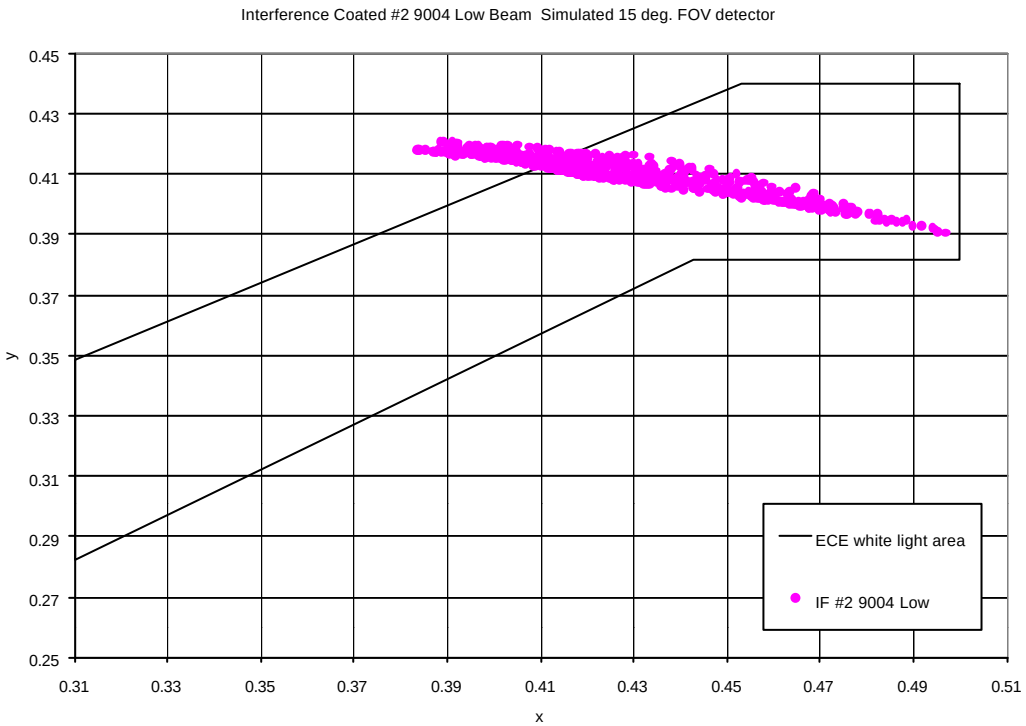


Figure C.7. Simulation of a 15° FOV detector response calculated with data from Figure C.6 (minor filament).

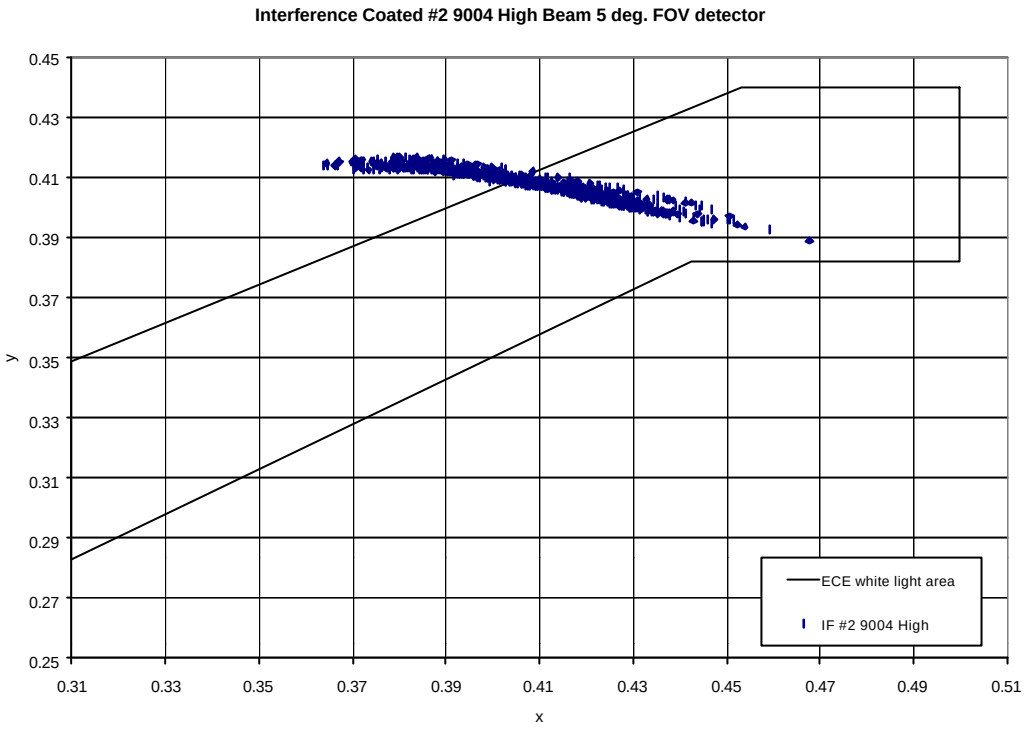


Figure C.8. Color coordinates *x* and *y* of interference coated 9004 bulb #2 with major filament energized, measured with 5° FOV detector.

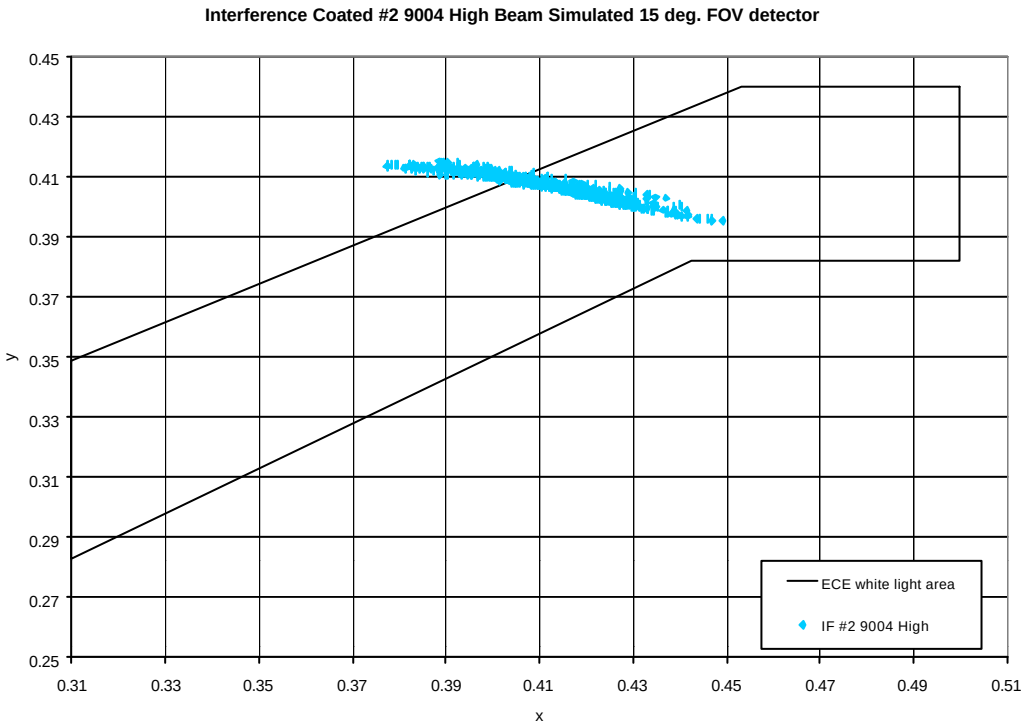


Figure C.9. Simulation of a 15° FOV detector response calculated with data from Figure C.8 (major filament).

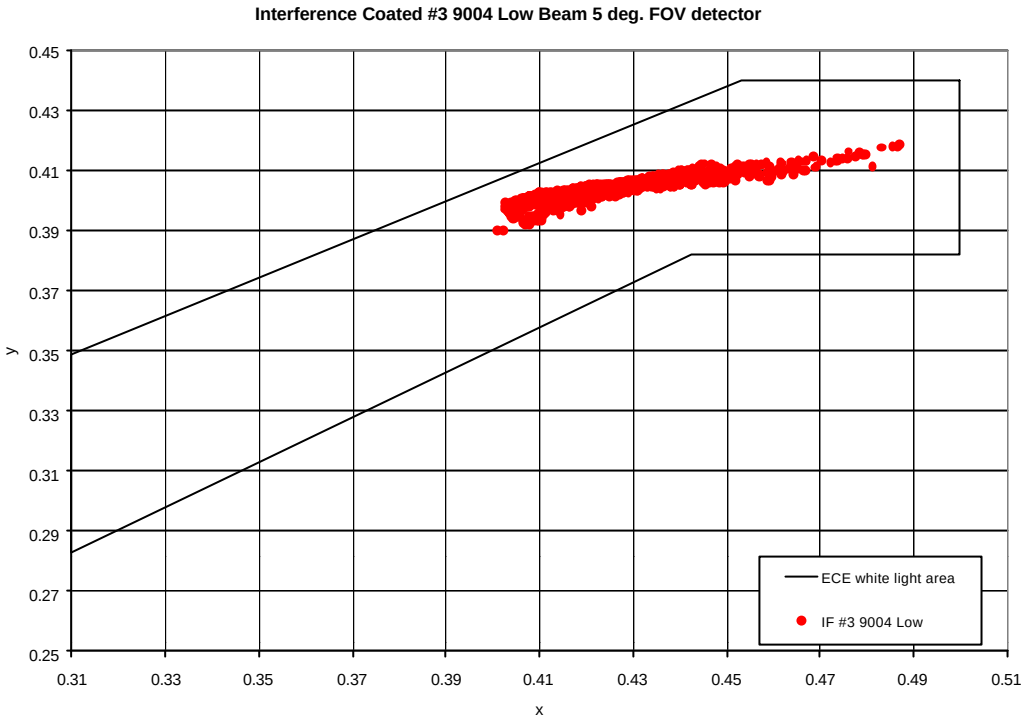


Figure C.10. Color coordinates *x* and *y* of interference coated 9004 bulb #3 with minor filament energized, measured with 5° FOV detector.

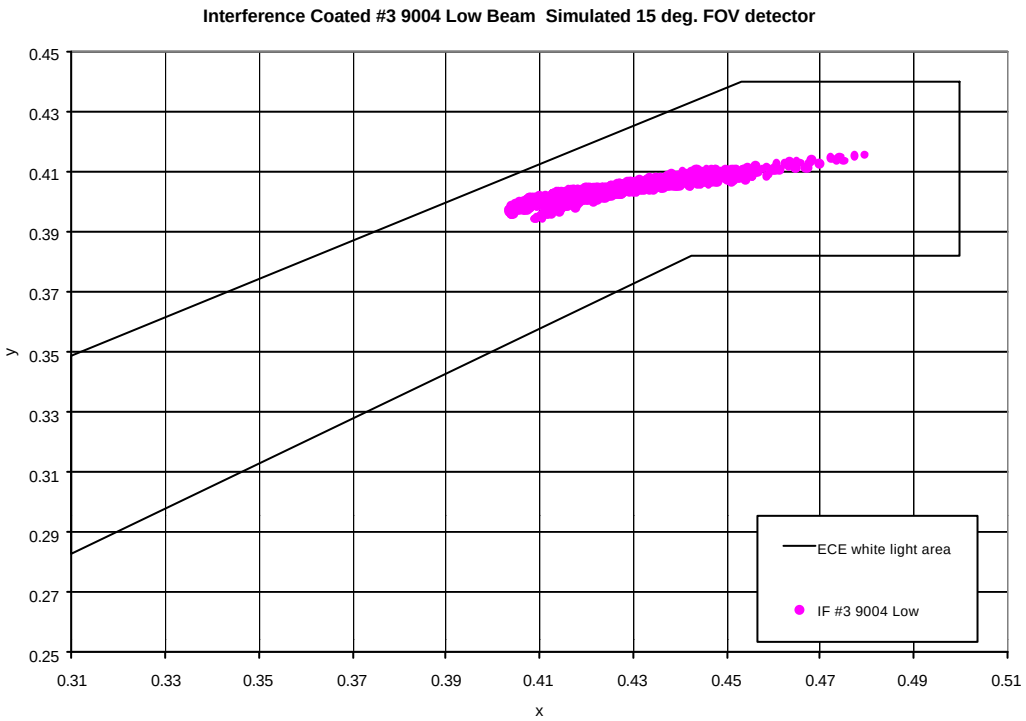


Figure C.11. Simulation of a 15° FOV detector response calculated with data from Figure C.10 (minor filament).

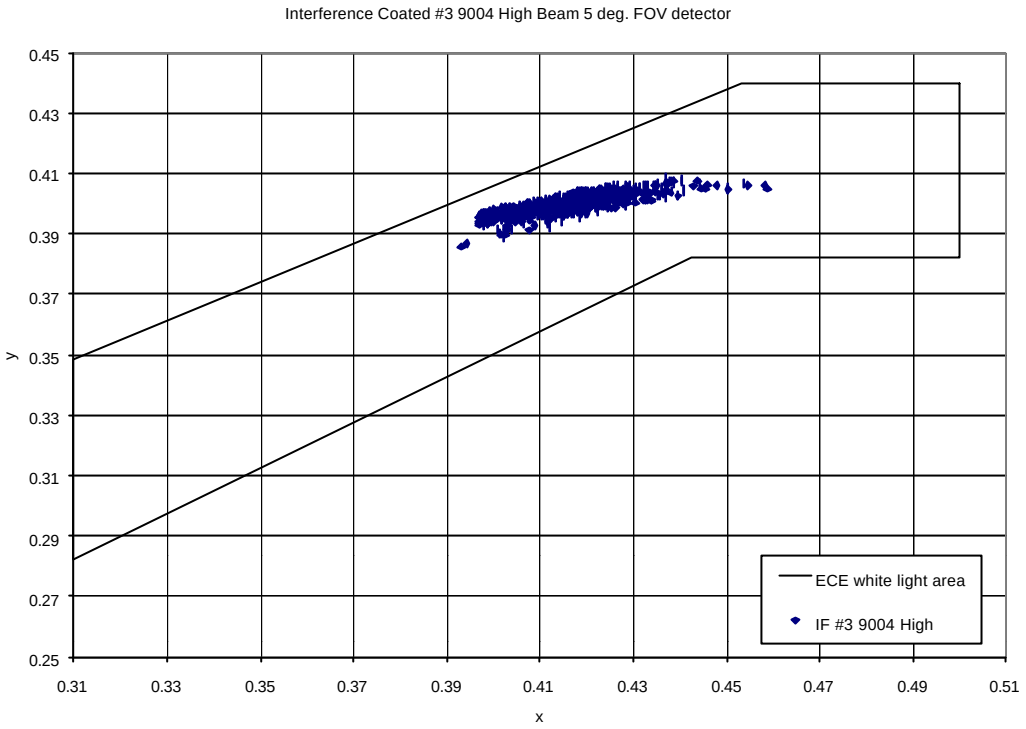


Figure C.12. Color coordinates *x* and *y* of interference coated 9004 bulb #3 with major filament energized, measured with 5° FOV detector.

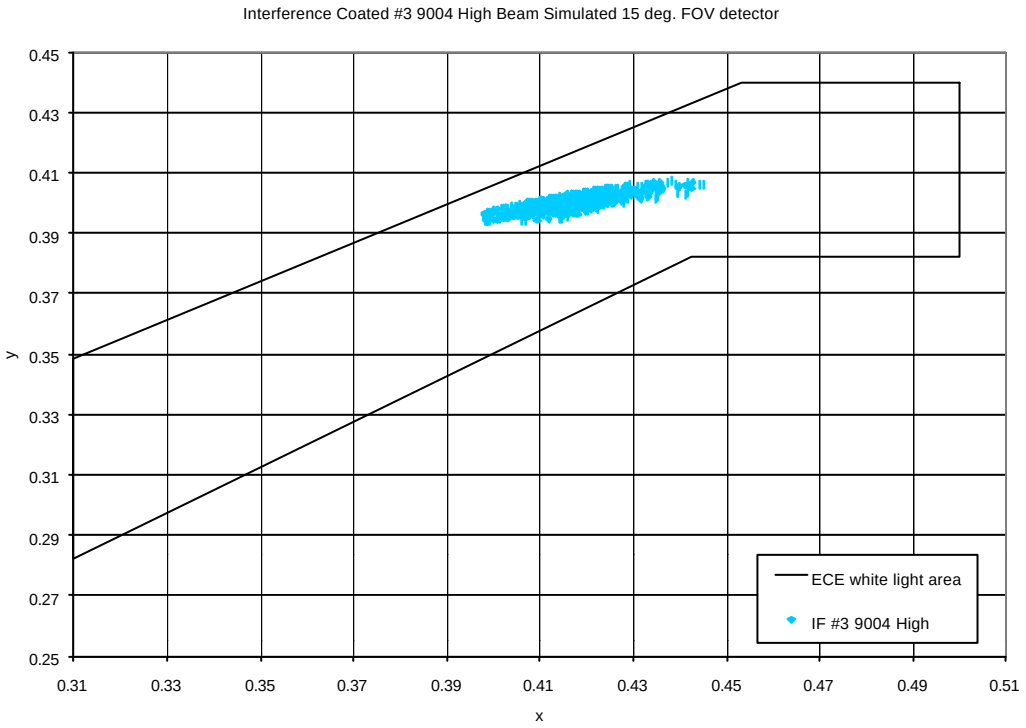


Figure C.13. Simulation of a 15° FOV detector response calculated with data from Figure C.12 (major filament).

List of contents, Annexes, the title of annex 5, amend to read:

"Annex 5 - Checking the colour of filament lamps"

Paragraph 2.1.2.3., amend to read:

"... the other characteristics of a filament lamp emitting white light, does not constitute a change of type of the filament lamp;"

Paragraph 2.4.2., amend to read:

".... If the applicant so desires the same approval code may be assigned to the filament lamp emitting white light and to the filament lamp emitting selective-yellow light (see para. 2.1.2.3.)."

Paragraph 3.1.5., amend to read:

"3.1.5. Standard (étalon) filament lamp: a filament lamp emitting white or amber light with reduced dimensional tolerances, used for the photometric testing of lighting and light-signalling devices. Standard filament lamps are specified in only one voltage rating for each category;"

Paragraph 3.4.2., amend to read:

"3.4.2. In the case of a filament lamp having a coated bulb, after the ageing period corresponding to paragraph 3.4.1. ..."

Paragraph 3.4.6., amend to read:

"..... shall be at least 85 per cent of the specified luminous flux of the relevant filament lamp emitting white light."

Paragraph 3.6., amend to read:

"3.6. Colour

3.6.1. The colour of the light emitted by the filament lamp shall be white unless otherwise specified on the relevant data sheet.

3.6.2. The colourimetric characteristics of the light emitted, expressed in CIE trichromatic coordinates, shall lie within the following limits:

finished filament lamps emitting white light:

limit towards blue:	$x = 0.310$
limit towards yellow:	$x = 0.500$
limit towards green:	$y = 0.150 + 0.640\ x$

limit towards green: $y = 0.440$
limit towards purple: $y = 0.050 + 0.750\ x$
limit towards red: $y = 0.382$;

finished filament lamps emitting selective-yellow light:

limit towards red: $y = 0.138 + 0.580\ x$
limit towards green: $y = 1.290\ x - 0.100$
limit towards white: $y = 0.966 - x$
($y = 0.940 - x$ and $y = 0.440$ for front fog lamps)
limit towards spectral value: $y = 0.992 - x$;"

finished filament lamps emitting amber light:

limit towards red: $y = x - 0.120$
limit towards yellow: $y = 0.390$
limit towards white: $z = 0.790 - 0.670\ x$.

3.6.3. The colour of the light emitted shall be measured by the method specified in annex 5. Each measured value shall lie within the required tolerance area. */ Moreover, the measured values shall satisfy:

$x_{max} - x_{min}$ # 0.05 and
$y_{max} - y_{min}$ # 0.05,

where x_{max}, x_{min}, y_{max}, y_{min} are the extreme colour coordinate readings. x_{max} and x_{min} do not have to be related to the measuring points of y_{max} or y_{min}.

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*/ For Conformity of Production purposes and for amber colour only, at least 80 per cent of the measuring results shall lie within the required tolerance area."

Paragraph 3.7., amend to read:

"..... above, for a filament lamp emitting white light as well as selective-yellow light; article 3 of the Agreement to which this Regulation is annexed...."

Paragraph 3.8.4., amend to read:

"3.8.4. Filament lamps emitting selective-yellow light shall be tested ..... remain unchanged. This test shall be left out if the approval is also given to the same type of filament lamp emitting white light."

Paragraph 3.9., amend to read:

"3.9. Standard filament lamps

Additional requirements for standard (étalon) filament lamps are given on the relevant data sheets of annex 1.
Bulbs of standard (étalon) filament lamps emitting white light shall not alter the CIE trichromatic coordinates of a luminous source having a colour temperature of 2856 K by more than 0.010 units in the x and/or y direction.
For standard (étalon) filament lamps emitting amber light, changes of the bulb temperature shall not affect the luminous flux which might impair photometric measurements of signalling devices. Moreover the colour shall be in the lower part of the tolerance area."

Annex 5, amend to read:

"Annex 5

CHECKING THE COLOUR OF FILAMENT LAMPS.

1. General

1.1. Measurements shall be made on finished lamps. Filament lamps with secondary (outer) bulb acting as colour filter shall be handled as filament lamp with primary bulb.

1.2. Tests shall be made at an ambient temperature of 23 °C ± 5 °C.

1.3. Tests shall be made at test voltage as specified in the relevant lamp data sheet.

1.4. Filament lamps shall be measured preferably in the normal operating position.

1.5. Before starting a test, the stabilisation of the temperature of the filament lamp shall be obtained by operating at test voltage for 10 minutes.

2. Colour

2.1. Colour tests shall be made with a measuring system that determines CIE trichromatic co-ordinates of the received light with an accuracy of ± 0.002.

2.2. The trichromatic coordinates shall be measured with a colourimetric receiver integrating over a right circular cone subtending an angle of minimum 5° and maximum 15°, preferably 15°, at the centre of the filament.

"2.3. Measuring directions
(See the figure below).

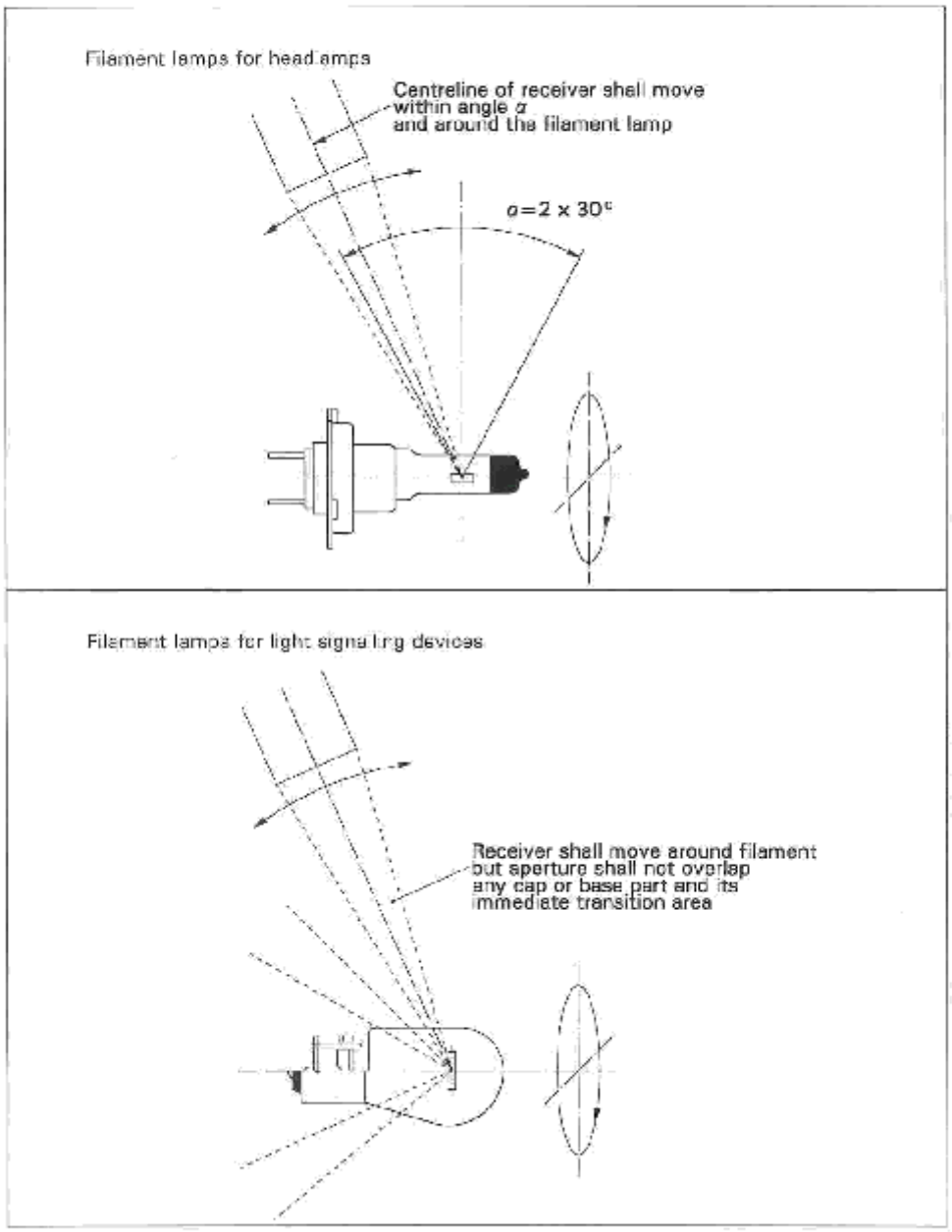
2.3.1 Initially, the receiver shall be positioned perpendicular to the lamp axis and to the filament axis (or plane in case of a curved filament). After measurement the receiver shall be moved around the filament lamp in bi-directional steps of about 30° until the area specified in paragraphs 2.3.2 or 2.3.3 is covered. In each position a measurement shall be made. However, no measurement shall be made when the centreline of the receiver coincides with the filament axis.

2.3.2. For filament lamps used in headlamps, measurements shall be made in directions around the filament lamp with the centreline of the receiver aperture located within an angle ± 30°, from the plane perpendicular to the lamp axis with the origin in the centre of the filament. In case of filament lamps with two filaments, the centre of the driving-beam filament shall be taken.

2.3.3. For filament lamps used in light signalling devices, measurements shall be made randomly around the filament lamp with exception of the area claimed or covered by the cap of the filament lamp, including the immediate transition area. In case of filament lamps with two filaments, the centre of the major filament shall be taken.

ANNEX 5

FIGURE ILLUSTRATING THE POSITIONS OF COLOURIMETRIC RECEIVER



B. JUSTIFICATION

At the forty-fourth session, GRE had considered document TRANS/WP.29/GRE/2000/10 in which it had been proposed to replace the colourless bulb requirement by a requirement that the colour of the light emitted by a filament lamp shall be white. Additionally, the method of measurement had been revised in the proposal.

Several questions (Q) had been raised during the GRE meeting, which were considered and are below answered (A) by GTB:

1. .Q: The expert from the United Kingdom questioned the spread of the measuring results as showed in figures C.10 to C.13 of informal document No. 1 which had been distributed during the forty-fourth session of GRE (TRANS/WP.29/GRE/44, para. 31).

   A: It resulted in an additional requirement given in paragraph 3.6.3.

2. Q: The expert from the United Kingdom also questioned the lack of a clear "go/no-go" decision.

   A: This is now covered in paragraph 3.6.3.

3. Q: The expert from Germany questioned whether a minimum aperture angle should be introduced.

   A: A minimum value of 5E is added in paragraph 2.2 of annex 5, however, the value of 15E is the preferred one.

4. Q: The expert of CLEPA commented on description of the measuring set-up.

   A: For that reason a figure visualising this set-up is added.

5. Q: The expert from Canada commented on the 10 minutes stabilisation time. (paragraph 1.5. of annex. 5).

   A: As the 10 minutes stabilisation time only serves to stabilise the filament lamp in order to get reproducible results, it is believed that this period should not be changed. For information please note that within IEC and ISO a bulb coating endurance test is in preparation.

6. Q: The expert from the Russian Federation commented that the addition of a colour reduces the luminous flux of the filament lamp.

   A: This is true in case all other characteristics of the filament remain the same. As the filament lamp has to comply with the luminous flux requirement, the filament should therefor be accommodated to produce an initially higher luminous flux.

7. Q: Outside the meeting room it was questioned whether a minimum number of measurements should be introduced.

A: A grid is given in paragraphs 2.3.1 and 2.3.2 of annex 5.

Additional comments (C) were raised during the GTB meeting and are reported below together with corresponding replies (R):

1. C: If GRE would accept the GTB proposal, the text part of Regulation No. 37 as well as the filament lamp data sheets of annex 1 of Regulation 37 should be screened on "colourless bulb" as this phrase shall disappear.

R: The amendments concerning the text of Regulation No. 37 were prepared and are contained in the current proposal (TRANS/WP.29/GRE/2000/10/Rev.1).

The filament data sheets of annex 1 to Regulation No. 37 remain to be screened on "colourless bulb". This shall be done in the future, when a data sheet is revised.

2. C: Paragraph 3.6.4 of document TRANS/WP.29/GRE/2000/10 concerned a requirement to standard (étalon) lamps.

R: In the current proposal this requirement is moved to paragraph 3.9.

In addition, as the data sheets of filament lamps emitting amber light specify a general requirement on the amber colour, the opportunity is taken in the current proposal to add this requirement to paragraph 3.9.

3. C: During its forty-fourth session GRE was very close to accepting a proposal to change the tolerance area for colour amber (TRANS/WP.29/GRE/44, paras. 51 to 55).

R: The new trichromatic coordinates of amber colour are introduced in the current proposal. Moreover, the proposal now correctly specifies the boundaries of the colour areas and uses in the equations the "=" symbol, similarly as it had been done in document TRANS/WP.29/GRE/2000/13.

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