



## The ASTM D6166 Gardner Index

The Gardner Scale is a visual scale [described in ASTM D1544, “Standard Test Method for Color of Transparent Liquids (Gardner Color Scale)”] originally developed in the 1920s to describe the color of drying oils, varnishes, fatty acids, polymerized fatty acids and resin solutions. These liquids are generally a moderately-saturated greenish or reddish-yellow color in the raw form, and get progressively clearer at higher levels of processing. The eighteen visual Gardner standards are defined by  $Y_{xy}$  ( $C/2^\circ$ ) values (given below). As the standards range from 1 to 18, the color goes from light to dark, increases in dominant yellow saturation, and shifts from a greenish tint to a red tint. While an L, a, b colorimetric scale is a superior way to quantify the sample colors in this wide range of color space, these Gardner standards are well entrenched in numerous industry and manufacturer specifications, and a colorimetric correlation to these standards will be required for the foreseeable future.

Gardner Color	Y	x	y
1	80	0.3177	0.3303
2	79	0.3233	0.3352
3	76	0.3329	0.3452
4	75	0.3437	0.3644
5	74	0.3558	0.3840
6	71	0.3767	0.4061
7	67	0.4044	0.4352
8	64	0.4207	0.4498
9	61	0.4343	0.4640
10	57	0.4503	0.4760
11	45	0.4842	0.4818
12	36	0.5077	0.4638
13	30	0.5392	0.4458
14	22	0.5646	0.4270
15	16	0.5857	0.4089
16	11	0.6047	0.3921
17	6	0.6290	0.3701
18	4	0.6477	0.3521

In June 1997, the ASTM D01.34 (Naval Stores) subcommittee approved an instrumental correlation to the visual Gardner Color Scale. This new instrumental Gardner scale is based on a 10-mm path length transmission measurement and is described in ASTM D6166, "Standard Test Method for Color of Naval Stores and Related Products (Instrumental Determination of Gardner Color)."

HunterLab has implemented this instrumental Gardner scale in EasyMatch QC. This single metric is called "Gardner D6166" to distinguish it from "Gardner-20mm", the Gardner scale based on Yellowness Index E313.

Gardner D6166 is calculated as follows:

$$G_{TM} = G_I + G_F$$

where

$G_{TM}$  = the Gardner color of the test material

$G_I$  = the integer portion of the test material's Gardner color value

$G_F$  = the fractional portion of the Gardner color value.

By comparing the x chromaticity coordinate of the test material with the x chromaticity coordinates for the D1544 visual Gardner Color standards, the integer portion of the Gardner color can be determined using this equation:

$$G_I = G_n, \text{ where } x_n \leq x_{TM} < x_{n+1}$$

where

$G_n$  = the Gardner color value which is lighter than the test material

$x_n$  = the x chromaticity coordinate of the Gardner color standard which is lighter than the test material

$x_{TM}$  = the x chromaticity coordinate of the test material

$x_{n+1}$  = the x chromaticity coordinate of the Gardner color standard which is darker than the test material.

The fractional portion of the Gardner color is calculated as follows:

$$G_F = \frac{(x_{n+1} - x_n)(x_{TM} - x_n) + (y_{n+1} - y_n)(y_{TM} - y_n)}{(x_{n+1} - x_n)^2 + (y_{n+1} - y_n)^2}$$

where

$y_n$  = the y chromaticity coordinate of the Gardner color standard which is lighter than the test material

$y_{TM}$  = the y chromaticity coordinate of the test material

$y_{n+1}$  = the y chromaticity of the Gardner color standard which is darker than the test material

$x_n$ ,  $x_{n+1}$ , and  $x_{TM}$  are as defined above.

The "Gardner-20mm" and "Gardner D6166" indices are both effective for instrumentally measuring the Gardner Color of chromatic yellow liquids, however:

- “Gardner D6166,” based on a chromaticity coordinate correlation, is thought to be a more robust correlation method for off-hue samples than the “Gardner-20mm” Yellowness Index correlation.
- The “Gardner D6166” index is defined in an ASTM test method which has wider acceptance than a manufacturer-specific metric like “Gardner-20mm.”

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