

Fundamentals of Color and Appearance

Module 12

Targets and Tolerances

Color Science Educational Series



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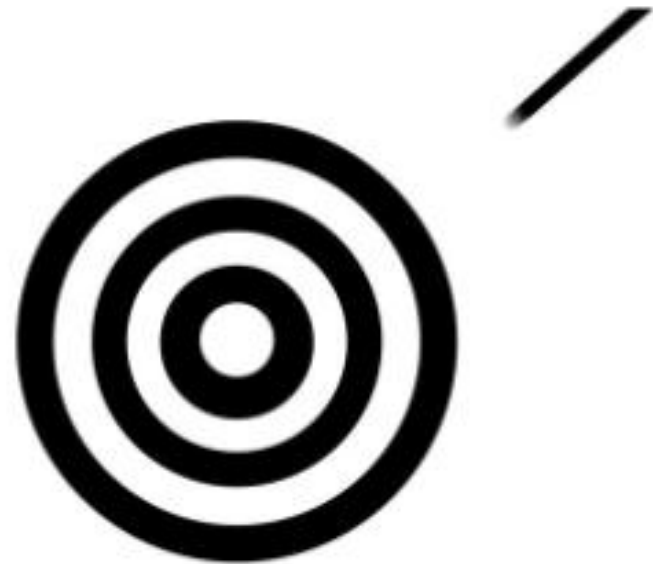
Fundamentals of Color and Appearance

Targets and Tolerances



How to create Targets and implement Tolerances

Targets are determined by measuring visually acceptable samples.



Fundamentals of Color and Appearance Targets and Tolerances



Agreement between customer
and supplier is essential.

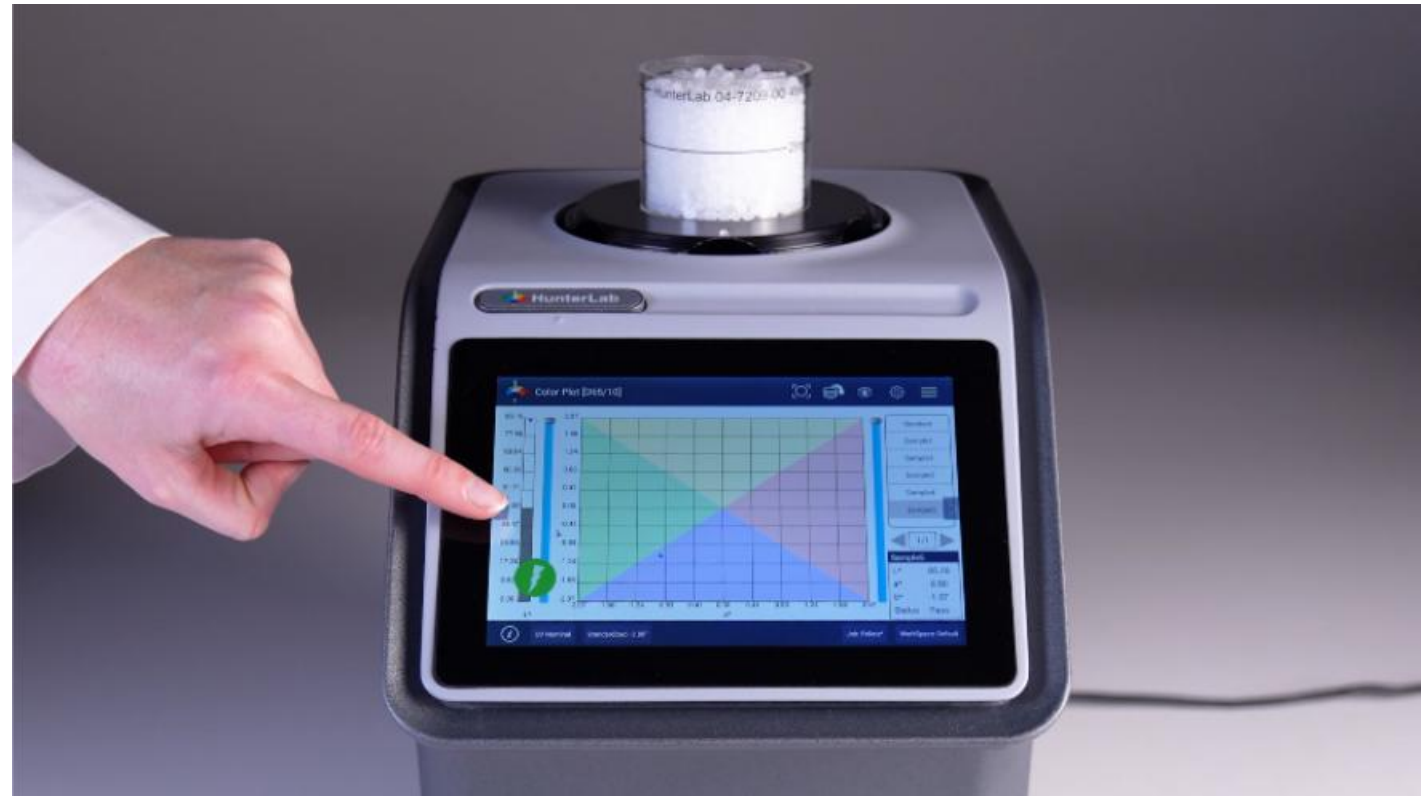


Fundamentals of Color and Appearance

Targets and Tolerances



Visual acceptance comes before instrumental measurement.



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Targets and Tolerances



The process begins with visual acceptance—examining a set of samples together and selecting which acceptable. Once there's agreement, we measure those samples to create our starting point for targets.



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Targets and Tolerances



A word of CAUTION:

- Different instruments, even from the same manufacturer, may give slightly different results.
- Inter-Instrument Agreement (IIA) must be considered when sharing targets across multiple sites.
- Demonstrate with example data.

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Targets and Tolerances



- Once there is agreement on visually acceptable samples, measure multiple samples, average the results, and calculate standard deviation.

Average	47.523	49.878	32.662
	L*	a*	b*
STD Dev	0.109	0.170	0.174
1	47.54	49.89	32.7
2	47.52	49.86	32.59
3	47.79	49.93	32.58
4	47.4	49.84	32.68
5	47.42	49.92	32.77
6	47.41	50.14	32.86
7	47.59	49.53	32.26
8	47.55	50.09	32.84
9	47.59	49.68	32.54
10	47.44	49.97	32.84
11	47.54	49.91	32.7
12	47.54	49.85	32.59
13	47.77	49.93	32.6
14	47.4	49.84	32.68
15	47.43	49.94	32.78
16	47.44	50.13	32.89
17	47.59	49.5	32.24
18	47.56	50.09	32.84
19	47.58	49.67	32.52
20	47.44	49.96	32.8
21	47.54	49.88	32.66
22	47.52	49.85	32.59
23	47.77	49.92	32.59
24	47.38	49.83	32.68
25	47.41	49.9	32.76
26	47.42	50.12	32.87
27	47.58	49.52	32.27
28	47.53	50.05	32.83
29	47.58	49.68	32.53
30	47.43	49.93	32.78

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Targets and Tolerances



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Targets and Tolerances



- Rule of thumb: $3 \times \text{Standard Deviation} = 99\%$ Confidence Level.
- Example: Target = (47.52, 49.88, 32.66) with tolerances of $\pm(0.33, 0.51, 0.52)$.

D65/10	L*	a*	b*
Target	47.52	49.88	32.66
99% CL Tol	0.33	0.51	0.52

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Targets and Tolerances



At this point we could combine the uncertainties, since they are random, we would take the square root of the sum of the squares.

Instrument #1 Data:

D65/10	L*	a*	b*
Target	47.52	49.88	32.66
99% CL Tol	0.33	0.51	0.52

Instrument #2 Data:

D65/10	L*	a*	b*
IIA	47.47	49.87	32.75
99% CL	0.43	0.56	0.51

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Targets and Tolerances



- Assumes that the starting target was correct and will not be affected by Lot-to-Lot variations.
- Did that first set of samples the customer approved represent the expected variation over many runs of the sample?
- Should we have used the IIA values instead of the single instrument target?

D65/10	L*	a*	b*
Target + IIA	47.52	49.88	32.66
99% CL	0.54	0.76	0.73



Color Tolerancing CIE and CMC

- New methods emerged in the late 1980s with computing power.
- CMC, CIE94, and CIE2000 models account for lightness, chroma, and hue differences.
- More realistic to human visual perception.

CMC came first followed by CIE94 and later CIE2000

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Targets and Tolerances



L:c Ratio

- Humans notice hue/chroma changes more than lightness shifts.
- L:c ratio (commonly 2:1) reflects this perception.
- Example: small hue change detected more readily than a similar lightness change.

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Targets and Tolerances



Compare CMC to Repeatability + IIA

D65/10	L*	a*	b*
Target + IIA	47.52	49.88	32.66
99% CL	0.54	0.76	0.73

We can enter our Target +IIA values into software that calculates CMC and then create to artificial targets representing our Upper and Lower Tolerances.

ID	L*	a*	b*	dL*	da*	db*	dE*	dE CMC	(l :c)
Target	47.52	49.88	32.66	47.52	49.88	32.66		-----	-----
Upper Tol	-----	-----	-----	0.54	0.76	0.73	1.18	0.47	2:1
Lower Tol	-----	-----	-----	-0.54	-0.76	-0.73	1.18	0.47	2:1

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This example shows that the CMC model describes our tolerances as being much better than a commercial match.

Notice that our smallest tolerance is for L^* , but color theory says that L^* is the least noticeable color attribute. For this color the L^* tolerance could be +/- 1.5 and we would still have a CMC less than 1

ID	L^*	a^*	b^*	dL^*	da^*	db^*	dE^*	dE CMC	(l : c)
Target	47.52	49.88	32.66	47.52	49.88	32.66		-----	-----
Upper Tol	-----	-----	-----	1.54	0.76	0.73	1.87	0.83	2:1
Lower Tol	-----	-----	-----	-1.54	-0.76	-0.73	1.87	0.83	2:1

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Targets and Tolerances



Visual acceptance is the mutual agreement between customer and supplier.

It is possible that Visually accepted product produces a tolerance greater than $CMC = 1$, your customer may not have been in the test group in 1994.

CMC came first followed by CIE94 and later CIE2000

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