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Report

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Report on Page Aerospace consultancy Joint Industry Project

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Scope

This report describes an investigation to determine if an improved calibration method could be developed for handheld tristimulus photoelectric colorimeters used to measure the chromaticity coordinates of white LED products.

Page Aerospace manufacture interior lighting systems for civil aircraft based on light emitting diode (LED) technology. The chromaticity of the light produced by these lighting system units is an import parameter of the product, and of the customer specification. The quality assurance process employed by Page Aerospace makes extensive use of Minolta CL-200 Chromameter hand-held tristimulus colorimeters. However, the performance of this class of instrumentation has presented Page Aerospace significant measurement problems due to the nature of the LED light output.

The aim of this investigation was to investigate the possibility of applying a different calibration process to the colorimeter that would enable the device to be used for the measurement of a generic class of white LED product. This will then provide Page Aerospace with a suitable measurement solution for the quality assurance of their products.

This investigation was funded under the DTI Measurement for Innovators Programme as a 'Consultancy' project. The project was undertaken by the National Physical Laboratory and Page Aerospace Ltd.

Description of the Underlying Problem

Photoelectric tristimulus colorimeters are based on a number of photoelectric detectors whose spectral responsivity has been corrected, usually through the use of coloured transmitting filtered, to approximate the CIE colour matching functions. As with all filtered detectors, an exact match to the desired responsivity function cannot be achieved and the residual differences between the actual and desired responsivity leads to error in the measurement. The magnitude of the error in the meter reading will depend on a number of factors, including the method by which the meter has been calibrated and spectral power distribution of the source under test. Spectral mismatch between the actual and desired spectral response of a detector can lead to significant errors, particularly when the spectral power distribution (SPD) of the source and the region of spectral mismatch coincide. This is illustrated in Figure 1 below.

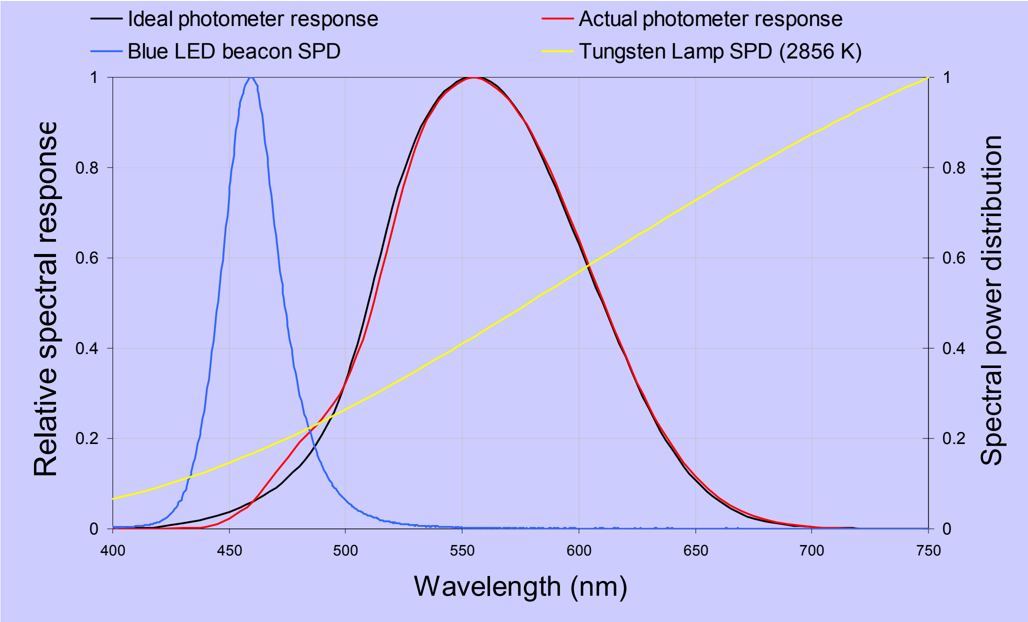

Figure 1 Spectral mismatch between the actual and desired spectral response of a filtered photodetector will lead to measurement errors.

A review of the data sheet for the colorimeters employed at Page Aerospace indicated that the manufacturers calibration procedure made use of a CIE Standard Illuminant A source, as is usual for this class of device. The spectral power distribution of a Standard Illuminant A is representative of incandescent tungsten filament operating at a correlated colour temperature of 2856 K. The white LEDs employed in the Page Aerospace products have a very different spectral power distribution to CIE Standard Illuminant A and this, together with the imperfect spectral correction of the colorimeter, results in a displayed error for the chromaticity (and illuminance) of the source under test.

One common approach to minimise the error caused by the imperfect spectral correction of filtered photodetectors (such as those used in photometers and colorimeters) is to calibrate the meter using a reference source whose special power distribution is similar to that of the source under test. However, the spectral power distribution of white LEDs can vary greatly, even for LED from the same manufacturers bin. As such, the validity of this approach for the tristimulus colorimeters employed at Page Aerospace was uncertain and required investigation.

Investigation Approach

The workplan for the investigation was as follows:

- Page Aerospace selected 10 white LED devices as representative of the normal variation of LEDs used within their products.
- The 10 LED devices were measured at Page Aerospace using 3 Minolta CL-200 Chromameters that were routinely used at Page Aerospace for measuring the colorimetric properties of LEDs and LED products.
- These LED devices were delivered to NPL where the spectral power distribution of each device was accurately measured using a well characterised and traceable spectroradiometer measurement facility. Every effort was made to keep the operating conditions of the LEDs as similar as possible between the measurements performed at NPL and those performed at Page Aerospace.
- The results of the measurements at NPL were used to calculate the colorimetric properties (CIE 1931 x & y chromaticity coordinates) for each device.
- The deviation of the measured values obtained using the Minolta hand-held meters and the values obtained using the facilities at NPL were investigated. This allowed the feasibility of providing a general correction factor to the displayed values of each Minolta meter for the measurement of white LED products to be investigated.

The corresponding part numbers and manufacturers bin allocation for the 10 white LEDs is given in Table 1.

	Part Number.	**Bin**
LED1	LXHL-PW01-QX0J	X0
LED2	LXHL-PW01-QX0J	X0
LED3	LXHL-PW01-QX0J	X0
LED4	LXHL-PW01-QX0J	X0
LED5	LXHL-PW01-QV1J	V1
LED6	LXHL-PW01-QV1J	V1
LED7	LXHL-PW01-QV0*	V0
LED8	LXHL-PW01-QV1J	V1
LED9	LXHL-PW01-QV1J	V1
LED10	LXHL-PW01-QV1J	V1

Table 1 LEDs selected by Page Aerospace

The colour boundaries for each manufacturers bin are given in Table 2. These are plotted on the CIE 1931 x, y chromaticity diagram in Figure 2.

X0	
x	y
0.316	0.333
0.317	0.32
0.308	0.311
0.305	0.322

V0	
0.346	0.359
0.344	0.344
0.329	0.331
0.329	0.345
0.346	0.359

V1	
0.367	0.4
0.362	0.372
0.329	0.345
0.329	0.369
0.367	0.4

Table 2 Colour Boundaries of the LED bins selected by Page Aerospace

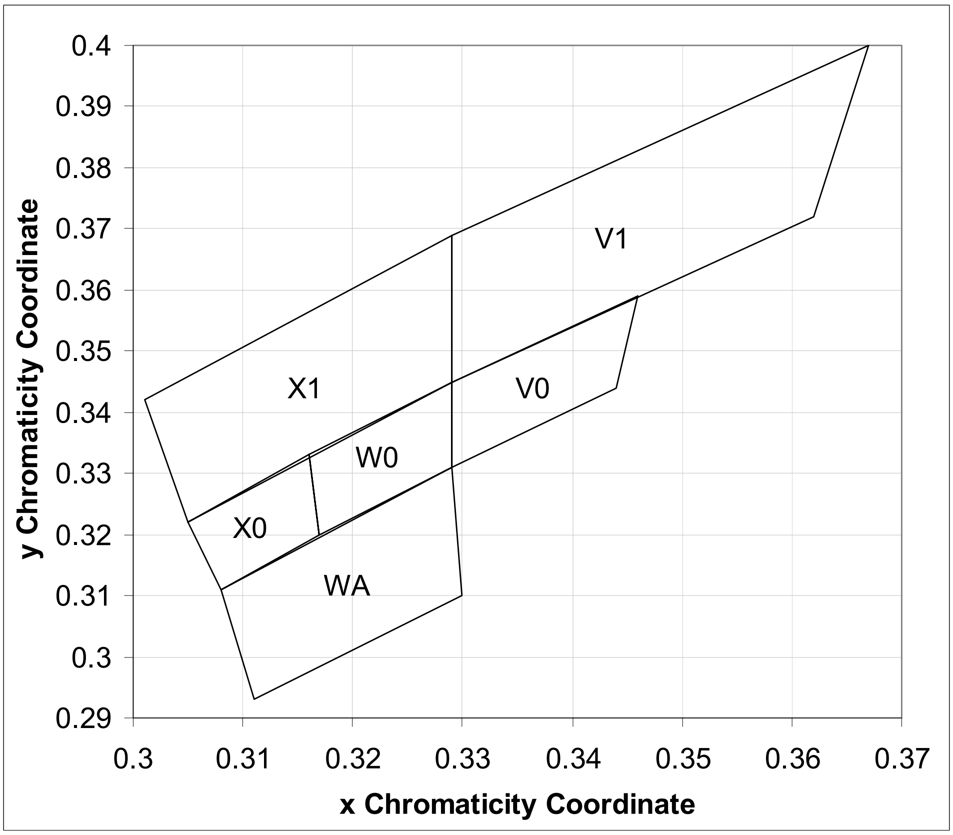

Figure 2 Graphical plot showing the colour boundaries of the LED bins selected by Page Aerospace.

Measurement Performed at NPL

The spectral power distribution of each of the 10 white LEDs was measured at the National Physical Laboratory using a high quality spectroradiometer measurement facility. A schematic of the facility is shown in the Figure 3 below.

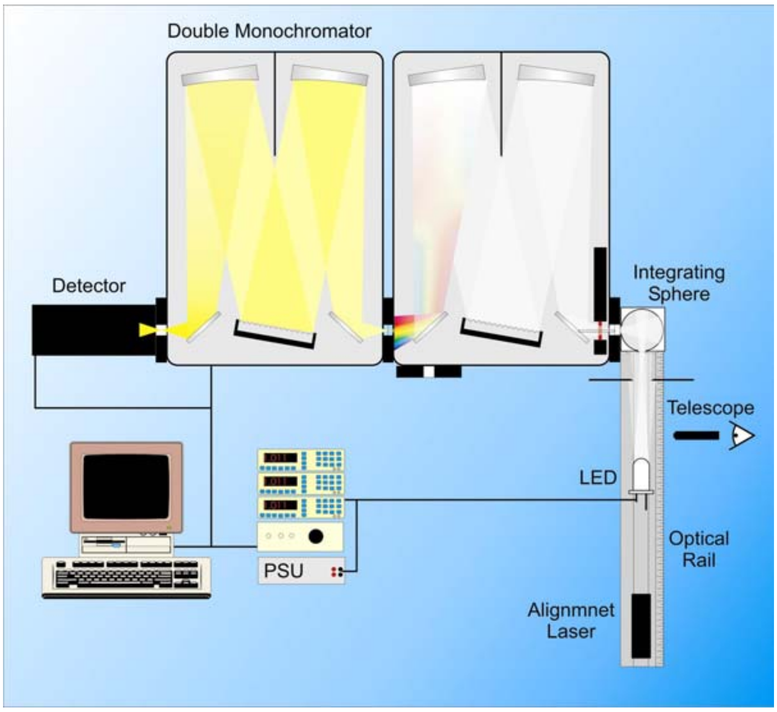

Figure 3 Schematic of the NPL spectroradiometer facility

Results of Measurements Performed at NPL

The results of the spectral power distribution measurements performed at NPL are shown in Figure 4 below.

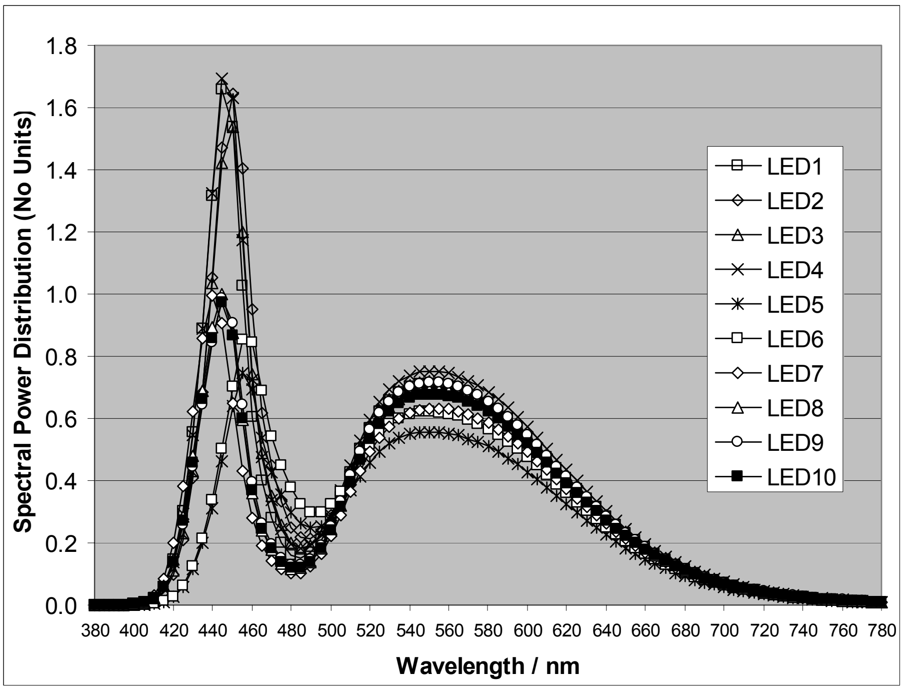

Figure 4 Results of the spectral power distribution measurement for the 10 white LEDs.

The spectral power distribution data was used to calculate the CIE 1931 x & y chromaticity coordinates for each LED. The results of the calculations are presented in Table 3 below.

	x Chromaticity	y Chromaticity
LED1	0.3047	0.3085
LED2	0.2973	0.3010
LED3	0.3072	0.3163
LED4	0.3041	0.3078
LED5	0.3255	0.3665
LED6	0.3212	0.3619
LED7	0.3318	0.3508
LED8	0.3330	03589
LED9	0.3341	0.3624
LED10	0.3325	0.3583

Table 3 Chromaticity coordinates for the 10 white LEDs calculated from the spectral power distribution measurement results.

Measurements Performed at Page Aerospace

The results of the Measurements are shown in the Table 4 below.

	Meter 1 Head: 74431061 Unit: 73421040		Meter 2 Head: 81431119 Unit: 81421032		Meter 3 Head: 80241042 Unit: 80221005	
	x	y	x	y	x	y
LED 1	0.3066	0.3238	0.3104	0.3209	0.3103	0.3187
LED 2	0.2982	0.3115	0.3020	0.3090	0.3022	0.3076
LED 3	0.3087	0.3288	0.3126	0.3261	0.3128	0.3244
LED 4	0.3052	0.3214	0.3090	0.3186	0.3090	0.3167
LED 5	0.3262	0.3692	0.3309	0.3670	0.3319	0.3666
LED 6	0.3222	0.3637	0.3269	0.3617	0.3281	0.3615
LED 7	0.3338	0.3682	0.3382	0.3645	0.3377	0.3616
LED 8	0.3349	0.3741	0.3388	0.3701	0.3397	0.3682
LED 9	0.3358	0.3768	0.3405	0.3734	0.3405	0.3711
LED 10	0.3349	0.3738	0.3395	0.3704	0.3393	0.3681

Table 4 Results of the measurements performed at Page Aerospace.

The 10 LED devices were measured at Page Aerospace using 3 Minolta CL-200 Chromameters that were routinely used for measuring the colorimetric properties of LEDs and LED products. Every effort was made to keep the operating conditions of the LEDs as similar as possible between the measurements performed at NPL and those performed at Page

Aerospace. This included the use of the same high quality power supply, operating current and stabilisation time period.

Analysis of Results

The values obtained from the measurements performed at NPL and Page Aerospace were used to calculate correction factors for the displayed reading for each of the three Minolta meters. Correction factors were calculated on the basis of three different scenarios:

1. A single correction factor for types of white LED
2. A single correction factor for all LEDs from a common bin
3. A separate correction factor for each 'grouping' of LEDs

The third scenario above was investigated due to the clear separation of two groups of LEDs in the V1 bin. The effect of applying the different correction factors is shown in the figures below. In Figure 5, the measurements on each individual LED are grouped together with a connecting line to illustrate the spread of results between the different meters.

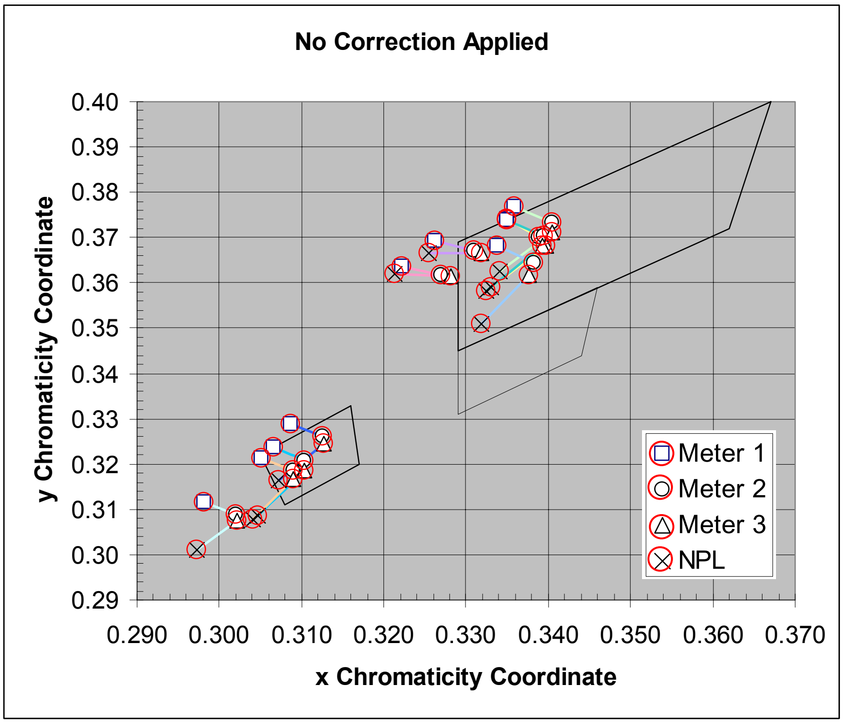

Figure 5 Graphical plot showing the measured chromaticity points of the LEDs (no correction applied to the Minolta Chromameter values).

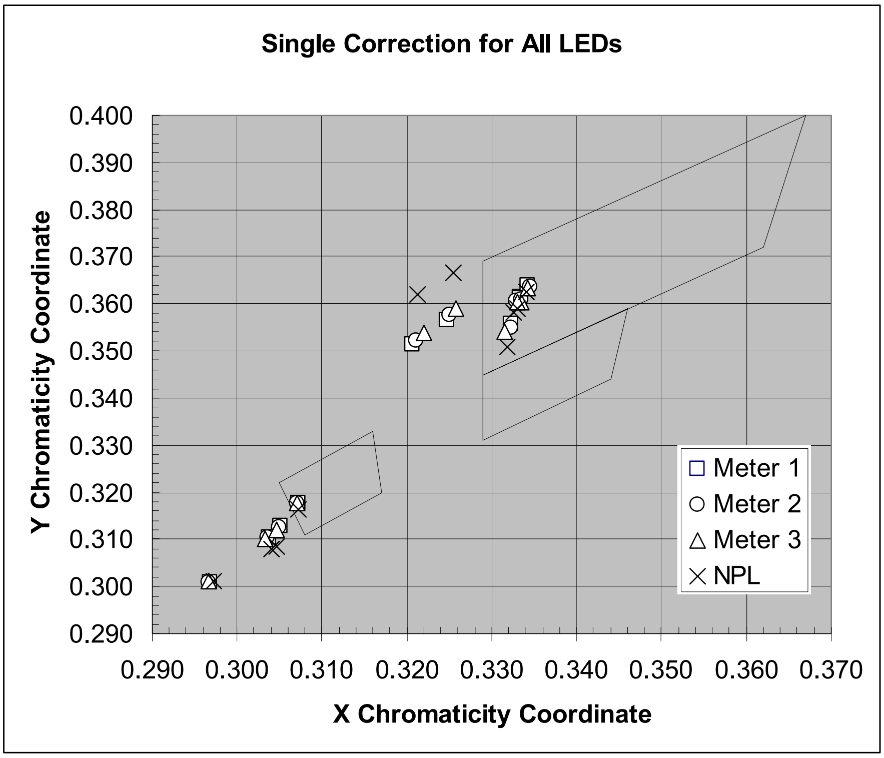

Figure 6 Graphical plot showing the measured chromaticity points of the LEDs (single correction factor applied to the Minolta Chromameter values for all white LEDs).

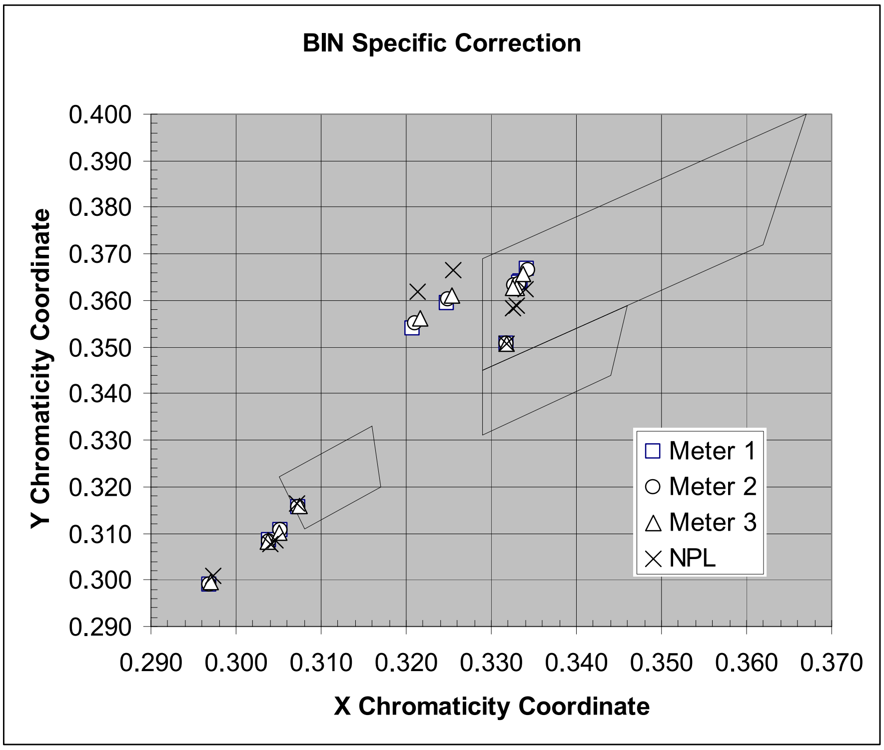

Figure 7 Graphical plot showing the measured chromaticity points of the LEDs (single correction factor applied to the Minolta Chromameter values for LEDs in a common bin).

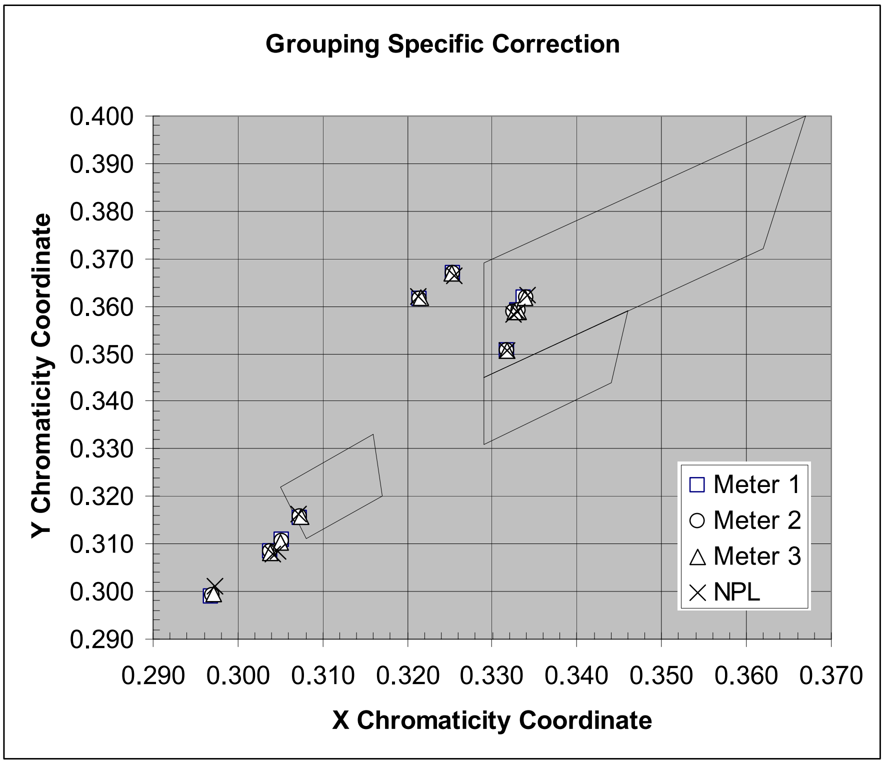

Figure 8 Graphical plot showing the measured chromaticity points of the LEDs (correction factor applied to the Minolta Chromameter values for each grouping of LEDs).

Conclusions and Recommendations

- The measurements performed at Page Aerospace show a discrepancy between the results obtained from each of the three, nominally identical, Minolta Chromameters. This highlights the need for regular traceable calibration of the meters. It is also advisable to regularly check the performance of the meters between calibration intervals.
- The results from the measurement performed at NPL show that the chromaticity coordinates of some of the white LEDs fall outside the colour boundaries of the manufacturers specification. This may be due to a difference in measurement conditions at the manufacturers site and NPL. Specifically, a difference in operational junction temperature is to be expected and this will be a major contributing factor.
- The chromaticity values obtained with the meters show a significant difference from the values calculated from the spectroradiometric measurements performed at NPL. The magnitude and direction of these differences varies from meter to meter and is dependant on the spectral power distribution of the LED.
- Calibrating the meters using a white LED reference transfer standard source significantly improves the accuracy of the results obtained with the meters.
- The best results re obtained when the meter is calibrated using a white LED reference standard that has a similar spectral power distribution to that of the LED under test. For the very best results it may be necessary to use two or more reference LEDs that span the colour boundary of a manufacturers bin.
- Although this investigation did not consider the illuminance response calibration of the meters, it is highly probable that the Minolta meters will also show an error in the measured illuminance values for white LED sources. This error could also be minimised through the use of a traceable calibrated white LED transfer standard.
- Calibrated traceable transfer standard LEDs can be provided by the National Physical Laboratory and a limited number of other accredited calibration laboratories outside the UK. However, due to the possibility of requiring a large number of calibrated LED transfer standards, a more cost effective solution may be for Page Aerospace to invest in measurement instrumentation that provides the ability to establish their own calibrated LED transfer standards.