Frequently Asked Questions

MacAdam Ellipses

What are MacAdam Ellipses or color ovals?

The goal of the original research was to determine a series of boundaries around several color targets (x, y coordinate) on the CIE chromaticity diagram, illustrating how much one can "stray" from the target (along various color axes) before perceiving a difference from the target color.

Original methodology used color matching, split field, less than 2-degree field, neutral background, one trained observer, 100 color targets, 25,000 matches. Starting points for color matching were varied. Subsequent experiments also used small numbers of observers; some kept constant luminance, while others allowed luminance to vary.

Methodology was created by MacAdam in 1943 for mathematically constructing ellipses about target points (somewhat useful to lamp industry and now part of ANSI standards).

MacAdam ellipses are described as having "steps," which really means "standard deviations." If a large sample of the population were used (which it wasn't) and if a trained observer could reliably repeat his observations (which he can't), then the steps would translate to probabilities for the general population as follows:

1 sd = 68.26 % of the general, color-normal population
2 sd = 95.44 % "
3 sd = 99.44 % "

Any point on the boundary of a "1-step" ellipse, drawn around a target, represents 1 standard deviation from the target. Note that this also means that if you draw a line through the target from that point, thereby creating a point on the opposite boundary, the 2 boundary points will be 2 standard deviations from one another (see next page.)

Any point on the boundary of a "2-step" ellipse represents 2 standard deviations from the target. For a "3-step" ellipse, the boundary represents 3 standard deviations from the target, and so on.

ANSI recommends that lamp manufacturers stay within a "4-step" ellipse. This means that, given a certain target point on the CIE diagram, lamp manufacturers are given a fairly wide range of perceptible differences. Consider that a point on the boundary of a 4-step ellipse is 8 standard deviations from a point on the opposite side of that same boundary.

OSRAM SYLVANIA guidelines say that we will stay within a 3-step ellipse. It is unknown what GE and Philips guidelines are, but it is likely that GE also uses a 3-step ellipse. All 3 major lamp manufacturers publicly claim to be within ANSI tolerances (4-step).

NOTES: Although there are ANSI standards for various chromaticity targets, each manufacturer chooses targets differing slightly from the standards. These target points vary among manufacturers for several reasons: color matching to existing lamps, phosphor preferences, perceived color preferences by customer base.

Also remember that perceived differences in color can depend upon such things as viewing angle, luminance, and size of object.

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Example of target on CIE chromaticity chart (x, y)

MacAdam 1-step ellipse

MacAdam 2-step ellipse

MacAdam 3-step ellipse (OSI)

MacAdam 4-step ellipse (ANSI)

Examples of lamp chromaticities trying to match target

NOTE: A and B are each 1 sd from the target, but 2 sd from each other

C and D are each 2 sd from the target, but 4 sd from each other.