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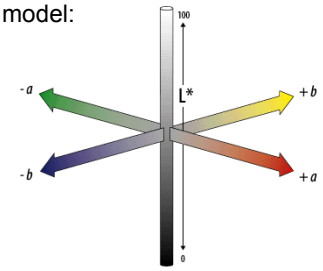
Introduction of Cie-Lab System

Several colormetric measurement systems have been developed in the past. Today the most popular is the Cie-Lab system, based on the measurement of the light incidence of a wavelength for each color. The results are displayed in a three-dimensional color system, which enables the user to express each color in a numeric value and so ensures its reproducibility.

Each color is clearly defined by three coordinates, named L*, a* and b*.

L* = light/dark value (axis)
a* = red/green value (axis)
b* = yellow/blue value (axis)

Cie-Lab model:



Color comparison results are based on the calculated differences between the coordinates in the 3-dimensional system. The reference value is called E*Lab.
To compare a determined color (here called “Y”) versus the reference color (here called “R”) both values are calculated as follows and the result is value ΔE*Lab.

$$\Delta E^*_{Lab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

with ΔL* = L*R – L*Y
Δa* = a*R – a*Y
Δb* = b*R – b*Y

Norms

Colormetric measurements are specified in following norms:

- DIN 5033 Part 1 measurement d/8
- BS 2782 Part 5: Method 530 A and 530 B / 1976
- ASTM E 1347

Tests are usually executed with different illuminations as

D 65 - Daylight

A - Nightlight /Neonlight

TL 84 - Neonlight with bluefilter.

D 65 is used as standard reference.

Color comparison basics

Materials / Products

In a comparison of equivalent technical colormetric results, the optical appearance of colors might still differ because of following reasons:

- Basic material of the color (e.g. paper, plastic, wood, metal, etc.).
- Surface roughness
- Kind of color pigments used.
- Raw material base of color.
- Kind of color production/application (e.g. printing on paper, extrusion of plastic, painting on wood or metal).
- Kind of e.g. HDPE product surface caused by production method (injection moulding, extrusion).

In addition metallic-effect colors may differ, depending on:

- The angle of setting up the test equipment to the color surface.
- Metal materials used for the metallic effect.

Human eye evaluation

Human eyes evaluate same ΔE*Lab values different, depending on the color. ΔE*Lab values start to be visible in general from > 0,8 for white and > 1,5 for red only, which means a ΔE*Lab of 1,5 for red is nearly not visible, but the same ΔE*Lab of 1,5 for white seems to be already close to the next color.

Test results

Test results of the same part and color might vary as follows:

- For each measurement	up to +/- 0,2 ΔE*Lab
- For different test equipment of the same model	up to +/- 0,2 ΔE*Lab
- For use of different test equipment brands / models	up to +/- 0,5 ΔE*Lab

RAL – color charts

To present our color variety of more than 200 colors for NOCX pipes we use the worldwide most popular RAL – color chart.
The RAL institute, established 1925 in Germany, was the first to develop a color chart of registered standard.
RAL colors are registered by so called RAL-numbers. Each RAL number/color has a reference value (L*, a*, b*) in the coordinate system as explained before.
If using the original RAL – reference values to reproduce our HDPE colors, the optical appearance slightly differs compared with the color of the RAL - color chart, because of the reasons explained above. Due to our experience we modify the technical HDPE color values in between a range of +/- 1 ΔE* to optimize the color appearance to comply to the RAL - color chart as close as possible.

Evaluation of test results

The following table should give you an idea for the evaluation of the ΔE* results.

Table 1: Color appearance quality

ΔE^*_{Lab}			**norm evaluation** of optical appearance for chromatic experts[1)]	**PESTEC color difference comparison from**		**RAL – color comparison** **Examples**
				0,3 m distance in room	**3,0 m** distance outside	
0	$< \Delta E^*_{Lab} <$	1,0	difference normally not visibel	No	No	-
1	$\leq \Delta E^*_{Lab} <$	2,0	very small aberration, visible only for trained eye	No	No	9016 versus 9053 7035 versus 9018
2	$\leq \Delta E^*_{Lab} <$	3,5	midium aberration, visible for untrained eye	very small	No	3000 versus 3001
3,5	$\leq \Delta E^*_{Lab} <$	5,0	noticable aberration	small	No	3000 versus 3002 3000 versus 3016
5	$\leq \Delta E^*_{Lab} <$	7,0	out of norm specifications	middle	Yes	9016 versus 9001 3000 versus 3013
7	$\leq \Delta E^*_{Lab} <$	9,0	out of norm specifications	noticable	Yes	9016 versus 1013 7035 versus 7038
9	$\leq \Delta E^*_{Lab} <$	12,0	out of norm specifications	clearly noticable	Yes	3000 versus 2002 3000 versus 3003 3000 versus 3018 7035 versus 1013 9016 versus 9002

[1)] The evaluation refers to high requirements for the production of colors used for, e.g. automotive or paint colors. We assume more practical evaluation can be considered for the use of NOCX HDPE pipes.

General ΔE* value comparison

To give our customers an idea of the color change expressed by ΔE* we provide the following comparison table referring to RAL reference values only.

Table 2: ΔE value comparison

RAL 7035 "Lichtgrau"		RAL 9016 "Verkehrsweiß"		RAL 3000 "Feuerrot"	
measured versus	ΔE*	measured versus	ΔE*	measured versus	ΔE*
RAL 7047	1,1	RAL 9010	1,6	RAL 3001	3,7
RAL 9018	2,4	RAL 9003	2,4	RAL 3002	4,0
RAL 9002	5,9	RAL 9001	6,8	RAL 3016	4,3
RAL 7044	7,7	RAL 1013	9,7	RAL 3013	7,0
RAL 7038	8,0	RAL 9002	10,1	RAL 3018	12,1
RAL 7032	10,5	RAL 1015	15,4	RAL 3003	12,3
RAL 1013	11,7			RAL 2002	12,8

Kommentar [s1]:

NOCX Pipe color tolerances

Tolerances of our NOCX pipe colors to the indicated original reference values are:

L* = +/- 1,0 a* = +/- 0,8 b* = +/- 0,8 but max. ΔE*Lab = +/- 1,0.

NOCX pipe color test

We have tested 2 colored NOCX – samples which have been exposed for more than 10 years to the sunlight on bridges in southern Europe.
RAL 9016, white
RAL 3000, red
As declared in our Technical Information (TI 110-29) on color recommendations for cable stayed bridges, red is the most difficult color to UV – stabilize, which was confirmed in our earlier UV – tests.

As shown in the attached graph, ΔE^*_{lab} of the tested color red RAL 3000, has varied in average of 4,25 from the original value, measured 11 years ago. Compared on the RAL – color chart, the red turned a little bit darker towards RAL 3002 color, but finally it remains the same color.

6.03.03
Equation: CIE Lab
CE-7000A - XA0761
STANDARD: Pipe Sample after Production

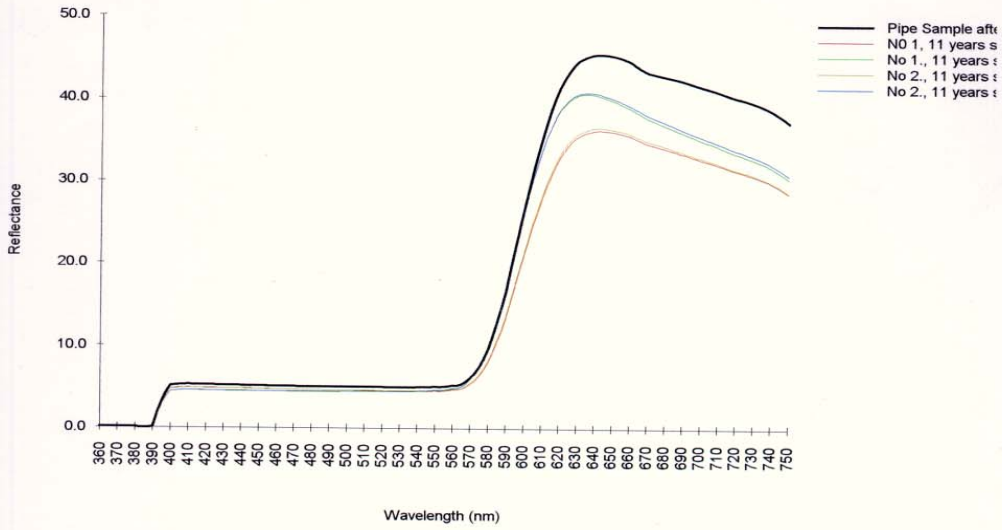
Optiview Quality Control Version 5.1.3.0226
Observer: 10°
Status: CRIOSS

15:40
Illuminant: D65

MEASUREMENT TYPE: Reflectance

Standard	*Illum*	*L**	*a**	*b**
Pipe Sample after Production	D65	40.483	41.473	23.035
	A	46.633	42.909	33.701
	TL84	44.080	41.637	29.158

Trial	*Illum*	*L**	*a**	*b**	*DL**	*Da**	*Db**	*DE**
N0 1, 11 years south europe	D65	37.128	36.913	19.164	-3.356	-4.560	-3.871	6.859
	A	42.561	38.520	28.618	-4.072	-4.389	-5.083	7.854
	TL84	40.269	37.263	24.491	-3.811	-4.373	-4.667	7.445
No 1., 11 years south europe	D65	39.258	40.681	24.308	-1.225	-0.792	1.273	1.936
	A	45.319	41.636	34.780	-1.314	-1.273	1.080	2.124
	TL84	42.955	41.268	30.635	-1.125	-0.368	1.477	1.893
No 2., 11 years south europe	D65	37.338	37.050	19.574	-3.145	-4.423	-3.462	6.437
	A	42.803	38.637	29.069	-3.830	-4.272	-4.631	7.374
	TL84	40.501	37.414	24.943	-3.579	-4.223	-4.215	6.958
No 2., 11 years south europe	D65	39.321	40.657	24.313	-1.163	-0.816	1.277	1.910
	A	45.381	41.646	34.780	-1.252	-1.263	1.080	2.080
	TL84	42.998	41.210	30.608	-1.082	-0.427	1.449	1.858



Multitrial Color Difference/Spectral Graph Report

Page 1

6.03.03
Equation: CIE Lab
CE-7000A - XA0761
STANDARD: Pipe Sample after Production

Optiview Quality Control Version 5.1.3.0226
Observer: 10°
Status: CRIOSS

15:40
Illuminant: D65

MEASUREMENT TYPE: Reflectance

	Standard	Illum	L*	a*	b*	Min Max	Min Max	Min Max	Max
	Pipe Sample after Production	D65	40.483	41.473	23.035	-1.000 1.000	-1.000 1.000	-1.000 1.000	1.000
		A	46.633	42.909	33.701	-1.000 1.000	-1.000 1.000	-1.000 1.000	1.000
		TL84	44.080	41.637	29.158	-1.000 1.000	-1.000 1.000	-1.000 1.000	1.000
	Trial	Illum	L*	a*	b*	DL*	Da*	Db*	DE*
1	NO 1, 11 years south europe sunny side up	D65	37.128	36.913	19.164	-3.356	-4.560	-3.871	6.859
		A	42.561	38.520	28.618	-4.072	-4.389	-5.083	7.854
		TL84	40.269	37.263	24.491	-3.811	-4.373	-4.667	7.445
2	No 1., 11 years south europe sunny side down	D65	39.258	40.681	24.308	-1.225	-0.792	1.273	1.936
		A	45.319	41.636	34.780	-1.314	-1.273	1.080	2.124
		TL84	42.955	41.268	30.635	-1.125	-0.368	1.477	1.893
3	No 2., 11 years south europe sunny side up	D65	37.338	37.050	19.574	-3.145	-4.423	-3.462	6.437
		A	42.803	38.637	29.069	-3.830	-4.272	-4.631	7.374
		TL84	40.501	37.414	24.943	-3.579	-4.223	-4.215	6.958
4	No 2., 11 years south europe sunny side down	D65	39.321	40.657	24.313	-1.163	-0.816	1.277	1.910
		A	45.381	41.646	34.780	-1.252	-1.263	1.080	2.080
		TL84	42.998	41.210	30.608	-1.082	-0.427	1.449	1.858

Color Difference

Page 1

NOCX pipe ΔE* assumption on color durability

Based on the tested colors, we assume following NOCX color results:
The ΔE* results shown in the chart below refer to the original pipe reference measurement after production with a tolerance of ΔE* = +/-1 to the RAL reference value.
The named color classes refer to our color recommendation chart, presented in TI 110-29, page 3, depending on kind of color and area section where the project is placed.

Table 3: Color class with longterm durability

Maximum ΔE* values of NOCX pipes				
color class	**< 7 years**	**<10 years**	**< 15 years**	**< 25 years**
excellent	ΔE ≤ 2,0	ΔE ≤ 3,0	ΔE ≤ 5,0	ΔE ≤ 8,0
good	ΔE ≤ 3,0	ΔE ≤ 4,0	ΔE ≤ 6,0	ΔE ≤ 10,0
critical	ΔE ≤ 5,0	ΔE ≤ 7,0	ΔE ≤ 9,0	ΔE ≤ 15,0

Conclusion

The colormetric measurement results of our tested NOCX pipes are excellent and support our uv – test results. They show an advanced color formulation, we developed for our pipes. The tested values are better than the common required values, specified for current projects and so fully comply with the requirements.